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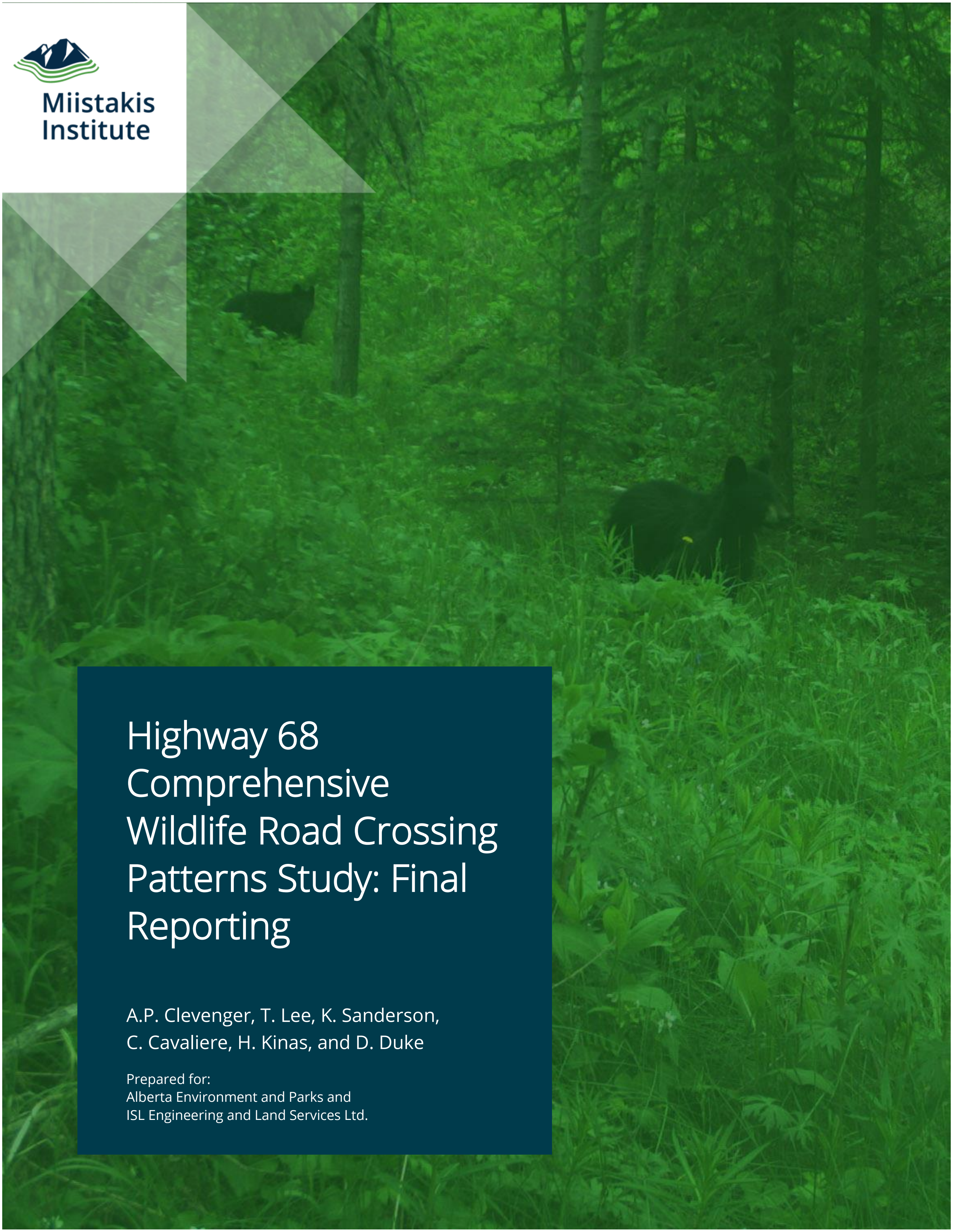

# Highway 68 Comprehensive Wildlife Road Crossing Patterns Study: Final Reporting

A.P. Clevenger, T. Lee, K. Sanderson,
C. Cavaliere, H. Kinas, and D. Duke

Prepared for:
Alberta Environment and Parks and
ISL Engineering and Land Services Ltd.

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January 2019

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# Contents

# Acknowledgements

This report is the product of Alberta Environment and Parks (AEP) efforts to obtain information on the impacts of an improved Highway 68 on wildlife movements and mortality. We would like to thank the following people that were instrumental in allowing us to conduct fieldwork and access the data required to address the management issue of safe and efficient highway along the Highway 68 Sibbald Flats corridor. Melanie Percy (AEP) was instrumental in making the project happen. John Paczkowski (AEP) provided field equipment (cameras, batteries, SD cards, locks etc) that enabled us to collect information on species distributions. Sandra Code and Scott Jevons (both AEP) provided GIS and data management support. Jay Honeyman and Brett Boukall (both AEP) assisted us with grizzly bear datasets in the region. Ian Clevenger assisted with camera set up and checking of cameras during the initial four months of the project. Nikki Heim (AEP) helped collect snow-tracking data on days we were unable to get out to Highway 68. At the start of this project valuable information was provided by Andrew Rees, Jeff Eamon, John Paczkowski, Dave Dickson, Melanie Percy, and Brett Boukall at a local knowledge workshop on Highway 68. Finally, we would like to thank Jodi Reade and AJ Evenson (Alberta Government) for securing government support for the project and to Kurt Alksne for managing the project for ISL Engineering and Land Services Ltd.

# Executive Summary

Highway 68 in southwestern Alberta may undergo future upgrades including paving gravel sections to facilitate increased traffic from recreational pressures. The highway runs through the Rocky Mountain Forest Reserve with access to a number of small Provincial Recreational Areas (PRAs) between Trans-Canada Highway and Highway 40. Paving would take place from the intersection of Highway 40 to the existing paved section of Highway 68 just east of Camp Cadicasu. An upgrade of this type will result in higher traffic volumes and increased travelling speeds, and subsequently have significant impacts on wildlife. Black and grizzly bears, elk, deer and moose, other smaller mammals and amphibians are currently found in the area thus highway mitigation measures to facilitate road crossings for wildlife would need to be considered as part of  any future upgrade of Highway 68.

The principle goal for this study was to develop and implement an assessment of wildlife movement patterns along the Highway 68 corridor, and from these findings provide recommendations on the key locations where mitigation would need to take place should an upgrade project occur.

To determine wildlife crossing patterns on Highway 68, we undertook a 20-month wildlife study with the following methods and components:

- Remote camera detections of species distributions;
- Snow-tracking surveys;
- Connectivity modeling for grizzly bear and moose; and
- Amphibian and reptile surveys.

## Wildlife Patterns along Highway 68

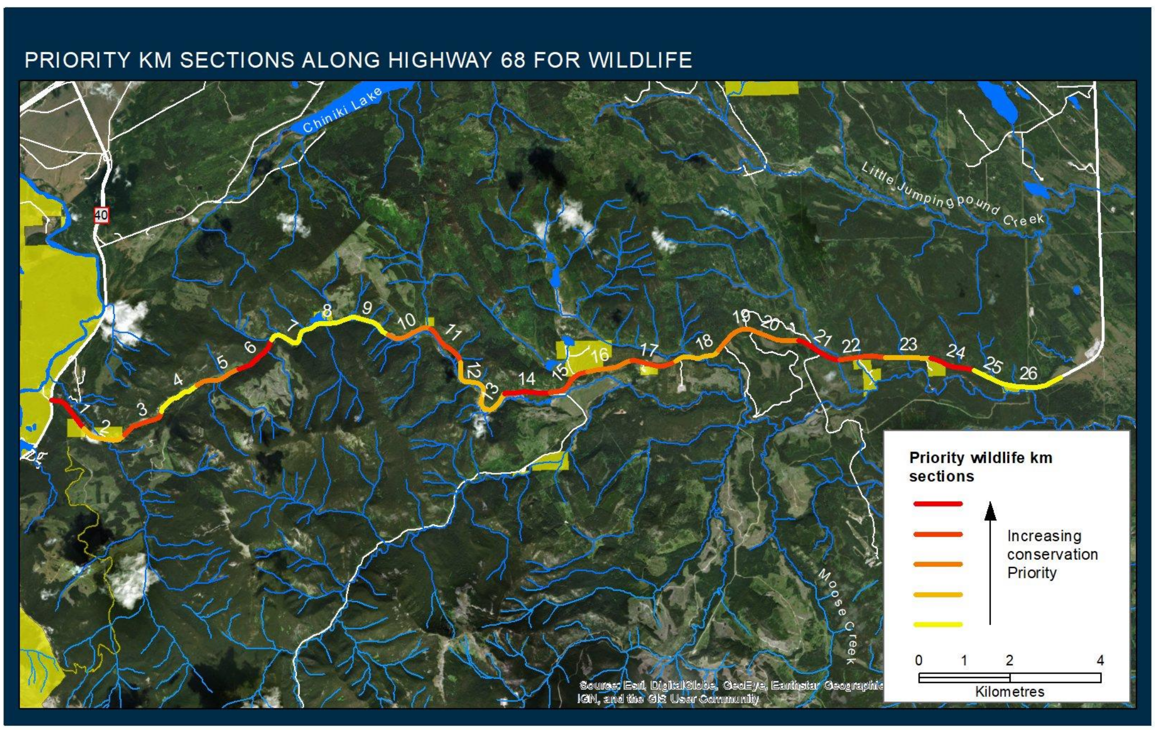
Remote camera monitoring occurred at 24 locations along Highway 68 from May 2017 through December 2018. During the 20-month period there were 4829 photographs of wildlife events, of which 82% (n = 3977) were ungulates, 15% (n = 739) were carnivores, less than 1.9% were lagomorphs (n=94) and birds (0.18%; n=2). A total of 18 species were detected at the camera sites.

We completed five snow-tracking days in 2018 resulting in an increase in winter crossing observations and included detections of coyote, cougar, moose, bobcat and wolf.

Camera and snow-tracking detections were used to determine species rate of activity per km/day in the Highway 68 study area. To address both transportation and resource management issues we developed two key synthesis layers to help inform recommendations for mitigation: *motorist safety risk* (based on sum of mule deer, white tailed deer, elk and moose detection rates) and *conservation concern* (based on grizzly bear, cougar and wolf detection rates).

To better understand how animals need to move around the landscape, we developed connectivity models for both moose (winter) and grizzly bear (three seasons) using Circuitscape connectivity modeling software. Connectivity models were used to better understand how wildlife move around the landscape including across Highway 68. To enable synthesis with camera and snow-tracking detection rates, we calculated the average connectivity value per km section using a 250 m buffer. Results indicated a substantial portion of Highway 68 is important for movement, as connectivity modeling indicated wildlife movement at multiple locations. For example, 50% of the highway study area is represented in the top 50% opportunity for grizzly bear movement in connectivity modeling with 54% of the study area is represented in the top 50% opportunity for moose movement in connectivity modeling.

To better understand movement patterns from multiple species and both transportation and resource management perspectives we created a synthesis map for large mammal species based on four key layers: *motorist safety risk, species of conservation concern, moose connectivity value* and *grizzly bear connectivity value*. All the layers were standardized from 0 to 1, and summed per kilometer to generate a cumulative value.



PRIORITY KM SECTIONS ALONG HIGHWAY 68 FOR WILDLIFE

Amphibian monitoring occurred via five auditory and visual surveys at nine wetland locations in 2017 and through the placement of three Acoustic Recoding Units (ARUs) in 2018. We recorded four amphibian species: Chorus frog (*Pseudacris maculate*), Wood frog (*Lithobates sylvatica*), Columbia spotted frog (*Rana luteiventris*) and Western toad (*Anaxyrus boreas*). Columbia spotted frog and Western toad are listed as sensitive species in Alberta.

To monitor for reptiles we placed cover boards at four sites with potential reptile habitat along Highway 68. No reptiles were recorded from the cover board survey or incidentally during the two year study.

## Mitigation Recommendations

Our main recommendation is to not improve the road; Highway 68 should remain as a low-volume road with low vehicle speeds, i.e. maintain the unpaved nature of the highway. This is based on the need to reduce regional impacts of increased road density, increased habitat fragmentation effects, increased human access off Highway 68 and other highways in the region. Road density is a useful surrogate for the negative effects of human land use on grizzly bear populations, but spatial configuration of roads is also an important factor. Two major highways are located near Highway 68, the bustling Trans-Canada Highway with more than 35,000 vehicles per day (increasing annually) during summer, and increasing traffic on Highway 40 in Kananaskis Country, currently with just under 2000 vehicle per day.

Should the decision be made to improve Highway 68 by paving, we propose a mitigation strategy based on cost-benefits and the current science and practice of road ecology.

### *Large Mammals*

The recommendations for improving motorist safety and wildlife connectivity for Highway 68 include a total of five different proven or promising mitigation measures.

| **Mitigation measure** | **Effectiveness** | **Type**[1] | **Category**[2] |
|---|---|---|---|
| Animal detection system | 87% | Driver | Promising |
| Fencing | 86% | Separate | Proven |
| Underpass with waterflow | 86% | Animal | Proven |
| Underpass – wildlife | 86% | Animal | Proven |
| Overpass – wildlife | 86% | Animal | Proven |

Based on the synthesis of wildlife movement patterns determined during this two year study, we propose five *Emphasis Mitigation Zones (MEZs)* along Highway 68 for consideration of mitigation.

MITIGATION EMPHASIS ZONES ALONG HIGHWAY 68


For large mammals we devised three categories of proposed mitigation structures with the following design criteria: *Primary* wildlife crossing structure, consisting of a 30-m wide overpass or extended bridge underpass 21 m wide and 3.5 m high; *Secondary* wildlife crossing structure, consisting of an open-span bridge underpass 11 m wide and 3 m high; *Tertiary* wildlife crossing structure, consisting of an open-span bridge underpass, or 3 x 7 m metal culvert or concrete box culvert 2.8 m wide x 2.6 m high.

For each MEZ we recommend a mitigation system to address both motorist safety and wildlife movement, although specific locations of recommended mitigation structures require further assessment.

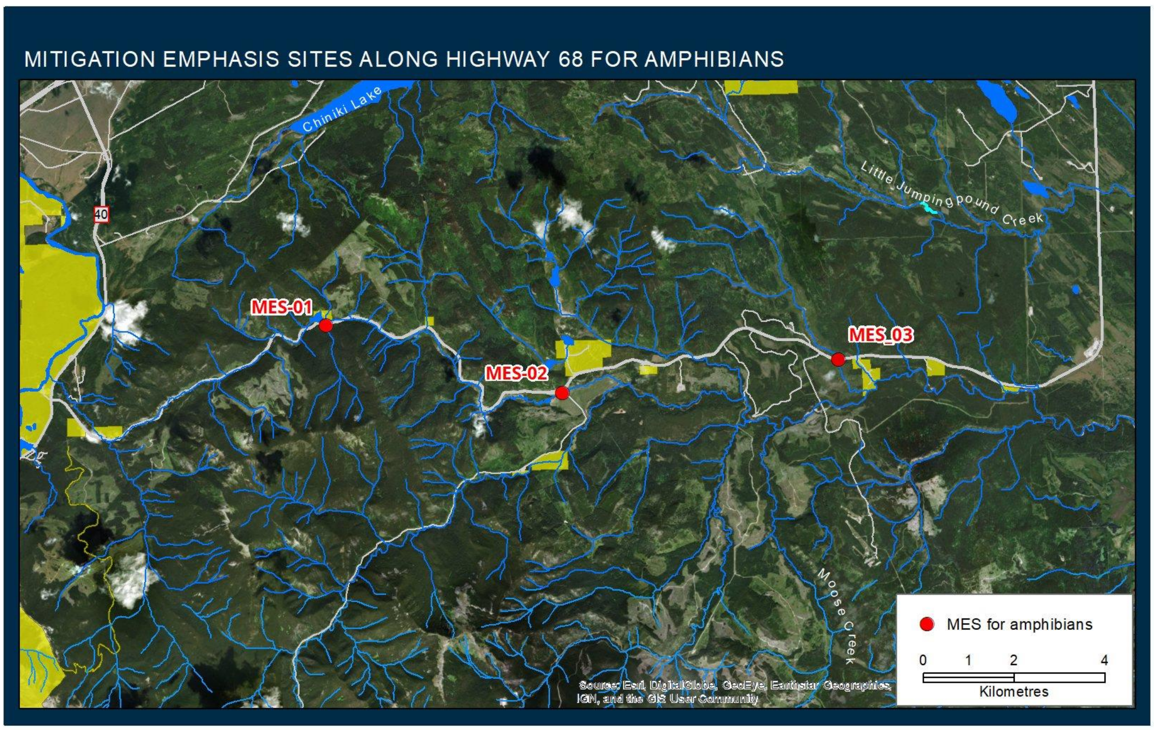
### *Amphibians*

There are many significant threats to amphibian populations including habitat loss and degradation, habitat fragmentation, environmental pollution, disease, climate change, and road mortality from traffic or entrapment in road drainage structures. In order to address the deleterious effects of roads, transportation agencies have over several decades tried to mitigate road impacts by providing dispersal passages and barrier structures.

Within the Highway 68 study area the current highway alignment bisects habitat critical for amphibian denning, overwintering, breeding and/or feeding. Similar to our recommendations for terrestrial mammal mitigation, the general objective is to connect important habitats by ensuring passages and barrier systems are designed for the target species to ensure functionality and conservation value. Specific objectives are to: 1) provide single/multi-species passage, and 2) provide for minimum connectivity where Highway 68 severs habitat and ensure at least some future connectivity of the target species or community, to enable at least a minimum amount of connectivity.

Four species of amphibians were detected in the study area that requires mitigation attention: three species of frogs (chorus frog, wood frog, Columbia spotted frog) and one species of toad (western toad). We recommend three *Emphasis Mitigation Sites (MES)* along Highway 68 for amphibian mitigation should the highway be upgraded.

For each amphibian MES we recommend a mitigation system to avoid or improve connectivity at specific locations based on the species and current road alignment.



MITIGATION EMPHASIS SITES ALONG HIGHWAY 68 FOR AMPHIBIANS

To better determine the need for Highway 68 upgrading there is a need to understand the long-term vision for Highway 68 from both Alberta Transportation and Alberta Environment and Parks. Currently Highway 68 has a low traffic volume with relatively low vehicle speeds, and represents a low risk to motorist safety and wildlife. The highway is situated within Rock Mountain Forest Reserve which has high wildlife conservation value, but bisects habitat for grizzly bears cougars, wolves, and two amphibian species of concern (Columbia spotted frog and Western toad). We encourage further dialogue on the conservation cost-benefits associated with paving Highway 68 as opposed to leaving the road unpaved to recreationists and incurring minimal disturbance to wildlife populations in the region.

# 1.0 Background

Alberta supports an extensive network of transportation infrastructure; 31,000 km of highway enables the efficient movement of people and goods (Government of Alberta 2017). Alberta is also home to the most diverse assemblage of large mammal species in Canada, including elk, moose, bighorn sheep, deer, black bear, cougar, wolf, wolverine, lynx and the provincially-threatened grizzly bear. Most of these species require large landscape for survival as they search for food, shelter, and mates. Inevitably, these movements bring animals into contact with roads and, too often, the vehicles driving on them.

The intersection of wildlife and people on highways raises two critical issues:

1. The impact of roads on the movement and mortality of wildlife; and
2. Risks to people and vehicles caused by collisions with wildlife.

Many species of wildlife avoid crossing roads, creating movement barriers across the landscape. These barrier effects reduce the amount of habitat available to animals, alter predator-prey interactions, and can reduce the viability of populations through genetic isolation. For some species like large carnivores, mortality from vehicle collisions is often the greatest cause of death. As such, roads can pose a major hurdle to wildlife management and conservation objectives.

Motorist safety is also compromised by wildlife-road interactions. Across Canada, about 6 large mammals are involved in a wildlife vehicle collision (WVC) every hour (L.P. Tardiff and Associates 2003). Alberta Transportation reported 9 human fatalities, 498 human injuries, and a total cost of $240 million in damages in 2008 as a result of WVCs. The majority of the collisions (85%) involved deer, followed by moose (11%), bears (2%), and other species (<2%) (AlbertaTransportation 2010).

Highway mitigation is a widespread and highly effective means to resolve issues of road-wildlife interaction. Mitigation may involve making drivers more alert (e.g., animal detection systems, variable message signs), separating wildlife and motorists (e.g., exclusion fencing, and crossing structures - overpasses and underpasses), and modifying animal behavior near the road (large boulder fields, vegetation manipulation). However, because mitigation measures are both expensive and often fixed (i.e., not portable), it is critical that their installation is strategic to maximize return on investment in meeting the management priorities of both wildlife and transportation agencies. It is not always clear when and where agencies share priorities. For example, a recent study in Montana was targeted at siting mitigation to yield the greatest positive impact for wildlife and people (McClure and Ament 2014). This study found that highway segments prioritizing connectivity (e.g., for rare carnivores) and segments with high risk of WVCs rarely occurred in the same place.

Highway 68 in southwestern Alberta may undergo future upgrades including paving to gravel sections to facilitate increased traffic from recreational pressures. Paving would take place from the intersection of Highway 40 to the existing paved section of Highway 68 just east of Camp Cadicasu. An upgrade of this type will result in higher traffic volumes and increased travelling speeds, and subsequently have significant impacts on wildlife. Wildlife including black and grizzly bears, elk, deer and moose, as well as many other smaller mammals currently use the area, and highway mitigations to facilitate road crossings for these species would need to be considered as part of any future upgrade of Highway 68.

