South Campbell Heights Environmental Study #1220-030-2015-008

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Executive Summary

Key Findings and Recommendations for the Special Study Area

This environmental assessment concerned a "Special Study Area"\and a larger "Environmental Study area". The key findings in this section concern mainly the Special Study Area (see main text for description of the two study areas).

Within the South Campbell Heights Special Study Area there are groundwater, surface water, archaeology and biodiversity concerns. Figure I (Highest Value Natural Recharge Areas) and Figure II (Highest Value Biodiversity Areas) depict the overlap of these values in the Special Study Area (and in areas immediately adjacent to the Special Study Area). Figure I presents the intersection of the Highest Value Biodiversity Areas to the Critical Recharge Areas identified through assessment of regional hydrology, which was subsequently cropped by the historic or ongoing aggregate extraction operations. Figure II is the spatial overlay of contiguous areas within, and extending out of, the Special Study area that were evaluated to be High or Very High value for Upland Biodiversity, Watercourse Biodiversity, and Large Tree Areas. The areas presented in both Figures I and II would be ideal for conservation or preservation within the Special Study Area.

Much of the Special Study Area is critical for groundwater recharge and baseflow contribution to local watercourses; particularly the upland regions, river riparian zones, and wetlands.

- The near surface aquifer, which comprises the Uplands, interacts heavily with surface waters. The Uplands region is susceptible to contamination and depletion of the water table through over production, potentially to be compounded by a decrease in rainfall recharge through land use change.
- The riparian and wetland areas actively exchange groundwater with the surficial aquifer. A decrease in groundwater recharge would have considerable negative effects for this exchange in the Special Study Area. As such, there is critical importance to maintain the infiltration capacity, and the *de facto* groundwater table, in the Special Study Area.

- Critical recharge areas include the Uplands surrounding the Little Campbell River, the Little Campbell River riparian area and floodplain, as well as the Wetland area near the confluence of Jacobsen Creek and the Little Campbell River.
- Groundwater contamination would be a concern for areas intended for light industrial or commercial development. The current primarily agriculture land use also requires appropriate farm management practices be followed to minimize potential contamination.

Our determination of Highest Value Natural Recharge Areas (Figure I) was restricted to coincide with high biodiversity value because of the capacity for management of infiltration from rainfall – as the major source of recharge for the area. Management of infiltration would require near or complete retention and infiltration capacity on each parcel, as well as careful management of total impervious area on a regional scale.

The entire area is of high archaeological potential, aside from three areas of historic and ongoing aggregate extraction. The proximity of prehistoric resources (Campbell River), possibility of culturally modified tree (CMT) encounters, a traditional use site, an archaeological site and established travel corridors would necessitate any development to invoke detailed study prior to permitting under the Heritage Canada Act.

Much of the area designated as high value in Figure II focuses on areas in or near the Hubs and Corridors of the Biodiversity Conservation Strategy. These are labelled in Figure II for context

- The Hubs and Corridors have many trees over a metre in diameter and approximately 100 years old, which are relatively rare in the lower mainland.
- The Hubs and Corridors support relatively intact ecosystems that house many species of wildlife.
- Hub I is on City land, making it important to retain in an area that has very low levels of protection (approximately 1%). Hub I contains many trees about 80 years old, some already 100 years old and 100cm diameter. It supports several species at risk including red-legged frogs and olive-sided flycatchers.
- Hub O, and areas around Hub O, although on private land, are very valuable to biodiversity. The area has a high density of large trees, a mix of forest types, and, in combination with Corridor 48, includes a rich wetland. Strong efforts should be made to protect this land.

- The largest Corridors, and most valuable, are the regional Corridors 49 and 50 along the Little Campbell River. The Little Campbell River itself is free of fish barriers in the Special Study Area and has wide, productive riparian zones. The red-listed Salish sucker, once thought extirpated from the River, has been found recently by A Rocha's surveys. We recommend restoration in some areas where Corridor 49 is narrow.
- Local Corridor 48 is valuable because of its connections through a biologically rich wetland. It would benefit from restoration along properties on 16th Avenue, to link the forests and wetlands of Hub O to forests and wetlands to the east.

  The value of Hubs and Corridors is in large part because they function as a network; removing some pieces diminished the function of all remaining pieces.

There are other areas outside the Special Study Area that are also very important for biodiversity – most notably the riparian buffers around the fish-bearing creeks (particularly West Twin and East Twin Creeks). These areas and others are described in more details in the next section of the executive summary and in the main text. Some should be the focus of restoration activities.

FIGURE I: Highest Value Natural Recharge Areas

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Surrey, BC	Environmental Assessment	City of Surrey	6/11/2015	Anna Jeffries	15.0073

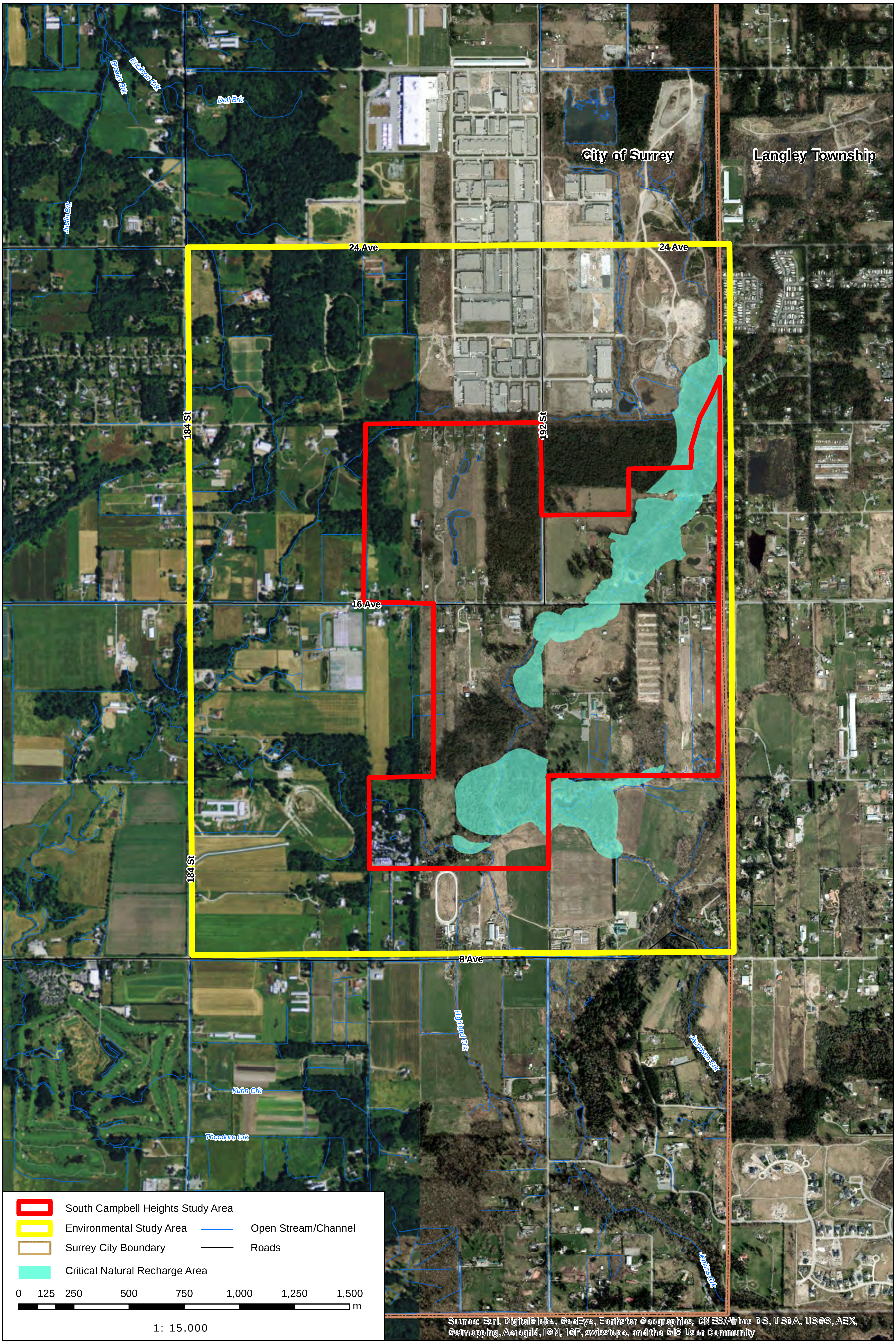
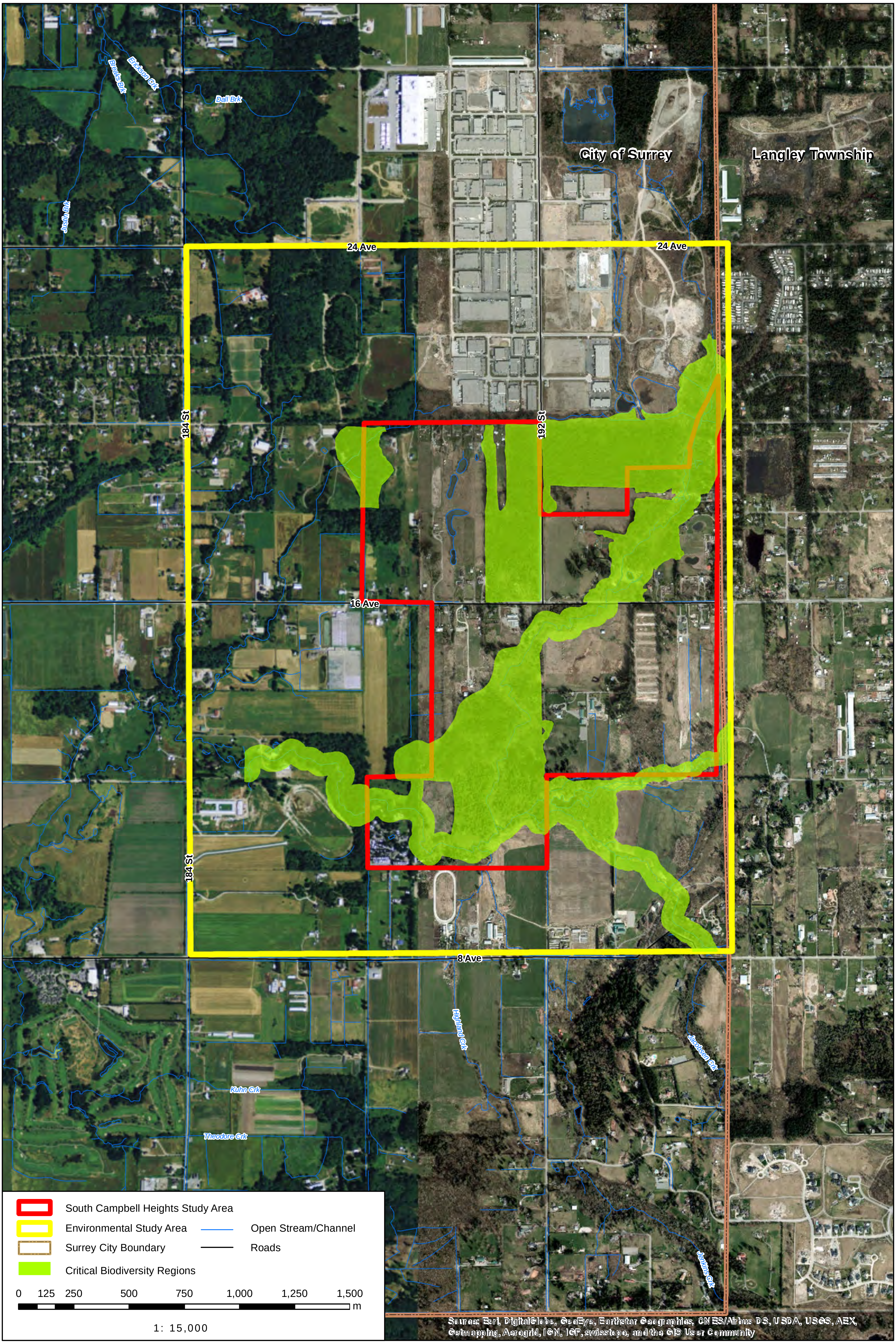


FIGURE II: Highest Value Biodiversity Areas

LOCATION:	PROJECT:	CLIENT:	MAP DATE:	DRAWN BY:	DOSSIER:
Surrey, BC	Environmental Assessment	City of Surrey	6/11/2015	Anna Jeffries	15.0073



General Summary

Madrone Environmental Services Ltd. was retained by the City of Surrey to conduct an environmental study for the Campbell River study area. Studies included assessing surface and groundwater hydrology, terrestrial vegetation conditions (including assessing hubs and corridors), large trees, fish habitat and riparian areas, wildlife, soils and terrain, hydrology and groundwater recharge, and archaeology. The results of each study and associated recommendations are summarized below.

A key part of our work is linked to assessing the Hubs and Corridors of the Biodiversity Conservation Strategy. These Hubs and Corridors in fact affect all aspects of our review, not just biodiversity. There are well-established benefits from sustaining forest cover. These include:

- **Supporting biodiversity**. Because they go up and down as well as sideways, forests support about 67% of terrestrial global biodiversity on 30% of the land mass (excluding Antarctica). (**Section 5.2; the study area is particularly rich)**
- **Providing watershed services** including water purification, regulation of groundwater and surface flow and stabilization of soils on slopes and streambanks. Their importance will increase as water quantity and quality become more critical issues with warming and drying. (**Section 5.1)**
- **Reducing the intensity of floods and moderating climate** through their effects on soil stability, rainfall and air temperature. This will prove increasingly helpful as the frequency of intense rainfall is expected to increase with climate change.[**Section 5.1**]
- **Extracting and storing carbon dioxide**. That in turn helps offset our injections of carbon dioxide into the atmosphere and slows the rate of global warming. (**Section 5.2 and Surrey's Climate Change Adaptation Strategy)**
- **Improving human health**. Forests greatly improve air quality by reducing ozone, particulate matter, sulfur dioxide, nitrogen dioxide and carbon monoxide – all of which are harmful to us. They also increase human birth weights and wellbeing generally, including aiding blood sugar control of diabetics. (**Section 5.4 notes importance of forest to First Nations' peoples; Surrey's Sustainability Charter and Environmental Management Plan reflect the links between forests and wellbeing** see Appendix 1.)

Surface and Groundwater Hydrology

- The South Campbell Heights study area is a generally gently undulating to rolling terrain composed of glacial outwash and a prograding deltaic deposit which contains the Brookswood aquifer prominent at surface.
- Brookswood aquifer is highly vulnerable to contamination from surface sources and is heavily developed, meaning that the aquifer is nearing or at capacity to provide water without decreasing the water table.
- Baseflow to watercourses and wetlands in the study area is largely controlled by local water table and groundwater recharge.
- A general decline is predicted for baseflow and recharge under changing land use due to increase in impervious surfaces and reduced opportunity for stormwater infiltration.
- A decline in baseflow will result in unfavourable stream conditions for fish species, including salmonids.
- Six areas are identified as critical to groundwater recharge to provide baseflow.
- Three recommendations were made to preserve or enhance baseflow.
- One recommendation for groundwater exchange with wetlands was made.
- One recommendation for critical recharge areas was made.
- Three recommendations are made to preserve groundwater integrity.
- Two recommendations are made to well owners extracting from the Brookswood Aquifer.
- One recommendation was made regarding well closure.
- A Well Closure Checklist has been developed for effective isolation/closure of abandoned or redundant wells.

Terrestrial Ecosystems

- Mature stands between 50 and 100 years old (structural stages 5 and 6) dominate the forested landscape. Small patches of younger forest (structural stage 3) occur sporadically. Both young forests and mature stands are of high value for maintaining biodiversity due to tree age, tree diameter and association with complex forest cover. These forests will recruit to old growth in the future. Even at their current age and condition they provide the dead wood components necessary to support birds, mammals and amphibians seeking cavity sites or down wood. They are home to many species of wildlife.

- Forest site conditions are typically moist to dry with medium nutrient status of the CDFmm1 biogeoclimatic variant. The most common ecosystem type on medium nutrient sites is dominated by Douglas-fir-overstories whereas western redcedar dominates most moister richer sites. Usually forests contain a mix of Douglas-fir, grand fir, and western redcedar trees in combination with broadleaf species such as red alder, black cottonwood and bigleaf maple.

- Although the CDFmm1 has the potential to contain a number of rare plants, none were observed in the study area during the brief survey period. More detailed surveys should be completed on a site specific basis and at a time of year to ensure that plants are identifiable.

- All the ecosystems within the CDFmm1 are red-listed (23) or blue-listed (4) (see Appendix IX). Almost all ecosystems identified in the study area are impacted by urban development or human activity and are disturbed, non-climax vegetation. Over time, these ecosystems could succeed to the more stable climax stage, so planning should incorporate suitable disturbed areas for preservation (although some are too degraded).

- Both old fields and cultivated fields help support a variety of wildlife species that use grass and shrub vegetation for feeding and nesting. Retaining agricultural fields also can contribute to preserving biodiversity in the area.

- Rural areas have habitat value from shrubs, hedgerows and landscaped trees. Many of these trees are remnants of the second-growth forests; others were planted for aesthetic reasons. Tree conservation increases local species richness and aids movement of wildlife. Therefore, City bylaws should be consulted and a certified arborist contacted before falling trees even for safety reasons (as per current regulations).

Hubs and Corridors

- Two main Hubs and several Corridors outlined in the Biodiversity Conservation Strategy (BCS) fall within the study area.
- Both Hubs are of high ecological importance with the northern Hub (I) being dominated by Douglas-fir overstory and the southern Hub (O) being dominated by western redcedar overstory. Both Hubs contain a mix of coniferous and deciduous trees species, multiple canopy layers and relatively natural understory vegetation.
    - Both Hubs (I and O) contain a mix of other species and both commonly have trees in excess of 70 cm dbh (diameter at breast height) and often in excess of 90 cm dbh. Many (estimate 40 to 50) trees more than 100 cm dbh exist in Hub I and many more trees larger than 100 cm dbh (too many to count during this project) occur in Hub O.
    - Sign and presence of many species of wildlife were seen and recorded in both areas, including invertebrates, amphibians at risk, Barred Owls, Great Horned Owls, Red-tailed Hawks, Douglas squirrel, deer, and songbirds. Hub I, close to the Little Campbell River (LCR) and Hub O with its numerous creeks, are both likely to support Pacific water shrew, red-legged frog, western toad and other species at risk.
    - Hub O is private land but strong efforts should be made to secure it over the long term, as intended by the BCS.
    - Hub I is city land and should not be developed if Surrey is serious about implementing the intent of the BCS – only 1% of the Campbell River Management Area is currently protected. The City should add its lands to that protection.
    - For both Hubs, their size and connections to riparian zones are important characteristics affecting biodiversity. Efforts should be made to expand Hub O when the City is successful in acquiring or cooperating with land owners in that area.
- Portions of 5 Regional Corridors and 3 Local Corridors flow through the study area.
    - The choice of Regional versus Local Corridor designation seems appropriate for each corridor.
    - Parts of Corridors that have been disturbed and could provide good opportunities for restoration include:

    - along the LCR north of A Rocha (private land) where the land has been cleared both sides of the creek;
    - along LCR south of 16th where the Corridor is narrow (private land);
    - along Corridor 46, Highland Creek (private land) which is open field habitat;
    - along the open farm area of West Twin Creek (private land) where riparian zones are field habitat ;
    - areas close to 12th Avenue where fields have been cleared between wetland areas (private land); and
    - in areas surrounding ponds and creeks along Corridor 55. The ponds in the developed area should be included in the Hub I (city land).
  - A Rocha and SHaRP already have done considerable restoration work in the area and should be contacted.
- Roads intersect Corridors and Hubs, and their impacts should be considered in future development. Where future roads or road expansions are planned, underpasses or other means of enabling wildlife to cross roads should be undertaken.

Large Trees

- No old-growth forest (>140 years, structural stage 7) remains in the study area, but many large trees established after logging between the 1880's and the 1920's are now more than 100 cm dbh and are common in the forested Hubs and Corridors, in farmland patches, and in residential lots. The highest density of large trees is in Hub O.
- Large trees are most often western redcedar, but many Douglas-fir also reach 1 m dbh. As well, occasional bigleaf maples and black cottonwoods achieve such size. Trees of this size are rare in the lower mainland.
- To maintain or enhance the role of large trees in the ecosystem, the City should place a high priority on the retention of large native conifers, namely Douglas-fir, western redcedar, grand fir, western hemlock and Sitka spruce. Large deciduous trees, while not as long-lived, are also an important resource, especially for cavity nesting birds, raptors and herons that prefer these trees for nesting.
- Maps of locations of big trees, or stands with big trees, are included in the report.

Fish Habitat and Riparian Areas

- All measures possible should be taken to minimize negative impacts to water quality and the surrounding habitat. Changes occurring within streams directly affect fish habitat, whereas changes to the quality of the adjacent vegetation strongly impact fish and wildlife using riparian zones. The streams in and adjacent to the study area flow into the LCR (and ultimately into Semiahmoo Bay). The LCR and many of its tributaries are known to contain fish, including threatened species such as the Salish Sucker.
- Based on development density, riparian setbacks from top of bank are currently set as:
  - 15 m for single family residential development
  - 30 m for higher density development (commercial, industrial, and multi-family)
  - 30 m for Local Corridors and 50 m for Regional Corridors
- Many of the watercourses are fishbearing and many of the fishbearing water courses are the core of Local and Regional Corridors. That is a positive step for protection of both terrestrial and aquatic habitat.
- Efforts should be made to remove barriers to fish passage, particularly along West Twin Creek and Jacobsen Creek.
- Efforts should be made to restore riparian buffers along highly disturbed sections of watercourses, particularly along West Twin Creek, East Twin Creek, Jacobsen Creek, and Highland Creek. Most of these areas are in agricultural lands, so cooperation from landowners is needed and incentives should be considered.

Wildlife

- Thirteen taxa of species at risk are confirmed for the study area, two more are likely present, four more appear extirpated from the area.
- Although many of the species at risk require forest cover, several exploit open fields or openings near forests (e.g., Band-tailed Pigeon, Barn Swallow, Olive-sided Flycatcher).
- Some species at risk have been confirmed very nearby (Vancouver Island beggarticks, Pacific water shrew, Painted turtle).

- Several wildlife species in the study area are not designated as at risk but are nonetheless rare in the lower mainland (and in BC more broadly). Fungi are not yet designated by COSEWIC, but several species in the area are on e-flora BC's "watch for" list because of their rarity. Considerable survey effort has been done in the City lands of Hub I and lists including rare species are appended.
- Consistent with current best management practices, with input from Ministry of Forests Lands and Natural Resource Operations (MFLNRO), and on a case by case basis, the City should consider a detailed survey and salvage for species at risk where a development is projected to occur within 500 m of a watercourse.
- For poorly known species at risk (e.g., Pacific water shrew, Trowbridge's shrew, the two bat species) surveys are recommended prior to any land clearing.
- A wildlife tree assessment should be conducted prior to development planning to ensure no listed species are impacted by wildlife tree removal and to identify wildlife trees that should be retained during development.
- All mature trees, particularly Douglas-fir and black cottonwood, should be assessed for Bald Eagle nests or nests of other raptors. Large Douglas-fir and cottonwood trees should be retained during development.
- Because several rare plant species are known or thought to occur in the study area, a site specific detailed rare plant survey should be conducted prior to any land clearing.
- Should land clearing commence between April 30 and August 31, a breeding bird survey must be conducted in accordance with the *Migratory Bird Convention Act* and Section 35 of the provincial *Wildlife Act* to ensure no breeding birds or active nests are destroyed.
- Local and regional Corridors and Hubs should be maintained as they provide living space and movement avenues for wildlife.
- New road construction or maintenance should consider installation of wildlife crossings or underpass structures. Wildlife crossings in urban areas can include culverts or open bottomed road crossings; on some lightly travelled roads traffic calming measures can be used. The most appropriate wildlife crossings will have to be studied as the planning process evolves and Corridor locations are determined.
- Current and future residents should be informed and educated about the potential for living with wildlife. The area is rich in species.

- Invasive plants have the potential to severely impact wildlife habitat, therefore an invasive plant inventory should be conducted in the study area and a strategy should be developed to control the spread and initiate remediation of impacted areas. Part of the strategy should include informing residents of the impacts on native plants and animals of dumping yard waste and horticultural debris in forested areas.

Archaeology

- One archaeological site (DgRq 3) and eight historic sites are located in close vicinity to the study area, with one of the historic sites (DgRq 14) within the study area.
- Three locations of low archaeological potential are identified within the study area where gravel extraction events have occurred.
- Despite these locations of low archaeological potential, the remainder of the study area is considered to have high archaeological potential due to the proximity of prehistoric resources (Campbell River), possibility of culturally modified tree (CMT) encounters, a traditional use site, an archaeological site and established travel corridors.

Land Use and Zoning

- The land currently zoned as "agricultural" seems appropriately zoned. Some areas with previous gravel extraction are difficult to rehabilitate due to poor fill quality; some of the filled areas are more productive than others.
- Some of the non-agricultural land would make productive farmland. Most of those areas are of the same climax ecosystem type as areas zoned agricultural.
- We do not recommend clearing trees for more farm or agriculturally zoned land. The low proportion of protected area in the Campbell River Management Area (see BCS), and in the study areas specifically, means every effort should be made to keep and maintain the city property in forest cover. As well, efforts shALRould be made to acquire (or otherwise secure for the long term) other forested areas (particularly Hub O).

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1 Objectives and Scope

The City of Surrey (The City) engaged Madrone Environmental Services to undertake a comprehensive Environmental Assessment of the South Campbell Heights Area. The assessment is a multi-disciplinary study embracing terrestrial and aquatic ecology, surface and subsurface hydrology, arboriculture, soils and surficial geology, archaeology, and conservation biology. Although comprehensive in scope, the contract had only a two month duration, which limits its intensity. The study is intended to provide a baseline study that will inform subsequent planning studies, such as an integrated stormwater management plan.

The purpose of the study was to:

1. Identify critical areas for wildlife, fish, sensitive ecosystems including riparian areas and wetlands;
2. Recommend measures to minimize and manage the impact of development on valued ecosystem and hydrologic features;
3. Identify and describe potential opportunities for biological conservation and retention of linkages or Hubs consistent with the Ecosystem Management Study (EMS) and the Biodiversity Conservation Strategy (BCS), and
4. Recommend measures to manage, protect, and/or enhance areas of significant ecological and hydrologic value.

Appropriate management and/or protection of riparian areas, wildlife habitat, and healthy functioning of streams will be a focus of this study, as will identification of ecologically important areas to contribute to the City's biodiversity hubs and corridors.

The first general objective will be to identify, inventory, map, prioritize and make recommendations for the protection and/or restoration and enhancement of the following key environmental features:

1. Watercourses and riparian areas, including wetlands, watersheds and recharge areas;
2. Fish habitat;
3. Critical wildlife habitat and potential for habitat for red and blue listed species, including nesting sites;

4 Ecologically significant areas potentially supporting rare plants or forest types;

5 Ecologically significant trees or forest stands of biodiversity or heritage value (including urban trees);

6 Sensitive or hazardous terrain or areas not suitable for development;

7 Natural recreation areas;

8 Potential habitat hubs and corridors, and opportunities for improving biodiversity in the regional area.

In addition there are several broad investigations required:

1 Conduct an archaeological review of lands within the Semiahmoo FN traditional territory.

2 Investigate the groundwater characteristics of the area with a focus on aquifer vulnerability and utilization, distribution, and quality of recharge areas. We see this as an important component of the study and will follow the RFP in assessing impacts of development, identifying natural areas for recharge, assembling an inventory of existing and abandoned wells under the Well Registry, and formulating recommendations and policies to protect groundwater resources as development proceeds.

3 Identify and communicate any pertinent environmental requirements under City, Provincial or Federal jurisdictions.

4 Finally, prepare a final report bringing together all of the various components of the study.

2 Study Area

The focus of the study is within the “South Campbell Heights Special Study area”, but the some aspects of the environmental assessment were assessed over a larger study area defined as the “Environmental Study Area” (See Figure 1). For clarity throughout the report, we refer to the Special Study Area as “South Campbell Heights study area” (SCH), and the Environmental Study Area as the “Campbell River Environmental Study Area”. After these two study areas were defined, a contract amendment added a third area (see Appendix II). That area overlaps with the broader Environmental Study Area and so discussion of areas north of 20th Avenue and east of 188 Street are being deferred until completion of that more intensive study.

FIGURE 1: South Campbell Heights Project Study Areas

LOCATION:	PROJECT:	CLIENT:	MAP DATE:	DRAWN BY:	DOSSIER:
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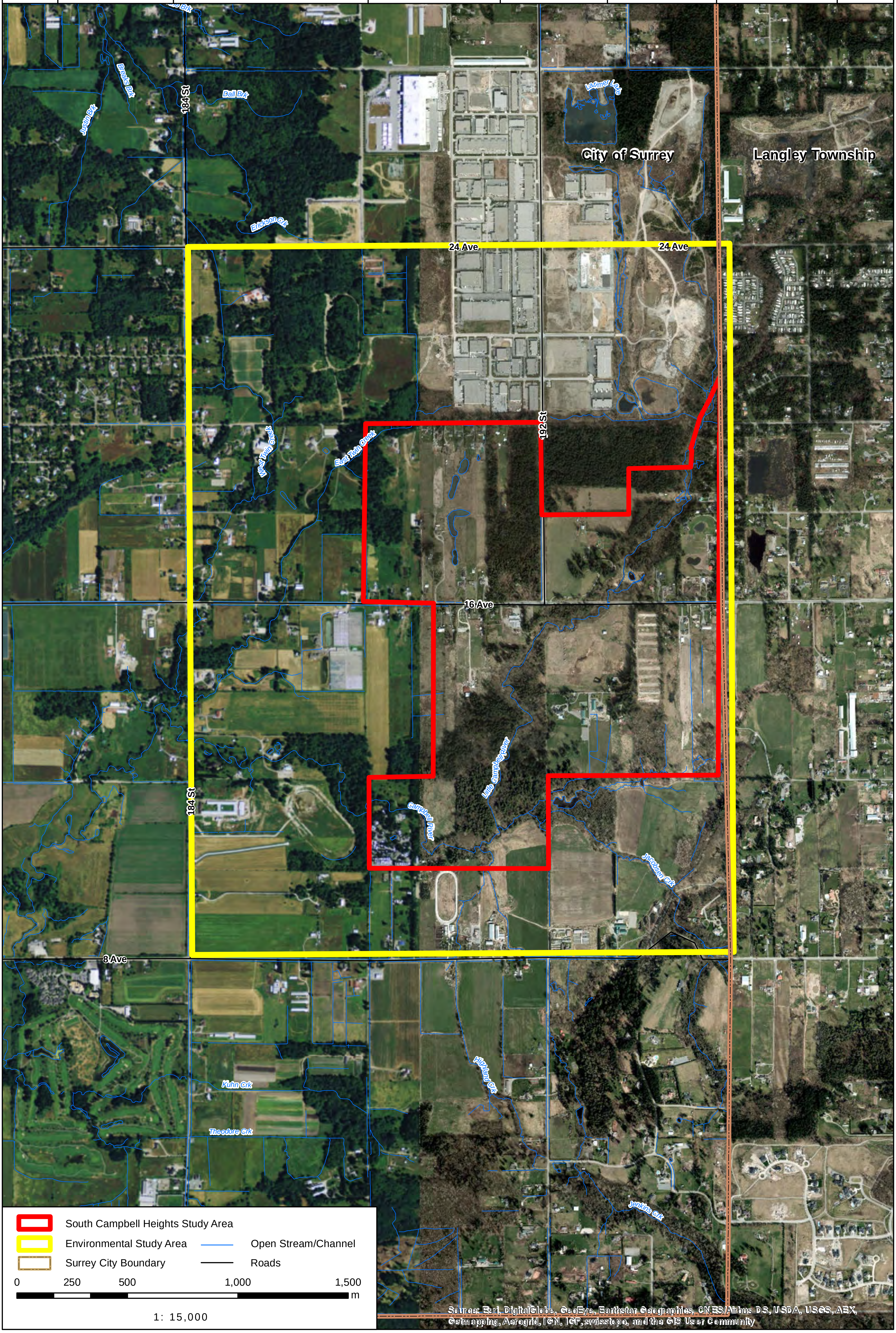


3 Regional and Physiographic Setting

The Campbell River Environmental Study area is located in South Surrey, between 8th Avenue to the south and 28th Avenue to the north and between 184th Street to the west and the Surrey Langley border (196 Street) to the east. It lies approximately 3 km northeast of Semiahmoo Bay and approximately 7 km north of the Canadian – United States border (see Figure 1). This area is part the Fraser Lowland in the Georgia Depression (Holland, 1976). The ecoregion and BEC zones are discussed in the vegetation section.

The study area is relatively flat terrain intersected by gullies of riparian systems, mainly the Little Campbell River. The Little Campbell River is also commonly called the Campbell River. We use both terms and the abbreviation (LCR). Elevations within the study area range from approximately 50 m above sea level in the northern areas, to 20 m above sea level in the southern areas.

The LCR forms the mainstem of the watershed and study area. Four other main watercourses have been previously identified in the study area. Each flows into the LCR. They include:

- East Twin Creek
- West Twin Creek
- Highland Creek (Hyland Creek)
- Jacobsen Creek

As well, Jenkins Creek and several unnamed tributaries feed these main watercourses. Wetlands are found in a few locations.

3.1 Bedrock Geology and Surficial Materials

The BC Geological Survey (MEMPR, 2008) mapped bedrock in the area as comprising of Eocene aged undivided sedimentary rocks of the Kitsilano formation. We did not encounter any bedrock exposures in the study area and it is likely that bedrock is deeply buried in several hundreds of metres of glacial and recent sediments.

The SCH can be divided into a lowland and upland area from southwest to northeast. The lowland of the SCH is a gently undulating to level ancient glacial outwash that contains the lower reaches of the Little Campbell River in a non-constrained floodplain. The upland area is level to rolling prograding delta deposit that has a 15 -20 m ancient channel cut where the constrained upper reach of the Little Campbell River resides.

Surficial materials in the 247 ha study area are primarily comprised of fine grained glaciofluvial and marine deposits of the Capilano and Salish lithostratigraphic units which discontinuously cover unconsolidated medium to coarse grain gravel and sand Sumas Drift deposits (Geological Survey of Canada, 1980). More details are provided in Section 4.1.

3.2 Climate

The nearest Environment Canada Station, White Rock STP (EC, 2015) is located approximately 4 km southwest of the study area at an elevation of 13 m above sea level. Climatic records are available for the 30 year period between 1981 and 2010. Average annual precipitation is 1108.2 mm, with 69 % of that occurring during the six month period from October to March. Average annual snowfall is 30.4 cm. This compares to 1189 mm annual average precipitation for Vancouver International Airport and 1830.8 mm for North Vancouver. This makes the Little Campbell River study area one of the driest locations in the Lower Mainland. Daily mean temperatures range from 7.0°C to 14.2°C with an annual average temperature of 10.6°C. This is one of the highest mean temperatures recorded in Canada.

The study area is located within the Coastal Douglas-fir moist maritime (CDFmm1) biogeoclimatic (BEC) variant. Restricted to low elevations along southeast Vancouver Island, some of the Gulf Islands, and a narrow strip along the Sunshine Coast and Lower Mainland, it lies in the rainshadow of the Vancouver Island and Olympic Mountains (Green and Klinka, 1994). The CDFmm1 is characterised by warm, dry summers and mild, wet winters with very long growing seasons (Green and Klinka, 1994). This BEC zone has one of the mildest climates in Canada (Green and Klinka, 1994) and as such, is highly attractive to development and human habitation.

4 General Approach and Methodology

The methodology presented in this section is organized by the four different disciplines that will be involved in the study:

1. Surficial geology/hydrology/hydrogeology
2. Biodiversity and conservation

3 Watercourses, wetlands and riparian areas and fisheries

4 Archaeology

The multi-disciplinary nature of this project required experts in each discipline to interact with each other; for example the connectivity between groundwater and water quality and fish habitat required our hydrogeologist to work closely with our senior ecologist, but results are presented in separate sections.

To fully appreciate the effect of small scale land use options, it is necessary to view them in the context of the greater landscape that they are a part of. To do otherwise would undermine the foundational work that environmental professionals have compiled for the City of Surrey to this point. Hence although we focus on our study area, we have also considered some landuses and ecological setting of areas surrounding the study area.

4.1 Background Information

Work on this project began by collating all relevant documents and maps for the study area. This included not only pertinent background provided to us by the City, but also information on surficial geology, soils, water, streams, water intakes, wells, fish habitat, species at risk and red/blue listed species from other sources. As well, contact was made with local environmental groups (A Rocha, SHaRP, Little Campbell Watershed Society; LCR Fish Hatchery), academics (Dr. Fred Bunnell) and naturalists (Corey Bunnell, Anthea Farr, Jude Grass) whose studies and experience include parts of the study area. Some people we would have liked to talk to were not available during the study window, for example a professor at Trinity Western Univeristy has done dendrology studies in the area (but is away until June 1). Main contacts are listed in Appendix III.

4.1.1 Surficial Geology, Hydrology and Hydrogeology

A progressive and iterative document review, aerial photo interpretation and field assessment were conducted for the South Campbell Heights surficial geology, hydrology and near-surface hydrogeology. Review of existing publications from academic, institutional, regional and provincial government sources provided a regional scale of understanding of quaternary origin and formation of topography.

Specific areas of the study site were targeted for field investigation through assessment of local hydrology. An area was targeted if hydrologic processes in it were unclear when assessed through document review.

Field observation included site visit, inventory of landform, surficial material, presence and abundance of water, soil type and conditions assessed through auger sampling, and photography. We also observed existing ditching, surface drainage patterns, overland transport pathways, and any seepage presenting at surface. While conducting site visits, we took opportunities to speak with local land owners about anecdotal evidence of local stream flow, groundwater levels, and any concerns they had regarding regional hydrology.

By collating field data with the document review, we compiled a unified concept of the South Campbell Heights hydrology that would be supported by field observation and documented surficial material, hydrology and hydrogeologic composition of the area. Any additional documents or information needed to complete our understanding of the South Campbell Heights hydrology was sought from regional experts, including employees of the City of Surrey.

For surficial geology, hydrology and hydrogeology, we reviewed but did not cite the following:

1. Soils of the Langley-Vancouver map area (BC MOE 1980);
2. Geological Survey sheet 92G2;
3. Comprehensive Groundwater Modelling Assignment for Township of Langley (Golder, 2003);
4. Vashon Drift: definition of the formation in the Georgia Depression, Southwest British Columbia (Hicock and Armstrong, 1985);
5. Hydrogeological Assessment for the Clayton Neighbourhood Concept Plan (Dillon,1997);
6. Studies completed on the LCR on summer low flows, groundwater-surface interactions (e.g.: by A Rocha), water quality, water temperature, invasive species and riparian condition (e.g.: LCR watershed water quality monitoring 2005-2007);
7. Impervious Surfaces of French Creek, Guthrie R. and Deniseger, J. 2001. B.C. Ministry of Water, Land and Air Protection;
8. The Water Act, B.C. Reg. 299/2004;

9 Publications from the B.C. Ministry of Community, Sport and Cultural Development regarding development of bylaws to facilitate land use change;

10 Environmental Guidelines from the City of Surrey Parks, Recreation & Culture department;

11 Well Protection Toolkit provided by the B.C. Ministry of Environment;

12 Derivation of Water Quality Guidelines to Protect Aquatic Life in British Columbia, 2012. Ministry of Environment Water Protection and Sustainability Branch;

13 Ecoregion Approach to setting water quality objectives, 2012. Ministry of Environment Water Protection and Sustainability Branch;

14 Agriculture Riparian Area Setback guidance documents from the B.C. Ministry of Agriculture;

15 The Riparian Area Regulation of the B.C. Ministry of Environment;

16 The Village of Belcarra Bylaw No. 455, 2012;

17 Water Well Reports obtained from the Ministry of Environment Water Well Application website;

18 Information from the City of Surrey website on current practices regarding stormwater management;

19 Available information from the BC Aquifer Classification System and other highly useful websites available from the BC Ministry of Environment (e.g.: well water elevation trends, well database, watershed delineation, etc.); and

Additional sources were cited in text and are accounted for in the unified bibliography.

