Amphibian Assessment Following the Accidental Release of Sodium Hydroxide into the Cheakamus River, British Columbia

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Table of Contents

1.0 INTRODUCTION

On August 5th 2005, a Canadian National train derailment occurred at mile 56.6 in the Cheakamus Canyon that resulted in a spill of 41,000 litres of sodium hydroxide (NaOH) into the Cheakamus River. The impact on aquatic life within the river was immediate and severe. For example, it is estimated that 90% of free-swimming fish in the river at the time of the spill were killed as a result of the spill (McCubbing et al. undated). Water testing indicated that the NaOH was quickly flushed from the system (McCubbing et al. undated). This suggests that individuals or species that were not in areas directly exposed to the spill, such as the river, but may frequent the system may not have been severely impacted (e.g., terrestrial adults).

This report summarizes an assessment of potential impacts of the Cheakamus spill on amphibian populations that occur within the Squamish Valley. A site visit was made on April 30, 2007 with a primary objective of confirming the presence of Red-legged Frogs in the Cheakamus River area; records of other native amphibian species were made at this time as well. Mike McArthur from Triton suggested the North Vancouver Outdoor School (NVOS) for a site visit due to its accessibility and large number of wetlands and ponds that might be suitable for breeding by amphibians. Surveys of upper reaches of the Cheakamus River for other studies did not reveal any ponds or wetlands due to the steep terrain and incised canyons (M. McArthur pers. comm.). Except for Coastal Tailed Frogs, all of the native aquatic-breeding amphibian species utilize standing water for breeding so that they are most common and abundant in low-lying or gently sloping terrain where wetlands and ponds are most likely to exist. As such, NVOS provided the highest probability of detecting Red-legged Frogs. Confirmation at this site would be sufficient to assume that Red-legged Frogs, and other native species, could potentially occur at other points along the Cheakamus River where suitable standing water habitat might occur.

2.0 WHY AMPHIBIANS?

Amphibians are a taxonomic group of concern regarding the spill into the Cheakamus River for several reasons:

- Numerous amphibian declines have been documented in recent decades, especially for Ranid frogs in the Pacific Northwest
  - habitat loss and degradation are cited as the major cause (Corn 1994)
  - three listed species occur in the Cheakamus River area
- Amphibians serve as indicators of environmental health and are extremely vulnerable to pollutants and climatic extremes because they have semi-permeable and highly vascularized skin used for subcutaneous respiration and hydration (Zug 1993); NaOH may have impacted amphibians via exposure to high pH (burning), extreme temperatures, and / or water loss and other osmotic stressors (Triton 2007a, Dupuis and Sander 2007).
- they are dependent upon both terrestrial and aquatic habitats—many breed in water in spring, then spend the remainder of the year in upland areas that contain both aquatic and terrestrial cover and foraging habitat; the majority of species in the Cheakamus River area breed in water and, as such, may have been directly exposed to the spill

- they have high site fidelity and move relatively little (e.g., most remain within 500 m of their breeding site, and breed in the same sites year after year), so that they cannot readily escape disturbances compared to other taxonomic groups

3.0 AMPHIBIAN SPECIES IN THE SQUAMISH VALLEY

3.1 Status

The majority of the nine native amphibian species found within the Squamish Valley are yellow-listed in BC (Table 1). Coastal Tailed Frog and Red-legged Frog are Blue-listed provincially, and along with the Western Toad these species are listed as *Special Concern* federally and fall under Schedule 1 of the Species at Risk Act (BC Species and Ecosystems Explorer 2003, COSEWIC 2007).

3.2 Breeding Habits

Six of the native species in the Squamish Valley breed in standing or very slow moving water (e.g., flows of > 5.0 cm/sec. are unsuitable; Richter and Azous 1995), while one species breeds in small, headwater creeks and two breed terrestrially (Table 1).

