PROJECT REPORT

Conserving Riparian Habitats and Species-at-Risk in the Wahleach Watershed

Prepared for: Fish and Wildlife Compensation Program

Prepared by: P. Burke, R. Murray, A. Robertson, A. Mitchell

Project: COA-F17-W-1211

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Data Accessibility Statement: Quercus Ecological and South Coast Bat Conservation Society submit this Technical Report for Fiscal Year 2017 inventories in the FWCP Coastal Region. Supporting information can be found at the Species Inventory Web Explorer hosted by the British Columbia Ministry of Environment. Bat acoustic records can be downloaded from the Global Biodiversity Information Facility (GBIF) or the Bat Acoustic Monitoring Portal on DataBasin, hosted by the Conservation Biology Institute. Spatial data, including riparian areas and wildlife habitat areas, can also be found on DataBasin. You can reach the primary author of this report at quercusecological@gmail.com.

This project *Conserving Riparian Habitats and Species-at-Risk in Wahleach Watershed* (COA-F17-W-1211) was funded by the Fish and Wildlife Compensation Program (FWCP). The FWCP is a partnership between BC Hydro, the Province of British Columbia, Fisheries and Oceans Canada, First Nations and public stakeholders to conserve and enhance fish and wildlife impacted by the construction of BC Hydro dams. www.fwcp.ca

EXECUTIVE SUMMARY

Species-at-risk in the Wahleach watershed have been impacted by recreational and commercial activities over the past century, including the introduction of fish to the original fish-less Wahleach Lake, timber extraction, metallic and non-metallic mineral mining, and construction of the Wahleach Hydroelectric Facility in 1952. The Fish and Wildlife Compensation Program (FWCP) was initiated in 1999 to restore fish and wildlife resources that were adversely affected by the development footprint of hydroelectric facilities in British Columbia. Footprint impacts include historical effects on fish and wildlife that have occurred because of reservoir creation, watercourse diversions, and the construction of dam and auxiliary structures.

In 2016 – 2017, the FWCP Coastal Region retained Quercus Ecological to inventory wildlife species-at-risk using riparian and wetland habitat in the Wahleach watershed. The purpose of the project was to fill data gaps on species distribution and abundance to prioritize future conservation and management action for species-at-risk. Previous information on species-at-risk was limited to desktop assessments made without empirical field data collected in the watershed. As a result, the project addressed the following four priority items identified in the Wahleach Watershed Plan (2011):

- **2.1** Riparian and wetland habitat mapping
- **2.2** Inventory of amphibians
- **2.3** Inventory of riparian and water-birds
- **2.4** Inventory of bats

Ten wildlife species-at-risk were detected during field inventories in 2016 – 2017: western toad (*Anaxyrus boreas*), coastal tailed frog (*Ascaphus truei*), northern red-legged frog (*Rana aurora*), great blue heron (*Ardea herodias fannini*), olive-sided flycatcher (*Contopus cooperi*), band-tailed pigeon (*Patagioenas fasciata*), black swift (*Cypseloides niger*), little brown myotis (*Myotis lucifugus*), fringed myotis, (*Myotis thysanodes*), and mountain beaver (*Aplodontia rufa*). Many of these species were detected in riparian and wetland habitats throughout the watershed. The project study area included the entire drainage basin emptying into Wahleach Creek plus additional adjacent lands in the Fraser River Floodplain and above Herrling Side Channel at the Wahleach Generating Station.

Field inventories and computer modeling were used to describe the spatial extent and distribution of riparian and wetland habitats in the Wahleach watershed. A variable-width spatial modeling framework was used to estimate the extent of functional riparian areas along stream channels throughout the project study area. The model delineated a riparian zone of 978.5 ha, or approximately 7.4 % of terrestrial habitat within the study area. A wetland assessment was conducted to classify two large, young wetland complexes along the margins of Wahleach Reservoir that have formed since inundation of reservoir. Soils, hydrology, and vegetation were used to delineate the wetland extent in the field at each site. 13.2 ha of wetlands and wet meadow were identified.

Field inventories were conducted to assess the distribution and relative abundance of amphibians in the reservoir, wetlands, and major creeks in the watershed. Amphibians were trapped in shallow waters during summer and surveyed in riparian habitat and wetland habitats adjacent to waterbodies. Amphibians were found in all basins surveyed in the watershed. Three amphibian species-at-risk were detected: coastal tailed frog, northern red-legged frog, and western toad. Neither Oregon spotted frog (*Rana pretiosa*) nor pacific giant salamander (*Dicamptodon tenebrosus*) were detected. Excellent breeding habitat was identified for western toad. The Wahleach region is strategically located at an important geographical nexus for riparian habitat adapted

species, such as western toad. Regional connectivity through this watershed may be important for longitudinal dispersal, climate resilience, and population persistence for many riparian species in the coming decades.

Field inventories were conducted to assess the presence of avian species-at-risk breeding in the watershed. Surveys targeted harlequin ducks, nesting raptors, colonial waterbirds (i.e. herons), and passerine point counts. Four avian species-at-risk were detected in the watershed: great blue heron, olive-sided flycatcher, band-tailed pigeon, and black swift. Potential breeding habitat was identified for black swift.

Field inventories were conducted to assess presence of mammal species-at-risk, including bats, carnivores, and Pacific water shrew. Passive bioacoustics monitoring and capture surveys were conducted to detect presence and relative activity levels of bat species across various habitats. Bat data collected in 2016 – 2017 will be valuable baseline information about bat community activity before the arrival of white-nose syndrome to southwestern British Columbia. Camera traps were used to characterize the large mammal community present in the watershed. An environmental DNA (eDNA) pilot survey targeting Pacific water shrew was conducted to test field protocols for future eDNA surveys and to detect species presence near known critical habitat and modeled habitat suitability. No Pacific water shrews were detected. Three mammal species-at-risk were detected in the Wahleach watershed: fringed myotis, little brown myotis, and mountain beaver. The latter two species are likely breeding in the watershed. Larger, wider-ranging mammal species-at-risk were not targeted by methods employed during this project.

Habitat features for amphibians, bats, birds, and other mammals were identified during field inventories. Important habitat areas were identified for species-at-risk detected in the watershed using aerial photos and spatial reference information. These data together with inventory results will inform future science-based conservation and management decisions in the Wahleach watershed.

The Wahleach watershed is a dynamic and diverse ecosystem that provides habitat for many wildlife species. We have identified additional footprint impacts to aquatic and terrestrial wildlife and habitat beyond what is described in the 2011 Wahleach Watershed Plan. Specifically, changes in the location and extent of wetlands and littoral regions in the watershed following construction and inundation may have had cascading effects on macroinvertebrates, fish, amphibians, birds, bats, and even large mammals. Footprint issues associated with inundation of the original lake have complicated, mixed effects on wildlife species present in the watershed. Habitat enhancements that would provide greatest benefit to wildlife species-at-risk in the Wahleach include protection of all remaining late seral and old growth forest, restoration of hydrological function to Wahleach North and South wetlands, species-specific improvement measures, and maintaining areas with restricted human recreational use.

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ABBREVIATIONS USED

Acronym or Term	*Meaning [Section Reference]*
asl	Above sea level
ASWS	Automated Snow Weather Station
BC CDC	British Columbia Conservation Data Centre
BC MOE	British Columbia Ministry of Environment
BCB	Boulder Creek Basin
˚C	Degrees Celsius (temperature)
CAR	*Canadian Aviation Regulations* (SOR/96-433) *[Section II]*
CTB	Central Basin
CWH	Coastal Western Hemlock biogeoclimatic zone
DEM	Digital elevation model
DDZ	Drawdown zone
DNA	Deoxyribonucleic acid
ESRI	Environmental Systems Research Institute
FBB	Four Brothers Basin
FCB	Flat Creek Basin
FRF	Fraser River Floodplain
FWCP	Fish and Wildlife Compensation Program
GPS	Global positioning system
GRTS	Generalized random-tessellation stratified
ha	Hectare (area)
IFPA	Hope Innovative Forest Practices Agreement *[Section I]*
kHz	Kilohertz (signal frequency)
km	Kilometer (area)
lb	Pound (mass)
LGB	Ludwig Basin
LiDAR	Light Detection and Ranging
LWB	Lower Wahleach Creek Basin
LZB	Lorenzetta Basin
m	Meter (distance)
mAh	Milliamp hour (energy capacity)
MW	Megawatt (energy)
RIC	Resource Inventory Committee
SARA	*Species at Risk Act* (S.C. 2002, c. 29)
TCS	Time-constrained surveys *[Section III]*
TEM	Terrestrial Ecosystem Mapping
TRIM	Terrain Resource Information Management
USFWS	U.S. Fish and Wildlife Service
UWB	Upper Wahleach Creek Basin
VES	Visual encounter surveys *[Section III]*
WHR	Wildlife habitat ratings
WREC	Wetland and Riparian Ecosystem Classification *[Section II]*

ACKNOWLEDGEMENTS

We thank Peters First Nation (Peters Band) and Stó:lō Nation Tribal Council for supporting this project. In particular, we would like to thank Peters First Nation Councillor Victoria Peters and Chief Norma Webb for allowing access to their lands and for writing a letter of support. We also thank Frances Genaille for welcoming us into the community and supporting our project from the beginning.

This project is the result of collaboration between the South Coast Bat Conservation Association (SCBats) and Quercus Ecological. This project would not have been possible without the support of Felix Martinez-Nuñez, Rylee Murray, Aimee Mitchell, Chris Currie, Ashley Robertson, and Nick Hindley who conducted fieldwork, analyzed data, and contributed to this report. Matt Strimas-Mackey, Jennifer Buchanan, Josefin Kuschela, Angela Fulton, John Saremba, Kirk Miles, Catherine Miles, and Laura Burke contributed in-kind support and over 230 hours of volunteer time to this project. Dr. Sinan Abood with the USDA Forest Service supported variable-width riparian modeling. Dr. Cori Lausen of Birchdale Ecological provided bat detectors and equipment for bat capture surveys. Aimee Mitchell of Athene Ecological provided materials and lab time to filter eDNA samples. Chris Currie provided safe, expedient passage across the reservoir. Susan Dulc of Aurora Ecological facilitated eDNA analysis at the Helbing lab at the University of Victoria. Jared Hobbs of Hemmera Envirochem, Inc. provided guidance in design of eDNA surveys and interpretation of results. Brent Wilson with BC Hydro supported access to site. Gary Belcourt with BC Hydro sourced geospatial data for riparian modeling. The Department of Zoology and Biodiversity Research Centre at the University of British Columbia provided field equipment for camera trap surveys and remotely piloted aircraft surveys. Stantec Consulting provided equipment for bat surveys. The Varsity Outdoor Club provided watercraft to access remote regions of the watershed.

Finally, Quercus Ecological gratefully acknowledges the financial support of the Fish and Wildlife Compensation Program for its contribution to the Riparian Habitats and Species-at-Risk in Wahleach Watershed. www.fwcp.ca.

SECTION I: STUDY AREA AND PROJECT SCOPE

This project was conducted as part of the Fish and Wildlife Compensation Program in 2016 – 2017 to compensate for the loss of habitat associated with construction of the Wahleach Hydroelectric Facility over sixty years ago. The purpose of this study is to provide preliminary information on the status of riparian and wetland habitats and wildlife species-at-risk in the Wahleach watershed.

Wahleach Watershed Study Area

The Wahleach watershed is located within the Cheam Range, part of the Chilliwack Group of the Canadian North Cascade Mountains, in southwest British Columbia (BC), Canada. Wahleach Creek, also known as Jones Creek, flows north into the Fraser River. Wahleach Creek drains a 13,750 hectare (ha) watershed which includes 273 km of perennial streams, 6.4 ha open standing water, and 105.9 ha of glacial ice. Elevations in the watershed range from 27 meters (m) above mean sea level at the confluence of Wahleach Creek with the Fraser River to 2,431 m at the summit of Welch Peak. The watershed contains nine creek basins, two wetland complexes, the Wahleach Reservoir, and a network of riparian habitats surrounding creeks and headwater tributaries, (see angling, off-road vehicle usage, hunting, and hiking. A poor ethic of stewardship, low rates of enforcement, and limited public trash receptacles in the watershed contribute to substantial litter and dumping associated with recreational activities. Most litter observed in the watershed was benign, but some toxic substances were identified and many plastic receptacles were found persisting in wetland and riparian habitats in the watershed. and Figure I-1). Basin size includes terrestrial habitat less open water to the high-water mark of the Wahleach Reservoir.

Table I-1. Creek basins and geomorphic characteristics in the Project Study Area

Basin	*Code*	*Basin Size[1]*	*Stream Length[2]*	*Riparian[1]*	*Open Water[1]*	*Glacial ice[1]*
Boulder Creek Basin	*BCB*	2,751	54.4	203.0	4.3	0.0
Upper Wahleach Creek Basin	*UWB*	2,182	66.7	206.7	0.2	22.9
Flat Creek Basin	*FCB*	2,069	39.3	147.8	0.0	83.0
Lower Wahleach Creek Basin	*LWB*	1,592	33.3	128.6	0.2	0.0
Lorenzetta Basin	*LZB*	1,382	15.2	70.4	0.0	0.0
Ludwig Basin	*LGB*	1,145	33.4	104.0	0.0	0.0
Central Basin	*CTB*	821	7.9	31.6	1.7	0.0
Fraser River Floodplain	*FRF*	766	9.0	55.7	NA	0.0
Four Brothers Basin	*FBB*	483	9.4	30.7	0.0	0.0

[1] Areal extent is expressed in hectares (ha) [2] linear extent is expressed in kilometers (km)

The study area occurs within the Coastal Western Hemlock (CWH) biogeoclimatic zone, a region of high productivity, high precipitation, and a climate moderated by oceanic air masses (Pojar et al. 1991). The CWH occurs across low elevations and major river valleys up to approximately 900 m in mountainous regions of western BC. Within the watershed, the biogeoclimatic zone can be subdivided into two sub-zones: the dry maritime (dm) and moist submaritime (ms). The dry maritime subzone occurs in the lower watershed, in the Fraser River floodplain and up to 500 m along lower Wahleach Creek. The moist submaritime zone occurs across most of the study area, at elevations between 500 and 1200 m (Green 2003a).

The climate in the study area is moderated by oceanic air masses. Mean annual air temperature at the Wahleach Reservoir (642 m) is about 6.47 degrees Celsius (˚C), with average summer high of 17.67 ± 3.55 ˚C to average winter low of -2.00 ± 2.45 ˚C. The surface of the reservoir freezes solid in some years, but only partially in others. Midwinter snow depth at the Wahleach Lake Upper Automated Snow Weather Station (ASWS; Station ID 1D09P) averages 134.2 ± 65.7 centimeters (cm) at 1,408 m in elevation. Temperatures at this elevation range from average summer high of 27.19 ± 3.1 ˚C to average winter low of -13.13 ± 5.0 ˚C.

Landslides and debris torrents occasionally occur in the study area, primarily driven by erosion associated with timber harvest and road building. A large landslide in the lower Wahleach watershed caused a large debris torrent at the confluence of 2.8 Mile Creek and Wahleach Creek in 1994 (McIntosh & Robertson 2001). Sediment is actively being transported from this slide into the lower reach of Wahleach Creek. Additional slides occurred decades ago, introducing large volumes of sediment into the reservoir (Stockner & Bos 2002).

The Wahleach watershed falls within the traditional territory of the Peters First Nation and Stó:lō Nation. The Peters Band and Omahil Indian Reserves occur within the study area along the Fraser River, near the confluence with Wahleach Creek. The Traditional Territory of the Stó:lō Nation is known as S'ólh Téméxw. The Stó:lō S'ólh Téméxw Land Use Plan identifies Sanctuary and Cultural Landscape Features within the study area. Protected Watersheds also occur in adjacent basins to the south and northeast of the study area.

The Wahleach watershed receives high recreational usage in summer, with most activities occurring on the northeastern shore of the reservoir. Two BC Hydro Recreation sites exist on the northeastern shore of the reservoir. Jones Lake Cabin Association built approximately 20 cabins along the eastern shore of the lake. Camping and swimming are the most common activities, followed by motorized and non-motorized boating, angling, off-road vehicle usage, hunting, and hiking. A poor ethic of stewardship, low rates of enforcement, and limited public trash receptacles in the watershed contribute to substantial litter and dumping associated with recreational activities. Most litter observed in the watershed was benign, but some toxic substances were identified and many plastic receptacles were found persisting in wetland and riparian habitats in the watershed.

Wahleach Hydroelectric Facility Footprint Impacts

The Wahleach Reservoir, also known as Jones Lake Reservoir, is an artificial lake created by raising the level of the original Wahleach Lake 21 m with an earthen dam at the outflow of Wahleach Creek on the northeast shore of the lake (FWCP 2011). Additional water is diverted into the reservoir from Boulder Creek. Power is produced by the force of water, diverted from the reservoir through a 4.2 mile tunnel under Four Brothers Mountain, to turn a generator located approximately 600 m in elevation below the reservoir. Water is discharged from the powerhouse into Herrling Island side channel on the south shore of the Fraser River. The reservoir drains 9,300 ha, approximately 68% of the Wahleach watershed.

The Wahleach Reservoir has a maximum water surface elevation of 641.6 m at the spillway crest. The reservoir fills during the freshet between April and June, with maximum water levels in July and August. The reservoir is drawn down between November and April, with average minimum water levels of 629.4 ± 4.6 m. maximum areal extent of the lake surface decreases can exceed 40% (from 517 ha to 306 ha) at full drawdown (Stockner & Bos 2002). At full depth, the reservoir has a maximum depth of 28 m, approximately 17 m deeper than the original Wahleach Lake. At full extent, the reservoir is three time larger than the original Wahleach Lake. See Figure I-3 and Table I-2 for comparison between original lake and reservoir extent. Measurements are derived here from a digital elevation model (DEM) described in Section II: Riparian Assessment.

The Wahleach Hydroelectric Facility began generating power in 1952 (Campbell & Wilson 2012). The construction of the dam, powerhouse, and inundation land in the watershed significantly altered habitat for fish and wildlife in Wahleach watershed. Filling the Wahleach Reservoir inundated approximately 211 ha of land, affecting local hydrology, wildlife habitat availability, and ecosystem nutrient regimes. The full extent of beneficial and deleterious effects on species-at-risk remain unknown. The Wahleach Generating Facility contributes 65 megawatt (MW) to the 1,996.8 MW electrical capacity in the Lower Mainland and coastal region of southwestern British Columbia.

The FWCP Wahleach Watershed Plan (2011) identifies the following footprint issues associated with construction of the reservoir:

- Loss of 30 ha of riparian habitat
- Loss of 8 km of river habitat
- Loss of 11 km of natural shoreline
- Reduced flow regime through Lower Wahleach Creek and loss of fish habitat
- Reduced large woody debris into Jones Creek
- Altered flow regime in Herrling Island side channel

Additional footprint issues in the Wahleach watershed associated with construction of dam and generating facilities are less easily quantified. Additional footprint issues associated with removing native vegetation and creating the reservoir may include the following:

- Loss of extensive littoral habitat following inundation (Stockner & Bos 2002)
- Altered lacustrine nutrient regimes
- Alteration of riparian and wetland vegetation communities (e.g. loss of redcedar swamp forest)
- Inundation of vernal pools and ponds in the Upper Wahleach Creek drainage
- Decreased system gross primary productivity (Utzig & Schmidt 2011)
- Trophic cascades for aquatic and terrestrial-riparian systems
- Aquatic connectivity barriers for some species (Figure I-3).

Additional footprint issues associated with water use and the large drawdown zone (DDZ) in the reservoir may include changes in vegetation community in littoral zone from desiccation, freezing and inundation (Gnabasik et al. 1997), trophic cascades for aquatic and terrestrial-riparian systems, aquatic connectivity barriers for some species (specifically fish into Boulder Creek), and changes to the benthic macroinvertebrate community (Furey et al. 2006; McEwen & Butler 2010), a critical food for fish, amphibians, bats, and birds.

Table I-2. Changes to original lake following reservoir construction

Basin	*Area*	*Shoreline*	*Maximum depth*	*Lake classification*
Wahleach Reservoir, high water	517 ha	17.9 km	28 m	extensive limnetic
Wahleach Reservoir, low water	306 ha	13.8 km	15 m	extensive limnetic
Wahleach Lake, original post-glacial lake	174 ha	7.6 km	11 m	extensive littoral

Previous studies in the Wahleach watershed

In 2001, a wildlife overview was completed by Robertson Environmental Services, Inc (McIntosh & Robertson 2001) at the request of the Wahleach-Jones Reservoir Water Use Plan Committee. This wildlife overview provides a broad characterization of the mammal community that may occur in the watershed through a comprehensive literature review and interviews. The report also identified data gaps on wildlife use of the watershed. Specific gaps identified include a lack of information on wildlife in the Lower Wahleach Creek area, a lack of information on wildlife use of Herrling Side Channel, and a lack of inventory information

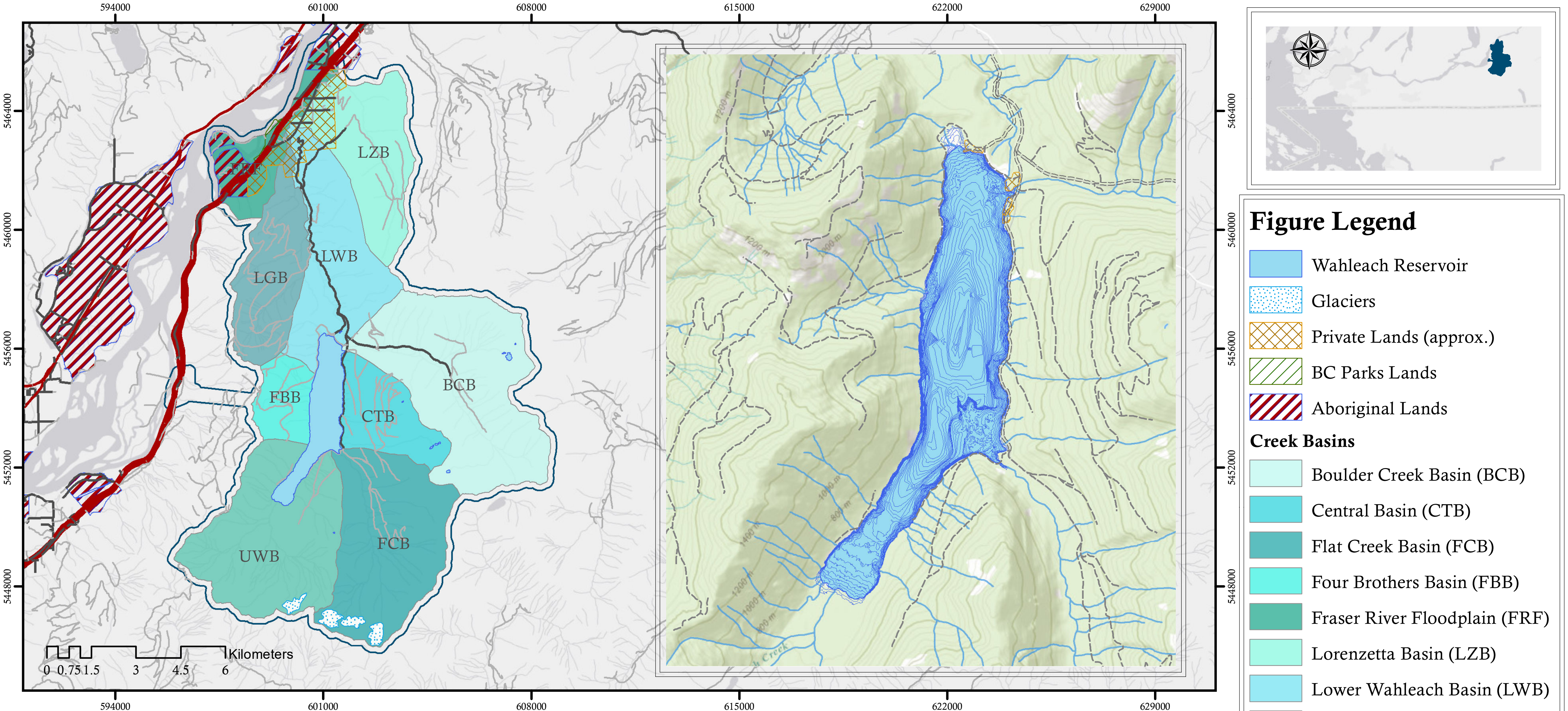

Figure I-1: Overview map of Wahleach watershed study area

This Project is funded by the Fish and Wildlife Compensation Program (FWCP). The FWCP is a partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations and public stakeholders to conserve and enhance fish and wildlife impacted by the construction of BC Hydro dams.