4.1.2 Biodiversity and Conservation

The City of Surrey has two main guiding policy documents: the *Official Community Plan* (OCP) and the *Sustainability Charter*. These documents provide a vision for sustainable development and give direction as to how it can be achieved. Much of the language in the OCP and the *Sustainability Charter* reflects the growing emphasis the City is placing on environmental protection, biodiversity, green infrastructure and sustainable development (see Appendix I). As well, the *Sustainability Charter, Climate Change Adaptation Strategy* and *Biodiversity Conservation Strategy* all recognize the importance of forests, water and natural spaces to human wellbeing and our ability to cope with or mitigate climate change.

As well, and more directly, the City's Biodiversity Conservation Strategy (BCS) provides detailed background, inventory and visions for achieving conservation objectives.

As well as municipal documents, we gathered lists and information on species and ecosystems at risk from BC Conservation Data Centre (CDC), Identified Wildlife lists, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), the Species at Risk Act (SARA) website, Fish Wizard and the Fisheries Inventory Summary System (FISS). We also checked web-based resources such as iMap, Habitat Wizard, Efauna BC, etc.). As well, local organizations, naturalists and academics were contacted to supply information (see Appendix III).

4.1.3 Fisheries

We are aware of a large amount of information on fisheries in Surrey. A key tool for the desktop phase of this study is the Surrey Watercourse Classification. This web-based tool is based on data collected by Surrey and other sources on presence or potential presence of salmonids and habitat attributes.

There are numerous programs, clubs, or societies that collectively have abundant information on fisheries and fish habitat in the area. The following are just a sample of this source of data:

1. The Little Campbell River Fish hatchery has information on fisheries in the watershed and the society is active in promoting awareness of conservation and potential (and actual) impacts on fish habitat (e.g.: Latimer Pond, and previously Stokes Pit);
2. Semiahmoo Fish and Game Club (in cooperation with other groups including A Rocha) has been working on restoration of the Little Campbell River, particularly in areas damaged by gravel extraction in the past;
3. Salmon Habitat Restoration Program (SHaRP) is a Surrey-based program focused on salmon stewardship; and
4. A Rocha is an environmental stewardship organization located in the heart of the study area and has conducted many watercourse assessments in the LCR watershed.

4.1.4 Archaeology

A search of previously recorded archaeological sites was conducted on the Remote Access to Archaeological Data (RAAD) database to determine the location, nature and distribution of known prehistoric and historic resources in the vicinity of the project area and a review of previous archaeological studies in the vicinity of the study area was completed. Additionally, a review of background literature concerning the anthropology, history, archaeology and palaeoenvironment of the study region, as well as a review of ethnographic literature and traditional use studies were conducted to place the study area in an environmental and cultural context. Heritage Inspection permits were applied for with the Stó:lō and Tsleil-Waututh First Nations. A Sto:lo database query was applied for and is presented in Appendix IV.

No fieldwork was conducted as a component of this AOA.

4.2 Field Assessment

The purpose of the field work is to field check areas of special concern for fisheries, terrain hazards, tree stands, hydrology, vegetation diversity, soils information, wildlife habitat suitability, and riparian habitat. The City of Surrey sent out letters to local landowners to alert them to the project. We then visited properties, asking for permission to enter and assess our topic areas. When landowners were not home, we attempted to obtain phone numbers to contact them by phone and arrange subsequent visit dates. Obtaining access to private land was largely successful and most landowners were cooperative, interested and willing to share information.

4.2.1 Surficial Geology, Hydrology and Hydrogeology

The field assessment portion of this phase consisted of a one day field visit to become familiar with the terrain/landforms, soils, streams and wetlands. This was carried out by Gordon Butt, M.Sc., P.Ag., P.Geo., and Thomas Elliot Ph.D., A.Ag. They assessed soils in road cuts or ditches; soil pits were necessary to gain an understanding of the land and water in the study area. This assessment was followed by office, then subsequent field visits to refine learnings. The outcome is a detailed understanding of the geomorphology, insight into the stratigraphy of the area, and a conceptual understanding of groundwater flow patterns (augmented by analysis of well log data).

4.2.2 Biodiversity and Conservation

For the biodiversity portion, the first steps were thorough background preparation, which included: assessing reports, consulting maps to identify areas and features of interest, identifying ranges of species, and determining actual locations of species. Google Earth and City of Surrey Cosmos Mapping were then used to refine areas where field assessments would be completed. Stands anticipated to have important wildlife habitat and significant trees were a priority, but we attempted to visit every property with any forest or watercourse in the study area. We walked priority areas, mapping locations and noting characteristics of key habitats, including: dominant vegetation, structural stages and attributes; habitat quality for focal wildlife species, riparian vegetation condition, presence of invasive species, and fish presence or barriers to fish presence. All large trees were initially measured, but then, where too abundant, were subjectively assessed. Photos were taken of important features and their locations were identified by GPS in the field and marked on the maps.

As well as gathering information on species, we assessed ecosystems in the field, noting vegetation types and densities, invasive species present and levels of disturbance. Each main area we assessed was summarized to meet information requirements of conservation evaluation field forms. The CDFmm1 contains a high number of provincially red-listed ecosystems and as such, the provincial government has created these forms to assist in collecting data on their integrity.

4.2.3 Watercourses, Wetlands and Riparian Areas and Fisheries

After reviewing the Watercourse Classification map provided by the City, and using air photo interpretation and other existing mapping, we identified riparian areas and watercourses that required field-checking. Ideally we wanted to walk every watercourse, but were not able to access some areas of private land. Wetlands were identified using descriptions from the Ministry of Forests handbook: Wetlands of British Columbia[1].

Once in the field, we assessed watercourses, wetlands, and riparian areas for importance and integrity, including width of riparian vegetation, known or suspected fish presence, connectivity to downstream habitats, quality of vegetation, degree of disturbance in the riparian zone, and land use on each side of the watercourse. If significant barriers to fish passage or other in-stream or riparian habitat features were noted that did not appear on Surrey's Watercourse Classification map, we collected GPS locations to update the mapping.

[1] MacKenzie, W.EH. and J.R. Moran. 2004. Wetlands of BC: a guide to identification. Research Branch, Min. Forests, Lands, & Natural Resource Operations. Land Management Handbook 52.

5 Results

5.1 Surface and Groundwater Hydrology

Groundwater hydrology in the South Campbell Heights Study Area (SCH) can be evaluated through inventory and assessment of the linked surface and subsurface hydrologic systems. To understand the linkage we account for surficial material, surface hydrology, influence of land use change, stormwater management and water extraction / utilization. From our accounting of these factors through document review and field assessment, we evaluated the following topics:

- Impact of development, through change in functional land use, on groundwater resources by assessing:
- components of land use critical to baseflow in the SCH;
- connectivity of existing wetlands with groundwater;
- Importance of specific natural areas in the SCH to local groundwater recharge, from which we will identify and make recommendations for private well owners to improve water security and quality.

Additionally, in this section we develop a list of recommendations on land use and preventative measures associated with development to maintain or improve integrity of the groundwater system. Lastly, we provide recommendations and a check list for effective isolation/closure of abandoned or redundant wells after municipal water supply connections are installed and – where appropriate – retention of wells for irrigation uses.

5.1.1 Introduction and Hydrology Concepts

Surface hydrology and groundwater of the South Campbell Heights Study Area (SCH) will be impacted by future development and land use change. Development may encroach on riparian areas, decrease infiltration to groundwater, and concentrate stormwater flows. The impact of development is dependent on the local susceptibility of surface and groundwater. We identify mechanisms through which development will influence the SCH surface and groundwaters, assess the vulnerability of critical components to SCH hydrology, and make recommendations for preservation, improvement as well as opportunities to expand positive influences on SCH hydrology. Here we outline the role of the riparian area, impervious surfaces, infiltration to groundwater, stormwater flow, effects of temperature on fish and a water budget mass balance approach.

The riparian area is a vegetated buffer between watercourse and surrounding terrain. Riparian areas are known to reduce lateral erosion of banks in stream reaches, provide shading to the watercourse, increase infiltration in the stream-groundwater exchange (hyporheic) zones, and mitigate the influence of common runoff contaminants (e.g. fertilizers, hydrocarbons, etc.). Our assessment of the SCH hydrology uses extent and integrity of riparian areas as indicators for watershed health and to predict impact of development.

Impervious surfaces do exist in nature, often in the form of clay or silt rich hardpan; they are more commonly associated with the built environment of human development. Pavement, building area footprints, and compacted soil are examples of impervious surfaces that resist the absorption of water into the ground. The amount of impervious surface as a percent of total area (percent total impervious area or %TIA) has been linked to watershed health (Schueler, 1994) and particularly groundwater recharge (Arnold & Gibbons, 1996). Researchers identified a notable impact on stream water quality at 10%TIA, and a degraded stream health at %TIA greater than 25% (Prisloe, Giannotti, & Sleavin, 2000).

Infiltration of precipitation to groundwater is essential for maintaining low flows in streams during dry periods. Groundwater recharge occurs primarily through rainfall on pervious surfaces that allow the water to pass into the subsurface. From this partially saturated subsurface area, known as the vadose zone, water is either bound onto the surface of soil material through ionic forces, utilized by vegetation in evapotranspiration, or drawn through pore networks by gravity until reaching the local fully-saturated area known as the water table.

Once water has reached the water table, we establish flow lines as delineations of travel time from the point of surface infiltration to the point of discharge from the water table.

The duration of travel along these flow lines is an important concept in areas where groundwater temperature is critical for stream health. Groundwater temperature generally decreases with depth – to a certain point – and residency time, with the typical temperature of near surface groundwater being 16 to 18°C. To determine flowline duration, a series of pressure sensors or tracer experiments would be valuable within the riparian area.

Contribution to stream flow from baseflow occurs throughout a watercourse through higher permeability sand or gravel bed sections of the river that have active exchange with the surrounding soil. The spatial extent of this exchange between watercourse and surrounding soil is termed the hyporheic zone. When a section of watercourse is losing water it is an outflow or efflux zone, whereas an influx zone is gaining water. An efflux zone has a water table lower (or with less pressure) than the stream bed – allowing for the outflow. Similarly, influx zones occur where surrounding groundwater is higher, or at higher pressure, than the stream bed.

Stormwater flow is the accumulation of precipitation through natural or artificial channels and delivery to watercourses. For a particular storm, a plot of stormwater flow volume against time, also called a hydrograph, will exhibit a building, peak and falling phase of stormwater flow. The flow volume and duration of peak phase in a hydrograph is important to groundwater recharge, stream erosion (aggrading or degrading), and flood levels. Hydrographs are used in management of stormwater flow to guide development of infiltration or detention sites that will lessen the peak or extend the duration of flow events. These integrated stormwater management plans are developed on watershed or basin scale. Within this study we comment on how land-use change and development in the SCH will require certain components of an integrated stormwater management plan.

Temperature and oxygen concentration serve as simple environmental variables to predict the suitability of stream habitat for salmon in coastal British Columbia. It has been shown that juvenile salmonids will avoid habitats with temperatures between 18ºC and 21ºC and that temperatures over 21ºC will impair juvenile growth and survival. Exposure to temperatures over 25ºC is lethal within two to three days (Carter 2005a). This decay in habitat quality is mostly due to the lower solubility of oxygen in warmer water. In lakes and ponds which become stratified in the summer, this can lead to anoxia below the thermocline. In flowing streams, oxygen concentrations tend to be higher due to the mechanical mixing of atmospheric oxygen into the moving water. Oxygen concentrations below 6 mg/l will impair the growth and survival of Chinook, Coho, and Steelhead Salmon, while concentrations below 3mg/l will be fatal (Carter 2005b). Watercourse temperature is affected in two ways by land use change: the temperature of runoff from impervious surfaces is typically several degrees warmer than runoff from a forest; and through increased immediate delivery of warmer water volume to the watercourse (Galli, 1991). For this study we use temperature as an indicator of degraded watercourse due to reduced influence of baseflow.

A water budget, or mass balance, approach to regional hydrology accounts for the volume and pathway of inflow and outflow to an area. A water budget is typically used when planning for stormwater management and land use change. In order to develop a water budget, the general characteristics of an area must be known – including watercourse dimensions and flow, groundwater levels, groundwater recharge rates and critical recharge pathways, surface water source and susceptibility to land use change. By taking inventory of these factors, a hydrologic model for an area can identify areas where decreased or increased flow will compromise the environment and water resources. Water budgets can be developed to set limits for extraction as well as discharge, and are toolkits that can be revised for performance assessment in the post-development phase of stormwater management plans.

5.1.2 Background Information and Field Observations

5.1.2.1 Surficial Materials and Soils

The Sumas Drift contains the predominantly near-surface Brookswood aquifer (Figure 2– Aquifers of the SCH) underlying the North and Eastern regions of the SCH at depths between 0 – 30 m. We observed the prograding deltaic deposits and eolian veneers of the Brookswood aquifer in the cut bank of an aggregate extraction operation south of 16 Avenue, east of 194 Street. Underlying the SCH are deeper Hazelmere Valley (70-100 m) and Langley Upland/Inter-till (50 – 65 m) aquifers, which have little hydraulic communication with surface hydrology and receive the majority of groundwater recharge from adjacent hydraulic units (Gartner Lee Limited, 1999). We will briefly discuss these aquifers as related to artesian conditions in this report.

Six soil associations within the SCH were mapped at a 1:25000 scale by Luttmerding (1981) (Table1 – Soil associations of the SCH). Of the six soil associations present, two are of hydrologic consequence – the Lynden and Sunshine soils – due to composition and interaction with surface hydrology. Lynden and Sunshine soils are generally sandy loams with underlying silty clay loam to clay glaciomarine and marine deposits. The dense subsoil will cause the normally well to moderately well-draining and moderately pervious soils to perch water and result in lateral water transfer under prolonged rains (Government of British Columbia, 2005; Luttermerding, 1981).

Sunshine soils were observed in southwest SCH along the Little Campbell River and Lynden soils were found in the Northwest of the SCH and were associated with the Twin Creeks catchment area, which intercepts surface hydrology in the Northwest study area (KWL, 2011). The Lynden soils were disrupted by large-scale aggregate extraction that occurred west of 192 Street in the country-block between 16 and 20 Avenue, directly south of 190 Street, and no longer exist in that area. Both the Sunshine and Lynden soil series exhibited a perched water table at the time of field observation, and in the case of the Lynden soils there is a perched surface water pond and wetland immediately west of 188 St, outside of the SCH.

FIGURE 2: Aquifers, Recharge and Groundwater Depth of South Campbell Heights

LOCATION:	PROJECT:	CLIENT:	MAP DATE:	DRAWN BY:	DOSSIER:
Surrey, BC	Environmental Assessment	City of Surrey	6/11/2015	Anna Jeffries	15.0073

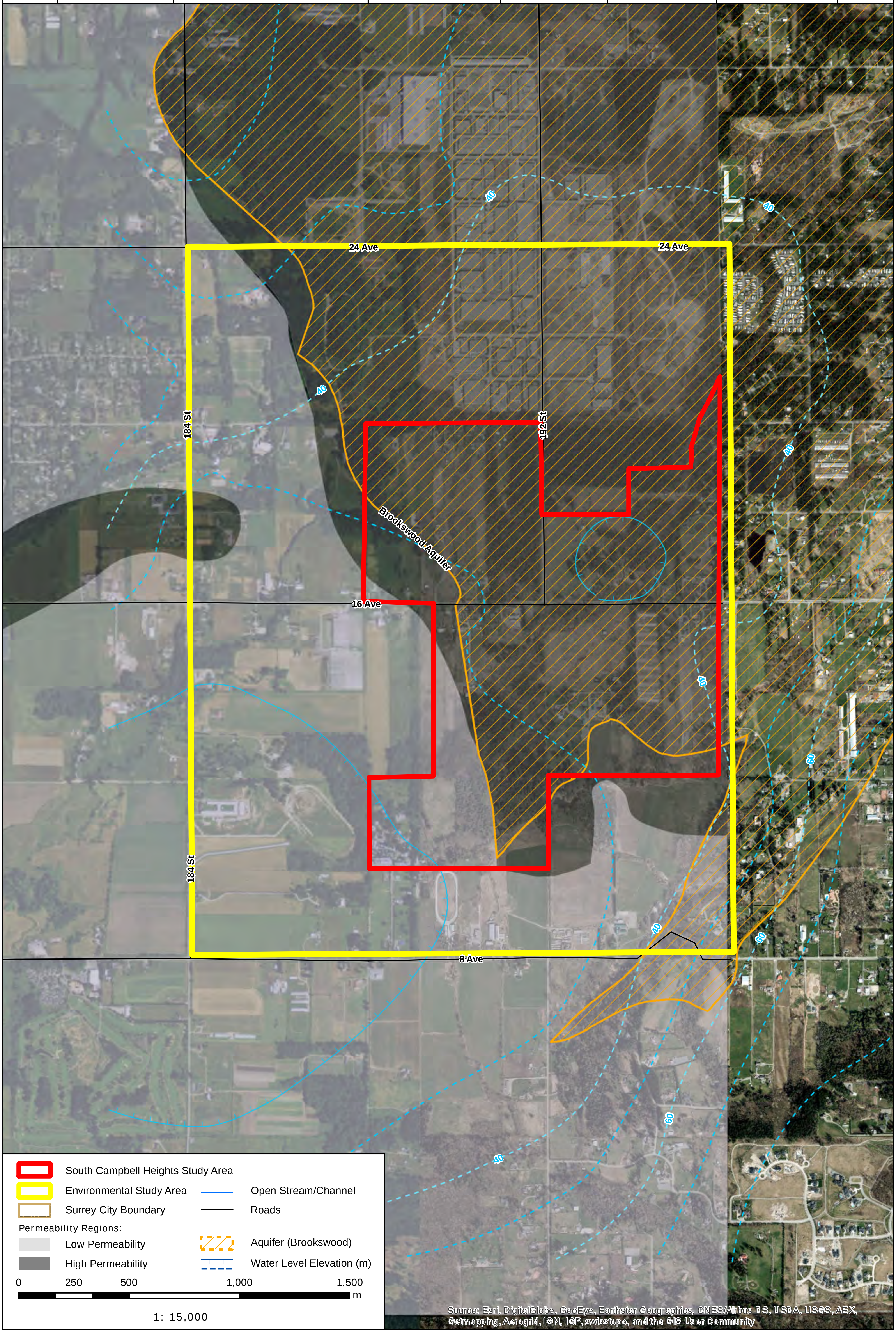


Table 1. Soil Associations and Characteristics of the South Campbell Heights Study Area

	Columbia	Sunshine	Lynden	Cloverdale	Lehman	Judson
Topography	Level to gently undulating, <5% grade	Gently undulating to gently sloping, <5% grade	Very gentle to gently sloping, <5% grade	Level to gently undulating, <5% grade	Level to very gently sloping, <4% grade	Slightly depressional to level or gently undulating, <2% grade
Parent Material	Deep, coarse textured, stratified glaciofluvial deposits	Coarse to moderately coarse textured, stone-free, littoral, glaciofluvial and fluvial deposits	Deep, coarse textured glaciofluvial, littoral, deposits	Deep, fine textured, stone-free marine sediments	Coarse textured glaciofluvial deposits with medium-textured eolian material on or mixed into the surface	Well-decomposed organic material overlying glaciomarine or glacial till
Texture	Loam to gravelly loamy sand	Sandy loam to loam	Loamy sand	Silty clay loam to clay loam	Loam to silt loam grading to sand and sand-gravel	Well decomposed (humic) to silty clay loam or silty clay
Drainage	Well to rapidly	Well to moderately well	Well to rapidly	Poor to moderately poorly	Poorly	Very poorly to poorly
Perviousness	Rapid	Rapid to moderate	Rapid	Slowly to moderately	Rapidly	surficially ? moderately pervious to slowly
Runoff	Slow	Slow	Slow	Slow	Slow	Slow
Water Holding Capacity	Low	Low	Low	High	Low to moderate	Very high

Additionally, in the SCH the Columbia soils broadly correlate to the extent of the Brookswood aquifer. The Columbia soils are a well to rapidly draining loam to gravelly loamy sand, overlain by a thin veneer of silty eolian deposits, and have slow surface runoff and low water holding capacity.

Floodplains of the Little Campbell River along the constrained upper reach have recent sediment deposits and humic material accumulations, which we assessed as former wetlands greater than 100 years based on age of established forest.

The SCH has historically, and is currently, undergoing aggregate extraction – principally from prograding deltaic deposits of the Sumas Drift late glacial advance into the lowlands roughly 12,000 years ago (Cameron, 1989). We identify where aggregate extraction has resulted in a water table at or near surface in Figure 3 – Surface Material.

5.1.3 Surface Watercourses

The surface hydrology of SCH includes rivers, creeks, wetlands, ponds, seepage faces from emerging groundwater and ephemeral streams (Figure 4 – Surface Watercourses). The prominent Little Campbell River flows south from a constrained reach in the northeast SCH until being joined by the Jacobsen Creek tributary. At this confluence, the Little Campbell River flows westward, and is immediately joined by the Highland Creek tributary, and continues out of the SCH. The Little Campbell River continues through the low gradient ancient outwash valley until joining the Pacific Ocean.

The Jacobsen and Highland Creek tributaries flow east and south, respectively. The Jacobsen and Highland tributary streams flow into a riparian wetland near the Little Campbell River confluence. In the case of Highland Creek – which originates along the base of an upland area where groundwater seepage is likely to be occurring – the confluence is within a narrow riparian strip with much of the upstream reach artificially channelized. Jacobsen Creek flows through an extensive wetland just in advance of the Little Campbell River confluence.

There are ponds in an area historically excavated for aggregates in the Northwest of the SCH which have water at ground surface, which is predicted to be at or below the elevation of the regional water table within the Brookswood aquifer (Figure 3, 4 and Photograph 1). Another series of ponds are located to the east of the Little Campbell River, just north of 16 Avenue, and are constructed features associated with the Little Campbell River Riparian Area (Photograph 2).

Photo 1. Groundwater ponds in NW study area.

Photo 2. Wetlands, pools and riffles along the Little Campbell River

FIGURE 3: Surface Materials

LOCATION:	PROJECT:	CLIENT:	MAP DATE:	DRAWN BY:	DOSSIER:
Surrey, BC	Environmental Assessment	City of Surrey	6/11/2015	Anna Jeffries	15.0073

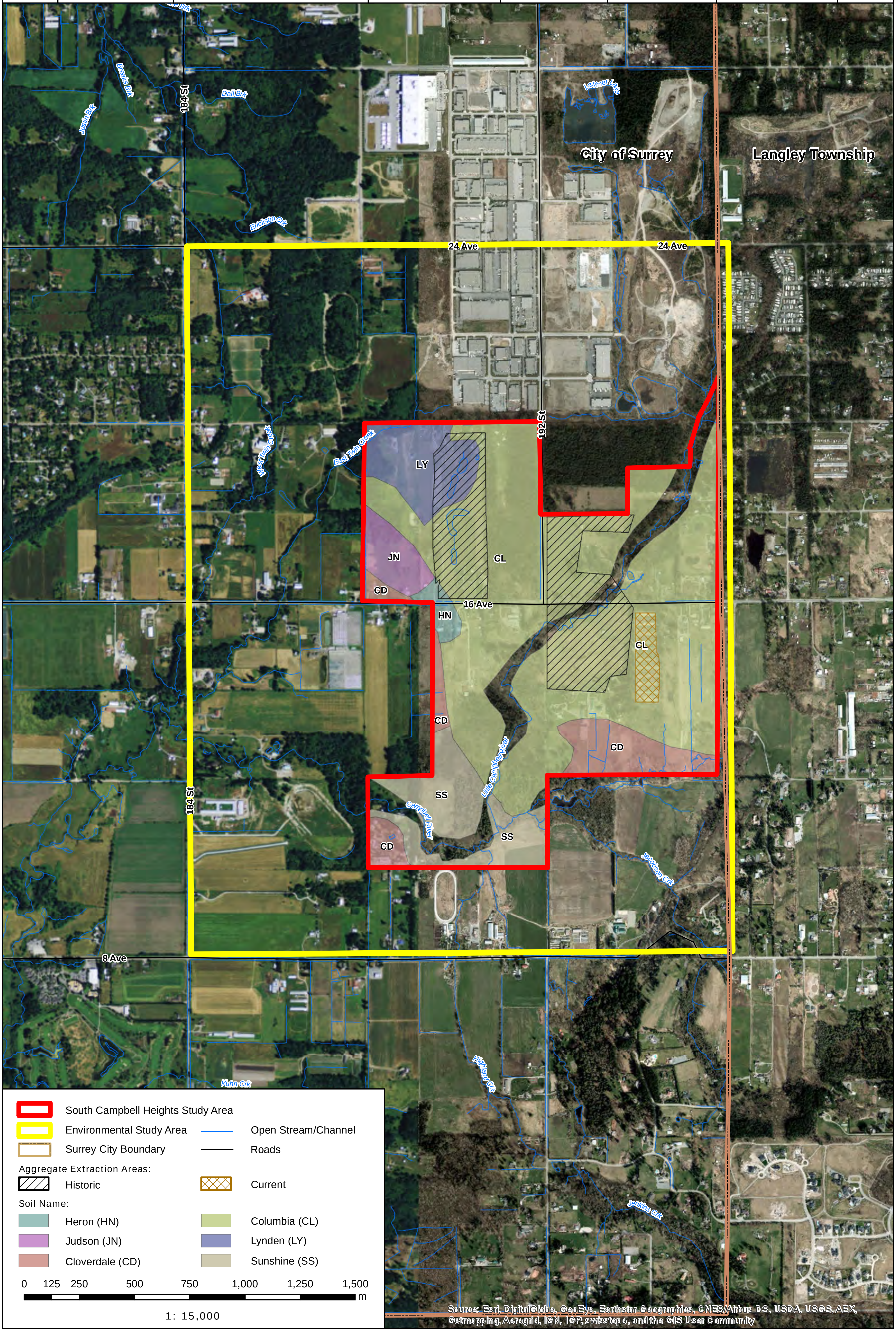
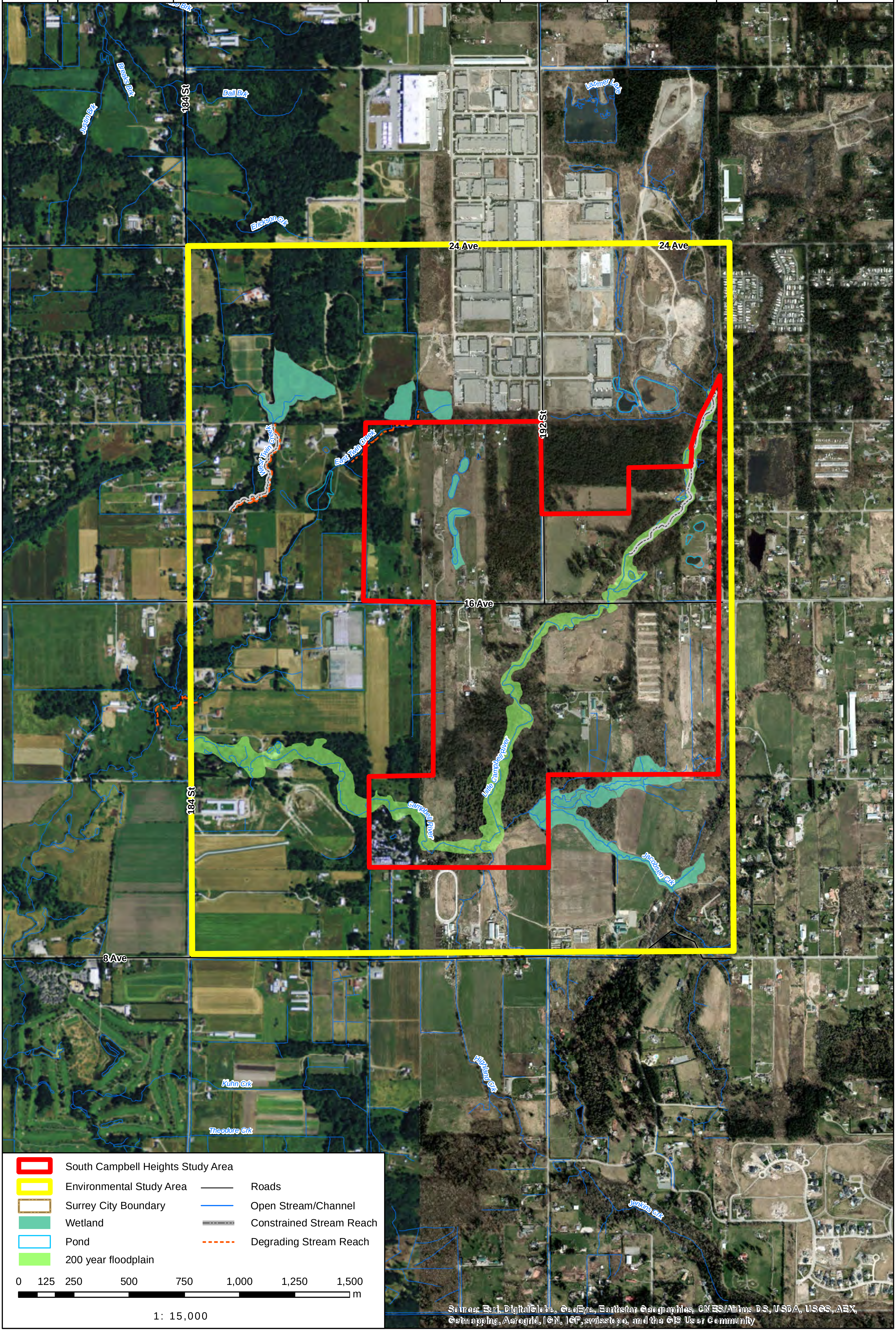


FIGURE 4: Surface Watercourses

LOCATION:	PROJECT:	CLIENT:	MAP DATE:	DRAWN BY:	DOSSIER:
Surrey, BC	Environmental Assessment	City of Surrey	6/11/2015	Anna Jeffries	15.0073



Seepage faces are present in the floodplain embankment on the upper reach of the Little Campbell River. The groundwater seepage is hydraulic connection to the surrounding upland area that drains into the organic rich riparian area along this section of the Little Campbell River.

There are numerous small ephemeral streams in the SCH, contributing both directly to the Little Campbell River and various surface water features in the landscape.

5.1.4 Baseflow, Recharge and Groundwater

Groundwater is in regular exchange with surface water of the SCH, with a net flux of groundwater to surface providing baseflow. Baseflow is defined as the net groundwater flow volume to rivers, creeks and seepage faces. Baseflow in the SCH is strongly linked to the water table of the near surface Brookswood aquifer. The Brookswood aquifer provides baseflow to the Little Campbell River during the full year. This is of particular importance during the summer (dry) season when there is little rainfall contribution to stream flow. Contribution to baseflow from the Brookswood aquifer was observed in the upper constrained reach where the river resides in an ancient incised channel with groundwater seepage emerging from the floodplain embankments.

The small catchment basins of Jacobsen and Highland Creeks are underlain by the Sunshine soil series. However, the Jacobsen Creek is on the terminal extent of the Brookswood aquifer, which corresponds to a wetland area receiving baseflow.

The surface ponds in the northwest SCH are almost entirely supplied by baseflow, as the water table is present at ground level in the historic aggregate extraction area. A minor amount of rainfall runoff accumulates in these ponds, although the delineation of runoff and groundwater at surface is difficult to define.

The majority of precipitation in the region falls during cool, rainy winters (October through March) and moderate, sunny and dry summers are common (Halstead, 1986). Precipitation in the SCH is controlled by topography, surficial material, persistent climatic conditions and vegetation (Golder Associates, 2005). The topography and surficial material are nearly ideal for groundwater recharge in the SCH – being relatively low gradient and rapidly pervious, except during heavy rainfall events where a perched water table will develop in some areas. In the Lynden and Sunshine soils, lateral flow from the perched water table delivers water to nearby floodplains and is transported downstream.

Some of this water will infiltrate through an efflux (groundwater recharge) reach and the remainder will pass downstream.

Pervious areas including forested lands are important for groundwater recharge that maintains or improves water table levels in the SCH. Anecdotal well records provided by private well owners during field work indicate a long-term decline in the water table in the SCH. The depth to water records from well driller logs does not support the trend, although the frequency of observation from the logs is less than the anecdotal well reports (BC Water Resources Atlas, Accessed May 20 2015). This inconsistency could be due to individual well characteristics, common difficulties with record keeping of the near-surface environment while drilling, periodicity and timing of observation, miscomprehension of subsurface hydrology by owners, or localized hydrologic drawdown due to extraction exceeding supply capacity of the aquifer.

Groundwater of the Brookswood aquifer within the SCH is between 0 and 15m from surface. This is most evident by the presence of groundwater ponds in the historic aggregate extraction site in the NW of the SCH. The presence of groundwater was confirmed by the surrounding saturated ground surface that covered the full extent of the excavated area. Proximity to surface means that the aquifer is vulnerable to contamination from point and non-point source pollutants, and was given a High – Highly vulnerable to contamination from surface sources rating by BC Ministry of Environment Water Protection & Sustainability Branch. The level of groundwater production from the Brookswood aquifer is also high relative to recharge, meaning that the aquifer is nearing or at capacity to provide water without decreasing the water table. Water extraction from the Brookswood aquifer will be addressed later in this document under Appendix V – Well Closures.

Groundwater from the deeper Hazelmere or Langley Upland/Inter-Till aquifers may present artesian conditions, where the hydraulic pressure in the confined aquifers is sufficient to drive water to ground surface. Under these conditions it is important to reduce groundwater waste through appropriate well management. Under section 77 of the Water Act, it is required to stop or control artesian flow that is not being utilized due to potential hazards such as erosion, flooding, or ground subsidence. Measures for handling artesian wells in the SCH are included in Section 5.1.10 – Recommendations for Well Owners.

The complexity of baseflow, recharge and groundwater is such that full treatment of the processes is not practical within the scope of this study. Golder Associates (2005) provide information on groundwater assessment within regional infiltration models of the Langley-

Surrey area, while Kerr Woods Leidal Associate (2011) deliver a scoping of an integrated stormwater management plan - which contains a water budget of the Little Campbell River Watershed. Stephens (2006) and Weight (2006) are excellent sources for comprehension of hydrogeology.

5.1.5 Change in Land Use

Land use can be managed to provide for social benefit and for natural systems, where an increase in the former has traditionally seen a decrease in the latter (Veldkamp, 2004). For example, a change in land use toward hard-surface built environments decreases infiltration and results in more rapid conveyance of stormwater via pipes and armoured channels. While it is advantageous to remove stormwater from the built environment, this type of stormwater management also reduces groundwater recharge through infiltration. Total impervious area as a percentage of total land provides an indicator of the hydrologic effect of development. %TIA is inversely correlated to:

- aquifer water table levels through a decrease of infiltration recharge;
- baseflow through decrease of local infiltration and near-surface vadose-zone transport of water; and,
- peak flow which may result in enhanced erosion and potential flooding (Ministry of Transportation and Communication, 1982).

Previous assessment by Golder Associates (2005) and Gartner Lee (1999) of the influence of land use change on surficial hydrology have demonstrated a decrease in local baseflow attributed to increased %TIA and water extraction. Golder Associates (2005) working in Langley found that current land use and associated %TIA increase has resulted in a predicted 12% decrease in baseflow from the pre-development scenario (Table2). The same numerical model of Golder Associates (2005) projected an additional 5.4% decrease in baseflow volume from the Brookswood aquifer as a result of %TIA increase due to the land use changes permitted by the Official Community Plan (OCP).

Table 2. Brookswood Aquifer Current Water Balance and OCP Build-Out (Golder Associates, 2005).

Aquifer Influx (m³/day)		Current (m³/day)	Full OCP (m³/day)	Weighted Change (%)
Boundaries	Rivers, Creeks	13,200	14,000	+1.1
	Recharge	36,800	36,800	0
Flow from Other Subsurface Geologic Units	Aquifers	1,900	1,800	-0.6
	Aquitards	18,300	17,900	+0.1
	Total	*20,200*	*19,900*	*-0.4*
Total Inflow		70,200	70,700	+0.7
Aquifer Efflux (m³/day)				
Boundaries	Rivers, Creeks, Seepage Faces	60,500	57,500	-4.3
	Minor Groundwater Use	1,100	1,900	+1.1
Flow to Other Subsurface Geologic Units	Aquifers	400	500	+0.1
	Aquitards	3,200	3,200	0
	Total	3,600	3,700	+0.1
Municipal Supply Wells	Brookswood #7	1,437	1,728	0.4
	Brookswood #9	1,903	2,592	1.0
	Brookswood #10	1,665	1,665	0
	Brookswood (Proposed)	0	1,630	2.3
	Ministry of Forests	65	65	0
	Total	*5,070*	*7,680*	*3.7*
Total Efflux		70,300	70,800	0.7
Baseflow*		47,300	43,500	-5.4

*Baseflow is the net volumetric flow to rivers, creeks, and seepage faces; calculated as the difference between outflow to rivers, creeks, seepage faces from groundwater (~60,500 m^3/day) and inflow to groundwater from Rivers and Creeks (~13,200 m^3/day).

These compounding trends are placing high demand on water produced from the Brookswood aquifer, which is currently listed as heavily developed (Government of British Columbia, 2005; Gartner Lee Limited, 1999). The limited amount of inflow from adjacent geologic units (Table 2) emphasises the importance of groundwater recharge through infiltration to sustain baseflow and meet increasing demand. This recharge requirement and general outflow of groundwater from the SCH area would make the groundwater hydrology highly susceptible to increase in %TIA (Golder Associates, 2005).

In Section 5.1.9 – Predictions and Recommendations for Groundwater) we discuss land uses that increase aquifer vulnerability or susceptibility to over production.

5.1.6 Stormwater Management and SCH Hydrology

A scoping study was conducted by Kerr Wood Leidal (KWL) in 2011 for integrated stormwater management plans (ISMPs). KWL subdivided the Little Campbell River area into seven areas, of which there are three (Sam Hill / Twin Creeks; Jacobsen / Highland Creek; and Fernridge / Campbell Heights – Figure 5 – ISMP and Recharge Areas of South Campbell Heights Study Area) of relevance to this study. The Fernridge / Campbell Heights area contains the majority of the Little Campbell River within the SCH, exclusive of the western and southern edges which are included in the Sam Hill / Twin Creeks and Jacobsen / Highland Creek ISMP areas, respectively. KWL ranked individual ISMP areas for importance while prioritizing development of ISMP, with the Fernridge / Campbell Heights, Sam Hill / Twin Creeks and Jacobsen / Highland Creeks ISMP areas ranking first, second and fourth – respectively.

