Memorandum

Date:	November 15, 2017
To:	Leanne Bilodeau, Associate Director Sustainability – UBCO Campus Planning and Development
From:	Tina Deenik, B.Sc., Mary Ann Olson-Russello, M.Sc., R.P.Bio. and Kyle Hawes, R.P.Bio.
File:	17-2260
Subject:	Information pertaining to Western Yellow-bellied Racer presence at the UBCO Campus, Kelowna, BC

1.0 INTRODUCTION

Ecoscape Environmental Consultants Ltd. (Ecoscape) was retained by the Campus Planning and Development Department at the University of British Columbia Okanagan (UBCO) to provide environmental consulting services pertaining to the presence of a Western Yellow-Bellied Racer (*Coluber constrictor mormon*) on the Okanagan campus. The Racer was reportedly observed by Robert Lalonde, Associate Professor of Biology on September 28, 2017 on the Pine Trail north of the campus residences and associated parking lot area (see Figure 1).

Western Yellow-Bellied Racers (herein referred to as Racers) are fast, heat-tolerant snakes found in the interior of BC and are typically associated with dry, open grassland habitats (Racer Management Team Working Group 2013). Five discrete population areas exist near Trail, Grand Forks, Midway, and within the Okanagan/Similkameen and Thompson/Fraser watersheds. The most abundant populations are thought to be in the south Okanagan and lower Similkameen. Racers are a listed species due to their susceptibility to habitat loss. The status of the Racer is listed as:

- Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC);
- Special Concern within the Species at Risk Act (SARA);
- S3 (vulnerable) by the Conservation Data Centre; and
- Provincially Blue Listed in BC.

Racers have been found in a variety of habitats from wet valley bottoms and riparian areas to rocky slopes to sandy terraces. The *2006 Columbia Basin Racer Inventory* revealed 92 new Racer observations, all of which were located in dry, open grassland and mixed shrub habitat with loose rock being an important habitat feature at all den locations (Dulisse 2007). Commonly they are associated with the bunchgrass, Ponderosa pine, interior Douglas-fir and dry interior cedar-hemlock biogeoclimatic zones below 900 metres (Environment Canada 2014). Juveniles and adults feed on insects and adults also consume small mammals, reptiles, birds and amphibians (Shewchuck 2001).

Hibernacula (winter dens) and nesting sites must be connected to summer foraging areas to achieve the basic needs of the Racer. Hibernacula consist of holes in the ground or among rocks typically on south-facing slopes. Racers may over winter in traditional hibernacula with several other snake species, or they may den individually and use different dens each year. Nesting sites also typically face south, but can be located in a variety of different substrates including sand, grass, decaying wood or rock (Environment Canada 2014).

Given the high amount of both foot and vehicle traffic on the UBCO campus, along with other types of disturbances, the University Planning Department engaged Ecoscape to help them understand their obligations to protect this species. They are most concerned with the potential implications of landscape maintenance, trail use and other low impact activities within the area where the Racer was documented. The UBCO Campus Plan does not include campus expansion within the Ponderosa pine woodland. Based on the projected campus growth to 2035, the Ponderosa pine woodland is not needed for development and will therefore be retained in its current state to promote ecological values (The Campus Plan 2015).

2.0 OVERVIEW OF THE WESTERN YELLOW-BELLIED RACER

The following information was obtained from reports referenced at the end of the memo, and is meant to be informative to UBCO in regards to future use of the campus lands by Racers.

- Under the provincial Wildlife Act, the Racer is protected in that it cannot be killed, collected or held in captivity without special permits (WLAP 2004b).
- Racers are non-venomous and pose no threat to humans; however, if approached they may strike out of self-defense.
- Foraging habitats include grassland, open-forest and riparian areas.
- Nesting and den sites (hibernacula) often occur on south-facing slopes in dry, open grassland and mixed shrub habitat with loose rock being an important habitat feature. Racers have been documented sharing egg-laying sites and hibernacula with other species (such as Gopher snakes).
- Rock crevices, mammal burrows, rocks, logs and other retreat sites are important microhabitats that are used for shelter and thermoregulation. Anthropogenic structures such as old wells, cisterns and building foundations may also be used.

- Racers can display site fidelity and will return to the same den year-after-year as well as repeatedly utilize the same foraging grounds and home ranges.
- Home ranges are discrete and often located within 1 - 2 km of the den. Average daily summer foraging movements of 100 - 200 m have been documented. More movement occurs in the early summer season (May-July) versus late season (September-October). Ranges often overlap with other snake species and individuals of the same species.
- Average dispersal distances from the hibernacula have been documented at 781 m for males and 663 m for females.
- Mating occurs after emergence from winter dens. Three to seven eggs are laid in June-July in rotting logs or stumps, loose sand, under rocks or in animal burrows on warm slopes. Eggs hatch in August, or two months after laying.
- The most significant threat to Racers is habitat loss due to urban and agricultural development. This includes road mortality and habitat fragmentation.
- Pesticide use is a concern for its direct effects on the snakes and indirectly on their insect prey.
- Road construction, urban developments, utility construction, and quarrying are the most likely activities to impact communal dens and hibernating populations.

3.0 METHODS

The initial Racer sighting occurred in late September when the overnight temperatures ranged between 4 and 6°C. Given the declining overnight temperatures, it was anticipated that the Racer would use a hibernaculum that was located relatively close to the sighting location. Hobbs and Sarell (2002) report that Racers return to their dens in response to the onset of colder nights when temperatures drop below 9°C. Identification of the hibernaculum is critically important as Racers, along with other snakes (e.g. Western rattlesnake and Great Basin gopher snake), are known to den communally and return to the same den each year. Hibernacula preservation is therefore critically important to the survival of these species.

Key habitat attributes of hibernacula generally include areas of cliff, rock outcrop, and/or talus with adjacent riparian, grassland, and/or open forest communities for foraging. Additional topographical factors considered important in determining hibernacula suitability include elevation, slope, and aspect. Accordingly, warm aspect sites with steeper slopes are considered to have higher suitability as potential denning areas.

Having considered the above criteria, field surveys focused on suitable denning habitats that were located in relatively close proximity to the initial Racer sighting location. Surveys were only conducted on days that were sunny and warm (~15°C). Optimal survey days were limited between the second and fourth week of October, as there were numerous days within that period that were overcast, rainy or cool. Surveys were conducted on October 10th, 15th, and 23rd, 2017, with two searchers actively looking for snakes. Searches were conducted by 'purposeful meandering' within suitable habitats at peak times of day when snakes would be most active.

4.0 RESULTS

Near the location where the Racer was initially sighted, there are two areas that exhibit characteristics with high habitat suitability for hibernacula presence:

- **Site 1:** the hilltop outcrop to the south east of the reservoir has both south and west facing aspects, as well as stockpiled rocks and boulders (Photos 1 and 2) (Figure 1). Upon inspection there were no obvious deep crevices; the site is also highly disturbed with material stockpiles, weeds and trail establishment; and
- **Site 2:** a smaller hill top and slope situated about 100 m south west of the first site consists of an intact Ponderosa pine forest with a southwestern aspect. Near the crest of the slope, there are areas of talus, exposed bedrock and substantial woody debris (Photos 3 to 5) (Figure 1).

During each site visit, the two sites were thoroughly searched for a duration of approximately 2 hours. The total search effort across all visits was estimated at 12 hours. On October 15, 2017, an adult Racer (total length 600 mm) was captured about 20 m downslope of the Site 2 hill top on the south west face (Photo 6). The weather was warm (15°C) and sunny, while preceding days had been cool, with overnight temperatures dropping to 0°C. No other snakes were detected during the search efforts.

Based on the capture location of the adult Racer, Ecoscape is confident that the hibernaculum is located within a complex of exposed bedrock and woody debris located near the crest of the slope at Site 2 (Figure 1). Because only one Racer was observed, it is difficult to know whether the hibernaculum supports multiple snakes and/or species.

5.0 RECOMMENDATIONS AND BEST MANAGEMENT PRACTICES

- The identified hibernaculum located within Site 2 should be left undisturbed, as well as a sizable buffer around the identified denning site. Figure 1 illustrates a recommended 200 metre non-disturbance buffer. Racers are known to re-use the same nesting and denning sites; therefore, it is likely that this individual, and possibly others, will continue to utilize this site as an overwintering den.
- Extra caution should be used for normal maintenance operations (i.e. landscaping) that occur within 800 metres of the identified hibernaculum. Because the average dispersal distances from hibernacula have been documented at 781 m for males and 663 m for females, it is reasonable to assume that the Racer could be using areas located up to a kilometer of the hibernaculum. Figure 1 illustrates an 800 m

dispersal distance from the identified hibernaculum. It encompasses the agricultural field, Ponderosa pine woodland and the north half of the developed campus, almost extending to Highway 97.

- Maintenance staff and contract landscapers should be informed of the rare snake presence and its potential to occur within landscaped areas. The use of lawn mowers are of particular concern as they can result in snake death. Where possible, maintained lawns should be replaced with xeriscape gardens and/or native shrubs. Xeriscape landscaping is more snake friendly and requires less water.
- Other than forest thinning for wildfire prevention, native vegetation clearing should not take place within the Ponderosa pine forest. Ideally, forest thinning should occur during the winter months when snow is on the ground and there is less potential for understory and wildlife disturbance.
- Informational signage could be developed and posted adjacent to the Pine Trail that informs the trail users of the important and rare wildlife that occur within the Ponderosa pine woodland. Other species of known presence include Swainson's Hawk, Great Basin spadefoot toad and Great Horned Owl.
- Signage could also be posted along UBCO campus roads that indicates rare species presence and encourages drivers to slow down and to watch for snakes basking on the road.
- Extra caution should be used if field classes are utilizing these natural areas for study-purposes to not disturb or change the existing conditions (i.e. stumps, logs and rocks should be left undisturbed).
- Efforts should be made to protect existing Racer habitat within the UBCO campus lands. Future sightings and locations of Racers should be documented to better understand their ranges and movement patterns.
- Mitigation and best management practices (BMPs) should be considered at the time of the campus expansion and/or development. Specific Reptile BMPs have been developed and are appended to this memo for convenience (WLAP 2004a).
- If in the future there are campus expansion plans within the identified sites, prior to disturbance, a Qualified Environmental Professional should be engaged to determine if the area has active snake use.
- Construction activities should be avoided during periods when Racers are congregated for breeding, nesting, or seasonal migrations.
- Areas containing wildlife that are sensitive to sensory disturbances should be off-limits to construction personnel; storage of equipment and materials, as well as parking of vehicles should take place elsewhere.

- Avoid locating infrastructure or roads near potential denning areas such as south-facing talus slopes. Confirmed den sites should be protected by a large buffer of undisturbed vegetation and avoided entirely.
- Snake-proof fences can be erected around high-density urban developments to prevent contact. The fences should lead snakes back towards undisturbed habitats.
- Leave the Ponderosa pine woodland undisturbed and route future trails along the edges of the intact woodland to minimize encounters that can result in the killing of snakes.
- If future encounters with snakes are becoming prevalent, rocks and other cover types may be removed from areas where snakes are not wanted. These cover objects should be re-located to other portions of the campus where snakes might be more welcome.
- Pesticides (i.e. insecticides and rodenticides) should not be used within the campus lands, as these chemicals may harm Racers.
- Maintain critical structural elements such as rock outcrops, talus slopes, friable soils, coarse woody debris, concentrations of boulders, or other unconsolidated materials and vegetative cover.

6.0 REFERENCES

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7.0 PHOTOS

Photo 1. Site 1 – Hilltop rocky outcrop located to the south east of the reservoir.

Photo 2. Site 1 – Stockpiled rocky debris that may provide potential habitat for Racers.

Photo 3. Site 2 – Open Ponderosa pine forested area.

Photo 4. Suspected hibernaculum located near the crest of Site 2.

Photo 5. Site 2 – Loose rock (west facing talus).

Photo 6. Racer identified at Site 2 on October 15, 2017.

Figure 1:

Western Yellow-Bellied Racer (*Coluber constrictor Mormon*) Habitat Locations at the University of British Columbia's Okanagan Campus, Kelowna, BC.

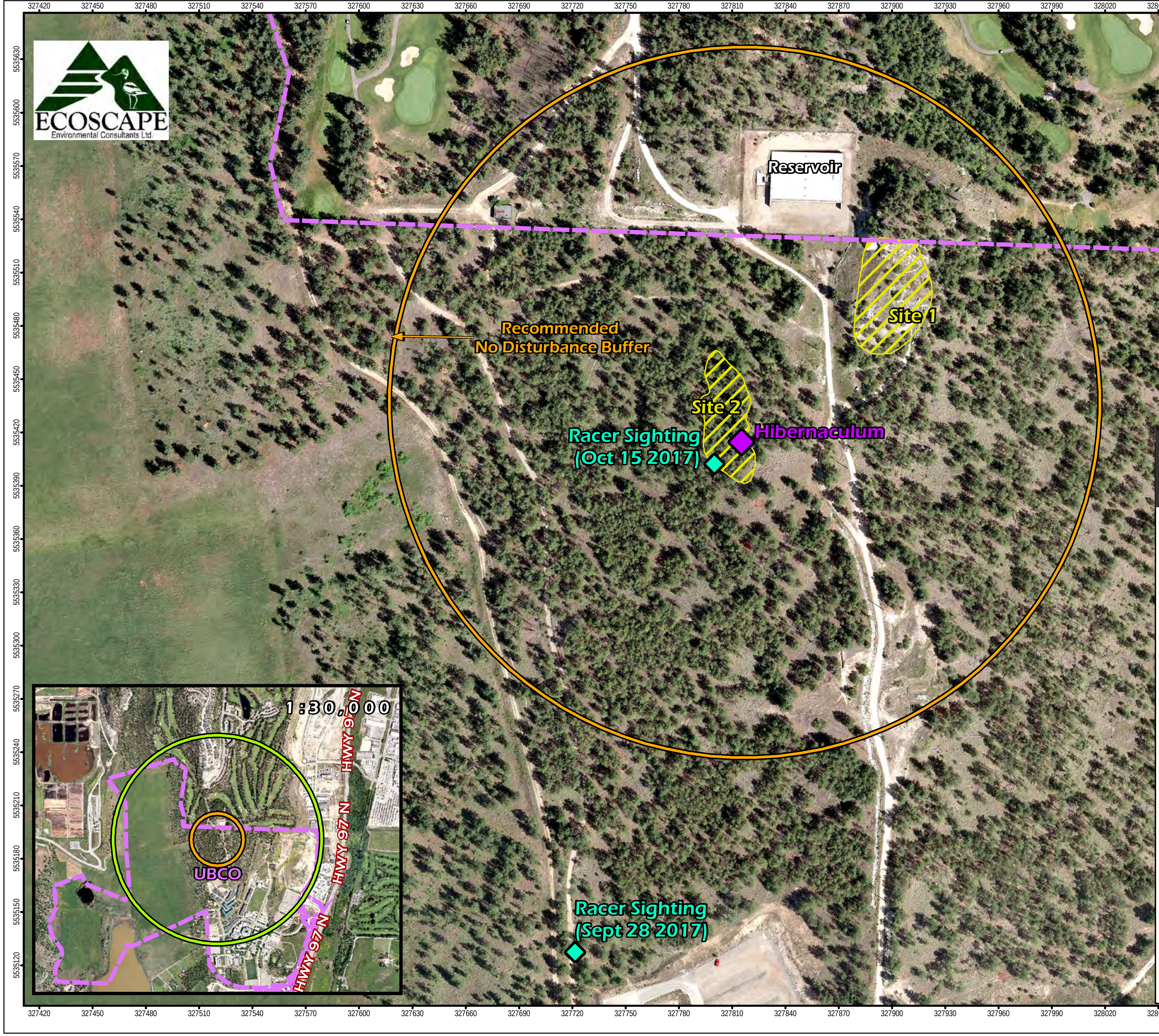

FIGURE 1

Western Yellow-Bellied Racer (Coluber constrictor mormon) Habitat Locations

Project:	Environmental Assessment
Location:	University of British Columbia Okanagan (UBCO) Campus, Kelowna, BC
Project No.:	17-2260
Prepared for:	UBCO Campus Planning and Development
Prepared by:	Ecoscape Environmental Consultants Ltd.
Drawn by:	Rachel Plewes
Checked by:	Tina Deenik
Projection:	NAD83-UTM Zone 11
Date:	November 21, 2017

N

LEGEND

- Hibernaculum
- Racer Sighting
- Identified Habitat Area
- Recommended No Disturbance Buffer
- Average Dispersal Distance
- Study Area (UBCO)

0 20 40 80 120 160 200 Meters

DISCLAIMER

The data displayed in this figure is for conceptual purposes only and should not be interpreted as a legal survey or for legal purposes. If discrepancies are found between the data portrayed in this report and that of a legal survey, the legal survey will supersede any data presented herein.

Appendix A:

Best Management Practices for Amphibians and Reptiles in Urban and Rural Environments in British Columbia

WLAP BMP Series

Best Management Practices for Amphibians and Reptiles in Urban and Rural Environments in British Columbia

November 2004

British Columbia
Ministry of Water, Land and Air Protection
Ecosystem Standards and Planning
Biodiversity Branch

Prepared for

BC Ministry of Water, Land and Air Protection
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The following persons kindly answered our queries and generously shared with us their extensive experience with amphibians and reptiles in different areas of the province: Patrick Gregory, Mike Sarell, Karl Larsen, Penny Ohanjanian, Brian Slough, Harry Higgens, Marc-Andre Beaucher, Doug Adama, Ross Clarke, Larry Halverson, and Bill Leonard (Washington State). Ted Davis, Marlene Caskey, Grant Bracher, and Susan Latimer provided useful review comments on an earlier version of this document.

Ode To A Toad

(by Larry Halverson)

Poor Old Toad

Tries to cross the road.
Here comes a car.
Didn't get far.

Crawling down a path
Sad aftermath,
Big shoe tread
Leaves another dead.

Poor old toad,
Miserable abode
Cold damp hole
Place got no soul.

Poor little beast
Ugly to say the least
It's just not so
Let your inhibitions go.

Look one in the eyes
You might be surprised.
Friendly little grin
Now is that such a sin?

Touch his lumpy back
But don't throw back!
You won't get a wart
Nothing of the sort.

Part of Nature's plan
He is a friend to man.
Toad saves us dollars
By eating creepy crawlers.

So if you encounter toad
Recall this simple ode.
Little toad should rate
We should appreciate.

Table of Contents

1 Introduction

Amphibians and reptiles are an ecologically important and interesting group of animals that require additional protection in British Columbia, especially in rural and urban environments. Because many amphibians and reptiles are inconspicuous and secretive in habits, they are generally poorly understood by the public and consequently do not receive the same level of attention as (arguably) more charismatic wildlife. However, amphibians and reptiles play important roles in ecosystems and are of scientific and educational interest. They possess interesting biological traits, such as behavioural thermoregulation, hibernation and metamorphosis, and are beneficial to society by consuming a variety of pest organisms such as insects and slugs; some snakes also feed on rodents. Amphibians and reptiles, in turn, form an important prey base for other animals in the ecosystem. Because their moist skin and eggs are exposed to the elements in water or on land, amphibians are sensitive to environmental change, and declines in this species group may be the first indication of adverse impacts on our ecosystems.

Amphibians and reptile populations are declining in many areas of North America due to habitat loss, contaminants, introduction of alien species, and disease. Yet, these populations and their habitats are largely unprotected by legislation, particularly on private land. The BC *Wildlife Act* prevents the collection, handling, and trade of all native wildlife but provides no habitat protection. The *Species at Risk Act* (SARA) (http://www.speciesatrisk.gc.ca/) provides for the protection of listed species and their residence and critical habitat. SARA applies primarily to federally managed species (aquatic species and migratory birds), and on federal lands. However, there are provisions for this protection to be provided on provincial Crown and private lands if laws of the province do not effectively protect a species or its residence and critical habitat. The *Forest Practices Code* and the new *Forest and Range Practices Act* also provide some protection for habitats on provincial forest lands for rare and endangered species, but management guidelines for rural and urban environments are lacking. Important habitats occupied by many amphibians and reptiles occur within low elevation areas, such as river valleys and wetlands. These areas are also focal points of human activity, which has resulted in extensive loss and alteration of habitats. Other factors with negative impacts, such as the introduction of harmful alien species and pollution, also affect these animals.

Opportunities exist for mitigating some impacts of urban and rural development activities on amphibians and reptiles, provided that effective tools and information are made available to developers, local governments, and the public. Although urban and rural habitats are often highly modified, they still can provide important habitat for some species of reptiles and amphibians in the province, including species at risk such as the Sharp-tailed Snake (*Contia tenuis*).

This report describes Best Management Practices (BMPs) designed to help maintain the viability of native amphibian and reptile populations in areas subject to land development activities in rural and urban areas of British Columbia. BMPs are not legislated requirements but recommendations for local governments, land developers, urban planners, and managers to protect amphibians and reptiles in urban and rural areas and to include these groups in biodiversity plans. BMPs for amphibians and reptiles must be practical and cost-effective, so that they can be readily used by land developers, consultants, landscape architects, local and regional governments, community groups, and the general public. Also, they must be supported by scientifically sound information. These measures also need to be monitored to assess their effectiveness and to identify and implement improvements, as required. This report outlines an approach that will address these requirements.

Section 2 of this report describes the rationale and need for protecting amphibians and reptiles in British Columbia and opportunities for local governments to protect them in rural and urban environments. Section 3 provides a detailed review and synthesis of literature pertaining to management practices for amphibians and reptiles. Section 4 presents a concise description of the status, distribution, and important life-history traits of species in the province and their compatibility with urban and rural environments. The BMPs for amphibians and reptiles are presented in Sections 5 and 6. A set of generic BMPs that apply to all areas of the province are described first, followed by a discussion of how they are to be applied in each of the nine Ministry of Water, Land and Air Protection (MWLAP) regions. A list of BMPs can be tailored to each region depending on the species present, their status, vulnerability of their habitats, and the type of land developments expected. Strategies for monitoring the effectiveness of BMPs and for promoting education and stewardship programs are presented in Sections 7 and 8.

Sections 5 and 6 (describing the BMPs) will form the basis for the amphibian and reptile section on the BC government web site describing BMPs for land developments. Those individuals requiring further background information, or the scientific basis of the BMPs, will be able to refer to Sections 2 and 3 of this report, which will be hyper-linked within the web-pages pertaining to BMPs.

The BMPs listed in this report are not intended to address requirements of each species of amphibian and reptile in detail, but to provide guidelines for habitat management measures that will have a positive impact on these groups. Additional measures are required for species at risk; these measures are described in great detail in the recovery strategies prepared for species listed as "endangered" or "threatened" by the Committee on Endangered Wildlife Species in Canada (MWLAP. Endangered Species (http://srmwww.gov.bc.ca/atrisk/). Rather, these guidelines provide a coarse filter approach that also benefits species that are widespread but not yet rare.

2 Background and Rationale

2.1 Rationale and Needs for Protecting Amphibians and Reptiles in British Columbia

Amphibians and reptiles have traditionally received less attention than groups perceived to be more charismatic by the public, such as mammals and birds. However, they play important ecological roles as both predators and prey, and are an integral component of biodiversity. Their physiology and ecology makes them well suited to serve as indicators of environmental health of both aquatic and terrestrial ecosystems.

There has been growing concern regarding the status of amphibian species around the world due to impacts such as habitat loss and degradation, introduction of nonnative species, and epidemic disease (Stebbins and Cohen 1995, Semlitsch 2000). In some cases, species have declined dramatically over a short period, while others have slowly lost populations throughout their range over time. For example, it is estimated that over 70% of Oregon Spotted Frog (*Rana pretiosa*) populations have been lost throughout their range in western North America (Hayes 1997). The dependency of this species on shallow, floodplain marshes has been in direct conflict with agricultural and urban/rural development that has resulted in the draining of wetland habitats.

In British Columbia, we have 19 native amphibian and 12 native reptile species, of which 47% and 58% are considered to be at risk (on the blue or red list) by the provincial Conservation Data Centre, respectively (see Section 4.0). For those species that have been evaluated by the Committee on the Status of Endangered Species within Canada (COSEWIC), 71% of amphibians and 67% of reptiles are listed as special concern, threatened, or endangered. The threats to amphibian species considered at risk are varied, not always clear, and compounded by the fact that non-threatened and declining species may be found occupying the same site. For example, both Northern Leopard Frogs (*Rana pipiens*) and Oregon Spotted Frogs, which are endangered, share habitats with other amphibian species that are not currently deemed to be at risk. Both species are threatened by habitat loss due to hydrological changes, as well as nonnative species. Northern Leopard Frog populations are also threatened by disease (Waye and Cooper 2001) and Oregon Spotted Frogs by contaminants in agricultural runoff (Haycock 1999). All identified threats to native amphibians and reptiles within British Columbia are in some way human-induced. Increased human population and land development will continue to threaten these groups.

Amphibians and reptiles are ectothermic, meaning that they derive their body heat largely from the environment. Reptiles, in particular, are known for their ability to behaviourally regulate their body temperature through basking and by actively seeking out suitable thermal conditions. Amphibians as a group are constrained by their requirement for moisture and hence are often not able to take advantage of thermal gradients in the environment. Ectothermy is one of the most important characteristics that influences the habitat requirements of these two groups of animals, and in turn, their management. Ectothermy is an efficient means of energy conversion, and much of the ingested food is converted into body mass, rather than being used in heat production through physiological processes as in birds and mammals (Pough 1980). This efficiency makes food readily available to animals further up the food web, including birds and mammals that prey on amphibians and reptiles. For example, amphibians consume large volumes of invertebrates, in both aquatic and terrestrial environments, and hence convert invertebrate biomass into a form that is available for larger animals. Their aquatic larvae feed on algae and plankton, and they in turn serve as a prey base for numerous macroinvertebrates (e.g., dragonfly and beetle larvae). Researchers have determined that, in some areas, amphibians attain a higher biomass than other vertebrates. For example, Davis (1996) estimated an average of 70,000 Western Red-backed Salamanders (*Plethodon vehiculum*) per hectare in areas of Goldstream Park on Vancouver Island. Reptiles are also an important predator base in many ecosystems, preying on invertebrates, amphibians, and small birds and mammals.

Amphibians and reptiles vary in their basic biology and ecology, so that management practices must take each group into account separately (Seburn and Seburn 2000). The main ways that these groups vary relates to their requirements for moisture and the development of their young. In contrast to reptiles, amphibians remain tied to moist environments, and most species in British Columbia require standing or running water to meet all of their life requirements. Amphibians are dependent upon moisture in order to breathe through their skin (subcutaneous respiration); in fact, some amphibians lack lungs altogether (all Plethodontid salamanders and Tailed frogs) and cutaneous respiration is their only means of gas exchange (Zug 1993). The combination of mountainous, forested areas and high rainfall in the Pacific Northwest, including coastal British Columbia, has resulted in a high amphibian species diversity and endemism (species found nowhere else) (Kiester 1971). The permeable skin and exposed (shell-less) eggs of amphibians make them vulnerable to impacts that affect aquatic and terrestrial environments. Because of their protective scales and their reproductive strategies of laying shelled eggs or bearing live young, reptiles as a group are less dependent upon moisture and water, which has allowed them to exploit more arid environments. In British Columbia, most amphibians and reptiles become dormant during cold winter months, and some become inactive during hot, dry summer months. The specific habitat requirements for these activities are unknown for many species.

Amphibians and reptiles as a group have relatively small home ranges and travel little compared to other vertebrate groups. Some species are highly philopatric, meaning that the majority of individuals return to natal breeding areas (where they were 'born') to reproduce when they reach sexual maturity. Individuals of many species also appear to have specific summer home ranges and over-wintering sites. The majority of individual amphibians are believed to remain within only a couple of hundred metres of breeding sites, and juvenile dispersal among populations is believed to be limited to less than 1 km for most species (Semlitsch 2000). As a result, populations can become easily isolated (Dodd and Cade 1998). In addition to relatively sedentary habits, many amphibian and reptile species are relatively long-lived, meaning that they will be exposed to disturbances within their environment for extended periods, and that they will have little opportunity to escape unsuitable conditions in either space or time.

Successful management of wildlife species is dependent upon an understanding of their range and distribution, as well as their habitat requirements. Adequate inventory data, and an understanding of the ecology of the species, are lacking for amphibians and reptiles throughout British Columbia. This is exacerbated for those species occupying more remote areas of the province, such as the north and central interior. As a result, predicting the impacts of, and species' compatibility with, urban and rural development is challenging.

There are many ways that amphibians and reptiles, and/or their habitats, can be protected, mainly through voluntary efforts. The *Species At Risk Act* (SARA) provides protection for individuals, residences, and critical habitats of those species listed as endangered or threatened. On federal lands, these protection requirements will come into effect once critical habitats have been identified and officially approved. Because the Act is relatively new, many uncertainties still exist on how it will be implemented and what the exact requirements and consequences will be. On private lands, it is expected that the focus will be on achieving protection goals through stewardship activities and actions of provincial and local governments; in extreme cases where effective actions are not being taken, the legal option provided by SARA allows the federal government to intervene. Species that are not listed by COSEWIC receive no direct protection from SARA but may derive benefits where they co-occur with species at risk.

In British Columbia, all wildlife, including amphibians and reptiles, are protected under the *Wildlife Act*. This means that, under the Act, a person commits an offence if they do any of the following without a license or permit:

- Imports or exports live wildlife, or the egg of a wildlife species into, or out of, British Columbia
- Traffics in live wildlife or wildlife meat
- Attempts to capture wildlife
- Has live or dead wildlife (or parts thereof) in his or her personal possession

- Ships or transports, or engages another person to ship or transport, wildlife or fish (or parts of them) in British Columbia
- Kills or wounds wildlife, other than prescribed wildlife, by accident or for the protection of life or property, and does not report promptly to an officer the killing or wounding and the location of the wildlife

Municipalities and regional districts have several tools for protecting land, including amphibian and reptile habitat:

> "Within the *Local Government Act* there are both broad tools (e.g., official community plans) and specific tools (e.g., tree protection bylaws) that could be used to address local environmental issues. In most cases, implementing stewardship at the local government level will involve stewardship clauses in several revised or new bylaws. The challenge is to create a set of coordinated local bylaws, to ensure that they integrate with provincial or federal regulations, and which together create a simple, effective and reinforcing environmental protection program." (Lanarc Consulting Ltd. 1997)

These tools include Development Permit Areas (DPAs), Regional District Planning Services, Advisory Planning Commission, zoning, landscaping, Flood Plain Designation, Tree Cutting Permit Areas, Development Cost Charges, and Conservation or Restrictive Covenants (Gawronski 1999). Not all of these tools can be implemented in both municipalities and regional districts. There are also many issues that are outside municipal jurisdiction, such as those related to The Agricultural Land Reserve system, federal and provincial lands, logging practices, agriculture, waste disposal, fish and wildlife resources, and air and water quality (Gawronski 1999). Regional districts have limited jurisdiction over federal and provincial lands, logging practices, agriculture, recreation, fish and wildlife resources, environmental protection, surface and ground water and drainage (Gawronski 1999). They do have jurisdiction over stormwater, drainage issues, and recreation within municipal parks.

The *Local Government Act* provides municipalities and regional districts with the possibility of developing stewardship bylaws, as a simple innovative and customized approach to counter degradation of the environment.

> "These powers in conjunction with a goal of environmental stewardship can be used to establish land use regulations (*bylaws*) that lay the groundwork for a strong environmental protection program" (Lanarc Consulting Ltd. 1997).

As an example, The District of North Vancouver has an environmental bylaw in place to "protect, preserve and conserve our natural setting and ecological systems of watercourses, trees, soils, lands and visual assets"

(Bylaw 6515). This bylaw protects aquatic areas, slope terrain, soil, and trees (Council for the Corporation of the District of North Vancouver 2002).

Municipalities can also designate Development Permit Areas to address specific conditions or accomplish other specified objectives. The DPAs must be part of an Official Community Plan (OCP), and DPAs can be amended as a bylaw to existing OCPs. As an example, Whistler council approved Development Permit Application No. 816 on the condition that the project implemented the recommendations for riparian enhancement by Cascade Environmental Resources (Resource Municipality of Whistler 2003). According to a mail-out questionnaire sent to most local governments within the province, 58 % of municipalities and 67 % of regional districts regulate natural environments, ecosystems, or biological diversity with DPAs (Gawronski 1999). The respondents represented a wide range of communities in terms of both size and location.

Within regional districts, the *Rural Land Use Bylaw* serves as a combined OCP, zoning bylaw and subdivision control bylaw (Gawronski 1999). Regional District Planning Services is one tool regional districts can use (Tools of the Trade. Local Government Planning in British Columbia 2002).

2.2 Public Perceptions of Amphibians and Reptiles

Historically, amphibians and reptiles have not been as popular among the public as other vertebrate groups, such as birds and mammals. This is reflected in the lack of support these groups have received for ecological research and the development of management practices compared to other vertebrate groups (Gibbons 1988). This trend has begun to shift for some species of amphibians and reptiles over the past decade; however, within these two groups, disparity remains among species regarding public interest and awareness.

Amphibians have always been more popular among the public than reptiles, largely because they are perceived as being more benign. The interest and knowledge of amphibians begins for many people as children, when they capture and raise tadpoles. Concern over amphibian population declines over the past decade has brought this group to the forefront of media attention and increased public awareness as a result, especially for frogs. Zoos and aquaria across North America have developed in-depth displays for this group, and recovery programs that work in partnership with these facilities provide opportunities for education. For example, the captive rearing of Oregon Spotted Frogs at the Vancouver Aquarium and the Vancouver Zoo have provided animals for display purposes and opportunities to educate the public about threats to native species. Amphibian monitoring programs are becoming more popular across North America, and around the world, such as the B.C. Frogwatch program established by MWLAP (http://wlapwww.gov.bc.ca/wld/frogwatch/index.htm). This is particularly true for frogs, which are often readily detected due to the vocalizations they produce during the breeding season. Frogs have also become popular emblems for advertising, logos, calendars, and artwork. This increased visual stimulus increases public interest and affection for this group, especially where brightly coloured, tropical species are used.

