STATUS OF RED-LEGGED FROGS (*Rana aurora aurora*) IN SURREY, BRITISH COLUMBIA

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We accept this thesis as conforming
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Abstract

There is growing evidence of amphibian population declines around the world. Red-legged frogs (*Rana aurora aurora*) are one species of amphibian in decline within the Lower Fraser Basin (LFB) in British Columbia, Canada. This study gathered baseline distribution information for red-legged frogs in twelve parks in Surrey, BC. The findings suggest that red-legged frog populations are most likely found within their range in the Lower Fraser Basin on sites where wetlands have high percent cover of aquatic vegetation and forest cover within a 200 m radius of the wetland. Specific park management recommendations were developed for the twelve study sites with the goal of sustaining red-legged frog populations within Surrey's protected area network in perpetuity. This study is the first step towards gaining the knowledge necessary to ensure the sustainability of this species in Surrey and perhaps their entire range within the LFB.

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1 Introduction and Literature Review

Biodiversity is declining worldwide at an unprecedented rate as evidenced by current global extinction rates, which are estimated to be up to 1000 times greater than past rates determined from the fossil record (Baillie, Hilton-Taylor, & Stuart, 2004; Wilson, 1999). Vertebrates, in particular, are disappearing at an even greater rate and amphibians are the taxa with the highest proportion of species threatened by extinction (Beebee & Griffiths, 2005; Stuart et al., 2004). Declining amphibian populations are now the focus of a growing number of studies throughout the world (Adams, 1999; Alford & Richards, 1999; Blaustein, 1994; Collins & Storfer, 2003; Fisher & Shaffer, 1996). The primary question regarding these declines is whether they are caused by global environmental change or local anthropogenic factors (Fisher & Shaffer, 1996). Most scientists are beginning to believe that amphibian declines are a result of both complex global and local environmental changes including habitat destruction, introduced predators, pollutants, disease, and climate change – all of which are driven or exacerbated by human activities (USDA Forest Service, 2002).

In British Columbia (BC), ten species of amphibians are currently considered at risk under the Federal Species at Risk Act (SARA) and nine species are considered at risk provincially in British Columbia (BC Ministry of Environment, 2007; Environment Canada, 2006). Red-legged frog (*Rana aurora aurora*) is listed as a species of special concern under both the federal SARA and provincially in BC (BC Ministry of Environment, 2007; Environment Canada, 2006). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended the red-legged frog for listing under SARA for several reasons. First, the species range in Canada is limited to the extreme southwest of BC, which is also the most human populated and developed area in the province (COSEWIC, 2004; Matsuda, Green, & Gregory, 2006). Second, populations of the subspecies found in BC have declined, particularly in urban areas, and the other subspecies (*Rana aurora draytonii*) is considered threatened in its southern range in the United States (COSEWIC, 2004; US Fish & Wildlife Service, 2005). Finally, the subspecies found in BC is highly susceptible to habitat degradation as well as predation and competition from introduced bullfrogs and green frogs (COSEWIC, 2004). Although this species is considered at risk, there is relatively little up-to-date, published information on the biology, threats, and current status of red-legged frogs in BC.

This chapter will review the biology of red-legged frogs, potential threats to their populations, their current status in BC, and will finally justify the need for this study to enhance our understanding and make recommendations for steps towards ensuring the sustainability of this species in BC. This understanding is required now while red-legged frog populations are likely still healthy and widespread enough that conservation measures necessary to guarantee their long-term survival are practical, achievable, and economically feasible.

1.1 Range of Red-legged Frogs

Red-legged frog is a true frog species that is found west of the Coast Mountain Range of Western North America from Southern British Columbia (BC) to Northern Baja, California (Matsuda et al., 2006). The range of red-legged frogs in BC is limited to Vancouver Island and the adjacent coastal areas of mainland BC, the Gulf Islands, and the Lower Fraser Basin from Hope to Vancouver (Matsuda et al., 2006). There are two subspecies, *Rana aurora aurora* (northern red-legged frog) and *Rana aurora draytonii* (California red-legged frog), and only *R. aurora aurora* is found in BC (Figure 1, Figure 2) (Matsuda et al., 2006). *R. aurora aurora* is of Special Concern at both the provincial and federal government levels in British Columbia (BC Ministry of Environment, 2007; Environment Canada, 2006) and *R. aurora draytonii* is listed as threatened federally in the United States and as a species of special concern in the State of California (US Fish & Wildlife Service, 2005).

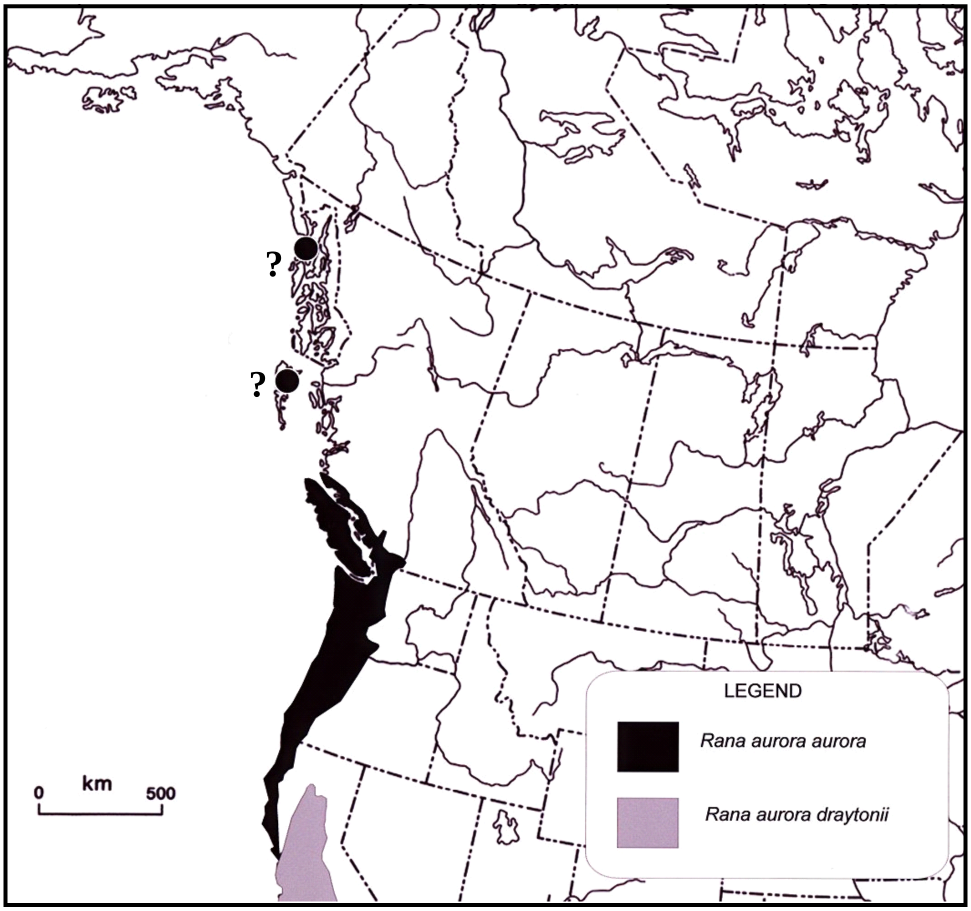

Figure 1. Distribution of the northern red-legged frog (Rana aurora aurora) and the California red-legged frog (Rana aurora draytonii) on the west coast of North America (COSEWIC, 2004).

Note: (?) indicates two historic records that were most likely misidentified Columbia spotted frogs.

Figure 2. Photographs of (A) northern red-legged frog (Rana aurora aurora) and (B) California red-legged frog (Rana aurora draytonii).

(A) © copyright James Bettaso, US Fish & Wildlife Service and (B) ©copyright Gary Nafis.

1.2 Biology of Red-legged Frogs

The life history of northern red-legged frogs involves three distinct stages, each with different habitat requirements. Adult frogs hibernate at the bottom of a pond or in saturated ground close to a water body from November to February (Briggs, 1987). Upon emerging from hibernation the adults move to breeding sites when daytime temperatures reach 4-5 $^{\circ}$C (Licht, 1969; Storm, 1960). Breeding typically lasts for two to four weeks in February and early March (Brown, 1975; Licht, 1969). The eggs are laid in masses of 500-1100 eggs attached to vegetation or woody debris in water with little to no flow at a depth of 30 cm or more (Matsuda et al., 2006; Briggs, 1987; Brown, 1975; Licht, 1969). After incubating for approximately five to six weeks, 11-12 mm long larvae (or tadpoles) hatch and spend a day or two crowded near the egg mass feeding off the algae that has grown on the surface (Maxcy, 2004; Storm, 1960). The aquatic larvae proceed through a series of developmental stages over the next three months, feeding on emergent and submerged aquatic vegetation throughout the wetland (BC Ministry of Environment, 2006). In the final aquatic stage, larvae metamorphose into juvenile red-legged frogs in June or July (Licht, 1974; Storm, 1960). This transitional phase involves the physiological changes that make it possible for the aquatic metamorphs to become capable of living in a terrestrial environment. Juvenile red-legged frogs are predatory and spend the majority of their time near the pond of their birth stalking insects and other small invertebrates (BC Ministry of Environment, 2006; Licht, 1986). Juvenile frogs generally become sexually mature at two to three years of age (Storm, 1960). Adult red-legged frogs feed on insects and other small invertebrates and tend to reside in forested habitats close to water, though they may travel far from standing water if the moisture conditions are right (Matsuda et al., 2006). Though the average longevity of red-legged frogs in the wild is unknown, females in captivity have lived between 12 and 15 years (Cowan, 1941).

1.3 Impacts to Red-legged Frog Populations

A number of factors ranging in scale from global to local may be responsible for declines in red-legged frog populations. Habitat loss and alteration occurs on a local scale, although it is a global problem and is considered to be the most significant threat to pond-breeding amphibian species (Semlitsch, 2003a). In BC, habitat loss has been proposed as the most likely cause for declining red-legged frog populations (COSEWIC, 2004). By destroying the wetland and terrestrial habitat on which red-legged frogs rely, the number of frogs in a population is reduced and entire populations may be extirpated. The human impact on red-legged frog habitat is clearly illustrated by the fact that the area covered by wetland within the Lower Fraser Basin dropped from 10% to 1% between 1827 and 1990 due to human agricultural and urban development (Boyle, Lavkulich, Schreier, & Kiss, 1997). Wetlands are critical to the survival of red-legged frogs and all other native pond-breeding amphibians for both breeding and rearing. The other major habitat type required by red-legged frogs is forest in close proximity to wetlands. Maxcy (2004) estimates that up to 90% of an adult red-legged frog's life is spent in forested habitat. Between 1827 and 1990, the percent cover of coniferous forest in the Lower

Fraser Basin decreased from 71% to 54% and the composition of this forest changed from 27% immature (<120 year old forest) in 1827 to 73% immature forest in 1990 (Boyle et al., 1997). Habitat loss is expected to continue due to human development pressures, as the current population in the Greater Vancouver Region (2,419,100) is expected to increase by 36.5% to 3,301,839 by 2031 and the population of the Greater Victoria Area (330, 000) is expected to increase by 29.7% to 428,000 by 2026 (BC STATS, 2005; Capital Regional District, 2006).

The secondary impact of habitat loss or alteration is the fragmentation of core habitats and the loss of connections between breeding ponds necessary to maintain metapopulations (Semlitsch, 1998). Metapopulations are groups of local populations connected by dispersing individuals that strengthen the populations through interbreeding (Peck, 1998). As the landscape becomes more fragmented through loss of habitat, the likelihood of extirpations increases and the likelihood of re-colonization decreases due to the greater distance and/or decreased habitat connectivity between amphibian populations (Semlitsch & Bodie, 2003). With increasing fragmentation of habitat and isolation of populations, genetic drift and inbreeding depression will compound the problem of reduced re-colonization, further increasing the likelihood of extirpation of individual populations (Hitchings & Beebee, 1997). A recent study in Australia looked at pond-breeding amphibians in an urban setting and the findings indicated that without management intervention, urbanization might lead to reduced amphibian species diversity, particularly where roads reduce the probability of re-colonization following local extinction (Parris, 2006). Habitat fragmentation by roads is likely a significant factor in local declines of red-legged frogs in the Lower Fraser Basin since mortalities due to traffic have been documented for this species and traffic mortality has been shown to have a significant negative effect on anuran densities in urban environments (Fahrig, Pedlar, Pope, Taylor, & Wegner, 1995; Waye, 1999). Red-legged frogs in BC may be particularly sensitive to habitat loss and fragmentation since it has been shown that amphibian species at the northern periphery of their range have an increased sensitivity to habitat loss and fragmentation (Swihart, Gehring, Kolozsvary, & Nupp, 2003).

Introduced species of predatory fish and non-native amphibians are a major threat to amphibian species around the world (Semlitsch, 2003b). The introduction of non-native amphibian predators, particularly bullfrogs (*Rana catesbiana*), is believed to be the other major factor, along with habitat destruction, causing red-legged frog declines in BC (COSEWIC, 2004). Most amphibian species, including red-legged frogs, are also easily preyed upon by fish and can be eliminated from a wetland by these predators (Hecnar & M'Closkey, 1997). The introduction of predatory fish, native or non-native, can have a drastic impact on frog populations whose breeding pond had previously not contained fish predators (Semlitsch, 2003b). The most studied non-native amphibian species that preys upon red-legged frogs is the bullfrog (*Rana catesbiana*). It is clear from past research that American bullfrogs negatively affect red-legged frogs, but the magnitude of this effect and the mechanism(s) are still not clearly understood (Adams, 2000; Hayes & Jennings, 1986; Kiesecker & Blaustein, 1997). Research to date has found that the impact is worsened if red-legged frogs are exposed to both bullfrogs and predatory fish (Kiesecker & Blaustein, 1998). The impact to red-legged frogs from bullfrogs appears to be due to direct predation. It may also be partially a result of more indirect means such as reduced ability to feed due to harassment and threat of predation, that force red-legged frog tadpoles to more marginal habitat (Kiesecker & Blaustein, 1997; Kiesecker & Blaustein, 1998; Kiesecker, Blaustein, & Miller, 2001).

Disease has also been implicated in recent years for widespread, global amphibian declines (Berger, L. et al, 1998; Laurance, McDonald, & Speare, 1996; Semlitsch, 2003b). Two diseases shown to cause mass mortality in amphibians are chytridiomycosis and ranavirus infections. The chytrid fungus *Batrachochytrium dendrobatidis* causes chytridiomycosis, an epidermal infection, in a large variety of frog species (McCallum, 2005). This fungal disease was only discovered after mass mortalities were reported in the United States, Canada, Puerto Rico, and Australia in seemingly pristine environments (C. N. Carey, Cohen, & Rollins-Smith, 1999; Johnson, 2006; Semlitsch, 2003b). *B. dendrobatidis* has also been recovered from dead or dying frogs in areas experiencing amphibian population declines in Central America, Australia, and New Zealand (Dazsak, Cunningham, & Hyatt, 2003; La Marca et al., 2005) and has caused mortality of frogs in laboratory studies (Berger, L. et al, 1998). The infection occurs in the keratinized cells of the epidermis in both larval and postmetamorphic amphibians; however, the mechanism by which this infection becomes lethal is still not understood (Longcore, Pessier, & Nichols, 1999; Ouellet, Mikaelian, Pauli, Rodrigue, & Green, 2005). This fungal disease may play a role in the decline of red-legged frog populations in BC since *B. dendrobatidis* has infected other frog species in BC (Ouellet et al., 2005).

Ranaviruses are known to infect amphibians and are highly virulent thereby causing mass mortalities (Dazsak et al., 2003; Mao, Green, Fellers, & Chinchar, 1999). These viruses have been linked to significant levels of mortality in tiger salamanders (*Ambystoma tigrinum*) in Canada and common frogs (*Rana temporaria*) in the UK (Bollinger, Mao, Schock, Brigham, & Gregory, 1999; Dazsak et al., 2003). Larval, metamorphosing, and juvenile amphibians are all susceptible to these viruses (Dazsak et al., 2003; Jancovich, Davidson, Morado, Bertram, & Collins, 1997). Ranaviruses likely enter through the gills, skin, and digestive tract and are transmitted through contact with infected food, feces, animals, or water (Jancovich et al., 1997). The disease appears to cause necrosis of a number of organs including the liver, kidneys, muscles, and digestive tract, resulting in organ failure (Semlitsch, 2003b). Ranaviruses have not been documented in red-legged frogs, but these viruses are present in BC. Deaths due to these viruses may be occurring in red-legged frogs without our knowledge due to the lack of investigation.

Water pollution is typically a local or regional factor that may play a role in the decline of amphibian species, though population declines have rarely been directly linked to chemical contamination alone (Semlitsch, 2003b). This does not necessarily mean that pollutants are not responsible for amphibian species declines, but that the impacts can be hard to quantify except in the case of mass mortality (Semlitsch, 2003b). There may be significant indirect effects from chemicals that impact the food chain such that food items for particular developmental stages of red-legged frogs are reduced in availability (Semlitsch, 2003b). An example of this might be the introduction of an herbicide to a wetland that reduces the growth of algae, thereby reducing the food available for tadpoles. This would result in slower growth for many tadpoles, and therefore fewer individuals would reach metamorphosis and eventually contribute to the breeding adult population. A study by Davidson, Shaffer and Jennings (2001) attempted to determine the connection between declines in the California red-legged frog subspecies (*Rana aurora draytonii*) and pesticides. This study concluded that there is an association between pesticides and other agrochemicals and the declines observed in southern red-legged frog populations. Due to the similar biology and life history of the northern red-legged frog and the California red-legged frog, a study in BC on the impacts of pesticides and other pollutants may reveal a similar association between chemical contaminants and population declines.

UV-B solar radiation is another suspected to be a cause of declining of amphibian species around the world (Semlitsch, 2003b). UV-B radiation levels are higher than in the past due to human impacts to the ozone layer that filters UV radiation, and this can cause genetic damage to amphibians (Semlitsch, 2003a). However, research conducted to date has not identified UVB solar radiation as an important factor in red-legged declines. Blaustein et al. (1996) and Ovaska et al. (1997) studied the effects of UV-B solar radiation on red-legged frog eggs and tadpoles, respectively. Both studies found that red-legged frog populations, as red-legged frogs have a high capacity to repair DNA damaged by UV-B radiation. Blaustein et al. (1996) concluded that interactions between UV-B exposures and other factors may be important in embryo mortality, but that exposure to exotic predators, pollution, and habitat alteration are likely more significant factors in the decline of red-legged frogs.