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on bat, amphibian, reptile, and small mammal populations in the study area. The report was produced from a desktop literature review without any field sampling.

The Hope Innovative Forest Practices Agreement (IFPA) produced multiple spatial data products in 2003 that include the Wahleach watershed (Green 2003b). Terrestrial Ecosystem Mapping (TEM) was developed at 1:20,000 scale in accordance with 1998 TEM Standard and wildlife habitat ratings (WHR) were developed for black-tailed deer (*Odocoileus hemionus*). Ongoing studies are being conducted by an independent power producer developing a run-of-river hydroelectric project on Lower Wahleach Creek. Associated with this development, the B.C. Ministry of Forests, Lands, and Natural Resource Operations is conducting a region-wide before-after control-impact (BACI) study for coastal tailed frog (*Ascaphus truei*), a phylogenetically unique species sensitive to stream disturbance.

2016 – 2017 Project Scope

The purpose of the project COA-F17-W-1211 was to fill data gaps on species distribution to prioritize future conservation and management action for species-at-risk in the Wahleach watershed. The project was aligned with the Priority Topics identified in the Wahleach Watershed Plan (Fish and Wildlife Compensation Program (FWCP) 2011). The project specifically addressed the following five objectives:

1. To measure and map habitats and wildlife features important to wildlife species-at-risk in the Wahleach watershed
2. To identify the presence, and where possible, the relative abundance, of small mammals, bats, birds, and amphibians present within riparian habitats of the watershed using established methodology,
3. To identify opportunities for conservation and restoration of biodiversity in the watershed,
4. To develop management recommendations to improve species-at-risk habitat, and
5. To increase community engagement in conservation and restoration in the region.

This Technical Report provides findings and recommendations following from research and information acquisition activities conducted to meet these objectives in 2016 – 2017. The Report is organized under inventory headings which are subject or taxa specific (e.g. Amphibian Inventories). Within each section, surveys methods, results, discussion, and recommendations for future surveys are addressed. The report concludes with a final section on conservation and management opportunities for terrestrial and amphibian species-at-risk in the watershed. In 2016-17, the following inventories were completed:

1. Habitat Inventories

- I.a. Riparian Habitat Delineation
- I.b. Wetland Assessment
- I.c. Remotely Piloted Aircraft Systems Survey

2. Amphibian Inventories

- II.a. Amphibian Trapping Survey
- II.b. Amphibian Time Constrained Survey

3. Avian Inventories

- III.a. Harlequin Duck Survey
- III.b. Avian Stick Nest Survey
- III.d. Breeding Passerine Survey

4. Mammal Inventories

IV.a. Environmental DNA (eDNA) Survey
IV.b. Camera Trap Survey
IV.c. Acoustic Bat Survey
IV.d. Bat Capture Survey

Study Limitations

This study provides preliminary findings from one year of inventory on species-at-risk in the Wahleach watershed. Given the broad scope of the project objectives and available funding, surveys targeted only presence and distribution of species, not abundance. Further, given the heterogeneity of wildlife occurrence and the single year of sampling conducted for this project, our results provide an incomplete characterization of at-risk species in the watershed. Additional assumptions and limitations of selected survey methods are discussed in each section of this Technical Report.

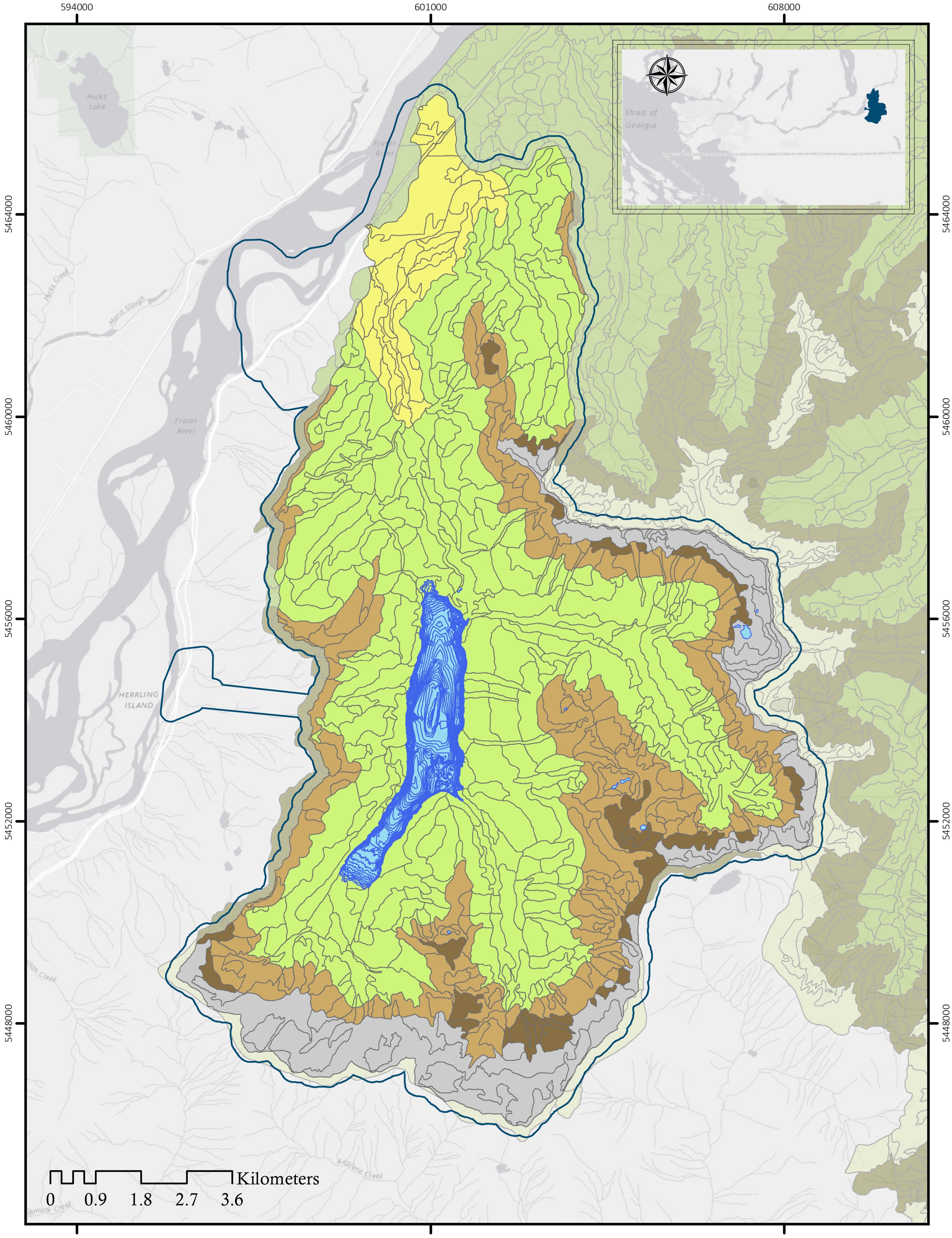

Figure I-2: Biogeoclimatic zones in the Wahleach watershed

This Project is funded by the Fish and Wildlife Compensation Program (FWCP). The FWCP is a partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations and public stakeholders to conserve and enhance fish and wildlife impacted by the construction of BC Hydro dams.

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Figure Legend

BGC Zones (Hope IFPA)

- AT
- CWHdm
- CWHms1
- MHmm2
- MHmmp

Open Water (1m bathy.)

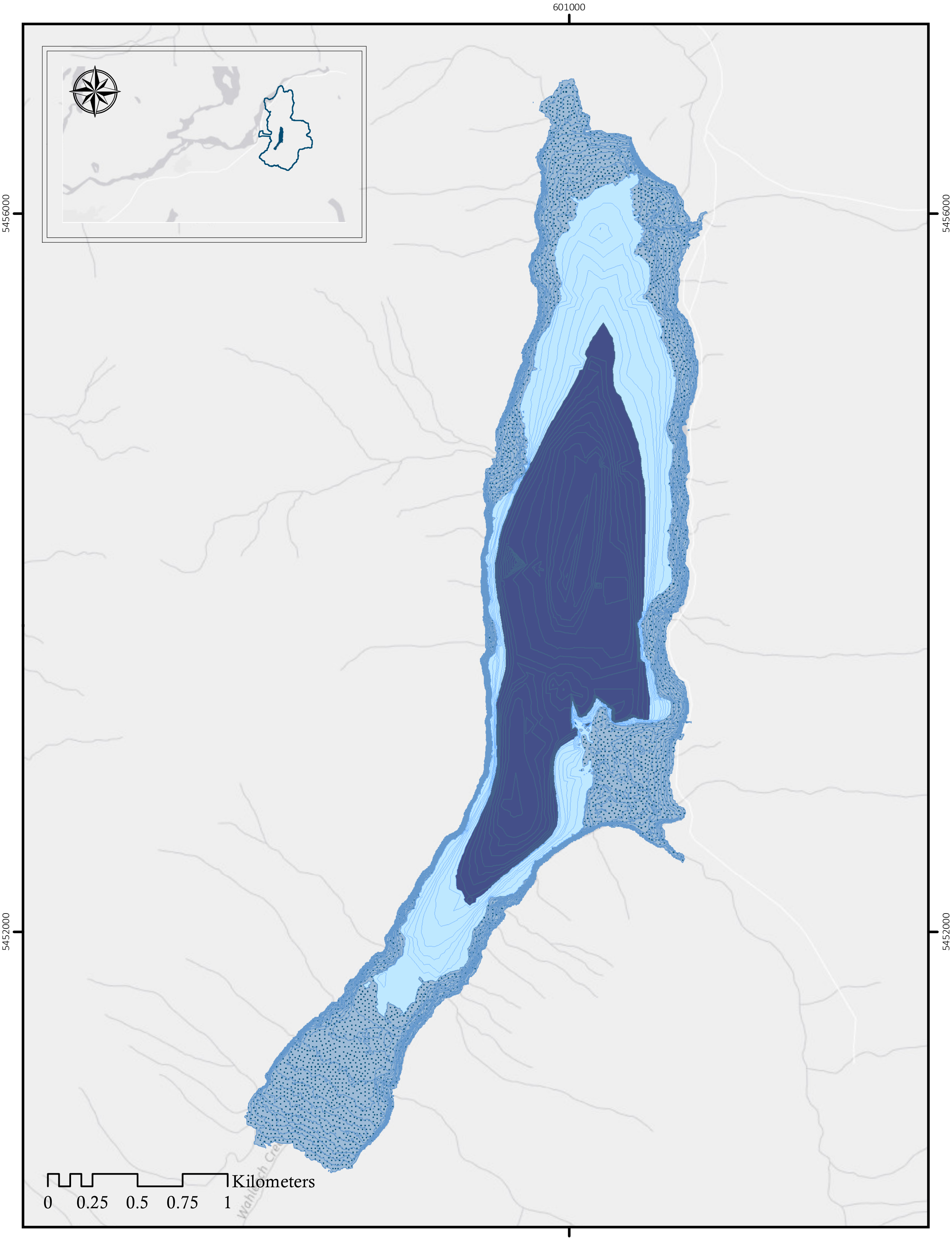

Figure I-3: Wahleach Reservoir and original lake extent

This Project is funded by the Fish and Wildlife Compensation Program (FWCP). The FWCP is a partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations and public stakeholders to conserve and enhance fish and wildlife impacted by the construction of BC Hydro dams.

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Figure Legend

Lake Extent

- Original Lake Extent
- Reservoir Low Water Level
- Reservoir Drawdown Zone

SECTION II: HABITAT INVENTORIES

The objective of habitat inventories conducted in 2016 – 2017 was to measure and map riparian habitats and wetlands with habitat value for wildlife species-at-risk in the Wahleach watershed.

Riparian Assessment

Riparian Assessment Methods

Riparian habitats are dynamic, diverse, and complex systems with high ecosystem service value. Many definitions exist to describe riparian areas. The BC Wetland and Riparian Ecosystem Classification (WREC) provides the straightforward definition of riparian zones as any terrestrial ecosystem adjacent to a waterbody (Mackenzie & Moran 2004). The BC Riparian Areas Regulation requires riparian habitat assessments within a fixed-radius buffer of 30 m from the high water mark or top of a ravine bank (RAR 2005). We use the definition of Illhardt et al. which considers the ecological function of riparian areas and incorporates flux of energy and materials through the ecosystem: "Riparian areas are the three-dimensional ecotones of interaction that include terrestrial and aquatic ecosystems, that extend down into the groundwater, up above the canopy, outward across the floodplain, up the near-slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at a variable width" (2000). This definition describes habitats of variable-width that are defined by ecological factors such as landscape geomorphology, hydrology, nutrient flow, soils, and vegetation.

The location and extent of riparian habitats within the Wahleach watershed were estimated using a variable-width spatial modeling framework called the Riparian Buffer Delineation Model (RDBM) version 5.0 (Abood & Maclean 2017). Variable-width spatial modeling more accurately depicts natural riparian conditions when compared to traditional fixed-width spatial modeling. For management purposes, variable-width riparian buffers more adequately protect riparian ecosystem services, while providing for multiple use of adjacent terrestrial habitat (Abood & Maclean 2011).

The RDBM model was run in ArcGIS Desktop 10 (ESRI 2015) using a digital elevation model (DEM), stream locations, wetland extent, lake extent, and an estimate of the 50 year flood height. The DEM was compiled from multiple remote sensing data products with various resolution. Most of the study area, including all lands above 650 m elevation, comes from Terrain Resource Information Management (TRIM) base data at +/- 10m horizontal and +/- 5m vertical accuracy. Light Detection and Ranging (LiDAR) data was available for the Fraser River Floodplain at elevations below 100m with +/- 20 cm accuracy. High resolution aerial photogrammetry was available for the Lower Wahleach Creek drainage from flights conducted in May 1991 with +/- 0.5 m accuracy. Stream and waterbody data were collected from the B. C. Freshwater Atlas. The 50-year flood height has been shown to be the optimal hydrologic descriptor of functional riparian habitats (Ilhardt et al. 2000), often coincides with the first terrace in a stream floodplain, and can be measured by long-term stream gauge data (Abood & Maclean 2011). The RDBM model is sensitive to changes in this parameter. However, long-term stream gauge data was not available at the time of this report, so flood height was conservatively estimated based on a linear relationship between stream order and flood height across many systems. The following flood heights were used: 0.50 m for first order streams, 0.55 m for second order streams, 0.75 m for third order streams, 0.95 for fourth order streams, and 1.25 for fifth order streams. Lake buffers were set to default of 30.48 m (Ilhardt et al. 2000). And sampling distance was set to 100 m with distance between sampling points of 1.5 m.

Riparian Assessment Results and Discussion

Riparian areas were modeled for all basins within the Project Study Area, including the Wahleach basin and the Fraser River Floodplain. Across the study area, 978.5 ha of riparian habitat was identified (see Table II-1 and Figure II-1). Approximately 7.4% of the terrestrial habitat within the Project Study Area is riparian habitat.

Table II-1. Variable-width riparian area model results

Basin	Riparian Area (ha)	% of Basin
Boulder Creek Basin	203.0	7.4 %
Upper Wahleach Creek Basin	206.7	9.5 %
Flat Creek Basin	147.8	7.1 %
Lower Wahleach Creek Basin	128.6	8.1 %
Lorenzetta Basin	70.4	5.1 %
Ludwig Basin	104.0	9.1 %
Central Basin	31.6	3.8 %
Fraser River Floodplain	55.7	7.3 %
Four Brothers Basin	30.7	6.4 %

Given the parameters outlined above used in the present model, the derived variable-width riparian habitat had high similarity with a traditional 30 m fixed-width buffer for low order streams (Strahler first and second order streams) in areas of moderate and steep topography. However, the model derived riparian habitat represented natural habitat much better in flatter terrain, near wetlands, along higher order streams, and in regions of wide riparian habitat around braided creek channels and in floodplains.

The FWCP Wahleach Watershed Plan estimates loss of 30 ha of riparian habitat to inundation during reservoir construction (FWCP 2011), but methods used to estimate that area are not known. Fixed-width riparian buffers were most likely employed, which would underestimate the full extent of riparian habitat that was lost. Future modeling of variable-width riparian areas below the reservoir high-water mark may provide more accurate estimates of historical riparian habitat in the watershed.

Wetland Assessment

Wetland Assessment Methods

A wetland assessment was conducted to classify and delineate large wetlands located in the Wahleach watershed. Wetland assessment surveys were conducted following approved methods outlined in the Land Management Handbook 25, Field Manual for Describing Terrestrial Ecosystems 2nd edition (British Columbia Ministry of Forests and Range & BC MOE 2010). Wetland type, class, and where possible association were identified using the Land Management Handbook 52, Wetlands of British Columbia (Mackenzie & Moran 2004). Wetland area was quantified using Google Earth Pro mapping and measurement tools assisted by digital field maps produced in ArcGIS, Google Earth imagery (Google Earth Pro 2017a, 2017b), field observations, and global positioning system (GPS) locations.

Wetlands were assessed by two surveyors in late summer and early fall when water levels had receded. Surveyors completed Ecosystem Field Forms (FS882, 2008) for each wetland sequence in the Wahleach watershed. Field inventories were completed on 14 – 16 September, 28 – 29 September, and 11 November 2016. Surveyors accessed wetland areas by vehicle, foot and boat. Within each wetland sequence, 20m x 20m