For the majority of the aquatic-breeding species, eggs and larva only occur within water from early spring to late summer or early autumn. As a result, these species may breed in water bodies across a range of hydroperiods. For three species, individuals may occur in water year round. Northwestern Salamander larva may follow one of two options: 1) metamorphose into terrestrial salamanders in approximately one year, or 2) remain permanently aquatic retaining their gills and reaching sexual maturity within a few years (i.e., becoming neotenic). Therefore, this species requires permanent water for breeding. Coastal Tailed Frogs tadpoles also have an extended developmental period (1 to 3 years) and require permanent creeks for breeding. Lastly, Rough-skinned Newt juveniles inhabit terrestrial environments until they reach sexual maturity, at which time adult males in some populations have been found to become largely aquatic remaining at the breeding site year round (Corkran and Thoms 2006, Matsuda et al. 2006).

3.3 Diet

The larva of all local frog and toad species are herbivorous, feeding on algae and plant materials. However, adult frogs and toads as well as all life stages of salamanders are carnivorous, feeding on a variety of aquatic and terrestrial invertebrates (Table 1).

4.0 SITE ASSESSMENT APRIL 2007

4.1 Methods

On April 30, 2007, a staff member from Triton Environmental (Mike McArthur) and myself (an amphibian biologist) made a site visit to the North Vancouver Outdoor School (NVOS). Based on maps and advice provided by the NVOS manager, we identified isolated ponds and side channels to survey that had the highest potential of containing lentic-breeding amphibians. The areas selected included some that were directly affected by the spill and others that were isolated from the main river (see Fig. 1).

The timing of the visual survey was purposely selected to coincide with amphibian breeding, especially the presence of egg masses; locating egg masses would confirm breeding in 2007 and

potentially indicate breeding sites used at the time of the spill. At each site we walked along the shoreline and / or through shallow waters visually searching for all life stages of amphibians both in and out of the water. When amphibians were observed, the species, life stage, water temperature, and location were recorded, and a photo was taken of each amphibian sampling location. The weather was ideal for visual surveys—mild, clear, and calm.

Because the main objective of the assessment was confirmation of the presence of Red-legged Frogs, more intensive techniques used to estimate relative abundance or absence were not employed (Fellers 1997). These latter techniques are usually employed when a more systematic design can be employed (e.g., within-pond microhabitats identified and measured) and repeat visits are possible within and among years (e.g., as part of a monitoring regime or as part of a research project) due to the high annual variability associated with climatic conditions and the patchy distribution of amphibians within and among sites (Feller 1997, RISC 1998). Visual surveys are a highly reliable technique for confirming the presence of breeding Red-legged Frogs, especially in relatively shallow ponds like those found at the NVOS, as the egg masses of this species are relatively large and have a high detectability rate (Fellers 1997, RISC 1998, E. Wind pers. obs.). Although the objective of the NVOS survey was presence, egg masses were counted where possible providing an estimate of the number of females that bred in early spring.

4.2 Results and Discussion

Four native amphibian species were confirmed to be breeding at sites within NVOS—Northwestern Salamander, Long-toed Salamander, Red-legged Frog, and Pacific Chorus Frog (Figure 1 and Table 2). Of the three listed species known to occur in the area, Red-legged Frogs were observed at four sampling locations, with breeding confirmed at two (Fig. 2); no Western Toads were observed at the site and surveys were not conducted for Coastal Tailed Frogs.

Sampling location 1 was a blind channel off of Gorbuscha West Channel and was surface fed. It was relatively deep, cool (8°C), and contained high amounts of woody debris. No amphibian breeding was observed at this site at the time of the survey, but a juvenile Red-legged Frog was observed on shore. It is difficult to predict whether breeding amphibians use this site, as numerous surveys are required. However, the fact that this area is likely frequented by fish from the channel (e.g., salmonids) suggests that it may have inherently low value for breeding amphibians—many native amphibian species select for fishless environments for breeding to avoid predation (e.g., see review by Wind 2004).