In order to ensure appropriate highway mitigation measures are considered, there is a need to know where wildlife are at greatest risk of collisions with vehicles and where important connectivity areas occur along Highway 68. In order to determine this we undertook a methodology for determining:

- wildlife road mortality (past and present),
- optimal connectivity for specific species (grizzly bears, moose), and
- wildlife distributions and occupancy along Highway 68.

The results from these methods will together inform appropriate highway mitigation recommendations for the upgrading of Highway 68.

## 1.1 Objectives

The principle goal for this study is to develop and implement a methodology to assess wildlife movement patterns along Highway 68.

Specific objectives to address this goal are:

- Determine where wildlife are at greatest risk for WVC,
- Determine connectivity/movement needs for grizzly bear, and
- Prioritize areas for optimal connectivity for a complement of species.

We report on the methods and results of the main areas of research below. In each section we summarize information collected and provide recommendations regarding the sufficiency of data to meet the overall objectives of the Highway 68 Comprehensive Wildlife Road Crossings Patterns study.

These findings represent final reporting after a two year wildlife and roads study along Highway 68 initiated in 2017 and completed at the end of 2018. Findings outlined in this report are supported by a 2017 year-end report which included moose connectivity modeling and local expert knowledge assessment of crossing locations. Camera detection rates and snow-tracking data were cumulative with 2017 results and incorporated into final analysis in this report.

# 2.0 Wildlife Occupancy and Distribution

## 2.1 Occupancy Methods

### *2.1.1 Camera-trapping methods*

To detect and record wildlife, we employed camera traps (Reconyx, Holmen, Wisconsin, USA; Bushnell Outdoor Products, Overland Park, Kansas USA) with an infrared sensor and flash to detect animal movement. Cameras used an infrared flash that was not visible to people or most wildlife.

Camera traps were set up in the highway corridor. We attempted to set cameras in each 1 x 1 km cell overlapping the highway corridor; however, some cells had low potential for wildlife movement. Cameras were placed in the most likely corridors and locations that wildlife move through, either across highway or in the vicinity. Some cameras were taken down (few photographs) and set in different locations to improve sampling.

We placed camera traps on a tree ~1 m from the ground and 1-2 m from the monitoring area (trail, open space). We aimed the sensor parallel to the ground to monitor a conical area approximately 1 m in diameter at 15 m distance. Camera traps recorded time and date for each event and 5 rapid-fire photographs for each event triggering. Monitoring was continuous since cameras were setup. Cameras were checked approximately every two weeks, when batteries and SD cards were switched out. Some cameras were not operative if batteries died. We calculate the number of days cameras were operating at each site as 'camera-days'.

Animal detections were considered independent if the time between consecutive photographs of the same species was more than 20 minutes apart, a convention which follows (O'Brien et al. 2010). For each event, we classified the species detected in the photograph, the number of individuals, and if identifiable mother with young. Camera traps also recorded humans, livestock and domestic dogs but were not quantified for this report.

We report number of animal detections and a relative abundance index (RAI) for each species. To compute the RAI for each species, all detections for each species are summed for all camera traps over all days, multiplied by 100, and divided by the total number of camera-days.

### *2.1.2 Occupancy Results*

SITE-RELATED INFORMATION

A total of 22 camera traps were set up in the highway corridor beginning on 5 May 2017 and ending on 4 January 2019. Camera surveys were conducted during 20 months at 24 locations (Figure 1), resulting in 12,427 camera-days. One camera was stolen (Site 24), and without damaging the camera or removing the security box, the SD card was removed from one camera (site 23). The number of camera-days at the camera trap sites averaged 478 camera-days per site (min: 78, max: 597).

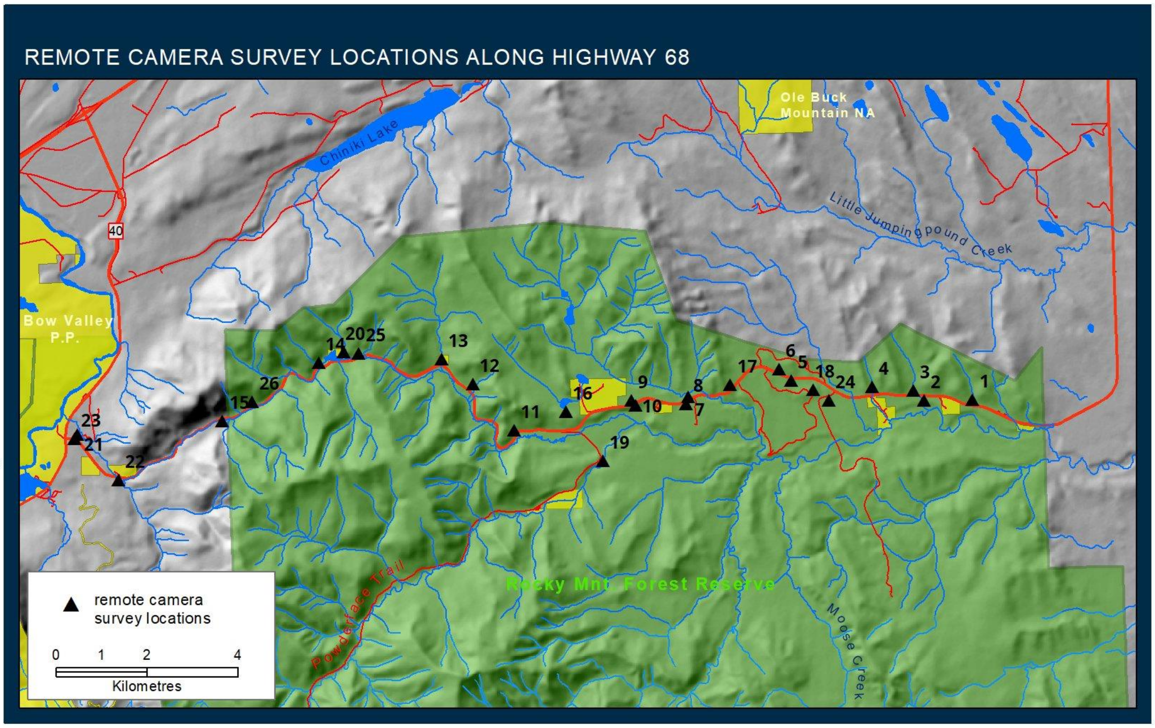



**Figure 1: Location of camera traps conducted along Highway 68**

SPECIES DETECTIONS

Camera traps recorded 4829 photographs of wildlife events, of which 82% (n = 3977) were of ungulates, 17% (n = 739) were carnivores, less than 1% were of lagomorphs (n=94) and birds (0.2%; n=9). A total of 18 species were detected at the camera sites (Table 1). Species captured on film included 7 carnivore species; 4 ungulates, 1 lagomorph and 2 birds.

**Table 1: Species detections and relative abundance index (RAI) at 22 camera trap sites along Highway 68 (Sibbald Flats Road), Alberta from May 2017 to January 2019.**

| Species | Detections at cameras | Number of sites detected | RAI[1] |
|---|---|---|---|
| White-tailed deer | 3328 | 25 | 24.82 |
| Mule deer | 534 | 24 | 4.57 |
| Moose | 83 | 17 | 0.50 |
| Elk | 32 | 12 | 0.40 |
| Total Ungulates | 3977 | 22 | |
| | | | |
| Coyote | 467 | 24 | 2.62 |
| Black bear | 155 | 21 | 2.08 |
| Cougar | 36 | 12 | 0.57 |
| Bobcat | 41 | 12 | 0.17 |
| Red fox | 28 | 11 | 0.54 |
| Grizzly bear | 9 | 7 | 0.10 |
| Wolf | 3 | 3 | 0.03 |
| Total Carnivores | 739 | 90 | |
| | | | |
| Snowshoe hare | 94 | 15 | 0.34 |
| Grouse | 8 | 6 | 0.07 |
| Striped Skunk | 4 | 3 | |
| Beaver | 1 | 1 | |
| Great Gray Owl | 1 | 1 | |
| Pine Marten | 1 | 1 | |

[1]: Relative abundance index: number of events/100 camera-days.

Among ungulates, white-tailed deer by far were detected most frequently at the camera traps (n=3328 events), followed by mule deer (n=534; events) (

Table 1 1). Moose (n=83) and elk (n=32) were rarely detected at the camera traps. Coyotes and black bears were the most frequently detected carnivores (n=467 & 155 events, respectively). Cougars (n=36), red foxes (n=28), bobcats (n=41) were sparsely detected in the study area along with grizzly bears (n=9) and wolves (n=3).

Occupancy in the study area was greatest for white-tailed deer as they were detected at 25 out of 25 camera sites (Table 1). Mule deer were detected at 24 of 25 sites, moose were detected at 18 sites, and elk were detected at less than half of the camera sites (12 sites). Coyotes had the highest occupancy among carnivores as they were detected at 24 of 25 camera sites, followed by black bears being detected at 21 sites. Cougars and bobcats were sited at 12 sites each, while red fox (n=11), grizzly bear (n=7) and wolves (n=3) were found at a third of the sites or less.

The relative abundance index (RAI) concurred with occupancy as white-tailed deer and mule deer had the highest RAI scores in the study area (Table 3). Among carnivores, coyotes and black bears had high RAI scores.

Time (nights) to first detection showed a skewed distribution for detecting ungulates (average: 33 days, s.d.24 days) and carnivore species (average: 47 days, s.d. 30 days. For individual species, days to first detection ranged from 13 for white-tailed deer to 47 for moose (Figure 2). Among carnivores the lowest time to first detection was for coyotes (average: 22 days, s.d. 28), while the longest was for bobcats (average: 111 days, s.d. 37).

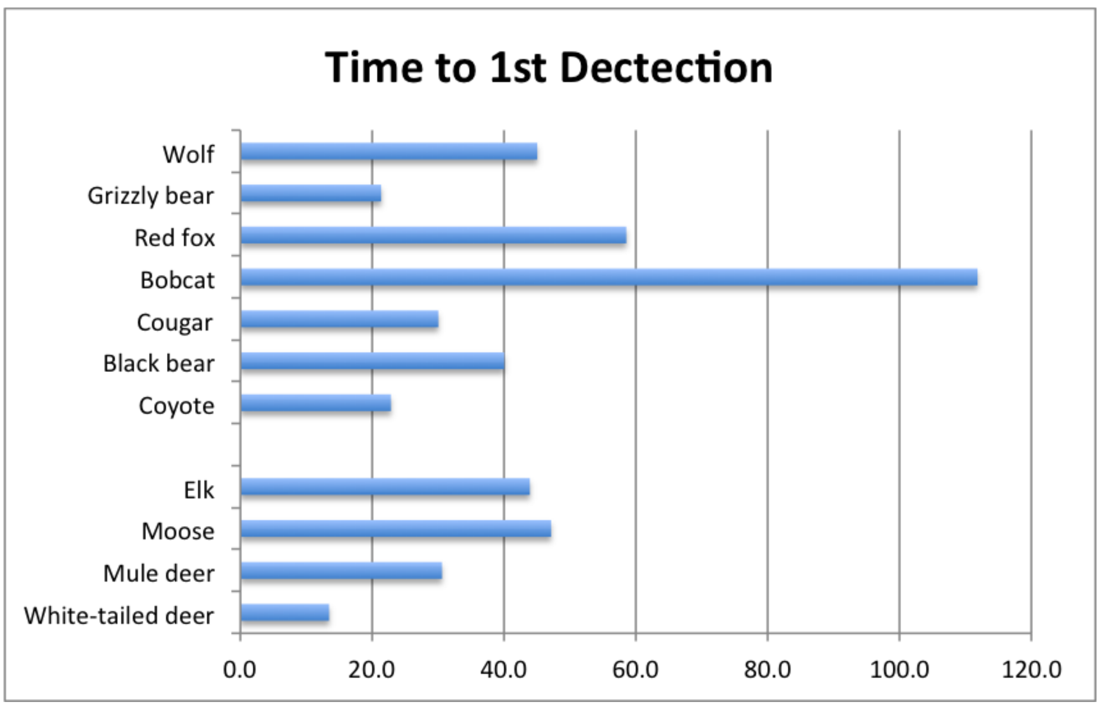



**Figure 2: Average number of days to first detection at camera traps for mammal species along Highway 68.**

## 2.2 Distribution Methods

### *2.2.1 Amphibians and Reptiles*

The paving of an existing gravel road is a concern for amphibians, especially along Highway 68 as amphibian habitat is located on both sides of the highway in localized areas. Paving the road would likely increase the speed limit and traffic volume, becoming an even greater barrier to movement than the already existing gravel road (Findlay, Bourdages, and Bourdages 2000; Hels and Buchwald 2001). Further, run-off and contaminants (hydrocarbons, salt, chemicals etc.) associated with paved roads have been shown to impact wetland habitats and amphibians that rely on them for their life requisites (Forman et al. 2003). To fulfill their life cycle, some species of amphibians move several kilometers from over-wintering habitat to breeding habitat (Pagnucco, Paszkowski, and Scrimgeour 2012). This movement can be obstructed by roads, which are compounded by the dangers of increasing speed limit and traffic volumes.

Based on range maps developed by Alberta Environment and Parks (Alberta Environment and Parks 2014) and habitat potential in the study area, the following amphibian species are expected: Western toad (*Anaxyrus boreas*) and Boreal chorus frog (*Pseudacris maculate*), with potential for Columbia spotted frog (*Rana luteiventris*) and Wood frog (*Lithobates sylvatica*).

Reptiles are slow-moving animals that are often attracted to roads for thermoregulation (Frissell and Trombulak 2000) and are often killed in large numbers by vehicles or their populations fragmented (Rosen and Lowe 1994).

We conducted field surveys of amphibians and reptiles using a variety of methods:

a) Spot-sampling surveys in late spring and early summer to identify areas of activity and movements,
b) Acoustic surveys using acoustic recording units (ARU) at select locations, and
c) Cover-board surveys for reptiles.

We supplemented the field data by reviewing existing observations and habitat mapping data of amphibians and reptiles and their habitat in study area using FWMIS data.

### AMPHIBIAN SPOT-SAMPLING SURVEY

Amphibian surveys were conducted using spot-sampling methods to identify areas of activity and potential movements in the highway corridor. Sampling sites were identified in field and characterized by ponds, lakes and slow-moving streams.

### AMPHIBIAN ACOUSTIC SURVEYS

Automated amphibian acoustic surveys were conducted at three sites between 13 May and 27 June 2018, with some variation of survey length per site. Acoustic Recording Units (ARUs) were deployed and set to record 10 minutes every hour, on the hour. Analysis occurred for the hours of 10:00pm to 12:00am, daily, for the survey period. This time frame was selected as it represents peak temporal calling period for amphibians. Because site 2 and 3 were within 100 m of each other, analysis of site 3 recordings only occurred on dates where site 2 recordings were too noisy to draw good results or the recording failed. Three sampling sites were identified in field and characterized by ponds, lakes and slow-moving streams.

### COVER-BOARD SURVEY – REPTILES

For reptiles, we surveyed for areas of potential reptile habitat (garter snake) within 100 m of Highway 68. Garter snake habitat consists of areas of areas of rock and talus. We obtained the geographic coordinates of any potential reptile habitat in the study area (Russell and Bauer 2000) and field inspected areas alongside the road that appeared to be suitable habitat.

During 2017, ground surveys consisting of inspections of suitable habitat (rocky/talus areas) were conducted to collect information on garter snakes in the study area.

In 2018, cover-boards were placed in select locations in the study area that met the criteria of being located 1) within 100 m of the road, and 2) consisted of suitable garter snake habitat (talus/rocky areas); the latter being habitat of target species (garter snakes) in the study area (Figure 3). Cover-boards consisted of a 4' x 4' piece of ¾" plywood. Boards are placed in or near preferred habitat of snakes. If snakes are in the area they will move under the boards to seek refuge. This method has been useful for estimating populations of certain amphibian and reptile species(Heyer et al. 1994). We placed pairs of cover-boards at each site. Pairs were used as one board had a tracking medium underneath (loamy soil) to detect presence if snakes had entered, but moved out from under the board prior to field check. The second board had no tracking medium below it. Boards were placed side-by-side. Boards were set out at 4 locations and sampled during five weeks. Sampling began on 9 July 2018, and checked weekly until 15 August 2018.

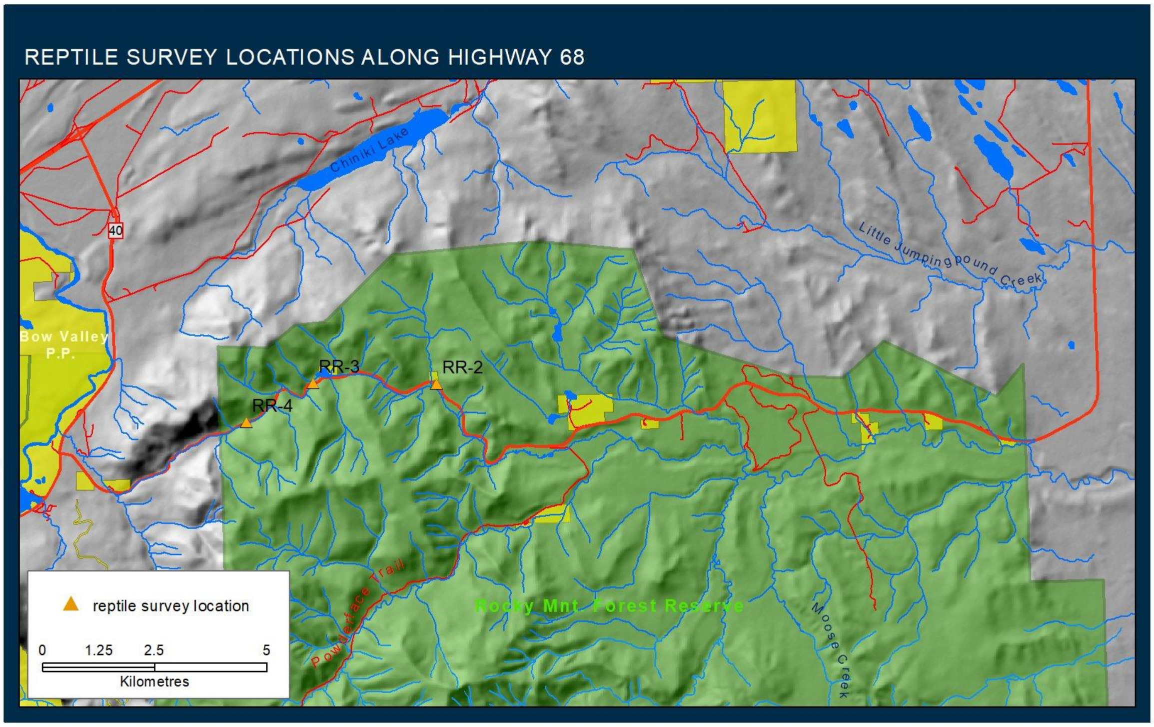



**Figure 3: Cover-board locations for reptile survey along Highway 68.**

## 2.3 Distribution Results

### *2.3.1. Amphibian Spot-Sampling Surveys*

**2017** - Amphibian surveys were conducted on 3 occasions in the study area between 31 May and 18 June 2017. Surveys for amphibians were used spot-sampling methods to identify areas of activity and potential movements in the highway corridor (Figure 4) (Heyer et al. 1994). Sampling sites were identified in the field and characterized by ponds, lakes and slow-moving streams.

There were three amphibian species detected during the study period: Chorus frog (, wood frog, and western toad.

<u>31 May 2017:</u>

Chorus frogs and western toads were detected at the sampling sites below. Amphibians were not heard at the other sampling sites in the study area.

- P8: Chorus frogs and western toads calling (few)
- P9: Chorus frogs calling (few); Wood frog (n=1) calling
- P10: Chorus frogs calling (many);
- P11: Chorus frogs calling (many) on north and south sides of highway.

- P12: Chorus frog (n=1) calling on north side.

2 June 2017:
No calling of amphibians detected at any of the sampling sites in the study area.

18 June 2017:
Efforts were made to locate tadpoles at the sampling sites. Tadpoles were found at:

- P9 (Homestead Pond). Chorus frog tadpoles were observed on the edge of the pond, primarily on the south side (n=20-30), with some also seen on the east side of the pond.
- P10 (south and across road from H68-P9): Wood frog observed and photographed. Few tadpoles seen and believed to be wood frog tadpoles.

The FWMIS records of amphibian detections were primarily in the western part of the study area (Figure 5); however, we were unable to detect any amphibians in those areas. The eastern end of the study area (Bryant Creek, Homestead Road) was the most active area for amphibian activity in 2017. Our observations concur with the one FWMIS record of a wood frog at P9, as we detected wood frogs across the highway at P10. Two sites with amphibian detections are bisected by Highway 68 (P9 & P10).