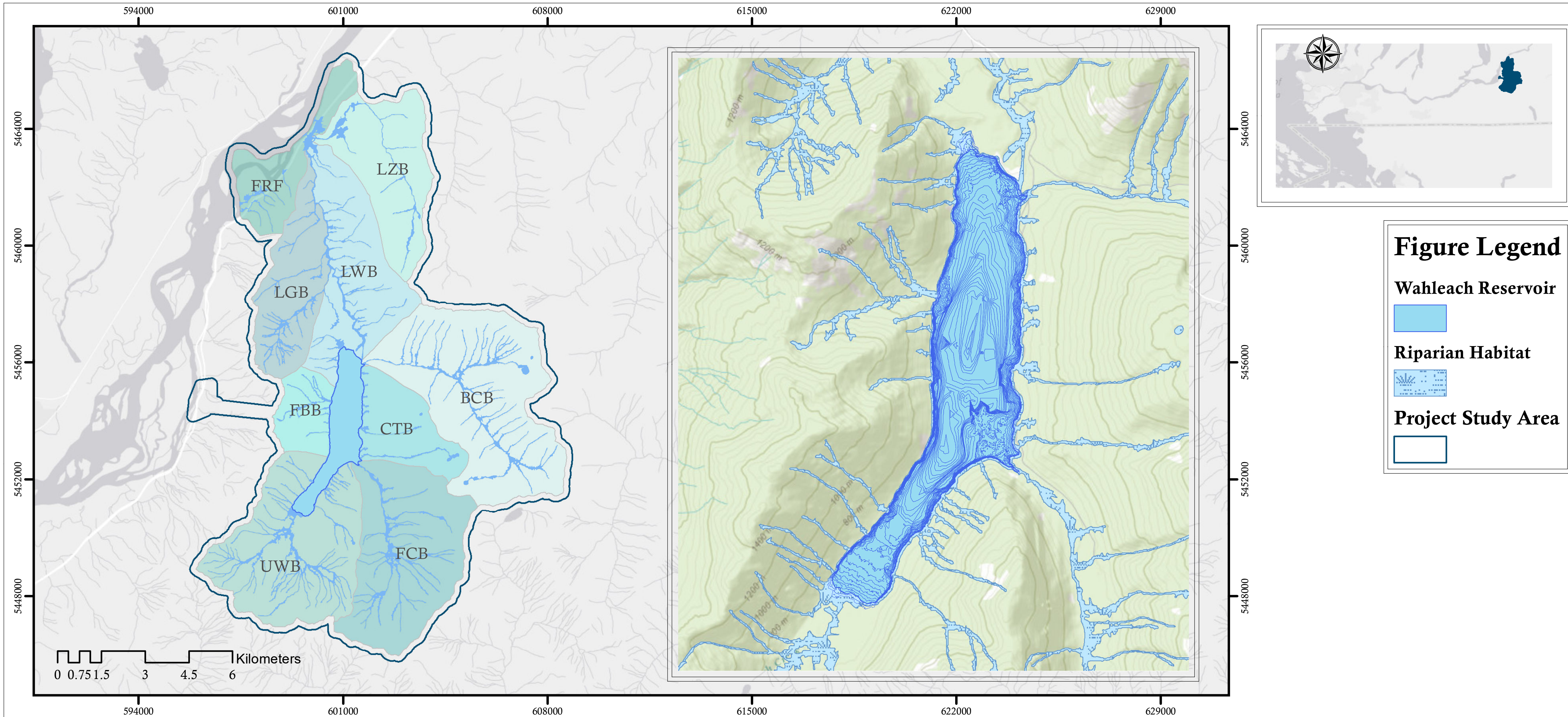

Figure II-1: Riparian areas in the Wahleach watershed

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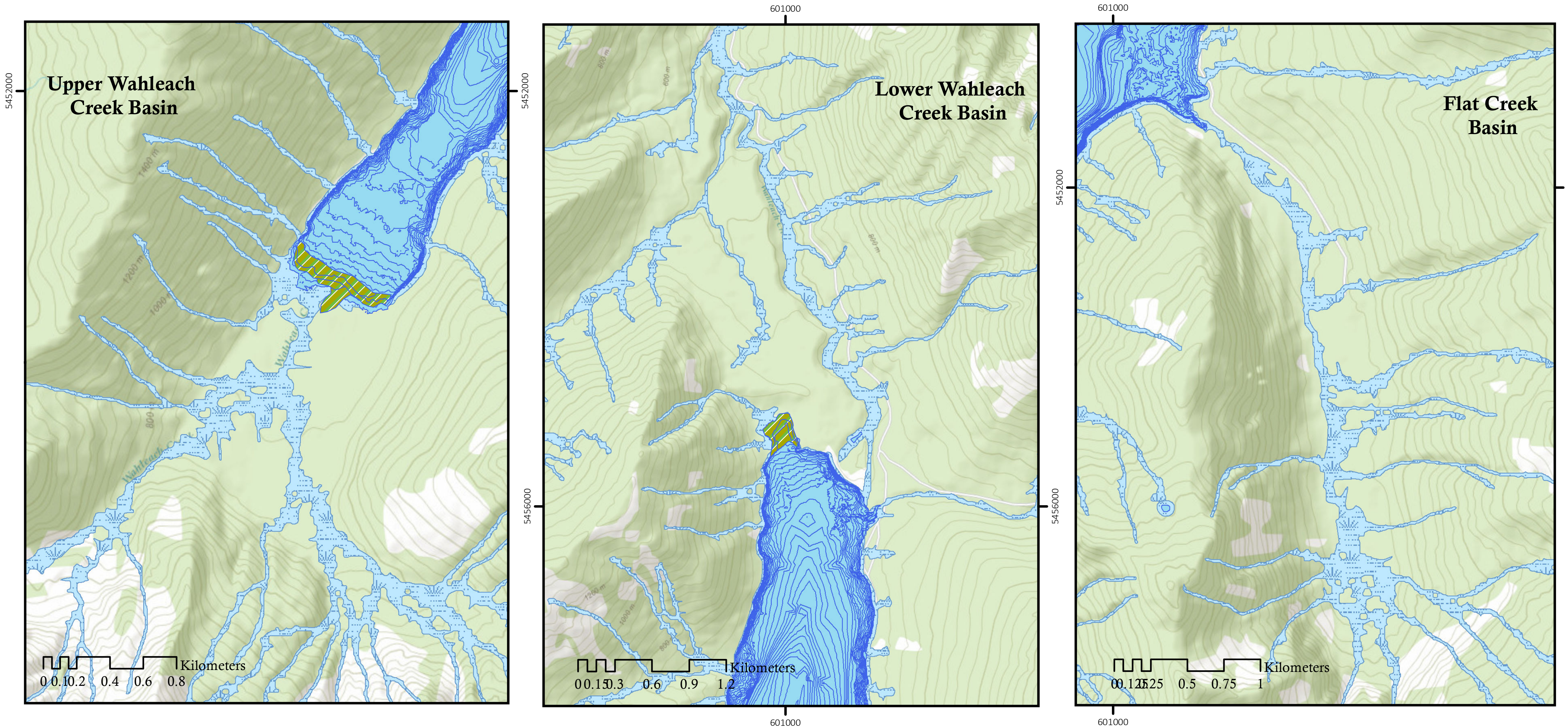

Figure II-2: Important riparian habitat complexes

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Figure Legend

- Wetlands
- Riparian Habitats

simple homogeneous plots were established. At each plot, site information, substrate, soils, and vegetation were described. Soils were assessed from a soil pit approximately 120 cm in depth using a soil auger.

Wetland Assessment Results and Discussion

Two wetland complexes were identified in the watershed (see Table II-2 and Figure II-2), the Wahleach North wetland (approximately 5.3 ha in size) and Wahleach South wetland (approximately 7.2 ha in size). The Wahleach North and Wahleach South wetlands share similar sequences of wetland classes and can be described as Lacustrine Fen / Swamp wetlands with fluctuating water levels. Water use associated with dam operations drives hydrology in both wetlands. The dynamic annual pattern of flooding and drying drives both soil characteristics and vegetation communities in these wetlands. Soils and vegetation are saturated for weeks during the summer growing season in both wetlands. Gleyed soils were not detected up to 1 m depth, though mottling was observed in the rich organic topsoil, suggesting some oxygen depletion in the soil. Vegetation was dominated by hydrophytes and facultative wetland plants.

A transitional wet meadow (approximately 0.7 ha in size) was identified on the eastern shore of the reservoir near the spillway. Additional small pocket wetlands, seeps, and vernal pools were detected but not mapped in riparian areas throughout the watershed.

Table II-2. Wetland assessment classification for Wahleach North and Wahleach South

Complex	Wetland	Class, Association	Area (ha)	Notes
North	WN-01	Fen, Wf53	1.72	Submerged during summer, up to 1.5m depth. Early seral species (*Equisetum* spp.) and emergent vegetation.
North	WN-02	Fen, Wf53	1.52	Taller herbaceous vegetation, shorter periods of inundation. Wet depressions and microhabitat.
North	WN-03	Swamp	2.09	Woody perennials (*Salix* sp.) and substantial LWD. Wet seeps.
South	WS-01	Fen	3.16	Emergent vegetation below HWL. Numerous channeled drainages and stumps throughout.
South	WS-02	Swamp	1.97	Region of woody perennials established beyond HWL.
South	WS-03	Swamp, Ws52	0.57	Dominant shrub layer (*Alnus rubra*) and *Lysichiton americanus*. Wildlife trees and potential roosting sites identified.
South	WS-04	Swamp	1.48	Braided channel, alluvial soil, deciduous trees, seeps, *Lysichiton americanus* and pooling water.
East	WE-01	Wet meadow	0.69	Degraded meadow on substrate associated with construction of earthen dam and spillway. Candidate for restoration.

The Wahleach North wetland complex is located west of the BC Hydro West Campground. The entire wetland is located within the reservoir DDZ, with maximum inundation occurring between June and October. Herbaceous vegetation in the North wetland is dominated by sedges in the genus *Schoenopletus*, known as bulrushes. The margins of the wetland are characterized by woody perennials (*Salix* spp.) and dense large woody debris (LWD), quickly transitioning to mature coniferous forest. Generally, the vegetation community is composed of early-seral species adapted to disturbance, including inundation and desiccation.

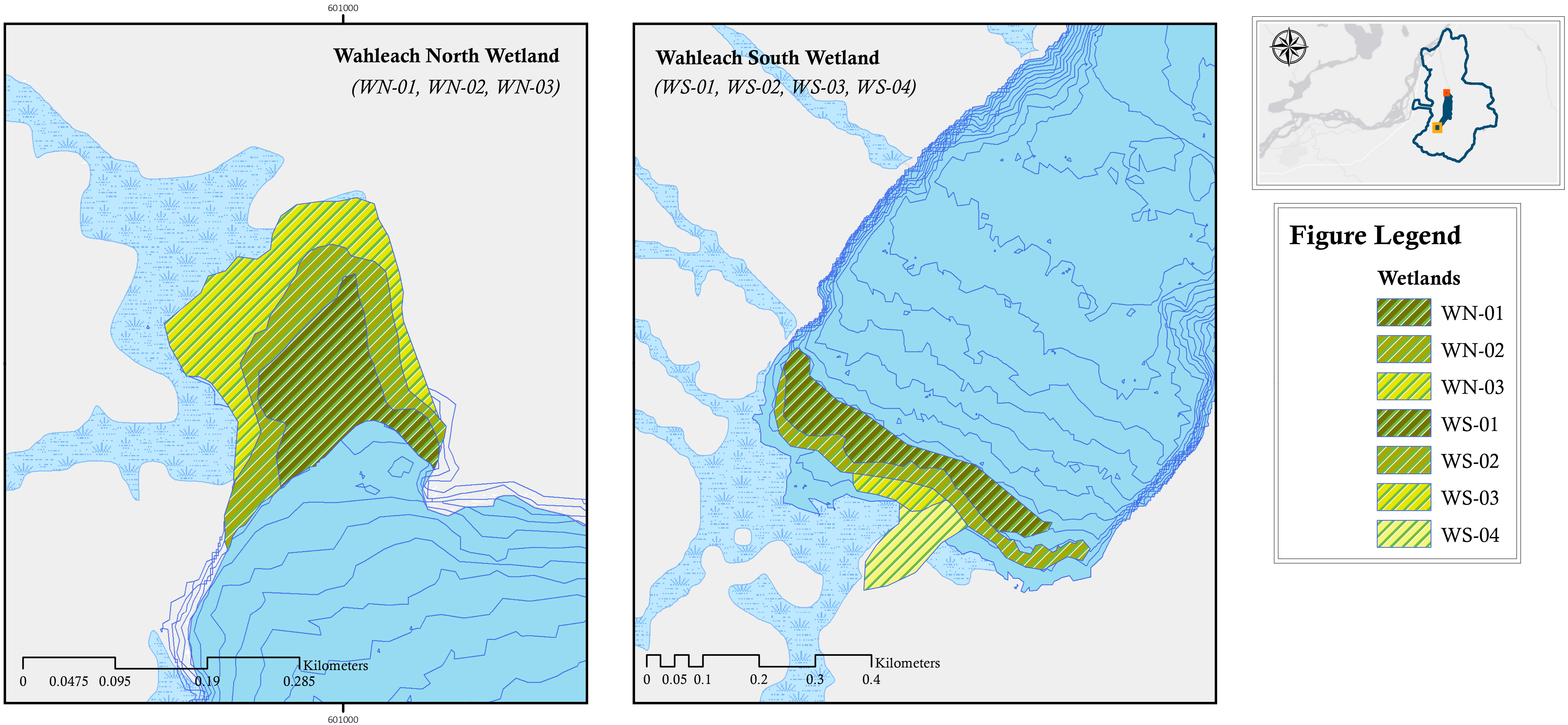

Figure II-3: Wetland complexes in the Wahleach watershed

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Author: P. Burke

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The Wahleach North wetland provides an active breeding site for western toad (*Anaxyrus boreas*) and suitable nesting habitat for passerines. Site disturbance at the North wetland include the presence of human waste, human refuse, compaction and ATV tracks, and fluctuating water levels. Water level fluctuations drive hydrological conditions which can disrupt amphibian breeding (see Appendix C, Image 1) and limit establishment of late successional wetland vegetation. The proximity of the site to road access and opportunity for public outreach and education make the North wetland a candidate site for a wetland enhancement project.

The Wahleach South wetland complex is located at the southern end of Wahleach Reservoir, below the steep north face of the Cheam Range. This site is accessible to the public by boat access and receives little human use. The vegetation community is similar to that found in the Wahleach North wetland. The wetland is 640 m long, but only 50 – 100 m wide, bisected by numerous channeled drainages that fan out into the reservoir. Several wildlife trees were identified in the area and western toad metamorphs were detected in dry ephemeral drainages upstream of the wetland. Field surveys in the South wetland were incomplete to do access, weather and time constraints.

Remotely Piloted Aircraft System Survey

The purpose of the remotely piloted aircraft system (RPAS) survey was to collect aerial images at a finer resolution than currently available aerial imagery. RPAS imagery collected can support future vegetation mapping, wetland delineation, and the development of a high resolution digital surface model to support wetland enhancement or restoration in the Wahleach North wetland.

Remotely Piloted Aircraft System Survey Methods

Aerial imagery was collected using a RPAS flying at low elevation above riparian and wetland habitats in the watershed. The RPAS consisted of a 3DRobotics (3DR™) Solo multi-rotor platform, a tri-axial gimbal with GoPro™ HERO4 sensor, and a 2.4 GHz radio controller. The controller communicated with the aircraft using 3DR Link secure WiFi network and the flight controller software was Pixhawk 2 Autopilot, which uses integrated backup for in-flight recovery and manual override. The aircraft measured approximately 0.4 m^2 with a payload weight of 1.8 kg (3.9 lbs) and was powered by Lithium polymer 5200 milliamp hour (mAh) battery with a direct current voltage of 14.8 V. Flight missions were programmed using the Tower application on a Nexus 5 mobile device running Android 4.4 "KitKat" operating system. The RPAS surveys were conducted under an exemption from Sections 602.41 and 603.66 of the *Canadian Aviation Regulations* (CARs) pursuant to the Advisory Circular *General Safety Practices – Model Aircraft and Unmanned Air Vehicle Systems* (AC 600-02; effective 2014-11-27). Missions occurred in class G airspace in the Lower Wahleach Creek and Boulder Creek basins prior to December 2016. Missions were conducted by one pilot-in-command / operations manager with ground school training and a visual observer. Five RPAS missions were conducted between 14 September and 22 September 2016. Flights occurred between 85 and 100 m above ground level. RPAS data is available for future vegetation community or wildlife habitat mapping.

Habitat Inventory Conclusions

The Wahleach watershed is a dynamic and diverse ecosystem that provides habitat for many wildlife species. We have identified additional footprint impacts to aquatic and terrestrial wildlife and habitat beyond what is described in the Wahleach Watershed Plan (FWCP 2011). Specifically, changes in the location and extent of wetlands and littoral regions in the watershed following construction and inundation may have had cascading effects on macroinvertebrates, fish, amphibians, birds, bats, and even large mammals. Footprint issues associated with inundation of the original lake have complicated mixed-effects on wildlife species present in the watershed. Habitat enhancements that would provide greatest benefit to wildlife species-at-risk in the

Wahleach include protection of all remaining late seral and old growth forest, restoration of hydrological function to Wahleach North and South wetlands, species-specific improvement measures, and maintaining areas with restricted human recreational use.

Recommendations for Future Habitat Inventories in the Wahleach Watershed

Improved bathymetry would support improved limnological modeling to predict the full extent of losses to wetland and littoral areas following construction of the Wahleach Reservoir. Emerging technologies, such as environmental DNA may be used to re-construct historical community assemblages using genetic material persisting in submerged sediments. We recommend a robust assessment of footprint issues be conducted to inform development of future restoration actions in the Wahleach watershed. Robust estimates of potential wetland extent prior to construction could improve understanding of footprint impacts in this watershed.

The value of the Wahleach wetlands at a landscape scale are poorly understood. Although the wetlands in the watershed have significantly altered hydrology and moderate anthropogenic impacts, high quality habitat for some species-at-risk is present. For example, western toad was present breeding in high densities in both the Wahleach North and Wahleach South wetlands. We suggest that a landscape assessment of wetland habitats in the Washington – British Columbia transboundary region be conducted to contextualize the regional value of the Wahleach wetlands. This work could support climate resilience planning and connectivity planning for species in the Wahleach watershed.

The riparian areas modeled for this project were developed without fine resolution stream flow data for unregulated streams in the Wahleach watershed, but were estimated using best professional judgement. The RDBM uses 50 year flood data as a proxy for describing hydrologic site conditions of a riparian system (Ilhardt et al. 2000; Abood & Maclean 2011). However, model output is sensitive to changes in the flood height. We recommend updating the model with real-time stream flow data and field verification of modeled riparian area extent. Further, a more fine-scaled DEM for upland would improve model results. If improved bathymetry becomes available and historical stream channels can be approximated, the RDBM model can be used to predict the full extent of riparian loses from inundation.

SECTION III: AMPHIBIAN INVENTORIES

The purpose of amphibian inventories was to detect presence, habitat associations, and important breeding and foraging areas within riparian and wetland habitats in the Wahleach watershed. Table III-1 identifies the status of five amphibian species-at-risk in the watershed.

Table III-1. Conservation status of amphibian species-at-risk in Wahleach watershed

Species	Scientific Name	Provincial	SARA	Detected
Western toad	*Anaxyrus boreas*	Blue	Special Concern (2005)	Yes
Coastal tailed frog	*Ascaphus truei*	Blue	Special Concern (2003)	Yes
Northern red-legged frog	*Rana aurora*	Blue	Special Concern (2005)	Yes
Oregon spotted frog	*Rana pretiosa*	Red	Endangered (2003)	No
Pacific giant salamander	*Dicamptodon tenebrosus*	Red	Threatened (2003)	No

Multi-taxa and species-specific surveys were conducted to characterize amphibian species-at-risk in the watershed. The following amphibian surveys were conducted in 2016:

- *Shoreline, in-stream, and riparian time-constrained surveys*
- *Visual encounter surveys*
- *Aquatic trapping for larval amphibians*

For the present section of this Technical Report, study methods, results, and discussion are provided for all surveys together.

Amphibian Inventory Methods

Amphibian surveys were conducted between June and August 2016, although incidental amphibian detections occurred throughout the field season. Sampling locations were distributed throughout the basins in the watershed to maximize detection of amphibian species across habitats (Figure III-1, Table III-2). Time-constrained surveys (TCS) were conducted at 12 sampling locations in four streams targeting coastal tailed frog larva and juvenile or paedomorphic life stages of pacific giant salamander. Each site was visited 3 times for a total of 36 in-stream 15-minute TCS (RISC 2000).

Time-constrained visual encounter surveys (VES) were conducted along the shoreline and riparian areas adjacent to trapping regions. Each VES was conducted for 20-minute replicates following standard provincial techniques (RISC 1998), which involve slow walking along the perimeter of each site visually searching for all life stages of amphibians. All species detected visually or acoustically were recorded. Larval western toad were detected but not enumerated during these surveys due to the high abundance in these habitats. Surveys were conducted in coordination with a multi-year Ministry of Forests, Lands, and Natural Resource Operations (MFLNRO) Before-After-Control-Impact (BACI) study of hydropower impacts to coastal tailed frog in the Lower Mainland. Although MFLNRO is collecting data across the region, here we present data for three TCS sites that were surveyed with identical protocol. Egg mass surveys for Northern red-legged frog were not conducted in spring 2016 due to timing and logistics and were limited to sites below 100 m in spring 2017 due to the late spring thaw. The timing of VES during summer likely limited positive detections for this species given low summer detectability.

Passive aquatic funnel traps were deployed in three regions of shallow water or inundated land at the edge of the reservoir that contained wetland vegetation. Additional traps were deployed at one pond in the Fraser

River floodplain. Five traps were set at each sampling location, each with a mesh size suitable for target amphibian larvae in the study area. Trap sets targeted all species and all life stages of wetland amphibians and were checked three times during a 72-hour period. All organisms caught in traps were identified, measured, and released.

Table III-2. Type, location, and survey effort for amphibian sampling

Basin	**Stream**		**Riparian**		**Reservoir**		**Trapping**		
	TCS	*visits*	*sites*	*visits*	*sites*	*visits*	*sites*	*traps/site*	*checks*
UWB	3	3	3	3	3	3	3	5	3
FCB	3	3	3	3	3	3	1	5	3
CTB	3	3	3	3	0	–	0	–	–
BCB	3	3	3	3	3	3	0	–	–
LWB	3	3	0	–	3	3	3	5	3
FRF	0	–	0	–	1	3	1	3	3

The symbol '–' represents an absence of visits for the respective survey type in the respective watershed basin.

At each terrestrial sampling location, the following habitat metrics were collected: dominant ground and overhead cover, percent cover, and vegetation type. At each aquatic sampling location, the following habitat metrics were collected: dominant underwater vegetation, above water cover, vegetation type, stream sediment size (Wolman 1954), stream embeddedness (Sylte & Fischenich 2002), bankfull width, and the geographic characteristics of elevation, slope, stream order, and basin size feeding into sample locations.

Using methods developed by Royle (2004) detection probability was calculated for the two most abundant organisms (coastal tailed frog and western toad) in order to understand spatial differences in our ability to detect the true abundance of animals of each species. Although these two species at this life stage were relatively abundant, low replication and minimal re-visits (i.e. 3) meant that we were not able to calculate relative abundance corrected for by detection probability. Therefore, intercept-only abundance models were fit using *pcount* in package 'unmarked' (Fiske & Chandler 2011) implemented in program R (R Development Core Team 2016). Detection covariates used to estimate abundance for coastal tailed frog were water temperature, time of day, and day of year. Detection covariates used to estimate abundance for western toad were air temperature, water temperature, and trap set interval length. Abundance models for each species were selected using AICc (Burnham & Anderson 2002). Using the most parsimonious models, average detection probability was predicted for each species in each basin.

Amphibian Inventory Results

Amphibians were found in all basins surveyed in the Wahleach watershed. Three amphibian species-at-risk were detected: coastal tailed frog, northern red-legged frog, and western toad (Figure III-2Western toad larvae occurred in greatest abundance in the south and north ends of the reservoir, where aquatic habitats are characterized by shallow warm water, emergent vegetation, and secluded from wind and wave action. Western toad larvae were also detected in a small patch of reed canary grass at the mouth of Flat Creek confluence with the reservoir where drift wood and a small bay also dampen wind and waves. This area however, was much deeper (>1m) and water cooler, and shaded. Northern red-legged frog larvae were caught in an area of LWB dominated by the presence of western toad larvae. In low elevation habitat adjacent to the Fraser River, the only amphibian species detected was Pacific chorus frog (*Pseudacris regilla*). One larvae and one adult were observed in and around backwater ponds in FRF (25m asl), and one adult was detected on the Wahleach FSR in the LWB (642 m asl).

In-stream and riparian surveys took place between 13 August and 15 September 2016. Coastal tailed frog tadpoles were the most abundantly observed species and life stage in streams (**Error! Reference source not found.**), but the numbers observed were low, and detection probability, which varied among sites, was consistently low with high uncertainty, p = 0.06 (0.00, 0.86) 95%CI (Table III-4). Detection was positively correlated with time of day and day of the year (Table III-5). The greatest number of coastal tailed frog larvae were detected in BCB, where 13 larvae were caught in one 15 minute TCS, and 41 larvae were caught in total across all three surveys. We observed >250 western toad metamorphs on 14 September in UWB during riparian VES, but all other sites had low abundances or no detection of toads.

We characterized habitat and vegetation at all sites we conducted trapping or surveys. We purposefully chose habitat within the Wahleach basin to maximize detection of amphibian species, so our sites are characteristic of amphibian habitat; however, especially with respect to wetlands along the reservoir, these habitats are not typical of the Wahleach basin. Our trapping regions were dominated by sedges and herbaceous plants (UWB, LWB) or reed canary grass (FCB, FRF; **Error! Reference source not found.Error! Reference source not found.**). Woody debris was also prominent across trapping sites. Shoreline transects were dominated by willows and other woody shrubs, also with abundant woody debris. Riparian zones around in-stream TCS and associated riparian VES habitats were characteristic of southern British Columbia mid-low elevation closed canopy temperate forest, and were dominated by coniferous trees and low lying ferns and understory such as salmonberry (**Error! Reference source not found.**). Highly disturbed areas, typically closer to the stream edge, were dominated by alder. Stream beds were dominated by (with exception of FCB) loose small to medium size (32-64 mm) gravels and cobble. Flat Creek had a sandy substrate.