Sampling location 2 was a side pond also located off of Gorbuscha West Channel. This pond was not hydrologically connected to the channel via surface water at the time of the April survey (i.e., water levels were below the pipe that connects the pond to the channel; Fig. 3); the water temperature was 9.8°C. However, the pond is connected via surface water to Gorbuscha West Channel during high flow periods or backwatering. According to the NVOS maintenance manager, the pond is permanently wet and does not appear to contain fish due to poor water quality (C. Halvorson pers. comm.). Three species of amphibian were observed breeding at this site, including Red-legged Frogs (Table 2). It is unknown whether sampling location 2 had any direct exposure to NaOH in 2005—e.g., depending on the timing and extent of the spring freshet, water levels may have been higher in August 2005 compared to April 2007, allowing for a surface connection to Gorbuscha West Channel. The current species richness and level of

breeding by amphibians suggests that water quality conditions were favourable for egg laying and development in spring 2007—e.g., this small pond contained one of the highest densities of Long-toed Salamander egg masses and larva I have ever observed. The development of larva through to metamorphosis was not monitored to assess when metamorphosis occurs at this site (i.e., whether larva or metamorph Red-legged Frogs would have been in the pond in early August 2005). The presence of Northwestern Salamander egg masses in the pond suggests that larva may be present in the pond year round, and potentially at the time of the spill, as metamorphosis in this species occurs more than 1 year after egg laying (Corkran and Thoms 2006, Matsuda et al. 2006).

Sampling location 3 was a largely isolated amphibian pond built after the 2005 spill. This site is largely ground water fed but is occasionally connected to a channel during high water periods. This pond was relatively warm at the time of the survey (14.5°C) and contained at least three breeding amphibian species. Sites such as this (e.g., largely isolated from the Cheakamus River hydrologically and warm in early spring) serve as important breeding sites for native amphibian species and as refugia from fish.

Sampling location 4 was a large beaver pond that receives flow from the Far Point intake directly connected to the Cheakamus River (i.e., is surface fed). It is used as a settling pond for silt coming in from the river. This area had deep silt, flowing water, and likely contains salmonids.

Of the four locations surveyed, two were exposed the spill during the first 2 hours after it occurred (before intake pipes could be closed; sampling locations 1 and 4). No breeding was observed at location 1, but Northwestern Salamander egg masses were observed at sampling location 4 (Fig. 4). Sampling location 2 may have been exposed to the spill depending on water levels at that time (it is connected to a channel that had exposure during the first 2 hours via a small pipe; Fig. 3).

5.0 POTENTIAL IMPACTS OF THE SPILL ON AMPHIBIAN POPULATIONS

5.1 Aquatic larva

This group likely had the greatest risk of exposure to the Cheakamus spill. However, the location and / or timing of the spill likely prevented exposure for the majority of lentic- and lotic-breeding amphibian species: 1) Long-toed Salamanders, Red-legged Frogs, and Pacific Chorus Frogs commonly breed in standing water or very low flow areas versus rivers, and they prefer fishless sites; 2) Metamorphosis of their larvae to the terrestrial form is usually completed before late summer in coastal areas depending on water temperature (pers. obs.). As such, even if metamorphosis had not been completed by early August 2005, few if any larva of these species would have been in water bodies directly connected to the main stem of the river, at least via surface flows. However, larva in side pools or ponds connected to the river via subsurface flows may have been impacted by the spill.

In contrast to other lentic-breeding species, Northwestern Salamander larva require permanent water for their development so that larva would have been present in waters along the Cheakamus River at the time of the spill. However, it is highly unlikely that individuals were present within the main stem, especially where flows exceed > 5.0 cm/sec. (Richter and Azous 1995). As a result, of all of the native amphibian species found in the Squamish Valley, the

Northwestern Salamander population had the greatest risk of exposure to the spill and any potential on-going water quality issues. Unfortunately, the extent of exposure or impacts cannot be ascertained. The presence of isolated water bodies along the river that could be used for breeding, and having a proportion of the adult population living in terrestrial environments would have ensured that some individuals survived the spill. The presence of Northwestern Salamander egg masses at both of the two potentially exposed NVOS sampling points in April 2007 may indicate limited exposure, continued persistence of the local population, or immigration from surrounding areas (e.g., onset of recovery).

For Coastal Tailed Frogs, the main stem of the Cheakamus River is too large for breeding, but tadpoles may have been present in streambeds at the confluence of the Cheakamus and several smaller tributaries (Dupuis and Sander 2007). Individuals in the water within the first few hours of the spill may have been impacted. Creeks were not assessed for Coastal Tailed Frogs during the site visit on April 30, 2007; surveys for this species should be conducted in late summer or early fall when water levels are at their lowest. Without pre-spill data on the presence and relative abundance of Coastal Tailed Frogs in tributaries of the Cheakamus and no post-spill field studies it is unclear what the extent of impacts of the spill may have been on this species. However, the fact that natal reaches occur at higher elevations or in tributaries (headwaters; Friele and Dupuis 2007) suggests that critical in-stream habitat for this species was not affected by the spill.

