Ministry of Environment
LOWER MAINLAND REGION

Characterization of Potential Pollution Sources in the Little Campbell River Watershed

Prepared for:

Ministry of Environment
Environmental Quality Section
Lower Mainland Region
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ENVIRONMENTAL QUALITY

Preface

This report is one in a series of water, groundwater and air quality reports that are being issued by the Lower Mainland Regional Office in fiscal year 08/09. It is the intention of the Regional Office to publish water, groundwater and air quality reports on our website (http:/wlapwww.gov.bc.ca/sry/p2/eq/index.htm) in order to provide the information to industry and local government, other stakeholders and the public at large. By providing such information it is hoped that local environmental quality conditions can be better understood and better decisions regarding water, groundwater and air quality management can be made.

It is to be emphasized that this report represents a collation and analysis of "best available information" related to current water uses, potential pollution sources and potential pollution sinks. The information presented in this report should be considered preliminary and subject to change as more information becomes available and as characteristics of the watershed change. It is provided as a "starting point" to assess what information is available and what information is not available. It is meant to provide a foundation from which to begin to tackle non-point source pollution in this watershed and it will help with on-going analysis of water quality monitoring information.

This project was a collaborative effort by the report authors, as outlined below:

- Pamela Zevit, R.P. Bio, Adamah Consultants: Report compilation and editing, Part One, Part Two, Part Three (agricultural waste and domestic pet waste management), Part Four (riparian and public lands as pollution sinks), Part Five,
- Nick Page, R.P. Bio, Applied Raincoast Ecology: Report editing, Part Three (urban NPS pollution issues), Part Four (wetlands, hydric soils and forests as pollution sinks) and
- Heather Goble, M.A.Sc, Mountainview Environmental Health Services: Part Three (human waste management and soil vulnerability).

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Glossary:

BMP	Best Management Practices
DO	Dissolved Oxygen
EIA	Effective impervious area – area of impervious surfaces directly connected to watercourses
Hydraulic failure	On-site SDS - the drain field or distribution system has become completely clogged, and sewage backs up in the house or breaks out on the surface of the field
Impervious Area	Hard surfaces such as roads, parking areas, and roofs that collect precipitation and rapidly convey it to streams through ditches and pipes. Impervious areas also prevent the infiltration of precipitation into the ground, and increase the volume and rate of surface runoff.
LCR	Little Campbell River
MAD	Mean Annual Discharge
MOE	Ministry of Environment
NPS	Non-point Source
OCP	Official Community Plan
POD	Point of Diversion – location where surface water is extracted
SDS	Sewage disposal system
Subsurface failure	On-site SDS - sewage is distributed into the drain field, but a plume of partially treated sewage moves through soil macropores, cracks or ditches
TIA	Total Impervious Area – area of impervious surfaces, including roads, parking lots, roofs
Treatment failure	On-site SDS - sewage is adequately treated within the soils of the drain field, but nitrate is not reduced before it reaches groundwater

EXECUTIVE SUMMARY

Background

This report has been prepared for the partners in the Shared Waters Alliance, an international working group focused on improving water quality in Semiahmoo Bay and the greater receiving waters of Boundary Bay.

Boundary Bay is considered an internationally important bird area on the Pacific Flyway. Its waters support a diverse ecosystem of flora and fauna including salmon, herring, eel grass meadows, and shellfish beds. This area is also an important recreational area used by local residents and tourists for swimming and boating.

The Canadian side of Boundary Bay once supported a significant shellfish resource, historically contributing over 50% of B.C.'s annual commercial oyster harvest. Shellfish harvesting requires a high level of water quality, and due to fecal coliform levels as well as the presence of fecal pollution sources, both Boundary and Semiahmoo Bays were closed to bivalve shellfish harvesting in the early 1970s.

In 2002, the Shared Waters Alliance initiated a circulation study of Boundary Bay (Hay & Company Consultants 2003), which indicated that the Little Campbell River (LCR) watershed is a significant contributor of fecal coliform to the Bay. Other water quality monitoring work has also indicated that the LCR watershed is impaired by non-point source pollution (Fleming and Quilty 2006).

As a result of this, the Shared Waters Alliance has placed increased emphasis on pollution source identification and remediation work in the Little Campbell watershed in an attempt to improve water quality. The development of a "watershed characterization" of pollution sources and water uses was identified as an important "next step". This information, provided in a watershed context, is meant to help support monitoring, modeling, watershed-based planning and pollution prevention initiatives.

Purpose

The purpose of this study was to collate and assess existing information on current water uses, potential pollution sources, particularly fecal coliform sources, and pollution "sinks", which provide natural water quality protection services. As a preliminary characterization study, the information and maps compiled for this report will provide stakeholders with a foundation for more effective management of non-point source pollution impacts in the Little Campbell River

Key Products

The Little Campbell River is a multi-jurisdictional watershed with portions in the Township of Langley, the City of Surrey, the City of White Rock, Semiahmoo First Nations land, and Whatcom County in the United States. This study brought mapping resources together from many jurisdictions to create a series of watershed-based maps. This study has resulted in the development of watershed maps for the Little Campbell River which show such things as watershed boundaries, sub-basin boundaries, aquifers and groundwater resources, soils, historic land cover, current land-use classification, watercourse mapping, water extraction sites, locations of on-site sewage disposal systems and habitat features that have the potential to act as pollution sinks.

Key Findings

The Little Campbell River is impacted by non-point source pollution, which is diffuse across the landscape and is cumulative. In order to systematically address non-point source pollution, particularly fecal coliform levels, there is an on-going need to consider spatial and temporal patterns in how water and land are used, as well as the relative intensity of water and land use. It is also important to consider how changes to natural drainage can affect the ability of pollutants move in a watershed, and how natural water quality protection services can be altered with land use change. This watershed characterization pulls together information on drainage features, water and land uses, and the watershed features that would be expected to contribute to natural "water quality protection" services. It is meant to summarize information where it is available, and to identify where information is lacking

Drainage and Soils

- Topography, drainage networks and soils were assessed and four sub-watersheds were delineated (West, Surrey, Langley and East).
- Nine local (third-order stream) watersheds and four mainstem watersheds were delineated.
- Soil information was assessed and the watershed was found to have a diverse mix of soils.

Water Uses

- Identified water uses include aquatic life, irrigation, livestock watering, domestic water use, and boating in the river and estuary, as well as swimming, boating and aquatic life use in Semiahmoo Bay which is fed by the river water.
- Collated information suggests that low summer-fall base flow in the Little Campbell River is likely a concern for fisheries resources.

- There are 1099 recorded wells and 82 surface water licences on the Canadian side of the watershed. Since there is insufficient information on exact water use by land owners, only estimates of surface water extraction levels have been made based on potential use and maximum licenced volumes.

- There are 37 known surface water licences for agricultural use, including irrigation (27), frost protection (1), livestock watering (8) and nurseries (1). Approximately 80% of the total licenced surface water volume, at the time of this assessment, was allocated for these agricultural purposes.

Land Use – Watershed Summary

- The Little Campbell River watershed is dominated by three land use types: 40.4% is agriculture, 41.1% is park or undeveloped lands and 18.5% is urban, transportation or industrial lands. This assessment is based on orthophoto analysis using 2004 orthophotos for the Canadian portion of the watershed and 1998 orthophotos for the US portion of the watershed.

- For the entire watershed, Total Impervious Area was estimated to be 9.99%. However, changing land use in the Campbell Heights area and the Highway 99 corridor is not reflected in this estimate since development in both areas has occurred since the 2004 photos (used for the analysis) were taken. Several studies have found that streams in watersheds with greater than 10% imperviousness exhibit a broader range of hydrologic, water quality and physical impacts (Schueler, 1994).

- Total Impervious Area was highest in the West sub-watershed (30.1%) and lowest in the Langley (4.2%) and East (4.6%) sub-watersheds. At the local and mainstem scales, the highest Total Impervious Area values were found in LW-8 (28.6%) and LW-9 (41.9%) local watersheds.

- There is approximately 260 kilometers of road in the watershed and the estimated total number of vehicle kilometers per day is over 1,067,000. Road length, road density, vehicle activity and number of road crossings are provided for the sub-watersheds and smaller local and mainstem watersheds. Roads are of interest because they contribute to watershed imperviousness, and they can convey contaminants, associated with motor vehicles, to local watercourses.

- Seventy-three spills were recorded in the watershed between January 1987 and May 2005, although the number of recorded spills declined substantially in the second half of the period of record. Ten occurred in the Township of Langley, 58 occurred in the City of Surrey and 5 occurred in the City of White Rock. The most common type of spill reported was hydrocarbons.

Land Use - Agricultural

- Based on Ministry of Agriculture and Lands windshield survey livestock estimates, horses make up the most frequent livestock type over the largest number of farms. Poultry farming only constitutes approximately 2% of livestock operations, but it appears to constitute the greatest density of animal types in the watershed. Overall, hobby farms tend to dominate, though some larger dairy farms and other operations are also present.

- Of the agricultural related complaints received between 1991 and 2004, from citizens believing there to be non-compliance with the Agricultural Waste Control Regulation, the majority were related to horse, beef cattle, poultry and hobby farm operations. Eighty four percent of the complaints received were related to uncontained manure storage and seepage to water bodies.

- Overall, the estimated daily weight of fecal waste produced from livestock appears to exceed the estimated daily weight of waste generated by the human population in the watershed. However, when considering estimates of waste production, it is important to realize that the amount of waste generated does not necessarily translate into direct fecal loading or contamination of water bodies.

- There is very little information available on agricultural drain tiles, in terms of age, state, extent of presence, and relative importance for conveying contaminants to receiving waters in this watershed.

Land Use – On-site Sewage Disposal Systems

- While it has been estimated that there are 2175 on-site sewage disposal systems in the watershed, there is little information on how many of these are properly functioning, how many are still in service, or how often they are serviced.

- The assessment of soils for on-site sewage disposal suitability found that a proportion of the on-sites are located in areas of the watershed that (i) have poorly drained soils not recommended for sewage disposal and (ii) are located in areas with soils that may be well draining, but could still pose pollution risks due to localized high water tables, perched water tables or soils that are too well draining.

Land Use – Domestic Pets

- Based on dog licences, the number of dogs in the watershed is estimated to be around 1180. Although the total estimated daily weight of fecal waste produced from dogs is lower than estimates of total daily fecal waste for other types of domestic animals considered, dog waste may be a significant source of fecal coliforms in the watershed. Pet waste may enter water bodies through stormwater runoff from impermeable surfaces in urban areas and in runoff from areas where dog walking occurs in close proximity to surface waters.

Land Use – Urban and Industrial

- Active or potential development or redevelopment sites in the Little Campbell River basin include High Point Residential Community (approx. 99 ha), Fernridge Community (approx. 390 ha), Campbell Heights Business Park (approx. 340 ha), Grandview Heights (approx. 412 ha), Douglas area near Douglas Border Crossing (approx. 84 ha), and on the eastern flank of Hwy 99 (approx. 143 ha).

Pollution "Sinks"

- Wetlands were likely widespread in the LCR watershed prior to land conversion.
- Potential pollution "sinks" in the watershed can be divided into three spatial units, the upper watershed, the South Surrey lowlands and the river mouth.
- Approximately 690 ha of wetland and floodplain was identified and mapped.
- Forest cover polygons and riparian buffers were assessed. In the LCR watershed, 45% of riparian buffers at least 30m in width are composed of forest cover.

Sustainability Issues

During the process of collating information for this study, a number of issues have been identified as having implications for habitat quality and water use in the LCR watershed. These include:

- Contaminants carried in agricultural and urban run-off,
- Nutrient loading contributing to potential eutrophication, and low dissolved oxygen levels with impacts to aquatic life,
- Low water levels in summer accentuated by withdrawals of surface water and groundwater and decreasing groundwater levels,
- Increasing urbanization and potential changes in pollution conveyance, water quality and stream hydrology,
- Potential impacts to downstream recreational use from surface water contamination,
- Economic loss due to closures of bi-valve shellfish harvesting,
- Declining habitat sustainability for at risk species (e.g. steelhead)
- Loss of natural ecological services (e.g. wetlands and functional riparian areas)

Recommendations

Steps recommended to be taken to improve the understanding of pollution sources in the watershed and to improve water quality in the receiving waters of Boundary Bay include:

- Planning that protects natural resource values, water quality and water uses,
- Public education and work with stakeholders on pollution prevention initiatives,
- Protection and restoration of pollution sinks,
- Monitoring to allow for adaptive management,
- Improving the function and maintenance of on-site sewage disposal systems,
- Forecasting future change in water quality and implications for water uses where possible,
- Filling data and knowledge gaps,
- Promoting international information sharing and cooperation to protect the receiving waters of Boundary Bay.

Planning, monitoring, forecasting, pollution prevention and protection/restoration efforts should be focused on parameters and issues that are currently, or could in the future, affect known water uses and user groups. Efforts should focus on water quality protection for livestock watering, irrigation, domestic use, recreational use (swimming and boating), commercial/First Nations shellfish harvesting, and aquatic life, including the commercially important anadromous fisheries resource. At this time, two important focus areas, needing attention in the LCR are fecal coliform levels and dissolved oxygen levels.

INTRODUCTION

This study is a preliminary characterization of point and non-point pollution sources in the Little Campbell River (LCR) watershed, whose waters feed into Boundary Bay. Once supporting a substantial shellfish industry, the Boundary Bay area has been subject to harvesting closures which started in Mud Bay in 1962 and expanded to include the whole Canadian side of the Bay in 1972 (Cheung, 2005) due to bacteriological contamination. The Canadian side of Boundary Bay remains closed to shellfish harvesting due to water quality concerns. Modeling work has identified the LCR watershed as a significant source of fecal contamination to Boundary Bay (Hay & Company Consultants 2003); however, limited information exists as to the exact location or sources of these contaminants.

The main threat to the LCR watershed is degraded water quality from: adjacent agricultural land use, increasing urban runoff and water withdrawal (Swain 1988, MOE 2003). However, recovering and maintaining watershed health involves the consideration of many variables. The focus of this study is to characterize potential sources of bacteriological (fecal coliform) contamination, which has the potential to impact upon several activities in the watershed: recreational use (boating and swimming), livestock watering, irrigation of ready-to-eat produce and other crops, and shellfish harvesting. It is also important to recognize that there are other factors that may act to reduce water quality in the watershed, such as excess nutrients and sediment.

Fecal coliform bacteria are present in the feces of warm-blooded organisms, including humans, cattle, and wildlife. The presence of fecal coliform bacteria in watercourses indicates the presence of feces, as well as the potential for pathogenic (disease-causing) micro-organisms. Fecal coliform bacteria are not pathogenic themselves, but are used as an indicator of pathogens that can cause gastro-intestinal disease in humans. Common sources of fecal coliform bacteria in mixed urban-agricultural watersheds are: animal manure used for agricultural fertilizer, leaking septic fields, cross-connections between storm and sanitary sewer systems, domestic pets, and wildlife.

While 98% of the LCR watershed is contained within Canada, decisions influencing water quality in B.C. may have an effect on water quality on the American side of Boundary Bay. The Drayton Harbor Conservation District and their partners have been working aggressively to improve water quality in watercourses draining to Drayton Harbor on the U.S. side of Boundary Bay. These efforts have resulted in the conditional re-opening of shellfish harvesting in Drayton Harbour. On the Canadian side, this report, along with the monitoring work completed on the Little Campbell River, will help establish a foundation for water quality improvement initiatives in the watershed.

Purpose

The purpose of this study is to collate and assess existing information on water uses, pollution sources (particularly fecal coliform) and pollution sinks in the LCR watershed. This study provides information on:

- Water uses, including irrigation, drinking water, aquatic life and recreational uses,
- Potential sources of enrichment and contamination of surface and groundwater,
- Watershed Features such as wetlands, riparian ecosystems and soils, that are expected to contribute to natural water quality protection and
- Factors with relevance to critical low flows and seasonal hydrological regimes,
- Restoration, protection and enhancement opportunities to protect water quality.

This is expected to provide background information to support community efforts to raise awareness of non-point source pollution issues, help to prioritize pollution reduction work, and support stormwater and pollution prevention planning. Ultimately the information is a baseline from which the protection of the LCR watershed and Boundary Bay can more effectively be achieved.

This report has been prepared for the partners of the Shared Waters Alliance, an international working group focused on improving water quality, particularly fecal coliform levels, in Semiahmoo Bay and Boundary Bay.

Methods and Approach

Data for this study was collated and assessed through several contributors and a team of consultants working with the main project manager in the Environmental Quality Section of the Ministry of Environment (Lower Mainland Region). Activities included personal communications, research and literature review as well as analysis of several sources of data from various agencies and stakeholders. Analysis of the spatial data was provided by staff with the Integrated Land Management Bureau.

The spatial (mapping) and associated attribute (archive report, statistical and reference) data for this study were drawn from a wide range of sources (Appendix 1) including:

- Federal: Environment Canada (EC), Canadian Wildlife Service (CWS)
- Provincial: Integrated Land Management Bureau (ILMB), Ministry of Agriculture and Lands (MAL), Ministry of Environment (MOE)
- Regional: Greater Vancouver Regional District (GVRD)
- Municipal: City of Surrey, City of White Rock, Township of Langley
- United States: Whatcom County, City of Blaine (Washington)
- Non-government: Langley Environmental Partners Society (LEPS), Little Campbell Watershed Society, Community Mapping Network (CMN)

Spatial data was imported from the above range of sources and compiled through ArcGis 9 and ArcView 3.2 software to provide complete coverage for the watershed where available. Available theme layers were set as stand alone coverage (single theme maps) or combined to provide a range of baseline maps and accompanying statistics (analyzed attributes).

PART 1: DELINEATION AND DESCRIPTION OF THE ANALYSIS AREA

1.0 LITTLE CAMPBELL RIVER WATERSHED

Located 35 km south of Vancouver (Map 1), the Little Campbell River (LCR) watershed is approximately 75 km^2, and includes broadleaf and coniferous forests, wetlands, riparian and estuarine habitats. The watershed is primarily within B.C.; however, approximately 2% extends into Washington State. Agriculture is the predominant land use (Township of Langley, southeast Surrey) with heavy urbanization occurring in the lower reaches (southwest Surrey and White Rock). The Semiahmoo First Nations Reserve is located at the mouth of the river.

1.1 Drainage Units & Characteristics

The LCR watershed has its origins in headwater seepage wetlands near 240th Street between 0 and 8th Avenue in the southern area of the Township of Langley. The river drains to the Boundary/Semiahmoo Bay area just north of the Canada/U.S. border. Within the LCR watershed, four distinct sub-watersheds have been delineated based on soil characteristics, aquifer vulnerability and susceptibility to septic contamination. Within these four sub-watersheds, nine local (third-order stream) watersheds (LW 1-9) and four mainstem watersheds (MS 1-4) were also delineated (Figure 1, Table 1). The outer watershed boundary overlays eleven aquifers, some of which are unconfined and overlap with neighbouring aquifers in other watersheds (Map 2).

Table 1. Mainstem and local watersheds within each Little Campbell River sub-watershed

Sub-watershed	*Area (ha)*	Local/Mainstem watershed	*Area (ha)*	Tributaries
East	*1142.2*	MS-1	*1142.2*	Kerfoot
Langley	*3106.6*	LW-1	*325.2*	'Unnamed-north'
		LW-2	*305.6*	'Unnamed-south'
		LW-3	*609.1*	Jacobson
		LW-4	*383.9*	Jenkins Highland
		MS-2	*1482.8*	-
Surrey	*2092.5*	LW-5	*468.3*	East Twin West Twin
		LW-6	*401.5*	Kuhn
		LW-7	*517.0*	Sam Hill Thomson
		MS-3	*705.6*	-
West	*1241.2*	LW-8	*824.1*	Fergus
		LW-9	*204.5*	McNalley
		MS-4	*212.5*	-
TOTAL	***7582.5***			

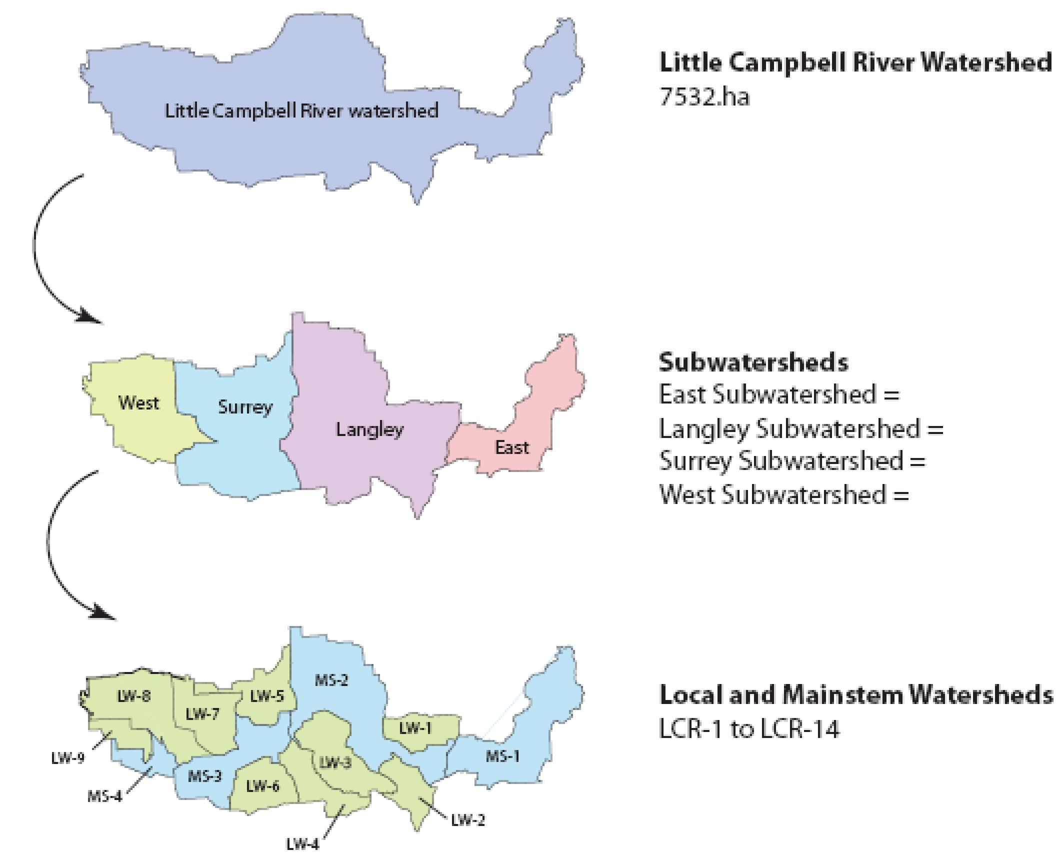
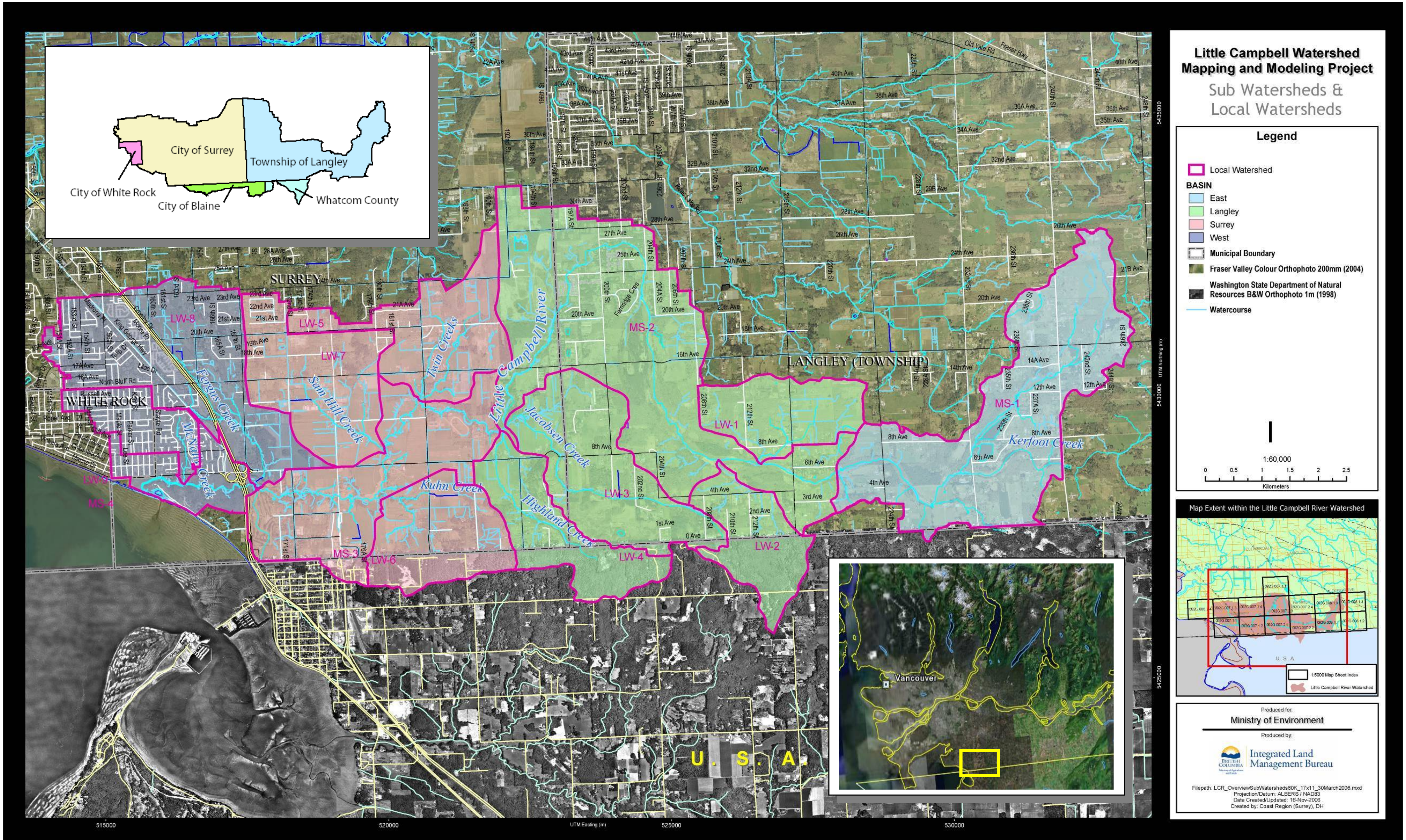


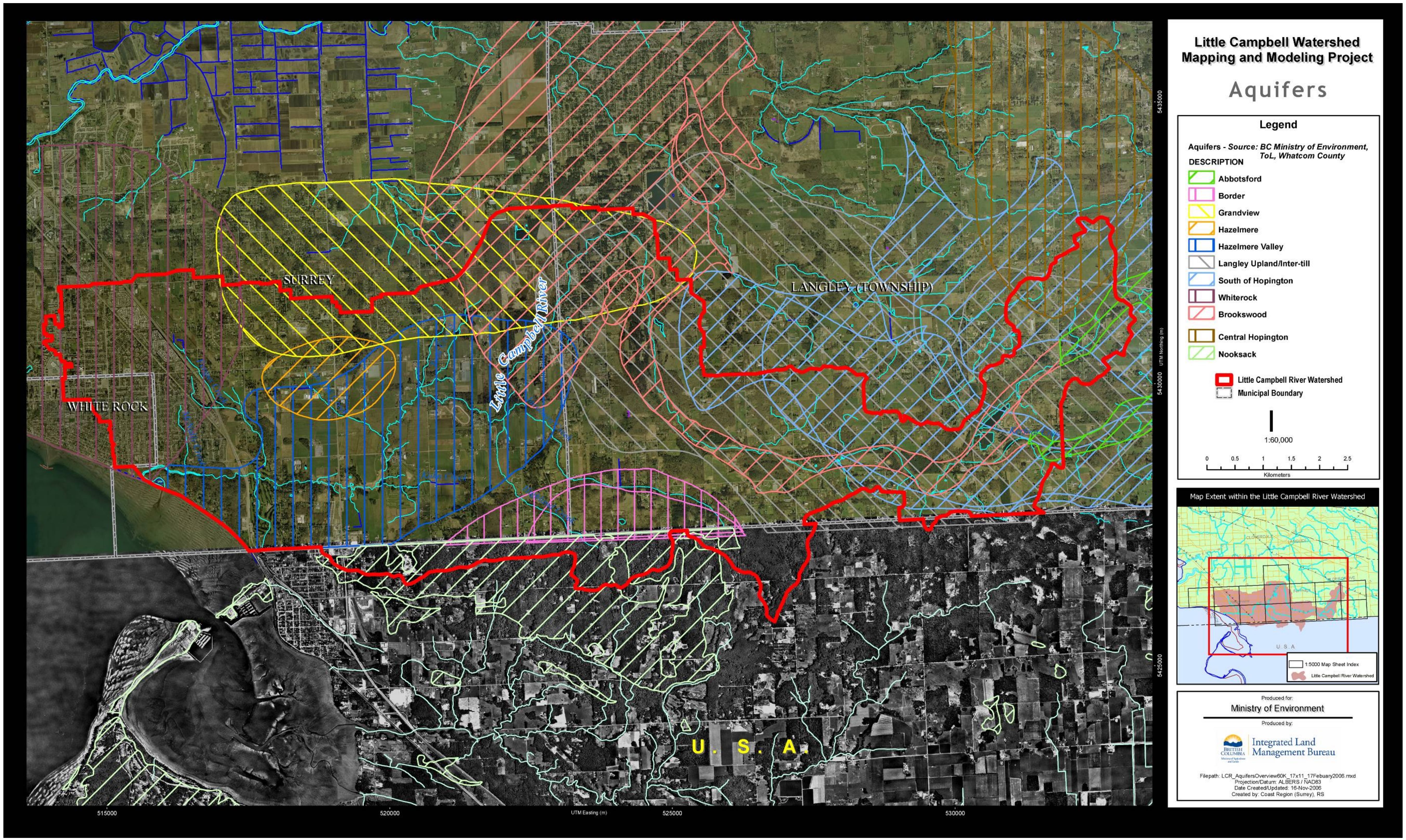
Figure 1: Delineation of drainage units within the Little Campbell River

1.1.1 East Sub-Watershed and Local Watersheds

The East sub-watershed, including Kerfoot Creek, is the most upstream portion of the LCR mainstem, and is fed by several first and second order streams (Map 1). While the Hopington and Abbotsford aquifers touch the boundaries of this area, neither the LCR watershed nor its tributaries directly overlay these aquifers. The Brookswood aquifer, however, does underlie the mainstem throughout this area (Map 2). The Brookswood aquifer is an unconfined aquifer susceptible to contamination from land use activities.



Map 1. The Little Campbell River watershed with drainage units defined, Insets: Regional context for the Little Campbell River Watershed (Google Earth 2006) **and local jurisdictional boundaries**



Map 2. Aquifers and groundwater resources of the Little Campbell River watershed

1.1.2 Langley Sub-Watershed and Local Watersheds

The Langley sub-watershed is east of the Surrey sub-watershed boundary and roughly located north of 0 Avenue and west of 220th Street (Map 1). Surficial flows have been known to disappear underground for a portion of the mainstem in this sub-watershed during summer months (approx. April to November). Adjacent landowners have indicated that this phenomenon has been occurring for at least the past 12 years. Beginning where the mainstem crosses 24th Avenue and extending approximately 1 km north, then west underneath 200th Street, this dry zone acts as a barrier, preventing upstream flows from connecting with the downstream portion of the river.

Within this sub-watershed, the riverbed is situated over the unconfined Brookswood aquifer, however most of the associated drainage areas located south of 12th Avenue lie outside the aquifer boundaries (Map 2). The aquifer supplies cooler groundwater to the river during the summer, maintaining water levels and moderating temperatures. The Langley sub-watershed also overlays part of the Border, South of Hopington and Langley Upland/Inter-till aquifers. The Border aquifer is thought to consist of two aquifers: a shallow unconfined aquifer (Border A), overlying a deeper, confined aquifer (Border B). Both South of Hopington and Langley Inter-till are also deeper, confined aquifers.

Four local watersheds with 3rd order streams are delineated in this area: Jenkins & Highland Creeks (LW-4), Jacobsen Creek (LW-3), 'unnamed - south' at 210th Street (LW-2) and 'unnamed - north' at 214th Street (LW-1).

1.1.3 Surrey Sub-Watershed and Local Watersheds

The Surrey sub-watershed is located approximately between 168th Street to the west, 192nd Street to the east, 22nd Avenue to the north, and 0 Avenue to the south (Map 1). This area is largely dominated by poorly drained soils with the exception of well-drained soils in the following areas: north of 16th Avenue within local watersheds formed by Thomson and Sam Hill Creeks (LW-7), south of 4th Avenue between 180th Street and 192nd Street within the local watershed formed by Kuhn Creek (LW-8) and the eastern half of the local watershed formed by the Twin Creeks (LW-5). The eastern half of Thomson and Sam Hill Creeks lie over part of the Brookswood aquifer (Map 2). This aquifer is largely unconfined and susceptible to contamination from land use activities. Well-drained soils in this area add to this concern.

1.1.4 West Sub-Watershed and Local Watersheds

The West sub-watershed is a wetland area formed near the mouth of the river that supports a wide variety of wildlife including migratory birds. This unit, including the estuary, is surrounded by medium-density residential developments in White Rock and south Surrey. Soil characteristics are unclassified by Luttmerding (1980) but are likely a mixture of poor and well drained soils. Soils immediately north and east of the West sub-watershed have been classified as poorly drained (Luttmerding 1980).

Fergus Creek, a relatively large 3rd order stream (LW-8) is located within this sub-watershed. Well-drained soils are located north and poorly drained soils south of 16th Avenue in the Fergus Creek system. Fergus Creek feeds into the mainstem approximately 2.5 km upstream of the river mouth. McNalley Creek (LW-9) is a 2nd order stream within this sub-watershed. It may have been a 3rd order stream but high density residential development encompasses the creek and obscures whatever natural watercourse may have existed. Stormwater drainage from residential areas in White Rock and Surrey feed into McNalley Creek, which enters the river approximately 750 m upstream of the river mouth.

1.2 Hydrology

The LCR watershed's hydrological makeup is a complex one in which interactions are difficult to define, making determination of how and where pollution sources are affecting water quality more challenging. One factor that complicates defining the LCR watershed's hydrology is the de-watered portion of MS-2 during summer months. This separation of flow causes the LCR to act like two separate systems during this time period. The watershed's drainage is also influenced by numerous roadside and agricultural drainage ditches, channelized watercourses, wetlands and irrigation ponds (Dreves 2006). Springs and seeps are present throughout the watershed, many of which have yet to be adequately mapped (Dreves 2006).

Watersheds draining the south side of the Fraser Valley and the Boundary and Semiahmoo Bay area are generally low gradient watersheds with historic meandering channels (North and Teversham, 1984). Natural hydrology in B.C.'s coastal systems typically show patterns of winter flooding (November –March) followed by low flows in summer (Figure 2). Virtually identical hydrological conditions for summer low flow periods have been identified over the last 40 years in surveys upstream of Sam Hill Creek (LW-7). Summer low flows continue to be a potential major perturbation to the system (WSC 1994).

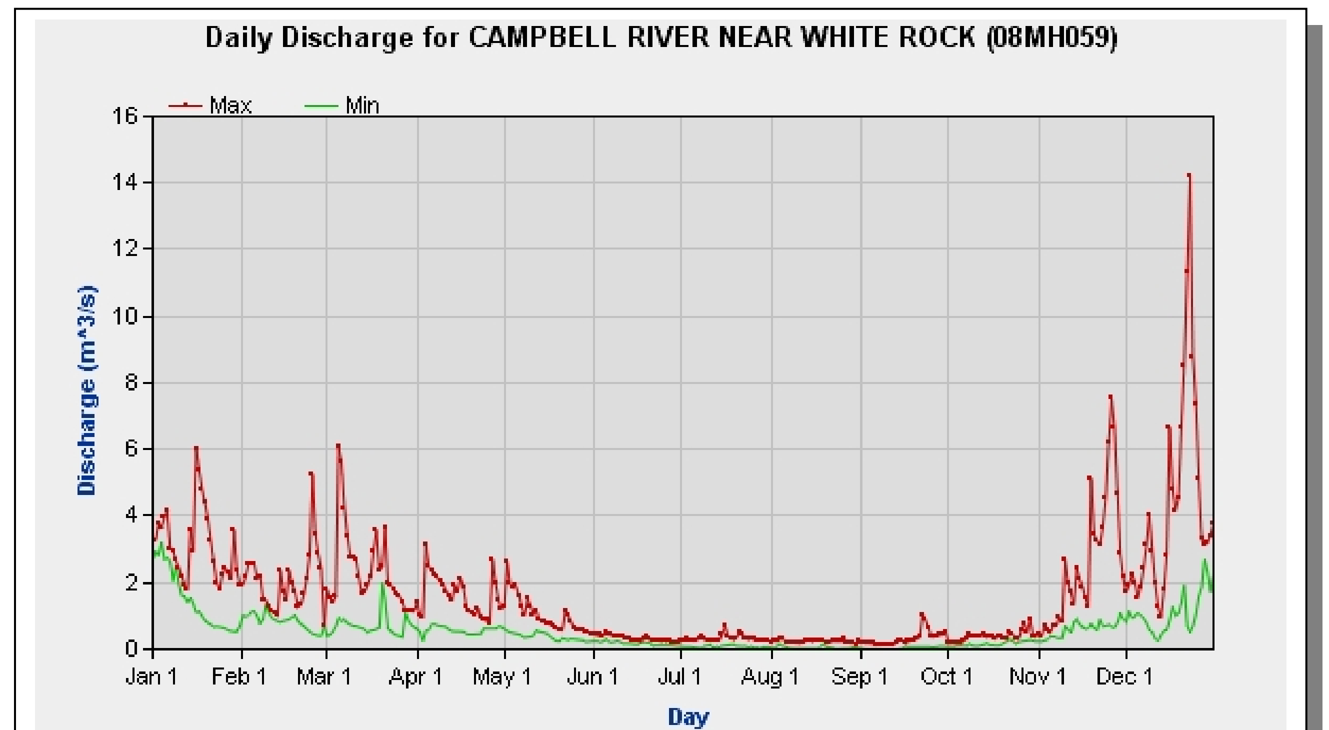


Figure 2. Annual hydrograph for the Little Campbell River mainstem taken upstream of the estuary in 1964 (Source: Water Survey of Canada Archive 1961-64 and 1994)

1.3 Water Quality

Water quality records for the LCR watershed date back to the early 1970s. Grab samples collected by MOE, Environment Canada, community groups (e.g. Little Campbell Watershed Society), and academic institutions (e.g. Kwantlen College) have been analyzed for a suite of parameters, and are summarized in report and database format (Fleming and Quilty 2006). The majority of these water quality data have been collected at a large number of locations, with a small number of samples collected at any given location. This “shotgun-type approach” has assisted in identifying site-level pollution and some general water quality patterns; however, the small number of samples (often as little as one) at any given site largely precludes in depth analysis. The conclusions summarized by Fleming and Quilty below, are therefore strictly preliminary.