Salamanders have lagged behind frogs in terms of public awareness and interest, partly due to their more secretive nature. Reptiles continue to be largely ignored by the general public, in part due to the fear many people have of snakes. People often react in fear of snakes when they are encountered, and snakes are sometimes killed as a result (Dodd 1993, Seburn and Seburn 2000). For example, vehicles have been observed purposely swerving to hit snakes and turtles encountered on roads (Seburn and Seburn 2000).

However, an increase in attention by the general public may not always be beneficial. For example, species that are readily observed may be more prone to harassment from humans and pets than secretive species, and can be 'loved to death'. For example, concern over declining amphibian populations in Australia led to incidences where amateur naturalists were found moving frogs into new water systems in hopes that they could help increase their populations. Local researchers pushed for regulations to make this practice illegal, due to concerns over the spread of disease and nonnative species (Nowak 2000, S. Orchard, pers. comm.).

2.3 Factors Affecting the Viability of Amphibian and Reptile Populations in Urban/Rural Areas

The highest diversity of amphibian and reptile species in British Columbia correlates with those geographic areas that have attracted the greatest urban and rural development within the province (Vancouver Island, the Lower Mainland, and the Okanagan). This means that a relatively large number of amphibian and reptile species are affected by the habitat loss and degradation associated with urban development.

The greatest threats from urban and rural development for amphibians and reptiles are habitat loss, habitat degradation (including pollution), barriers to movement, predation and competition from nonnative species, and harassment from humans and pets. These issues become interconnected and act in concert within an urban setting. For both groups, habitat loss is the biggest issue related to urban development, whether it be basking and denning sites for reptiles, or aquatic breeding sites for amphibians. The requirements of amphibians for moisture, standing or running water for reproduction, and movement between breeding sites and seasonal habitats affect their ability to coexist with humans in an urban setting. Loss of cover, such as forest and riparian vegetation, as well as moist microhabitats and wet areas, in combination with the elevated temperatures associated with urban areas, increase the susceptibility of amphibians to desiccation. This in turn limits the movement of amphibians within urban areas and effectively isolates populations, as do barriers to movement, such as buildings and roads, and the loss of wetland sites. Reptiles require well-protected thermoregulation and denning sites, talus and rock outcrops, as well as foraging areas. Their populations can be greatly impacted by roads, pets, harassment, and even persecution by humans. For both groups, nonnative species, such as Bullfrogs (*Rana catesbeiana*), and opportunistic predators associated with human access and urban areas, such as raccoons and crows, can adversely impact populations.

2.4 Compatibility of Amphibians and Reptiles with Urban Environments

As with most taxonomic groups, the compatibility of amphibians and reptiles with urban development is species-specific and highly variable. A few species are largely compatible, several others may coexist with these developments if special provisions are made, and some are incompatible because they require large, relatively undisturbed natural areas. Amphibians most closely associated with forest cover, especially older, more mature forest, or that require specific habitat features such as ephemeral wetlands or intact upland areas are less likely to be found in urban environments, unless large parks or reserves are preserved. Numbers of some species are greatly reduced in urban areas, but the reasons remain unclear. For example, anecdotal evidence suggests that Western Toad (*Bufo boreas*) populations have declined in the Lower Mainland and on southeastern Vancouver Island (Wind and Dupuis 2002). However, lack of information on the distribution of the species and possible reasons for the decline makes it impossible to pinpoint the exact mechanisms and whether urbanization is a conclusive factor. Situations such as this emphasize the need for inventory and monitoring, as well as studies into the basic habitat requirements of amphibians and reptiles.

Several species of amphibians and reptiles appear to be amenable to some level of disturbance, as long as critical habitats have been identified and adequately protected. Species with small home ranges and highly aquatic species may be more readily maintained in natural areas within an urban setting. For example, some terrestrial salamanders move very little throughout their lifetime, and highly aquatic species rarely venture far from water, so that reserves and riparian buffers should meet the majority of their habitat needs. For reptiles, buffers around critical habitats such as dens, rock outcrops, and talus will help to maintain viable populations within urban areas. For both groups, maintaining connectivity among populations is critical.

2.5 Opportunities for Protection and Management

There are numerous ways that local governments can encourage developers to take responsibility for protecting amphibians and reptiles (see Section 5.0 on BMPs):

- An important first step is the *mapping of critical habitats for amphibians and reptiles* to identify these areas before development begins so that they can be incorporated into management plans. This can be accomplished by contacting regional amphibian and reptile experts, reviewing wildlife studies that have been conducted in the local area, and via the implementation of a volunteer-based inventory and monitoring program; local naturalist groups, and non-profit organizations and stewardship groups can serve as a valuable resource to begin such a program.
- Promote the use of the BMPs recommended in this document as evidence that other jurisdictions have recognized the importance of managing habitat for amphibians and reptiles. Make this document as readily available to all developers as possible; this can be accomplished via mail outs, the internet, and the production of educational materials, such as pamphlets, that can be given away at conferences, meetings, and road shows.
- Provide incentives for the protection of amphibian and reptile habitats. For example, a tax break could be given to developers that place buffers around small wetlands and seeps, and along creeks, as well as connective corridors to surrounding upland habitats. Awards could be developed for those companies that demonstrate initiative and creativity in protecting important amphibian and reptile habitats. This could be accomplished by working with amphibian and reptile conservation groups, such as the Canadian Amphibian and Reptile Conservation Network (CARCNET).
- Promote the concept that amphibians can serve as indicators of environmental health. This can be accomplished via the implementation of a regional inventory and monitoring program that operates in a variety of areas to track populations and species richness across varying degrees and types of developments.
- Use the support for local monitoring programs as evidence of the public's knowledge and interest regarding amphibians and reptiles. The loss of frog populations, especially those that produce audible breeding calls, will not go unnoticed by the general public, and will not reflect well on those responsible for development. The information collected through inventories and monitoring programs could be used as evidence of the use, importance, and knowledge of amphibian and reptile areas that require some form of protection, as well as public support. Developers can use this information as an important public relations tool, promoting themselves as environmentally friendly to amphibians and reptiles when they protect important habitats for these groups that have been identified via inventory and monitoring.
- Demonstrate that it can be fairly easy to protect basic habitat requirements for amphibians and reptiles, which in turn will protect numerous other species as a result (such as rare aquatic plants and dragonflies). The use of monitoring programs will demonstrate the array of species that can be preserved within urban areas. Make the

results of inventory and monitoring program readily available to the general public.

The above tools can be used to educate developers about the importance of amphibians and reptiles and their status in British Columbia, federally and globally, and how impacts to these populations affect numerous other species, including humans (e.g., insect control and rodent control). In turn, developers can promote themselves as 'amphibian and reptile friendly' by following the BMPs recommended in this document, by seeking the expert advice of an amphibian and reptile expert before development begins, working with the expert to find creative solutions to habitat protection issues, and by following their recommendations throughout construction. Developers can promote and support monitoring programs (financially or in-kind), and allow access to their sites for inventories and monitoring.

3 Literature Review of Management Practices

3.1 Review of Habitat Protection Practices

In British Columbia, most amphibians and some reptiles are semi-aquatic and require both aquatic and terrestrial habitats for successful completion of their life-cycle. With the exception of one group (Plethodontid salamanders, which are completely terrestrial), all our amphibians have aquatic eggs and larvae (Green and Campbell 1984). Juveniles and adults of these semi-aquatic species rely on terrestrial habitats to varying degrees, according to species-specific requirements. Conversely, turtles and some snakes use aquatic habitats for foraging and other activities, but move to terrestrial areas for breeding or over-wintering (Gregory and Campbell 1984).

While the importance of protecting aquatic breeding habitats of amphibians has long been recognized, terrestrial habitats that are equally essential for their different life-history requirements have often been neglected. Protecting terrestrial habitat peripheral to aquatic breeding sites is now considered essential for the viability of amphibian populations and are a conservation priority (Dodd and Cade 1998, Semlitsch 1998, 2000, 2002). Similarly, for reptiles the protection of critical habitats alone, such as snake dens and turtle nesting areas, is insufficient to maintain viable populations, if the needs of these animals for foraging and other essential activities are not met. Ensuring the availability of sufficient habitat of suitable quality for reptiles and amphibians can be challenging in populated areas, where space is at premium, human disturbance is intense, and remnant habitats are subject to disturbance and contamination from various by-products of human activities and land-use practices. Within densely populated areas, it may not be possible to maintain viable populations of some species that undertake long seasonal migrations or require much space, such as the Western Toad or Gopher Snake (*Pituophis catenifer*). On the other hand, species that are more sedentary and relatively tolerant to human disturbance, such as the Pacific Treefrog (*Myla regilla*), Northern Alligator Lizard (*Elgaria coerulea*) and Garter snakes (*Thamnophis* species), are more likely to persist within urban landscapes, provided that critical habitat features for their survival are maintained.

3.1.1 Protection of critical habitats

Critical habitats (as the term is used here) include aquatic breeding sites for amphibians, caves and seepage areas for some salamanders, turtle nesting grounds, snake hibernacula, and other sites that animals use for essential life-history activities. A relatively large proportion of the local or regional population may congregate in such habitats during certain seasonal periods. These habitats are often spatially discrete and may be confined to relatively small areas, and hence are amenable to protective measures. During land-use planning and environmental impact assessments for specific projects, critical habitats for amphibians and reptiles should be identified and protected from development. Additional needs to encompass all life-history phases are discussed in the subsequent sections, below; needs for habitat connectivity are discussed in Section 3.3.

For amphibians, even very small (0.2 – 0.3 ha), temporal ponds and pools can be valuable and support several species (Semlitsch and Brodie 1998, Snodgrass et al. 2000). Surveys in British Columbia have also emphasized the value of small wetlands here (Wind 2002). Studies in several areas of North America have shown that small wetlands do not necessarily support fewer species of amphibians than do large wetlands (Hecnar and M'Closkey 1996, Snodgrass et al. 2000). Furthermore, small wetlands, due to their shorter hydroperiods (see Section 3.5), often support a unique complement of species that may be absent from larger, more permanent water bodies (Snodgrass et al. 2000). Semlitsch and Brodie (1998) drew attention to the importance of small wetlands as breeding and dispersal habitat for amphibians and the role such habitats play in contributing to local and regional amphibian species richness. Even wetlands that are too small to support viable populations over the long-term can act as a source of emigrants during favourable years or as stepping-stones for migrating species, provided that travel routes are available to allow for dispersal movements. If such connectivity can be provided within populated landscapes, the value of protecting a local site is greatly enhanced and acquires wider significance.

For reptiles, critical habitats that need protection include nesting sites of freshwater turtles. One native species, the Painted Turtle (*Chrysemys picta*), occurs in British Columbia. Its egg-laying and nursery habitats are specific with respect to exposure (southern aspect), substrate type (dry and light soils with little vegetation cover), and distance from aquatic habitat (within 150 m) (Habitat Atlas for Wildlife At Risk; South Okanagan & Lower Similkameen 2002). Such areas are often in short supply, resulting in the concentration of much of the local population in specific areas during the egg-laying period. The Painted Turtle can coexist with humans, provided that measures are taken to protect its nesting grounds from development and human disturbance. Several ongoing projects in the Kootenay area are implementing such measures, including the use of fences to direct movements of turtles to alternative nesting grounds away from roads and heavily used portions of a recreational area, and altering access to control human disturbance of nesting areas (R. Clarke, pers. comm.).

Snake denning sites are typically located on south-facing slopes in rocky upland sites, where the 3-dimensional structure of the habitat allows access to crevices below the frost line but above the water table. Communal hibernation is a phenomenon of northern climates and appears to result from a combination of a shortage of suitable sites and from social and/or physiological factors (Gregory 1984). In the arid southern interior of the province, the protection of communal snake denning sites, which may harbour several species at risk, is of particular concern (Habitat Atlas for Wildlife At Risk; South Okanagan & Lower Similkameen 2002). These species include the Western Rattlesnake (*Crotalus viridis*), Gopher Snake, and Racer (*Coluber constrictor*) (Habitat Atlas for Wildlife At Risk; South Okanagan & Lower Similkameen 2002). Snake dens are susceptible to human disturbance and need to be identified and protected from development. Because over-wintering sites with appropriate characteristics are often in short supply, relocation to other areas is typically not an option for displaced snakes.

3.1.2 Protection of sufficient habitat for all essential activities

Although there is a general agreement of the importance of terrestrial habitats peripheral to aquatic amphibian breeding sites, the required dimensions for such "buffer zones" are often debated. Recent studies suggest that to maintain viable populations these buffers have to be much larger than previously thought (e.g., Semlitsch 1998, Trenham 2001, Richter et al. 2001). Based on a synthesis of information on terrestrial movements of six species of mole salamanders (family Ambystomatidae), Semlitsch (1998) estimated that a buffer zone of 164 m from the edge of wetlands would protect 95% of the population. He suggested that upland buffers of similar dimensions might be required for other semi-aquatic amphibians in wetland habitats. For stream-dwelling species, forested riparian buffer strips of 30 – 100 m might be required (Semlitsch 2000 and references therein). In the southern United States, narrow (< 25 m) riparian zones along streams supported fewer species of amphibians and reptiles than did wider zones of 30 m or more (reviewed by Dickerson 2001). This difference reflected greater diversity of habitats within the wider zones, such as a distinct forest canopy, shrub understory, and well-developed litter layer.

In urbanized areas, the requirement for adequate terrestrial buffers is particularly important, because the surrounding habitat is often even more impermeable to amphibian movements than, for example, clear-cut forest. Careful consideration of buffer dimensions and habitat connectivity is required to avoid misdirecting conservation efforts towards those species that require terrestrial habitats in excess to what can be provided.

Although urban ponds and wetlands may not support a full complement of species, amphibians that require relatively little upland habitat and are tolerant of various human disturbances can persist and even thrive in such habitats. Ostergaard and Richter (2001) examined amphibian use of 52 residential storm water ponds in western Washington State and found a surprising diversity of species (5 native and one exotic species, all of which also occur in British Columbia). The Pacific Treefrog was the most commonly encountered species, followed by the Northwestern Salamander (*Ambystoma gracile*), Bullfrog (*Rana catesbeiana*; exotic), Long-toed Salamander (*Ambystoma macrodactylum*), Red-legged Frog (*Rana aurora*), and Rough-skinned Newt (*Taricha granulosa*), in that order of frequency of pond occupancy. Of the possible species, the Western Toad, a widespread forest-dwelling species, and the Oregon Spotted Frog, a species that is now very rare, were not found. The presence of the Northwestern Salamander and Red-legged Frog were positively correlated with forested cover within 200 m of the pond, suggesting that these species may require wider buffer zones and/or connective corridors around wetlands than do the other species observed.

Similar to the protection of amphibian habitats, the maintenance of sufficient buffer zones and habitat connectivity is necessary to satisfy all habitat requirements of reptiles. For large snakes, the area around hibernacula that needs to be protected can be considerable. For example, an undisturbed buffer zone of 1 km is suggested for known den sites and other critical habitats of the Western Rattlesnake and Gopher Snake (Habitat Atlas for Wildlife At Risk; South Okanagan & Lower Similkameen 2002).

Critical habitats for completely terrestrial amphibians (Woodland salamanders) and reptiles (lizards and some snakes) that are widely dispersed within suitable habitats are typically difficult to identify. These animals do not undertake seasonal migrations and occupy the same general habitats year-round. For such species to survive in populated landscapes, conservation efforts should focus on protecting habitat patches that contain critical habitat features, such as abundance of downed wood for salamanders and rock outcrops and slopes for lizards and some snakes. One species (the Coeur d'Alene Salamander [*Plethodon idahoensis*]) that occurs in British Columbia occupies caves and crevices in fissured rock formations in seepages, splash zones of waterfalls, and riparian areas along creeks.

Home ranges of Plethodontid salamanders (Ovaska 1988, Davis 2002) and the two species of lizards native to British Columbia (Rutherford and Gregory, *in press*) are typically small (< 10 m). Movements of small, non-migratory snakes also typically occur within relatively small areas (< 45 m for the common Northwestern Garter Snake (*Thamnophis ordinoides*); Macartney et al. 1988; < 30 m for the rare Sharp-tailed snake; Engelstoft and Ovaska 1999), facilitating their coexistence with humans in urbanized areas. However, because of the apparently poor dispersal abilities of these animals, particularly Plethodontid salamanders and lizards, each habitat patch should be sufficiently large to support viable populations. Allowing for at least occasional dispersal and gene-flow through forested greenways or riparian management areas is expected to be beneficial. Within urban areas in Australia, How and Dell (2000) found that even small (1 ha) habitat patches supported several species of lizards and snakes, provided that habitat degradation by fire and predation was controlled.

3.1.3 Maintaining habitat quality

In addition to retaining sufficient areas of aquatic and terrestrial habitats for amphibians and reptiles, preventing degradation of the quality of these habitats is important. Aquatic habitats in particular should be shielded from contamination with sediments and pollutants (see Section 3.4). Vegetation and microhabitat features important to amphibians and reptiles should be maintained. For example, basking sites surrounded by water, such as floating logs, are important for freshwater turtles and should be maintained (Habitat Atlas for Wildlife At Risk; South Okanagan & Lower Similkameen 2002).

In terrestrial habitats, features important for amphibians and reptiles should be maintained and protected from disturbance and removal. Downed logs, bark, and other woody material in various stages of decay (often referred to as coarse woody debris) provide shelter and feeding sites for a variety of wildlife, including amphibians and reptiles (Maser and Trappe 1984, Aubry et al. 1988). Clean-up activities in parks often result in the removal of woody debris, but these practices should be discouraged. In the arid interior of British Columbia where fires may be a problem, larger trunks can be retained while smaller branches and stems that provide fuel for wild fires can be removed (S. Latimer, pers. comm.). Rock outcrops and talus slopes should be protected from trampling by routing paths away from these areas and discouraging off-road recreational activities. Rock outcrops provide shelter and, when on south-facing slopes, suitable thermal conditions for lizards and snakes (Huey et al. 1989). Talus provides excellent habitat with many hiding places for salamanders, some frogs, lizards, and snakes, and is important as egg-laying habitat for some species (Herrington 1988).

Some amphibians (such as Mole salamanders – family *Ambystomatidae*, including the Northwestern, Long-toed, and Tiger Salamanders – and Great Basin Spadefoots [*Spea intermontana*]) and reptiles (such as the Sharp-tailed Snake) spend much of their life in underground tunnels. Mole salamanders rely on tunnel systems excavated by other animals, primarily rodents, and the availability of suitable burrows is essential for their survival during adverse dry periods in summer and cold periods in winter. Great Basin Spadefoots require soft, fine-grained soils for burrowing and their ability to find refuges can be severely impaired in urban areas. Jansen et al. (2001) investigated the ability of one species of Great Basin Spadefoot to burrow in different types of substrates common in urban areas. The animals burrowed with ease in sand but were unable to burrow in grass sod; juveniles were also unable to burrow in gravel. The authors suggested that maintaining sandy areas is critical to the survival of these animals in urban landscapes.

Habitat quality within urban landscapes may also be compromised by exotic predators and competitors and invasive plants, as discussed in Section 3.7, and by direct human disturbance, as discussed in Section 3.6.

3.1.4 Maintaining natural processes

Natural processes, such as fire, floods, and vegetation succession can have either beneficial or harmful effects on habitats of particular species (Semlitsch 2000). Over time, ponds and marshes may turn into terrestrial shrub-lands through successional processes, forested buffer zones around these habitats may burn or blow down, and turtle nesting grounds may become choked with grass and weeds. Controlling natural processes is essential to maintain habitat quality over the long-term, particularly in small habitat patches within urban areas, where alternative habitats are scarce. For aquatic-breeding amphibians, maintaining natural hydroperiods, i.e., the pattern of filling and drying of ponds, is essential (see Section 3.5).

3.1.5 Maintaining habitat connectivity and metapopulation dynamics

While the protection of amphibians and reptiles at isolated sites within urban landscapes may have much social value as an educational tool, maintaining habitat connectivity that allows for dispersal movements greatly enhances the conservation value of such sites and the long-term survival of populations. Semlitsch and Brodie (1998) pointed out that perhaps the greatest difficulty for ensuring long-term viability of amphibian populations in disturbed landscapes concerns the disruption of population processes at landscape levels. Many amphibian populations consist of a number of subpopulations that are linked through dispersal (Gill 1978, Sinsch 1992, Sjögren Gulve 1994). These larger populations are termed metapopulations, and their long-term persistence depends on a complex pattern of emigration and immigration among subpopulations, and on recolonization of habitat patches that have become vacant due to natural disturbances or by chance. Disruptions to these processes are intensified within urban landscapes, where connections between habitat patches are reduced. Section 3.3 discusses ways to provide habitat connectivity for amphibians and reptiles in urban environments.

3.1.6 Principles of habitat management

The management of habitats for amphibians and reptiles in urban environments is fundamentally similar to their management in other disturbed landscapes. However, differences exist in the emphasis, scale, and specific tools for achieving the common goals. Semlitsch (2000, 2002) discussed principles for the management of habitats for aquatic-breeding amphibians. The following recommendations are modified from these principles to focus on amphibians and reptiles in British Columbia, based on the literature review in the previous sections:

- Identify and protect critical habitats (such as aquatic breeding sites of amphibians, caves and seepages for some salamanders, snake dens, and turtle nesting grounds) from development and human disturbance

- protect sufficient habitat peripheral to critical habitats to allow for all essential life-history activities to continue (such as terrestrial foraging habitats for semi-aquatic amphibians)

- prevent degradation of habitat quality in both aquatic and terrestrial habitats by controlling contamination, human access, spread of exotic species, and other measures as deemed necessary

- preserve habitat attributes important for amphibians and reptiles, such as coarse woody debris, rock outcrops, talus, and appropriate substrates for burrowing

- maintain and manage natural processes, such as hydro-periods and vegetation succession, so that habitats continue to provide suitable conditions for target species over the long term

- avoid fragmentation of habitats (i.e., isolation, edge effects); where habitats are already fragmented, provide habitat continuity that allows for movements of animals
- provide sufficient habitat and landscape linkages so that population processes that depend on emigration and immigration and gene flow can be maintained

3.2 Review of Habitat Restoration and Enhancement

As natural habitats continue to be degraded and diminish in both area and numbers, management practices for wildlife, including amphibians and reptiles, are focusing on habitat restoration and enhancement measures (Morrison et al. 1994, Sinclair et al. 1995, Semlitsch 2002). In highly modified landscapes, such as urban areas, restoration and enhancement measures are often required to maintain viable populations of amphibians and reptiles (Kingsbury and Gibson 2002). Habitat restoration includes re-establishing ecological processes, historical disturbance regimes, and/or habitat features that have been modified by human activities or natural events. Habitat enhancement involves improving habitat quality by adding or augmenting features important for particular species or groups. Because pre-disturbance conditions for particular sites are seldom known in detail, the line between restoration and enhancement is often blurred. Habitat restoration, as used here, is considered to encompass enhancement measures that attempt to mimic natural patterns typical to a habitat type and region, regardless of the pre-existing conditions of particular sites.

Habitat restoration for amphibians and reptiles can be carried out at different spatial scales and can range from restoration of habitat connectivity at a broad scale to landscaping practices and individual actions by residents in their backyards and gardens. To be successful, both large- and small-scale restoration projects require careful planning and knowledge of the requirements of the target organisms. Furthermore, the effectiveness of the measures needs to be monitored to assess their success (See Section 7.0).

3.2.1 Restoration of landscape level processes

Maintenance of habitat connectivity is important for the long-term viability of amphibian and reptile populations. Within urban settings, greenways and park systems can provide avenues for animal movements. To facilitate such movements, it is necessary to pay particular attention to habitat quality in these areas (see sections below for specific restoration measures). Equally important, it is necessary to restrict efforts to habitats that were naturally continuous rather than to create travel routes where none existed before development (Harris and Scheck 1991). Structures that facilitate road crossings by amphibians and reptiles are discussed in Section 3.3.

Habitat connectivity that allows access for nonnative species such as Bullfrogs or other potential predators or competitors is detrimental to amphibians and reptiles. In such cases, restoration activities may consist of blocking access for these organisms. Because amphibians can use terrestrial dispersal habitats, disrupting the continuity of aquatic habitats by changes in drainage patterns or installation of barriers will prevent movements of nonnative. In areas where Bullfrogs are a problem, special efforts should be taken to prevent their spread to new areas (see Section 3.7).

The creation of new wetlands can contribute to the restoration of amphibian habitats at the landscape scale. New ponds placed at strategic locations within a disturbed landscape can increase overall habitat, and reduce isolation among populations by providing stepping-stones for migrating and dispersing amphibians (Semlitsch 2002). Similar measures may be beneficial for reptiles, such as Garter snakes, that use wetland areas for foraging.

Wetlands of varying sizes, depths, hydroperiods, and timing of inundation within the landscape contribute to the diversity of amphibian and reptile faunas, and restoring this diversity is a key factor when conserving or restoring wetlands in disturbed areas (Paton and Crouch 2002, Semlitsch 2002). The construction of new breeding areas or hibernacula for amphibians and reptiles may sometimes be useful in the context of landscape-level restoration. If successful, this type of habitat enhancement can help restore linkages to sub-populations across the landscape, increase the carrying capacity of an area for amphibians and reptiles, and encourage previously excluded species by opening up travel corridors (Highways Agency [Britain] 2001).

3.2.2 Restoration of aquatic habitats

Restoration of wetland habitats:

Amphibians and reptiles use wetlands across a spectrum of pond-permanence for essential life-history activities. For example, temporary ponds dry annually, semi-permanent ponds dry in some years and not others, and permanent ponds never dry. Temporary wetlands include vernal pools, floodplain pools, and other shallow depressions that undergo a periodic, annual pattern of filling and drying. Amphibians that breed in temporary water bodies avoid predation by fish and other aquatic or semi-aquatic animals that have poor overland dispersal abilities. Semi-permanent and permanent wetlands include marshes, ponds, lakes, excavated dugouts, and beaver ponds. Permanent water bodies are essential for amphibians that require multiple years for aquatic larval development. A study conducted in Michigan demonstrated that amphibian distribution among ponds with varying degrees of pond-permanence is species specific (Skelly et al. 1999), suggesting that maximum biodiversity can only be attained if a variety of ponds are available across the landscape. Freshwater turtles require permanent water bodies for foraging, over-wintering and other activities, while many semi-aquatic snakes (such as several species of garter snakes) use both types of wetlands for foraging. Several species of amphibians opportunistically use both temporary and permanent water bodies, but their breeding success and survival characteristics may vary between the two types of wetlands. Adams (2000) found that survival of tadpoles of the Red-legged

Frog and Pacific Treefrog was reduced in permanent ponds in the Puget Lowlands, Washington State. This result was only partially explained by direct adverse effects of fish and bullfrogs in permanent ponds.

Adams (1999) pointed out that in the Pacific Northwest of the United States human activities have resulted in a shift from temporary wetlands toward more permanent water bodies, which has led to the spread of exotic species with apparent adverse effects on some native amphibians, such as the Red-legged Frog. A similar regional shift has probably taken place within populated parts of southern British Columbia, as shallow temporal wetlands have been drained for agriculture and urbanization.

Temporary wetlands can be successfully restored for amphibians and reptiles but are very difficult to create anew because of complexities involved in generating natural filling and drying patterns (Kingsbury and Gibson 2002). Restoring natural hydroperiods that permit pond drying is an important management technique for reducing predation on amphibians and competition among species (Semlitsch 2002). Where such wetlands have been made permanent through human activities, restoring their temporary nature may simply involve breaking existing drainage tiles or filling in drainage ditches (Kingsbury and Gibson 2002). Techniques such as these have been used with success (Nyberg and Lerner 2000). The creation of temporary pools, on the other hand, has resulted in premature pool drying and extensive mortality of trapped larvae (DiMauro and Hunter 2002). Because amphibians and reptiles that use temporary wetlands need terrestrial habitat for much of the year, the availability of sufficient upland areas of good quality habitat adjacent to the wetland should be ensured.

Permanent wetlands can be either restored or created anew for amphibians and reptiles (Kingsbury and Gibson 2002). Restoration of natural drainage patterns is an important first step in rehabilitating a degraded wetland. Often, eliminating human-made drainages into and out of a water body is sufficient to restore these patterns and control extreme fluctuations in water levels. In urban environments, paved surfaces increase run-off and can result in extreme peak flows. Using alternatives to hard surfaces, such as porous pavement, appropriate management of storm-water, and sufficiently wide buffer zones around wetlands can help alleviate such problems (Canadian Wildlife Service, Ontario Region 2000). Introduced aquatic predators are often a problem for amphibians in permanent wetlands and may need to be controlled through removals or manipulation of the hydroperiod (see Section 3.7).

The rehabilitation of a wetland, whether permanent or temporary, often requires reducing siltation and pollutants entering these water bodies. Establishing or restoring a vegetated buffer zone around wetlands is a well-known method that helps filter out contaminants. Buffers also provide terrestrial habitat for amphibians and reptiles, especially if native plants are used and intact forest floor structure is provided. The construction of holding ponds along drainage channels is an option to reduce contamination for some permanent wetlands (Kingsbury and Gibson 2002). Pesticide applications above water and in riparian zones should be eliminated (see

Section 3.4 on sensitivity of amphibians and reptiles to different contaminants). Providing diverse habitats within wetlands is beneficial for amphibians. Warm shallow areas, mixed with deeper vegetated littoral zones provide a suitable mixture of microhabitats and thermal gradients (Semlitsch 2002).

Creating shallow pools adjacent to permanent wetlands is an option in some cases to increase habitat diversity for amphibians and reptiles (Kingsbury and Gibson 2002). Other techniques to restore both temporary and permanent wetlands that are beneficial to amphibians and reptiles include controlling exotic weeds by mechanical means (such as pulling or girdling), preventing entry of excess nutrients through sewage management, and restoring connectivity to upland habitats.

Restoration of stream habitats:

Key elements in urban stream restoration include providing riparian buffer strips composed of native vegetation, maintaining stream habitat complexity, and controlling water quality (Lind 1996). Small headwater streams typically support only amphibians, whereas both amphibians and reptiles may occur along larger streams (Dickerson 2001). In British Columbia, three species (Pacific Giant Salamander and two species of Tailed frogs) inhabit small headwater streams (Cannings et al. 1999). A few other species, such as the Northwestern Salamander and Red-legged Frog, may breed in pocket pools within small streams, but these species use a variety of other types of water bodies as well. Both the Pacific Giant Salamanders and Tailed frog require cool, clear, permanent streams for breeding and larval development. Habitat restoration for these species should include activities that reduce sediment accumulation and contamination of their stream habitats, re-establish natural stream flow patterns, and restore adjacent terrestrial habitat. Scouring of the streambed and riparian zones reduces their quality as habitat and is detrimental to these species. The maintenance and, where needed, restoration of abundant shelter, such as rocks and boulders in the aquatic habitat and coarse woody debris within the riparian zone, is also beneficial for these species.

A variety of amphibians and some reptiles occupy larger streams and their backwaters. Restoring natural undulations and creating backwater areas are options for improving the quality of channeled streams for these groups (Kingsbury and Gibson 2002). Similar to small streams, maintaining vegetated riparian buffers is extremely important to reduce the entry of contaminants and sediments into the water and to provide upland habitat for amphibians and reptiles. Holding ponds and grass filter strips are additional options for controlling siltation, excess nutrients, pesticides and heavy metals entering the water.

Maintaining diversity of habitat features is a key consideration when restoring habitats for both amphibians and reptiles (Dickerson 2001). Where important microhabitat features, such as floating logs or other basking sites for reptiles, have been removed, they can be replaced. Amphibians such as the Western Toad and Spotted frogs also use such habitat features.

3.2.3 Restoration of terrestrial habitats

Habitat restoration of riparian buffers and upland habitats for amphibians and reptiles may simply involve leaving these areas in their natural state and allowing them to recover through natural processes. Eliminating intensive landscaping practices, such as mowing or using weed-eaters within riparian zones, is often sufficient to initiate recovery. Controlling exotic, weedy plants may be needed, especially in small habitat patches. Buffers along urban streams are thought to be particularly effective when composed of native species (Lind 1996). Monocultures of exotic weedy species, such as Scotch Broom or blackberries, are unlikely to provide useful habitat for amphibians and reptiles, although such areas may receive some use by tolerant species of reptiles, such as the Northwestern garter snake that frequents disturbed habitats.

As in aquatic habitats, maintaining a diversity of structural components and habitat features in terrestrial habitats is beneficial for amphibians and reptiles (Burbrink et al. 1998, deMaynadier and Hunter 1998, Semlitsch 2000). Burbrink et al. (1998) found that relatively narrow (<100 m wide) riparian areas supported a similar number of species as very wide (>1000 m) zones. Habitat heterogeneity and proximity to core areas were more important correlates of species richness than was the width of the riparian zone. While forest openings benefit some species of amphibians and reptiles, others, such as some salamanders and Tailed frogs, require forest floor conditions that resemble those of the forest interior. deMaynadier and Hunter (1998) found that in eastern North America, salamanders, as a group, were more adversely affected by drier conditions at forest edges than were frogs. Edge effects for sensitive species, such as Woodland salamanders (family *Plethodontidae*), were estimated to extend about 25 – 35 m from the edge into the forest. Reduced abundance of coarse woody debris, leaf litter, and other structural features of the forest floor were identified as potentially limiting factors for amphibians near forest edge.