Due to the biology of lentic-breeding amphibian species, namely their capacity for relatively large annual reproductive outputs (Berven 1990, Green 2003), populations along the Cheakamus River likely have the potential for rapid recovery if some larva were killed as a result of the spill.

5.2 Aquatic adults

The potential exists that some adults of all seven aquatic-breeding amphibian species in the area to have been in water bodies connected to the Cheakamus River in mid summer for hydration, cover, and / or for foraging. However, adult Northwestern Salamanders, Rough-skinned Newts, and Coastal Tailed Frogs would likely experience the greatest risk of exposure to the Cheakamus spill based on their ecology.

A proportion of Northwestern Salamander larva may become neotenic adults, remaining aquatic throughout their lifetime. As with larva, these aquatic adults would have been present in water bodies along the Cheakamus River at the time of the spill but were likely not present in the mainstem itself, especially where flows exceed > 5.0 cm/sec. (Richter and Azous 1995). It is unclear whether the presence of Northwestern Salamander egg masses at both of the two potentially exposed NVOS sampling locations in April 2007 were the result of breeding neotenes or terrestrial adults, or whether they represent persistence or recovery (e.g., immigration). The fact that adults of two life forms coexist in an area means that some proportion of the adult population would have survived the spill.

As with Northwestern Salamanders, some adult Rough-skinned Newts may become permanently aquatic upon reaching sexual maturity (e.g., usually males) and a pool of terrestrial adults would have been present at the time of the spill. However, the exact proportion of adult Northwestern Salamanders or Rough-skinned Newts that might be aquatic versus terrestrial within a given

population is unknown, and the limited surveys and lack of pre-spill data at the Cheakamus site limit my ability to estimate those numbers.

Coastal Tailed Frogs are closely tied to water, inhabiting small streams (headwaters) and riparian areas year round (Matsuda et al. 2006). Some adults may have been in riparian areas of the main stem in August 2005 and perished due to exposure to the spill but the majority of the adult population were likely in tributaries versus within or along the Cheakamus River (Dupuis and Sander 2007).

5.3 Terrestrial juveniles and adults

It is highly likely that the majority of juvenile and adult anurans and salamanders were in riparian and upland areas at the time of the spill versus in aquatic habitats. Juvenile and adult lentic-breeding amphibians avoid desiccation in the heat of summer by seeking moist microsites either in riparian areas or in upland forests (e.g., crevices, underground burrows, leaf litter, downed wood), and by becoming largely inactive. They also time their movements to coincide with mild, wet periods (e.g., on rainy days and at night). Amphibian species have the ability to absorb moisture through their skin to varying degrees so that they do not necessarily have to immerse themselves in water to hydrate, and they can readily inhabit upland terrestrial areas in summer. For example, anurans can sit on moist ground and absorb water through the skin on their thighs and abdomen and they store large quantities of water in their bladders for resorption later (Zug 1993). Red-legged Frogs are commonly seen along the shoreline of ponds in mid summer on Vancouver Island (pers. obs.) and they use riparian areas as travel corridors (Chan-McLeod 2002). Northwestern and Long-toed Salamanders as members of the mole salamander family spend the majority of their terrestrial existence under ground (Matsuda et al. 2006, Zug 1993). The location of burrows and crevices are likely overriding factors in their distribution fossorially (e.g., bedrock and soil type) versus proximity to water (e.g., Faccio 2003; Regosin et al. 2003).

As such, some adult amphibians were likely present along the shoreline of the Cheakamus River at the time of the spill in August 2005 but a large proportion of the population of these species may have been present outside the impact zone at the time of the spill—the number that may have been in waters directly exposed to the spill above or below ground is impossible to predict. Post-spill assessments (such as our April 2007 breeding survey) and monitoring would provide evidence of continued persistence of local populations.