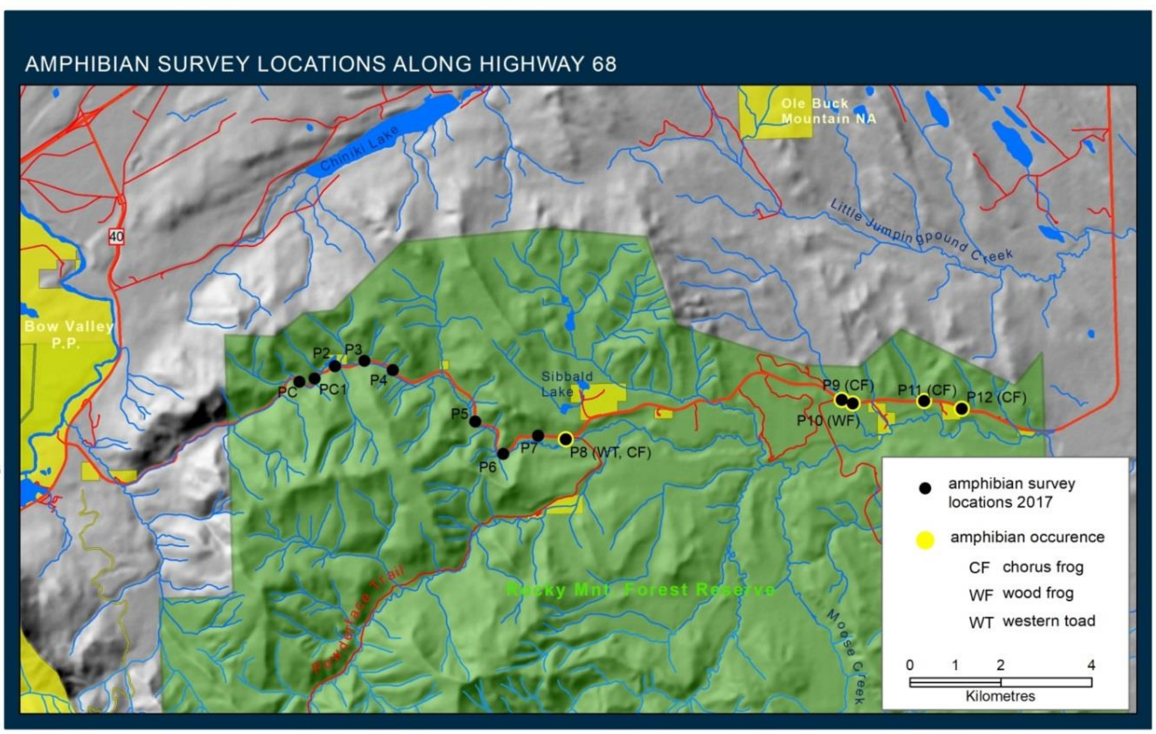



**Figure 4: Location of species detections obtained from amphibian field survey conducted along Highway 68, May-June 2017**

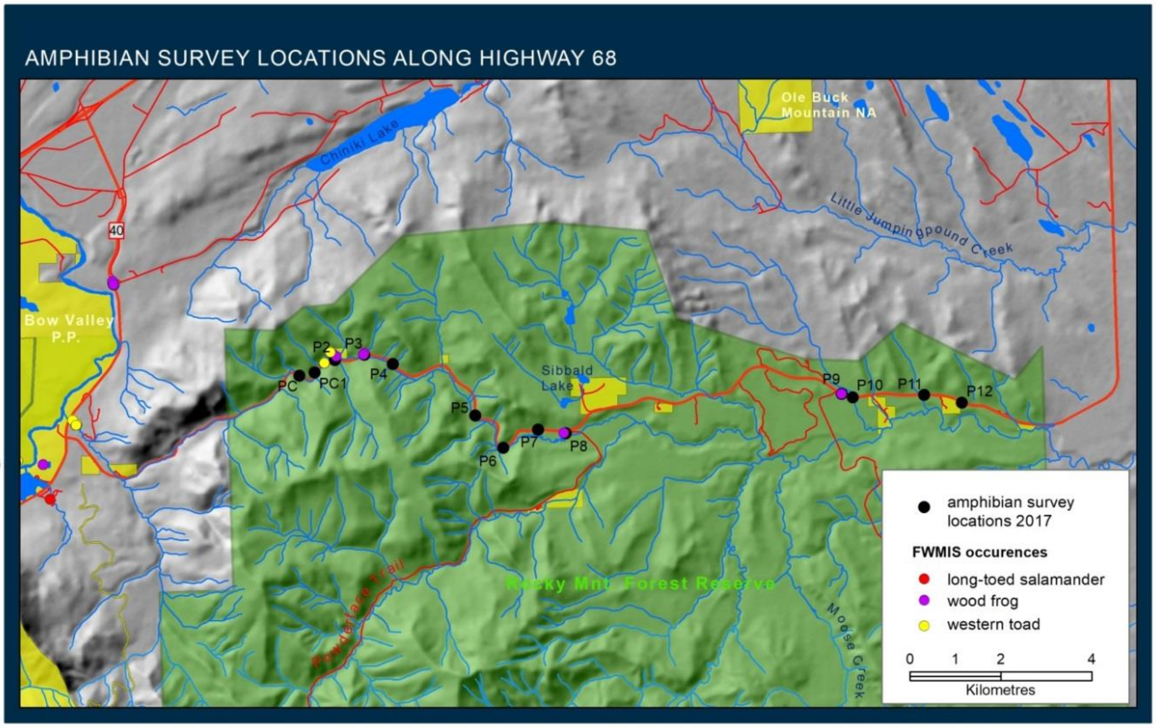



**Figure 5: Location of amphibian species detections obtained from the province of Alberta FWMIS database.**

The large pond at the Powderface Road junction (P8) had chorus frogs and western toads. Chorus frogs were most common at the sampling sites where we detected amphibians in the eastern end of the study area near Bryant Creek and Homestead Road. Most of our amphibian detections provide new information of amphibian species occurrence in this area and the FWMIS database.

**2018 -** Amphibian surveys were conducted on 2 occasions in the study area between 31 May and 25 June 2018. Surveys for amphibians were conducted using the same spot-sampling methods as 2017 to identify areas of activity and potential movements in the highway corridor (Figure 8)(Heyer et al. 1994). Sampling sites were identified in the field and characterized by ponds, lakes and slow-moving streams. Less sampling effort was used in 2018 as acoustic survey methods were used to provide additional data on amphibian presence in the highway corridor.

### *2.3.2. Acoustic Amphibian Survey*

In 2018, western toad and wood frog were identified at all three ARU sites, while chorus frog was recorded at site 3 only. Western Toad is listed as a sensitive species in Alberta (see Figure 3).

Top calling index for each species for survey period:

- Western toad: Constant chorus

➢ Wood frog: Constant chorus

Lastly, Columbia spotted frogs were observed at Sibbald Flats Meadows PRA on Sept 1, 2018, photo verification was confirmed by Kris Kendal (Alberta Conservation Association). Columbia spotted frog is a sensitive species in Alberta (Figure 6).

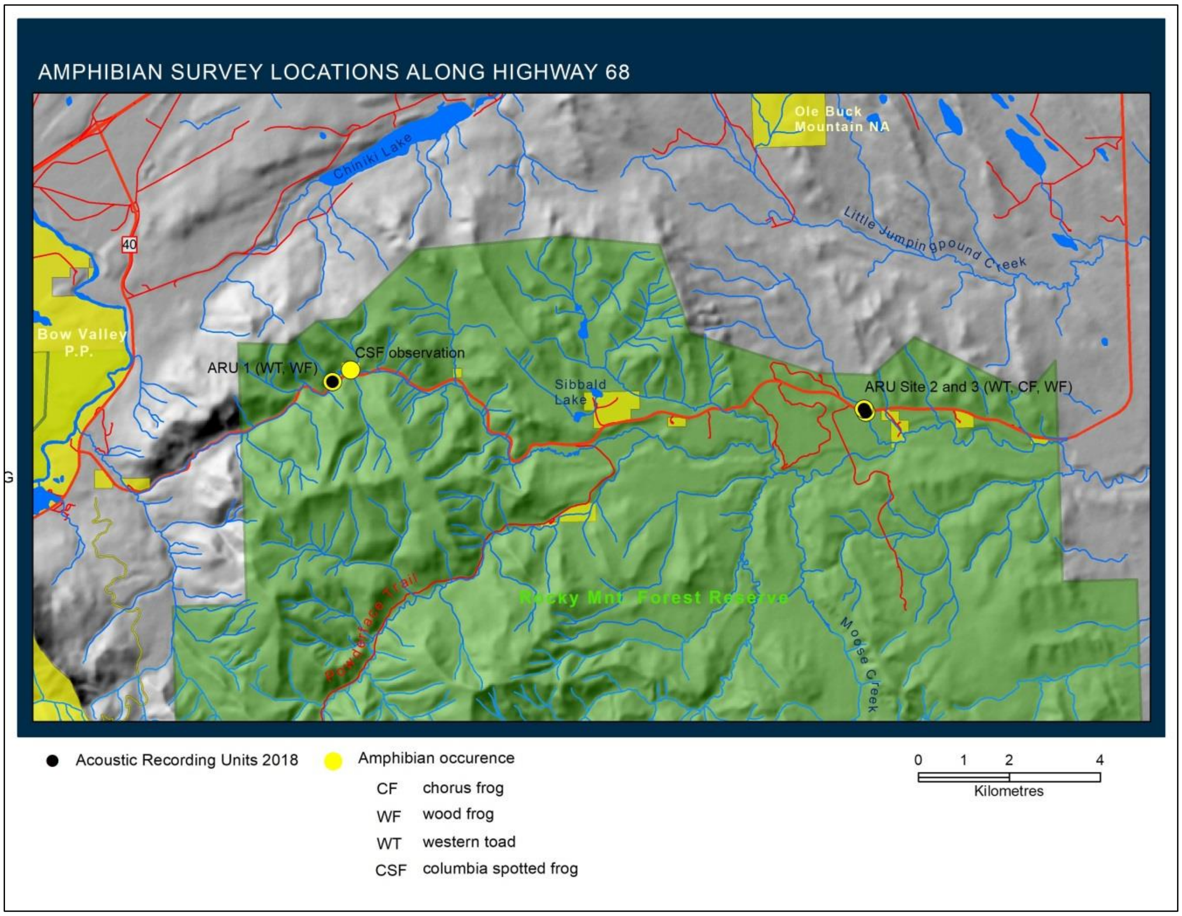



**Figure 6: Location of acoustic monitoring sites**

### *2.3.3. Acoustic Amphibian Survey – Incidental Observations*

ARU data was also classified for bird species, and incidental observations from site 1 and 2 (Figure 6) are listed in
Table 2. Of note a number of species are listed as sensitive in Alberta.

**Table 2: incidental species recorded on ARUs**

| | Incidental Species Observed (auditory) | Provincial Status (2015) (Alberta Environment and Parks 2018) | Federal (SARA) Status (Government of Canada 2018) |
|---|---|---|---|
| Site 1 | Canada goose | Secure | Not listed |
| Site 1 | owl species | N/A | N/A |

| | | | |
|---|---|---|---|
| Site 1 | Lincoln's Sparrow | Secure | Not listed |
| Site 1 | Sora | **Sensitive** | Not listed |
| Site 1 | Spotted Sandpiper | Secure | Not listed |
| Site 2 | Alder Flycatcher | **Sensitive** | Not listed |
| Site 2 | Barred owl | **Sensitive** | Not listed |
| Site 2 | Canada goose | Secure | Not listed |
| Site 2 | Clay-coloured sparrow | Secure | Not listed |
| Site 2 | Dark-eyed Junco | Secure | Not listed |
| Site 2 | Greater Yellowlegs | Secure | Not listed |
| Site 2 | Lincoln's Sparrow | Secure | Not listed |
| Site 2 | Sandhill Crane | **Sensitive** | Not listed |
| Site 2 | Sora | **Sensitive** | Not listed |
| Site 2 | White-crowned sparrow | Secure | Not listed |
| Site 2 | White-throated sparrow | Secure | Not listed |
| Site 2 | Wilson's snipe | Secure | Not listed |
| Site 2 | Cougar* | Secure | Not listed |
| Unkn | Grebe species (Clark's or Western) | **May be at Risk** (Clark's grebe), **At Risk** (Western grebe) | Not listed (Clark's grebe), **Special Concern** (Western grebe) |

*unconfirmed

### *2.3.4. Cover-board Survey – Reptiles*

During summer 2017, ground surveys for reptile habitat and occurrence were conducted on 7 September at 3 sites in study area, in areas of talus habitat. We were unable to detect any garter snake activity at any of the three sites visited.

During summer 2018, cover-boards were used to sample garter snake occurrence. Of the 5 weeks of sampling we were unable to detect any reptile activity at the four sampling locations. At one location we detected a vole (species unidentified) that was nesting underneath the cover-board. There are no reported observations of any reptile species in the FWMIS dataset.

## 2.4 Snow-track Road Crossing Survey

### *2.4.1 Methods*

Road surveys were conducted during winter months when snow-tracking conditions enabled data to be collected on species presence and movements and activity in the Highway 68 corridor. Surveys were conducted by two people (driver, observer) that drove Highway 68 at 40-50 km/hour searching for medium- and large-sized mammal tracks adjacent to or crossing the highway. Data collected were species identified from the tracks, number of individuals, direction of travel (crossing road, parallel, "loitering" = neither crossing nor parallel). We limited our data collection to mammal species coyote-size and larger.

### *2.4.2 Results*

One track survey of Highway 68 study area was conducted by Alberta Environment and Parks (AEP) staff (N. Heim) on 21 November 2017. During this outing 8 coyotes, 7 wolf and 1 cougar track were detected.

During 2018, 5 track surveys were conducted between 12 January and 31 March. Each track survey was 20 km in length. During the 3 month sampling period 112 coyote, 14 cougar, 10 moose, 4 bobcat and 3 wolf detections were recorded (Figure 7).

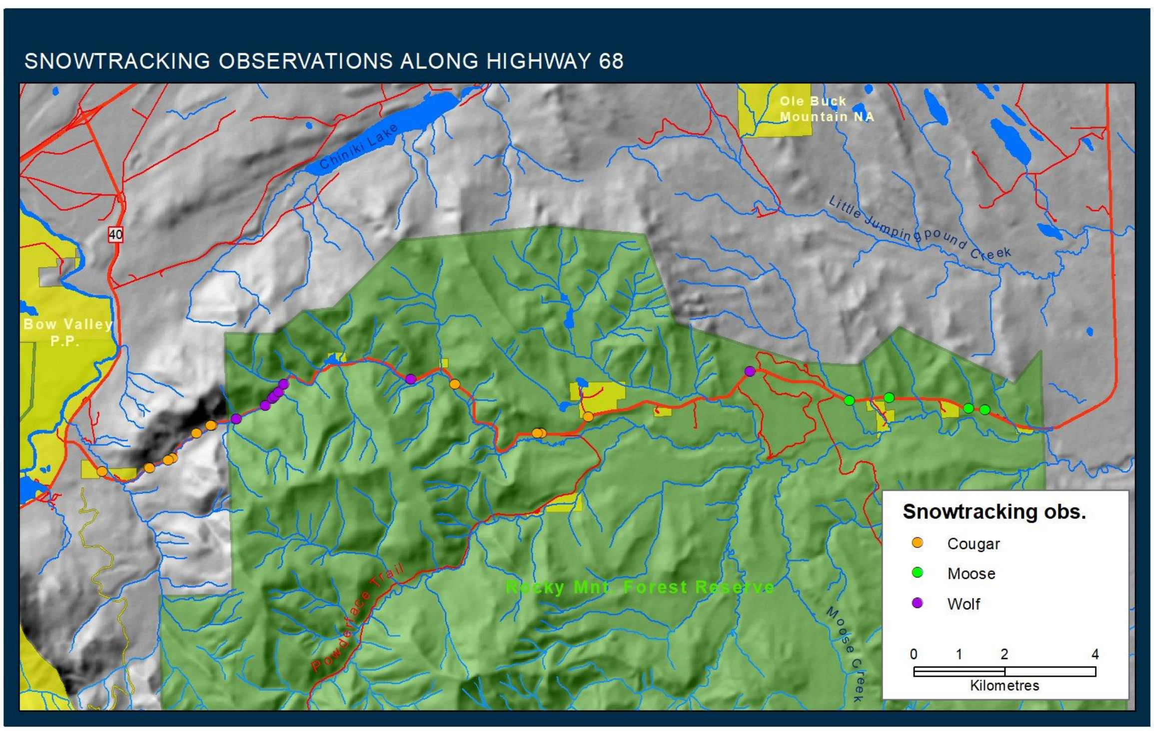



**Figure 7: Snow-tracking observations (wolf, cougar and moose)**

# 3.0 Connectivity Modeling

Research has shown that road-kill locations on their own are not sufficient to identify key areas to mitigate roads for wildlife. Information on where important travel corridors and safe passage occur are needed (A.P. Clevenger and Huijser 2011).

To maintain healthy wide-ranging mammal populations it is important to consider connectivity between core habitat patches (K. R. Crooks and Sanjayan 2006). Studying how the landscape facilitates or impedes animal movement between habitat patches is important for developing strategies to maintain wildlife healthy populations. Highway 68 represents an important component of a larger landscape where individual animals need to move between habitats to ensure regional population stability.

An important consideration to maintaining healthy populations of wide-ranging mammals in Kananaskis Country is ensuring habitat is maintained and animals are able to move unimpeded around the landscape. This is complicated by competing land uses, such as increasing traffic volume and human presence which may contribute to fragmentation of the landscape and imped wildlife movement (Apps et al. 2007). A major concern for Highway 68 includes reduced movement opportunities due to avoidance behaviour for sensitive species such as grizzly bear and/or increases in animal mortality associated with roads (A. Clevenger et al. 2010).

For connectivity models, we focused on species that have extensive home ranges, disperse long distances, are associated with unique habitat types, and need to cross roads frequently. During Phase 1 of the research we modeled connectivity for moose as a species of focus, as they are frequent in the area, typically occur in lowland habitats and create concerns from a motorist safety perspective. Paving Highway 68 (currently gravel) will result in an increase in traffic volume, speed and risk of moose-vehicle collisions, a concern for motorist safety.

During Phase 2 of the research we modeled connectivity for grizzly bears as a species of focus, as they are an at risk species in Alberta and dependent on large landscapes to meet their life requirements. Increasing traffic volumes on Highway 68 could result in avoidance behavior of grizzly bears reducing their ability to move around the landscape to access important resources.

Connectivity models can be useful for identifying important habitat linkages and areas for highway mitigation. Previously, Geographic Information System (GIS) generated habitat models have been used to determine the regionally important locations for wildlife crossing structures (A.P. Clevenger and Wierzchowski. 2006). Recent attention has focused on the use of landscape resistance models to guide highway mitigation efforts. Circuitscape is open source software that borrows algorithms from electronic circuit theory to predict connectivity in heterogeneous landscapes, (www.circuitscape.org). Recently it was shown to outperform other models in predicting areas of wildlife-vehicle collisions (Girardet, Conruyt-Rogeon, and Foltête 2015), thus serving a dual purpose in this project. Circuitscape modelling assumes animals are on a random walk (Codling, Plank, and Benhamou 2008).

This moves away from direct-route models such as least cost models, allowing for multiple pathways to be assessed rather than a best-fit line (McRae et al. 2008).

## 3.1 Methods

To create a study area for modeling we buffered Highway 68 by 20 km. We used the following datasets in our analysis:

- RSF models for grizzly bear representing three seasons, developed from grizzly bear RSF models (Nielsen 2007),
- Grizzly bear GPS data provide by Alberta Parks,
- Alberta Biodiversity and Monitoring Institute (ABMI) Human Footprint (HF) (2014), and
- Alberta Government Base Features 1:20k DEM.

Circuitscape requires two inputs: focal nodes to represent movement starting points for grizzly bears on the landscape, and resistance surface that assigns each landscape pixel with a value that represents the ease of movement.

We used a published grizzly bear RSF model for three seasons (Season 1: May 15 to June 15, Season 2: June 16 to July 31, Season 3: Aug 1 to Oct 15) developed for Alberta by Dr. Scott Nielson to create a resistance surface to use in connectivity modeling (Nielsen 2007). We also received data from Alberta Environment and Parks (AEP) of grizzly bear GPS data, representing five bears from 2012 to 2017. The grizzly bear RSF models were displayed using 10 bins (quantiles) and to see how well the RSF models represented known grizzly bear detections we plotted the number of grizzly bear GPS points for each season per RSF bin. A higher bin value indicated a high resource value for grizzly bears, so you would expect a linear trend increasing from bin 1 to 10.

The resistance value represents the relative effort required for an animal to travel across a pixel on the landscape. The map of resistance values is used to derive all possible pathways for modeled electrical current to traverse the landscape from focal one point or region to another. The resistance surface was derived using the RSF for each season by applying a negative exponential using the following function:

$$f = 100 - 99\frac{1 - \exp(-ch)}{1 - \exp(-c)}$$

where f is the friction value ranging from 1 to 100 and the function C=1 and h is the RSF score from 0 to 1 (Trainor et al. 2013). Recently there has been some scrutiny on the use of habitat modeling representing how animals move around a landscape. Mateo-Sanchez et al. (2015) found that resistance surfaces based on habitat models may tend to overestimate landscape resistance in areas with low habitat suitability (Mateo-Sánchez et al. 2015). The negative exponential was used to enable a gradual change in friction values when suitability values are relatively high; if the function is not applied there is a drastic increase in friction values as habitat suitability declines beyond the mid-range (Trainor et al. 2013).

The resulting resistance surface did not include roads, a key concern for our analysis. We therefore superimposed highways from Alberta base features onto the resistance surface and created resistance values based on assessment of the weighted average annual daily traffic volume[1] and expert opinion (Table 3).

**Table 3: Resistance values for highways in the modelling area.**

| Highway | WAADT[1] | Resistance Score |
|---|---|---|
| 1 | 24,000 | 8 |
| 40 | 1,840 | 4 |
| 1A | 1,960 | 4 |
| 1X | 1,170 | 4 |
| 68 | 400 | 4 |

[1] Weighted average annual daily traffic volume.