Habitat features critical for amphibians and reptiles may need to be restored where these features have been depleted, degraded, or removed (Dickerson 2001). Important habitat features for these groups include downed wood, bark, and other coarse woody debris, especially large-diameter pieces, in various stages of decay (Aubry et al. 1988, deMaynadier and Hunter 1995). Leaving fallen trees and woody debris on site is a simple way to ensure availability of shelter and feeding sites for amphibians and reptiles. The adoption of this measure may mean modifying existing gardening, landscaping, or park maintenance practices. Within urban parks, public education may be required to ensure that newly fallen trees, especially large trunks, are not hauled away for firewood. The addition of coarse woody debris to sites from where it has been removed or depleted is also an option (Kingsbury and Gibson 2002).

Rocks and talus are important habitat features for reptiles, and when sufficient moisture is present, also for amphibians (Kingsbury and Gibson 2002). Rocky outcrops on south-facing slopes are particularly important for lizards and snakes and provide them with warm, sheltered locations for thermoregulation, egg-laying, and nursery sites. Where such slopes occur adjacent to foraging habitats, such as in the forest or near riparian areas, they are particularly valuable. With the exception of a few species, all reptiles that occur in British Columbia exist at the northern limits of their distribution in the southern or central part of the province (Gregory and Campbell 1984). The availability of suitable warm sites is critical to their survival here, and such sites can be in short supply.

Rock outcrops and talus can be restored in areas where they have been disturbed or removed. In Australia, the addition of artificial rock and paving stones within a park helped promote prey species for an endangered species of snake and created shelter for the snakes as well. Natural rocks had been depleted at this site because of illegal collecting for garden ornamentation and other uses (Webb and Shine 1999, Goldingay and Newell 2000). Collectors also targeted the new structures, and the authors suggested that they should be placed far (>450 m) from access trails to prevent vandalism.

Turtle nesting grounds and snake hibernacula will sometimes benefit from restoration activities. The Painted Turtle requires warm, sparsely vegetated openings on well-drained soils for nesting. Vegetation cover hinders nest excavation and lowers soil temperatures for incubation, and plant roots can interfere with hatching (Clarke and Gruenig 2002). Successful measures to restore and enhance turtle nesting grounds include pulling plants and roots to increase the area of exposed soil. These measures have been used at several sites in the Kootenay area of British Columbia (R. Clarke, pers. comm.).

On Pelee Island, Ontario, habitat restoration for the endangered Blue racer (*Coluber constrictor foxii*) has included the construction of artificial hibernacula (B. Porchuk, personal communication). On the Gulf Islands, British Columbia, habitat restoration is in progress for the endangered Sharp-tailed snake. Restoration measures include the construction of artificial hibernacula and dry-stack rock walls (to provide shelter) and the removal of invasive, introduced plants (C. Engelstoft, unpublished data). The use of the structures by snakes will be monitored with the help of landowners.

In the Sacramento area of California, guidelines have been created for the restoration and creation of habitat for the Giant Garter Snake (*Thamnophis gigas*), including details on upland and aquatic components of habitat, species of plants to be used in restoration, necessary buffer widths from roads, basking retreats, guidance for construction activities in the area, and monitoring protocols (Sacramento Fish and Wildlife 2003).

Reducing access to the public by re-routing trails may be necessary to reduce soil compaction and to promote natural recovery of terrestrial amphibian and reptile habitats (see Section 3.6). Sometimes fencing is required to protect critical habitats. Within a large urban park near Calgary, Alberta, restoration of a Garter snake hibernaculum was attempted to repair damage caused by human foot-traffic to the slope where the site was located. Cavities within the structure were beginning to cave in due to erosion. The slope was fenced off to reduce human disturbance to the snakes and to restore vegetation on the slope (Fish Creek Provincial Park 2002). Fencing has been used around turtle nesting grounds in British Columbia to reduce human disturbance to nests within areas that receive high recreational and other use by humans (Clarke and Gruenig 2002, R. Clarke, pers. comm.).

3.2.4 Avoiding ecological traps

While there are numerous examples of amphibian use of restored or created wetlands (e.g., Laan and Verboom 1990, Mierzwa 2000, Nyberg and Lerner 2000), often the success of restoration projects has not been adequately evaluated for amphibians and reptiles. Such evaluation is especially important for artificial wetlands, which may act as ecological traps rather than contributing to local or regional populations (DiMauro and Hunter 2002). Where existing habitats are restored to a state that approximates their former condition, the risk of inadvertently creating ecological traps is reduced.

Many amphibians readily use a variety of artificial water bodies as breeding sites (Monello and Wright 1999). When restoring or creating wetland habitat for amphibians, care should be taken that the new water bodies have adequate depth for the target species to complete their larval development. DiMauro and Hunter (2002) noted that if these precautions are not taken, created pools may simply trap larvae in an area that does not have a sufficient hydroperiod for them to survive through metamorphosis, as is often the case in anthropogenic vernal pools created during industrial forest-management activities. They found that artificial pools dried up sooner than did natural pools and often resulted in mass mortality of larvae. Amphibians readily used both types of pools for breeding, and if the fate of the egg masses had not been monitored, these adverse effects would have gone undetected. The fate of metamorphosed juveniles in the surrounding upland area depends on the quality of the terrestrial habitat and is often unknown. For forest-dwelling species care should be taken to leave shade trees adjacent to the pools and to ensure sufficient canopy cover around the pools (DiMauro and Hunter 2002).

Similarly, ponds created for amphibians along roadsides may function as ecological traps by subjecting animals entering and leaving them to increased mortality. Snakes that feed on amphibians may be attracted to such areas and subjected to increased mortality while crossing the road or using the road surface for thermoregulation. Too often, the effectiveness of artificial wetlands and other structures created for amphibians and reptiles has not been adequately tested through follow-up monitoring. Within populated and recreational areas, vandalism to structures created for amphibians and reptiles may harm the animals using them. Webb and Shine (1999) and Goldingay and Newell (2000) both found that vandalism occurred to rock outcrops that were created as habitat enhancement for snakes near trails within parks.

3.2.5 Principles of habitat restoration for amphibians and reptiles

The following principles for habitat restoration are based on the synthesis of the literature review, presented in the previous sections:

- A diversity of habitats and habitat features promotes species diversity and long-term survival of amphibian and reptile populations, and should be kept in mind when restoring habitats
- Restoration activities may involve either increasing connectivity to allow for dispersal and migratory movements of amphibians and reptiles, or blocking continuity of habitats to prevent access by their predators and competitors, such as introduced nonnative or bullfrogs
- Whereas permanent wetlands suitable for amphibians can be created, creating temporary wetlands is very difficult; where they exist naturally, however, both types of wetlands are amenable to restoration
- Restoration of natural drainage patterns for temporary and permanent wetlands is beneficial for amphibians and reptiles
- Riparian buffer zones, necessary for control of contaminants that enter a water body, also provide essential terrestrial habitat for amphibians and reptiles. However, for many species relatively wide buffer zones and habitat connectivity are required to provide sufficient upland habitat
- Often, restoration objectives can be achieved through natural vegetation succession and resisting intensive management practices, such as mowing and weeding (although within ponds, plants may need to be removed to maintain some open water areas)
- Practices that promote the establishment of native vegetation are beneficial for amphibians and reptiles, as they restore habitat diversity and natural ecosystem processes
- Maintaining and restoring habitat features important for amphibians and reptiles, such as large pieces of coarse woody debris and rock outcrops, enhances the quality of terrestrial habitats for these animals
- The maintenance and restoration of south-facing rocky slopes adjacent to foraging habitat in the forest or wetlands provides warm, sheltered sites for snakes and lizards for egg-laying, nursery, or over-wintering.
- The creation of artificial structures (rock or brush piles) for shelter, over-wintering, or nesting can be beneficial for reptiles in areas where natural sites for these activities have been degraded or reduced in numbers.
- Inadvertent creation of ecological traps, which attract amphibians and reptiles to sites where their survival is impaired, should be avoided.
- Careful planning is important for all restoration and habitat enhancement activities.

3.3 Review of Habitat Connectivity and Barriers to Movement

Human developments and activities can pose barriers to movements of wildlife, thereby restricting gene flow, subdividing populations, and exerting profound effects on demography, spatial structure, and persistence of populations. Such effects are particularly significant for smaller wildlife, such as amphibians and reptiles that are relatively sedentary when compared to other groups of vertebrates and that often have complex, spatially structured populations (Gibbs 1998). Landscape level management of such "metapopulations" (populations that are divided into smaller units that are connected through dispersal) is particularly important (Marsh and Trenham 2001, Semlitsch 2000).

In urban and rural environments, roads and other linear developments, housing and industrial areas, parking lots, steep embankments, and other constructions pose complete or partial barriers to animal movements (Harris and Scheck 1991). Because of their linear nature, prevalence in landscapes, and the vast tracts of lands that they intersect, roads represent a special case of movement barriers. Environmental impacts of roads are numerous and varied; more than 20 categories of effects on wildlife have been identified, including changes to drainage patterns, edge effects, run-off of contaminants and sedimentation, and invasions by exotic species (Forman and Deblinger 2000). This section is restricted to the consideration of roads as barriers to movements and a source of mortality to amphibians and reptiles. The two effects are interconnected, and amphibian road mortality during migratory movements, which can be highly visible and draws public attention, has been used as a focal point for efforts aimed at restoring habitat connectivity (Langton 1989a). Where roads act as complete or near-complete barriers to animal movements through aversion and avoidance, the effects are more difficult to discern but may be equally severe in terms of population fragmentation. For example, deMaynadier and Hunter (2000) found that logging roads significantly impacted movements of some salamanders, whereas those of several species of frogs were unaffected. Providing for landscape connectivity for relatively sedentary groups, such as Woodland salamanders and small lizards, can be challenging, because their movements are more diffuse than those of migratory species, such as many frogs and some snakes.

3.3.1 Vulnerability of amphibians and reptiles to road mortality

Harris and Scheck (1991) identified several reasons for significant mortality of wildlife on roads. Two of his categories apply to amphibians and reptiles: Mass mortality results where (a) roads bisect natural migration routes (amphibians, snakes, turtles), or (b) new habitat is attractive and serves as an ecological trap (snakes, turtles). Amphibians that undertake seasonal migrations between spatially separated spawning, feeding, and over-wintering sites are particularly vulnerable to mortality on roads (Langton 1989b). These species include amphibians with an "explosive" breeding pattern (Wells

1977), which involves mass migrations to breeding sites within a typically short breeding season. Carr and Fahrig (2001) found that, according to predictions, densities of Northern Leopard Frogs, which wander widely, showed a negative correlation with traffic intensity (up to 1.5 km from breeding sites), whereas densities of Green Frogs (*Rana clamitans*), which are more sedentary, showed no such correlations. They suggested that movement patterns are an important determinant of the severity of road impacts on amphibian populations, and that those species that undertake long seasonal migrations are most likely to be affected by roads. Reptiles that undertake seasonal migrations between hibernation and foraging sites (some snakes, especially northern populations) or between nesting and foraging/over-wintering sites (freshwater turtles) are also vulnerable. Migrating amphibians and reptiles typically cross roads along specified stretches of roads. Although effects in terms of mortality can be devastating (van Gelder 1973, Fahrig et al. 1995, Hels and Buchwald 2001), these routes are often amenable to mitigation measures, such as fencing and crossing structures.

The asphalt surface of paved roads retains heat and can act as an ecological trap for reptiles that seek warm conditions to raise their body temperature. Road-kill of reptiles warming up on roads has long been recognized as a significant source of mortality for some populations (Barbour 1944 cited in Harris and Scheck 1991). The effects can be particularly severe where roads are close to snake hibernacula or turtle nesting sites. Amphibians, in contrast, are more dependent on moisture than are reptiles, and typically do not use the warm road surface for thermoregulation, although roadside ditches may attract some species.

3.3.2 Measures to mitigate road mortality and improve habitat connectivity

Avoidance of key habitats:

Routing of new roads to avoid important wetlands and key migration routes is the best measure to minimize effects of roads on amphibian populations (Podloucky 1989, Ryser and Grossenbacher 1989). However, in cases where such intrusions are unavoidable, where knowledge of migration routes is incomplete or inaccurate, or where roads already exist, other solutions must be found. In Europe, the problem of mortality of migrating amphibians on roads has long been recognized, and various solutions have been attempted (Langton 1989a and papers therein). The above authors stress that mitigation should not be used as an excuse to intrude on key habitats, such as important wetlands that have high biodiversity values.

Temporary measures:

Temporary measures include road closures, display of traffic signs, speed reduction zones, and transport of trapped animals across the road by humans. In rural areas of Germany, wide-scale nocturnal closures of secondary roads during the migration period of amphibians have been deployed with success (Podloucky 1989). In areas where reasonable diversion routes existed and the migration period was short (days or weeks rather than months), the results were acceptable to the public. In most areas of North America, however, road closures are unlikely to be well received. However, temporary road closures remain a cost-effective option for special, local situations where initiated by residents. Nocturnal closing of bicycle trails in parks is also a viable option in some special cases. Traffic signs and speed reduction zones are generally ineffective, although signs can have high educational value and serve to draw the attention of the public to the problem (Ryser and Grossenbacher 1989). Transport of migrating amphibians across roads by humans is a surprisingly widely used option in parts of Europe (Feldmann and Geiger 1989, Meinig 1989, Zuiderwijk 1989). It has also been used with success in parts of North America (Linck 2000). The method is safe and effective when the animals are trapped using drift fences. However, it is highly labour-intensive, depends on extensive volunteer efforts, and can only be viewed as a temporary solution to the problem. Such projects can serve as a focus for stewardship and public education programs.

Permanent measures:

Permanent mitigation measures include tunnel systems, other crossing structures, and relocations of breeding sites (Podloucky 1989, Ryser and Grossenbacher 1989). Relocation of a breeding site consists of completely blocking off access to the road with a permanent fence and creating or enhancing alternative, substitute breeding grounds on the side of the road with foraging and over-wintering habitat. For amphibians this method is an option where most of the habitat is on one side of the road, and the spawning grounds are in the middle of farmland, built-up area, or by the road (Podloucky 1989, Schlupp et al. 1989). Schlupp et al. (1989) found that even a species with a high fidelity to traditional breeding sites (Common Toad [*Bufo bufo*]) can adjust to new sites, although considerable initial effort was involved. This method has also been used with success for the Painted Turtle in British Columbia (Clarke and Gruenig 2002; see Section on "Fencing and road crossing structures for reptiles", below).

Apart from the routing of new roads to avoid important wetlands and migration routes, road-crossing structures are considered the only permanent solution with wide applicability to reduce mortality of wildlife in heavily roaded areas (Harris and Scheck 1991). This category includes tunnel systems designed specifically for amphibians and reptiles (see below), as well as other systems that facilitate movements of a wide variety of wildlife. Examples of general wildlife measures include wildlife bridges, viaducts, and expanded bridges (Jackson and Griffin 2000). If properly placed, all these measures probably facilitate movements of amphibians and reptiles in urban and rural landscapes, although their use by these animals has received little or no testing.

Wildlife bridges consist of large (up to 30 m wide) underpasses designed with a variety of wildlife in mind (note: not to be confused with wildlife overpasses, which allow animals to travel over the road; terminology according to Jackson and Griffin 2000). Dry conditions within these structures may deter their use by amphibians. Providing cover (such as rocks) along the inside walls of the underpass may facilitate movements by small wildlife, as done at a wildlife bridge along the Inland Island Highway on Vancouver Island (R. Dolighan, pers. comm.). Viaducts consist of elevated roadways across river valleys and incorporate both terrestrial and aquatic habitats. Species of amphibians and reptiles that use riparian areas for movement corridors could benefit from habitat connectivity provided by these structures. Expanded bridges serve similar functions and provide upland habitat in addition to aquatic travel routes. Because of their openness, expanded bridges tend to facilitate the passage of a wider variety of wildlife than do culverts (Jackson and Griffin 2000). Expanded bridges and viaducts potentially provide habitat connectivity for a variety of amphibians and reptiles that do not undertake mass-migrations and that may be reluctant to use tunnels. However, to provide for passage of migrating amphibians and reptiles, these structures must be placed in sections of the road where it intercepts the migration route and accompanied with fencing to prevent road mortality. In such cases, the deployment of special tunnel systems in appropriate locations is often a more appropriate solution.

3.3.3 Amphibian road crossing structures

For decades several western European countries, notably Switzerland, Germany, and Great Britain, have deployed tunnel systems constructed specifically to allow amphibian passage across roads (Langley 1989a and papers within). Such “toad tunnel” systems typically consist of drift fencing or walls to prevent animals entering the road, a guiding system to direct them to the underpasses, and the tunnels themselves, which are placed at intervals across a critical section of the road that interrupts an amphibian migration route. The first tunnel system was constructed in 1969 in Switzerland. One of these early systems, Etang de Sepey, near Lausanne, has been monitored for many years and is among the most successful of such systems. In North America, an amphibian tunnel system was constructed in 1988 for the Spotted Salamander (*Ambystoma maculatum*) in Amherst, Massachusetts – this system is also highly successful with a crossing efficiency of about 70% for animals that encounter the drift fences (Jackson and Tyning 1989). Other amphibian tunnel systems exist in Texas and California, and still others are under consideration in Oregon and Florida (CARCNET 2000a). In British Columbia, amphibian tunnel systems are present at two localities along a new section of the Inland Island Highway on Vancouver Island: in the vicinity of Piercy Creek, west of Courtnay, where the highway intersects a wetland, and near Qualicum, where it intercepts a migration route to Hamilton Marsh and other smaller, breeding ponds (Fitzgibbon 2001).

A tunnel system must allow for movements of adults entering and leaving breeding ponds and of metamorphosed juveniles leaving ponds (Podloucky 1989). Proper location of tunnel systems is of utmost importance and requires knowledge of species composition, migration routes, and the location of amphibian seasonal habitats. Of the early amphibian tunnel systems in Europe, a disconcerting number were found be virtually non-functional (Podloucky 1989, Ryser and Grossenbacher 1989). The problems included lack of planning, poor fencing that allowed animals to breach the fence or circumvent it around the ends, poor directing systems that failed to guide animals towards the tunnels, and unsuitable tunnels that deterred animals from entering them. One-way entrances to tunnels, consisting of a vertical "chute" that prevented animals from climbing out and turning back have resulted in mortality in some cases.

Tunnels:

Amphibian tunnels have been constructed of a variety of materials, including concrete, steel, PVC piping, and polymer surface products. Steel is deemed undesirable because of its high conductivity and coldness during spring migratory periods (CARCNET 2000a). Observations of animals at the tunnel entrance have revealed hesitancy and repeated unsuccessful entry attempts (Buck-Dobrick and Dobrick 1989, Langton 1989c, Jackson and Tyning 1989). This "tunnel hesitancy" is interpreted to be due to a change in microclimatic conditions, particularly in temperature, light and humidity, that the animals perceive as localized climate deterioration. Solutions include the use of large (such as 1 m diameter) tunnels that permit airflow and increase incident light at the tunnel exit (Dexel 1989). Smaller diameter tunnels (as small as 0.2 m in diameter) can be effective if they contain slots to allow for the entrance of ambient light and moisture (Brehm 1989). Examples of the latter include grated tunnels placed flush with the road surface.

Length of tunnels of the existing systems is highly variable, but most tunnels tend to be less than 15 m. For example, the successful Etang de Sepey system includes 30 cm-diameter tunnels that are, on the average, 12 m-long (Krikowski 1989). However, amphibian movements have been observed through tunnels as long as 42 m at that site. The tunnels at the successful Amherst site are 7 m-long (Jackson and Tyning 1989). At the Vancouver Island site the culverts are 30 – 35 m long (Fitzgibbon 2001). The effectiveness of longer tunnels spanning 4-lane highways has not been adequately tested (Jackson and Griffin 2000).

The optimal distance between tunnels within a system depends on movement patterns and behaviour of target species. In practice, intervals of about 50 m between tunnels appear to be suitable for a number of species and situations (Ryser and Grossenbacher 1989). Jackson and Tyning (1989) found that the Spotted Salamander, a burrowing species that might not be easily directed, readily moved distances up to 30 m along drift fences.

Drift fences and tunnel entrances:

Drift fences have been constructed of various materials, including concrete, rigid plastic, and polythene sheets (CARCNET 2000a). The fencing should be constructed of durable materials and regularly inspected for damage (Ryser and Grossenbacher 1989). Berms with sloping earth and retaining walls can also be deployed along portions of the system. Fences less than 50 cm in height appear to be suitable for most species (CARCNET 2000a). If the target species is a burrower, such as a Mole salamander (family Ambystomatidae), steps must be taken to prevent animals from burrowing under the fence. Jackson and Tyning (1989) found that burying the bottom 6

– 10 cm of the drift fence effectively contained the Spotted Salamander at the Amherst site. To prevent breaching by climbing amphibians, various fence designs that curve inwards or create an overhang have been used (CARCNET 2000a). Overhanging vegetation close to the fence has resulted in animals climbing over the fence onto the road; to be effective, fencing must be kept clear of obstructions and vegetation (Ryser and Grossenbacher 1989).

Zigzag or WW-shaped drift fences, with tunnels at the bottom angles function to guide animals to the tunnel entrances. However, where drift fences must parallel the road, additional structures are needed to guide amphibians to the tunnel entrance (Brehm 1989). “Swallow-tail” entrances consist of two short, curved walls angled towards the tunnel entrance and divided in the middle by a barrier; “standard” entrance consists of drift fences or walls angled towards the tunnel entrance; “one-way” entrances deploy a mechanism similar to pitfall traps to cause the animals to drop into the tunnel entrance (CARCNET 2000a). One-way entrances necessitate the deployment of two parallel tunnels to facilitate seasonal movements in each direction. All these entrance types have been used with success.

Potential problems:

Apart from problems and challenges associated with the design of effective tunnel systems discussed above, flooding has been identified as a problem in some cases, especially where a stream passes through the tunnel (Buck-Dobrick and Dobrick 1989). In such situations species such as toads that prefer terrestrial routes are excluded. To avoid this problem the tunnel system in Amherst, Massachusetts, incorporated special flood control measures such as shunting water away from tunnels and using plastic mesh rather than sheeting for drift fences to facilitate drainage (Jackson and Tyning 1989). Fencing systems and tunnels may also facilitate predation and result in high mortality, as observed along drift fences for some amphibians (Reading 1989; fences were unassociated with tunnel systems). Crossing structures may not be suitable in situations where predation is a problem.

Vancouver Island Inland Island Highway tunnel systems:

The tunnels at the Vancouver Island sites consist of corrugated, zinc-galvanized, steel pipe culverts that also function in drainage (wet culverts) and similar dry culverts set in the gravel ballast at various elevations (Fitzgibbon 2001). The dry culverts were installed specifically to facilitate movements of amphibians and other small animals. The culverts are about 30 – 35 m in length, and vary from 1 m (at Piercy Creek) to 60 cm (at Hamilton marsh) in diameter. At both sites, drift fencing along the bottom section of a large-mesh ungulate fence, which parallels the road, was installed to direct animals away from the road. Angled fences that funnel towards the tunnel entrances were installed to guide animals into the culverts. Special, innovative barriers are used at one-way gates in the large-mammal fence to prevent movements of animals onto the highway.

The effectiveness of this system has not been monitored systematically. The drift fences at the Qualicum site successfully intercept a mass migration of juveniles of the Western Toad from the breeding grounds in late summer, and at least some of these animals pass through the tunnels (R. Dolighan, pers. comm.). Initial monitoring of culvert use during the spring migration period, before the fencing was completed, indicated that most amphibians circumvented 30 m-long temporary fences leading to the culverts, although some animals did pass through them (Blood 2000, cited in Fitzgibbon 2001). About 80% of amphibians that passed through the culverts were Rough-skinned Newts. The proportion of the migrating newts using the culverts was estimated to be only about 20%, suggesting that the animals were hesitant to use the culverts.

Fitzgibbon (2001) investigated the effectiveness of corrugated steel culverts with different attributes in facilitating movements of the Rough-skinned Newt in experimental enclosures. The culverts were similar to those deployed in the tunnel systems across the Inland Island Highway but of smaller diameter (30 cm) and shorter length (10’ sections). Attributes of culverts investigated included openness, interior wetness, interior light, and substrate type. The culvert openness was varied by comparing culverts of different diameter (30 cm, 40 cm, and 50 cm) but of the same length, which resulted in different aperture/length ratios. Interior lighting was provided by sectioning the culvert horizontally and covering the top half with clear polythene sheeting. In the substrate experiments the effectiveness of unlined and polymer cement-coated culverts and those with a soil substrate were compared. The newts preferred dark culverts to those with light, but no other differences were detected. The time that newts remained in the culverts ranged from minutes to hours. A potential problem with galvanized steel culverts identified during the study was leaching of metals, which can have toxic effects on amphibians. The concentrations of aluminum, copper, lead, and zinc in water samples from new culverts exceeded the British Columbia Approved Water Quality Guidelines for the protection of freshwater aquatic life.

Principles for effective tunnel systems:

Recommendations for effective amphibian tunnel systems include the following (synthesized from Dexel 1989, Brehm 1989, CARCNET 2000a,b, and review above):

- Proper location of tunnels and fences based on knowledge of target species and their migration routes
- Orientation of tunnels from winter/foraging grounds to breeding grounds
- 2-way tunnels with large diameter (such as 1 m) are effective and also allow for passage of a variety of other animals

- Smaller tunnels with slots for ambient light and moisture can be effective; these include grated tunnels placed flush with the road surface
- Proper construction and maintenance of fencing to avoid breaching and circumvention by animals
- Where fencing is parallel to the road, guiding systems are needed to direct animals to tunnels
- Interval between tunnels 50 m or less
- Taking appropriate control measures to avoid flooding of tunnels
- Monitoring of tunnel use to assess its effectiveness and need for refinements

3.3.4 Fencing and road crossing structures for reptiles

Compared to amphibian tunnel systems, relatively little information is available on mitigating measures for road mortality of reptiles. The most intensive research on this problem is from the Narcisse Snake Den Area in Manitoba, where the massive over-wintering aggregations of the Red-sided Garter Snake (*Thamnophis sirtalis*) in limestone pits are an internationally renowned phenomenon (reviewed in CARCNET 2000a, b). Snakes are subjected to road mortality during their spring and autumn migration movements while crossing a highway, located within a few hundred meters from the denning area, and in the autumn while they meander in the vicinity of the dens and on the thermally attractive road surface. Initial mitigative measures involved the erection of drift fences leading to existing culverts. Even low (30 cm-high) fences have been successful in directing snakes towards tunnels, and some snakes pass through them.

Two other types of tunnels have been tried at this site (CARCNET 2000a). One of these is similar to amphibian tunnels and consists of a 20 cm polymer concrete channel covered with an iron grate that lets in ambient light and heat. Experimental releases of snakes at the tunnel entrance have been encouraging. However, this system is unlikely to be durable enough to be deployed on a highway with heavy traffic on a long-term basis. In 2000, several 6" – 12" pipes were installed under the highway using horizontal boring equipment. This method is attractive, because numerous tunnels can be created with relatively little cost and without damaging the road surface. Whether these pipes are effective remains to be evaluated.

Measures to induce snakes to move through the tunnels have been sought. Such measures include using snake pheromones and artificially creating thermal gradients in the tunnels. So far, results of these experiments have been inconclusive. Speed reductions and signs along the highway were ineffective.

Another example to mitigate road mortality of reptiles involves projects for the Painted Turtle at three localities (near Cranbrook, Revelstoke, and Argenta) in southeastern British Columbia (R. Clarke, pers. comm.). Studies were initiated by the Columbia Basin Fish & Wildlife Compensation Program in response to concerns that turtles were killed on roads while moving to the nesting grounds in the spring. At the Cranbrook site, the erection of a 700 m-long fence and the development of an alternative nesting area on the same side of the highway where the turtles over-winter and forage within a marsh have been successful in preventing mortality (Clarke and Gruenig 2002). At the Argenta site, during the nesting season, turtles are directed to an enhanced nesting area by portable plastic construction fences erected along the shoulder of the road. This system has successfully prevented mortality along a gravel road that does not receive heavy traffic. At the Revelstoke site, the turtles cross a highway to access marshes and nesting areas on both sides of the road over a relatively long (1.7 km) stretch, and fencing with an overpass system was deemed impractical. Unlike at the other two sites, the turtles have been reluctant to use alternative nesting areas, and road mortality continues to be a problem. At all sites, interpretive and road signs and public education programs have supplemented other mitigative measures.

3.3.5 Landscape linkages

In conjunction with roads, residential developments, industrial parks, recreational facilities, parking lots and other types of developments can act as barriers to movements of those amphibians and reptiles that are able to co-exist with humans within populated areas. Harris and Scheck (1991) listed several options for providing landscape connectivity for wildlife, some of which apply for amphibians and reptiles. Recreational greenway parks and streamside management zones may benefit some species, provided that such connectivity does not facilitate invasion by nonnative or exotic species such as Bullfrogs that can adversely affect native species (see Section 3.7). Natural and restored ecosystems within parks and greenways are more useful for amphibians and reptiles, and other wildlife, if they are relatively large and wide (rather than narrow strips) and receive little human disturbance (rather than heavy, intrusive use). Sufficiently wide streamside management zones can also provide important habitat and serve as movement routes for a variety of wildlife. Information on specific habitat requirements of target species is required to assess the suitability existing riparian management zones as movement corridors for amphibians and reptiles (Burbrink et al. 1998). These authors found that the presence of upland forest habitat and fishless ponds, rather than the width of the riparian zone, was an important determinant of the use of these areas by a number of species.

Hedgerows, fence-rows, windbreaks, and narrow cover strips are not beneficial for wildlife as movement corridors, unless their alignment in the landscape happens to be congruent with animal movements (Harris and Scheck 1991). However, where they are appropriately placed and composed primarily of native plants, these features can be useful for small wildlife that require cover such as some snakes and lizards.

Not all habitats need to be connected; nor are such efforts desirable. A general principle is to restore connectivity among patches of similar habitats and where connections existed previously (Harris and Scheck 1991). For amphibians and reptiles, connectivity implies providing travel routes between essential seasonal habitats that are spatially separated, connecting small patches of similar habitat that were fragmented by human activities, and providing sufficient connectivity among habitat components to permit population processes at landscape level scales. Semlitsch and Brodie (1998) and Semlitsch (2000) stressed the importance of small isolated ponds and wetlands as stepping stones for amphibian dispersal, so facilitating recolonization of habitat patches subjected to local extinctions and the long-term persistence of a species across the landscape. The nature of landscape level processes is incompletely understood for populations of most amphibians and reptiles in British Columbia, and a prudent approach is to protect a diversity of aquatic and adjacent terrestrial habitats at scales that allow for movements of animals among habitat patches.

3.4 Review of Management Practices for Pollution Control

3.4.1 Sensitivity to contaminants

Amphibians and reptiles in the vicinity of populated areas are exposed to a wide variety of chemical substances and other contaminants that have the potential to affect their health, survival, and persistence in these landscapes. Main types of contaminants generated in urban environments include sediments, organic matter, nutrients, pesticides, heavy metals, and petrochemicals (Cox 1979). Run-off from roads may contain surfactants and road salts that can harm amphibians. Insecticides or herbicides used on golf courses, public parks and gardens, road-sides, right-of-ways, and residential gardens contribute to environmental contamination. Many compounds potentially interfere with hormone signals during sensitive developmental periods of amphibians and reptiles (Crump 2001). All these substances can be transported far from their points of origin through surface run-off or in ground water and will eventually end up in ponds and wetlands, which act as sinks for most chemical contaminants (Semlitsch 2000). Storm water run-off is recognized as a main source of contamination of water-bodies in urban settings (BC Ministry of Water, Land and Air Protection 2001a).

Amphibians are sensitive to environmental pollutants because of their permeable skin and eggs, their position in the foodweb as mid-level consumers, and their potential for prolonged exposure to contaminants in both aquatic and terrestrial habitats (Bishop 1992, Berrill et al. 1993, Stebbins and Cohen 1995). All frogs and the majority of salamanders in British Columbia undergo early development in aquatic habitats, where they may be exposed to chemical contaminants during critical developmental periods, such as during embryonic and metamorphic periods when their major organ systems either develop or undergo profound changes. Their sensitivity varies widely among species, even within groups of related species. For example, toxicity of carbaryl (an insecticide) varied significantly among related species of frogs, and differences also existed among populations within species, suggesting local adaptations (Bridges and Semlitsch 2000). Environmental contamination can have profound effects on the persistence of amphibian populations within landscapes, mainly through indirect effects on their survival and reproduction, and should be considered a contributing factor to amphibian population declines (Semlitsch 2000).

The scale-covered skin of reptiles decreases the direct absorption of chemical substances from the environment. Some reptiles, however, may be highly sensitive to some types of contaminants, such as endocrine disruptors (EDCs), because of their unusual sex determination mechanisms (see section on EDCs, below). In addition, many reptiles, such as turtles, are long-lived (Gibbons and Semlitsch 1982) and can be adversely affected through ingestion of contaminated prey and through bioaccumulation of contaminants. Reptiles that occupy or frequent aquatic habitats, such as turtles and several species of garter snakes, may be chronically exposed to pollutants in these water bodies both directly and indirectly through their prey.

3.4.2 Erosion and siltation

Siltation of streams and ponds may occur from various construction activities and from erosion associated with roads and vegetation removal. Siltation can harm eggs and gilled larvae of amphibians (Semlitsch 2000). In addition to interfering with respiration, it severely degrades habitat, particularly for stream-dwelling species. Sediment accumulation in stream habitats interferes with foraging by Tailed frog tadpoles and fills in cracks and crevices that provide shelter and foraging areas for larvae of the Coastal Giant Salamander. Sediments can also affect amphibians indirectly by adversely affecting aquatic invertebrates that they feed on. Where sediment run-off contains toxic materials, their impacts on amphibians are magnified (Maxwell 2000).