Within the scoping study of these ISMP areas, KWL (2011) noted that development of the Fernridge / Campbell Heights ISMP Area to the OCP (predicted completion in 2018) would see an increase in %TIA from 7% to 46%. The predicted %TIA increase for Sam Hill / Twin Creeks (10% to 34%) and Jacobsen / Highland Creeks (3% to 22%) had a similar increase.

The ISMP Scoping Study identified a requirement to maintain a 200-year floodplain associated with the Little Campbell River in each of these ISMP areas. Additionally, the study recommended a stormwater management criterion to protect watercourse health and minimize erosion as follows:

> *"Volumetric Reduction for Environmental and Erosion Protection: Provide 25 mm of capture during a 25 mm 24-hour rainfall event through evaporation, evapotranspiration,*

> *infiltration, or reuse in poor-draining soils. This capture amount corresponds to approximately 50% of the 2-year 24-hour rainfall. This target is less onerous than the DFO guideline, but is the target recommended in the Provincial Stormwater Guidebook and has been used in a number of other Surrey projects (KWL, 2011)."*

Existing municipal stormwater and drainage criteria require that all developments and re-developments apply:

- Flood protection criteria;
- Detention criteria for flood, erosion and environmental protection;
- Erosion and sediment control bylaw standards for the protection of water quality during construction and post-construction; and
- Riparian protection and restoration using the provincial Riparian Areas Regulation and municipal bylaw(s) where appropriate.

Lastly, KWL recommended that implementation of a Little Campbell River Watershed ISMP include a suite of data collection (hydrogeology/geotechnical and drainage system inventory, as well as biodiversity and riparian inventory) and that water quality, as well as fish and benthic environment be investigated. Current implementation of the scoping study has required that the recommended interim stormwater volume reduction criterion for drainage servicing be included in the development applications and inquiries received for parcels within the study area.

5.1.7 Hyporheic Zone Hydrology of the SCH

A considerable portion of the SCH is in direct hydraulic exchange with the Little Campbell River, either gaining (influx) or losing (efflux) water volume in different reaches at various times of the year. The hyporheic zone, as the area in influx/efflux exchange with a watercourse, generally spatially correlates with the floodplain of small rivers and creeks. The exchange of soluble nutrients between the stream and soil is critical to watercourse and riparian health, as well as fish spawning (Lawrence, et al., 2013; Weight, 2008). The hyporheic zone and exchange can be reduced through lowering of water table or decrease in baseflow, as well as by degrading stream reaches.

If a stream reach is degrading or has a fluvial plain less than four times the active channel width (known as a constrained channel) there is reduced hydraulic exchange (Dahm et al. 2006). Restoration of degraded stream channels where efflux or influx is restricted should be considered as part of a regional integrated stormwater management plan. Consequently, we identify regions of degrading reaches, natural or imposed constrained channels, or other factors that may isolate or reduce the hyporheic zone in Figures 2 and 4.

5.1.8 Effects of Temperature on Fish Habitat

A primary concern for managing development in the SCH area is the effect of habitat alteration on local fish species. The Little Campbell River is known to have spawning areas for Chum Salmon (*Oncorhynchus keta*), Coho Salmon (*O. kisutch*) and Chinook Salmon (*O. tshawytscha*) (Department of Fisheries and Oceans 2015). Although field assessments have been limited in recent years, it has been noted that as many as 300 Chum and Chinook Salmon, and over 2000 Coho Salmon, can return to spawn in the Little Campbell River. The Semiahmoo Fish and Game Club maintains a hatchery on this system which annually produces about 10,000 Steelhead Salmon (O. mykiss), 35,000 Chinook Salmon, 50,000 Coho salmon and 10,000 Cutthroat Trout (*O. clarkii*) (Department of Fisheries and Oceans 2015). The hatchery suggests that more than 3,500 salmon return annually to their counting fence, although they do not provide a breakdown by species (Semiahmoo Fish and Game Club 2015). Other fish Species that are known to be present are; Prickly Sculpin (*Cottus asper*), Coastrange Sculpin (*C. aleuticus*), Pumpkinseed (*Lepomis gibbosus*), Fathead Minnow (*Pimephales promelas*), and Threespine Stickleback (*Gasterosteus aculeatus*) (British Columbia Ministry of Environment 2015). Given that Coho and Steelhead Salmon spawn in the river, it likely also serves as rearing habitat for their juveniles which spend two years in freshwater before going to sea for maturation to adulthood. The other fish species described above likely use the river throughout their life histories.

In a study of the Little Campbell River, Juteau (2008) found that oxygen concentration was only very rarely below 6mg/l. Temperatures recorded in this study also suggest that 18ºC can be exceeded for weeks at a time in the summer, particularly in reaches near the mouth of the river. The maximum recorded temperature in almost three years of monitoring of the mainstem of the Little Campbell River was 21.98º. Somewhat higher temperatures were observed in some of the tributary streams and drainage ditches. Given these observations, the mainstem of the Little Campbell River likely represents a generally favourable habitat for the rearing of juvenile salmonids, though salmon may move within the system in an effort to find cooler waters in the summer. Most of the other species found in the system can tolerate similar or somewhat higher temperatures and lower oxygen concentrations.

The above considerations suggest that some survey work to delineate the summer distribution of salmonids in this area would be useful in guiding development plans. Identification of such habitats would be helpful in planning riparian buffers around favoured salmonid habitats to provide shade and food. Riparian vegetation is beneficial to fish production and survival because the cover provides shade which keeps temperatures lower and helps juvenile fish avoid common local avian predators such as Great Blue Herron (*Ardea herodias*), and Common Mergansers (*Mergus merganser*). The vegetation also provides a habitat for insects and other invertebrates which are an important food source for juvenile salmonids and other fish in the river.

5.1.9 Evaluating the Impact of Land Use Change on Groundwater

5.1.9.1 Component of Land Use Critical to Baseflow

Local and perched water table levels are critical to baseflow. The higher the local water table, the greater the net volume of water that flows to surface through rivers, creeks, wetlands and seepages. Local water table is linked to groundwater recharge, which is dominated by rainfall and infiltration in the SCH. Changes in land use that decrease infiltration are increased %TIA and alteration of stormwater pathways resulting in rapid conveyance to surface watercourses. Secondary influences of land use change on local water table include alteration of flow lines through excavation of the land surface and extraction of water from the Brookswood aquifer.

%TIA is the component of land use change that redirects rainfall away from groundwater, reducing recharge from developed areas. Regional impacts are best addressed through managing %TIA and mitigating %TIA increases using integrated stormwater management planning. The %TIA is currently increasing under current land use trends, and has been projected to increase under the Official City Plan of Surrey (KWL, 2011). The SCH currently has a low amount of %TIA, primarily from road surfaces and agricultural structures. A shift in land use from agriculture to industrial, commercial and medium density residential – as well as a change in agricultural land use toward greenhouses – could dramatically increase the %TIA in the SCH area.

We recommend that the City of Surrey manage %TIA associated with development through permitting requirements that stipulate no off-parcel stormwater flow resulting from increased %TIA.

To mitigate increasing %TIA and preserve current baseflow for all areas, the regional groundwater table will need to be maintained through management of stormwater. Stormwater management for the SCH that promotes retention and volumetric reduction of stormwater through infiltration on the landscape would be essential to preserve contribution to baseflow in areas surrounding the Little Campbell River. Options for retention and volumetric reduction include increased landscape material on the pervious portion of parcels, bioswales or constructed infiltration ponds.

We recommend that the City of Surrey require developers to use a retain, reduce, infiltrate approach to stormwater flow management in order to mitigate increased %TIA associated with development, which includes existing and previously recommended integrated stormwater management criteria noted in KWL (2011).

Excavation of surficial material through processes such as aggregate extraction can alter local flow lines. Altered flow lines may redirect subsurface flow away from wetlands, decrease baseflow, shorten flow lines or have no discernable consequence.

The active and historic extraction areas do not appear to have suppressed the local groundwater table, evident by the water table at surface in the northwest historic extraction site. These groundwater fed ponds in this area provide habitat and aesthetic value, similar to Latimer Lake, but may increase vulnerability of the Brookswood aquifer to surface contamination. The balance of value for ecologic and human service against groundwater protection will have to be considered before identifying a course of action for areas of SCH where the water table is at or near surface due to historic aggregate extraction.

We were able to observe that aggregate extraction within the SCH has shortened flow lines between land surface and groundwater table/seepage face by a reduction in distance travelled. Correspondingly, the ongoing aggregate extraction in the southeast SCH has shortened the residence time of water in the subsurface between infiltration and emergence in the nearby incised floodplain channel of the Little Campbell River. A study of local groundwater flow would be required to fully resolve the impact of aggregate extraction.

We recommend the commissioning of near surface hydrogeology studies to determine the impact of historic aggregate extraction sites on local water table and groundwater flow in the South Campbell Heights that will guide future efforts to reduce vulnerability of the Brookswood aquifer to surface contamination.

5.1.9.2 Impact of Land Use Change on Wetland Exchange with Groundwater

Wetlands within the SCH are supplied by surface water from creeks and by baseflow in varying proportions. A change in land use will alter the volume and rate of rainfall infiltrating to supply baseflow to these wetlands. Fortunately, some of these wetlands can rely on surface water supply if a localized increase in %TIA reduces baseflow.

Temperature influence from baseflow is localized, while the critical nutrient and oxygen exchange services of the hyporheic zone is dependent on baseflow. Therefore, reduction of baseflow to wetlands will result in temperature increase, potential decrease of wetted area in dry periods, and potentially stagnation or other decrease in water quality.

We identified the humic soils and ponds along the upper reaches of the Little Campbell River as being primarily baseflow supplied and susceptible to %TIA increase in the uplands to the east. The Jacobsen Creek wetlands are supplied by a balanced surface water flow from ditching to the north and by Jacobsen Creek to the south, as well as baseflow from the terminal edge of the Brookswood aquifer to the north. The area surrounding this wetland is pervious and local infiltration supplies baseflow. However, the volumetric exchange with groundwater is currently unknown for this wetland.

There are predominantly groundwater supplied ponds in a former aggregate quarry in the northwest of the SCH. The groundwater supplied ponds will be influenced by fluctuations of the groundwater table, including artificial depression through drawdown surrounding a groundwater production well.

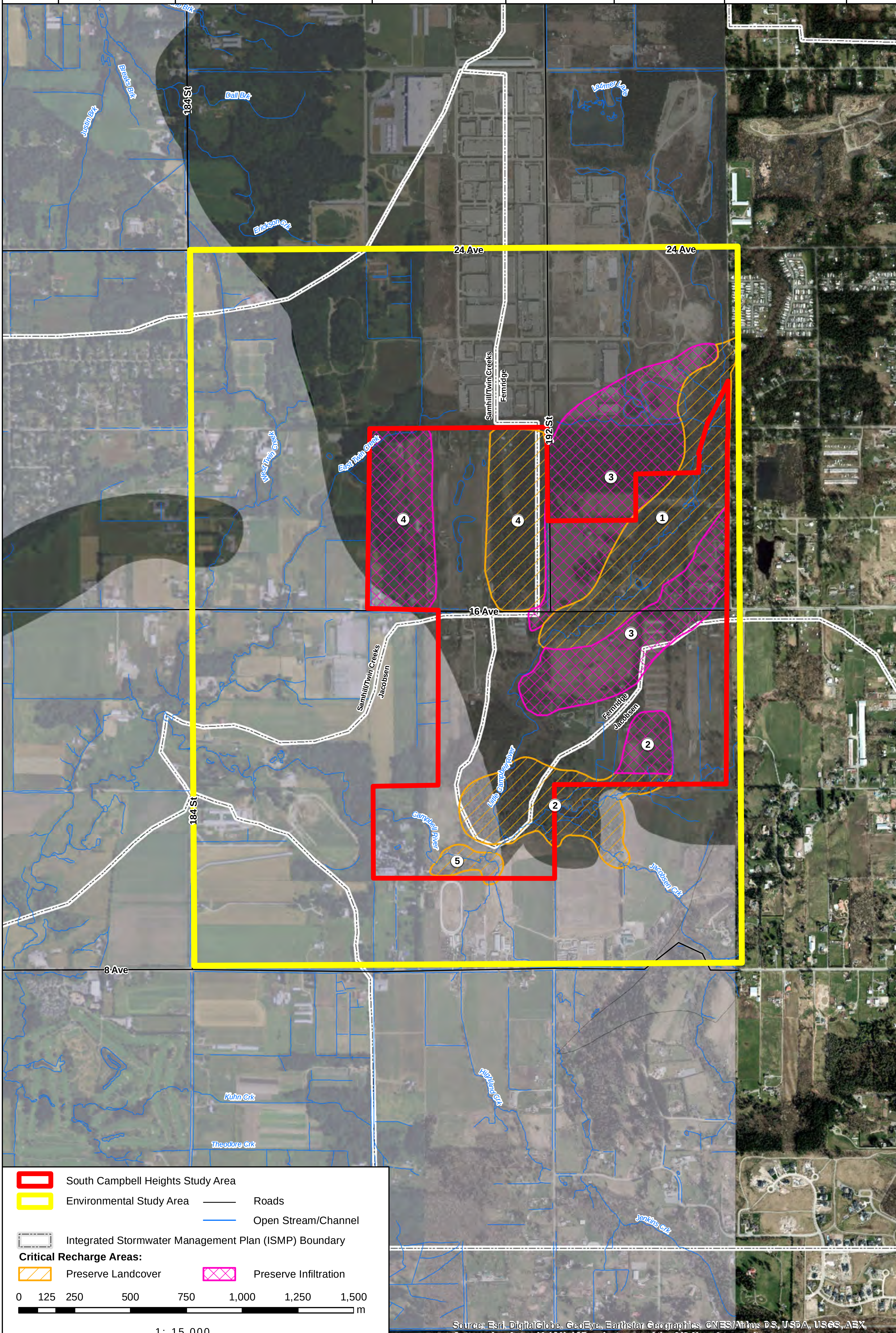
We recommend restricted surface and groundwater extraction in the catchment area of wetlands to ensure the local water table is preserved for hyporheic exchange with groundwater.

5.1.9.3 Importance of Specific Natural Areas in the SCH to Local Groundwater Recharge

To evaluate how land use change will impact groundwater in a local scale, we have delineated specific land types that provide groundwater recharge capacity for the SCH and discuss how development will alter the baseflow (Figure 5 – Integrated Storm Water Management Plan and Recharge Areas of South Campbell Height Study Area).

FIGURE 5. ISMP and Recharge Areas of South Campbell Heights Study Area

LOCATION:	PROJECT:	CLIENT:	MAP DATE:	DRAWN BY:	DOSSIER:
Surrey, BC	Environmental Assessment	City of Surrey	6/11/2015	Anna Jeffries	15.0073



We recommend that the recharge areas critical to baseflow in the SCH be considered as greenspace, or areas of special concern for watershed and groundwater health, and be preserved through development planning.

1 *We have identified the following critical recharge areas in the SCH:Riparian area of the constrained Little Campbell River*. The riparian area and floodplain of the Little Campbell River, particularly where constrained in the upper reaches, within the SCH is of importance to baseflow due to the concentration of groundwater flow through local topography and large hyporheic zone. Following the Riparian Area Regulation (RAR), no development will occur in the constrained reach of the Little Campbell River. However, land use change outside of the 15m RAR setback from gully edge may decrease infiltration and increase local hydrograph peak if stormwater is directed toward the watercourse. While there is a riparian setback criteria, it is pre-dated by residences established within 15m of stream center, let alone of the gully crest, in this constrained reach of the Little Campbell River.

2 *Riparian area of Jacobson Creek and associated wetlands*. Since the associated wetland is in part supplied by the Brookswood aquifer which delivers baseflow from the north, this area will be susceptible to increase in %TIA south of 16 Avenue. The riparian coverage and integrity should be maintained under land use change through existing RAR criteria or larger buffers as delineated by the Biodiversity Conservation Strategy (see section 5.3.3).

3 *Upland area from the upper reach of the Little Campbell River*. The upland areas surrounding these upper reaches are also contributors to baseflow due to the ancient incision into the thick glacial deposit, which now contains the Brookswood Aquifer. The high-moisture regime required for accumulation of organic soils and active seepage along the floodplain embankment evidence emerging groundwater. Land use in the upland area will influence the amount and timing of overland and baseflow recharge to the Little Campbell River. The adjacent riparian area may decrease due to a lack of moisture which reduces hyporheic exchange and degrades riparian health. The reducing riparian coverage and integrity would result in water temperature increase.

Upland Area Surrounding Historic Aggregate Extraction in the Northwest SCH:

The eastern side of this area is currently forested and provides a good groundwater recharge service, although a portion of the recharge is quickly brought to surface through seepage from the adjacent embankment. To the west of this area is a small stream and pond whose catchment area extends outside of the SCH study area. This area contributes baseflow to the adjacent stream and pond, as well as providing recharge to local groundwater.

1 Riparian area of Highland Creek. This portion of the Highland Creek is primarily supplied by surface water emerging from the slope base of regional highlands to the south. Local land use change should not significantly impact this watercourse if RAR setback criteria are observed due to the limited reliance on baseflow.
2 Riparian area of the non-constrained portion of the Little Campbell River. The lower reaches, in the southwest of the SCH, are not constrained and as such the riparian area is more representative of the hyporheic zone where active exchange with groundwater occurs. Some increase in %TIA would be sustainable; however stormwater management plans should be in place to ensure optimal volumetric retention and infiltration.

Instrumentation and data gathering to evaluate groundwater flow of these areas would better define the requisite area to preserve sufficient contribution to baseflow.

5.1.9.4 Predictions and Recommendations for Groundwater Integrity

Groundwater integrity is the combined capability of regional groundwater to supply water volume of sufficient quality to preserve natural systems and provide for human extraction and use.

Agricultural areas with potential point source groundwater and surface water pollutants (e.g., Agricultural buildings, tanks, etc.) would need to be evaluated for Agricultural Building Setbacks from Watercourses in Farming Areas[2], particularly if the Brookswood aquifer is to be used for municipal water supply. An aerial photo examination of the SCH area identified few existing buildings that would need field verification to determine if corrective measures would be needed.

With a change from the current agricultural land use, there may be reduced water quality threats associated with manure, fertilizer and pesticide applications. Nutrient loading and fecal coliform levels, as common agriculture related contaminants, were last evaluated by the City of Surrey throughout the Little Campbell River in 2008 (Province of BC, 2008) and are currently being monitored by the A Rocha non-government organization.

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[2] http://www.agf.gov.bc.ca/resmgmt/publist/800Series/823400-1_Agriculture_Building_Setback_Factsheet.pdf

If fecal coliform is found to be elevated, a source tracking study to identify contributors could be conducted to best target and provide mitigation options. Some options would include the Code of Agricultural Practice for Waste Management[3], and the Agricultural Building Setbacks from Watercourses in Farming Areas[4].

We strongly recommended that the fecal coliform testing and nutrient level monitoring program continue and expand in collaboration with ongoing efforts from the A Rocha non-governmental organization.

Current agricultural practices in the Surrey area are shifting toward increased %TIA (e.g. greenhouse, covered equestrian centers, etc.) activities. Furthermore, agricultural land conversion to other land use is common, where subsequent development will increase %TIA. Since the SCH is largely an agricultural area, a shift in agriculture practice or change in land use and development would alter the regional %TIA. As the current agriculture land could see a considerable regional increase in %TIA, individual parcel stormwater practices should be inventoried and evaluated to guide development of future agriculture land stormwater best management practices.

We recommended that issuance of building permits for agricultural impervious surfaces (e.g. greenhouses, equestrian rings, etc.) include a water and stormwater management questionnaire and current management practices within the SCH.

Lastly, the shift toward industrial or commercial land use will see point-source pollution issues – typically hydrocarbons – also be a consideration for the near surface Brookswood aquifer. Implementation of low impact design and on-site multi-tiered stormwater management would decrease the risk to the vulnerable Brookswood aquifer.

We recommended that the City of Surrey consider specific guidance on multi-tiered treatment of stormwater for industrial or commercial land in the SCH to enhance water infiltration and quality.

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[3] http://www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/131_92.htm

[4] http://www.agf.gov.bc.ca/resmgmt/publist/800Series/823400-1_Agriculture_Building_Setback_Factsheet.pdf

5.1.10 Recommendations for Well Owners

Any well owners within agricultural areas should be made aware of the Environmental Farm Plan program of the BC Ministry of Agriculture and Lands coupled with the BC Agriculture Council (http://www.bcac.bc.ca/efp_documents.htm).

Enhancing riparian buffers around watercourses and wetlands will improve interception of potential non-point source contaminants on the Columbia and Sunshine/Lynden soil series. If wells are located within the northwest or southwest of the SCH, owners should consider enhanced riparian buffers to minimize potential contaminant flow into groundwater from watercourses or wetland hyporheic zones.

The Brookswood aquifer is vulnerable to surface contamination. Consequently, any active potable groundwater well drawing from the Brookswood aquifer should have a groundwater Well Protection Plan. Private well owners or drillers are not required to develop a well protection plan under the Water Act: Groundwater Protection Regulation (B.C. Reg 91/2009). However, well owners and professionals can develop such a plan through available government resources such as the Ministry of Environment Well Protection Toolkit:
http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/well_protection/wellprotect.html.

We strongly recommend that the City of Surrey assist well owners drawing from the Brookswood aquifer develop a Well Protection Plan.

We recommend that well owners drawing from deeper aquifers consider a Well Protection Plan.

Well owners drawing from the Hazelmere and Langley Upland aquifers should also consider Well Protection Plans; however the transfer of contaminants to these deeper units is limited by adsorption in the subsurface. In the case of certain contaminant types, such as dense non-aqueous phase liquids, there is very little management possible and groundwater protection efforts for these contaminants should focus on prevention and mitigation.

The planned extension of municipal water supply to residential, industrial and commercial units within the SCH would reduce extraction from the Brookswood aquifer. Closure of both potable and irrigation wells drawing from the Brookswood aquifer would improve the baseflow to surficial waters (watercourses, ponds, wetlands and seepages) by increasing the height of the local water table.

Owners of artesian wells who are not utilizing the flow to supplement wetlands or watercourses are required to prevent the flow through capping or permanent closure of the well. Capping is the easiest solution until the five-year not in use time limit is met, at which point the well should be decommissioned or closed.

A well closure checklist can be found in Appendix V. In BC, deactivation and closure of wells is regulated: the specific regulation is presented in Appendix VI.

5.1.11 Summary of Recommendations

A “Class D” costing of all recommendations made hereafter is included in Appendix XIV.

5.1.11.1 Recommendations for Preservation and Enhancement of Baseflow

We recommend that the City of Surrey manage percent total impervious area associated with development through permitting requirements that stipulate no off-parcel stormwater flow resulting from increased percent total impervious area.

We recommend that the City of Surrey require developers to use a retain, reduce, infiltrate approach to stormwater flow management in order to mitigate increased %TIA associated with development, which includes existing and previously recommended integrated stormwater management criteria noted in KWL (2011).

We recommend the commissioning of near surface hydrogeology studies to determine the impact of historic aggregate extraction sites on local water table and groundwater flow in the South Campbell Heights that will guide future efforts to reduce vulnerability of the Brookswood aquifer to surface contamination.

5.1.11.2 Recommendations to Maintain Groundwater Exchange with Wetlands

We recommend restricted surface and groundwater extraction in the catchment area of wetlands and associated watercourses to ensure the local water table is preserved for hyporheic exchange with groundwater.

5.1.11.3 Recommendation for the Identified Critical Recharge Areas

We recommend that the recharge areas critical to baseflow in the SCH be considered as greenspace, or areas of special concern for watershed and groundwater health, and be preserved through development planning.

5.1.11.4 Groundwater Integrity Recommendations

We strongly recommended that the fecal coliform testing and nutrient level monitoring program continue and expand in collaboration with ongoing efforts from the A Rocha non-governmental organization.

We recommended that issuance of building permits for agricultural impervious surfaces (e.g. greenhouses, equestrian rings, etc.) include a water and stormwater management questionnaire and current management practices within the SCH.

We recommended that the City of Surrey consider specific guidance on multi-tiered treatment of stormwater for industrial or commercial land in the SCH to enhance water infiltration and quality.

5.1.11.5 Recommendations to Well Owners

We strongly recommend that the City of Surrey assist well owners drawing from the Brookswood aquifer develop a Well Protection Plan.

We recommend that well owners drawing from deeper aquifers consider a Well Protection Plan.

5.1.11.6 Recommendation for Well Closure

We recommend that the City of Surrey consider bylaws regarding the closure of private wells after connection to municipal supply, using the Model Well Regulation bylaw provided by the Ministry of Environment.

5.2 Biodiversity

Our assessment of the biodiversity values in the study area first describes the general vegetation and species composition (focusing on species at risk) in the study area, then reviews results of assessments of each Corridor and Hub described in the Biodiversity Strategy. The Biodiversity Conservation Strategy is a key document intended to guide proposed development in Surrey and the field verification of the Hubs and Corridors it identifies is one of the main contributions of this assessment.

5.2.1 Vegetation

The BC Ecoregion Classification and the Biogeoclimatic Ecosystem Classification (BEC) systems offer frameworks for describing the variation of vegetation, climate and topography in the study area. Ecoregions and biogeoclimatic zones represent the broad scale regional and climatic landscape units.

The Little Campbell River study area is situated in the City of Surrey within the Lower Mainland Ecoregion within the Georgia Depression Ecoprovince, in the Fraser Lowland (FRL) Ecosection (Demarchi, 1996). Temperatures throughout the area are modified by the ocean and the Strait of Georgia (Demarchi, 1996). The Ecosection has among the most hours of sunshine in the Province and perhaps the most important factor affecting terrestrial ecology in this area is the summer moisture deficit, which arises from the relatively dry summers and moist, mild winters.

The Little Campbell River is situated within the Coastal Douglas-Fir (CDF) biogeoclimatic zone[5] in the Moist Maritime subzone variant (CWHmm1). The CDFmm1 is located adjacent to the Coastal Western Hemlock xm1 (very dry maritime) biogeoclimatic variant. The common tree species are Douglas-fir, western hemlock, and western redcedar; however, the location of the project, combined with the forest succession and disturbance factors, leads to a variety of vegetation and ecosystem types.

[5] The Biogeoclimatic Ecosystem Classification (BEC) system is a framework that groups similar sets of landscapes into a site classification. Sites are classified on their potential to produce similar vegetation communities within similar environmental site conditions. Site series are representative ecosystems in each biogeoclimatic subzone in the Province. Site series are specific to a subzone and primarily correspond to forested ecosystems that repeat across each biogeoclimatic subzone. The typical site conditions, such as soil, terrain and climate combined with the interaction of vegetation, animals and insects make up the ecosystems / site series (Green & Klinka, 1994). Additional non-forested ecosystems, such as wetlands, are also based on the BEC system (Mackenzie & Moran, 2004).

The CDFmm1 covers only the southeast side of Vancouver Island and some of the southern mainland coast. The temperature and climate in the CDFmm1 are generally warm and dry in the summer months with moist, mild winters (Green & Klinka, 1994).

Before European colonization the area was presumably covered by mature forests of Douglas-fir, western redcedar, and western hemlock. These forests began to be modified by Europeans in the nineteenth century. Relatively low human density in the area has permitted remnant patches of forest habitat to re-establish; in addition, agricultural use of the land creates some field habitats. As such, the potential for urban wildlife to occur throughout and beyond the boundaries of the study area is highly likely.

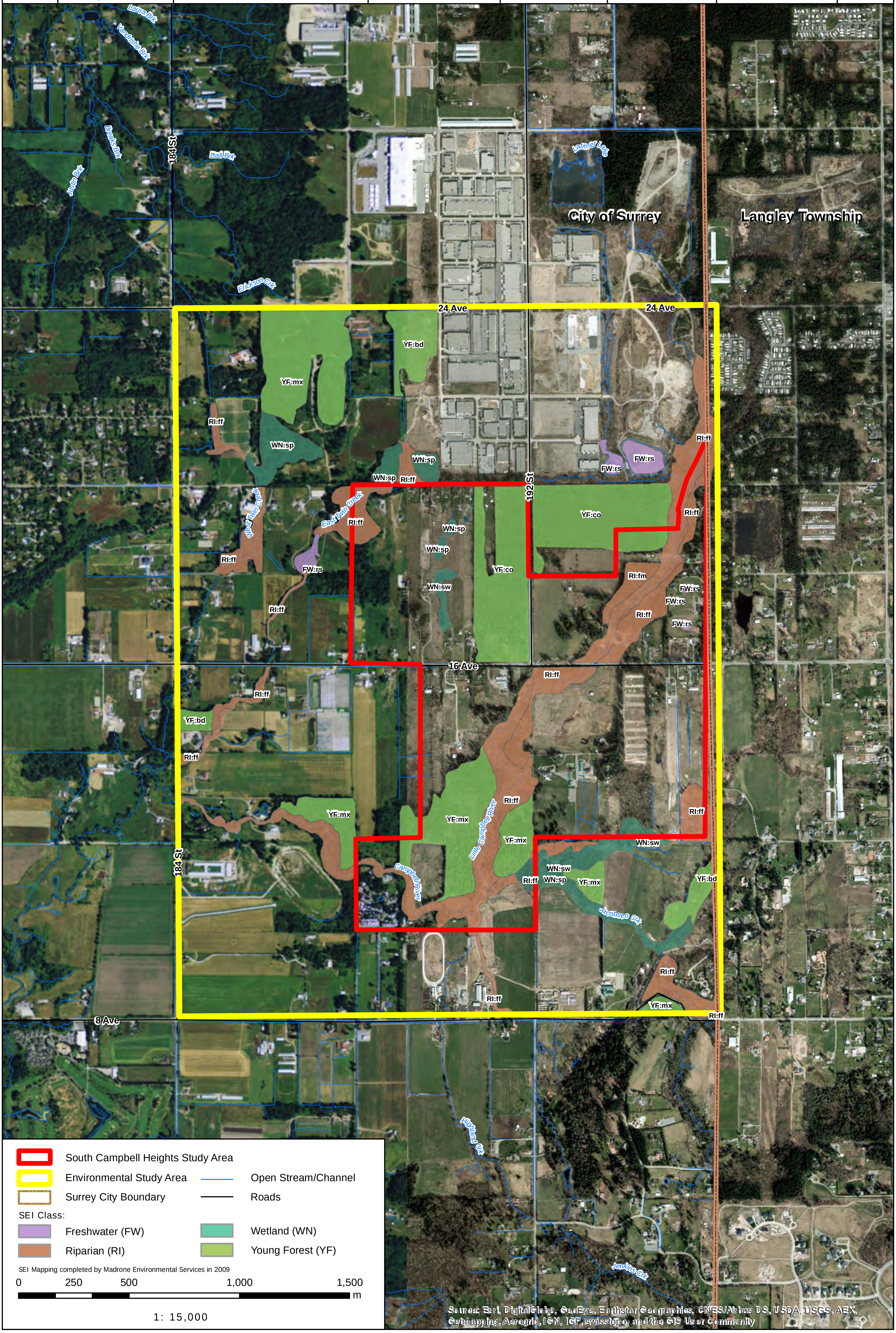
5.2.1.1 Main Vegetation Types

The short duration of the project did not allow us to undertake full TEM mapping of the study area. Rather, we used Sensitive Ecosystem Mapping that Madrone completed for Metro Vancouver during 2010, then field checked as many forested polygons as possible within the time frame allotted. Below we describe the agricultural land, residential land, then describe the forests and more natural areas that are the main focus of this assessment.

The following SEI map (Figure 6, Appendix VII) provides more detail within these categories.

FIGURE 6: Sensitive Ecosystem Inventory (SEI)Mapping within Study Area

LOCATION:	PROJECT:	CLIENT:	MAP DATE:	DRAWN BY:	DOSSIER:
Surrey, BC	Environmental Assessment	City of Surrey	6/11/2015	Anna Jeffries	15.0073



Agricultural Land

Agricultural land reserve is present mainly along the edges of the study area because the middle area was not zoned “agricultural” (see Figure 7). Nonetheless, considerable non-agricultural land in the environmental study area is zoned for agricultural use. The majority of the land appears to be used as hay meadow and/or pasture. Hobby farms are plentiful throughout the area. Horse operations and greenhouses are typical uses of larger parcels. In general, the northern half of Little Campbell River study area is less intensively farmed than the lowlands to the south.

Rural areas contain some vegetation and habitat value from hedgerows and remnant patches of forest. Tree cover on some farms is low, as would be expected in farmland; however, relatively large areas of undeveloped land that has abundant forest cover does occur where streams intersect back portions of properties. These patches of remnant forest trees are generally distributed at the back-ends of properties that front on 8th and 16th Avenues. In many areas, they form large irregular polygons of forest that are shared by several properties. An example of these areas is identified as Hub O in the Biodiversity Conservation Strategy, where the second-growth forest contains complex canopy structure, a mix of species, and many large trees (a meter or more in diameter) (See Figure 10 Hubs and Corridors).

Residential Land

The Little Campbell River study area, although largely rural and agricultural, also contains some residential lots. These lots are mainly near the Langley border and back onto the Little Campbell River.

Tree cover in residential areas tends to be high, in part because buffers along the river have been respected. Many properties also have large trees in their front yards. These are large conifers, mainly Douglas-fir and western redcedar which established during or after logging and are generally between 80 and 120 years old, with diameters in the range of 60 cm to 140 cm and heights of 25 m to 35 m. (see Figure 12 Large trees).

Mature Forested Land

No old growth forests exist in the study area, but second growth forests are entering the mature seral stage. Forests in the study area are primarily coniferous or mixed conifer-deciduous forest. Some areas, particularly beside streams and wetlands, have deciduous cover (in decreasing order of abundance: red alder, paper birch, black cottonwood, bigleaf maple and willow species). Most of these areas appear to have been under continuous deciduous forest cover for 80 to 120 years.

MADRONE environmental services ltd.	FIGURE 7: South Campbell Heights Project Study Areas and Agricultural Land Reserve Boundary				
	LOCATION: Surrey, BC	PROJECT: Environmental Assessment	CLIENT: City of Surrey	MAP DATE: 6/11/2015	DRAWN BY: Anna Jeffries	DOSSIER: 15.0073

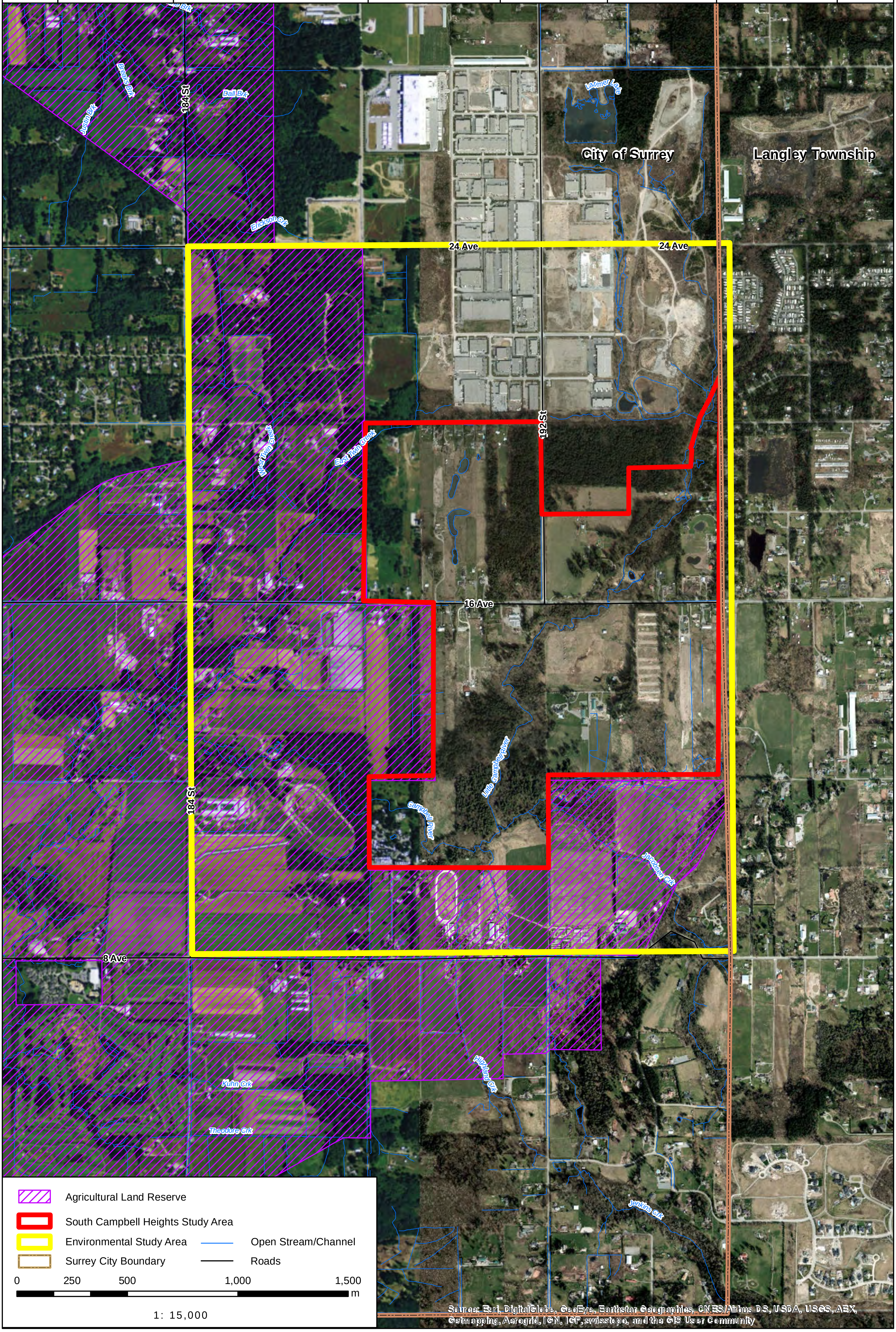


Photo 3. Typical deciduous stream-side vegetation.

Some polygons can be described as mixedwood stands, containing some mixture of coniferous and deciduous cover (Photo 3). As well, there are large stands of predominantly coniferous forest, on City land, farmland and even on residential lots (see Figure 12 Large trees). Forest site conditions are typically moist to dry with medium nutrient status. On these sites, Douglas-fir often dominates the canopy with lesser contributions of grand fir, and western redcedar, and broadleaved species such as red alder and bigleaf maple. In richer, moister sites, western redcedar dominates the overstory with more hemlock and cottonwood in the mix.

Photo 4. Typical mature forest vegetation.

We consider the young forests and mature stands (structural stage 5 and 6; 50 to 100 years old, photo 4) that dominate the study area to be of high value for maintaining biodiversity. These forests, particularly those in structural stage 6, already have abundant large trees and, if protected, will recruit to old growth in the future. Currently, these forests provide high habitat value for many birds, mammals and other wildlife. The forest is used in many ways by numerous species and in many different life stages. A dead tree component is very rare in younger forests in the lower mainland, but is quite abundant in the remnant forest patches in the study areas. These dead and dying trees provide food and shelter for cavity using species. Other species, such as bats or nuthatches, nest or seek cover behind loose bark on dead or dying trees; whereas amphibians and invertebrates use shedding bark or dead trees as cover once they fall to the ground.