Climate change is another global factor that may impact amphibians, though there have been few studies to date. Climate change could potentially have direct effects on amphibians by altering climate and rainfall enough to dry breeding ponds early in the year. Tadpoles may not have enough time to metamorphose, or moisture levels in terrestrial environments may not be high enough to support adult amphibians whose skin must remain moist. This direct effect is theoretically possible, but no conclusive evidence exists that climate change is directly responsible for mortality in any amphibian populations (C. Carey & Alexander, 2003). Climate change could also have more indirect effects on amphibians through temperature changes that alter the phenology of breeding (C. Carey & Alexander, 2003). Initiation of breeding in amphibians is controlled by temperature, so climate change could lead to changes in breeding timing that may affect breeding success (C. Carey & Alexander, 2003). One study found that an increase in average maximum temperature by 0.11 to 0.24 °C over a 17-year period corresponded with a two to seven week earlier breeding season initiation in two frog and three salamander species (Beebee, 1995). Interestingly, the timing of breeding initiation for another species of frog did not change in this same area over the same time period (Beebee, 1995). Another investigation of amphibians in North America found that four of six species were breeding earlier when records for 1900-1912 were compared to records from 1990-1999 (Gibbs & Breisch, 2001). While these studies have found some evidence of climate change impacts for amphibians in general, one has concluded that it is not an important factor for red-legged frogs. For example, three major findings of the study on the California red-legged frog subspecies (*Rana aurora draytonii*) point to the fact that climate change is not a factor in their decline: i) the lack of a clear north-south gradient in population declines, ii) an increase in population declines with elevation, and iii) a lack of association between mean precipitation and population declines (Davidson, Shaffer, & Jennings, 2001). The effect of climate change on northern red-legged frog populations has not been studied. However, it seems reasonable to assume that if the Intergovernmental Panel on Climate Change's prediction of a mean global temperature increase of 1.4-4.8 °C, and the associated changes in rainfall pattern between 1990 and 2100 are accurate, red-legged frog populations may be significantly affected in the future (Intergovernmental Panel on Climate Change, 2001). The specifics and magnitude of the effects on red-legged frogs as a result of this predicted climate change have not been studied and are difficult to predict.

1.4 Current Status

If red-legged frog populations in the Lower Fraser Basin of British Columbia are to be maintained or enhanced, it is first necessary to understand their current status. There is little published evidence of this understanding for BC populations since the only recent study on this species in BC is a 2003 study on Vancouver Island (Allaye Chan-McLeod, 2003). Prior to this, a series of studies were undertaken by Licht on populations in Langley, BC between 1969 and 1986, which provide insight into the breeding behaviour, foraging behaviour, and habitat requirements of this species (Licht, 1969, 1974, 1986). While these studies provide important information on the life history of red-legged frogs in the Lower Fraser Basin, the information regarding population status is outdated and is primarily based on a single site.

This study seeks to gather up-to-date information on the status of red-legged frogs in the City of Surrey, BC. The City of Surrey is an ideal location for this study for several reasons:

- it is in the heart of the range of red-legged frogs in BC;
- it is the largest municipality in BC in terms of geographic area;
- the human population in the City of Surrey is expected to have the greatest increase of any BC municipality over the next 25 years (Greater Vancouver Regional District, 2006); and
- the majority of the homes for the additional 216,000 people moving to Surrey over the next 25 years will primarily involve the development of greenfield sites that may be currently supporting red-legged frog populations.

Since habitat destruction is believed to be the major factor in red-legged frog population declines in BC, the pressure to create homes for these additional people in areas that may currently be functioning as red-legged frog habitat makes Surrey an ideal test case for red-legged frog conservation (COSEWIC, 2004). The recommendations of this study will be presented to the City of Surrey and are expected to lead to measures to protect red-legged frog populations since the City of Surrey Official Community Plan (2002), the City of Surrey Parks and Recreation Master Plan (1996), and the City of Surrey Parks Natural Area Strategic Master Plan (2001) all identify a desire to protect and enhance the City's native wildlife.

1.5 Research Problem

Red-legged frogs are federally and provincially listed as a species of special concern in BC (BC Ministry of Environment, 2007; Environment Canada, 2006). Habitat within their limited range in BC is continuing to disappear. Little current, published information is available on the distribution, habitat requirements, and response to human impacts of red-legged frogs in BC. This information gap must be filled to ensure adequate planning for the sustainability of this species. The first step in this process is the establishment of the current distribution of red-legged frogs. The research question for this thesis study is therefore: are red-legged frogs present in suitable aquatic habitats in parks within Surrey, BC?

1.6 Research Hypotheses

Ho: Red-legged frogs are not present in suitable aquatic habitats in parks within Surrey, BC.

Ha: Red-legged frogs are present in suitable aquatic habitats in parks within Surrey, BC.

1.7 Research Objectives

The primary objective of this research is to provide baseline distribution information for red-legged frogs in Surrey, BC. This understanding of the current distribution of red-legged frogs in Surrey parks will be used in conjunction with known habitat requirements and potential threats to provide park management recommendations that will promote the conservation and enhancement of red-legged frog populations in the City of Surrey. The information gathered in this study will also serve as an important component of the baseline information required for additional studies that will provide the knowledge necessary to ensure the sustainability of this species throughout their entire range within the Lower Fraser Basin.

2 Research Methodology

2.1 Research Site Selection

This study was conducted in twelve municipal parks in the City of Surrey, British Columbia, Canada during the spring and summer of 2006 (Figure 3). Potential study sites consisted of wetlands on municipal parkland with permanent or near permanent freshwater. These sites were identified using a three-stage process involving the use of ESRI ArcMap GIS software and spatial databases projected in UTM Zone 10, NAD83 datum that were made available by the City of Surrey. First, high-resolution raster aerial photography (0.1 m resolution) was reviewed in ArcMap to identify all wetlands within municipal parkland that could potentially support red-legged frogs. The GIS layer describing lot ownership was also critical as only wetlands found in municipal parkland were to be considered. The GIS layer of known water bodies was helpful when scanning for potential wetland sites as tree cover obscured some smaller wetlands. In addition to reviewing aerial photography, past experience working in parks throughout Surrey helped to identify additional potential study sites that were not detected using the aerial photography. When more than one wetland occurred within a single park, the wetland that was believed to provide the best combination of upland terrestrial and aquatic habitat was selected for the potential list of sites. This exercise resulted in the identification of 23 potential wetland study sites (Table 1).

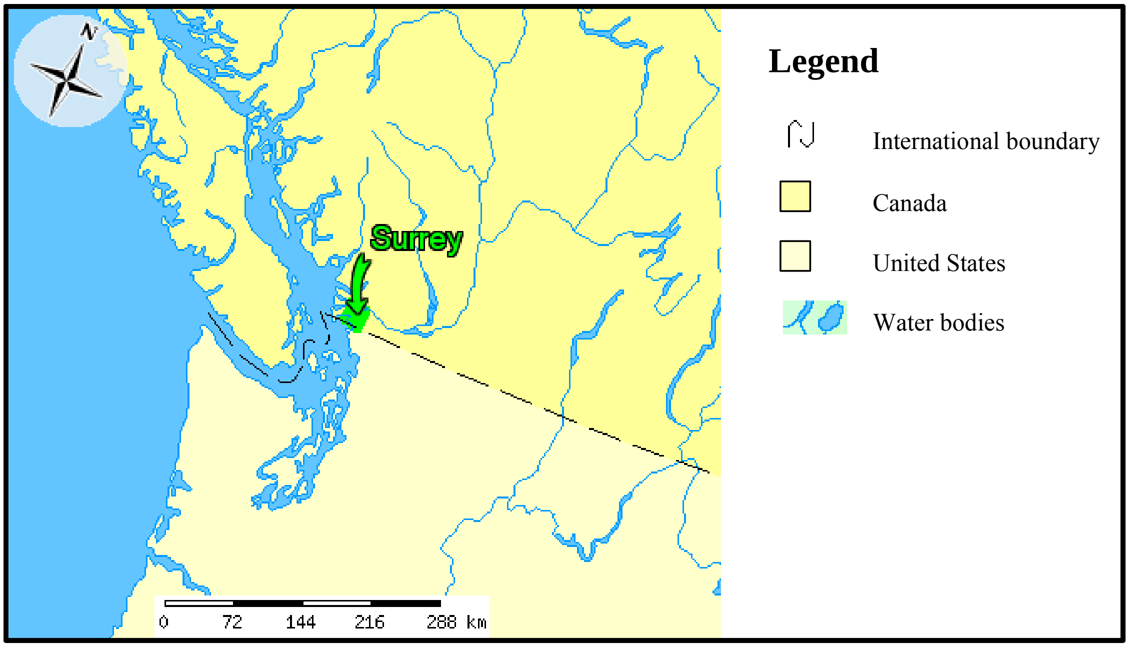

Figure 3. Location of the City of Surrey.

Table 1. Potential wetland study sites identified by park name and classified by terrestrial habitat quality.

Park	Terrestrial Habitat Quality[a]	Identification Method
Bothwell	High	Aerial photography
Colebrook	High	Aerial photography
Crescent	High	Aerial photography
Green Timbers Urban Forest	High	Aerial photography
Hi-Knoll	High	Personal knowledge
Surrey Bend	High	Aerial photography
Surrey Lake	High	Aerial photography
43 Z Utility Right-of-Way	Medium	Aerial photography
Elgin Heritage	Medium	Aerial photography
Hawthorne	Medium	Aerial photography
Latimer Lake	Medium	Aerial photography
Port Kells	Medium	Personal knowledge
Sullivan	Medium	Aerial photography
Sunnyside Acres Urban Forest	Medium	Personal knowledge
60E Greenbelt	Low	Aerial photography
Boundary	Low	Aerial photography
Chantrell Creek	Low	Aerial photography
Cougar Creek	Low	Aerial photography
Fraser Heights	Low	Aerial photography

Park	Terrestrial Habitat Quality[a]	Identification Method
Glenwood	Low	Aerial photography
Guildford Heights	Low	Aerial photography
Semiahmoo Trail	Low	Aerial photography
Southmere Village	Low	Aerial photography

[a] The high habitat quality class included candidate wetlands where the 200 m buffer zone contained 75% or greater red-legged frog habitat. The medium habitat quality class included candidate wetlands where the 200 m buffer zone contained between 25-75% red-legged frog habitat. The low habitat quality class included candidate wetlands where the 200 m buffer zone contained less than 25% red-legged frog habitat.

Once the complete list of potential study sites was generated, the sample was stratified based on the percentage of terrestrial habitat that existed within a 200 m buffer area surrounding each wetland. The 200 m terrestrial buffer was selected as an approximation of the average core habitat requirement of pond-breeding amphibians based on the findings of previous studies. A literature review by Semlitsh and Bodie (2003) looked at existing research on terrestrial habitat use by 19 frog species associated with wetlands to determine core habitat requirements. Core habitat was found to range between 159-290 m from the wetland. Another study by Semlitsh (1998) found that a 164 m buffer zone around wetlands encompasses the core habitat of 98% of pond breeding salamander species. The 200 m buffer was created for each of the study sites by first creating a polygon layer in ArcMap for the wetlands, then using this layer and the buffer function in ArcMap to generate a second layer that represented the 200 m terrestrial buffer around each of the wetlands (Figure 4).

This new terrestrial buffer layer was intersected with the City of Surrey's park natural area habitat layer to determine the area of each habitat type that fell within each of the 200 m buffers. This process left some areas of the 200 m buffer zones unclassified, so to ensure that 100% of all buffer areas were accurately described, further layers were created. These unclassified areas within the 200 m buffer zones were digitized as one of three new layers describing developed areas, habitat within contiguous private lands, and fragmented habitat within private lands. The developed areas layer consisted of those areas within the 200 m buffer zones that contained residential, commercial and industrial development. The habitat within private lands was not groundtruthed, so it was classified as contiguous habitat if it appeared in the aerial photographs to be primarily covered by native vegetation with no manmade structures present or it was classified as fragmented habitat if it was separated from the park habitat by residential, commercial or industrial development (including roads).

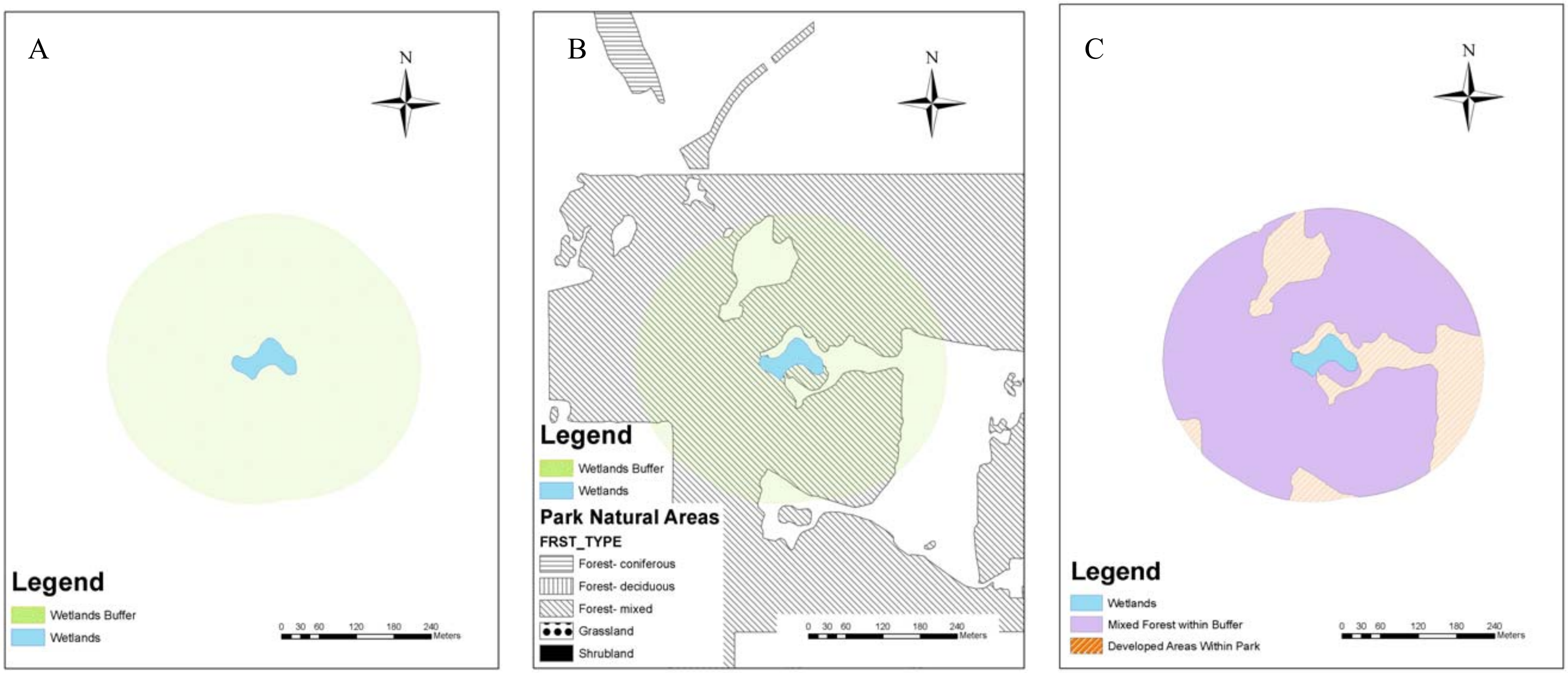

Figure 4. Illustration of the process completed in ArcMap to determine the areas of habitat and developed areas within the 200 m wetland buffer for each of the twelve study sites.

Note: For each of the twelve study sites a 200-metre buffer was created around each wetland (A) and then the habitat layer was intersected (B) to determine the areas of different habitats and developed areas within the 200 m buffer (C). Example used is Crescent Park.

The next step was to classify each site as having high, medium, and low terrestrial habitat value based on the percentage of the area within the buffer that was red-legged frog habitat. Areas were considered red-legged frog habitat if they were classified as forest, shrubland, or grassland in the City of Surrey GIS habitat database or they were included in the newly created 'habitat within adjacent private lands' and 'fragmented habitat within private lands' GIS layers. Differentiating between the quality of these habitats for red-legged frogs is not possible since it is currently not understood what constitutes high versus low value red-legged frog terrestrial habitat (Maxcy, 2004). For this reason, all landscapes that were native or naturalized plant communities were considered to be red-legged frog habitat. The City of Surrey's definitions for natural area habitat classes are listed in Table 2. The 'high' stratification class included only those candidate wetlands where the 200 m buffer zone contained 75% or greater red-legged frog habitat. The 'medium' stratification class included only those candidate wetlands where the 200 m buffer zone contained between 25-75% red-legged frog habitat. Finally, the 'low' stratification included only those candidate wetlands where the 200 m buffer zone contained less than 25% red-legged frog habitat. This stratification resulted in seven 'high' terrestrial habitat value sites, seven 'medium' terrestrial habitat value sites, and nine 'low' terrestrial habitat value sites.

Table 2. City of Surrey habitat type definitions.

Habitat Type[a]	Definition
Mature Coniferous Forest	A native or naturalized vegetation community that is dominated by coniferous trees that are greater than 50 years old. There may be up to 30% deciduous tree cover.
Young Coniferous Forest	A native or naturalized vegetation community that is dominated by coniferous trees that are less than 50 years old. There may be up to 30% deciduous tree cover.
Mature Mixed Forest	A native or naturalized vegetation community that is dominated by a mix of coniferous and deciduous trees that are greater than 50 years old. There must be greater than 30% of both coniferous and deciduous tree cover.
Young Mixed Forest	A native or naturalized vegetation community that is dominated by a mix of coniferous and deciduous trees that are less than 50 years old. There must be greater than 30% of both coniferous and deciduous tree cover.
Mature Deciduous Forest	A native or naturalized vegetation community that is dominated by deciduous trees that are greater than 50 years old. There may be up to 30% coniferous tree cover.
Young Deciduous Forest	A native or naturalized vegetation community that is dominated by deciduous trees that are less than 50 years old. There may be up to 30% coniferous tree cover.

Habitat Type[a]	Definition
Shrubland	A native or naturalized vegetation community that is dominated by the presence of shrubs. No more than 70% of the area may be dominated by grasses.
Grassland	A native or naturalized vegetation community that is dominated by the presence of grasses. Greater than 70% of the area must be dominated by grasses.

Note: Habitat type definitions from City of Surrey (2002) Natural Area Inventory Methodology. [a] Forest age class (young or mature) is based on the most prevalent species in the stand.

The third and final step for selecting research sites was the random selection of four sites from each of the three terrestrial habitat strata for a total of 12 study sites. Not all sites were included in the study since it would have made the data collection impractical considering time constraints. The final site selection was completed by randomly assigning a numeric value to each of the potential research sites then using the random number generator in Microsoft Excel to select four sites from each of the three strata.

2.2 Study Sites

Of the 23 potential study sites identified within the City of Surrey Parks system, four from each of the three terrestrial habitat strata were randomly selected (Table 3). The geographic location of each of these sites is indicated in Figure 5. A description of each of the study sites follows.

Table 3. List of study sites grouped by terrestrial habitat value.