, Table III-1). Neither Oregon spotted frog nor pacific giant salamander were detected. Coastal tailed frog and western toad were found in most basins, but their presence, and relative abundance differed. All three SARA species detected were present in the LWB and FCB. Both coastal tailed frog and western toad were detected in UWB, CTB, and BCB. The most common species detected was western toad (Table III-3).

Trapping and shoreline surveys took place between 23 – 27 June 2016, after which most amphibian breeding had occurred and embryos had hatched. Clutch locations and specific breeding sites were therefore not identified. The most abundant larvae present during the trapping period were those of western toads (Figure III-3) with a moderate detection probability, $p = 0.42$ (0.41, 0.43) 95%CI, which was similar across all sites

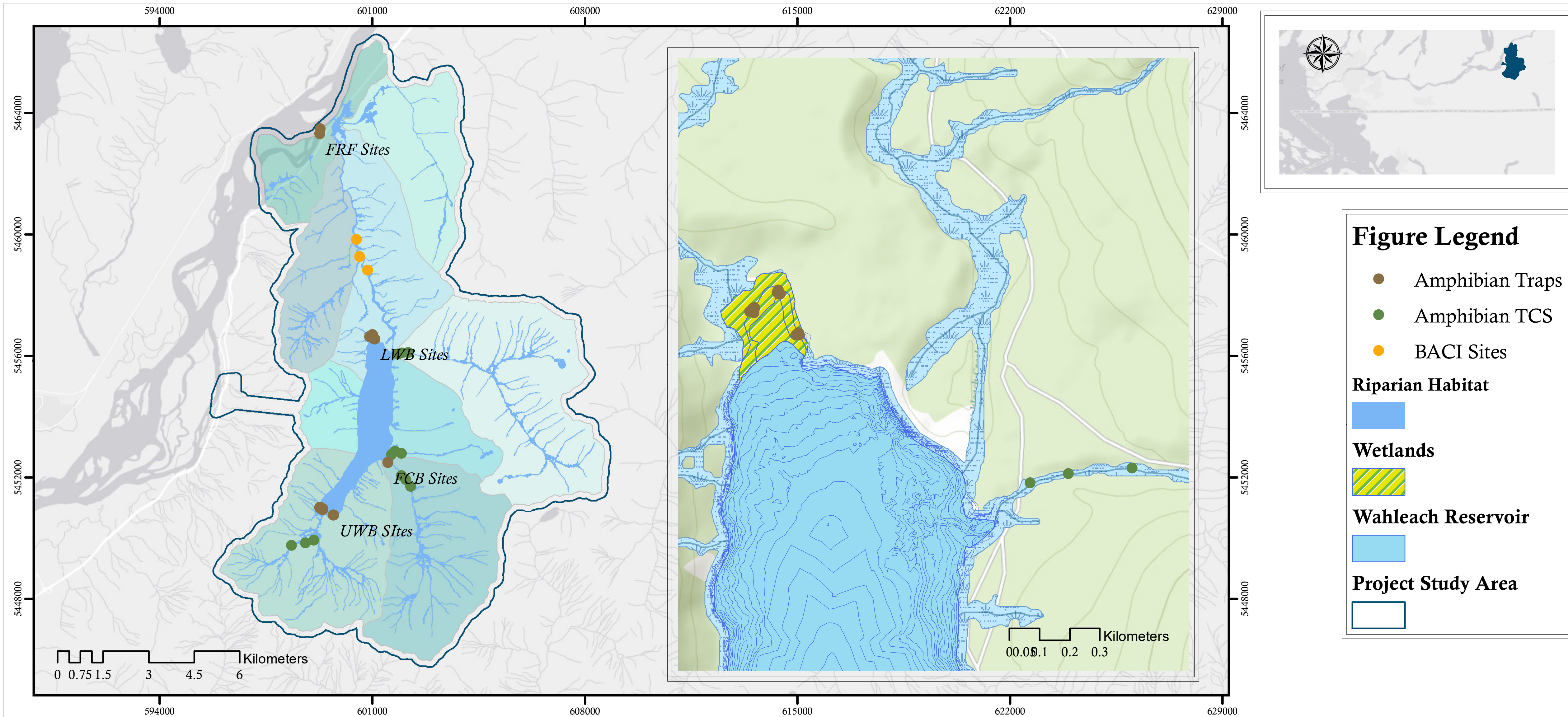

Figure III-1: Amphibian sample locations

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Author: P. Burke

traps were deployed (Table III-4). Detection of all other species was too low to be able to calculate probability. Detection was positively correlated with the amount of time the trap was deployed and water temperature, and negatively correlated with air temperature (Table III-5).

Table III-3. Species-at-risk detected in amphibian traps and visual encounter surveys

		Red-legged frog		Western toad		Coastal tailed frog		Pacific giant salamander	
		juv.	ad.	juv.	ad.	juv.	ad.	juv.	ad.
traps	FCB	-	-	1	-	-	-	-	-
	LWB	2	-	1000s	2	-	-	-	-
	UWB	-	-	1000s	-	-	-	-	-
	FRF	-	-	-	-	-	-	-	-
VES	BCB	-	-	-	-	-	-	-	-
	FCB	-	1	-	8	1	-	-	-
	FRF	-	-	-	-	NA	NA	-	-
	LWB	-	-	1000s	6	NA	NA	-	-
	UWB	-	-	1000s	4	-	-	-	-
	CTB	-	-	-	-	-	-	-	-

Table III-4. Detection probabilities of species-at-risk amphibian larvae

Western toad detection probability			
Basin	**p**	**Lower 95%CI**	**Upper 95% CI**
UWB	0.41	0.40	0.43
FCB	0.44	0.43	0.45
LWB	0.42	0.40	0.43
FRF	0.44	0.43	0.46
Coastal tailed frog detection probability			
Basin	**p**	**Lower 95%CI**	**Upper 95% CI**
UWB	0.06	0.00	0.89
FCB	0.07	0.00	0.91
CTB	0.04	0.00	0.85
BCB	0.05	0.00	0.83
LWB	0.06	0.00	0.81

Table III-5. Combinations of covariates N-mixture models

Western toad detection models	ΔAICc	AICc weight
~ no. hrs since last deployment + air temp + water temp	0	1
~ no. hrs since last deployment + air temp	223.64	0
~ no. hrs since last deployment + water temp	271	0
~ air temp + water temp	297.25	0
~ no. hrs since last deployment	324.3	0

~ air temp	414.1	0
~ water temp	837.86	0
~ null	866.92	0
Coastal tailed frog detection models	**ΔAICc**	**AICc weight**
~ time of day + day of year	0	0.617
~ time of day	2.94	0.142
~ time of day + water temp	3.13	0.129
~ time of day + day of year + water temp	3.53	0.105
~ day of year	9.98	0.004
~ day of year + water temp	11.23	0.002
~ water temp	14.33	0
~ null	15.49	0

Western toad larvae occurred in greatest abundance in the south and north ends of the reservoir, where aquatic habitats are characterized by shallow warm water, emergent vegetation, and secluded from wind and wave action. Western toad larvae were also detected in a small patch of reed canary grass at the mouth of Flat Creek confluence with the reservoir where drift wood and a small bay also dampen wind and waves. This area however, was much deeper (>1m) and water cooler, and shaded. Northern red-legged frog larvae were caught in an area of LWB dominated by the presence of western toad larvae. In low elevation habitat adjacent to the Fraser River, the only amphibian species detected was Pacific chorus frog (*Pseudacris regilla*). One larvae and one adult were observed in and around backwater ponds in FRF (25m asl), and one adult was detected on the Wahleach FSR in the LWB (642 m asl).

In-stream and riparian surveys took place between 13 August and 15 September 2016. Coastal tailed frog tadpoles were the most abundantly observed species and life stage in streams (**Error! Reference source not found.**), but the numbers observed were low, and detection probability, which varied among sites, was consistently low with high uncertainty, p = 0.06 (0.00, 0.86) 95%CI (Table III-4). Detection was positively correlated with time of day and day of the year (Table III-5). The greatest number of coastal tailed frog larvae were detected in BCB, where 13 larvae were caught in one 15 minute TCS, and 41 larvae were caught in total across all three surveys. We observed >250 western toad metamorphs on 14 September in UWB during riparian VES, but all other sites had low abundances or no detection of toads.

We characterized habitat and vegetation at all sites we conducted trapping or surveys. We purposefully chose habitat within the Wahleach basin to maximize detection of amphibian species, so our sites are characteristic of amphibian habitat; however, especially with respect to wetlands along the reservoir, these habitats are not typical of the Wahleach basin. Our trapping regions were dominated by sedges and herbaceous plants (UWB, LWB) or reed canary grass (FCB, FRF; **Error! Reference source not found.Error! Reference source not found.**). Woody debris was also prominent across trapping sites. Shoreline transects were dominated by willows and other woody shrubs, also with abundant woody debris. Riparian zones around in-stream TCS and associated riparian VES habitats were characteristic of southern British Columbia mid-low elevation closed canopy temperate forest, and were dominated by coniferous trees and low lying ferns and understory such as salmonberry (**Error! Reference source not found.**). Highly disturbed areas, typically closer to the stream edge, were dominated by alder. Stream beds were dominated by (with exception of FCB) loose small to medium size (32-64 mm) gravels and cobble. Flat Creek had a sandy substrate.

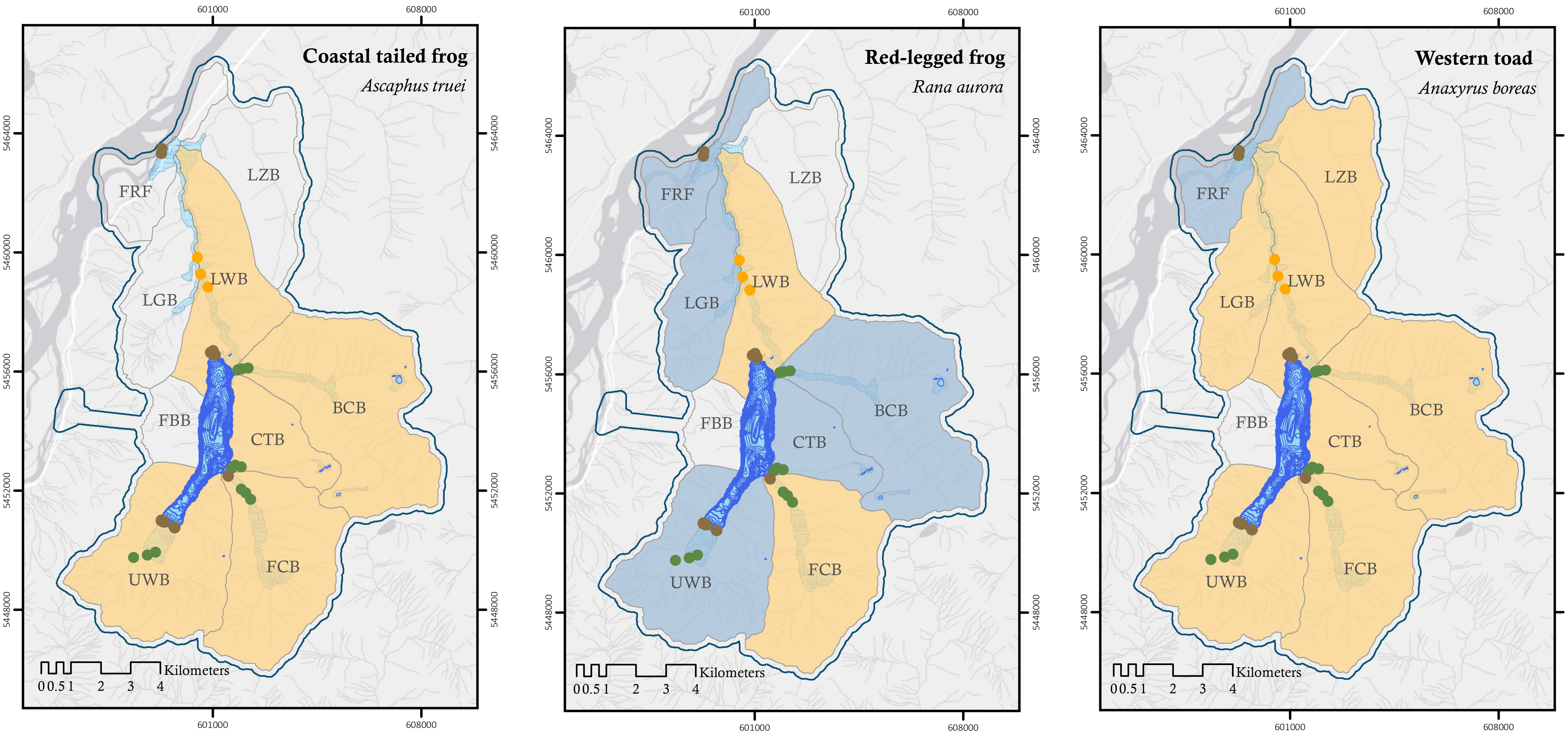

Figure III-2: Amphibian species-at-risk survey results

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Date: 2017-05-19

Author: P. Burke

Figure Legend

- Not detected
- Not surveyed
- Present

Amphibian Inventory Conclusions

Eight of the eleven species of amphibians native to the south coast of British Columbia were detected in the Wahleach watershed, including three species listed under SARA as 'Special Concern' (COSEWIC 2012; Environment and Climate Change Canada 2016a, 2016b). Our low detection of all species, including other common non-conservation priority species, indicate that further surveys, with higher effort, may be required to report absence of other species at risk with higher certainty. Wetlands and the warm water littoral zones of the reservoir provide breeding habitat for multiple amphibians, including two species at risk. The coarse woody debris accumulations in riparian habitats above the littoral zone and stumps left along the submerged shoreline provide structure and potentially hibernation sites for amphibians.

Oregon spotted frogs typically live in low lying floodplain wetlands and are not likely to occur at elevations higher than 200m above sea level (Pearl & Hayes 2004). Habitat present at Wahleach Reservoir, which occurs at ~650m, is not likely suitable for Oregon spotted frogs under current climatic conditions.

Western toads appear to be abundant and breeding in large numbers in shallow waters of the littoral zone surrounding the reservoir. Adults were detected in riparian habitats throughout the Wahleach watershed, with breeding activity and egg laying in April and May, when the drawdown zone (DDZ) is greatest. During this time, wetlands and littoral areas supporting larval development in summer were dry, except for vernal pools in the DDZ formed from rain and snow melt. These vernal pools in the DDZ may become ecological traps for western toad and other amphibians when exsiccation occurs before reservoir waters fill them during spring freshet. We observed one vernal pool in the north wetland with tens of thousands of tadpoles slowly dry up before the larvae were able to metamorphosize (Appendix A, Image 1, 2 & 3). Although this single breeding site failed, nearby egg laying sites in moving water successfully sustained a breeding toad population in the north wetland. Where additional suitable habitat is present, water levels may not be critical for western toads in the Wahleach watershed. Toad larva can develop quicker and metamorphose earlier in the summer during adverse conditions or low water availability, however, low reservoir levels have also been shown to decrease larval survival (Bull 2009). Wetland restoration in the Wahleach watershed should consider western toad breeding in design and development of restored wetland habitat and function.

Northern red-legged frogs, also found to be present in the same inundated areas, have a slower life history and permanent but shallow wetlands are important to the species larval stage (Licht 1974; O'Regan et al. 2014). The Fraser River Floodplain pond surveyed appeared to be well suited for both western toads and northern red-legged frogs, but none were detected during summer 2016 or during an egg mass survey in April 2017. The low elevation may mean breeding occurred earlier or larval stages were overlooked during the survey. However, the pond is also highly modified, dominated by Reed canary grass, and adjacent to train tracks and a freeway which may constrain adult dispersal to and from the ponds (Patla & Peterson 1997).

Coastal tailed frogs, a species that has similar habitat requirements to Pacific giant salamander, are present within most basins of the Wahleach watershed. Detectability is low for this species using TCS methods. Timber operations have left riparian buffers of intact forest along primary streams, but dense canopy cover from second growth forests may be blocking sunlight and limiting stream productivity, resulting in low abundances of coastal tailed frog larvae (Dupuis & Steventon 1999; Wahbe & Bunnell 2003). Populations of stream dwelling amphibians including coastal tailed frog may be impacted by introduced Kokanee (*Oncorhynchus nerka*) that spawn in Boulder and Flat Creeks (Feminella & Hawkins 1994). This salmonid generally feeds on zooplankton in limnetic open waters away from the shore, and is not native to Wahleach watershed. Although amphibians would not normally encounter salmonids at such elevations (Nelson 1968; Burgner 1991), both coastal tailed frog larvae and Pacific giant salamanders are known to co-exist in streams with spawning and resident salmonids (Atlas & Palen 2014). While no coastal tailed frog larvae were detected in lower Flat Creek before and during Kokanee spawning, this may also be due to the low slope and embeddedness of the stream. Coastal tailed frog larvae require interstitial spaces between cobbles for foraging and hiding from predators (Altig & Brodie 1972) and were detected incidentally in higher order streams in Flat Creek basin. Further, Boulder Creek had the highest detections of coastal tailed frog larva despite actively spawning Kokanee.

Wahleach watershed is a highly-impacted drainage with past and active logging, altered hydrology, and high human visitation – by foot, motor-vehicle, and power and paddle boats. Despite these impacts, habitat in the watershed sustains some amphibian diversity. Specifically, the south end of the reservoir has a shallower gradient, compared to the eastern and western shores, which allows for emergent vegetation and slower changes in hydrology. The northwest corner of the reservoir also has a lower gradient which supports emergent vegetation which may make for quality amphibian habitat. As well, a number of streams and creeks that cascade from the basin ridges provide habitat for coastal tailed frogs, and other riparian amphibians. Care should be taken by reservoir and forestry managers to continue to safeguard these refuges and connectivity between them within this highly-impacted ecosystem.

Recommendations for Future Amphibian Inventories in the Wahleach Watershed

Given limited time for amphibian surveys in 2016, estimates of abundance and habitat correlations are not available for amphibian species-at-risk detected in the Wahleach watershed. Low sample replication (3 to 5 survey visits) and species-specific detection precluded the detection probabilities for presence/absence (Mackenzie et al. 2002), i.e. the probability of detecting a species at all for a given area, or for abundance (Royle 2004), i.e. the probability of detecting the true number of individuals over repeated surveys. As well, we were not able to use the models of Mackenzie et al. (2002) or Royle (2004) to estimate habitat correlations of species presence. Northern red-legged frog egg mass surveys should be conducted during early spring to assess presence and distribution for this species.

Western toad breeds in high density in the Wahleach watershed. This species likely contributes to riparian ecosystem processes given the significant annual biomass of aquatic larvae and dispersal of metamorphs into terrestrial habitats (COSEWIC 2012). Monitoring should be conducted to ensure population trends remain stable over time. Direct counts for this species are not appropriate, give then large numbers of both adults and juveniles. An indirect measure of abundance, such as biomass, could be used to monitor trends. Hibernation sites should be identified, protected, and improved in the watershed. And the role of the species in nutrient transfer from aquatic to terrestrial systems should be explored.

To improve climate resilience and provide longitudinal landscape dispersal for multiple species, habitat connectivity for western toad should be maintained and improved within the Wahleach watershed. The Wahleach watershed is strategically located at an important geographical nexus for riparian habitat adapted species (see Figure III-3). The Washington Wildlife Habitat Connectivity Working Group (2011) developed transboundary linkage zones for multiple species using resistance mapping and circuit theory modeling in Washington and British Columbia. Because no previous data on western toad presence was available for the Wahleach watershed, the regional landscape model identifies a connectivity barrier along the Fraser River between Chilliwack Lake (habitat concentration area #60) and Harrison lake (habitat concentration area #57). Acknowledging the Wahleach watershed as an important regional linkage zone will be important for future transboundary conservation efforts. Further research on demographic connectivity of riparian species in this region is recommended.

Pacific giant salamanders occur at the northern extent of their range in the North Cascades of British Columbia. After extensive surveys, the species has been detected in approximately 75 streams in 15 fourth order watersheds in the Chilliwack River drainage (BC MOE 2010). Pacific giant salamander is a large, stout salamander that breeds in high gradient mountain streams. The species is known from drainages directly adjacent to the Wahleach watershed, approximately 2.4 km southeast in Foley Creek tributaries (BC CDC 2014a) and approximately 3.6 km southwest in Bridal Veil Creek (BC CDC 2014b). Geographic distribution is constrained by high mountain peaks, large rivers, and anthropogenic habitats, which may prevent dispersal into the Wahleach system. However, given the proximity to known populations, the presence of suitable habitat in the watershed, and new techniques for detection of aquatic species-at-risk, additional inventories for pacific giant salamander are recommended.