Recent (2000-2003) data were statistically summarized, and mapped. Overall, Fleming and Quilty’s analysis of the data found that water quality in the Little Campbell River locally ranged from good to abysmal; appearing to be consistently better in the upstream half of the watershed. At many sampling locations, measures of bacteriological contamination were extremely high. Spatial analysis of the fecal coliform data is shown in Figure 3. Twin Creeks appeared to be particularly problematic, with especially high fecal coliform levels. The culverts that enter the Little Campbell River near its mouth, also showed extremely poor water quality for several parameters. Nutrient and metals concentrations were variable throughout the watershed. Exceedance of guidelines was locally observed for several metals, and while nitrate levels were generally not in violation, they may have been sufficiently high to lead to eutrophication problems. Turbidity and pH generally fell within acceptable ranges.

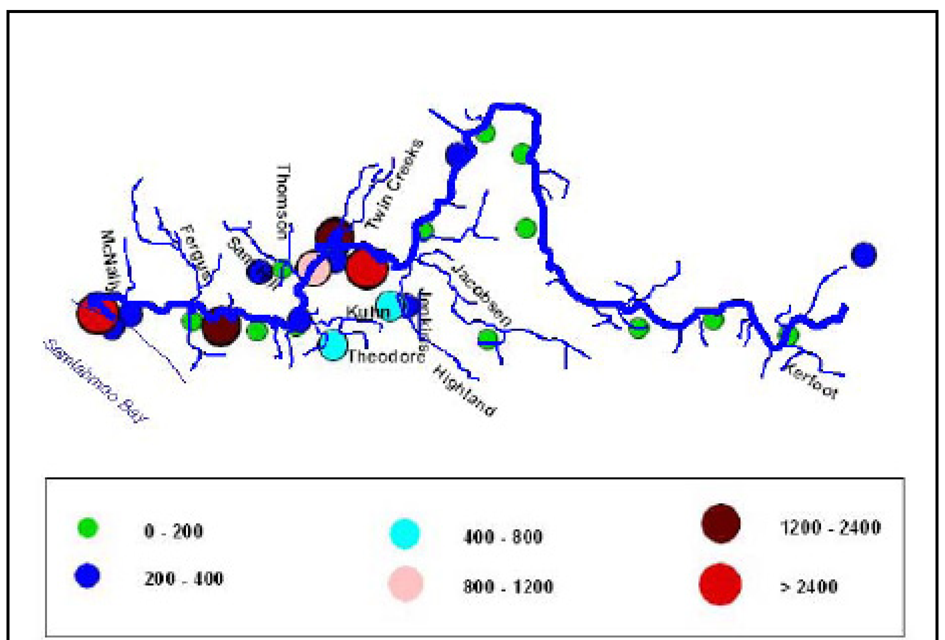


Figure 3. Spatial distribution of fecal coliform (cfu/100mL) in the Little Campbell River watershed (2000-2003) (from Fleming and Quilty, 2006)

1.3.1 Water Quality Objectives

Water quality objectives are established in British Columbia for water bodies to protect the most sensitive designated water uses at a specific location. Objectives were prepared for the LCR along with other tributaries to Boundary Bay in 1988 and were last monitored for attainment in 2002 (MOE 2003). Water quality parameters were measured that may be affected by human activity currently, or in the future: aquatic life, wildlife, irrigation, livestock watering, and primary-contact recreation (Appendix 2). Fecal coliform levels were used as an indicator of bacteriological contamination.

Two sites have been designated for monitoring water quality objectives attainment in the LCR watershed: upstream at 216th Street and downstream at 176th Street. Historically, the watershed has consistently not met objectives for fecal coliform and suspended solids at the downstream location nor for dissolved oxygen (DO) at the upstream location.

Objectives for fecal coliforms, suspended solids, ammonia, and nitrite were met in 2002 at both sites, indicating a general improvement since 1983. Fecal coliform counts were, however, still highest at the downstream site, indicating possible contamination from diffuse sources upstream (MOE 2003).

In 2002, objectives for dissolved oxygen (DO) were not met on any of the five sampling dates at the upstream location and on only two of the five dates at the downstream location. While conditions at the downstream site have remained fairly stable, DO conditions at the upstream site are poor and have deteriorated over the last 30 years. The cause of the historically poor DO conditions at the upstream site is likely related to the very low flow conditions, coupled with the presence of oxygen-demanding substances from both natural and agricultural sources.

The Water Quality Index rating (Table 2) for the protection of aquatic life in the LCR watershed was Marginal in 2002, mainly due to very low DO conditions at the upstream site (MOE 2003).

Table 2. Canadian Council of Ministers of the Environment (CCME) Water Quality Index scale

Excellent: 95–100	Water quality is protected with a virtual absence of threat or impairment; conditions are very close to natural or pristine levels.
Good: 80–94	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels
Fair: 65–79	Water quality is usually protected, but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels
Marginal: 45–64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor: 0–44	Water quality is almost always threatened and impaired; conditions usually depart from natural or desirable levels.

Note: Please refer to *Canadian Water Quality Guidelines for the Protection of Aquatic Life: CCME Water Quality Index 1.0 User's Manual* for more technical information on the index (available at www.ccme.ca/assets/pdf/wqi_usermanualfctsht_e.pdf).

1.4 Soils and Geology

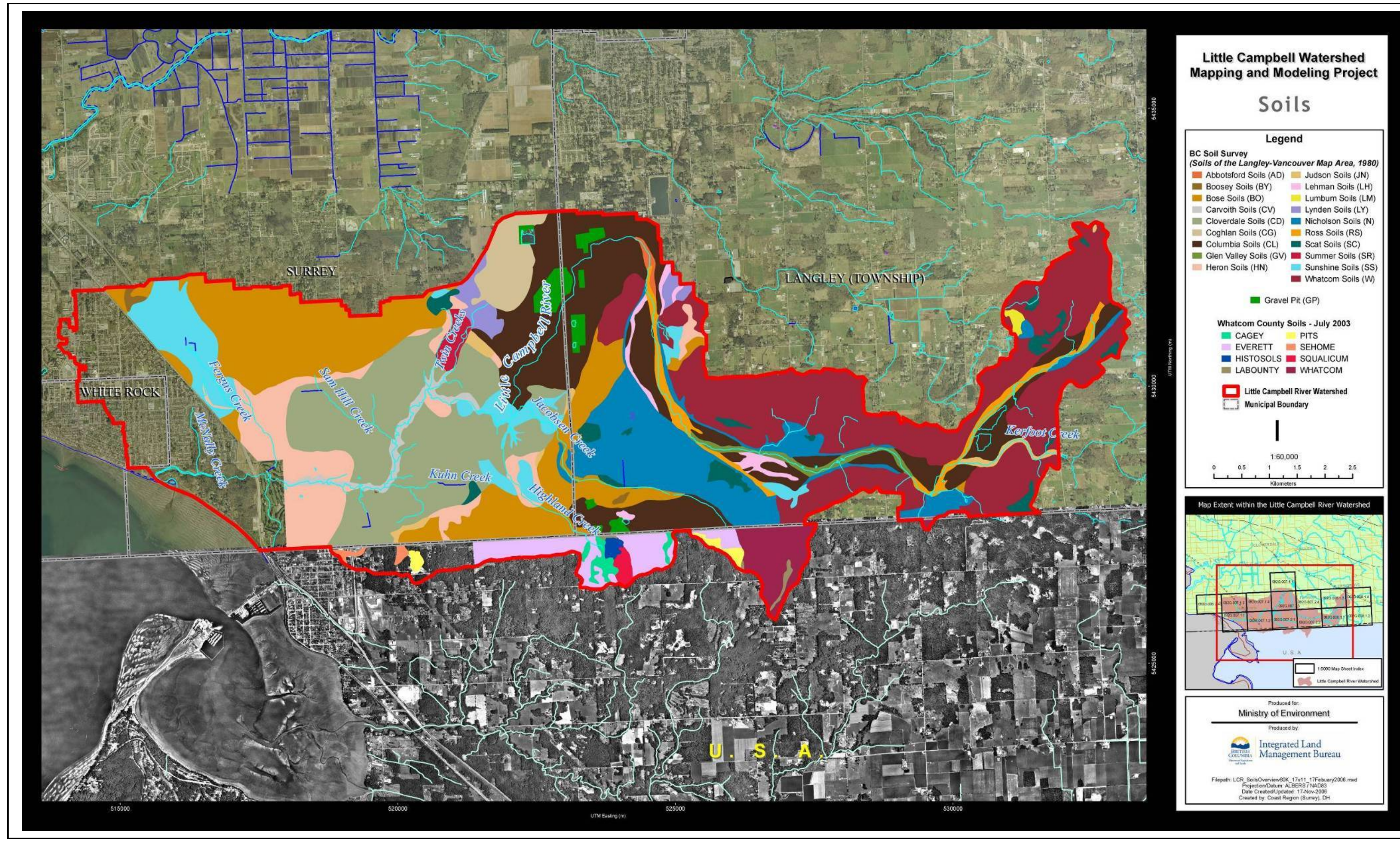
Geomorphology and soils in the LCR watershed are significant factors effecting water quantity and quality. Most watersheds along the south coast (Lower Mainland) have a common mosaic of humic soils overlaying glacial till and clay layers (CanSIS 2006) but the LCR watershed with its mix of soils is much more diverse (Map 3).

Soil type definitions are based on upland and lowland characteristics from Geomap Vancouver (Natural Resources Canada 2005). Thick silt and clay of marine origin are the most widespread surface sediments in the Surrey, White Rock, and Langley-Aldergrove uplands. Water infiltration is often poor because the sediments are fine grained; this can result in poor surface drainage. Silt and clay deposits exposed during construction activities erode easily and can be a source of stream siltation.

Deposits of gravel and sand up to 40 m thick are widespread on uplands between Langley and Abbotsford. Most areas mapped as gravel and sand are at risk of flooding and have a moderate to high liquefaction potential. Gravel and sand deposits are permeable (they transmit water), and can be important aquifer areas, as evidenced by the Abbotsford and Brookswood aquifers. Thick gravel and sand deposits are also important sources of aggregate; there are numerous gravel pits in south Langley.

The lowland floodplain contains rich agricultural soils that generally are poorly drained due to the flat terrain and shallow water table (Natural Resources Canada 2005). The mixture of peat, marine and gravel soils combine to provide the agricultural opportunities, groundwater and gravel resources that proliferate across the watershed (Bertrand et al. 1991).

As part of this study, soils were classified by geomorphological characteristics and inherent vulnerabilities for groundwater and aquifer contamination. In particular, soil types were related to risk of on-site sewage disposal system failure (Section 3.2.1.1).



Map 3. Soils and geology of the Little Campbell River watershed

1.5 Climate

The LCR watershed is influenced by the marine environment of Semiahmoo and Boundary Bays along its southwestern lowlands and the open soil, forested, and low density urbanizing areas of its uplands. The watershed falls within the Coast Mountains physiographic area and the Coastal Western Hemlock biogeoclimatic zone (Meidinger and Pojar 1991). The influence of warm ocean currents and moisture-laden winds result in generally mild summers and winters, high humidity, and abundant precipitation (Table 3).

Changes to the climate of the Greater Vancouver region and broader Georgia Basin/Puget Sound eco-region are beginning to emerge as an issue for watershed management. There is no indication that such changes are beginning to affect the Little Campbell at this time; however, projected changes in precipitation rates and temperature regimes can, and likely will, impact watersheds like the Little Campbell, which is already experiencing nutrient loading, low summer flows, low dissolved oxygen levels and partial urbanization (Taylor and Langlois 2000). Tentative quantitative estimates of the potential effects of climatic changes to steelhead in the watershed, have not identified acute thermal risks (causing immediate fish mortality), however chronic elevated temperatures may impede growth and have cumulative effects (Fleming and Quilty 2006).

Table 3. City of White Rock and south Township of Langley, average temperature and precipitation (Calculation Information for 1971 to 2000 Canadian Climate Normals or Averages, Source: Environment Canada http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html)

White Rock	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Temperature Daily Av. (°C)	4.1	5.6	7.5	9.9	12.7	15.2	17.1	17.2	14.8	10.7	6.6	4.2	10.5
Precipitation (mm)	144.3	107.1	96.1	75.2	66.5	55.8	40.4	43.1	51.1	103.1	165.8	153.5	1102
Township of Langley (south)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Temperature Daily Av. (°C)	2.2	4.4	6.3	8.6	11.8	14.2	16.7	17	14.2	9.8	5.1	2.7	9.4
Precipitation (mm)	176	172.1	135.2	102.7	82.8	72.9	52.7	56.4	76.4	141	207.5	211.3	1486.9

1.6 Land Use & Land Cover

The Semiahmoo First Nations are the first known humans to inhabit the LCR watershed area several hundred years ago; however, extensive changes to land cover did not begin until after the American and British began arriving in the 1850's. With the advent of the gold rush in B.C., the area was used to establish posts and trail connections from Semiahmoo Bay along the north side of the river to the Surrey and Fort Langley upland areas (Brown 1998). Historic land cover extrapolated from the Land Surveyors Notebook of 1850 indicates the watershed was dominated by coniferous and deciduous forests interspersed with open grasslands (Map 4).

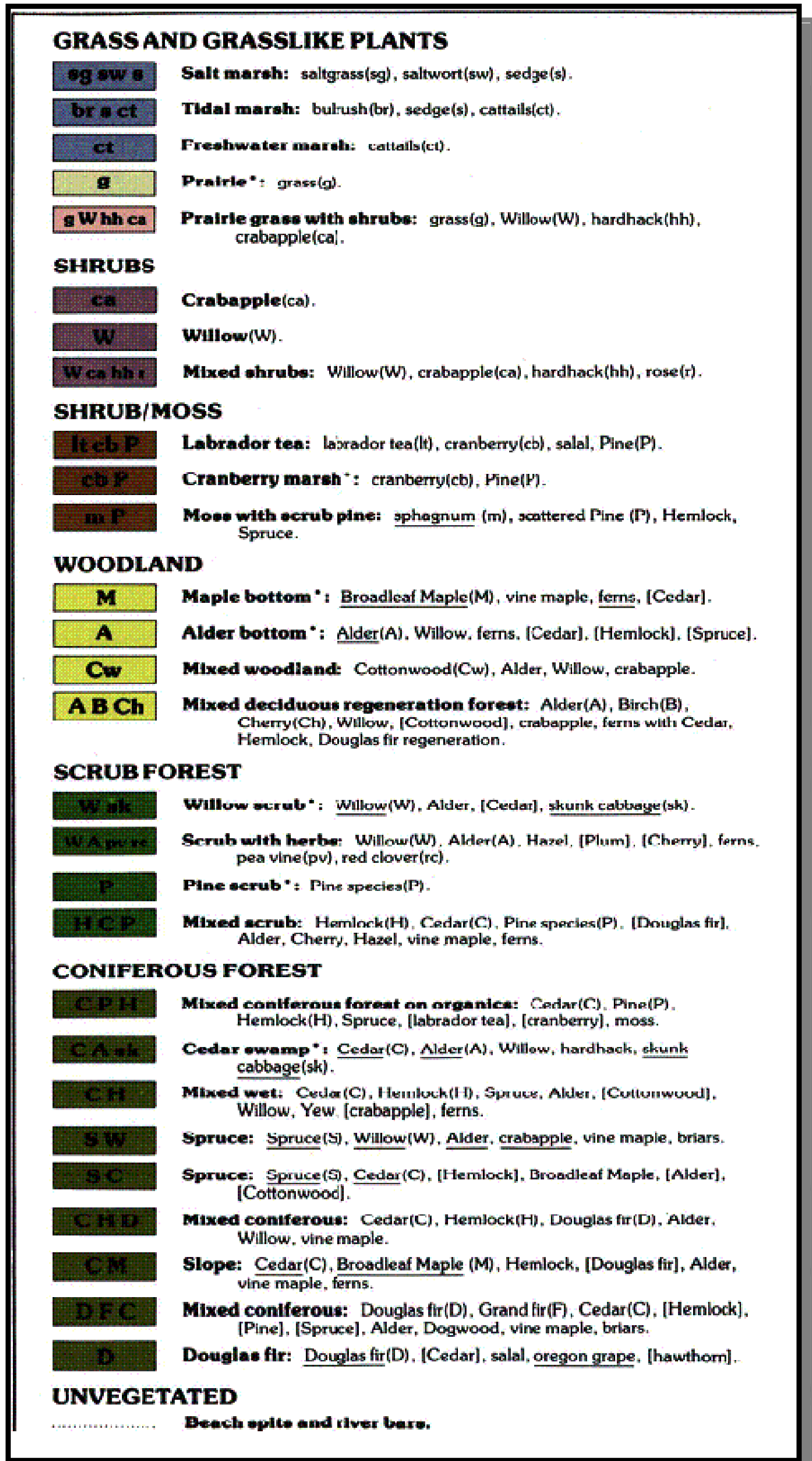
Early land use focused on resource extraction (logging and fishing), but by the end of the 1850's, settlers began arriving in greater numbers, transforming the landscape to more agrarian uses. Agriculture still generally dominates the watershed today, though the nature and intensity of farming is changing (MAL 2005). While past farming practices were spread across large acreages and reflected a mix of operations (crop, pasture, dairy), hobby farming and smaller more concentrated operations such as poultry, exotic meat suppliers, and equestrian centers are now more typical (MAFF 2002, MAL 2005). Land use in the watershed is transitioning to more residential, commercial, industrial and recreational uses (Map 5). The GVRD is expected to double its population by 2036, with areas like the Surrey and Langley lowlands absorbing a significant amount of urban growth (GVRD 1999).

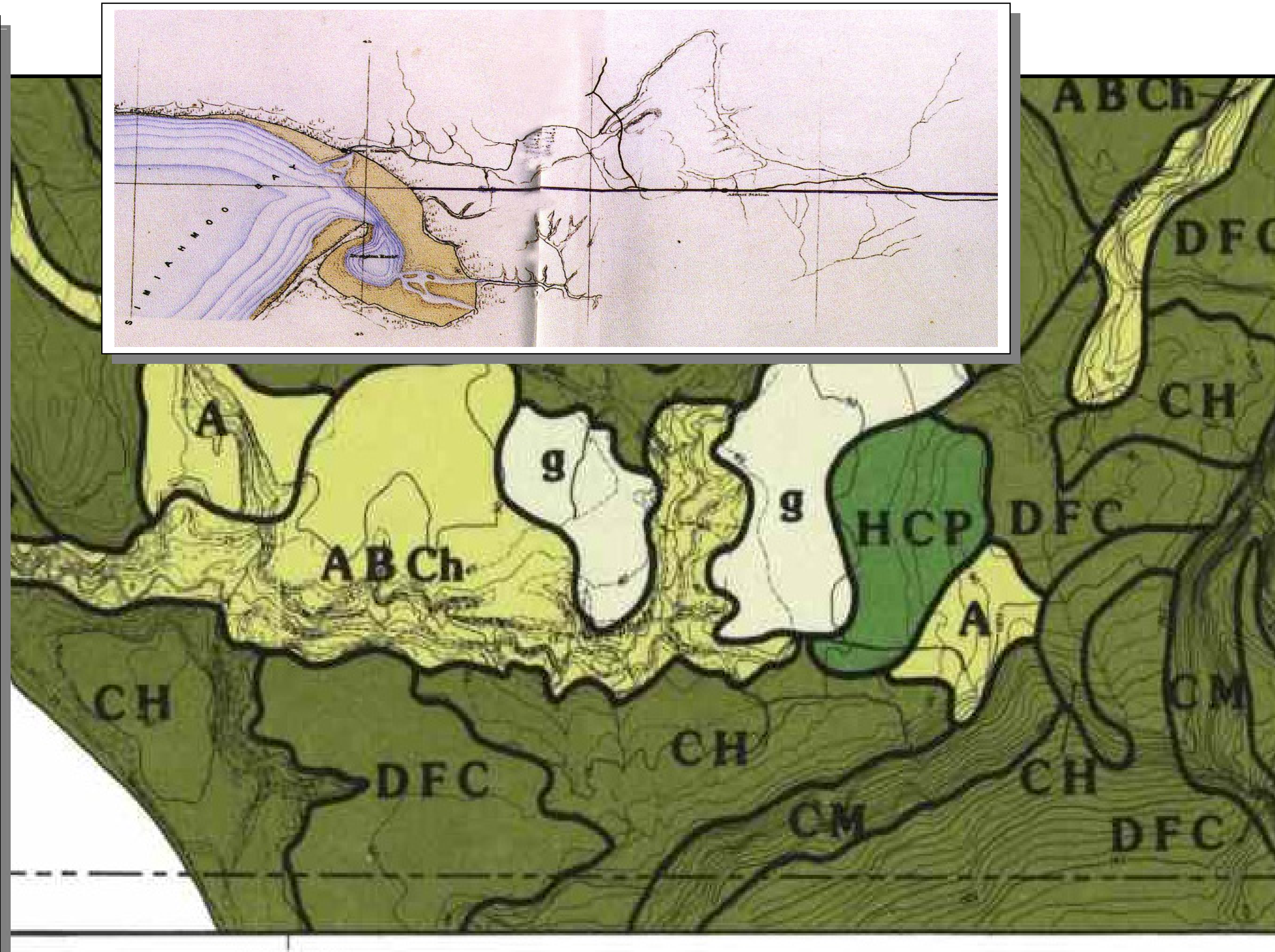
1.7 Flora and Fauna

The Little Campbell River Overview Assessment (Drever and Brown 1999) and the Township of Langley's Wildlife Conservation Strategy (LEPS 2005) have identified a diverse array of fish and wildlife resources in the watershed.

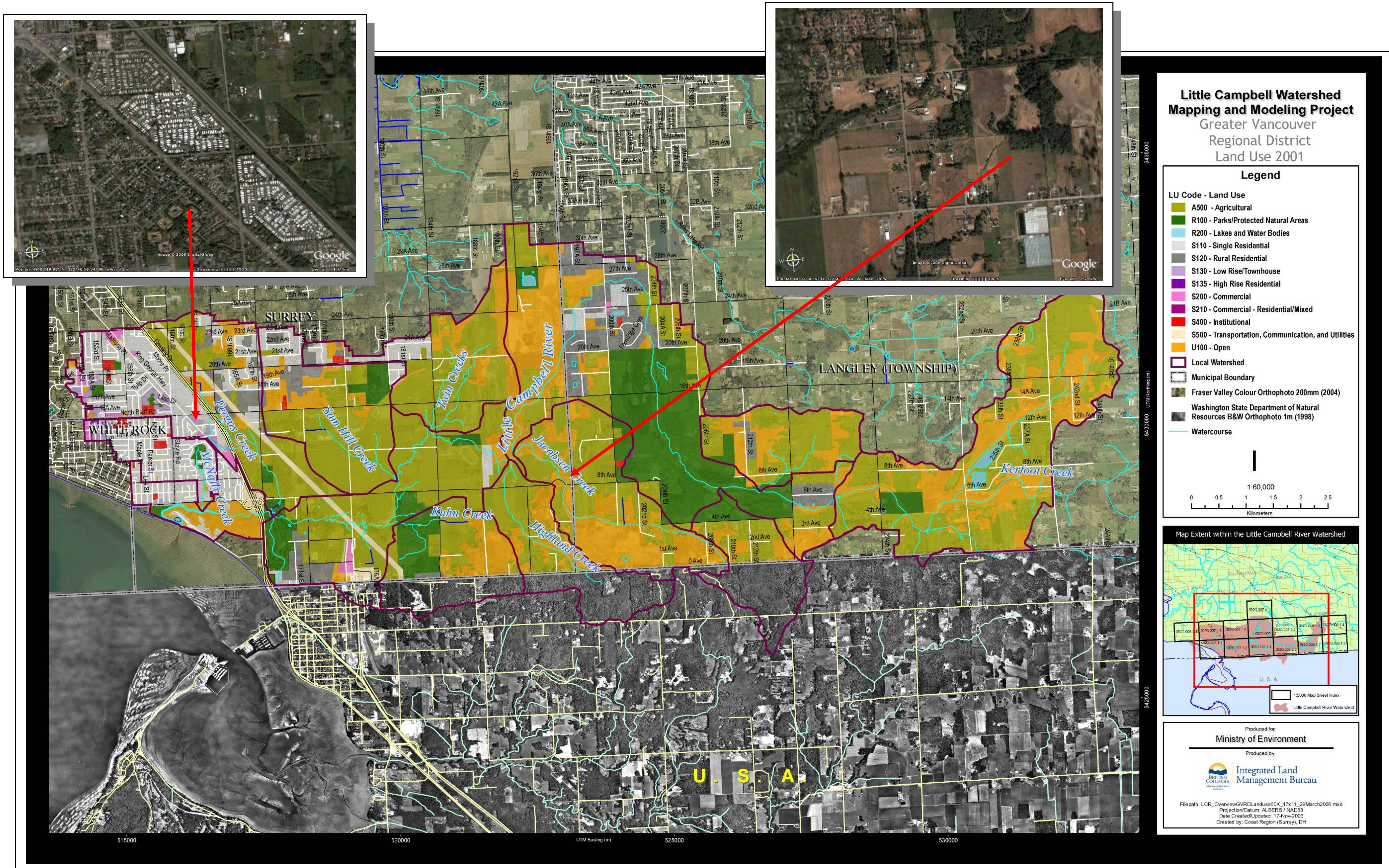
The watershed supports significant runs of Pacific salmon including coho, chinook, chum and pink, as well as endangered steelhead. Productive spawning and rearing habitat exists along the main river and in the lower reaches of several tributaries (MOE 2006). Watercourses within the watershed have been classified according to fish habitat value and observed fish presence (Map 6). The LCR watershed has been identified for steelhead recovery as part of the Georgia Basin Steelhead Recovery Program (BCCF 2006). Another species of fish, the Salish sucker, is now considered extirpated from the watershed. While it may be considered for recovery at some time in the future, two threats to its survival in the watershed include impacts from introduced non-native species and hypoxia (low dissolved oxygen). Hypoxia is linked with reduced flows, increased temperatures and eutrophication in the river system.

Boundary Bay is the top-rated Important Bird Area (IBA) in Canada (Cuthbert 2006). Mudflats and eelgrass beds provide food for many shorebird species and rearing habitat for out-migrating juvenile salmon. The watershed also includes significant habitat for riparian-dependent species, including the endangered Pacific water shrew (Drever and Brown 1999).

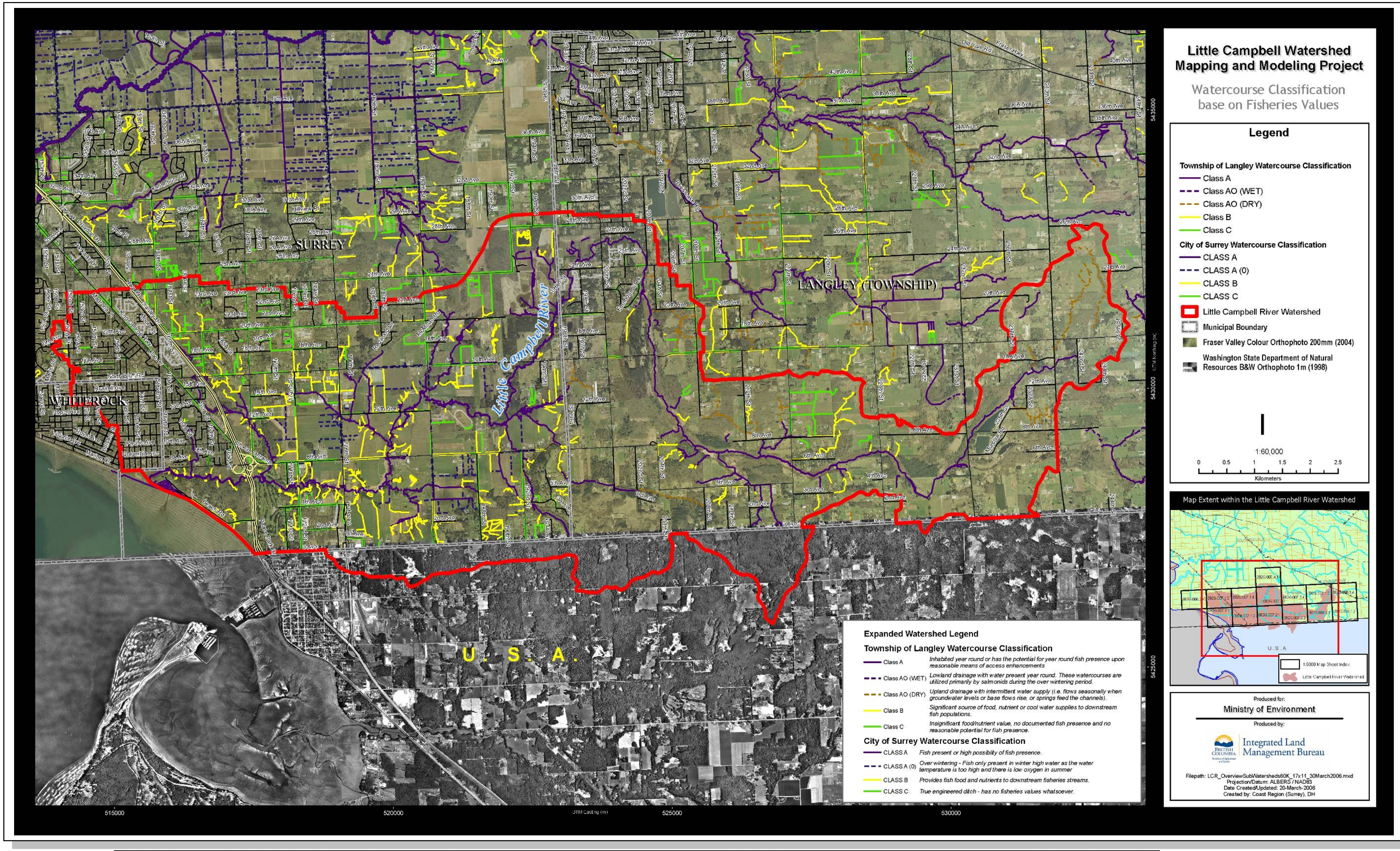




Map 4. Land cover of the Little Campbell River watershed circa 1859-1880 (Source: Environment Canada 1979 - from the "Vegetation of the Floodplains of the Lower Fraser, Serpentine and Nikomekl Rivers 1859-1890 by M.E.A. North and J.M. Teversham UBC 1984)**, Inset – British Boundary Map (circa 1850's) showing the Little Campbell River and Drayton Harbour watersheds.**



Map 5. Land use classification for the Little Campbell River watershed (Source: GVRD land use classification 2001), **Inset – typical urban rural fringe are in southwest Surrey, and agricultural area in south Langley**



Map 6. Classification of watercourses in the Little Campbell River watershed based on fisheries values.

PART 2: CHARACTERIZATION AND ASSESSMENT OF WATER USES

2.0 HYDROLOGICAL RESOURCE USE

The hydrologic regimes of watersheds in the Lower Fraser Valley vary according to climate, surficial geology and land use (Rood, 1997). Annual hydrographs follow the precipitation cycle with the largest flows occurring in November, December and January, when a series of Pacific storms typically move across the coast, and minimum flows typically occur after the dry weeks in July, August and September (Rood 1997).

Summer base flows in the Little Campbell River (LCR) watershed are recharged primarily from groundwater sources. These same sources are subject to continual extraction from groundwater and surface water licenses, many of which hit peak demand at critical low flow periods (Index 1 and 5, Figure 4, Rood & Hamilton 1994). As a result, irrigation extractions can increase stress on aquatic resources that are already pressured by low summer flow levels. The LCR watershed was identified as being a sensitive stream for fish flows by the Province under the Fish Protection Act in 2000, though it has yet to be designated for flow recovery (Ptolemy 2006). The implications of designation would be that a full recovery plan for fish flows would be developed and implemented (Queen's Printer 2000).

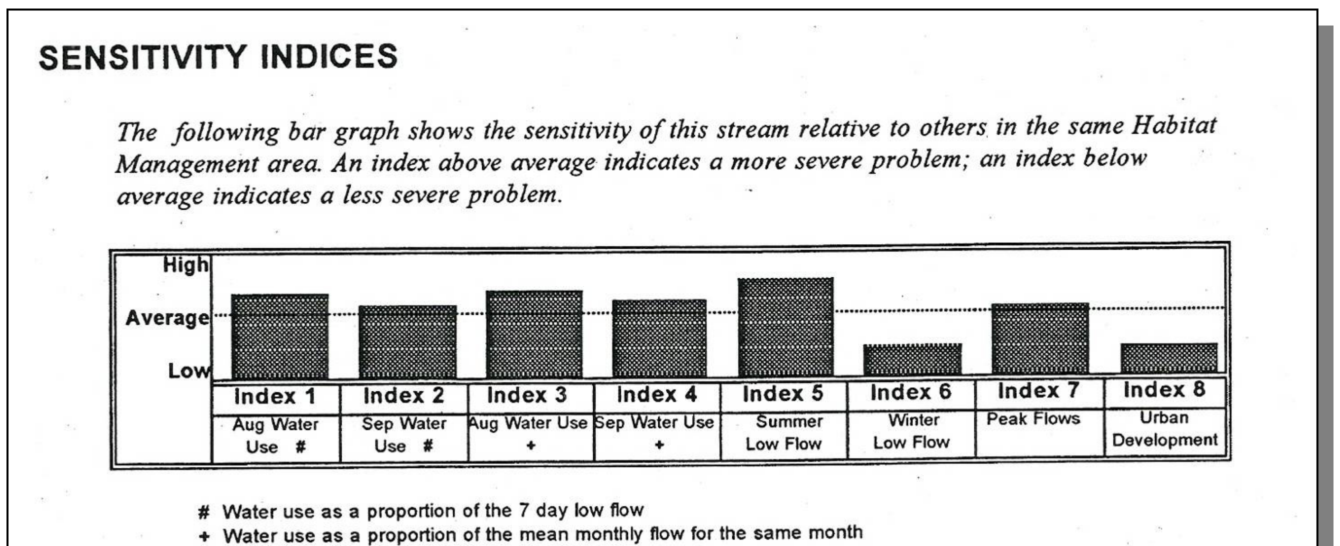


Figure 4. Sensitivity indices for water use on the Little Campbell River watershed (Source: Rood & Hamilton 1994)

Even though flow records for the LCR watershed are sporadic and of short-duration, they do show that, when compared to other nearby watersheds, the summer-fall base flows are deficient (Ptolemy 2006). In a drought year such as 1987 (Figure 5), the low residual flows in the river at WSC Station 08MH123 (above Sam Hill Creek) in the months of June-September are a result of both surface and groundwater use. The residual flows averaged 128 L/s or about 8% mean annual discharge (MAD). In the absence of water diversions or pumping, the June-September flows would have been closer to 12% MAD or 202 L/s. For most coldwater salmon streams, 10% Mean Annual Discharge (MAD) is considered a minimum threshold to sustain aquatic life (Stephens et al., 2002). With drought events becoming a potential regular condition as a by-product of climate change, the LCR watershed will likely see even greater impacts in the future (Ptolemy 2006).

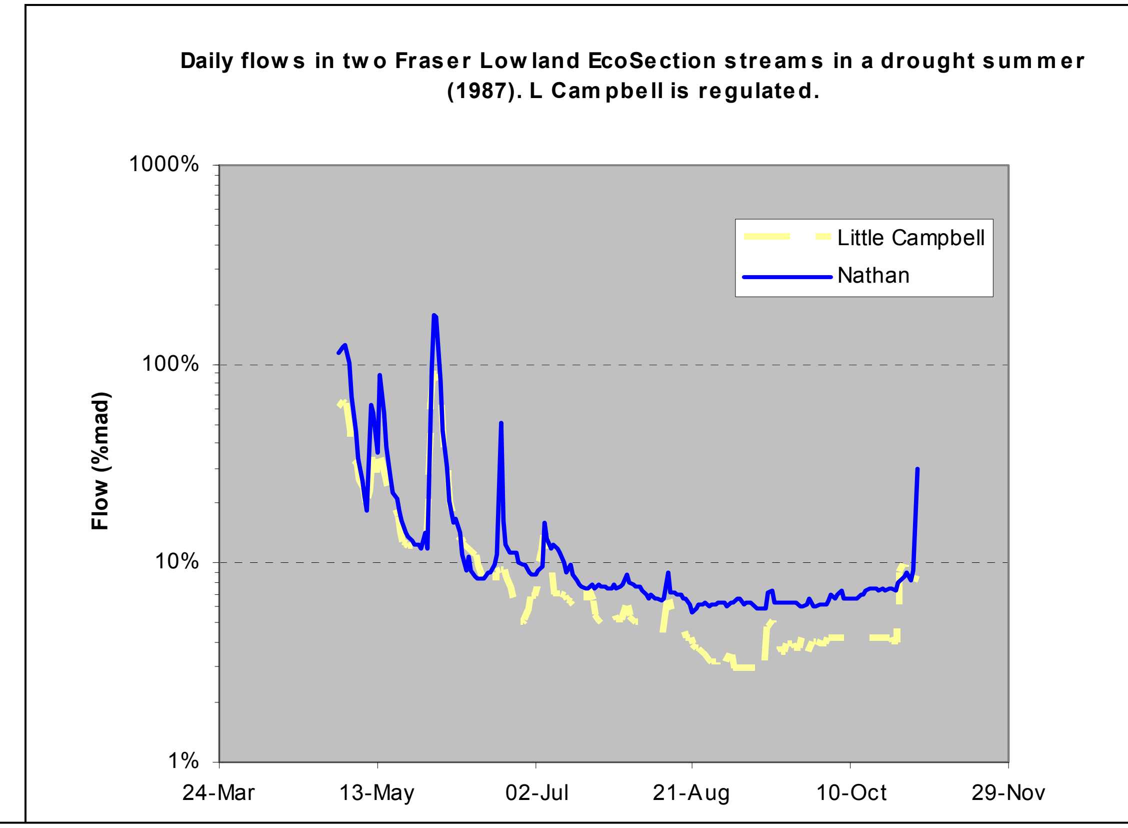


Figure 5. Little Campbell River hydrograph compared with a neighboring smaller system considered less impaired (Nathan Creek) for critical flow periods during a drought year

A groundwater model was completed for the Township of Langley to determine the capacity of their aquifers to sustain current and future withdrawals (Golder & Associates 2005). Modelling results approximated a potential 4% loss of baseflow in the LCR watershed since 1960 (pre-development conditions) and predicted that a further 5% loss could be expected by 2018 if land use development and population growth rates continue according to the official community plan (OCP). For unconfined aquifers (such as the Brookswood), increased withdrawal rates would likely cause water level declines and water to be drawn from adjacent watercourses resulting in baseflow reductions. It was estimated that withdrawal rates from the Brookswood aquifer since 1960 have reduced baseflow by 12% and an additional 8% reduction in baseflow was predicted to occur by 2018. Future withdrawals from some of the shallow aquifers such as the Brookswood will not be sustainable without compromising baseflow in local watercourses. In contrast, some of the deeper aquifers may be capable of sustaining increased withdrawals as they appear to draw water from a much larger area.