High Habitat Value	Medium Habitat Value	Low Habitat Value
Crescent Park	43 Z Utility Right-of-Way	Boundary Park
Elgin Heritage Park	Bothwell Park	Cougar Creek Park
Hi-Knoll Park	Hawthorn Park	Guildford Heights Park
Green Timbers Urban Forest Park	Port Kells Park	Semiahmoo Trail Park

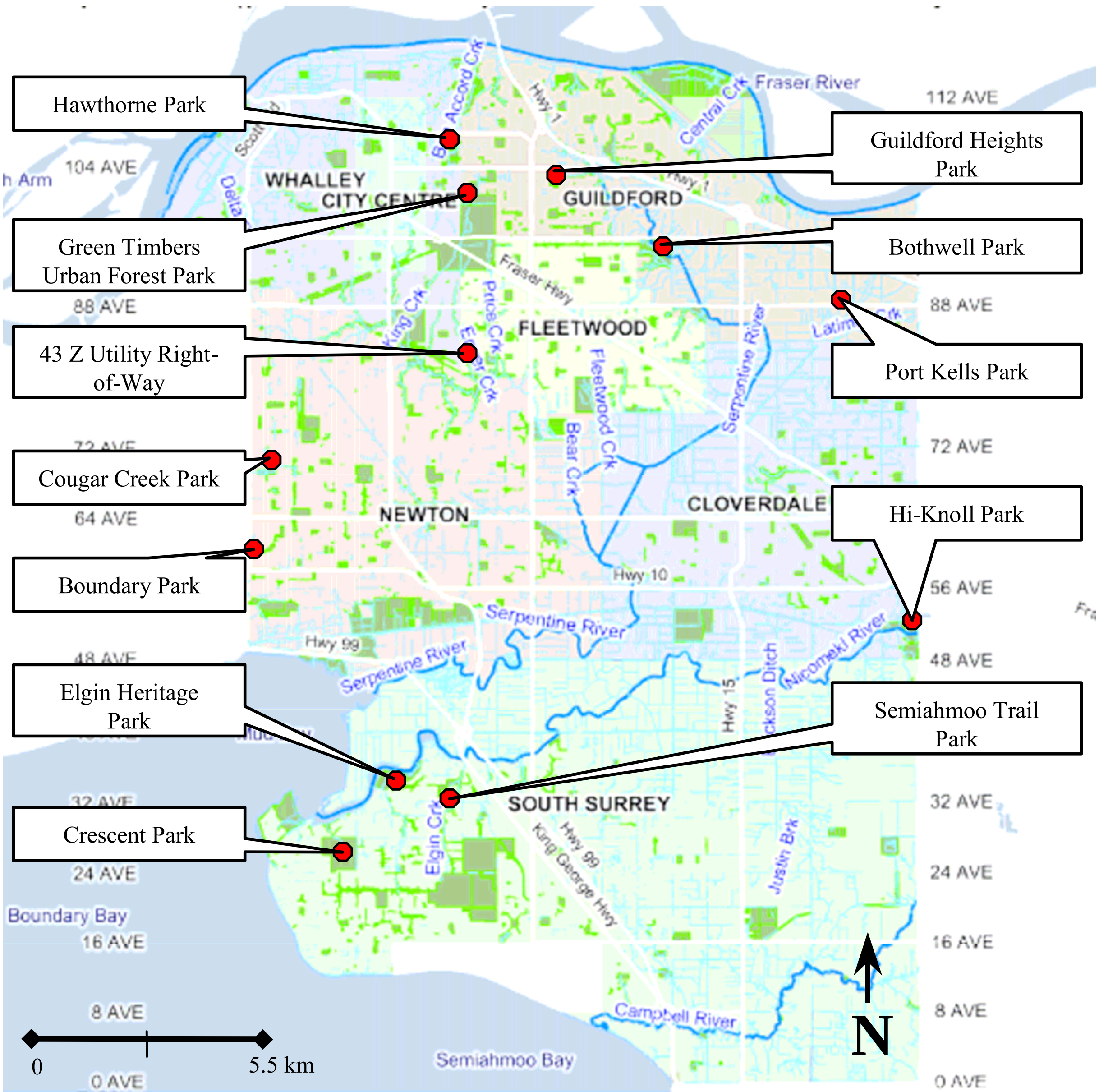

Figure 5. Study site locations in Surrey.

2.3 Spatial Analysis of Habitat

Spatial analysis of the terrestrial habitat at each wetland study site was conducted using ArcMap GIS software. The research site selection process described above divided each terrestrial buffer zone into mature coniferous forest, young coniferous forest, mature mixed forest, young mixed forest, mature deciduous forest, young deciduous forest, shrubland, grassland, developed areas, contiguous habitat within private lands, and fragmented habitat within private lands. Next, values were determined for total habitat within the 200 m buffer (every classification except developed areas) and total contiguous habitat within the 200 m buffer (all forest classes, shrubland, grassland, and unfragmented private habitat). These two values were calculated as the negative impact of habitat fragmentation on amphibian populations has been well documented (Fahrig et al., 1995; Knutson et al., 1999; Kolozsvary & Swihart, 1999; Rubbo & Kiesecker, 2005; Semlitsch, 1998; Silva, Hartling, Field, & Teather, 2003). The total habitat and total contiguous habitat within the 200 m buffer provide an accurate picture of the amount and continuity of the terrestrial habitat available to red-legged frogs within each of the buffer zones.

2.4 Habitat Classification

2.4.1 Terrestrial

The spatial analysis described above divided each of the 200 m terrestrial buffer zones into a mosaic of habitats. These habitat types are quite general and do not describe the plant species found within. In order to provide a more complete picture of the habitat found within the buffer zones, the vegetation communities were described based on dominant plant species using the field sampling methodology outlined in the Province of British Columbia's Field Manual for Describing Terrestrial Ecosystems (Meidinger, 1998) (Appendix I). The forms and the definitions from this manual were used to describe each vegetation layer, but the field sampling followed a modified version of the methodology described in the Field Manual for Describing Terrestrial Ecosystems (Meidinger, 1998).

The first step in describing the vegetation involved reviewing the aerial photograph and GIS habitat data layers to generate preliminary estimates of the percent cover of deciduous and coniferous trees. The dominant plant species in each vegetation class was then determined during a site visit to each park on July 16, 2006. Each of the tree and shrub canopy layers were described, as well as the herbaceous layer. Dominant plant species were defined as those plants that covered greater than 1% of the 200 m terrestrial buffer area. Species observed during site visits that had less than 1% cover were not recorded. Tree canopy layers were defined by the presence of woody plants greater than 10 m tall (Meidinger, 1998). There was a maximum of three different tree canopy layers on each site as described in the Field Manual for Describing Terrestrial Ecosystems (Meidinger, 1998):

- A1 or Dominant trees - the dominant trees in a stand that are either older than the main canopy or are simply the largest of the age class of trees that make up the main canopy;

- A2 or Main tree canopy - the main canopy of the forest whose crown makes up the upper layer of foliage; usually the major component of the stand; and

- A3 or Sub-canopy trees - trees greater than 10 m tall that do not reach the main canopy. These trees are either suppressed trees of the same age class as the main canopy or trees that are younger than the main canopy.

Shrub canopy layers were defined by woody plants, including tree regeneration, less than 10 m tall except low or trailing woody plants that are considered part of the herbaceous layer (Meidinger, 1998). Following the Field Manual for Describing Terrestrial Ecosystems (Meidinger, 1998) up to two different shrub layers on each site were described:

- B1 or Tall shrub layer: All woody plants 2-10 m tall including tree regeneration; and
- B2 or Low shrub layer: All woody plants less than 2 m tall including immature shrubs and trees, except low woody or trailing plants less than 15 cm that are considered herbs.

The herbaceous layer were defined by the presence of herbaceous plant species regardless of height and including woody plants less than 15 cm tall (Meidinger, 1998). The herbaceous layer was not broken down into sub-layers. It included vascular plants and ferns, but not mosses and other non-vascular plants. Due to lack of expertise in plant identification, there were instances where plant species were grouped together such as grasses where all species were simply grouped together as 'grass species' or for *Salix* (willow) where the total cover of all *Salix* species was recorded.

The description of the vegetation within the 200 m terrestrial buffer zones was intended to give a good conceptual description of the study area, but it was not intended as a variable in the research. For this reason, the vegetation data described above was gathered in the field by simply walking the buffer zone, identifying the plant species within each of the layers described above that covered greater than 1% of the terrestrial buffer area, and estimating the percent area of the 200 m terrestrial buffer zone covered by each plant species.

2.4.2 Wetland

The vegetation communities within the wetlands were not described in as much detail as the terrestrial buffer zone plant communities because it was assumed that the disturbed and modified terrestrial areas were more likely to affect the presence or absence of red-legged frog egg masses than the plant communities within the breeding ponds. Rather than classifying vegetation within each wetland, characteristics believed to be relevant to the success of red-legged frog populations were described for each wetland during the site visit on July 16, 2006. The parameters measured by visual approximation for each wetland included:

- percentage of wetland surface area in open water;
- percentage of surface area containing emergent aquatic vegetation (e.g.: *Typha latifolia*);
- percentage of surface area containing submerged aquatic vegetation (e.g.: *Potamogeton richardsonii*);
- percentage area containing coarse woody debris; and
- percentage of area containing fine woody debris.

The percentage of surface area containing coarse woody debris refers to the percentage surface area in each wetland containing a tree or part of a tree with a stem diameter greater than 20 cm. The percentage of surface area containing fine woody debris refers to the percentage surface area in each wetland containing a tree or part of a tree with a stem diameter less than 20 cm. Of these surface area parameters, only open water was considered to be mutually exclusive with the other parameters. Since the remainder of these cover types were not mutually exclusive, the total value of wetland cover for a site may be greater than 100%.

Each of these wetland habitat characteristics was reported as they were considered to be indicative of the quality of the habitat for red-legged frogs. Percent surface area containing emergent aquatic vegetation, submerged aquatic vegetation and fine woody debris were measured because red-legged frog egg masses are typically laid on aquatic vegetation or tree/shrub branches and the shallow areas that support aquatic vegetation are important areas for the tadpoles to find food and cover (Adams, 1999; Briggs, 1987; Corkran & Thoms, 2006; Licht, 1969; Matsuda et al., 2006; Maxcy, 2004; Storm, 1960). Conversely, percent surface area in open water was measured since wetlands with emergent aquatic vegetation were found to be more likely to be occupied by amphibians than those wetlands with greater areas of open water (Adams, 1999). The percent surface area containing coarse woody debris (CWD) was also recorded because CWD is believed to be an important structural habitat component for red-legged frog tadpoles (Maxcy, 2004).

2.5 Egg Mass Sampling Protocol

Each of the twelve study sites was visited six times, once per week, for the weeks of March 5, 2006 through to April 14, 2006 inclusive, to determine the presence/absence of red-legged frog egg masses. This time period was selected to catch the peak and the end of the laying season to ensure that maximum egg mass counts for the year were observed during site visits.

During each of the six site visits the entire perimeter of the wetlands, as well as interior areas with laying habitat, were searched for red-legged frog egg masses. This included observations with the naked eye and with binoculars. Due to the relatively small size of the wetlands studied, less than one hectare, this methodology enabled the entire area of each wetland to be sampled. In addition to the presence and absence of red-legged frog egg masses, a number of other parameters were observed and recorded during each visit. These parameters were date, surveyor, park, survey start time, survey end time, wind condition, precipitation, water temperature, air temperature, amphibian species observed, number observed, and comments. The data collection utilized was a modified version of the form described in the Inventory Data Forms for Pond-breeding Amphibians and Painted Turtle (BC Ministry of Environment, Lands and Parks, 1998) (Appendix II). Wind condition and precipitation were recorded according to the scales described in this same document (BC Ministry of Environment, Lands and Parks, 1998).

2.6 Water Quality

A number of water quality parameters were also measured at each of the study sites on April 14, 2006 including turbidity, temperature, salinity, dissolved oxygen, and pH. Turbidity is a combination of small, suspended particles and living organisms in the water column (Jones, Palmer, Motkaluk, & Walters, 2002). High levels of turbidity often indicate eutrophication, erosion, presence of storm water, and other negative impacts that could lower the amphibian habitat quality of a given wetland (Jones et al., 2002). Turbidity was tested using an Orbeco-Hellige Model 966 Portable Turbidimeter. Water grab samples were taken using an optically matched glass vial (measuring 28mm x 61mm) that was inserted directly into the turbidity meter. Turbidity readings are reported in NTUs or Nephelometric Turbidity Units. The resolution of the NTU readings for the range used (0-200 NTU) is 0.1 NTU and the accuracy is ± 2% (Orbeco Analytical Systems Inc., nd). Three different grab samples were collected from randomly selected locations at each wetland and the average value of these three samples was reported as the turbidity reading for the wetland.

All other water quality parameters were measured using an YSI 556 MPS multimeter (YSI Incorporated, nd). This device uses a series of probes to measure a number of water quality parameters including temperature, dissolved oxygen, salinity, and pH. Water temperature was recorded primarily as a predictive indicator of when egg masses were likely to begin to appear at each site, provided that breeding adults were present. Female red-legged frogs are known to start laying egg masses in breeding ponds once the water temperature reaches at least 4 ˚C (Licht, 1969; Licht, 1974). Dissolved oxygen level was recorded because low levels of dissolved oxygen have been shown to slow development of amphibian tadpoles, thereby decreasing the percentage of individuals able to reach metamorphosis particularly in breeding sites that dry up quickly each year (Babbitt, Baber, & Tarr, 2003; Gerlanc & Kaufman, 2005). Salinity was recorded because this water quality measure could potentially exclude the use of a wetland by any amphibian species. Amphibians are extremely sensitive to salinity due to their inability to osmoregulate (Gomez-Mestre, Tejedo, Ramayo, & Estepa, 2004). All of the major rivers in Surrey are tidal, so there was the potential for saline or brackish conditions in some of the wetlands studied. Finally, pH was recorded during the water quality sampling because pH levels have been shown to affect development and fitness of larval frogs (Ultsch, Bradford, & Freda, 1999). Specifically, pH levels below 4.5 have been shown to impact growth and increase mortality in amphibian species (Freda & Dunson, 1985; Sadinski & Dunson, 1992).

Water quality sampling using the YSI multimeter was done by submerging the probe approximately 30 cm below the surface of the water at a distance of 1 m from shore, and swinging the probe side-to-side at 30 cm/s. The side-to-side motion was recommended in the YSI multimeter manual to ensure accurate dissolved oxygen readings, as the steady state polarographic sensor consumes oxygen. As a result, the polarographic sensor will give steadily lower readings if not kept in continual motion (YSI Incorporated, nd). Each of the parameters was recorded once the respective value had stabilized for 10 seconds.

The YSI multimeter measures water temperature using a thermistor with a range of –5 to 45 °C, an accuracy of ±0.15 °C, and a resolution of 0.01 °C (YSI Incorporated, nd). Conductivity is measured using a 4-electrode cell with a range of 0 to 200 mS/cm, an accuracy of ±0.5% of reading or ±0.001 mS/cm (whichever is greater), and a resolution of 0.001 mS/cm to 0.1 mS/cm (range-dependent). Salinity is determined from the conductivity and temperature readings within a range of 0 to 70 parts per trillion (ppt), an accuracy of ±1.0% of reading or 0.1 ppt (whichever is greater), and a resolution of 0.01 ppt. Dissolved oxygen in mg/L is measured by a steady state polarographic sensor with a range of 0 to 50 mg/L, an accuracy of ±2% for readings between 0 and 20 mg/L and ±6% for readings between 20 and 50 mg/L, and a resolution of 0.01 mg/L. pH is measured using a glass combination electrode with a range of 0 to 14 units, an accuracy of ±0.2 units, and a resolution of 0.01 units.

Three different readings for each of these parameters were taken from the same random locations as the turbidity sampling. As with the turbidity sampling, the final water quality parameter values reported for each wetland were determined by averaging the three readings.

2.7 Bullfrog Presence/Absence

Any bullfrog observations made during regular weekly red-legged frog surveys were recorded. For each site at which bullfrogs had not been confirmed using this method, a brief bullfrog presence/absence survey was conducted on July 16, 2006. The survey involved a 15-minute time-constrained visual and auditory search for juvenile and adult bullfrogs around the perimeter of each wetland.

3 Results

3.1.1 Bothwell Park

General: Bothwell Park is located in the Guildford area of Surrey in a neighbourhood that is still largely rural with large lots and agricultural lands, though there have been recent small lot, single family residences built on the park's southern border. This park is a mosaic of mature mixed forest and grassland covering a total area of 39.0 hectares. The majority of the area is in a natural state with the exception of a playground, one softball field and a small lawn area with a picnic shelter totaling 1.3 ha. The Serpentine River runs through the park and acts as a partial source of water for the wetland, if not the primary source. A large regional park covering about 250 ha, Tynehead Park is located directly north of Bothwell Park across a busy two-lane road.

Wetland Study Site: The wetland on this site appears to be naturally occurring; perhaps an historic side channel of the Serpentine River, and beaver activity is currently enhancing the total area of the wetland. The wetland covers 2424 m^2 and is located at 517658 easting, 5446780 northing. The source of water for the wetland appears to be periodic overflows from high flow events in the Serpentine River and regular surface flows from the Park. Groundwater may enter the wetland, but there is no information available to substantiate this. The water level appears to be currently controlled by a small blockage, likely created by a beaver, at the southern or downstream end of the pond. Water flowing out of the pond enters the Serpentine River. Water flows between the pond and the river at certain times of the year, so fish may have access to the wetland.

The wetland cover consists of primarily emergent aquatic vegetation and open water (Figure 6). The 22.1 ha terrestrial buffer around this wetland includes 83.7% habitat dominated by mature mixed forest and grassland, with 70.3% of the 22.1 ha in an unfragmented state (Figure 6). The plant species composition within the 200 m buffer is described in Appendix III by vegetation layer.

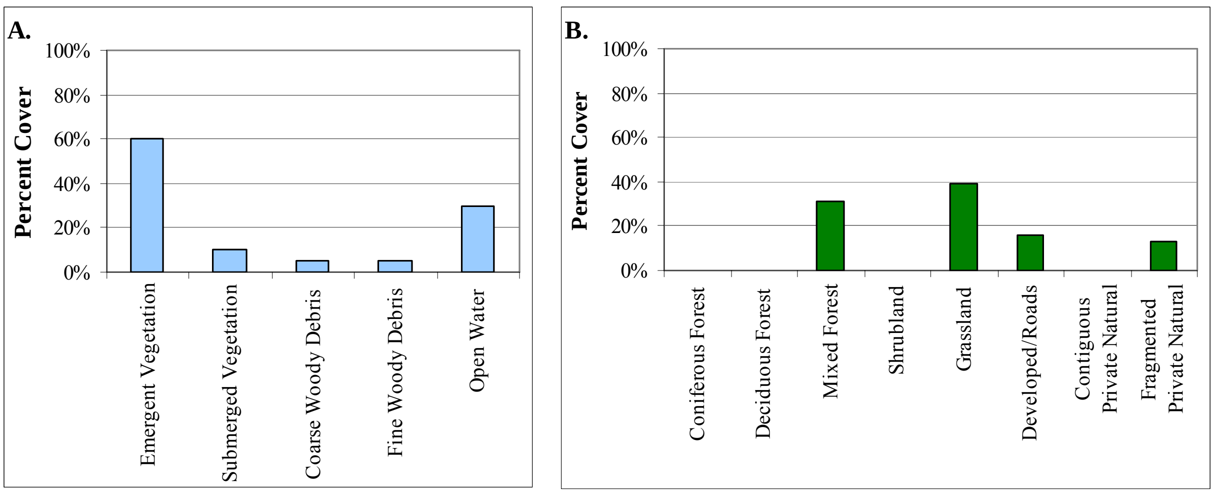

Figure 6. Wetland aquatic vegetation cover (a) and terrestrial vegetation cover within the 200 m buffer (b) for Bothwell Park.