5.4 Terrestrial-breeding salamanders

The two terrestrial breeding salamander species known to occur in the Squamish Valley spend the majority of their time, especially in summer, in moist microsites (e.g., under and within logs, leaf litter, crevices, underground, etc.; Matsuda et al. 2006). Some of these moist sites may have been partially fed by waters coming from the river and exposed individuals to the spill (Dupuis and Sander 2007). However, as with the mole salamanders, bedrock and soil type are likely important factors influencing the location of suitable subterranean sites, so that proximity to riparian areas may not be a critical factor for these species.

Terrestrial forests and riparian environments were not searched specifically for terrestrial salamanders during the site visit on April 30, 2007, and no pre-spill data is available for these

species along the river. Therefore, it is difficult to determine impacts of the spill on local populations. Post-spill assessments and monitoring would provide evidence of continued persistence of local populations.

5.5 Impacts to the amphibian food base

Amphibians as a group are both herbivorous and carnivorous. Therefore, impacts to the invertebrate prey base, algae, or aquatic plants from the spill may have affected local amphibian populations. Studies have shown that the biomass and overall abundance of benthic invertebrates in the main stem of the river experienced a rapid recovery within the first weeks and months after the 2005 spill (Triton 2007b). Impacts to invertebrate populations outside of the main stem of the river are unknown (e.g., in side ponds), as are those to the herbivore food base. If those were minimal and / or recovered quickly, then there was likely little indirect impact to local amphibian populations from the spill in relation to their food base because, as mentioned previously, the majority of amphibians likely inhabited water bodies outside of the main stem of the river or they were in upland forests.

6.0 CONCLUSIONS

The timing of the spill and the biology of most of the amphibian species found in the area likely reduced the potential for the Cheakamus spill to have had a significant negative or long-term effect on local populations, in terms of the number or proportion of individuals of any life stage or species that may have been killed, due to the fact that:

1) No dead amphibians were found along the Cheakamus River after the spill (M. McArthur, pers. comm.) as observed elsewhere after exposure to such a spill (e.g., Moore 2005).
    a. any losses that might have been incurred as a result of the spill were likely not significant in terms of overall amphibian numbers, and the potential for recovery rapid due to the high reproductive output of aquatic-breeding amphibians and metapopulation dynamics (Gill 1978, Sinsch 1992, Sjögren Gulve 1994).
2) The majority of amphibian larva would not have been exposed to the spill in 2005 because
    a. amphibians do not breed in the main steam of large rivers such as the Cheakamus River
    b. the majority of amphibians likely do not breed in waters directly connected to the Cheakamus River due to low water temperatures and the presence of fish
        i. optimal habitat for native lentic-breeding amphibians includes isolated or fish-free ponds, wetlands, and lakes
    c. based on the phenology of coastal populations at that elevation, it is highly likely that larval metamorphosis had taken place for the majority of species and individuals before the spill occurred (see exceptions below)
3) The majority of individuals of most species were likely in terrestrial environments at the time of the spill (i.e., in summer foraging habitat)
    a. newly metamorphosed young of the year were likely occupying riparian and terrestrial environments in early Aug.
    b. outside of the breeding season, adults occupy home ranges in summer that include hundreds of metres of riparian and upland habitat
    c. many adults become dormant or fossorial during dry, hot weather

A site visit in April 2007 confirmed the presence of the Blue-listed Red-Legged Frog along the Cheakamus River. Four other aquatic-breeding amphibians were also observed during that visit. It is extremely difficult to determine from the April visit, or from future surveys, whether the presence of amphibians in 2007 represents persistence or post spill recovery (e.g., via immigration). Aquatic-breeding amphibian populations are highly variable in space and time due to a wide range of variables (e.g., climatic conditions). The greatest impacts from the spill likely occurred for Northwestern Salamanders and Coastal Tailed Frog, the former of which was found breeding at NVOS in 2007 (due to persistence and /or recovery) and the latter of which was not surveyed but likely does not occur within the main stem of the river (Dupuis and Sander 2007).