Focal nodes were created as a series of random points (n=100) around the edge of the study area. Koen et al (2014) found placement of focal nodes around the edge of the study area is least likely to bias results from node placement on connectivity modeling results (Koen et al. 2014). Since our question is focused on where grizzly bears are most likely to cross Highway 68, positioning nodes along the edge of the study area seemed appropriate. The same focal nodes were used for all three grizzly bear seasons.

We used Circuitscape software to model connectivity for each grizzly bear season. All three grizzly bear seasons were integrated by taking the average value per pixel. To identify important crossing locations we created a 250 m buffer around each km segment on Highway 68, and calculated the average connectivity value. Data was then displayed in quantiles to identify the top 50% and 25% of movement opportunities for grizzly bear per season.

## 3.2 Results

The RSF models for three grizzly bear seasons were compared to known grizzly bear data from AEP (Figure 8, Figure 9, Figure 10) to see how well the Alberta wide RSF modeling represented our study area. Season 1 (Figure 8) and season 3 (Figure 10) show a linear trend with higher representing higher number of known grizzly bear points. Season 2 (Figure 9) RSF bins do not reflect the known grizzly bear locations and there appears to be a negative trend line – so lower RSF values are more favorable than higher RSF values. A limitation of this study is the use of an RSF model developed for a broader landscape not

[1] http://www.transportation.alberta.ca/mapping/

accurately reflecting local grizzly bear resource selection. An important consideration is the comparison of a low number of known grizzly bear points (n=200-1200) per season.

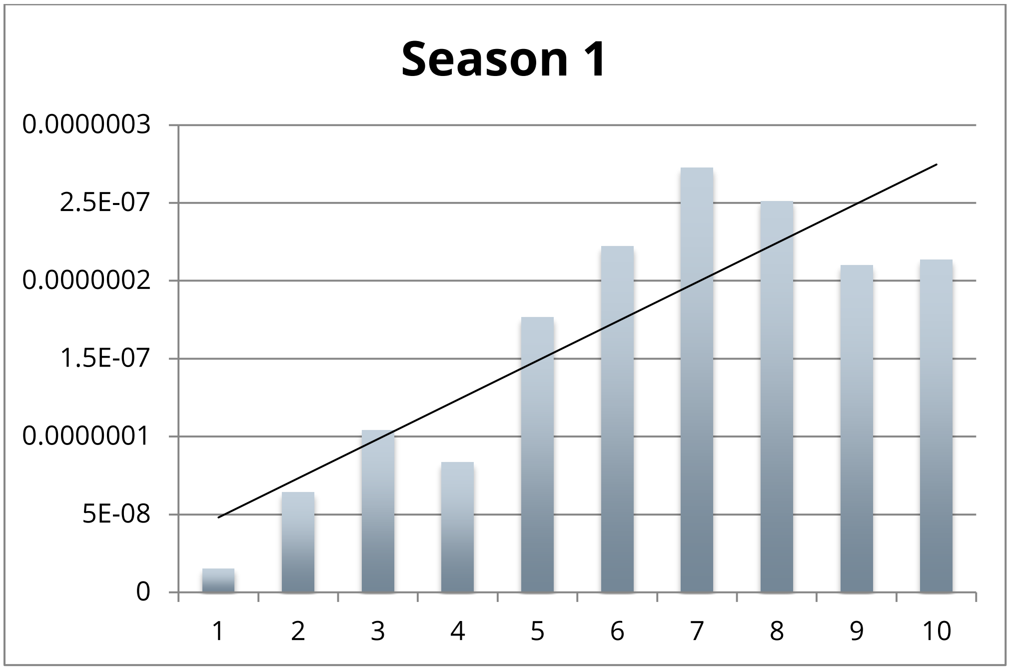



**Figure 8: Season 1 plot of RSF bin and number of grizzly bear GPS points**

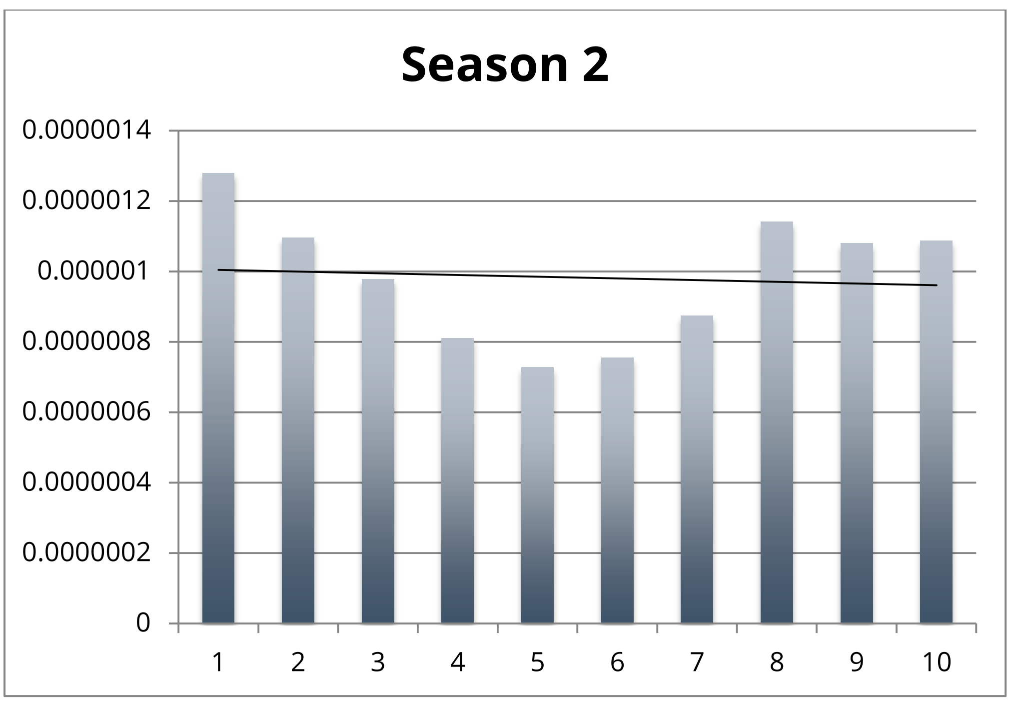



**Figure 9: Season 2 plot of RSF bins and number of grizzly bear GPS points**

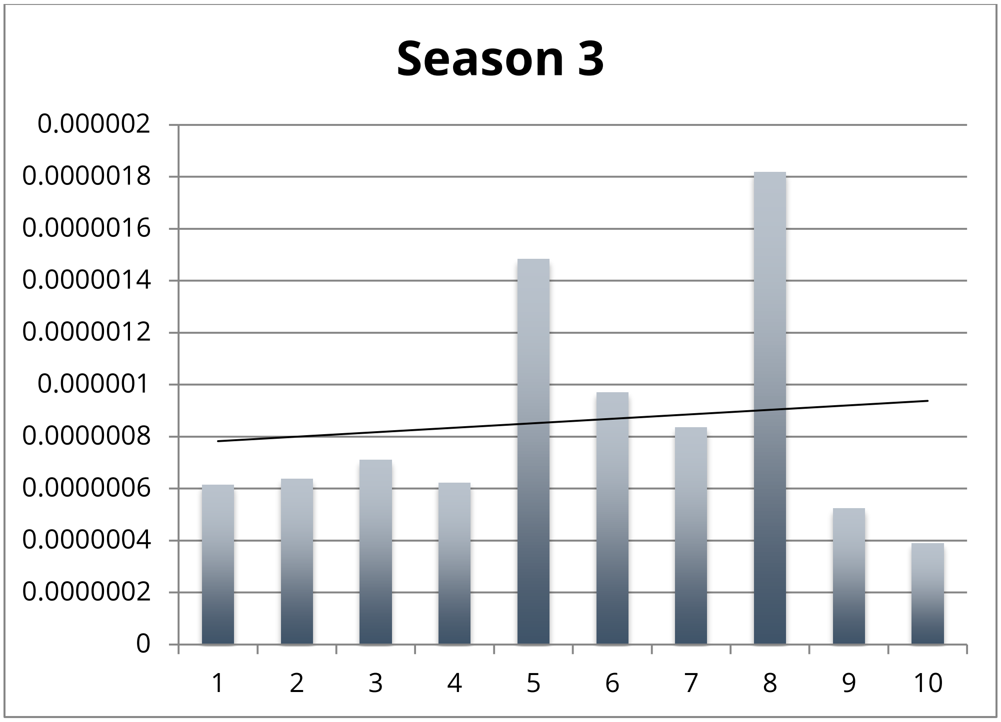



**Figure 10: Season 3 plot of RSF bins and number of grizzly bear GPS points**

The Circuitscape results are displayed in (Figure 11), after integration of all three grizzly bear seasons. Figure 12 highlights the top 50% (darker purple represents better movement opportunity) of optimal movement for grizzly bears across Highway 68.

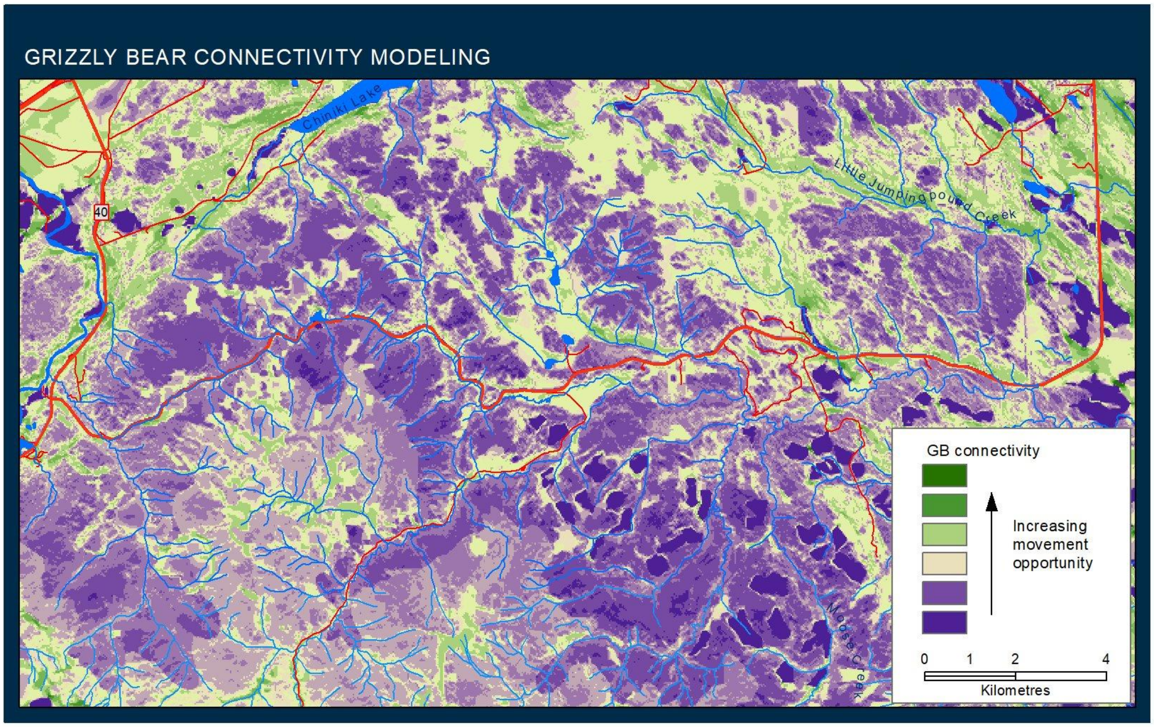



**Figure 11: Grizzly bear connectivity model aggregate of three seasons (average connectivity value per pixel)**

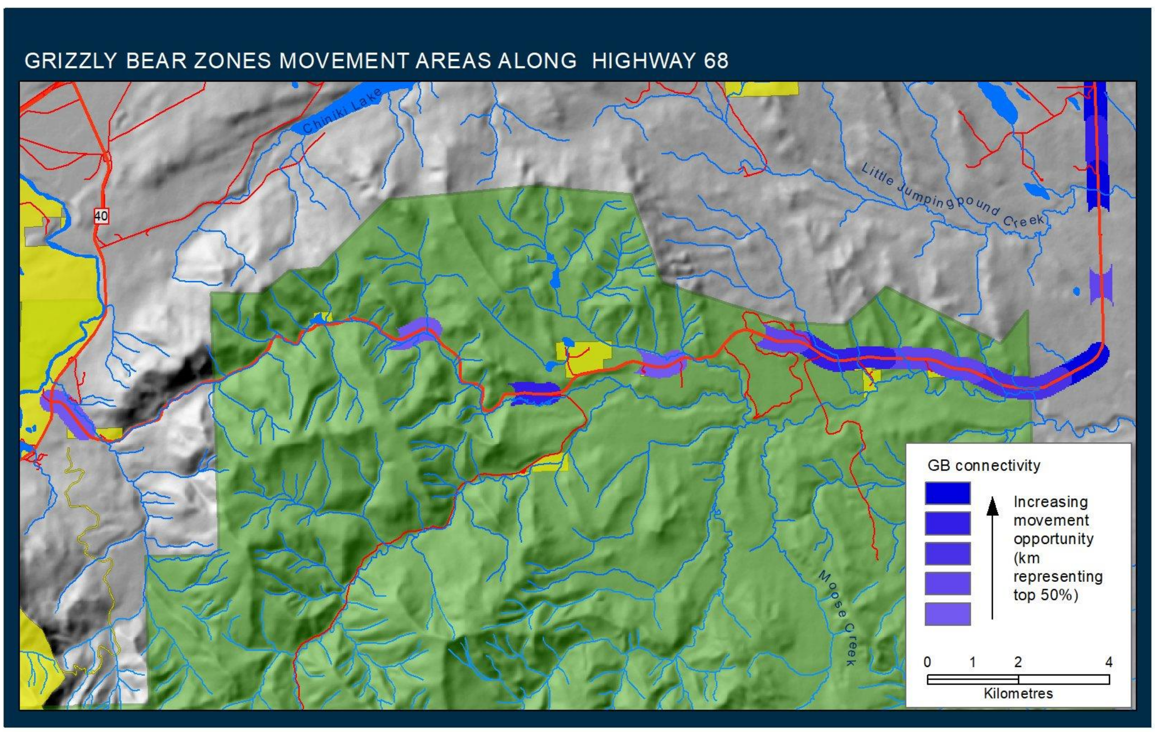



**Figure 12: Top 50% of movement opportunity for grizzly bear across Highway 68, darker blue represents top 10%**

# 4.0 Synthesis

Connectivity models can be useful for identifying important wildlife corridors, but, like all models, they are gross oversimplifications of biological reality. Assigning values to landscape variables and ranking their relative importance to landscape scale movement is a somewhat subjective process. Thus, the most powerful inference from connectivity models based on expert opinion can be drawn when the results are congruent with different model types and with other data sources. Our objective was to use landscape resistance-based movement modelling in conjunction with field data collected from camera traps and winter snow-tracking to identify and prioritize areas for along Highway 68 for cross-highway connectivity (objective no. 3). The synthesized data encompassed a range of species and transportation and resource management objectives for the Highway 68 corridor.

## 4.1 Methods

For each camera site we considered the frequency of use (species detection rate per km/day) and total diversity of species occurrence within kilometer sections. Priority road segments for species detections were calculated as a daily rate per camera per kilometer. The daily rate enabled us to account for inconsistency in the total time each camera was in the field. Camera placement focused on areas where wildlife was likely to cross based on expert opinion in the field and therefore some kilometer sections were not monitored by camera trap. If there were more than two cameras in a kilometer section the detection rates calculated per camera were averaged. Snow-tracking species detection rates were also considered per km/day and results were summed with the camera detection rate per kilometer.

To address transportation objectives we used the species detection rates per km from camera and snow-tracking to predict kilometer sections with increased motorist safety risk from collisions with ungulates (moose, mule deer, white tailed deer and elk), based on the assumption that a paved road will result in increased traffic volume and therefore increased risk of wildlife vehicle collisions. To address resource management objectives we determined the kilometer sections where species of concern (grizzly bears, cougar and wolf) have higher rates of detection.

We compared our connectivity model outputs for moose (see final report for Highway 68 in 2017) and grizzly bear with camera occupancy data. The camera data were restricted to locations in the study area where we had cameras set up, while the connectivity models show predicted movement freely throughout the entire study area including areas between camera locations. Results from connectivity modeling were equated to kilometer sections along Highway 68 by placing a 250 m buffer around each segment and calculating the mean connectivity value. Results were standardized from 0 to 1 and displayed in quantiles.

We expect there is some overlap between connectivity models, but know that grizzly bear and moose habitat linkages may not converge for all species in the study area.

Lastly, we created a synthesis map, by standardizing each species layer from 0 to 1, and summing four key layers per kilometer, moose connectivity, grizzly bear connectivity, motorist safety risk, and species of conservation concern. The layer was displayed as five quantiles representing very high, high, medium, low and very low km segments along Highway 68.

## 4.2 Results

### *Camera and Snow-tracking Detection Rates*

Species diversity per km is displayed in Figure 13 to determine richness of species detected on camera or via snow-tracking along Highway 68. Species diversity was highest for kilometer 1, 20, 22 and 23.

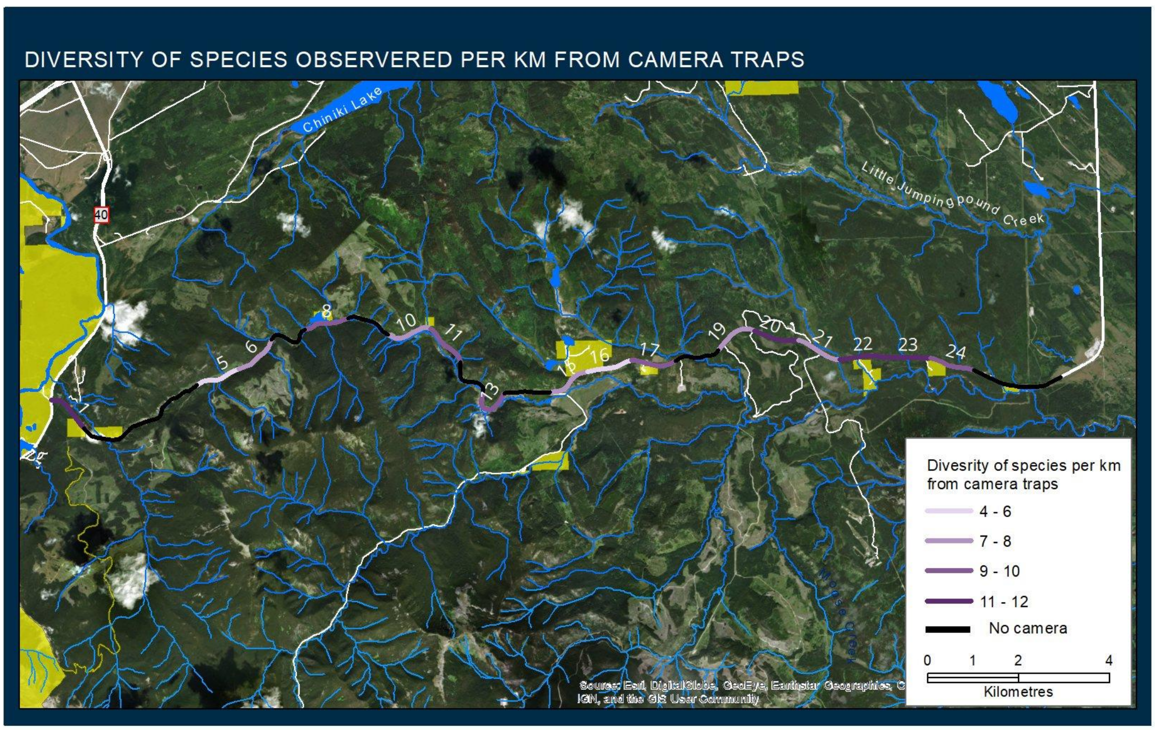



**Figure 13: Species diversity per km along Highway 68**

Areas along Highway 68 with a motorist safety risk were determined using detection rates summed per kilometer for moose, mule deer, white tailed deer and elk (Figure 14). Increased motorist safety risk from wildlife vehicle collisions will be a concern if the road is paved and traffic volumes increase along Highway 68. Camera detection rates along the highway provide a surrogate assessment of where wildlife vehicle collisions are likely to occur based on occupancy and rates of ungulates. Kilometer sections along Highway 68 with a potential very high (deep red) and high (orange-red) level of risk include 1, 15-17 and a long stretch from 20-24. It is important to note that in some kilometers there were no cameras (represented as black lines on maps), because placement was based on expert opinion of most likely locations to capture wildlife.

Areas along Highway 68 where species of concern, including grizzly bear, wolf and cougar are most likely to be detected are displayed in Figure 15. Kilometer sections along Highway 68 with very high (deep red) and high (orange-red) importance for carnivores include 5-6, 11 and 19. It is important to note that in some areas there was no camera (black), although placement was based on expert opinion of best placed for wildlife movement.