3.1.2 <u>Crescent Park</u>

<u>General:</u> Crescent Park is located in South Surrey and is surrounded entirely by suburban residential development. This park covers a total area of 52.0 hectares with the majority of this area being a mixed mature forest with the exception of a playground, two baseball diamonds, several soccer fields, and three parking lots that total 7.4 ha.

<u>Wetland Study Site:</u> The wetland studied is the headwaters for a small creek that leaves the park and travels down a steep slope before entering the Nicomekl River Estuary. This wetland was man-made for aesthetic purposes approximately 20 years ago, but has naturalized

since that time. The wetland covers 3384 m^2 and is located at 510099 easting, 5433072 northing. The source of the water for the wetland appears to be surface and shallow groundwater from the park. The water level appears to remain relatively stable based on the characteristics of the shoreline and the weir at the outfall that ensures the water level only reaches a specific, maximum depth.

The wetland cover consists of greater than 50% submerged aquatic vegetation (Figure 7). The 18.4 ha terrestrial buffer around this wetland includes 80.2% unfragmented, mature mixed forest, with the remaining 19.8% of the area covered by developed area/roads (Figure 7). The plant species composition within the 200 m buffer is described in Appendix III by vegetation layer.

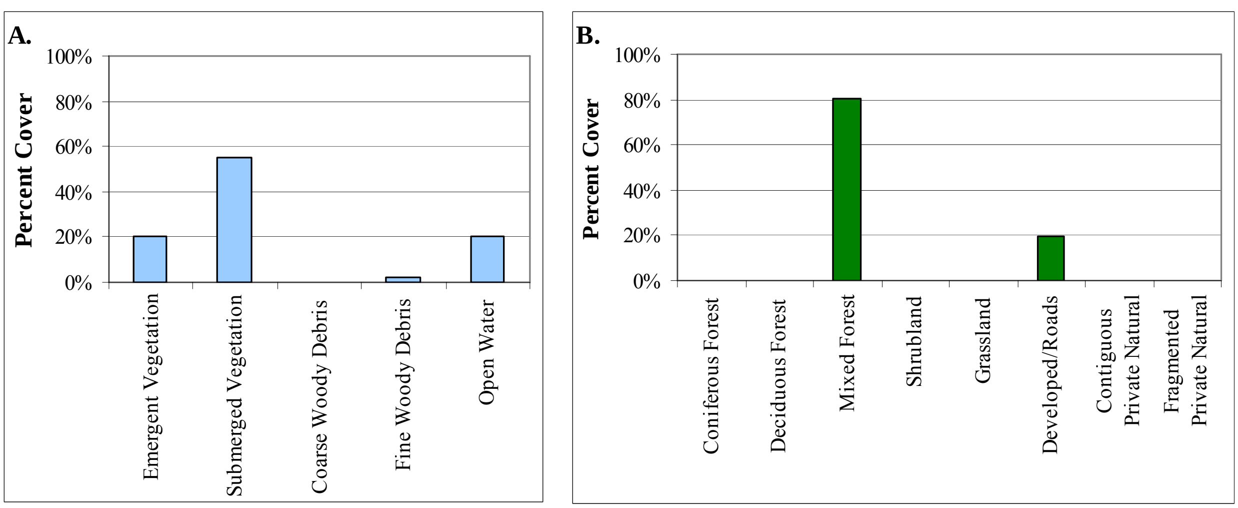

Figure 7. Wetland aquatic vegetation cover (a) and terrestrial vegetation cover within the 200 m buffer (b) for Crescent Park.

3.1.3 Green Timbers Urban Forest Park

General: Green Timbers Urban Forest Park is located in the Whalley area of Surrey and is surrounded by suburban and urban development. Nearly all of the 392 ha within this park are in a natural state, but three two-lane roads and one four-lane road heavily fragment this natural area. This park contains the largest mature forest of any of the study sites and is the last remnant of the forest stand that was the first reforestation site in British Columbia in the early 1930s (City of Surrey, 2006). Green Timbers Urban Forest Park is also the headwaters of three salmon-bearing streams that drain to the Serpentine River and eventually to the Pacific Ocean.

Wetland Study Site: The wetland on this site was man-made in 1997 and covers 3458 m^2 located at 513020 easting, 5447720 northing. The wetland has a central serpentine channel totalling 1006 m^2 with water depths that ranged between 20 cm and 75 cm for the duration of this study. The remaining 2,452 m^2 of the wetland was wet for the duration of the study, but had no measurable depth of water. These wet areas are submerged during higher flow periods in the spring and fall. The source of the water for this wetland is a combination of groundwater drawn up by an electric pump, surface flows from the park, and storm water from the parking lot and neighbouring residential development. The wetland drains over a waterfall with a 2 m drop to a 142 m long channel that drains to Green Timbers Lake, a man-made lake also created in 1997. The waterfall feature is a barrier that prevents fish access to the wetland. From Green Timbers Lake, the water drains to King Creek, a salmon-bearing stream that drains to the Serpentine River and eventually to the Pacific Ocean.

The serpentine channel is the only area in the wetland that contains water in the spring and it has a heavy cover of both emergent and submerged aquatic vegetation (Figure 8). The combined cover for the two types of aquatic vegetation exceeds 100% because the majority of the area contains both emergent and submerged aquatic vegetation.

The 17.6 ha terrestrial buffer around this wetland includes 94.6 % habitat dominated by mature coniferous forest and grassland, with 94.2% of the 17.6 ha in an unfragmented state

(Figure 8). The plant species composition within the 200 m buffer is described in Appendix III by vegetation layer.

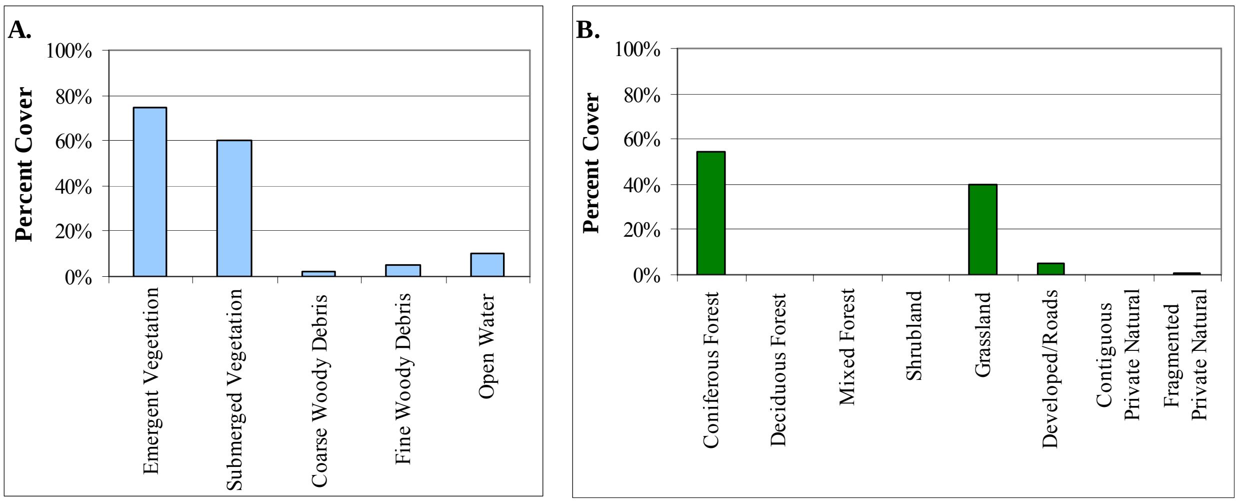

Figure 8. Wetland aquatic vegetation cover (a) and terrestrial vegetation cover within the 200 m buffer (b) for Green Timbers Urban Forest Park.

3.1.4 Hi-Knoll Park

General: Hi-Knoll Park is located in the Cloverdale area of Surrey and has rural areas and farmlands to the south and west, industrial lands to the north, and suburban residential development to the east. The park contains a mix of mature coniferous forest and floodplain grassland and covers a total area of 34.0 ha. There are no sports fields or playgrounds, but a transmission line corridor runs through the park in a generally north-south direction. In addition, a moderately busy two-lane road bisects the park. To the south of this road is the forested knoll after which the park is named, and to the north is the floodplain of the Nicomekl River. Two streams are located in the park; Anderson Creek, which comes from the south and drains into the Nicomekl River, and McLellan Creek, which drains into the Nicomekl River from the north.

Wetland Study Site: The wetland on this site appears to be naturally occurring, likely an historic side channel of Anderson Creek. The wetland covers 368 m^2 and is located at 523094 easting, 5437641 northing. The source of the water for the wetland is Anderson Creek as it is connected to this wetland during high flow periods. For this reason, it is likely that this wetland contains fish.

The wetland cover consists of primarily open water with a minor component of emergent aquatic vegetation cover (Figure 9). The high percentage of the wetland area that is open water does not appear to be a result of the depth of water, but rather the extensive leaf drop from the deciduous forest cover that suppresses growth of aquatic plants.

The 14.9 ha terrestrial buffer around this wetland includes 85.2% habitat with a mix of mature deciduous forest and shrubland, with 79.6% of the 14.9 ha in an unfragmented state (Figure 9). The plant species composition within the 200 m buffer is described in Appendix III by vegetation layer. The majority of the tree cover in the forest is an A3 layer because much of the terrestrial buffer for this wetland is under electric transmission lines and therefore the tree height is controlled by regular pruning.

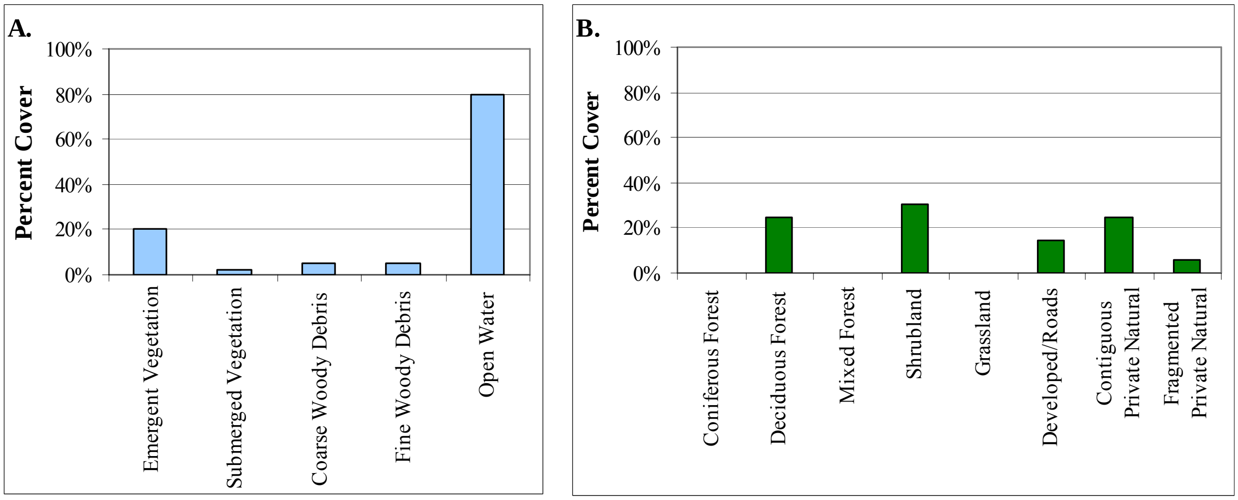

Figure 9. Wetland aquatic vegetation cover (a) and terrestrial vegetation cover within the 200 m buffer (b) for Hi-Knoll Park.

3.1.5 <u>43 Z Utility Right-of-Way</u>

<u>General:</u> 43 Z Utility Right-of-Way is an unnamed park located in the Guildford area of Surrey that is surrounded by other riparian corridor parks that make up a network of greenbelts. The exception is the northern perimeter of the park that is bordered by recent residential development. This park covers a total area of 7.8 ha entirely in a natural state with mixed forest and grassland areas. This area measurement for the Park can be misleading as the network of riparian corridor parks, with which it is contiguous, covers about 30 ha.

<u>Wetland Study Site:</u> Bear Creek runs through the park and the wetland drains into Bear Creek, but there is no fish-accessible connection between the two, so it is unlikely that there are fish in the wetland. The wetland on this site appears to be naturally occurring, though a culvert directing storm water into the wetland was installed in 2000. The wetland covers 1121 m^2 and is located at 513397 easting, 5444006 northing. The source of the water for the wetland is a combination of residential storm water and surface flows from the park and neighbouring

properties. Based on observations of the wetland perimeter, the water levels do not appear to fluctuate greatly.

The wetland cover consists of primarily open water (Figure 10). The 15.7 ha terrestrial buffer around this wetland includes 61.8% unfragmented habitat with a combination of mature mixed forest and grassland (Figure 10). The plant species composition within the 200 m buffer is described in Appendix III by vegetation layer.

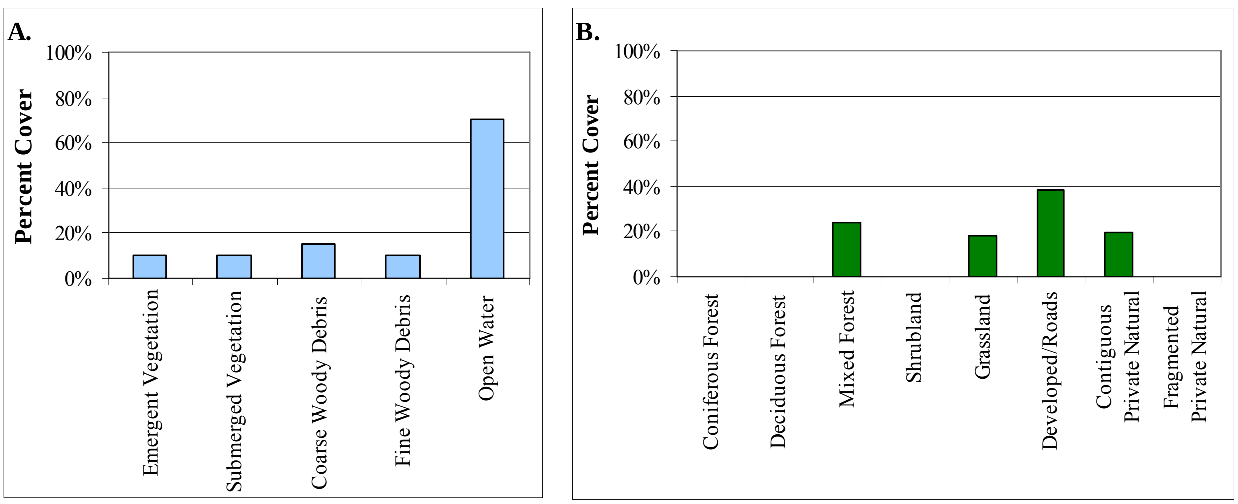

Figure 10. Wetland aquatic vegetation cover (a) and terrestrial vegetation cover within the 200 m buffer (b) for 43 Z Utility Right-of-Way.

3.1.6 Elgin Heritage Park

General: Elgin Heritage Park is located in South Surrey and is bordered by the Nicomekl River (which is brackish in this location) on the north side and a two-lane road and large lot residential development on the south side. This park covers a total area of 23.5 ha with the majority of the area in a natural state with the exception of a few historical buildings and their associated landscaping, a small marina, and two parking lots totaling 2.9 ha. The natural areas in Elgin Heritage Park are a mosaic of salt marsh, grassland, and mature mixed forest.

Wetland Study Site: The wetland on this site may have been the historic path for nearby Chantrell Creek that was diverted early this century, likely to create farmland. The wetland is currently fed by surface and groundwater sources, with the exception of high flow periods in the winter when Chantrell Creek will sometimes overflow its banks and the floodwaters will enter the wetlands in Elgin Heritage Park. The wetland covers 6949 m^2 and is located at 511175 easting, 5434668 northing. This wetland tends to hold a lot of water in the winter and the levels slowly subside through the spring and summer before being replenished in the fall. The occasional contribution from Chantrell Creek during high flow periods may introduce fish into the wetland.

No detailed 200 m terrestrial buffer vegetation and wetland composition data were gathered for this site because it was deemed to be irrelevant once it was determined that the salinity levels in the wetland meant that it could not support red-legged frog egg masses.

3.1.7 Hawthorne Park

General: Hawthorne Park is located in the Whalley area of Surrey and is surrounded by suburban and urban development. This park covers a total area of 22.3 hectares with the majority of this area being a mature deciduous forest with a minor, younger coniferous component, with the exception of a playground, a water spray park, a parking lot, and some horticultural garden areas totaling 3.8 ha. Bon Accord Creek runs through the Park and the wetland study site is part of this creek system. In addition, Green Timbers Urban Forest is just over half a kilometre from Hawthorne Park, though amphibians moving between these areas would have to cross multiple busy roads and residential development to do so.

Wetland Study Site: The wetland on this site was constructed in 1999 and consists of a large pond connected to Bon Accord Creek. The wetland covers 8512 m^2 and is located at

512630 easting, 5449122 northing. The source of the water for the wetland is a combination of the inflow from Bon Accord Creek, storm water from neighbouring residential development, and surface runoff from the park. The wetland generally drops off steeply on its banks leaving little area for the growth of aquatic vegetation. Based on observations of the wetland perimeter it appears that the water levels can fluctuate greatly.

The wetland cover consists primarily of open water (Figure 11). The 25.2 ha terrestrial buffer around this wetland includes 43.1% unfragmented mature deciduous forest and 56.9% developed area/roads (Figure 11). The plant species composition within the 200 m buffer is described in Appendix III by vegetation layer.

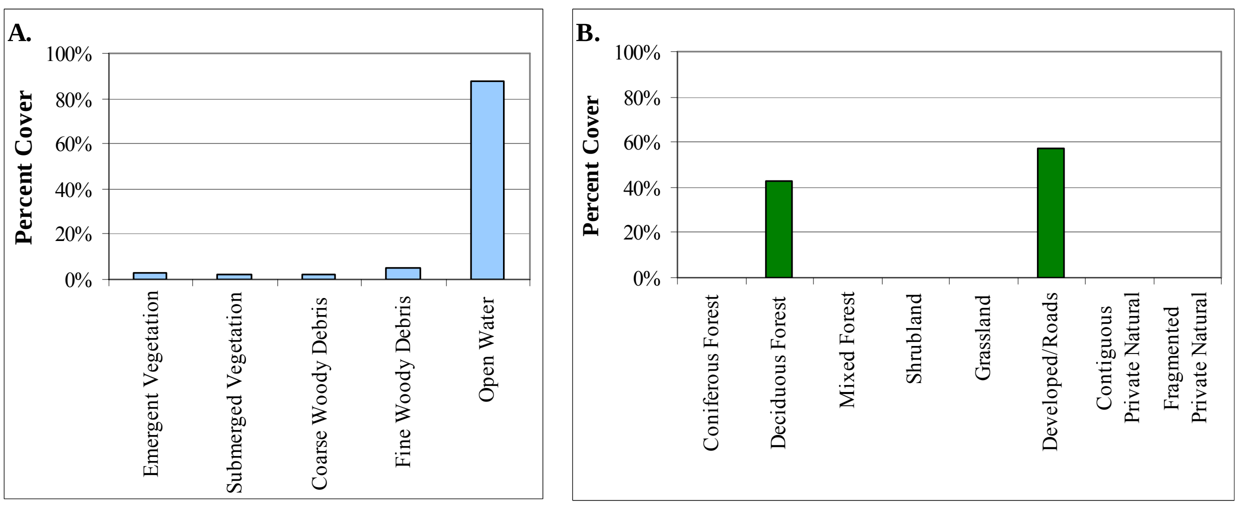

Figure 11. Wetland aquatic vegetation cover (a) and terrestrial vegetation cover within the 200 m buffer (b) for Hawthorne Park.