3.4.3 Toxicity of chemical substances

Metals:

A great number of chemical compounds produce acute or sublethal toxic effects on amphibians in response to experimental exposures (reviewed by Harfenist et al. 1989). Heavy metals are highly toxic to amphibians, especially to embryonic stages. Metals also readily accumulate in amphibian body tissues and can persist for long periods. For example, in one laboratory study the half-life of zinc residues accumulated by the Rough-skinned Newt was 3.5 years (Birge et al. 1977, cited in Harfenist et al. 1989). Amphibians may be chronically exposed to metals in heavily roaded areas in urban environments.

Pesticides:

Pesticides are common chemical substances in aquatic habitats of amphibians. Semlitsch (2000) pointed out that insecticides – all of which are neurotoxins – can persist in the environment for relatively long periods because they are sequestered in sediments and animal tissues. In laboratory experiments, common effects of insecticides on amphibians included direct mortality and alteration of behavior, morphology, or development (review in Harfenist et al. 1989). Carbamate, organochloride (except cyclodienes that were highly toxic), and pyrethroid insecticides were moderately toxic to amphibians, and exposure typically resulted in either mortality or behavioural and developmental abnormalities. Herbicides and fungicides had a wide range of toxicity to amphibians, precluding generalizations (Harfenist et al. 1989). Berrill et al. (1993) found that embryos of several species were unaffected by low concentrations of various common herbicides, including glyphosate, but that newly hatched tadpoles exhibited temporary or permanent paralysis, depending on concentrations of the substances. Acute toxicity of glyphosate has also been found under laboratory conditions on several species of Australian frogs (Mann and Bidwell 2001). One study suggested that glyphosate might have subtle, non-lethal effects on amphibian development under field conditions (Glaser 1998 cited in Ferguson and Johnston 2000). Bishop (1992) summarized toxicological effects of commonly used pesticides in Canada on amphibians. Effects included acute toxicity and sublethal effects on growth, development, reproduction, and behaviour. Semlitsch (2000) and Boone and Semlitsch (2002) argued that such sublethal effects might contribute to amphibian declines without evidence of mass mortality through complex interactions with abiotic and biotic factors operating in natural habitats (see Section 3.4.6, below). Therefore, the effects of pesticides on amphibian populations can be much greater than would be predicted from acute toxicity tests in the laboratory alone.

Pesticide formulations typically include surfactants and carrier substances that may themselves have toxic effects on sensitive non-target organisms. The effects of these compounds on amphibians have received relatively little study. Mann and Bidwell (2001) found that in response to experimental exposure to non-ionic surfactants tadpoles of all six species tested exhibited lethargy, the magnitude of which was dose-dependent. In a summary report, Seburn and Seburn (2000) citing Taylor (1997) stated that surfactants can impair respiration of tadpoles and metamorphosed frogs.

Nitrates:

Elevated concentrations of nitrates commonly occur in water bodies within human-modified landscapes, and have been recognized as a problem for amphibians (Halliday 2000). Within urban and rural environments, potential sources of nitrates include golf courses, lawn and garden fertilizers, industrial waste, hobby farming, and sewage treatment areas. Experimental exposures in the laboratory have shown acute toxicity to amphibian larvae, and even very low concentrations can result in behavioural changes and developmental abnormalities (reviewed in Rouse et al. 1999, Halliday 2000). Marco and Blaustein (1999) and Marco et al. (1999) found that experimental exposure of amphibian larvae to nitrates at levels considered safe to humans resulted in reduced growth, increased incidence of deformities, paralysis, and mortality. Several species of amphibians that also occur in British Columbia were tested in these studies. Rouse et al. (1999) found that nitrate concentrations in many water bodies around the Great Lakes exceeded the lethal threshold for amphibians, illustrating the scope of the threat to amphibians and other sensitive aquatic organisms.

Road salts:

Road salts enter the environment through surface run-off and ground water transport from road surfaces and from disposal of snow cleared from roads (Environment Canada. Assessment Report – Road Salts). Small ponds and water courses within large urban areas are most likely to be contaminated with these substances. Road salts elevate salinity of water and deteriorate the quality of ponds and pools as amphibian habitats. The impact zone of road salts can extend considerable distances away from the source, depending on conditions. Forman and Deblinger (2000) suggested that road salts altered freshwater habitats up to 200 –1500 m from a busy suburban highway corridor. Highest concentrations usually occur after spring thaws, but concentrations in the summer can also be high through delays in percolation of contaminated water through ground water (Environment Canada. Assessment Report – Road Salts). Most of our amphibians breed in the spring and hence may be exposed to a flush of increased salinity during critical early periods in their development. Salt formulations also often contain toxic ferrocyanides that may occur in sufficiently high concentrations to harm sensitive aquatic species in areas wit high road densities (Environment Canada. Assessment Report – Road Salts).

Harfenist et al. (1989) reviewed toxicity studies of road salts on amphibians. Both potassium and sodium chloride were highly toxic. Calcium chloride was much less toxic, and very high concentrations were required to cause mortality. In one field study, however, embryonic survival of experimentally transplanted salamander eggs was lower in road-side pools with high concentrations of road-salts than in control, woodland pools (Turtle 2000). During migrations, amphibians may be directly exposed to road surfaces treated with salt. Mass mortalities of migrating salamanders while crossing salted roads have been reported (deMaynadier and Hunter 1995). Physiological effects of road salts include impairment of respiration and osmoregulatory balance (Harfenist et al. 1989).

3.4.4 Biomagnification

Chemicals that persist in the environment are subject to magnification, and their concentrations can increase by orders of magnitude as they move through the foodweb. Although the use of some toxic chemical compounds notorious for biomagnification, such as organochloride pesticides, have been phased out in North America, many other substances with this propensity remain in wide use. Examples include PCBs (polychlorinated biphenyls) that are widely used in fire retardants in electrical equipment, plastics, preservatives, and varnishes (Stebbins and Cohen 1995). Semlitsch (2000) pointed out that amphibians are able to accumulate organophosphates to levels higher than many other aquatic organisms (e.g., some fish and invertebrates), which are more likely to succumb to such contamination. Metals represent another group of substances that accumulate in amphibian tissues and are subject to bioaccumulation (Harfenist et al. 1989). Because amphibians are important prey for a number of mammals, birds, and reptiles, contamination of their habitats with metals, pesticides, and other bioaccumulating substances will be passed on to these predators through the food web in high concentrations.

As higher order predators, reptiles are thought to be particularly susceptible to contaminants through bioaccumulation (Seburn and Seburn 2000). Contaminants in the tissues of the mother can be off-loaded to eggs through the yolking process, as documented for the Snapping Turtle (*Chelydra serpentina*; Bryan et al. 1987 cited in Stebbins and Cohen 1995). Consequences of contamination include reduced hatching success and malformations in hatchlings (reviewed in Seburn and Seburn 2000). These authors stated that in the Great Lakes area Snapping Turtles appear to be similar to fish-eating birds with respect to metabolic fate of PCBs. Other reptiles may be similarly affected but are poorly studied with respect to contaminants. One study in India (Kaur 1988) documented high concentrations of lead in shed skins of snakes and lizards collected from polluted urban areas when compared to animals collected from rural areas.

3.4.5 Endocrine disrupting substances

Endocrine disrupting substances (EDCs) are compounds that have the potential to interfere with hormonal action of animals and disrupt physiological and developmental pathways. A wide variety of substances released by human activities can act as EDCs, including components of insecticides, herbicides, surfactants, plastics, and paints (WWF. Toxic Chemicals. Endocrine Disruptors). EDCs are particularly insidious because they exert their effects at minute concentrations, and these effects typically do not increase with dosage, as do those of most other types of pollutants. Often the effects of EDCs are confined to relatively short, critical developmental periods. Because they seldom result in direct mortality, such effects can initially go undetected if not specifically investigated. Because of their sensitivity to hormonal effects, amphibians have been investigated as indicator organisms of environmental contamination with potential EDCs (Heppell et al. 1995, Veldhoen and Helbing 2001, Crump 2001 and references therein).

Amphibians and reptiles that occur near human habitations are subjected to a wide range of potential EDCs (Crump 2001). Several studies have investigated responses of amphibians to environmental sex-steroids, particularly to estrogens or estrogenic contaminants (reviewed in Crump 2001). Exposure of tadpoles to these substances can result in changes in the sex ratio through phenotypic feminization, and suppress or enhance the differentiation of secondary sexual characteristics, such as colouration and vocal sac development. Exposure of adult females can alter reproductive characteristics, including maturation and yolking of eggs and fertilization success. Other effects of environmental sex-steroids on amphibians include abnormal larval development and malformations. All frogs and most salamanders that occur in British Columbia undergo metamorphosis, during which major organ systems and tissues are reorganized. Amphibian metamorphosis is hormonally regulated and involves the pituitary-thyroid axis and the release of thyroid hormones. Environmental EDCs that interfere or interact with hormone signals during metamorphosis can alter the timing of events or change developmental pathways. Extreme effects, such as the transformation of tails into legs, can be produced artificially through such mechanisms (Maden 1993). Acceleration of amphibian metamorphosis has been documented in response to experimental exposure to several compounds, including pesticides (Cheek et al. 1999; see Crump 2001 for additional references).

Reptiles are also sensitive to endocrine disrupting substances, especially during embryonic development. The sex of many reptiles, such as turtles, is determined by temperature during the incubation period, rather than having a genetic basis (Crews et al. 1995). Crews et al. (1995) showed that the exposure of turtle eggs to estrogenic contaminants changed the pattern of temperature-dependence, resulting in altered sex-ratios that under natural conditions could be non-adaptive.

3.4.6 Synergist effects and interactions

While acute toxicity of amphibians to a wide range of contaminants has been demonstrated in laboratory experiments (Harfenist et al. 1989), Boone and Semlich (2002) and Semlitsch (2000) argued that concentrations of most substances under natural conditions are typically too low to cause direct mortality of these animals. Sublethal effects, such as altered developmental timing, body size, or behaviour, are thought to generate the main mechanisms through which contaminants affect amphibian populations. Many, if not most population level effects are indirect and exert their influence through complex interactions that occur in natural habitats. For example, studies have shown that the effects of carbaryl (an insecticide) on tadpole survival vary with competition intensity, pond hydro-period, and predator environment in a complex way (Boone and Semlitsch 2001, 2002).

Under natural conditions, individual contaminants seldom exist alone but are present with an assortment of other compounds of both anthropogenic and natural origin. Therefore, amphibians developing in such “chemical soups” are exposed to the combined effects of these substances and their breakdown products, which may variously enhance or modify the effects of each other and interact with abiotic factors. Abiotic factors that modify toxicity of various compounds to amphibians include acidity, temperature, and UV-radiation (Semlitsch 2000, Crump 2001). Acidic conditions mobilize metals from sediments and increases toxicity of various contaminants. UV-B radiation increases toxicity of some pesticides to amphibians and reduces survivorship. Such interactions appear to be the rule rather than the exception.

3.4.7 Population level effects

Links between amphibian population declines and contamination are difficult to establish, and evidence is rarely conclusive (Semlitsch 2000). Atmospheric transport of pollutants from the heavily agricultural Central Valley have been linked to precipitous declines of amphibian populations in the Sierra Nevada

Mountains in California (Sparling et al. 2001). Agricultural run-off has also been linked to amphibian malformations in Quebec (Ouellet et al. 1997). Other wide-scale patterns are more speculative. For example, Findlay et al. (2001) found that species richness of frogs in Ontario was negatively correlated with density of roads within 1 km from wetlands, which in turn was correlated with elevated levels of nutrients and pesticides in surface waters. Whether contaminants played a role in those declines was unknown.

Populations of some amphibians are surprisingly tolerant to conditions within populated landscapes. Ostergaard and Richter (2001) surveyed small, residential storm-water control ponds in Washington State for amphibians and found that most of the ponds examined were used for breeding by frogs and salamanders. The most common species was the Pacific Treefrog. However, some species, such as the Western Toad were notably absent. Whether these populations were self-sustaining or simply population sinks (sustained by emigrants) was not investigated. Knutson et al. (2002a,b) investigated amphibian use of small farm ponds subjected to contaminated run-off from agricultural fields. A number of amphibian species used the ponds for breeding, and preliminary results suggested that their reproductive success was not impaired, except where subjected to consistently elevated nitrogen concentrations.

3.4.8 Mitigation measures

Semlitsch (2000) and Boone and Semlitsch (2001) pointed out that in many cases existing environmental standards are not adequate to protect amphibians because of the complexities involved in their responses to chemical contaminants. Levels deemed safe based on acute toxicity testing in the laboratory may not be equally safe under natural conditions. Similar considerations apply to reptiles that are capable of accumulating contaminants in their tissues and are susceptible to subtle, indirect effects through processes such as environmental sex determination. Therefore, any measures that reduce contamination of aquatic and terrestrial breeding habitats are beneficial to these organisms. Within urban and rural landscapes, mitigative efforts should concentrate on reducing pollution loads in amphibian breeding habitats in wetlands and streams, because such habitats act as catchments for various contaminants and result in exposure of animals during their critical developmental periods. Mitigative strategies include reducing the use of chemical compounds at the source, containing contaminants through appropriate storm-water and sewage management, and trapping and filtering contaminants from ground water by vegetative buffers and other means before they enter water bodies. Municipal Best Management Practices (BC Ministry of Water, Land and Air Protection 2001b) provide detailed options for such measures in urban environments.

Restriction of the use of chemicals near pools, ponds, streams, and ditches is essential to safeguard aquatic amphibian breeding habitats (Semlitsch 2000). Chemicals that should be restricted over and adjacent to water bodies include herbicides and growth retardants to control vegetation, road salts, fire retardants, and insecticides. Adopting integrated pest control methods that reduce reliance on chemical herbicides and insecticides on golf courses, parks, greenways, and on private and municipal lands will reduce contamination of aquatic habitats. Such strategies include increased use of native plants, pest-resistant varieties of exotics, and design features that minimize and confine intensively managed areas, such as turf requirements on golf courses (BC Ministry of Environment, Lands and Parks, Habitat Protection Branch 1994).

In urban areas with high road density, road salts can contribute significantly to contamination of aquatic water bodies and reduce their quality as amphibian habitat. Strategies to minimize such contamination include reducing the content of ferrocyanide in road salt formulations, using products alternative to road salts, appropriate location and containment of run-off from patrol yards, and attention to disposal of snow piles (Environment Canada. Assessment Report – Road Salts).

Vegetation buffers are a commonly used method to filter out and reduce levels of contaminants before they enter water bodies (BC Ministry of Water, Land and Air Protection 2001b). Riparian buffers around ponds, pools, and streams intercept sediments and a variety of contaminants and prevent erosion of banks. In urban landscapes, vegetated borders around facilities, parking lots, golf courses, and commercial centres serve to retard the spread of sediments and contaminants (Landowner Resource Centre 2000). Vegetated riparian buffers, in combination with other methods, can reduce nitrogen contamination of amphibian breeding sites (Rouse et al. 1999). Additional measures needed for the protection of aquatic organisms include reduced use of chemical fertilizers, appropriate sewage control, and increasing depth of tile drainage systems (Rouse et al. 1999, Seburn and Seburn 2000).

With respect to fish, public support and involvement have resulted in increased compliance with water quality regulations and adoption of more environmentally friendly lifestyle choices (Pinkerton 1991). Public education and stewardship are similarly essential for reducing contamination of amphibian and reptile habitats in urban and rural areas (see Section 8.0 on Stewardship).

3.5 Review of Management Practices for Hydrology

Amphibians and reptiles use a variety of aquatic environments with different depths and degrees of permanence. The permeable nature of amphibian skin makes them dependent upon moist terrestrial habitats such as gullies, riparian areas, and wet depressions; their skin must be kept moist to allow for subcutaneous respiration (Zug 1993). Amphibians do not drink water but absorb it through their skin. Some species seek standing water, while others require only moist environments for rehydration. For example, frogs have highly vascularized ventral surfaces that can extract moisture from the surface of soils (Zug 1993). These physiological requirements influence the behaviour and distribution of amphibians within the environment. For example, many amphibian species use riparian corridors for seasonal migrations and/or for dispersal (Northern Leopard Frogs; Seburn et al. 1997; Red-legged Frogs on Vancouver Island; Chan-McLeod 2002).

Beyond a requirement for moist environments, most amphibians and some reptiles in British Columbia also require standing or running water to meet some of their life-history requirements. In addition to breeding in water, some highly aquatic species also overwinter under water (Green and Campbell 1984). Painted Turtles and some Garter snakes use wetlands for foraging (Gregory and Campbell 1984). Surveys in Washington State revealed that even species that do not breed in water, such as terrestrial Woodland salamanders, are sometimes common in riparian areas near wetlands (Richter and Azous 1995).

The summer range of many amphibian and reptile species include a variety of habitats used for rehydration and foraging (Kramer 1974, Davis 2000, Bull and Hayes 2001). Wetland use shifts through time in response to climatic conditions and successional changes in vegetative cover (Skelly et al. 1999). Therefore, wetland and riparian conservation must operate from a landscape perspective. Many amphibians demonstrate faithfulness to their natal breeding sites (i.e., philopatry; Gill 1978, Berven and Grudzien 1990), and their ability to switch to alternative breeding sites is uncertain if their habitats are disturbed. In combination with the relatively sedentary habitats of these animals when compared to other vertebrate groups, philopatry to breeding or overwintering sites increases the vulnerability of amphibian and reptile populations to the loss and degradation of their habitats.

The main issues associated with hydrology in relation to urban/rural development and amphibians and reptiles are:

- *Habitat degradation* as a result of changes to flow rates and water levels (such as depth of a water body and duration of hydroperiod) that affect habitat quality, and

- *Direct habitat loss* as a result of pond drainage or filling, creek diversion, water extraction, and building and paving, especially for small wetlands and creeks.

3.5.1 Habitat degradation

Most aquatic-breeding amphibians have specific habitat requirements for egg-laying and larval development, and changes to the conditions in their breeding habitats can reduce fitness and survivorship. The length of larval development varies from weeks to years among amphibian species, and is affected by geographical and physical location, such as elevation and aspect. Hence, the duration of pond hydroperiod is crucial. Also, thermal tolerance limits vary across species, as does palatability (susceptibility to predation). Vegetative cover, such as riparian and emergent vegetation, is an important factor in providing cover from climatic extremes and shelter from predators.

A key factor in breeding site selection for semi-aquatic amphibian species is pond permanence (Skelly et al. 1999). Species with short larval periods often select for ephemeral wetlands, where they are subject to a reduced predation pressure. In environments with fewer predators larvae can attain a greater body size at metamorphosis, which can increase adult fitness (Alford 1999, Ultsch et al. 1999). Ephemeral water bodies are often shallow and offer a warm environment that helps speed development. However, some species have relatively narrow thermal tolerance limits and are very specific in their habitat requirements (e.g., Spotted frog, Licht 1971; Tailed frog, Dupuis and Steventon 1999). Water temperature is affected by water source, exposure to wind and sun, and water depth. Changes to source and rates of inflow and outflow (such as runoff from impermeable surfaces and stream blockage), the water table (such as wells), percent cover of riparian and emergent vegetation (such as removal of surrounding forest cover), and changes to basin/channel shape and size (such as dredging) can all affect the permanence of water bodies and water temperature.

Some amphibian species are not well adapted to flowing water, and must select for calm areas within streams and wetlands. A study in Washington State found that Northwestern Salamanders, Red-legged Frogs, and Pacific Treefrogs were more frequently found in water bodies with low flow rates (< 5.0 cm/sec; Richter and Azous 1995). In the same study, large water-level fluctuations (> 20 cm change, on average) depressed species richness (Richter and Azous 1995). Changes to peak flows and flood rates can displace amphibian larvae and increase their vulnerability to predation. If water levels rise and ponds become more permanent, there is an increased likelihood that predator-prey interactions will be affected, especially if the changes facilitate invasions by nonnative amphibians, fish, or aquatic weedy plants (see Section 3.7). Shallow shoreline areas with emergent vegetation may be lost with increased water levels; these areas provide important egg-laying sites for amphibians.

The presence, distribution and type of emergent and submerged vegetation are important for many species. Some species lay their eggs on plants that are of a specific diameter: Red-legged Frogs, Long-toed Salamanders and Northwestern Salamanders select thin-stemmed emergent plants, such as rushes, sedges, herbs, and grasses (see references within Richter and Azous 1995). Changes to water levels as a result of water diversion and other causes may result in changes to vegetative communities; these effects may include changes in the percent cover of emergent/submerged vegetation. This may impact the suitability of the habitat for species such as the Red-legged Frog, which prefers ponds with > 50% cover of emergent vegetation (Hayes and Jennings 1988). Riparian vegetation is also important for young, newly transformed amphibians dispersing into terrestrial environments (Jameson 1956, Richter 1997). Changes in water regimes can also result from the introduction of weedy species that choke out native vegetation. Habitat characteristics and microhabitats present within the wetland are typically more important than wetland size. Where larger wetlands have denser populations of amphibians, this likely reflects the proportion of suitable microhabitats within the wetland rather than the size of the habitat patch itself (Richter and Azous 1995).

Beavers play an important role in the hydrological regime of many areas of British Columbia by building dams that modify water regimes, flooding new areas and creating ponds. Management practices for beavers should take into account effects their activities may have amphibians, such as the Oregon Spotted Frog (Haycock 1999).

3.5.2 Habitat loss

Wetland habitats have been lost at alarming rates throughout the world, mainly due to agriculture and urban/rural developments. In southern Canada, approximately 50% of wetlands have been lost, mainly to agriculture (Biodiversity Science Assessment Team 1994). This value is even higher in more urbanized/higher density areas. For example, approximately 75% of wetlands have been lost from the Greater Victoria and Vancouver areas, 25% of which has been due to urbanization; the north arm of the Fraser Estuary has lost 96% of its wetlands (Nowlan and and Jeffries 1996). Development and flood control have reduced the amount of riparian and wetland habitat in the South Okanagan to less than 4% of the total area (BC Ministry of Water, Land and Air Protection. Habitat Atlas for Wildlife at Risk). Richter and Azous (1995) found a significant decrease in species richness of amphibians in watersheds where urbanization constituted >40% of the land area in Washington State. Observations of amphibian and reptile fauna over a 15-year period in a suburban area near Indianapolis, Indiana, revealed that almost 70% of the species were no longer found (Minton 1968). Urbanization of the area had resulted in the draining of numerous ponds and creeks that formerly provided habitat for these animals. Besides the direct filling in or draining of wetlands, the high demand for water in some areas (such as the Okanagan) means that groundwater reserves are being depleted; hence permanent wetlands are becoming seasonal, and temporary sites too ephemeral for their use by amphibians as breeding sites (Seburn and Seburn 2000).

Ponds are often drained for rural/urban development, especially small wet areas that do not require any protection by law. Reduced density of wetlands, large or small, has serious implications for local and regional populations of amphibians, which are often organized as metapopulations and maintained through dispersal processes (see Section 3.3). The size of wetlands and streams is not a good indication of the importance of the habitat for amphibians and reptiles (Richter and Azous 1995, Bull and Carter 1996, Adams 1999). Although amphibians require all types of wetlands, ponds, and streams for their survival, protection is usually largely based on size, and small, ephemeral wet areas in particular are often lost (Gibbs 1993, BC Ministry of Forests 1995).

Wetland protection usually considers sites in isolation rather than their role within a larger landscape context; as a result, small isolated wetlands are most likely to lose species (Richter and Azous 1995). A study of a toad population in Great Britain, where a breeding pond was preserved within a housing development, demonstrates the complexity of the issue of habitat loss for amphibians. Despite the protection of the main part of its breeding habitat, the Common Toad population declined over a ten-year period post-development, likely due to a combination of competition from other frog species that began breeding at the site, and changes to the surrounding terrestrial environment, such as barriers to movement and mortality on roads (Cooke 2000). Small wetlands are more difficult to maintain as functional ecosystems because they are less resistant to perturbations than larger areas (Richter and Azous 1995). Therefore, connectivity to other wetlands is important. Gibbs (1993) conducted a simulation model of the loss of small (< 4.05 ha), legally unprotected wetlands in Maine and determined that turtles, among other groups, were at significant risk of extinction due to their low density and reproductive capacity. A study in Switzerland found that a set of small ponds had greater conservation value than one large area for a variety of aquatic organisms; however, larger areas may have species not found in small sites (Oertli et al. 2002).

3.5.3 Management Recommendations

Creation or replacement of wetlands is not a realistic option for the compensation of wetland loss. A study in Washington State has shown that for the past 10 years of wetland mitigation in response to United States federal law (for every acre of wetland lost, 1.78 acres must be replaced) only 13% of projects have been ecologically successful (Johnson et al. 2002). The best solution for the conservation of amphibians and reptiles is to maintain or restore the natural hydrological regime of an area.

- Recognize the importance of small wetlands and streams. Management plans should consider all wetlands and streams, regardless of their size, flow rates, depth, or duration.

- Avoid draining wetlands, regardless of their size, depth or duration.

- Avoid altering flow regimes of creeks, surface runoff, or groundwater and avoid impermeable surfaces. Impermeable surfaces alter the flow of water throughout an area, and carry pollutants (see Section 3.4). Provincial guidelines promote the use of 'absorbent landscaping' and infiltration facilities (Stephens et al. 2002), and BMP's used in the United States and Europe recommend the use of porous materials for parking lots, pavement, and roads. http://www.wildlifetrust.org.uk/berksbuckoxon/publications/takeaction/TA16.pdf

- Protect riparian and emergent/submerged vegetation. The maintenance of hydrological regimes and water quality is dependent in part on vegetation to intercept runoff, for evapotranspiration, and filtration (see Sections 3.4, 3.5).

- Avoid creating permanent ponds or sink habitats. Deep, permanent water bodies, especially those where the shallow littoral zone has been lost, are unsuitable to most native amphibian species. The creation of steep-sided embankments due to dredging water courses/bodies to make them deeper, or to channelize them, results in habitat degradation and loss. It is often recommended that trenches, basins, drains, ditches, and detention ponds be used to control runoff. However, it is critical that permanent ponding areas are not created as a result of construction because they can collect contaminants from runoff, act as vectors for the spread of nonnative species, and potentially become sink habitats (see Sections 3.1 and 3.2; Di Mauro and Hunter 2002). These areas should be designed so that they can be drained and/or dry each winter to avoid the establishment of predators, such as fish and/or Bullfrogs.

- Restore ponds and creeks to increase the proportion of wet areas and potential amphibian and reptile habitat within the landscape. This can be accomplished by removing a proportion of vegetation that may be choking the system, eradicating nonnative species, repairing natural flow regimes, removing sources of pollutants, limiting human access, and planting with native species in littoral zones. For example, frog abundance increased in a natural area of Illinois where restoration work raised water levels (by 10 cm) within ephemeral wetlands, so that pond duration was extended each year; they removed constructed features (such as ditches), adjusted the outflow dimensions to slow flow rates, removed invasive species that shaded the wetlands, and planted native species (Nyberg and Lerner 2000).

- Follow provincial BMP's for Water Quality in BC (http://wlapwww.gov.bc.ca/wat/wq/NPS_web_page/BMP_Compendium/BMP_Introduction/BMP_Home.htm).

3.6 Controlling Access

When humans have access to natural areas, habitat quality for wildlife is often degraded as a result (Mazgajska 1996, Maitland and Morgan 1997). Once an area has access, recreational facilities and activities are often developed, including campgrounds, picnic areas, boat launches, trails, and sport fishing. These developments and activities create suitable conditions for opportunistic predators such as raccoons, skunks, and crows, they increase pollution, and they deteriorate water quality. Depending on the intensity of use, access increases the potential for contact and interactions with wildlife and invasions by nonnative species. Networks of trails are often used in both summer and winter by hikers, mountain bikers, horseback riders, and snowmobilers. Recreational developments are often centred around lakes, streams, or other water bodies, resulting in damage to sensitive shoreline and riparian habitats. For example, studies have shown that shoreline development results in a significant loss of woody debris and vegetation in aquatic and riparian areas of lakes (Christensen et al. 1996, Meyer et al. 1997). Recreational development in turn increases human use.

The main issues associated with access, recreation, and parks in relation to urban/rural development and amphibians and reptiles are:

- *Harassment* of wildlife, including amphibians and reptiles, by humans and pets, and noise and lights from buildings and vehicles. Humans sometimes capture, handle, harm or disturb amphibians and reptiles.

- *Habitat degradation* by humans, pets, and vehicles. Human use can degrade riparian and shoreline areas; roads and trails increase edge habitat and facilitate introductions or the spread of nonnative species and wildlife diseases. Humans can pollute the environment through the dumping of garbage, vehicle leaks and emissions, and other means.

3.6.1 Harassment

People:

Humans can directly harm amphibians and reptiles when they are encountered. A common occurrence is children capturing amphibian tadpoles and retaining them in aquaria (Schlauch 1976). These animals often die as a result or are released into inappropriate environments. People who encounter snakes often react with fear and may attempt to kill the animal (Dodd 1993, Seburn and Seburn 2000).

Indirectly, amphibians can be disturbed by the lighting and noise associated with recreational facilities and vehicles, particularly when in breeding choruses (Maxell 2000). Numbers of wild, opportunistic predators, such as ravens, raccoons, and other species, are often artificially inflated in the presence of humans, in part due the availability of human refuse (Maxell 2000, Seburn and Seburn 2000, Hamilton and Wilson 2001). Hikers climbing on scree or talus slopes can damage reptile denning and basking sites and may also cause direct injury to reptiles sheltered under rocks. Often, angling pressure is directly related to the density of roads (Hamilton and Wilson 2001). Anglers can disturb and damage amphibian breeding habitat by trampling emergent vegetation in shallow water zones.

Pets:

Over half of British Columbia residents own pets (Scott and Dyer 1997). Wildlife populations already stressed in urban environments are greatly impacted by harassment from pets (Coleman et al. 1999). A study of a wildlife information and rescue dataset from Sydney, Australia revealed that dogs and cats were responsible for 42% and 10% of attacks on Bluetongue Lizards (*Tiliqua scincoides*), respectively; lizards attacked by dogs versus cats had less of a chance of surviving (Koenig et al. 2002). Cats are detrimental to wildlife, because their hunting instinct prevails regardless of how well fed they are; they are responsible for killing millions of wild animals each year, including amphibians and reptiles (Ogan and Jurek undated, Scott and Dyer 1997, Gray 1999). For example, 78 million birds and mammals are estimated to be killed by house and feral cats in the United Kingdom annually, and 20 – 150 million animals in Wisconsin alone (Gray 1999). Cats have been recorded to kill animals as large as 3.5 kg (Ogan and Jurek, undated). Even if cats do not kill their prey, they often play with it, which can result in injuries (Gray 1999; e.g., snakes – E. Wind, pers. obs.).

Rural cats range over larger areas than cats living in urban centres, but the density of cats in urban areas can be quite high, as they do not displace each other from feeding stations (Ogan and Jurek, undated). A study of feral cats in rural areas found that they can cover an average of 1.4 km in a day, within a home range of 30 – 40 ha (2 – 4 km across), versus free-ranging cats in New York that had an average home range of 1.7 – 2.6 ha (Ogan and Jurek, undated). This suggests that wandering cats may impact wildlife in parks/reserves in close proximity to urban environments, and wildlife living in parks that back directly onto housing developments are highly likely to encounter cats. Feral cats use abandoned farm buildings, rock outcrops and burrows, trees, shrubs, culverts, and hedgerows for resting and foraging (Ogan and Jurek, undated).

3.6.2 Habitat degradation

Many of the adverse effects of roads on amphibians and reptiles extend to trails as well (Hamilton and Wilson 2001). These effects carry well beyond the physical area occupied by the road or trail. Habitats are degraded because plants and animals are introduced and can spread along these linear corridors. Horses, hikers, and ATV's increase soil compaction, sedimentation, and the spread of weeds; impacts are greatest in alpine, bog, and arid areas (Hamilton and Wilson 2001). Areas with wet soils are at greatest risk from trampling by human foot traffic, which creates suitable conditions for invasive species and increases sedimentation. Snowmobiles compact snow over wetlands, which reduces the water holding capacity of the snow and increases peak spring flows; snowmobiles and ATV's contribute to changes in wetland vegetation communities as well. There is a relationship between increased risk of fire and human access to natural areas.

Shoreline and riparian areas are sensitive habitats that are impacted by access for humans and the development of recreational areas (Sukopp 1971). Humans and pets can trample shoreline vegetation and littoral zones. For example, humans and pets playing and swimming from beach areas may uproot shallow littoral vegetation that amphibians use for egg-laying, and eggs may be dislodged or trampled. Larvae use shoreline vegetation for cover as well. A study investigating the effects of development along shoreline areas of lakes in Wisconsin found reduced frog populations as a result of altered native vegetation, especially shrubs (Meyer et al. 1997). Stirred up sediments may choke out emergent vegetation and reduce water quality by increasing turbidity. Loss of canopy and vegetative cover can alter water temperatures, and increase sedimentation where trails run along streams, and where beaches and docks are developed (Hamilton and Wilson 2001). Increased edge habitat associated with trails, roads, and recreational facilities changes floral and faunal communities by altering predator-prey dynamics. Boats and anglers may release nonnative baitfish, inadvertently introduce diseases or weedy species from their gear, and may be responsible for litter such as lead weights and lures that can adversely affect wildlife (Maitland and Morgan 1997).

People frequently leave litter on trails and in recreational areas, and may dump garbage and pollutants illegally into ditches and parking lots. Studies have shown that pollutants enter water bodies from both motorized and non-motorized water-related activities. For example, 30% of fuel from two-stroke marine engines is discharged unburned into water (Hamilton and Wilson 2001), and the running of a four-stroke outboard motor for a short period of time results in measurable amounts of volatile organic compounds present in water and significant increases in water temperature (Juttner 1994).