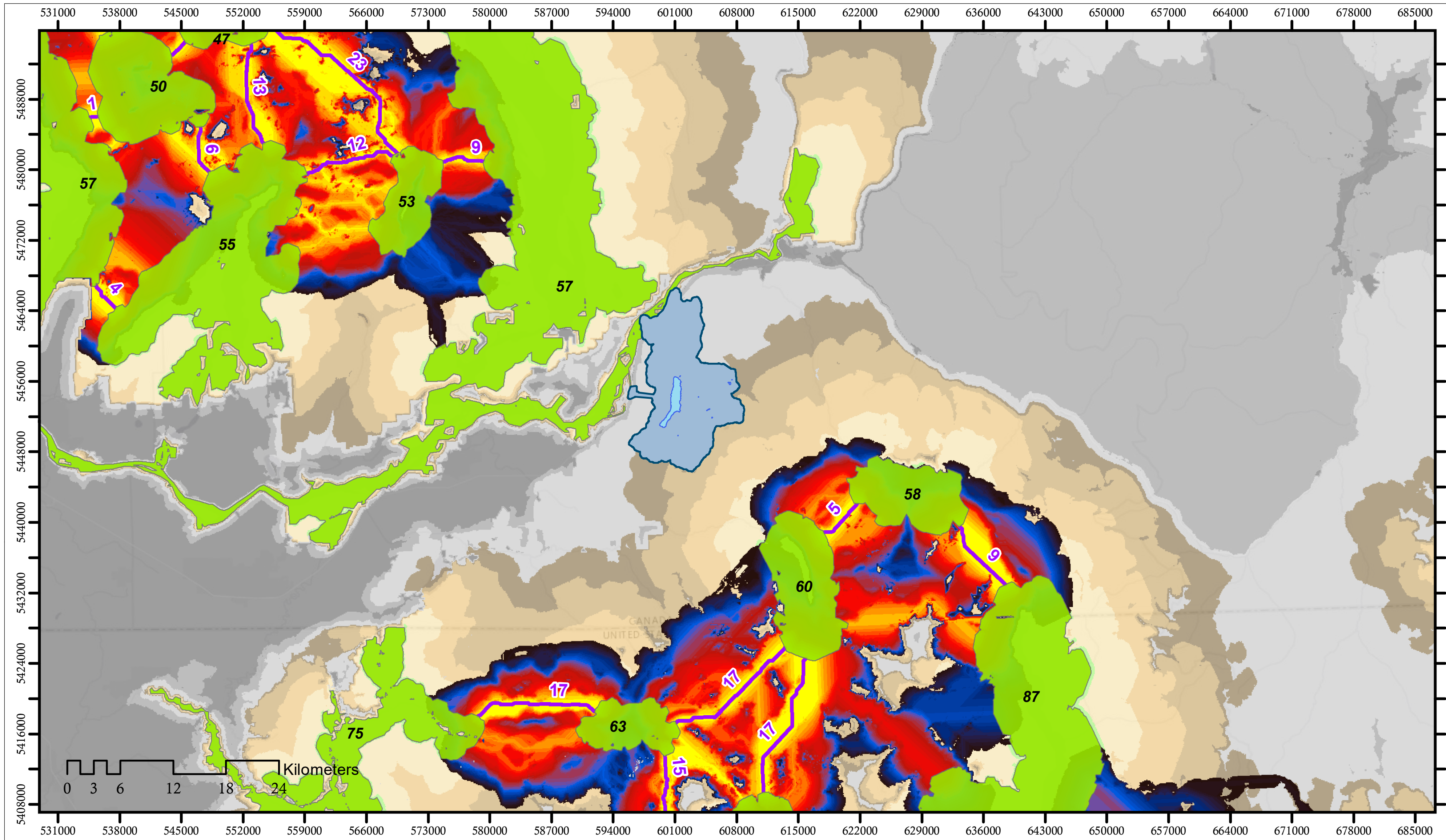

Figure Legend

- Wahleach Reservoir
- Wahleach Study Area
- Habitat Concentration Areas
- Least Cost Path (kms)

Cost Weighted Distance (kilometers)

- HCA
- 1 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 50
- 51 - 100
- over 100

Figure III-3: Western toad landscape connectivity

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Date: 2017-04-30
Author: P. Burke

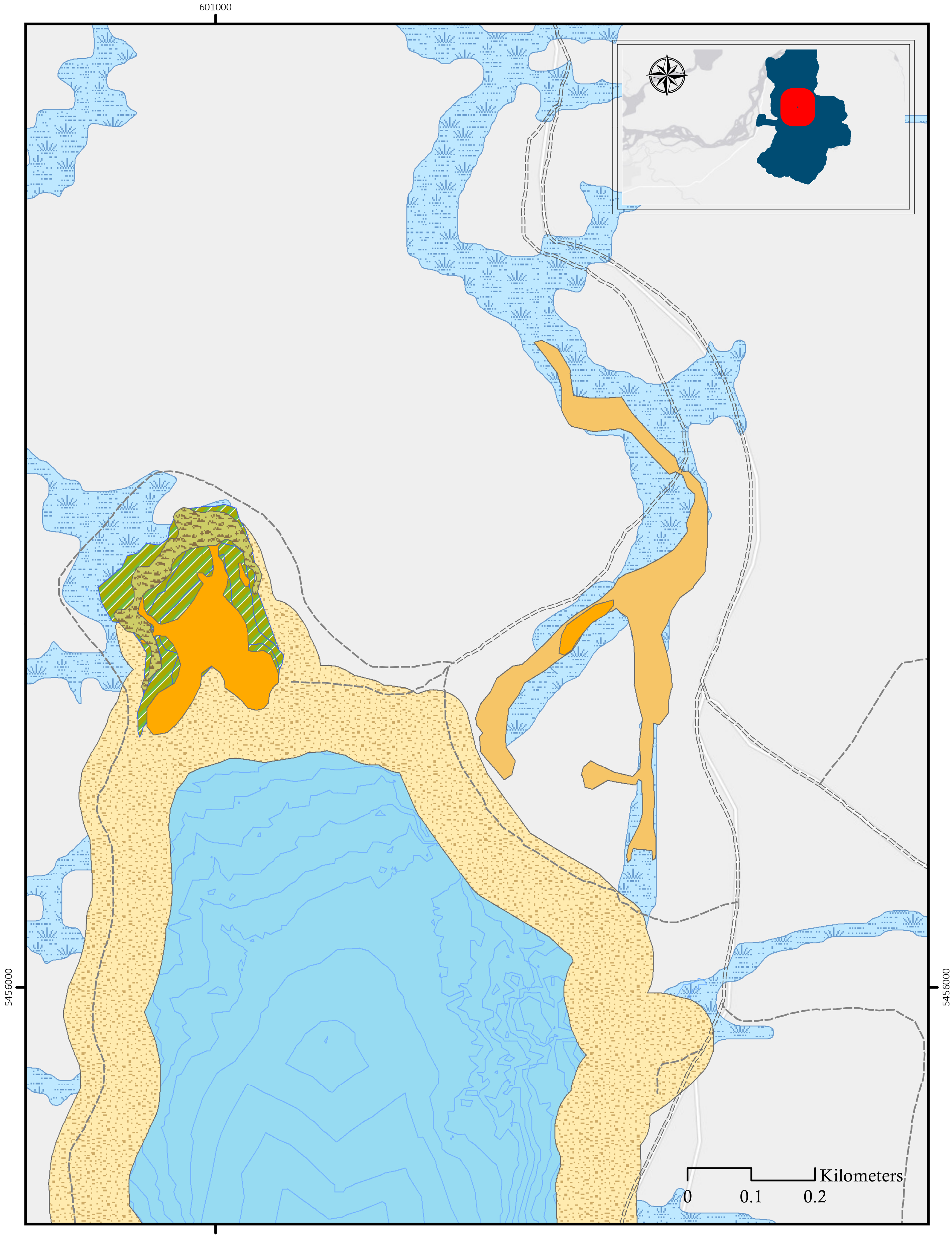

Figure III-4: Western toad habitat features in Lower Wahleach Basin

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Author: P. Burke

Date: 2017-05-18

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Figure Legend

- Breeding habitat
- Foraging habitat
- Hibernation structure
- Hibernation habitat

Wetlands

Riparian Habitats

SECTION IV: AVIAN INVENTORIES

The objective of avian inventories was to detect presence of bird species and to locate sensitive habitat features (e.g. nests) within riparian and wetland habitats of the Wahleach watershed. Table IV-1 identifies the status of eight avian species-at-risk in the Wahleach watershed.

Table IV-1. Conservation status of avian species-at-risk in Wahleach watershed

Species	Scientific Name	COSEWIC	BC List	Detected
Great blue heron	*Ardea herodias fannini*	Special Concern (2008)	Blue	Yes
Olive-sided flycatcher	*Contopus cooperi*	Threatened (2007)	Blue	Yes
Band-tailed pigeon	*Patagioenas fasciata*	Special Concern (2008)	Blue	Yes
Black swift	*Cypseloides niger*	Endangered (2015)	Blue	Yes
Barn swallow	*Hirundo rustica*	Threatened (2011)	Blue	No
Harlequin duck	*Histrionicus histrionicus*	-	Yellow	No
Western screech owl	*Megascops kennicotti kennicottii*	Threatened (2012)	Blue	No
Northern goshawk	*Accipiter gentilis laingi*	Threatened (2012)	Red	No

Field inventories were conducted to characterize presence of avian species-at-risk in the watershed. The following avian inventories were conducted in 2016 – 2017:

- *Harlequin duck riverbank survey*
- *Avian stick nest survey*
- *Passerine point count survey*

For the present section of this Technical Report, study methods, results, and discussion are provided for each survey independently.

Harlequin Duck Riverbank Survey

Harlequin duck is a medium-sized sea duck that selects fast flowing riverine habitats for breeding. The eastern population of harlequin duck is listed as special concern by COSEWIC. Harlequin duck is listed in the Wahleach Watershed Plan as a species of conservation concern that may be present in the watershed (FWCP 2011).

Harlequin Duck Riverbank Survey Methods

A walking river shoreline transect was conducted during the harlequin duck pre-incubation period on 2016 May 26 along the lower reaches of Wahleach Creek, according to provincial survey recommendations (RIC 1998a). Approximately 3.4 kilometers of shoreline were walked through a steep canyon downstream of 2.8 Mile Creek. The bank, pools, and suitable habitat was visually scanned for presence of ducks along the creek.

Harlequin Duck Riverbank Survey Results and Discussion

No harlequin ducks were observed during the survey and little suitable habitat was found in Lower Wahleach Creek drainage. In the lower reaches of the stream, the channel is composed of waterfalls and pools with predominately bedrock substrate. Turbidity in the creek was high due to sediment washing into the creek from the 2.8 Mile Creek landslide. The terrain in Lower Wahleach Creek is challenging to traverse and harlequin ducks are difficult to detect in optimum conditions. Cassirer and Groves suggest shoreline surveys underestimate the total number of breeding pairs by 25 – 35 % (1994). Further, suitable habitat for harlequin duck breeding may be present upstream of the 2.8 Mile Creek slide, where the slope of the creek is more moderate, less sediment is entering the system, and more cobble and boulder substrate is present.

Avian Stick Nest Survey

Avian Stick Nest Survey Methods

Surveys for nests of large-bodied birds were conducted opportunistically throughout 2016 – 2017. Stick nest surveys are suitable for detecting breeding activity and distribution for large-bodied birds with conspicuous nests, such as great-blue heron, bald eagle (*Haliaeetus leucocephalus*), and osprey (*Pandion haliaetus*). Surveys were conducted from the ground and from the water, but not from the air. Observers scanned vegetation in suitable areas with binoculars and watched for birds flying to and from nest sites.

Avian Stick Nest Survey Results and Discussion

One active osprey nest was detected in the Upper Wahleach Basin in June 2016. The nest was located above the surrounding canopy in a large conifer near the south wetland (see Figure IV-2). One fledgling osprey was observed in the nest on 2 July 2016. Adults were observed foraging across the reservoir, at the Wahleach North wetland, the inflow at Boulder and Flat Creeks, at the Wahleach South wetland near the nest, and along the shoreline. A minimum buffer of 100 m of undisturbed forest is recommended around this nest (BC MOE 2013).

No additional stick nests or rookeries were detected. Given the length of time observers spent in and on the Wahleach Reservoir in 2016 – 2017 and the lack of bald eagle and heron observations, it is unlikely that either of these species currently use the riparian or wetland habitats at the reservoir. One great blue heron was detected along the Fraser River during surveys (see Figure IV-2). One adult bald eagle was observed flying over the reservoir on 26 July 2017.

Breeding Passerine Survey

Passerines are perching birds, sometimes referred to as songbirds, but more specifically are members of the most diverse taxonomic order of birds: the *Passeriformes*. Passerines were detected in the Wahleach watershed during spring breeding bird point count surveys and incidentally to other surveys.

Breeding Passerine Survey Methods

Surveys were designed to detect breeding passerine species-at-risk using established sampling standards (RIC 1999; Siegel et al. 2007). Backcountry unlimited-radius point counts were conducted by a biologist trained in auditory identification of bird song and distance estimation. Birds were identified during 10 minute counts conducted within the first four hours after sunrise at points separated by a minimum of 250 m to ensure sample independence. Sample locations were selected using a random-systematic design and occurred in riparian and wetland habitats within 4 of the 9 creek basins in the study area (Figure IV-1). At each sample location, ambient noise and weather conditions were recorded. During point counts, species, distance, and azimuth were recorded for each bird detected, including flyovers. Ten minute samples were partitioned into birds detected during first 3 minutes, following 2 minutes, and final 5 minutes to facilitate comparison with the North American Breeding Bird Survey (BBS) program. Each sample location was visited once during 2016 – 2017. Given budget limitations, sample replicates were not conducted.

Breeding Passerine Survey Results and Discussion

Thirty avian species were detected during point-count surveys, including 2 species-at-risk: band-tailed pigeon and olive-sided flycatcher. An additional 22 species were detected incidentally to point count surveys

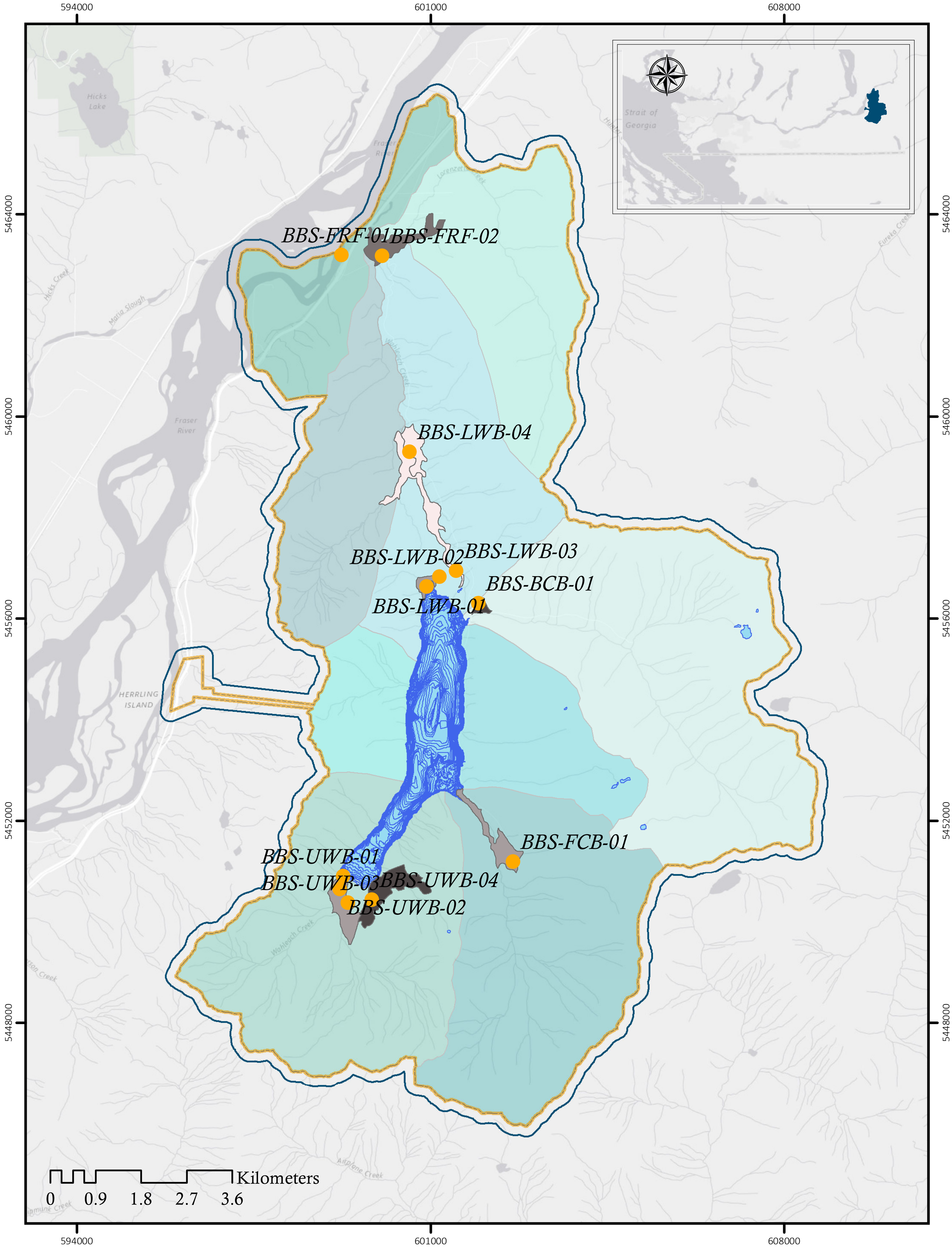

Figure IV-1: Passerine unlimited-radius point count survey sample locations

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Date: 2017-09-12

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Figure Legend

Point Count Sites

TEM Units

AD
AM
AO
RF

Wahleach Reservoir

including 2 additional species-at-risk: black swift and great blue heron. The 4 species-at-risk were detected at low density, with less than three total observations for each species. Although great blue heron is unlikely to nest in the study area and no rookeries were detected, suitable breeding habitat exists for the other three avian species-at-risk.

Avian community assemblage was similar across sampling sites near the reservoir in Boulder Creek, Flat Creek, Upper Wahleach Creek and Lower Wahleach Creek basins (mean elevation 645.3 ± 59.4m). This community differed from that detected at sites in the Fraser River Floodplain (mean elevation 38.2 ± 10.9m). High elevation sites had 22% overlap in species composition with low sites, while the low elevation sites had 41% overlap with species from higher elevations. Here we present diversity of species and an index of abundance for each creek basin in the study area from uncorrected count data and incidental observations (Table IV-2).

Table IV-2. Uncorrected results of breeding passerine surveys

	Point Counts		Incidental	
Basin	No. species (counts)	Abundance[1]	No. species	SAR
Boulder Creek (BCB)	8 (1)	10	4	No
Fraser River Floodplain (FRF)	13 (2)	24	3	Yes
Lower Wahleach Basin (LWB)	18 (4)	34	19	No
Upper Wahleach Basin (UWB)	19 (4)	48	24	Yes
Central Basin (CTB)	- (0)	-	3	No
Flat Creek Basin (FCB)	- (0)	-	5	No

[1] Abundance here is uncorrected count data from field sampling

Species abundance and density were estimated from point count data using detection functions in the R package 'Distance' (Thomas et al. 2010; Marshall et al. 2016). Given low sampling effort, we were unable to estimate abundance or density for the species-at-risk detected during counts. A truncation distance of 125m was used and the most parsimonious model was selected using AIC. Here we present abundance and density estimates for the six most common species detected during point counts (**Error! Not a valid bookmark self-reference.**). Given access constraints, absence of a strict random survey design, and low sample effort abundance estimates may be biased. Density is abundance per km².

Table IV-3. Species abundance and density estimates

Species	**Abundance**	**Density**
Varied thrush	70.5	0.39
Pacific wren	104.1	0.42
Wilson's warbler	137.1	0.55
Pacific-slope flycatcher	186.0	1.16
American robin	56.5	0.52
Warbling vireo	131.4	0.73
Townsend's warbler	80.0	0.59

Avian Inventory Conclusions

The Wahleach watershed provides habitat for a diverse avian community that uses riparian and wetland areas for breeding, foraging, migration, and other life requisites. Three avian species-at-risk were detected during inventories and we suggest that presence of western screech owl, barn swallow, and northern goshawk is also likely in the watershed.

Band-tailed pigeon is a large frugivorous bird that occurs in British Columbia at the northern extent of its North American range. The species was observed in the study area during the breeding season (8 June 2016, 26 July 2017, and 11 April 2017) at locations between the Fraser River and the reservoir. This species is known to brood multiple times per season, usually with one egg per clutch, with peak nesting during May and June in British Columbia (Keppie & Braun 2000). The species occurs at low density in the Wahleach watershed and likely nests on the ridges rising out of the Fraser River Floodplain in the Lower Wahleach Creek and Lorenzetta Creek Basins. Band-tailed pigeons have substantial fidelity to breeding region, which may be linked to presence of mineral sites, important and potentially limiting habitat features for this species (Keppie & Braun 2000). Populations of band-tailed pigeon are slow to recover from declines given their long lifespan (22 years) and low reproductive rate (Environment and Climate Change Canada 2016c).

Black swift is an incompletely studied aerial insectivore with widespread negative population trend over recent decades (COSEWIC 2015). Causes for decline in this species are not well understood, but thought to be associated with reduction in aerial prey or changes in climate that affect nesting habitat. The species nests in specialized habitat in cliffs, behind waterfalls, and caves which occur in the high elevations of the Wahleach watershed (see Figure IV-2). We have identified potential black swift nesting areas based on the following nest characteristics: 1) running water, 2) high relief, 3) inaccessibility, 4) darkness, and 5) unobstructed flight path (COSEWIC 2015). In British Columbia, breeding occurs between June and September, with hatching occurring in mid-July (Lowther & Collins 2002). Nests are reused and given high breeding site fidelity, conservation of potential nest sites is important for conservation measure. Black swifts were observed in the Wahleach watershed foraging over forested hillsides and high over the reservoir during spring (27 April 2016 and 11 May 2016).

Olive-sided flycatcher is a medium-sized insectivore with a wide geographic range, sparse distribution, and a negative long-term population trend (Environment and Climate Change Canada 2015). This species was detected during point counts and incidentally to other surveys (12-13 May 2016 and 9 June 2016). All detections were in proximity to recent timber harvest blocks with substantial edge habitat. This species prefers heterogenous coniferous and mixed habitat with forest openings, often near wetlands or open water, often in montane habitats, and frequently associated with natural disturbance like wildfire (Environment and Climate Change Canada 2015).

Recommendations for Future Avian Inventories in the Wahleach Watershed

In 2015, a western screech owl was detected incidentally during amphibian surveys near the reservoir spillway in the Lower Wahleach Creek Basin by a B. C. Ministry of Environment. Suitable habitat exists for western screech owls throughout the Wahleach watershed. We recommend future nocturnal call-playback (CPB) surveys to detect breeding territories according to established protocols (RIC 2006). We also recommend nesting status and productivity surveys (Hobbs 2013) to follow up positive detections. Barred owl (*Strix varia*) was detected in both the Lower Wahleach Basin near the spillway and in the Upper Wahleach Basin, which may limit western screech owl occupancy in the watershed.

Northern goshawk *laingi* subspecies was not detected during 2016 – 2017, but suitable habitat likely occurs on the mountains surrounding the Wahleach Reservoir. Primary threats to the species include loss of mature forest through commercial timber harvest (COSEWIC 2013). The loss of mature timber associated with construction of the Wahleach Reservoir reduced breeding opportunities in the watershed. We recommend call-playback surveys to detect present of this species and identify breeding territories (RIC 2001).

The Management Plan for band-tailed pigeon in Canada recommends the identification and monitoring of mineral sites as a high priority conservation measure (2016). Although mineral sites were not identified in

2016 – 2017, future studies could seek to locate and protect these important habitat features for this species. A band-tailed pigeon telemetry study in the Wahleach watershed would delineate home ranges and identify habitat associations for the species. A summer telemetry study might help locate a mineral site in the watershed which could be an important long-term monitoring site to determine population trends and contribute to the Pacific Flyway trend assessment (Environment and Climate Change Canada 2016c).