2.1 Demand & Issues by Water Use Type

The LCR watershed has a long history of extraction issues. In 1959 it was considered fully subscribed for water use. Then in 1969 the restriction was lifted and further licenses for irrigation and domestic use have since been granted (Drever and Brown, 1999). Declining water levels related to human activities are mostly a result of intensive local groundwater pumping for industry, agriculture and domestic supplies combined with decreased recharge due to increasing imperviousness in urbanizing areas (Golder & Associates 2003).

Surface water license and groundwater well location data (MOE 2006b) were used to estimate potential water extraction. Data for extraction on the U.S. side were not included as part of this study and are not likely significant from a watershed perspective. It was assumed that all surface water licenses extract the maximum allowable volume per day; however, water licenses are not currently monitored. An accurate estimate of groundwater extraction is also difficult to determine, due to historic voluntary submission of well records. Recent amendments to the B.C. Water Act, including the Groundwater Protection Regulation, (http://www.qp.gov.bc.ca/statreg/reg/W/Water/Water299_2004/299_2004.htm) require the identification of new well uses and locations; however, the number of wells and amount of water being extracted remains uncertain.

In total, 82 surface water licenses (points of diversion) ranging from domestic to irrigation to conservation (salmon hatchery) compete for water resources (Table 4 and Map 7). The majority of licenses occur downstream of Campbell Valley Regional Park (Drever and Brown 1999). Surface waters are not the only hydrological resource being extracted in this watershed - source aquifers have also been tapped through 1099 wells (Table 5 and Map 8). Twenty-five percent of the wells are for domestic use; however the majority of wells (73%) do not have a known designated use. These "unknown" use designations most likely refer to private wells, which would typically be used for domestic or irrigation needs (Graham 2006). Withdrawals are not limited to the mainstem. Most major tributaries are subject to extraction as well (Table 6). Appendix 3 provides a more detailed breakdown of surface water license information for the watershed.

Table 4. Surface water licenses (points of diversion) in the Little Campbell River watershed (Source: MOE 2006b - Water Resources Atlas http://srmapps.gov.bc.ca/apps/wrbc/)

Use Type	Number of Licenses	Total Licensed Volume (m^3/day) (Potential total 3524.51 m^3/day)	% of Licensed Volume
Irrigation	27	1713.29	48.6%
Frost Protection	1	1182.79	33.6%
Conservation[1]	1	978.74	n/a
Watering	4	213.51	6.1%
Fire Protection	1	122.34	3.5%
Land Improvement	18	117.59	3.3%
Livestock Watering	8	71.37	2.0%
Domestic	15	49.55	1.4%
Nurseries	1	54.07	1.5%
Unknown	6	0.00	0.00

[1] Water is cycled through salmon hatchery system then re-inputted into channel downstream, therefore volume is not included in potential total extraction

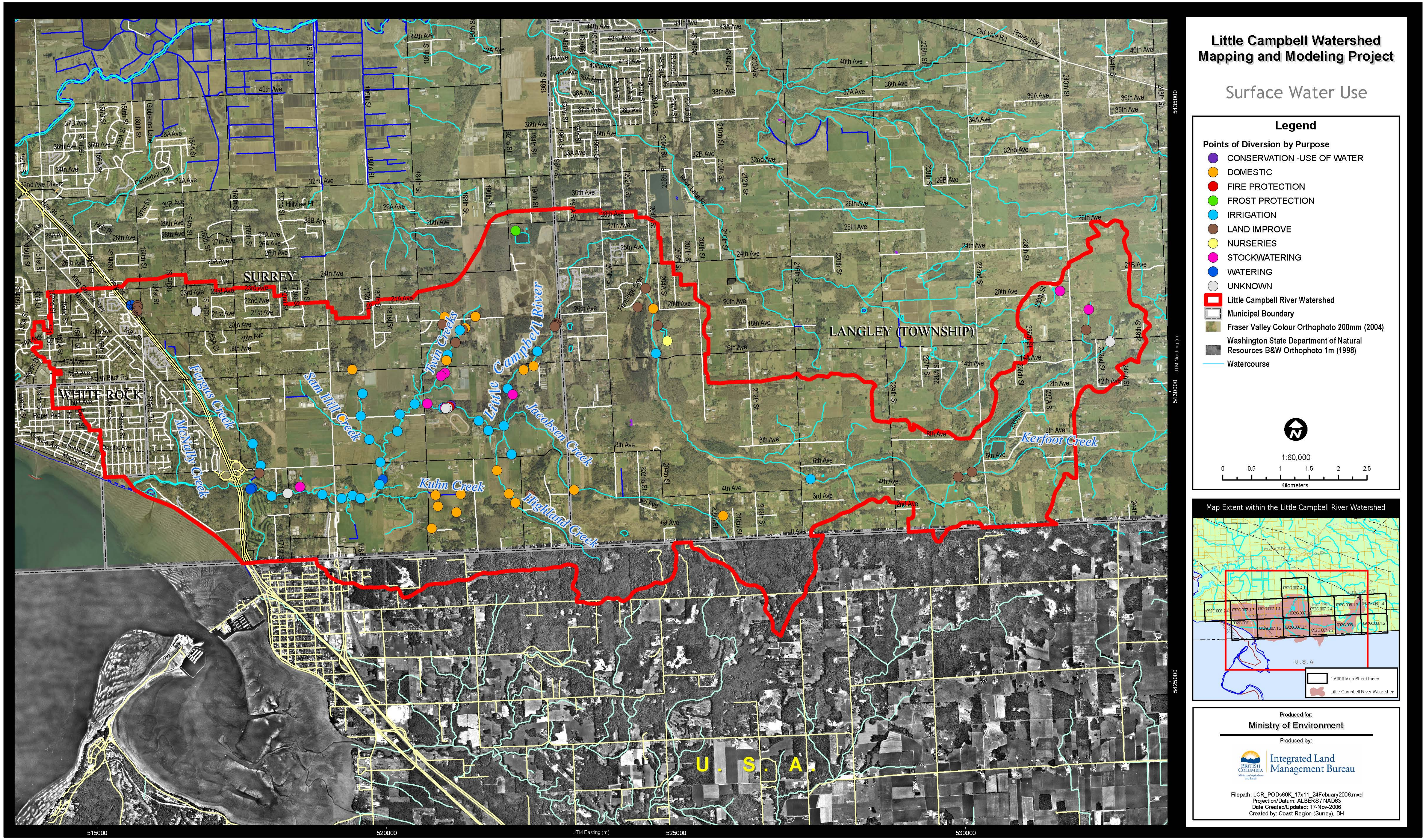
Table 5. Groundwater well use in the Little Campbell River watershed (Source: MOE 2006b - Water Resources Atlas http://srmapps.gov.bc.ca/apps/wrbc/)

Use Type	Number of Wells
Unknown	797
Domestic	276
Municipal	8
Irrigation	3
Commercial/Industrial	8
Community Water Supply	3
Other	3
Observation	1

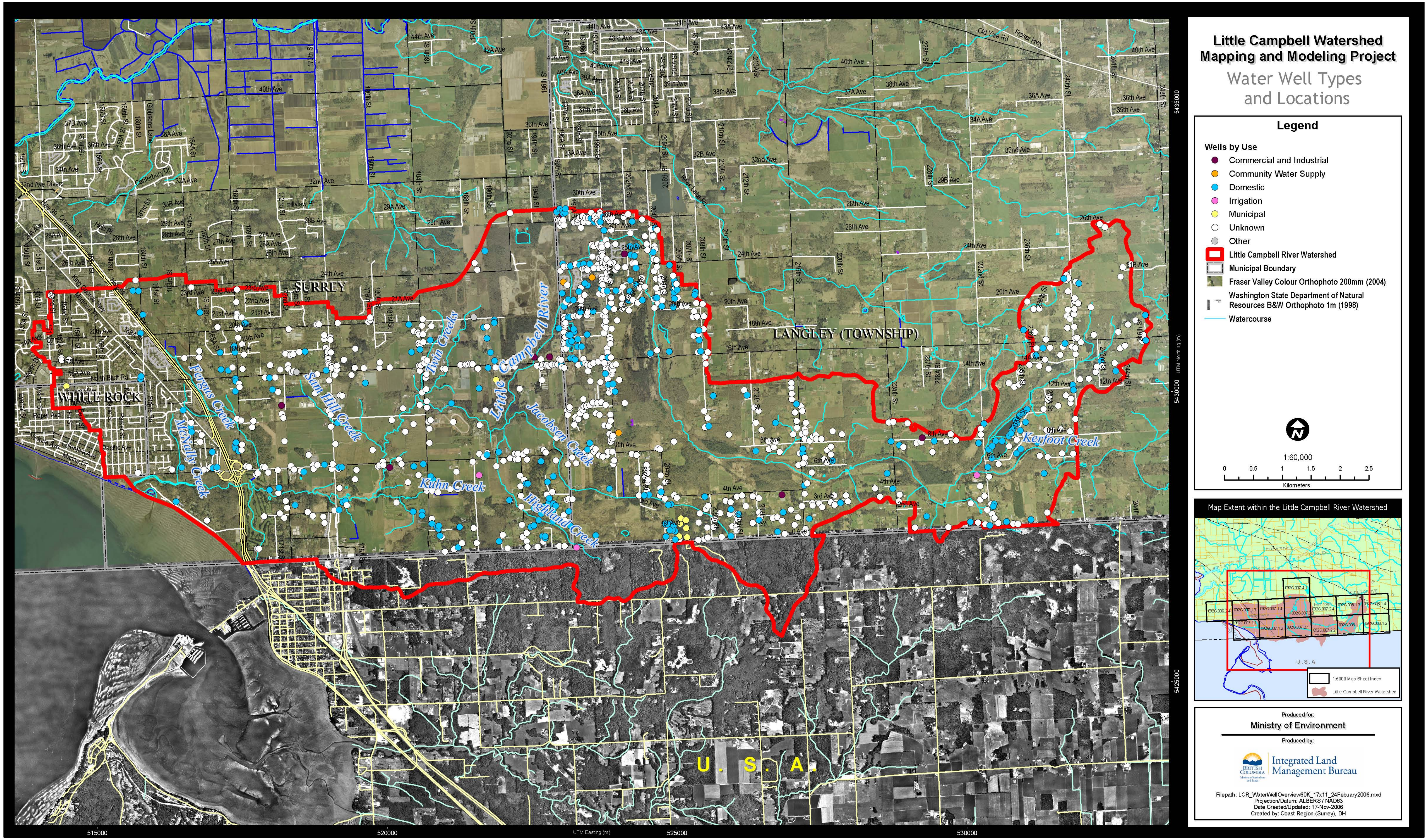
Table 6. Distribution of water use by drainage unit within the Little Campbell River watershed

Little Campbell River Watershed			Surface Water Demand (Number of POD's)		Groundwater Demand (Number of Wells)	
Sub-watershed	**Local & Mainstem watersheds**	*Associated tributaries*	**82 known** Total Licensed Volume **= 3524.51 m^3/day**		**1099 known**[2],	
East Sub-watershed	MS-1	*Kerfoot Creek*	7	7	165	165
Langley Sub-watershed	LW-1	*Unnamed north (214th St.)*	25	0	627	38
	LW-2	*Unnamed south (210th St.)*		1		34
	LW-3	*Jacobson Creek*		1		122
	LW-4	*Highland Creek, Jenkins Creek*		5		55
	MS-2			18		378
Surrey Sub-watershed	LW-5	*East Twin Creek, West Twin Creek*	40	12	229	57
	LW-6	*Kuhn Creek, Theodore Creek*		1		30
	LW-7	*Sam Hill Creek, Thomson Creek*		5		76
	MS-3			22		66
West Sub-watershed	LW-8	*Fergus Creek*	10	8	76	59
	LW-9	*McNally Creek*		0		7
	MS-4			2		10

[2] Two unidentified wells fall on the border between sub-watersheds and therefore have not been recorded



Map 7. Location and distribution of surface water extraction sites in the Little Campbell River watershed (Source: MOE 2006b - Water Resources Atlas http://srmapps.gov.bc.ca/apps/wrbc/)



Map 8. Location and distribution of well extraction sites in the Little Campbell River watershed (Source: MOE 2006b - Water Resources Atlas http://srmapps.gov.bc.ca/apps/wrbc/)

2.1.1 Agricultural Uses

In the LCR watershed, there are 27 known extraction locations for irrigation and they constitute the largest demand of surface water extractions, almost 50% of total licensed volume (1713.29 m^3/day). Along with irrigation, livestock watering is also a component of agriculture extraction. In reviewing the estimated livestock densities (Section 3.2.2.4), the maximum amount of water used by livestock is estimated to be approximately 512 m^3 per day (Table 7). Not all farms use surface water extraction; though undocumented, some groundwater wells may also be used as a water supply for livestock.

Frost protection represents the second highest form of agricultural water demand; however extraction occurs during winter, when precipitation naturally replenishes channel flow, and only occurs for a few days per year. Both irrigation and livestock watering reach their peak extraction levels during the summer, coinciding with summer low flows. Combined with additional water uses, also corresponding to summer low flows, it is not surprising that the river mainstem has been completely de-watered in lowland reaches during some years (Riley 2006).

Table 7. Potential water demand for livestock groups in the Little Campbell River Watershed (based on estimated livestock densities from Table 15, Section 3.2.2.2 and estimated average daily water consumption, MAL, 2006)

Livestock Type	Estimated Number of Animals	Estimated Average Daily Water Consumption (USG/day)	Volume (m^3/day), Total Potential Extraction estimated to be approx. 512 m^3/day
Llamas/Alpacas	108 – 370	2.5	1.0 – 3.5
Sheep/Goats	103 – 550	2.7	1.1 – 5.6
Beef Cattle	305 – 710	9.6	11.1 – 25.8
Dairy Cattle	307 – 650	24.0	27.9 – 59.1
Horses	1790 – 6970	12.0	81.3 – 316.6
Poultry	approx. 450,000	6.0 per 100	approx. 102.2

Extraction can have an impact on the agricultural users that depend upon the water supply. As surface water demand exceeds capacity and creates severe draw down conditions, pollutants and contaminants normally diluted can become concentrated or surpass guideline levels.

Contaminated watering sources can be a hazard for livestock (MAL 2006). Pathogen contaminated irrigation waters used on crops that are typically eaten raw (e.g. spinach, berries) can pose a potential health risk to consumers (Payette 2006). If irrigation waters are contaminated with fecal material, produce may become contaminated with pathogens, such as cyclospora or shigella, which can cause gastrointestinal illness in humans.

2.1.2 Domestic Water Uses

Aquifers and their groundwater resources are the major source of domestic water supply for residents and businesses in much of south Surrey and the southwest portion of the Township of Langley. The actual impacts of well extraction, however, are difficult to calculate as there is no recording mechanism to determine exact use rates on a well to well basis. What can be estimated however, is the average amount of water used per day, based on the number of domestic wells, and the average use of 1 m^3 per household per day (Environment Canada 2004). The majority of the properties within the watershed are not serviced by GVRD water supply, and therefore we can assume that they have another source of water such as a well for domestic use on-site.

Contamination of domestic water supplies, especially groundwater, is beginning to pose an increasing risk to human health and safety. Elevated levels of nitrate nitrogen in excess of the Canadian Drinking Water Quality Guideline of 10 mg/L, have been found in a significant number of domestic wells in the Langley area (MOE 2008). Elevated nitrate and other toxins can have effects on humans, livestock, wildlife, and aquatic organisms.

Several of Langley's aquifers are considered vulnerable, with water levels and/or levels of contamination of increasing concern (Langley in Action, 2003). In 2001 and 2002, there was a total of 17 Boil Water Advisories issued in the Township of Langley (Langley in Action, 2003). Water quality is a concern for the large number of residents who draw their water from private wells. Most of these residents live in rural areas where the groundwater may be subject to contamination from on-site sewage disposal systems and/or intensive agriculture.

The Drinking Water Protection Act addresses water quality protection for community systems, but not for individual private wells. The Groundwater Protection Regulation addresses wellhead protection for new private wells and the decommissioning of old wells; however, there are few legislative tools to address water quantity issues. Recent amendments to the B.C. Water Act include guidance around Water Management Plans, which can address water quantity concerns; however, there is not yet an example of a completed Water Management Plan, although work is currently underway towards this.

2.1.3 Fish and Wildlife

While a driving factor in this study has been the issue surrounding shellfish harvesting and recovery, the watershed supports a considerable number of other ecologically sensitive and commercially important fish and wildlife species, including steelhead salmon

While the watershed is considered highly productive from a fisheries perspective, summer flows are well below 20% of mean annual discharge (MAD). Natural summer 7-day mean low flow is 4% of MAD while domestic irrigation and industry water demand is 70% of MAD, resulting in some sections going dry in the summer months (BCCF 2006). Such flow perturbations can severely affect fishery resources as well as benthic (substrate) organisms that drive fisheries food chains in coastal watersheds. Areas of useable habitat become reduced, fish become stranded and passage to cooler more stable headwater areas is impeded. Rising temperatures and decreasing oxygen levels create a lethal environment for endemic coldwater dependent aquatic life (Drever and Brown 1999).

Hydrogeologic modelling has shown that current and future withdrawals have and will continue to reduce baseflow in watercourses within the LCR watershed, especially those that are connected with unconfined and shallow aquifers such as the Brookswood (Golder & Associates 2005). Portions of the LCR mainstem located within the Brookswood aquifer boundaries have been known to become dewatered during summer months and have been observed dry as late as November. The watershed and the aquatic life it supports are dependent upon groundwater recharge to sustain surface flows and reduce water temperatures during low precipitation periods in the summer and early fall. If groundwater resources are regularly depleted to the extent of no-flow or anoxic conditions in surface waters, recurring fish kills may result.

Little information is available on impacts of low flows and degraded water quality to terrestrial wildlife or various ecosystems in the LCR watershed. Water quality, quantity, and flow timing can all have an effect on related habitats, such as wetlands. Wetlands in the LCR watershed support hundreds of species, including waterfowl and other birds, fish, amphibians, reptiles and invertebrates. As well, in some areas within the watershed, wetlands are used for processing stormwater (Sec. 4.1). This incoming water may not only be substandard in its quality, but the quantity can be erratic in volume and timing. This factor could have direct effects on fish and wildlife, if the flows were not effectively regulated by wetlands.

2.1.4 Recreation

Clean, safe water resources are also important for recreational use. In the LCR watershed and Semiahmoo Bay area several recreational sectors ranging from kayaking to angling are dependent on water quality and water quantity objectives being met. While no detailed statistics are presently available, both the public and businesses are impacted from loss of recreational opportunity as well as loss of revenue when beach closures or fish kills happen (Zatwarnitski 2006).

Repercussions of degraded watershed health are not just limited to aquatic recreational opportunities. The Little Campbell estuary is part of a significant flyway and winter feeding area for waterbirds (FSBS 2003). Wildlife viewing is a considerable recreational activity in the watershed and bay (Cuthbert 2006). As food chains in the watershed become impaired from increased contamination and decreased water availability, wildlife dependent on benthic organisms, shellfish and other food organisms are impacted.

Other uses such as canoeing, kayaking and swimming can also be significantly impacted by NPS pollution events and fluctuating water volumes, especially where they occur frequently or are of such a duration as to limit activities. The Little Campbell estuary and Semiahmoo Bay afford a valuable local opportunity for kayaking and ecotourism (Zatwarnitski 2006). As well, the City of White Rock hosts an annual sailing regatta in the Bay every spring as part of an effort to attract tourists during off-season periods.

Beach closures are put into effect when coliform levels indicate potential health hazards to both humans and domestic pets. This may occur after heavy rains when overland flow and stormwater flush fecal matter from the surrounding landscape (e.g. pets, wildlife, livestock, failing on-site sewage disposal systems or sanitary sewer systems) into the watershed. Local tourism operations are dependent on the opportunities that the Little Campbell and the Bay provide. Degraded water quality can result in algal blooms, odour, and loss of clarity and thereby has the potential to negatively impact on recreation activities in the watershed (Zatwarnitski 2006).

PART 3 – CHARACTERIZATION AND ASSESSMENT OF POLLUTION SOURCES

3.0 POINT AND NON-POINT POLLUTION SOURCES

Pollution sources in the watershed can be divided into two basic categories - point (direct) and non-point (indirect). Point sources may include end-of-pipe permitted discharges from industry or commercial operations, and are often easily identified. Non-point sources (NPS) however, are more complex as they come from a host of sources such as failing septic systems, animal wastes infiltrating groundwater, or stormwater runoff from upland development (Figure 6).

There is general consensus that the water quality in the LCR watershed is impaired (Drever and Brown 1999, MOE 2003, Fleming and Quilty 2006, MOE 2006). The river at times surpasses thresholds for its ability to support aquatic life and meet recommended objectives (Swain 1988). While this report focuses largely on bacteriological sources of contamination, it is also important to note that other contaminants (such as metals, suspended sediments, pesticides and elevated nutrients) may contribute to declining water quality in the watershed.

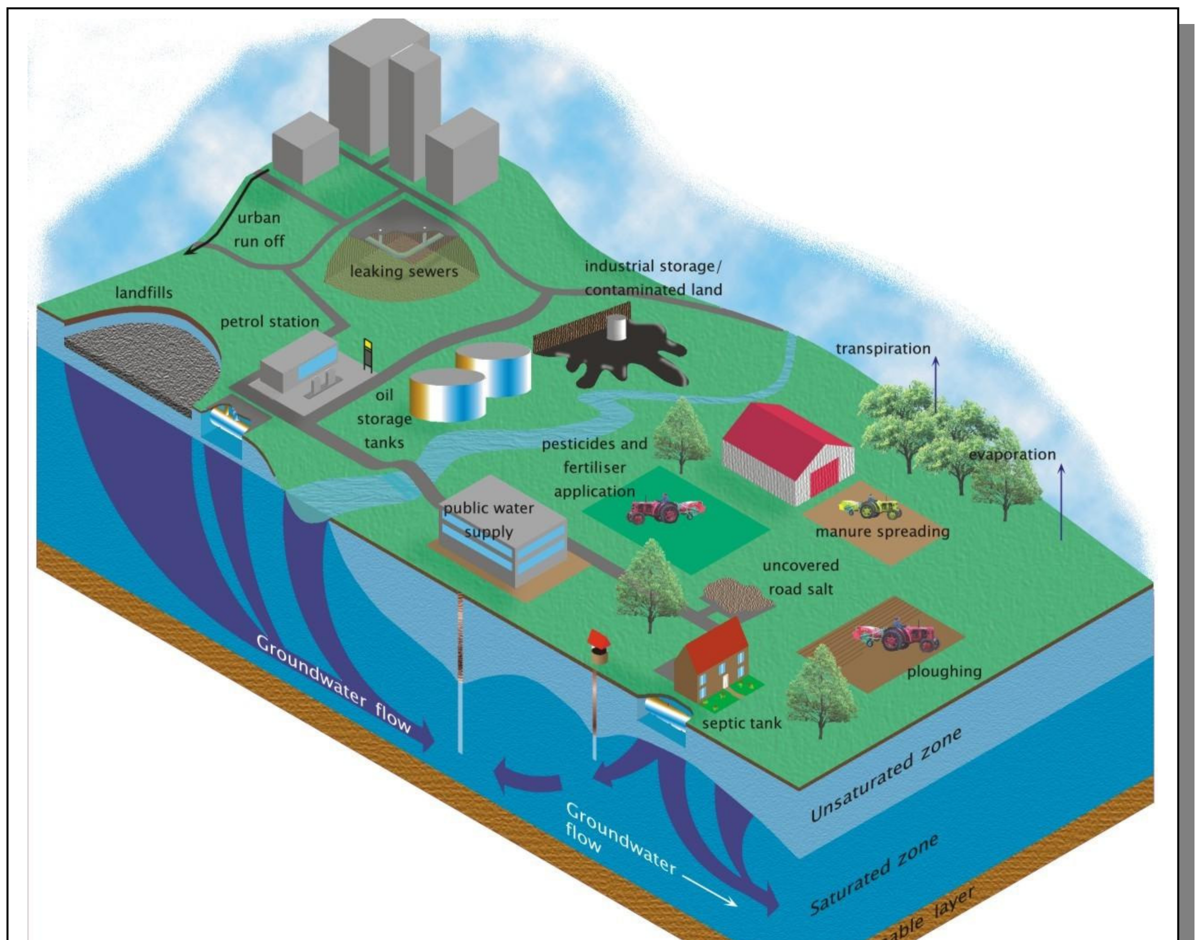


Figure 6. Pathways for point and non-point source pollution in the Little Campbell River watershed (Source: Township of Langley's groundwater protection program www.tol.bc.ca/Engineering/Environment/Groundwater_Protection).

3.1 Point Sources - Permitted Discharges

While NPS pollution may be the greatest source of contamination to the LCR watershed, there are regulated activities that may also contribute to degraded water quality. In the watershed there are three permitted discharge sites that deal with recreational and residential sewage treatment facilities. These permits are subject to change with potential amendments in the future. Through the introduction of the Municipal Sewage Regulation under the Environmental Management Act, permits are being replaced by allowable standards under the regulation. Currently there is one site within the watershed that discharges effluent under the regulation (Table 8).

Table 8. Permitted and regulated discharges in the Little Campbell River watershed
(Source: MOE – Environmental Protection Division Electronic Permits File Cabinet)

Permit Effluent and Regulated Effluent Sites	Location	Type	Discharge Provisions[3]	Potential Impact
PE 4645, active	Surrey	Mobile Home Park Domestic Sewage	Max 123m^3/day to tile field after batch tank processing, BOD_5 20mg/l, TSS 30mg/l	Potential to affect water quality due to tile field discharge proximity to river
PE 1558, active	Surrey	Effluent discharge for recreational vehicle (RV) & tent campground	Max 46m^3/day, BOD_5 20mg/l, TSS 30mg/l, secondary treatment	Potential for exceeding drain field/septic facility capacity, leaching to surrounding groundwater
PE 225, active	Surrey	Mobile Home Park Domestic Sewage (2 locations) 65 units	Max 23.2m^3/day (treated) to tile field after settling in septic tank, discharge shall be equivalent to or better than typical septic tank quality	Potential for exceeding drain field/septic facility capacity, leaching to surrounding groundwater
RE 16959, planned development	Langley	99 home development - sewage system	Max 210 m^3/day	Not available

[3] BOD_5 - level of biochemical oxygen demand over a five day period, TSS-total suspended solids, or non filterable residue @ 105°C

3.2 Non-Point Sources

Previous water quality monitoring work identified the following key NPS pollution areas of concern for bacteriological, nutrient and metals loading throughout the watershed (Moore 2001):

- Failing septic tile fields, potentially contributing bacteriological contamination and elevated nutrient levels. There are likely a number of failing tile fields in the watershed, and their impact to the river water quality may be quite meaningful.
- Culvert discharges near the river mouth are ongoing contributors of suspended solids, and intermittent contributors of elevated bacteriological levels (Environment Canada 2003).
- The Sam Hill Creek system has shown elevations in organic nitrogen and nitrate, and the swale water sampled on 12^{th} Avenue (that directly enters the river) has also been elevated in ortho phosphate.
- The Twin creeks systems continue to be a source of bacteriological contamination. Recent sampling has identified West Twin as the contaminant source, with both the creek waters themselves and an incoming ditch along 184^{th} St. having high fecal coliform levels.
- In the river mainstem, downstream of a feedlot in south Surrey, algal blooms and elevated fecal coliform levels have been regularly observed.
- Agriculture assessments have identified three horse riding properties along the mainstem, downstream of Highland Creek, where large uncovered manure piles were allowing contaminated runoff to potentially impact the nearby channel.

In addition, sampling in the LCR watershed mainstem has shown intermittent suspended solids, nitrate and fecal coliform elevations throughout the watershed.

3.2.1 Human Sewage

On average, human sewage production is 0.12 kg per adult per day, with an average composition of 71% water and 29% dry matter (Schmidt and Thews 1987, in Pipoli 2005). Population density measures allow us to predict the potential amount of human waste (sewage) produced per day in the LCR watershed. The population residing within the LCR watershed is estimated to be around 194,000 - based on State of Washington – Whatcom County population density (State of Washington 2006) and B.C. Smart Growth 2001 population density and estimated growth rates (Alexander and Tomalty 2001); therefore the potential total sewage produced averages 23,280 kg per day. Fecal coliform concentrations in raw sewage range from $1.0*10^5$ to $5.5*10^7$ MPN (colonies) per 100mL (Saleem et al 2003, Messalem et al 2000). Human sewage production in the LCR watershed (amount and fecal coliform characteristics) is compared with livestock manure production in Section 3.2.2.4 (Figure 7).

On-site sewage disposal systems (SDS) and municipal sanitary sewer networks with treatment plants on the Fraser River are the two methods of sewage treatment and disposal in the LCR watershed (Map 9). Newer subdivisions in the LCR watershed are moving towards sanitary sewer networks and treatment infrastructure. Since 1978 White Rock has been tied into the main GVRD treatment facility at Annacis Island, as are some Surrey residential and commercial developments. However many areas of south Surrey and Langley still rely on traditional septic field treatment for residential and commercial facilities (Table 9). The main concern at present is the potential for SDS failure due to poor maintenance as well as inappropriate site installation in vulnerable soils (Goble 2006).

3.2.1.1 On-site Sewage Disposal Systems

A concern in the LCR watershed is lack of knowledge of the exact number of on-site sewage disposal systems (SDS) and more specifically the extent and degree of failure. While it has been estimated that there are 2175 on-site SDS there is little information on how many of these are properly functioning, how many are still in service or how often they are serviced.

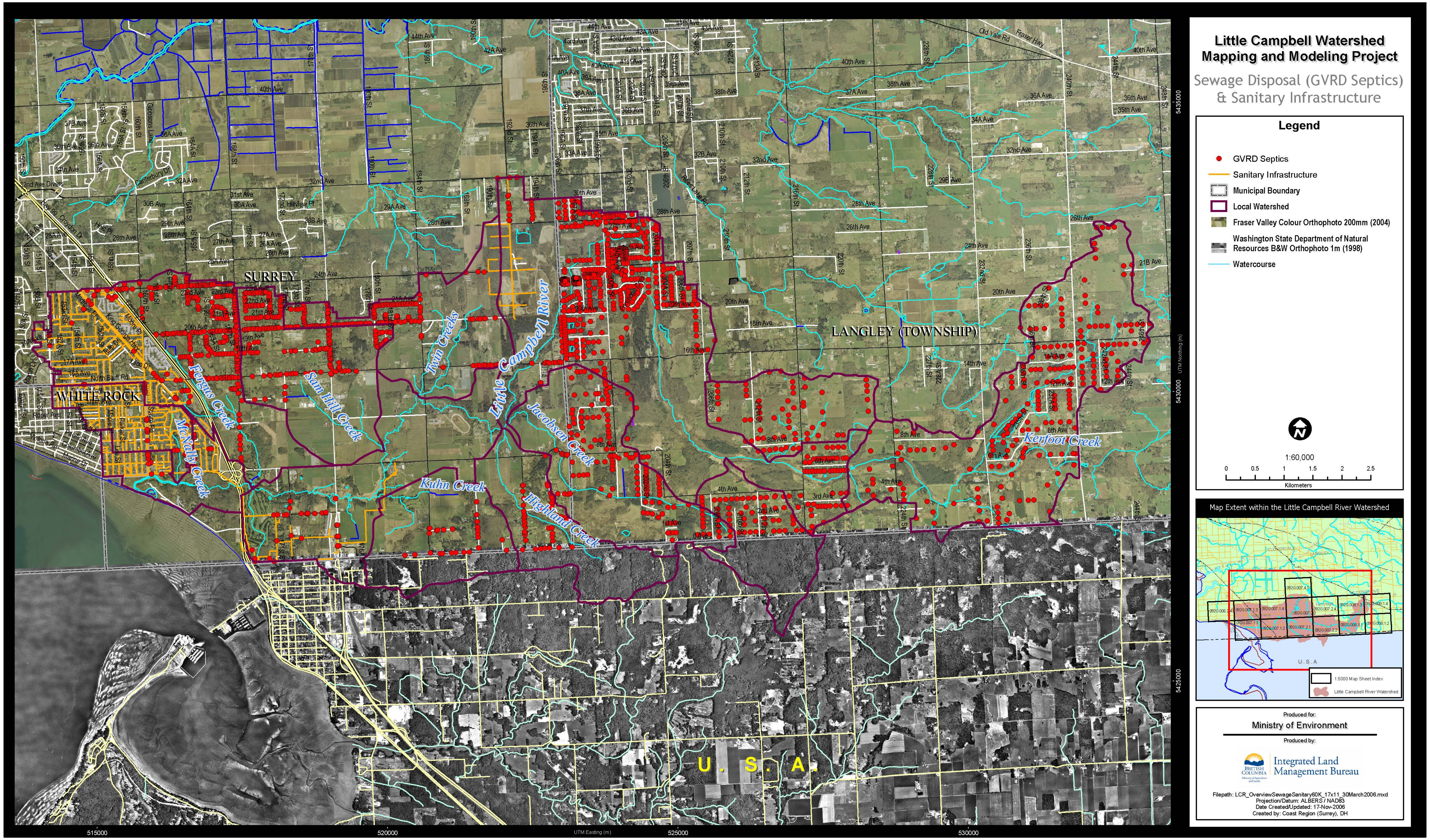
At the watershed level, a failing system may be considered one that discharges effluent with pollutant concentrations that can impair downstream water quality. In the Puget Sound area, SDS along shorelines have up to 25% failure rates (PSWQAT 2001). In B.C. a failure rate of up to 30% has been suggested (Schmidt 2006). Failures can usually be placed into one of three categories: hydraulic failures, subsurface failures, and treatment failures (see glossary).

Age of the SDS is an important factor in predicting the likelihood that a malfunction will occur, however the age of on-site SDS is difficult to determine. Issues contributing to managing the problem include: lack of records, undocumented repairs, unknown length of time between SDS failure and filing for system repair, and not knowing the age of the system at the time of failure (Goble 2006). In some instances on-site SDS are installed in unsuitable soils. Repair of a malfunctioning SDS in unsuitable soils is difficult if not impossible. Instead, replacement with an alternate SDS designed to function in soils unsuitable for conventional SDS systems, or connection to municipal sanitary sewer network may be required.

Sewage Disposal System Risk of Failure:

Eleven sewage disposal repair applications for locations within the LCR watershed had been filed with the local health unit in 2004 and 2005. This may not be representative of the number of sewage disposal failures in the watershed as repairs are often carried out without filing an application (Goble 2006). All repairs occurred in either the Surrey or Langley sub-watersheds. Repair locations are identified by sub-watershed and soil group (Table 10).

Repairs to on-site SDS were conducted in Group A (4), B (5) and D (2) soils. Seven out of eleven repairs were within the Langley sub-watershed. This is not surprising considering the large population serviced by on-site SDS in the area (6,240). The repairs to SDS in Group A soils were all located in high density residential areas in the Brookswood aquifer. Repairs to SDS in Groups B and D soils were scattered throughout the Langley and Surrey sub-watersheds in areas of low population densities.