Most of the forest is in structural stage 6. The areas in structural stage 5 provide less habitat values due to the closed canopy and lack of understory diversity and richness; however, habitat richness increases as these forests develop through structural stage 6 (typically beyond 60 years). Gradually the canopy differentiates; some trees die, creating gaps, dead standing trees and coarse woody debris. These processes create more diversity that will support a wider range of wildlife species. The value of second-growth forests in structural stage 5 is not only for their present habitat condition, but also for the habitat value that will be gained as they age and develop.

Conservation of biological diversity can be improved when forest reserves are protected and managed to reduce the effects of fragmentation and to provide connectivity between developed lands (see discussion under Corridors and Hubs). The Hubs and Corridors discussion in section 5.3 includes a more in depth description of the forested conditions and connections in the study area and how they affect conservation priorities.

Young Forest or Shrub

Young forest or shrub lands are areas that have been cleared in the decades since the 1920's, and now support pole or shrub size deciduous forest consisting mainly of red alder; conifers are rare in these young forests.

This land cover is unusual in the Little Campbell River study area, but some polygons exist to the north of Hazelmere RV Park and to the east of the thoroughbred farm on 8th Avenue (18923 8th Avenue).

Photo 5. A stand of pole-size red alder probably established after this area was cleared, then abandoned, 20 to 40 years ago. There are no other tree species including conifers. Over time, the canopy will start to break up but conifer establishment is not assured due to the strong response of understory brush species.

5.2.1.2 Environmentally Sensitive Areas

No ESAs have been identified in the study area.

5.2.1.3 Rare Plants

The study area within the CDFmm1 variant has the potential to contain 2 rare plant species (Appendix VIII rare plants); however, the Little Campbell River study area contains no records of occurrences of species of conservation concern (BC Species and Ecosystem Explorer [CDC], 2015). We observed no rare plants during our fieldwork; however, this does not conclusively rule out their occurrence. A more detailed vegetation survey would be required to ensure that rare plants are not present.

Plant species-at-risk, like other species at risk, are protected from harm by the federal Species-at-Risk Act and the provincial Wildlife Act. Plant species-at-risk and their habitat potentially occur within the study area and therefore their life history requirements must be considered. It is important to determine the potential for, and needs of, species-at-risk during planning to mitigate the inherent pressure of development and to protect the future viability of biodiversity in the Little Campbell River study area. More detailed surveys should be done before any developments are approved.

5.2.1.4 Rare Ecosystems

All of the forested ecosystems mapped in the study area are considered at-risk in BC, including 23 red-listed and 4 blue-listed site series (Appendix IX). These ecosystems are threatened or of special concern due to development and forest harvesting pressures throughout the south coast of BC. The majority of these forests are mature mixed coniferous and deciduous forests. Although they are not yet old growth, they are still classed as red or blue listed ecosystems. It cannot be overemphasized how unusual it is to have complex forest structures with high densities of large trees within the lower mainland – the Hubs and Corridors identified in the study area have some exemplary, rare, highly valuable forests that merit protection.

A list of potential rare ecosystems for the CDFmm subzone can be found in Appendix IX

5.2.1.5 Wildlife Trees

Dead and dying trees (snags) provide habitat for cavity nesting birds, small mammals and bats. After they have fallen, the coarse woody debris provides security cover, travel pathways, and dens for small mammals in addition to recycling nutrients in the forest ecosystem.

The most important tree species for cavity nesters are western redcedar, Douglas-fir and black cottonwood (Fenger *et. al*. 2006). These species are important for their size and, in the case of Douglas-fir and redcedar, the longevity of their presence on the forest floor. Other important species are bigleaf maple, black cottonwood, paper birch and red alder, but these decay much faster and persist for a shorter time. Nonetheless they are preferred nesting sites for many cavity-using species, in part because they often have heart rot earlier than coniferous species, making them easier to excavate.

Wildlife trees were observed in the all the mature forest patches, but the abundance of snags in various stages of decomposition, and thus condition, varied from place to place. Our field reconnaissance confirmed evidence of standing snags, cavity nests, woodpecker foraging activity and plentiful coarse woody debris. Forest patches showing this type of evidence of wildlife activity are highly valued resources for biodiversity. The forested patches in the study area are highly suitable habitat for birds, small mammals and bats. Wildlife trees are a significant factor in the valuation of ecosystem health for wildlife.

5.2.1.6 Weeds and Introduced Vegetation

Weeds are considered unwanted plants. Some weeds are noxious or invasive; others are less of a problem. Noxious weeds are typically non-native plants that have been introduced to British Columbia without the insect predators and plant pathogens that help keep them in check in their native habitats. For this reason and because of their aggressive growth, these alien plants can be highly destructive, competitive and difficult to control.

A number of introduced weedy plant species and escaped ornamental vegetation were observed during the field visits, mainly along roadside ditches, exposed stream edges, old fields, rural residences and forest clearings. Introduced plant species include Himalayan blackberry (*Rubus discolor*), Canada thistle (*Cirsium arvense*), scotch broom (*Cytisus scoparius*), tansy ragwort (*Senecio jacobaea*), Policeman's helmet (*Impatiens glandulifera*), small touch-me-not (*Impatiens parviflora*), clovers (*Trifolium* spp.), field bindweed (*Convolvulus arvensis*), Japanese knotweed (*Polygonum cuspidatum*), English ivy (*Hedera helix*), and English holly

(*Ilex aquifolium*). On abandoned fields and in many riparian zones we noted well-established, introduced grass species, especially canary reed grass (*Phalaris arundinacea*).

The B.C. Weed Control Act imposes a duty on all land occupiers to control designated noxious plants. The purpose for the Act is to protect our natural resources and industry from the negative impacts of foreign weeds (BC Weed Control Act 1985); however, it is up to the City and property owners to decide how far the introduced vegetation needs to be managed. Some weeds may be tolerated for the long-term, but some will need continuous management to prevent potential changes to native vegetation communities.

Of the species listed as noxious weeds on the BC Weed Control Act (Ministry of Agriculture and Lands, 2007), the most commonly seen on the study area were Japanese knotweed and Canada thistle. Each reproduces aggressively and is difficult to eradicate. Tansy ragwort is also on the noxious weed list because it is toxic to cattle, but it is only present in small numbers in the study area.

A detailed invasive plant survey would need to be carried out in order to assess the threats and potential management recommendations.

5.2.2 Wildlife Habitat

Wildlife in the study area includes a wide range of species, some designated 'at risk'. Many studies by A Rocha, academics and naturalists have identified species in the area (see Appendices XII which has a partial list of species at Hub I). The study area also is home to many fungi and invertebrates, some of them also rare. These small, often overlooked, species are among the most important in the ecosystem, shredding and decomposing organic materials to create the basis for all food chains. Many small mammals, amphibians, reptiles and birds inhabit the forests and fields. The largest animals are bear and deer, though bears are uncommon. As habitat becomes fragmented into smaller pieces, populations of large animals and those sensitive to disturbance or predation from edges decline. Maintaining large core areas (Hubs) helps maintain some of these species over time, but many species historically present in the area that require large forest areas or those that need old trees are now rarely or never found in the lower mainland (e.g., cougar, marbled murrelet).

In terms of species at risk, the study area is potentially home to 22 taxa of endangered wildlife (Table 3). Several bat species potentially in the area are not listed but designated CF2 because there is conservation concern but insufficient data to list them informatively (e.g., Californian myotis, Silver-haired bat). Assessment revealed 13 endangered taxa confirmed present and 4 likely extirpated from the area. Presence of some small wildlife species could not be assessed within the study period (e.g. bats). We provide our assessment for all taxa in Table 3 and Appendix XI.

Table 3. Wildlife Species at Risk[a] Expected in the Study Area

Common Name	Scientific Name	Provincial Status[abc]	Federal Status
INVERTEBRATES			
Blue dasher	*Pachydiplax longipennis*	*Blue/CF4*	*Not assessed*
Dun skipper	*Euphyes vestris*	*Red/CF2*	*Threatened (May 2013)*
Monarch butterfly	*Danaus plexippus*	*Blue/CF2*	*Special Concern (April 2010)*
Audouin's night-stalking tiger beetle[c]	*Omus audouini*	*Red/CF1*	*Threatened (Nov 2013*
Oregon forestsnail	*Allogona*	*Red/CF*	*Endangered*
Pacific sideband snail	*Monadenia fidelis*	*Blue/CF2*	*Not Listed*
Puget Oregonia Snail	*Crystomastix devia*		*Extirpated (Nov 2002)*
AMPHIBIANS & REPTILES			
Red-legged frog	*Rana aurora*	*Blue/CF1*	*Special Concern (Nov 2004)*
Western toad	*Anaxyrus boreas*	*Blue/CF2*	*Special Concern (2012)*
Painted turtle	*Chrysemys picta Pacific coast pop.*	*Red/CF2*	*Endangered (2006)*
FISH			
Salish sucker	*Catostomus sp. 4*	*Red/CF1*	*Threatened (Nov 2012)*
BIRDS			
Band-tailed Pigeon	*Patagioenas fasciata*	*Blue/CF2*	*Special Concern (Nov 2008)*
Barn Owl	*Tyto alba*	*Blue/CF2*	*Threatened (Nov 2010)*
Barn Swallow	*Hirundo rustica*	*Blue/CF2*	*Threatened (May 2011)*
Great Blue Heron fanniini	*Ardea herodias fannini*	*Blue/CF1*	*Special Concern (April 1997, 1998)* [d]

Northern Goshawk laingii	*Accipiter gentilis laingii*	*Red/CF1*	*Threatened (May 2013)*
Olive-sided flycatcher	*Contopus cooperi*	*Blue/CF2*	*Threatened (Nov 2007)*
Peregrine Falcon anatum	*Falco peregrinus anatum*	*Red/CF2*	*Special Concern (Apr 2007)*
Western Screech-owl kennicottii	*Megascops kennicottii kennicottii*	*Blue/CF1*	*Threatened (May 2012)*
MAMMALS			
Keen's myotis	*Myotis keenii*	*Blue/CF 1*	*Data Deficient (Nov 2003)*
Pacific water shrew	*Sorex bendirii*	*Red/CF1*	*Endangered (April 2006)*
Snowshoe hare	*Lepus americanus washingtonii*	*Red/CF1*	*Not assessed*
Townsend's big-eared bat	*Corynorhinus townsendii*	*Blue/CF2*	*Not assessed*
Trowbridge's shrew	*Sorex trowbridgii*	*Blue/CF2*	*Not assessed*

[a] See Appendix X for a description of conservation status ranking criteria.

[b] CF indicates BC's Conservation Framework ranking that assigns a species or ecological community a conservation priority of 1 (highest) through 6 (lowest) for each of the three Conservation Framework Goals. The three goals of the Conservation Framework are:

1. Contribute to global efforts for species and ecosystem conservation
2. Prevent species and ecosystems from becoming at risk
3. Maintain the diversity of native species and ecosystems

The ranking summarized is the highest ranking received for any of the three goals.

[c] Species with two dates indicate a reassessment

[d] Unlikely to be present, but nearby

For each taxon we note the role of forest Corridors and Hubs or other habitat. Field observations and underlying biology related to any recommendations is summarized in Appendix XI. As well as species of conservation concern (Table 3 above), habitat suitability for other regionally significant species is addressed, including black bear, black-tailed deer, Bald Eagle and other raptors. Order follows Table 3.

5.2.2.1 Invertebrates

The study area is rich in invertebrates but only a few are listed as of concern.

- **Blue dasher (Blue listed/CF4)** Present**.** Forest Hubs I and O serves to provide important pond-side cover.

- **Dun skipper (Red listed/CF2)** Present near the study area. Forest cover assists primarily in encouraging continued stream flow and reducing drying at favoured habitats.
- **Monarch butterfly** (**Blue listed/CF2)** Present. Monarchs are unlikely to settle in the study area without specific plantings of milkweed in open areas or encouraging home owners to do so.
- **Audouin's night-stalking tiger beetle (Red listed/CF1)** Unlikely present.
- **Oregon forestsnail (Red-listed/CF1**) Present. Forest Hubs provide excellent habitat where bigleaf maple is common, particularly if undisturbed; Corridors permit dispersal.
- **Pacific sideband snail (Blue-listed/CF2)** Likely present; not seen. Will benefit from forest Hubs and Corridors in the study area.

5.2.2.2 Amphibians & Reptiles

Unlike solely terrestrial species, amphibians require a wet environment for at least part of their lifecycle. Wetlands, streams and ponds, whether seasonal or permanent, are important habitat for them. Wetlands and wet areas provide the breeding and rearing grounds for amphibians as well as innumerable invertebrates that provide prey for them and other species. Wetlands are likewise important for the painted turtle.

There is very little legislative protection for wet areas that are unconnected to streams by surface flow; however, with proper planning, wet areas can easily be protected and integrated into a community plan. Due to the extensive filling of wetlands in the Lower Mainland, most remaining wet areas should be protected from development and conversion. They should be buffered from human encroachment and treated as especially sensitive ecosystems.

Most amphibians, including those at risk, disperse into upland terrestrial habitat in the adult stage. Protecting connectivity to upland habitats is vital to ensuring habitat is available for all life stages of amphibians. Both Hubs and Corridors provide important habitat.

- **Red-legged frog (Blue listed/CF1)** Present and relatively common in both wetlands and upland forests. Forest Corridors and Hubs help meet critical needs both by maintaining water supply for breeding and for adults when upland.

- **Western toad (Blue listed/CF2)** Present; not as common as the red-legged frog. Movement patterns suggest that corridors between wetland and upland habitats are particularly helpful.
- **Painted turtle (Red listed/CF2)** Likely extirpated in the study area, but present very nearby. It is possible that once sales of red-eared sliders are halted, painted turtles can be reintroduced.
- **Salish sucker (Red listed/CF1)** Present. Streamside corridors will benefit the species by providing bank-side vegetation. Hubs will aid in reducing rapid streamflow during high rainfall events.

5.2.2.3 Birds

The varied habitat throughout the Campbell River study area (composite of active and fallow farm fields interspersed with mature and regenerating stands of mixed forest and riparian areas) provides a great diversity of nesting, foraging and roosting habitats and sustains a high diversity of bird species in the area. Opportunistic sampling of the 20th Avenue portion of Hub I, for example, found 51 species (see Appendix XII).

- **Bald Eagle (not listed)** Present and frequent. No eagle nests were found, but nests are present in the surrounding area and may be present. Suitable nest and perching trees are present in both Corridors and Hubs.
- **Band-tailed pigeon (Blue listed/CF2)** Present. Local mineral licks were not found but these pigeons may move considerable distances to use them. Potential for this species is moderate throughout the study area because of abundant elderberry, salmonberry, huckleberry shrubs and Himalayan blackberry thickets. Major threats are unwitting destruction of mineral licks and encouragement of young, dense forests with few berry-producing shrubs.
- **Barn Owl (Blue listed/CF2)** Present. Overall potential for barn owls in the study area is moderate to high.
- **Barn Swallow (Blue listed/CF2)** Present. Habitat suitability in the study area is high for this species.
- **Great Blue Heron *fanninni* (Blue listed/CF1)** Present and common. No heron rookery found; however, Corridors and Hubs provide a significant number of large

mature black cottonwood trees for perching and for nesting near foraging sites. Hub O and Corridor 48 have important wetland foraging habitat.

- **Northern Goshawk *laingi* (Red listed/CF1)** Present and uncommon as expected for a top predator. Forest Hubs could supply nesting habitat while Corridors provide more foraging area.
- **Olive-sided Flycatcher (Blue listed/CF2)** Present (in Hub I this season). The juxtaposition of edge (Corridors), Hubs (older stands) and water provide particularly suitable habitat and should be maintained in concert with the national Species Recovery Plan.
- **Peregrine Falcon *anatum* (Red listed/CF2)** Present for short periods, but unlikely to breed. The mixture of forested and open cover of the Biodiversity Conservation Strategy serves primarily to provide feeding areas as it moves about.
- **Western Screech-owl kennicottii (Blue listed/CF1)** Unlikely**.** The current Corridor and Hub design in the study area provides good quality habitat for Western Screech-owls. However, they have not been seen recently and may not return because Barred owls (*Strix varia*) have expanded into the area and prey on Screech-owls.
- **Other owls and raptors** Raptors were often seen soaring overhead, particularly at the Little Campbell Hatchery and along 12th Avenue (Corridor 48). A pair of Great Horned Owls was also observed in the 12th Avenue area (Hub O) and young owls seen in forests near 20th Avenue. A number of barred owls were also seen during our site visits. There are a number of positive habitat elements for raptors in the study area, and management practice should retain these. Fortunately, most raptors and owls are relatively tolerant of human development, so with foresight and sensitive planning their needs can be integrated into community planning.

5.2.2.4 Mammals

A number of unlisted small mammals are known or expected to reside within the Little Campbell River study area. Some of these are sensitive to habitat loss and have very specific habitat requirements. Two unlisted larger species are noted.

- **Black bear (unlisted)** Present, but usually travelling through. There is a moderate to high potential for black bear within the study area that will not encompass their entire home range. We recommend no specific measures to accommodate black bears.

- **Black-tailed deer (unlisted)** Present and common. The existing design of Hubs and Corridors will sustain them, depending on what ultimately happens between the reserved areas.
- **Keen's myotis (Blue listed/CF1)** Presence unknown. Keen's myotis has been reported from very near the study area. Portions of the area appear to be ideal habitat – older forest near water. The area has not been surveyed for bats and the species may be present. Several provincial bat species are likely to occur but are poorly known; a bat survey would be helpful.
- **Pacific water shrew (Red listed/CF1)** Presence unknown. Suitable habitat and collections nearby suggest it is present. Given the shrew's natural history, wider riparian buffers than are conventionally applied would be helpful.
- **Snowshoe hare (Red listed/CF1)** Unlikely. Probably already extirpated from the lower Fraser Valley and the area has minimal suitable habitat.
- **Townsend's big-eared bat (Blue/CF2)** Presence unknown. Potential foraging opportunities exist in the forest patches and fields; little is known of forested roost sites. Other bat species (e.g., little brown bat, big brown bat), may be present in the study area due to numerous cavities and diverse riparian conditions.
- **Trowbridge's shrew (Blue/CF2)** Present. We rate the habitat suitability in the study area as high. No specific management measures appear required other than retaining existing riparian corridors.

5.2.2.5 The Little Things that Run the World[6]

Globally, priority to assessing 'at risk' status has been directed to things large enough to see easily. COSEWIC does not designate fungus and insects are poorly reviewed. Fungi, insects and bacteria all are critical to life, playing key roles in decomposition and nutrient cycling that support all other life. Despite their importance, these groups are rarely considered in environmental assessments. We did not survey them, but some surveys by others are included in Appendix XII and XIII. Some of the fungi in Hub I are rare (see Appendix XIII and Bunnell et al. 2014). The system of Hubs and Corridors in the study area helps support a large array of small species, generally overlooked but essential to sustaining nature and us.

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[6] See Bunnell, C., F. Bunnell, and A. Farr. 2014. Slime molds and fungal species in and near Brooksdale forest biodiversity plots. A Rocha Canada Conservation Science Series. A Rocha Canada, Surrey, BC.

5.3 Context: Little Campbell River Study Area in Surrey's Biodiversity Conservation Strategy and Green Infrastructure Network

Our initial reviews of Surrey's Biodiversity Conservation Strategy indicate that the study area (which falls within the Campbell Heights Management Area and Campbell Heights Management Area of the BCS) contains a mix of habitat suitability levels related to biodiversity. Much of the area is considered high to very high suitability, in part due to large areas of natural riparian features and relatively large patches of remaining forest.

A historical perspective is useful when considering the value of conservation areas including the Hubs and Corridors of Green Infrastructure Networks identified by Surrey's BCS. The Little Campbell River Study Area represents a landscape that has, over time, undergone a complete conversion from an intact coastal forest ecosystem to one that is a mixture of fragmented forest patches, old field habitat, residential suburban areas, and light industrial areas. Historically, wildlife that occupied the Fraser Lowlands had ample living space and few impediments to migration and dispersal. Today in the study area gradually maturing second-growth forest patches in upland areas and stream side buffers are the main habitat remnants and dispersal avenues for forest-dwelling wildlife populations. Further reductions in forested habitat will continue to reduce living space and dispersal opportunities. In today's fragmented forests, corridors are particularly important for species with limited mobility, such as amphibians and small mammals, (less so for highly mobile species such as birds). For larger animals or more sensitive animals associated with forests, usually large patches of forest are important to maintain populations. Any further reductions in forest cover in large patches will further reduce wildlife in the area.

Surrey has a goal of maintaining 40% forest cover. Depending on how that forest cover is distributed, it could significantly contribute to maintaining biodiversity. At present only 1 % of the Little Campbell River Management Area of the BCS is protected and 4 % (30 ha) of the Campbell Heights Management Area is protected.

5.3.1 Corridor Design

Wildlife corridors can be thought of as a transportation network for species in the fast lane and for species in the slow lane (McKenzie 1995). Medium to large mammals, such as deer, coyotes and skunks will use corridors to move directly between distinct refuge forest patches, such as the wildlife hubs. Other small mammals, invertebrates and amphibians could take generations to pass from one area to another; in essence, occupation of the corridor is a kind of reproductive daisy-chain of genetic mixing (McKenzie 1995). The result, however, is an interwoven fabric, or a habitat matrix on the landscape where distinct meta-populations[7] have sustained genetic viability over the long term through protected dispersal and reproductive opportunities.

Ultimately, corridor size and placement are decisions for planners and politicians; however, the ecology underlying wildlife corridors must be taken into consideration so as to not nullify their utility. A corridor must at least provide the basic needs of wildlife, including: food, water and cover while accounting for potential impediments to survival, such as: invasive plants and animals, domestic animals, traffic, noise, and human encroachment (Bond 2003).

A narrow corridor provides a basic travel pathway, useful for bold and versatile species; however, a narrow corridor is typically entirely edge habitat. Edge habitat has numerous drawbacks including: increased edge-specialist predation, greater impact of invasive plants, greater potential of human encroachment, and little to no benefit for species adapted to interior or 'core' habitat. A wide corridor maintains habitat viability for edge-specialist predators while providing most of the life requisites of core dwellers.

- Larger sites provide a greater variety of habitats. A 40 ha site will tend to support a greater diversity of species and habitats than a 10 ha site.
- Diversity is better. Greater ecosystem diversity tends to support greater species diversity. Maintaining a diversity of ecosystems helps ensure a variety of food sources and cover as well as retain preferred breeding and rearing areas.
- Linkages help. There is a better chance of preventing fragmentation effects if individuals or whole populations can safely move from one area to the next.
- Redundancy helps ensure sustainability. If there is only one remaining population of a species, the chances of extirpation are very high. Having several populations in different locations increases overall species survival.
- Small habitats can be critical to species survival. The collective influences of many small habitats can be as great as a single larger park. These small habitats are critical areas for many urban species, and some may contain remnant populations of rare or endangered species.

[7] A **metapopulation** consists of a group of spatially separated populations of the same species which interact at some level.

- Buffers help protect core areas. The impacts of human activity and other ecosystem stressors, such as invasive species, tend to be greatest at the edges of ecosystems. A buffer area helps protect core areas from these impacts. Bond (2003) suggests buffers can be achieved by conservation easements on development which occur adjacent to wildlife corridors and to enact strict lighting restrictions near corridors. Much wildlife activity occurs between dusk and dawn and increased lighting in wildlife reserve areas could impact safety and concealment of prey species. More suggestions from Bond include requiring only native vegetation in conservation easement buffer zones adjacent to corridors, and a landowner education program to help relieve the problem of invasive plants and domestic pets on natural wildlife habitat.

5.3.2 History of Corridor and Hub Design in Surrey

In 2009 Surrey commissioned a report to present an analysis of the natural areas remaining in the city. The authors of the report, from HB Lanarc, used Geographic Information System (GIS) data to assess all of the natural spaces within the municipality of Surrey and rank them according to their value for wildlife and for sustaining the natural environment. This was referred to as the "Green Infrastructure Network" (GIN). The report was commissioned as part of a City initiative to "strategically manage ecosystems" throughout the City and to inform the Official Community Plan update of 2009-2010.

The GIN is composed of four main components: Hubs, Sites, Corridors and the Matrix, which are determined according to size, value for wildlife and use for wildlife. Hubs are "large areas of complex ecological processes", Sites are "smaller sites of less complex ecological activity", Corridors are "pathways" between Hubs and the Matrix is the rest of the land base (Figure 8).

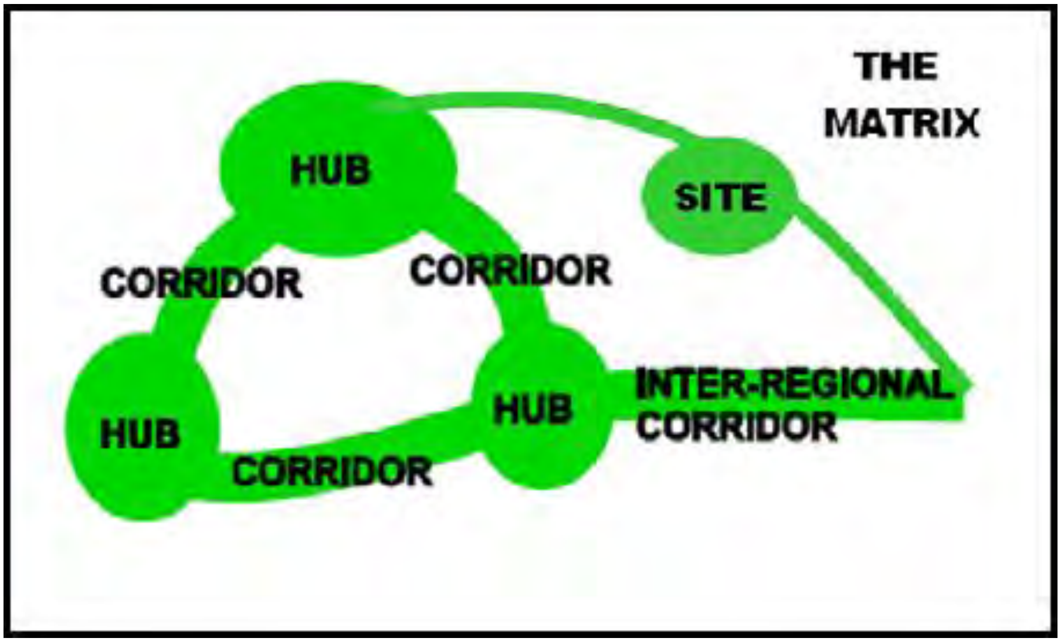

FIGURE 8. THIS GRAPHIC ILLUSTRATES THE INTERCONNECTIVITY BETWEEN HUBS, SITES, CORRIDORS AND THE MATRIX AS OUTLINED IN THE ECOSYSTEM MANAGEMENT STUDY.

The preservation and integration of natural areas in the City can be thought of as a network and is referred to as the Green Infrastructure Network (HB Lanarc 2009).

Hubs are defined as the largest intact natural areas that '*can support populations of many native wildlife species*'. The minimum size threshold for Hubs was selected by the authors as 10 ha. It was acknowledged that the greater the Hub size, the better; however, limitations in the functionality of their methodology resulted in important ecological features being excluded when a greater size threshold was selected. Sites are smaller green areas (0.25 to 10 ha) with less capacity to sustain a species population, but with some ability to address those smaller features missed by Hubs.

The authors also defined "least cost pathways" to identify the most natural route between Hubs and Sites with the least cumulative resistance to movement. The pathways, or wildlife corridors, provide dispersal routes for plants and wildlife as well as for abiotic processes such as "water, energy and materials". A least cost pathway was buffered by 50 m on each side and resulted in a 100 m buffered Corridor.

Hubs are:

Hubs Characteristics	Sites Characteristics	Recommendations for the Management of Hubs and Sites
• Large intact habitat areas >10ha • Provides habitat for a diversity of species • Source areas for wildlife dispersal • Provides interior (core) habitat and refuge areas • Supports species with larger home ranges • Refuges for species less tolerant of human disturbance • May contain regionally important habitat	• Small habitat patches <10ha • Provides habitat for fewer species • Supports species with smaller home ranges • Species more tolerant to human disturbance • May contain locally rare or sensitive habitat • May not be connected to GIN	• Acquire, restore and enhance prioritized core areas of unprotected hubs and sites; • A natural areas management plan should be developed for each hub to limit disturbance from people and pets. This should include an analysis of habitat features and designation of wildlife refuge areas within hubs. Plan should include limitations on access and recreation based on habitat sensitivity. • In each hub and site, manage for a diversity of habitat types and features. Create or enhance aquatic features (creeks, lakes, wetlands) where feasible.

Corridors are linear habitat areas that encourage the movement of species between fragmented Hubs and sites. This allows species to access new habitat features required to meet their life needs. It also allows for dispersal from source patches (areas with local population surplus) to other areas of habitat. The ability to re-colonize is important to maintain genetic diversity among species populations. Corridors are also used to meet other objectives. For example, recreational greenways are often planned in conjunction with wildlife corridors; however, this requires the consideration of ecological sensitivity and potential impacts of human disturbance.

Corridors are:

Regional Corridors Characteristics	Local Corridors Characteristics	Recommendations for the Management of Corridors
• Wider corridors (target 50-100 metres) • Designed to provide movement for a wide range of species including those that are less tolerant of human disturbance • Limited recreation • Regional connectivity • Connect large habitat areas • Riparian corridors of larger watercourses	• Narrower corridors (target 10-50 metres) • Designed to provide movement of species that are more tolerant of human disturbance • Greenways through developed areas • Hydro right of ways • Connect smaller sites, fragmented habitat areas • Riparian corridors of smaller watercourses	• Acquire, restore and enhance prioritized habitat areas along corridors • Enforce target corridor widths for regional and local corridors • Recreation trails and facilities should be located along one edge of any corridor. Trails should be outside the riparian setback areas and a minimum distance of 10m above the top of bank for ravines. Direct crossing of corridors should be avoided • Identify private land owners encroaching into protected corridors

Surrey's GIN was comprised of 88 Hubs (>10 ha) and 843 Corridors (100 m wide) plus Sites and the Matrix (HB Lanarc 2009).

Surrey's Ecosystem Management Study (EMS 2011) updated the 2009 work described above and refined the identified Hubs, Sites and Corridors. The Hubs and Corridors were further refined in the Biodiversity Strategy of 2014 (Figure 9). In the BCS, 33 Hubs and 144 Corridors are defined but many of those are not protected or secure.

N
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the future lives here.
Biodiversity Strategy
GREEN INFRASTRUCTURE NETWORK
GREEN INFRASTRUCTURE NETWORK
PROTECTED HUBS AND SITES
UNPROTECTED HUBS AND SITES
REGIONAL CORRIDORS
LOCAL CORRIDORS
SUPPORTING PARK SITES
AGRICULTURAL LAND RESERVE
JUNE 2014
Data Sources: City of Surrey
Data Developed By: Diamond Head Consulting Ltd.
Map Design: Ecoplan International
112 AVE
104 AVE
96 AVE
88 AVE
80 AVE
72 AVE
64 AVE
56 AVE
48 AVE
40 AVE
32 AVE
24 AVE
16 AVE
8 AVE
0 AVE
120 ST
128 ST
144 ST
152 ST
160 ST
168 ST
176 ST
184 ST
192 ST
196 ST
KING GEORGE BLVD
FRASER HWY
HIGHWAY 1
HIGHWAY 10
HIGHWAY 15
HIGHWAY 99
HARVIE ROAD
Surrey Bend Park
Invergarry Park
Hawthorne Park
Green Timbers Urban Forest
Tynehead Regional Park
Bear Creek Park
Port Kells Park
Fleetwood Urban Forest
Surrey Lake Park
Colebrook Park
Mound Farm Park
Hi-Knoll Park
Serpentine Fen Park
Elgin Park
Blackie Spit Park
Crescent Park
Sunnyside Acres Urban Forest
Latimer Lake Park
Redwood Park
NORTH

Figure 9

5.3.3 Ecological Assessment of Hubs and Corridors in the Study Area

The Biodiversity Conservation Strategy outlines the following management objectives, opportunities and risks in the Little Campbell Management Area and in the Campbell Heights Management Area (both overlap our study area).

5.3.3.1 Management Objectives:

- Protect and enhance riparian habitat along the Little Campbell River and its tributaries to support fish and wildlife, and protect and improve water quality;
- Promote sustainable agricultural practices and development on agricultural land to support biodiversity (e.g. wetland preservation);
- When development is proposed adjacent to natural areas, encourage alternative development concepts that allow for greater protection of these natural areas;
- Maintain large rural lot sizes;
- Remove fencing and promote secure movement corridors for large mammals;
- Work with agricultural landholders to maintain migratory bird habitat;
- Increase the cover of forested habitat;
- Increase forest and shrub cover in riparian areas of streams, wetlands and ponds.

5.3.3.2 Opportunities:

- Large remnant forest patches have not yet been developed;
- Natural non-dyked riparian areas can be enhanced adjacent to the Little Campbell River system;
- Large forest patches in Langley and Washington provide contiguous high value habitat areas;
- Golf courses could be naturalized;
- Abundant area of non-developed land could be enhanced;
- High number of functioning fish bearing creeks could be enhanced;
- Most disturbed riparian areas are not developed and could be enhanced;
- Farm BMPs (Beneficial Management Practices) and Environmental Farm Plans can guide management;
- Old gravel pits provide opportunities for restoration.

5.3.3.3 Constraints

- Limited planning/management authority on agricultural land;
- Major transportation corridors (Pacific Highway, 99)
- Large scale development in progress in Campbell Heights.

Within our study areas, The Biodiversity Strategy identified several Hubs and Corridors (Figure 9 above). The BCS provides a map of green infrastructure that numbers the Hubs and Corridors. The BCS gave each Hub and Corridor an ecological rating, target width and description.

We consider each Hub and Corridor in our study area, note the description in BCS, then add or update that description with our office and field observations. We note any suggested amendments to their categorization or extent.

Four elements were considered when ranking Hubs and Corridors for potential ecological value. Ranking took into account the value of:

- Critical habitat for significant wildlife species and for support of biodiversity;
- Significant and valuable tree stands or specimens, including tree species and areas with a high potential for retention;
- Watercourses, watersheds and groundwater recharge areas (including associated features such as wetlands and riparian zones); and
- Natural areas with potential to provide habitat corridors linking to other green spaces within and beyond the study area.

We also assessed forest and properties not included in the Hubs and Corridors. We have made note of where those may be useful additions to, or where their management might augment, the current Hubs and Corridors.

Most Hubs and Corridors, while delineated in the Biodiversity Conservation Strategy, are not currently protected. Only1 % of the Little Campbell River Management Area is protected, the lowest of all the Management Areas identified in the Biodiversity Strategy. This has serious implications – areas of low protection are areas where there is more onus on the City to protect its lands, especially because other areas desired for protection are on private land where the City has much less control. Hub I is an example of City land that should be protected.

5.3.3.4 Assessment by Hub and Corridor Number:

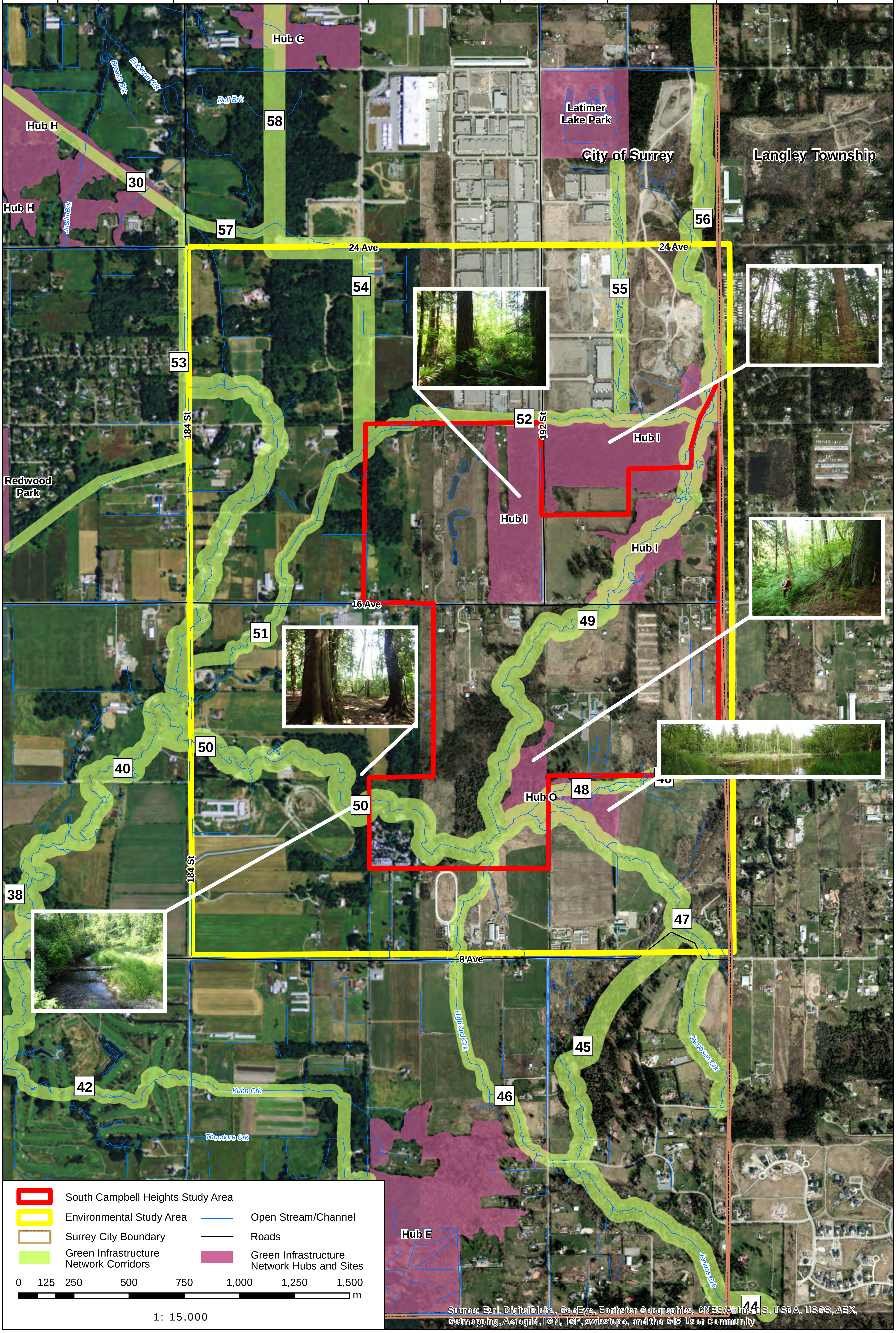
Our assessment of each Hub and Corridor summarizes the bulk of our field work and provides the most valuable recommendations from our study regarding biodiversity. To summarize our findings:

- Two main Hubs and Several Corridors outlined in the BCS fall within the study area (Figure 10).
  - Both Hubs are of high ecological importance with the northern Hub (I) being dominated by Douglas fir overstory and the southern Hub (O) being dominated by western redcedar overstory. Both Hubs contain a mix of coniferous and deciduous trees species, multiple canopy layers and relatively natural understory vegetation.
  - Both Hubs (I and O) contain a mix of tree species and both have trees commonly in excess of 70 cm dbh and often in excess of 90 cm dbh. Some trees more than 1 m dbh exist in Hub I and many trees larger than 1 m dbh (too many to count during this project) are found in Hub O.
  - Sign and presence of many species of wildlife have been recorded in both areas, including invertebrates, amphibians at risk, Barred Owls, Great Horned Owls, Red-tailed Hawks, Douglas squirrel, deer, and songbirds. Hub I, close to the Little Campbell River, and Hub O with its numerous creeks, both likely support Pacific water shrew. red-legged frogs, western toad and other species at risk.
  - Hub O is private land but strong efforts should be made to secure it over the long term.
  - Hub I is city land and should not be developed if the BCS is at all important -- only 1 % of the Campbell River Management Area, and only 30 ha of Campbell Heights Management Area, are currently protected; the City could add its lands to that protection.
  - For both Hubs, their size and connections to riparian zones are important characteristics affecting biodiversity. Efforts should be made to expand Hub O when the City is successful in acquiring land or cooperating with land owners in the area.