3.6.3 Management Recommendations

Recreational facilities are often located where ponds, wetlands and/or creeks are found, and conflicts can arise when these areas overlap with critical habitats for wildlife, including those of amphibians and reptiles. It is important that people and pets are kept away from critical habitats to avoid degradation of the environment, harassment, and the spread of nonnative species and disease.

- Limit access to important amphibian and reptile habitats (e.g., shoreline areas, denning and basking sites). To protect critical habitats, humans should be excluded from some natural areas, or parts thereof. Design trail systems to encourage people to stay on designated trails via board walks, fencing and plantings, and offer viewing positions from a distance, such as viewing platforms. In addition, buffers can be placed around critical habitats, to deter human access. For example, trails and campgrounds should be placed away from critical shoreline areas, breeding and basking sites. Entry into areas can be limited at certain times of the year via trail closures during the breeding season and juvenile dispersal. Although education of young people about amphibians and reptiles is important (see Section 8.0), schools and playgrounds should not be located near critical habitats where rare and endangered amphibians and reptiles are found (e.g., talus slopes, rock outcrops, creeks and wetlands). This will minimize the risk of contact and harassment, the potential for nonnative species establishment, such as the release of Bullfrog tadpoles (see Section 3.7), and in some areas of the province potential injury from snake bites.

- Limit access of free-roaming pets into parks and reserves. The placement of housing developments directly beside critical amphibian and reptile natural areas should be avoided when possible, or buffered. Strict bylaws and adequate enforcement regarding free-roaming pets, with signage informing residents that animals will be trapped and removed, may help to discourage the public from allowing their pets off-leash or having unsupervised access to natural areas. To control harassment by dogs, use of an area can be prohibited and/or restricted by leash laws and seasonal usage (e.g., exclusion during breeding periods). The use of fencing and signage about pets in and around creeks/ponds would limit disturbance to riparian areas. The most effective control of cats will come through the design/planning phase, through laws/legislation, and public education.

- Have strict garbage control so that feral animals and opportunistic predators are not inadvertently fed or attracted to natural/critical areas (Coleman et al. 1999).

3.7 Review of Management Practices for Nonnative species

For the purposes of this report, nonnative species include those not native to the province, those found outside of their native range within the province, and species found within their range but introduced into areas where they have not historically been found. This may include fish stocked legally or illegally, nonnative amphibians (e.g., Bullfrogs), aquatic and riparian weed species (e.g., Reed Canarygrass [*Phalaris arundinacea*]), and released pets (e.g., Goldfish [*Carassius auratus*] and Sliders [*Trachemys scripts*]). Nonnative species can affect amphibians and reptiles directly through predation and competition for resources, and indirectly through habitat and community alteration and the introduction of disease (Wind, in review). For example, European Wall Lizards (*Podarcis muralis*) were introduced to Vancouver Island, and may be impacting native Northern Alligator Lizards through competition for resources; the European Wall Lizard is associated with human disturbed environments (N. Bertram, pers. comm.). In addition, the effects of nonnative species can be transferred through the food web. For example, the distribution and abundance of the Western Terrestrial Garter Snake (*Thamnophis elegans*) in the Sierra Nevada of California are closely linked to those of amphibian populations, which have been in decline as a result of decades of fish stocking (Matthews et al. 2002).

The issue of nonnative species is of greater concern for aquatic than for terrestrial amphibians and reptiles in British Columbia. Aquatic ecosystems are in many ways similar to islands in their vulnerability to invasive species when compared to larger, more heterogeneous environments: they have discrete environmental boundaries, limited habitat areas, and fewer refugia, and invading aquatic species have high dispersal abilities (Dudley 1994, Drost and Fellers 1995). North American freshwater ecosystems are losing species at the same rate as some of the most stressed land-based ecosystems in the world such as tropical forests, in part due to invasive species. Researchers predict that 20% of North American freshwater fishes and 25% of aquatic amphibians are in danger of extinction during the next century (Ricciardi and Rasmussen 1999). The major threats to aquatic species varies across North America; eastern species face harmful agricultural pollution, whereas western species are greatly affected by introduced species such as nonnative fish (Drost and Fellers 1995, Richter et al. 1997). The majority of lakes that have been stocked in the west, including British Columbia, were originally fishless, and native species are poorly adapted to survival in the presence of these aquatic predators (Wind, in review). Freshwater aquatic vertebrate species have the highest proportion of threatened or endangered species within British Columbia. Introduced species have been identified as a threat, or likely threat, for at least 84% of provincially red and blue listed freshwater fish species, and 56% of listed amphibians (Wind, in review). Despite these threats, amphibians and reptiles and their habitats are underrepresented in provincial conservation efforts (Haas 2000).

The main issues associated with nonnative species in relation to urban/rural development and amphibians and reptiles are:

- *The creation of suitable conditions for nonnative species*; i.e., changes to pond permanence, water quality, habitat complexity, and species composition, which influence the suitability of water bodies or courses for nonnative species.

- *The facilitation of the introduction and spread of nonnative species and disease;* access to water bodies or courses for people, pets and vehicles increases the chance of introduction of nonnative species. Fish stocking (legal or illegal), the dumping of unwanted pets (such as turtles and Goldfish), and illegal collecting and transfer of nonnative species (e.g., children collecting and moving tadpoles or fish) are all possible means that facilitate the spread of invasive species. Such introductions, in turn, facilitate the spread of wildlife diseases.

3.7.1 Habitat alteration

In populated landscapes in western North America there has been a trend towards an increased proportion of permanent wetlands at the expense of temporary wetlands (Adams 1999). Urban development often results in the draining and replacement of ephemeral ponds with permanent water bodies. For example, golf courses, city parks, and landscaped environments around buildings tend to have permanent water bodies associated with them. However, many aquatic-breeding amphibians prefer semi-permanent or ephemeral breeding sites, in part because these water bodies tend to have fewer and typically, smaller predators than do permanent wetlands (Skelly et al. 1999). Ephemeral wetlands are less vulnerable to invasion by nonnative species and strictly aquatic organisms are excluded (see references within Adams 1999). Wider distribution of permanent wetlands within the landscape facilitates the spread and establishment of nonnative aquatic species.

Changes to habitat quality may create conditions conducive to nonnative species. If flow regimes, water source, canopy cover, vegetative cover, and shoreline composition are altered, nonnative species may be better able to out-compete native species for resources, and/or be more effective predators. For example, in California, nonnative fish dominate disturbed habitats, whereas native species are more common in undisturbed areas (Moyle 1976). The presence of one nonnative species can influence the survivorship of others. For example, there is some evidence that Bullfrog survival can be enhanced by the presence of exotic aquatic vegetation (Kupferberg 1996 in Maxell 2000), and studies in Oregon have found that nonnative fish feeding on predatory macroinvertebrates can also facilitate the survival of Bullfrogs (see Wind, in review). The presence of Bullfrog larvae can increase the susceptibility of Red-legged Frog larvae to predation by Smallmouth Bass (*Micropterus dolomieui*) (Kiesecker and Blaustein 1998).

3.7.2 Introduction and spread of nonnative species and disease

Habitat disturbance facilitates the introduction and spread of nonnative species, as does the accessibility of the site to humans (see Section 3.6). Range expansions by nonnative species are greatly facilitated by humans, either through the legal or illegal collection and transfer of animals, or as an unintentional by-product of industrial or recreational activities. The decision as to which lakes in the province are stocked with fish by the British Columbia government is closely related to demand – where there are more people, there is a greater demand for recreational fishing opportunities, and a greater proportion of lakes are stocked (Wind, in review). Therefore, as the human population increases, the probability that more lakes in an area will be stocked either legally or illegally also increases. In addition, anglers sometimes illegally release game fish into new water bodies, and they often release unwanted baitfish (Wind, in review).

Humans aid in the expansion of Bullfrogs by releasing individuals into new waterways, such as tadpoles caught and reared by children, and by creating permanent water bodies for agriculture and ornamental ponds (Hammerson 1982, Adams 2000). Bullfrog tadpoles have also been unintentionally spread through the transport of Goldfish and farmed fish (Lanno 1996, Banks et al. 2000). In Georgia, Bullfrogs have been observed using drains and pipelines to move throughout urban areas (Neill 1950).

The introduction of nonnative species may result in the spread of diseases to native amphibian species; diseases are considered a major factor in the decline of many species around the globe (Daszak et al. 1999), including the Western Toad in North America (reviewed in Wind and Dupuis 2002). Bullfrogs are suspected of having played a role in the introduction of diseases to native amphibian populations in Europe (Nuttall 1997), and in South America (Hanselman 2002). Nonnative fish can also introduce and spread diseases to native amphibian populations (Whittington et al. 1987, Blaustein et al. 1994, Whittington et al. 1996, Gillespie and Hero 1999 and references therein, Mao et al. 1999, Kiesecker et al. 2001).

Many amphibian species prefer a proportion of open-water habitat within wetlands they use for breeding. Nonnative weedy species often choke out native species, and fill in open-water areas. For example, Eurasian Water-milfoil, (*Myriophyllum spicatum*) is a serious problem in lakes in the Okanagan region (Living Landscapes 1996). In the Lower Mainland, Oregon Spotted Frog populations are threatened in part by the loss of open-water habitat, as Reed Canarygrass has invaded their shallow marsh habitats (Haycock 1999). Most riparian areas are particularly susceptible to nonnative plants because of their fertile soils. The seeds of nonnative weedy species are carried on the feet of humans, pets, horses, cattle, vehicle tires, and on the hulls of boats.

3.7.3 Management Recommendations

The eradication of an introduced species once it has become established is often difficult, if not impossible, especially where control measures threaten the ongoing existence of native species of concern (Wind, in review). The best line of defence is a proactive approach to eliminate the risk of introduction or spread of nonnative species and disease. For example, Bullfrog populations have become established on eastern Vancouver Island, the Sunshine Coast, the Lower Mainland, and in the southern Okanagan. Their spread to other areas within the province, especially sensitive environments like the Gulf Islands, must be prevented.

- Avoid draining or altering ephemeral pond habitats or microhabitats (e.g., littoral zone or shoreline areas). Protect ephemeral pond habitats and maintain connectivity among sites. Avoid altering the habitat quality of ponds and microhabitats by changing water flow regimes, connectivity among sites, the amount of canopy cover, runoff, and turbidity.

- Limit the creation of permanent pond habitats, and/or drain ponds in winter, to avoid the introduction or spread of Bullfrogs, nonnative fish, or released pets. Where artificial ponds are created (such as on golf courses or as a landscaping feature around buildings), design them so that they can be manually drained in winter, and plant native species only[1]. Avoid the pooling of water and require that water be constantly drained from sites where it collects during construction, at gravel pits, or along roadways. Although pond creation can be beneficial in some circumstances (see Section 3.2 on habitat restoration), the risk permanent ponds pose to native species through the introduction and spread of nonnative species should be considered.

- Limit human access to important wetland sites (see Section 3.6). Protect critical wetlands and creeks by prohibiting public access to shoreline areas, and by placing buffers around/along them.

- Avoid transporting soil or vegetation from wetlands out of a watershed to avoid the transfer of Bullfrog larvae and/or weedy plant species.

- Prohibit fishing and fish stocking in amphibian habitats. If angling is permitted in the area, there is a high potential that nonnative species may be introduced.

- Display educational signage regarding the illegal capture and release of animals, and the threats that nonnative species pose to native biodiversity.

- **Eradication measures:** Attempting to remove nonnative species, once they have become established is very time consuming, and has little chance of success, especially where the potential for immigration

[1] Ponds do not have to remain dry throughout winter; they must simply dry in order to kill off fish, Bullfrogs, and other predators that require permanent water.

from surrounding areas is high. If nonnative species are detected early on, pond drainage is probably the best method of removing fish and nonnative amphibians from water bodies, provided there is low potential for reintroduction via inflow from surrounding areas. Physical removal through trapping, netting, and other means may be possible for small areas with no inflow. Chemical treatments have been used in the past but they negatively impact native amphibians and reptiles, and require permits (see Wind, in review).

3.8 Data gaps and problem areas

Although the general principles for the conservation and management of amphibians and reptiles are reasonably well understood (Dodd 1993, Semlitsch 2000, 2002), specific details required for their implementation are often lacking. For example, we know that terrestrial habitats peripheral to aquatic breeding sites are essential for semi-aquatic amphibians, but the effective dimensions for such buffer zones are poorly known and untested for most species. Little is known of movements and habitat use patterns of most amphibians in terrestrial environments because of past emphasis on breeding sites and difficulties associated with studying movements of small, secretive animals (Davis 1999). Similarly, movements and habitat use patterns of reptiles are often poorly known. This lack of adequate basic information is true for most amphibians and reptiles of British Columbia.

In most cases, information on the occurrence and habitat use of different species of amphibians and reptiles within urban and rural environments is based on anecdotal observations. For many species, we lack adequate information on factors that affect their persistence within these areas.

Remnant natural habitats in urban and rural areas are often degraded due to intense human use of surrounding areas or direct disturbance. Various restoration measures have been proposed and attempted to rehabilitate such areas. The effectiveness of specific restoration measures of aquatic and terrestrial habitats for amphibians and reptiles needs to be tested.

A further challenge concerns the identification and delineation of critical habitats, such as breeding sites or hibernacula for reptiles or prime habitats for terrestrial salamanders. Such habitats cannot be protected from development if their locations are unknown. Important sites for small, secretive species can be easily overlooked if not specifically searched for.

Population processes at larger spatial scales are thought to be important for long-term persistence of populations, but these processes are poorly known for most amphibian and reptile species in British Columbia (Davis 1999). Knowledge about such metapopulation processed is essential to determine appropriate conservation and mitigation measures. For example, conservation efforts that focus on a site that acts as a population sink may be misdirected. For semi-aquatic amphibians, such sites may be ponds where the survivorship of eggs, larvae, or metamorphosed juveniles is low and where the local population is maintained by emigration from more productive sites. Knowledge of the importance of metapopulation dynamics is also needed to determine the optimal degree of connectivity among habitat patches. In urban and rural environments fragmentation of natural habitats is typically extensive, and connections may need to be created.

4 Species of Amphibians and Reptiles in British Columbia

4.1 Overview

The number of native amphibians and reptiles in British Columbia is the highest in Canada. The 34 species recorded for the province include 9 salamanders, 11 frogs (including one toad; toads are technically frogs), 2 turtles, 3 lizards, and 9 snakes. Regionally, several species are considered extirpated: Western Pond Turtle (*Clemmys marmorata*) in the Vancouver Island Region, Gopher Snake in the Vancouver Island and Lower Mainland Regions, and Northern Leopard Frog and Pigmy Short-horned Lizard (*Phrynosoma douglasi*) in the Okanagan. The Green Frog and Bullfrog are alien to the British Columbia amphibian fauna, and the Pacific Treefrog and possibly the Red-legged Frog are native to other parts of British Columbia, but have been introduced to Haida Gwaii (Queen Charlotte Islands). One population of Northern Leopard Frogs on Vancouver Island originates from introduced specimens (Green and Campbell 1984).

The accounts accompanying this report were compiled from existing sources, including both primary and secondary literature, interviews with herpetologists from different regions of British Columbia, and the personal expertise and observations of the authors. Secondary sources included fieldguides: Green and Campbell (1984), Gregory and Campbell (1984), Leonard et al. (1993), Storm and Leonard (1995), Corkran and Thoms (1996), and St. John (2002).

Each account contains the following: status (provincial, national, and global); distribution in British Columbia and within different Regions, a brief description of life-history and habitats; and an assessment of compatibility with urbanization. These accounts are included in Appendix 1.

4.2 Compatibility ratings for amphibians and reptiles with urban and rural areas

Table 1 provides a summary of the compatibility ratings for all species of amphibians and reptiles that occur in the province. Because little is known about the compatibility of most species with urbanization, these assessments are based on the best judgment of the team involved and of professionals with particular knowledge about individual species. There was a general impression that although the ratings for individual species seem appropriate, the compatibility assessment required “a leap of faith”. Amphibians and reptiles such as the Painted Turtle, Great Basin Spadefoot, and many other species can live to a considerable age. It is easy to assume that urban ponds and disturbed areas support viable populations when in fact the animals observed in these habitats may represent "living dead" populations (populations with a low probability for long-term persistence). For species that wander widely, urban areas could be population sinks that rely on immigration for persistence. Other populations might simply be too small for long-term viability.

However, these compatibility ratings have value as an initial effort to assess which species might benefit most from management efforts. Even species rated as low compatibility, such as the Coastal Giant Salamander, can benefit from some of the Best Management Practices outlined in this report. Urbanization is encroaching into the habitats of this and other species, and although measures might be taken to mitigate these impacts (such as cleaning up streams and leaving forested buffer zones along them) the effectiveness of such measures are uncertain. Mitigation strategies for urban and rural developments should never be used an excuse to encroach on critical habitats for wildlife or to distract attention from the importance of protecting larger tracts of natural habitats.

Table 1: Estimated compatibility of amphibian and reptile species in British Columbia with urban and rural areas – (* where overall compatability Low, Moderate or High is the degree to which key features of a species' requirements are met)

Highlighted species are considered to be at risk in British Columbia and are on the provincial red- or blue-lists.

SALAMANDERS:

Common Name	Scientific Name	Breeding habitat (category)	*Overall compatibility	Urban	Rural	Greenspaces and urban parks	Requirements for compatibility
Northwestern Salamander	*Ambystoma gracile*	Pond	Moderate	X?	X	X	Moist forest with cover and aquatic breeding sites
Long-toed Salamander	*Ambystoma macrodactylum*	Pond	Moderate to high	X	X	X	Standing water (temporary or permanent); abundant shelter in terrestrial habitat; sensitive to nonnative

Common Name	Scientific Name	Breeding habitat (category)	Overall compatibility	Urban	Rural	Greenspaces and urban parks	Requirements for compatibility
Tiger Salamander	*Ambystoma tigrinum*	Pond	Low to moderate?	X	X	X	Permanent, alkaline ponds and lakes; rodent burrow and hollows in adjacent terrestrial habitat; sensitive to nonnative; vulnerable to disease introduction; reduced road mortality
Pacific Giant Salamander	*Dicamptodon tenebrosus*	Stream	Low to moderate		X		Clear, clean, permanent streams and adjacent moist, forested riparian areas; abundant cover for both larvae and adults
Wandering Salamander	*Aneides vagrans*	Terrestrial	Moderate to high	X	X	X	Abundant coarse woody debris and moisture
Ensatina	*Ensatina eschscholtzii*	Terrestrial	Moderate		X	X	Abundant coarse woody debris and moisture
Coeur d'Alene Salamander	*Plethodon idahoensis*	Terrestrial	Low to moderate		X		Seepages, caves, or other very most sites; rocky substrates; sensitive to riparian management
Western Red-backed Salamander	*Plethodon vehiculum*	Terrestrial	Low to moderate		X	X	Forest cover; moisture; abundant coarse woody debris or other shelter
Rough-skinned Newt	*Taricha granulosa*	Pond	Moderate	X?	X	X	Reduce road mortality during mass migrations; access to extensive terrestrial habitat

FROGS:

Common Name	Scientific Name	Breeding habitat (category)	Overall compatibility	Urban	Rural	Greenspaces and urban parks	Requirements for compatibility
Coastal Tailed Frog	*Ascaphus truei*	Stream	Low to moderate		X		Clear, clean, permanent, fast-flowing streams and adjacent, moist, forested riparian areas
Rocky Mountain Tailed Frog	*Ascaphus montanus*	Stream	Low to moderate		X		Clear, clean, permanent, fast-flowing streams and adjacent, moist, forested riparian areas
Great Basin Spadefoot	*Spea intermontana*	Pond	Moderate	X	X	X	Sandy substrates for burrowing; temporary and semi-permanent ponds; sensitive to nonnative; reduced road mortality
Western Toad	*Bufo boreas*	Pond	Low to moderate		X		Reduce road mortality during mass migrations; access to extensive terrestrial habitat; vulnerable to disease introduction
Pacific Treefrog	*Pseudacris regilla*	Pond	High	X	X	X	Ponds with emergent vegetation, shallow littoral zones, and no nonnative and/or bullfrogs
Boreal (= Striped) Chorus Frog	*Pseudacris maculata (= triseriata)*	Pond	Moderate	X	X	X	Semi-permanent ponds with emergent vegetation, shallow littoral zones, and no nonnative

Common Name	Scientific Name	Breeding habitat (category)	Overall compatibility	Urban	Rural	Greenspaces and urban parks	Requirements for compatibility
Red-legged Frog	*Rana aurora*	Pond	Low to moderate		X		Forested areas and aquatic breeding sites with emergent vegetation; sensitive to nonnative and bullfrogs
*Bullfrog	**Rana catesbeiana*	Pond	High	X	X	X	Invasive exotic; permanent water bodies; fish may facilitate survival
*Green Frog	**Rana clamitans*	Pond	High	?	X		Exotic; permanent water bodies
Columbia Spotted Frog	*Rana luteiventris*	Pond	Moderate		X	X	Aquatic habitats for year-round use; sensitive to nonnative and riparian management
Oregon Spotted Frog	*Rana pretiosa*	Pond	Low		X		Extensive shallow marshes with floating vegetation and open water areas; sensitive to bullfrogs, invasive aquatic plants, and nitrate contamination
Northern Leopard Frog	*Rana pipiens*	Pond	Low to moderate		X		Breed and over-winter in wetlands; sensitive to nonnative and riparian management; vulnerable to disease introduction
Wood Frog	*Rana sylvatica*	Pond	Low to moderate		X		Extensive use of forested areas; aquatic breeding sites

TURTLES:

Common Name	Scientific Name	Overall compatibility	Urban	Rural	Greenspaces and urban parks	Requirements for compatibility
Painted Turtle	*Chrysemys*	High	X	X	X	Reduce road mortality during migrations; appropriate nesting grounds near permanent ponds or lakes
*Slider	**Trachemys scripta*	High	X	X	X	Introduced

LIZARDS:

Common Name	Scientific Name	Overall compatibility	Urban	Rural	Greenspaces and urban parks	Requirements for compatibility
Northern Alligator Lizard	*Elgaria coerulea*	Moderate to high	X	X	X	Cover such as rocks, bark down wood
Western Skink	*Eumeces skiltonianus*	Moderate		X	X	Cover such as rocks, bark down wood
*Common Wall Lizard	**Podarcis muralis*	High	X	X	X	Introduced and spreading in the Victoria area

SNAKES:

Common Name	Scientific Name	Overall compatibility	Urban	Rural	Greenspaces and urban parks	Requirements for compatibility
Rubber Boa	*Charina bottae*	Moderate		X		Forested areas; cover provided by rocks or down wood
Racer	*Coluber constrictor*	Low			X	Extensive foraging areas; cover; den sites
Sharp-tailed Snake	*Contia tenuis*	Moderate to high	X	X	X	Good cover; rocky forest openings with southern exposure for egg-laying

Common Name	Scientific Name	Overall compatibility	Urban	Rural	Greenspaces and urban parks	Requirements for compatibility
Night Snake	*Hypsiglena torquata*	Low		X?	X?	Rock outcrops; cover
Gopher Snake	*Pituophis catenifer*	Low		X	X	Extensive foraging areas; good cover for shelter; den sites; superficially resembles rattle snakes and may be subjected to persecution
Western Terrestrial Garter Snake	*Thamnophis elegans*	Moderate to high	X	X	X	Herbaceous or shrub areas; cover; wetlands or wet meadows for foraging
Northwestern Garter Snake	*Thamnophis ordinoides*	High	X	X	X	Herbaceous or shrub areas; cover
Common Garter Snake	*Thamnophis sirtalis*	Moderate to high	X	X	X	Forest, herbaceous, or shrub areas; cover; wetlands or wet meadows for foraging
Western Rattlesnake	*Crotalus viridis*	Low			X	Extensive areas for foraging and seasonal movements; den sites; venomous and may be subject to persecution

Breeding habitat (category) – for amphibians only. Pond: standing or slow-moving water; Stream – fast-flowing, cool, clear streams; Terrestrial – terrestrial habitats (plethodontid salamanders).

Urban – relatively densely populated area, such as within a city, town, or suburban areas

Rural – less densely populated area with fragmented natural areas present

Greenspaces and urban parks – city parks, riparian zones, and recreational areas within populated areas

Requirements for compatibility – Key features of a species' requirements that need to be addressed (see individual species accounts for a more complete description of habitat requirements).

X – indicates potential or recorded use of the above areas by a portion of a population (rare or occasional use by individuals is not sufficient)

? – indicates that the species are known from urban or rural areas in other parts of its range, but has not been found in these habitats in British Columbia

5 Provincial BMPs for Amphibians and Reptiles

5.1 Best Management Practices for Amphibians and Reptiles: Summary

British Columbia has a rich fauna of amphibians (frogs, toads, and salamanders) and reptiles (turtles, lizards, and snakes), including several species that are on the provincial red- and blue-lists of species at risk; some are nationally endangered or threatened. Because of widespread population declines over the past decades, there is growing public concern for their well being. Amphibians and reptiles play important roles in ecosystems as both prey and predators. Many are beneficial to people as consumers of pest insects, slugs, or rodents. Because of their semi-permeable skin and exposed eggs, amphibians are particularly sensitive to environmental changes and contamination of their habitats on land and in water. The presence of thriving amphibian populations is an indication of a healthy environment.

There are many ways local governments, land-use planners, and developers can incorporate measures that benefit amphibians and reptiles into their zoning, management, or development plans (see summary below).

More specific information for each region of the province can be found in Section 6.

All species of amphibians and reptiles:

- Try to locate developments and roads away from key habitats for amphibians and reptiles, such as wetlands, streams, and nesting and denning sites (see Section 5.3.3 on page 70 for details).

- Maintain buffers of undisturbed native vegetation around and adjacent to key amphibian and reptile habitats and discourage human access to these areas. (see Section 5.3.3 on page 70 for details)

- Provide suitable landscape linkages to allow movements of animals between important seasonal habitats; riparian management areas, parks, and greenways can connect habitats. (see Section 5.3.3 on page 70 for details)

- Minimize road kill of animals migrating between seasonal habitats by locating roads and infrastructure away from these areas; consider special road-crossing structures where this is unavoidable. (see Section 5.3.5 on page 77 for details)

- Control the spread of nonnative animals and plants; introduced Bullfrogs and fish compete with and prey on native amphibians; weedy exotic plants can overtake native vegetation and choke wetlands. (see Section 5.3.9 on page 83 for details)

- Encourage residents to take an interest in protecting these species by providing interpretive materials such as signs and brochures (see Section 5.3.10 on page 86 for details)

Pond-breeding amphibians (most species in Table 1):

- Preserve all wetlands, ponds, pools, and streams – however small or ephemeral; these small areas can be very important for amphibians.
- Protect shallow water areas and their vegetation from trampling and other disturbance; these areas serve as breeding habitat and cover for many amphibians.
- Avoid altering natural patterns of flooding and drying of wetlands; temporary wetlands often have few predators and are important for amphibians.
- Maintain sufficient terrestrial habitat or access to terrestrial habitat for amphibians to complete all life history phases.

Amphibians inhabiting fast-flowing streams (Coastal Giant Salamander and Tailed frogs):

- Maintain moist forested habitat with abundant coarse woody debris along streams (at least 30 m wide on both banks; the wider, the better).
- Take special care to avoid siltation of stream habitats.
- Avoid altering stream-flow patterns, and maintain small pools within streams (pocket or step pools) and abundant in-stream cover.

Terrestrial salamanders (Plethodontid salamanders; see Table 1 for species):

- For coastal species, preserve moist, wooded areas.
- Avoid removing downed logs and bark, especially large diameter pieces; downed wood in various stages of decay provides shelter and egg-laying sites.
- In the interior, within the range of the Coeur d'Alene salamander, preserve seepages, riparian splash zones, caves, talus, and other moist, rocky sites.

Painted Turtle:

- Protect nesting habitats adjacent to wetlands from disturbance and human access; typically these sites are located on dry and light soils with little vegetative cover on a southern slope within 150 m from water.

- Route new roads away from nesting areas and migration routes to avoid disturbance and road mortality; fencing can be used to direct turtles away from existing roads.

Lizards, Rubber Boa, and Garter snakes:

- Protect south-facing, rocky slopes, used as basking, hibernation, or nursery sites.

- Retain talus (layers of weathered rock, often at the base of slopes), rock outcrops with fissures, and coarse woody debris, which provide shelter for reptiles.

- Provide access to wetland foraging areas for garter snakes.

Large snakes of the arid interior (see Table 1 for species):

- Avoid locating buildings or roads near potential denning areas such as south-facing talus slopes. Where not possible, use cluster housing located as far as possible from these sites, or zone them for low-density developments only (see Section 6: "Thompson and Okanagan" for more suggestions). Consider using drift fences around residential areas to reduce interactions with people.
- Inform the public of the value of snakes as unique components of biodiversity and of their beneficial role as consumers of pest insects, slugs, and rodents; discourage the killing of snakes of any kind.

5.2 Objective of Best Management Practices (BMPs) described in this report

Many species of reptiles and amphibians in British Columbia occupy ranges that overlap with centers of human habituation, yet their habitats are not effectively protected by current legislation, particularly on private land. This BMP document furnishes management approaches based on best available science necessary to avoid or minimize development impacts and help protect, restore or enhance habitats of amphibians and reptiles in urban and rural environments. The ultimate goal is to minimize habitat loss and maintain viability of those populations of amphibians and reptiles that overlap with urban/rural areas. It is realized that while mitigation will be feasible for some species, those species that require extensive natural areas will have low compatibility with urbanization and will have to be protected through other means.

The BMPs are designed for use by those who are directly involved in or responsible for the development of urban and rural areas including land developers, consultants, landscape architects, and planners in municipal and regional governments and other agencies.

The BMPs and guidelines focus on amphibians and reptile species that are potentially compatible with urban and rural environments. An assessment of the compatibility of amphibians and reptile to urban and rural environments is shown in Table 1 (see Section 4.2). Species deemed to have a low compatibility with these environments should be a managed with utmost care, because developed areas may act as "sink" habitats, contributing little if at all to the viability of the local population. The needs of those species that are wide-ranging or have very restrictive habitat requirements can be best addressed by the integrated efforts of provincial and local government agencies and stewardship initiatives using landscape-level management tools.

5.3 Planning and Design Phases of Development

The planning and design phases are key to proactive minimization of impacts resulting from land development on amphibian and reptile populations and their habitats. Critical habitats need to be identified early in the planning process and, for many species with low to moderate compatibility with urban environments, *the best way to maintain populations is to set aside these critical areas and maintain connectivity between them*, rather than trying to mitigate impacts, relocating habitats, or restoring them. Landscape-scale mapping of habitats (SEI) and capability mapping are useful in determining what to look for and where to undertake more extensive inventory. This scale of mapping is also useful for planning linear developments to minimize impacts.

5.3.1 Habitat assessment and species inventories

Inventories are of utmost importance because they generate the baseline information that is crucial for successful management of amphibians and reptiles. Management depends on accurate information on the species present and their seasonal use of habitats within the development area. It is also important to identify the needs for access to breeding, foraging and overwintering areas, which may be located outside the development area.

a) Identify all critical habitats within and adjacent to the development area:

- Because most amphibians and reptiles use more than one habitat type during their life cycle, it is necessary to conduct surveys during all seasonal periods when species expected to be found in the area are active, and to conduct several site visits during each season to ensure that all species are detected and their habitat use is fully described. **If resources are limited, surveys during the breeding and seasonal movement periods should be emphasized.**

- Examples of critical habitats include talus slopes, hibernacula, nest sites, and foraging areas for reptiles, aquatic breeding sites for amphibians, and movement corridors for both reptiles and amphibians.

b) Use standard, specialized survey techniques appropriate to each group of animals:

- Special care must be taken to ensure that all species and habitat types important for amphibians and reptiles are surveyed adequately. Several species of amphibians and reptiles are secretive and require specialized inventory techniques. For example, the Sharp-tailed Snake, Night Snake (*Hypsiglena torquata*), and Rubber Boa (*Charina* bottae) can be inactive for long periods and use underground refuges extensively. The Coeur d'Alene Salamander is found in talus, seepage slopes and caves, and attention to these special habitat features, however small in area, is crucial. Many other species, such as the Coastal Giant Salamander and Northwestern Salamander, are also secretive and difficult to find in terrestrial habitats.

- All surveys must comply with RISC standards set by the Province. These standards are currently available for snakes, Plethodondid (Woodland) salamanders, pond-breeding amphibians and Painted Turtle, and stream-dwelling amphibians (Tailed frogs and Coastal Giant Salamander). For further information on habitat assessment and surveys prior to development, see the BC Government web site on land development (BC Ministry of Water, Land and Air Protection 2003).

- Where ponds, marshes or streams are present adjacent to the development, documentation of hydroperiods (patterns of drying and filling), sedimentation loads, flow volumes and peak flows are important as baseline information so these can be compared to post-development conditions.

Check-list:

- Has the survey been conducted by a qualified individual?

- Was the survey undertaken at an appropriate spatial scale to capture all critical habitat features?

- Were appropriate methods used for surveys (RISC standards)?

- Did surveys occur in appropriate seasons, considering the activity periods of all potential species?

- Were natural processes, such as pond permanence, sedimentation load, flow volumes and peak flows documented?

5.3.2 Site determination for development infrastructure

Proper siting of infrastructure involves minimizing fragmentation of habitat and protecting critical habitats of amphibians and reptiles, such as wetlands and associated natural shoreline vegetation, breeding and overwintering sites, and travel corridors (see Section 5.3.3). Often this is the most important measure that can be taken to protect amphibian and reptile habitats. Roads should by-pass important habitats, and, if necessary, crossing structures such as underpasses and fencing may be required where roads intersect movement corridors, to minimize road mortality (see Section 5.3.5).

- Designate protected areas early in the planning process to ensure that the highest quality habitats are preserved.

- Try to design around key habitat features for amphibians and reptiles; route roads away from these habitats; disturb as little natural vegetation as possible.