**Figure 14: Motorist safety risk per km based on camera detection rates of ungulates**

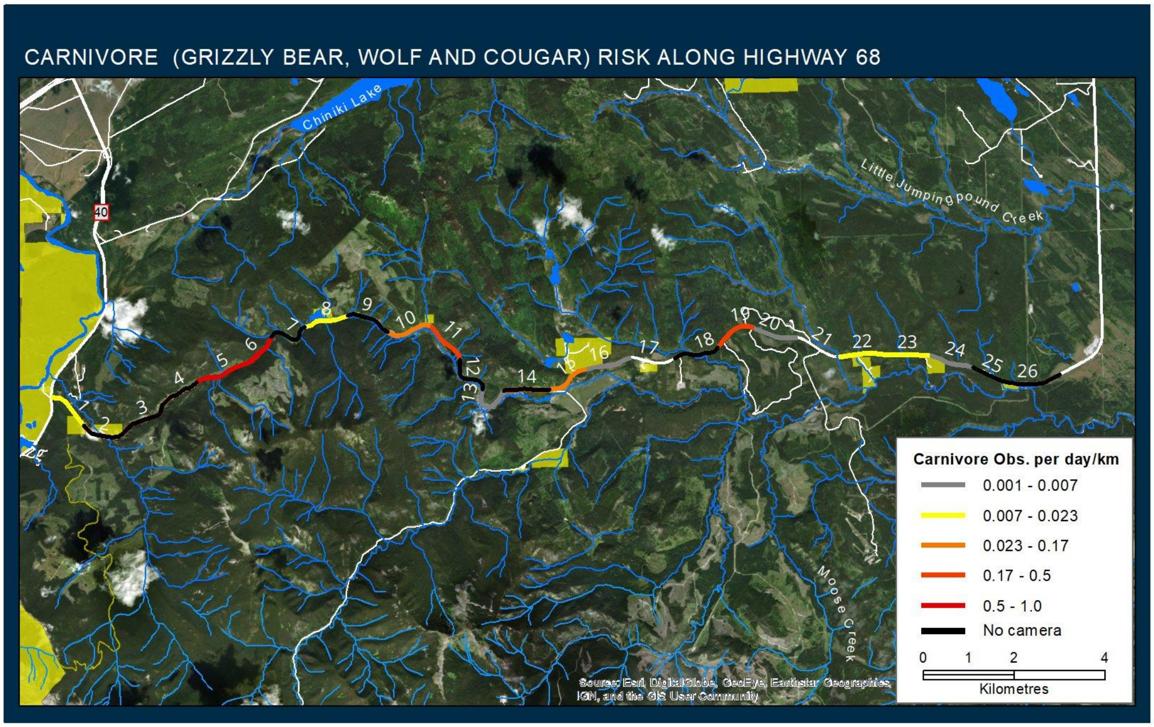



**Figure 15: Species of concern along Highway 68**

## *Grizzly Bear and Moose Connectivity Modeling*

In addition to camera and snow-tracking detection rates, connectivity models were also developed for moose (motorist safety risk), and grizzly bear (at risk species).

For moose, Figure 16 displays moose movement opportunities across Highway 68 from connectivity modeling, data is displayed in quantiles, with the top quantile (25%) or best opportunities represented in dark blue, and second quantile (25% to 50%) of opportunities represented by light blue. The modeling indicates kilometer sections 1, 10-12, 14, 17 and 21 are best opportunity areas for moose movement. Camera and snow-tracking detection data is also displayed on Figure 16 indicating kilometer sections along Highway 68 with very high (deep red) and high (orange-red) importance for moose include 16-17, 20-22 and 24. There is a strong overlap between the connectivity modeling and camera and snow-tracking detections for kilometer sections 11, 17 and 21, increasing our confidence in these areas being important for moose along Highway 68.

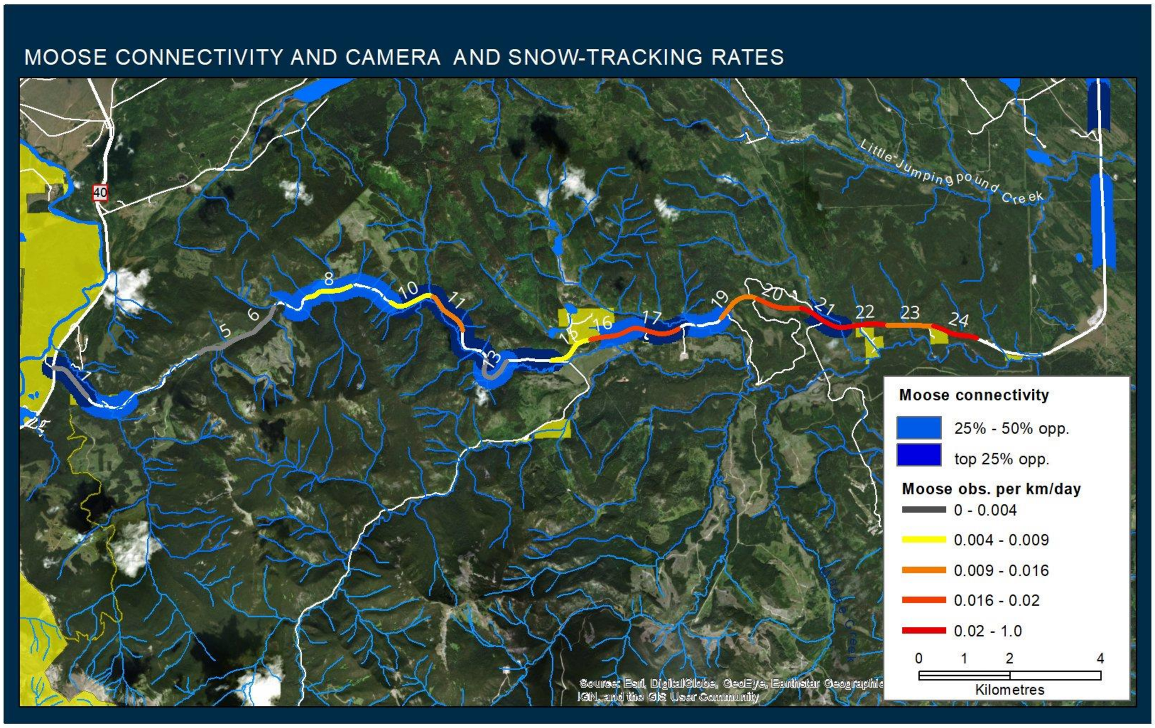



**Figure 16: Moose connectivity modeling movement areas and camera and snow-tracking detection rates**

For grizzly bear, Figure 17 displays grizzly bear movement opportunities across Highway 68 from connectivity modeling, data is displayed in quantiles, with the top quantile (25%) or best opportunities represented in dark blue, and second quantile (25% to 50%) of opportunities represented by light blue. The modeling indicates kilometer sections 14, 21 and 22 are the best opportunity areas for grizzly bear movement. Camera data for grizzly bear is displayed as presence and absence per kilometer as there were only 9 detections in total (Figure 17) identifying three kilometer sections where grizzly bears were detected, 5, 16 and 19.  There is no overlap between the connectivity modeling and camera detections for grizzly bears.

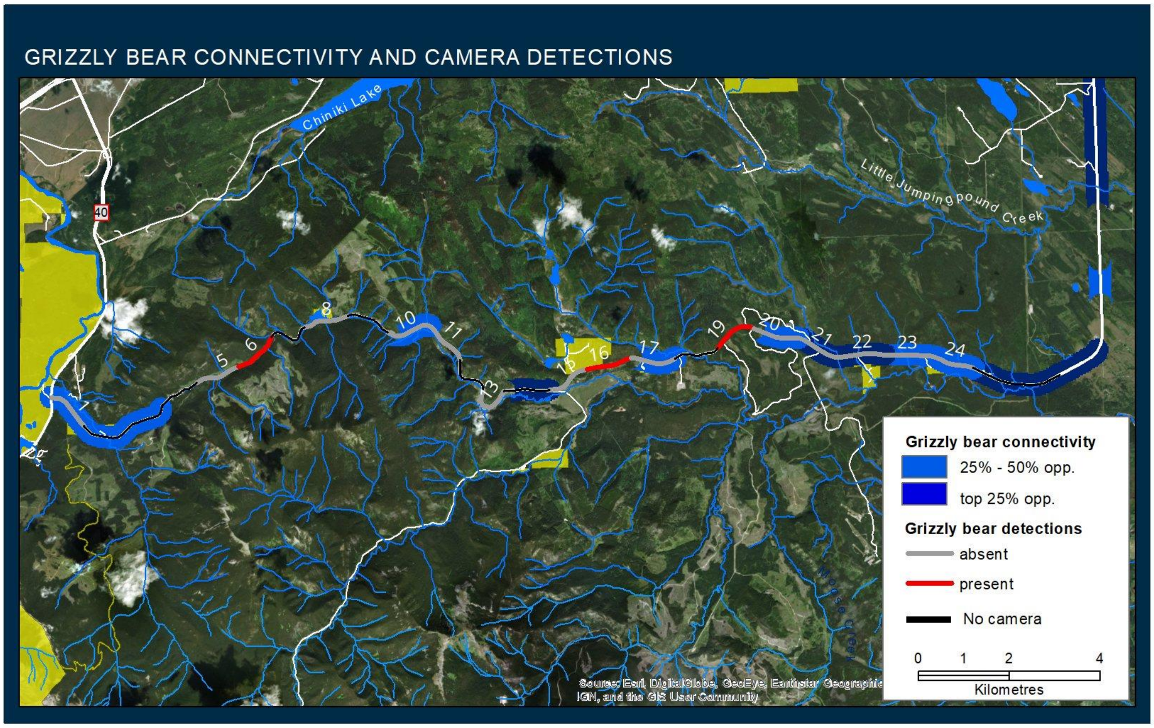



**Figure 17: Grizzly bear connectivity modeling and camera detections along Highway 68.**

## *Cumulative Assessment to identify Priority Sections*

Our results indicate that from the perspective of transportation and resource management, priority highway sections differ. This is a challenge for making recommendations on where best to focus future investment in mitigation. To accommodate multiple competing interests, we summed up four species layers per kilometer section to help provide balanced approach to investment in the future. We summed the following results per kilometer section (all data was standardized from 0 to 1):

- Species of conservation concern (camera and snow-tracking detection rates)
- Grizzly bear connectivity value (averaged per kilometer section)
- Motorist safety risk (camera and snow-tracking detection rates)
- Moose connectivity value (averaged per kilometer section)

The results (Figure 18) displayed using quantiles, identify kilometer sections 1, 6, 14, 21 and 24 as very high priority (red), with kilometer sections 3, 11 15, 17 and 22 as high priority (orange-red). It is important to note that a large section of Highway 68 is important for wildlife movement and the current condition of low traffic volume and human use is conducive to this area supporting complement of large mammals.

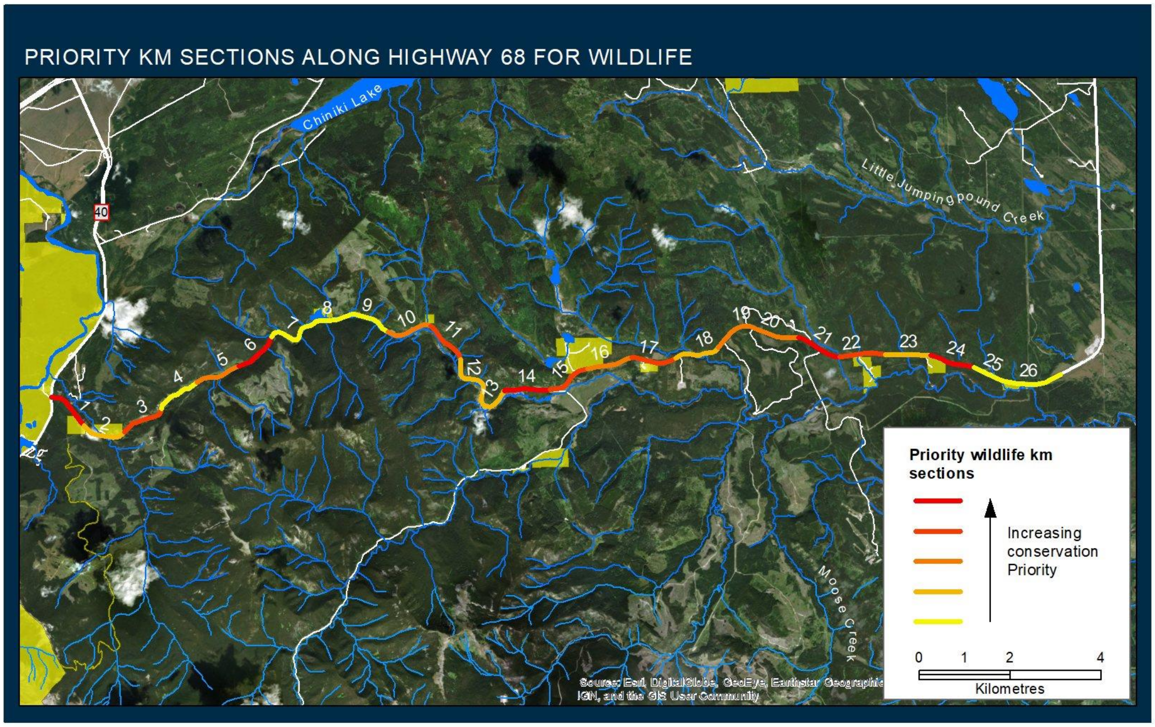



**Figure 18: Cumulative wildlife priority km sections along Highway 68**

# 5.0. Mitigation Development

## 5.1. Terrestrial Mammal Considerations

### *Rule of Thumb: Avoid, Mitigate, Compensate or Withdraw*

Mitigation is only one of the planning alternatives transportation agencies have to reduce or eliminate impacts of road construction and expansion projects on wildlife, including amphibian populations. Transportation projects generally can 1) have road alignments that *avoid* critical wildlife habitat, 2) *mitigate* affected wildlife populations and habitats, or 3) *compensate* for the loss of wildlife habitat, commonly used when projects eliminate or alter amphibian habitats. Transportation projects can also be *withdrawn* and not go ahead as planned; this is usually due to the high costs of the project construction, operation and maintenance compared to the benefits (Alamgir et al. 2017).

If a project is to go forward, before initiating project planning for wildlife habitat connectivity, the first step in *avoiding* impacts from road construction on wildlife populations and their habitats is to make alignment adjustments to prevent conflicts.

If the impacts cannot be avoided, then *mitigation* is an alternative. In North America this is the most common approach when roads impact wildlife habitat. Today there are many examples of mitigation techniques and strategies implemented for wildlife in nearly every North American landscape (Van Der Ree, Smith, and Grilo 2015).

Finally, if projects are unable to avoid or mitigate their impacts then the third option consists of *compensation* measures. The compensation principle holds that for road construction or expansion there is no net loss of habitat, natural processes or biodiversity. This typically occurs with small vertebrate populations and their habitat (amphibians, reptiles, small mammals).

### *Alternatives and Consequences*

The two future alternatives for Highway 68 are to remain unpaved or at some point in time to be paved. For this project, the final objective (no. 4) was to identify and recommend a range of suitable, cost-effective mitigation techniques for a range of wildlife species along Highway 68.

Currently Highway 68 is a low-volume (currently at weighted average annual daily traffic volume of 400 vehicles) unpaved road with relatively low vehicle speeds. The impacts of the highway at the current traffic levels are insignificant ecologically. Mortality of wildlife due to the highway is extremely rare (Alberta Parks, personal communication) and there are no known or perceived effects of habitat fragmentation or barriers to wildlife movement given the low traffic volume.

Should there be changes to the road surface (paving), straightening the alignment (increasing vehicle speeds) and increasing recreational opportunities (campsites, trails, bike paths, etc.) in the area, rapidly new impacts will occur. Two key impacts include increase in wildlife vehicle collisions, and increased fragmentation of the landscape for more sensitive species. These impacts due to infrastructure and increased human activity will be long-lasting and often times irreversible, and typically increase in magnitude over time (Forman, R.T. et al. 2003). In addition, we must consider the cumulative effects of increasing road impacts at a regional scale, such as increased access and increased habitat fragmentation. For sensitive species in our study such as grizzly bears this equates to loss of core areas for breeding female grizzly bears, and greater landscape resistance (reduced movement opportunities) for all grizzly bears including breeding females (Boulanger and Stenhouse 2014; Cristescu et al. 2016; Coogan et al. 2018).

We have identified and prioritized the location of proposed mitigation along Highway 68, based on our synthesized data for a range of species and transportation and resource management objectives.

We have devised three categories of proposed mitigation structures with the following design criteria (Table 4): **High quality or primary** wildlife crossing structure, consisting of a 30 m wide overpass or extended bridge underpass 21 m wide and 3.5 m high; **Secondary** wildlife crossing structure, consisting of an open-span bridge underpass 11 m wide and 3 m high; **Tertiary** wildlife crossing structure, consisting of an open-span bridge underpass, or 3 x 7 m metal culvert or concrete box culvert 2.8 m wide x 2.6 m high.

### *Rationale for design criteria*

Our design guidelines for the three categories of proposed wildlife crossing structures are based on our long-term research results in nearby Banff National Park that includes the same suite of species found in our study area (Anthony P. Clevenger and Waltho 2000; A.P. Clevenger and Waltho 2005; Clevenger and Barrueto 2014).

**Table 4: Design type and structural guidelines for three categories of recommended wildlife crossing structures on Highway 68.**

| CATEGORY | CROSSING DESIGN TYPE | RECOMMENDED DIMENSIONS |
|---|---|---|
| Primary | Overpass | Width: 30 m (minimum)<br>Length:[1] |
| | Underpass<br>(open span) | Height: 3.5 m<br>Width: 21 m<br>Length:[1] |
| Secondary | Underpass<br>(open span or arched culvert) | Height: 3 m<br>Width: 11<br>Length:[1] |
| Tertiary | Elliptical culvert | Height: 3 m<br>Width: 7 m<br>Length:[1] |
| | Concrete pre-fab box culvert | Height: 2.6 m<br>Width: 2.8 m<br>Length:[1] |

[1] Length will be based on constructed width of highway at location.

## 5.2. Amphibian Considerations

### *Rationale for design criteria*

We used a current review of the literature to consider the conservation objective of amphibian mitigation systems. Despite many hundreds of herpetofauna road impact mitigation systems being installed in Europe and some in North America, few studies have discussed their objectives or extended beyond rudimentary evaluation of use (T. Langton et al. 2017). Noticeable is the lack of reference to the detailed purpose of a constructed passage and barrier system, beyond the simple objective of minimalizing road mortality of animals and moving as many target animals as possible back and forward through a system under or over a highway.

Previous evaluations of herpetofauna passage systems constructed and studied in-situ or ex-situ, most sampled movements for relatively brief periods. The literature reflects a general absence of definition of what mitigations systems are trying to achieve. In response to this, and with the aim of more clearly identifying how mitigation projects might fall into different categories, three approaches can be identified that might require different success/failure criteria.

- *Approach A. Multiple crossings - community mitigation*
  Systems with passages and barriers where the aim is for all members of the natural community, endangered and common, require 'total connectivity' and the passage enables movement of the entire community, due to the importance of the habitat, species assemblage or landscape-scale movement pattern, to satisfy policy needs such as multi-species connectivity and climate change amelioration.

- *Approach B. Single species mitigation*
  Systems with passages and barriers seeking to enable passage for large or significant number of individuals away from or towards a critical place of aggregation (denning, overwintering, breeding or feeding) and their return with or without juvenile cohorts in large numbers.

- *Approach C. Minimum connectivity (severance avoidance) mitigation*
  Systems with passages and barriers where a road severs habitat that is more evenly spaced than with Approach A and where the aim is to ensure at least some future connectivity of the target species or community, to enable at least minimum continued genetic connectivity (at least one successful breeding individual crossing in each direction per generation time). This may require a critical minimum number of animals crossing to satisfy population viability analysis estimates.

Four species of amphibians were detected in the study area that requires mitigation attention: 3 species of frogs ( chorus frog, wood frog, Columbia spotted frog) and 1 species of toad (western toad). Our mitigation recommendations follow the most current information (based on literature reviews) on passage use and barrier efficacy for herpetofauna (Ontario Ministry of Natural Resources and Forestry 2016; T. Langton et al. 2017).

It is the smaller passages (<0.9 m diameter or span) where key variables that are considered most likely to influence passage-use have been most intensively studied (T. Langton et al. 2017). These are principally passage light levels, floor substrate type and quality, wetness/humidity and temperature. These factors interact with each other.

Approach B and C are desired mitigation systems for amphibians in the Highway 68 study area where the highway alignment bisects habitat critical for denning, overwintering, breeding or feeding. Similar to terrestrial mammal mitigation, the general objective is to connect important habitats, ensure passages and barrier systems are designed for the target species to ensure functionality and conservation value. Specific objectives are to: 1) provide single/multi-species passage, and 2) provide for minimum connectivity where Highway 68 severs habitat and ensure at least some future connectivity of the target species or community, to enable at least a minimum amount of connectivity.

Below are design features of mitigation measures for amphibian taxa (frogs, toads) that we recommend in the Highway 68 study area (Table 5).