3.1.8 Port Kells Park

General: Port Kells Park is located in the Port Kells area of Surrey and is surrounded by large residential lots (> 1 acre) and farmlands. This park covers a total area of 13 ha with approximately two-thirds of this area in a natural state. The remaining areas are covered by a playground, swimming pool, two softball diamonds, and an asphalt parking lot totaling 4 ha. The natural area is comprised of mature coniferous forest with a significant deciduous component, and is bisected by Latimer Creek.

Wetland Study Site: The wetland on this site is clearly man-made, though it could not be determined whether water is being diverted into this pond through pipes or if it is strictly fed by surface and potentially groundwater flows. The wetland covers 613 m^2 and is located at 522679 easting, 5445286 northing. Water flows out of the wetland through a pipe onto the forest floor and eventually into Latimer Creek. Though Latimer Creek contains fish, it seems unlikely that fish enter this wetland due to the lack of a distinct channel between the Creek and wetland.

The wetland cover consists of primarily open water (Figure 12). The high percentage of open water in the wetland does not appear to be a result of the depth of water, but rather the extensive leaf drop from the deciduous forest cover that suppressed growth.

The 14.5 ha terrestrial buffer around this wetland includes 46.2% habitat dominated by mature deciduous forest, with 42.0% of the 14.5 ha in an unfragmented state (Figure 12). The plant species composition within the 200 m buffer is described in Appendix III by vegetation layer.

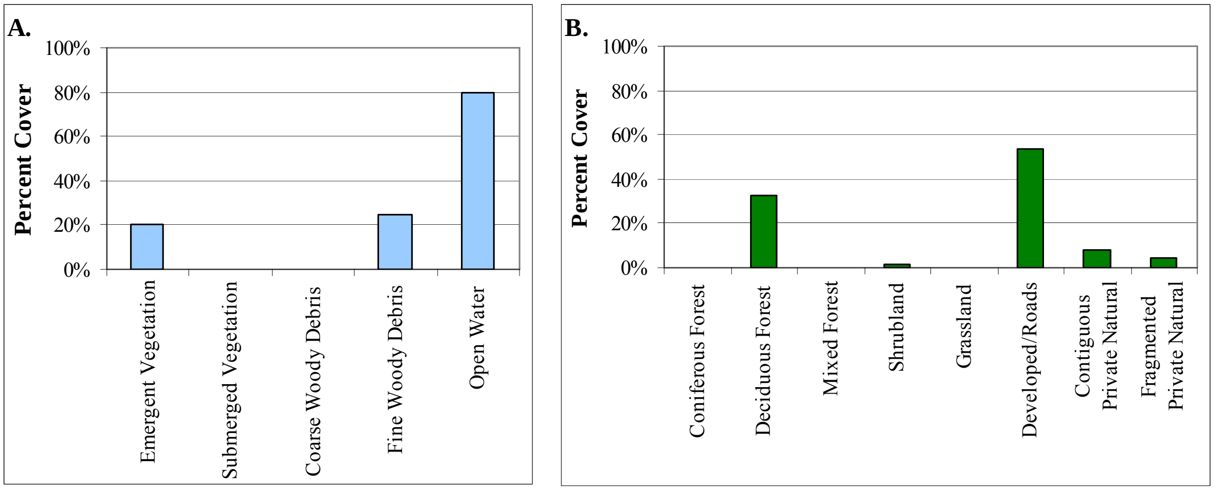

Figure 12. Wetland aquatic vegetation cover (a) and terrestrial vegetation cover within the 200 m buffer (b) for Port Kells Park.

3.1.9 Boundary Park

General: Boundary Park is located in the Newton area of Surrey and is entirely surrounded by residential development. This park covers a total area of 8.3 ha, with the majority of the area maintained as mowed lawn. The natural area in the Park is forested and covers 2.9 hectares, though the majority of this forest (2.7 ha) is located at the opposite end of the park from the wetland and is separated by about 570 m of mowed lawn. Watershed Park in the Corporation of Delta (a neighbouring municipality) is more than a square kilometre in size and only about 160 m from the wetland, however there is an extremely busy four-lane road between the wetland and Watershed Park.

Wetland Study Site: This wetland is a man-made storm water detention facility that was constructed in 1985. The water in this wetland is therefore largely storm water from surrounding residential areas, with a minor component of surface flows from the Park. The variable nature of the storm water flows means that the water levels in the pond vary greatly. The wetland covers 8385 m^2 and is located at 508182 easting, 5439948 northing. This wetland is not directly connected to a water body that contains fish, but fish were observed during egg mass surveys and are likely present as a result of the illegal introduction of non-native fish.

The wetland cover consists almost entirely of open water (Figure 13). The 20.8 ha terrestrial buffer around this wetland includes a total of 4.2% mature coniferous forest, largely fragmented, and 95.8% developed area/roads (Figure 13). The plant species composition within the 200 m buffer is described in Appendix III by vegetation layer.

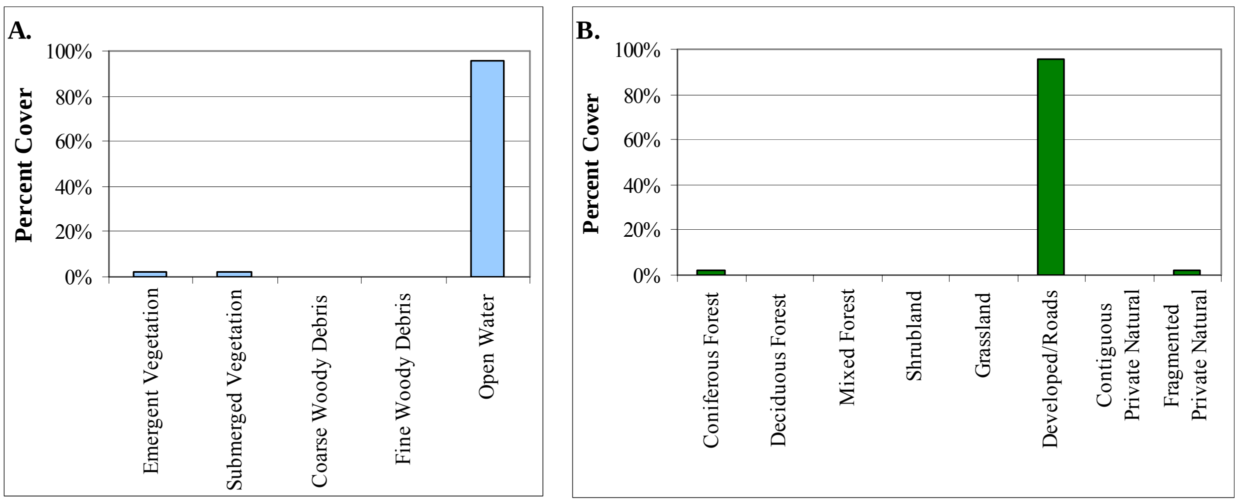

Figure 13. Wetland aquatic vegetation cover (a) and terrestrial vegetation cover within the 200 m buffer (b) for Boundary Park.

3.1.10 Cougar Creek Park

General: Cougar Creek Park is located in the Newton area of Surrey and is entirely surrounded by suburban residential development. This park covers a total area of 5.7 ha, most of which is either sports field or mowed lawn area. The natural area within Cougar Creek Park covers 2.6 ha.

Wetland Study Site: Cougar Creek runs through the park and the wetland. The wetland was constructed as a storm water detention facility in 1998 and covers 9332 m^2 and is located at

508283 easting, 5441760 northing. The source of the water for the wetland is storm water conveyed by Cougar Creek and other sources of water that feed the Creek including surface flows. Due to the storm water flows, the water levels fluctuate greatly in this wetland. As this wetland is part of the Cougar Creek system, it contains fish.

The wetland cover consists almost entirely of open water (Figure 14). The 30.0 ha terrestrial buffer around this wetland includes 17.7% habitat dominated by young deciduous forest, with 7.2% of the 30.0 ha in an unfragmented state (Figure 14). The plant species composition within the 200 m buffer is described in Appendix III by vegetation layer.

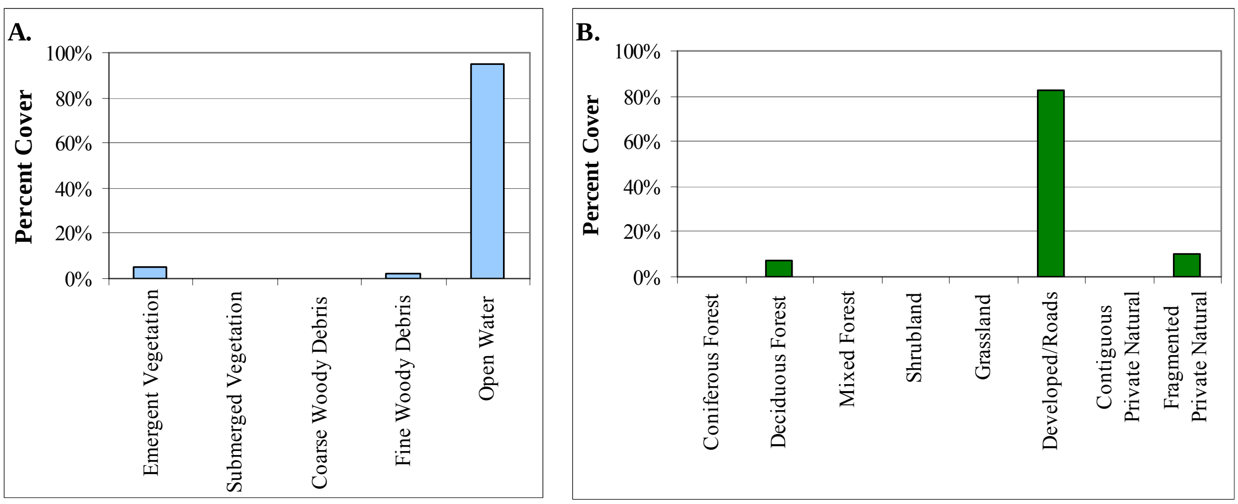

Figure 14. Wetland aquatic vegetation cover (a) and terrestrial vegetation cover within the 200 m buffer (b) for Cougar Creek Park.

3.1.11 Guildford Heights Park

General: Guildford Heights Park is located in the Guildford area of Surrey and is surrounded by commercial and high-density residential development. This park covers a total area of 6.5 ha with roughly 50% of the area in a natural state and the remaining 50% as cultured lawn and active recreational areas. There is a small pocket of remnant forest near the wetland, but the remaining wetland perimeter is planted with a variety of native plants that are not fully established at this point.

Wetland Study Site: This wetland and the majority of the natural area surrounding it are man-made and were only completed in 2001. The wetland serves as a storm water detention pond and has an outlet that leads to a tributary of the Serpentine River. This constructed wetland now serves as a major component of the Serpentine River headwaters since the majority of the historical headwaters are now developed as impermeable surfaces. The wetland or detention pond covers 9746 m^2 and is located at 515030 easting, 5448575 northing. The wetland is subject to frequent and substantial fluctuations in water level and poor water quality. The wetland does not contain fish, though the City of Surrey is working to remove barriers so that fish can move into this wetland in the future.

The wetland cover consists primarily of open water with some emergent aquatic vegetation (Figure 15). The 22.4 ha terrestrial buffer around this wetland includes 16.6% habitat with a combination of mature mixed forest and shrubland, with 13.7% of the 22.4 ha in an unfragmented state (Figure 15). The plant species composition within the 200 m buffer is described in Appendix III by vegetation layer. Much of the shrub cover listed is found within the recently planted area around the wetland that consists of immature trees and shrubs.

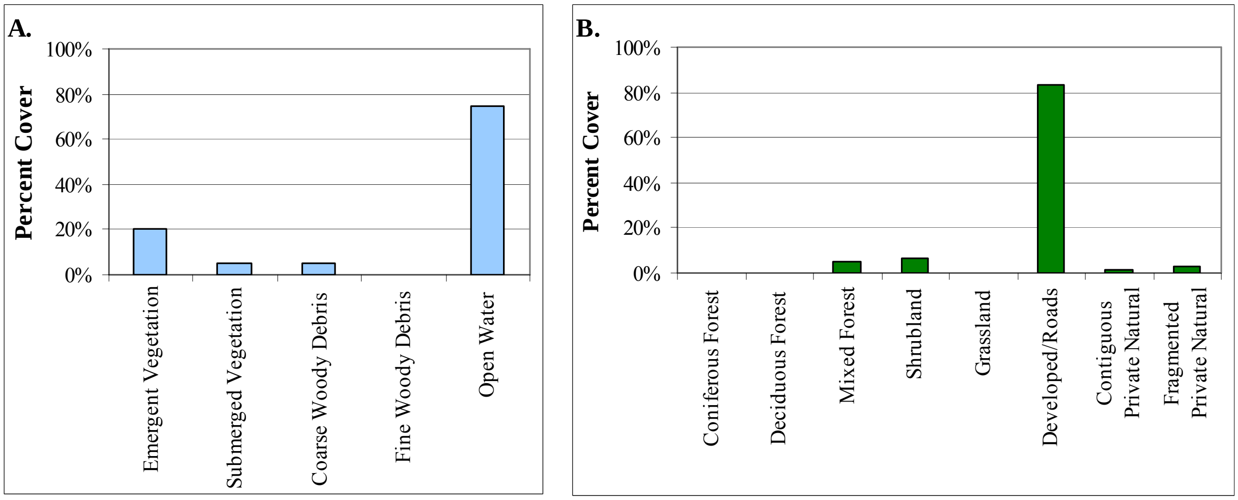

Figure 15. Wetland aquatic vegetation cover (a) and terrestrial vegetation cover within the 200 m buffer (b) for Guildford Heights Park.

3.1.12 <u>Semiahmoo Trail Park</u>

<u>*General:*</u> Semiahmoo Trail Park is located in the South Surrey area in a neighbourhood that has been traditionally large rural lots, but in the last ten years has seen extensive high density single family residential and multifamily residential development. This small neighbourhood park covers a total area of 3.5 ha with the majority of this area in a natural state, except for walking trails and a 0.5 ha grassy area that is mowed a few times a year. Walking trails are present around the wetland and through patches of young deciduous forest in the park.

<u>*Wetland Study Site:*</u> The wetland in the park is separated from the majority of the forest by a small, dead-end two-lane road that serves only a small number of homes. The wetland itself is a feature that was built within the last ten years as part of the redevelopment of the area to higher density residential neighbourhoods. The wetland serves as a storm water detention facility and as such receives the majority of its flows from storm water runoff and a minor component from the small catchment area within the Park. The sporadic and sometimes extreme flows into the pond mean that the pond levels fluctuate greatly, which is evident by the nature of

the vegetation and erosion on the banks of the wetland. The wetland does not appear to contain fish or be directly connected to a fish-bearing watercourse.

The wetland cover consists primarily of submerged aquatic vegetation and open water (Figure 16). The 17.8 ha terrestrial buffer around this wetland includes 17.5% habitat with a combination of young coniferous and deciduous forest, with 10.2% of the 17.8 ha in an unfragmented state (Figure 16). The plant species composition within the 200 m buffer is described in Appendix III by vegetation layer.

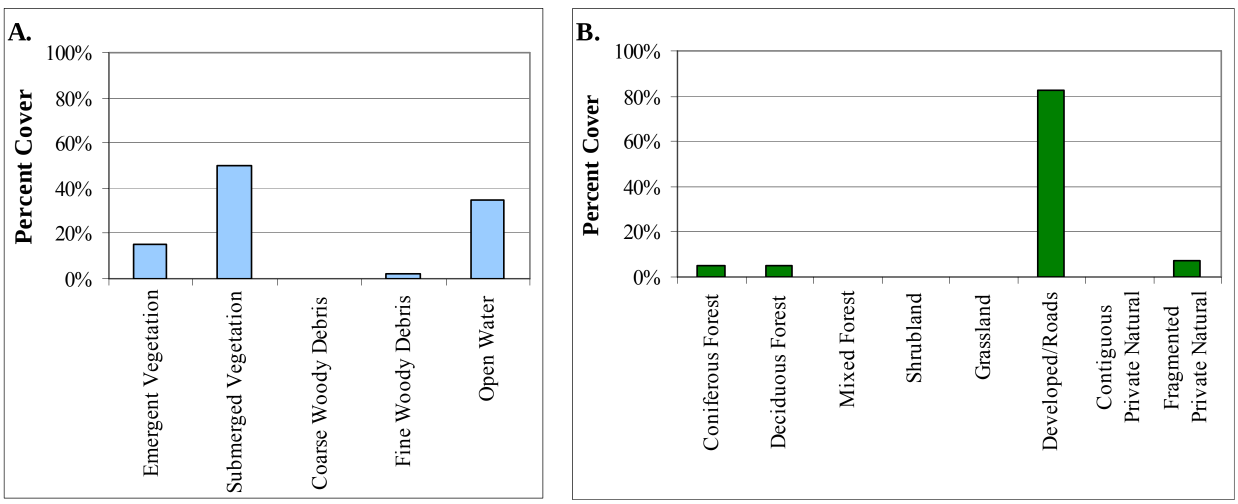

Figure 16. Wetland aquatic vegetation cover (a) and terrestrial vegetation cover within the 200 m buffer (b) for Semiahmoo Trail Park.

3.2 Water Quality

Water quality varied significantly among the study sites. The Green Timbers Urban Forest Park wetland had the highest dissolved oxygen level (9.46) (Table 4). The Elgin Heritage Park wetland had an extremely high salinity (1.143 ppt), which precluded the presence of any egg masses. Cougar Creek Park, Hi-Knoll Park, and Hawthorne Park wetlands all had turbidity readings above 12 NTU, indicating poor water quality. The Hi-Knoll Park wetland site had the lowest pH by far at 4.99, while the Elgin Heritage wetland had the highest pH at 7.38. Both of these pH levels, though on opposite ends of the spectrum, may have reduced the value of these wetlands as red-legged frog breeding and rearing sites.

Table 4. Water quality results and red-legged frog egg mass presence by site.