- Landowners, developers, and consultants should work together with urban planners and biologists to ensure that the best habitats for amphibians and reptiles are protected and that connectivity of habitats in the development area is maximized with habitats in surrounding green space, riparian areas and parks.

- Cluster housing and other means of concentrating infrastructure should be developed in areas of low habitat quality, so that areas of high-quality habitat can remain undisturbed.

Check-list:

- Does the siting of the project ensure that critical habitats are protected; does the location of the infrastructure avoid critical habitats and habitat features for amphibians and reptiles?

- Is connectivity of habitats maintained by careful site planning?

- Are barriers to movement minimized by proper location of roads and other infrastructure?

5.3.3 Habitat protection

After surveys and assessment of habitat quality have been conducted, it is important to protect the identified habitat components and movement corridors to maintain the viability of populations of amphibians and reptiles present. These practices include protecting critical habitat features and providing sufficient space, connectivity, and habitat diversity needed for all life-history stages. In addition, mitigation measures are required to maintain the quality of the habitat.

a) Protect critical habitats and special areas:

Special areas for amphibians and reptiles (see below) need complete protection and should be set aside from developed areas. A protective buffer adjacent to these areas and connectivity to undisturbed habitat need to be maintained. Some special sites, such as hibernacula of large snakes in the Okanagan, or breeding ponds of toads and frogs on Vancouver Island, may be small in area but might contain a significant proportion of the local or regional population of one or more species. Their relatively small size makes them amenable to protection as long as sufficient space for movements to other required habitats, such as foraging areas, is retained. Nesting and hibernation sites often contain unique environmental features, and individuals may have to travel long distances to such sites.

The following critical habitats need to be identified and protected:

- Nesting sites of freshwater turtles. One native species, the Painted Turtle, occurs in British Columbia. Its egg-laying and nursery habitats are specific with respect to exposure (southern aspect), substrate type (dry and light soils with little vegetation cover), and distance from aquatic habitat (within 150 m).

- Snake hibernacula, denning sites, and foraging areas. Several species hibernate in communal denning sites, including an assemblage of species in the arid southern interior region of the province, such as the Western Rattlesnake, Gopher Snake, and Racer. These species often can be found in the same den site. The Common Garter Snake (*Thamnophis sirtalis*), which has a wide distribution within the province, also hibernates communally in some areas, particularly in northern environments.

- Breeding ponds and streams used by multiple species of amphibians

- Mass migration corridors of toads, some frogs and salamanders

- Seepage areas and caves for the Coeur d'Alene Salamander

- Cool, forested stream habitats for Tailed frogs and Coastal Giant Salamander

b) Protect all necessary habitat components in sufficient quantities:

Managers should strive to maintain a diversity of aquatic and terrestrial habitats and provide suitable landscape linkages to allow movements of animals between important seasonal habitats. Because they are ectothermic (deriving their body temperature from the environment rather through physiological means as do mammals and birds), amphibians and reptiles are strongly influenced by their environment, and their survival is dependent on the array of habitats available to them. Reptiles regulate their body temperature by selecting warm microhabitats if they are cold and cooler areas when they are hot. Secure basking and resting areas are a required part of their daily range. Snakes, for example go to basking areas or warm surfaces after a meal to facilitate digestion. Many species need access to foraging areas that might be separate from basking or refuge areas. Amphibians have moist skin and require ready access to water or moist microhabitats. With the exception of one group of forest salamanders that are completely terrestrial, all species in British Columbia require water for breeding. Many amphibians become inactive during periods of dry weather and need moist refuges to survive.

Most amphibians and some reptiles require both aquatic and terrestrial habitats for successful completion of their life-cycles, and this results in additional management challenges. While the importance of protecting aquatic breeding habitats of amphibians has long been recognized, terrestrial habitats that are equally essential for their different life-history have often been neglected. Similarly, for reptiles, the protection of critical habitats alone, such as snake dens and turtle nesting areas, is insufficient to maintain viable populations if the habitats for foraging and other essential needs are not met.

If viable populations are to be maintained, the following habitat components need to be protected :

- Wetland and upland habitats for amphibians and reptiles - Although only a few amphibians (Plethodontid salamanders) are completely terrestrial, almost all require terrestrial habitats in addition to standing or flowing water.

- Diversity of habitats, including both temporary and permanent wetlands and adjacent upland habitats. Temporary wetlands that have an annual pattern of drying and filling provide a valuable and diminishing resource for amphibians and reptiles. Many species of amphibians rely on temporary wetlands that are free of large aquatic predators and contain abundant food.

- Wetlands, ponds, pools, and streams – however small – that are used by breeding amphibians.

- Habitat features important for amphibians and reptiles, such as coarse woody debris, rock outcrops, talus, and appropriate substrates for burrowing. For example, the Wandering Salamander (*Aneides vagrans*), a species sometimes found in urban and rural areas on Vancouver Island, seeks refuge within decaying logs and would benefit greatly from practices that maintain large-diameter coarse woody debris and logs on the forest floor. Great Basin Spadefoots require sandy soils for burrowing and are unable to burrow on turf and gravel substrates and through paved surfaces. These animals must have underground burrows to survive periods of adverse dry or cold periods.

c) Maintain habitat quality; provide undisturbed buffer zones adjacent to important habitats:

- Amphibians and reptiles need undisturbed natural vegetation adjacent to wetland areas for foraging and to complete life-history stages. Buffer zones also serve to protect the water quality of wetlands by filtering out pollutants and sediments. The recommended widths of buffer zones as determined by best available science vary considerably according to the species present. A buffer zone of at least 30 m (the wider the better) on each side of a stream or along a wetland might benefit many species. For very small wetlands, a 3:1 ratio of undisturbed upland habitat to water is recommended (Canadian

Wildlife Service, Ontario Region 2000). For example, a pond 1/3 ha in size should have a surrounding buffer area of 1 ha. The size of the buffer zone will depend on the size of the development and the availability of adjacent, alternative habitats, such as green spaces and parks. Sites that are isolated and surrounded by urban development should have large buffer zones.

- Undisturbed native vegetation left adjacent to important terrestrial habitats for amphibians and reptiles helps protect these sites; such sites include snake denning areas, talus slopes, turtle nesting sites, and foraging areas.

d) Allow natural processes in the area to continue:

- Maintain natural hydrology of wetlands and streams, so that these habitats continue to provide suitable conditions for semi-aquatic species over the long term.

- Retain natural vegetation whenever possible; the maintenance of natural ecosystem processes will promote high species diversity of amphibians and reptiles.

- In upland habitats, avoid compaction and disturbance of the ground including soil, litter layer, and coarse woody debris; avoid removing natural vegetation and mowing grassy areas adjacent to wetlands.

- Small-scale prescribed burns can be considered to maintain fire-adapted ecosystems; the maintenance of the open nature of grassland and savannah habitats benefit several species that inhabit the arid interior, such as the Gopher Snake, Western Rattlesnake, Racer, and lizards.

- Changing the frequency or intensity of natural disturbance regimes has well-known effects on ecosystems and might affect amphibians and reptiles.

e) Maintain original connectivity of habitats and populations:

- Avoid fragmentation of habitats; where habitats are already fragmented, provide habitat continuity that allows for movements of animals. If the development area lies adjacent to green spaces or parks, ensure that connectivity is maintained by setting aside undisturbed habitat for travel routes to these areas. If a stream flows through the area, maintain a buffer zone of undisturbed vegetation, so that a travel corridor is maintained.

- Movement corridors must be of sufficient width and contain habitat attributes that are attractive to amphibians and reptiles.

- Protection of undisturbed riparian areas such as along meandering creeks is an excellent option for maintaining connectivity of populations and habitats; however, it is crucial that no gaps of unsuitable habitat exist.

- Maintain connectivity within the development area by designing a network of natural areas between key habitats such as wetlands and upland foraging areas.

Check-list:

- Are all identified critical habitats intact after construction?

- Are all identified habitat components intact and protected?

- Are there sufficient undisturbed buffers adjacent to critical habitats in place?

- Are natural processes such as hydrology similar to pre-development conditions?

- Is a monitoring plan in place?

5.3.4 Habitat restoration and enhancement

Habitats in urban and rural environments are often highly modified, and restoration activities may be required for populations of amphibians and reptiles to survive in these areas. Habitat restoration involves establishing a clear goal with respect to ecological processes. Historical disturbance regimes, habitat features that have been modified by human activities, and the probability of natural catastrophes need to be considered. Habitat enhancement involves improving habitat quality by adding or augmenting features important for particular species or groups. For purposes of this report, the term 'habitat restoration' will also include habitat enhancement activities.

Habitat restoration for amphibians and reptiles can range from restoration of habitat connectivity at the large scale to small-scale landscaping by residents in their backyards and gardens. To be successful, both large- and small-scale restoration projects require careful planning and knowledge of the requirements of the target organisms. Consideration should also be given to the time-scale required to achieve restoration objectives. If restoration objectives are ambitious, large areas of habitat may be totally unsuitable until the required habitat attributes are gradually restored; recovery may take decades. If a degraded habitat is being restored for amphibians or reptiles, there needs to be a source of colonists.

A diversity of habitats and habitat features promotes species diversity and long-term survival of amphibian and reptile populations. Where important microhabitat features such as floating logs or other basking sites for reptiles have been removed, they can be replaced. Often, restoration objectives can be achieved through natural vegetation succession and avoiding intensive management practices, such as mowing and weeding. Inadvertent creation of ecological traps, which attract amphibians and reptiles to sites where their survival probability is low, should be avoided. For example, a wetland should not be created near a road where animals are likely to be killed during migrations. Careful planning is important for all restoration and habitat enhancement activities.

a) Restoring original connectivity of habitats:

Maintenance of habitat connectivity is important for the long-term viability of amphibian and reptile populations and the following practices may be required to achieve connectivity in fragmented urban and rural environments:

- Restoration activities may involve increasing connectivity to allow for dispersal and migratory movements of amphibians and reptiles. Careful planning should ensure that nonnative species such as fish or Bullfrogs do not use new corridors to invade wetlands.

- Restoration efforts should focus on habitats that were naturally continuous rather than to create travel routes where none existed before development.

- Connectivity can be achieved by restoring natural vegetation in upland habitats between wetlands, repairing gaps in riparian travel corridors adjacent to streams, restoring drained wetlands as stepping stones between core habitat areas, and building structures to facilitate road crossings by amphibians and reptiles (see Section 5.3.5).

b) Restoration of wetlands and wetland complexes:

Amphibians and reptiles use wetlands across a spectrum of pond-permanence for different life-history phases and activities. Temporary wetlands include vernal pools, floodplain pools, and other shallow depressions that undergo a periodic, annual pattern of filling and drying. Amphibians that breed in temporary water bodies avoid predation by fish and other aquatic or semi-aquatic animals that have poor overland dispersal abilities. Semi-permanent and permanent wetlands include marshes, ponds, lakes, excavated dugouts, and beaver ponds. Permanent water bodies are essential for amphibians that require multiple years for aquatic larval development. Freshwater turtles require permanent water bodies for foraging, over-wintering and other activities, while many semi-aquatic snakes (such as several species of Garter snakes) use both types of wetlands for foraging.

- Avoid creating permanent wetlands or changing temporary wetlands into permanent ponds, especially in areas where nonnative species such as Bullfrogs have become established. Restore buffers of native vegetation adjacent to wetlands, focus on providing a variety of habitat types within the buffers; often this can be achieved by simply leaving areas in their natural state.

- Restore natural drainage patterns for a temporary wetland by removing drainage tiles, fill in drainage ditches, or remove dams and berms.

- Sometimes the quality of riparian vegetation adjacent to wetlands can be improved by removing invasive, introduced plants. Restoring shallow water zones with native, emergent and submerged vegetation helps to restore natural ecosystem processes.

- Habitat complexity of wetlands can be increased by re-contouring eroded or modified shorelines using irregular or undulating patterns.

c) Restoration of stream quality:

In British Columbia, three species (Coastal Giant Salamander and two species of Tailed frog) inhabit small headwater streams. A few other species, such as the Northwestern Salamander and Red-legged Frog, may breed in pocket pools within small streams, but these species use a variety of other types of water bodies as well.

- Key elements of stream restoration consist of providing a protective buffer zone of natural vegetation along the stream, maintaining stream habitat complexity to provide refuges, nest sites and foraging areas, and controlling water quality.

- Restore channelized or eroded streams by creating a more natural meandering channel with stabilized banks; this will increase habitat diversity.

- For Tailed frogs and the Coastal Giant Salamander, stream restoration includes reducing sedimentation, restoring natural water flows (including numerous pocket pools), and allowing streamside vegetation to recover.

d) Restoration of terrestrial habitats:

Areas with a diversity of terrestrial and aquatic habitats tend to support the greatest diversity of amphibian and reptiles.

- Control exotic, weedy plants, especially in small habitat patches that are susceptible to invasion.

- Maintain or restore important habitat features for amphibians and reptiles including downed logs, bark, and other coarse woody debris, especially large-diameter pieces, in various stages of decay. Within urban areas, public education may be required to ensure that newly fallen trees are not hauled away for firewood. In the arid interior where wild fires may be a problem, removal of branches and smaller pieces might be necessary. The addition of large pieces of coarse woody debris to sites from where it has been removed or depleted is also an option.

- Talus and flat rocks can be restored in areas where they have been disturbed or removed. Rocks and talus are important habitat features for reptiles, and when sufficient moisture is present, also for amphibians.

- Measures to restore turtle nesting grounds involve pulling plants and roots to increase the area of exposed soil; the creation of sparsely vegetated openings on well-drained soils in warm microclimates may be beneficial.

- Where natural refuges have been degraded, artificial structures (rock or brush piles) may be constructed to provide shelter, over-wintering sites, or nesting sites for reptiles.

Check-list:

- Are the desired conditions of the wetlands, streams, or riparian and upland zone satisfactorily established?

- Do native amphibian and reptiles use the restored habitats?

- If so, are steps taken to identify potential problems, such as increased mortality of animals or poor survival of eggs or young in the restored habitats?

- Is restored native vegetation developing as planned?

- Are introduced species re-invading?

- Is there a monitoring plan in place; is it implemented; are the results summarized periodically; is there regular reporting on the effectiveness of the restoration measures?

5.3.5 Maintain habitat connectivity across roads and reduce road mortality

Roads, housing and industrial sites, parking lots, steep embankments, improperly designed culverts, and human-dominated spaces can be barriers to animal movements and thereby fragment populations. Large numbers of amphibians and reptiles can also get killed when crossing roads. Mortality of amphibians and reptiles can be severe where roads bisect seasonal migration routes. Semi-aquatic amphibians that undertake migrations between spawning, feeding, and over-wintering sites are particularly vulnerable to mortality on roads. Reptiles that migrate between hibernation and foraging sites (some snakes) or between nesting and foraging and over-wintering sites (freshwater turtles) are also vulnerable.

Routing of new roads to avoid important wetlands and key migration routes is the best measure to minimize effects of roads on amphibian and reptile populations. Where avoidance is impossible or roads already exist, fencing and crossing structures can be used.

Permanent mitigation measures include tunnel systems, other crossing structures, and relocations of breeding sites. Recommendations for effective amphibian and reptile tunnel and fencing systems adjacent to roads include the following:

a) Tunnel and fencing systems:

- Proper location of tunnels and fences is based on specific knowledge of target species and their migration routes in the area; orient tunnels along known routes between winter/foraging grounds and breeding grounds.

- Tunnels can be constructed of a variety of materials, including concrete, steel, PVC piping, and polymer surface products. Steel is thought to be less desirable because of its high conductivity and coldness during spring migratory periods; metals leaching from galvanized steel may be harmful to amphibians.

- Tunnels with large diameter (such as 1 m) are effective and also allow for passage of a variety of other animals; interval between tunnels should be 50 m or less.

- Smaller tunnels with overhead openings for ambient light and moisture are effective; the small openings are covered by metal grates to minimize interference with vehicle movements along roads.

- Tunnels should not exceed 30 – 35 m in length.

- Ensure that drainage is adequate to avoid flooding of tunnels.

- Fencing is needed to intercept movements of animals and direct them towards the tunnels. Where the drift fencing is parallel to the road, additional fences are needed to funnel the animals towards the tunnel entrance; drift fences can be constructed of various materials, including concrete, rigid plastic, and polyethylene sheets. Fences should be sufficiently long, be constructed of durable materials, and be regularly inspected for damage. Berms with sloping earth and retaining walls can also be deployed along portions of the system.

- Fences about 50 cm in height appear to be suitable for most species; bury the bottom 6 – 10 cm of the drift fence to prevent animals from tunneling underneath.

b) Relocation of breeding sites:

- Where the probability of road mortality is high, relocation of breeding sites may be an option. This might involve construction of a permanent fence to keep animals away from the road and the creation or enhancement of alternative breeding sites. This is an option where most habitats are on one side of the road.

c) Stream culverts:

- For stream-dwelling amphibians (Coastal Giant Salamander and Tailed frogs), open bottom culverts are thought to facilitate movements of animals across roads. This culvert design eliminates contact with steel and maintains natural substrates along the bottom of the culvert.

Check-list:

- Do the targeted species of amphibians and reptiles use the structures provided?
- Are road mortalities reduced?
- Are there problems with animals breaching the fences or going around them?
- If breeding sites were relocated, are animals using the new areas as planned?
- Who is responsible for ensuring that the structures are functioning properly?
- Does the monitoring plan address the effectiveness of the structures; has it been implemented; are the results summarized on a regular basis?

5.3.6 Pollution Control Measures for Amphibians and Reptile Habitats

Amphibians and reptiles in the vicinity of populated areas are exposed to a wide variety of contaminants that have the potential to affect their health, survival, and persistence in these landscapes. The main types of pollutants include pesticides, sediments, organic matter, nutrients, heavy metals, and petrochemicals. Some chemical compounds act as endocrine disrupters (EDCs) and can interfere with hormone signals during sensitive developmental periods. Heavy metals are highly toxic to amphibians. All these substances can be transported through surface run-off or in ground water and will eventually end up in ponds and wetlands. Pesticides are often the most common contaminants in amphibian and reptile habitats.

The main sources of pollutants in urban and rural environments include:

- Run-off from roads, which may contain surfactants, road salts, petrochemicals, metals, and other compounds from automotive exhaust.

- Insecticides or herbicides, which are often used on golf courses, parks, road-sides, right-of-ways, and residential lawns and gardens.

- Storm water run-off, which is recognized as a main source of various contaminants in water-bodies in urban settings.

- Faulty sewage systems and excessive use of fertilizers, both of which contribute to nitrogen pollution of water bodies.

Amphibians are sensitive to environmental pollutants because of their permeable skin and eggs, their position in the foodweb as mid-level consumers, and their potential for prolonged exposure to contaminants in both aquatic and terrestrial environments. All frogs and some salamanders in British Columbia undergo early development in aquatic habitats, where they may be exposed to chemical contaminants during critical developmental periods, such as during embryonic and metamorphic periods when their major organ systems either develop or undergo profound changes.

The scale-covered skin of reptiles decreases the direct absorption of chemical substances from the environment. Some reptiles, however, may be highly sensitive to endocrine disrupting compounds because of their unusual sex determination mechanisms (in some species, sex is not genetically fixed but is determined based on environmental conditions during the incubation period). Reptiles that occupy or frequent aquatic habitats, such as turtles and several species of Garter snakes, may be chronically exposed to pollutants, both directly from the water and indirectly through their prey.

Management practices that can be used to minimize the impacts of contaminants on amphibians and reptiles include the following:

- Contain contaminants through appropriate storm-water and sewage management.

- Trap and filter contaminants from ground water by vegetative buffers and other means before they enter water bodies.

- Eliminate the use of chemicals near pools, ponds, streams, and ditches to safeguard aquatic amphibian breeding habitats. Chemicals that should be restricted near water bodies include herbicides and growth retardants to control vegetation, road salts, fire retardants, and insecticides.

- Adopt integrated pest control methods that reduce reliance on chemical herbicides and insecticides on golf courses, parks, greenways, and on private and municipal lands. Such strategies include increased use of native plants, pest-resistant varieties of exotic plants, and design-features that minimize and confine intensively managed areas, such as turf requirements on golf courses (BC Ministry of Environment, Lands and Parks, Habitat Protection Branch 1994).

- Adopt Best Management Practices for controlling pollutants in urban environments (BC Ministry of Water, Land and Air Protection 2001b).

Check-list:

- Are there initiatives in place to reduce insecticide and herbicide use in target areas; are they working?

- Are the levels of sediments, organic matter, nutrients, insecticides, heavy metals, petrochemicals, surfactants, road salts in run-off and ponds at desired levels? Are they increasing or decreasing?

- Is there a plan in place to identify problems and test water quality for the presence of potential endocrine disruptors? Can amphibians within the project area function as an early warning system of pending contamination problems?

- Is there a monitoring plan in place; is it implemented; are the results summarized periodically; and is there regular reporting on the water quality in amphibian and reptile habitats?

5.3.7 Management of water regimes

The productivity of wetlands is dependent on periodic drawdowns and water fluctuations. Streams and wetlands should be retained no matter how small or ephemeral they may be. Undisturbed terrestrial and emergent vegetation is important for filtration, bank stability, and to slow down runoff.

a) Adopt following management measures to help maintain natural water regimes:

- Avoid draining wetlands, regardless of their size, depth or duration.

- Avoid altering natural water fluctuations of wetlands or channelizing streams; avoid altering stream flows.

- Maintain natural contours and edges of streams and wetlands.

- Avoid channeling water onto impermeable surfaces; this leads to rapid run-off and contamination of wetlands.

- Protect riparian and emergent/submerged vegetation.

- Avoid creating ponds that are potential sink habitats (ie, attract amphibians and reptiles but result in their reduced survival). Deep, permanent water bodies, especially those where the shallow shoreline areas have been lost, are unsuitable to most native amphibian species.

Steep-sided embankments (resulting from dredging to make ponds deeper or to channelize streams) are undesirable.

b) Restore damaged water regimes to improve habitats for reptiles and amphibians (also see Section 5.3.4):

- Repair natural flow-regimes; cases removing drainage ditches or re-contouring channelized streams or altered shorelines of ponds can contribute towards this goal.
- Remove vegetation that may be choking the system.
- Retain native vegetation in shallow shoreline and riparian areas.
- Remove sources of pollutants and sedimentation.

Check-list:

- Are water bodies within and adjacent to the development maintaining their natural hydroperiods?
- Is the diversity of habitats established as desired?
- Do amphibians and reptiles continue using the wetlands?
- Are these populations producing young, and are the young surviving?
- Are steps taken to detect potential problems, such as premature drying of ponds and mortality of amphibian larvae?
- Are natural wetland features retained or restored?
- Is a monitoring plan in place; has it been implemented; are the results summarized periodically; is there regular reporting on the effectiveness of the measures taken?

5.3.8 Controlling access and type of human activities

Amphibian and reptile populations and their habitats can be affected by the overuse of an area by people engaged in recreational activities. Easy access into an area can damage habitats by trampling and erosion. Many amphibians lay their eggs in shallow water zones where people can inadvertently disturb them. Human access can also lead to the introduction of exotic plants and animals, which can have serious impacts on populations of native species (see Section 5.3.9).

Recommendations for limiting access are as follows:

- Locate roads, parking lots, bicycle paths and hiking trails away from sensitive amphibian and reptile habitats, such as breeding ponds, nesting sites, basking areas, denning sites, talus slopes, rock outcrops, and foraging areas.

- Keep focal areas of human activity away from amphibian and reptile habitats to minimize the risk of contact and harassment, and the potential for the introduction of nonnative species (e.g., through release of Bullfrog tadpoles or fish).

- Keep hiking trails narrow to allow amphibians and reptiles and other wildlife to cross them easily. Trails should be maintained to prevent erosion and widening by overuse. Design trail systems so that people are encouraged to stay on the designated trails (e.g., via board walks, chiptrails, fencing, and plantings) and offer viewing positions from a distance (e.g., platforms).

- Keep bicycles, trail bikes, and ATVs away from sensitive areas.

- Post signs near access points to educate the public about the consequences of damaging habitats and disturbing amphibians and reptiles.

- Limit access and density of free-roaming pets; educate the public about the need to keep dogs and cats away from critical wildlife habitats; have strict garbage control so that feral animals or opportunistic predators are not being unintentionally fed or attracted to sensitive habitats.

Check-list:

- Is foot-traffic contained on provided trails?

- Are day-use areas interfering with sensitive habitats?

- Are ATVs and off-road bikes effectively kept out of sensitive areas?

- Are signs effective?

- Are pets kept out of sensitive areas?

- Are garbage bins used by people, and are they secure from opportunistic wildlife?

- Who is monitoring and reporting on the effectiveness of the actions?

5.3.9 Introduced species management and controlling spread of wildlife diseases

Introduced species consist of species not native to the province, species found outside of their native range within the province, and species found within their range but introduced into areas where they have not historically been found. This includes stocked fish (legally or illegally), nonnative amphibians, aquatic, weedy plant species, and released pets (such as Goldfish and exotic turtles). Nonnative species affect amphibians and reptiles through predation and competition for resources, alteration of habitats and community structure, and the introduction of wildlife diseases.

Once a nonnative species has become established, its eradication is very difficult. The best line of defense is a proactive approach that prevents the introduction or spread of nonnative species and wildlife diseases.

Recommendations for preventing the introduction or spread of nonnative species and wildlife diseases are as follows*:*

a) Maintain natural environments and ecosystem processes:

Habitats disturbed by altering water regimes, planting exotic vegetation, or introducing pollutants or sediments, facilitate the spread of weedy alien species. The following measures help reduce the risk of the spread and establishment of nonnative species that threaten native amphibians and reptiles in aquatic habitats.

- Avoid draining ephemeral pond habitats or destroying littoral zone or shoreline areas. Protect ephemeral pond habitats and maintain connectivity among sites through upland areas. Avoid altering the habitat quality of ponds and microhabitats by changing water flow regimes, connectivity among sites, amount of canopy cover, or runoff/water turbidity.

- Avoid creating permanent ponds that cannot be drained. Where artificial ponds are created (for example, on golf courses or in landscaped areas around buildings), design them so that they can be manually drained in winter, and plant native species only.

- At development sites, do not allow water to pool, and/or require that water be constantly drained from sites where it collects during construction, such as at gravel pits and along roadways. Alien species can spread along ditches and where water is allowed to pool.

b) Limit human access to important amphibian and reptile habitats (see also Section 5.3.8)

- Easy access to water bodies for people increases the chance that fish stocking (legal or illegal), the dumping of unwanted pets (such as turtles and Goldfish), and illegal collecting and transfer of nonnative species (such as moving of tadpoles and fish) will occur. This in turn facilitates the spread of wildlife diseases.

- Restrict fishing in amphibian breeding habitats. If angling is permitted, there is a high potential that nonnative species will be introduced through release of bait.

c) Prohibit fish stocking in amphibian and reptile habitats:

- Nonnative fish can have severe impacts on amphibians using permanent wetlands and streams. Reptiles that feed on amphibians are also affected.

d) Do not plant or allow the spread of exotic species of plants within natural areas:

- Introduced plants such as purple loosestrife (*Lythrum salicaria*) and Eurasian water-milfoil out-compete native plant species and can quickly overrun wetland habitats. This reduces the diversity of habitats available to amphibians and reptiles.

e) Block access by nonnative species to aquatic amphibian habitats:

- Where needed, use barriers to prevent access by fish to aquatic habitats.

- Block connectivity of artificial channels that allow or facilitate the spread of fish or Bullfrogs.

f) Display signs or provide brochures:

- Educate the public about illegal capture and release of animals, and the threats that nonnative species pose to native biodiversity (see section 8 for broader education strategies).

g) Implement eradication measures in appropriate circumstances:

- Pond drainage is probably the best method of removing fish and nonnative amphibians from water bodies, especially if the risk for reintroduction via inflow from surrounding areas is low. Physical removal through trapping, netting, and other means may be possible for small areas with no inflow. Chemical treatments have been used in the past but they negatively impact all species and are usually not suitable.

- In small areas, continuous eradication measures can be successful in reducing the abundance of nonnative species.

- Attempting to remove nonnative species, once they have become established, is very time-consuming and has little chance of success where the potential for immigration from surrounding areas is high.

Check-list:

- Is the proportion of native habitats decreasing?

- Are invasive plants monitored and eradicated?

- Are Bullfrogs or nonnative fish present in aquatic habitats used by amphibians and reptiles?
- Is the public informed and involved in maintaining the native environment?
- Are features or structures to combat introduced species working?
- Who is maintaining these features or structures?
- Who is monitoring and reporting on the effectiveness of the actions?

5.3.10 Public education/information program

The likelihood that conservation measures for amphibians and reptiles in urban and rural environments are successful depends on the involvement of local residents and grass-roots groups. The first step is to make people aware of the species present, their value to society and role in ecosystems, their sensitivity and vulnerability to human activities, and the specific conservation measures undertaken in their area. The next step is to provide opportunities for stewardship and involvement in on-the-ground activities; these actions include viewing of wildlife, participation in restoration projects, and monitoring the effectiveness of actions taken. Section 8.0 provides a strategy for promoting public education and stewardship initiatives for amphibians and reptiles at a broad scale in British Columbia.

a) Awareness of amphibians and reptiles

- Display signs and provide pamphlets and self-guided tours in the development area, so promoting the protection of amphibians and reptiles.
- Indicate where additional information on amphibians and reptiles can be found (such as web sites, field guides, and natural history clubs).

b) Participation in conservation initiatives

- Promote residents' participation in restoration projects on the site, in the maintenance of structures (if present), and in adaptive management.
- Work with interested residents to establish stewardship groups. These groups can form partnerships with local governments, natural history groups, and amphibian and reptile conservation programs and organizations (such as Frogwatch and CARCNET). A more complete listing of resources to facilitate stewardship is found in Section 8.

Check-list:

- Are sign and pamphlets being kept up to date?

- Who distributes pamphlets and brochures?
- Who is coordinating resident stewardship programs?
- Who is monitoring and reporting on the effectiveness of the actions?

5.4 Construction Phase

The conservation measures for amphibians and reptiles developed during the Planning and Design Phases (described above) need to be implemented during the Construction and Operational Phases. The construction phase poses several challenges for mitigation because there will be intensive, albeit temporary, human activities involving heavy machinery, loud noises, potential release of contaminants, and disturbance resulting from the presence of numerous workers. The Construction Phase also is the best time to implement conservation measures requiring heavy equipment, including restoration and enhancement, and construction of road crossing systems for wildlife.

a) Avoid contamination and damage to wetlands and terrestrial habitats:

- Avoid damage to habitats and accidental mortality of animals due to activities of construction personnel and machinery (employ BMPs for access control, hydrology, and public education, as described above).
- Avoid pollution, contamination, erosion, unnecessary vegetation removal, and soil compaction.
- Have an emergency response plan in place to contain and clean up accidental spills safely and quickly.

b) Avoid causing mortality and unnecessary disturbance to amphibians and reptiles:

- Areas containing wildlife that are sensitive to sensory disturbances should be off-limits to construction personnel; storage of equipment and materials, as well as parking of vehicles, should take place elsewhere.
- Use temporary fencing to limit access to sensitive habitats.

c) Timing and location of construction:

- Avoid construction activities during periods when amphibians and reptiles are congregated for breeding, nesting, or seasonal migrations; migrations could involve movements of snakes near hibernacula and mating areas in the spring and autumn, migrations of juvenile frogs, toads, and salamanders to foraging habitats in late summer, or movements of turtles to terrestrial nesting sites.

- Do not impinge upon sensitive habitats for amphibians and reptiles, such as wetlands, riparian areas, talus slopes, nest sites, and denning areas.

d) Have an a biologist on site as needed:

- A biologist knowledgeable about amphibians and reptiles and the mitigation plans for the site needs to be present to monitor activities when (a) habitat for these animals is being restored, (b) special structures, such as road crossing tunnel systems are constructed, or (c) when endangered species are expected to occur at the site.

- The biologist will ensure that (a) impacts on reptile and amphibians are minimized, (b) make workers aware of sensitive habitats and how to implement mitigative measures, and (c) oversee and direct possible construction or restoration activities for these groups.

e) Habitat restoration/enhancement:

- Take advantage of heavy equipment in the area and the stockpiling of materials, such as soil, rocks, gravel, and coarse woody debris.

- Adjustments to the restoration plan may be required and should be supervised by the on-site biologist

f) Implement road crossing systems:

- Cost and time requirements are much less if these systems are installed at the same time as new road construction or upgrading.

g) Inform construction workers about the intent of the BMPs and why they are important

Check-list:

- Were critical habitats undisturbed during construction?

- Were the construction workers aware of amphibian and reptile species present in the area and of the relevant BMPs?

- Were there any serious spills? If so, how were they dealt with?

- Was soil unnecessarily compacted? If so, what was done to rectify the situation?

- Were restoration and enhancement actions implemented satisfactorily?

- Who is monitoring and reporting on the effectiveness of the actions?

5.5 Operational Phase

Conservation measures should be fully implemented at the beginning of the operational phase of the development. During this phase, the effectiveness of all measures needs to be monitored and improvements made as follows:

- Employ principles of adaptive management to improve effectiveness of BMPs or to mitigate unforeseen impacts.
- Maintain structures used to protect amphibians and reptiles.
- Engage in ongoing habitat restoration, where required.
- Monitor quality of aquatic and terrestrial habitats.
- Engage in ongoing control of nonnative species.
- Engage in ongoing public education and encourage stewardship activities.

Check-list:

- Are the experiences incorporated into refinement of management practices on an ongoing basis?
- Are all structures (such road crossing tunnel systems or fences) maintained?
- Who is responsible for ongoing public education?
- Were restoration and enhancement actions implemented satisfactorily?
- Who is monitoring and reporting on the effectiveness of the actions?