The reproductive capacity of olive-sided flycatcher in British Columbia timber harvests needs to be understood. This disturbance-dependent species occupies an ecological niche associated with recent natural disturbance, including fire and windthrow. Recent studies have demonstrated that olive-sided flycatchers select harvested forest tracts in higher densities than naturally occurring disturbances, but have higher nest failure in artificially disturbed forest in the norther Rocky Mountains (Robertson & Hutto 2007). Timber harvests may therefore become ecological traps for this species when nest failure is high. Robertson identified specific habitat management techniques to maintain olive-sided flycatcher fitness within anthropogenic disturbances (2012).

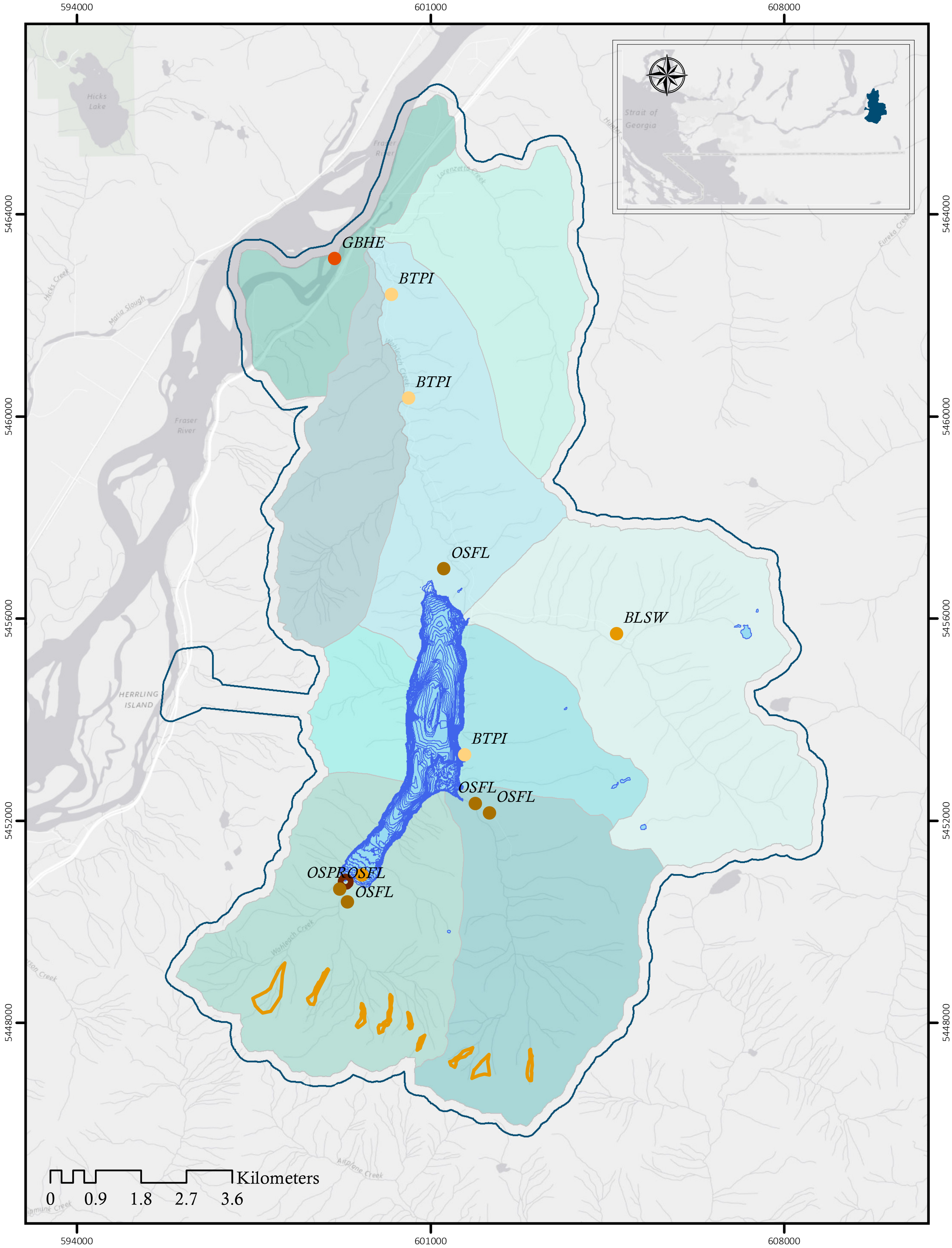

Figure IV-2: Avian species-at-risk and habitat features detected

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Author: P. Burke
Date: 2017-09-12

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Figure Legend

Avian species-at-risk

- Band-tailed pigeon
- Black swift
- Great blue heron
- Olive-sided flycatcher

Osprey Nest Buffer (100m)

Black Swift Nesting Habitat

SECTION V: MAMMAL INVENTORIES

The purpose of mammal inventories was to detect presence of mammal species and to locate sensitive habitat features within riparian and wetland habitats of the Wahleach watershed. Mammal species-at-risk that potentially occur within the Wahleach watershed are listed in Table V-1.

Table V-1. Conservation status of mammal species-at-risk in Wahleach watershed

Species	Scientific Name	Provincial	COSEWIC Status	Detected
Little brown myotis	*Myotis lucifugus*	Yellow	Endangered (2013)	Yes
Fringed myotis	*Myotis thysanodes*	Blue	Data Deficient (2004)	Yes
Townsend's big-eared bat	*Corynorhinus townsendii*	Blue	-	No
Keen's myotis	*Myotis keenii*	Blue	Data Deficient (2003)	NA
Pacific water shrew	*Sorex bendirii*	Red	Endangered (2016)	No
Mountain beaver	*Aplodontia rufa*	Yellow	Special Concern (2012)	Yes
Fisher	*Martes pennanti*	Blue	-	No
Wolverine	*Gulo gulo luscus*	Blue	-	No
Grizzly bear	*Ursus arctos ssp.*	Blue	-	No
Mountain goat	*Oreamnos americanus*	Blue	-	No

Multi-taxa and species-specific surveys were conducted to characterize mammal species-at-risk in the watershed. The following surveys were conducted in 2016 – 2017:

- *Environmental DNA pilot study for Pacific water shrew*
- *Camera trap surveys for large mammals*
- *Passive bat acoustic surveys*
- *Bat capture surveys*

For the present section of this Technical Report, study methods, results, and discussion are outlined for each specific survey.

Environmental DNA Pilot Survey

Environmental DNA (eDNA) refers to genetic material that is shed by organisms into the environment. This genetic material persists at low concentration in soils, water and air, and can be collected and analyzed to determine species present at a site. The term eDNA also refers to the rapidly maturing technology of collecting and analyzing genetic material from environmental samples. This method is less invasive and often more cost effective for detecting aquatic species-at-risk than conventional surveys, especially when species have heterogeneous distributions and occur at low densities in the environment (Goldberg et al. 2016).

To conduct eDNA surveys, genetic material of target organisms is collected from parent material, most commonly from surface water, but also soil or from the atmosphere. DNA is extracted from each environmental sample, amplified, and matched to DNA from known target taxa. Species presence is inferred for locations with positive genetic matches. Given the high sensitivity of eDNA methods, precautions must be taken to prevent genetic contamination of samples through cross-contamination both in the field and in the lab. Additionally, the interpretation of positive results must be considered in the context of local biophysical processes and methods used in data analysis. Uncertainties exist in our understanding of origin, transport, deposition, and persistence of eDNA for different organisms in natural systems (Barnes & Turner 2016). Despite these limitations, eDNA shows promise as an environmental monitoring tool with broad application.

eDNA Pilot Survey Methods

Pacific water shew critical habitat occurs in British Columbia just west and south of the Wahleach watershed, but models suggest suitable forested riparian habitat exists for this species within the watershed, particularly along Lower Wahleach Creek (see Figure V-1 and Figure V-2). Pacific water shrew habitat generally occurs below 650 m in elevation, but individuals have been detected as high as 850 m (Environment and Climate Change Canada 2014). We conducted a pilot eDNA survey targeting Pacific water shrew to test field protocols for future eDNA surveys and to detect species presence within suitable habitat for our target species. Due to the high cost, logistical complexity, low probability of detection, and potential for trap mortality during conventional inventories, eDNA analysis is a significant methodological improvement in detection of Pacific water shrew. However, many aspects of Pacific water shrew ecology that make conventional inventories difficult also apply to eDNA. In particular, our limited understanding of water shrew microhabitat preferences and the apparent low density of occurrence across the range require high sampling effort.

Recommend best practices for the collection and analysis of eDNA from aquatic systems have recently been developed (Goldberg et al. 2016; Hobbs et al. 2017). Surveys followed BC MOE RISC standards for collection and analysis of eDNA in Freshwater Aquatic Ecosystems (Hobbs et al. 2017). On 22 September 2016, fifteen 1 liter (L) water samples were collected at sites in undisturbed riparian or wetland vegetation and presence of woody debris between 600 – 700 m elevation (Figure V-2). Three sample replicates were collected *in situ* at each of five sample sites spaced approximately 50m apart: 4 sites in the thalwag with moving water (lotic systems) and 1 site with standing water (lentic system). Field controls were rigorously maintained to minimize potential for contamination during collection and filtering of water samples.

Water samples were packed on ice to reduce degradation of genetic material and filtered in a lab within 8 hours of collection. Samples were filtered using a vacuum pump to remove eDNA material from the water using a 47 mm diameter cellulose membrane with 0.45 µm pore size. DNA was preserved in ethanol in a 2 mL vial and sent to the Helbing Lab at the University of Victoria Department of Biochemistry & Microbiology for sample extraction, amplification, and quantification. DNA was extracted from each water sample using Qiagen DNeasy Blood and Tissue Kit (QIAGEN Inc., Mississauga, ON, Canada) using the manufacturer's recommendations. Purified DNA was amplified using quantitative real-time polymerase chain reaction (qPCR) for eight assay replicates (Veldhoen et al. 2016; Hobbs et al. 2017). First, samples are tested for inhibitors which could mask detection of target DNA. Once samples are confirmed to have amplifiable DNA, additional qPCR is conducted to match genetic material to class (e.g. mammals) and then species. Primers for Pacific water shrew were developed in 2015 and were validated through a rigorous evaluation protocol to test target and amplification specificity.

eDNA Pilot Survey Results and Discussion

Pacific water shrew DNA was not detected at sites sampled in 2016 based on negative results for all water sample replicates (N = 15) and all assay replicates (N = 128). Although Pacific water shrew was not detected in water samples, we caution that our pilot study was not designed to be an exhaustive inventory of all possible habitats in the watershed. Important limitations in our design include: a small number of sites relative to extent of suitable habitat and collection of water samples after early fall rains, which dilutes samples. Further, understanding of the genesis, transport, and persistence of Pacific water shrew DNA in water needs to improve. Because this semi-aquatic species does not consume prey or latrine directly in aquatic environments, genetic material likely occurs at lower volumes and is more difficult to detect than for fully aquatic species. A more focused inventory is required to confidently say the species is not present in the Wahleach watershed.

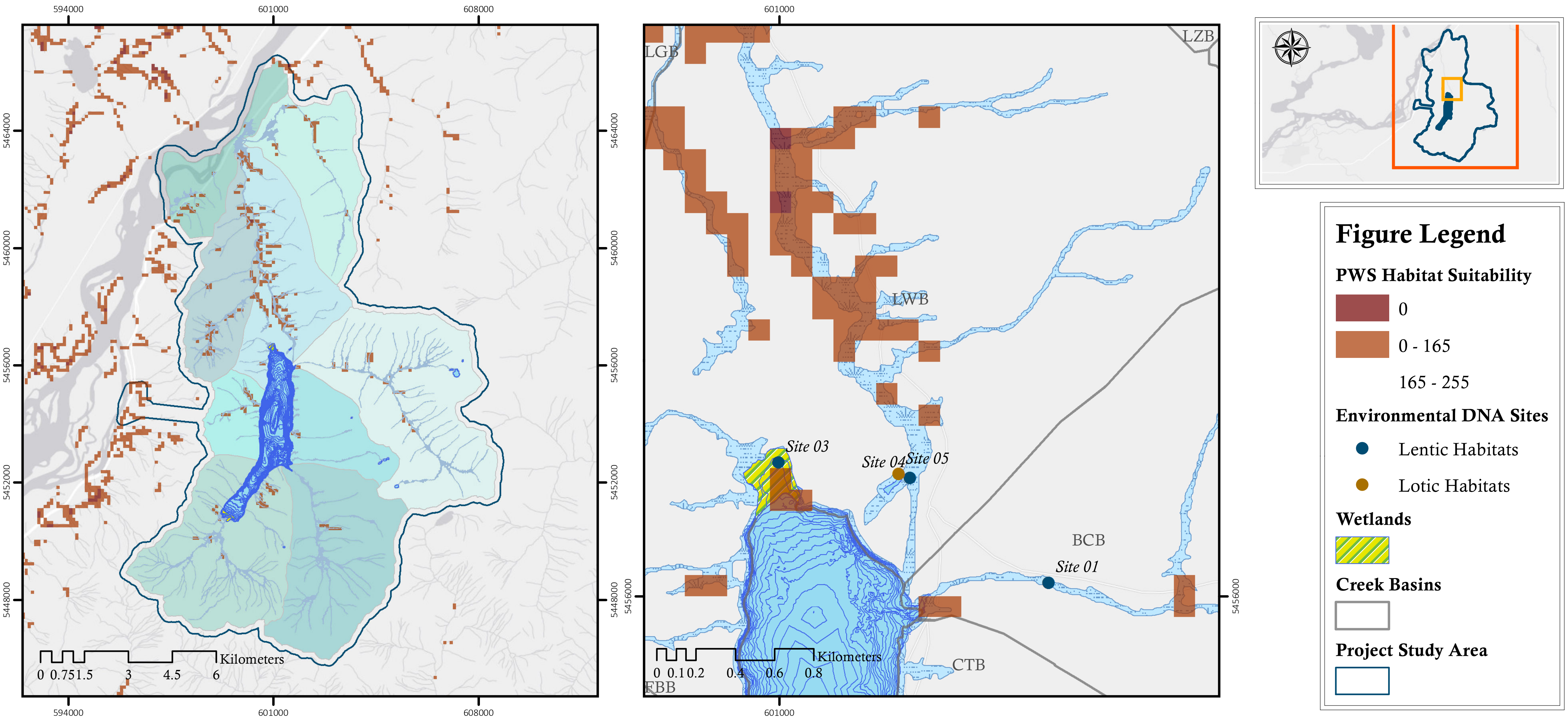

Figure V-1: Pacific water shrew habitat model and eDNA sample sites

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Author: P. Burke

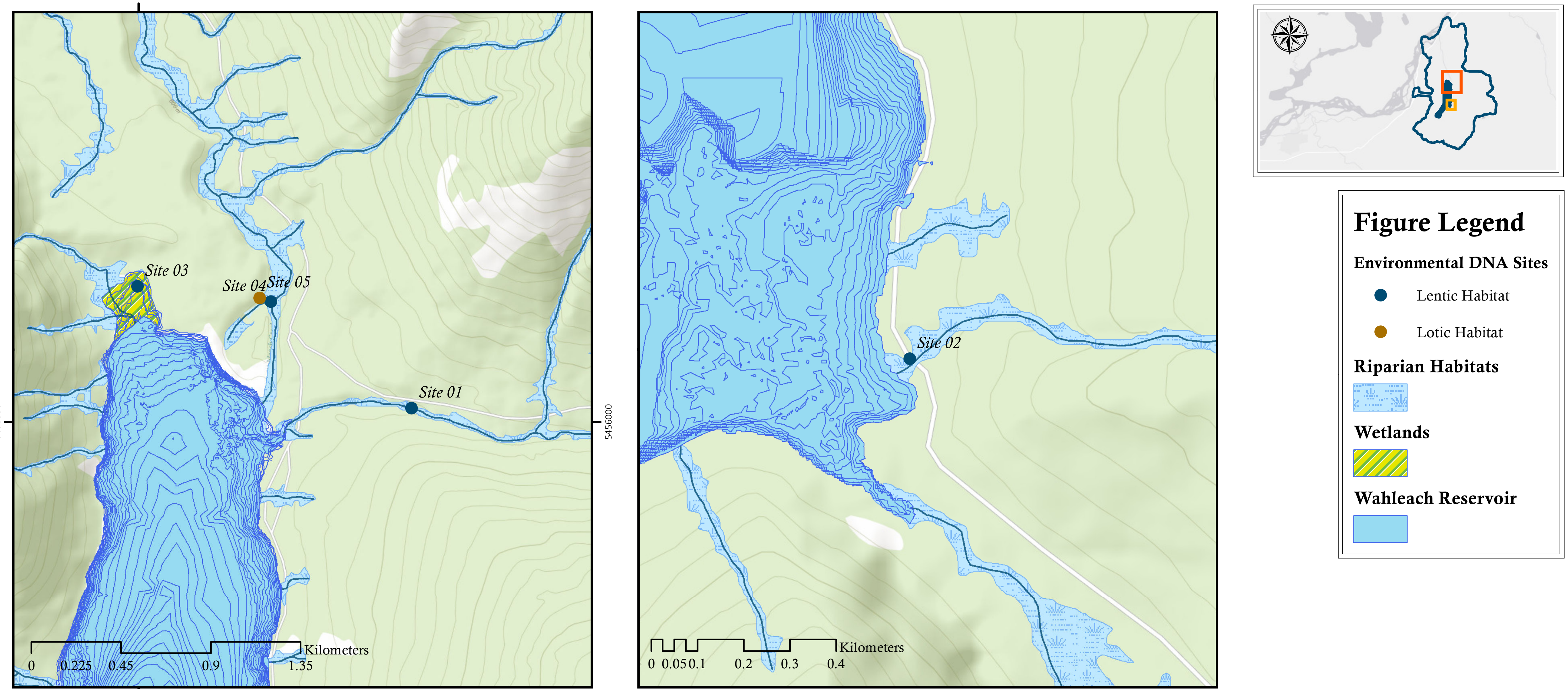

Figure V-2: Environmental DNA sample locations

Date: 2017-05-19

Author: P. Burke

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Camera Trap Surveys

Camera traps are remote, non-invasive, passively operating digital cameras that collect images of animals with minimal disturbance. These devices are triggered by an infrared sensor when heat sources (such as the body heat released from ectotermic animals) pass across the field of view. Camera traps provide cost-effective and continuous record of animal activity and can be deployed to target a variety of taxa. Camera traps are also important tools for monitoring phenology, such as tree flowering, periods of snow cover, cloud cover, etc. Camera traps were used in the present study to determine presence of large mammal species-at-risk in the riparian habitats of the Wahleach watershed.

Camera Trap Survey Methods

Camera trap stations were selected opportunistically in the major basins of the watershed. At each station, a single Reconyx Hyperfire HC500 passive infrared camera trap was deployed approximately 30 – 40 cm above the ground, adjusting for slope. At the local scale, cameras were located to maximize focal species detections such as at animal trail crossings, valley bottoms, or near wildlife sightings. Cameras were active 24 hours per day, providing a continuous records of animal activity at each station. No baits or attractants were used. Camera settings were standardized to minimize detection bias: trigger sensitivity was set to high, picture interval was set to 1 s for three consecutive images, and a delay between triggers was set for 30 s. For each image, species, the number of individuals, sex, and age class was recorded for wildlife detections. Human activity was also detected by camera traps, but not analyzed. Images and associated data were managed in digiKam (Caulier et al. 2016), an open source digital photo management software and the R package "captrapR" (Niedballa et al. 2016). Images were analyzed using a single observer approach, as the likelihood of misidentification was low given low species diversity.

Camera Trap Results and Discussion

Eight camera trap stations were deployed between 21 April 2016 and 26 February 2017 for a total of 583 camera-days. Camera stations were deployed between 423 and 1066 m ($\bar{x}$ = 677 m), within Flat Creek Basin, Boulder Creek Basin, Upper Wahleach Basin, and Lower Wahleach Creek Basin (see Figure V-3Figure V-3). No species-at-risk were detected during camera trap surveys. Nine species were detected, including two bird species: American robin (*Turdus migratorius*) and American crow (*Corvus brachyrhynchos*) and seven mammal species: American black bear (*Ursus americanus*), Black-tailed deer (*Odocoileus hemionus columbianus*), bobcat (*Lynx rufus*), cougar (*Puma concolor*), mouse (Cricetidae Family), snowshoe hare (*Lepus americanus*), and Douglas squirrel (*Tamiasciurus douglasii*). Black bear was the most common species, being detected at seven of eight stations, with deer being the second most common species detected (see Table V-2).