- Portions of 5 Regional Corridors and 3 local corridors flow through the study area.
  - The choice of regional versus local seems appropriate for each Corridor.
  - Parts of Corridors that have been disturbed are good opportunities for restoration:
    - along the LCR N of A Rocha (private land) where the land has been cleared both sides of the creek. Remove invasive species; add native vegetation;
    - along LCR south of 16th where Corridor is narrow (private land). Add width to Regional Corridor;
    - along Corridor 46, Highland Creek (private land) which is open field habitat. Restore riparian vegetation to disturbed farmland;
    - along the open farm area of West Twin Creek (private land). Restore riparian vegetation to disturbed farmland;
    - areas close to 12th Avenue (private land along Corridor 48) where fields have been cleared between wetland areas. Restore wetland vegetation and join Corridor segments; and
    - in areas surrounding ponds and creeks along Corridor 55. The ponds in the developed area should be included in the Hub I (city land).
- Roads intersect Corridors and Hubs and their impacts should be considered in future development. Where future roads or road expansions are planned, then underpasses or other means of enabling wildlife to cross roads should be undertaken.

FIGURE 10: Photos from Biodiversity Hubs in Study Area

LOCATION:	PROJECT:	CLIENT:	MAP DATE:	DRAWN BY:	DOSSIER:
Surrey, BC	Environmental Assessment	City of Surrey	6/11/2015	Anna Jeffries	15.0073



Hub I: Location: City land east and north of A Rocha

From Biodiversity Strategy

High ecological value; moderate risk of development. Large intact forested area with important aquatic and riparian habitat. It includes two reaches of the Little Campbell River. A large portion of this natural area is owned by the City.

Recommendation: Protect this area as a park through acquisition. Create wetlands in old fields adjacent to forests.

From Field Assessment

This Hub is composed of three main areas: 1) area north of A Rocha: uplands; 2) slopes and floodplain of Little Campbell River; and 3) area east of 192 Street and north of 16th. Avenue.

Vegetation

- Area north of A Rocha: Uplands have many Douglas-fir 60 to 80 cm diameter (dbh), minor component of western redcedar, bigleaf maple, a few areas of younger (30 to 50-year-old) alder. Relatively natural understory. Some trees are more than 100 cm dbh.
- Slopes to Little Campbell River also are dominated by natural vegetation. Some very large cedar trees (>100 cm dbh).
- Area east of 192nd Street and north of 16th Avenue: Several Douglas-fir and western redcedar larger than 100 cm diameter. We measured most of them. Some large bigleaf maple also approximately 100 cm diameter.
- Naturalists and A Rocha studies have compiled lists of fungi and byrophytes (e.g., Bunnell 2014 and Appendix XII and XIII.

Wildlife Habitat

All areas have sign of deer use; Barred Owl have been observed on the east slopes of Little Campbell River. Naturalists and A Rocha studies have compiled lists of invertebrates and vertebrates in the area – it is rich in species diversity and home to several rare species (see Appendix XII and XIII). Connection from uplands area west of 192nd Street through to LCR are important for biodiversity.

Significant Trees

Several Douglas-fir and western redcedar larger than 100 cm diameter. We measured most of them. Some large bigleaf maple are also present, and were approximately 100 cm diameter. Large spruce occur in the flood plain of the LCR.

Watercourses and Fish

Discussed under Corridor 49.

Conclusion

Concur with BCS -- all areas of Hub I are of high ecological importance. Given development to north has removed essentially all forest cover from fairly contiguous areas, and 192nd Street cuts the Hub in two for many species, the City could consider adding adjacent areas to northeast of Hub I. Those include pond habitat and some habitats of tributaries to LCR.

Corridor 52: Location: City land along 20th Avenue along south edge of industrial land, north of City Property of Hub I

From Biodiversity Strategy

A Regional Corridor. High ecological value; moderate risk of development. A riparian corridor for tributary of Little Campbell River. Partially protected as park. Provides movement east to west south of the Campbell Heights industrial area. East portion proposed to be protected as Hub I. Suggest traffic calming and signage at 192nd Street.

From Field Assessment

Vegetation

Although near areas of mature mixed coniferous second growth forest (Hub I, primarily Douglas-fir with lesser components of western redcedar, bigleaf maple, alder and Sitka Spruce), the Corridor itself is dominated by young alder. West of 192nd Street the Corridor has more maple and a few mature conifers but no watercourse (watercourse is east of 192nd St.). While it is a narrow Corridor by itself, the adjacency of Hub I makes it an important zone of protection.

Wildlife Habitat

Corridor 52 provides habitat for many species that use deciduous cover including deer, beaver, and many resident and migratory birds that use shrub habitat and deciduous cover.

Watercourse Condition and Fish

Young seral natural vegetation was observed along both sides of tributary along 20thAvenues easement, east of 192nd street. No barriers to fish on LCR.

Significant Trees

Many Douglas-fir, three western redcedar and one spruce were measured to be approximately 100 cm in diameter.

Conclusion

Concur with BCS: Corridor 52 is a high ecological value Corridor.

Corridor 49: location: Along Little Campbell River, from 12th to 20th Ave

From Biodiversity Strategy

A Regional Corridor with high ecological value and a high risk of development. It provides riparian habitat for the Little Campbell River. Corridor 49 includes continuous forested areas along river. The north portion is proposed to be protected as Hub I, to protect land adjacent to riparian setback.

Recommendation: Naturalize all areas within natural floodplain. Work with adjacent landowners to naturalize adjacent private land and remove barriers to movement. Traffic calming and signage at 16 Ave.

From Field Assessment

Vegetation

This Corridor consists of mature second-growth forest, primarily Douglas-fir with lesser components of western redcedar, bigleaf maple, alder and Sitka Spruce. It has complex canopies and natural vegetation along most of the Corridor.

Wildlife Habitat

Corridor 49, a large riparian corridor, provides habitat for a large number of species, likely including Pacific water shrew.

Watercourse Condition and Fish

Natural vegetation occurs on both side of LCR. The LCR has a large floodplain. Fish in LCR are listed in section5.4.5.

Significant Trees

Several large diameter trees (>100 cm) were observed along Corridor 49 including many Douglas-fir, western redcedar and spruce.

Conclusion

Concur with BCS: very high ecological value Corridor. The little Campbell River is the largest watercourse in the Study Area and has largely intact riparian buffers. Some opportunities for restoration exist (see Figure 11,watercourses and restoration areas in section 5.4):

- Allow areas of old gravel excavations to regrow to beyond top of bank to ensure corridor width maintained south of 16th Avenue.
- Encourage private land owner (at site of old bridge) to replant riparian vegetation along private land between city land of Hub I and A Rocha property.
- The City should assess water quality flowing into LCR in a tributary that runs from gravel pits just north of 20th Avenue (at about 195th Street) to assess if the large amounts of iron apparent in the water are an issue. The area north of 20th Avenue will be discussed more fully in the report for the extended study area.

Hub O: Location: 12th Avenue and 192nd Street.

From Biodiversity Strategy

Hub O has high ecological value, and a moderate risk of development. It is an intact patch of mixed and deciduous forest containing a large pond and wetland complex. Hub O connects three reaches of the Little Campbell River and associated Corridors. It provides a large valuable forested area with wetland, aquatic and riparian habitat.

From Field Assessment

Because this land has no access from any roads, this Hub was accessed from properties that front on 16th Avenue and others that front on 8th Avenue. All land is private land. Hub O is on moister, richer sites than portions of Hub I and together they provide example of a variety of ecosystems in the CDFmm1.

Vegetation

This area is a more productive sites series than north of 14th Avenue. It contains richer soils, and an understory dominated by stinging nettle, indicating high nitrogen content in soil. Some wetlands and marshes are included in Corridor and Hub.

Wildlife Habitat

The wildlife habitat value is high with many songbirds in shrub layers of wetlands. Barred Owls (pair), Great Horned Owls (pair), Red-tailed Hawk, deer (few), nesting Evening Grosbeaks, and many other birds seen during field day. The wetland had three herons foraging, and a red-legged frog (likely).

Significant Trees

Hub O contains the highest density of trees > 100 cm diameter in the study area. Those large trees are predominately western redcedar but also grand fir, Douglas fir and bigleaf maple of similar sizes. Prism sweeps with BAF 4 often recorded half the included trees as approximately 100 cm diameter.

Watercourses and Fish

Fish were observed in various tributaries and likely in the wetland (not assessed fully, but coho and lamprey seen in Jacobsen Creek at Hub O).

Conclusion

Concur with BCS and emphasize the high ecological significance conclusion. Although this is all private land, this area is among the richest, most natural in the study area. The combination of many creeks, wetlands, and highly productive forest create niche spaces for many wildlife. The absence of roads along the edges adds to the intactness and diversity of species seen (the farm areas buffer the forest from impacts of people and pets). Strong efforts should be made to maintain this area in natural habitat and to restore some connections to the east (along Corridor 48, see below).

- Consider adding areas of horse farm and paintball property if they ever became available (19022 16th Avenue and 18923 8th Avenue). At the very least, encourage land owners to keep those areas natural.

Corridor 48: location east along 12 th Avenue from Hub O

From Biodiversity Strategy

Corridor 48 is a Local scale Corridor with a moderate ecological value and moderate risk of development. It is the riparian corridor for Jacobson Creek, and consists of mostly natural forested habitat. This site provides connectivity east towards Campbell Valley Regional Park.

Recommendation: Work with adjacent landowners to naturalize adjacent private land and remove barriers to movement. Protect land adjacent to riparian setback.

From Field Assessment

This Corridor extends from Hub O along a tributary and wetlands along the approximate latitude of 12th Avenue. It was accessed from properties that front on 16th Avenue and others that front on 8th Avenue. All land is privately owned, the 8th Avenue side is agricultural land, but some of the 16th Avenue properties are not.

Vegetation

Mature second growth forest, primarily Douglas-fir with lesser components of western redcedar, bigleaf maple, alder and Sitka Spruce. Many wet areas – both open marsh and more closed, spirea-dominated areas. These wetlands are especially sensitive ecosystems, and very valuable for biodiversity.

Wildlife Habitat

Corridor 48 provides habitat for deer and beaver, as well as multistoried bird habitat for birds. Red-tailed Hawks were observed over many days (so a nest is likely close by but was not seen). The wetlands provide habitat for herons, and likely for red-listed Pacific water shrew.

Watercourse Condition and Fish

Natural vegetation occurs on both sides of wetlands. Area at back of 19516 16th Ave. has been filled after gravel excavation and cleared to south edge of the property. That southern edge of the property could be re-vegetated or left to become part of the natural corridor. Many fish species are in the LCR (see section 5.4.5); fish in Jacobsen Creek include *steelhead (O. mykiss), cutthroat trout, rainbow trout, coho salmon, and chinook salmon (Habitat Explorer, iMap).*

Significant Trees

Corridor 48 contains a mixed forest with more deciduous species along wetland portions. Several large diameter trees (100 cm) were recorded in more upland areas close to Hub O including cottonwoods; Douglas-fir, western redcedar and spruce.

Conclusion

This Corridor is a Local corridor which seems appropriate; it adds valuable habitat to Hub O, especially wetland habitat. The Corridor would be made stronger by the addition of more land at the back of properties off 8th and 16th. Farmers on 8th Avenue have changed natural drainage in fields but may be amenable to adding riparian buffer strips at very north edges of their properties.

Corridor 47: Location: Jacobsen Creek to 8th Ave (leads into corridor 45, a regional Corridor outside our study area leading south to Hub E):

From Biodiversity Strategy:

Corridor 47 is a Regional Corridor of moderate ecological value and moderate risk of development. It includes riparian habitat for Jacobsen Creek as well as fragmented natural areas including one park. Sections are highly disturbed by agriculture development. It provides connectivity east towards Campbell Valley Regional Park. Recommendation: Protect land adjacent to riparian setback. Work with adjacent landowners to naturalize adjacent private land and remove barriers to movement. Traffic calming and signage at 8th Ave.

From Field Assessment:

This Corridor extends from Hub O southeast along Jacobsen Creek from approximately 12th Avenue to 8th Avenue. It was accessed from properties that front on 16th Avenue and from 8th Avenue. We were not permitted on (19359 or 19339 8th Avenue) to assess conditions on those farms.

Vegetation

The Corridor falls largely in a farmer's field, with small willows and shrubby vegetation along both stream sides. At the north end of the Corridor, large cottonwood trees are present, but these overlap with Hub O. South of the farmers' field the Corridor becomes large, partly protected by the City of Surrey along the ravine at 8th Avenue. There the forest is primarily deciduous, with many bigleaf maples, cottonwoods, and some alder. A few large cedar occur sporadically.

Wildlife habitat

Many deer trails, and one deer was seen in the ravine along 8th Avenue. Evidence of beaver and many songbirds observed.

Watercourse condition and Fish Presence

Corridor 47 contains a narrow buffer of shrubs and small trees through farmer's field, then natural vegetation close to 8th Avenue. There is a man-made fish barrier at 8th Avenue end. No fish seen above barrier: The barrier appears to be noted in slightly the wrong spot on Surrey Fish Classification maps. Habitat above barrier is very good for fish if they could get there.

Significant Trees

One western redcedar approximate 123 cm dbh was recorded, but otherwise young forest, mostly deciduous.

Conclusion

This Corridor is a Regional Corridor but needs some restoration through farmland to achieve desired widths. Corridor 47 adds valuable habitat to Hub O. It would be made stronger by addition of wider riparian buffers through farmland. Jacobsen Creek is a salmon –bearing creek and would benefit from wider riparian buffers and by removal of the fish barrier (but that would be an expensive remediation) see photos in Figure 11.

Corridor 46: Location: Highland Creek north of 8th Avenue

From Biodiversity Strategy

Corridor 46 is the riparian corridor for Highland Creek, which runs towards Hub E. It has moderate ecological value and moderate risk of development. Highly disturbed riparian area with fragmented natural areas.

Recommendation: Work with adjacent landowners to naturalize adjacent private land and remove barriers to movement. Protect land adjacent to riparian setback. Traffic calming and signage at 192nd St and 8 th Ave.

From Field Assessment

This Corridor extends from Hub O southeast along Highland Creek from approximately 12th Avenue to 8th Avenue. Access was not permitted from properties that front on 8 th Avenue, so characteristics were ascertained from a distance and are not precise.

Vegetation

The corridor falls largely in agricultural land with small willows, shrubby vegetation or pasture along the streamsides. The north end of the Corridor enters the young and mature forest of Hub O.

Wildlife Habitat

Some hedgerow type habitat.

Watercourse Condition and Fish Presence

Some shrubs and small trees, but mostly grass along creek. Fish presence indicated as 'orange' on Surrey's map but not assessed in field.

Significant Trees

None.

Conclusion

This Corridor is a Local Corridor which seems appropriate. Even to be a useful Local Corridor it would benefit from restoration of native trees and shrubs along riparian zones. This Corridor would add valuable habitat to Hub O if it could be made stronger by adding more natural riparian buffers through farmland. See photos. It is not clear why this Corridor was chosen over Jenkins Creek. As time goes on, the City should decide where the best restoration options exist (Highland Creek or Jenkins Creek), and perhaps then decide on the best Corridor to be pursued further (there may be reasons of which we are not aware, for choice of corridor).

Corridor 50: Along little Campbell River through hatchery and into Hub O

From Biodiversity Strategy:

This is a Regional Corridor, with. high ecological value, and moderate risk of development; 100 m width desired. It contains riparian habitat for the Little Campbell River, consisting of fragmented natural areas, providing movement through agricultural land. It includes one small protected park.

Recommendation: Protect land adjacent to riparian setback. Naturalize all areas within natural floodplain. Work with adjacent landowners to naturalize adjacent private land and remove barriers to movement. Traffic calming and signage at 184th St.

From Field Assessment:

Vegetation

Mature second growth forest, primarily Douglas-fir with lesser components of western redcedar, bigleaf maple, alder and Sitka spruce.

Wildlife Habitat

The area provides habitat for deer and beaver, as well as multistoried bird habitat for birds. Barred Owl and Red-tailed Hawk have been observed on the site. Barn Owls nest in the barn, and Barn Swallows were observed at the hatchery. It is also home to a very active "superbeaver".

Watercourse Condition and Fish Presence

Natural vegetation occurs on both sides of LCR. It has a large floodplain. Remediation work was done to add riffle pool conditions. Riparian planting has been added in places (in cooperation with A Rocha). Fish species in LCR are listed in Section 5.4.5.

Significant Trees

Many Douglas-fir, western redcedar and Sitka spruce approximately 100 cm diameter were recorded in this Corridor, as well as several cottonwoods and a bigleaf maple of similar size.

Conclusion

Concur with BCS: Corridor is of very high ecological value. The little Campbell River is the largest watercourse in the study area and, within the study area, has largely intact riparian buffers. Ensure the Corridor includes city protected land east of the hatchery. This area has abundant large trees – many having 100 cm or more dbh.

As well, consider adding into conservation status, the forests north of 18843 and 18855 8th Avenue (the RV park) that run east to the forests at the south end of 18952 to 19038 16th Avenue (the south end of the paintball property). They have many valuable features and large trees, much like the forests in Hub O. We observed Great Horned Owls in those forests (as well as Pileated Woodpecker, Hairy Woodpecker, Evening Grosbeaks and many other birds). Encourage landowners to maintain those in natural conditions.

Corridor 51: Location: East Twin Creek (from 16th to 20th Avenue).

From Biodiversity Strategy

This is a Local Corridor, with moderate ecological value and moderate risk of development; 60 m target width. It is the riparian corridor for East Twin Creek, although highly disturbed with fragmented natural areas.

Recommendation: Work with adjacent landowners to naturalize adjacent private land and remove barriers to movement. Protect land adjacent to riparian setback. Traffic calming and signage at 184 St and 16 Ave.

From Field Assessment

Vegetation

At north end of study area, the Corridor is mature second-growth forest, primarily Douglas-fir with lesser components of western redcedar, bigleaf maple, and alder. It is all on private land, and contains many large trees. To the south the creek flows through hedgerows, deciduous trees and pasture.

Wildlife Habitat

The area provides good habitat for deer as well as multistoried bird habitat for birds; hundreds of owl casts with many little skulls were recorded. Young Great Horned Owls occur in area.

Watercourse Condition

Natural vegetation occurs on both side of East Twin Creek in property south of 20th Avenue, but then the creek flows into fields for most of the extent of the corridor. SHaRP has done in depth assessments of the riparian zones and instream conditions.

Fish Presence

It is classed as fish-bearing by Surrey. Fish in East Twin include coho and lamprey.

Significant Trees

Many Douglas-fir, western redcedar and spruce approximately 100 cm in diameter occur on the property. Some cottonwoods and bigleaf maple approximately that size were also recorded. The Corridor is on the private property.

Conclusion

Concur with BCS: moderate ecological value Corridor. Could be high value if restoration work undertaken along creek in field portions of Corridor. Forested portions at north end have high value, complex canopy, large trees and abundant wildlife values. The City might consider acquiring (that property is for sale at present).

Upper part of Corridor 40: Location: West Twin Creek (from 13th Ave. at 184th St. north to 20th Ave.).

From Biodiversity Strategy

This is a Regional Corridor with moderate ecological value and high risk of development. It links to Corridor 53 (a Regional Corridor out of study area) and provides riparian habitat for the primary reach of the Little Campbell River. With fragmented natural areas, it provides scattered high value wetland communities and movement through agricultural lands.

Recommendation: Protect land adjacent to riparian setback. Naturalize all areas within natural floodplain. Work with adjacent landowners to naturalize adjacent private land and remove barriers to movement. Work with golf course to enhance natural habitat. Traffic calming and signage at 8th Ave, 16th Ave, 20th Ave and 184th St.

From Field Assessment: (note: this Corridor extends west and south beyond our study area)

Vegetation

The area is a mix of disturbed farm fields with some patches of coniferous and deciduous forest, including some areas of mature second growth forest. There are some areas of grass in fields where surface water disappears. Natural vegetation is present from 18th Avenue to close to 20th Avenue. Very large cedar and cottonwoods north of 18th Avenue.

Wildlife Habitat

The area provides habitat for many species. Deer, songbirds and beaver sign observed during site visits.

Watercourse Condition and Fish Presence

Corridor 40 contains natural riparian conditions and a mix of gravel and sand/organic substrates from 18th to 29th Avenues. Very disturbed riparian vegetation from 18th to 16th Avenues interspersed with some areas of forest and some areas of restoration. A Rocha has assisted private landowners at 1724 184th St. and at the United Church at the corner of 184 th Street and 16th Avenue. Riparian planting has been added in places (in cooperation with A Rocha). Fish (coho) were seen below the 'dry' field portion but not above. Rainbow trout, threespine stickleback and Prickly Sculpin have been reported in iMap.

Significant Trees

Many Douglas-fir, western redcedar and spruce in forest between 18th and 20th Avenues. Three significant western redcedar at the United Church at corner of 184th St and 16 th Ave.

Conclusion

Concur with BCS: very high ecological value Regional Corridor which protects the little Campbell River and West Twin Creek. Some residential areas have respected creek and riparian buffers. Some farms have cooperated with A Rocha and removed grazing from creek or fenced horses away from creek. Nonetheless, many areas of the streamside are quite disturbed and are opportunities for restoration.

Although we walked the forests between 20th and 24th Avenues and 184 to 188 Streets, our investigation of Corridors 53 and 58 that run along the edge of that area were not in depth, thus Corridor 53 and 58 received only a general assessment and we will revisit them during our assessment of the neighbouring amended study area.

Corridor 53. Location: 184 th St. from 20 th to 24 th Avenue

This Corridor links to Hub H, a large intact forested area outside of our study area. That Hub includes mature forest with trees of significant size. BCS recommends protecting that Hub as a park through acquisition; high ecological value and high risk of development.

From Biodiversity Strategy

Corridor 53 is a Local level Corridor with 50 m target width. It has high ecological value and moderate risk of development. The Corridor is an edge buffer for agricultural land and includes fragmented natural areas. It follows 184 th Street, providing connectivity from Redwood Park north to proposed Hub H and G. It provides important edge habitat to agricultural field habitat.

Recommendation: Establish and protect a forested corridor on perimeter of agricultural land. Traffic calming and signage along 184 th St.

From Field Assessment

Our field assessment was very brief and we will revisit this Corridor during our work in the Amended study area (although it falls outside the amended area, it is in that northern section of the overall study area). Although the BCS designates it as a high value ecological buffer, at present it is fragmented, in private land, with little forest, and has a road running its length. It contains no watercourses, nor any obvious large trees. We will revisit during the assessment of the added area.

Corridor 58: Location: out of study area to NW

From Biodiversity Strategy

Regional Large forested natural area. Follows edge of agricultural land and runs through proposed Hub G. This forested area provides an important north south wildlife movement corridor.

Recommendation: Protect as much of this forested corridor as possible. Traffic calming and signage at 40 th Ave, 32 nd Ave and 24 th Ave. High ecological value and moderate risk of development

From Field Assessment:

Just as for Corridor 53, our field assessment was very brief and we will revisit this corridor during our work in the Additional study area (although it falls outside the amended area, it is in that northern section of the overall study area). This corridor has more intact with more forest than Corridor 53. It contains no watercourses, nor any obvious large trees. Land between Corridors 53 and 58 does contain watercourses and sparse forest cover, but neither is in high ecological condition. We will revisit during the assessment of the added area.

Summary of Hubs and Corridors

Given its commitment to forest Corridors and Hubs, the City would gain by noting the well-established benefits of sustaining forest cover. These include:

- Improving human health. Forests greatly improve air quality by reducing ozone, particulate matter, sulfur dioxide, nitrogen dioxide and carbon monoxide – all of which are harmful to us. They also increase human birth weights and wellbeing generally, including aiding blood sugar control of diabetics.
- Extracting and storing carbon dioxide. That in turn helps offset our injections of carbon dioxide into the atmosphere and slows the rate of global warming.
- Supporting biodiversity. Because they go up and down as well as sideways, forests support about 67% of terrestrial global biodiversity on 30% of the land mass (excluding Antarctica).
- Providing watershed services, including water purification, regulation of groundwater and surface flow and stabilization of soils on slopes and streambanks. Their importance will increase as water quantity and quality become more critical issues with warming and drying.
- Reducing the intensity of floods and moderating climate through their effects on soil stability, rainfall and air temperature. This will prove increasingly helpful as frequency of intense rainfall increases.

5.4 Watercourses and Fisheries

Riparian habitat is the interface zone that links aquatic and terrestrial ecosystems. Riparian areas support high levels of biodiversity and the City recognizes the importance of riparian areas to protect water quality and to provide fish habitat.

Protected riparian setbacks are required adjacent to streams and the ocean foreshore. Setbacks are designed to maintain the biological function of riparian ecosystems by protecting riparian vegetation which contributes to fish and wildlife values.

Riparian vegetation plays a number of key roles and provides important inputs to fish habitat such as: shade to regulate water temperature; leaf litter for nutrient input into the water; insect-drop into the water (potential source of food for fish); and large woody debris (LWD) which provides security habitat for fish and also helps stabilize stream banks which decreases erosion and sediment input into the water.

To help ensure the adequate protection of riparian areas and associated fish habitat, the City of Surrey has adopted the Land Development Guidelines developed by the Habitat Management Division of Fisheries and Oceans Canada (DFO) and the Integrated Management Branch of the Ministry of Environment (MoE). The width of riparian setbacks adjacent to watercourses located in the City of Surrey is dependent upon the classification (i.e. fish value) and the proposed density of development adjacent to the watercourse.

Watercourses have been assessed and classified based on habitat attributes and connectivity to fish habitat:

- Class A (red): Inhabited by salmonids year round or potentially inhabited year round.
- Class AO (red-dashed): Inhabited by salmonids primarily during the over-wintering period or potentially inhabited during the over-wintering period with access enhancement.
- Class B (yellow): No fish present but offer significant food/nutrient value to connected fish habitat
- Class C (blue): Insignificant food/nutrient value. No fish present.

Regarding proposed densities of development: if less than six units per acre are proposed adjacent to a Class A, AO or B watercourse, the setback is 15 m; if more than 6 units per acre are proposed the setback becomes 30 m.

All commercial developments result in a setback of 30 m. Riparian setbacks are not required for Class C watercourses but riparian areas of those watercourses must be managed in a way that maintains the conveyance of water.

Individual property owners also have the option of using the standards set out in the provincial Riparian Areas Regulation (RAR), should variances be requested to the default City of Surrey riparian setback areas.

Because Hubs and Corridors follow, to a large degree, watercourses, the riparian widths in the study area are often wider than those that would be the default under City of Surrey standards or those calculated under a provincial Detail Riparian Areas Assessment. For the LCR for example, there would be a 30 m default width, but because it is a Regional Corridor, the buffer is targeted to be at least 50 m on each side to achieve the desired 100 m wide Regional Corridor. The provincial Detailed Assessment would result in less than the 30 m defaults on many smaller streams in the non-agricultural portion of the study area. RAR does not apply to land under agriculture, nor do Surrey defaults, but riparian best practices should be followed.

Due to the extensive stream classification work carried out by the City of Surrey and the default riparian setbacks, we did not, in our riparian and fisheries assessments focus on the calculation of widths for riparian buffers. Our main objectives of the riparian and fish habitat assessment were to:

- Describe the general distribution of fish and fish habitat throughout the study area;
- Describe the biological function of existing riparian vegetation adjacent to fish habitat;
- Identify candidate areas for fish habitat enhancement; and
- Assess the accuracy of the existing stream classification mapping provided by the City of Surrey.

A Rocha and SHaRP have done extensive and intensive stream mapping in the study area and we have used the information and reports they shared with us, particularly for West and East Twin Creeks and Jacobsen Creek. We walked the length of most watercourses but only mapped locations where the COSMOS stream classification did not show the watercourse or seemed to have a fish passage barrier in the wrong spot.

5.4.1 Pre-Field Research

Prior to field assessments, we accessed the Habitat Wizard website (Habitat Wizard, 2015) to determine the location of any known fish habitat and to ascertain documented fish presence. A detailed stream classification mapping layer (provided by the City of Surrey, Cosmos mapping layer) was used as a base map for the riparian and fish habitat assessment. Previous reports produced by A Rocha and SHaRP were also reviewed, as these were directly related to the study area. Of particular relevance were the reports assessing West Twin, East Twin and Jacobsen Creeks.

5.4.2 Field Assessments

During field surveys we focused on known fish habitat (e.g. Jacobsen Creek and West Twin Creek) to help develop potential prescriptions for habitat improvement. We also visited Class B creeks to check for potential fish presence or the existence of fish habitat. Where feasible (i.e. considering access onto private property and the scope of the assessment), the accuracy of the existing City of Surrey stream classification map was assessed. At this overview level, not all existing drainage classifications were checked for accuracy. Classification updates may occur when development occurs on a lot by lot basis, given the more focused level of detail.

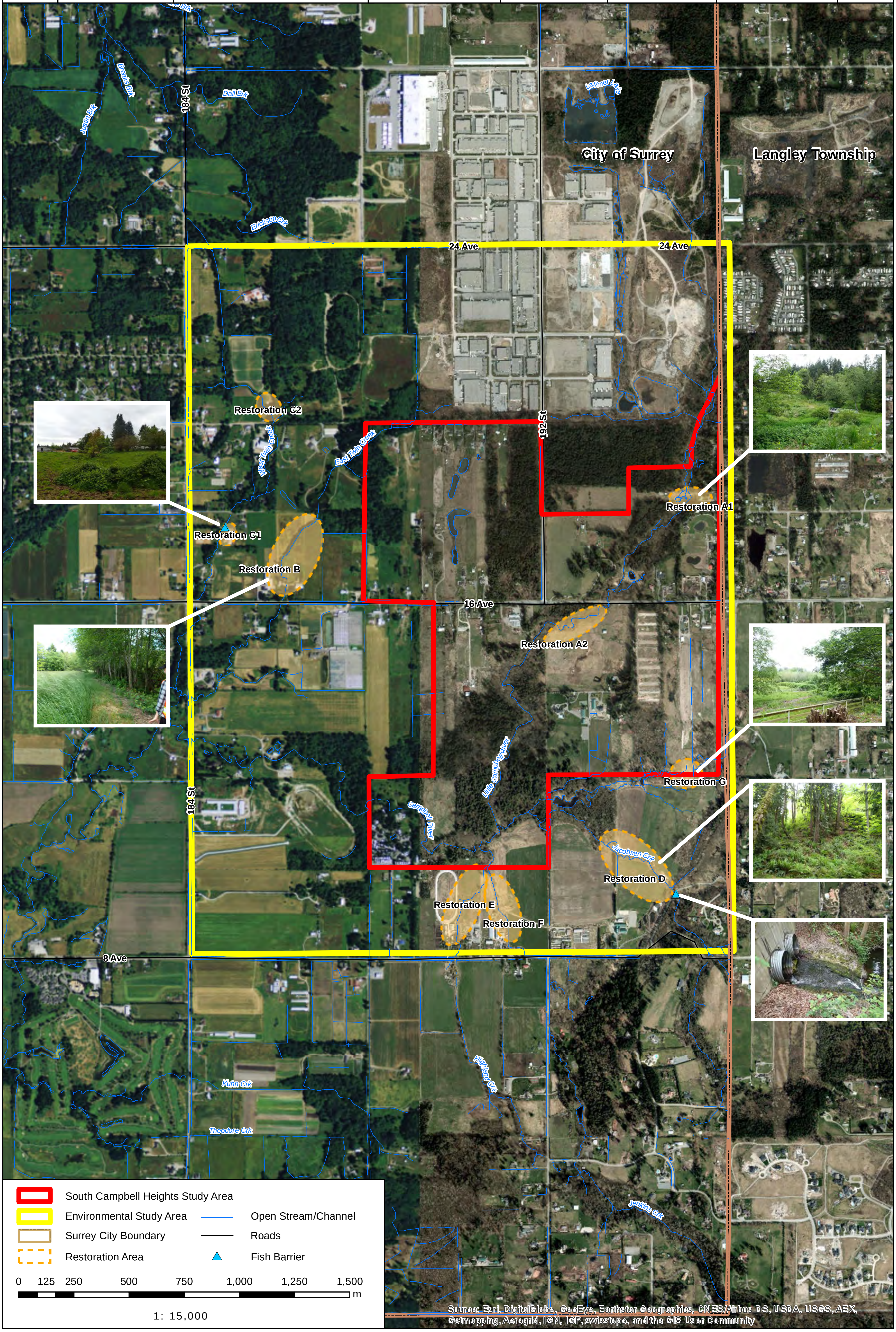
Where discrepancies were observed between mapped drainages and drainages in the field, the drainage was located using a hand-held GPS unit for inclusion into Surrey's mapping system. Throughout the field assessment, we made general notes regarding the extent of riparian vegetation and surrounding land uses.

5.4.3 Riparian and Fish Habitat Assessment Results

Figure 11 displays the distribution of drainages and drainage classification based on existing City of Surrey mapping. The maps also show classification updates and potential habitat enhancement/restoration areas. Riparian setbacks have been added as per the Corridors in the BCS and existing protocols used by the City of Surrey. As future development densities are unknown at present, all Class A, AO and B drainages have been associated with the maximum 30 m riparian buffer.

FIGURE 11: Selected Watercourse Restoration Areas and Fish Barriers

LOCATION:	PROJECT:	CLIENT:	MAP DATE:	DRAWN BY:	DOSSIER:
Surrey, BC	Environmental Assessment	City of Surrey	6/11/2015	Anna Jeffries	15.0073



5.4.4 Fish Habitat and Fish Distribution

There are numerous fish-bearing creeks in the study area and very few class C watercourses. Land development, mainly as a result of roads, extensive ditching and agriculture, has restricted the natural distribution of fish and fish habitat in certain parts of the study area.

5.4.5 The Little Campbell River

The Little Campbell River (aka the Campbell River) (Watershed Code 900-000500) flows south and west through the study area. The Little Campbell is known to support a range of fish species (as per the species list in Habitat Wizard, including chinook salmon (*Oncorhynchus tshawytscha)*, coho salmon (*O. kisutch)*, sockeye salmon *(O. nerka*), chum salmon (*O. keta*), steelhead (*O. mykiss*), westslope cutthroat trout (O. clarki lewisi), coastal cutthroat trout (*O. clarki clarki*), including anadromous form, rainbow trout (*O. mykiss)*, redside shiner (*Richardsonius balteatus*), prickly sculpin (*Cottus asper*), three-spined stickleback (Gasterosteus aculeatus), peamouth chub (*Mylocheilus caurinus*), brown catfish (*Ameiurus nebulosus*), carp (Cyprinus sp.), pumpkinseed fish (*Lepomis gibbosus*), yellow perch (*Perca flavescens*), brassy minnow (*Hybognathus hankinsoni*), coastrange sculpin (*Cottus aleuticus*), dolly varden (*Salvelinus malma*), fathead minnow (*Pimephales promelas*), flathead chub (*Platygobio gracilis*), kokanee, (*O. nerka*, but not ocean going), lake lamprey (*Entosphenus macrostomus*), salish sucker (*Catostomus* sp.), and slimy sculpin (*Cottus cognatus*).

During the field assessment, we observed fish both in the mainstem Little Campbell River and connected tributaries (including ditches). The majority of the fish we observed were rearing juvenile coho salmon fry. The mainstem river exhibits a perennial flow regime and offers relatively diverse habitat where it flows through the study area. Deep pools for cover and security are well represented, as are riffles with adequate gravel for spawning. Large woody debris (LWD) is abundant along many reaches.

5.4.6 East Twin Creek

No fish have been recorded along East Twin Creek in Habitat Explorer or iMap, but during our assessments and previous assessments by SHaRP, coho fry and spawning adults use the creek. We also saw lamprey during our visit. More species also are likely to use the creek.

As noted in the discussion of Corridor 51, there is natural vegetation along both sides of East Twin Creek in property south of 20th Avenue, but the creek then flows into fields for most of its extent between 18th and 16th Avenues. SHaRP has done in depth assessments of the riparian zones and instream conditions and A Rocha has undertaken some restoration in that area.

5.4.7 West Twin Creek

West Twin Creek contains coho salmon, rainbow trout, threespine stickleback and Prickly Sculpin (iMap, accessed 2015).

As noted in the discussion of corridor 40, natural riparian conditions and mix of gravel and sand/organic substrates characterize the watercourse between 18th to 20th Avenues. Very disturbed riparian vegetation was noted from 18th to 16th Avenues, but some areas had retained forest cover and some areas have had restoration activities. A Rocha has assisted private landowners at 1724 184th St. and at the United Church at the corner of 184th Street and 16th Avenue. Riparian planting has been added in places (in cooperation with A Rocha). Some barriers, in the form of open fields where surface water disappears, exist on West Twin Creek. Fish (coho) were seen at 16th Avenue, south of the 'dry' field portion, but not north of that barrier.

5.4.8 Jacobsen Creek

Jacobsen Creek contains steelhead (*O. mykiss*), cutthroat trout, rainbow trout, coho salmon, and chinook salmon (Habitat Explorer, iMap).

As noted in the discussion of Corridor 47, the riparian buffer of Jacobsen Creek is relatively natural in Hub O, but even then is exposed to light on the south side and would benefit from planting of trees for shade and to control blackberries. Away from Hub O, the buffer becomes narrow and dominated by shrubs and small trees as it passes through farmers' fields. The creek then passes through natural vegetation in the ravine close to 8th Avenue; unfortunately that natural area is upstream of a culvert and spillway under a driveway into the complex at 19527 to 19575 8th Avenue which creates a fish barrier. No fish were seen above that barrier.

5.4.9 Highland Creek

Highland Creek contains coho salmon (iMap), at least near the confluence with the LCR. Fish presence is indicated as 'yellow' (indicating no fish presence but significant fish food) on Surrey's map but was not assessed in the field. Further assessment would be useful given iMap suggest there may be fish in the creek.

As noted in the discussion of Corridor 46, the riparian areas along Highland Creek fall largely in agricultural land with only a narrow strip of small willows and shrubby vegetation along the stream sides.

5.4.9.1 Updates to the Existing City of Surrey Stream Classification Map

The existing City of Surrey stream mapping represents a relatively accurate portrayal of the drainage network throughout the study area. During the field assessment, stream locations were field checked where feasible. Only two main adjustments are noted for the City's stream mapping and classification.

- Two very small tributaries off of West Twin Creek were noted north of 18th Avenue.
- The fish barrier on Jacobsen Creek seems to be the manmade spillway and culvert under the driveway at the blue triangle point on Figure 11 and not further upstream as shown on COSMOS. The red classification should not go beyond that point.