Map 9. Areas within the Little Campbell River watershed serviced by SDS and sanitary sewer systems **(Source: City of White Rock, Surrey, Township of Langley, GVRD 2006)**

Table 9. Distribution of onsite sewage disposal systems and associated soil groups by drainage unit in the Little Campbell River watershed **(Source: GVRD, Township of Langley, City of Surrey, City of White Rock)**

Drainage Unit			**Estimated Number of On-site Sewage Disposal Systems (SDS)**		**LCR Soil Groups**
Sub-watershed	**Local & Mainstem watersheds**	*Associated tributaries*	**Total: 2175**		**Containing SDS**
East Sub-watershed	MS-1	*Kerfoot Creek*	223	223	A-32 B-158 C-9 D-24
Langley Sub-watershed	LW-1	*Unnamed north (214th St.)*	1124	60	B
	LW-2	*Unnamed south (210th St.)*		49	A-3 B-43 D-3
	LW-3	*Jacobsen Creek*		142	A-32 B-106 D-4
	LW-4	*Highland Creek, Jenkins Creek*		45	A-8 B-34 D-3
	MS-2			828	A-684 B-121 D-23
Surrey Sub-watershed	LW-5	*East Twin Creek, West Twin Creek*	439	174	A-14 B-144 D-16
	LW-6	*Kuhn Creek, Theodore Creek*		26	B-20 D-6
	LW-7	*Sam Hill Creek, Thomson Creek*		205	B-199 D-6
	MS-3			34	D
West Sub-watershed	LW-8	*Fergus Creek*	389	354	A-3 B-271 D-80
	LW-9	*McNally Creek*		14	B-6 D-8
	MS-4			21	A-2 B-7 D-12

Table 10. Summary of sewage disposal system repairs for 2004 – 2005 and associated sub-watershed, LCR soil group and soil types (Source: Fraser Health Authority Environmental Health Services repair application records for 2004-5)

Year of repair	**Sub-watershed**	**LCR Soil group**	**Soil type**
2004	Langley	Group A	Cl
2004		Group B	N-SC
2004		Group B	BO-W-SC
2004		Group D	SC
2004	Surrey	Group A	Cl, GG
2004		Group B	BO
2004		Group D	SR-HN-SS
2005	Langley	Group A	CL
2005		Group A	CL
2005		Group B	W-SC
2005	Surrey	Group B	BO

Sewage Disposal System Associated Soil Groups

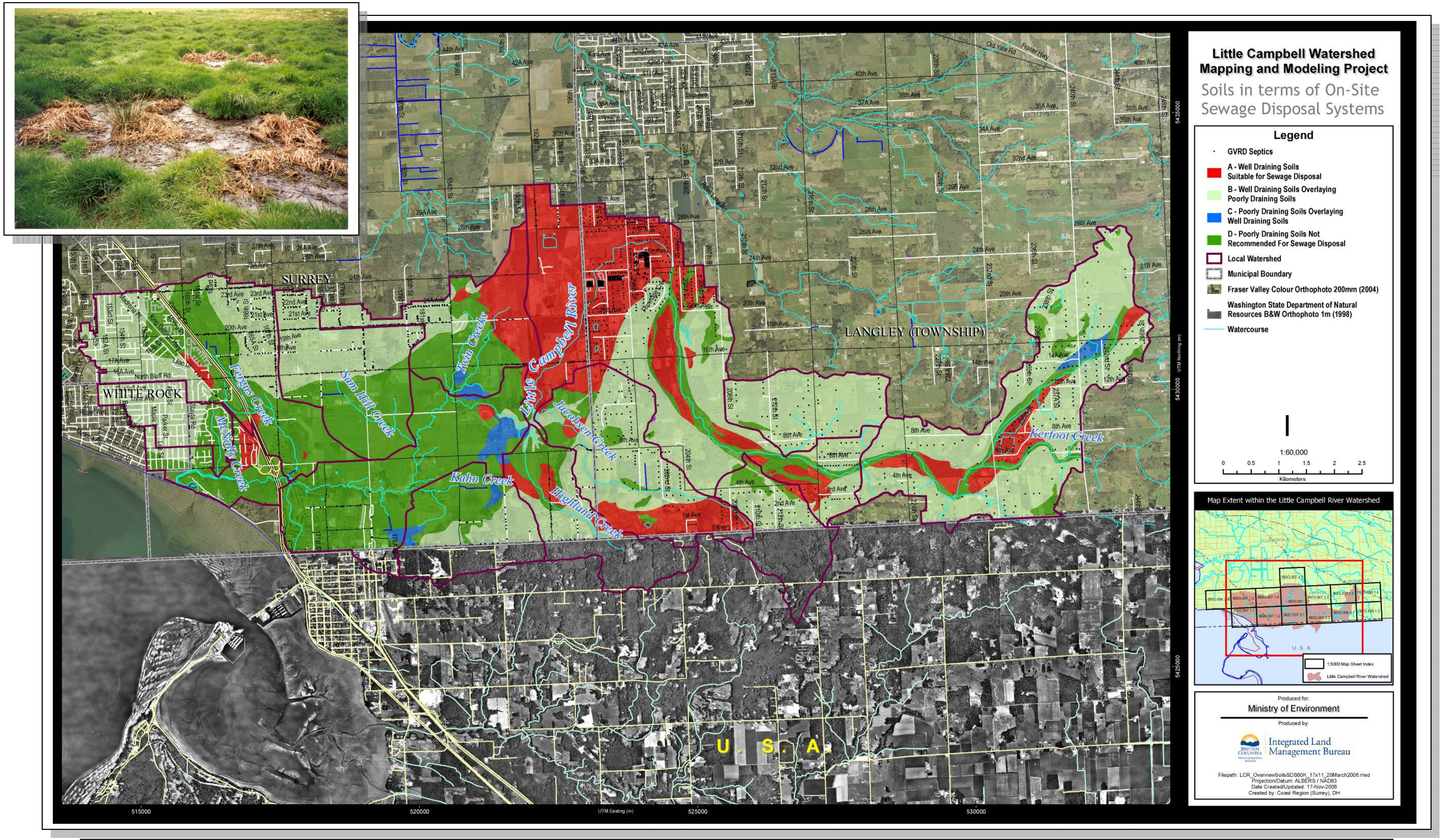
Soils throughout the LCR watershed were assessed based on drainage characteristics and suitability for on-site sewage disposal (Map 10). Four soil groups were identified and are described as follows:

Soil Group A: Well draining soils suitable for on-site sewage disposal; however, high water table may be present in some areas. Other areas may be too well draining in that nearby streams or unconfined aquifers may be contaminated by sewage effluent not adequately cleansed by the soils prior to reaching the water source.

Soil Group B: Well draining soils overlaying poorly draining soils. These areas are prone to perched water table due to the poorly draining underlying soils. High water tables are common in these areas during prolonged periods of rain. Some of the soils in this category have been classified as moderately well drained but are compact and poorly drained below the surface layers.

Soil Group C: Poorly draining soils overlaying well draining soils. In theory SDS should be suitable for such soil profiles if they are of conventional design. However the layer of poorly draining soils are often 5 or more feet deep – often too deep for the septic system to function properly and protect groundwater sources. Perched water tables are common in Group C soils. SDS do not function well in perched water tables due to saturated soil conditions and reduced subsoil permeability. Hydraulic failure is common when on-site SDS malfunction in Group C soils with deep, poorly draining upper soil layers.

Soil Group D: Poorly drained soils not recommended for sewage disposal. Function of SDS are severely impaired by high water table and compact sub-soils.



Map 10. . Soil group vulnerability classes for the Little Campbell River watershed (Inset: Example of a failing septic system).

Based on soil drainage and groundwater characteristics, each sub-watershed was assessed to determine the potential for SDS failure.

West Sub-Watershed
Very little of this area was included in the government soil survey (Luttmerding 1980, 1981, 1981a) upon which soil evaluations for this study were based. No information is available for the Semiahmoo First Nations lands, White Rock, or South Surrey west of King George Highway. Risk assessments for SDS failure in these areas are not as critical compared to other sub-watersheds since the vast majority of residential developments in the West sub-watershed are serviced by municipal sanitary sewer systems. The exception to this is the Semiahmoo First Nations lands.

Developments serviced by on-site SDS in the Fergus Creek local watershed are dominated by Group B and D soils. Functionality of SDS in both soil groups can be problematic, especially Group D soils.

Surrey Sub-Watershed
Developments serviced by on-site SDS in the Surrey Sub-watershed mainly occur in Group B (363 SDS) and D soils (62 SDS).

Group 'B' soils are predominant in the northwest portion of the Surrey sub-watershed. Urban residential developments in this area, near the headwaters of Sam Hill Creek and West Twin Creek local watersheds, are serviced by on-site SDS. The most common Group B soil in this area is Bose (BO). Bose soils are characterized by sands and gravels at a depth of approximately 30 to 150 cm overlying less permeable silty clay loam or glacial till. Operation of SDS in Group B soils is inhibited by perched water tables and compact sub-soils. Effluent from malfunctioning systems may be carried by stormwater drainage systems or migrate with groundwater flow.

Group D soils dominate the Surrey sub-watershed with Cloverdale (CD) soils being the most common. Cloverdale soils have a shallow clay layer (approximately 20 cm to 75 cm depth) and perched water tables. SDS in these Group D soils operate poorly due to low subsoil permeability and high water tables. The residential developments serviced by on-site SDS located in the southwest portion of the Surrey sub-watershed may have an increased risk of malfunction. Group D soils located near the mainstem of the river are susceptible to inundation from flooding and have an intimate ground to surface water connection. Malfunctioning SDS in Group D soils near the mainstem can contaminate both ground and surface waters.

Group A soils are present in the east side of the Surrey sub-watershed where few properties (14) are serviced by on-site SDS. The majority of this soil type overlays the Brookswood aquifer, an unconfined aquifer that is vulnerable to contamination. There is potential for on-site SDS in Group A soils to contaminate groundwater since the rapid rate of filtration may lead to inadequate treatment of sewage effluent. The Brookswood aquifer supplements flows in the LCR during dry periods. Therefore mobile contaminants - such as nitrates - from malfunctioning SDS may be carried by groundwater to the river and its tributaries.

Group C soils are infrequent patches found on the east side of the Surrey sub-watershed. There are no records of SDS in Group C soils within this sub-watershed.

Langley Sub-Watershed
Group A soils in this area overlay unconfined aquifers; either the Brookswood aquifer or the Border A aquifer. The majority of SDS (727, 65%) in this sub-watershed are located in Group A soils, concentrated near the mainstem where it bends to the north (MS-2). These Group A soils are dominated by Columbia (CL), Lynden (LY) and Sunshine (SS) soil types. All are characterized by gravelly or coarse textured subsoil that may lead to incomplete filtration of septic effluent and subsequent contamination of the aquifers.

Developments serviced by SDS in Group B soils (364, 32%) are dispersed throughout the Langley sub-watershed. The majority of Group B soils are Whatcom (W) overlaying Scat (SC) to the east and Nicholson (N) overlaying Scat (SC) to the west. Whatcom soils are well drained and permeable at the surface, to approximately 75 cm depth, but compaction rapidly increases with depth. Nicholson are well drained to approximately 25 cm depth with compacted sub-soils. Nicholson, Whatcom and Scat soils are associated with perched water tables. These soils are unsuitable for conventional on-site SDS due to compact sub-soils and periodic saturated conditions.

Group D soils are intermingled with patches of well-drained (Group A) soils along the mainstem of the river. This can result in subsurface lateral flows from Group D to Group A soils, and inadequately treated sewage effluent reaching the LCR and tributaries. Effluent from on-site SDS in these soils may pool on the surface and be carried by stormwater runoff if the systems malfunction. Few SDS (33, 3%) are present in these soils within the Langley sub-watershed.

East Sub-Watershed
Group B soils dominate the East sub-watershed and also contain the greatest number of SDS (158, 71%). This category of soils is not suitable for subsurface SDS due to poor drainage generally accompanied by compact sub-soils and perched water tables. On-site SDS that rely on subsurface drainage are prone to lateral flows and subsequent breakout to the surface of the land with inadequate sewage treatment. Lateral flow of SDS effluent is an important consideration in areas adjacent to Columbia soils in this area because they overlay the unconfined Brookswood aquifer.

Thirty-two SDS (14%) are located in Group A soils within this sub-watershed. These well-drained soils are located near the mainstem of the river and overlay the Brookswood aquifer. The most common Group A soil type in the East sub-watershed is Columbia (CL). Due to the permeable nature of this gravelly subsoil, sewage disposal effluent from on-site systems may not be adequately treated by the soil prior to reaching the groundwater and nearby streams.

Group D soils are located in patches scattered throughout the East sub-watershed, usually in low lying areas. A narrow strip of poorly drained soils runs along the mainstem of the LCR. Ross (RS), Scat (SC), and Judson (JN) soils dominate Group D soils in this area of the watershed. There are 24 SDS (11%) installed in this soil category. Septic system function is severely impacted by high water tables and dense, compact sub-soils characteristic of the Ross, Judson, and Scat soil types.

There is a small patch of Group C soils near the east side of this sub-watershed containing 9 SDS (4%). Septic system malfunction may occur if perched water tables are characteristic of this area.

3.2.1.2 Municipal Sanitary Infrastructure:

Approximately 95% of the watershed land area is serviced by on-site SDS (2175), and approximately 5-6% is serviced through sanitary systems (Map 9). The City of White Rock is the only municipality of the three influencing the watershed, with virtually all of its sanitary treatment being serviced through the GVRD's sanitary treatment plant facility (STP) at Annacis Island. Prior to that (1962-1977) White Rock had its own STP near the river mouth that employed secondary treatment. The plant included settling, sludge removal, comminution, flow recycling and post chlorination for the April-October period. Average discharge of secondary treated material was 2900 m^3/day annually for summer flows and 12000 m^3/day in the winter. Flows in excess of 9100 m^3/day were bypassed to Semiahmoo Bay untreated. By 1978 all city flows were diverted to Greater Vancouver Sewerage and Drainage District trunk line to Annacis Island (pumping from the foot of Oxford Street). In 2001, the City significantly upgraded the conveyance pipe which delivers eastside flows to the GVRD pump-station at Oxford.

The next major area to be serviced and removed from septic field treatment is the Campbell Heights area south of 32 Avenue (Baron 2006). The Township of Langley has the lowest percentage of the watershed being serviced (approx. 30 residents or <1%). Sewage is pumped west from the south Langley (Brookswood) area via the Surrey system to the GVRD STP at Annacis Island. The High Point development near 0 Avenue will have installed a new sanitary sewer line up 200th Street by November 2006. Residents along 200th Street (approx. 100 lots in the LCR watershed) will have the option of connecting into this sewer main (McCormick 2006).

In areas serviced by municipal sanitary sewer, effluent has the potential to reach watercourses via cross connections with stormwater systems, overflow events and compromised transport system components (i.e. pump stations). While risk of contamination due to sanitary sewer malfunctions are not known in the LCR watershed, where detected they are addressed as a priority (Baron 2006).

3.2.2 Animal Manure

The LCR watershed is dominated by agricultural land use supporting various scale livestock and hobby farm operations. One of the water quality concerns associated with agriculture is the potential release of fecal coliform bacteria resulting from poor manure management practices. Manure contamination of water sources may occur through various points of entry. Direct livestock access to watercourses, improper manure storage, drain tile infrastructure, and/or improper land application of manure (either at excessive rates, wrong time of year, or too close to watercourses) may result in surface runoff during precipitation or flooding events, or leaching into underlying shallow permeable soils (and subsequently groundwater).

3.2.2.1 Agricultural Land Use

Agricultural Land Use Inventory data, collected by the B.C. Ministry of Agriculture and Lands (MAL, 2005, MAL, 2002) have been used for the following analysis (Tables 11 & 12). City of Surrey was most recently inventoried in 2004 and Township of Langley in 2001. Table 11 summarizes the number of operations of each agricultural land use type in the watershed, spatially represented in Map 11, and Table 12 shows the estimated animal densities at these operations, where scale of operation was estimated. Average densities are approximate, based on a windshield survey from adjacent roads, not a detailed count of livestock (Zimmerman 2006). Appendix 4 provides a more detailed breakdown of all farm types, including those of unknown scale. Table 13 shows the distribution of livestock operations throughout the watershed by watershed unit, including those of unknown scale.

Though generally occurring in small densities, the most frequent livestock type over the largest number of farms are horses and horse use, accounting for 38% of all livestock operations. While poultry farming only constitutes about 2% of livestock operations, if average numbers are correct they constitute the greatest density of animal types in the watershed. Hobby farms (small scale operations) tend to dominate, though some large-scale dairy farms and other operations are also present.

3.2.2.2 Manure Management Practices

Manure management typically involves production, storage and application. Potential contamination from manure collection and storage facilities may result from overflow events, allowing concentrated runoff to flow directly into a watercourse. Impacts would generally be linked to storm events. By following best management practices (BMPs), such as adequate and secure storage and maintaining proper setbacks from watercourses, impacts can be avoided. During application, manure is distributed over a large area. If manure is applied at the appropriate time, at rates that match crop nutrient requirements and with appropriate buffers for the crop type and time of year, the risk of contamination can be minimal (Schmidt 2006). Guidelines for appropriate manure handling practices are available in the Agricultural Waste Control Regulation (http://www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/131_92.htm). If BMPs are not followed, the risk of watercourse contamination will be elevated.

Liquid and solid manure must be managed differently due to their varying nutrient levels and rates of transport through the soil. Manure may be transported off site for disposal. This is most commonly done in the poultry industry; however, the frequency and volume is unknown.

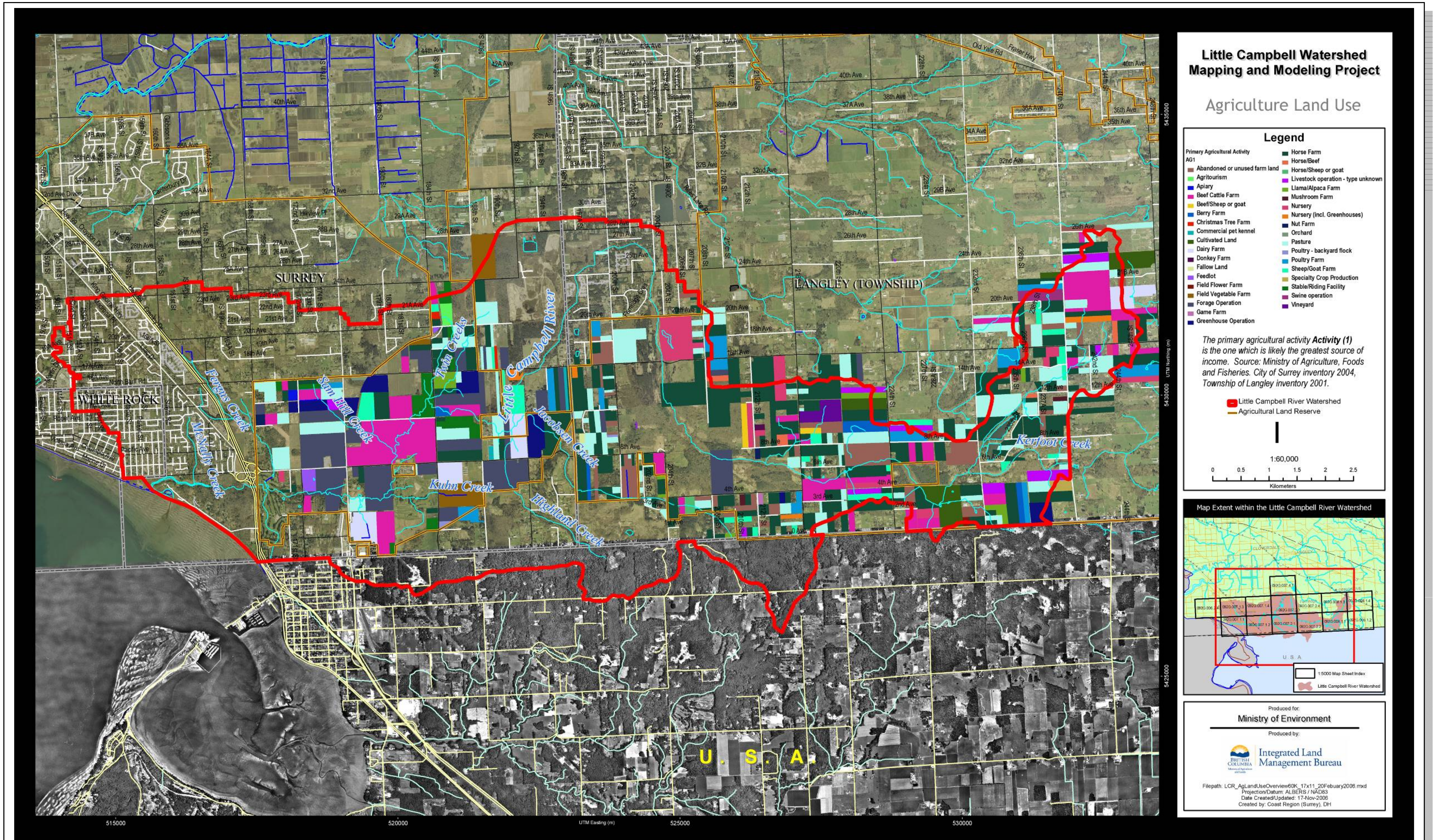
Table 11. Summary of agricultural land use types in the Little Campbell River watershed.
Source: MAL 2005, MAFF 2001.

Agricultural Land Use	Number of Operations	Percent of Total
Horse Farm	289	37.9%
Pasture	157	20.6%
Forage Operation	61	8.0%
Abandoned or unused farm land	45	5.9%
Beef Cattle Farm	39	5.1%
Nursery/Greenhouses	37	4.9%
Sheep/Goat Farm	25	3.3%
Combined Livestock (Beef/Sheep/Goat/Horse)	19	2.5%
Poultry Farm	17	2.2%
Stable/Riding Facility	12	1.6%
Llama/Alpaca Farm	10	1.3%
Dairy Farm	7	0.9%
Berry Farm	6	0.8%
Field Vegetable Farm	6	0.8%
Commercial Pet Kennel	4	0.5%
Cultivated Land	4	0.5%
Poultry - backyard flock	4	0.5%
Christmas Tree Farm	3	0.4%
Feedlot	3	0.4%
Nut Farm	3	0.4%
Mushroom Farm	2	0.3%
Orchard/Vineyard	2	0.3%
Agritourism	1	0.1%
Apiary	1	0.1%
Donkey Farm	1	0.1%
Field Flower Farm	1	0.1%
Game Farm	1	0.1%
Specialty Crop Production	1	0.1%
Swine	1	0.1%

Table 12. Estimated number of livestock in the Little Campbell River watershed (where scale of operation is estimated).
Source: MAL 2005, MAFF 2001.

		Horses	**Beef Cattle**	**Dairy Cattle**	**Sheep/ Goats**	**Llamas/ Alpacas**	**Poultry[4] (farm)**	**Poultry (backyard)**	**Mixed Livestock**
Small Operations	Number of Operations	197	16	1	15	2	0	1	4
	Average Densities	*1-10*	*1-10*	*1-50*	*1-10*	*1-10*	-	*1-10*	*1-10*
	Potential Livestock Count	197-1970	16-160	1-50	15-150	2-20	0	1-10	4-40
Medium Operations	Number of Operations	66	17	6	8	5	2	1	7
	Average Densities	*11-50*	*11-50*	*51-100*	*11-50*	*11-50*	*25,000*	*11-50*	*11-50*
	Potential Livestock Count	726-3300	187-350	306-600	88-400	55-250	50,000	11-50	77-350
Large Operations	Number of Operations	17	2	0	0	1	2	0	0
	Average Densities	*51-100*	*51-100*	*101-200*	*51-100*	*51-100*	*200,000*	-	-
	Potential Livestock Count	867-1700	102-200	0	0	51-100	400,000	0	0
	Total Number of Operations	**280**	**35**	**7**	**23**	**8**	**4**	**2**	**11**
	Total Livestock Count	**1790-6970**	**305-710**	**307-650**	**103-550**	**108-370**	**450,000**	**12-60**	**81-390**

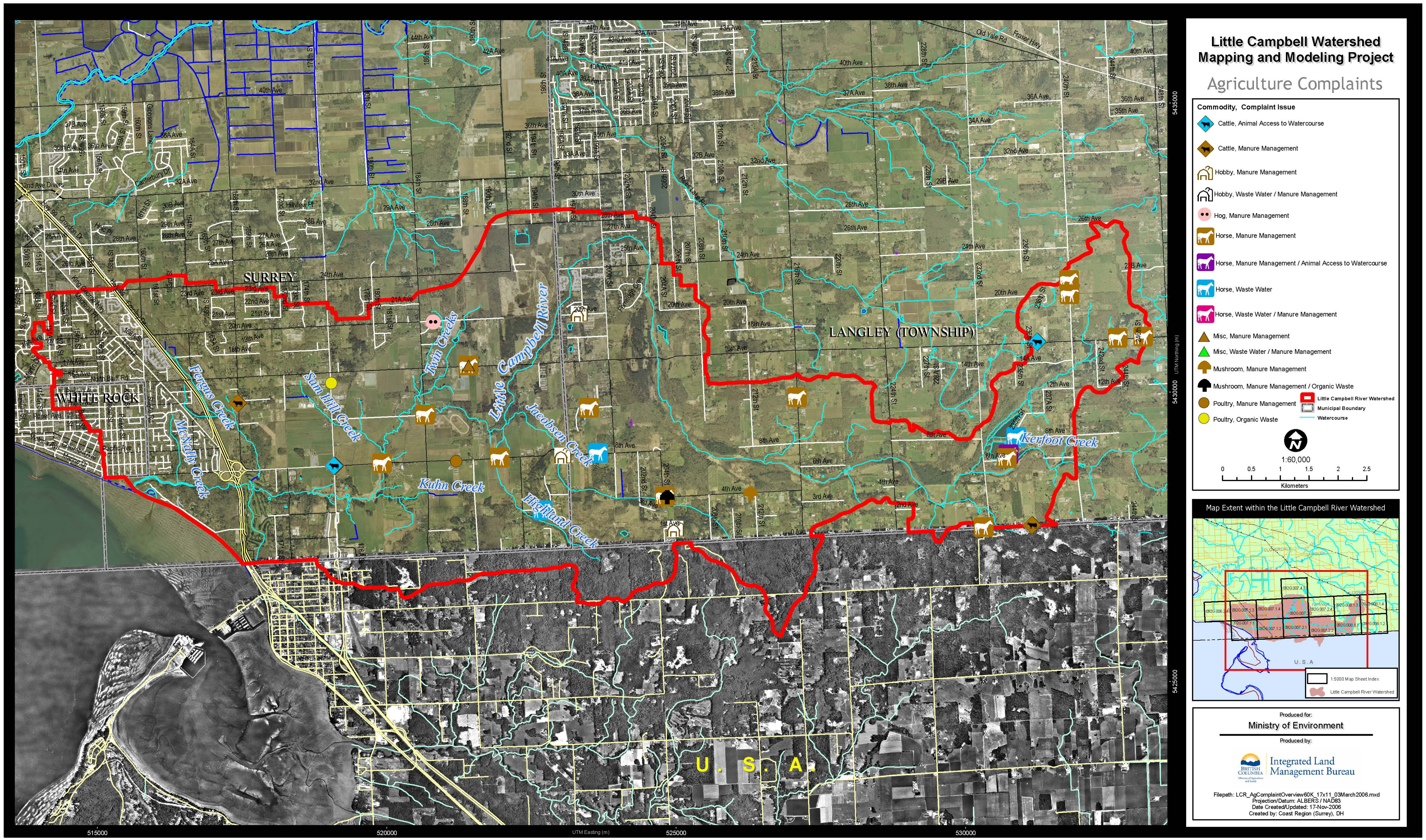
[4] Limited data are available for poultry farm densities; operations classified as farms are considered commercial high density versus backyard flocks which are generally non-commercial; home use is limited to 200 birds per household (Erickson 2006). As well, available data for the LCR does not differentiate between broilers and layers; numbers are based on averages from typical operations.



Map 11. . Agricultural land use mosaic of the Little Campbell River watershed. (Source: Surrey Agricultural Land Use Inventory - MAL 2005, Langley Agricultural Land Use Inventory – MAL 2001)

Table 13. Distribution of livestock operations by drainage unit in the Little Campbell River watershed

Drainage Unit			Horses		Beef Cattle		Dairy Cattle		Sheep/Goats		Llamas/Alpacas		Poultry (farm)		Poultry (backyard)		Combined Livestock	
Sub-watershed	**Local & Mainstem watersheds**	*Associated tributaries*	**Total Operations: 289 Approx. #: 1790-6970**		**Total Operations: 39 Approx. #: 305-710**		**Total Operations: 7 Approx. #: 307-650**		**Total Operations: 25 Approx. #: 103-550**		**Total Operations: 10 Approx. #: 108-370**		**Total Operations: 17 Approx. #: 450,000**		**Total Operations: 4 Approx. #: 12-60**		**Total Operations: 19 Approx. #: 81-390**	
East Sub-watershed	MS-1	*Kerfoot Creek*	77	77	18	18	1	1	10	10	3	3	5	5	0	0	9	9
Langley Sub-watershed	LW-1	*Unnamed north (214th St.)*	187	38	8	3	3	0	10	1	6	1	10	0	0	0	9	4
	LW-2	*Unnamed south (210th St.)*		19		0		0		4		0		1		0		1
	LW-3	*Jacobsen Creek*		68		2		1		2		3		3		1		1
	LW-4	*Highland Creek, Jenkins Creek*		2		0		1		0		2		0		0		0
	MS-2			60		3		1		3		0		6		0		3
Surrey Sub-watershed	LW-5	*East Twin Creek, West Twin Creek*	25	11	12	2	3	0	7	3	1	0	2	0	0	2	1	0
	LW-6	*Kuhn Creek, Theodore Creek*		1		1		1		0		0		1		1		0
	LW-7	*Sam Hill Creek, Thomson Creek*		5		4		0		1		0		1		0		1
	MS-3			8		5		2		3		1		0		0		0
West Sub-watershed	LW-8	*Fergus Creek*	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
	LW-9	*McNally Creek*		0		0		0		0		0		0		0		0
	MS-4			0		0		0		0		0		0		0		0



Map 12. Areas where potential agricultural NPS pollution problems and non-compliance have been reported. (Source: MOE Regional Agriculture Complaints database, 1992 – 2004)

3.2.2.3 Agricultural Waste Control Compliance

A potential tool for preliminary identification of areas of concern exists through analyzing compiled information on agricultural complaints in the watershed. Agricultural complaints occur when a particular agricultural operation is identified as potentially being in non-compliance with the Agricultural Waste Control Regulation (AWCR). These incidents can be represented spatially to identify areas of potential concern (Table 14, 15 and Map 12).

Table 14. Reported agricultural related complaints by commodity type within the Little Campbell River watershed (Source: MOE Regional Agriculture Complaints database, 1991 – 2004)

Commodity	Number of Complaints	Percent of Complaint Types
Horse	44	46%
Beef Cattle	14	15%
Poultry	14	15%
Hobby	10	10%
Mushroom	6	6%
Miscellaneous	4	4%
Dairy	2	2%
Hog	1	1%
Nursery	1	1%

Table 15. Reported agricultural related complaints by issue area within the Little Campbell River watershed (Source: MOE Regional Agriculture Complaints database, 1992 – 2004)

Issue Area	Common Area of Concern	% of Complaint Types
Manure Management	Uncontained manure storage, seepage to water bodies	84%
Organic Waste	Decomposing carcasses, leachate	5%
Animal Access	Erosion, natural area vegetation impacts, fecal waste contamination to water resources	5%
Wood Waste	Leachate, contamination of water sources	5%
Unknown Source	Potential associated decrease in aquatic species e.g. fish numbers	2%

It is difficult to determine how representative these analysis results are in describing agricultural NPS pollution issues in the watershed, since the complaints database largely depends on observations and reports from the public (not an unbiased, complete random sample). The results of this analysis however, indicate some patterns that appear to fit trends identified in agricultural land use and activities. For example, the majority of concerns appear to be associated with horses, and horse farms comprise the greatest agricultural land use. In reviewing the complaints, the most frequent issue raised was improper manure storage. Issues of organic waste, livestock access and wood waste make up a small component of the complaints.

Additional compliance activities, such as aerial surveys and compliance audits, have been used in other areas to identify non-compliance in particular commodity groups. In general, smaller-scale hobby farm operations have been found in non-compliance more frequently than larger-scale commercial operations (Rushworth and Younie 2006). It is suspected that the greater degree of non-compliance amongst hobby farms is related to fewer available resources and lack of awareness regarding statutory requirements and best management practices.

3.2.2.4 Manure Production Estimates per Livestock Type

Another tool that can be used to measure the potential impact of animal manure is the calculation animal unit equivalents (AUE). AUE's represent the amount of manure generated per livestock type, based on a literature-derived baseline. This is primarily based on work done by the American Society of Agricultural Engineers (ASAE) that calculated mean manure production and associated fecal coliform production per day depending on livestock type (ASAE 2003). Data values represent fresh (as voided) feces and urine combined, using 1000 kg of live animal mass as the unit equivalent (Table 16). Actual values will vary due to differences in diet, age, productivity, and management.

Table 16. Potential manure production per animal based on animal unit equivalent calculations **(Source: ASAE 2003)**

		Livestock Type							
Parameter		**Dairy Cattle**	**Beef Cattle**	**Horse**	**Pig**	**Goat**	**Sheep**	**Poultry (Layer)**	**Poultry (Broiler)**
Typical Mass **(kg)**		**640**	**360**	**450**	**61**	**64**	**27**	**1.8**	**0.9**
Animal Unit Equivalents **(per 1000 kg live animal mass per day)**	**Manure production (kg)**	**86**	**58**	**51**	**84**	**41**	**40**	**64**	**85**
	Fecal coliform (colonies * 10^{10})	**16**	**28**	**0.092**	**18**	**n/a**	**45**	**7.5**	**n/a**
Estimated Manure Production per Animal (kg)		**55.04**	**20.88**	**22.95**	**5.12**	**2.62**	**1.08**	**0.12**	**0.08**
Estimated Fecal Coliform Production per Animal per Day (colonies * 10^{10})		**10.24**	**10.08**	**0.04**	**1.10**	**n/a**	**1.22**	**0.01**	**n/a**

These calculations can be manipulated using a modelling system being considered by Environment Canada to calculate the greatest potential for daily loadings and contamination. The true variability in manure storage and management exceeds present modelling capability; the modelling process is treated conceptually rather than explicitly (Hamilton 2006). The numbers of animals and the resultant fecal waste volumes provide a limited indication of potential impacts and should be looked at in context. As an example, 100 dairy cows with direct uncontrolled access to surface waters are likely to be more of a problem than 500 housed cows whose manure is appropriately contained in a non-permeable storage facility and then spread according to guidelines. In some cases, the risk of bacteriological contamination associated with agricultural waste may be more a function of manure management (or mismanagement) than the density of livestock or volume of manure generated (Schmidt 2006).

From the LCR watershed data, it appears that horses contribute the greatest amount of manure production per day; however, cattle and poultry contribute the greatest amount of fecal coliform production. Table 17 and Figure 7 provide estimates of potential daily manure production. These values do not necessarily link to pollutant loads in watercourses and are provided only for a general picture of potential manure production in the watershed overall. Figure 7 includes human sewage production in order to compare with livestock contributions in the watershed. A rough estimate of human sewage generated in the watershed was obtained by considering the human population in the watershed and the average waste generated per person (estimated to be 0.0955kg/day/person based on Parker and Gallagher 1988). The relative contribution of wildlife (e.g. waterfowl, deer) to manure and fecal coliform production is unknown; however, this can be built into modeling work, if conducted, to provide approximate values.

Table 17. Estimates of potential daily manure production from primary livestock types in the Little Campbell River watershed, based on animal unit equivalent calculations

Livestock Type	**Estimated Number of Livestock**	**Potential Manure Production** (kg/day)
Beef Cattle	305 - 710	6,368 – 14,824
Dairy Cattle	307 - 650	16,897 – 35,776
Horses	1790 - 6970	41,081 – 159,962
Sheep/Goats[5]	103 - 550	191 – 1,018
Poultry[6]	450,000	45,000

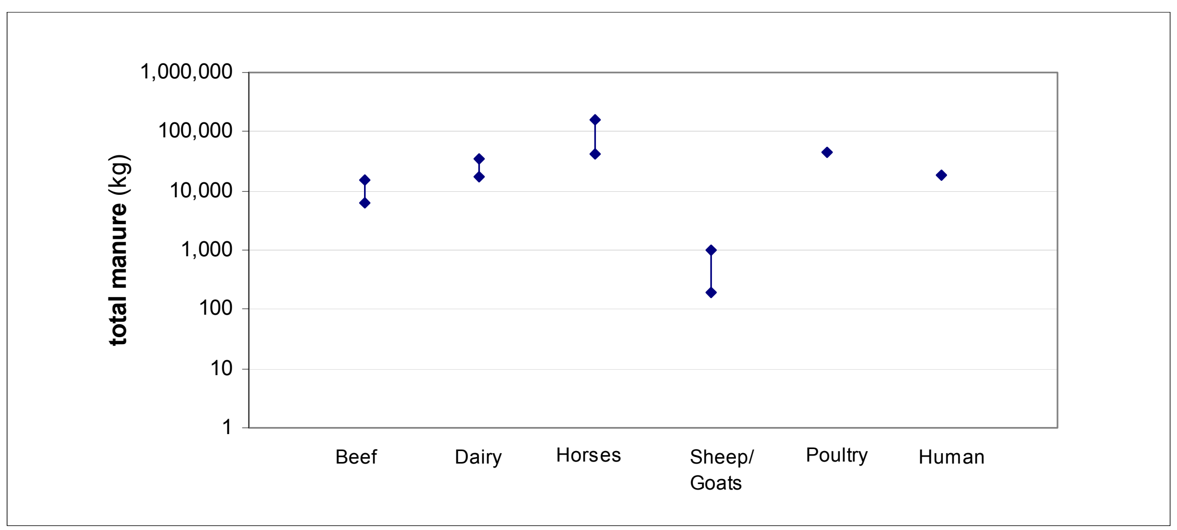


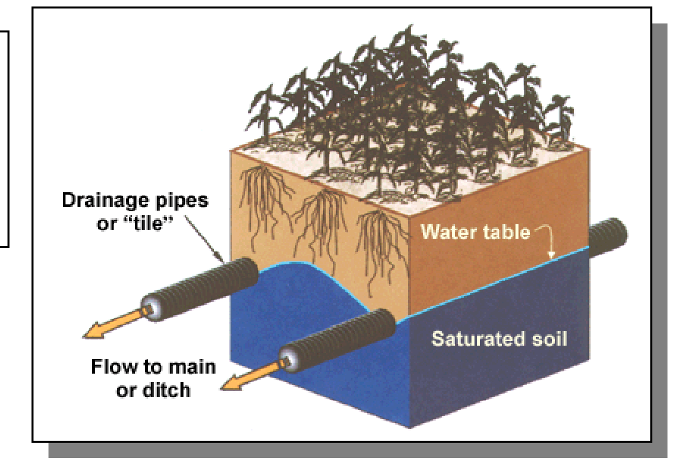
Figure 7. Potential daily manure production estimates from primary livestock types and humans in the Little Campbell River watershed.

[5] Combined average of sheep and goat manure production data (1.85 kg/animal/day)
[6] Combined average of layer and broiler manure production data (0.1 kg/animal/day)

3.2.2.5 Agricultural Drainage Infrastructure

In addition to surface runoff from improper manure management or direct livestock access to watercourses, agricultural NPS pollution may enter the LCR via drain tiles. Drain tiles are a common and traditional method of drainage on agricultural lands (Figure 8). They are often installed when an operation is first developed and can be overlooked as a potential conduit of both surface and groundwater contamination as the location and condition of the drain tiles are often forgotten over time (Schmidt 2006). In some areas, surface inlets or intakes (risers extended from underground pipes to the surface) remove excess surface water from low spots in fields (Busman and Sands 2002).

Figure 8. Typical drain tile design
Subsurface drainage pipes are typically placed at depths of 3 to 4 feet in poorly drained soils.
http://www.extension.umn.edu/distribution/cropsystems/DC7740.html



Drainage water in watercourses can be degraded by surface contaminants infiltrating the drain field through flow pathways, overland flow to surface ditches, and by erosion at drain outlets (MAFF 2005). Freshly-spread liquid manure may flow through the soil, into subsurface drainage tiles and from there to watercourses, causing a risk of fecal contamination.

The age of many farms and presence of drain tile infrastructure is largely unknown in the LCR watershed. While some ad hoc work has been done to date to map drain tile end of pipe locations (Dreves 2006), insufficient information exists to determine the extent or state of drain tiles in the watershed (Schmidt 2006). As farm ownership is transferred, or agricultural use changes, their location may become even more obscure.

3.2.2.6 Domestic Pet Waste

Domestic pet waste is a potentially significant source of bacterial contamination in the LCR watershed. Genetic studies by Alderiso et al. and Trial et al. (cited in Schueler and Holland 2000) both concluded that 95% of the fecal coliform found in urban stormwater examined was of non-human origin (e.g. dogs, cats, wildlife). Bacterial source tracking studies in a watershed in the Seattle, Washington area also found that nearly 20% of the bacteria isolates that could be matched with host animals were matched with dogs. It has been estimated that for watersheds of up to 20 square miles (50 square km) draining to small coastal bays, two to three days of droppings from a population of about 100 dogs would contribute enough bacteria and nutrients to temporarily close a bay to swimming and shellfish harvesting (US EPA 1983).