Park	Terrestrial Habitat Value	Red-legged Frog Presence	Temp. (°C)	Turbidity (NTU)	Salinity (ppt)	Dissolved Oxygen (mg/L)	pH
Bothwell	High	Y	9.3	7.9	0.030	2.46	6.53
Crescent	High	Y	9.2	3.4	0.040	5.28	6.26
Green Timbers	High	Y	7.4	6.6	0.013	9.46	6.45
Hi-Knoll	High	N	8.2	12.3	0.030	2.52	4.99
43 Z ROW	Medium	Y	9.7	4.3	0.040	2.52	6.81
Elgin	Medium	N	10.3	8.6	1.143	5.17	7.38
Hawthorne	Medium	Y	8.4	12.0	0.033	7.60	6.64
Port Kells	Medium	N	6.4	2.6	0.060	2.50	7.26
Boundary	Low	N	10.9	11.0	0.060	8.84	7.18
Cougar Creek	Low	N	9.2	13.1	0.047	7.76	6.86
Guildford Heights	Low	N	8.8	10.6	0.047	8.03	6.94
Semiahmoo Trail	Low	Y	10.6	5.5	0.063	8.47	6.12

3.3 Egg Mass Presence / Absence

Red-legged frog egg masses were observed at six of the twelve study sites (Table 5). Green Timbers Urban Forest Park and Bothwell Park had the highest red-legged frog egg mass counts with maximum counts of 182 and 135 egg masses, respectively. Three of the sites with red-legged frog egg masses were classified as having high value terrestrial habitat, two had medium value terrestrial habitat, and one had low value terrestrial habitat.

Table 5. Red-legged frog egg mass counts for each site by date surveyed.

Park	Terrestrial Habitat Value	Week of March 5	Week of March 12	Week of March 19	Week of March 26	Week of April 2	Week of April 9
Bothwell	High	0	10	56	97	**135**	96
Crescent	High	0	11	**16**	9	9	4
Green Timbers	High	0	0	159	163	**182**	113
Hi-Knoll	High	0	0	0	0	0	0
43 Z ROW	Medium	0	3	7	**10**	9	7
Elgin	Medium	0	0	0	0	0	0
Hawthorne	Medium	0	0	0	0	2	**3**
Port Kells	Medium	0	0	0	0	0	0
Boundary	Low	0	0	0	0	0	0
Cougar Creek	Low	0	0	0	0	0	0
Guildford Heights	Low	0	0	0	0	0	0
Semiahmoo Trail	Low[a]	0	2	0	1	**4**	2

Note: The maximum red-legged frog egg mass count for each site is shown in bold text.

[a] The terrestrial buffer for this wetland may function more like a medium value site due to significant canopy cover on adjacent private property.

Observations of other native pond-breeding amphibian egg masses were also made when searching for red-legged frog egg masses. These observations were only incidental while searching for red-legged frog egg masses, and therefore cannot be considered a comprehensive count. The species observed and maximum number of egg masses observed on each site is listed in Table 6. No native pond breeding amphibian egg masses were found on any of the sites where red-legged frog egg masses were absent. Crescent Park was the only site with red-legged frog egg masses, but no other pond-breeding amphibian egg masses. The two sites with the greatest number of red-legged frog egg masses, Green Timbers Urban Forest Park and Bothwell Park, also had the highest egg mass counts of other native pond-breeding amphibians.

Table 6. Maximum egg mass count of other native pond-breeding amphibians by site.

Park	**Terrestrial Habitat Value**	**Pacific Tree Frog** ***(Hyla regilla)***	**Northwestern Salamander** ***(Ambystoma gracile)***	**Long-toed Salamander** ***(Ambystoma macrodactylum)***
Bothwell	High	11	15	2
Crescent	High	0	0	0
Green Timbers	High	52	11	20
Hi-Knoll	High	0	0	0
43 Z Utility ROW	Medium	1	16	1
Elgin Heritage	Medium	0	0	0
Hawthorn	Medium	0	5	0
Port Kells	Medium	0	0	0
Boundary	Low	0	0	0
Cougar Creek	Low	0	0	0
Guildford Heights	Low	0	0	0
Semiahmoo Trail	Low	31	0	3

3.4 Bullfrog Presence / Absence

Bullfrog (*Rana catesbiana*) presence/absence was noted during the weekly surveys and also during the one dedicated survey on July 16, 2006. Bullfrogs were present in two of the high value terrestrial habitat sites (Crescent Park and Hi-Knoll Park), none of the medium value terrestrial habitat sites, and two of the low value terrestrial habitat sites (Boundary Park and Cougar Creek Park). Of the six sites where red-legged frog egg masses were found, only one also contained bullfrogs (Crescent Park), while three of the six sites devoid of red-legged frog egg masses contained bullfrogs. The Crescent Park wetland contained bullfrogs and was the only wetland where red-legged frog egg masses were the only native amphibian egg masses observed.

3.5 Water Quality and Presence/Absence Correlations

Red-legged frog egg mass presence was tested for correlation with all of the water quality variables, bullfrog presence, and the presence of each of the other pond-breeding amphibian species found during the surveys. Specifically, the maximum red-legged frog egg mass count for each site was tested for correlation with each of the water quality variables, while the presence/absence of red-legged frog egg masses was tested for correlation with bullfrog and pond-breeding amphibian species presence/absence. For the water quality parameters, the ordinal values were used to undertake a Spearman Correlation. The Spearman Correlations showed that the only significant correlation was a negative correlation between salinity levels and the number of red-legged frog egg masses, though pH was significant at the 10% level (Table 7).

Table 7. Correlation and significance values for maximum red-legged frog egg mass counts and water quality parameters.

	Spearman correlation value	Significance level
Temperature	-0.013	0.968
Salinity	-0.581	0.048
Turbidity	-0.478	0.116
Dissolved oxygen	0.024	0.940
pH	-0.556	0.060

For correlations with the presence/absence of bullfrogs, as well as other pond-breeding amphibian species, a Pearson's R correlation was completed. A significant, positive correlation was found between red-legged frog egg mass presence and the presence of northwestern salamander egg masses, Pacific tree frog egg masses, and long-toed salamander egg masses (Table 8). No significant correlation was found between red-legged frog egg mass presence and bullfrog presence.

Table 8. Correlation and significance values for red-legged frog egg mass presence and the presence of other species of native pond-breeding amphibians.

	Pearson's R correlation	Significance level
Bullfrog presence/ absence	-0.354	0.260
Northwestern salamander presence/absence	0.660	0.019
Pacific tree frog presence/absence	0.895	0.000
Long-toed salamander presence/absence	0.839	0.001

Bullfrog presence was also tested for correlation with the presence of each of the other pond-breeding amphibians found in this study using the Pearson's R correlation method. There was no significant correlation between bullfrog presence and the presence of northwestern salamander egg masses, Pacific tree frog egg masses, and long-toed salamander egg masses (data not shown).

3.6 Terrestrial Habitat Stratification

The stratification of the data based on high, medium, and low value of the 200 m terrestrial wetland buffer provided some interesting observations; however, it does not allow for meaningful statistical analysis due to the small sample size (Table 9). The data suggest that both the total number and average number of red-legged frog egg masses are related to the terrestrial habitat classification with increasing terrestrial habitat value leading to increased egg mass numbers. When the number of red-legged frog egg masses is totaled by terrestrial habitat classification, the increase in number of egg masses from low to medium and medium to high terrestrial habitat value is greater than an order of magnitude. The numbers for the other native pond-breeding amphibians are not as clear, though the low value sites do not support substantial populations of these species since no egg masses of other native pond-breeding amphibians were observed at any of the low value sites. Bullfrog presence did not appear to be related to terrestrial habitat value since bullfrogs were present in two of the high value terrestrial habitat sites, none of the medium value terrestrial habitat sites, and two of the low terrestrial habitat value sites.

Several trends also appeared evident in the stratified water quality data. The low value terrestrial buffer sites had higher water temperatures and turbidity readings than the medium and high values sites. The dissolved oxygen readings by terrestrial habitat value showed that the average reading was nearly twice as high for the low value sites than the high and medium value sites. The periodic high volumes of storm water entering the low value terrestrial habitat sites in particular likely lead to elevated turbidity and dissolved oxygen levels. The average salinity value was highest in the medium value sites, but this is likely an artifact rather than a trend since it is heavily skewed by one site, Elgin Heritage Park, which had a salinity reading of 1.143 ppt. The pH values in the high value terrestrial habitat sites averaged nearly a full pH unit lower than the medium value sites and about 0.7 pH units lower than the low value sites.

Table 9. Egg mass and water quality results summarized by terrestrial buffer habitat value stratification.

Strata	High	Medium	Low
Total red-legged frog egg masses	333	13	4
Average red-legged frog egg masses	83	3	1
Total Pacific tree frog egg masses	63	1	0
Average Pacific tree frog egg masses	32	0	0
Total northwestern salamander egg masses	26	21	0
Average northwestern salamander egg masses	7	5	0
Total long-toed salamander egg masses	22	1	0
Average long-toed salamander egg masses	6	0	0
Number of sites with bullfrogs present	2	0	2
Average temperature	8.5	8.7	9.9
Average turbidity	7.6	6.9	10.1
Average salinity	0.028	0.319	0.054
Average dissolved oxygen	4.93	4.45	8.28
Average pH	6.06	7.02	6.78

4 Discussion

4.1 Current Status of Red-legged Frogs in Surrey

The results of this study showed that red-legged frogs are found within most suitable aquatic habitats in Surrey, BC. The study results also suggest that red-legged frog populations may be more likely found within their range in the Lower Fraser Basin on sites where wetlands have high percent cover of aquatic vegetation and forest cover throughout the majority of the 200 m terrestrial buffer area. The study sites were located throughout the Surrey and the distribution of the populations identified did not indicate a broad geographic pattern. Based on the results, there is potential for red-legged frogs to be found anywhere within the Surrey, and potentially the entire Lower Fraser Basin, where adequate aquatic and terrestrial habitat components exist.

4.2 Habitat Requirements

The stratified results suggest that adjacent terrestrial habitat is important for the success of red-legged frog populations. The strongest evidence of this terrestrial habitat requirement is the nearly ten-fold increase in red-legged frog egg mass counts from low value terrestrial habitat sites to medium value terrestrial habitat sites and the greater than ten-fold increase in egg mass counts from medium value terrestrial habitat sites to high value terrestrial habitat sites. This is not surprising since red-legged frogs spend the majority of their life in terrestrial habitat adjacent to wetlands (Maxcy, 2004) and feed almost exclusively in terrestrial environments (Licht, 1986). Though causation cannot be drawn from this study, these numbers seem to indicate that efforts to preserve red-legged frog populations would be more successful if a 200 m terrestrial habitat buffer zone surrounding breeding ponds was protected.

The presence of red-legged frog egg masses also appeared to be related to the percent cover of aquatic vegetation within the wetlands. Sites where red-legged frog egg masses were found had on average 62% aquatic vegetation cover compared to only 15% on sites where no red-legged frog egg masses were found. This is consistent with Adams (1999) finding that wetlands with greater than 50% emergent vegetation were more likely to be occupied by red-legged frogs. Aquatic vegetation is important for red-legged frog tadpoles to find cover and food and as substrate for egg mass attachment (COSEWIC, 2004; Maxcy, 2004). Without adequate aquatic vegetation, a red-legged frog tadpole may not have sufficient foraging areas and is more likely to be taken by a predator. The association between aquatic vegetation cover and red-legged frog egg mass presence may also indicate a relationship between aquatic vegetation cover and pond permanence since aquatic vegetation will only grow in sufficiently shallow areas that also tend to be susceptible to seasonal drought. Wetlands that dry up, or nearly dry up, in the late summer can fulfill all red-legged frog aquatic habitat requirements while excluding or discouraging use of the aquatic habitat by bullfrog and fish predators. The association between red-legged frog egg masses and aquatic vegetation, combined with the spread of bullfrogs throughout much of the range of red-legged frogs in BC, means that red-legged frogs could prove to be most successful in wetlands with shallower depth (perhaps even ephemeral hydrology) to reduce competition from bullfrogs and fish that require permanent ponds, generally with a greater depth (Adams, 1999).

Terrestrial and aquatic habitat requirements derived from this study could be used as a screening tool for locating potential red-legged frog breeding ponds and for red-legged frog conservation planning. Researchers planning to do more in-depth studies of red-legged frog populations may consider selecting wetlands that have 60% or greater aquatic vegetation cover and greater than 75% intact terrestrial habitat within their 200 m buffer zone. In terms of conservation planning, these criteria could be utilized as a coarse filter to determine candidate sites for acquisition to protect red-legged frog and other native pond-breeding amphibian populations. Also, when planning for development of parks in Surrey and other jurisdictions, these terrestrial habitat and aquatic habitat criteria could be used as the minimum standards that must not be impacted to ensure the sustainability of existing red-legged frog populations. Finally, when red-legged frog presence has been confirmed on sites with lesser terrestrial and aquatic habitat characteristics, such as Hawthorne Park, these habitat criteria could be set as habitat restoration targets.

4.3 Park Management Recommendations

4.3.1 General

Based on the findings of this study, and knowledge from past studies, several recommendations for general park management for red-legged frog conservation can be made:

1. Natural pond breeding habitats should be protected in their current state and urban storm water should not be directed into these ponds unless it is necessary to avoid redirecting historic surface flows away from the pond, and the water quality has been ensured by use of a biofiltration structure. This is important as urban storm water will change the hydrology of ponds and contribute additional pollutants that can alter the habitat and have negative impacts on amphibian populations (Riley et al., 2005).

2. Man-made pond breeding habitats should have shallow areas (30 to 60 cm) that encourage red-legged frog breeding and discourage bullfrog colonization.

3. Man-made ponds should be managed and created such that approximately 60% of the surface area contains emergent and/or submerged aquatic vegetation.

4. Seventy-five percent or greater of the 200 m terrestrial buffer zone around the wetland must be managed as terrestrial habitat favouring forest over grassland areas, though a component of grassland of up to 40% did not appear to be a negative factor for red-legged frogs in this study.

5. Metapopulation dynamics for red-legged frogs is not currently understood due to lack of investigation. Regardless, genetic diversity must be maintained through metapopulation dynamics and this will require landscape level planning that incorporates breeding ponds, core terrestrial habitat, and undisturbed habitat corridors between breeding sites.

4.3.2 Bothwell Park

The wetland appears to be functioning well as red-legged frog breeding habitat as demonstrated by the 135 red-legged frog egg masses found on the site during a single visit. Also, egg masses of three other species of native pond-breeding amphibians were present. Five major factors may explain why this wetland supports thriving native amphibian populations:

1. mature forest adjacent to the wetland that has been essentially undisturbed for more than 50 years;

2. barrier between the wetland and the Serpentine River that likely ensures fish do not enter the wetland;

3. significant drying of the wetland in the summer months, which makes the wetland less desirable to bullfrogs and fish predators;

4. greater than 60% aquatic vegetation cover in the wetland, which provides high value rearing habitat for tadpoles; and

5. no water pollutants enter the wetland from urban storm water.

Although the park appears to function as good habitat already, there are six steps that could be taken to protect and improve this status.

1. The barrier between the wetland and the Serpentine River should be maintained (i.e. avoid alteration that would provide fish access to this wetland).

2. The vegetation community within the 200 m buffer area should be managed to restrict invasive plant species and be replanted with native species. It is particularly important to manage the Himalayan blackberry (*Rubus discolor*) on site, since it has already formed a partial barrier along one edge of the wetland and has the potential to continue to spread into the grassland habitat that surrounds the majority of the wetland. Himalayan blackberry forms thickets that exclude native plant communities supporting red-legged frogs.

3. As this park is largely undeveloped at this point, future development must be sensitive to the habitat that currently supports red-legged frogs. At a minimum, this would involve not disrupting the wetland and the 200 m terrestrial buffer around the wetland.

4. Sources of poor quality water such as urban storm water should not be diverted into this wetland and other existing flows to the wetland should be protected and maintained.

5. Plantings of native trees and shrubs should be undertaken to create connections from the wetland through the grassland areas to the mature forest in order to provide preferential movement corridors between the high quality terrestrial habitat and the wetland.

6. Habitat corridors connecting this wetland with nearby habitat outside of the Park boundaries, particularly Tynehead Regional Park, which is likely host to healthy populations of red-legged frogs should be maintained. These connections are critical to maintain the local metapopulation, so that stochastic events that may significantly reduce or extirpate individual populations will not lead to permanent loss of red-legged frog populations. Such habitat connections allow for re-colonization by individuals from other populations within the metapopulation.

4.3.3 Crescent Park

This site appears to have all the habitat components that would make it an excellent site for red-legged frogs, yet the number of egg masses observed was quite low. There are many potential reasons for these low egg mass numbers including the fact that amphibian populations can fluctuate significantly from year to year (Berven, 1990; Pechmann et al., 1991). It is possible that this was a year where little breeding occurred at this site. Other factors that may explain this lower than expected number of egg masses are habitat alteration around the wetland perimeter (e.g. mowed lawn areas and a gravel trail) disruption from humans and their pets who frequent the area, and predation by bullfrogs, which were observed at the site.

Several measures could be taken to improve habitat and enhance the red-legged frog population at this site.

1. Monitoring of egg mass numbers in the wetland should be conducted over the next two breeding seasons to determine if the low numbers observed in 2006 were an anomaly.

2. Nearly half of the immediate perimeter of the wetland is currently mowed lawn and gravel pathway frequented by people and their dogs. The survival rate of both adult and juvenile red-legged frogs moving to and from the wetland would be increased by re-vegetating 50% or more of the disturbed perimeter to increase connectivity with the forest. This re-vegetated area should be fenced to prevent human and dog access while allowing the free movement of amphibians and other wildlife.

3. The shallow wetland upstream of this site does not seem to support red-legged breeding currently, likely due to the depth of water (<30 cm). Excavating this wetland an additional 30-50 cm in depth would make additional breeding and rearing habitat available in a location where there is less human disturbance than the pond that contained egg masses in 2006. Once enhanced, native amphibians inhabiting this wetland may also receive a reduced level of predation by bullfrogs, since bullfrogs require permanent and deeper water bodies to complete their lifecycle (Adams, 2000; Matsuda et al., 2006).

4. A program of bullfrog control could be developed with the goal of eradication. Eradication seems possible in this location due to the limited size of the wetland and relatively long distance to the next nearest potential breeding pond (there are no other sites suitable for bullfrog breeding within the Park or within a distance of 1.2 km).

5. The forest surrounding the wetland is critical to the value of this site for red-legged frogs and no component of this forest should be removed in any future park developments.

4.3.4 Green Timbers Urban Forest Park

The 182 red-legged frog egg masses observed during a single visit and the presence of egg masses of three other native amphibian species suggests that this man-made wetland is functioning well as native amphibian breeding habitat. Four major factors may explain the high value of this wetland:

1. a large mature forest adjacent to the wetland that has been essentially undisturbed for more than 70 years;

2. the waterfall at the outfall of the wetland, which precludes fish access to the wetland;

3. the shallow depth of the main serpentine channel in the wetland (30-60 cm), which likely discourages bullfrog presence and breeding; and

4. the heavy aquatic vegetation cover (>75%), which provides high value rearing habitat for tadpoles.

The excellent forest habitat adjacent to the wetland is particularly important because it has likely supported a population (or populations) of red-legged frogs for decades, if not much longer. The creation of the wetland on this site may have significantly increased the breeding and rearing habitat for red-legged frogs and boosted their historic population numbers.