5.4.10 Recommendations for watercourses

5.4.10.1 Candidate Areas for Habitat Restoration and Enhancement

Restoration and/or enhancement of fish habitat would be most beneficial in areas that are known to currently support fish, or in immediately adjacent areas with sufficient potential (e.g. adequate water availability). Even restoring class A and AO streams (red on the map) will be significant work and requires cooperation from landowners. Marginal habitat that currently supports fish can be improved in several locations, which would result in increased fish productivity.

A Rocha and SHaRP reports for West Twin, East Twin and Jacobsen provide excellent summaries of restoration opportunities; here we selected high priority areas. Figures 11 displayS the five candidate areas (labeled "A" to "E") that were identified as having the most potential for habitat restoration and enhancement.

A. The Little Campbell River:

1. South of 16th where the buffer should be wider to provide a Regional Corridor
2. In the gap of forest between A Rocha and City land at about 18 th Avenue. Although some gaps in forest cover are not too detrimental to the stream, invasive species should be controlled.

B. East Twin Creek between 18 th and 14 th Avenues. Create more natural riparian buffers.

C. West Twin Creek:

1. Between 18 th and 16 th Avenues. Create more natural riparian buffers.
2. North of 20 th Avenue in farm fields. Create more natural riparian buffers.

D. Creek between 12 th and 8 th Avenues. Create more natural riparian buffers.

E. Highland Creek between 12 th and 8 th Avenues. Create more natural riparian buffers.

F. Jenkins Creek between 12 th and 8 th Avenues. Create more natural riparian buffers

G. Along Corridor 48 where land is cleared between wetlands. Re-establish shrub and tree vegetation.

In all cases, the habitat enhancement/restoration that is described represents suggested measures that would require detailed design prior to implementation.

5.4.10.2 General Opportunities for Fish Habitat Improvements

As well as the specific areas for restoration noted above, and other specific areas noted by A Rocha and SHaRP reports, general habitat enhancement opportunities occur throughout areas of existing fish habitat. Instream modifications would lead to increased habitat diversity and an associated increase in fish productivity. Instream habitat enhancement projects that would be of benefit include (but are not limited to): log bank cover construction, rock/log weir construction, strategic instream boulder placement, gravel catchment/placement, installing wing/flow deflectors, LWD placement and off channel habitat development.

Riparian planting (including planting to increase bank stabilization) would be a habitat improvement option adjacent to existing fish habitat. As well, preventing movement of domestic livestock into creeks and riparian would vastly improve some areas.

Recommendations for Aquatic Habitat and Streams

- Identify factors and habitat features that are limiting fish populations;
- Remove barriers to fish movement;
- Enhance reaches with poor instream habitat diversity. Include large woody debris structures, pools and side channels;
- Inventory and maximize the quality of salmonid spawning habitat;
- Continue to carry out water quality monitoring for all red coded stream systems;
- Minimize recreation trail creek crossings. Where necessary, ensure fencing to prohibit access to the water;
- Ensure fish passage through all infrastructure crossings of red coded creeks during redevelopment;
- Pursue opportunities to daylight watercourses.

Wetlands and Ponds

- Encourage retention and integration of existing wetlands into new development;
- Protect a 30m riparian terrestrial buffer around all wetlands and ponds;
- Protect wetlands in policy ensuring no net loss during development;
- Create new wetlands when possible as part of stormwater management;
- Work with golf courses to expand wetland communities;
- Inventory and remove invasive plant species from wetlands and ponds;
- Monitor and manage invasive wildlife (i.e., Bullfrogs, Carp);
- Create naturalized islands in larger wetlands/ponds for wildlife refuge;
- Promote the installation and maintenance of bird boxes.

Recommendations for Riparian Habitat

- Implement pioneer succession restoration strategies outlined in the City of Surrey Restoration Prescriptions for Municipal Ponds and Riparian Systems;
- Enforce Streamside Protection and Enhancement Areas (SPEA) setbacks from top of bank for Class A & B watercourses;
- Re-establish required setback distance and restore natural habitat for SPEAs as a condition of re-development;
- Identify opportunities to introduce vegetation within the riparian areas of dyked river systems;
- Work with golf courses to ensure minimum 10m riparian buffer from all red coded creeks and a minimum of 50% of wetland perimeter is naturalized; naturalization of south banks is a priority for creek shading.
- Where tree and plant species diversity is low, develop planting plans to protect and improve ecological integrity of SPEAs;
- Encourage the creation of wildlife trees in riparian areas. Prioritize the retention of conifer species that are >30cm in diameter. Retain a height that is 2/3 the distance to the nearest target;
- Increase cover and connectivity of large woody debris to provide ground cover corridors;
- Promote lower canopy and shrub cover within 10m of creeks;
- Locate recreation trails and facilities on only one side of riparian corridors. Trails should be outside the Streamside Protection and Enhancement Area and at a minimum distance of 10m above the top of bank for ravines;
- Inventory and remove invasive plant species from riparian areas. Prioritize their removal based on their risk to the integrity of the ecosystem (i.e., – knotweed);
- Install fencing between trails and creeks where dogs and humans continue to access the creek;
- Riparian communities associated with red coded ditches should be naturalized with at minimum a shrub community.

Recommendations for the Management of Invasive Species

- Complete a comprehensive invasive species management strategy that includes plants, animals and insects; consider new species that may arrive due to climate change;
- Maintain a spatial inventory of invasive species in all natural areas;
- Prioritize efforts to control invasive species at a local level to those areas with sensitive ecosystems and rare plant communities;
- Quarantine soils removed from development sites that are contaminated with noxious weeds;
- Co-operate with the Canadian Food and Inspection Agency to monitor for invasive insect species;
- Adopt or create a notification system for the public to report invasive plant and animal species;
- Install preventative structures (fencing, ditches) to prohibit dumping of garbage and gardens waste;
- Increase the fines and enforce penalties for dumping of waste in natural areas.

5.5 Large Trees

5.5.1 Original Forest Cover

The Little Campbell River Study Area lies within the Coastal Douglas-fir Zone in the mm1 (moist maritime) variant in which the climatic climax overstory vegetation is generally accepted to consist of Douglas-fir, with lesser amounts of western redcedar, western hemlock (in wetter sites) and lesser still, Sitka spruce.

Natural disturbance (usually fire) return intervals are very long (Wong et al. 2003) which suggests that the original forest cover consisted of very large trees that clearly had not experienced extensive forest fires or other stand-destroying events in recent history.

An interesting website History of Surrey by Jack Brown (Brown, 1998) describes the forests of the area at that time:

> *"The mature evergreen rain forest which existed on the uplands of Surrey at the time of the earliest logging operations contained some of the best timber on the Pacific Coast. The cedars*

> [redcedar] *and firs* [Douglas-firs]*, which dominated the uplands, were both giant species when fully matured; some of the virgin timbers were as great as eighteen and very occasionally twenty-five feet in diameter."*
>
> *"In very early days the Douglas-fir was considered by far the most valuable and useful timber to be found in British Columbia. After a survey of the timber tracts in the Fraser Valley the Royal City Planing Mills of New Westminster decided that the best stand of Douglas Fir to be found anywhere, and some declared it was the best in the world, was the tract of heavy timber found south of the Nicomekl River in Surrey Municipality."*\

5.5.2 Logging and Farming History

The Little Campbell River study area was part of a thriving logging industry from the late 1880's to the mid 1920's. The Little Campbell River supported a shingle Mill in the late 1800's. Logging was carried out initially by oxen, later by horses, and finally donkey engines and railways. By 1927 most of the prime timber was logged. At that time, although sawmills continued to thrive in South Surrey, the timber supply shifted eastwards to Langley and beyond.

In this assessment of tree resources, it is assumed that original clearing of forest was essentially complete by the mid-1920's or 1930's and that trees that established after the abandonment of forest land are likely to be 80 – 120 years old.

Pioneer farming started in the 1870's, but was centered in the lowlands closer to the Fraser River. A slow influx of early settlers cleared small farms to provide produce to the expanding population of sawmill workers and loggers. With the waning of the local logging industry, agricultural markets shifted to feeding the growing population of the Lower Mainland, which in general had been increasing in response to improving road and rail access.

The depression years of the 1930's resulted in the arrival of farmers from the prairies. Farming in Surrey expanded with this influx. Farming activity increased, but with an overall trend towards smaller parcel size (according to Brown (1998), farm parcels of 2.5, 5, and 10 acres were common). Local agriculture mainly consisted of small-scale poultry and dairy.

Historical photos gathered for a previous project show the progression of land clearing and development since the 1940's. The latest change in development in the South Campbell areas has been from the introduction of light industry and commercial buildings. Those developments entailed clearing large blocks of forested land between 20th Avenue and 24th Avenue and 188 St. and 194 Street.

5.5.3 Existing Land Cover

Today, forest land occupies less than 30% of the area. Some large patches exist, such as between 12th and 15th Avenues (near Hub O), and at Hub I (20th Avenue and 192 Street). Even these relatively large patches are small compared to the historical extent. Other areas of forest are along the Little Campbell River itself where the steep slopes of the creek have protected the slopes and valley bottoms. Some of the forest remaining is city land, and some is privately owned.

5.5.4 Significant Trees

The City of Surrey recently enacted Surrey Tree Protection Bylaw, 2006 No 16100. This identifies trees of value in several categories that require protection and specifies penalties for cutting. In this bylaw, the categories of trees identified are:

1. Protected tree (any tree with a DBH >30 cm; or any replacement tree, or any tree planted as a requirement of an application or permit).
2. Any tree within a high sensitivity ESA.
3. A specimen quality tree (i.e., any tree deemed to be of exceptional value).
4. A significant tree (any one of 253 individual trees identified in Schedule B of the bylaw); and any tree of the following species:
    - Arbutus,
    - Garry oak,
    - Pacific dogwood,
    - Pacific Yew,
    - Coast redwood,
    - Dawn redwood,
    - Giant redwood
    - Maidenhair tree, and
    - Monkey puzzle tree.

In our field surveys the majority of trees were >30 cm dbh and thus each is significant. We observed relatively few significant *species* of trees, either in landscaped residential areas or native forest areas. Our study area does not have any ESAs. To identify trees of exceptional value we chose to survey trees having a diameter of 1 metre (100 cm) or greater. Our aging of a few trees in the study area (by increment coring) suggest trees of that size are approximately 100 years old.

5.5.5 Locations of Large Trees

During our initial field work, we attempted to visit all forested areas in the study area and measure the diameter of any tree approximately 1 m wide. That approach worked well until we encountered stands with very many trees approximately 1 m wide. There was not enough time available to provide locations or measure them all. As a result, our maps include both the locations of individual large trees, and a delineation of polygons that contain high densities of large trees. The discussion of each Hub and Corridor (Section 5.3.3) noted the relative presence of large trees. As well, many areas outside of Hubs and Corridors also had significant numbers of large trees, both in remnant forest patches (sometimes large) on farms and also in smaller numbers in residential yards. Figure 12 shows the polygons and some example trees at various locations.

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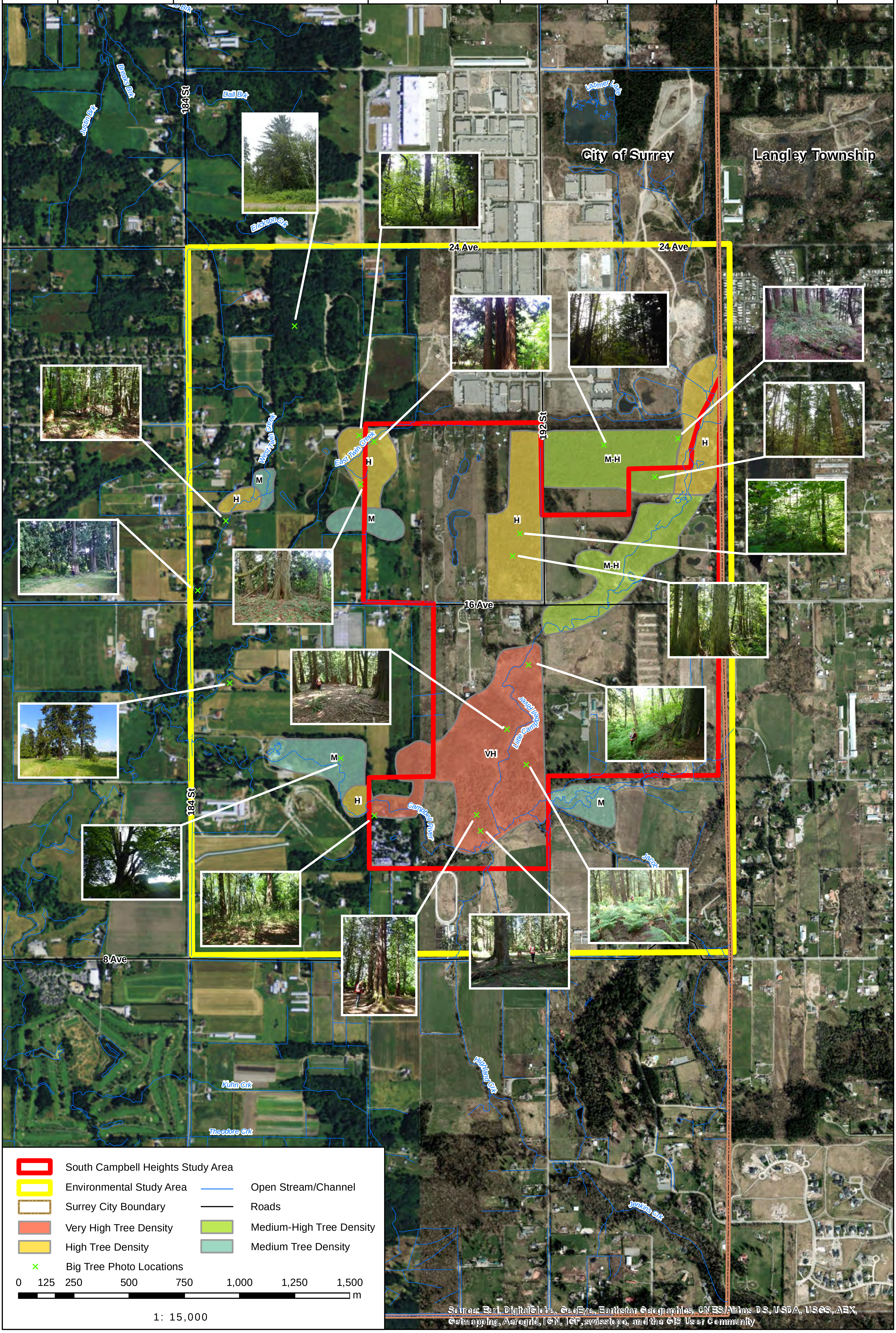
FIGURE 12: Areas with Medium to Very High Large Tree Densities in the Study Area

LOCATION:	PROJECT:	CLIENT:	MAP DATE:	DRAWN BY:	DOSSIER:
Surrey, BC	Environmental Assessment	City of Surrey	6/11/2015	Anna Jeffries	15.0073



Although no old-growth trees remain, by conserving those trees that are in the order of 100 years old, Surrey has a head-start in replacing this lost resource.

5.6 Archaeology

5.6.1 Introduction

The study area is located within asserted traditional territories of the Semiahmoo, Stó:lō, and Tsleil-Waututh First Nations. This study was conducted under Stó:lō Nation Cultural Heritage Investigation Permit 2015-030, and Tsleil-Waututh Nation Cultural Heritage Investigation (permit number pending).

The goal of this project is to identify and assess potential for unrecorded archaeological sites to be present within the study area. This assessment does not address any potential impacts to traditional and contemporary use sites within or near the study area. This report is provided without prejudice toward First Nations treaty negotiations or Aboriginal Rights and Title, and does not constitute aboriginal consultation.

5.6.2 Natural History

The study area lies within the Fraser Lowland region, characterized by low elevation, gently rolling hills of glacial drift and separated by wide valleys of alluvium. During the Pleistocene, glacial ice blanketed the region. Circa 13,000 years BP, glacial recession resulted in a sea level rise of 150 m or more above present elevations (Armstrong 1981; Mathews 1973). The Fraser River stabilized by 11,000 BP and within approximately 6000 years sea levels established current levels (Mathews et al. 1970).

5.6.3 Ethnography

The study area is within asserted traditional Coast Salish territories of the Semiahmoo First Nation, speakers of a Northern Straits Salish dialect, and of the Stó:lō and Tsleil-Waututh First Nations, speakers of the Downriver dialect of the Halkomelem language (McHalsie 2001; Smith 2001; Suttles 1979, 1990; Thompson and Kinkade 1990).

Traditionally, the Coast Salish used rectangular cedar plank houses as primary dwellings. Villages often consisted of one or more houses as well as a number of smaller structures on the foreshore of sheltered bays or watercourses. Temporary shelters of rush mats were used in some locations for shorter seasonal occupations and, at some resource procurement locations, permanent plank or bark covered houses were built (Barnett 1955; Suttles 1974, 1979, 1990).

A wide variety of objects including tools, weapons and hunting and fishing gear were manufactured by flaking stone (particularly basaltic and granodioritic stone), grinding stone (particularly slate, but also nephrite and others) and working bone, antler and shell (Mitchell 1990; Suttles 1990).

A variety of plant materials were extremely important, most prominently, red cedar (*Thuja plicata*), which was employed to manufacture houses, canoes, boxes, clothing, bags, baskets and mats, among other items (Barnett 1955; Turner 1998). Blankets and clothing were sometimes woven from dog hair (*Canis familiaris*), mountain goats (*Oreamnos americanus*) and other materials, such as stinging nettle (*Urtica dioica*) fibres. Nettle fibres were also used for textiles and cordage (Schulting 1994; Turner 1995; Wells 1966).

Among the Coast Salish, fishing was the principal economic activity. Salmon (*Oncorhynchus sp.*), was particularly exploited, but also Pacific herring (*Culpea pallasii*), flat fish and many other fish species. Clam gardens and other methods of aquaculture were also practiced. Birds were hunted, particularly waterfowl, and both land and sea mammals, including deer elk and seal, were hunted using a variety of methods (Barnett 1955; Monks 1987; Suttles 1990; Groesbeck et al. 2014; McKechnie et al. 2014).

Plant foods, such as blueberry, cranberry and wapato were also gathered for subsistence (Pojar and Mackinnon 1994; Turner 1974, 1995). Coast Salish followed an annual round, congregating in the ceremonial season at winter villages and dispersing to hereditarily owned resource sites throughout the remainder of the year.

Ethnographically three social classes were recognized: a large upper class of nobility held rights and titles and sacred and ritual knowledge; a smaller commoner class; and a small number of slaves owed by the most wealthy households. A detailed ethnographic description of Coast Salish lifeways can be found in Barnett (1955), Suttles (1974, 1979, 1990), Ham (1982).

5.6.4 Archaeology

Archaeological research in the Strait of Georgia region dates back to the beginning of the twentieth century. Charles Borden (1950) and Arden King (1950) developed the first culture history by studying variations in artifact types over time. Subsequent syntheses were produced by Borden (1968, 1970) and Mitchell (1971, 1990). A generalized sequence for the region has developed based on the works above, as well as Carlson (1960, 1970), Ham (1982), Ham et al. (1986), Matson (1976), Matson et al. (1980), and Mitchell (1971). Summaries of this sequence can be found in Carlson (1983, 1990) and Mitchell (1990). Matson and Coupland (1995), Ames and Maschner (1999) and others have offered more recent syntheses, although there remains some disagreement on terminology. No synthesis has been provided to incorporate the research of the last twenty years.

In the early Holocene following the glacial recession and initial peopling of the coast, a generalized coastal adaptation within small mobile groups of primarily maritime hunter-gatherers manifested coast-wide. This is known as the Lithic stage (10,000-5500 BP; also commonly known as Old Cordilleran or Pebble Tool Tradition). By the mid-Holocene, with environmental stability and sea level and river gradients reaching near modern levels, human populations grew and began to develop social differentiations and new regional adaptations. Four archaeological phases are commonly recognized in the Strait of Georgia region staring with Charles phase, beginning at approximately 5500 BP, followed by Locarno Beach phase (ca. 3300 BP), Marpole phase (ca. 2400 BP) and finally, the Strait of Georgia phase (ca. 1500 BP). Increasing population size and social complexity are thought to continue to develop until reaching a plateau of complexity in Marpole phase, resembling ethnographic populations, which Matson and Coupland (1995) termed the "Developed Northwest Coast Pattern." However, others observe a climax in Marpole phase and subsequent decline in both population and complexity in the Strait of Georgia phase (Borden 1983; Carlson 1983, 2008; Angelbeck 2009; Angelbeck and Grier 2012; Hickok 2013).

Recently there have been calls for a re-evaluation of some of our current theories and interpretations. The emphasis on salmon may be overstated, and subsistence economies may have been more diverse in the past. Also, the relationship between salmon, storage and cultural complexity may have been more complicated (Monks 1987; Moss 2011; Groesbeck et al. 2014; McKechnie et al. 2014). Moss (2011) asserts that coastal mid-Holocene environmental stabilization varied by time and location and was not coast-wide around 5000 BP (contra Fladmark 1975, 1982).

The introduction of ground stone technology, beads and labrets at around 4000 BP, mid-Charles phase, coincides with a florescence of extravagantly beaded burials, suggesting a possible shift in culture and the beginnings of social hierarchies; possibly warranting a division of Charles phase (Curtin 1991; Ames et al. 2010; Cybulski 2011). Ames et al. (2010) also show that ground stone increases in proportion over time, but does not replace flaked stone. Clark (2010) demonstrated that 'Marpole' was focused in areas that are traditionally Halkomelem speaking and limited in time and space.

The decline in the Strait of Georgia phase may have been brought about by a possible epidemic of treponemal infection in the preceding phases not previously accounted for in the archaeological interpretation of the region (Hickok 2013). Treponemal infection produces syphilis and, when congenital, can severely impact fertility rates (Curtin 2005; Hickok 2013). The early Strait of Georgia phase appears to have been a time of increased conflict, which Angelbeck (2009; Angelbeck and Grier 2012) advocates as a period of heterarchy with competing chiefs, and suggests a return to elite hegemony in the last 500 years, suggesting another possible new phase (Schaepe 2009; Angelbeck 2009; Angelbeck and Grier 2012).

5.6.5 History

The earliest recorded European contact in the Lower Fraser area occurred in 1791 with a Spanish expedition lead by Eliza. However, his writings indicate that the aboriginal population informed him of previous visitations by a large ship and overland traders with horses, and showed him a few engraved brass bracelets. The next year, the Spanish once again visited the region with an expedition led by Galiano (Wagner 1933:186-187). An English expedition led by Vancouver also arrived in 1792, establishing an observatory at Birch Bay (Newcombe 1923; Welsh and Cameron 2010). Traveling down the river from the interior, Simon Fraser reached the mouth of the Fraser River in 1808 (Lamb 1960).

In the early 1820s the Hudson's Bay Company began exploring the region seeking beaver pelts. By 1827 they had established Fort Langley on the Lower Fraser above the head of the delta. The fort soon became a center for trade over a wide region (Suttles 1990:470-471). The Oregon Treaty of 1846 established the boundary between the United States and British claimed territory.

The British assert their sovereignty over British Columbia. In 1858 the Fraser River Gold Rush brought many people to the region, and in 1859 Governor James Douglas adopted a policy of "benevolent assimilation" of the aboriginal population (K. Carlson 2001). The history of the region from the indigenous perspective is presented in the volume *A Stó:lō Coast-Salish Historical Atlas* (K. Carlson 2001).

5.6.6 Site Types

Site types that have been recorded in the region comprising the study area include habitation, subsistence feature, short-term procurement, lithic scatter, trail, rock art and historic sites. Discovered sites are not limited to a single type and may consist of one or more of these site components.

Sites types expected to be discovered within the immediate vicinity of the study area would likely be limited to habitation, subsistence feature, CMT and lithic scatter sites. A description of each site type follows below.

5.6.6.1 Habitation Sites

Prehistoric habitation sites are most common in areas with significant hydrology features. More commonly these sites are associated with nearby shorelines, lakes, rivers and large streams, but they may also be found near gullies, creeks and other small drainages. Sites are not limited to extant water features and thus can also be associated with palaeo-shorelines and dry riverbeds or lakebeds.

In the Fraser Valley, two predominant feature types typify habitation sites. The first of these types is identified by large, round or rectangular depressions called housepits. These depressions represent the cultural legacy of pithouses, which served as partially subterranean winter homes for indigenous peoples along the Fraser Valley and its tributaries. Alternately, the remains of plank houses are reflected in the archaeological record by long and shallow rectangular depressions or linear berms of sediment. These features are usually associated with vertical post-holes where support timbers once provided structural integrity.

Habitation sites have high heritage significance and are important informants for the archaeological study of past ways of life, particularly in the case of ethnographically documented villages. Due to the intensified, diachronic activity that accompanies habitation these sites almost invariably have multiple components and therefore include other features such as cache pits, sweat lodge depressions, roasting pits, CMTs, lithic scatters, funerary features, and rock art.

5.6.6.2 Subsistence Feature Sites

Subsistence features are archaeological remains associated with hunting, fishing, gathering, storing and processing foods. In the archaeological record of the Fraser Valley these types of remains are represented by cache pits, roasting pits, above ground caches, fish weirs and shellfish gardens. Cache pits and roasting pits are often associated with water sources and are frequently associated with larger, multiple-component sites. Fish weirs and shellfish gardens are invariably associated with productive water sources and, as such, may also be associated with multiple component sites. However, subsistence features can be discovered anywhere food resource procurement activities have taken place and are often discovered as caches or temporary camps at variable distances from primary habitation sites.

5.6.6.3 Lithic Scatters

Lithic scatter sites are specialized locations where stone resource procurement activity has occurred. As such, these sites represent the extraction of raw resources for the production of stone tools and also areas of stone tool manufacture from previously extracted manuports (unformed, mobile, lithic resources for stone tool production). Lithic scatters often consist of lithic detritus in the form of reduction flakes and debitage from tool production or maintenance, but scatters may also include stone tool discoveries. Scatters may be associated with multiple-component sites or may represent isolated lithic finds, which often mark hunting events or other nomadic activities.

5.6.6.4 Culturally Modified Trees

Culturally modified trees (CMTs) are the remains of arboreal resource procurement sites and are represented by trees that have been modified by indigenous peoples for traditional uses. First Nations people exploited several species of tree resources in the Fraser Valley, including pine, yellow cedar and red cedar. Pine bark was harvested for cambium as a food resource, while cedar was used much more intensively. Cedar bark was used for weaving, basketry and matting; planks could be removed from standing trees for building materials; and trees were felled for carving, canoe making or building structures.

5.6.7 Findings

5.6.7.1 Previous Studies

Two regional archaeological studies addressed the study area in the past (Kenny 1975; Yip & Gose 1979). These broad regional surveys lack specific application to the study area.

In 1991, the Keenlyside site (DgRq 3) was revisited and new boundaries were established for the component of the site situated on the northern side of the river (Zacharias 1991). This study is discussed in more detail below.

5.6.7.2 Recorded Historic and Archaeological Sites

Nine sites have been recorded within two kilometers of the study area. Of these, one site (DgRq 14) is situated within the proposed study area. Only DgRq 3, the Keenlyside site, represents a site of archaeological significance. The remainder of these sites are historic and summarized below in Table.

Table 4. Historic Sites within 2 km of Study Area

Borden	Relative Dist.	Est.	Description
DgRp 8	1950 m SE	1924	Lochiel School
DgRq 14	Within Study Area	1933	Brookland Estate
DgRq 16	750 m W	1905	Hazelmere United Church – carpenter gothic style
DgRq 46	1600 m W	1881	Redwood Park – planted
DgRq 72	575 m W	1891	Great Northern Railway right of way
DgRq 76	1750 m NW	1924	East Kensington Elementary School
DgRq 81	1500 m SW	1890	Kitzel House/Root House

The Keenlyside site (DgRq 3) is roughly 350 meters east-west by 550 meters north-south, laterally bisected by Campbell River. Prior to highway developments in the 1960s, the Campbell River was a productive salmon spawning habitat and historical events of indigenous riverine resource exploitation have been recorded in the area, particularly at the mouth of the river (Zacharias 1991). Abundant cultural materials have been discovered at the site including ground and chipped stone tools, burnt mammal antler and bone artifacts, as well as some shell fragments (Zacharias 1991). The cultural matrix of the site on the north side of the river is highly disturbed as a result of historical agricultural activity and extends up to 25 to 60 cm into the subsurface at which point culturally sterile sands and gravels represent local glacial sedimentation (Zacharias 1991).

On the northwestern side of the site, a plow-disturbed cultural surface of unidentified age was encountered in the substrate (Zacharias 1991). This component is composed of greasy, black loams, charcoal and ash and was described as a layer in direct superposition to glacial sediments (Zacharias 1991). The presence of charcoal and ash throughout the sedimentary matrix been proposed as a possible widespread anthropogenic burning event, for the purposes of encouraging floral regrowth to attract game and improve wild plant crops (Zacharias 1991). Little is known about the site on the southern side of the river, although a re-examination of photographs of the artifact collection suggests an affiliation to the Locarno Beach Phase (Zacharias 1991).

5.6.7.3 Traditional Use / Ethnography

Traditional use sites (TUS) manifest in several different forms throughout the Fraser Valley, including geographical features, resource extraction sites, settlement sites and locations with significant associations to mythology (McHalsie 2001; Suttles 1979). Traditional use sites are:

> *…any geographically defined site that has been traditionally used by one or more groups of people for some type of activity. These sites will often lack the physical evidence of human-made artifacts or structures, but will maintain cultural significance to a living community of people. Traditional use sites are usually documented with the assistance of oral, historical and archival sources. Examples include: sacred sites, ritual bathing pools, resource gathering sites and sites of a legendary or past event of cultural significance (Ministry of Forests, Lands, and Natural Resource Operations 2007) .*

One TUS has been documented within two kilometers of the study area. Approximately 1250 meters west of the study area is a small area of land on the northwest bank of Campbell River, known as Á:lôxwet in Halq'emélem (McHalsie 2001). The name translates as "put something away", "save something", "don't want it to go to waste", or "there's not much" (McHalsie 2001).

5.6.8 Evaluation

The study area boundaries enclose an area of high archaeological potential due to the proximity to the nearby archaeological site DgRq 3, the nearby Á:lôxwet TUS, recorded and modeled travel corridors and the Campbell River, a historically rich salmon spawning ground (Zacharias 1991).

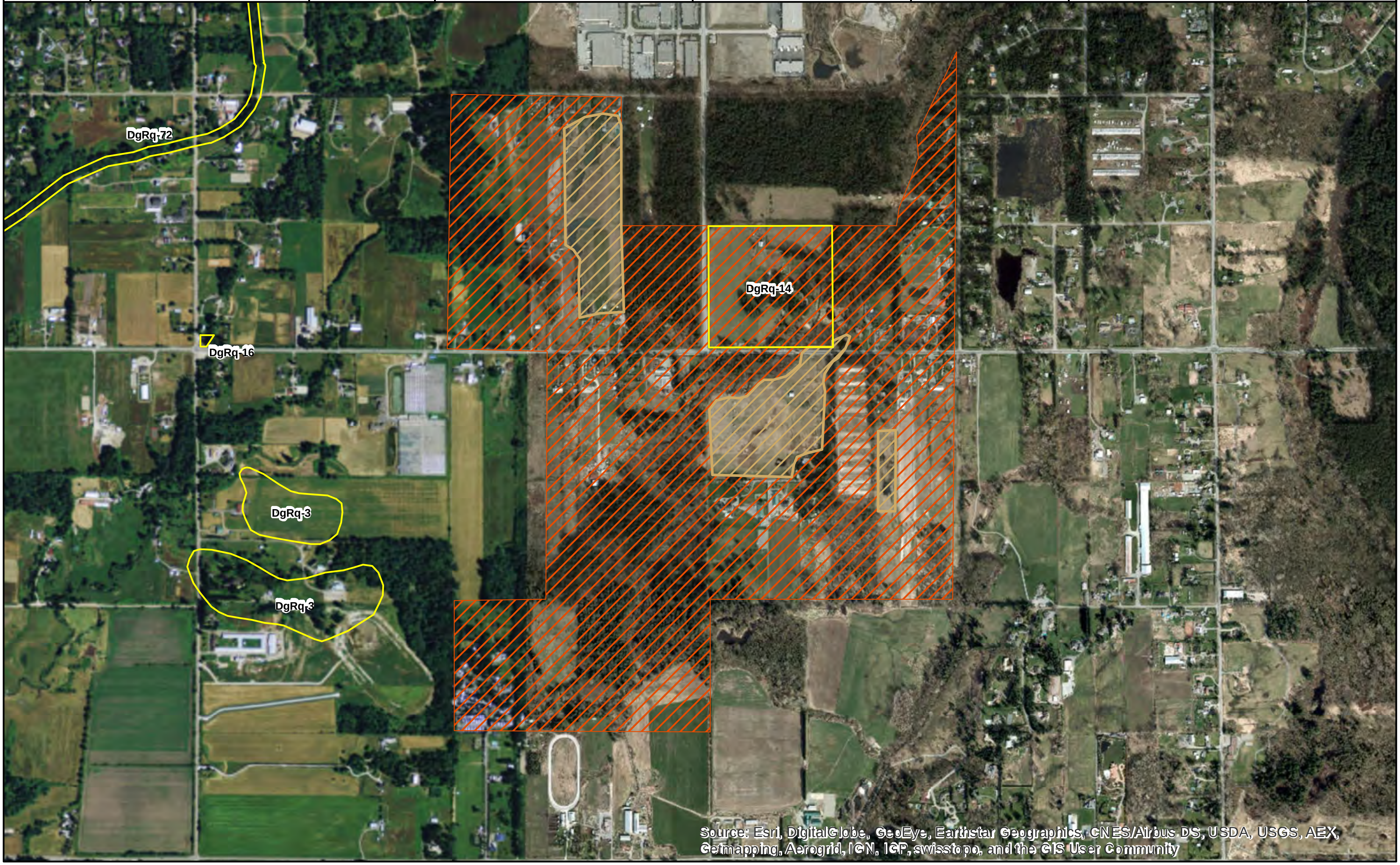
A Madrone vegetation survey crew noted the presence of large redcedars suggesting the possibility for CMTs to be present in the study area.

The study area has been previously disturbed by road construction, agricultural development, residential development and extensive gravel extraction. As a field component was not a part of this study, the extent of gravel extraction is uncertain. However, review of LIDAR mapping and communications with ground crews that have worked in the area has helped establish three major locations of gravel procurement intensification. This process would have removed all potential culture bearing sediments in these locations resulting in three discrete areas of low archaeological potential (Figure 13).

The remainder of the study area is considered to have high archaeological potential.

FIGURE 13: Areas of Archeological Potential

LOCATION:	NTS MAP:	CLIENT:	MAP DATE:	DRAWN BY:	DOSSIER:
Surrey, BC	92G/2	City of Surrey	6/11/2015	Anna Jeffries	15.0073



Archeology Site
Areas of High Archeological Potential
Areas of Low Archeological Potential

0 250 500 1,000 m

1: 25,000

5.6.9 Recommendations

Madrone recommends the following:

- No further archaeological studies for the three locations identified as having low archaeological potential (Figure 13);
- That any proposed developments within the remainder of the study area be reviewed by a professional archaeologist to determine the extent of any future archaeological studies in the study area; and,
- The Surrey Heritage Advisory Commission should be consulted regarding management of heritage site DgRq 14.

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APPENDIX I - Summary of Surrey Plans, Policies and Guidelines

There are a number of land use plans and other City plans and policies that play a role in shaping the Biodiversity Preserve and the surrounding area. These are summarized below.

City of Surrey Sustainability Charter (2008)

The Sustainability Charter is the overarching policy document for the City of Surrey. It provides a framework and reference for all other policies and City actions.

Environmental Goals

To demonstrate good stewardship of the land, water, air and built environment, protecting, preserving and enhancing Surrey's natural areas and ecosystems for current and future generations while making nature accessible for all to enjoy.

Specific Goals

1. Terrestrial Habitat and Life. Create a balance between the needs of Surrey's human population and the protection of terrestrial ecosystems, considering:
a. Interconnecting Surrey and the areas outside Surrey through wildlife corridors, parks and natural areas;
b. Protecting to the extent possible, existing urban forests and natural coverage, protecting trees and maximizing the city's tree canopy;
c. Maintaining farmland and promoting food self- sufficiency and production without negatively affecting existing natural areas.

2. Water Quality/Aquatic Habitat and Life. Protect Surrey's ground water and aquatic ecosystems for current and future generations, considering:
a. Groundwater;
b. Surface runoff;
c. Drinking water sources;
d. Creeks, streams, and river systems;
e. Sources of pollutants entering aquatic systems;
f. Natural riparian systems; and
g. Native ocean and freshwater habitats.

3. Air Quality. Preserve clean air for current and future generations, considering:
a. Local air quality;
b. Stability of the global atmosphere; and
c. Air quality issues related to both human and ecosystem health.