6 Regional BMPs

The ecological principles of amphibian and reptile management and specific protection measures and best practices (BMPs) that apply to land development in most urban and rural areas of the province are described in detail in Section 5. This section shows how BMPs can be applied to each region of the province by describing the species and habitats present, important factors limiting populations, and the major threats and special issues pertaining to the conservation of amphibians and reptiles. Several focal species are highlighted (colour coded) in each region because they are rare or endangered (red and blue), occur nowhere else (yellow), or are widespread and particularly amenable to management practices. Status reports and recovery strategies are available, or are in preparation, for a number of species of amphibians and reptiles at risk (COSEWIC http://www.cosewic.gc.ca/index.htm).

For a brief overview of the distribution of amphibians and reptiles in British Columbia, a list of the species indicating whether they are native, introduced, or extirpated can be found in Table 2. For more detailed information about the occurrence and abundance of each species, see Appendix 1 (Species Accounts).

Table 2: Occurrence of amphibians and reptiles in the MWLAP's regions.

Highlighted common names indicate that the species is on the provincial red- or blue list of species at risk.

Common Name	Vancouver Island	Lower Mainland	Okanagan	Thompson	Kootenay	Cariboo	Skeena	Omineca	Peace	*Scientific Name*
Salamanders:										
Rough-skinned Newt	X	X				X	X			*Tricha granulosa*
Long-toed Salamander	X	X	X	X	X	X	X	X	X	*Ambystoma macrodactylum*
Northwestern Salamander	X	X					X			*Ambystoma gracile*

Common Name	Vancouver Island	Lower Mainland	Okanagan	Thompson	Kootenay	Cariboo	Skeena	Omineca	Peace	Scientific Name
Tiger Salamander			X							*Ambystoma tigrinum*
Coastal (= Pacific) Giant Salamander		X								*Dicamptodon tenebrosus*
Western Red-backed Salamander	X	X								*Plethodon vehiculum*
Coeur d'Alene Salamander					X					*Plethodon idahoensis*
Ensatina	X	X								*Ensatina eschscholtzii*
Wandering (= Clouded) Salamander	X									*Aneides vagrans*
Frogs:										
Rocky Mountain Tailed Frog					X					*Ascaphus montanus*
Coastal Tailed Frog	X	X				X	X			*Ascaphus truei*
Great Basin Spadefoot			X	X						*Spea intermontana*
Western Toad	X	X	X	X	X	X	X	X	X	*Bufo boreas*
Pacific Treefrog	X	X		X	X	X	I	X		*Pseudacris (= Hyla) regilla*
Boreal (= Striped) Chorus Frog						X			X	*Pseudacris maculate (= triseriata)*
Red-legged Frog	X	X					I			*Rana aurora*
Wood Frog			X	X	X	X	X	X	X	*Rana sylvatica*
Columbia			X	X	X	X	X	X	X	*Rana luteiventris*

Spotted Frog										
Common Name	**Vancouver Island**	**Lower Mainland**	**Okanagan**	**Thompson**	**Kootenay**	**Cariboo**	**Skeena**	**Omineca**	**Peace**	*Scientific Name*
Oregon Spotted Frog		X								*Rana pretiosa*
Northern Leopard Frog	I		EX		X					*Rana pipiens*
Green Frog*	I	I								*Rana clamitans*
Bullfrog*	I	I	I							*Rana catesbeiana*
Turtles:										
Painted Turtle	X	X	X	X	X	I				*Chrysemys picta*
Western Pond Turtle		EX								*Clemmys marmorata*
Slider*	I	I								*Trachemys scripta*
Lizards:										
Northern Alligator Lizard	X	X	X	X	X	X				*Elgaria coerulea*
Western Skink			X	X						*Eumeces skiltonianus*
Pigmy Short-horned Lizard			EX							*Phrynosoma douglassi*
European Wall Lizard*	I									*Podarcis muralis*
Snakes:										
Rubber Boa		X	X	X	X	X				*Charina bottae*
Sharp-tailed Snake	X									*Contia tenuis*
Racer			X	X						*Coluber constrictor*
Gopher Snake (coastal)	EX	EX								*Pituophis catenifer catenifer*

Common Name	Vancouver Island	Lower Mainland	Okanagan	Thompson	Kootenay	Cariboo	Skeena	Omineca	Peace	*Scientific Name*
Gopher Snake (interior)			X	X						*Pituophis catenifer deserticola*
Common Garter Snake	X	X	X	X	X	X	X	X	X	*Thamnophis sirtalis*
Northwestern Garter Snake	X	X				X				*Thamnophis ordinoides*
Western Terrestrial Garter Snake	X	X	X	X	X	X	X		X	*Thamnophis elegance*
Night Snake			X							*Hypsiglena torquata*
Western Rattlesnake			X	X						*Crotalus viridis*

X = species occur in the region
I = introduced*
EX = extirpated

6.1 Region 1: Vancouver Island

The Vancouver Island region consists of Vancouver Island itself and a small strip of the mainland coast adjacent to northeastern part of the island. This region encompasses a variety of habitats ranging from icy peaks to temperate rainforests, and arid landscapes. Most precipitation occurs during the winter, and the summer is typically dry and warm. The mountainous spine of Vancouver Island has a marked influence on climate. The western and northern parts of the island have a wet climate and contain moist temperate rainforests, dominated by western redcedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis*), and western hemlock (*Tsuga heterophylla*). The mainland portion of the region contains similar forests. Southeast of the mountainous spine of the island, old-growth Douglas-fir (*Pseudotsuga menziesii*) forests once dominated the landscape, but only small remnants of these forests are left. Threatened Garry oak (*Quercus garryana*) ecosystems with many rare plants are found at lower elevations along the southeastern coast of Vancouver Island and on the Gulf Islands.

a) Composition of amphibian and reptile faunas of this region:

- 10 native and 3 introduced species of amphibians (Table 2)

- 6 native and 2 introduced species of reptiles (1additional species of native reptile is extirpated from this region) (Table 2)
- Red-listed species: Sharp-tailed Snake, Gopher Snake (coastal populations; extirpated)
- Blue-listed species: Coastal Tailed Frog (mainland portion of the region only), Red-legged Frog, Painted Turtle
- Species unique to Region 1: Sharp-tailed Snake, Wandering Salamander
- Additional species with core areas (much of BC population) in Region 1: Western Red-backed Salamander, Red-legged Frog, Ensatina (*Ensatina eschscholtzii*), Northwestern Garter Snake

b) Main threats to amphibians and reptiles in urban/rural areas:

- Habitat loss and alteration
- Introduction of nonnative species

Urbanization on the east coast of Vancouver Island and the Gulf Islands poses a threat to the endangered Sharp-tailed Snake, in particular, but also to local populations of other amphibian and reptiles. Introduction of nonnative species is a growing problem in this region, particularly on southeastern Vancouver Island. The introduced Bullfrog has spread along the east coast of Vancouver Island, posing a major threat to pond-breeding amphibians; the introduced European Wall Lizard around Victoria could potentially threaten the native Northern Alligator Lizard. Nonnative fish has been widely introduced into lakes and ponds as well.

c) *Habitat protection and restoration practices for red- and blue-listed species:*

- **Sharp-tailed Snake** has a very localized distribution on southern Gulf Islands and southeastern Vancouver Island. This species is compatible with low-density developments: it is small, harmless, and non-threatening, and can tolerate some human activities and habitat alteration. Even if the species is not found, care should be taken with all construction activities that take place in potential habitats within the species' range; these snakes are very secretive and seldom seen, even when present. A RENEW Recovery Strategy is in progress and contains detailed habitat protection guidelines for this species. The following BMPs are applicable within the range of this species:
    - Protect south-facing rocky slopes within small forest openings from development and trampling
    - Avoid routing roads or bicycle trails at the base of such slopes

  - If this species is found, please notify the Conservation Data Centre (http://srmwww.gov.bc.ca/cdc/)

- **Coastal Tailed Frog** occupies the mainland portion of this region. This species inhabits forested, fast-flowing, clear and cool streams and adjacent riparian areas.
  - Tadpoles are relatively easy to find, clinging to rocks, and surveys should focus on this life-history phase.
  - BMPs for stream-dwelling amphibians are recommended for this species (see Section 5.1-Summary on page 66).
  - Additional information on habitat protection measures for this species can be found at the Identified Wildlife, MWLAP (2003) website http://wlapwww.gov.bc.ca/wld/identified/.
- **Red-legged Frog** is widespread in forests throughout this region but may be declining. Region 1 supports a large portion of the provincial population. The following BMPs are applicable within the range of this species:
  - Protect wetland breeding habitats using practices described in Section 5.3.3 on page 70.
  - Provide connectivity between terrestrial forest habitats and aquatic breeding sites (see Section 5.3.3).
  - Additional information on habitat protection measures for this species can be found at the Identified Wildlife, MWLAP (2003) website http://wlapwww.gov.bc.ca/wld/identified/.

d) Widespread, compatible species:

The following species are relatively compatible with urban developments and should respond favourably to habitat protection and restoration efforts:

- Pacific Treefrog (see BMPs pond-breeding amphibians in Section 5.1-Summary on page 66).
- Northwestern Garter Snake, Common Garter Snake, Western Terrestrial Garter Snake, Northern Alligator Lizard (see BMPs for lizards in Section 5.1-Summary on page 67).

e) Additional issues:

- **Western Toad and Rough-skinned Newt** are vulnerable to road mortality during seasonal migrations. Use BMPs described in Section 5.3.5 on page 77.
- **Wandering Salamander** is found only on Vancouver Island and some of the Gulf Islands. It can survive in urban and rural environments provided that abundant downed logs with loose bark and other moist coarse woody debris are retained.

- Take actions to reduce the spread of introduced Bullfrogs, nonnative fish, and other introduced species (see BMPs in Section 5.3.9 on page 83).

6.2 Region 2: Lower Mainland

The Lower Mainland region covers the western slopes of the Coast Mountains from the United States border to north of Bute Inlet and includes a variety of habitats ranging from rock and ice to highly productive temperate rainforest at lower elevations. Western hemlock, western redcedar, and Douglas-fir are dominant tree-species in coastal rainforests of this region. In the south, the Fraser River forms an extensive flat-bottomed valley and delta, which contains most of the human population of the region. Bogs and marshes were once abundant on this floodplain, but most wetlands have been diked and drained since the 1940s. Much of the valley bottom has been converted into farmland and urban developments (Cannings and Cannings 1996).

a) Composition of amphibian and reptile faunas of this region:

- 11 native and 2 introduced species of amphibians (Table 2)
- 6 native and 1 introduced species of reptiles (2 additional species of native reptiles are extirpated from this region) (Table 2)
- Red-listed species: Oregon Spotted Frog, Coastal Giant Salamander, Western Pond Turtle (extirpated), Gopher Snake (coastal populations; extirpated)
- Blue-listed species: Coastal Tailed Frog, Red-legged Frog, Painted Turtle
- Species unique to Region 2: Oregon Spotted Frog, Coastal Giant Salamander

b) Main threats to amphibians and reptiles in urban/rural areas:

- Habitat loss and alteration
- Draining and filling of wetlands
- Pollution from agricultural areas
- Introduction of nonnative species

Almost 50% of the population of British Columbia lives in the Lower Fraser Valley. Vancouver is the fastest growing city in Canada (City of Vancouver 2003). Consequently, natural areas on the Lower Mainland have been greatly modified and fragmented. Habitat loss and alteration associated with urban expansion onto mountain- and hillsides are a growing threat to forest-dwelling species. Introduced Bullfrogs occur in many wetlands and pose a threat to native amphibians.

c) *Habitat protection and restoration practices for red- and blue-listed species:*

- **Oregon Spotted Frog** populations have declined throughout the species' range in North America, and this species is very rare. Its Canadian distribution is restricted to a small area of the Fraser Valley. The following recommendations apply to this species:
    - Wetland habitats where this species occurs should be protected, and developments should be located away from these areas.
    - If this species is found, please notify the Conservation Data Centre (http://srmwww.gov.bc.ca/cdc/)

- **Coastal Giant Salamander** is restricted to the Chiliwack River watershed and adjacent smaller drainages. This is the only place in Canada where the species occurs. These salamanders inhabit cool, clear forest streams and adjacent riparian areas.
    - BMPs for stream-dwelling amphibians are recommended for this species (see Section 5.1-Summary on page 66).
    - If this species is found, please notify the Conservation Data Centre (http://srmwww.gov.bc.ca/cdc/)
    - Additional information on habitat protection measures for this species can be found at the Identified Wildlife, MWLAP (2003) website http://wlapwww.gov.bc.ca/wld/identified/.

- **Coastal Tailed Frog** occurs in moist forests within this region. It inhabits fast-flowing, clear streams and adjacent forested riparian areas.
    - Tadpoles are relatively easy to find, clinging to rocks, and surveys should focus on this life-history phase.
    - BMPs for stream-dwelling amphibians are recommended for this species (see Section 5.1 on page 66).
    - Additional information on habitat protection measures for this species can be found at the Identified Wildlife, MWLAP (2003) website http://wlapwww.gov.bc.ca/wld/identified/.

- **Red-legged Frog** is widespread in forested habitats within this region but may be declining. The following BMPs are applicable within the range of this species:
    - Protect wetlands and streams using practices described in Section 5.3.3 on page 70.
    - Provide connectivity between terrestrial forest habitats and aquatic breeding sites (see Section 5.3.3 on page 70)

d) Widespread, compatible species:

The following species are relatively compatible with urban developments and should respond favourably to habitat protection and restoration efforts:

- Pacific Treefrog (see BMPs for pond-breeding amphibians in Section 5.1-Summary on page 66)
- Northwestern Garter Snake, Common Garter Snake, Western Terrestrial Garter Snake, Northern Alligator Lizard (see BMPs in Section 5.1-Summary on page 67)

e) Additional issues:

- **Western Toad and Rough-skinned Newt** are vulnerable to road mortality during seasonal migrations. Use BMPs described in Section 5.3.5 on page 77.
- Take actions to reduce the spread of Bullfrogs, nonnative fish, and other introduced species (see BMPs in Section 5.3.9 on page 83).
- Undisturbed riparian and forested habitats are becoming highly fragmented in the Fraser Valley. Use BMPs that address landscape connectivity among fragmented wetlands, riparian zones along creeks, and patches of moist forested habitat (see Section 5.3.3 on page 70).
- Poor water quality, channelization of streams, and alteration of water regimes have a major impact on wetland habitats. Use BMPs that prevent contamination of wetlands (Section 5.3.6 on page 79) and maintain appropriate water fluctuations (Section 5.3.7 on page 81).

6.3 Regions 3 and 8: Thompson and Okanagan

The Thompson-Okanagan area has a high diversity of ecosystems, encompassing at least eight different biogeoclimatic zones. Open ponderosa pine (*Pinus ponderosa*) forest and grasslands dominate the landscape at lower elevations (Habitat Atlas for Wildlife at Risk South Okanagan and Lower Similkameen). At mid-elevations in the Interior Douglas-fir zone, open stands of Douglas-fir, ponderosa pine and lodgepole pine (*Pinus contorta*) predominate. At higher elevations lodgepole pine forests are widespread and larch (*Larix* species) forest can be found in the Eastern Shuswap. Waterbodies are scattered throughout the region and range from large lakes to small alkaline ponds. Wetlands are relatively rare and very productive habitats in the dry grassland ecosystems at low elevations.

The open ponderosa pine and grassland ecosystems are fire-adapted and influenced by dry, hot summers and mild winters. Native grasslands are dominated by perennial grasses, scattered bushes, and crusts of lichens and mosses. The grassland ecosystems can be divided into the Upper, Middle and Lower Grasslands (Cannings and Cannings 1996). The Lower Grassland (also called the shrub-steppe) is dominated by big sagebrush (*Artemisia* *tridentata*) and bluebunch wheatgrass (*Pseudoroegneria spicata*) communities. The rare antelope-brush (*Purshia tridentate*) community is found in the southern Okanagan Valley. The Middle Grassland is dominated by prairie sagewort (*Artemisia frigida*), common rabbit-brush (*Ericameria nauseosus*), and junegrass (*Koeleria macrantha*). Above 800 m, the Upper Grassland is dominated by bluebunch wheatgrass and different species of Fescues. This ecosystem is the wettest of the grasslands and is rich in wildflowers.

The Thompson-Okanagan region supports a high diversity of reptiles and amphibians and several rare and unique species are present. Many of the species found south of the United States border occur at the northern extremity of their distribution here. Reptiles in particular thrive in the relatively arid ecosystems. The Southern Interior Reptile and Amphibian Recovery Action group has been established to develop recovery strategies for the Western Rattlesnake, Gopher Snake, Night Snake, Tiger Salamander, and Great Basin Spadefoot. Detailed management practices and guidelines will be available from this Action group.

a) Composition of amphibian and reptile faunas of this region:

- 7 native and 1 introduced species of amphibians (1 additional native species is extirpated)
- 10 native species of reptiles (1 additional native species is extirpated)
- Red-listed species: Tiger Salamander, Northern Leopard Frog (extirpated); Night Snake, Pigmy Short-horned Lizard (extirpated)
- Blue-listed species: Great Basin Spadefoot, Painted Turtle, Racer, Gopher Snake, Western Rattlesnake
- Species unique to Regions 3 or 8: Tiger Salamander, Great Basin Spadefoot, Western Skink (*Eumeces skiltonianus*), Racer, Gopher Snake, Night Snake, Western Rattlesnake

b) Main threats to amphibians and reptiles in urban/rural areas:

- Habitat loss and alteration
- Draining of wetlands

The dry grasslands and open pine forests of this region are some of the most threatened ecosystems in British Columbia. The rapidly expanding wine industry, agriculture, recreational developments, and urban development are the main threats to natural habitats. The antelope-brush community is particularly threatened due to its location in the southern Okanagan, a highly desired human settlement area because of climate..

Many wetlands have been drained or filled in for urban development, roads, or agricultural purposes. Where waterbodies have been retained, the riparian zones have been often severely degraded, affecting many species of amphibians and reptiles.

c) *Habitat protection and restoration practices for red- and blue-listed species:*

- **Tiger Salamander** occurs in the arid bunchgrass and Ponderosa Pine habitats in the Okanagan. It uses wetlands for breeding; juveniles and adults forage in adjacent riparian areas. Degradation of wetlands and their margins is a major threat to salamanders. The following BMPs are applicable within the range of this species:
  - Use buffer zones around wetlands (see Section 5.3.3 on page 70)
  - Use fencing to prevent trampling of shoreline areas by people or animals
  - Avoid the introduction of sport fish into permanent lakes and ponds occupied by these salamanders
  - Avoid using water from wetlands for irrigation or water required for development areas
  - Where appropriate, use fencing around swimming pools, or use raised edges (above ground level), to guard against amphibians seeking moisture and drowning in chlorinated pools
  - If this species is found, please notify the Conservation Data Centre (http://srmwww.gov.bc.ca/cdc/)

- **Night Snake** is secretive, nocturnal, and extremely rare. It probably has a low compatibility with urban and rural environments. It may be confused with young rattle snakes. These rear-fanged, venomous, small snakes pose little threat to people; the venom has to be applied by "chewing" and is not known to be toxic to humans. The following BMPs are applicable:
  - To avoid interactions with humans, remove rocks and other cover form areas where snakes are not wanted.
  - Educate residents about the beneficial role snakes play in the ecosystem as consumers of insects and rodents. Educate them about the rarity and uniqueness of this species and the need to protect and not kill snakes.
  - Additional information on habitat protection measures for this species can be found at the Identified Wildlife, MWLAP (2003) website http://wlapwww.gov.bc.ca/wld/identified/.

- **Great Basin Spadefoot** occupies semi-arid grasslands, shrubby areas, open woodlands in both the Thompson and Okanagan regions. It occupies mainly ephemeral wetlands and is able to breed and complete its development very rapidly. The species is vulnerable to the modification of ephemeral wetlands and terrestrial habitats with soil suitable for burrowing. The following BMPs are applicable within the range of this species:

- Conduct surveys at appropriate times of the year, so that small ephemeral wetlands and pools are identified
- Maintain undisturbed buffer zones adjacent to ephemeral wetlands occupied by this species
- Provide areas with sandy substrates for burrowing; these animals are unable to burrow through gravel or turf
- Where appropriate, use fencing to protect ephemeral ponds and surrounding riparian habitats
- Where appropriate, use fencing around swimming pools, or use raised edges (above ground level), to guard against amphibians seeking moisture and drowning in chlorinated pools
- Use BMPs for pond-breeding amphibians to control pollution and to provide habitat connectivity (see Sections 5.3.6 on page 79 and 5.3.3 on page 70).

- **Painted Turtle** occupies a variety of permanent water bodies in both the Thompson and Okanagan regions. This species is compatible with urban and rural developments, provided that appropriate protection measures are taken, such as protecting upland nesting areas. See Section 5.1-Summary on page 66 for BMPs applicable for this species.

- Western Rattlesnake, Racer, and Gopher Snake. These large snakes occupy arid zones in both the Thompson and Okanagan regions. The Western Rattlesnake is venomous. It has a low compatibility with urbanization because it requires large areas and is often persecuted. The Racer and Gopher Snake are harmless to people, but because they often induce fear and may be mistaken for rattlesnakes and killed, they are also deemed largely incompatible. The following BMPs are applicable within the range of the Western Rattlesnake:
    - Avoid locating infrastructure or roads near potential denning areas such as south-facing talus slopes; plan them at a landscape scale in conjunction with biological information (such as SEI mapping and species capability mapping). Confirmed den sites should be protected by a large buffer of undisturbed vegetation and avoided entirely.
    - Where the above sites cannot be set aside, local governments should zone them for low-density developments only. Cluster housing developments located as far as possible from these sites is also an option.
    - These snakes are highly mobile, and road-crossing structures should be considered if movement corridors are detected near roads (see Section 5.3.9 on page 83).

- o Snake-proof fences can be erected around high-density urban developments to prevent contact. The fences should lead snakes back towards undisturbed habitats.
- o To avoid interactions with humans, remove rocks and other cover types from areas where snakes are not wanted. These cover objects can be re-located to other portions of the property where snakes might be welcome.
- o Leave portions of the development area undisturbed and route trails away from these natural areas to minimize encounters that can result in the killing of snakes.
- o In municipalities with high numbers of human-snake encounters, trained rescue personnel should be available to safely capture and re-locate snakes that are reported to be endangering the public. Snakes should be relocated within the same general area (e.g., within 1 – 2 km) of the capture site, to increase their probability for survival.
- o Educate residents about the beneficial role snakes play in the ecosystem as consumers of insects and rodents and on ways to avoid interactions.
- o Additional information on habitat protection measures for these species can be found at the Identified Wildlife, MWLAP (2003) website http://wlapwww.gov.bc.ca/wld/identified/.

d) Widespread, compatible species:

The following species are relatively compatible with urban developments and should respond favourably to habitat protection and restoration efforts:

- Pacific Treefrog and Long-toed Salamander (see BMPs for pond-breeding amphibians in Section 5.1-Summary on page 66).
- Northern Alligator Lizard, Western Skink, Common Garter Snake, and Western Terrestrial Garter Snake (see BMPs in Section 5.1-Summary on page 67).
- Painted Turtle (see above).

e) Additional issues:

- Take action to reduce the spread of introduced Bullfrogs, nonnative fish, and other introduced species (see BMPs in Section 5.3.9 on page 83).

6.4 Region 4: Kootenay

This region encompasses the southeastern portion of British Columbia and contains several mountain ranges including the western slopes of the Rocky Mountains and the Columbia Mountains. These ranges are divided by flat-bottomed valleys, including the Rocky Mountain and East Kootenay

Trenches, which contain valuable wildlife habitat. The region has a diverse array of ecosystems, including seven distinct biogeoclimatic zones. Vegetation ranges from inland temperate rain forest to remnants of grasslands. The valley bottoms contain extensive wetlands and forested floodplain habitats, and open ponderosa pine forest. Lower valley slopes contain open forests of Douglas-fir, ponderosa pine, and lodgepole pine, interspersed with grasslands. In wetter parts of the interior Douglas-fir forest, western larch (*Larix occidentalis*) dominates early successional stages. Engelmann spruce (*Picea engelmannii*)-subalpine fir (*Abies lasiocarpa*) forest can be found at higher elevations.

a) Composition of amphibian and reptile faunas of this region:

- 8 native species of amphibians (Table 2)
- 5 native species of reptiles (Table 2)
- Red-listed species: Rocky Mountain Tailed Frog, Northern Leopard Frog
- Blue-listed species: Coeur d'Alene Salamander, Painted Turtle
- Species unique to Region 4: Coeur d'Alene Salamander, Rocky Mountain Tailed Frog, Northern Leopard Frog

b) Main threats to amphibians and reptiles in urban/rural areas:

- Loss and alteration of grasslands and valley bottom habitats
- Draining of wetlands
- Road mortality

The main activities affecting amphibians and reptiles in this region are agriculture, forestry, mining, hydro-electric impoundments, and recreational developments. Urbanization is largely restricted to valley bottoms. The grasslands and valley bottom wetland habitats are threatened by human activities, as also is the case in other parts of southern British Columbia. Extensive road mortality has been reported for Western Toads at Summit Lake Provincial Park, east of Nakusp (P. Ohanjanian. pers. comm.), and Painted Turtles around Cranbrook, Revelstoke, and Argenta (R. Clarke, pers. comm.).

c) *Habitat protection and restoration practices for red- and blue-listed species:*

- Northern Leopard Frog was once widespread in the East Kootenays, but is now restricted to the Creston area. A RENEW Recovery Strategy has been prepared for this species and contains detailed management practices. The following BMPs are applicable:

- Wetland breeding habitats used by this species should be protected, and developments located away from these sites.
- Where migration movements cross roads near a development, use BMPs described in Section 5.3.5 on page 77, to reduce road mortality.
- If this species is found, please notify the Conservation Data Centre (http://srmwww.gov.bc.ca/cdc/)

- Rocky Mountain Tailed Frog is found only in this region. This species inhabits forested, fast-flowing, clear streams and adjacent riparian areas. Detailed management guidelines for this species have been prepared by Ascaphus Consulting (2002). The following BMPs are applicable:
  - Tadpoles are relatively easy to find, clinging to rocks, and surveys should focus on this life-history phase.
  - BMPs for stream-dwelling amphibians are recommended for this species (see Section 5.1-Summary on page 66).
  - Additional information on habitat protection measures for this species can be found at the Identified Wildlife, MWLAP (2003) website http://wlapwww.gov.bc.ca/wld/identified/.
- Coeur d'Alene Salamander is unique to the Kootenay region, where it has a scattered distribution pattern. These salamanders are deemed to have a low compatibility with urban and rural environments because of their specialized habitat needs and the fragile nature of those environments. They are associated with moist, rocky sites, such as seepages, caves, moist talus, and stream sides. Suitable sites may be very small, and it is important that they are identified and recognized before construction. The following BMPs are applicable:
  - Avoid locating developments or infrastructure where rocky, moist habitats for these salamanders are present.
  - Be careful when siting quarries where roads pass through karst landscapes, or where caves or seepage areas may be disturbed.

- **Painted Turtle** is widespread within this region and occupies a variety of permanent water bodies. This species is relatively compatible with urban and rural developments, provided that appropriate protection measures are taken, such as buffering upland nesting sites. See Section 5.1-Summary on page 66 for BMPs applicable for this species.

d) Widespread, compatible species:

The following species are relatively compatible with urban developments and should respond favourably to habitat protection and restoration efforts:

- **Rubber Boa** is widespread within the region and probably moderately compatible with urban and rural environments. This attractive, harmless snake is secretive and seldom seen. The following BMPs are applicable:

- Maintain abundant cover, such as moist, downed wood, bark, flat rocks, and talus
- Avoid soil compaction; it reduces the availability of soft soils for nesting.
- Additional information on habitat protection measures for this species can be found at the Identified Wildlife, MWLAP (2003) website http://wlapwww.gov.bc.ca/wld/identified/.

- Pacific Treefrog (see BMPs for pond-dwelling amphibians in Section 5.1-Summary on page 66)
- Northern Alligator Lizard, Common Garter Snake, and Western Terrestrial Garter Snake (see BMPs in Section 5.1-Summary on page 67)

e) Additional issues:

- **Western Toad** is vulnerable to road mortality during seasonal migrations. Use BMPs described in Section 5.3.5 on page 77.
- Take actions to reduce the spread of nonnative fish and other introduced species (see BMPs in Section 5.3.9 on page 83).

6.5 Region 5: Cariboo

This region covers an area from the west coast to the Cariboo Mountains in the east. To the west, moist temperate rain forest stands dominate the landscape. Common tree-species are western hemlock and western redcedar. To the east, the Coastal Mountains create a rain shadow on the Chilcotin Plateau; lodgepole pine stands are predominant in this area, and montane forests with Douglas-fir and ponderosa pine also occur here. Grasslands penetrate into the southeast corner of the region. Sub-boreal spruce (*Picea* species) forests occur in northern sections. Engelmann spruce-sub-alpine fir forests are present at higher elevations and on the western slopes of the Cariboo Mountains.

The Cariboo Region contains important wetland habitats for amphibians and reptiles, including abundant permanent and temporary ponds and shallow margins of lakes. The human population of the Cariboo region is relatively small, and urban and rural land development influences a small proportion of the range of amphibians and reptiles that occur within the region. The main impacts on wildlife habitats are from forestry, ranching, and hydroelectric developments. However, urbanization can have localized effects on populations of amphibians and reptiles.

a) Composition of amphibian and reptile faunas of this region:

- 8 native species of amphibians (Table 2)

- 5 native and 1 introduced species of reptiles (Table 2)
- Blue-listed species: Coastal Tailed Frog

b) Main threats to amphibians and reptiles in urban/rural areas:

- Habitat loss and alteration in productive, valley bottom areas
- Draining or altering wetlands

c) *Habitat protection and restoration practices for blue-listed species:*

- **Coastal Tailed Frog** occurs in moist forests within the coastal portion of this region. It inhabits fast-flowing, clear streams and adjacent forested riparian areas.
    - Tadpoles are relatively easy to find, clinging to rocks, and surveys should focus on this life-history phase.
    - BMPs for stream-dwelling amphibians are recommended for this species (see Section 5.1-Summary on page 66).
    - Additional information on habitat protection measures for this species can be found at the Identified Wildlife, MWLAP (2003) website http://wlapwww.gov.bc.ca/wld/identified/.

d) Widespread, compatible species:

The following species are relatively compatible with urban developments and should respond favourably to habitat protection and restoration efforts:

- Pacific Treefrog, which occurs in the Fraser Valley (use BMPs for pond-breeding amphibians in Section 5.1-Summary on page 66)
- Northern Alligator Lizard, which occurs in the Fraser Valley and possibly in the Bella Coola area (use BMPs in Section 5.1-Sumamry on page 67)
- Common Garter Snake and Western Terrestrial Garter Snake, which are widespread within the region (use BMPs in Section 5.1, as above)

e) Additional issues:

- Protect important wetland breeding habitats of the Western toad, Columbia spotted frog, and Wood frog (use BMPs in Section 5.3.3 on page 70). Very large concentrations of these frogs gather at breeding sites that can be source populations for vast areas. A few productive breeding sites may sustain local and regional populations of these species.
- Protect hibernacula of Garter snakes; Garter snakes often hibernate communally in northern environments, and suitable sites may be in short supply. Use BMPs in Section 5.3.3 on page 70).

- Restrict activities that alter or disturb shallow, seasonal pools along beaches; such pools provide important breeding habitat for the Western Toad.
- Mitigate road mortality of amphibians (such as the Western Toad) and Garter snakes that undertake seasonal mass migrations. Land developments that intersect seasonal travel routes or occur adjacent to snake hibernacula should ensure that roads are placed away from these areas and that road mortality is addressed. Use BMPs described in Section 5.3.5 on page 77.
- Take actions to reduce the spread of nonnative fish and other introduced species (see BMPs in Section 5.3.9 on page 83).

6.6 Region 6: Skeena

Habitats in this region include coastal temperate rain forest, dominated by western redcedar, western hemlock, and Sitka spruce. Mountain hemlock (*Tsuga mertensiana*) and subalpine fir dominate higher elevation forests. Floodplains contain dense stands of spruce, cottonwood, and alder (*Alnus* species), and often have an abundant shrub layer. The eastern portion of the region is within the Sub-boreal spruce zone, with extensive white spruce (*Picea glauca*) and subalpine fir stands. Lodgepole pine, birch (*Betula* species), and aspen are also common.

Logging, mining and, to a lesser extent, agriculture are the main threats to amphibian and reptile habitats. Fish stocking of lakes that were naturally fish-free probably has adverse effects on local aquatic amphibian faunas (B. Slough, pers. com. 2003). Urban development is restricted to portions of the region, but can affect local populations of amphibians and reptiles.

Coastal habitats are important to a diversity of amphibians due to the relatively mild climate. This allows species such as the Rough-skinned Newt and Northwestern Salamander to extend their ranges northward. Northern distributional limits are poorly known for a number of species, including the Ensatina that was only recently confirmed for this region. Surveys in the coastal forests may reveal the presence of other, undocumented species as well.