The most important recommendation for this site would be to continue to manage the wetland in the same manner. Specifically, the serpentine channel should not be deepened and the waterfall should remain in place to continue to exclude fish from the wetland. Green Timbers Urban Forest Park is popular and receives many visitors on a daily basis, so it is important to ensure that people and their animals do not enter the wetland. The existing split-rail cedar fence around the entire wetland keeps people out, but is not a barrier to red-legged frogs and other wildlife and should be maintained. In order to maintain the flows through the serpentine channel it will be necessary to periodically remove aquatic plants that proliferate, primarily *Typha latifolia*. In order to minimize the impact of these maintenance works, the vegetation should be selectively removed by hand rather than with heavy machinery. Additional breeding and rearing habitat could also be created in the wetland since currently less than a third of the area (only the serpentine channel) holds standing water greater than 10 cm deep in the spring and summer months. It would be relatively easy to excavate several new wetted areas as small side channels of the central serpentine channel. If side channels are created they should not be any deeper than the existing serpentine channel to avoid encouraging bullfrog colonization.

4.3.5 Hi-Knoll Park

Terrestrial habitat on this site seems to be of sufficient size and quality to support a significant population of red-legged frogs; however, no red-legged frog egg masses were found. An absence of red-legged frog egg masses is likely due to the attributes of the wetland rather than the terrestrial habitat (e.g. poor water quality and high level of predation by bullfrogs and fish predators). Water quality in this wetland may make it less desirable for red-legged frogs as it has a pH that is more than a full point lower than all of the other study sites (pH=4.99), the second highest turbidity level of all 12 sites (12.3 NTU), and an extremely low dissolved oxygen level (2.52 mg/L). Low dissolved oxygen levels may be partially a result of the heavy deciduous canopy cover that drops large amounts of organic material into the wetland, and creates a high oxygen demand to break down the organic materials.

Enhancement activities are not recommended for this site because is already populated with bullfrogs and most likely fish. The selective tree removal needed to improve the water quality would be detrimental and potentially contrary to the federal Fisheries Act since the wetland is within the riparian area of a salmon-bearing stream. Further review of the aerial photography revealed at least three wetlands on private property within 500 m of the park that may provide breeding habitat for red-legged frogs. One of the sites was briefly visited during the study and four red-legged frog egg masses were found. Two steps could be taken to promote the long-term sustainability of red-legged frogs in this area of Surrey. First, the City could explore the opportunity to purchase the adjacent or nearby lands that contain wetlands to protect these breeding sites from development. Second, a shallow wetland could be created within the easement of the hydro transmission lines in the section of the Park that is north of Colebrook Road. The forested habitat in this area of the Park likely supports adult red-legged frogs, so a new wetland would most likely be utilized and could be beneficial to adult frogs that might otherwise cross Colebrook Road to reach a breeding pond.

4.3.6 43Z Utility Right-of-Way

The wetland appears to support a small breeding population of red-legged frogs. The low dissolved oxygen level (2.52 mg/L) in this wetland may limit red-legged frog populations. There may also be other water quality concerns since this wetland is partially fed by residential storm water. Substantial losses of juvenile and even adult red-legged frogs may occur from pets, vehicles, and other anthropogenic disturbance due to development on the north side of the park (within 10 m of the wetland). It is assumed that predation is not a significant factor since fish do not appear to have access to the wetland and no bullfrogs were observed.

A number of steps could be taken to conserve and enhance red-legged frogs populations on this site:

1. The least costly item would be to clean up the garbage and debris that has been dumped in this wetland. Items such as paint may be contributing pollutants to the water.

2. Himalayan blackberry should be removed where it is present on the perimeter of the wetland and the area should be replanted with native shrub species.

3. The water quality should be monitored in the recently constructed wetland to the northeast of the study site to determine if it is adequate to support red-legged frogs. If the water quality is adequate, then the southern perimeter of this wetland should be planted with appropriate native plant species to provide cover. In addition, the forest edge to the south of this new wetland requires the removal and eradication of Himalayan blackberry that could deter movement of red-legged frogs between the forest and wetland.

4. The City of Surrey should consider securing the forested portions of five large private lots to the southeast of this Park that currently provide a significant amount of terrestrial habitat.

4.3.7 Elgin Heritage Park

The terrestrial habitat in this Park is adequate to support red-legged frogs, but the water quality sampling revealed that the wetland is brackish and therefore does not provide red-legged frog breeding habitat. Habitat enhancement efforts for red-legged frogs are not recommended unless hydrological changes are made to create a freshwater wetland.

4.3.8 Hawthorne Park

The egg mass surveys indicate that a small breeding population of red-legged frogs is present in this Park. Minimal shallow areas and associated aquatic vegetation may be a limiting factor as these areas are critical refuge and feeding areas for tadpoles (BC Ministry of Environment, 2006; COSEWIC, 2004). High turbidity levels in the wetland could also indicate a water quality problem. In addition, the proximity of the wetland to roads (<15 m) may mean that there are high levels of mortality from traffic. Fahrig et al. (1995) studied the impacts of roads on frogs in a community in Ontario and found that traffic exerts a negative effect on frog populations.

As the lack of aquatic vegetation appears to be the limiting habitat factor on this site, creating shallow bench areas in the wetland could best enhance red-legged frog populations. Soil could be placed along the border of the wetland to create benches with water depths of 30 to 60 cm that could be planted with aquatic vegetation. If this is not possible due to the potential impact on storm water capacity, then an area of lawn along the southern edge of the pond could be excavated as a shallow bench expansion to the wetland. This would provide the necessary red-legged frog spawning and rearing habitat, while increasing the capacity for storm water retention. These vegetated benches may also partially address water quality problems by filtering silt and other pollutants from the water. The forested, terrestrial habitat is functioning quite well on this site and needs to be maintained to ensure that red-legged frogs are sustained in this park.

4.3.9 <u>Port Kells Park</u>

The terrestrial habitat on this site seems to be of sufficient size and quality to support a population of red-legged frogs; however, no red-legged frog egg masses were found in the pond that was monitored. The lack of red-legged frog egg masses is likely due to the attributes of the wetland, rather than those of the terrestrial habitat. This wetland had the lowest water temperature (6.4 °C) and the lowest dissolved oxygen (2.50 mg/L) reading of all study sites, likely due to the complete deciduous canopy closure over the wetland. The canopy shades the water, keeping temperatures low, and the tremendous amount of leaf drop into the wetland creates a high oxygen demand to break down this organic matter. In addition to these factors, the broad floodplain of Latimer Creek that runs through the Park may provide breeding areas that are used preferentially by red-legged frogs.

Measures to conserve and enhance red-legged frogs populations in this park should not be focused on the wetland monitored in this study. This wetland is small (613 m^2) and does not warrant the costly and disruptive work that would be required to improve its value as red-legged frog breeding habitat. Instead, further effort should be undertaken to determine whether red-legged frogs and other pond-breeding amphibians are spawning in other areas of the park. Concurrently, the private lands with contiguous habitat should be searched for active spawning. If breeding ponds are located in the park, specific enhancement recommendations can be determined at the time. If breeding ponds are located on adjacent private lands, land acquisition or another means of protection such as conservation covenants should be considered by the City of Surrey.

4.3.10 Boundary Park

The wetland appears to be devoid of native pond-breeding amphibians. The only amphibian species noted was bullfrogs. Predation from bullfrogs could be an issue for native amphibians, however the lack of terrestrial habitat is likely a more significant factor (i.e. less than 2% of the 200 m terrestrial buffer was classified as unfragmented natural habitat). Also, the wetland is lacking adequate rearing habitat for red-legged frog tadpoles since there is only 2% emergent and 2% submerged aquatic vegetation cover.

Red-legged frog habitat enhancement efforts are not recommended for Boundary Park. This wetland and the surrounding parkland would require significant work in order to support red-legged frogs. Alteration of the current park would be cost prohibitive and may be seen as extremely disruptive to current park users. In addition, the only nearby population available to re-colonize would be found in Watershed Park and it is unlikely that adults would successfully travel across Scott Road (a busy four lane road) to reach this wetland. A great blue heron (*Ardea herodias fannini*) was sighted on two separate visits and on one of these occasions was seen eating a bullfrog. Bullfrogs appear to be the only amphibian species able to survive in the wetland and they are providing food for native wildlife. Bullfrog eradication efforts are not recommended for this park.

4.3.11 Cougar Creek Park

No native amphibians were observed during any of the site visits to this park. Predation from bullfrogs could be an issue, however the lack of terrestrial habitat (less than 10% of the 200 m terrestrial buffer was classified as unfragmented natural habitat) is likely a more significant factor. Also, the wetland lacks adequate rearing habitat for red-legged frog tadpoles, as there is only 5% emergent and no submerged aquatic vegetation present. The turbidity, which was the highest of all of the sites tested at 13.1 NTU, may also be indicative of poor water quality.

Red-legged frog habitat enhancement efforts are not recommended for Cougar Creek Park. The water quality in the wetland is poor, fish and bullfrogs are present, the terrestrial habitat in the park is inadequate to support red-legged frogs, and there are no nearby parks or other remnant habitats that are likely to support red-legged frogs that could re-colonize this site. The wetland and terrestrial habitat may be adequate to support other native pond-breeding amphibians such as Pacific tree frog or northwestern salamander, so there may be value in undertaking bullfrog eradication efforts. The wetland should be monitored for one more season to assess the use by all species of native pond-breeding amphibians. If it is found that some native amphibian species are breeding within the wetland, bullfrog eradication efforts should be considered. It will be a challenge to keep the wetland free of bullfrogs, as Cougar Creek runs right through the wetland and is likely a corridor for bullfrog movement that would lead to frequent bullfrog reintroductions.

4.3.12 Guildford Heights Park

No native or non-native amphibian species were observed in this wetland. A number of factors may explain this absence of amphibians:

1. This wetland was created less than five years prior to this study and is still developing into a functioning ecosystem.

2. This site has minimal terrestrial habitat with 83.4% of the 200 m buffer occupied by high-density residential and commercial development and only 16.6% functional habitat.

3. It is unlikely that amphibians will be able to migrate to this wetland from other remnant habitat areas due to the high density, high traffic urban development surrounding this park.

Red-legged frog habitat enhancement efforts are not recommended for Guildford Heights Park. Though the wetland has all necessary habitat attributes to support red-legged frog breeding and rearing, the terrestrial habitat within the park is not adequate to support red-legged frogs and there is little potential to restore or acquire terrestrial habitat in the future.

4.3.13 Semiahmoo Trail Park

The egg mass surveys in Semiahmoo Trail Park indicate that a very small breeding population of red-legged frogs is present in this park. The wetland seems to have adequate spawning and rearing habitat, as well as sufficient water quality, to support a healthy red-legged frog population, but the terrestrial habitat surrounding the wetland is limited. Minimal unfragmented habitat within the 200 m terrestrial buffer area (10%) is likely a limiting factor for the red-legged frog population. In addition, this wetland has only been in existence for about nine years, so there may not have been time to establish a large, established breeding population.

Two distinct measures could be made to conserve and enhance the red-legged frog population currently breeding on this site. First, the City of Surrey should acquire the forested portions of the large residential lots to the east of Semiahmoo Trail Park. This acquisition will protect the terrestrial habitat of the red-legged frogs and other native, pond-breeding amphibians since terrestrial habitat within close proximity to the Semiahmoo Trail Park wetland is a limiting factor. Second, planting areas currently maintained as infrequently mowed lawn (approximately 7000 m^2) would maximize the value of the terrestrial habitat in the park and improve the habitat connectivity by providing a corridor between the Semiahmoo Trail Park wetland and Sunnyside Acres Urban Forest Park. Sunnyside Acres Urban Forest Park is a mature second growth forest with more than 130 ha of high value terrestrial habitat for red-legged frogs, as well as several small wetland areas, located approximately 630 m from the wetland in Semiahmoo Trail Park. Based on this available habitat, it is logical to assume red-legged frogs are present in Sunnyside Acres Urban Forest Park, though their presence has not been confirmed. A corridor between the two parks could allow for movement between the forested areas of Sunnyside Acres Urban Forest Park and Semiahmoo Trail Park wetland for breeding, though the frogs would have to cross 28th Avenue. Even if this distance and the road between these parks prevents movements for breeding purposes, such a connection may allow for periodic breeding between populations or re-colonization in the event of extirpation. Interpopulation breeding is critical to maintain the genetic diversity that is important for the long-term stability of the local red-legged frog metapopulation.

4.4 Red-legged Frogs as an Indicator Species

The protection of a network of wetlands, wetland terrestrial habitat buffers, and terrestrial movement corridors in the City of Surrey would not only sustain red-legged frog metapopulations, but also a wide range of native wildlife and plant species required for sustainable ecosystems. This is true because red-legged frogs are an excellent indicator species or a species, “whose presence suggests a certain habitat, environmental condition, association of other species or other factor” (Schaefer, Rudd, & Vala, 2004). Schaeffer, Rudd and Vala (2004) created a list of nine criteria for selecting indicator species of biodiversity and red-legged frogs meet seven of these nine criteria (Table 10). The authors suggest that a set of complementary indicators is necessary to monitor for biodiversity, since no one species would meet all of the criteria. With the addition of a small number of other native wildlife species, red-legged frogs could be an important component of a set of indicator species that could be used to monitor changes in biodiversity in the Lower Fraser Basin. Red-legged frog's value as an indicator species is the reason that park management recommendations made in this chapter are believed to be valuable steps towards not only long term conservation of red-legged frog populations, but a wide variety of other native wildlife that utilize some or all of the same habitats as red-legged frogs.

Table 10. Criteria for selecting indicator species of urban biodiversity.

Criteria	Explanation	Criteria Met by Red-legged Frog
Sensitive to environmental stress	An effective indicator species should be sensitive to any physical, chemical or biological stress in order to provide an early signal reflecting the health of its ecosystem.	Yes
Specialist	Specialists are more sensitive to habitat changes and meeting their needs is assumed to provide the needs for generalists. This will not guarantee that suitable habitat will be provided for all species, so it is more important that the indicator species is associated with the habitat attributes of interest.	No
Permanent resident	This is important since migratory species (as opposed to permanent residents) are subject to a variety of sources of mortality and measured declines in their abundance may not be related to the habitat in question.	Yes
Regional breeder	This criterion applies to birds and anadromous fish primarily since there are cases when migratory species are indicators because healthy breeding habitats are often critical to sustain their populations.	No

Criteria	Explanation	Criteria Met by Red-legged Frog
Native	Native species are those that occur in a region in which they evolved. In North America they include species present prior to European settlement.	Yes
Habitat requirements similar to those of other species	Species whose life cycles are intertwined or correlated with other assemblages are valuable as indicators. Suitable habitat for an indicator species may indicate that it is suitable for other species that are more difficult or expensive to monitor.	Yes
Habitat heterogeneity	Habitat diversity plays a prominent role in the determination of species richness and there is often a positive correlation between habitat diversity and species diversity.	Yes
Visible and identifiable	Indicator species that are easy to recognize and appeal to the general public may be more effective since public awareness and understanding are necessary to support conservation initiatives through expenditure of tax dollars.	Yes
Easy and cost effective	Must be able to inexpensively measure, collect or assay indicator species long term to assess the status of biodiversity over time.	Yes

Note: Criteria developed by Schaeffer, Rudd and Vala (2004).

4.5 Limitations and Assumptions

A number of limitations and assumptions must be explicitly stated as they impacted the data interpretation, as well as the scope and certainty of the recommendations. These limitations and assumptions were understood from the outset of the study and are primarily a result of the preliminary nature of the study, which focussed on collection of presence/absence data rather than determining causal relationships.

4.5.1 <u>Contribution of Egg Masses to Later Development Stages</u>

This study is a snapshot in time of the status of red-legged frog populations in a number of specific sites in Surrey, BC. Amphibian populations can naturally fluctuate from year to year, so the population estimates based on the egg mass count from a single year could be misleading in terms of the status of particular populations. It must also be noted that the egg masses observed were not followed through further developmental stages to investigate survival to the larval, juvenile, or adult stages. However, when Licht (1974) followed 10,880 red-legged frog eggs laid in the Little Campbell River floodplain (approximately one kilometre east of Surrey) he found that 9901 eggs survived to the tadpole stage (91%), 522 of these tadpoles survived to successfully metamorphose into juveniles (4.8%), and only 272 frogs (2.5%) survived to the end of the first year. Licht's findings could be used to extrapolate the expected numbers of tadpoles, juveniles, and adults that would result from the egg masses observed, assuming an average number of eggs per egg mass. Though no numbers can be definitively provided for the contributions of the egg masses counted in this study to the tadpole, juvenile and adult stages, it is safe to assume that only a small fraction will eventually contribute to the adult breeding population. Also, it was assumed that the contributions to the breeding population would be larger for Green Timbers Urban Forest Park and Bothwell Park than the other sites where fewer red-legged frog egg masses were observed.

4.5.2 <u>Correlation Versus Causation</u>

The experimental design did not allow for determination of causation. All relationships drawn out in the results were correlations, so they do not address whether one factor influenced one or more other factors.

4.5.3 <u>Metapopulations</u>

This study did not address the status of metapopulations. Genetic diversity must be maintained to preserve this species in the long term and this requires the maintenance of metapopulations, or a set of populations connected across a landscape by processes of migration, gene flow, extinction, and colonization (Semlitsch & Bodie, 2003). Although the recommendations in some cases considered the need to ensure habitat connections to maintain metapopulations, the observations in the field were not collected or analyzed in the context of metapopulations.

4.5.4 <u>Water Pollution</u>

Funding available for this study limited the scope of the water quality parameters that were monitored. Only parameters that could be measured with field-based equipment owned by the City of Surrey were collected. More expensive laboratory testing of grab samples could have been undertaken if funding had been available. Such laboratory analysis may have revealed pollutants in the study wetlands that may have helped to explain the egg mass findings. For this reason, only indirect inferences were made in regards to water quality based on the turbidity and dissolved oxygen readings, as well as the assumption that urban storm water leads to the addition of pollutants. For this reason, no connections could be made between specific water pollutants and the status of red-legged frogs on the study sites.

4.5.5 Predators

Bullfrogs and fish are understood to be the predators most likely to cause significant declines in red-legged frog populations (Adams, 1999; Kiesecker & Blaustein, 1998; Kiesecker et al., 2001). Fish presence was not determined as part of the fieldwork in this study, but fish access was inferred and was clear in most cases. Bullfrog presence/absence data were based on limited sampling. A single fifteen minute time constrained search of each wetland, as well as sightings during the red-legged frog egg mass surveys may not have been adequate to locate bullfrogs on all sites where they were present. This could mean that sites where no bullfrogs were reported may actually contain bullfrogs. If this is the case on any of the study sites then bullfrog predation as a contributing factor to the absence or low number of red-legged frog egg masses observed would have been overlooked. This is a standard limitation for time constrained presence/absence surveys, as they can never determine for certain that a species is not present.