**Table 5: Design type and structural guidelines for recommended mitigation measures for amphibian species detected on Highway 68 (adapted from Langton et al. 2017).**

| Taxa | Mitigation type and environment | Design recommendations |
|---|---|---|
| **Frogs**<br>*Chorus frog*<br>*Wood frog*<br>*Columbia spotted frog* | Passage construction and use | Frogs may use all crossing types and passages at or above 500 mm diameter are preferred with a non-concrete floor but there may be high variation in behaviour of species. |
| | Passage environment | Light levels in passage and passage size/length and state of flood may influence passage use rates and speed of crossing by frogs. This will vary between species. |
| | Barrier | Frogs require high barriers of 900 mm or more and with an overhang for some species. May not locate passage entrance without deflection boards. |
| **Taxa** | **Mitigation type and environment** | **Design recommendations** |
| **Toads**<br>*Western toad* | Passage construction and use | Toads may use all crossing types and passages at or above 500 mm diameter or smaller if slotted surface. |
| | Passage environment | Light levels in passage and passage size/length, temperature and wetness may influence passage use rates. |
| | Barrier | Toads generally do not |

| | | |
|---|---|---|
| | | jump as high as frogs but may climb and require smooth sided barriers of at least 450 mm. Barriers should be angled not flat to the passage. |

Large crossing structures such as those designed for terrestrial mammals can accommodate amphibian passage needs by having greater opportunity to provide cover with objects such as flat rocks, vegetated mounds composed of branches and logs and covered with sod, or rock piles. With large structures multi-species fencing designs should be used. For example, combining 0.635 cm mesh with 2.4 m high, large animal page-wire fencing (see **Appendix A, Sheet B**).

### *Design Considerations for amphibian tunnels*

Crossing structures can play an integral role in mitigating the impacts of roads on amphibians. Below are important considerations for planning designs that are most effective.

- Tunnels with natural substrate, arch tunnels and round tunnels buried 0.3-0.4 m into the ground are the primary recommended tunnel types because they meet essential criteria, such as providing natural substrate bottoms and a flat crossing surface.
- Terrestrial tunnels should be as level as possible for the entire length of the structure. One exception to this is that open-top tunnels should be installed with the highest point in the middle of the tunnel to allow for drainage and natural cleaning of the tunnel.
- Tunnel entrance bottoms should be at ground-level so animals do not need to ‘step up’ or ‘step down’ to enter the structure.
- At terrestrial tunnels, water should be diverted away from the entrances with drainage ditches or sloped excavation.
- If culverts are intended for drainage, or tunnels are large enough, a dry bench placed above the water mark can be integrated into the tunnel, in which case the bench must access dry ground at both entrances to be effective.

### *Construction design and materials*

The most comprehensive review for herpetofauna is Luell et al. (2003) the COST 341 review for Europe; *Habitat Fragmentation due to Transportation Infrastructure* (Bekker and Iuell 2003). Clevenger & Huijser (2011) *Wildlife Crossing Structure Handbook: Design and Evaluation in North America* provides some additional information(A.P. Clevenger and Huijser 2011).

Table 6 and Table 7outline materials and general design types used for amphibian tunnel systems.

**Table 6: Tunnels (<0.9 m diameter/span)**

| Geography | Variation/types |
|---|---|
| North America | • Mostly concrete, polymer concrete and steel construction.<br>• Mostly rectangular, arched, round, half or three quarter round in cross section.<br>• Typical 10-20 m or more in length according to road and embankment width.<br>• May be placed singly or in series and usually but not always with barrier guide wall and fencing types.<br>• Either bare (polymer concrete) or with soil. |

**Table 7: Barriers**

| Geography | Variation/types |
|---|---|
| North America | • Sometimes built in association with a taller deer or livestock fence. Usually 500 mm high plus or minus 200 mm, with around 200 mm in addition underground to prevent under-digging. Most barriers have overhangs to reduce over-climbing.<br><br>*Guide walls*<br>• Guide walls are solid permanent structures that may also have a soil/slope retention purpose. Made from steel, concrete or polymer concrete they are built into the road embankment as an integral part of the road structure.<br><br>*Fencing*<br>• Thin polythene/geotextile/plastic material including shade cloth may be used for temporary applications but lacks strength and durability.<br>• Formed (extruded) plastic (polypropylene/polyethylene) sheeting, 1, 2 or 3 mm thick is commonly used, fixed vertically or at an angle on wood, plastic or metal posts. Thicker injection-molded plastic curved panels are also used with plastic, recycled plastic, wood or steel support posts. Lifespan expectation is 10-25 years plus.<br>• Galvanised (zinc coated) steel or other steel alloys designed for rust-proofing is used for more permanent barriers, as is polymer (resin) concrete. Lifespan expectation is generally 40-100 years plus.<br>• Steel mesh with fine holes is sometimes coloured brown to help blend into the landscape. Here, solid materials may catch soil-blow and become buried and plastics may distort through expansion warping or degrade due to high UV light exposure. |

A number of companies manufacturing purpose-made wildlife passage and barrier materials specifically aimed at herpetofauna are shown in Table 8. Animex and Ertec Environmental Systems are located in the US and Animex has a representative in Canada (Ontario). Both ACO and Animex products have been implemented in Canadian herpetofauna road projects (Ontario Ministry of Natural Resources and Forestry 2016).

**Table 8: Companies manufacturing wildlife passage and barrier materials specifically aimed at herpetofauna.**

| Name | Headquarters<br>Areas covered | Web link to information |
|---|---|---|
| ACO | Germany<br>Worldwide | http://www.aco-wildlife.com/home/ |
| Animex | Worldwide<br>UK | https://animexfencing.com/ |
| Ertec Environmental Systems | Sacramento<br>USA | http://ertecsystems.com/Products/Wildlife-Exclusion-Fence---Special-Status-Species-Protection |
| Maibach Vul GmbH | Germany<br>Europe | https://www.maibach.com/amphibienschutz.html |
| Volkmann and Rossbach GmbH | Germany<br>Europe | http://www.amphibienschutz.de/zaunhersteller/volkmann/volkmann.htm |

# 6.0. Recommendations

## 6.1 Terrestrial Mammals and Traffic Volume

Highway 68 today is a low-volume unpaved road with relatively low vehicle speeds. There are no real impacts to wildlife from the highway at the moment. Mortality of wildlife due to the highway is rare and there are no effects of habitat fragmentation or barriers to movement given the low traffic volume. It is important to understand how wildlife mortality and cross-highway movements change with varying levels of traffic volume, i.e., should the highway configuration change through paving and widening and subsequent increases in traffic volume.

### *Effect of traffic volume on mortality and crossing success*

Road-related mortality and reduced wildlife movements have the biggest effect on keeping wildlife populations viable over the long term. However, the degree to which these factors depress or threaten populations depends on the level of traffic volume. A conceptual model shown in Figure 19 describes the effect traffic volume has on 1) animal avoidance of roads, 2) the likelihood of them getting killed while trying to cross, and 3) successful crossing attempts.

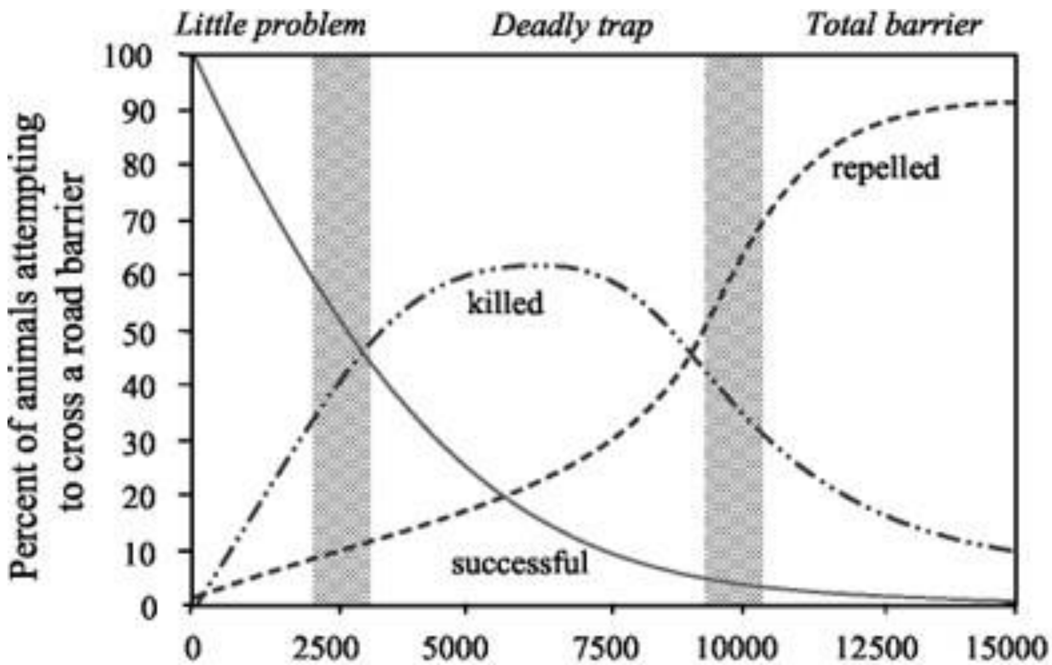



**Figure 19: Conceptual model from Seiler (2003) on the effect of traffic volume (X-axis) on the percentage of animals that successfully cross a road (Y-axis).**

Figure 19 represents a conceptual model on the effect of traffic volume (X-axis) on the percentage of animals that successfully cross a road (Y-axis), are repelled by traffic noise and vehicle movement, or get killed as they attempt to cross. The conceptual model indicates that most collisions occur on intermediate roads (Seiler 2003).

At low traffic volumes (<2500 annual average daily traffic volume (AADT)) the proportion of traffic-related mortalities is generally low, as is the number of animals that may be repelled by the road and traffic disturbance, thus having little or no impact on the population.

As traffic volumes increase to moderate levels (2500–10,000 AADT) mortalities are expected to be high, the number of animals repelled by roads will likely increase, and the proportion of successful crossings should start to decrease dramatically.

At high traffic volumes (>10,000 AADT), only a small proportion of attempted road crossings are expected to be successful. A large proportion of the animals approaching the road are likely repelled due to disturbance and heavy traffic volume, thus traffic-related mortality rarely occurs at all.

The model is particularly useful for understanding how wildlife mortality and cross-highway movements change with varying levels of traffic volume. Low rates of road-related mortality on a busy highway might be interpreted as evidence that impacts are negligible to wildlife, but in actuality the impacts may be that species have become locally extinct or that traffic disturbance effectively keeps them far from the highway surface. The thresholds and shape of the distribution in the model may be species-specific.

### *Triggering Mitigation Action: Traffic Volume Threshold*

There has been some thought about the threshold of traffic volume above which roads become a deadly trap, as the conceptual model describes, and when there is an urgent need for management intervention. It is unclear whether 2000–3000 vehicles per day is a threshold transportation agencies should be concerned about. How abundant species are, their behavior and their biological needs will strongly affect what the threshold levels are for different wildlife. Nevertheless, the model provides a basis for further examination of two-lane or low-volume road impacts on mortality and fragmentation of wildlife populations.

### *Grizzly Bears and Wildlife Crossing Structures*

As context for our mitigation recommendations we stress that the design and implementation of functional wildlife crossing structures should promote adequate interchange within the populations affected by roads, allow access to important resources, and ultimately enhance the demographic and genetic viability of wildlife populations.

There is a large and growing body of evidence that demonstrates wildlife species are capable of using a range of wildlife crossing structure types, thereby reducing mortality and increasing connectivity (Jeffrey W. Gagnon et al. 2011; Van Manen et al. 2012; Sawyer, Lebeau, and Hart 2012). Grizzly bears are a focal species for mitigation where road projects impact their habitats and populations, such as the Highway 68 corridor. Grizzly bears use a variety of structure types frequently with preference for large crossing structures (Clevenger and Barrueto 2014).

Recent research, however, identified the specific crossing structure design needs that are critical for breeding females to cross highways (Ford, Barrueto, and Clevenger 2017). This work demonstrated several important management considerations for road mitigation in grizzly bear range:

1. That crossing structure designs targeted at the preference of family groups might be one of the most effective methods to enhance viability of populations in this area;
2. Designing some crossings to be ‘family friendly’ might increase the use of the crossing structure network in general with time, and make all designs more cost-effective; and
3. Ensuring that both males and family groups have options to cross highways may reduce intra-specific predation. Adult male bears often kill young bears, and will displace family groups from prime habitat.

The study concluded that highway mitigation that does not address the passage needs of breeding females is not effective highway mitigation and will not result in mitigating connectivity of breeding females or ensure long-term viability of the local population.

## 6.2 Recommendations for Highway Improvements and Mitigation

Our main recommendation is to not improve the road; Highway 68 should remain a low-volume road with low vehicle speeds, i.e. maintain the unpaved nature of the highway. This is based on the need to reduce regional impacts of increased road density, increased habitat fragmentation effects, increased human access off Highway 68 and other highways in the region (Boulanger and Stenhouse 2014; Coogan et al. 2018; Lamb et al. 2018). Road density is a useful surrogate for the negative effects of human land use on grizzly bear populations, but spatial configuration of roads is an important factor. Two major highways are located near Highway 68, the bustling Trans-Canada Highway with more than 35,000 vehicles per day (increasing annually) during summer and increasing traffic on Highway 40 in Kananaskis Country, currently with just under 2000 vehicle per day.

Should the decision be made to improve Highway 68 by paving, in this report we propose a mitigation strategy based on cost-benefits and the current science and practice of road ecology (M. P. Huijser et al. 2008; M. Huijser and Duffield 2009; Rytwinski et al. 2016).

### *Highway Mitigation Design and Prioritization*

Synthesis of occupancy data and connectivity modeling helped identify 5 segments along Highway 68 that will be the most problematic in terms of WVCs and ensuring safe movement of wildlife in the corridor. Within these zones there will be recommendations for **primary, secondary** and **tertiary** mitigation structures.

#### PROCESS

Most mitigation assessments that rely heavily on site-specific information using WVC data, radio telemetry and/or modeling (Beckman et al. 2010; Lee, Clevenger, and Ament 2012; Kociolek et al. 2015). This assessment utilizes spatial distribution of wildlife and species-specific connectivity modeling in the Highway 68 corridor that tells us about where WVC could likely occur and movements conflict with an improved highway and increased traffic volumes.

We identified 1 km segments (few or many) that were associated with occupancy data and movement models. Uncertainty regarding the decision of project approval, timing of highway improvement project and project specifics (alignment, road widening, level of service, i.e., traffic volumes) make it difficult at this time to prescribe detailed site-specific recommendations for mitigating the impacts of the road on wildlife populations.

We identified the location of proposed mitigation along Highway 68, based on our synthesized data encompassing a range of species and transportation and resource management objectives for the Highway 68 corridor. In this section we review each of the zones identified as areas of conflict between wildlife habitat connectivity and movement, given future increases in traffic volume. We present recommendations for terrestrial wildlife species in the Highway 68 project area. The mitigation needs of amphibians are addressed separately below.

### IDENTIFICATION OF MITIGATION EMPHASIS ZONES

Our synthesis of connectivity models and occupancy data identified 5 main segments along Highway 68 sites deemed necessary for mitigation measures (hereafter, mitigation emphasis zones; Table 9). We used the following data to aid in identifying critical zones for mitigation along Highway 68:

1. Moose connectivity modeling (Figure 16)
2. Moose camera and snow-tracking detections per km (Figure 16)
3. Grizzly bear connectivity modeling (Figure 11)
4. Motorist safety risk (sum of deer, elk, moose occupancy; Figure 14)
5. Carnivores of conservation concern (sum of grizzly bear, wolf, cougar occupancy ;Figure 15)
6. Cumulative priority sections 1-5 (Figure 18)

### MITIGATION EMPHASIS ZONES

As described above, *mitigation emphasis zones* (MEZ) are specific locations within the study area where opportunities for reducing wildlife–vehicle collisions (WVC) and improving connectivity for all wildlife are highest, including fragmentation-sensitive species (Figure 20). We developed recommendations for mitigation opportunities at each mitigation emphasis site along the Highway 68 study area. The relative importance of each zone, and within zone, varies by focal species and regional conservation and mitigation concerns across the Highway 68 corridor (Table 9).

Focusing highway mitigation efforts in these five main areas should provide for motorist safety, help reduce wildlife mortalities and maintain or improve habitat linkages and animal movement through transitional habitat along these highway segments.

### Table 9: Summary of Highway 68 wildlife MEZs

| Site name | km # | Focal species | Concerns | Priority |
|---|---|---|---|---|
| MEZ-01 | 1-2 | Common species + moose and cougar | Motorist safety and local connectivity of moose and cougar | High |
| MEZ-02 | 6 | Common species + grizzly bear, wolf and cougar | Local connectivity of grizzly bears and species of concern | Moderate |
| MEZ-03 | 10-12 | Common species + moose and cougar | Regional connectivity for moose and grizzly bear; riparian habitats | Moderate |
| MEZ-04 | 14-17 | Common species + grizzly bear and moose | Regional connectivity for moose and grizzly bear; motorist safety | High |
| MEZ-05 | 19-24 | Common species + grizzly bear and moose; species of concern | Regional connectivity for moose and grizzly bear; motorist safety; species of concern; high species diversity | High |


Figure 20: Mitigation Emphasis Zones along Highway 68

### *Mitigation Measures*

Devising measures that effectively mitigate the impacts of roads with the dual purpose of providing safe passage for motorists and wildlife is the new norm today for transportation agencies (Kociolek et al. 2015). A recent meta-analysis of WVC reduction measures revealed that fencing and wildlife crossing structures led to an 83% reduction in WVCs, compared to a 57% reduction for animal detection systems, and only 1% for reflectors (Rytwinski et al. 2016).

The most comprehensive evaluation of WVC reduction measures was prepared for a report to the U.S. Congress, commissioned by the Federal Highway Administration (Huijser et al. 2008). The report summarized 36 different WVC mitigation measures currently in use throughout the world. The mitigation measures were grouped into four types:

- Measures that attempt to influence driver behaviour (18);
- Measures that attempt to influence animal behaviour (10);
- Measures that seek to reduce wildlife population size (4); and
- Measures that seek to physically separate animals from the roadway (4).

As part of the report, a Technical Working Group was convened that included seven national experts in the area of WVC. One of their tasks was to rank the current animal–vehicle collision mitigation measures into three categories:

1. Measures that are *proven* and should be implemented (where appropriate).
2. Measures that appear *promising* but require further investigation.
3. Measures or practices that are proven *ineffective*.

The recommendations for improving motorist safety and wildlife connectivity for Highway 68 include a total of five different proven or promising mitigation measures. Information sheets on these measures are found in **Appendix A**, including information on gates and ramps that are accessory to fencing and wildlife crossing structures. Table 10 includes a list of the five measures, their effectiveness in reducing WVCs (if data are available), the target of the measure (type) and the ranking category as presented in the Huijser et al. (2008) report.

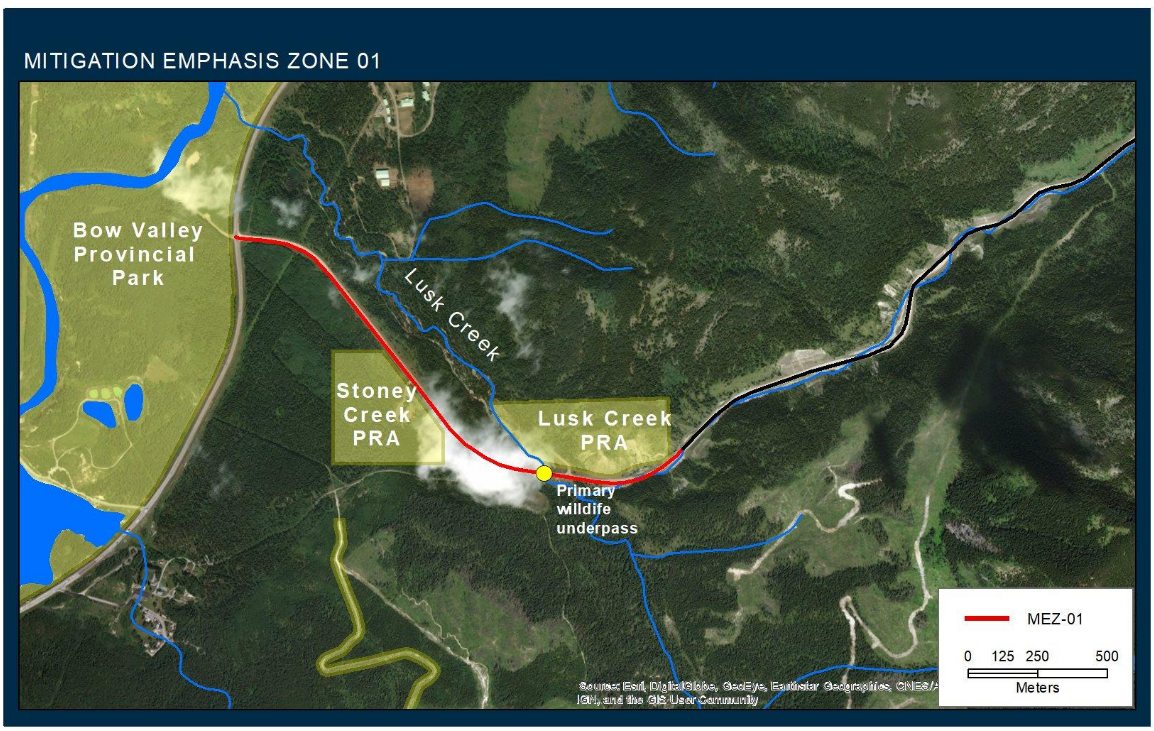
**Table 10: Wildlife mitigation measures, their focus and effectiveness.**

| Mitigation measure | Effectiveness | Type[1] | Category[2] |
|---|---|---|---|
| Animal detection system | 87% | Driver | Promising |
| Fencing | 86% | Separate | Proven |
| Underpass with waterflow | 86% | Animal | Proven |
| Underpass – wildlife | 86% | Animal | Proven |
| Overpass – wildlife | 86% | Animal | Proven |

[1] *Driver*: Measures that attempt to influence driver behaviour; *Animal*: Measures that attempt to influence animal behaviour; *Size*: Measures that seek to reduce wildlife population size; *Separate*: Measures that physically separate animals from the roadway. From Huijser et al. 2007.
[2] *Proven*: Measures that should be implemented (where appropriate); *Promising*: Measures that appear promising, but require further investigation. From Huijser et al. 2007.