Without pre-spill data on amphibian species along the Cheakamus River, it is difficult to determine whether local populations were significantly affected by the spill. However, a thorough knowledge of the biology of the species in combination with the timing of the spill provides insight into the most likely scenarios. Future monitoring would likely not be cost-effective or provide any greater insight into the effects of the spill due to low power to detect trends associated with the inherent variability of amphibian populations among sites and years and numerous confounding factors—e.g., NVOS is used as fish hatchery and an area where habitat is enhanced primarily for fish (e.g., side channels have been created) so that an absence of breeding by amphibians in side channels or areas directly connected to these channels or the main river at NVOS may relate more to the presence of fish versus the spill itself (Wind 2004).

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Table 1. Basic life history of native amphibian species found within the Squamish Valley.

Common Name	Scientific Name	Provincial Status[a]	Federal Status[b]	Breeding Phenology	Larval Diet	Adult Diet
Lentic Breeding (lakes, wetlands, ponds, ditches, backwaters and slow moving rivers)						
Northwestern Salamander	*Ambystoma gracile*	Y	NAR	**Breed** in early spring (e.g., April) **Larva** metamorphose in late summer of at least 2nd year *or* remain permanently aquatic (neotenic adults)	carnivorous (invertebrates)	carnivorous (invertebrates)
Rough-skinned Newt	*Taricha granulosa*	Y		**Breed** in spring and summer **Larva** in water until autumn	carnivorous (invertebrates)	carnivorous (invertebrates)
Long-toed Salamander	*Ambystoma macrodactylum*	Y	NAR	**Breed** in early spring (e.g., April) **Larva** in water until late summer	carnivorous (invertebrates)	carnivorous (invertebrates)
Western Toad	*Bufo boreas*	Y	SC	**Breed** in spring (e.g., May) **Larva** in water until late summer	herbivorous (algae)	carnivorous (invertebrates)
Red-legged Frog	*Rana aurora*	B	SC	**Breed** in early spring (e.g., April) **Larva** in water until late summer	herbivorous (algae)	carnivorous (invertebrates)
Pacific Chorus Frog	*Pseudacris regilla*	Y		**Breed** in spring and summer **Larva** in water until late summer	herbivorous (algae)	carnivorous (invertebrates)
Stream Breeding (small, fast, mountain streams)						
Coastal Tailed Frog	*Ascaphus truei*	B	SC	**Breed** in late summer **Eggs** laid in summer **Larva** in water for 1 to 3 years; metamorphose in spring or late summer	herbivorous (algae)	carnivorous (invertebrates)
Terrestrial Breeding (under and within logs, under rocks, in crevices, underground)						
Western Red-backed Salamander	*Plethodon vehiculum*	Y	NAR	**Breed** in autumn **Juveniles** born in spring (tiny replicas of adults)	carnivorous (invertebrates)	carnivorous (invertebrates)
Ensatina	*Ensatina escholschltzii*	Y	NAR	**Breed** in autumn **Juveniles** born in spring (tiny replicas of adults)	carnivorous (invertebrates)	carnivorous (invertebrates)

[a] Y=Yellow, B= Blue, R=Red

[b] SC=Special Concern, NAR=Not at Risk

References: Corkran and Thoms 2006, Matsuda et al. 2006.