4. The Built Environment. Establish a built environment that is balanced with the City's role as a good steward of the environment:

a. Minimize the impacts of development on the natural environment;
b. Promote the use of native species and reducing the impact of invasive species;
c. Promote permeable surfaces where possible in new developments;
d. Incorporate opportunities for natural areas and urban wildlife;
e. Protect unique and valuable land forms and habitats;
f. Reduce energy and resource consumption in the built environment;
g. Minimize solid and liquid waste;
h. Establish guidelines and practices that create green buildings; and
i. Express community environmental values in new developments

Official Community Plan (OCP, 2014)

This EA project supports the objectives of the OCP by adhering to several of its policies including:

- D1.2—Establish plans, strategies and policies to enhance and manage the green infrastructure network
- D1.4—Preserve riparian areas and watercourses in their natural state and link them with upland natural areas to develop a connected network of natural areas throughout Surrey
- D1.9—Encourage ecological restoration of riparian and/or significant natural areas to improve stream health, to support biodiversity and to improve the ecological health of the green infrastructure network
- And others

Biodiversity Conservation Strategy (BCS, 2014)

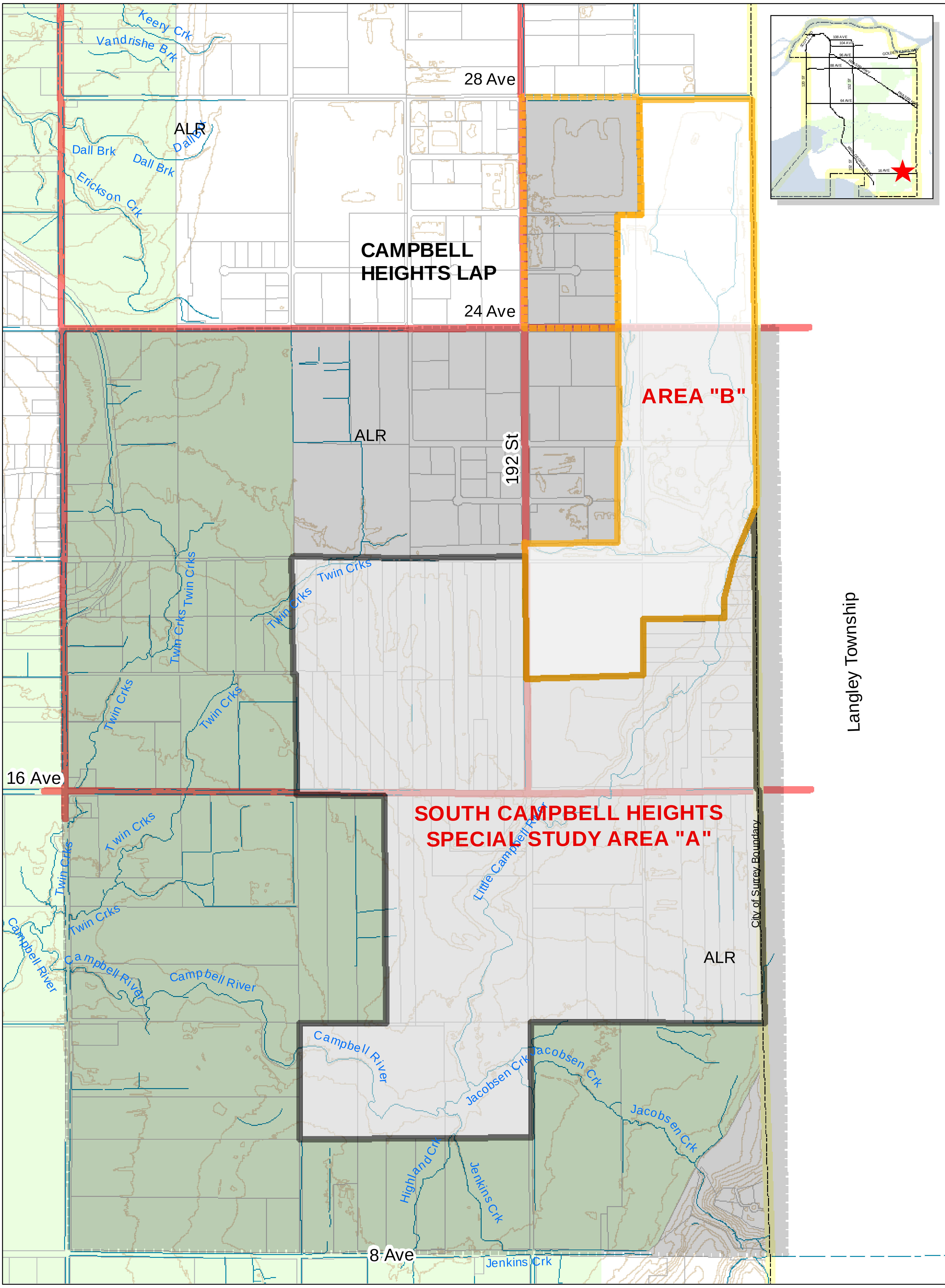
The BCS builds on the 2011 Ecosystem Management Study (EMS) that identifies all key habitats in the City. The identified Hubs and Corridors are critical components of the Green Infrastructure Network (GIN); these Corridors have high ecological values that support species at risk. The GIN is an interconnected network of protected open space and natural areas that conserves ecosystem values and functions and provides benefits to people and wildlife. The most relevant recommendations from the BCS are discussed in the main text.

Ecosystem Management Study (EMS, 2010)

Adopted in 2011, the EMS identifies and ranks all the habitat Hubs, Corridors and Sites in the City. Identifying the green infrastructure in the City was the first step in being able to protect and enhance green infrastructure in perpetuity. The study ranks the natural areas with a weighted scale to provide an ecological significance score. Some of the metrics used to calculate the weighted score include vegetation naturalness, habitat size, diversity and integrity, and total impervious area. This was a building block of the BCS.

APPENDIX II - Amended Study Area

South Campbell Heights Special Study Area & Area B Addendum



SOUTH CAMPBELL HEIGHTS SPECIAL STUDY AREA

Context Map for Environmental Study

N

0 50 100 200 300 400 500 Meters

City of Surrey Planning & Development Department

Legend

- SouthCampbellHeightsStudyArea
- EnvironmentalStudyArea
- SouthCampbellHeightsStudy "Area B"
- EnvironmentalStudyArea_Extension "Area B"
- Open Stream/Channel
- Surrey City Boundary
- Arterial Roads
- Lots
- Contours - 5 metre
- ALR

1:12,500

APPENDIX III – Contacts

Main Contacts

Contact Name, position	Contact Number
Dr. Fred Bunnell, Anthea Farr, Corey Bunnell; Naturalists	604-576-7731
Margaret Cuthbert; Friends of Semiahmoo;	604-536-2636
Jude Grass; Naturalist	604-538-8774
Deb Jack; Surrey Environmental Partners	604-590-3037
Christy Juteau; A Rocha BC	778-980-4344
Ron Meadley; Little Campbell River Watershed Society	778-867-3507
Roy Thompson; Little Campbell River Fish Hatchery	604-535-8366
Liana Ayach; SHaRP (Salmon Habitat Restoration Program)	604-591-4383
Several landowners (usually without names and phone numbers, but some available on request).	

MADRONE
environmental services ltd.

APPENDIX IV – STO:LO Permit

SRRMC TUS Database Search Result – Data Sheet
PROJECT: SHIP 2015-030 Hamm – South Campbell Heights AOA
REQUESTED: Steven Hamm / Madrone Environmental Services Ltd.
DATE: April 22, 2015

The information provided in this report is the result of a digital database review for the above referenced project conducted by the Stó:lō Research and Resource Management Centre (SRRMC) on behalf of Madrone Environmental Services Ltd. This review is limited in scope and is not to be considered a comprehensive treatment of First Nations interests or concerns associated with the proposed project. This assessment focuses on the relationship between cultural heritage resources defined in the Stó:lō Heritage Policy and the proposed project plan(s). This report is intended to provide information useful to Madrone Environmental Services Ltd. and the City of Surrey in the archaeological overview assessment process. This report does not constitute consultation and does not in any way satisfy or complete the First Nation consultation requirements of Madrone Environmental Servicces Ltd. and the City of Surrey with the Stó:lō Nation, the Stó:lō Tribal Council, or any other First Nations or First Nations organizations.

***Findings*:**

1. Halq’eméylem Place Name
2. Archaeological and Historic Sites
3. Documented and GIS-modeled Travel Routes
4. High Archaeological Potential

Halq’eméylem Place Name: 1 within 2 km of Study Area (as depicted)

Place Name	Comment	Proximity to Study Area
Á:lôxwet	a small area of land on the northwest shore of Campbell River; “put something away”; “save something”; “don’t want it to go to waste”; “there’s not much”	1,250 m W

Places on the landscape with Halq’eméylem names are important to distinguish, in that they have the potential to provide insight into the cultural significance of a particular place, such as the significance of the geographic location itself, activities or events that took place there, or stories of the distant past, when the world was transformed into its present form (*sx̱wóx̱wiyám*). There are over 700 Halq’eméylem place names throughout S’ólh Téméxw. They also exist as places of power in a living landscape, upon which people seek spiritual power through various Stó:lō ceremonial and ritual activities.

Archaeological and Historic Sites: 8 within 2 km of Study Area (as depicted)

Borden ID	Site Type	Proximity to Study Area
DgRp-8	historic school – Lochiel School	1,950 m SE

APPENDIX V – Well Closures

Well Closure Checklist

This checklist was developed to help private well owners in the assessment and deactivation of existing water supply wells in the South Campbell Heights Study Area. Material for this checklist was gathered from the Water Act: Groundwater Protection Regulation (B.C. Reg 91/2009) and the Ministry of Community, Sport and Cultural Development (2012) document Model Well Regulation Bylaw: A Guide for Local governments (http://www.cscd.gov.bc.ca/lgd/infra/library/Model_Well_Regulation_Bylaw_Guide.pdf).

The BC Ministry of Environment Well Closure form is included in the appendix and can also be found online: http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/identification/well_construct_close_form_lithology.pdf

As a progressive initiative, the Village of Belcarra developed and adopted Well Closure bylaw from the Model Well Regulation Guide, with specifics of that implementation found here: http://www.belcarra.ca/bylaws/vob-bylaw-455_well_regulation.pdf.

We recommend that the City of Surrey consider bylaws regarding the closure of private wells after connection to municipal supply, using the Model Well Regulation bylaw provided by the Ministry of Environment.

Well Management Checklist - Closure	Cased	No Casing
Identify the Closure requirements of the well (see Table Below)	☑	☑
Contact a Qualified Well Driller (QWD), a person working under direction of a QWD, or a qualified professional with competency in hydrogeology to conduct the work.	☑	☑
Ensure that the QWD or professional retrieve and complete the Well Closure Form (http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/identification/well_construct_close_form_lithology.pdf) Fulfilling details in red to best possible completeness	☑	☑
Provide the Professional with a copy of the well construction report (well record) or a copy of the well data from BC Water Resources Online (http://maps.gov.bc.ca/ess/sv/wrbc/) if available;	☑	☑
If applicable, supply a copy of the written confirmation of any alternative specifications prescribed by the MOE or hydrogeologist;	☑	☑
Pull well casing out of borehole;	☑	
Have well filled in intervals of backfill (maximum 20ft) and sealant (minimum 3ft) or alternative specifications as per prescribed requirement;	☑	☑
Record details of the closure describing the depths, types and amounts of sealant and backfill material;	☑	☑
Remove and retain well ID tag for submission with Well Closure Report;	☑	☑
Excavate around the well head to a minimum of 4 feet depth from surface;	☑	☑
Cut and remove the top section of well casing up to a maxium of 1ft from surface;	☑	
Fill top of well with Closure Plug of length indicated in table below;	☑	☑
Install pitless adaptor and backfill to land surface with mild compaction as per Figure Below.	☑	☑
Compile Well Closure Report, Construction or Well Report, Details of Closure, and Well ID tag for submission to the Comptroller of Water Rights at: Ground Water Data Technician Water Stewardship Division, Ministry of Environment PO Box 9362 Stn Prov Govt Victoria, BC V8W 9M2	☑	☑

Well Closure – Closure requirements

Class of Well	Sub-class of Well	Method of Drilling	Oriental of Well	Closure Plug Required?		Minimum Length of Closure Plug (in feet)		Well Closure Report Required for Submission?
				Hole depth <= 15 ft	Hole depth > 15 ft	Hole depth <= 15 ft	Hole depth > 15 ft	
Water Supply	Domestic	Drilling	Vertical	Required	Required	3V	15V	Yes – See Schedule 3
		Drilling	Horizontal	Optional	Required	Not specified	15V	Yes – See Schedule 3
		Driving	Vertical	Required	Required	3V	3V	Yes – See Schedule 3
		Jetting	Vertical	Required	Required	3V	15V	Yes – See Schedule 3
		Excavating	Vertical	Required	Required	3V	3V	Yes – See Schedule 3
	Non-Domestic	Drilling	Vertical	Required	Required	3V	15V	Yes – See Schedule 3
		Drilling	Horizontal	Required	Required	3V	15V	Yes – See Schedule 3
		Driving	Vertical	Required	Required	3V	3V	Yes – See Schedule 3
		Jetting	Vertical	Required	Required	3V	15V	Yes – See Schedule 3
		Excavating	Vertical	Required	Required	3V	3V	Yes – See Schedule 3

Explanation

Optional: A closure plug is not required, but is recommended.

3 V : The length of the closure plug must be at least 3 feet, unless a professional hydrogeologist or an MOE professional hydrogeologist confirms in writing that a lesser length will not significantly increase the risk of a contaminant entering the well or aquifer. (V indicates Vertical feet)

15 V : The length of the closure plug must be at least 15 feet, unless a professional hydrogeologist or an MOE professional hydrogeologist confirms in writing that a lesser length will not significantly increase the risk of a contaminant entering the well or aquifer.

Submit : Submit the final well closure report to the Comptroller of Water Rights.

APPENDIX VI – Well Regulations

Deactivated and Closure of Wells (BC Reg 91/2009, Section 9)

The criteria by which a well must be deactivated or closed is as follows:

(1) The owner of a well that is not used for 5 years must ensure that, promptly after the end of that period, the well is deactivated or closed in accordance with section 6 of the Code.

(2) The owner of a well that has been deactivated or not used for 10 years must ensure that, promptly after the end of that period, the well is closed in accordance with section 6 of the Code.

(3) Subsections (1) and (2) do not apply to

(a) a well that is actively maintained

i. with the intent of future service,

ii. for use as a backup water supply, or

iii. that has yet to be put into use, or

(b) an existing geotechnical well.

(4) If an engineer has reason to believe that there is or may be

(a) a threat of a contaminant entering a well, ground water or the environment, or

(b) a threat to property or public safety,

the engineer may order the well owner to alter the well in accordance with specifications as directed by the engineer, or to close the well in accordance with the specifications set out in section 6 of the Code or specifications as directed by the engineer, and the owner must comply with the order within 90 days after the order is made or as otherwise directed by the engineer.

(5) If it is not feasible, within 90 days, either to comply with an order issued under subsection (4) or to meet the requirements for deactivating or closing a well under section 6 of the Code, the owner of a well may

(a) deactivate or close the well by applying to an engineer for approval of alternative specifications for deactivating or closing the well and, for that purpose,

i. the engineer may require the owner of the well to obtain alternative specifications recommended by a qualified professional who has competency in the field of hydrogeology or geotechnical engineering with respect to the requirements for deactivating or closing the well,

ii. the owner of the well must deactivate or close the well in accordance with the alternative specifications approved by the engineer, and

iii. a copy of the alternative specifications must be

a. attached to the well closure report, or

b. retained by the owner for a period of 5 years if a well closure report is not required, or

(b) deactivate or close the well in accordance with alternative specifications recommended by a qualified professional who has competency in the field of hydrogeology or geotechnical engineering, provided that

(i) the qualified professional gives written confirmation to the owner that the alternative specifications achieve the same results for deactivating or closing a well as required by section 6 of the Code, and

(ii) a copy of the alternative specifications and the written confirmation is

(A) attached to the well closure report, or

(B) retained by the owner for a period of 5 years if a well closure report is not required.

(6) A person who voluntarily deactivates or closes a well must do so in accordance with section 6 of the Code.

(7) For the purposes of section 69 (3) (d) of the Act, a qualified well pump installer may deactivate a well.

APPENDIX VII – SEI CODES and STRUCTURAL STAGES

Table 1: Sensitive Ecosystems and Associated Typical Structural Stages Mapped in the Study Area.

SEI Class	SEI Subclass	Brief Description	Typical Structural Stages Mapped
RI: Riparian		Ecosystems associated with and influenced by freshwater	
RI	ff: fringe	Narrow band near ponds or lake shorelines, or streams with no floodplain	2b, 2d, 3a, 3b, 4, 5, 6, and 7
RI	fm: medium bench	Medium bench floodplain terraces	4, 5, and 6
WN: Wetland		Terrestrial – freshwater transitional areas.	
WN	sp: swamp	Shrub or tree-dominated wetlands	2b, 3a, 3b, 4 and 5
WN	sw: shallow water	Permanently flooded, water less than 2m deep at mid-summer.	None mapped for this project, but 2c would be applicable

Table 2: Other Important Ecosystems for Metro Vancouver Mapped in the Study Area (adapted from Appendix A of "Mapping Procedures for the MV SEI" - March 28, 2011).

Other Important Ecosystem Class	OIE Subclass	Brief Description	Typical Structural Stages
YF: Young Forest		Large patches of forest – stands > 30 yrs, < 80 yrs, ≥5ha	
YF	co: coniferous	Conifer-dominated (> 75% of stand composition)	5
YF	mx: mixed	Stand composition > 25% conifer and > 25% broadleaf	5
YF	bd: broadleaf	Broad-leaf dominated (> 75% of stand composition)	5
FW: Reservoirs (Freshwater)			
FW	rs: reservoir	Artificial water body behind a dam	Not applicable
Non-OIE	**Subclass**	**Brief Description**	**Typical Structural Stages**
YF: Young Forest		Small patches of forest – stands > 30 yrs, < 80 yrs, <5ha	
YF	co: coniferous	Conifer-dominated (> 75% of stand composition)	5
YF	mx: mixed	Stand composition > 25% conifer and > 25% broadleaf	5
YF	bd: broadleaf	Broad-leaf dominated (> 75% of stand composition)	5

B. Structural Stage Description

Structural Stage	Description
1	**Sparse/Bryoid** – Initial stages of primary and secondary succession; bryophytes and lichens often dominant; time since disturbance < 20 years for normal forest succession, may be prolonged (50-100+ years) where there is little or no soil development (bedrock, boulder fields); total shrub and herb cover <20%; total tree cover <10%.
1a	**Sparse** – less than 10 % vegetation cover.
1b	**Bryoid** – bryophyte and lichen-dominated communities (>50% of total vegetation cover).
2	**Herb** – Early successional stage or herb communities maintained by environmental conditions or disturbance (e.g. snow fields, avalanche tracks, wetlands, flooding, grasslands, intensive grazing, intense fire damage); dominated by herbs (forbs, graminoids, ferns); some invading or residual shrubs and trees may be present; tree cover <10%, shrubs ≤20% or <33% of total disturbance <20 years for normal forest succession; many non-forested communities are perpetually maintained in this stage.
2a	**Forb-dominated** – includes non-graminoid herbs and ferns.
2b	**Graminoid-dominated** – includes grasses, sedges, reeds, and rushes.
2c	**Aquatic** – floating or submerged; does not include sedges growing in marshes with standing water (classed as 2b); or
2d	**Dwarf shrub-dominated** – dominated by dwarf woody species
3	**Shrub/herb** – Early successional stage or shrub communities maintained by environmental conditions or disturbance; dominated by shrubby vegetation; seedlings and advance regeneration may be abundant; tree cover <10%, shrub cover >20% or ≥33% of total cover.
3a	**Low shrub** – dominated by shrubby vegetation <2 m tall; seedlings and advance regeneration may be abundant; time since disturbance <20 years for normal forest succession; may be perpetuated indefinitely by environmental conditions or disturbance.
3b	**Tall shrub** – dominated by shrubby vegetation that is 2 m-10 m tall; seedlings and advance regeneration may be abundant; time since disturbance <40 years for normal forest succession; may be perpetuated indefinitely.
4	**Pole sapling** – Trees >10 m tall, typically densely stocked, have overtopped shrub and herb layers; younger stands are vigorous (usually >10-15 years old); older stagnated stands (up to 100 years old) are also included; self-thinning and vertical structure not yet evident in canopy – this often occurs by age 30 in vigorous broadleaf stands, which are generally younger than coniferous stands at the same structural stage; time since disturbance < 40 years for normal forest succession; up to 100+ years for dense (5000-15000+ stems per ha) stagnant stands.
5	**Young forest** – Self-thinning has become evident and the forest canopy has begun to differentiate into distinct layers (dominant, main canopy, and overtopped); vigorous growth and a more open stand than in Stage 4; begins as early as age 30 and extends to 50-80 years; time since disturbance generally 40-80 years, depending on tree species and ecological conditions.
6	**Mature forest** – Trees established after the last disturbance have matured; a second cycle of shade-tolerant trees may have become established; understories become well developed as the canopy opens up; time since disturbance generally 80-140 to 80-250 years.
7	**Old forest** – Old, structurally complex stands comprised mainly of shade-tolerant and regenerating tree species, although older seral and long-lived trees from a disturbance such as fire may still dominate the upper canopy; snags and coarse woody debris in all stages of decomposition and patchy understories typical; understories may include tree species uncommon in the canopy because of inherent limitations in these species under the given conditions; time since disturbance generally >140-250 years.

APPENDIX VIII - Potential Rare Plants in the CDFmm subzone

Potential Rare Plants in the CDFmm subzone

Scientific Name	English Name	Prov Rank	COSEWIC	BC Status	SARA
Bidens amplissima	*Vancouver Island beggarticks*	*S3*	*SC*	*Blue*	*1-SC*
Lupinus rivularis	*Streambank lupine*	*S1*	*E*	*Red*	*1-E*

APPENDIX IX - Potential Rare Ecosystems in the CDFmm subzone

Potential Rare Ecosystems in the CDF mm

Scientific Name	English Name	Prov Rank	BC Rank	BGC	Identified Wildlife?
Abies grandis / Mahonia nervosa	grand fir / dull Oregon-grape	S1	Red	CDFmm/04	
Abies grandis / Tiarella trifoliata	grand fir / three-leaved foamflower	S1	Red	CDFmm/06	
Alnus rubra / Carex obnupta [*Populus trichocarpa*]	red alder / slough sedge [black cottonwood]	S1	Red	CDFmm/14	
Alnus rubra / Lysichiton americanus	red alder / skunk cabbage	S2	Red	CDFmm/Ws52	
Carex lasiocarpa - Rhynchospora alba	slender sedge - white beak-rush	S2	Red	CDFmm/Wf53; CWHmm1/Wf53	
Carex lyngbyei Herbaceous Vegetation	Lyngbye's sedge herbaceous vegetation	S2	Red	CDFmm/Em05	
Deschampsia cespitosa ssp. *beringensis - Hordeum brachyantherum*	tufted hairgrass - meadow barley	S2	Red	CDFmm/Ed01	
Deschampsia cespitosa ssp. beringensis - Symphyotrichum subspicatum	tufted hairgrass - Douglas' aster	S2	Red	CDFmm/Ed02	
Distichlis spicata var. spicata Herbaceous Vegetation	seashore saltgrass Herbaceous Vegetation	S2S3	Red	CDFmm/Em03	
Dulichium arundinaceum Herbaceous Vegetation	three-way sedge	S2	Red	CDFmm/Wm51	
Eleocharis palustris Herbaceous Vegetation	common spike-rush Herbaceous Vegetation	S3	Blue	CDFmm/Wm04	
Juncus arcticus - Plantago macrocarpa	arctic rush - Alaska plantain	S1	Red	CDFmm/Ed03	
Leymus mollis ssp. *mollis - Lathyrus japonicus*	dune wildrye - beach pea	S1S2	Red	CDFmm	
Menyanthes trifoliata - Carex lasiocarpa	buckbean - slender sedge	S3	Blue	CDFmm/Wf06	
Myrica gale / Carex sitchensis	sweet gale / Sitka sedge	S2	Red	CDFmm/Wf52; CWHmm1/Wf52	
Pinus contorta / Sphagnum spp. CDFmm	lodgepole pine / peat-mosses CDFmm	S1	Red	CDFmm/10	
Populus trichocarpa - Alnus rubra / Rubus spectabilis	black cottonwood - red alder / salmonberry	S3	Blue	CDFmm/08	

Scientific Name	English Name	Prov Rank	BC Rank	BGC	Identified Wildlife?
Pseudotsuga menziesii - Arbutus menziesii	Douglas-fir - arbutus	S2	Red	CDFmm/02	
Pseudotsuga menziesii / Mahonia nervosa	Douglas-fir / dull Oregon-grape	S2	Red	CDFmm/01	Y (Jun 2006)
Ruppia maritima Herbaceous Vegetation	beaked ditch-grass Herbaceous Vegetation	S2	Red	CDFmm/Em01	
Salix sitchensis - Salix lasiandra var. *lasiandra / Lysichiton americanus*	Sitka willow - Pacific willow / skunk cabbage	S2	Red	CDFmm/Ws51	
Sarcocornia pacifica - Glaux maritima	American glasswort - sea-milkwort	S2	Red	CDFmm/Em02	
Thuja plicata / Achlys triphylla	western redcedar / vanilla-leaf	S1	Red	CDFmm/12	
Thuja plicata / Oemleria cerasiformis	western redcedar / Indian-plum	S1	Red	CDFmm/13	
Thuja plicata - Pseudotsuga menziesii / Eurhynchium oreganum	western redcedar - Douglas-fir / Oregon beaked-moss	S1	Red	CDFmm/05	
Thuja plicata / Symphoricarpos albus	western redcedar / common snowberry	S1	Red	CDFmm/07	
Typha latifolia Marsh	common cattail Marsh	S3	Blue	CDFmm/Wm05	

APPENDIX X. Conservation Ranking

Species Status Ranking Systems

Federal Ranking System

The Committee On the Status of Endangered Wildlife in Canada (COSEWIC) assesses the status of wild species in Canada. The application of ranking criteria by COSEWIC describes the relative condition of a particular species and gives some indication as to the likelihood of extinction. For example, a species that is "Endangered" faces imminent extirpation or extinction; a species that is "Threatened" is likely to become endangered if limiting factors are not reversed (Table 1). Species ranked as G1 are considered of greatest risk for global extinction, and are therefore of highest management priority.

Table 1. Federal Species at Risk Ranking and Definitions.

Rank	Description
X – Extinct	Species no longer exists.
XT - Extirpated	Species no longer exists in Canada, but it still occurs elsewhere.
E - Endangered	Species is facing imminent extirpation or extinction.
T - Threatened	Species is likely to become endangered if limiting factors are not reversed
SC - Special Concern	Species that are sensitive to human activities and natural events, but are not considered to be Endangered or Threatened.
DD - Data Deficient	Species with inadequate information to make direct / indirect assessment.
NAR - Not at Risk	Species that have been evaluated, but are considered not to be at risk.

Provincial Ranking System

Within BC, the Conservation Data Centre (CDC) is responsible for assigning provincial status of indigenous species. The CDC is a branch of the Ministry of Water, Land and Air Protection (MWLAP). The coding is by colour, with red indicating species at greatest risk (threatened and endangered species), and yellow indicating the lowest level of risk (Table 2).

Table 2. Provincial Ranking System and Definitions

Rank	Description
Yellow List	*Indigenous species, subspecies and natural plant communities deemed not to currently be at risk in B.C.*
Blue List	*Indigenous species, subspecies and natural plant communities of Special Concern in B.C.*
Red List	*Indigenous species, subspecies and natural plant communities that are extirpated, endangered or threatened in B.C. These species either have, or are candidates for, official extirpated, endangered, or threatened status in B.C.*

Section 34 of the *B.C. Wildlife Act* states:

A person commits an offence if the person, except as provided by regulation, possesses, takes, injures, molests or destroys:

(a) A bird or its egg,
(b) The nest of an eagle, peregrine falcon, gyrfalcon, osprey, heron or burrowing owl, or the nest of a bird not referred to in paragraph (b) when the nest is occupied by a bird or its egg.

In this regard, "nest" is defined as “a structure, or part of a structure, prepared by or used by an animal of the class Aves to hold its eggs or offspring”.

APPENDIX XI – Wildlife Descriptions

Wildlife at risk and other important species potentially in the study area.

(Note: For each description, generally only a single key reference is provided.)

Invertebrates

The study area is rich in invertebrates but only a few are listed as of concern.

Blue dasher (Blue listed/CF4) Seen in Hub I. In BC, this dragonfly is largely limited to extreme southwest where it can be common at ponds and lakes with abundant vegetation in the water and along the shore. Common in wooded areas near breeding habitat, but usually near sunny edges. Prey smaller than that of the co-occurring pondhawks. Males defend territories aggressively; both sexes defend feeding perches. Paulson, D. 2009. Dragonflies and damselflies of the west. Princeton University Press.

Dun skipper (Red listed/CF2) Documented near the study area (e-fauna BC). Dun skipper is known from southern Vancouver Island, the Lower Mainland and the Fraser Canyon north to Lillooet. Its only known food plant is a sedge, *Cyperus esculentus*, but it may use other *Cyperus* spp. Limited to moist to mesic grassy areas. Little else is documented about its ecology. Guppy, C.S & J.J. Shepard. 2001. Butterflies of British Columbia. UBC Press.

Monarch butterfly (**Blue listed/CF2**) Present but uncommon in the study area. In BC, Monarchs lay eggs on showy milkweed (*Asclepias speciosa*) and at least one generation matures successfully each summer. The number of adult Monarchs in BC varies from year to year, but they are generally uncommon. In the late summer and fall, BC Monarchs presumably migrate south to California to hibernate. Milkweed is not native to the west coast of BC, so normally migrants to our area cannot breed successfully. Any milkweed species can host the larvae. Monarchs are good at finding very isolated patches of milkweed and using them as larval food plants, such as in scattered flower gardens. The Xerces Society Project Milkweed is encouraging the distribution of milkweed seed. COSEWIC. 2010. COSEWIC assessment and status report on the Monarch *Danaus plexippus* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ONT.

Audouin's night-stalking tiger beetle (Red-listed/CF1) There are now nine known sites in BC, all on the extreme southern coast. Populations at two sites near Victoria have been extirpated by urban development. Habitat includes almost any open area: grassy areas, sparsely vegetated habitats, coastal bluffs, meadows, open forests, older agricultural fields (no crops present for a number of years). Adults are ground crawlers, heat lovers, and wanderers in forest meadow margins and areas that include open, sunny sites. The closest occupied sites to the study area are nearby in the Boundary Bay area. However, the species is flightless, with only moderate running ability and is unlikely to disperse through denser vegetation. They are unlikely to be present in the study area, but no one appears to have searched. COSEWIC. 2013. COSEWIC assessment and status report on the Audouin's Night-stalking Tiger Beetle *Omus audouini* in Canada.Committee on the Status of Endangered Wildlife in Canada. Ottawa, ONT

Oregon forestsnail (Red listed/CF1) The species has been reported by A Rocha from the area and Steensma et al.(2009) have documented populations nearby. The Oregon forestsnail is found in mixed-wood and deciduous forests, typically dominated by bigleaf maple. A dense cover of low herbaceous vegetation is usually present. This snail is most often found in areas with rich soils, extensive coarse woody debris and cool shade. Moist, rich soils, bigleaf maple and stinging nettle are strong habitat indicators. The species prefers undisturbed habitat. COSEWIC 2002. COSEWIC assessment and status report on the Oregon forestsnail *Allogona townsendiana* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, ONT. • Proulx, Gilbert et al. 2003. A Field Guide to Species at Risk in the Coast Forest Region of British Columbia. International Forest Products and BC Ministry of Environment. • Steensma, K.M.M. et al. 2009. [Internet] Life history and habitat requirements of the Oregon forestsnail, *Allogona townsendiana* (Mollusca, Gastropoda, Pulmonata, Polygyridae), in a British Columbia population. Invertebrate Biology. 1-11. 2009.

Pacific sideband snail (Blue listed/CF2) The largest land snail in the province and relatively common in wet, lower elevations of coastal BC. Primarily a species of coastal lowlands in deciduous, mixed or coniferous forests generally, but sometimes in open woods and grassy places. Adult snails are most often encountered in spring when crawling in the open on the ground or climbing up the trunks of shrubs and trees, as high as 6.7 m above ground. Brown and Durand (2007) studied both developed and undeveloped sites and concluded the species preferred natural sites. They provide detailed habitat descriptions from areas east of the study area. Brown, D. & R. Durand. 2007. Habitat assessment of the Pacific sideband (*Monadenia fidelis*) in the lower Fraser Valley British Columbia. Fraser Valley Conservancy Society.
http://www.sccp.ca/sites/default/files/species-habitat/documents/Pacific sideband habitat

Amphibians & Reptiles

Red-legged frog (Blue-listed/CF1) A Rocha has monitored 57 wetland sites within or near the study area, a few for 7 consecutive years, and is preparing a report that will define favourable breeding sites. We found breeding habitat for the frog throughout the study area. Adults have been documented in the forest. This species requires suitable aquatic areas for breeding and upland terrestrial habitats nearby for adults during the non-breeding season. Adult frogs prefer cool, moist forest habitats, generally with standing water and abundant coarse woody debris. They can migrate long distances from breeding waterbodies to upland areas (1 km or more), but prefer adjacent forest. Waye, H. 1999. COSEWIC status report on the red-legged frog *Rana aurora* in Canada Committee on the Status of Endangered Wildlife in Canada. Ottawa, ONT. • Maxey, K.A. 2004. Red-Legged Frog Species Information. BC Ministry of Environment, Victoria, BC. http://www.env.gov.bc.ca/wld/frpa/iwms/documents/Amphibians/a_redleggedfrog.pdf

Western toad (Blue/CF2) Western Toads breed in a variety of natural and artificial aquatic habitats, with or without tree or canopy cover, coarse woody debris, or emergent vegetation. Ponds must be of sufficient duration to host the young until June or July when they metamorphose. After breeding, adult western toads disperse into terrestrial habitats such as forests and grasslands. They may roam far from standing water, but they prefer damp conditions. They spend much of their time underground and often shelter in small mammal burrows, beneath logs and within rock crevices. Forest cover is often sought during winter. Toadlets emerge *en masse* in large numbers and move overland becoming susceptible to vehicle traffic. They recently have been declining in southwestern BC. Reasons are unclear but developments around wetlands are a major factor destroying or isolating wetlands from upland sites. Wind, E. & Dupuis, L. 2002. Status of the Western toad *Bufo boreas* in Canada. Report written for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Canadian Wildlife Service, Environment Canada. Ottawa, ONT. • B.C. Frogwatch Program Victoria, BC. ww.env.gov.bc.ca/wld/frogwatch/publications/factsheets/frogs/western-toad.htm

Painted turtle (Red listed/CF2)
There is suitable painted turtle habitat in the study area. Unfortunately, the species has been displaced by exotic red-eared sliders that have lost their charm as pets and now effectively outcompete painted turtles. Surveys of 29 ponds and wetlands in the lower Fraser Valley, including 6 that previously hosted painted turtles, found only one site with painted turtles as well as sliders – Burnaby Lake (Bunnell (2005); another close to the study area has since been reported. He found a strong correlation between slider presence and the accessibility of the wetland to humans. Sliders are now breeding in the general area and the painted turtle is likely extirpated in the study area. Providing more favourable habitat will help little until red-eared slider sales are effectively stopped. Bunnell, C.G.

2005. Field survey of red-eared sliders (*Trachemys scripta elegans*) in the lower Fraser valley, British Columbia in 2005. Wildlife Afield 2(2):51-57.

Fish

Salish sucker (Red listed/CF 1) Entrapped by the ice age, the Salish sucker became a new species, now found only in a few small lakes and streams in and around Puget Sound in Washington State and in the Fraser Valley. In British Columbia, Salish suckers are most often found in the headwaters of small streams. Adult suckers prefer the slow waters of relatively deep pools with plenty of aquatic and bank-side vegetation. Young suckers are found in more shallow areas with abundant vegetation in the stream. Suitable watersheds have been adversely affected by forest removal and farming for many decades, and increasingly by accelerated urban development. Such activities reduce the amount of slow-moving waters and deep pools in their referred headwater streams. Spawning grounds have been either physically removed or covered in silt, and headwater areas that used to flow year round are now drying up in the summer due to increased water withdrawal and road construction. Efforts to sustain the species now focus on restoration. Blood, D.A. no date. Salish sucker. Wildlife in British Columbia at risk. http://www.env.gov.bc.ca/wld/documents/salishsucker.pdf • Fisheries and Oceans Canada website: http://www.dfo-mpo.gc.ca/species-especes/species-especes/salishsucker-meuniersalish-en

Birds

Bald Eagle (not listed) The Bald Eagle has specific requirements for nesting and perching: large trees (>75 cm dbh) that protrude above canopy) provide nesting, tall live trees (>35m) protruding above canopy provide winter roost sites and perch sites throughout the year. Ideally, these are near aquatic habitats with fish and aquatic birds. This species is no longer at risk and noted because it is iconic and many suitable nest and perch trees are available in the study area. It appears to be declining elsewhere in Surrey. Blood, D.A. and G.G. Anweiler. 1994. Status of the bald eagle in British Columbia. B.C. Environment, Lands and Parks, Victoria, BC. Wildlife Working Report No. WR-62

Band-tailed pigeon (Blue listed/CF2) Prior to regulation of hunting, this species suffered major declines throughout its range. It is now protected in BC under the BC Wildlife Act, and in Canada by the Migratory Birds Convention Act (1994). It has a low reproductive rate (only 1 or 2 eggs per year), but has recovered significantly. Breeding and nesting occur in openings in mature forests of all kinds, city parks, open shrub areas and golf courses, with most nests found in coniferous trees and about a quarter in deciduous trees. Prime foraging areas are rich in berry-producing shrubs (particularly elderberry) and bud-producing deciduous trees. A necessary part of the bird's nutrition is mineral licks, where the most reliable counts are obtained. When not breeding, they tend to use farmland and other open areas bordered by trees suitable for roosting. Campbell, R.W., N.K. Dawe, I. McTaggart-Cowan, J. M. Cooper, G.W. Kaiser and M.C.E. McNall. 1990. The birds of British Columbia. Volume 2. Royal British Columbia Museum, Victoria, BC and Canadian Wildlife Service, Delta, BC. • COSEWIC. 2008. COSEWIC assessment and status report on the Band-tailed Pigeon *Patagioenas fasciata* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Barn owl (Blue listed/CF2) Barn Owls use the barn at the Little Campbell River fish hatchery, and banding had just occurred for the two young of this year at time of survey. During a previous assessment by Madrone for the Grandview Heights area of Surrey (2008), we acquired evidence of Barn Owls in that area. Generally, Barn Owls nest and forage in agricultural areas. The Fraser Valley represents the core of their breeding range in the Lower Mainland. Non-breeding habitat includes open country associated with agricultural areas, riparian woods and edges of mixed woodlands. Breeding most often occurs in association with agricultural areas in man-made structures though nests are occasionally found in tree cavities. Up to 85% of their prey is made up of Townsend's voles *(Microtus townsendii)*. Because they are low flying in search of rodent prey, they suffer uncommonly high mortality to vehicle traffic. Campbell, R.W., N.K. Dawe, I. McTaggart-Cowan, J. M. Cooper, G.W. Kaiser and M.C.E. McNall. 1990. The birds of British Columbia. Volume 2. Royal British Columbia Museum, Victoria, BC and Canadian Wildlife Service, Delta, BC. • Fraser, D.F., W.L. Harper, S.G. Cannings, and J.M. Cooper. 1999. Rare birds of British Columbia. B.C. Minist. Environ., Lands and Parks, Wildl. Branch and Resour. Inventory Branch, Victoria, BC.

Barn Swallow (Blue listed/CF2) Barn Swallows were observed foraging in numerous open fields throughout the study area and nests were seen in the outbuildings at the Little Campbell River fish hatchery. The B*arn Swallow* is the most widespread species of swallow in the world. They forage in open field habitats, typically near water. Formerly they nested in caves, but now often nest in barns or other buildings and under bridges in close proximity to a pond or lake with mud suitable for nest building. Barn Swallows commonly reuse the same nesting area in successive years. They were hunted for the hat trade in the 19th C and are still hunted for food in parts of their wintering range, but are recovering from the decline in most areas. Recovery is less apparent in British Columbia. Cornell Laboratory of Ornithology – http://www.allaboutbirds.org/guide/barn_swallow/lifehistory

Great Blue Heron *fanninni* (Blue listed/CF1) Three herons were seen during one visit to the wetlands at 12th Avenue. This subspecies of Great Blue Herons forages in water shallow enough for it to stalk prey, including flooded agricultural fields, ditches and the seashore. There are ample foraging sites in the study area. Nesting opportunities are more limited because they require groups of large trees generally within 3 km of foraging sites. Those opportunities have been reduced by development. A suitable nesting site must include an established colony and alternative sites that can be used in case of disturbance. In the past few decades, at least 21 colonies have been abandoned in BC. Colony surveys in the province suggest that the reproductive rate for herons has declined considerably since the 1970s. Christmas Bird Count data show significant population declines of 19 to 26% over the past three generations of herons. Proulx, Gilbert et al. 2003. A Field Guide to Species at Risk in the Coast Forest Region of British Columbia. International Forest Products and BC Ministry of Environment. • Species at Risk Public Registry http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=292

Northern Goshawk *laingi* (Red listed/CF1) Over half of the global range of this subspecies occurs in coastal BC, where it favours mature and old coniferous forest. It is resident, and needs a relatively large home range that contains a sufficient year-long food supply. Major prey items include red squirrel and Sooty Grouse, perhaps Band-tailed Pigeons in the study area. Although it may breed in younger, more even-aged stands, it tends to nest in areas dominated by mature or old-growth trees, or in stands with similar structural characteristics (e.g., relatively closed, multi-layered canopies with some large live trees and snags). It prefers to breed in larger, intact patches of forest rather than small isolated stands. Food supply encourages this subspecies to be a short distance, non-migratory wanderer. Some argue it is representative of intact old growth forest. The major threat to the species has been conversion of older multistoried forest to younger, denser, even-aged stands. COSEWIC. 2013. COSEWIC assessment and status report on the Northern Goshawk *Accipiter gentilis laingi* in Canada.Committee on the Status of Endangered Wildlife in Canada. Ottawa, ONT.