Licensing information was used to identify the number of dogs within the watershed by municipality (Table 18). A rule of thumb estimate for dog waste production is that 1 dog produces an estimated 0.5 pounds (0.23 kg) of feces per day (Commonwealth of Massachusetts 2004, Draft). This translates to an estimated 1180 dogs in the LCR watershed producing approximately 270 kg of feces per day. Licensing records likely underestimate the true number of dogs (Riley 2006) and therefore potential waste production is approximate. The number of cats (feral and free ranging) that may be present in the watershed could not be assessed as these animals are not regulated and per capita numbers were not available for the study area.

Table 18. Estimate of waste production from domestic dogs in the Little Campbell River Watershed **(Source: Dog licensing information from City of Surrey, Township of Langley, and City of White Rock)**

Municipality	Estimated Number of Licensed Dogs in Watershed	Estimated Potential Waste Production (kg/day)
White Rock	449	103
Surrey	281	64
Township of Langley	451	103

As with proposing estimates of livestock waste, it is important to realize that the amount of waste generated does not necessarily translate into direct fecal loading or contamination. This can only be determined by identifying the amount of pet waste that actually reaches surface water resources. Pet waste cleanup is at the owner's discretion; areas with high frequency of off-leash use and recreational walking may be source areas for contamination. Three such areas exist in the watershed: 1) Campbell Valley Regional Park, 2) along the estuary in and around the Semiahmoo First Nations Reserve and 3) the railway line along Semiahmoo Bay. While GVRD supplies dog waste bags and has designated off-leash areas well away from any watercourse in the regional park (Jarvis 2006), the area around the estuary is highly suspect for dog waste accretion (Cuthbert 2006). This area is actually incorrectly listed as an off-leash "doggy park" on one local website though not municipally approved as such.

3.2.4 Urban and Industrial Activities

While land cover in the LCR watershed is dominated by agriculture and rural land uses; urban, and to a lesser extent light industrial activities, are prevalent in some areas. Urban areas are concentrated in the West sub-watershed encompassing residential areas in the City of White Rock and the western margin of the City of Surrey, as well as near the Blaine border crossing (Map 5). Industrial activities are confined to the developing Campbell Heights Business Park (www.campbellheights.ca) in the north central portion of the watershed (Surrey sub-watershed) and a small area near the 176th Street border crossing. All industrial activities in the LCR watershed are considered light-industrial (e.g. warehousing, furniture manufacturing, wholesale and retail sales of products produces on site).

Urban land use can be a source of nutrients and fecal coliform bacteria from septic fields and landscape sources, but are most often associated with elevated metals, hydrocarbons, and construction-phase sediment in urban stormwater (May et al. 1997, Ebbert et al. 2000). Industrial land use can also contribute specific chemical contaminants such as solvents, high temperature water, or metals; although in the case of the LCR watershed, contaminant levels from light industrial activity in the Campbell Heights area maybe similar to those associated with intensive urban development.

3.2.4.1 Changing Land Use

There are a number of areas in the LCR watershed in which land use changes have recently occurred or will occur in the next two to fifteen years. Most are found in the northern portion of the watershed in the City of Surrey where they are guided by Neighbourhood Concept Plans (NCPs) though some areas of Township of Langley do have community planning processes underway (Appendix 5). Incremental redevelopment also occurs in the City of White Rock but on the scale of small sites or properties rather than large neighbourhood planning units. Development is also occurring in the City of Blaine, but it appears to be outside the boundary of the LCR watershed.

Active or potential development or redevelopment sites in the LCR watershed include (Map 13):

- The High Point Residential Community is proposed in the south portion of the Langley sub-watershed. This is a 98.7 ha planned residential community located in an old gravel mining area. The development proposal includes 157 lots (0.2 to 0.8 ha in size) and 35 ha of parkland (www.highpointlangley.com).

- The Fernridge Community is a 389.1 ha rural and single family residential area in the northern corner of the Langley sub-watershed that may be the site of increased residential use in the next 5 to 15 years. The LCR mainstem flows through the area. Planning has not begun on the site.

- The Campbell Heights Business Park is a large (339.2 ha in watershed) light-industrial complex on the northern edge of the Surrey sub-watershed that may be surrounded by residential development in the future. It spreads north into the Nicomekl River watershed as well. Most of the site is an old gravel pit (Stokes Pit) with relatively little existing infrastructure. Campbell Heights is currently being developed and is guided by a comprehensive NCP (City of Surrey 2004).

- Grandview Heights in a large (412.0 ha in watershed) mixed residential area on the western edge of the Surrey sub-watershed with two neighbourhood commercial centers. Land use is also guided by a NCP (City of Surrey 2005).

- Development will also occur in the Douglas area near the Canadian side of the Douglas Border Crossing west of 176th Street. This area is relatively small (84.1 ha) compared to the NCP areas in the City of Surrey. It includes a broad range of residential and commercial land use, as well as small amount of light-industrial land use (City of Surrey 1999).

- The eastern flank of the Highway 99 corridor through the LCR watershed will be redeveloped into commercial-light industrial area (City of Surrey 2004a). A habitat preservation area surrounding Fergus Creek will be protected as part of the proposed land use. The portion of the development site in the watershed is 143.1 ha.

3.2.4.2 Imperviousness

Urbanization is associated with a range of water quality, hydrologic, and biological changes in streams (Booth and Reinelt 1993, Schueler 1994, Karr and Chu 1999), and considerable research has shown predictable declines in a variety of measures of stream quality with increasing urbanization (May et al. 1997, Morley and Karr 2002, Booth et al. 2004). Most changes are linked to the development of impervious areas and their associated stormwater drainage systems, but also to declining watershed forest cover (see Section 4.4), loss of riparian forest, increasing road density, and the introduction of contaminants from industrial, transportation, and landscape-related activities.

Imperviousness is a broad indicator of the effect of urban land cover on watershed processes (Schueler 1994, Arnold and Gibbons 1996, May et al. 1997). Impervious areas, particularly roads and parking areas, are effective at capturing sediment-bound contaminants or spills, from which they are transported to streams. Several studies have found that streams in watersheds with greater than 10% imperviousness exhibit a broader range of hydrologic, water quality, and physical impacts (Schueler 1994).

Both Clausen et al. (2003) and Hurd and Civco (2004) found that fecal coliform bacteria were moderately correlated with total imperviousness in urbanizing watersheds in Connecticut. Impervious areas are not a direct source of fecal coliform bacteria but rather are associated with land uses that contribute fecal coliform through septic systems or animal waste. While imperviousness is an effective indicator of broad range water quality and hydrologic impacts in urban watersheds, it is a poorer measure of effects of agricultural and rural land use on watershed condition (Wang et al. 1997, Page et al. 1999, Rosenau and Angelo 2005).

Two measures of imperviousness are typically used for watershed assessments: 1) total impervious area (TIA); and, 2) effective impervious area (EIA).

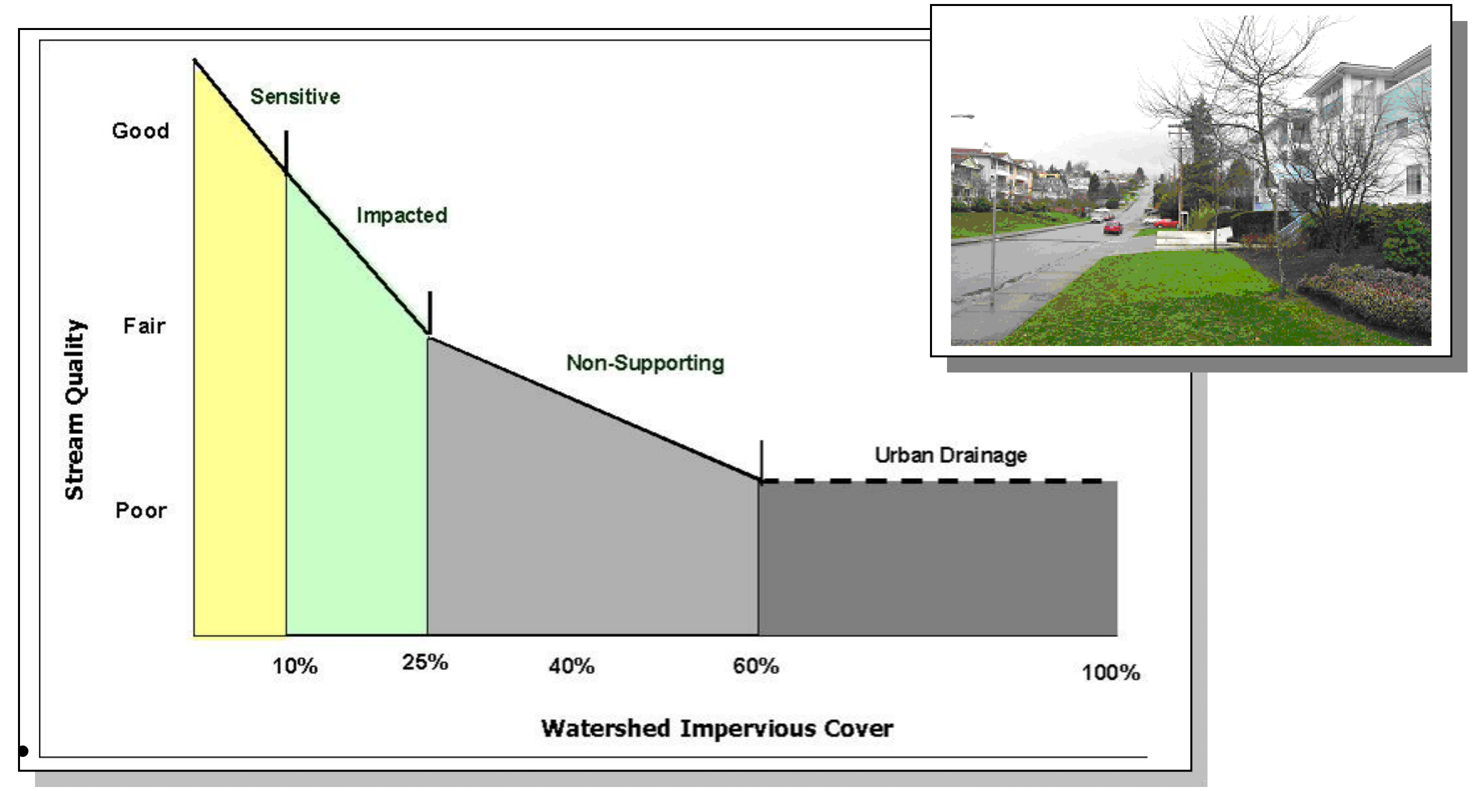
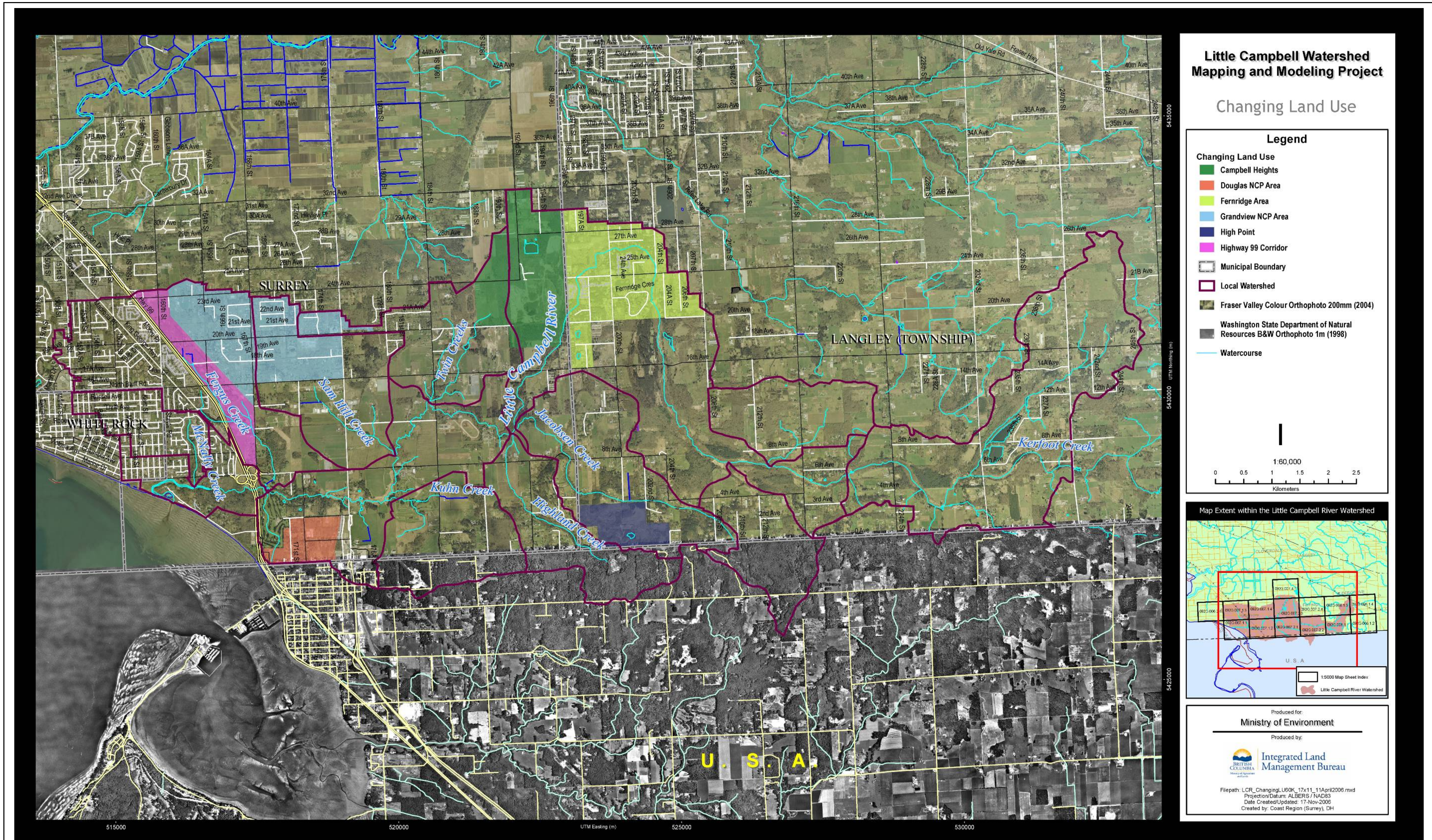


Figure 9 Graphical depiction of declining stream quality in relation to increasing imperviousness. Stream quality includes water quality, physical characteristics, and the biological community (Source: http://www.stormwatercenter.net/.) Impervious areas are a ubiquitous component of the urban landscape. Even many lawns in residential areas are so compacted they act as semi-impervious areas. Photo of residential area in the City of White Rock near the Little Campbell River estuary (N. Page).

Imperviousness Estimates for the Little Campbell River Watershed

Imperviousness has been previously estimated for the LCR watershed by Rood and Hamilton (1994), GVRD (1999), and Drever and Brown (1999). Their methods and results are briefly summarized in Appendix 6 as context for assessing imperviousness and Appendix 7 provides more detailed information on land use.

To measure current land use in the LCR watershed and estimate total and effective impervious area, similar methods as used by the GVRD (1999) were applied. Land use was re-classified using recent orthophotos (2004 for Canada and 1998 for the US). Land use was separated into 14 Corporate Land Use Classification System (CLUCS) land use types (Table 19). Appendix 8 outlines the CLUCS TIA conversion factors for the 1999 study as well as for this study. This is the first time land use in the entire LCR watershed has been assessed; previous studies have excluded the portion of the watershed in Whatcom County. Land use in the LCR watershed is dominated by three types: 40.4% is agriculture; 41.1% is park or undeveloped lands; and 18.5% is urban, transportation, or industrial lands (Map 5).



Map 13. Current and planned development areas located within the Little Campbell River watershed

Table 19. Land use and imperviousness estimates (TIA and EIA) for the Little Campbell River watershed.

LU Code	Land Use Description	Area (ha)	%TIA	%EIA	TIA (ha)	EIA (ha)
A200	Large-scale greenhouses	3.19	90.0%	85.0%	2.87	2.71
A500	General agriculture	3063.47	6.5%	1.5%	199.13	45.95
M300	Extraction (gravel pits, mining)	50.79	0.0%	0.0%	0.00	0.00
R100	Parks (designated)	136.65	1.0%	0.0%	1.37	0.00
S110	Single Family Residential	787.93	40.0%	27.0%	315.17	212.74
S120	Rural Residential	356.18	10.0%	4.0%	35.62	14.25
S130	Low Rise/Townhouse	82.12	80.0%	72.0%	65.69	59.12
S140	Mobile Home Parks	17.65	50.0%	34.0%	8.82	6.00
S200	Commercial	16.18	90.0%	86.0%	14.56	13.91
S300	Industrial	6.29	75.0%	60.0%	4.72	3.78
S400	Institutional	27.48	90.0%	86.0%	24.73	23.63
S500	Transportation and Communication	62.57	90.0%	86.0%	56.32	53.81
U100	Open (green space)	2967.35	1.0%	0.0%	29.67	0.00
W200	Lakes and reservoirs	14.72	0.0%	0.0%	0.00	0.00
	Total Area + Estimated Imperviousness	**7592.56**			**758.66**	**435.90**
	TIA and EIA Values				**9.99%**	**5.74%**

Due to the high proportion of agricultural land in the watershed, %TIA was confirmed in the field using two representative agricultural areas totaling 383 ha: a less intensive agricultural area in the East sub-watershed and a more intensively farmed area in the Surrey sub-watershed. All impervious surfaces were identified, including roads, and compared to the total area of the polygon. TIA was 4.9% in the less intensive agricultural area compared to 8.1% in the more intensively farmed area. Average TIA values in agricultural areas in the watershed were estimated to be 6.5%, and EIA was estimated to be 1.5% for agricultural lands in the LCR watershed.

For the entire watershed, TIA was estimated to be 9.99% and EIA was estimated to be 5.74% (Table 20). This is slightly higher than previous estimates. The increase may be related to incremental urbanization since the last estimates were made or the increase in TIA conversion values from 5.0% to 6.5% for agricultural land use (for example, a 1.0% change in the estimate of TIA in agricultural areas results in a 0.4% change in watershed imperviousness). However, the inclusion of forested areas along the southern edge of the watershed in Whatcom County and the better separation of undeveloped (U100) areas within agricultural and rural areas likely offset the change in TIA conversion values for agricultural land use. Previous assessments have generally included small patches of forest or other undeveloped areas within agricultural, rural, or residential polygons.

It is important to note that changing land use in the Campbell Heights area and the Highway 99 corridor is not reflected in the 2004 dataset; development activities in both areas has occurred since the 2004 photos were taken. As a separate measure of effective impervious area, an equation developed by Dinicola (1989) was used to calculate EIA ($EIA = 0.15 \times TIA^{1.41}$). The estimated EIA in the LCR watershed based on this relationship is 3.85%.

TIA was highest in the West sub-watershed (30.1%) and lowest in the Langley (4.2%) and East (4.6%) sub-watersheds (Table 23). At the local and mainstem watershed scale, the highest TIA values were found in LW-8 (28.6%) and LW-9 (41.9%) local watersheds, while the lowest were found in the LW-2 (2.8%), LW-3 (3.9%), and LW-4 (3.1%) local watersheds.

Table 20. Imperviousness estimates (TIA and EIA) for drainage units in the Little Campbell River watershed

Drainage Unit			**Area (ha)**		**TIA (ha)**		**EIA (ha)**		**TIA %**		**EIA %**	
Sub-watershed	**Local & Mainstem watersheds**	*Associated tributaries*	**Total: 7582.6**		**Total: 590.2**		**Total: 435.9**		**Total: 9.99%**		**Total: 5.74%**	
East Sub-watershed	MS-1	*Kerfoot Creek*	1142.2	1142.2	53.1	53.13	12.9	12.86	4.6%	4.6%	1.1%	1.1%
Langley Sub-watershed	LW-1	*Unnamed north (214th St.)*	3106.6	325.2	131.3	14.86	39.3	3.17	4.2%	4.6%	1.3%	1.0%
	LW-2	*Unnamed south (210th St.)*		305.6		8.50		1.49		2.8%		0.5%
	LW-3	*Jacobsen Creek*		609.1		24.03		5.22		3.9%		0.9%
	LW-4	*Highland Creek, Jenkins Creek*		383.9		12.01		2.24		3.1%		0.6%
	MS-2			1482.8		71.92		27.16		4.9%		1.8%
Surrey Sub-watershed	LW-5	*East Twin Creek, West Twin Creek*	2092.5	468.3	200.4	42.09	109.4	20.05	9.6%	9.0%	5.2%	4.3%
	LW-6	*Kuhn Creek, Theodore Creek*		401.5		17.14		5.10		4.3%		1.3%
	LW-7	*Sam Hill Creek, Thomson Creek*		517.0		55.24		27.94		10.7%		5.4%
	MS-3			705.6		85.89		56.30		12.2%		8.0%
West Sub-watershed	LW-8	*Fergus Creek*	1241.2	824.1	373.9	235.8	274.4	171.9	30.1%	28.6%	22.1%	20.9%
	LW-9	*McNally Creek*		204.5		85.62		63.35		41.9%		31.0%
	MS-4			212.5		52.47		39.15		24.7%		18.4%

3.2.4.3 Roads and Transportation Activities

Roads are a ubiquitous component of watershed development and they directly and indirectly affect water quality and hydrology. Roads account for a high proportion of impervious areas (Dinicola 1989) and road density was strongly correlated with total imperviousness in a study of urbanization effects in Puget Sound (May et al. 1995). Road density and the number of road-stream crossings can be better predictors of biological condition in small streams than imperviousness (Alberti et al., in press in Avolio 2003).

Roads are also effective at collecting contaminants associated with motor vehicles and conveying them to watercourses through surface drainage systems. Contaminants related to transportation activities include heavy metals from automobile components, hydrocarbons from lubricants, and toxic effluent from leaking radiators. Research in Seattle has shown that concentrations of zinc, copper, lead, nickel, and mercury in highway runoff are highest during peak transit periods (Wilson 2005). Salt or sand used for de-icing may also degrade water quality. Most roads are accompanied with ditches or catch basins and pipe systems to ensure adequate drainage; these systems are also effective at transporting contaminants to streams and rivers.

Road network information, including location and road type, was obtained from spatial datasets from the Township of Langley, City of Surrey, City of White Rock, and Whatcom County, supplemented with spatial data from the B.C. Digital Road Atlas. Estimated daily vehicle use data was available in different formats from the Township of Langley and the City of Surrey on average annual daily traffic (AADT), but separate estimates of road length and type were calculated for the City of White Rock and Whatcom County using ortho-photos. Additional data on the number of registered motor vehicles in the Canadian portion of the watershed were obtained from the Insurance Corporation of B.C.. However, these data are referenced by postal code and more analysis is needed to subdivide according to different drainage units. Vehicle use data could be used to calculate a new indicator of potential vehicle-related impacts based on the total number and density of vehicles within each drainage unit.

Potential effects of roads on water quality in the LCR watershed were measured using six indicators: road length, road density, vehicle activity, vehicle activity density, road-stream crossings, and road-stream crossing density (Table 21).

Road Length and Road Density: The total length of roads (all types) was measured within the watershed and each watershed sub-unit. Road length in different road classes (e.g. arterial, collector, lane) was also calculated. The density of roads was expressed as km of road per square kilometer. Both are general indicators and do not address the intensity of road use.

Vehicle Activity and Vehicle Activity Density: Traffic volume information and road length were used as an estimate of the number of vehicle kilometers (Vkm/dy) in watershed unit per day (e.g. each kilometer that one vehicle drives is considered a vehicle kilometer). Relative density of the number of vehicle kilometers per square kilometer of watershed area (Vkm/dy/km^2) was also measured.

Road-Stream Crossings and Road-Stream Crossing Density: The number of road-stream crossings was calculated for each watershed unit. This was also expressed as the number of road-stream crossings per kilometer of stream channel. Road-stream crossing density is a common measure of road-related impacts in urban and forested watersheds because it estimates the cumulative effect of hydrologic changes, stream channel medications, loss of riparian vegetation, and runoff from roads (Avolio 2003).

Table 21. Road type, length, and density by drainage unit in the Little Campbell River watershed. See Appendix 9 for detailed breakdown

Drainage Unit			**Road Length**		**Road Density**		**Vehicle Activity**		**Vehicle Activity Density**		**Road Crossings**		**Road-Stream Crossings**	
Sub-watershed	**Local & Mainstem watersheds**	*Associated tributaries*	(km) **Total: 262.67**		(km/km2) **Total: 3.46**		(VKm/dy) **Total: 1,067,795**		(Vkm/dy/km2) **Total: 235,220**		(No.) **Total: 52**		(No./km) **Total: 0.45**	
East Sub-watershed	MS-1	*Kerfoot Creek*	19.43	19.43	1.7	1.7	39,357	39,357	3,448	3,448	8	8	0.48	0.48
Langley Sub-watershed	LW-1	*Unnamed north (214th St.)*	65.76	4.58	2.12	1.41	178,939	2,820	23,720	867	23	3	0.38	0.49
	LW-2	*Unnamed south (210th St.)*		6.11		2		16,176		5,293		5		0.71
	LW-3	*Jacobsen Creek*		10.13		1.66		21,908		3,597		4		0.43
	LW-4	*Highland Creek, Jenkins Creek*		7.93		2.07		24,109		6,280		3		0.47
	MS-2			37.01		2.5		113,926		7,683		8		0.25
Surrey Sub-watershed	LW-5	*East Twin Creek, West Twin Creek*	52.98	12.24	2.53	2.61	258,676	66,865	45,787	14,277	14	7	0.53	1.27
	LW-6	*Kuhn Creek, Theodore Creek*		9.06		2.26		10,256		2,554		1		0.21
	LW-7	*Sam Hill Creek, Thomson Creek*		13.26		2.56		62,396		12,068		2		0.61
	MS-3			18.42		2.61		119,158		16,888		4		0.31
West Sub-watershed	LW-8	*Fergus Creek*	124.5	61.72	10.03	7.49	590,824	334,578	162,265	40,599	7	4	0.54	0.64
	LW-9	*McNally Creek*		36.65		17.92		59,789		29,230		1		0.67
	MS-4			26.13		12.29		196,456		92,437		2		0.39

There is a total of 263 kilometers of road in the LCR watershed (Table 24). Fifty percent are local roads (standard two-lane rural and residential roads), while 34% are collector roads, and 7% are arterial roads. Only 4% is highway, but is likely an important source of road-related contaminants because of its high vehicle use.

All road-related indicators except for road-stream crossings showed a clear pattern of increased road activities in the West sub-watershed and then declining activity further east. Road density varied from as high as 10.3 km/km^2 in the West sub-watershed to 1.7 km/km^2 in the East sub-watershed. The mean road density for the watershed was 3.46 km/km^2.

The total number of vehicle kilometers per day in the watershed was over 1,067,000. Both vehicle activity and vehicle activity density were highest in the West sub-watershed that contains Highway 99 and the intensively developed residential areas of White Rock and southwest Surrey. The lowest vehicle activity occurred in the rural East sub-watershed.

The number of road-stream crossings and road-stream crossing density were not consistent with the other road-related indicators in the LCR watershed. A total of 52 road crossings were identified of which 37 (71%) occurred in the Langley and Surrey sub-watersheds. The Surrey sub-watershed had the highest density of road-stream crossings (0.53 crossings/km), while the Langley sub-watershed had the lowest density (0.38 crossings/km). The lack of road crossings in the intensively urbanized West sub-watershed is likely related to the intensive urban development that has resulted in the loss of stream channels, and hence, precluded opportunities for stream crossings.

3.2.4.4 Reported Spills

Records of spills[7] are a measure of potentially acute water quality problems. Their distribution in the watershed can be used as an indicator of water quality problems not captured by land cover or water quality measurements. Unfortunately, the under-reporting of spills and the variable severity of spills make them a more general indicator than the specific information associated with their reporting suggests.

Spill records are maintained by the B.C. Ministry of Environment which has the responsibility for managing spill response activities under the B.C. Environmental Management Act. Since May 1996, spill records have been kept in digital format while older records are maintained in hard-copy format. For our analysis, only spills between May 1996 and November 2005 were used. Spill records from the City of Blaine or Whatcom County were not obtained. Eight spill categories were identified: 1) animal waste; 2) chemical substances; 3) hydrocarbons; 4) metals; 5) radioactive materials; 6) sediment; 7) solvents; and 8) unknown materials.

Seventy-three spills were recorded during the study period (Table 22). The number of reported spills declined substantially in the second half of the period of record. Between 1996–2001 an average of 10.4 spills were reported per year while from 2002–2005 an average of 4.2 spills were reported per year. It is unknown if this reflects changes to reporting intensity or an actual decline in the number of spills. The distribution of spills by municipality was variable: 10 occurred in the Township of Langley; 58 in the City of Surrey, and 5 in the City of White Rock. The most common type of spill reported was of hydrocarbons (31.5%), followed by unknown materials (27.4%), and chemical materials (16.4%).

Table 22. Types of reported spills in the Little Campbell River watershed (January 1987 to May 2005). **See Appendix 10 for detailed breakdown and supporting information.**

Spill Class	No. of Spills
animal waste	7
chemical	12
hydrocarbon	23
metal	1
radioactive	2
sediment	6
solvent	2
unknown	20
Grand Total	**73**

7 Based on the BC Environmental Management Act - Spill Reporting Regulation - BC Reg. 263/90 a spill is the "release or discharge … into the environment of a substance in an amount equal to or greater than the amount listed." The listed amounts are described in a schedule under the Act.

3.2.4.5 Stormwater Management Activities

There are some specific stormwater management activities in the LCR watershed that focus on water quality issues but none that specifically address sources of fecal coliform bacteria.

The City of Surrey plans to incorporate low impact development (LID) practices into redevelopment and new development areas. Integrated stormwater management plans (ISMP) for the Fergus Creek local watershed and the entire LCR watershed are currently underway and will recommend approaches for mitigating the impacts of intensifying urban development.

Recent development of a light industrial zone in the Campbell Heights area near the north central edge of the watershed has employed a number of stormwater BMP’s. Portions of the development utilize the porous soils in the area and allow stormwater to infiltrate directly into the ground. Elsewhere a more conventional stormwater collection system is used, with Stormceptor facilities (oil-water separators), an open channel, and a seasonally flooded pond (Dube and Baron 2006). However, there have been recent concerns about changes to subsurface hydrology in the Campbell Heights area which has affected water levels in Latimer Lake (David Suzuki Foundation 2005). As well, construction activities have resulted in sediment control problems on one tributary to the LCR (Dube and Baron 2006).

In Langley, two examples of recent or upcoming developments that use stormwater management techniques are the community of Brookswood-Fernridge and High Point Estates. The Brookswood Neighbourhood used infiltration swales to reduce surface runoff (Condon and Gonyea 2000). These swales made use of the areas permeable soils (Brookswood aquifer). Secondary drainage infrastructure ensured adequate surface drainage if infiltration capacity was overwhelmed. Redevelopment in this area is expected to continue over the next 5 to 15 years.

Conceptual plans for the High Point development area in south Langley indicate a number of general approaches to environmental protection including preserving a natural wetland, augmenting existing stream flows, and protecting riparian zones (Appendix 11). The development’s website states that: “stormwater will be collected and managed through best practices approved by the GVRD” (www.highpointestates.ca). The Environmental Impact Assessment for the development site provides more specific direction on stormwater management and notes that: “through the implementation of the stormwater best management practices groundwater and surface water impacts should be minimal” (ENKON 2003). Some of the proposed stormwater management activities include: 1) curbless roads; 2) biofiltration ditches; 3) rock pits for infiltration of roof runoff; 4) the use of compost amendments to maintain soil porosity; 5) biofiltration wetlands; and 6) protection of existing surface drainage to Jacobsen Creek.

The City of White Rock has recently undertaken several projects to narrow streets and add infiltration areas to road margins.

PART 4 – CHARACTERIZATION AND ASSESSMENT OF POLLUTION SINKS

4.0 ECOSYSTEM SERVICES AND POLLUTION SINKS

Pollution sinks are watershed-level processes and features that use biological and physical processes to capture or transform contaminants before they impair water quality in streams and rivers; for example: depressional wetlands, floodplain or hydric soils, headwater stream channels, and riparian vegetation. While there has been an increased emphasis on best management practices to minimize the effects of agricultural, urban, and industrial activities on water quality in the past two decades, there has been less attention paid to the protection or restoration of these pollution sinks (Stanley et al. 2005, Verhoeven et al. 2006).

4.1 Potential Pollution Sinks

To identify areas of the landscape that are important for removing fecal coliform bacteria and nitrate from the LCR watershed, the model proposed by Stanley et al. (2005) was generally followed. For the purposes of this study, the focus was on the first component of the assessment process – identifying watershed features which may act as potential pollution sinks. More work will be needed to measure both how much these sinks have been impaired by human disturbance (e.g. wetland loss, drainage) and their potential for restoration. Inconsistencies between datasets and lack of appropriate information limited the ability to identify some processes and features. Forests, which can also play a role in offsetting NPS pollution, were added as an indicator of intact biological, hydrologic, and chemical processes at a watershed scale.

Sources and Sinks for Fecal Coliform Bacteria

Common sources of fecal coliform bacteria in mixed urban-agricultural watersheds are animal manure used for agricultural fertilizer, leaking septic fields, cross-connections between storm and sanitary sewer systems, domestic pets, and wildlife. Fecal coliform mortality can be due to predation, starvation, UV radiation, and water conditions, such as pH, and salinity (Roszak and Colwell 1987 in Stanley et al. 2005). These processes are time dependent but likely occur in a variety of terrestrial and aquatic areas. Suspended sediments, on the other hand, may reduce bacterial mortality.

Stanley et al. (2005) identified depressional wetlands as the primary landscape feature in which the mortality of fecal coliforms can be increased by increasing residence time. Depressional wetlands increase sediment settlement which may trap bacteria adsorbed to particles. Floodplains and riparian zones may also act as sinks for fecal coliform bacteria through sediment removal; however, this effect has not been substantiated.

Sources and Sinks for Nitrate:

Both nitrogen-based fertilizers and animal waste (e.g. livestock manure, faulty septic systems and pet waste) are sources of nitrate (Eghball and Gilley 1999). Nitrate is one of the most soluble and mobile forms of nitrogen and is rapidly transported from agricultural or urban areas into streams or aquifers (Stanley et al. 2005). Excessive amounts of nitrate in streams, lakes and coastal systems can cause eutrophication, where large amounts of nutrients cause algal blooms resulting in oxygen depletion and hence poor water quality (Knutson and Naef 1997). Nitrate can be removed from shallow groundwater by plant uptake or conversion into nitrogen gas by denitrifying bacteria in anaerobic conditions. Nitrate moves quickly through the soil column, therefore processes which slow down the movement of groundwater increase opportunities for denitrification to occur.

Sinks for nitrate occur where groundwater flows through the root zone, under anaerobic conditions, where organic carbon accumulates, and where surficial geology results in longer residence times for water or soil. These conditions typically occur at the interface of terrestrial and aquatic ecosystems such as wetlands, floodplains or riparian areas with shallow ground water, and small streams in headwater areas (Stanley et al. 2005).

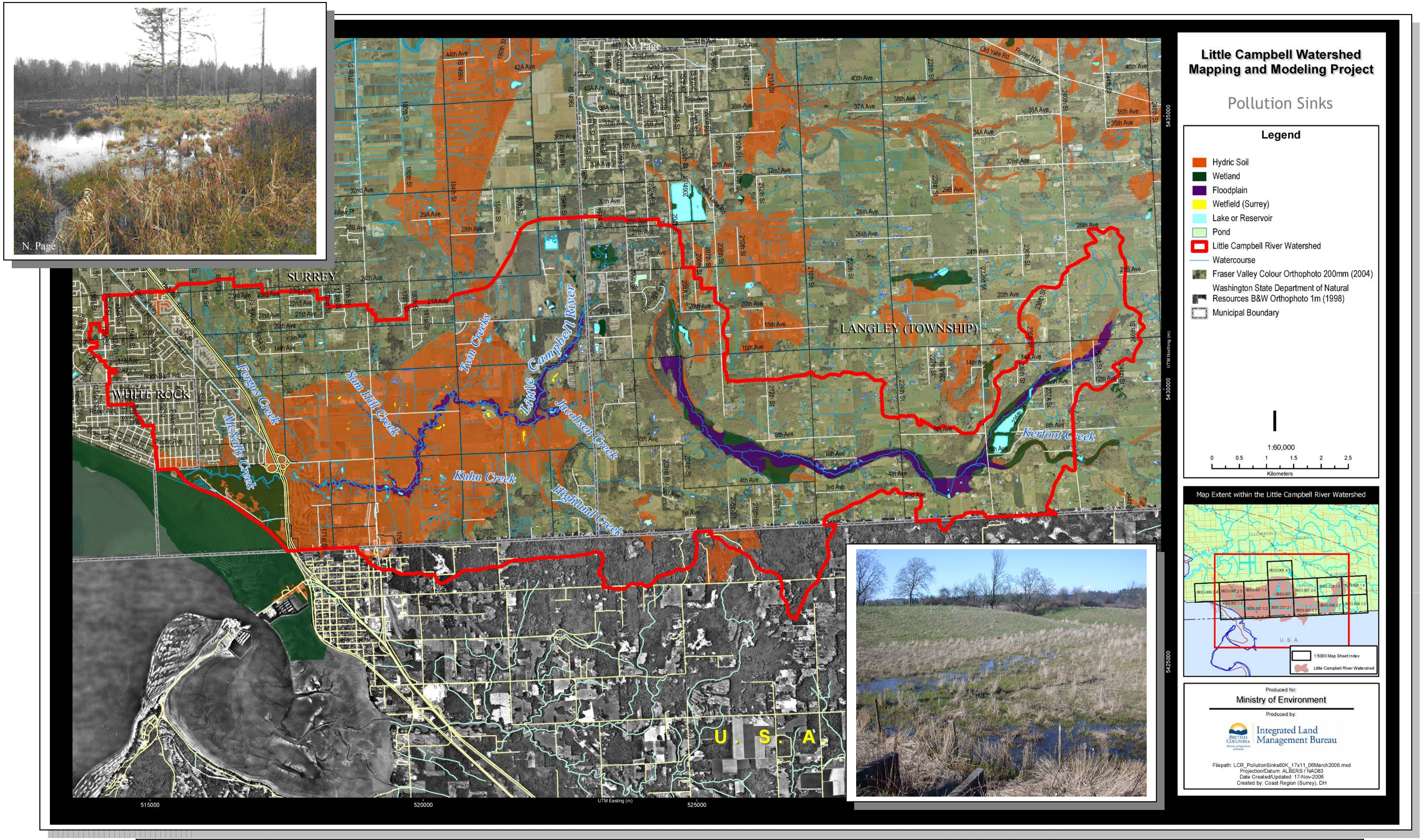
Potential Pollution Sinks within the Little Campbell River Watershed

Potential pollution sinks in the LCR watershed can be divided into three spatial units (Map 14):
1) the upper watershed, including Campbell Valley Regional Park,
2) the south Surrey lowlands, and
3) the river mouth.