## 6.3 MEZ Recommendations (Terrestrial Mammals)

### MEZ-01 – Km 1-2




**Location:** Km segments 1 and 2 (from junction Hwy 40 and Hwy 68)

**Wildlife objective:**

- Reduce wildlife–vehicle collisions in this section of highway, primarily deer, elk, moose and bears.
- Provide safe movement for all wildlife species across highway, primarily deer, elk and cougars.

**Target species:**

- WVC reduction: Common species including deer, elk and moose.
- Regional conservation & connectivity: Grizzly bears

**Mitigation priority:** High

**Mitigation recommendations:**

This zone had high scores for Human Safety, Moose Connectivity and Cumulative Scoring, and moderate scores for Cougar Occupancy. It is an area where WVC can be problematic, primarily with deer and also elk. Elk were scarcely detected in the Highway 68 corridor, at only half the sites (12 sites) 32 times (Table 1). Two cameras were situated in MEZ-01 and both detected elk 10 and 7 times, respectively over the course of the 20-month project, while other cameras detected elk 3 times or less.

The area is important in terms of local connectivity and also for maintaining regional connectivity for moose and grizzly bears. Modeling of regional connectivity for grizzly bear movement indicated this location was particularly important. Situated near Lusk Creek, it is a natural travel corridor for wildlife year-round. Species of interest in this area consist of deer, moose, wolves, cougars, grizzly and black bears.

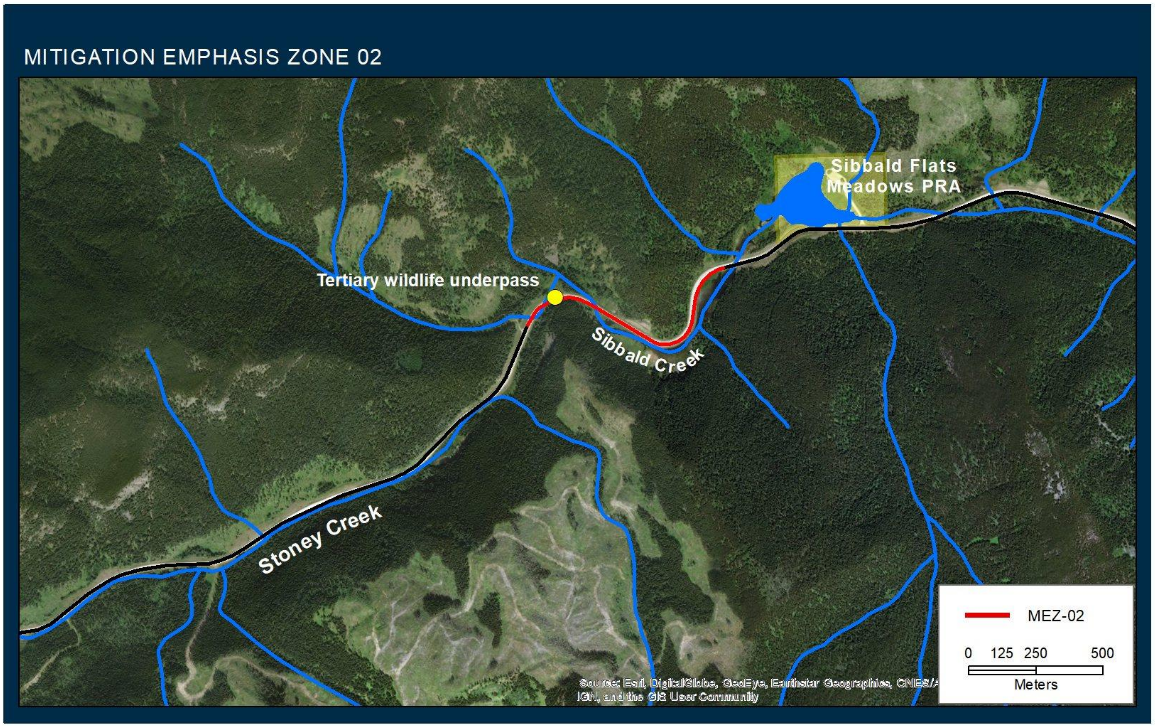
Recommended mitigation at the site consists of a **primary** *wildlife underpass or overpass* and associated *fencing*. The recommended dimension for the underpass is >3.5 m high and minimum 21 m wide (see *wildlife underpass,* **Appendix A, Sheet A & B**). The minimum dimension of the wildlife overpass option is minimum 30 m wide. Both passage structures are based on the high probability of key fragmentation-sensitive species (grizzly bear, wolves) movement through this area and need for regional scale connectivity. Either overpass or underpass should be suitable for the target species in the area including moose. Final determination of specific location and type of structure will depend largely on terrain and road grade. Retrofitting Lusk Creek culvert to a large open span that allow for wildlife passage on both sides above high water levels would ensure hydrological and wildlife connectivity function at this location.

*Wing fencing* within MEZ-01 will be used to guide wildlife to the underpass. Each mitigation situation is different and will require a site-specific assessment, but as a general rule, fence ends should terminate at a wildlife crossing structure.

If a wildlife crossing cannot be installed at the fence ends, then fences should be designed to terminate in the least suitable location or habitat for wildlife movement—i.e. places wildlife are least likely to cross roads. Examples of terminations and fence technical specifications are given in **Appendix A, Sheet C**.

*Jump-outs*: Jump-outs or escape ramps should be located appropriately to allow animals to escape the right-of-way should they gain access within the fenced area. We recommend a pair of jump-outs (one on each side of highway) close to the fence end (<100 m) and another pair 200-300 m from the first pair. Examples and technical specifications are given in **Appendix A, Sheet D**.

## MEZ-02 – Km # 7




**Location:** Km segment 7

**Wildlife objective:**

- ➢ Reduce wildlife–vehicle collisions in this section of highway, primarily deer and bears.
- ➢ Provide safe movement for all wildlife species across highway

**Target species:**

- WVC reduction: Common species including deer.
- Regional conservation & connectivity: Grizzly bears

**Mitigation priority:** Moderate

**Mitigation recommendations:**

This zone had moderately high scores for Grizzly Bear Connectivity, Species of Concern and Cumulative Scoring. It is an area with moderate probability of WVC, primarily with deer.

The area is important in terms of local connectivity and also for maintaining regional connectivity for wildlife. Situated at the confluence of two drainages that converge at Sibbald Creek, it is a natural north-south travel corridor for wildlife. Species of interest in this area consist of deer, moose, wolves, cougars, grizzly and black bears.

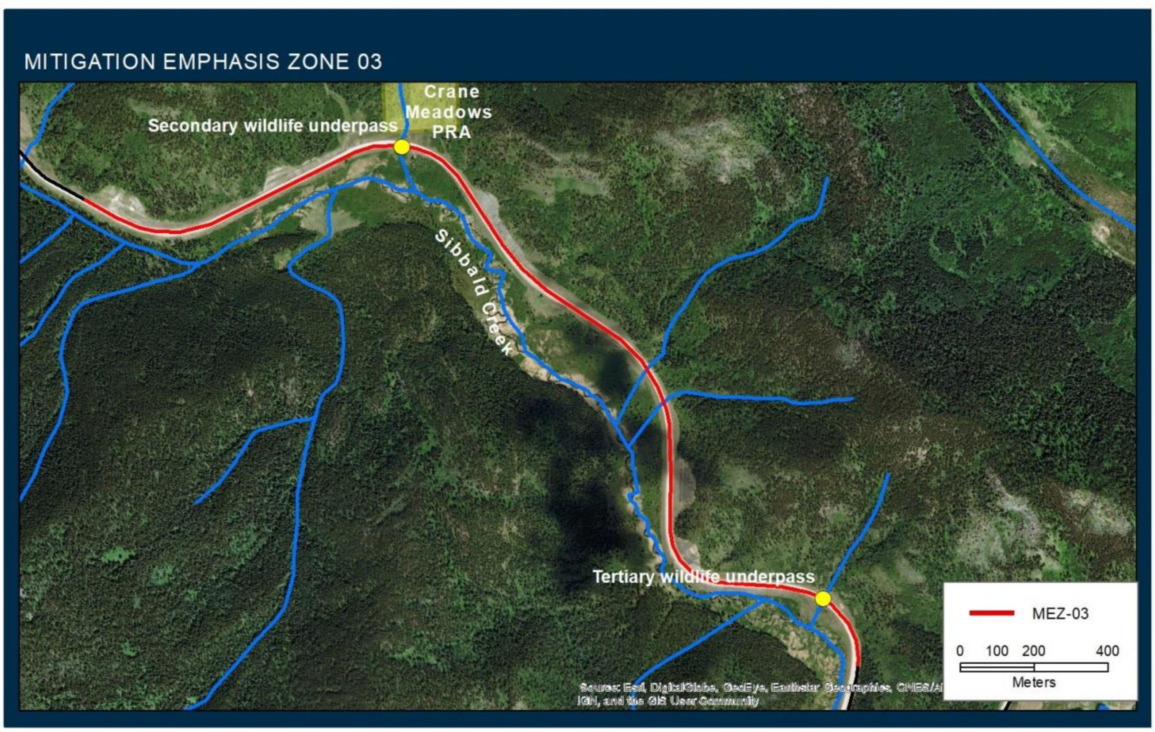
Recommended mitigation at the site consists of a **tertiary** *wildlife underpass* and associated *fencing*. The recommended dimension for the underpass is >3 m high and minimum 7 m wide elliptical culvert or box culvert 2.8 wide x 2.6 m high (see *wildlife underpass,* **Appendix A, Sheet B**). The passage structure is based on the high probability of common species (deer, cougars, wolves, black bears) movement through this area and need for local scale connectivity. Final determination of what structure type to build will depend largely on terrain and road grade.

*Wing fencing* within MEZ-02 will be used to guide wildlife to the underpass. Each mitigation situation is different and will require a site-specific assessment, but as a general rule, fence ends should terminate at a wildlife crossing structure.

If a wildlife crossing cannot be installed at the fence ends, then fences should be designed to terminate in the least suitable location or habitat for wildlife movement—i.e., places wildlife are least likely to cross roads. Examples of terminations and fence technical specifications are given in **Appendix A, Sheet C**.

*Jump-outs*: Jump-outs or escape ramps should be located appropriately to allow animals to escape the right-of-way should they gain access within the fenced area. We recommend a pair of jump-outs (one on each side of highway) close to the fence end (<100 m) and another pair 200-300 m from the first pair. Examples and technical specifications are given in **Appendix A, Sheet D**.

## MEZ-03 – Km # 10-12




**Location:** Km segments 10-12

**Wildlife objective:**

- Reduce wildlife–vehicle collisions in this section of highway, primarily deer, moose and bears.
- Provide safe movement for all wildlife species across highway

**Target species:**

- WVC reduction: Common species including deer.
- Regional conservation & connectivity: Grizzly bears and moose

**Mitigation priority:** Moderate

**Mitigation recommendations:**

This 3-km zone had moderately high scores for Moose Connectivity, and moderate scores for Cougar Occupancy, Species of Concern and Cumulative Scoring. It is an area with low to moderate probability of WVC, primarily with deer.

The area is important in terms of local connectivity and also for maintaining regional connectivity for wildlife, particularly moose and grizzly bears. MEZ-03 is situated alongside the riparian habitat at Sibbald Creek where the Sibbald valley opens up and is at its widest, whereas most sections to the west are either narrow or in steep rugged terrain. The Sibbald Flats riparian shrublands and forests support a diverse animal community, including moose, grizzly bears (observed feeding on a moose on 13 Oct. 2017), white-tailed deer and a host of other vertebrates (terrestrial and semi-aquatic). Where Km 10 and 11 join there is a prominent north-south drainage that feeds into Sibbald Creek. This drainage is one of the few north-south drainages in the study area that provides a regional connection with habitats on the north side of the range (Bow River-Chiniki Lake). In the Sibbald drainage the connection provides a conduit to several major drainages in the southern part of the study area, in addition to the east-west aligned Sibbald Flats riparian floodplain.

MEZ-03 therefore contains a natural north-south travel corridor of regional importance for wildlife. Species of interest in this area consist of deer, moose, wolves, cougars, grizzly and black bears. Recommended mitigation at 2 sites within MEZ-03 consists of a:

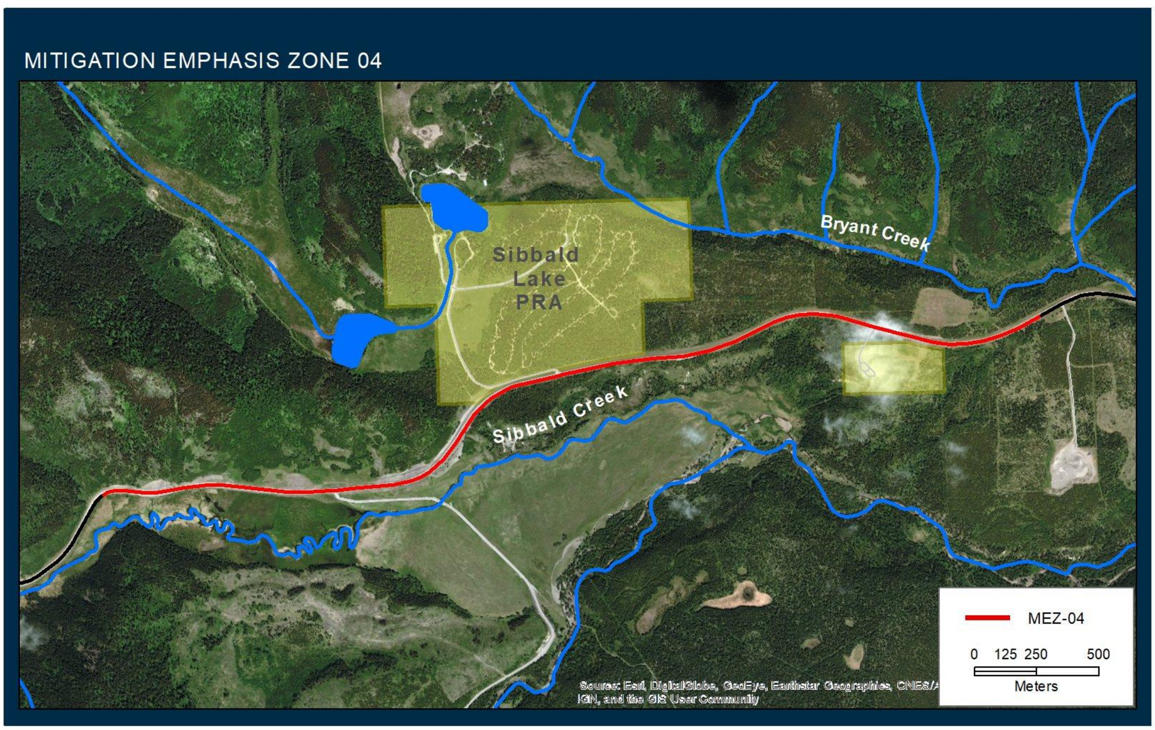
1) **secondary** *wildlife underpass* and associated *fencing* located where Km 10 meets Km 11. The recommended dimension for the underpass is >3 m high and minimum 11 m wide elliptical culvert (see *wildlife underpass,* **Appendix A, Sheet B**). The passage structure is based on the high probability of movement by key fragmentation-sensitive species (grizzly bear, wolves) and moose through this area and the need for regional scale connectivity. The underpass should be suitable for the target species in the area. Final determination of location will depend largely on terrain and road grade.
2) **One tertiary** *wildlife underpasses* and associated *fencing* located mid Km 12, also associated with north-south drainage patterns in addition to east-west within the Sibbald Flats floodplain. The recommended dimension for the underpasses is >3 m high and minimum 7 m wide elliptical culvert or box culvert 2.8 wide x 2.6 m high (see *wildlife underpass,* **Appendix A, Sheet B**). The passage structure is based on the high probability of common species (deer, cougars, wolves, black bears) movement through this area and need for local scale connectivity. Final determination of what structure type to build will depend largely on terrain and road grade.

*Continuous fencing* between crossing structures within MEZ-03 will be used to guide wildlife to the underpass. Each mitigation situation is different and will require a site-specific assessment, but as a general rule, fence ends should terminate at a wildlife crossing structure.

If a wildlife crossing cannot be installed at the fence ends, then fences should be designed to terminate in the least suitable location or habitat for wildlife movement—i.e., places wildlife are least likely to cross roads. Examples of terminations and fence technical specifications are given in **Appendix A, Sheet C**.

*Jump-outs*: Jump-outs or escape ramps should be located appropriately to allow animals to escape the right-of-way should they gain access within the fenced area. We recommend a pair of jump-outs (one on each side of highway) close to the fence end (<100 m) and another pair 200-300 m from the first pair. Examples and technical specifications are given in **Appendix A, Sheet D**.

## MEZ-04 – Km # 14-17




**Location:** Km segments 14-17

**Wildlife objective:**

- Reduce wildlife–vehicle collisions in this section of highway, primarily deer, moose and bears.
- Provide safe movement for all wildlife species across highway, primarily deer and cougars.

**Target species:**

- WVC reduction: Common species including deer and moose.
- Regional conservation & connectivity: Moose and grizzly bears

**Mitigation priority:** High

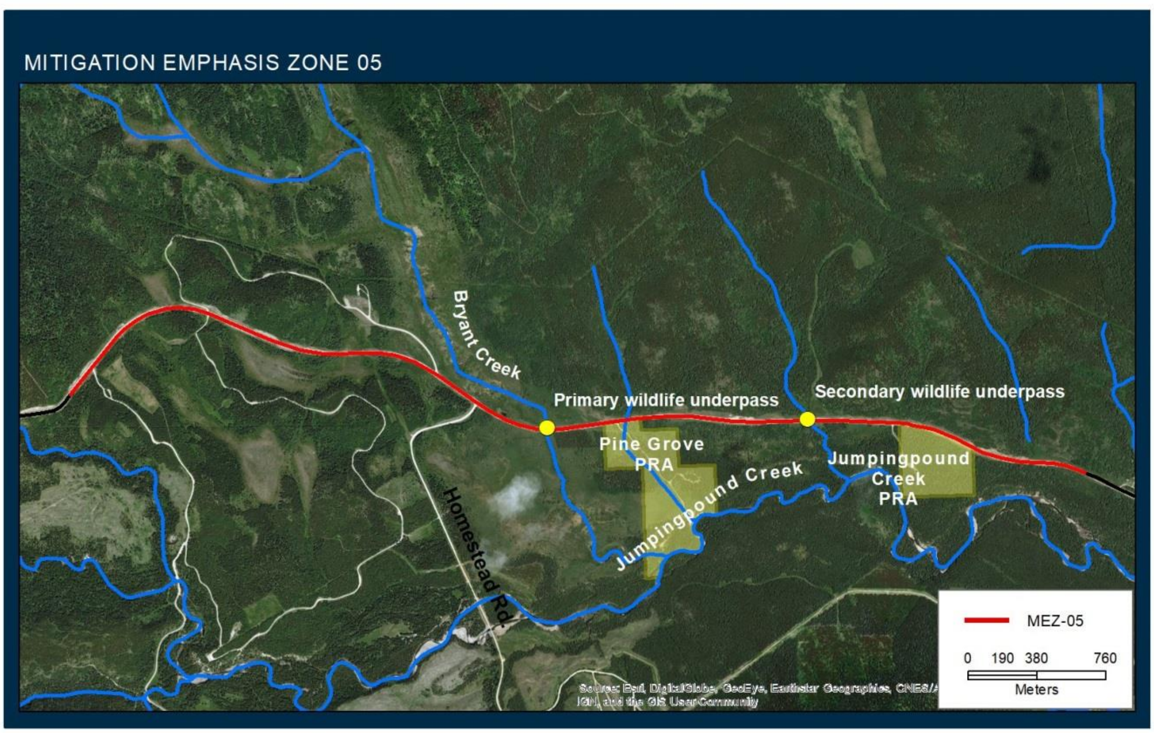
**Mitigation recommendations:**

This zone had high scores for Moose and Grizzly Bear Connectivity and Cumulative Scoring, and moderate scores for Motorist safety and Cougar Occupancy. It is an area where WVC can be problematic, primarily with deer.

The area is important in terms of local connectivity and also for maintaining regional connectivity for moose and grizzly bears. Modeling of regional connectivity for grizzly bear movement indicated this location was particularly important. The zone encompasses the Sibbald Flats floodplain (Km 14) including the Powderface road junction (Km 14-15). The existing highway climbs steeply from the road junction towards the Sibbald Flats Lake Campground (Km 15-16), a popular destination in summer. This location presents difficulties for mitigating road impacts with fencing and crossing structures given the open floodplain, road junction and close proximity to a popular campground.

Recommended mitigation at the site consists of a installing a radar-based *animal-detection system* (ADS) focused on this segment of Highway 68. Because of the site-specific problems at this location we do not recommend fencing or wildlife underpasses, but installation of an ADS with motorist warning signage (see **Appendix A, Sheet E**).