Olive-sided Flycatcher (Blue listed/CF2)
The species breeds in open coniferous or mixedwood forests, often located near water or wetlands with the presence of tall snags. It was listed by COSEWIC as threatened because of an annual rate of population decline of 3.4%. Reasons for the decline are unclear, but deforestation is considered part of the problem. Key breeding habitat requirements include: coniferous or mixedwood forest; open to semi-open areas within forests (ideally mature to old forest); tall snags and/or residual live trees for nests, singing and foraging perches; nearby water or wetlands supporting a high abundance of aerial insects. Several reproductive features make it vulnerable: small clutch size, only one brood per season, reliance on aerial insects which increases vulnerability to inclement weather, lengthy breeding season which increases exposure to predation and the longest migration of any North American flycatcher species. These attributes increase the likelihood of decline and increase the time of potential recovery.

Environment Canada. 2015. Recovery Strategy for Olive-sided Flycatcher (*Contopus cooperi*) in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa, ONT.

Peregrine Falcon *anatum* (Red listed/CF2) The peregrine usually nests alone on cliff ledges or crevices, preferably 50 to 200 m in height, but sometimes on the ledges of tall buildings or bridges, always near good foraging areas. Suitable nesting sites are usually dispersed. Adults demonstrate a high degree of breeding site fidelity and are known to reuse the same nest site for decades. It feeds primarily on birds that it typically catches in flight. Its prey also may include bats, rodents and other mammals. The peregrine appears to have recovered from the dramatic decline due to use of DDT and other organochlorine pesticides. This subspecies is now estimated to number somewhat less than 1,000 globally. Environment Canada. 2015. Peregrine Falcon anatum/tundrius. Species at Risk Public Registry, Government of Canada. http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=995

Western Screech-owl kennicottii (Blue listed/CF1) In BC, the Western Screech-Owl is generally found in lower elevation forested or treed environments. The *kennicottii* subspecies is found in a variety of coniferous and mixed forests, but is most often associated with riparian zones having broadleaf maple or black cottonwood. It is a small owl and a secondary cavity nester, largely dependent on the excavations made by large woodpecker species. These typically are in trees >50 cm dbh. The species is resident; pairs defend territories year-round. They are generalist predators, feeding primarily on small mammals and large insects, but also small birds, fish, frogs and slugs. Populations around Metro Vancouver and Victoria have all but disappeared in the past 10 to 15 years. The culprit is the Barred Owl which has moved west and preys upon them. We saw Barred Owls during our brief assessment (1 single owl and 1 pair). COSEWIC. 2012. COSEWIC assessment and status report on the Western Screech-Owl *kennicottii* subspecies *Megascops kennicottii kennicottii* and the Western Screech-Owl *macfarlanei* subspecies *Megascops kennicottii macfarlanei* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ONT.

Other owls and raptors Habitat requirements of these species are variable and include *large trees for nesting and perching, hedge rows and hydro/gas utility* corridors (excellent foraging grounds for Red-tailed Hawks), an abundance of forest edge ecosystems and agricultural fields, both old fields and those in production.

Mammals

Black bears (unlisted) In areas of ample human presence, black bears can become proficient skulkers. We saw no black bears, but there is sign along some stream edges (uncommon). On BC's coast, black bears tend to avoid wet soil and den in or under large diameter trees, snags or stumps. Their movements vary with the food resource and at extremes exceed the size of the study area. Male home ranges range from about 25 to 150 km^2, while females are 20% of that or less. Males are looking for other mates, while females are maintaining an area in which to raise cubs. Bears do not digest high fibre diets well and home ranges typically encompass several feeding areas as they seek digestible forage. Travel routes often are through well forested areas that provide cover, typically connect feeding areas. In the general area of the study, bears are likely to follow fall salmon migrations, even into suburban areas and will often wander or sneak through rural areas connected to more suitable habitat. Bunnell, F.L. &d A.N. Hamilton. 1984. Forage digestibility and fitness in grizzly bears. International Conference of Bear Research and Management 5: 179-185. • Bunnell, F.L., & D.E.N. Tait. 2004. Population dynamics of bears - implications. Pp. 75-98 *in* C.W. Fowler and T.D. Smith, eds. Dynamics of large mammal populations. 2nd Ed. J. Wiley and Sons, Inc.

Black-tailed deer (unlisted)
Deer are common in the study area. Several deer and abundant deer sign were observed in essentially all forested areas of the study area. Their home ranges are measured in ha rather than km^2 and the local climate is s sufficiently mellow that there is no migration. They bed down in shrubby areas or tall grasses of agricultural fields and seek cover and forage in forested areas where they browse on vegetation of the shrubby understory. They roam more widely in the summer, in pursuit of the most succulent vegetation. Bunnell, F.L. 1990. Black-tailed deer ecology and forest management. Pp. 31-63 in J.B. Nyberg and D.W. Janz, tech. eds. Deer and elk habitats in coastal forests of southern British Columbia: A handbook for forest and wildlife managers. B.C. Ministries of Forests and Environment, Victoria, BC.

Keen's myotis (Blue listed/CF1) Almost all of this species' range is in coastal BC. Many of its known roosting sites are in caves or buildings. Its physical structure suggests that, like other long-eared bats, it nests and roost in forests. Older forests are the natural candidate simply because it requires cavities. The challenge is that the bat is small enough that it has proven difficult to track readily. What little is known suggests that insect-rich, low elevation coastal forest and riparian areas are important foraging areas. Broadly, rock faces and knolls with crevices that are solar or geothermally heated are important maternity roosts while tree cavities and loose bark are important natural roost sites. Chatwin, T.A. 2004. Keen's Long-eared Myotis *Myotis keeni*. Accounts and Measures for

Managing Identified Wildlife – Accounts V. Ecosystems Branch, Ministry of Environment, Victoria, BC. • COSEWIC. 2003. COSEWIC assessment and update status report on Keen's long-eared bat
Myotis keenii in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa, ONT.

Pacific water shrew (Red listed/CF1) We did not observe Pacific water shrews in our fieldwork, nor did A Rocha's short trapping program capture any. The CDC tracking list notes an adult Pacific water shrew was collected in Fraser Heights from a forested slough – storm sewer outflow in a residential neighbourhood and a capture, September 1992, at Fergus Creek, south Surrey. The study area is in the core of the Pacific water shrew range in BC which stretches from Squamish to Chilliwack. The species is the world's smallest diving mammal and a riparian habitat specialist that hunts in aquatic areas. It specializes in habitats near slow-moving water and swamps, marshes and wetlands (either permanent or ephemeral), where it pursues prey under water. Small streams <10 across are preferred. No specimen has been recorded more than 350 m from a watercourse and virtually every other recorded capture of Pacific water shrew has been within 50 m of water. Most recent occurrence records were found within 60 m of a watercourse but dispersing individuals have been found >1 km from a water feature. Existing Riparian Areas Regulation legislation is beneficial for protecting narrow travel corridors; however, retaining a wider, 100 m, buffer on riparian areas where moderate to high habitat suitability occurs (with adjacent low suitability) is an important way to protect Pacific water shrew home ranges. The greater buffer area is important for the shrew because the forest strip on the outer edge of the buffer protects the vital micro-climate conditions in the interior riparian zone. The species is extremely rare and for that reason, current best management practices recommend sampling for Pacific water shrew only in habitats of low habitat suitability and assuming it is present in areas of moderate to high habitat suitability. South Coast Conservation Program and references therein – http://www.sccp.ca/species-habitat/pacific-water-shrew

Snowshoe hare (Red listed/CF1) During our surveys**,** burrows were rarely observed but were likely occupied by eastern cottontail (*Sylvilagus floridanus*). Mountain beaver, which also burrow, are not present in the study area. Genetic analyses confirm that form *washingtonii* is discrete from other snowshoe hare subspecies. Unlike other subspecies, it does not produce a white winter coat, but remains brown year round. Generally, hares prefer dense coniferous and mixed forests for cover, but also forage in more open habitats. They feed on twigs, buds and bark in winter and on herbaceous vegetation in summer, usually in twilight or darkness. They are prey for several carnivorous mammals and birds. Museum specimens indicate that the subspecies was common across the Fraser Valley prior to urbanization, but only a handful of confirmed sightings have been made in recent decades, the latest two from road kill in 1970 (Burnaby Lake) and 1997 (Mission).

Reasons for the decline likely are a combination of loss and fragmentation of forest or woodland habitat by urban and agricultural development, predation by domestic pets and competition with introduced cottontails. Nagorsen, D.W. 2005. Rodents and Lagomorphs of British Columbia. Royal BC Museum, Victoria BC. • Species @ Risk a primer for British Columbia – http://www.speciesatriskbc.ca/node/8092

Townsend's big-eared bat (Blue/CF2) This is one of the few bats in BC consistently found hibernating. Little is known about the ecological needs of the species in BC, particularly for the coastal form. By default it is commonly assessed using criteria for Keen's myotis, of which little more is known. Given how few hibernacula are found, the total population is likely very small. Suitable wildlife trees were found at some sites but no rock faces or caves, where the species roosts or hibernates, were observed.
Blood, D.A. 1998. Townsend's big-eared bat. BC Ministry of Environment, Land and Parks, Victoria, BC. • Nagorsen, D.W. and R.M. Brigham. 1993. Bats of British Columbia. Royal British Columbia Museum, Victoria, BC.

Trowbridges shrew (Blue/CF2) Trowbridge's shrew has been captured in the study area by A Rocha. The species lives in varied habitats throughout the Fraser Valley and Lower Mainland. Trowbridge's shrews are strong burrowers, particularly in deep, organic layers of soil, and are common where those burrowing conditions are available, plus deep litter, ample canopy and a low water table. It often occupies forest habitat with significant ground litter on the fringe of riparian areas. Throughout their range, vegetative material can comprise 60% of their diet, but they also eat mollusks, worms, conifer seeds, fungi, insects and arachnids. Cannings, S.G., L.R. Ramsey, D.F. Fraser and M.A. Fraker. 1999. Rare amphibians, reptiles, and mammals of British Columbia. Ministry of Environment, Lands and Parks, Wildlife Branch and Resources Inventory Branch, Victoria, B.C. • *Sorex trowbridgii* Trowbridge's Shrew. Smithsonian National museum of Natural History – http://www.mnh.si.edu/mna/image_info.cfm?species_id=332

APPENDIX XII – Some species observation in Hub I (20^{th} Avenue)

Partial list of fungal species in the 20th Avenue woods

C. Bunnell, A. Farr, and F. Bunnell

Table 1 Slime mold (Protista, not a fungus)

Scientific Name	Common Name
Lycogala epidendrum	Wolf milk
Trichia decipiens	no common name

Table 2 Fungus

Scientific Name	Common Name
Agaricus praeclaresquamosus	Flat-top agaricus
Amanita muscaria	Fly Amanita
Amanita pantherina	Panther Amanita
Armillaria mellea complex	Honey mushroom
Boletus chrysenteron	Red-cracked bolete
Boletus zelleri	Zeller's bolete
Bovista plumbea	Lead-coloured puffball
Cantharellus formosus	Pacific golden chanterelle
Chlorophyllum olivieri	Shaggy parasol
Clavulina sp	Coral mushroom
Clitocybe gibba	Funnel cap
Coprinopsis atramentaria	Inky cap
Cystoderma amianthinum	Unspotted Cystoderma
Dacrymyces stillatus	Common jelly-spot
**Entoloma rhodopolium* group	Rosy entoloma
Fomes fomentarius	Horse's hoof or Tinder polypore
Ganoderma oregonense	Western varnished conk
Gymnopilus picreus	no common name
Heterobasidion annosum	Conifer-base polypore
Hygrophoropsis aurantiaca	False chanterelle
Hypholoma fasciculare	Sulphur tuft
Lepiota atrodisca	Black-eyed parasol
**Leptonia parva*	Blue-black Leptonia
Leptonia serrulata	Blue-toothed Leptonia
Lycoperdon perlatum	Gem-studded puffball
Marasmius androsaceus	Horsehair fungus

Scientific Name	Common Name
Marasmius salalis	no common name
Mycena atroalboides	no common name
Mycena pura	Lilac bonnet
Mycena purpureofusca	Purple edge bonnet
Nidula candida	Common gel bird's nest
Nidula niveotomentosa	White barrel bird's nest
Oligoporus guttulatus	Sweaty cheese
Panellus longinquus	no common name
Panellus serotinus	Late oyster mushroom
Peniophora aurantiaca	No common name
Phaeolus schweinitzii	Dye polypore
Phlebia radiata	Radiating Phlebia
Pholiota flammans	Flaming pholiota
Pleurotus porrigens	Angel wings
Pseudohydnum gelatinosum	Cat's tongue
Rhytisma punctatum	Speckled tarspot
Spinellus fusiger	Bonnet mold
Stereum hirsutum	Hairy parchment
Strobilurus trullisatus	Douglas-fir cone mushroom
Stropharia ambigua	Questionable Stropharia
Trametes versicolor	Turkey-tail
Tremella aurantia group	Jelly fungus [Witch's butter is applied to several species}
Tyromyces chioneus	White cheese polypore
Xylaria hypoxylon	Candlesnuff fungus

Table 3 Invertebrate Species in the 20th Ave. Woods and Ponds.

(Data collected by A. Farr and C. Bunnell 2014: May 18, May 28, June 21, Aug 4, Oct 11; 2015: March 1, April 6, May 13, May 18, May 24)

Scientific Name	Common Name
Dragonflies & Damselflies	
Amphiagrion abbreviatum	Western Red Damsel
Emallagma caruncul atum	Tule Bluet
Ischnura cervula	Pacific Forktail
Ischnura perparva	Western Forktail
Ischnura erratica	Swift Forktail

Scientific Name	Common Name
*Pachydiplax longipennis**	Blue Dasher
Sympetrum illotum	Cardinal Meadowhawk
Libellula lydia	Common Whitetail
Libellula quadrimaculata	Four-spotted Skimmer
Libellula foresnsis	Eight-spotted Skimmer
Anax junius	Common Green Darner
Rhionaeshna californica	California Darner
Bees & Wasps	
Bombus vosnesenskii	Yellow-faced Bumblebee
Bombus mixtus	Mixed Bumblebee
Bombus bifarius	Black notched Bumblebee
Bombus melanopygus	Orange-rumped Bumblebee
Apis mellifera	Honeybee
Osmia sp.	Mason bee
Lasioglossum sp.	Sweat bee
Sceliphron sp.	Mud dauber wasp sp.
Nomada sp.	Parasitic bee sp. (red)
Butterflies & Moths	
Papilio rutulus	Western Tiger Swallowtail
Vanessa atalanta	Red Admiral
Vanessa cardui	Painted Lady
Polygonia satyrus	Satyr Anglewing
subfamily *Polyommatinae*	Blue sp.
Pieris rapae	Cabbage White
Adela sp.	Longhorn Moth
Malacosoma californicum	Western Tent Moth
Other Insects	
Cimbex americana	Elm Sawfly
Musca domestica	House fly
Calliphoridae sp.	Bluebottle fly sp.
Dibolia borealis	Northern Plantain Beetle
Helophilus trivittatu	Hoverfly
Scaeva sp..	Hoverfly sp.
Cicadellidae sp.	Leafhopper sp.
Camponotus sp.	Carpenter Ant sp.
Formicidae sp.	Ant sp. (large, black)
Formicidae sp.	Ant sp. (small, black)
Aphididae sp.	Aphid sp.

Scientific Name	Common Name
Cercopidae sp.	Spittlebug sp.
Culicidae sp.	Mosquito sp.
Curculionidae sp.	Weevil sp.
Non-insects	
Harpaphe haydeniana	Cyanide millipede
	Millipede sp. (tiny)
Lumbricidae sp.	Earthworm sp.
Ariolimax columbianus	Banana slug
Arion rufus	Chocolate arion slug
Limax maximus	Spotted leopard slug
Oxyloma sp.	Amber snail sp.
Cepaea nemoralis	Grove snail
Haplotrema vancouverense	Robust Lancetooth
Vespericola columbianus	Northwest Hesperian
Misumena vatia	Goldenrod crab spider
	Ground spider sp.
Araneidae sp.	Orb weaver sp.
Various Aquatic Invertebrates	
Corixidae sp.	Water Boatman
Dytiscidae sp.	Predaceous Diving Beetle
Gerridae sp.	Water Strider sp.
	Aquatic snail sp.
Hirudidae sp.	Aquatic Leech sp.

* = Blue-listed; Species of Special Conservation Concern

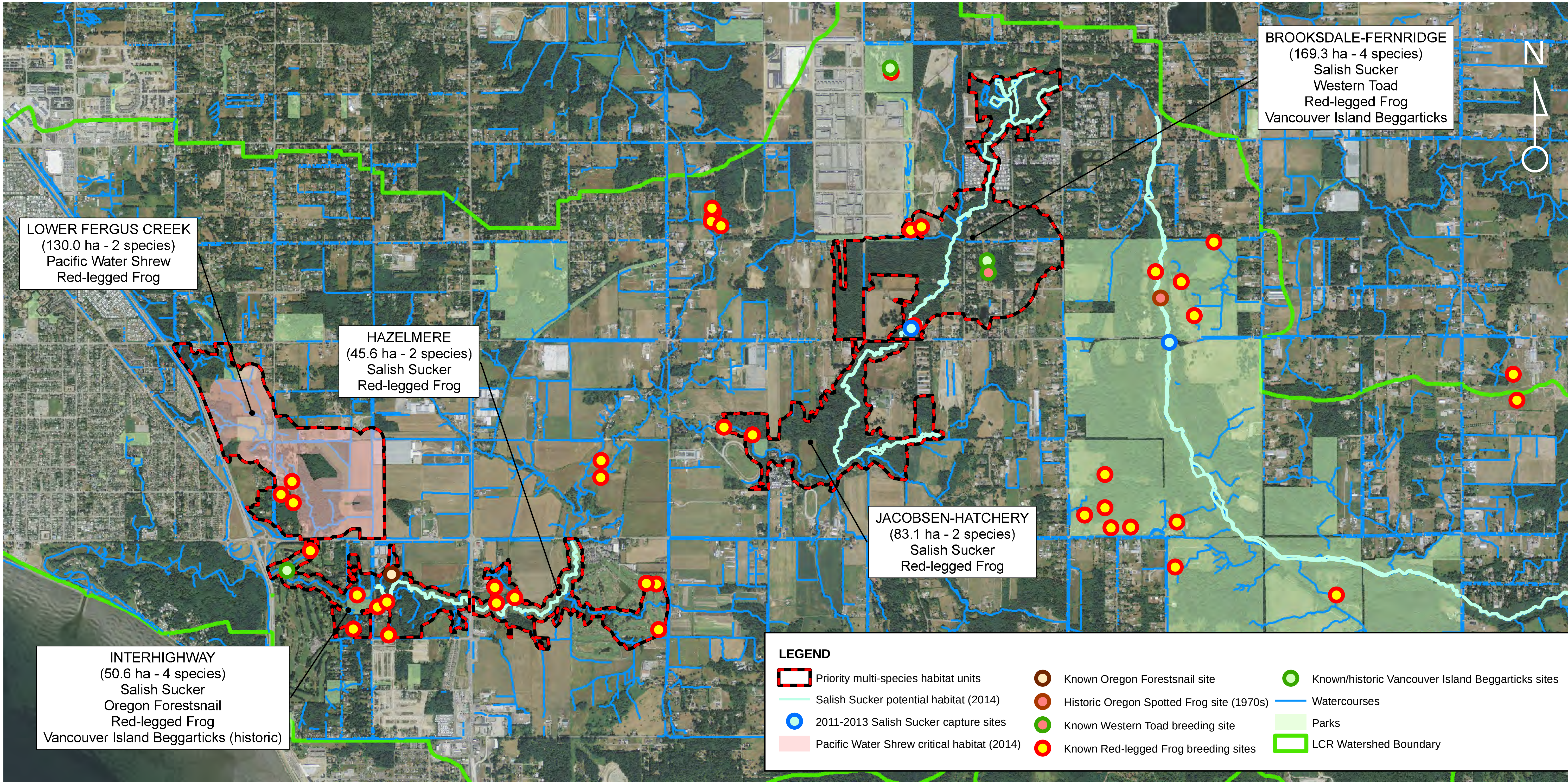
Table 4 **Vertebrate Species observed in the 20th Ave. woods and Ponds**.

Common name	Scientific Name
Birds	
Great Blue Heron	*Ardea herodias*
Canada Goose	*Branta candadensis*
Gadwall	*Anas strepera*
Mallard	*Anas platyrhynchos*
Ring-necked Duck	*Aythya collaris*
Green-winged Teal	*Anas carolinensis*
American Wigeon	*Anas americana*
Bufflehead	*Bucephala albeola*
Lesser Scaup	*Aythya affinis*
Bald Eagle	*Haliaeetus leucocephalus*

Common name	Scientific Name
Red-tailed Hawk	*Buteo jamaicensis*
Hawk sp.	*Accipiter* sp.
Turkey Vulture	*Cathartes aura*
Virginia Rail	*Rallus limicola*
Spotted Sandpiper	*Actitis macularius*
Wilson's Snipe	*Gallinago delicata*
Mourning Dove	*Zenaida macroura*
Great Horned Owl	*Bubo virginianus*
Rufous Hummingbird	*Selasphorus rufus*
Belted Kingfisher	*Megaceryle alcyon*
Pileated Woodpecker	*Hylatomus pileatus*
Northern Flicker	*Colaptes auratus*
Hairy Woodpecker	*Leuconotopicus villosus*
Pacific-slope Flycatcher	*Empidonax difficilis*
Common Raven	*Corvus corax*
Northwestern Crow	*Corvus caurinus*
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*
Violet-green Swallow	*Tachycineta thalassina*
Black-capped Chickadee	*Poecile atricapillus*
Red-breasted Nuthatch	*Sitta canadensis*
Brown Creeper	*Certhia americana*
Bewick's Wren	*Thryomanes bewickii*
Pacific Wren	*Troglodytes pacificus*
Marsh Wren	*Cistothorus palustris*
Golden-crowned Kinglet	*Regulus satrapa*
Ruby-crowned Kinglet	*Regulus calendula*
Varied Thrush	*Ixoreus naevius*
Swainson's Thrush	*Catharus ustulatus*
American Robin	*Turdus migratorius*
Orange-crowned Warbler	*Vermivora celata*
Yellow-rumped Warbler	*Setophaga coronata*
Yellow Warbler	*Setophaga petechia*
Wilson's Warbler	*Cardellina pusilla*
Black-throated Gray Warbler	*Setophaga nigrescens*
Black-headed Grosbeak	*Pheucticus melanocephalus*
Spotted Towhee	*Pipilo maculatus*
White-crowned Sparrow	*Zonotrichia leucophrys*
Song Sparrow	*Melospiza melodia*

Common name	Scientific Name
Dark-eyed Junco	*Junco hyemalis*
Brown-headed Cowbird	*Molothrus ater*
American Goldfinch	*Spinus tristis*
Mammals	
Beaver	*Castor canadensis*
Coyote	*Canis latrans*
Douglas Squirrel	*Tamiasciurus douglasii*
Eastern Gray Squirrel	*Sciurus carolinensis*
Coast Mole	*Scapanus orarius*
Amphibians	
Pacific chorus frog	*Pseudacris regilla*
Bullfrog	*Lithobates catesbeianus*
Western Toad	*Anaxyrus boreas*
Northwestern Salamander	*Ambystoma gracile*
Ensatina	*Ensatina eschscholtzii*
Fish	
Three-spine stickleback	*Gasterosteus aculeatus*
Coho Salmon	*Oncorhynchus kisutch*
Reptiles	
Garter Snake sp.	*Thamnophis* sp.

APPENDIX XIII – Species at Risk Occurrence Maps from A Rocha



A ROCHA
Environmental Stewardship

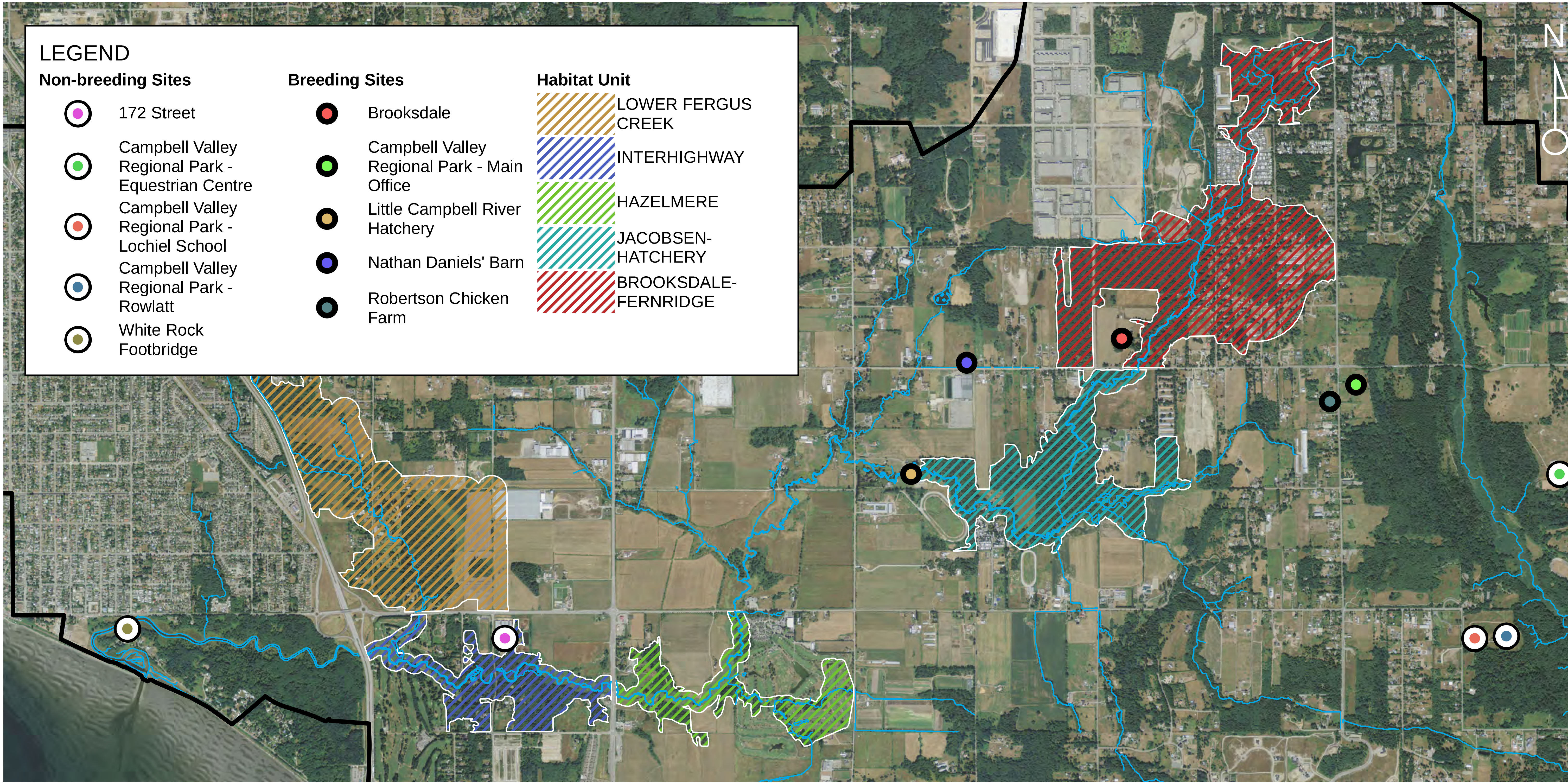
Implementing Riparian and Wetland Stewardship for Species at Risk
in the Little Campbell River Watershed

A Rocha Canada

Project No.	Date:
12-059	October 2014

0 500 1,000 1,500 m

MAP 1
Little Campbell River Watershed Stewardship Plan
Priority Multi-species Habitat Units in Lower Watershed



CANADA A ROCHA Environmental Stewardship

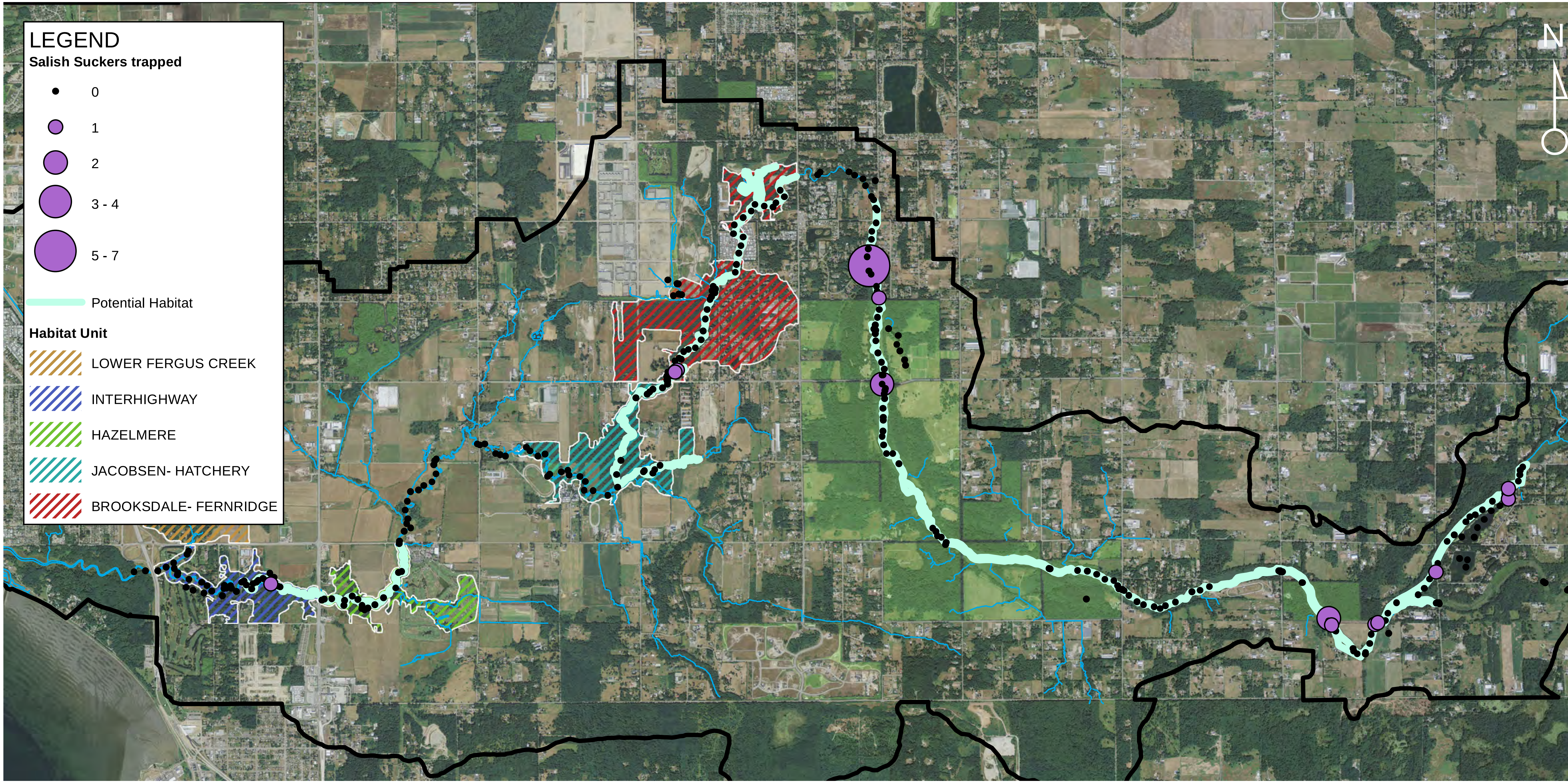
Implementing Riparian and Wetland Stewardship for Species at Risk
in the Little Campbell River Watershed

A Rocha Canada

Project No.	Date:
13-231	December 2014

0 0.5 1 km

MAP 5
Barn Swallow Survey Sites for 2014 to 2018



CANADA A ROCHA Environmental Stewardship

Implementing Riparian and Wetland Stewardship for Species at Risk
in the Little Campbell River Watershed

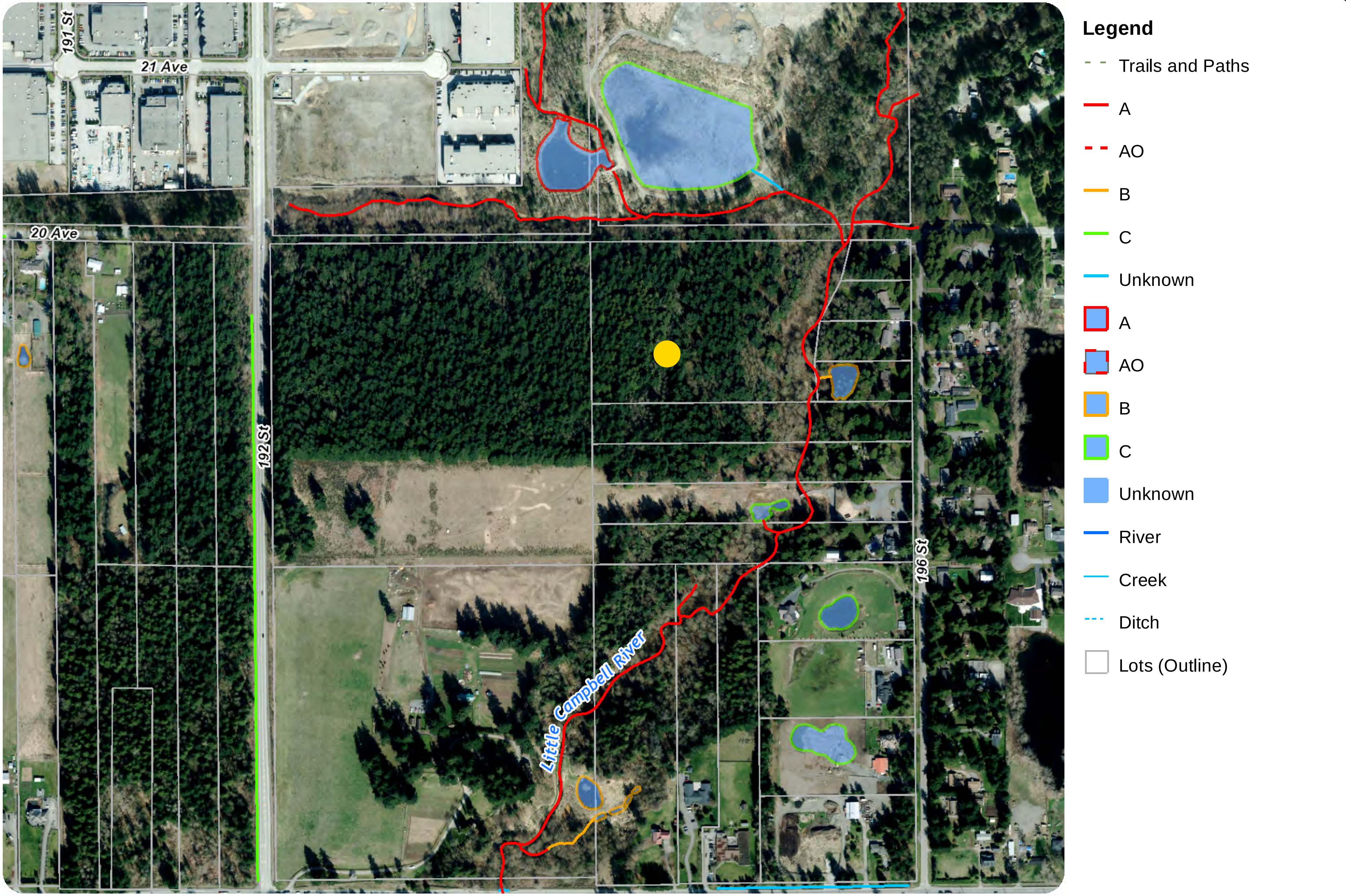
A Rocha Canada

Project No.	Date:
13-231	December 2014

0 600 1,200 1,800 m

MAP 7
Salish Sucker Survey Sites from 2011 to 2014

Approximate location of Olive-sided Flycatcher



Olive-sided flycatcher, observed 28-May-2015 during regular A Rocha bird survey

Scale: 1:6,340

0 0.04 0.08 0.16 0.24 km

Map created on: 28/05/2015

APPENDIX XIV – Class "D"Cost Estimates for Recommendations

Class "D" Cost Estimates for Recommendations

Achieving a Zero-Runoff stormwater management target

Industrial/Commercial (~85 %TIA) Parcels using standard methods - $67,000 – $124,500/ha

Scenario 1 – high permeability soil

- 100 m^3 of infiltration chambers/ha ($65,000/ha)
- Irrigation re-use system ($2,000/ha)

Scenario 2 – low permeability soil

- 250 m^3 of infiltration chambers/ha ($162,500/ha)
- Irrigation re-use system ($2,000/ha)

Medium Density Residential (~30 %TIA) Parcels using standard methods - $42,000 – 82,000/ha

Scenario 1 – high permeability soil

- 500 mm additional landscaping thickness ($5,000/ha)
- Retention and infiltration pond ($350/$m^3$, estimate 100 m^3 pond/ha at $35,000 not including the land)
- Irrigation re-use system ($2,000/ha)

Scenario 2 – low permeability soil

- 1000 mm additional landscaping thickness ($10,000/ha)
- Retention and infiltration pond ($350/$m^3$, estimate 200 m^3 pond/ha at $70,000 not including the land)
- Irrigation re-use system ($2,000/ha)

Engineering Costs

- Standard Stormwater management report (2 – 10ha) $3500
- Integrated Stormwater Management report (2 – 10ha) $5000
- Multi-teir Volume Based Stormwater Management Design and Reporting (2 – 10ha) $7000

Near Surface Hydrogeologic, Wetland Connectivity, and Critical Recharge Area Studies – $23,500 - $62,000/ha

- Piezometer flow network ($7,500/ 3-piece piezometer nest, 2 nests per ha for areas of concern)
- Wellbore fragment analysis ($3,500)
- Pump and Tracer testing ($10,000)
- Data gathering and Reporting ($10,000)

Continue and enhanced water quality monitoring $10,000 – $30,000 per annum

- Provide instrumentation and funding for volunteer programs
- Establish new sensor stations and provide access to data gathered for analysis by citizen-scientists.

Well Closure Recommendations - $0 - $6,000 per well

- Depending on the type of bylaw developed, either well closure costs are full, partial or no responsibility of the well owner.