Table V-2 Summary of camera trap detections, not adjusted for effort

Station	Basin	Elevation	Bear	Bird	Deer	Bobcat	Cougar	Mouse	Hare	Squirrel
WCT-WMBW	UWB	716	3	-	3	-	-	-	-	-
WCT-WUDH	UWB	668	9	-	-	-	1	-	-	-
WCT-WFCT	FCB	646	7	-	2	-	-	-	-	-
WCT-WLFT	FCB	777	1	-	5	2	-	-	-	-
WCT-WBCK	BCB	1066	5	-	3	-	-	-	-	-
WCT-WFGU	LWB	423	-	-	-	-	-	-	-	-
WCT-WFSR	LWB	468	4	-	-	5	-	-	1	1
WCT-WNWL	LWB	652	1	3	-	-	-	31	-	2

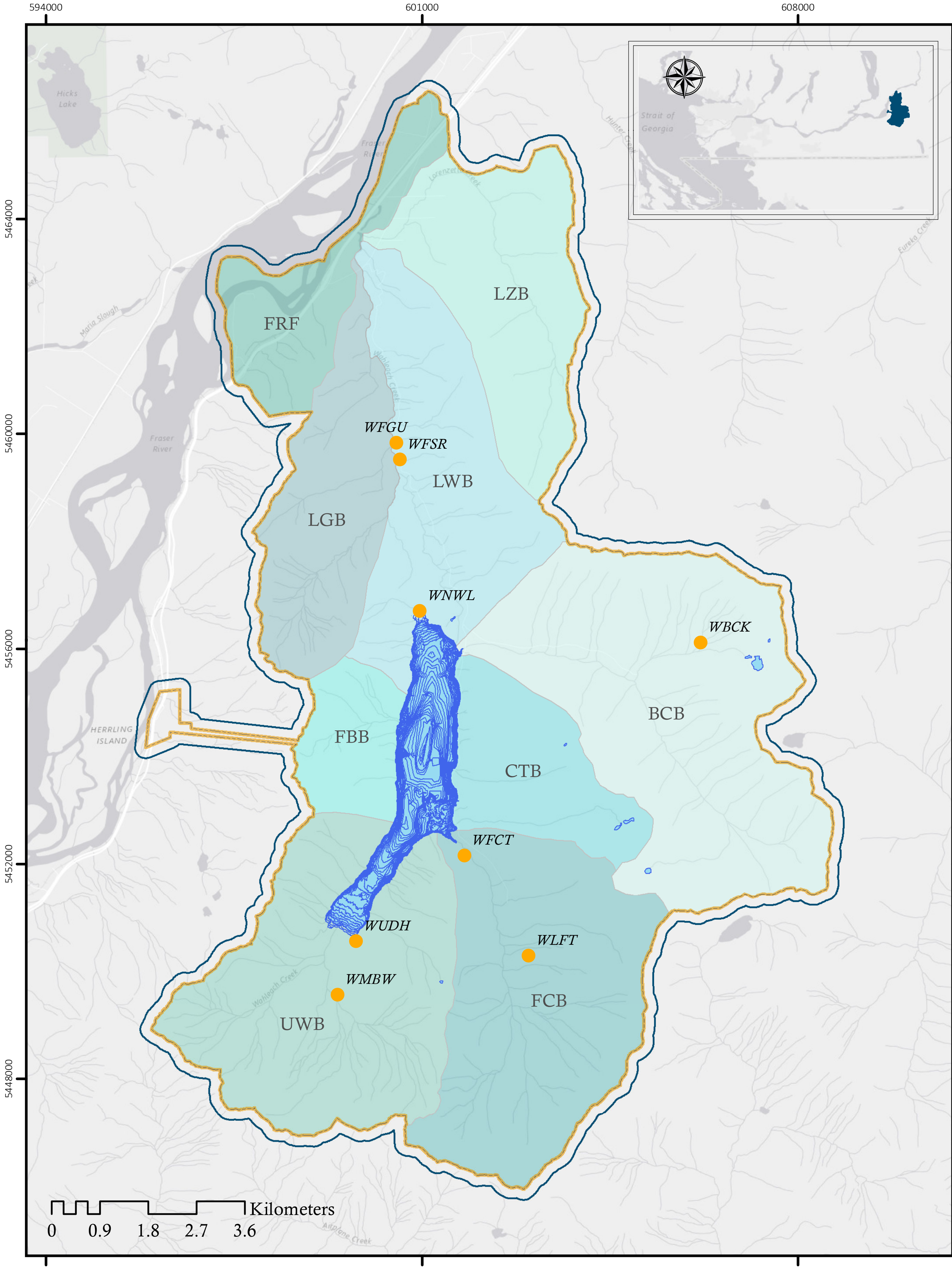

Figure V-3: Camera trap sample locations

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Camera Trap Stations

Wahleach Reservoir

Project Study Area

Acoustic Bat Survey

The purpose of acoustic bat surveys was to characterize the bat community across habitats and seasons using bioacoustic recording devices. An important survey objective was to document the presence and distribution of colony-roosting bats using robust and repeatable methods in advance of expected population declines resulting from the bat disease WNS.

Acoustic Bat Survey Methods

Passive bioacoustic monitoring was conducted between 12 May 2016 and 10 January 2017 in the Wahleach watershed. Sampling locations were selected using a generalized random-tessellation stratified (GRTS) survey design using the Spatial Survey Design and Analysis "spsurvey" statistical package (Kincaid & Olsen 2016) in R (R Development Core Team 2016). Stratification was based on terrestrial ecosystem mapping (TEM) units (Green 2003b) delineated for the Hope IFPA (see Figure I-2). Sampling locations were spatially balanced to ensure sampling represented multiple habitat types across all creek basins in the Wahleach watershed (Stevens & Olsen 2004).

Passive bioacoustic equipment was deployed at 19 monitoring stations in riparian and wetland habitats (Figure V-4). Each station consisted of one Wildlife Acoustics Song Meter SM2BAT192 or SM3BAT monitor with SMM-U1 or SMX-US ultrasonic microphones powered by external sealed lead acid batteries charged by 20-watt solar panels. Monitoring stations were deployed using best practices to maximize detection of high quality free-flying foraging calls to support accurate species identification (Loeb et al. 2015; Craig & Lausen 2016). Stations were deployed in areas of low vegetative clutter, away from open water, with an elevated microphone 5 – 10m above ground level. At each station, a metric of relative clutter was estimated and canopy structure was calculated using Gap Light Analyzer (Frazer et al. 1999).

Monitoring stations recorded full-spectrum bat echolocation calls autonomously each night beginning 30 minutes before sunset and ending 30 minutes after sunrise, providing a continuous record of bat activity within 40 – 60 m of the microphone. Monitoring occurred within three periods coinciding with bat phenology in the Wahleach watershed: 1) spring migration and early pregnancy: Mid-March to mid-June; 2) birthing and pup rearing: Mid-June to the first week of August; 3) pup volancy, swarming, and onset to hibernation: mid-August to the end of October; and 4) overwinter: November through mid-March.

Echolocation call files were processed in Kaleidoscope Version 4.0.4 (Wildlife Acoustics 2016) using advanced signal processing and converted from full-spectrum to zero-cross. Files were batch processed using filters and hand-vetted by a biologist trained in identification of acoustic files using AnalookW 4.1z (Corben 2015). Bat acoustic data summaries are archived with the Bat Acoustic Monitoring Portal (BatAMP) on Data Basin and with the Global Biodiversity Information Facility.

Acoustic Bat Survey Results and Discussion

Nine bat species were identified from 11,095 echolocation call sequences recorded during surveys, including two species-at-risk: little brown myotis and fringed myotis. Bats were recorded in riparian habitats across all basins of the watershed and over the reservoir itself. *Myotis* spp. were visually observed foraging low over the reservoir, at distances over 200 m from shore, with greatest abundances over shallow waters near wetlands. Acoustic sampling occurred for 443 nights during 2016 – 2017. Stations sampled bat activity for periods between 5 and 105 day periods (average 23.3 ± 23.4 days). Calculate relative activity index, using all data (q40, LFUN, etc.). 5 minute increments. Need to break out data one line for each bat (have not done this). Calculate occupancy for MYLU, MYTH, and TABR.

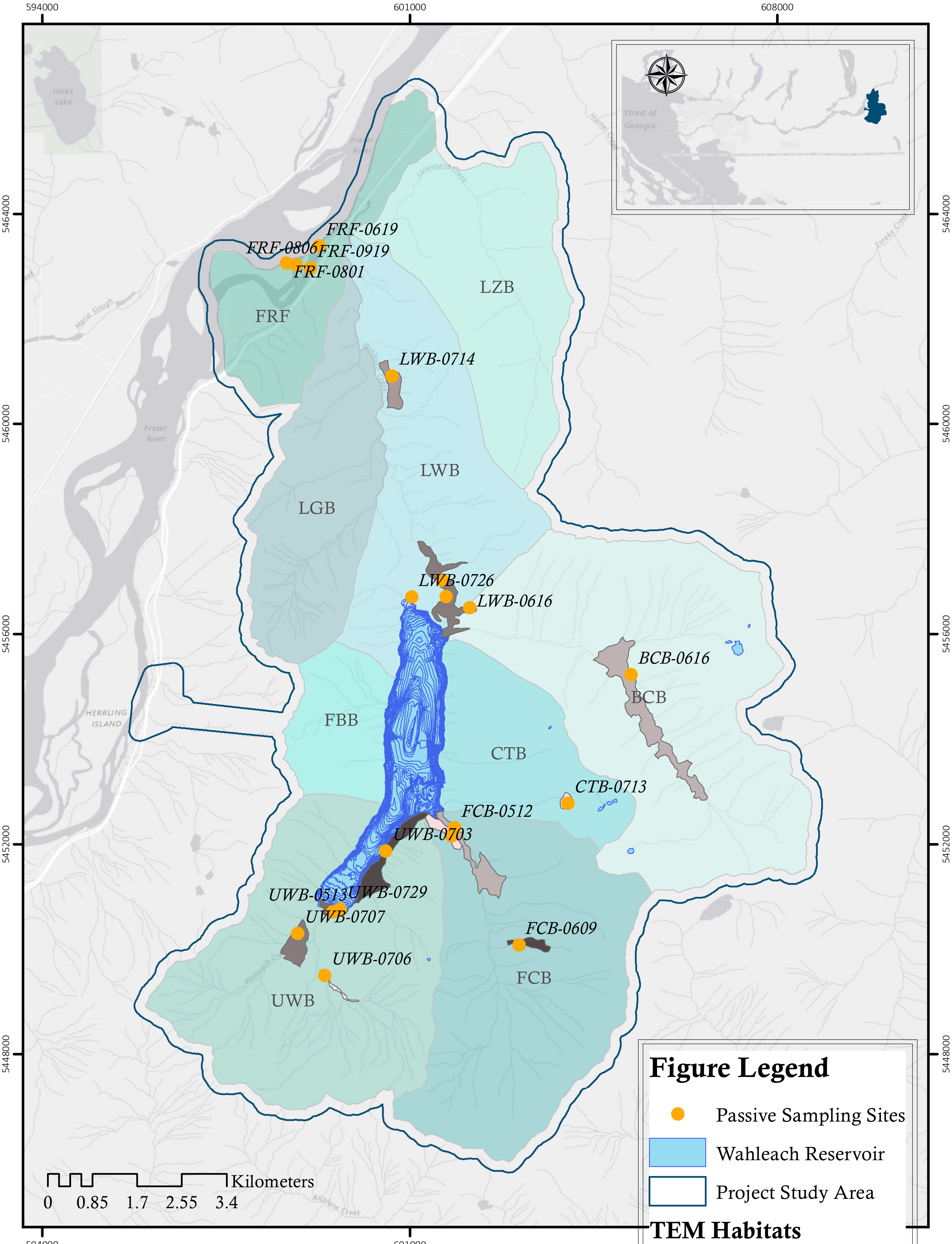

Figure V-4: Passive acoustic bat sampling stations

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Table V-3. Bat species detected during passive acoustic monitoring

Species	Scientific Name	BCB	CTB	FCB	FRF	LWB	UWB
Townsend's big-eared bat	*Corynorhinus townsendii*	No	No	No	No	No	No
Big brown bat	*Eptesicus fuscus*	No	No	Yes	Yes	Yes	Yes
Silver-haired bat	*Lasionycteris noctivagans*	Yes	No	Yes	Yes	Yes	Yes
Hoary bat	*Lasiurus cinereus*	Yes	Yes	Yes	Yes	Yes	No
California myotis	*Myotis californicus*	Yes	Yes	Yes	Yes	Yes	Yes
Long-eared myotis	*Myotis evotis*	No	Yes	Yes	Yes	Yes	Yes
Little brown myotis	*Myotis lucifugus*	Yes	Yes	Yes	Yes	Yes	Yes
Fringed myotis	*Myotis thysanodes*	No	No	Yes	Yes	Yes	No
Long-legged myotis	*Myotis volans*	No	No	No	No	No	No
Yuma myotis	*Myotis yumanensis*	No	No	No	Yes	Yes	Yes
Brazilian free-tailed bat	*Tadarida brasiliensis*	No	No	Yes	Yes	No	Yes

Bat Capture Survey

The purpose of the bat capture survey was to confirm presence of species detected during acoustic surveys and conduct early surveillance for wing damage characteristic of white-nose syndrome (WNS) infection in the regional bat population. Capture using mist-nets is a safe and effective method for detecting multiple bat species in targeted habitats.

Bat Capture Survey Methods

Bats were benignly captured in riparian habitats and wetlands throughout the Wahleach watershed using mist-nets during summer 2016. Bat capture was conducted according to established guidelines (RIC 1998b) and relevant WNS decontamination protocols (BC MOE 2016; USFWS 2016). Bats were captured in the summer following pup volancy. Sample locations were selected opportunistically, based on professional judgement and experience of the surveyors. Net locations were strategically deployed to maximize capture of individuals and a diversity of species. Habitat features such as corridors through forest, streams, rock outcrops, wetlands, potential roost locations, and bodies of water were targeted. Mist nets with 38 mm mesh of 75 denier polyester (Avinet; Portland, Maine, USA) were deployed in an array of 3 – 6 nets at each site. Nets ranged from 6 – 12 m in length and were deployed both individually and stacked, between ground level and up to 7.8 m above the ground, depending on local conditions. Nets were open between sunset and up to four hours after sunset, with inspections every 10 – 20 minutes. Bat capture was conducted between 26 July and 15 August 2016.

Bats captured in mist nets were removed by trained biologists with rabies vaccinations. Bats were placed in cotton bags for one hour to eliminate food, which may introduce bias during mass measurement. Bats were handled minimally, using new disposable gloves for each bat, per WNS decontamination guidelines. Morphometric data was collected from each bat, including mass, forearm, ear and tragus length to identify species. Sex, age and reproductive status were recorded to contribute to understanding regional demographics. For every captured bat, one tissue sample was collected from the wing membrane (plagiopatagium) using a 3 mm sterile biopsy punch for genetic analysis following the standard tissue sampling protocol for bats (Wilmer & Barratt 1996). A fur sample from the nape of the neck and a guano sample were also collected from most species. Wings and muzzle of all bats were swabbed with a cotton tip and sent to Dr. Glenna McGregor at the Animal Health Labs in Abbotsford to screen for *Pseudogymnoascus destructans*, the fungus that causes WNS. Equipment was disinfected as per WNS guidelines. Bats were inspected for signs of WNS infection using the four-point wing damage index (WDI; Reichard & Kunz 2009).

Species of bats in the genus *Myotis* are morphologically similar and can be difficult to distinguish in the hand. Echolocation call characteristics were recorded to differentiate little brown myotis and Yuma myotis (see Lusczc et al. 2016). However, given uncertainty in species identification due to poor echolocation sequences or non-diagnostic morphology, four wing biopsies were sent to Wildlife Genetics International in Nelson, B. C. for genetic identification. DNA in each tissue sample was purified using Qiagen DNeasy Blood and Tissue kits (Qiagen, Toronto, ON, Canada), then compared with reference DNA from known species (Qiagen 2006). Specifically, the species test involves a partial sequence analysis of a hypervariable region of the mitochondrial 16S rRNA gene, which is a commonly used genomic tool for species identification (Yang et al. 2014). Strict quality control practices were maintained to prevent cross contamination of genetic samples in the lab. Remaining tissue for future genetic analyses will be archived with the Royal British Columbia Museum.

Bat Capture Survey Results and Discussion

Fifteen individual bats representing three species were captured, including 13 federally Endangered little brown Myotis, one California myotis, and one Yuma myotis (Table V-4). Townsend's big eared bat, fringed myotis, and Keen's myotis were not caught during surveys.

Table V-4. Bat capture survey results for 2016 inventory in Wahleach watershed

		sex ratio (N = 15)		*age structure (N = 15)*		
Species Common Name	**Scientific Name**	**Female**	**Male**	**Juvenile**	**Sub-Adult**	**Adult**
California myotis	*Myotis californicus*	0	1	0	0	1
Little brown myotis	*Myotis lucifugus*	7	6	2	8	3
Yuma myotis	*Myotis yumanensis*	0	1	0	1	0

Although only a small population was sampled, an even age structure was detected across all species (7 female and 8 male bats). The detection of two juvenile little brown myotis suggests that breeding for this species is occurring in the Wahleach watershed, although nursery roosts were not detected. Little brown myotis nursery roosts are often located in anthropogenic structures, but may also be found in natural cavities in trees, rock piles, or cliffs with appropriate temperature regimes (Fenton & Barclay 1980). This species roosts opportunistically during much of the year, but selects cavities with specific thermal regimes for nursery roosts. Natural nursery roosts have been found in a hollow of a live aspen (*Populus tremuloides*; Barclay & Cash 1985), in balsam poplar (Crampton & Barclay 1998), and in cliff faces (Randall et al. 2014) for little brown myotis and in multiple pine species and Douglas fir (*Pseudotsuga menziesii*) for California myotis (Brigham et al. 1997). Randall (2014) found that roosting behavior was different for male and female little brown myotis in the boreal forest at the northern extant of the species range. Males selected natural roosts closer to foraging areas, whereas females exclusively selected anthropogenic structures, even at relatively large distances (i.e. > 5 km) from foraging areas. This study implies that conservation of key foraging areas and roost sites are important for bat species persistence.

Roosts are an important habitat feature for bats that provide thermal stability for growth, protection from predators, and sites for social interaction. In British Columbia, forest-dwelling bats use natural cavities, exfoliating bark, and cavities excavated by woodpeckers for roosts (Vonhof & Barclay 1996). Vonhof and Barclay found that roosting under tree bark was the most common natural tree roosting behavior and that bats select for particular stages of decay, where bark is exfoliating but not so loose as to fall from the trunk. Tree height and an open canopy have been shown to be important characteristics for tree roosts of forest-dwelling bats, likely due to thermal benefits of increased solar radiation (Vonhof, Maarten J., Barclay 1996; Brigham et al. 1997; Kalcounis-Ruppell et al. 2005). Forest-dwelling bats tend to shift roosts every few days (Lewis 1996), so specific roost sites are less important than habitat patches with an abundance of roost options. Old stands have been shown to be important for roosting and foraging bats (Crampton & Barclay 1998). Harvesting timber from old stands reduces roost potential and may have long term implications on bat populations.

Most bats (73%) captured were sub-adults or juveniles, likely due to trap naiveite and the ability of adults to avoid nets. The highest trapping success occurred at nets deployed over the surface of water where bats were caught foraging for insects flying within 1 m of the water surface. Bats were observed foraging over much of the reservoir, with greatest concentrations of flight activity over shallow waters.

We did not detect any scarring on bat wing tissues suggesting WNS presence in the Wahleach bat population. Although we swabbed wings to detect fungal spores, the timing of swabs collected in late summer does not match timing when the spores or fungal hyphae are most detectable in spring. We have archived the swabs for future analysis.

Mammal Inventory Conclusions

Three mammal species-at-risk were detected in the Wahleach watershed, two of which are likely breeding: little brown myotis and mountain beaver. Detection of fringed myotis along the Fraser River was surprising, given that this species generally inhabits drier sites east of the Coast Mountains. This species may use the Fraser River as a corridor between seasonal use sites. Further investigation of habitat use in coastal regions should be undertaken.

Recommendations for Future Mammal Inventories in the Wahleach Watershed

Mountain beaver (*Aplodontia rufa*) occur in riparian habitats at mid and upper elevations in the Wahleach watershed. An approved Wildlife Habitat Area (#02-012) occurs on 78.5 ha of riparian and floodplain forest in Upper Wahleach Basin (see Figure V-5). This area is characterized by mixed mature forest of cottonwood and spruce, with abundant salmonberry and elderberry shrub cover, braided creek channels, and rich gravel soils. One mountain beaver burrow was identified at 1045 m in an avalanche opening within Boulder Creek Basin. The south-facing site was rich with abundant herbaceous cover, running water, and soil suitable for burrowing. Similar habitat occurs near treeline in multiple basins of the watershed and likely support a metapopulation of mountain beavers that disperse from high quality lower elevation habitat.

Bat capture will be an important method for assessing bat response to the devastating zoonotic disease WNS in western Canada. This disease is causing unprecedented mortality in populations of hibernating bats in eastern North America (Frick et al. 2010). In 2016, WNS was detected in King County, Washington (Lorch et al. 2016) less than 250 km from the Wahleach watershed. In British Columbia, nine species of colony-roosting bat species are at risk of population declines from WNS, including six with no previous exposure to the disease. We recommend spring WNS surveillance be conducted at FWCP watersheds throughout the Lower Mainland in 2018 to assess presence of WNS in British Columbia. Spring WNS surveillance should include mist netting conducted during Canada's WNS annual surveillance period, which ends 30 May (CWHC 2014) and in accordance with provincial recommendations to prevent human transmission of the disease (MOE 2016). The objective of spring mist netting will be to collect guano and wing tissue swabs from bats soon after hibernation ends when fungal loads are highest. In addition to catching bats, guano should be collected in traps at known maternity roosts and under bridges where bats may rest temporarily at night roosts. Spring WNS surveillance in FWCP watersheds should be conducted in cooperation with the Canadian Wildlife Health Cooperative (CWHC) and regional biologists in British Columbia and Washington. Samples

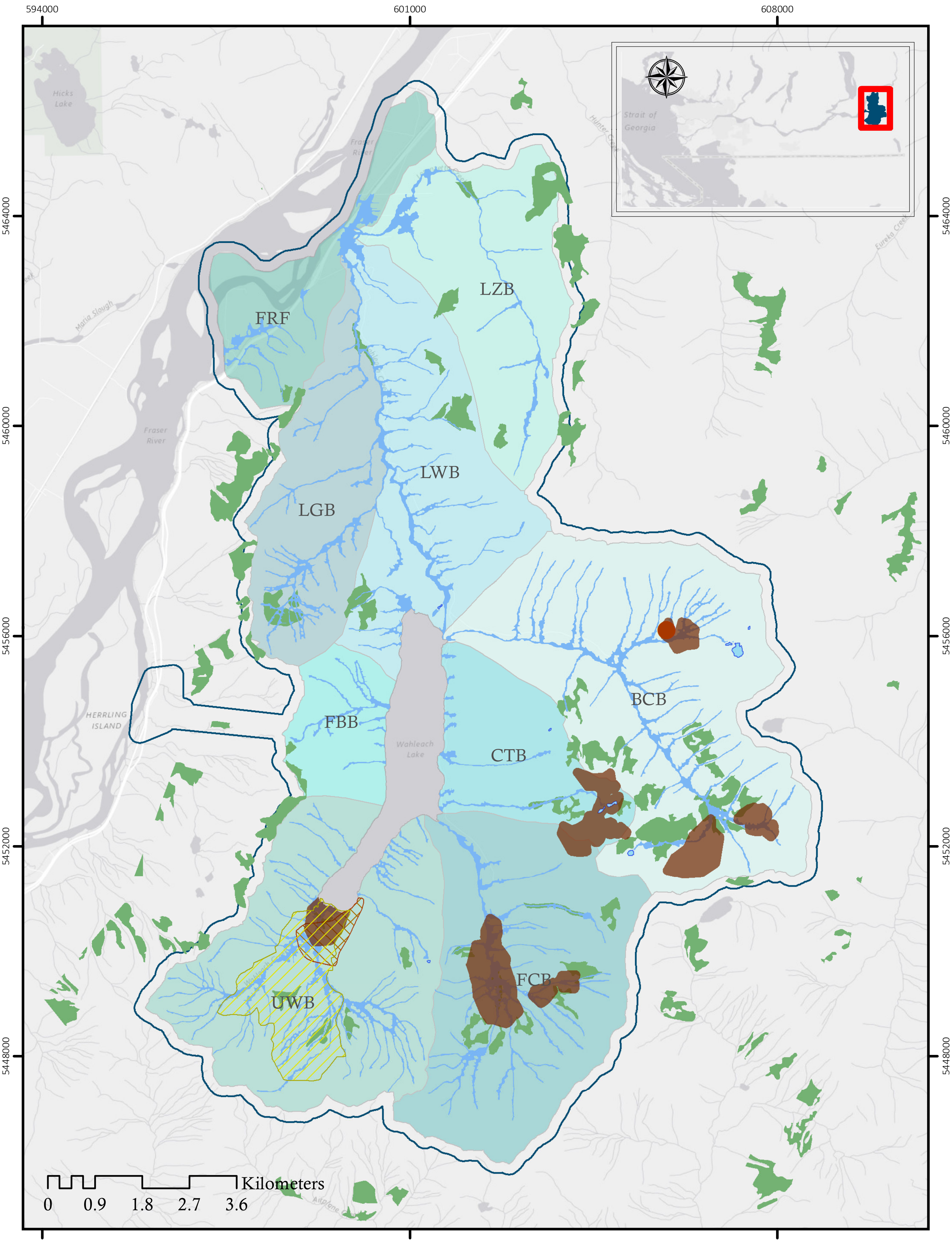

Figure V-5: Mammal species-at-risk habitat features

This Project is funded by the Fish and Wildlife Compensation Program (FWCP). The FWCP is a partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations and public stakeholders to conserve and enhance fish and wildlife impacted by the construction of BC Hydro dams.