The first is the assemblage of wetlands, floodplain, and hydric and alluvial soils that follow the river from the eastern margin of the watershed to approximately midway along its length. A portion of this unit is contained within Campbell Valley Regional Park, but most is privately owned land. Previous water quality assessments indicate that despite the rural and agricultural development in the upper watershed, fecal coliform are rarely above 200 CFU/100 ml and nitrate concentrations are rarely above 0.5 mg/L in this area. Further analysis is required to confirm the effectiveness of these remaining wetlands and floodplains as pollution sinks.

The second potential pollution sink is the hydric soils, scattered wetlands, and floodplain of the Surrey south lowlands. This area is associated with intensive agricultural land use as well as elevated fecal coliform (>800 CFU/100 ml) and nitrate levels (>1.5 mg/L). Very few wetlands currently occur in this area although flooded fields and inundation of floodplain areas were observed in the winter of 2005/6. Agricultural activities often extend into the floodplain.

The third area is the floodplain forest and estuarine marshes at the mouth of the LCR. Less is known about the physical conditions in this unit than the other two. Most of the unit is contained within the Semiahmoo Indian Reserve.



Map 14. Location of potential pollution sinks (wetlands, floodplains, hydric soils and headwater areas) for the Little Campbell River watershed (Inset: Examples of wetlands in the Little Campbell River watershed. **Wetlands like these in the southeastern portion of the LCR watershed (left) and saturated floodplain (hydric) soils (right) can act as pollution sinks**

4.1.1 Wetlands and Floodplains

Wetlands were likely widespread in the LCR watershed prior to development. However, no detailed historic vegetation mapping has been undertaken for the watershed and the pre-development wetland distribution would have to be inferred from topography, soils, and current vegetation patterns (Figure 10). The historic vegetation map (Map 4) identifies one area in the watershed as 'Prairie -grass" which may have been a major wetland complex. Forested wetlands were likely the dominant wetland type and non-forested wetlands such as marshes likely occurred sporadically. Wetlands occurred in the central floodplain valley (from 200th Street to the eastern boundary of the watershed); and, the central lowlands of the Surrey sub-watershed (estuary to Surrey–Langley border).

Figure 10. Differences in wetland conditions in the Little Campbell River watershed. Left: A portion of the river in the Surrey sub-watershed that has been extensively developed for agriculture and some urban development. The meandering river channel is visible but most of the floodplain is cleared for agriculture. Right: The central valley which is largely shrub swamp and marsh with very little clearing or agricultural development.

The distribution of wetlands and floodplains in the LCR watershed were identified from four sources:

1) Wetland and floodplain information in the Township of Langley was obtained from existing data layers supplemented with provincial TRIM mapping for larger features such as lakes and reservoirs. The Township of Langley maps floodplains based on flood frequency (1 in 5 yr; 1 in 100 yr). The 1 in 5 yr line was used for floodplain delineation in this study.
2) Wetlands in Whatcom County were described based on wetland mapping from Critical Areas Ordinance maps (Whatcom County 2005).
3) Wetland and floodplains in the City of Surrey and City of White Rock were identified through orthophoto interpretation of topography, soils, flood features such as seasonally flooded fields, and stream channel location. They were subdivided into ponds and other distinct wetland features, seasonally flooded fields, and forested swamps and other indistinct wetlands. No field confirmation was undertaken and the overall extent of some wetland types was likely underestimated.
4) Previous wetland mapping from the Canadian Wildlife Service and the B.C. Ministry of Sustainable Resource Management was also reviewed to determine if other wetlands were missed.

A total of 693.3 ha (9.9%) of wetland and floodplain was identified in the watershed (Table 23). Most occurrences were in the central valley (Langley and East sub-watersheds); a large natural wetland complex with extensive shrub swamps dominated by Pacific hardhack and red-osier dogwood interspersed with marshes vegetated primarily with reed canary grass. A portion of this area is in Campbell Valley Regional Park. Very few natural wetlands remain in the Surrey lowlands (3.2%) of the Surrey sub-watershed and agricultural use has resulted in drainage, vegetation removal of floodplains, and some infilling. Remnant wetlands remain along the river corridor and many floodplain areas are too wet to be cultivated. The estuary remains an important wetland in the West Sub-watershed, including the forested wetland in the Semiahmoo Indian Reserve. The City of White Rock has very few wetlands, most likely due to sloped topography rather than urban land use effects.

Table 23. Summary of wetlands and floodplains by drainage unit in the Little Campbell River watershed.

Drainage Unit			Wetland and Floodplain Area (ha)		Wetland and Floodplain Area %	
Sub-watershed	**Local & Mainstem watersheds**	*Associated tributaries*	**Total: 693.29**		**Total: 9.93%**	
East Sub-watershed	MS-1	*Kerfoot Creek*	231.26	231.26	42.55%	42.55%
Langley Sub-watershed	LW-1	*Unnamed north (214th St.)*	302.95	1.27	9.76%	0.39%
	LW-2	*Unnamed south (210th St.)*		12.8		4.27%
	LW-3	*Jacobson Creek*		8.21		1.35%
	LW-4	*Highland Creek, Jenkins Creek*		4.31		1.12%
	MS-2			276.36		18.63%
Surrey Sub-watershed	LW-5	*East Twin Creek, West Twin Creek*	66.31	0.92	3.17%	0.20%
	LW-6	*Kuhn Creek, Theodore Creek*		1.09		0.27%
	LW-7	*Sam Hill Creek, Thomson Creek*		5.29		1.02%
	MS-3			59		8.36%
West Sub-watershed	LW-8	*Fergus Creek, Murray Creek*	92.77	0.05	7.47%	0.01%
	LW-9	*McNally Creek*		2.34		1.15%
	MS-4			90.38		42.52%

4.1.2 Hydric Soils on Shallow Slopes

Hydric soils are soils that have: "formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part" (USDA 2006). They typically occur where drainage is poor because of a perched water table or depressional topography, or in floodplains where the local water table is frequently or periodically near the surface. Like wetlands and floodplains, saturated or hydric soils provide anaerobic conditions and slow water movement which accelerates denitrification. Hydric soils are also important because they are an indicator of the historic distribution and abundance of wetlands in watersheds in which vegetation change or drainage has removed other indicators (Stanley et al. 2005).

Hydric soils were identified using soil mapping of the Langley-Vancouver area (Luttmerding 1980) supplemented with similar mapped information for Whatcom County. Mapping did not include the City of White Rock so soils information was interpreted from topography and information provided in older soil mapping (Department of Agriculture 1938). Descriptions of soil texture, drainage, and water table features were used to identify their potential distribution in the watershed. Field surveys and evaluation of soil chroma were not undertaken. Stephen Stanley also reviewed the Langley-Vancouver soil descriptions and compared them to US Army Corps of Engineers 1987 Wetland Delineation Manual (USCOE 1987). Soil polygons with hydric soil were included as either the primary or secondary soil series. Table 24 describes hydric soil series in the Canadian portion of the watershed.

Hydric soils are not widespread in the LCR watershed (12.3% of total area), but are common in the central lowlands in the Surrey sub-watershed (27.9% of total area) (Map 14). Their occurrence coincides with the intensively farmed agricultural lands in that sub-watershed. The Langley sub-watershed had only 3.72% of total land cover in hydric soils. More than 90% of hydric soils in the watershed are classified as Cloverdale soil series (moderately fine to fine-textured marine deposits) that are poorly drained because of a dense subsoil and have a high water and nutrient-holding capacity (Bertrand et al. 1991). Almost all of the lowlands are less than 2% slope, indicating that this area likely supported depressional wetlands historically.

Table 24. Summary of hydric soils by drainage unit in the Little Campbell River watershed.

<table>
<tr><th colspan="3">Drainage Unit</th><th rowspan="2">Hydric Soil Area (ha)
Total: 855.66</th><th colspan="2">Hydric Soil Area %</th></tr>
<tr><th>Sub-watershed</th><th>Local & Mainstem watersheds</th><th>Associated tributaries</th><th colspan="2">Total: 12.26%</th></tr>
<tr><td>East Sub-watershed</td><td>MS-1</td><td>Kerfoot Creek</td><td>47.66</td><td>8.77%</td><td>8.77%</td></tr>
<tr><td rowspan="5">Langley Sub-watershed</td><td>LW-1</td><td>Unnamed north (214th St.)</td><td rowspan="5">115.54</td><td rowspan="5">3.72%</td><td>0.02%</td></tr>
<tr><td>LW-2</td><td>Unnamed south (210th St.)</td><td>3.79%</td></tr>
<tr><td>LW-3</td><td>Jacobson Creek</td><td>4.12%</td></tr>
<tr><td>LW-4</td><td>Highland Creek, Jenkins Creek</td><td>6.77%</td></tr>
<tr><td>MS-2</td><td></td><td>3.56%</td></tr>
<tr><td rowspan="4">Surrey Sub-watershed</td><td>LW-5</td><td>East Twin Creek, West Twin Creek</td><td rowspan="4">584.53</td><td rowspan="4">27.93%</td><td>17.77%</td></tr>
<tr><td>LW-6</td><td>Kuhn Creek, Theodore Creek</td><td>14.29%</td></tr>
<tr><td>LW-7</td><td>Sam Hill Creek, Thomson Creek</td><td>28.05%</td></tr>
<tr><td>MS-3</td><td></td><td>42.34%</td></tr>
<tr><td rowspan="3">West Sub-watershed</td><td>LW-8</td><td>Fergus Creek, Murray Creek</td><td rowspan="3">107.93</td><td rowspan="3">8.70%</td><td>9.77%</td></tr>
<tr><td>LW-9</td><td>McNally Creek</td><td>0.65%</td></tr>
<tr><td>MS-4</td><td></td><td>12.29%</td></tr>
</table>

4.1.3 Undisturbed Headwater Streams:

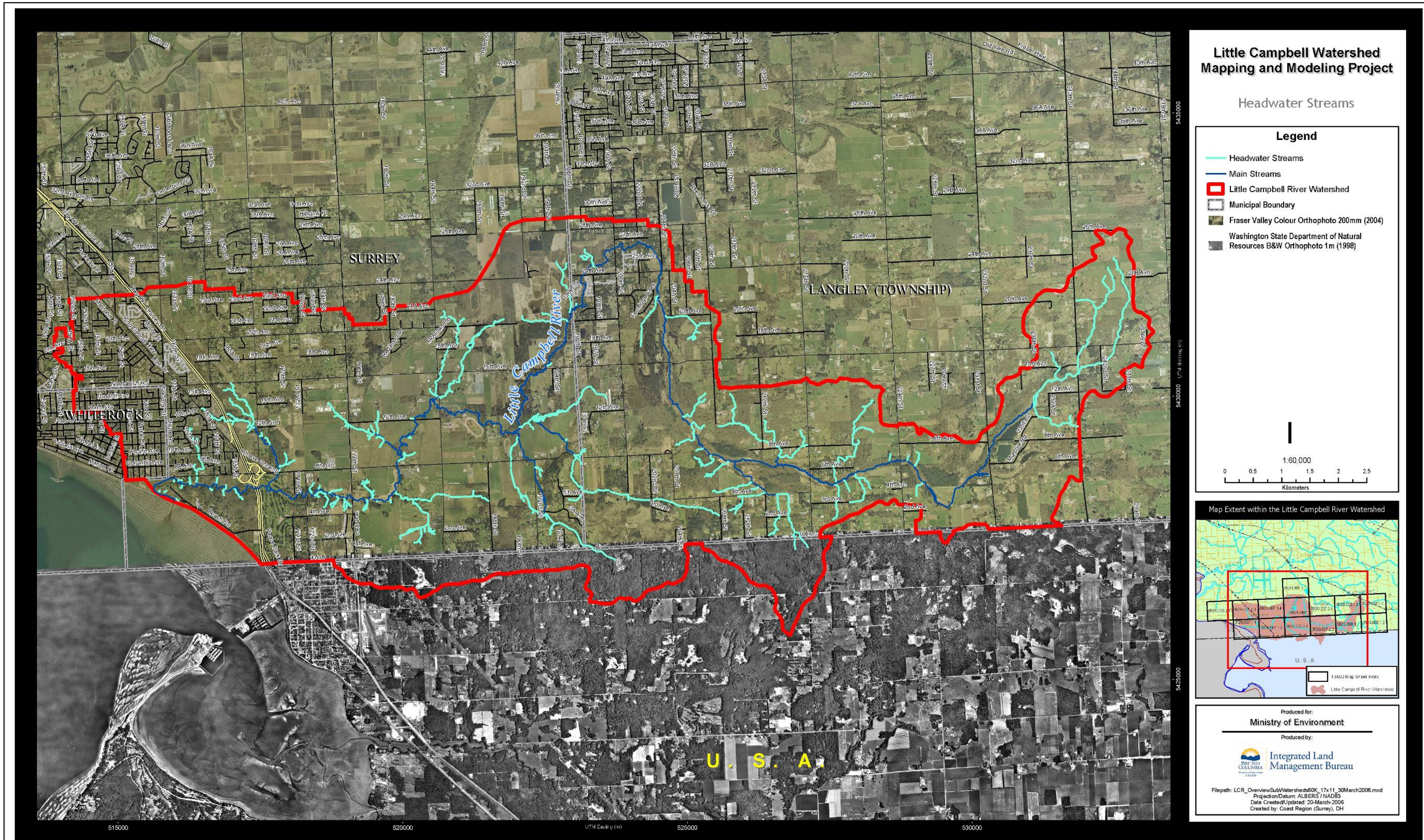
Headwater streams and their associated riparian zones play a critical, but often under-estimated role, in the origin and movement of sediment, organic matter, and nutrients in watersheds (Peterson et al. 2001, Gomi et al. 2002, Moore and Richardson 2003). Headwater streams are small and have seasonal flow regimes in response to precipitation; many flow intermittently. Horton (1945) and Naiman (1983) determined that headwater streams typically form 85% of the total watercourse length in a watershed (cited in Peterson et al. 2001). They are also closely linked to the surrounding terrestrial ecosystem through sediment-water interactions, soil-water nutrient movement, and interactions between the stream and riparian vegetation (e.g. shading, litterfall, wood debris).

Like wetlands and floodplains, most of the ability of headwater streams to capture or transform contaminants occurs in the interface between water and soil. The large surface to volume ratio of small streams is thought to result in the rapid uptake and processing of nitrate, for example (Peterson et. al. 2001). Shallow subsurface groundwater in headwater riparian zones passes by plant roots, soils rich in organic carbon and seasonal anaerobic conditions. In combination, these are important conditions for nitrate uptake and denitrification. However, patterns of denitrification likely vary considerably in riparian zones depending on topography and soil porosity (Stanley et al. 2005).

Because the stream channel network in the LCR watershed has been extensively modified through drainage and stream relocations, identifying headwater streams is difficult. In addition, stream mapping varied considerably between the three primary jurisdictions in the watershed (Langley, Surrey, and Whatcom County) making it difficult to identify headwater streams at a consistent level of detail. To increase comparability, all anthropogenic watercourses such as ditches and drainage channels were excluded, as well as the LCR mainstem (4th order channel). This created a stream channel network that included all mapped natural stream channels between 1st and 2rd order (Map 15, Table 25). 1st and 2nd order channels are shown in light blue and 3rd and 4th order channels are show in dark blue. Headwater streams occur in every sub-watershed and local or mainstem watershed in the study area. LW-3, 8 and 9 and MS-2 and 4, had a slightly higher proportion of forested headwater streams.

Table 25. Summary of total headwater streams and forested headwater streams by drainage unit in the Little Campbell River watershed.

Drainage Unit			Headwater Streams (km)		Headwater Stream Density (km/km^2)		Forested Headwater Streams (ha)		Forested Headwater Streams %	
Sub-watershed	Local & Mainstem watersheds	*Associated tributaries*	Total: 73.31		Total: 0.00097		Total: 203.93		Total: 47.98%	
East Sub-watershed	MS-1	*Kerfoot Creek*	11.49	11.49	0.00101	0.00101	21.62	21.62	60.35%	60.35%
Langley Sub-watershed	LW-1	*Unnamed north (214th St.)*	36.07	5.53	0.00116	0.0017	114.53	14.25	37.83%	44.75%
	LW-2	*Unnamed south (210th St.)*		5.17		0.00169		12.67		42.84%
	LW-3	*Jacobsen Creek*		8.18		0.00134		26.95		62.13%
	LW-4	*Highland Creek, Jenkins Creek*		4.79		0.00125		13.81		51.26%
	MS-2			12.40		0.00084		46.85		62.37%
Surrey Sub-watershed	LW-5	*East Twin Creek, West Twin Creek*	18.38	5.65	0.00088	0.00121	38.19	13.00	41.63%	41.76%
	LW-6	*Kuhn Creek, Theodore Creek*		5.03		0.00125		7.82		31.61%
	LW-7	*Sam Hill Creek, Thomson Creek*		2.92		0.00056		2.60		15.86%
	MS-3			4.78		0.00068		14.77		51.47%
West Sub-watershed	LW-8	*Fergus Creek, Murray Creek*	7.77	4.85	0.00063	0.00059	29.61	16.20	31.68%	56.95%
	LW-9	*McNally Creek*		1.52		0.00074		6.14		65.13%
	MS-4			1.40		0.00066		7.27		64.97%



Map 15. Distribution of headwater streams in the Little Campbell River watershed.

4.1.4 Forests and Riparian Areas

To supplement our understanding of the functioning of watershed-level processes in the LCR watershed, the abundance and distribution of forest cover and forested riparian area was assessed. Forests and riparian areas are not proven pollution sinks but forested areas represent land cover where water quality and hydrologic processes are generally unimpaired by human activities.

Forests are a critical component of watershed hydrologic processes as they intercept precipitation in the tree canopy. A study of water dynamics in Puget Sound catchments found that interception and transpiration associated with vegetation was substantial: in mixed forest, (which is dominant in the Little Campbell), 38% was intercepted and 35% was transpired, and in pasture 15% was intercepted and 39% was transpired (Bauer and Mastin 1997). Based on these estimates, conversion of forest to pasture can result in a 19% increase in the amount of runoff. Soils in forested areas are also important for hydrology; they are highly permeable and convey water into shallow subsurface layers.

The role of forests in maintaining water quality is less direct, particularly at a watershed scale. Riparian forests are known to reduce the transfer of contaminants and nutrients, particularly nitrogen, from adjacent agricultural lands through capture of particulate matter and through subsurface denitrification (Verhoeven et al. 2006, Peterjohn and Correll 1984). The potential for groundwater denitrification and nitrate uptake by plants is high in riparian areas with shallow groundwater (Stanley et al. 2005, Gold et al. 2004). Groundwater traveling close to the surface in riparian areas passes by plant roots, soils rich in organic carbon and seasonal anaerobic conditions. In combination, these are important conditions for nitrate uptake and denitrification. Trapping of sediment and particulates that bind with contaminants are more readily facilitated through wider riparian buffers with a mosaic of herbaceous, shrub and tree layers.

Research in the Pacific Northwest has shown that red alder is an important source of nitrogen, phosphorous, magnesium, and potassium to streams (Volk 2004, Compton et al. 2003). Concentrations of dissolved nitrate in stream water may increase up to 0.3 mg/L in watersheds of 2.5–15% red alder (Volk 2004). Forests in the LCR watershed were measured without subdivision into conifer and deciduous components or by species composition. A preliminary estimate of the cover of red alder in the LCR watershed, however, is from 10–20% of the total watershed area.

Undifferentiated (deciduous, coniferous, or mixed forest) forest cover polygons larger than 200 square meters were delineated using orthophotos. Forest was defined as woody vegetation greater than 5 m in height with at least 50% canopy closure. Orthophoto coverage for the watershed was inconsistent and included colour 2004 orthophotos for City of Surrey, City of White Rock, and Township of Langley, and black and white 1998 orthophotos for portions of the watershed in Whatcom County. A total of 902 forest polygons were mapped in the watershed encompassing an area of 2453.65 ha or 32.4% of the total watershed area. Polygon size ranged from 0.01 ha to 151.2 ha with a mean of 2.74 ha.

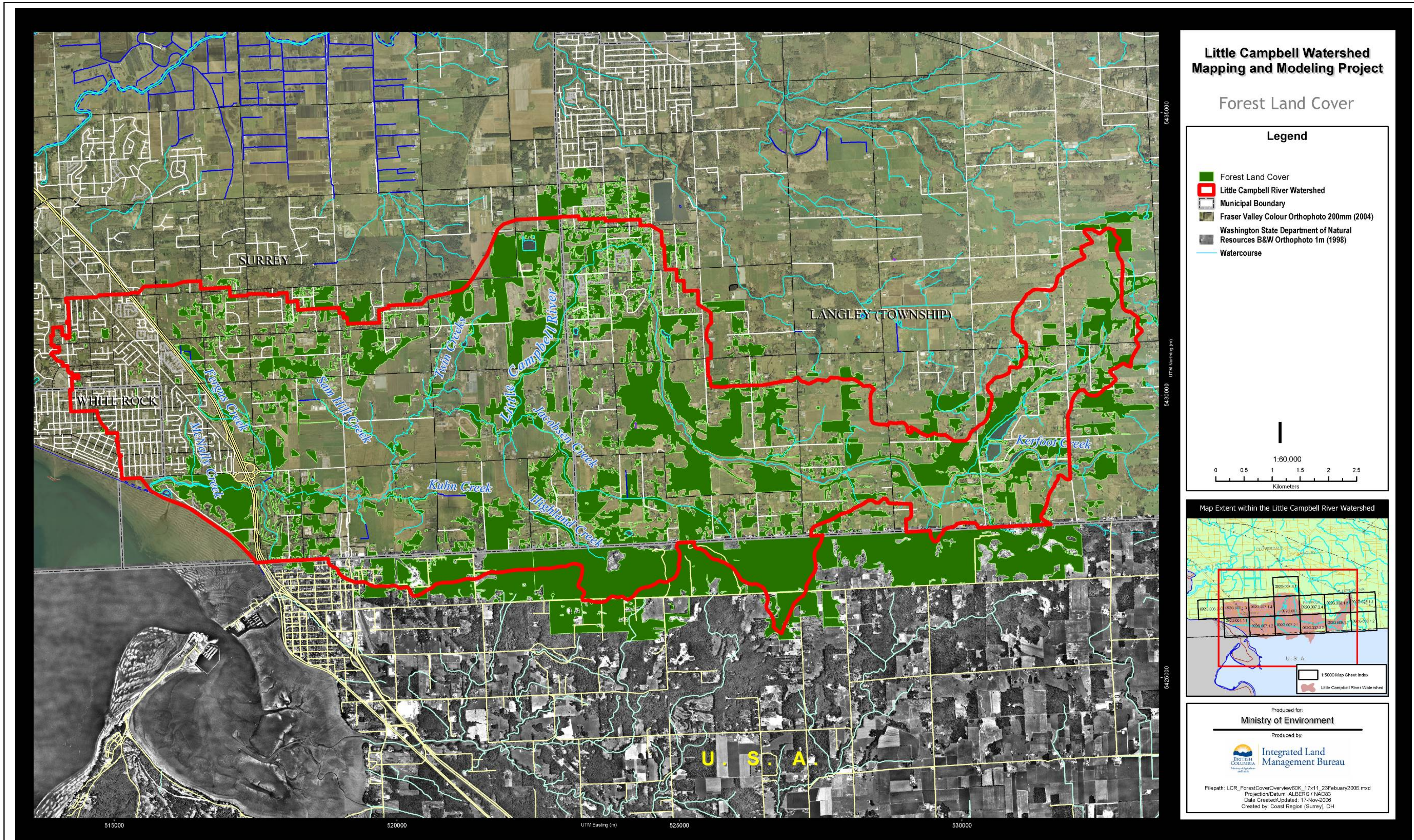
Table 26 and Map 16 describe the distribution of forested areas within the watershed. Forest was most prevalent in the Langley sub-watershed (44.0%) and least common in the West sub-watershed (16.3%). The largest patches of forest were found in Whatcom County (two patches >140 ha) and in the vicinity of Campbell Valley Regional Park (patches of 149.1 ha and 99.9 ha). The forest patch within the Semiahmoo Indian Reserve was also large (62.8 ha).

The US portion of the watershed had a much higher proportion of forest cover (84.1%) than the Canadian portion (28.7%). Most forest was deciduous (red alder or black cottonwood).

Table 26. Summary of forest cover by drainage unit for the Little Campbell River watershed.

Drainage Unit			**Area (ha)**		**Forest Area (ha)**		**% Forest Area**	
Sub-watershed	**Local & Mainstem watersheds**	*Associated tributaries*	**Total: 7582.56**		**Total: 2453.65**		**Total: 32.40%**	
East Sub-watershed	MS-1	*Kerfoot Creek*	1142.2	1142.2	340.64	340.64	29.7%	29.7%
Langley Sub-watershed	LW-1	*Unnamed north (214th St.)*	3106.6	325.2	1366.01	100.02	44.0%	30.8%
	LW-2	*Unnamed south (210th St.)*		305.6		195.49		65.2%
	LW-3	*Jacobson Creek*		609.1		228.3		37.4%
	LW-4	*Highland Creek, Jenkins Creek*		383.9		210.04		54.5%
	MS-2			1482.8		632.14		42.6%
Surrey Sub-watershed	LW-5	*East Twin Creek, West Twin Creek*	2092.5	468.3	544.6	125.76	26.0%	26.8%
	LW-6	*Kuhn Creek, Theodore Creek*		401.5		162.64		40.5%
	LW-7	*Sam Hill Creek, Thomson Creek*		517		122.21		23.6%
	MS-3			705.6		134		19.0%
West Sub-watershed	LW-8	*Fergus Creek, Murray Creek*	1241.2	824.1	202.4	126.73	16.3%	15.4%
	LW-9	*McNally Creek*		204.5		11.43		5.6%
	MS-4			212.5		64.23		30.2%

In the LCR watershed, riparian areas range from exposed soils on agricultural lands to native forest communities to shrubs and grasses (Drever and Brown 1999). The degree to which riparian buffers are protected and maintained in a natural state, and their relative size are governed by different policies and regulatory requirements. In B.C., riparian areas on non-agricultural lands are regulated by local governments through the Riparian Areas Regulation (MOE 2006a). Before development may occur, a qualified environmental professional must conduct an assessment of the riparian area as per the regulation (MOE 2006a).



Map 16. Present extent of forested land cover in the Little Campbell River watershed.

Development may also be subject to Department of Fisheries and Oceans approval. Activities on agricultural lands have variable BMP's for setbacks adjacent to watercourses. Buffers can be designated based on DFO requirements or adjacent agricultural use (e.g. 100 meters for storage of dead animals) (MAFF 2005).

In the LCR watershed, 45% of riparian buffers, at least 30m in width, are composed of forest cover (Table 27). It is unknown how much riparian area is vegetated within the watershed; this could be a next step for assessment. A suggested minimum target being contemplated for habitat rehabilitation in the GVRD is for 75% of third order watershed riparian zones to be continuously vegetated with 30m wide vegetated buffers (Lee and Rudd 2003, Env Can and CWS 2004).

Table 27. Summary of drainage units showing percentage of forested riparian buffers (30 meters on either side of watercourse)

Drainage Unit			**Area of watershed unit within 30m riparian area (ha)**		**Percent of forested riparian area**	
Sub-watershed	**Local & Mainstem watersheds**	*Associated tributaries*	**Total: 626.59**		**Total: 45.03%**	
East Sub-watershed	MS-1	*Kerfoot Creek*	76.37	76.37	6.36%	6.36%
Langley Sub-watershed	LW-1	*Unnamed north (214th St.)*	149.03	32.78	8.48%	2.41%
	LW-2	*Unnamed south (210th St.)*		34.65		2.17%
	LW-3	*Jacobson Creek*		48.78		4.83%
	LW-4	*Highland Creek, Jenkins Creek*		36.79		3.10%
	MS-2			150.31		12.71%
Surrey Sub-watershed	LW-5	*East Twin Creek, West Twin Creek*	303.32	31.76	25.10%	2.10%
	LW-6	*Kuhn Creek, Theodore Creek*		24.73		1.25%
	LW-7	*Sam Hill Creek, Thomson Creek*		18.75		0.55%
	MS-3			73.78		4.58%
West Sub-watershed	LW-8	*Fergus Creek, Murray Creek*	97.86	35.84	5.50%	3.14%
	LW-9	*McNally Creek*		9.58		1.00%
	MS-4			30.93		2.24%

4.1.5 Parks and Other Greenspaces

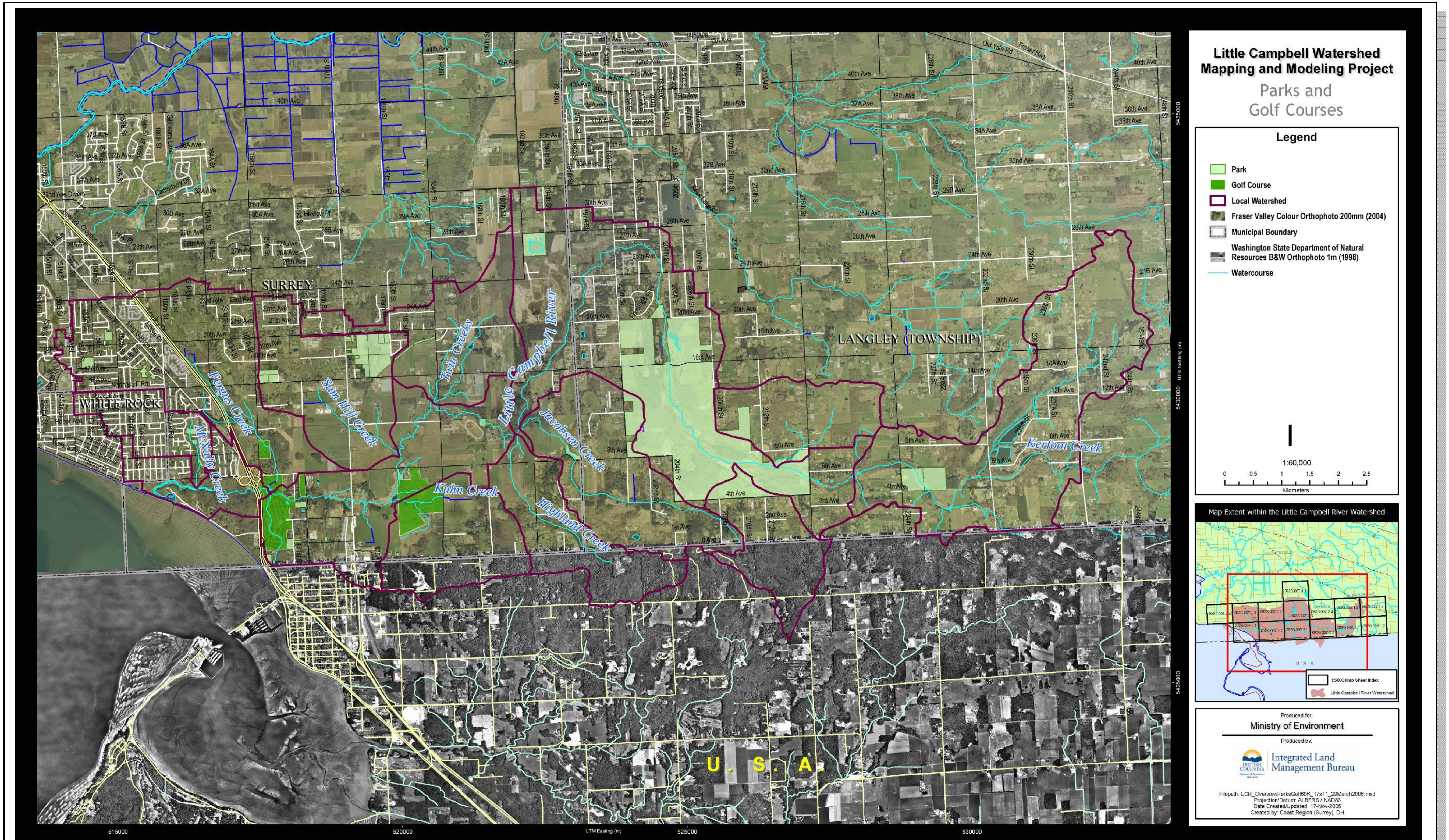
In reviewing the literature, a great deal of information exists on the values of parks and protected areas for preserving the ecological function of landscapes, providing refugia for species or acting as carbon sinks to mitigate greenhouse gas emissions. As well, many watershed protection and stormwater planning initiatives recognize the need to allocate areas of the land base for BMP's such as constructed wetlands, absorbent landscaping and other runoff treatment facilities (GVRD 2002). Natural areas and vegetated landscapes are also important to the maintenance and recharge of groundwater resources. However, the direct potential for parks and publicly accessible lands such as golf courses to serve as NPS pollution sinks has not been as widely explored.

There are 85 parks in the watershed (Table 28 and Map 17), the majority of which are managed for human use as opposed to maintaining natural values. The GVRD has the largest area of parkland (544 ha) in the form of Campbell Valley Regional Park, located in the Langley sub-watershed.

While parks and their associated ecological communities such as wetlands and urban forests provide potential value for NPS pollution reduction, they are not without their own set of pollution challenges. For example, equestrian use and dog walking may cause disturbance to sensitive habitats and potentially contribute to fecal contamination and nutrient loading to surface waters. To address these issues, groups like the Campbell Valley Park Association are working with stakeholders to implement codes of practice and ethics for use of the park trails and natural areas. Compliance and effectiveness monitoring will be key to the success of these programs.

There are seven golf courses in the LCR watershed covering 133.6 ha all of which are located in the western portion of the watershed (Surrey-White Rock area). Golf courses can adversely effect the environment due to runoff from fertilizer and pesticide applications; however, a well-managed, properly irrigated golf course can also act as a potential sink. Integration of naturally occurring wetlands and riparian buffers can assist their functionality as pollution sinks. It is unknown whether the seven existing golf courses in the watershed are currently managed in such a way.

Grasslands also may act as a potential sink when nitrogen is held by soil biota and organic matter. Mild winters in the lower mainland allow cool season grasses to have a long growing season and they are extremely efficient at utilizing nitrogen. The cover they provide also can act as a filter, ensuring higher infiltration of precipitation instead of surface runoff.



Map 17. Distribution of parks and publicly accessible lands in the Little Campbell River watershed

Table 28. Distribution of parks and publicly accessible lands by drainage unit in the Little Campbell River watershed

Drainage Unit			**Number of Parks** (some parks overlap more than one watershed)		**Parkland Area (ha)**		**Number of Golf Courses**		**Golf Course Area (ha)**	
Sub-watershed	**Local & Mainstem watersheds**	*Associated tributaries*	**Total: 85**		**Total: 725.5**		**Total: 7**		**Total: 133.6**	
East Sub-watershed	MS-1	*Kerfoot Creek*	4	4	60.4	60.4	0	0	0	0
Langley Sub-watershed	LW-1	*Unnamed north (214th St.)*	12	1	582	21.7	0	0	0	0
	LW-2	*Unnamed south (210th St.)*		1		32.1		0		0
	LW-3	*Jacobson Creek*		2		28.7		0		0
	LW-4	*Highland Creek, Jenkins Creek*		0		0		0		0
	MS-2			8		499.5		0		0
Surrey Sub-watershed	LW-5	*East Twin Creek, West Twin Creek*	36	7	65.4	36.3	4	0	115.2	0
	LW-6	*Kuhn Creek, Theodore Creek*		0		0		1		43.2
	LW-7	*Sam Hill Creek, Thomson Creek*		21		52		0		0
	MS-3			8		98		3		72
West Sub-watershed	LW-8	*Fergus Creek, Murray Creek*	33	22	175.2	121.4	3	2	19	15
	LW-9	*McNally Creek*		11		53.8		0		0
	MS-4			0		0		1		4

CONCLUSIONS & RECOMMENDATIONS

Summary of Findings

The purpose of this study was to collate and assess existing information on current water uses, potential pollution sources, particularly fecal coliform sources, and potential pollution "sinks", that provide natural water quality protection services to the LCR watershed.

Areas of Concern – Water Use and Potential Pollution Sources

Table 29 summarizes the available information on factors of interest within the LCR watershed with respect to water use (surface and groundwater extraction), and potential pollution sources from agricultural and urban settings.

Water Use – Areas of Concern

The main issues identified through the characterization of **water use** in the LCR watershed are:

- water extraction and low base flows, particularly during summer months, with implications for aquatic life, and
- unknown water use demand and watershed/aquifer capacity,
- water uses, including aquatic life, shellfish harvesting, livestock watering and recreational use, are vulnerable when water quality is impacted by land use activities,

Water is heavily extracted from surface and groundwater within the Little Campbell River watershed. The greatest density of groundwater wells was found within the Langley Sub-watershed, especially within mainstem watershed two (MS-2) and local watershed 3 (Jacobsen Creek) overlying the Brookswood aquifer. The Brookswood aquifer is particularly vulnerable to groundwater extraction due to its qualities as an unconfined and shallow aquifer. Low flows are a concern in the watershed, especially during summer months, when extraction rates are highest and precipitation is lowest. Modeling work commissioned by the Township of Langley (Golder & Associates 2005) has suggested that since 1960, post development impacts to groundwater resources have resulted in a loss of up to 4% of base flows for the LCR watershed. The study also predicted that a further 5% loss in baseflow could be expected if land development and population growth rates continue as outlined in the OCP (Golder & Associates 2005). While the watershed is considered highly productive from a fisheries perspective (BCCF 2006), when compared to other nearby watersheds current summer-fall base flows are considered deficient (Ptolemy, 2006)

An accurate estimate of groundwater extraction demand is difficult due to historic voluntary submission of well records. The location and number of wells, the actual timing of extraction and the extent to which users exceed capacity is largely unknown. In addition, many of the well records within the existing database are recorded as "unknown use" (75%). These data gaps make it difficult for decision-makers to determine water-use thresholds and to effectively manage water resources in the LCR watershed. A detailed census of water use is not yet being conducted in the watershed; however, municipalities are focusing on water conservation efforts, and the Township, in partnership with the MOE, are now developing a water management plan, the first one of its kind in B.C. (Dixon-Warren 2006).

Non-point source pollution is diffuse and cumulative. Fecal coliform levels are of interest in the Little Campbell River where there are livestock watering and irrigation water uses and near the mouth in Semiahmoo Bay where boating and swimming occur. Although fecal coliform levels have been a focus in this report, other contaminants generated from land use activities, such as increased urbanization, can, if in high enough concentrations, impact water uses.