4.5.6 Other Impacts Not Considered

There are a number potential factors in red-legged frog population declines that may be related to the status of these frogs in Surrey that were not considered in the study design or park management recommendations within this chapter. These factors were discussed in the Introduction and Literature Review and include disease, UV-B radiation, and climate change. No information was collected on diseases since this was outside the scope of the study and no disease has yet been linked to mass mortality or population declines in red-legged frogs. The impact of UV-B radiation was also beyond the scope of this study and, as was mentioned in the introduction, studies have shown that it is unlikely that UV-B radiation plays a significant role in red-legged frog declines (Blaustein, Hoffman, Kiesecker, & Hays, 1996; Ovaska, Davis, & Flamarique, 1997). Finally, the impacts of climate change are clearly beyond the scope of this study and have just begun to be studied with respect to amphibians.

4.6 Future Research

4.6.1 Recommended Research Techniques

There are a number of practical recommendations for techniques that could be utilized in future red-legged frog research based on the experience gained in this study. First, aerial photo interpretation appears to be an effective first step in identifying potential breeding ponds. All of the high and medium value terrestrial habitat sites studied, where wetlands could be discerned from the aerial photo, were found to contain red-legged frog egg masses (Elgin Heritage Park was an exception as the water was brackish and could not support native amphibians). The wetlands studied at Hi-Knoll Park (high terrestrial habitat value) and Port Kells Park (medium terrestrial habitat value) did not contain red-legged frogs, but these sites were identified from personal knowledge and were not visible from the aerial photography. Second, egg masses are probably the easiest life stage to monitor in order to determine population estimates since egg masses are easily identified and can be observed any time of the day during breeding season. Finally, as the egg masses are often attached to vegetation or woody debris near to the shore, it would be relatively easy to set up an enclosure around an egg mass to monitor the survival to the tadpole stage or conduct other tadpole-based studies.

4.6.2 Recommended Research Studies

This study is the first in a series of studies that must be completed to gain the knowledge necessary to conserve red-legged frogs in BC. Similar population studies must be completed throughout the range of red-legged frogs in BC to generate a comprehensive understanding of their status. Concurrently, studies attempting to gain a more in-depth understanding of threats to this species and their metapopulation dynamics are required. These studies could be completed on populations within Surrey and other known populations within BC.

If a series of focussed research studies are completed to gain the knowledge necessary to conserve and enhance red-legged frog populations throughout their range in BC perhaps this species will never reach the endangered status earned by the Oregon spotted frog (*Rana pretiosa)*, the only other ranid species found in the Lower Fraser Basin (COSEWIC, 2004). The first step in a series of studies should involve monitoring for red-legged frog presence for several years in historic sites and candidate sites where red-legged frogs have not previously been recorded (COSEWIC, 2004). Next, radio-tracking studies must be completed with both adults and newly metamorphosed juveniles to get a better understanding of their home range in order to refine the area of core terrestrial habitat required surrounding breeding ponds (Maxcy, 2004). Juvenile tracking is important since these individuals are most likely to travel the long distances required for interpopulation breeding and colonization (Cushman, 2006). An understanding of red-legged frog movements will provide valuable information for planning a network of corridors and wetlands. Finally, studies aimed at better understanding all aspects of metapopulation dynamics are important since even the best, undisturbed breeding sites can experience reproductive failure due to stochastic events such as drought (Semlitsch, 2003a). The sustainability of red-legged frogs in BC will depend on increased understanding, and protection, of habitats to maintain metapopulation dynamics in addition to individual breeding populations.

Several research initiatives could be pursued specifically within the City of Surrey to build upon the knowledge gained in this study. First, all other permanent or semi-permanent wetlands in Surrey with greater than 60% terrestrial red-legged frog habitat within the 200 m terrestrial buffer should be part of a comprehensive presence/absence study to identify all wetlands that are active red-legged frog breeding sites. This percentage of buffer habitat is suggested since it is roughly the same as the habitat area in the 43Z Utility Right-of-Way site in this study, which had 62% intact habitat in the 200 m buffer and a low maximum red-legged frog egg mass count of ten. Though this was a low egg mass count, of all the study sites this site may best represent the minimum habitat requirements for a breeding population. Through the course of this proposed study, it would also be important to note the sites where no egg masses were found, but possess the terrestrial and wetland characteristics believed to be necessary to support red-legged frogs. These sites will be important because either it was coincidentally a year when no adults bred within these wetlands or they do not currently support a red-legged frog population. Whichever scenario applies, these sites are important from the perspective that they could be part of a network of breeding sites. By identifying all of the currently active and potential breeding sites, it will then be possible to plan for a network of protected sites in the Surrey Parks system that will ensure red-legged frog populations are sustainable in the City of Surrey. It will not be sufficient to protect a few of the large populations identified (i.e. Green Timbers Urban Forest Park and Bothwell Park) since these populations would likely suffer from a lack of genetic diversity over time due to inbreeding if there are no opportunities for interbreeding with other nearby populations. This effect has been documented in the common frog (*Rana temporaria*) in the UK where urban populations have rapidly become less genetically diverse than their rural counterparts and are experiencing higher levels of mortality and developmental abnormality (Hitchings & Beebee, 1997). Sites with large populations are critical, but they must be connected by corridors to other breeding sites to ensure that metapopulation dynamics are maintained or enhanced to ensure the sustainability of red-legged frogs as a species in the City of Surrey.

A second study that could be conducted within the City of Surrey to provide critical insight into the terrestrial habitat requirements and metapopulation dynamics of red-legged frogs would be radio tracking within Green Timbers Urban Forest Park and Bothwell Park. It was interesting that these two parks had by far the largest breeding populations of red-legged frogs considering grassland occupied nearly 40% of their 200 m terrestrial buffer. This is of interest because all red-legged frog studies describe their terrestrial habitat as forested (Corkran & Thoms, 2006; Matsuda et al., 2006; Maxcy, 2004). This study could track both juveniles and adults to provide information on adult home ranges and juvenile dispersal radius, while also demonstrating the level of use of the grassland areas. If it is determined that the grassland terrestrial habitats on these two sites are used by adults, then red-legged frog terrestrial habitat requirements may need to be reconsidered. If it is determined that the juveniles utilize or traverse the grassland areas frequently, then grassland areas should be considered as corridors between breeding populations when designing a protected area network. It may be that these grassland areas are used periodically when the moisture conditions are adequate, similar to the finding that rainfall increased permeability of forest clearcuts on Vancouver Island to red-legged frogs (Allaye Chan-McLeod, 2003). If this is the case, it may mean that grassland areas could suffice as marginal corridors between breeding sites.

If the studies suggested here are conducted in a timely manner the knowledge gained will form the groundwork for a successful recovery and conservation strategy for red-legged frogs that will ensure their sustainability as a species in BC.

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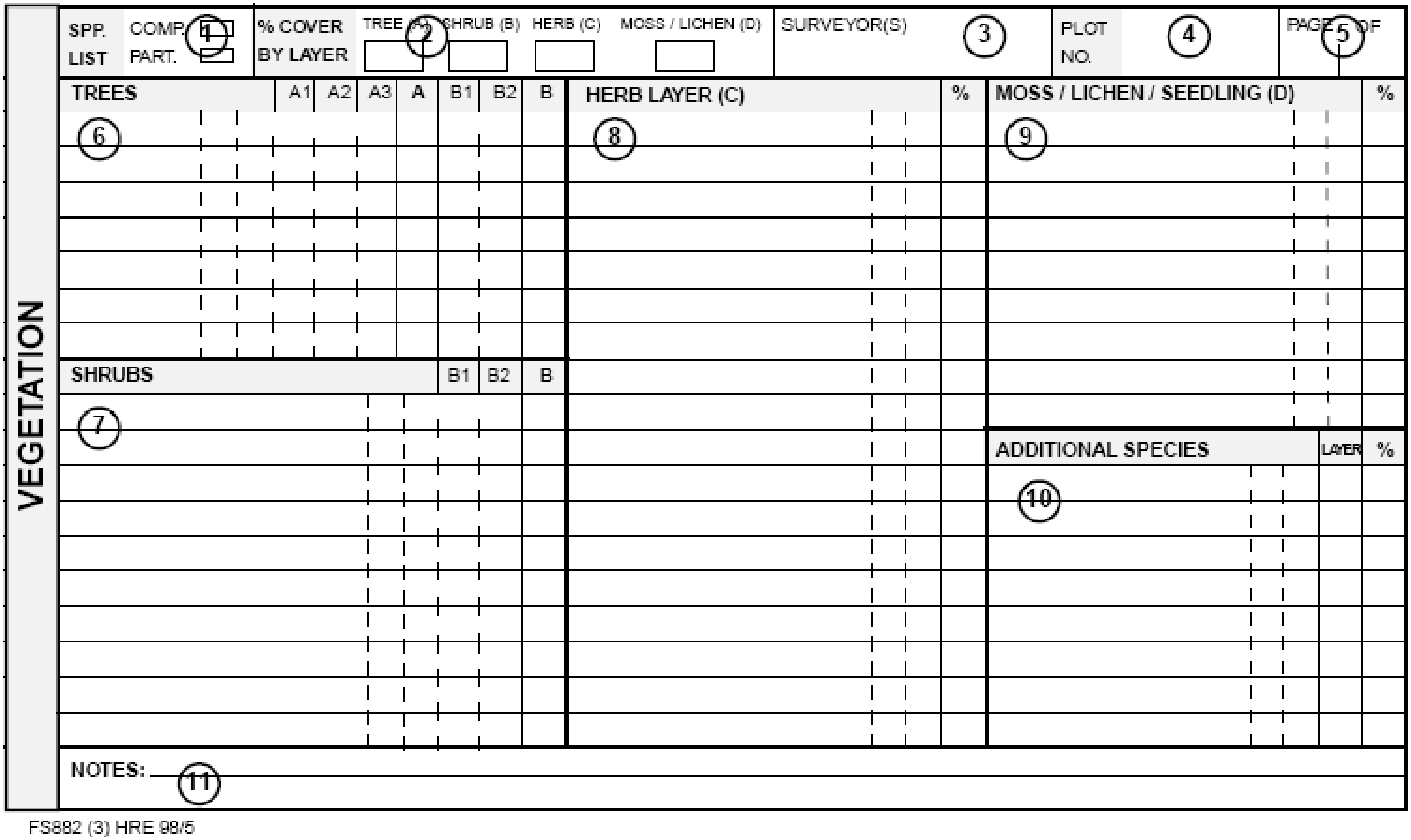
Appendix I. Province of British Columbia's Data Form for Describing Terrestrial Ecosystems



Note: Circled numbers correspond to methodologies used to gather the data specific to each section of the form (as described in Meidinger,1998).

Appendix II. Amphibian Field Data Collection Form

Amphibian Data Collection Form

Page ______ of ______

SECTION 1 - General Survey Information

1. Date	2. Surveyor	3. Park Name	4. Survey Time	
			Start	End

6. Weather & Water Conditions: descriptions can be found on separate code sheet

a) Wind	0 1 2 3 4 5 6	
b) Precip	N F M D LR HR S	
c) Water Temperature (Celcius)		
d) Air Temperature (Celcius)		

Comments (predators observed, site disturbance, unusual species observed, etc.)

SECTION 2 - Observation Information

Obs #	**Species** (common name)	**Life Stage** A or L or E	**Number Observed**	**Diam of egg mass** (cm)	**Water Depth** (cm)	**Dist Eggs Below Surface** (cm)	**Dist From Shore** (cm)	**Notes** (including substrate attached to)

Appendix III. Terrestrial Buffer Plant Community Data

Bothwell Park

Forest Layers

A1		A2		A3	
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
Thuja plicata	10	*Alnus rubra*	20	n/a	-
Pseudotsuga menziesii	5	*Picea sitchensis*	5	n/a	-
n/a	-	*Acer macrophyllum*	5	n/a	-

Shrub Layers

B1		B2	
Species	**% Cover**	**Species**	**% Cover**
Rubus spectabilis	20	n/a	-
Rubus discolor	10	n/a	-
Salix species	5	n/a	-

Herb Layer

Species	% Cover
Grass species	40
Juncus species	15
Impatiens species	10

Crescent Park

Forest Layers					
A1		**A2**		**A3**	
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
Picea sitchensis	3	*Pseudotsuga menziesii*	25	*Thuja plicata*	10
Abies grandis	2	*Acer macrophyllum*	20	*Abies grandis*	3
n/a	-	*Alnus rubra*	15	*Alnus rubra*	3
n/a	-	*Thuja plicata*	10	n/a	-

Shrub Layers			
B1		**B2**	
Species	**% Cover**	**Species**	**% Cover**
Acer circinatum	30	*Rubus spectabilis*	35
n/a	-	*Rubus parviflorus*	10
n/a	-	*Symphoricarpus albus*	7

Herb Layer	
Species	**% Cover**
Polystichum munitum	35
Rubus ursinus	10
Maianthemum dilatatum	10
Athyrium felix-femina	5
Typha latifolia	4
Geranium robertianum	2
Scirpus species	2

Green Timbers Urban Forest Park

Forest Layers					
A1		A2		A3	
Species	% Cover	Species	% Cover	Species	% Cover
n/a	-	*Pseudotsuga menziesii*	25	n/a	-
n/a	-	*Tsuga heterophylla*	5	n/a	-

Shrub Layers			
B1		B2	
Species	% Cover	Species	% Cover
Alnus rubra	25	*Rubus spectabilis*	25
Populus balsamifera ssp. trichocarpa	15	*Spirea douglasii*	10
Thuja plicata	5	*Cornus stolonifera*	10
n/a	-	*Physocarpus capitatus*	1

Herb Layer	
Species	% Cover
Grass species	30
Polystichum munitum	10
Solidago canadensis	10
Lupinus perennis	5

Hi-Knoll Park

Forest Layers					
A1		A2		A3	
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
n/a	-	*Acer macrophyllum*	10	*Alnus rubra*	40

Shrub Layers			
B1		B2	
Species	**% Cover**	**Species**	**% Cover**
Sambucus racemosa	5	*Rubus spectabilis*	30
Physocarpus capitatus	5	*Rubus parviflorus*	30
Cornus stolonifera	5	*Acer macrophyllum*	15
n/a	-	*Urtica dioica*	15
n/a	-	*Alnus rubra*	10

Herb Layer	
Species	**% Cover**
Grass species	15
Polystichum munitum	5
Rubus ursinus	5

43Z Utility Right-of-Way

Forest Layers					
A1		A2		A3	
Species	% Cover	Species	% Cover	Species	% Cover
n/a	-	*Tsuga heterophylla*	10	n/a	-
n/a	-	*Thuja plicata*	5	n/a	-
n/a	-	*Pseudotsuga menziesii*	5	n/a	-

Shrub Layers			
B1		B2	
Species	% Cover	Species	% Cover
Alnus rubra	15	*Rubus spectabilis*	30
Populus balsamifera ssp trichocarpa	5	*Rubus discolor*	25

Herb Layer		
Species	% Cover	
Grass species	25	

Hawthorne Park

Forest Layers					
A1		A2		A3	
Species	% Cover	Species	% Cover	Species	% Cover
Populus balsamifera ssp trichocarpa	15	*Betula papyrifera*	15	n/a	-
n/a	-	*Alnus rubra*	15	n/a	-
n/a	-	*Tsuga heterophylla*	10	n/a	-
n/a	-	*Pseudotsuga menziesii*	10	n/a	-
n/a	-	*Thuja plicata*	5	n/a	-

Shrub Layers			
B1		B2	
Species	% Cover	Species	% Cover
Alnus rubra	10	*Rubus spectabilis*	20
Salix species	10	*Rubus discolor*	15
Populus balsamifera ssp trichocarpa	2	*Oemleria cerasiformus*	5
n/a	-	*Vaccinium membranaceum*	5
n/a	-	*Gaultheria shallon*	2

Herb Layer		
Species	% Cover	
Rubus ursinus	10	
Maianthemum dilatatum	10	
Athryium felix-femina	5	

Port Kells Park

Forest Layers					
A1		**A2**		**A3**	
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
Populus balsamifera ssp trichocarpa	1	*Thuja plicata*	5	*Alnus rubra*	5
n/a	-	*Alnus rubra*	1	n/a	-

Shrub Layers			
B1		**B2**	
Species	**% Cover**	**Species**	**% Cover**
Rubus spectabilis	40	n/a	-
Spirea douglasii	15	n/a	-
Salix species	15	n/a	-

Herb Layer		
Species	**% Cover**	
Lysichiton americanum	3	

Boundary Park

Forest Layers					
A1		**A2**		**A3**	
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
n/a	-	*Pseudotsuga menziesii*	2	*Thuja plicata*	1
n/a	-	*Alnus rubra*	2	*Betula papyrifera*	1
n/a	-	*Thuja plicata*	2	n/a	-
n/a	-	*Populus balsamifera ssp trichocarpa*	1	n/a	-

Shrub Layers			
B1		**B2**	
Species	**% Cover**	**Species**	**% Cover**
Populus balsamifera ssp trichocarpa	1	*Rubus spectabilis*	3
Salix species	1	*Lamium* spp	2
n/a	-	*Mahonia aquifolium*	1
n/a	-	*Hedera helix*	1
n/a	-	*Vaccinium membranaceum*	1
n/a	-	*Acer circinatum*	1

Herb Layer	
Species	**% Cover**
Polystichum munitum	2

Cougar Creek Park

Forest Layers					
A1		**A2**		**A3**	
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
Populus balsamifera ssp trichocarpa	4	n/a	-	*Alnus rubra*	10
Picea sitchensis	2	n/a	-	*Populus balsamifera ssp trichocarpa*	4

Shrub Layers			
B1		**B2**	
Species	**% Cover**	**Species**	**% Cover**
Alnus rubra	5	*Rubus spectabilis*	20
Salix species	2	*Rubus discolor*	15
n/a	-	*Cornus stolonifera*	10

Herb Layer		
Species	**% Cover**	
Grass species	15	

Guildford Heights Park

Forest Layers					
A1		A2		A3	
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
n/a	-	*Thuja plicata*	5	n/a	-
n/a	-	*Pseudotsuga menziesii*	2	n/a	-
n/a	-	*Acer macrophyllum*	2	n/a	-

Shrub Layers			
B1		B2	
Species	**% Cover**	**Species**	**% Cover**
Alnus rubra	3	*Crataegus douglasii*	2
Acer circinatum	2	*Salix* species	2
n/a	-	*Spirea douglasii*	2
n/a	-	*Rubus spectabilis*	2
n/a	-	*Rubus discolor*	2
n/a	-	*Cornus stolonifera*	1
n/a	-	*Thuja plicata*	1
n/a	-	*Pseudotsuga menziesii*	1

Herb Layer	
Species	**% Cover**
Grass species	7
Solidago canadensis	1
Polystichum munitum	1

Semiahmoo Trail Park

Forest Layers					
A1		**A2**		**A3**	
Species	**% Cover**	**Species**	**% Cover**	**Species**	**% Cover**
Picea sitchensis	2	n/a	-	*Alnus rubra*	20
Populus balsamifera ssp trichocarpa	2	n/a	-	*Populus balsamifera ssp trichocarpa*	15

Shrub Layers			
B1		**B2**	
Species	**% Cover**	**Species**	**% Cover**
Alnus rubra	10	*Rubus spectabilis*	20
Salix species	5	*Rubus discolor*	15
n/a	-	*Cornus stolonifera*	10

Herb Layer		
Species	**% Cover**	
Grass species	15%	