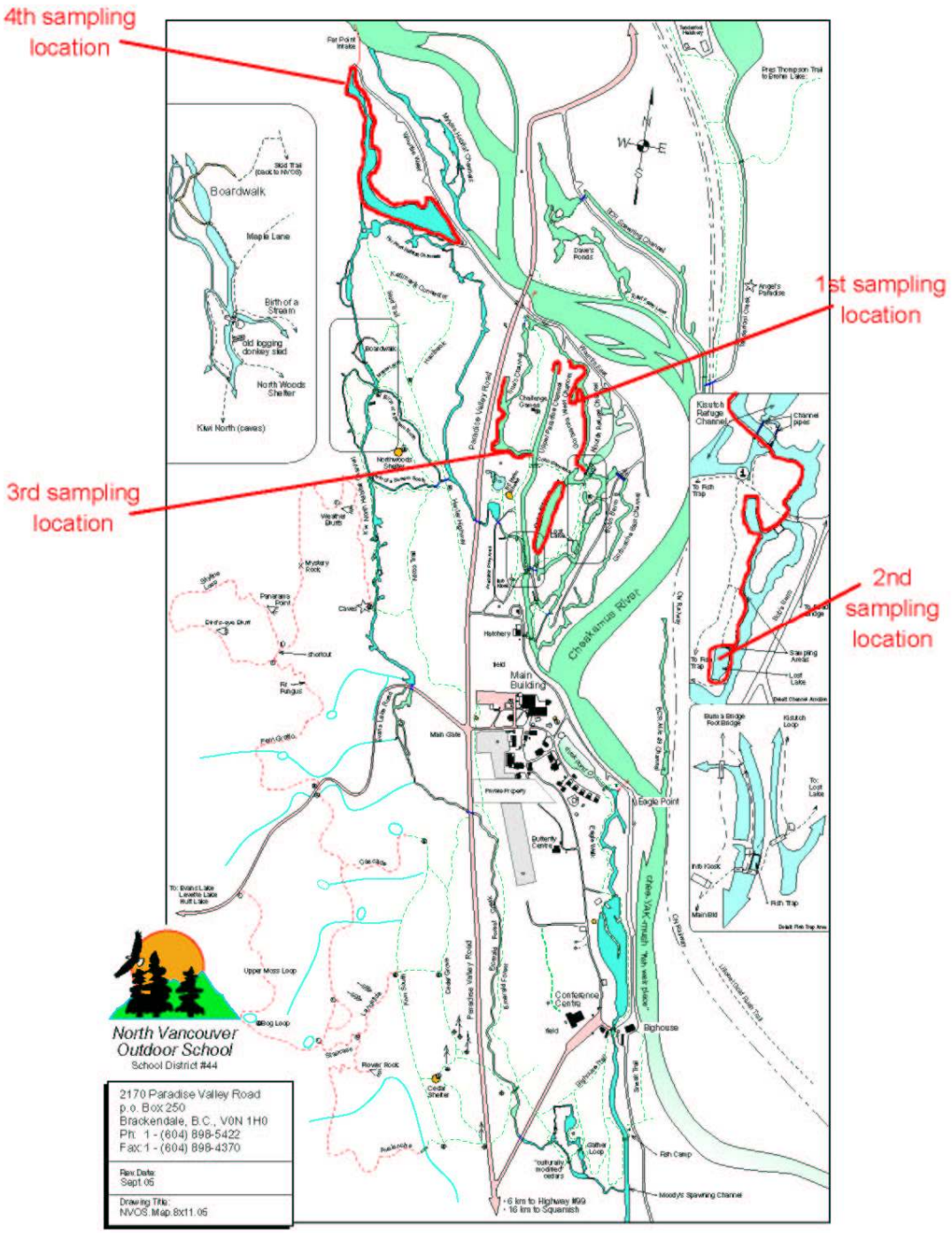

Figure 1. Shoreline areas of the North the Vancouver Outdoor School visually surveyed for amphibians in April 2007; amphibians were observed at four sampling locations.

Table 2. Locations where amphibians were observed during visual surveys along the Cheakamus River at the North Vancouver Outdoor School

Sampling Location	General Description	Species and Life Stages Identified	Extent of Exposure to Spill
1	Blind channel off of Gorbuscha West Channel	1 Red-legged Frog juvenile	First 2 hours of spill (surface fed)
2	Side pond off of Gorbuscha West Channel	4 Red-legged Frog egg masses and numerous hatchling tadpoles Many Long-toed Salamander egg masses and hatchling larva 3 Northwestern Salamander egg masses	Unclear – connected to Gorbuscha West Channel via a small pipe; no flow / connection observed in April 2007 (surface fed)
3	Isolated, man-made amphibian pond	Red-legged Frog egg masses and hatchling tadpoles Long-toed Salamander hatchling larva Pacific Treefrog egg masses	None - built after the spill (and not connected to any main channels or the river; primarily ground water fed).
4	Beaver pond	1 Red-legged Frog adult 4 Northwestern Salamander egg masses	First 2 hours of spill (surface fed)

Figure 2. Red-legged Frog adults and eggs were observed at sites within the North the Vancouver Outdoor School in Squamish, BC

Figure 3. Pipe connecting sampling location 2 to Gorbuscha West Channel.

Figure 4. Sampling location 4 had 2 hours of exposure to the 2005 spill and confirmed Northwestern Salamander breeding in 2007.