The Queen Charlotte Islands (Haida Gwaii) have a depauperate amphibian fauna. The Western toad is the only native amphibian. The Pacific treefrog has been introduced and is now well-established; the Red-legged frog was only recently documented from the islands and is probably introduced. There are no reptiles on the islands.

a) Composition of amphibian and reptile faunas of this region:

- 7 native and 2 introduced species of amphibians (Table 2)
- 2 native species of reptiles (Table 2)

- Blue-listed species: Coastal Tailed Frog

b) Main threats to amphibians and reptiles in urban/rural areas:

- Habitat loss and alteration
- Draining or altering wetlands

c) *Habitat protection and restoration practices for blue-listed species:*

- **Coastal Tailed Frog** occurs in moist forests within the coastal portion of this region. It inhabits fast-flowing, clear streams and adjacent forested riparian areas.
    - Tadpoles are relatively easy to find, clinging to rocks, and surveys should focus on this life-history phase.
    - BMPs for stream-dwelling amphibians are recommended for this species (see Section 5.1-Summary on page 66).
    - Additional information on habitat protection measures for this species can be found at the Identified Wildlife, MWLAP (2003) website http://wlapwww.gov.bc.ca/wld/identified/.

d) Widespread, compatible species:

The following species are relatively compatible with urban developments and should respond favourably to habitat protection and restoration efforts:

- Common Garter Snake and Western Terrestrial Garter Snake, which are widespread within the region (see BMPs in Section 5.1-Summary on page 67)
- Northwestern Salamander and Rough-skinned Newt, which are moderately compatible with urban and rural developments, provided that moist forests with abundant coarse woody debris and wetland breeding habitats are available.

e) Additional issues:

- Protect important wetland breeding habitats of the Western toad, Columbia spotted frog, and Wood frog (use BMPs in Section 5.3.3 on page 70). Very large concentrations of these frogs gather at breeding sites that can be source populations for vast areas. A few productive breeding sites may sustain local and regional populations of these species.
- Protect hibernacula of Garter snakes; Garter snakes often hibernate communally in northern environments, and suitable sites may be in short supply. Use BMPs in Section 5.3.3 on page 70).

- Restrict activities that alter or disturb shallow, seasonal pools along beaches; such pools provide important breeding habitat for the Western Toad.
- Mitigate road mortality of amphibians (such as the Western Toad) and garter snakes that undertake seasonal mass migrations. Land developments that intersect seasonal travel routes or occur adjacent to snake hibernacula should ensure that roads are placed away from these areas and that road mortality is addressed. Use BMPs described in Section 5.3.5 on page 77.
- Take actions to reduce the spread of nonnative fish and other introduced species (see BMPs in Section 5.3.9 on page 83).

6.7 Regions 7 and 9: Omineca and Peace

The Peace Region of northeastern British Columbia is a land of extremes. The winter is influenced by arctic air masses, and the summers are hot. The taiga plains contain vast boreal forests with numerous bogs and fens. Further south, along the Peace River, grasslands and extensive stands of trembling aspen (*Populus tremuloides*) are found. To the west, the northern Rocky Mountain region contains extensive areas of alpine tundra, coniferous forest at mid-elevations, and mixed wood forest and grasslands at lower elevations. There are no large lakes on the taiga plain, but small lakes are abundant. The wetlands include black spruce (*Picea mariana*) bogs. Muskeg is another common landscape feature with open stands of black spruce and tamarack (*Larix laricina*).

The Omineca Region lies mainly within the Sub-boreal Interior and Northern Boreal Mountains Ecoprovinces, and contains dense coniferous forests. Common tree species include hybrid white spruce (*Picea engelmannii x glauca*), subalpine fir, black spruce and lodgepole pine. Aspen and birch are common seral species and cottonwood is found in floodplain habitats.

The amphibian and reptile diversity of northeastern British Columbia is low, but these animals can be locally abundant. This area is home to the hardiest of the amphibian and reptile species.

Forestry, mining, oil and gas exploration and hydro-electric developments are the main potential threats to amphibian and reptile habitats. Agriculture and urbanization might threaten some habitats, particularly in the Peace River area. The human population is small in these regions, but urban and rural developments can affect local populations of amphibians and reptiles.

a) Composition of amphibian and reptile faunas of this region:

- 6 native species of amphibians (Table 2)
- 2 native species of reptiles (Table 2)
- Species with core areas (much of BC population) in Regions 7 or 9: Boreal Chorus Frog in the Peace Region

b) Main threats to amphibians and reptiles in urban/rural areas:

- Habitat loss and alteration
- Draining or altering wetlands

c) Widespread, compatible species:

The following species are relatively compatible with urban developments and should respond favourably to habitat protection and restoration efforts:

- Pacific Treefrog (restricted to southwestern portion of Omineca Region) and Boreal Chorus Frog (Peace Region only) (see BMPs for pond-breeding species in Section 5.1-Summary on page 66)
- Common Garter Snake and Western Terrestrial Garter Snake (see BMPs in Section 5.1-Summary on page 67)

d) Additional issues:

- Protect important wetland breeding habitats of the Western Toad, Columbia Spotted Frog, and Wood Frog (use BMPs in Section 5.3.3 on page 70). Very large concentrations of these frogs gather at breeding sites that can be source populations for vast areas. A few productive breeding sites may sustain local and regional populations of these species.
- Protect hibernacula of Garter snakes; Garter snakes often hibernate communally in northern environments, and suitable sites may be in short supply. Use BMPs in Section 5.3.3 on page 70).
- Restrict activities that alter or disturb shallow, seasonal pools along beaches; such pools provide important breeding habitat for the Western Toad.
- Mitigate road mortality of amphibians (such as the Western Toad) and Garter snakes that undertake seasonal mass migrations. Land developments that intersect seasonal travel routes or occur adjacent to snake hibernacula should ensure that roads are placed away from these areas and that road mortality is addressed. Use BMPs described in Section 5.3.5 on page 77.
- Take actions to reduce the spread of nonnative fish and other introduced species (see BMPs in Section 5.3.9 on page 83).

7 Strategy for Monitoring the Effectiveness of BMPs

7.1 Rationale for monitoring

A monitoring program is needed to ensure that the steps taken to protect, restore, or manage habitats and populations of amphibians and reptiles are successful and meet set targets and goals. Broad-scale monitoring addresses whether biodiversity goals have been achieved and needs to be carried out at the landscape level, or even larger scales, whereas monitoring at local scales focuses on the effectiveness of a particular management or mitigation measure, such as the use of a road crossing structure by amphibians and reptiles. Both types of monitoring practices are necessary to ensure that scarce resources, funding, and efforts are appropriately directed towards those management practices that are most effective. Scale is also important for aquatic-breeding amphibians, because their populations typically fluctuate widely from year to year. Rather than monitoring their abundance within a local area, such as a pond, it may be more biologically relevant to monitor changes to the distribution or loss of local populations over a wider area.

By definition, monitoring is long term and spans multiple years. Long-term monitoring is required because effects may take years to filter through a population and become detectable. Furthermore, populations of many aquatic-breeding amphibians fluctuate widely from year to year, and surveys carried out during a short period might lead to erroneous conclusions about the effectiveness of particular management practices. Periodic monitoring should be an ongoing and integral part of ecosystem management and be incorporated into management plans for wildlife, including amphibians and reptiles.

Because natural ecosystems are extraordinarily complex and characterized by a multitude of interactions and poorly understood processes, there is always uncertainty about the outcome of even well-tested management methods when applied to particular local or regional conditions. With reference to environmental contaminants and their effects on aquatic amphibians, Semlitsch (2000) and Bridges and Semlitsch (2000) stressed the importance of synergistic effects and interactions, which often either magnify or change the nature of an impact in unexpected ways. They suggested that multiple factor rather than single factor hypotheses are needed to adequately address and test the effectiveness of particular environmental standards or management practices. The potential for interactions and unexpected responses should be kept in mind when designing monitoring programs.

A monitoring program is also essential because many of the recommendations are based on the ecology of animals under natural conditions and have never been adequately tested in disturbed habitats or with interacting stressors. For example, recommended buffer widths adjacent to wetlands are based largely on movements of animals within larger areas of intact habitats. The effectiveness of buffer zones of different widths in protecting critical habitat has rarely been tested. In most cases, it is unknown how well they maintain water quality, temperature, filter our sediments, and maintain natural predator-prey dynamics.

The testing of the effectiveness of the Best Management Practices for wildlife, and for amphibians and reptiles as described in this report, is often best carried out within the context of adaptive management. Monitoring in this context ensures that management practices are refined, modified, or altered as needed. Adequate monitoring is also integral to the current "results-based" approach adopted by provincial government agencies for natural resource management and conservation.

7.2 Monitoring strategies at the landscape level

Local governments can address broad management and conservation goals for urban and rural areas within zoning and land use plans. It is important to ensure that amphibians and reptiles are included within these plans both as important contributors to biodiversity and as indicators of ecosystem health. Monitoring programs designed to determine whether biodiversity goals have been achieved should include amphibian and reptile species richness as one facet. As a performance measure, the species richness for these groups could be expressed as the proportion of a possible set of species present within a defined area (such as a region or a district). Monitoring might include surveys of critical habitats, such as ponds and streams, within the district at periodic intervals and assessment of the number of amphibian and reptile species present. Parks, greenways, and riparian management zones may be good targets for such a program.

Hermy and Cornelis (2000) developed an indicator approach for monitoring biodiversity within urban and suburban parks. They pointed out special problems associated with biodiversity monitoring in these parks, which typically consist of a mosaic of small habitat patches, have conflicting multifunctional goals, and have managers that do not necessarily have a tradition for managing habitats to meet biodiversity objectives. Their method consisted of measuring and monitoring habitat diversity, on one hand, and species richness (i.e., the number of species present) of certain surrogate or indicator groups, on the other hand. Amphibians were included as one of the surrogate groups.

Amphibians possess several characteristics that make them good indicators for monitoring ecosystem heath. These characteristics include: semi-permeable skin and eggs; a biphasic life cycle that exposes many species to contaminants both on land and in water; and critical periods in their development when they are particularly susceptible to environmental contaminants, such as during embryonic development within eggs, and metamorphosis of aquatic larvae. Monitoring species richness or population trends of amphibians may serve as an early warning system of ecosystem deterioration. Plethodontid salamanders, in particular, might be suitable for such a purpose because their natural, year-to-year population fluctuations are low (lowest among all vertebrates; Gibbs et al. 1998). The Ecological Monitoring and Assessment Network (EMAN) and Parks Canada have recently developed a standardized protocol for monitoring population trends of plethodontid salamanders at EMAN ecological plots, within parks, or as a part of other environmental programs (Zorn and Blazeski 2002). In addition to monitoring populations, developmental stages of aquatic-breeding amphibians may be used for bioassays of environmental pollution. For example, the laboratory of Dr. Helbing at the University of Victoria is working on a molecular bioassay using amphibian metamorphosis as the focus for detecting the presence of biologically significant concentrations of endocrine disrupting substances (i.e., contaminants that interfere with hormone signals of vertebrates) in water bodies (C. Helbing, pers. comm.). This work has so far focused on the introduced Bullfrog as a model organism, but plans exist to extend the assay to native species. Once developed, this method can be a useful tool for monitoring water quality and ecosystem health.

7.3 Effectiveness monitoring of individual management measures

Effectiveness monitoring should be incorporated into each project to ensure that the measures implemented are functioning as expected. Without such testing, well-intended efforts may be wasted, or worse, the measures may give the impression that the problem has been solved when in fact it has not. For example, the majority of the early amphibian tunnel systems in Europe were later found to be virtually non-functional (Podloucky 1989, Ryser and Grossenbacher 1989). Typically, no monitoring was conducted after the tunnels were constructed (Podloucky 1989). Had systematic monitoring been incorporated into the plan for each project, the problems (which often included faulty technical design features) would have been detected much earlier.

Another potential problem area is with the construction of new habitat, such as ponds for aquatic-breeding amphibians and hibernacula and other structures for reptiles. Too often, it is unknown whether amphibians and reptiles use these new habitats or features. Furthermore, use by itself does not necessarily ascertain that the new habitats are producing surviving young and contributing to the local population. In the worst case, they may act as ecological traps that attract animals to areas where they either suffer increased mortality or where their reproductive success is impaired. Artificial structures, such as rock outcrops for snakes, can be vandalized (Webb and Shine 1999), which might increase accidental mortality of animals. When appropriately used, the creation of new habitat can be very effective, but careful follow-up monitoring is always needed. As a rule, the more invasive or intensive a management method is, the more care required to ensure that it is functioning as intended.

The level of detail required and the length of monitoring will depend on specific projects and objectives. Effectiveness monitoring often involves intensive follow-up efforts initially after the implementation of mitigation measures, and periodic monitoring thereafter. Monitoring should always be carried out over multiple years to ensure that potential longer-term effects are detected and problem areas are identified.

Sufficient detail must be collected to adequately address potential problem areas. In many cases, effectiveness monitoring requires information on the fate of individual animals or their survivorship at different life-history stages. For example, it may be necessary to know whether an artificial pond is largely self-sustaining and produces surviving young, or whether it acts as a population sink and is sustained by emigration. In addition, mole salamanders, toads, and turtles, in particular, may live for decades, and their presence does not necessarily indicate the presence of a viable population. Collecting information on reproduction and survival of young is necessary to avoid the syndrome of the "living dead" or populations that are doomed to extinction in the absence of recruitment. For road crossing tunnel systems, initial follow-up involves testing whether animals use the structures. It may involve calculating fence-efficiency (proportion of animals encountering the fence that enters into the tunnel) and tunnel-efficiency (proportion of animals that enter tunnels and go through them) (Jackson and Tyning 1989). Potential problems need special attention, such as whether animals breach the fence or go around it. Because structures may deteriorate, migration routes may change, and new problems may develop, periodic monitoring of the continued use of these systems is necessary.

7.4 Standard methods for sampling amphibians and reptiles

Many effective sampling methods are available for amphibians and reptiles. Heyer et al. (1994) provide a summary of standard methods for measuring and monitoring amphibian populations. Olson et al. (1997) discuss standard sampling methods and experimental and monitoring designs for amphibians in wetland and pond habitats. The Resources Information Standards Committee has developed standard methods for amphibians and reptiles of British Columbia. These standards exist for Plethodontid salamanders (RISC 1999), aquatic-breeding amphibians and the Painted Turtle (RISC 1998a), Coastal (=Pacific) Giant Salamander and Tailed Frog (RISC 2000), and snakes (RISC 1998b). Krebs (1989) provides basic methods for experimental design and statistical analysis in ecological studies.

The sampling method selected will depend on the target species or group and the level of detail needed for a particular purpose or experimental design. For example, if the monitoring objectives call for information on species richness of aquatic-breeding amphibians, then one might gather information on the number of species present in each pond sampled. In this case, only presence/absence ("not detected") data are required. On the other hand, if the design calls for comparisons of species diversity (using one of the many indices available) or abundance of a particular species in different areas, for example in natural and artificial ponds, then one needs to use an appropriate method for obtaining relative abundance estimates. Although conceptually simple (addressing questions such as what type of pool has higher densities of animals), obtaining accurate measures of relative abundance of amphibians, reptiles, and other small wildlife is often surprisingly difficult.

Because their life-history patterns and activities are highly seasonal, it is very important that amphibians and reptiles are surveyed at appropriate times of the year. Because their activity is greatly influenced by environmental conditions, it is important that surveys are carried out during optimal weather and moisture conditions. Because many species are secretive, nocturnal, or partially fossorial (living underground), they can be difficult to find, even where abundant. These are all considerations that must be taken into account when implementing a monitoring program. The distribution of many amphibians and reptiles are patchy in the environment, and survey efforts must be carried out at an appropriate scale that these dispersion patterns into account.

Populations can be impacted by numerous factors, and the monitoring design must be put into a wider context. For example, amphibian populations may be studied within a pond, but the impacts on terrestrial habitats may be more important.

As with all biological studies, it is important to understand exactly what the objectives of the monitoring program are. If the objectives call for pre-/post-disturbance comparisons, it must be ensured that adequate baseline information is collected initially. Consulting with an experienced herpetologist is desirable for the design of monitoring studies to ensure that all these factors are considered.

7.5 Recommendations for monitoring strategies

- Design monitoring programs with clear objectives and identify performance criteria and targets for both short- and long-term objectives

- Design monitoring programs so that the results can be summarized at periodic intervals and applied to the refinement of management measures, as needed

- Ensure that amphibians and reptiles are included in biodiversity goals by local governments and land use planners, and establish monitoring programs to determine how well these goals are achieved. Performance criteria at the landscape level may include: no net loss of aquatic, riparian, or forest habitat used by amphibians and reptiles; no net loss of species richness; no increase in the spread of introduced species.

- Promote the inclusion of amphibians into a set of biodiversity indicators and monitor their species richness and population trends at sites where other environmental attributes are also measured. Performance criteria may include:
    - a statistically significant decline in relative abundance of particular species over several years
    - reduced number of egg-masses by aquatic breeding amphibians
    - reduced survival of certain life-history stages
    - disappearance of sensitive species from the complement of species
    - addition of introduced species
    - changes in gene expression during sensitive life-history stages, as determined through molecular bioassays.
- Incorporate effectiveness monitoring into each management practice to ensure that the measures are functioning as expected (include effectiveness monitoring in the mitigation plan)
- Whenever ponds or structures have been created, or habitat has been extensively modified, conduct sufficient follow-up monitoring to ensure that the new habitat does not act as an ecological trap that attracts animals, resulting in reduced survivorship
- Collect information at appropriate spatial scales and levels of detail for each project and according to available standard methods for amphibians and reptiles
- Use monitoring as a tool within adaptive management of amphibians and reptiles
- Review and summarize results of monitoring programs at set, periodic intervals and refine and modify management or mitigation measures as appropriate

8 Strategy for Public Education and Stewardship

8.1 Strategy for educating developers, planners, local government personnel

8.1.1 Rationale

A comprehensive list of management guidelines (BMPs) for protecting amphibians and reptiles in urban and rural environments was provided in Sections 5 and 6. These are not legislated requirements but voluntary best practices for land developers and local government to use as tools to protect biodiversity in rural and urban areas of the province. Unfortunately, many species of amphibians and reptiles are poorly known to the public and have received little attention by local governments. For BMPs to be accepted and implemented effectively, general awareness needs to be raised about the ecological importance, status, and vulnerabilities of these animals.

Increasing the awareness by the public and landowners about the importance of amphibians and reptiles in the ecosystem, their imperilled status in many developed areas of the province, and their sensitivity to human activities, will benefit the conservation of these species in the long term. Unfortunately most amphibian and reptile species are poorly understood and are often given lower priority in conservation projects. For example, many people are afraid of snakes and will kill them even though most are completely harmless and beneficial because they feed on pest animals. Others may capture amphibians and reptiles for pets or inadvertently injure them. Introductions of nonnative species, such as Bullfrogs, can result in severe, irreversible impacts on native species.

The key to many of the issues surrounding conservation of amphibian and reptiles in urban and rural environments is attitudes and information. This section outlines an approach to improve public awareness. Specific initiatives are also included to facilitate the adoption of BMPs and allow them to be effectively implemented for the benefit of our native amphibians and reptiles. Impersonal communications are unlikely to initiate actions, so we have suggested establishment of an information centre, which has staff that can meet with agencies and individual that are interested in implementing the BMPs.

The strategy targets planners, developers, and the public. These groups are all an integral part of successful implementation of the BMPs and stewardship of amphibians and reptiles in urban and rural areas (see section 8.2). Local government planners are responsible for the integration of all land use objectives and can ensure that developments are environmentally appropriate. The developer, consultants and landscape architects, working with local governments, will implement the BMPs within their development projects.

8.1.2 Goals

The goals of the strategy are to increase public awareness of the importance and conservation needs of amphibians and reptiles and to disseminate information on BMPs for protecting these species and their habitats in urban and rural environments.

8.1.3 Objectives

- Inform regional and municipal planners, developers, stewardship groups and general public about the BMPs and the need to protect amphibians and reptiles

- Provide the rationale and scientific basis for recommendations, as required

- Provide easy access to information

8.1.4 Recommended action

a) Initiate new public awareness programs for amphibians and reptiles

- Initiate "snake aware" campaigns in areas such as the Okanagan, including information on the following: the valuable role of snakes in the ecosystems; their status and vulnerability; how to behave around venomous snakes; who to contact if a venomous snake needs to be removed; and how to snake-proof portions of your property.

- Investigate the possibility of establishing monitoring and information centres for reptiles. Existing programs, such as the "Frog Watch" program, could be expanded to include a "Reptile Watch" program

- Because of their accessibility, conservation projects in urban and rural environments can provide a showcase for public education about native reptiles and amphibians, their habitats, and conservation needs. Interpretive signs, self-guided trails, brochures and guided field trips could be used to showcase specific projects.

- Encourage the media to report on conservation issues and problems, such as road mortality of turtles or the plight of endangered amphibians such as the Oregon Spotted Frog. Build on these opportunities (by supporting and forming partnerships with grass-roots community groups) to create focal points for public awareness and stewardship programs involving amphibians and reptiles.

b) Promote existing programs on amphibians and reptiles

Examples of organizations providing excellent information on amphibians include:

- Frog Watch: A partnership between EMAN, CNF and Environment Canada. The goal of this initiative is to monitor frog populations with the assistance of the public to detect possible declines. This program trains volunteers in British Columbia and across Canada. The volunteers often become advocates at the local level and raise the awareness of amphibians and their conservation needs. The frog watch program also includes turtles, because these reptiles are in the same aquatic habitats as frogs.

- Canadian Amphibian and Reptile Conservation Network: CARCNET is a national initiative that works towards "… conserving Canada's native species of amphibians and reptiles, and their ecological and evolutionary functions in perpetuity" (http://www.carcnet.ca/english/carcnethome.html; accessed Mar. 5, 2003).

- Make community groups aware of Government web sites and other resources pertaining to reptile and amphibian conservation

c) Increase awareness of Best Management Practices for amphibians and reptiles in urban and rural environments:

Provide a "BMP" information centre responsible for the following tasks:

- Develop a information depository with information about the effectiveness, construction advice, and approximate cost of individual BMPs

- Collect articles and reports about projects

- Lobby for economic incentives for developers to implement appropriate BMPs, e.g. lower permit cost or tax incentives

- Provide advice about specific BMPs and specific situations including the following: having personnel meet with agencies and interested individuals and groups; how to choose BMPs; when and where to implement them; construction suggestions; possible funding sources; and list of experts that can be consulted

- Develop brochures about the importance of implementing these BMPs, about individual BMPs, and the benefit of implementing BMPs for the developer and for government

- Develop presentations and posters that can be shown to interest groups

- Develop a website that provides information in downloadable form

- Update BMPs as they develop

Target information to elected officials, local government planners and developers

- Distribute brochures and pamphlets to elected official in regions and municipalities, individual planners and developers
- Give presentations and displays at conferences
- Write articles in professional magazines and journals describing the BMPs and where to get information and help
- Give presentations to elected officials in city councils
- Lobby planner and developer's associations to promote the use of the BMPs (e.g. Canadian Mortgage and Housing Corporation; Greater Vancouver Home Builders' Association; Renovator's Council)

8.2 Strategy to promote stewardship initiatives for protecting amphibians and reptiles

8.2.1 Rationale

Stewardship refers to the careful management of the natural environment through partnerships and can involve landowners and community groups in partnership with government agencies, industries, or non-profit organizations. Because many important amphibian and reptile habitats close to urban centers are located on private lands, land stewardship involving property owners and residents is critical.

Stewardship programs entail actions to rectify a problem or to protect important habitat by purchasing land, instituting conservation covenants, or establishing stewardship agreements. These programs can be of educational or practical nature and often are a combination of both. For successfully implementing stewardship programs, it is important that all partners operate in a mutually respectful way (Benson 2001).

Stewardship initiatives are gaining popularity in many areas of British Columbia. In and around Victoria alone, there are more than 100 groups working on equally many initiatives (http://www.conservationconnection.bc.ca/Search.asp#list).

8.2.2 Goal

The goal of this strategy is to facilitate the successful implementation of stewardship projects for amphibians and reptiles in urban and rural environments.

8.2.3 Objectives

- Promote partnerships, which are key to successful stewardship programs.

- Identify sources of funding and other resources that landowners, community groups, and local governments can use to design, implement, and monitor the effectiveness of stewardship projects in urban and rural environments.

- Encourage participation at the grassroots level, so that residents receive on-the -ground exposure to stewardship activities, so increasing their interest, level of concern, and commitment to the conservation of reptiles and amphibians in their area.

8.2.4 Recommended action

a) Increase awareness of opportunities for forming partnerships:

Actively seek out and help public and community (grassroots) groups that are interested in stewardship; make them aware of the benefits of partnerships. Partnerships are an excellent way to pool resources, including funding, organizational, logistically, and scientific support. Without funding and support provided by partners, few initiatives will succeed and persist over the long-term. Several conservation organizations and the federal and provincial governments are actively seeking partnerships with landowners, community groups, naturalist clubs and municipalities. The following are examples of such organizations:

Canadian Amphibian and Reptile Conservation Network (CARCNET):

- This is a national, non-profit organization that focuses on the conservation of amphibians and reptiles.

- Through its membership it has a vast source of expertise on amphibians and reptiles and conservation tools for them across Canada and can provide information and advice.

Nature Conservancy and Land Conservancy:

- The Nature Conservancy strives to prevent loss or degradation of significant habitat across Canada while the Land Conservancy focuses on habitats of provincial importance.

BC Hydro:

- Through the Columbia Basin Compensation Program, BC Hydro provides funding for research and stewardship projects on wildlife in the Kootenay region.

- Existing projects involving amphibians and reptiles include mitigation of collision mortality of the Painted Turtle, Northern Leopard Frog reintroductions, and research on Tailed frog/forestry interactions.

Ducks Unlimited:

- This group is very active in restoring, enhancing, and protecting wetlands in BC; prime focus is on waterfowl productivity, but other species of wildlife including amphibians and reptiles can also benefit.

- Forms partnerships with local governments, landowners, and conservation groups.

World Wildlife Fund Canada:

- Provides funding for conservation of endangered species and their habitats, including amphibians and reptiles, mainly through the Endangered Species Recovery Fund in partnership with Environment Canada.

Environment Canada:

- For those amphibian and reptiles that have been listed as endangered or threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), the federal government has five programs in place to fund stewardship initiatives (http://www.speciesatrisk.gc.ca/species/programs/index_e.cfm; accessed March 2003). EcoAction, Endangered Species Recovery Fund, and Habitat Stewardship Fund can provide funding for endangered species by non-governmental groups.

Provincial Government:

- *Ministry of Water, Land and Air Protection:* does not fund stewardship projects directly but will support contribution and transfer agreements involving conservation of habitat on private lands; also provides many resources to facilitate Stewardship projects, including BMPs for Land Devlopment.

- *Ministry of Transportation and Highways:* provides funding to improve mitigative measures associated with road construction and maintenance.

- *Forest Investment Account:* Supports studies and conservation projects in forest and rangeland areas.

- *BC Parks:* Interested in stewardship/interpretive partnerships in some areas.

Regional Governments:

- Provide funding and support for local stewardship projects (eg, SHIM project in the Fraser Valley).

Habitat Conservation Trust Fund:

- Has provided funding for several projects involving amphibians and reptiles, including effects of introduced Bullfrogs on native amphibians and habitat identification for the Gopher Snake and Western Rattlesnake.

Nature Trust of BC

- Provides support and promotes conservation projects.

Habitat Acquisition Trust:

- Promotes stewardship opportunities on Vancouver island (eg, Urban Forest Stewardship Project)

b) Increase awareness of incentive programs to protect private lands

- Ecological Gifts Program (Federal Government) provides financial (tax) incentives for land donations.

- Contribution and Transfer Agreements (Provincial Government).

c) Increase awareness of covenants and land trusts to protect habitat

- Conservation covenants are voluntary but binding legal agreements that allow landowners to permanently preserve natural features of their property, while still retaining ownership and use.

- Land trusts are private non-profit societies created to acquire and protect land for conservation purposes; the Land Trust Alliance of BC educates and co-ordinates activities of public/conservation groups about land trusts.

- Several land acquisition funds are working on protecting important habitat by purchasing or negotiating conservation covenants and stewardship agreements. A list of more than 30 groups that work on a regional or local level can be found the Land Trust Alliance of British Columbia's in registry.

d) Promote Recent Initiatives:

Some municipalities have adopted naturalization as a way to preserve biological diversity and restore or enhance endangered ecosystems. Naturalization is an approach to manage land that uses native plants to restore or create natural occurring ecosystems. The District of Saanich, for example, is naturalizing some of their highly groomed parks and has created a wetland as a part of their wastewater treatment in an attempt to enhance amphibian habitat (Professional Environmental Recreation Consultants Ltd. & Urban Systems 2001). One of the key obstacles identified by staff is the difficulty of changing public perception and attitudes that natural landscapes are not just "weeds" or "untidy scrub." Through public education, the municipality is confident that these obstacles will be overcome in time" (Ingram 2001).

e) Provide information on conservation management techniques and life-history requirements of amphibians and reptiles:

- Many landowners and grassroots community groups lack the tools and information required to successfully complete stewardship projects. Provincial government and local governments can help by providing access to this information. Initiatives for promoting the use of BMPs for land developers and consultants are described in Section 8.1.

- Because habitat degradation often is incremental, it is essential to ensure that landowners, planners and developers understand that even small features such as natural ponds are important at the landscape level.

- The Painted Turtle projects in the Kootenay region are an example of a stewardship program that attempted to enhance the survivorship of Painted Turtles by on the ground action and public education. The results of the work were reasonably successful, but the greatest lesson was the obvious need for public education on the biology and conservation measures necessary for Painted Turtles (R. Clarke, pers. comm.).

- Small grassroots projects often provide focal points for amphibian and reptile conservation, and these initiatives can be fostered and expanded to larger multi-faceted conservation and education programs with appropriate funding and partnerships. For example, the elaborate "toad tunnel" systems in parts of Europe owe their existence to resident groups who were concerned about mass mortality of migrating amphibians while crossing roads. Initial rescue operations attracted volunteers, drew media attention, and raised awareness of the problem and of amphibian conservation in general.

9 Relevant Links

Amphibian Web. University of Berkley, California. http://elib.cs.berkeley.edu/aw/lists/

BC Conservation Data Centre. http://srmwww.gov.bc.ca/cdc/

BC Frogwatch Program. http://wlapwww.gov.bc.ca/wld/frogwatch/

BC Ministry of Sustainable Resource Management and Ministry of Water, Land and Air Protection. Endangered Species. http://srmwww.gov.bc.ca/atrisk/

BC Ministry of Sustainable Resource Management. Resources Information Standards Committee. (standard inventory methods for elements of British Columbia's biodiversity). http://srmwww.gov.bc.ca/risc/pubs/tebiodiv/index.htm

BC Ministry of Water, Land and Air Protection. Best Management Practices for Land Development - Vancouver Island Region. http://wlapwww.gov.bc.ca/vir/pa/bmp_dev2.htm

BC Ministry of Water, Land and Air Protection. Water Quality – Municipal Best Management Practices. http://wlapwww.gov.bc.ca/wat/wq/nps/BMP_Compendium/Municipal/Municipal_Home.htm

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Committee on the Status of Endangered Wildlife in Canada (COSEWIC). http://www.cosewic.gc.ca/index.htm

Habitat Atlas for Wildlife At Risk. South Okanagan and Lower Similkameen. http://wlapwww.gov.bc.ca/sir/fwh/wld/atlas/

Identified Wildlife. Ministry of Water, Land and Air Protection (MWLAP). Volume 2, to be released in spring 2003. http://wlapwww.gov.bc.ca/wld/identified/species_table_of_contents.htm#amph

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NatureServe. http://www.natureserve.org/

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12 Glossary

Amphibia – a class of vertebrates that includes frogs and toads, salamanders, and a group of tropical, burrowing, wormlike animals called caecilians

Anura – frogs and toads; an order of amphibians

Ectothermy – deriving body heat from the environment (as do amphibians and reptiles) rather than through physiological means (as do birds and mammals); ectothermic animals are sometimes referred to as "cold-blooded"; however, this term is a misnomer, as their blood is not necessary any cooler than that of "warm-blooded" birds and mammals; where suitable thermal gradients are available in the environment, many reptiles can maintain their body temperature within relatively narrow limits through behavioural means

Endemic – organisms that are native to a particular area and found nowhere else

Fossorial – adapted to life underground

Larvae – free-living aquatic young of amphibians; larvae of frogs are called tadpoles, whereas those of salamanders are referred to simply as larvae

Metamorphosis – transformation of aquatic amphibian larvae into terrestrial forms; larval tissues and organs undergo major reorganization at this time

Metapopulation – A population that is divided into smaller subpopulations within the landscape; the persistence of the metapopulation depends on some degree of dispersal between these subpopulations; many amphibian populations, in particular, appear to be organized as metapopulations

Mole salamanders – salamanders of the family Ambystomatidae; terrestrial phases of these salamanders typically spend much time in underground burrows, hence their common name; Mole salamanders found in British Columbia include the Northwestern Salamander, Long-toed Salamander, and Tiger Salamander

Philopatry – affinity to a particular site

Plethodontid salamanders – Woodland salamanders belonging to the family Plethodontidae; these salamanders lack lungs, and respiration takes place through the moist skin; all Plethodontid salamanders in British Columbia are completely terrestrial without an aquatic larval stage

Ranid frogs – "true" frogs of the family Ranidae; examples of ranid frogs in British Columbia include the Red-legged Frog, Northern Leopard Frog, and Bullfrog (introduced)

Reptile – a class of vertebrates that includes turtles, lizards, snakes, and some other groups not found in British Columbia (such as alligators and tuataras)

Sink habitats – habitats that may attract animals but where their reproduction or subsequent survival of young is poor; these habitats contribute few or no immigrants to the surrounding areas

Sink populations – populations within sink habitats that contribute little or nothing to the local and regional populations

Source populations – populations that occupy productive sites where their reproduction and subsequent survival of young is good; these populations act as sources of immigrants to surrounding areas

Toad – this term refers to a family of frogs (Bufonidae), one representative of which occurs in British Columbia (Western Toad); Great Basin Spadefoots are often (incorrectly) referred to as toads. It is correct to call toads frogs, but not vice versa.

Thermoregulation – the process of obtaining heat from the environment; most reptiles thermoregulate behaviourally by moving to warm sites when cold and to cool sites when hot

Appendix 1: Species Accounts