In the Little Campbell River aquatic life has been impacted by low dissolved oxygen, particularly in the upper watershed. Elevated fecal coliforms at the mouth of the Little Campbell River contribute to fecal coliform levels in the Bay that have triggered the closure of bi-valve shellfish harvesting.

Potential Pollution Sources - Areas of Concern

Potential sources of bacteriological contamination within the watershed include human waste (from sanitary sewers and on-site sewage disposal systems), agricultural waste (from improper manure management and drain tile fields), and domestic pet waste.

Human Waste (Sewage):

The main issues identified through the characterization of **human waste management** in the LCR watershed are:

- areas containing a high density of on-site sewage disposal systems (SDS), particularly those installed in vulnerable soils where SDS system failure is more likely to occur; and
- lack of SDS information regarding their location, age, condition, or history of failure.

On-site sewage disposal systems (SDS) may present a greater risk of contamination than sanitary sewers due to their widespread, high density distribution across the watershed and their greater potential for failure. The greatest concentrations of SDS were in the Langley sub-watershed (1124) and its corresponding MS-2 drainage unit (828). While soils in this area show somewhat mixed vulnerability for SDS failure, it is important to note that this area of the watershed also supports the largest local concentration of wells (378), and overlays a major aquifer system (Brookswood). Another area of interest is the East sub-watershed, which although it has the lowest number of sub-watershed SDS (223), does have the second highest number of local wells (165) in MS-1. This area, the headwaters of the LCR, overlays two of the largest and higher profile aquifers in the area (Brookswood and Hopington).

Three local watersheds may be of particular concern (LW-1, 7 and 9) due to the predominance of more vulnerable soil types. They do not support a high concentration of SDS; however, even small amounts of fecal coliform leaching from failed septic fields are sufficient to contaminate surface or groundwater.

While it has been estimated that there are 2175 septic systems there is little information on how many of these are properly functioning, how many are still in service or how often they are serviced. Age of on-site SDS is difficult to determine due to lack of records and undocumented repairs; and many landowners are unaware that their property contains an SDS. A critical concern in the LCR watershed is lack of knowledge of the exact number of septic systems and more specifically the extent and degree of failure.

Animal Manure:

The main issues identified through the characterization of **animal manure management** in the LCR watershed are:

- the high density of horses, corresponding with the greatest number of Agricultural Waste Control Regulation (AWCR) complaints;
- the high density of hobby farm operations, typically having a lower level of compliance with the AWCR than larger commercial operations;
- improper manure management;
- potential contamination through agricultural drain tile systems;
- areas where pet-owners allow their dogs to remain off-leash near the river; and
- unknown number of domestic animals, particularly cats, that may contribute to fecal contamination in the watershed.

While there is a great deal of information on the amount and nature of livestock and agricultural land use in the watershed, there is little knowledge of the extent of contamination on a site-specific basis for all operations in the watershed.

Horses are the primary livestock type in the watershed. Recent agricultural land use inventories (MAL 2005, MAL 2001) indicate 289 horse farms plus 12 stable/riding facilities throughout the watershed. The Langley sub-watershed supports the greatest number of these farms, ranging from 138 small-scale to 9 large-scale farms. Local and mainstem watersheds LW-1, LW-2, LW-3, LW-4, and MS-2) show the highest concentrations of horse operations. Horse access and facility management also constitute the largest number of agricultural waste complaints in the regional MOE database.

Despite the dominance of horses in the watershed, cattle and poultry appear to contribute the greatest amount of fecal coliform production. There are not many dairy or beef cattle operations in the watershed (39 beef, 7 dairy). A few medium and large-scale farms do exist, and are located mainly in the Surrey and Langley sub-watersheds. Non-compliance issues associated with cattle operations in the watershed have been related to improper manure management (storage and application) as well as direct livestock access to watercourses (MOE Regional Agricultural Complaints database 1991-2004). Cattle produce a significant amount of manure, which tends to be much more liquid than horse manure, and requires concerted efforts for adequate containment and storage prior to use as fertilizer (Schmidt 2006).

Poultry is not a dominant livestock type by number of operations, but does produce large volumes of manure. The two potentially largest concentrations of poultry occur in the East sub-watershed (MS-1). The regional MOE agricultural waste complaints database indicates that there have been incidences of non-compliance in the poultry industry (14 complaints since 1991), mainly due to improper manure storage (uncovered piles).

While large-scale farms with high-density livestock have the potential for producing greater amounts of manure, relatively lower levels of compliance with the Agricultural Waste Control Regulation have been found at smaller hobby style farms (Rushworth and Younie 2006). It is suspected the greater degree of non-compliance amongst hobby farms is related to fewer available resources and lack of awareness regarding statutory requirements and best management practices (Schmidt, Rushworth 2006).

Many agricultural operations use drain tiles as drainage infrastructure. Drain tiles may transport bacteriological contamination into watercourses if not managed properly. Unfortunately, it is unknown how many farms contain drain tile infrastructure, how old these structures are, and if they are transporting contaminants to the LCR watershed.

Domestic pet waste is a potentially significant source of bacterial contamination in the LCR watershed. The number of dog licenses was calculated for each municipality on the Canadian side of the watershed. The Township of Langley and the City of White Rock had the greatest number of dog licenses (451 and 449 respectively). Areas where dogs are allowed off-leash adjacent to watercourses such as Campbell Valley Regional Park and the LCR estuary area within Semiahmoo First Nations Reserve lands have been identified as areas of concern. The potential contribution of bacteriological contamination from other domestic pets (e.g. cats) or wildlife (e.g. waterfowl) is unknown.

Urban Runoff:

The main issues identified through the characterization of **urban runoff** in the LCR watershed are:

- rapid urban development and population growth, resulting in increased impervious area and increased movement of contaminants into watercourses.

Table 29. Summary of 'best available information' on water and land use characteristics with relevance to water quality in the Little Campbell River watershed by drainage unit

Little Campbell River Watershed Drainage Units				Surface Water Demand (Number of Points of Diversion)		Groundwater Demand (Number of Wells)		Number of On-site Sewage Disposal Systems (SDS)		Dominant livestock operations (potential manure production in lbs/day)		Total Impervious Area (TIA) %		Effective Impervious Area (EIA) %		Road Density (km/km^2)	
Sub-watershed	**Local & Mainstem watersheds**	*Associated tributaries*	*Area (ha)* Total = **7582.5**	**82 known** Total Licensed Volume = **3524.51 m^3/day**		**1099 known**		**Estimated Total: 2175**		Horses - 289 operations (90,037 – 350,591lbs/day) Dairy Cattle - 7 operations (37,546 – 79,495 lbs/day) Beef Cattle - 39 operations (14,792 – 34,435 lbs/day) Sheep/Goats - 25 operations (422 – 2,255 lbs/day) Poultry - 21 operations (approx. 94,500 lbs/day)		**Total: 9.9%**		**Total: 5.7%**		**Total: 3.5**	
East Sub-watershed	MS-1	Kerfoot Creek	1142.2	7	7	165	165	223	223	Horses - dominant, but med and large-scale beef cattle, dairy, sheep/goat and poultry also present	Horses - dominant, but med and large-scale beef cattle, dairy, sheep/goat and poultry also present	4.60%	4.60%	1.10%	1.10%	1.7	1.7
Langley Sub-watershed	LW-1	*Unnamed north (214th St.)*	*325.2*	25	0	627	38	1124	60	Horses - dominant, but med and large-scale beef cattle, dairy, sheep/goat and poultry also present	Horses - dominant	4.20%	4.60%	1.30%	1.00%	2.1	1.4
	LW-2	*Unnamed south (210th St.)*	*305.6*		1		34		49		Horses - dominant		2.80%		0.50%		2
	LW-3	*Jacobsen Creek*	*609.1*		1		122		142		Horses - dominant with one large-scale dairy cattle operation		3.90%		0.90%		1.7
	LW-4	*Highland Creek, Jenkins Creek*	*383.9*		5		55		45		Med and large-scale horse operations, one large-scale dairy cattle operation		3.10%		0.60%		2.1
	MS-2		*1482.8*		18		378		828		Horse and beef cattle - dominant		4.90%		1.80%		2.5
Surrey Sub-watershed	LW-5	*East Twin Creek, West Twin Creek*	*468.3*	40	12	229	57	439	174	Horses - dominant, but med and large-scale beef cattle, dairy, sheep/goat and poultry also present	Horses - dominant	9.60%	9.00%	5.20%	4.30%	2.5	2.6
	LW-6	*Kuhn Creek, Theodore Creek*	*401.5*		1		30		26		Med beef and dairy cattle operations and med poultry operation		4.30%		1.30%		2.3
	LW-7	*Sam Hill Creek, Thomson Creek*	*517*		5		76		205		Limited small-scale horse and beef cattle operations		10.70%		5.40%		2.6
	MS-3		*705.6*		22		66		34		Horse and beef - dominant		12.20%		8.00%		2.6
West Sub-watershed	LW-8	*Fergus Creek*	*824.1*	10	8	76	59	389	354	Only one medium scale beef cattle operation	One med-sized beef cattle operation	30.10%	28.60%	22.10%	20.90%	10	7.5
	LW-9	*McNally Creek*	*204.5*		0		7		14		No significant livestock operations		41.90%		31.00%		17.9
	MS-4		*212.5*		2		10		21		No livestock operations		24.70%		18.40%		12.3

Although the majority of the LCR watershed is currently rural, urban areas will continue to increase as development continues. Local watersheds in the West sub-watershed already have impervious cover considered above the 10-15% threshold for maintaining aquatic ecosystem health. Several urban and light industrial developments are being built or are in the planning stage within the watershed. Areas with current and proposed urban development are of concern regarding the potential for NPS pollution including sediments, fecal coliforms, increased water temperatures, hydrocarbons and other chemicals.

Areas to Protect and Restore – Ecosystem Services and Pollution Sinks:

Table 30 summarizes potential pollution sinks identified within the LCR watershed by drainage unit. For the purposes of this study the focus was on identifying watershed features which may potentially contribute to the capture, transformation or removal of fecal coliform bacteria and/or nitrate. More work will be needed to measure both how much these sinks have been impaired by human disturbance (e.g. wetland loss, drainage) and their potential for restoration. Potential pollution sinks in the LCR watershed mainly consisted of wetlands, floodplains, and hydric soils (Map 14). Riparian areas, forest cover, and parkland can also aid in mitigating pollution impacts.

Wetlands, Floodplains and Hydric Soils

A total of 693.3 ha (9.9%) of wetland and floodplain was identified in the watershed. Most occurrences were in the central valley (Langley and East sub-watersheds); a large natural wetland complex with extensive shrub swamps. A portion of this area is in Campbell Valley Regional Park. Very few natural wetlands remain in the lowlands of the Surrey sub-watershed (3.2%) and land use has resulted in drainage, vegetation removal in floodplains, and some infilling. Remnant wetlands remain along the river corridor and many floodplain areas are too wet to be cultivated. The estuary remains an important wetland in the West Sub-watershed, including the forested wetland in the Semiahmoo Indian Reserve. The City of White Rock has very few wetlands; this is most likely due to sloped topography limiting wetland development rather than urban land use effects.

Hydric soils are not widespread in the LCR watershed (12.3% of total area), but are common in the central lowlands in the Surrey sub-watershed (27.9% of total area). Their occurrence coincides with the intensively farmed agricultural lands in that sub-watershed. Almost all of the lowlands are less than 2% slope, indicating that this area likely supported depressional wetlands historically. The Langley sub-watershed had only 3.7% of total land cover in hydric soils.

Riparian Areas, Forest Cover and Parkland

Headwater streams and their associated riparian zones play a critical, but often under-estimated role, in the origin and movement of sediment, organic matter, and nutrients in watersheds. Headwater streams occur in every sub-watershed and local or mainstem watershed in the study area. Local watershed (LW)-3 and 8, and mainstem watershed (MS)-1, 2 and 4, had a slightly higher proportion of forested headwater streams.

The role of forests in maintaining water quality is less direct, particularly at a watershed scale; however, riparian forests are known to reduce the transfer of nutrients and other contaminants. Forested areas were most prevalent in the Langley sub-watershed (44.0%) and least common in the West sub-watershed (16.3%). The largest patches of forest were found in Whatcom County (two patches >140 ha) and in the vicinity of Campbell Valley Regional Park (patches of 149.1 ha and 99.9 ha). The forest patch within the Semiahmoo Indian Reserve was also large (62.8 ha). Most forest was deciduous (red alder or black cottonwood).
Forty-five percent of the LCR's riparian buffers at least 30 meters in width are composed of forest cover. A suggested minimum target being contemplated for habitat rehabilitation in the GVRD is for 75% of third order watershed riparian zones to be continuously vegetated with 30 meter wide vegetated buffers (Lee and Rudd 2003, Environment Canada 2004). Analysis of the percentage of total stream length that is actually vegetated and the associated buffer width would be a next step for assessment.

There are 85 parks in the watershed, the majority of which are managed for human use as opposed to maintaining natural values. The GVRD has the largest area of parkland (544 ha) in the form of Campbell Valley Regional Park, located in the Langley sub-watershed. While parks and their associated ecological communities such as wetlands and urban forests provide potential value for NPS pollution reduction, they may also contribute to pollution contamination in the form of pet and/or equestrian waste, depending on park use. There are 7 golf courses in the LCR watershed covering 133.6 ha all of which are located in the western portion of the watershed (Surrey-White Rock area). Golf courses can adversely affect the environment due to runoff from fertilizer and pesticide applications; however, a well-managed, properly irrigated golf course can also act as a pollution sink.

The preliminary assessment of potential pollution sinks in the LCR watershed identified two areas as the most functional and most important to protect and/or restore.

- The extensive floodplain wetlands along the central and eastern portion of the river. Levels of fecal coliform bacteria and nitrate are generally lower in the portion of watershed with intact floodplain wetlands despite the agricultural and rural land use in the East sub-watershed. Protection of the remaining floodplain wetlands is critical for maintaining these processes; there are also restoration opportunities in wetlands affected by agriculture.
- The lowlands of the City of Surrey contain a large area of hydric soils on shallow slopes that historically likely had forested and non-forested wetlands. It is unknown how much these hydric soils contribute to reducing NPS pollution, but the lack of floodplain wetlands such as off-channel ponds and shrub swamps likely substantially reduces the potential for fecal coliform bacteria removal. A preliminary assessment found many opportunities to restore floodplain wetlands, however, most are on private land.

Table 30. Summary of factors contributing to ecosystem services and potential pollution sinks in the Little Campbell River watershed by drainage unit

Drainage Unit			Wetland and Floodplain Area (ha)		% Wetland and Floodplain Area		Hydric Soil Area (ha)	% Hydric Soil Area		Headwater Streams (km)		Forested Headwater Streams (ha)		Forest Area (ha)		% Forest Area		Number of Parks		% Parkland Area	
Sub-watershed	**Local & Mainstem watersheds**	*Associated tributaries*	**Total: 693.29**		**Total: 9.93%**		**Total: 855.66**	**Total: 12.26%**		**Total: 73.31**		**Total: 203.93**		**Total: 2453.65**		**Total: 32.40%**		**Total: 85**		**Total: 9.57%**	
East Sub-watershed	MS-1	*Kerfoot Creek*	231.26	231.26	42.55%	42.55%	47.66	8.77%	8.77%	11.49	11.49	21.62	21.62	340.64	340.64	29.7%	29.7%	4	4	5.29%	5.29%
Langley Sub-watershed	LW-1	*Unnamed north (214th St.)*	302.95	1.27	9.76%	0.39%	115.54	3.72%	0.02%	36.07	5.53	114.53	14.25	1366.01	100.02	44.0%	30.8%	12	1	18.73%	6.67%
	LW-2	*Unnamed south (210th St.)*		12.8		4.27%			3.79%		5.17		12.67		195.49		65.2%		1		10.50%
	LW-3	*Jacobsen Creek*		8.21		1.35%			4.12%		8.18		26.95		228.3		37.4%		2		4.71%
	LW-4	*Highland Creek, Jenkins Creek*		4.31		1.12%			6.77%		4.79		13.81		210.04		54.5%		0		0.00%
	MS-2			276.36		18.63%			3.56%		12.40		46.85		632.14		42.6%		8		33.69%
Surrey Sub-watershed	LW-5	*East Twin Creek, West Twin Creek*	66.31	0.92	3.17%	0.20%	584.53	27.93%	17.77%	18.38	5.65	38.19	13.00	544.6	125.76	26.0%	26.8%	36	7	3.13%	7.75%
	LW-6	*Kuhn Creek, Theodore Creek*		1.09		0.27%			14.29%		5.03		7.82		162.64		40.5%		0		0.00%
	LW-7	*Sam Hill Creek, Thomson Creek*		5.29		1.02%			28.05%		2.92		2.60		122.21		23.6%		21		10.06%
	MS-3			59		8.36%			42.34%		4.78		14.77		134		19.0%		8		13.89%
West Sub-watershed	LW-8	*Fergus Creek, Murray Creek*	92.77	0.05	7.47%	0.01%	107.93	8.70%	9.77%	7.77	4.85	29.61	16.20	202.4	126.73	16.3%	15.4%	33	22	14.12%	14.73%
	LW-9	*McNally Creek*		2.34		1.15%			0.65%		1.52		6.14		11.43		5.6%		11		26.31%
	MS-4			90.38		42.52%			12.29%		1.40		7.27		64.23		30.2%		0		0.00%

Positive Steps Being Taken

A number of activities have been initiated to increase awareness about water quality concerns in the LCR watershed, to restore riparian habitats, to prevent pollution sources from entering the river, and to improve water quality.

Local community groups such as the Langley Environmental Partners Society (LEPS) and the Little Campbell Watershed Society are working on riparian area improvements and landowner contact programs to raise public awareness of how to best manage potential pollution sources. The Horse Council of B.C., in partnership with LEPS and the Ministry of Environment, is providing educational resources to its members addressing concerns surrounding manure management and its potential impact to the environment. The City of Surrey has also worked on landowner contact programs, business waste awareness programs and riparian enhancement work, including riparian fencing projects.

A positive initiative in the agriculture industry was the development of the Canada – B.C. Environmental Farm Plan Program (EFPP). The EFPP aims to encourage farmers and ranchers to be better stewards of the land through adoption and implementation of a variety of best practices. The program is voluntary and is being used in various sectors (http://www.bcac.bc.ca/efp_programs.htm). As well, both the City of Surrey and the Township of Langley have developed agricultural plans to deal with the growing urban/rural interface that is evolving throughout the watershed (Zbeetnoff 1999).

The City of Surrey and the Township of Langley are working on an Integrated Stormwater Management Plan for the LCR watershed. The Ministry of Environment (MoE), working in partnership with the Shared Waters Alliance, has initiated this pollution source and sink characterization to help support planning and pollution prevention initiatives. Environment Canada and the Ministry of Environment (MoE) have worked in partnership with local community volunteers to collect water quality samples to help identify pollution hotspots. MoE has installed an automated water quality monitoring station, a network of temperature loggers, and carried out a year long surface water quality study in 2006 in the LCR watershed.

With respect to ground water source protection, the Province of B.C. and respective municipalities are working towards more effective and long-term protection of drinking water and aquifers through legislation and upgrades to infrastructure. The Township of Langley in particular has an extensive and publicly supported groundwater protection strategy and outreach campaign. The Township, MOE, LEPS, and the Community Mapping Network have helped facilitate the Private Well Network, a community based initiative designed to promote regular and affordable water quality testing (http://www.shim.bc.ca/atlases/pwn/about.cfm). This well network system allows individuals and neighborhoods to build a profile of the health of their aquifers and identify where contamination is of concern.

Recommendations

Steps recommended to be taken by Shared Waters Alliance partners cooperatively to improve the understanding of pollution sources in the watershed and to improve water quality in the receiving waters of Boundary Bay include:

1. Planning that Protects Natural Resource Values, Water Quality and Water Uses
   - Support planning processes and tools that have the potential to consider the costs and benefits of alternate scenarios, incorporate measures to protect environmental quality, manage adaptively and value all water uses.

2. Public education and working with stakeholders on pollution prevention initiatives
   - Engage the public, various land use sectors and user groups (e.g. “weekend” hobby farmers, equestrian facility operators, large-scale farming operations, pet owners, land owners with onsite-SDS) to increase adoption of BMP’s and improve source control practices.
   - In addition to **bacteriological** impacts on the LCR watershed, the following parameters/impacts should also be worked on through coordinated actions:
     - indirect **nutrient** impact and direct **oxygen-demanding substances** impact on dissolved oxygen levels, and their effects on the fisheries resource,
     - direct impacts on aquatic life due to elevated **metals** and **hydrocarbons** from urban, commercial and industrial land use areas,
     - potential **pesticide** and other chemical impacts from agricultural, commercial and industrial areas, and
     - **flash runoff** impacts on sub-watershed hydrology and riparian habitat from increases in percent impervious surface area.

3. Protection and Restoration of Pollution Sinks
   - Protection of the function of floodplains, wetlands and hydric soils should be a management priority. The south Surrey lowlands area is recommended to be the focus of restoration activities with the goal of maintaining or increasing the abundance of forested and non-forested wetlands.

4. Monitoring

   Focus future ambient water quality monitoring in the LCR on:
   - Trend monitoring, to assess whether baseline conditions are improving or worsening
   - Event monitoring, to determine any change in event relevance
   - Monitoring to support forecast modelling
   - Effectiveness monitoring after remedial measures and/or best management practices are implemented
   - Regulatory compliance monitoring

5. Upgrading Sewage Disposal Systems
- Invest in protection of surface and groundwater resources through improved maintenance and upgrading of on-site sewage disposal systems. Focus efforts in areas where on-site SDS are installed in vulnerable soils, initially prioritizing those systems that overlay aquifers used for drinking water.
- In areas serviced by sanitary sewer, municipal monitoring of stormwater drainage systems could address sewage contamination, to identify possible cross connections, overflows or compromised transport system components.

6. Forecasting
- Use forecasting where possible to predict responses of the watershed to changes in land use practices and climate in order to examine consequences or benefits of plans and assess relative effectiveness of pollution prevention initiatives.

7. Filling Critical Data and Knowledge Gaps, such as the
- Number of failing on-site sewage disposal systems, and linkage to degraded receiving water quality
- Density and type of livestock
- Extent to which livestock access to watercourses is an issue (for habitat and water quality impacts)
- Site-specific manure management practices
- Locations, uses and rates of well and surface water extraction
- Maximum groundwater extraction threshold to maintain surface water base flows
- Evaluation of the role of wetlands, particularly the Campbell Valley wetlands and other pollution sinks in reducing nutrient and fecal coliform levels.

8. International coordination
- Work toward greater coordination between Canadian and American management and regulatory approaches to protect the receiving waters of Semiahmoo Bay.

Planning, monitoring, forecasting, pollution prevention and protection/restoration efforts should be focused on parameters and issues that are currently, or could in the future, affect known water uses and user groups. Efforts should focus on water quality protection for livestock watering, irrigation, domestic use, recreational use (swimming and boating), commercial/First Nations shellfish harvesting, and aquatic life, including the commercially important anadromous fisheries resource. At this time, two important focus areas, needing attention in the LCR are fecal coliform levels and dissolved oxygen levels.

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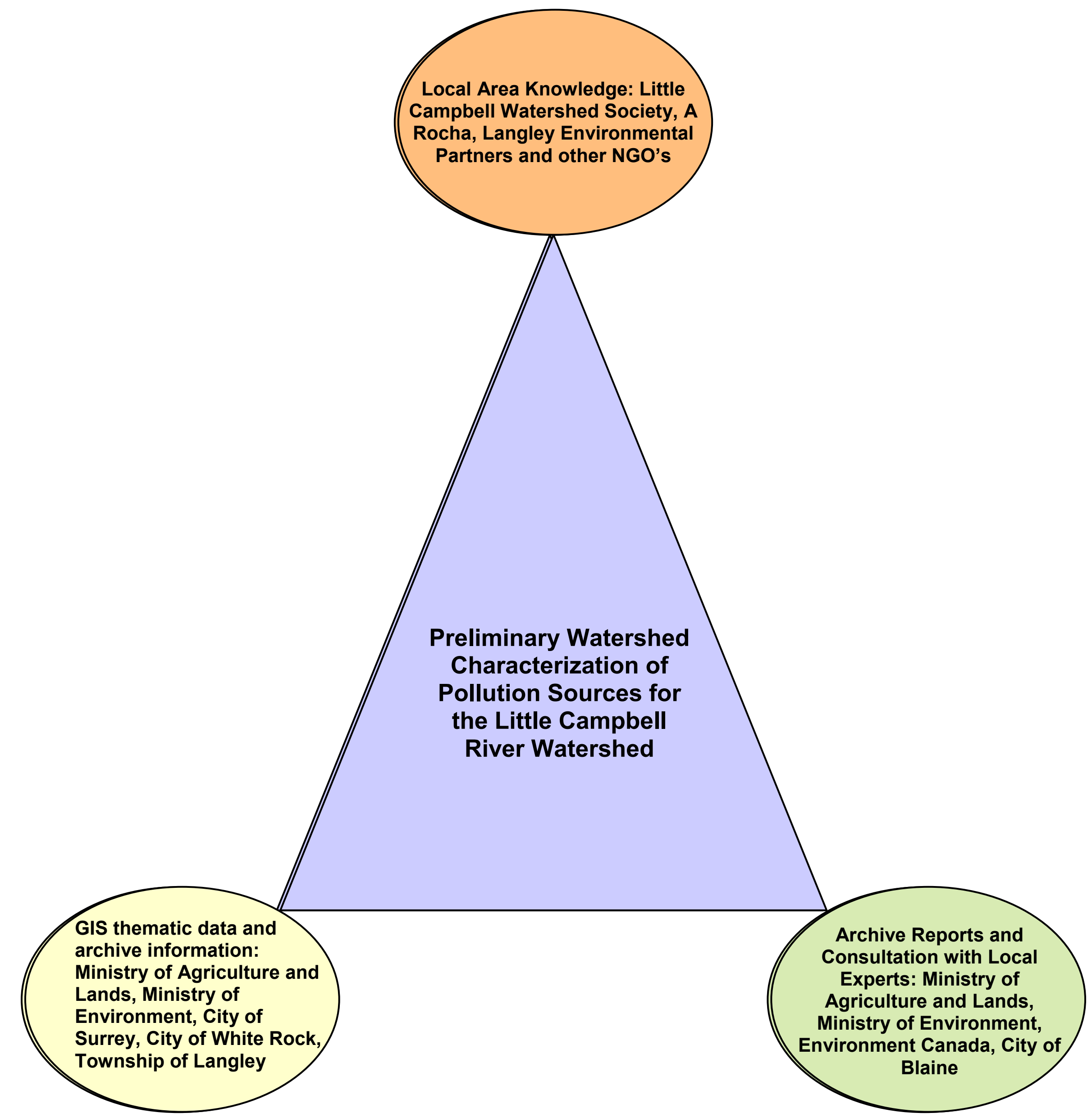
APPENDICES

Appendix 1: Spatial components for the Little Campbell River watershed pollution characterization study

Objective	Spatial Component to be Developed for Study	Source/Reference
Part 1: Delineation and Description of Analysis Area	Orthophoto of watershed	MOE/MAL/ US
	Map of primary catchment and sub-catchment boundaries	MOE, Surrey, Langley
	Map of soil classes	MOE/MAL/US
Part 2: Characterization of Water Uses	Map of permitted water licenses information, known well locations	MOE, Surrey, Langley, Community Mapping Network (wells)
	Map of aquifers	MOE/MAL/US
Part 3: Pollution Non-point Sources – Human Waste (Sewage)	Map of on-site sewage disposal systems and areas of concern for failure	GVRD on-site sewage disposal system inventory, Surrey, Langley, White Rock
Part 3: Pollution Non-point Sources – Agriculture	Map of agricultural land-use classification	MAL
	Map of livestock density breakdown	MAL/MOE
	Map of livestock issues (access, manure containment etc.) where known	Little Campbell Watershed Langley Environmental Partners Society, City of Surrey, MOE
Part 3: Pollution Non-point Sources – Impervious Surfaces, Vehicles and Industry	Map of current land use/OCP zoning and a map showing all neighbourhood concept plans being implemented	GVRD, Surrey, Langley
	Map showing traffic use patterns	GVRD, Surrey, Langley
	Map of works that have been put in place (e.g. stormceptors, constructed wetlands) to help improve/protect water quality	Surrey, Langley, White Rock
	Map of stormwater outfalls	MOE, Surrey, Langley, White Rock
Part 4: Preliminary Assessment of Pollution Sinks	Map of watershed areas in wetlands, parks, and percentage of riparian corridor 30m wide	MOE, Surrey, Langley, GVRD, CWS/EC



Appendix 2: Relevant water quality objectives for the Little Campbell River watershed (abridged from Swain 1988).

Parameter	Water Quality Objective
fecal coliform	less than or equal to 200 MPN/100 mL as a geometric mean from Apr. - Oct. less than or equal to 400 MPN/100 mL as a 90th percentile from Apr. - Oct.
suspended solids	10 mg/L maximum increase when upstream values are less than or equal to 100 mg/L; 10% maximum increase when upstream values exceed 100 mg/L
substrate sedimentation	no significant increase (95% confidence level) by weight in particulate matter for particles up to 3 mm in diameter
turbidity	5 NTU maximum increase when upstream values are less than or equal to 50 NTU; 10% maximum increase when upstream values exceed 50 NTU
ammonia-nitrogen, total	maximum concentration of total ammonia nitrogen for protection of aquatic life (e.g. 20.5 mg/L @ pH 7.0 and 10°C). average 30-day concentration of total ammonia nitrogen for protection of aquatic life (e.g. 1.84 mg/L @ pH 7.0 and 10°C).
nitrite-nitrogen	maximum and 30-day average allowable nitrite (N) concentration (varies with chloride concentrations (e.g. @ chloride <2 mg/L, max. nitrite = 0.06 mg/L and av. nitrite = 0.02 mg/L)
oxygen, dissolved	6.0 mg/L minimum (June to October)
	8.0 mg/L minimum (June to October, long-term objective)
	11.0 mg/L minimum when salmonid eggs, larvae or alevin are present

Appendix 3: Breakdown of Surface Water Licenses in the Little Campbell River Watershed (Source B.C. Water Resources Atlas 2006) http://www.env.gov.bc.ca/wsd/data_searches/wrbc/index.html)

GD=Imperial Gallons per day, CS=Cubic Feet per second, AF=Acre feet per year TF= Total Flow (0 total flow – used for keeping pond up to a certain level)

Stream Name	COUNT	PURPOSE	UNITS	TOTAL QUANTITY	Total in m^3/day
Campbell River	1	CONSERVATION	CS	0.400	978.739
Bell Creek (E. Twin)	1	DOMESTIC	GD	500.000	2.273
Caine Spring	1	DOMESTIC	GD	1500.000	6.819
Campbell River	1	DOMESTIC	GD	500.000	2.273
Green Brook	1	DOMESTIC	GD	500.000	2.273
Highland Creek	3	DOMESTIC	GD	1100.000	5.001
Holcomb Spring	1	DOMESTIC	GD	1000.000	4.546
Hooser Spring	1	DOMESTIC	GD	1000.000	4.546
Jacobson Creek	1	DOMESTIC	GD	800.000	3.637
Kuhn Creek	2	DOMESTIC **(Cancelled)**	GD	2000.000	9.092
Parkland Spring	1	DOMESTIC	GD	500.000	2.273
Stewart Brook	1	DOMESTIC	GD	500.000	2.273
Stokes Creek (W. Twin)	2	DOMESTIC	GD	2500.000	11.365
Theodore Creek	2	DOMESTIC**(Cancelled)**	GD	2000.000	9.092
Trio Spring	1	DOMESTIC	GD	500.000	2.273
Campbell River	1	FIRE PROTECTION	CS	0.050	122.342
Latimer Pond	1	FROST PROTECTION	AF	350.000	1182.791
Campbell River	18	IRRIGATION	AF	371.450	1255.279
Ellen Creek	1	IRRIGATION	AF	30.000	101.382
Fergus Creek	2	IRRIGATION**("Abandoned")**	AF	10.350	34.977
Sam Hill Creek	1	IRRIGATION	AF	50.000	168.970
Stokes Creek (W. Twin)	3	IRRIGATION	AF	35.180	118.887
Thomson Creek	2	IRRIGATION	AF	10.000	33.794
Bell Creek (E. Twin)	1	LAND IMPROVE **("Abandoned")**	GD	500.000	2.273
Campbell River	2	LAND IMPROVE	GD	1500.000	6.819
Cocteau Spring	1	LAND IMPROVE	GD	1000.000	4.546
Coen Spring	1	LAND IMPROVE	GD	1000.000	4.546
Coffin Spring	1	LAND IMPROVE	GD	1000.000	4.546
Cohan Spring	1	LAND IMPROVE	GD	1000.000	4.546
Ellen Creek	1	LAND IMPROVE	TF	0.000	0.000
Fergus Creek	1	LAND IMPROVE	GD	5000.000	22.730
Formosa Brook	3	LAND IMPROVE	TF	0.000	0.000
Kerfoot Creek	1	LAND IMPROVE	TF	0.000	0.000
Marmont Creek	1	LAND IMPROVE	TF	0.000	0.000
McLean Pond	1	LAND IMPROVE	TF	0.000	0.000
Regilla Creek	1	LAND IMPROVE	TF	0.000	0.000
Stokes Creek	2	LAND IMPROVE	AF	20.000	67.588
McLean Pond	1	NURSERIES	AF	16.000	54.070
Campbell River	4	STOCKWATERING	GD	13500.000	61.371
Gay Creek	1	STOCKWATERING	GD	1000.000	4.546
Marmont Creek	1	STOCKWATERING	GD	200.000	0.909
Stokes Creek (W. Twin)	2	STOCKWATERING	GD	1000.000	4.546
Campbell River	3	WATERING	AF	62.180	210.131
Formosa Brook	1	WATERING	AF	1.000	3.379
Campbell River	3	UNKNOWN	-	0.000	-
Stamp Brook	2	UNKNOWN	-	0.000	-
Sunnyside Springs	1	UNKNOWN	-	0.000	-

Appendix 4: Scale of livestock operations in the Little Campbell River watershed based on estimated number of livestock (Source MAL Land Use Inventory 2004-05)

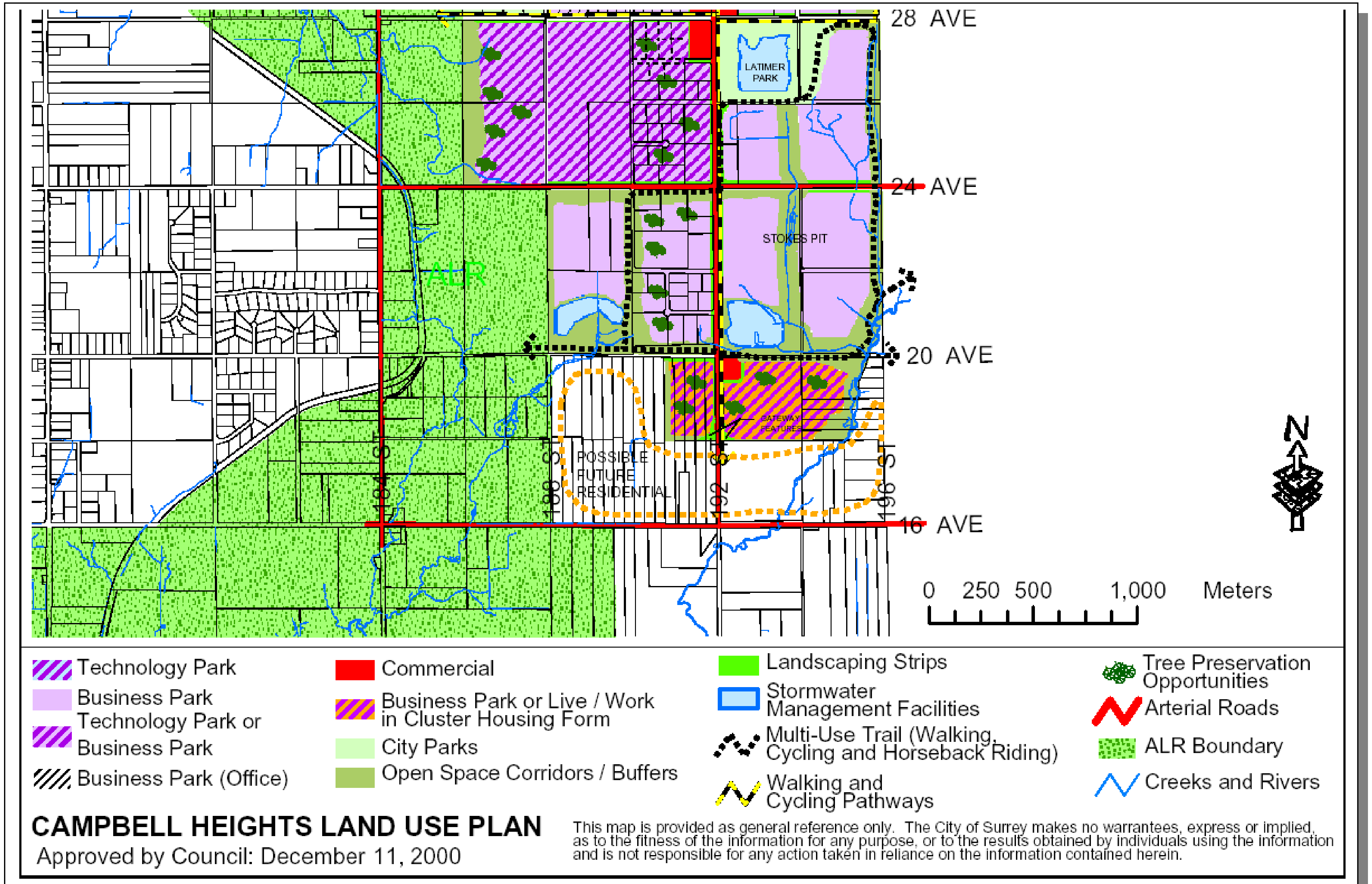
Agricultural Land Use Type	Scale of Operation	Sub-watershed	Local watershed	Number of operations
Abandoned or unused farm land		East	MS-1	17
Abandoned or unused farm land		Langley	LW-1	3
Abandoned or unused farm land		Langley	LW-2	7
Abandoned or unused farm land		Langley	LW-3	7
Abandoned or unused farm land		Langley	MS-2	10
Agritourism		Surrey	LW-5	1
Apiary		Surrey	LW-7	1
Beef Cattle Farm		East	MS-1	3
Beef Cattle Farm	medium	East	MS-1	6
Beef Cattle Farm	small	East	MS-1	9
Beef Cattle Farm	medium	Langley	LW-1	1
Beef Cattle Farm	small	Langley	LW-1	2
Beef Cattle Farm	medium	Langley	LW-3	1
Beef Cattle Farm	small	Langley	LW-3	1
Beef Cattle Farm	medium	Langley	MS-2	2
Beef Cattle Farm	small	Langley	MS-2	1
Beef Cattle Farm	medium	Surrey	LW-5	1
Beef Cattle Farm	small	Surrey	LW-5	1
Beef Cattle Farm	medium	Surrey	LW-6	1
Beef Cattle Farm	large	Surrey	LW-7	1
Beef Cattle Farm	medium	Surrey	LW-7	1
Beef Cattle Farm	small	Surrey	LW-7	1
Beef Cattle Farm	unknown	Surrey	LW-7	1
Beef Cattle Farm	large	Surrey	MS-3	1
Beef Cattle Farm	medium	Surrey	MS-3	3
Beef Cattle Farm	small	Surrey	MS-3	1
Beef Cattle Farm	medium	West	LW-8	1
Beef/Sheep or goat	medium	Langley	LW-1	2
Beef/Sheep or goat	medium	Langley	MS-2	1
Berry Farm		East	MS-1	2
Berry Farm		Langley	LW-1	1
Berry Farm		Langley	LW-3	1
Berry Farm		Langley	MS-2	1
Berry Farm		Surrey	MS-3	1
Christmas Tree Farm		East	MS-1	1
Christmas Tree Farm		Surrey	LW-5	2
Commercial pet kennel		Langley	LW-3	1
Commercial pet kennel		Langley	LW-4	1
Commercial pet kennel		Langley	MS-2	1
Commercial pet kennel		Surrey	MS-3	1
Cultivated Land		East	MS-1	3
Cultivated Land		Langley	LW-1	1
Dairy Farm	small	East	MS-1	1
Dairy Farm	medium	Langley	LW-3	1
Dairy Farm	medium	Langley	LW-4	1
Dairy Farm	medium	Langley	MS-2	1