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Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -123.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

Author: P. Burke

Date: 2017-05-19

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QUERCUS ECOLOGICAL

Figure Legend

- Grizzly Bear WHA
- Mountain Beaver Burrow
- Mountain Beaver Habitat
- Mountain Beaver WHA
- Riparian Habitat
- Old Growth Mgt Area
- Wahleach Reservoir
- Project Study Area

for lab testing should be collected, stored, and shipped to the Animal Health Centre in Abbotsford, British Columbia according to the Canadian Bat WNS Necropsy Protocol (CWHC 2014).

The identification of bat hibernacula in British Columbia will be another important component of understanding and managing risk to bat populations from WNS. Multiple hibernacula sites occur within the Wahleach watershed, including: the Lucky Four Mines, the Blue Chip Mine, and the maintenance access tunnel to the Wahleach penstock. We recommend bat hibernacula inventory using passive acoustic monitors at potential overwinter sites in the watershed. Locations of important bat habitat features can be found in Figure V-6.

Based on data collected for this project, little brown myotis appears to be breeding in the Wahleach watershed. Not much is known about natural roost for this species in British Columbia. We recommend a telemetry study to identify summer roosts and habitat preferences for this and other species present in the watershed.

Fisher are medium-sized carnivores occurring at low densities across southern British Columbia. These animals select late seral forests and show an affinity for forested riparian habitats. Female fishers in British Columbia exclusively raise pups in cavities of large-diameter black cottonwood - balsam poplar (*Populus balsamifera*) in proximity to areas with security cover, foraging opportunities, and snow interception (Weir 2003). Suitable breeding habitat for this species occurs in the UWB. On 12 May 2016, a large-diameter hole was detected in a wildlife tree (UTM Zone 10 599134.8E, 5450835.6N) that appeared to be large enough for a fisher. We recommend surveys for this species in the Upper Wahleach Creek Basin.

A subspecies of the snowshoe hare (*Lepus americanus washingtonii*), known as brown hare due to the lack of a winter white pelage, occurs at low elevations of the Fraser River Valley. The species occurs in low density and population status is unknown (Zevit 2009). Tracks were detected in the snow on 8 January 2017 in the Upper Wahleach Basin that may have been left by this subspecies. We recommend setting camera traps in suitable habitat overwinter targeting this subspecies.

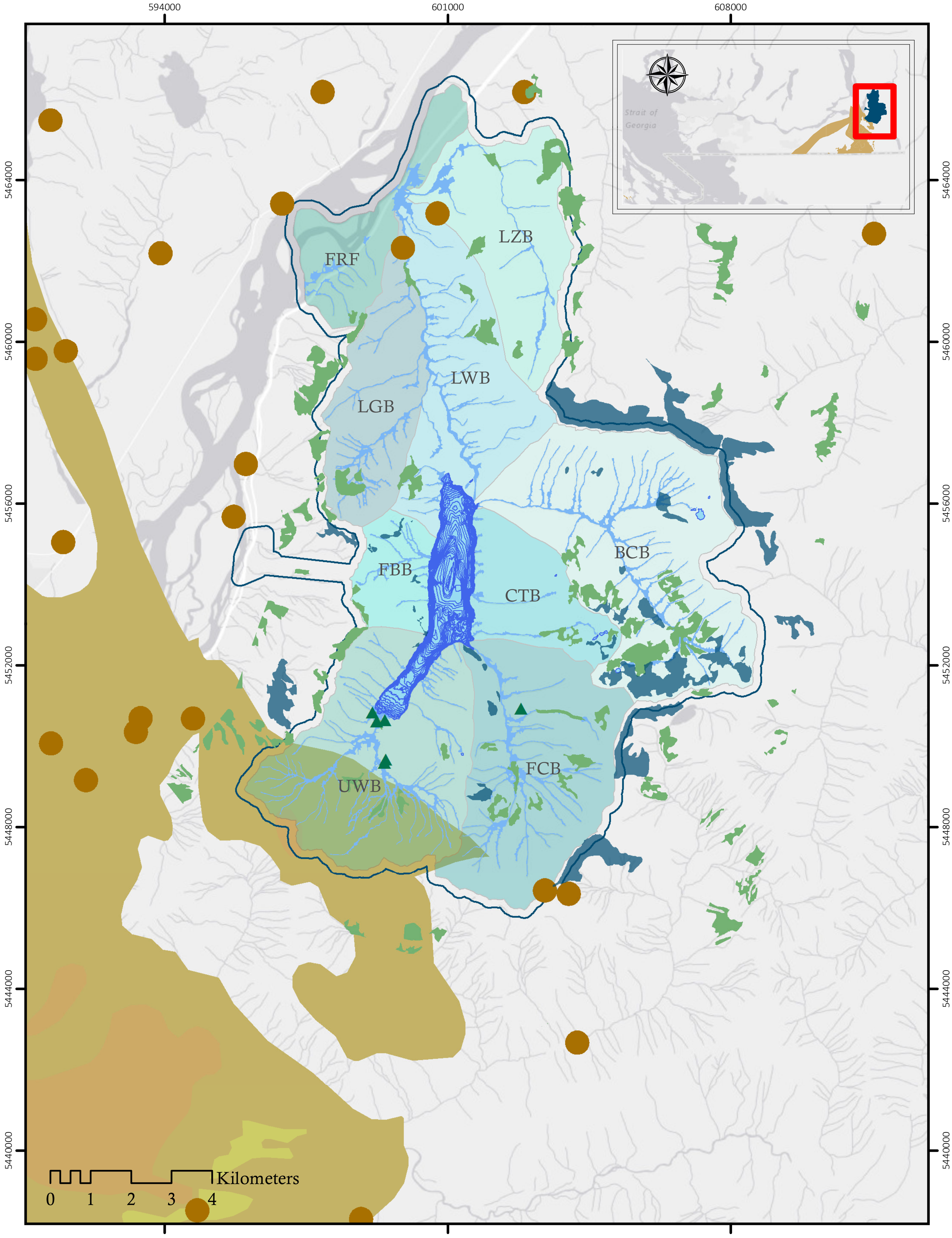

Figure V-6: Bat habitat features

This Project is funded by the Fish and Wildlife Compensation Program (FWCP). The FWCP is a partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations and public stakeholders to conserve and enhance fish and wildlife impacted by the construction of BC Hydro dams.

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Coordinate System: NAD 1983 UTM Zone 10N
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Latitude Of Origin: 0.0000
Units: Meter

QUERCUS ECOLOGICAL

Author: P. Burke
Date: 2017-05-19

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Figure Legend

- Potential Karst Geology
- Talus Habitat
- Wildlife Trees
- Riparian Habitat
- Old Growth Mgt Area
- Mines
- Wahleach Reservoir
- Project Study Area

SECTION VI: CONSERVATION & MANAGEMENT RECOMMENDATIONS

Species-at-risk in the Wahleach watershed face a variety of threats to the continued persistence of local populations, including climate change, timber extraction, industrial development, recreational impacts, and natural environmental stochasticity. Informed conservation and management strategies can support future viability of these species in the face of these challenges. In this section, we provide specific actions that would support species-at-risk and enhance their habitats in the watershed. We have further identified additional research priorities for species-at-risk at the end of each inventory section.

Wetland and Riparian Conservation and Management

Construction of the Wahleach Reservoir contributed to a direct loss of 211 ha of dry land, 30 ha of riparian habitat, and 11 km of natural shoreline (FWCP 2011). Although the extent of wetland loss is unknown because wetlands were not characterized prior to construction, it is expected that historical wetlands occurred on the northern and southern margins of the original lake (see Figure I-3). Following construction of the reservoir, the Wahleach North and Wahleach South wetland were likely established in regions that previously supported terrestrial vegetation. We have identified 12.3 ha of wetlands and meadows along the margins of the reservoir that have likely established over the past 65 years. Here we recommend future improvements to these habitats to support wildlife species-at-risk.

The alteration of the natural hydrologic cycle in the Wahleach watershed impacts wetland and riparian habitat along the margins of the reservoir. McIntosh and Robertson (McIntosh & Robertson 2001) recommended maintaining the existing riparian and wet meadow habitats in the study area, but did not provide an estimate of the size of these habitats. We recommend maintaining at least 12.3 ha of wetlands and wet meadows in the watershed and improving these habitats for species-at-risk.

Wetlands may be improved by creating perched wetlands within the Wahleach DDZ to reduce effects of seasonal inundation and desiccation which limit succession of wetland vegetation. Enhanced wetlands engineered to support a natural wetland hydrology may increase abundance and diversity of vegetation and wildlife. The CLBWORKS-29 project is one example where BC Hydro is conducting feasibility studies with the objective to increase the amount of shallow-water habitat to benefit reptiles, amphibians, and waterbirds (Golder Associates Ltd. 2009). The GMSMON-15 project is at a more advanced stage (MacInnis et al. 2016). BC Hydro is currently monitoring the effectiveness of two wetland enhancement projects in the Williston Reservoir. The Peace Project Water Use Plan: Reservoir Wetland Habitat Monitoring 2016 report states that effectiveness monitoring for the second full year post-construction at the Airport Lagoon and first full year post-construction at the Beaver Pond appear to support preliminary predictions for increased abundance, diversity and use, however additional monitoring is still required.

Continuous seepage into the area provides a permanent water source making a dike or series of dikes a viable treatment option. "The design of the Beaver Pond berm using geosynthetic tubes has proven to be constructible" in the Williston Trial Wetlands Project and may be considered here (GMSWORKS-17). When retaining water, careful considerations should be made to avoid flooding bird nesting habitat and stranding fish and to include First Nations to ensure Archaeological Assessments are conducted prior to disrupting the site. Additional enhancements may include: limiting human and ATV access, particularly during sensitive stages in the western toad life-cycle, providing signage and information boards, building elevated boardwalks and look outs with opportunities for First Nation engagement and participation.

Based on topography, available bathymetry, and the stumps remaining in the DDZ, we expect that a 20 ha western red cedar swamp occurred historically at the inflow of Flat Creek. Similar habitat of this extent does not currently occur in the watershed. Restoration of red cedar swamp in the watershed or nearby would support amphibians, bats, birds, and other riparian adapted species.

Amphibian Conservation and Management

The loss of 30 ha of riparian habitat and 11km of natural shoreline when the reservoir was created likely reduced available amphibian breeding habitat in the watershed. Further, the loss of littoral habitat that supports amphibian breeding and amphibian prey potentially impacted amphibian populations in the watershed. The loss of littoral habitat has not been quantified, but the original lake in the watershed likely had an extensive littoral zone (Stockner & Bos 2002). The impoundment of the lake shifted production from a post-glacial littoral system to a pelagic system.

Avian Conservation and Management

Given raptor nesting and habitat at the Wahleach South wetland, it is recommended that large trees and standing timber be retained within 500 m of the south shore of the Wahleach Reservoir. Swallows have been observed roosting in the cabins owned by the Jones Lake Cabin Association (McIntosh & Robertson 2001). In 2016, swallows were observed foraging over the reservoir and in high density at the Wahleach South wetland. One tree swallow nest was observed near this wetland. Given the high-quality foraging habitat, the potential for loss of roosting sites on private land, and the presence of swallow species-at-risk, we recommend preparing a swallow and martin nest box installation and management plan for the Wahleach South wetland. Retaining mature timber within 500 m of the south shore of the Wahleach Reservoir may support swallow nesting.

Mammal Conservation and Management

The loss of 30 ha of riparian habitat in the Wahleach watershed likely reduced the number of natural roost sites for forest-dwelling bats. Bats select large trees with relatively open canopies for maternity roosts. The large diameter mature trees that were cut for the project potentially supported maternity colonies for multiple species given the diameter of standing stumps, the proximity to foraging areas, the high solar radiance along the lake shore, and the open canopy along the lake edge.

Bats have been observed using the cabins owned by the Jones Lake Cabin Association (McIntosh & Robertson 2001). In 2016, bats were observed foraging over the reservoir up to 200m from shore. Given the high-quality foraging habitat, the loss of natural roosts from the construction of the reservoir, the potential for loss of roosting sites on private land, the presence of bat species-at-risk, and the potential impacts of WNS on bats in the watershed, we recommend preparing an artificial bat roost installation and management plan for the Wahleach North wetland. This wetland has high bat activity, good foraging sites nearby, and is visible and accessible to the public.

Closing Remarks

A final recommendation is to increase signage and educational materials in the watershed to connect the large recreational user group with conservation and management in the watershed. Consider the Wahleach North wetland for a wetland enhancement project. This site has good road access and excellent public outreach and education potential. Given proximity to major urban areas and high summer recreational activity, a boardwalk, interpretive signs, and an updated kiosk could increase conservation awareness in the watershed. A strategically designed boardwalk could reduce ATV traffic in the wetland. And a citizen science monitoring program to connect visitors with Wahleach ecology could be designed and delivered virtually through a custom mobile phone app or an existing platform like iNaturalist.

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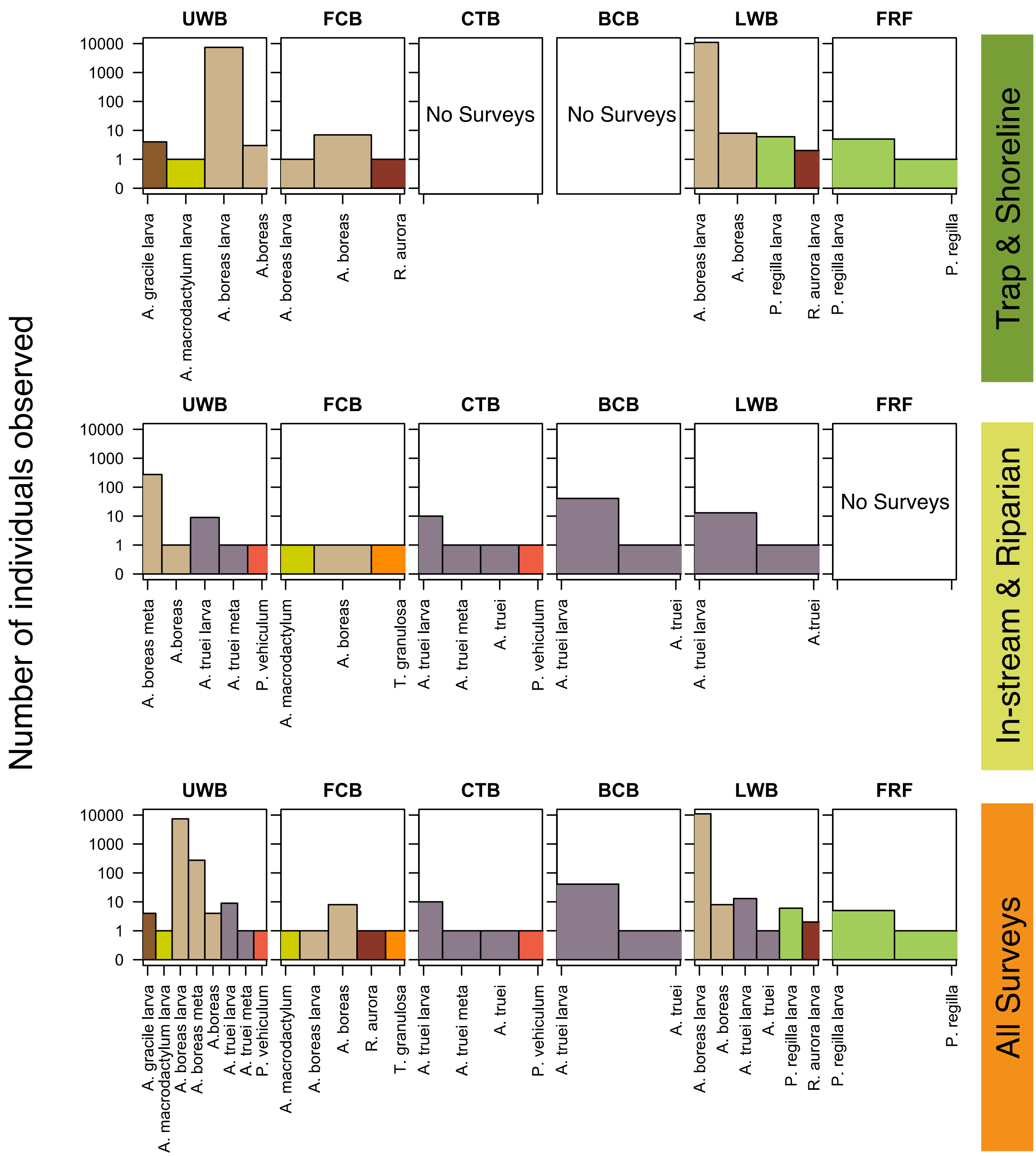
Appendix A

Supporting material for Amphibian Inventories

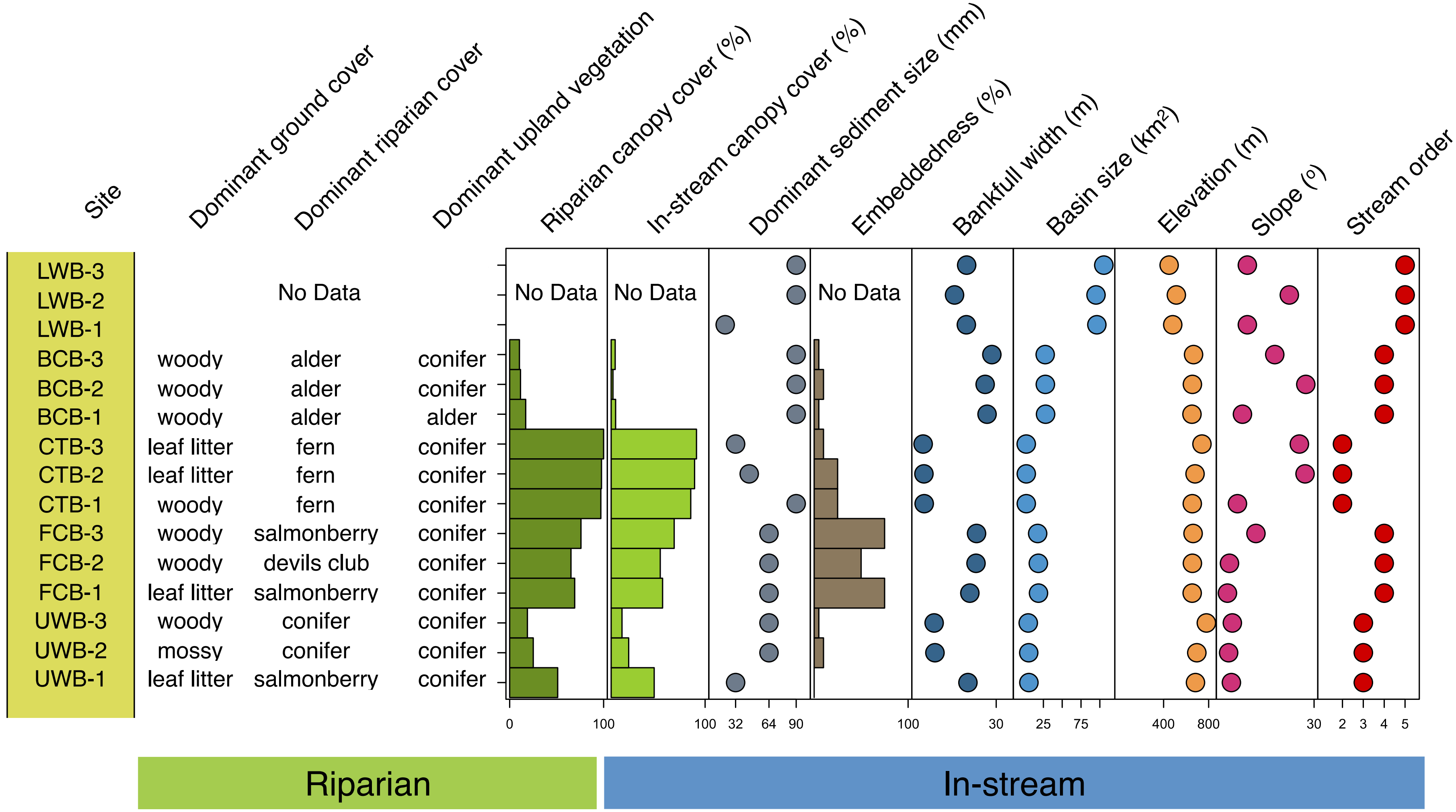
Appendix A, Image 1 & 2. Ecological trap for breeding western toads. Eggs were laid in this vernal pool in mid-April, with abundant tadpoles seen here on May 27, 2017. However, the pool dried up (through evaporation and drainage into the sandy substrate).

Appendix A, Image 3. Ecological trap for breeding western toads. Eggs were laid in this vernal pool in mid-April, with abundant tadpoles seen here on 27 May 2017. However, the pool dried up (through evaporation and drainage into the sandy substrate) by early summer.

Appendix A, Figure 1. Total number of individuals of all amphibian species and life stages encountered across all survey types in the Wahleach drainage basin and delineated sub-watersheds. Species names without life stage designation are adults. Only species detected are shown. Surveys also targeted all life stages of *D. tenebrous* and *R. pretiosa* but were not detected.



Appendix A, Figure 2. Dominant vegetation and percent cover of vegetation types for shoreline VES and trapping regions. Shoreline VES (and associated riparian vegetation) was adjacent to trapping regions. Emergent and underwater vegetation was characterized for the whole sub-trapping region within each sub-watershed.



Appendix A, Figure 3. Dominant vegetation for riparian VES adjacent to in-stream TCS sites, canopy cover, and associated stream characteristics. Sediment, embeddedness, and bankfull width taken during first survey. Basin size, elevation, slope and stream order were calculated using geospatial data implemented in GIS software.