Agricultural Land Use Type	Scale of Operation	Sub-watershed	Local watershed	Number of operations
Dairy Farm	medium	Surrey	LW-6	1
Dairy Farm	medium	Surrey	MS-3	2
Donkey Farm	small	Langley	LW-1	1
Fallow Land		Langley	LW-3	1
Feedlot		Surrey	LW-5	1
Feedlot	small	Surrey	LW-5	1
Feedlot	large	Surrey	MS-3	1
Field Flower Farm		East	MS-1	1
Field Vegetable Farm		Surrey	LW-5	4
Field Vegetable Farm	medium	Surrey	LW-6	1
Field Vegetable Farm	medium	Surrey	MS-3	1
Forage Operation		Langley	LW-1	1
Forage Operation		Langley	LW-2	1
Forage Operation		Langley	LW-3	5
Forage Operation		Langley	LW-4	5
Forage Operation		Langley	MS-2	8
Forage Operation		Surrey	LW-5	11
Forage Operation		Surrey	LW-6	3
Forage Operation		Surrey	LW-7	6
Forage Operation	large	Surrey	LW-7	1
Forage Operation		Surrey	MS-3	17
Forage Operation		West	LW-8	3
Forage Operation	large	West	LW-8	1
Game Farm	medium	Langley	LW-2	1
Greenhouse Operation		East	MS-1	1
Greenhouse Operation		Langley	LW-2	1
Greenhouse Operation		Langley	LW-3	1
Greenhouse Operation		Langley	LW-4	1
Greenhouse Operation		Langley	MS-2	1
Greenhouse Operation	large	Surrey	LW-5	1
Greenhouse Operation		Surrey	LW-7	4
Greenhouse Operation	large	Surrey	LW-7	2
Greenhouse Operation	large	Surrey	MS-3	1
Greenhouse Operation		Wests	LW-8	1
Horse Farm		East	MS-1	5
Horse Farm	large	East	MS-1	6
Horse Farm	medium	East	MS-1	25
Horse Farm	small	East	MS-1	41
Horse Farm		Langley	LW-1	1
Horse Farm	large	Langley	LW-1	2
Horse Farm	medium	Langley	LW-1	13
Horse Farm	small	Langley	LW-1	22
Horse Farm	medium	Langley	LW-2	4
Horse Farm	small	Langley	LW-2	15
Horse Farm		Langley	LW-3	2
Horse Farm	large	Langley	LW-3	5
Horse Farm	medium	Langley	LW-3	8
Horse Farm	small	Langley	LW-3	53
Horse Farm	large	Langley	LW-4	1

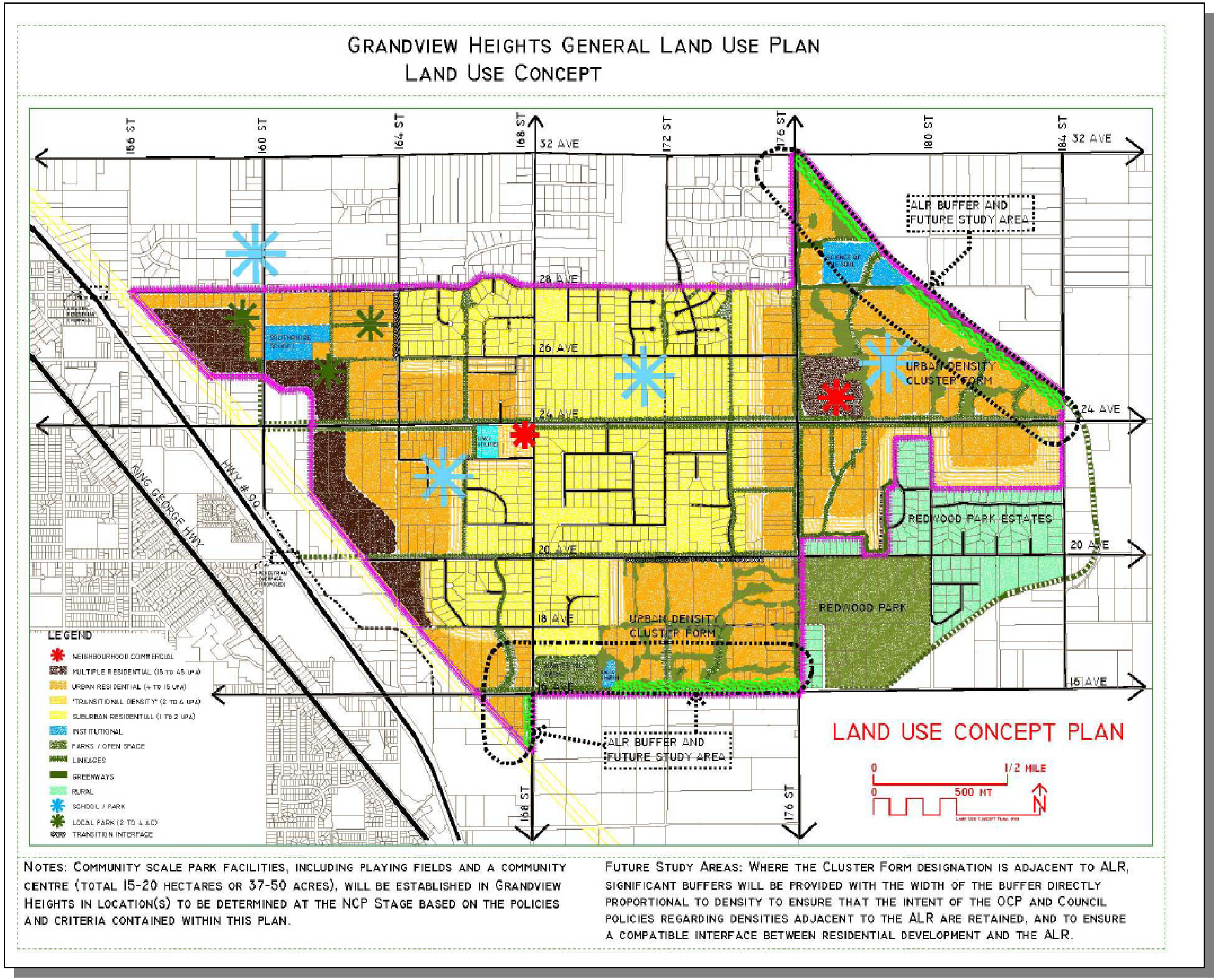
Agricultural Land Use Type	Scale of Operation	Sub-watershed	Local watershed	Number of operations
Horse Farm	medium	Langley	LW-4	1
Horse Farm	large	Langley	MS-2	1
Horse Farm	medium	Langley	MS-2	11
Horse Farm	small	Langley	MS-2	48
Horse Farm		Surrey	LW-5	1
Horse Farm	large	Surrey	LW-5	2
Horse Farm	medium	Surrey	LW-5	3
Horse Farm	small	Surrey	LW-5	5
Horse Farm	small	Surrey	LW-6	1
Horse Farm	small	Surrey	LW-7	5
Horse Farm	medium	Surrey	MS-3	1
Horse Farm	small	Surrey	MS-3	7
Horse/Beef	small	East	MS-1	3
Horse/Beef	small	Langley	LW-1	1
Horse/Beef	medium	Langley	MS-2	1
Horse/Sheep or goat	medium	Langley	LW-3	1
Horse/Sheep or goat	medium	Langley	MS-2	1
Livestock operation - type unknown		East	MS-1	5
Livestock operation - type unknown	medium	East	MS-1	1
Livestock operation - type unknown		Langley	LW-1	1
Livestock operation - type unknown		Langley	LW-2	1
Livestock operation - type unknown		Surrey	LW-7	1
Llama/Alpaca Farm		East	MS-1	1
Llama/Alpaca Farm	large	East	MS-1	1
Llama/Alpaca Farm	medium	East	MS-1	1
Llama/Alpaca Farm	medium	Langley	LW-1	1
Llama/Alpaca Farm	medium	Langley	LW-3	2
Llama/Alpaca Farm	small	Langley	LW-3	1
Llama/Alpaca Farm	medium	Langley	MS-2	1
Llama/Alpaca Farm		Surrey	LW-5	1
Llama/Alpaca Farm	small	Surrey	LW-5	1
Mushroom Farm		East	MS-1	1
Mushroom Farm		Langley	LW-2	1
Nursery		East	MS-1	7
Nursery		Langley	LW-1	2
Nursery	small	Langley	LW-1	1
Nursery		Langley	MS-2	4
Nursery		Surrey	MS-3	1
Nursery		Wests	LW-8	1
Nursery (incl. Greenhouses)		East	MS-1	1
Nursery (incl. Greenhouses)		Langley	LW-2	1
Nursery (incl. Greenhouses)		Langley	LW-3	1
Nursery (incl. Greenhouses)		Langley	MS-2	3
Nursery (incl. Greenhouses)		Surrey	LW-5	1
Nut Farm		Langley	LW-1	1
Nut Farm		Langley	MS-2	1
Nut Farm		Wests	LW-8	1
Orchard		Surrey	LW-7	1
Pasture		East	MS-1	55

Agricultural Land Use Type	Scale of Operation	Sub-watershed	Local watershed	Number of operations
Pasture		Langley	LW-1	9
Pasture		Langley	LW-2	5
Pasture		Langley	LW-3	25
Pasture		Langley	LW-4	1
Pasture		Langley	MS-2	32
Pasture		Surrey	LW-5	15
Pasture		Surrey	LW-7	4
Pasture		Surrey	MS-3	7
Pasture		West	LW-8	4
Poultry - backyard flock		Langley	LW-3	1
Poultry - backyard flock		Surrey	LW-5	1
Poultry - backyard flock	small	Surrey	LW-5	1
Poultry - backyard flock	medium	Surrey	LW-6	1
Poultry Farm		East	MS-1	2
Poultry Farm	large	East	MS-1	2
Poultry Farm	medium	East	MS-1	1
Poultry Farm		Langley	LW-2	1
Poultry Farm		Langley	LW-3	3
Poultry Farm		Langley	MS-2	6
Poultry Farm	medium	Surrey	LW-6	1
Poultry Farm		Surrey	LW-7	1
Sheep/Goat Farm		East	MS-1	2
Sheep/Goat Farm	medium	East	MS-1	3
Sheep/Goat Farm	small	East	MS-1	5
Sheep/Goat Farm	medium	Langley	LW-1	1
Sheep/Goat Farm	medium	Langley	LW-2	1
Sheep/Goat Farm	small	Langley	LW-2	3
Sheep/Goat Farm	small	Langley	LW-3	2
Sheep/Goat Farm	medium	Langley	MS-2	1
Sheep/Goat Farm	small	Langley	MS-2	2
Sheep/Goat Farm	medium	Surrey	LW-5	1
Sheep/Goat Farm	small	Surrey	LW-5	2
Sheep/Goat Farm	medium	Surrey	LW-7	1
Sheep/Goat Farm	small	Surrey	MS-3	1
Specialty Crop Production		East	MS-1	1
Stable/Riding Facility		Surrey	LW-5	4
Stable/Riding Facility	large	Surrey	LW-5	1
Stable/Riding Facility	large	Surrey	LW-6	1
Stable/Riding Facility	small	Surrey	LW-6	1
Stable/Riding Facility	large	Surrey	LW-7	1
Stable/Riding Facility	medium	Surrey	LW-7	1
Stable/Riding Facility		Surrey	MS-3	1
Stable/Riding Facility	large	Surrey	MS-3	2
Swine operation		East	MS-1	1
Vineyard		Langley	LW-1	1

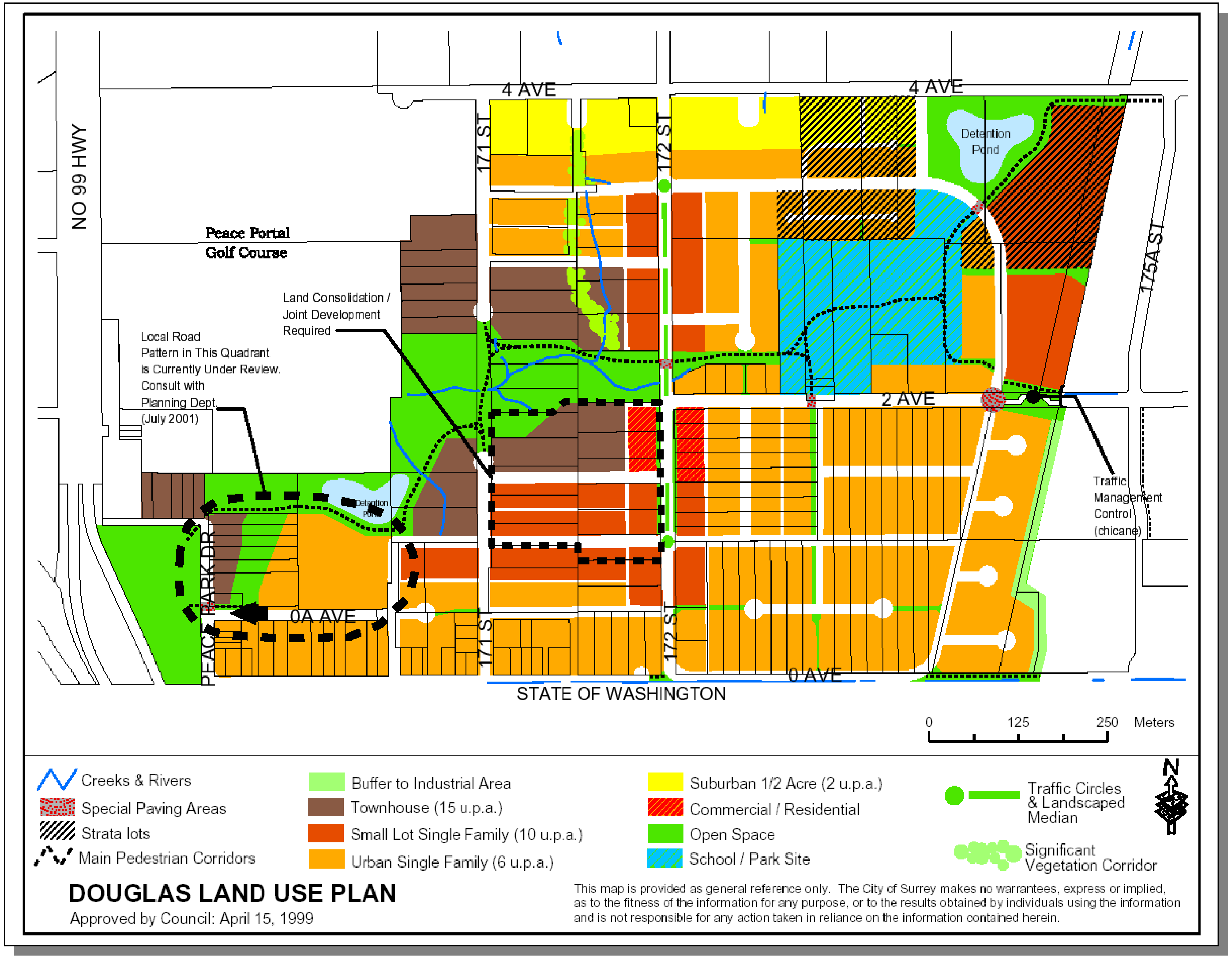
Appendix 5: Neighbourhood Concept Plans (NCP's) for the City of Surrey and Community Plans for Township of Langley



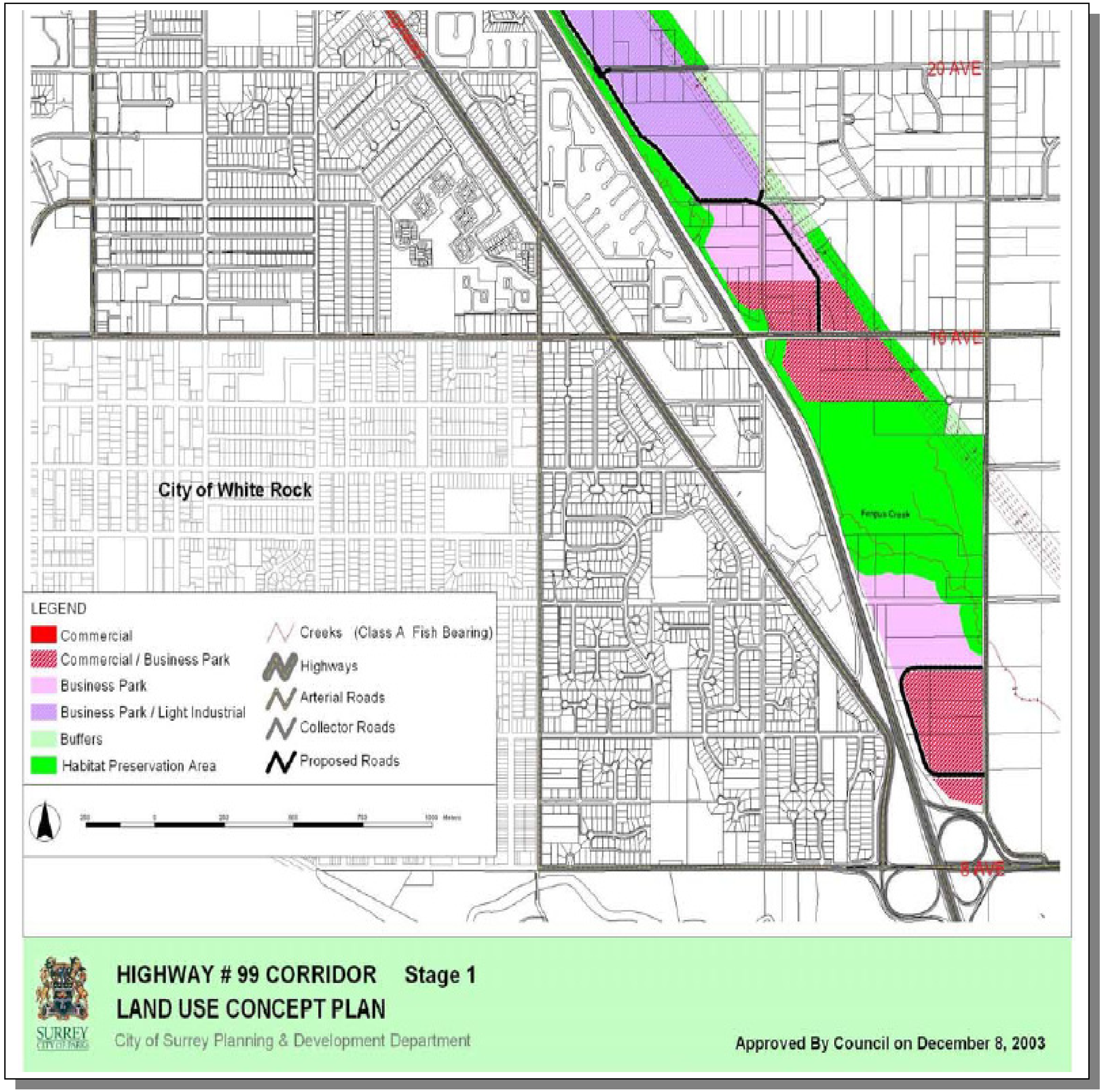
Campbell Heights land use plan **(southeast Surrey sub-watershed and southwest Langley sub-watershed) Source: City of Surrey**



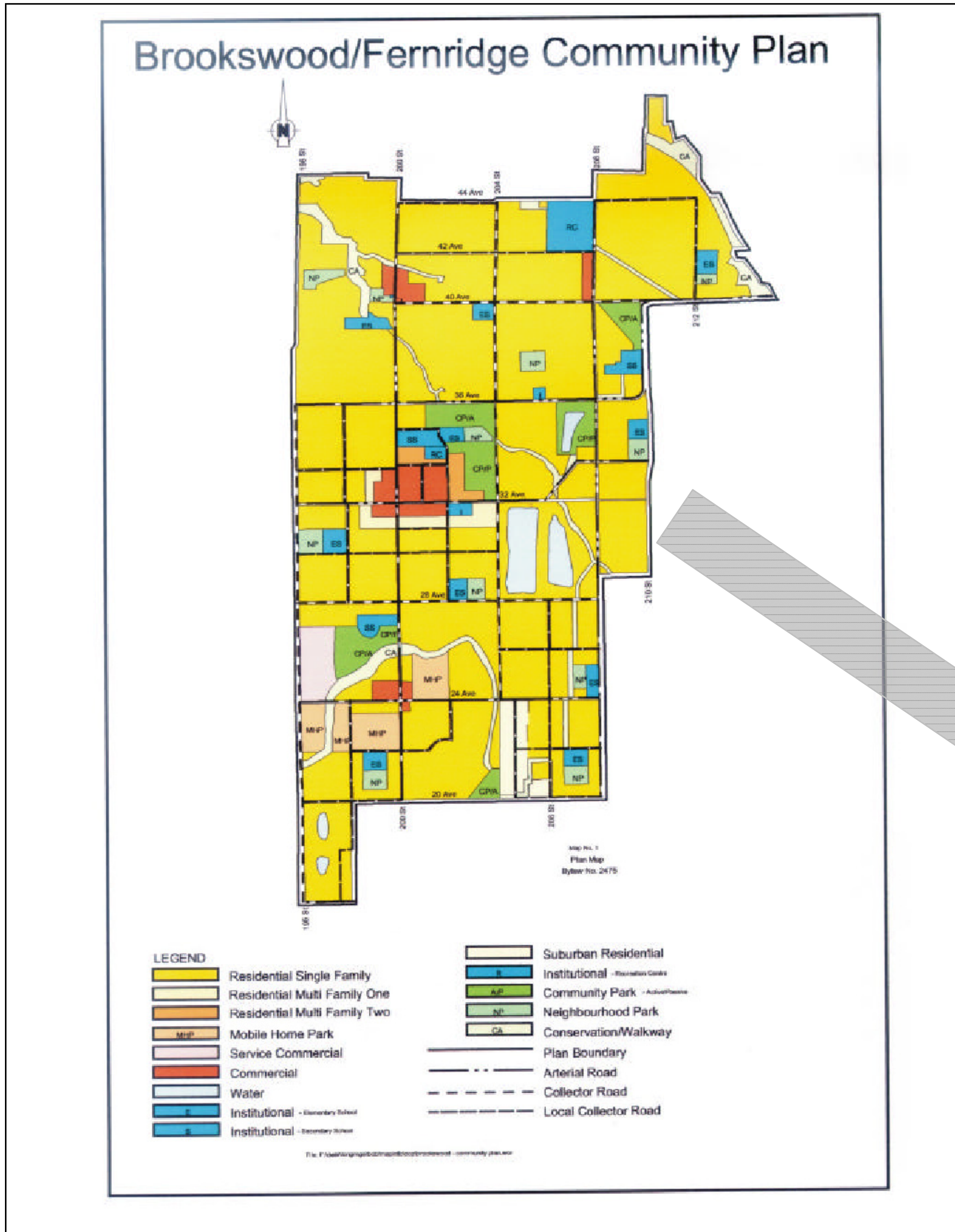
Grandview Heights general land use plan/land use concept
(south Surrey sub-watershed)
Source: City of Surrey 2005

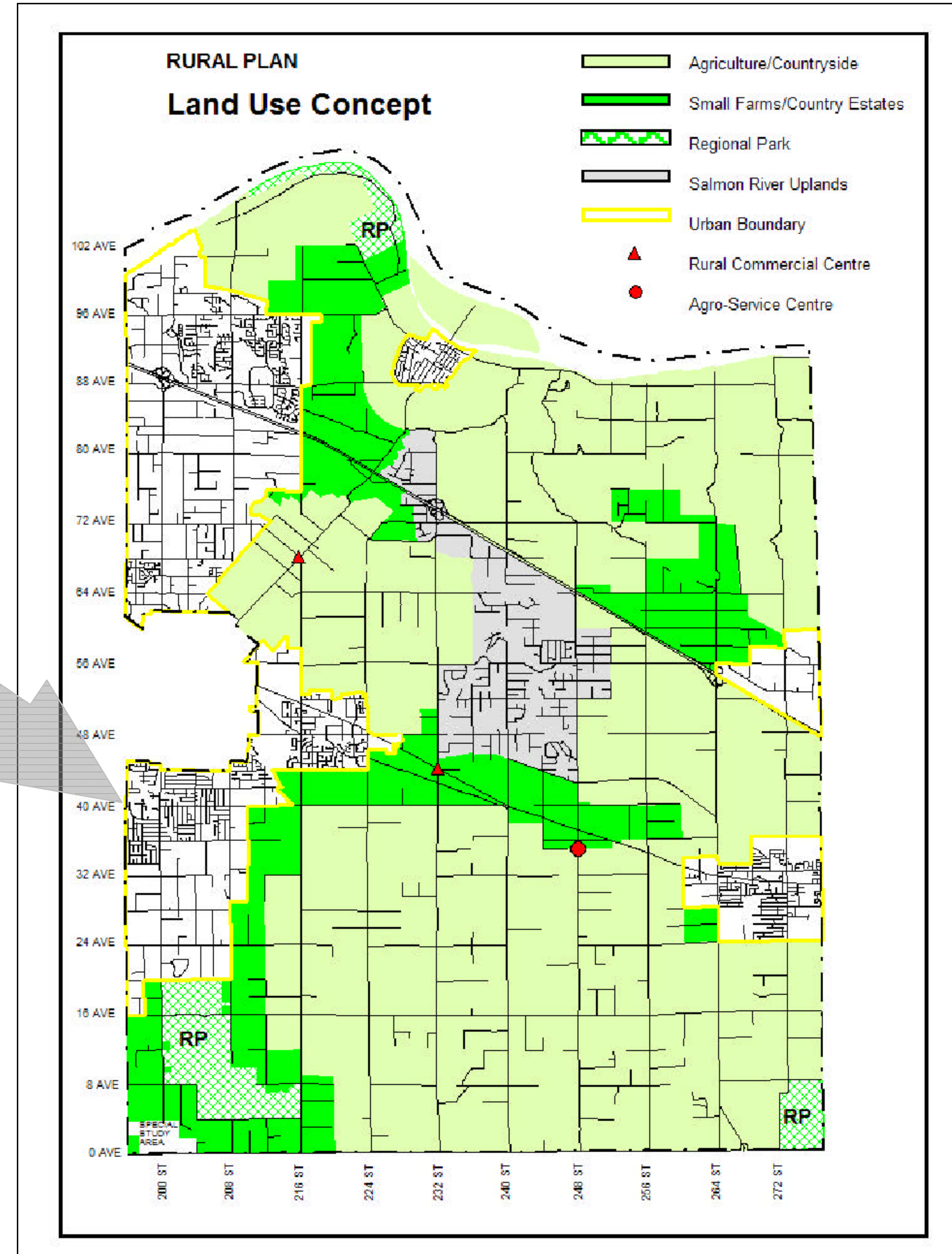


Douglas land use plan (south Surrey sub-watershed) Source: City of Surrey 1999



Douglas land use plan (south Surrey sub-watershed) Source: City of Surrey 1999





Brookswood/Fernridge community plan and Township of Langley rural land use concept plan (Langley sub-watershed). Source: Township of Langley 2003/2004

Appendix 6: Summary of Methods and Results for Previous Imperviousness Assessment Studies of the Little Campbell River Watershed (Rood and Hamilton 1994, GVRD 1999, Drever and Brown 1999, and GVRD 2001).

Rood and Hamilton (1994) assessed land cover in the Canadian portion of the Little Campbell River watershed and estimated effective impervious area. They used zoning plans supplemented with air photos from the early 1990s (no specific date provided) to estimate land use. Effective impervious area was calculated using values in Alley and Veenhuis (1983) and Dinicola (1990). Land cover classes included: 1) agriculture and vacant land; 2) low density single-family residential; 3) medium density single family-residential; 4) high density single-family residential; 5) multi-family development; 6) commercial, industrial, and transportation facilities; and 7) greenhouses.

Their analysis was found that agriculture and undeveloped land accounted for 65% of the watershed which was substantially lower than the 88% found by Dreven and Brown (1999). Urban land cover (residential, commercial, industrial, transportation, and greenhouses) accounted for 35% of the watershed. They calculated an effective impervious area of 3.9% for the Canadian portion of the watershed.

Drever and Brown (1999) assessed land use in the Little Campbell River watershed as part of a comprehensive study of fish, fish habitat, watershed characteristics, and restoration options (Figure 24). They used 1996 ortho photos to determine land use in 11 categories: 1) agriculture; 2) recreation and natural protected areas; 3) lakes; 4) single family residential; 5) rural residential; 6) townhouse residential; 7) apartments; 8) commercial; 9) institutional; 10) transportation, communication, and utilities; and 11) open space and undeveloped. Similar to the study by Rood and Hamilton (1994) only lands within Canada were evaluated.

Their analysis found that almost half the watershed (45%) was used for agriculture, while undeveloped open space including parks accounted for 43%. Urban land use including residential, commercial, and industrial lands was only 13% of the total watershed area. They did not calculate imperviousness directly, however, we used their land use figures and TIA and EIA conversion values for representative land use types and calculated TIA as 6.8% and EIA as 4.7%.

The Greater Vancouver Regional District (GVRD) used land use types defined by the provincial Corporate Land Use Classification System (CLUCS) to determine total impervious area in watersheds and catchments in the GVRD in 1999 (GVRD 1999). Land use was based on interpretation of 1996 ortho photos. They also predicted TIA for 2036 TIA based on a relationship between population and TIA. They recommended using values from May et al. (1997). Relevant to the Little Campbell River watershed, this included a value of 5% TIA for agricultural lands to account of roads, greenhouses, and other impervious surfaces. The estimated TIA for the Little Campbell River watershed was 9.1% in 1996 and the predicted TIA was 18% in 2036.

Appendix 7: Detailed breakdown of land use in the Little Campbell River watershed (GVRD 2001)

Sub-watershed	Local watershed	Land Use CODE	Land Use Definition	Area m^3
Surrey	MS-3	A500	General Agriculture	4199970.85
Surrey	MS-3	R100	Parks Designated	405270.20
Surrey	MS-3	S120	Rural Residential	20490.13
Surrey	MS-3	S500	Transportation & Communication	84572.65
Surrey	MS-3	U100	Open (Green Space)	923157.11
West	LW-8		Unknown	3406673.43
West	LW-8	A500	General Agriculture	2192083.52
West	LW-8	R100	Parks Designated	126662.08
West	LW-8	S110	Single Family Residential	71015.64
West	LW-8	S120	Rural Residential	1010071.67
West	LW-8	S200	Commercial	11340.40
West	LW-8	S500	Transportation & Communication	24696.35
West	LW-8	U100	Open (Green Space)	1398604.98
West	LW-9		Unknown	2024199.13
West	LW-9	S110	Single Family Residential	266.61
West	LW-9	U100	Open (Green Space)	21019.71
West	MS-4		Unknown	891420.76
West	MS-4	A500	General Agriculture	120.46
West	MS-4	R100	Parks Designated	93108.76
West	MS-4	S110	Single Family Residential	133824.25
West	MS-4	S130	Low Rise Townhouse	586.36
West	MS-4	S200	Commercial	2651.50
West	MS-4	S500	Transportation & Communication	131987.74
West	MS-4	U100	Open (Green Space)	871608.50

Appendix 8:

Summary of conversion factors for calculating TIA, and recommendations for percentage imperviousness values from CLUCS land use classes (GVRD 2001)

CLUCS Land Use Code	%TIA	%EIA	Description of Code
A200	90%	85%	Large-scale greenhouses
A500	6%	1.50%	General agriculture
F100	0%	0%	Forested (designated forest lands)
M300	0%	0%	Extraction (gravel pits, peat mining)
R100	1%	0%	Parks (designated)
S110	40%	27%	Single Family Residential
S120	10%	4%	Rural Residential
S130	80%	72%	Low Rise/Townhouse
S140	50%	34%	Mobile Homes
S200	90%	86%	Commercial
S300	75%	60%	Industrial
S400	90%	86%	Institutional
S500	90%	86%	Transportation and Communication
U100	1%	0%	Open (green space)
W200	0%	0%	Lakes and reservoirs

Corporate Land Use Classification System codes and %TIA and %EIA values used in the 2006 Little Campbell River watershed assessment (*indicates extrapolated values for similar land use types)**.**

CLUCS Land Use Code	% TIA[8]	%EIA[9]	Description
A500	6.5%	1.5%[10]*	General agriculture
A200	75%*	60%*	Large-scale Greenhouses
F100	0%	0%	Forested (designated forest lands)
M300	0%	0%	Extraction (gravel pits, peat mining)
S110	40%	27%*	Single Family Residential
S120	10%	4%	Rural Residential
S130	80%	72%*	Low Rise/Townhouse
S140	50%	34%*	Mobile Home Parks
S200	90%	86%	Commercial
S300	75%	60%*	Industrial
S400	90%	86%	Institutional
S500	90%	86%	Transportation and Communication
R100	1%	0%	Parks (designated)
U100	1%	0%	Open (green space)
W200	0%	0%	Lakes and Reservoirs

[8] TIA values based primarily on May et al. (1997) but see Page et al. (1999) for more detail
[9] EIA values based primarily on Dinicola (1989)
[10] Estimated from typical agricultural land use in the LCR

Appendix 9: Road type and length by drainage unit in the Little Campbell River watershed

ROAD_TYPE	Sub-watershed	Local watershed	LENGTH_(M)
arterial	West	MS-4	1878.87
arterial	Surrey	LW-5	429.73
arterial	Surrey	LW-7	2392.28
arterial	Surrey	MS-3	2481.15
arterial	West	LW-8	4952.38
arterial	East	MS-1	1768.44
arterial	Langley	MS-2	3454.93
collector	West	LW-9	1930.62
collector	West	MS-4	4633.84
collector	Langley	LW-2	2843.24
collector	Langley	LW-1	1324.59
collector	Langley	LW-4	4584.70
collector	Surrey	LW-6	3986.42
collector	Surrey	LW-5	7516.46
collector	Surrey	LW-7	3321.03
collector	Langley	LW-3	5438.86
collector	Surrey	MS-3	8273.19
collector	West	LW-8	19446.90
collector	East	MS-1	5329.05
collector	Langley	MS-2	12890.10
freeway	West	MS-4	2217.42
freeway	Surrey	MS-3	828.76
freeway	West	LW-8	6605.52
lane	West	LW-9	253.01
lane	West	MS-4	536.42
lane	West	LW-8	13.86
local	West	LW-9	21275.70
local	West	MS-4	9579.34
local	Langley	LW-2	2004.51
local	Langley	LW-1	3260.03
local	Langley	LW-4	2187.29
local	Surrey	LW-6	1797.92
local	Surrey	LW-5	4288.82
local	Surrey	LW-7	7545.34
local	Langley	LW-3	4154.85
local	Surrey	MS-3	4117.43
local	West	LW-8	24608.60
local	East	MS-1	12330.30
local	Langley	MS-2	17040.30
ramp	West	MS-4	1936.27
ramp	West	LW-8	673.59
strata	West	MS-4	326.63
strata	Surrey	MS-3	495.22
strata	West	LW-8	5424.08
strata	Langley	MS-2	3622.76
Whatcom	Langley	LW-2	1259.75
Whatcom	Langley	LW-4	1156.83

ROAD_TYPE	Sub-watershed	Local watershed	LENGTH_(M)
Whatcom	Surrey	LW-6	3280.48
Whatcom	Langley	LW-3	535.60
Whatcom	Surrey	MS-3	2223.15

Appendix 10: Types of reported spills in the Little Campbell River watershed (January 1987 to May 2005). Source MOE spills database.

SPILL_TYPE	Sub-watershed	Local watershed	COUNT
animal waste	East	MS-1	1
animal waste	Langley	MS-2	1
animal waste	Surrey	MS-3	2
animal waste	West	LW-8	2
chemical	Langley	LW-2	1
chemical	Langley	LW-3	1
chemical	Langley	LW-4	1
chemical	Langley	MS-2	2
chemical	Surrey	LW-5	3
chemical	Surrey	MS-3	1
chemical	West	LW-8	2
chemical	West	MS-4	1
hydrocarbon	Langley	LW-3	1
hydrocarbon	Langley	LW-4	1
hydrocarbon	Langley	MS-2	5
hydrocarbon	Surrey	LW-7	1
hydrocarbon	Surrey	MS-3	4
hydrocarbon	West	LW-8	3
hydrocarbon	West	MS-4	1
radioactive	Surrey	MS-3	2
sediment	Langley	MS-2	2
sediment	Surrey	MS-3	1
sediment	West	LW-8	2
sediment	West	MS-4	1
solvent	West	MS-4	1
unknown	Langley	LW-3	1
unknown	Surrey	LW-7	1
unknown	Surrey	MS-3	1
unknown	West	LW-8	12
unknown	West	MS-4	2

Appendix 11: High Point concept plan with water quality treatment (constructed wetlands) provisions