## MEZ-05 – Km # 19-24




**Location:** Km segments 19-24

**Wildlife objective:**

- Reduce wildlife–vehicle collisions in this section of highway, primarily deer, moose and bears.
- Provide safe movement for all wildlife species across highway, primarily deer and cougars.

**Target species:**

- WVC reduction: Common species including deer and moose.
- Regional conservation & connectivity: Grizzly bears

**Mitigation priority:** High

**Mitigation recommendations:**

This zone had high scores for Motorist Safety, Moose and Grizzly Bear Connectivity, Cumulative Scoring and Species Diversity, and moderate scores for Cougar Occupancy. It is an area where WVC can be problematic, primarily with deer. The highest diversity of species was detected in this part of the study area.

The area is important in terms of local connectivity and also for maintaining regional connectivity for moose and grizzly bears into the Little Jumping Pound (north) and Jumping Pound (south) drainages. Modeling of regional connectivity for moose and grizzly bear movement indicated this location was particularly important. There is one major wildlife corridor for wildlife year-round at Bryant Creek and Jumping Pound Creek. Species of interest in this area consist of deer, moose, wolves, cougars, grizzly and black bears.

Recommended mitigation at 2 sites within MEZ-05 consists of a:

1. **Primary** *wildlife underpass or overpass* and associated *fencing* at Bryant Creek (between Km 21 and 22). The recommended dimension for the underpass is >3.5 m high and minimum 21 m wide (see *wildlife underpass,* **Appendix A, Sheet A & B**). The minimum dimension of the wildlife overpass option is minimum 30 m wide. Both passage structures are based on the high probability of key fragmentation-sensitive species (grizzly bear, moose, wolves) movement through this area and need for regional scale connectivity. Either overpass or underpass should be suitable for the target species in the area. Final determination of location and what structure type to build will depend largely on terrain and road grade. Retrofitting Bryant Creek culvert to a large open span that allows for wildlife passage on both sides above high water levels would ensure hydrological and wildlife connectivity function at this location, including amphibian connectivity (**Appendix A, Sheet F**). This design option would also provide for amphibian passage at this critical location (see **4.2 Amphibians** below).
2. **Secondary** *wildlife underpass* and associated *fencing* at Km 23. There are several north-south drainages in MEZ-05, however this location aligns well with the Jumping Pound drainage (south) and drainages north that lead into the Little Jumping Pound watershed (north). The recommended dimension for the underpass is >3 m high and minimum 11 m wide elliptical culvert (see *wildlife*

*underpass,* **Appendix A, Sheet B**). The passage structure is based on the high probability of movement by key fragmentation-sensitive species (grizzly bear, wolves) and moose through this area and the need for regional scale connectivity. The underpass should be suitable for the target species in the area. Final determination of location will depend largely on terrain and road grade.

*Continuous fencing* between the two crossing structures within MEZ-05 will be used to guide wildlife to the underpass. Each mitigation situation is different and will require a site-specific assessment, but as a general rule, fence ends should terminate at a wildlife crossing structure.

If a wildlife crossing cannot be installed at the fence ends, then fences should be designed to terminate in the least suitable location or habitat for wildlife movement—i.e., places wildlife are least likely to cross roads. Examples of terminations and fence technical specifications are given in **Appendix A, Sheet C**.

*Jump-outs*: Jump-outs or escape ramps should be located appropriately to allow animals to escape the right-of-way should they gain access within the fenced area. We recommend a pair of jump-outs (one on each side of highway) close to the fence end (<100 m) and another pair 200-300 m from the first pair. Examples and technical specifications are given in **Appendix A, Sheet D**.

## 6.3 Amphibians

There are many significant threats to amphibian populations including habitat loss and degradation, habitat fragmentation, environmental pollution, disease, climate change, and road mortality from traffic or entrapment in road drainage structures (Beebee 2013). In order to address the deleterious effects of roads, transportation agencies have over several decades tried to mitigate road impacts by providing dispersal passage and barrier structures (T. E. J. Langton 1989; Jackson , S.D., Smith 2015; Hamer, Langton, and Lesbarrères 2015).

The threats of roads to amphibian populations can be direct or indirect. *Direct threats* consist of vehicle-related mortality, physical barriers and genetic fragmentation, while *indirect threats* are due to environmental alteration (e.g., chemicals, sedimentation, noise, vibration and light pollution) and road infrastructure (e.g., drainage systems). The four species detected in the study area (*chorus frog, wood frog, Columbia spotted frog, western toad*) would be most threatened from highway improvements by both direct (mortality, barriers) and indirect threats (habitat loss, chemicals, sedimentation).

Amphibians have certain life history attributes that make them vulnerable to road effects. Species with large range sizes, or long directional movements or migrations, tend to be more at risk than less mobile species where annual mortality overtakes recruitment. Some species have low reproductive rates and occur at low densities, exacerbating the road mortality effects on population persistence.

None of the four species have life history attributes that subject them to road impacts more than most amphibian species. None of the species have large home ranges, make exceptionally large movements or migrations, or have low reproductive rates. However, Columbia spotted frog is listed as Sensitive in the current Status of Alberta Wildlife report and may occur at low densities, therefore road operation and road alignments may have detrimental effects on their population persistence in the Sibbald Flats watershed.

### *Mitigation Emphasis Sites*

As described above, *mitigation emphasis sites (MES)* are specific locations within the study area where opportunities for reducing road-related mortality and improving connectivity for all wildlife are highest, including amphibian species. Focusing highway mitigation efforts in these areas should help reduce amphibian road-kill and maintain habitat linkages and movement through their habitat.

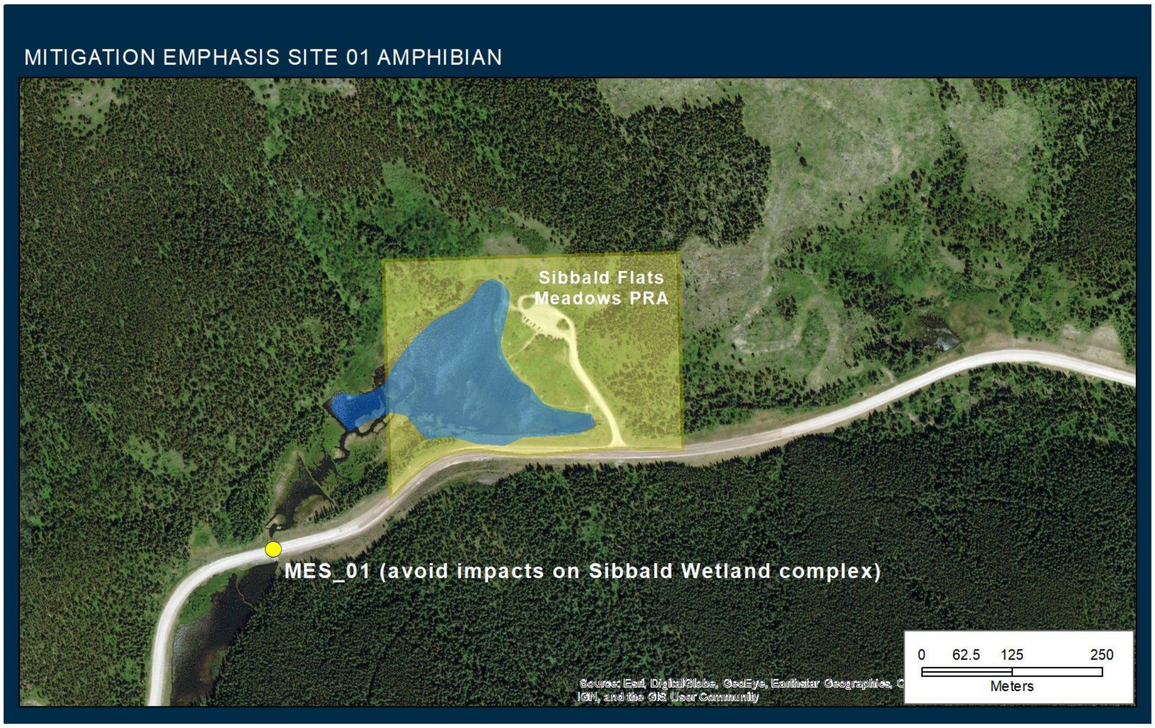
Four species of amphibians were detected in the study area that require mitigation attention: three species of frogs (*chorus frog, wood frog, Columbia spotted frog*) and one species of toad (*western toad*). We developed recommendations for mitigation opportunities at each mitigation emphasis site for amphibians along the Highway 68 study area. Highway 68 is currently a low-volume unpaved road with low vehicle speeds. The impacts of the highway at the current traffic levels are insignificant ecologically. Mortality of amphibians due to the highway is unknown but believed to be low given the biology and ecological requirements of the species found in the study area. There are no known or perceived effects of habitat fragmentation or barriers to movement given the low traffic volume.

If changes are made to Highway 68 (road surface paving, straightening the alignment and increasing recreational opportunities in the area) new impacts will occur and these will require proper mitigation of impacts.

We identified three locations of proposed mitigation for amphibians along Highway 68, based on our field sampling (acoustic recording, acoustic and visual surveys) collected during the study (see **Amphibians and Reptiles, Sect. 2.2.1**).

Our design guidelines for amphibian mitigation measures are based on technical guidelines described above in **Section 5.1 Mitigation Development**.

## Mitigation Recommendations (Amphibian)
## AMPHIB MES-01 – Km 8




**Location:** Sibbald Pond. (Km segment 8)

**Target species:**

- Columbia spotted frog (CSF).

**Wildlife objective:**

- Avoid impacts to CSF habitat
- The CSF is classified as Sensitive in the current Status of Alberta Wildlife report.
- Populations are extremely limited in distribution and threatened by introduced fish.

**Mitigation/Conservation priority:** High

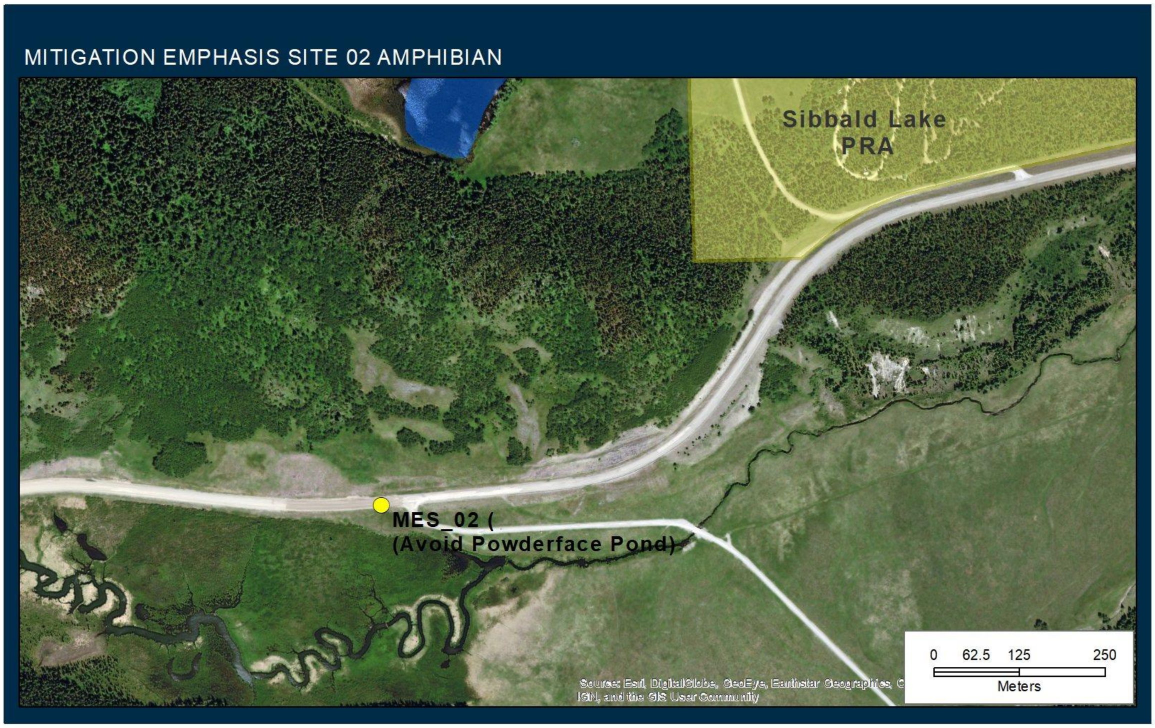
**Mitigation/Conservation recommendations:**

Mitigation is only one of the planning alternatives transportation agencies have to reduce or eliminate impacts of road construction and expansion projects on wildlife, including amphibian populations and their habitats. Transportation projects can have road alignments that *avoid* critical amphibian habitat such as places of aggregation (denning, overwintering, breeding or feeding) or occupied habitat of sensitive or listed species.

Mitigation of the impacts of Highway 68 on the CSF population at this location should consist of examining alignments and construction activities early in the project planning stage so they will avoid CSF and other amphibian populations near Sibbald Pond and their habitats.

There are no structural recommendations for this MES.

## AMPHIB MES-02 – KM 14-15




**Location:** Powderface Pond (Km segment 14-15)

**Target species:**

- Chorus frog (CF), western toad (WT).

**Wildlife objective:**

- Avoid impacts to Powderface Pond and CF and WT habitat
- Protect existing wetlands and quality amphibian habitat

**Mitigation/Conservation priority:** High

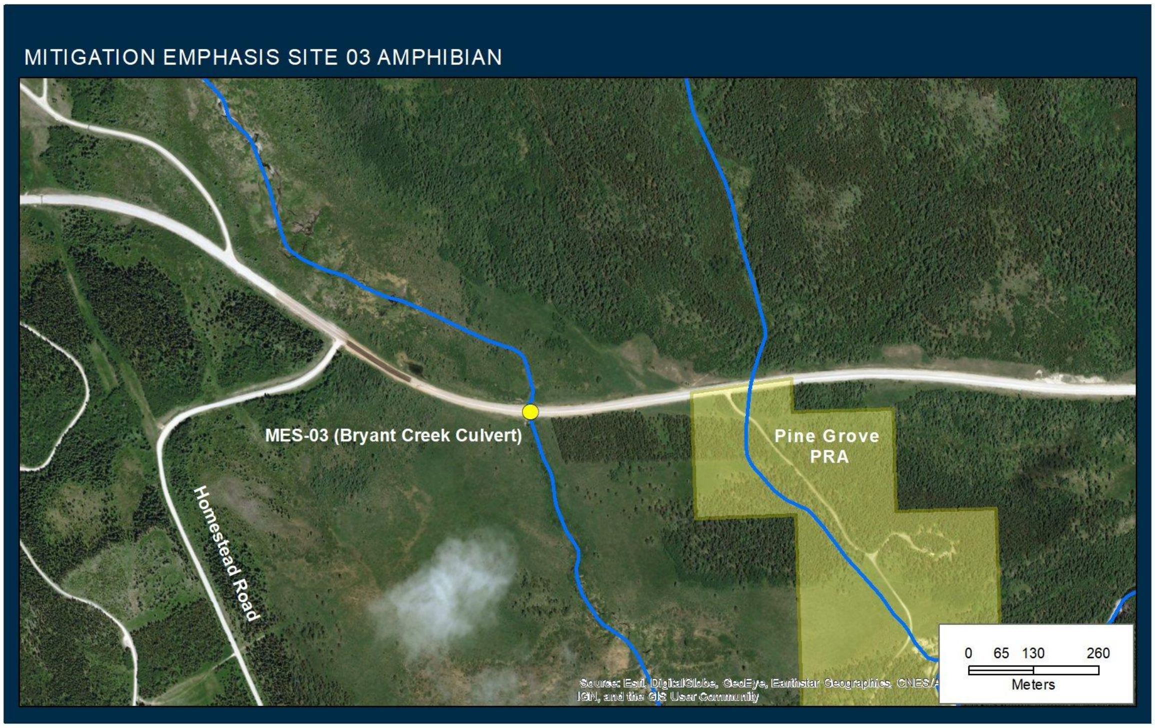
**Mitigation/Conservation recommendations:**

Similar to MES-01, mitigation is seen as only one of the planning alternatives transportation agencies have to reduce or eliminate impacts on amphibian populations and their habitats. Avoiding critical habitat such as places of aggregation (denning, overwintering, breeding or feeding) will have the greatest ecological gain in conserving amphibian populations.

Mitigation of the impacts of Highway 68 on the Powderface Pond and amphibian species living there should consist of examining alignments and construction activities early in the project planning stage. Selecting alignments and activities that avoid the pond and the amphibian populations living there is the most effective measure to ensure CF and WT populations continue to thrive there.

There are no structural recommendations for this MES.

## AMPHIB MES-03 – KM 17-18 – Byrant Creek




**Location:** Homestead Pond/Bryant Creek (Km segments 17-18)

**Target species:**

- Chorus frog (CF), western toad (WT), wood frog (WF)

**Wildlife objective:**

- Avoid impacts to Homestead Pond and Bryant Creek and habitat.
- Maintain connectivity between habitats by mitigating barrier effects of road.
- Protect existing wetlands and quality amphibian habitat in the area.

**Mitigation/Conservation priority:** High

**Mitigation/Conservation recommendations:**

The Jumping Pound floodplain including Bryant Creek is important habitat for these three species of amphibians. Wetlands and several ponds are located here and occupied by CF, WT and WF. Currently Highway 68 bisects these ponds which historically were connected as one wetland complex. The mitigation recommendation at MES-03 is to restore connections between ponds and habitat fragmented by the road.

We recommend *Approach B and C* (see 3.2 Amphibians) as desired mitigation systems for amphibians in the Highway 68 study area where the highway alignment bisects habitat critical for denning, overwintering, breeding or feeding. The objective is to connect important habitats, ensure passages and barrier systems are designed for the target species to ensure functionality and conservation value. Specific objectives for MES-03 are to: 1) provide multi-species passage, and 2) provide for minimum connectivity where

Highway 68 severs habitat and ensure at least some future connectivity of the target species or community.

Mitigation at the site could consist of one of two configurations:

1. **Separate/Exclusive Design**. Construction and installation of amphibian tunnels and associated *fencing*. The recommended design and dimensions for amphibian tunnels and barriers for these 3 species is found in
2. Table 6 and Table 7. The tunnel design is based on the high probability of the 3 species use and movement through this area and need for local scale connectivity. There is an existing culvert at the site and this would need to be upgraded for a highway improvement project on Highway 68. Retrofitting Bryant Creek culvert to a span bridge or arched tunnel that allow for passage of amphibians and small mammals on both sides above high water levels would ensure hydrological and small vertebrate connectivity function at this location.
3. **Combined/Inclusive Design**. In conjunction with mitigation recommendations for large mammals in the area design, construct a large crossing structure at **MEZ-05**. The structure would be designed so the underpass spans Bryant Creek adequately to provide for movement of multiple terrestrial species, including amphibian species through the underpass (**Appendix A, Sheet F)**. This inclusive design would meet hydrological needs, the requirements of terrestrial mammals and their passage needs, and connectivity needs of amphibians. Large crossing structures also provide greater opportunity to provide cover objects such as flat rocks, vegetated mounds composed of branches and logs and covered with sod, or rock piles that help to maintain humid substrates.

   *Fencing:* With large structures multi-species fencing designs should be used. For example, combining 0.635 cm mesh with 2.4 m high, large animal page-wire fencing

# 7.0. Conclusion

The intent of this study was to collect preliminary data to support future recommendations for highway mitigation to facilitate wildlife movement across Highway 68. In 2018, we continued to collect species distribution and occupancy baseline data for amphibians, reptiles, and medium to large mammals.

To better determine the need for Highway 68 upgrading there is a need to understand the long-term vision for Highway 68 from both Alberta Transportation and Alberta Environment and Parks. Currently Highway 68 has a low traffic volume with relatively low vehicle speeds, and represents a low risk to motorist safety and wildlife. The highway is situated within Rock Mountain Forest Reserve which has high wildlife conservation value, but bisects habitat for grizzly bears cougars, wolves, and two amphibian species of concern

(Columbia spotted frog and Western toad). We encourage further dialogue on the conservation cost-benefits associated with paving Highway 68 as opposed to leaving the road unpaved to recreationists and incurring minimal disturbance to wildlife populations in the region.

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# 9.0 Appendix A: Mitigation Measure Information Sheets (A-F)

Mitigation measure information sheets are based on the *Handbook for Design and Evaluation of Wildlife Crossing Structures in North America* (A.P. Clevenger and Huijser 2011).

Sheet A: Wildlife Overpasses

Sheet B: Wildlife Underpasses

Sheet C: Fencing

Sheet D: Gates and Ramps

Sheet E: Animal Detection Systems

Sheet F: Wildlife Underpasses with Water Flow

# Wildlife Overpasses SHEET A

## General design

Except for a landscape bridge, a wildlife overpass is the largest crossing structure to span highways. It is primarily intended to move large mammals. Small mammals, low-mobility medium-sized mammals and reptiles will utilize these structures if habitat elements are provided on the overpass. Semi-arboreal, semi-aquatic and amphibian species may use the structures if they are adapted for their needs. Types of vegetation and their placement can be designed to encourage crossings by bats and birds.

*Recently completed wildlife overpass without landscaping (Photo: Tony Clevenger).*

## Use of the structure

Wildlife overpasses are intended for the exclusive use of wildlife. Prohibiting human use and human-related activities adjacent to the structure is highly recommended.

## General guidelines

- To ensure performance and function, wildlife overpasses should be situated in areas with high landscape permeability, that are known wildlife travel corridors and that experience only minimal human disturbance.
- Maximize continuity of native soils adjacent to and on the wildlife overpass. Avoid importation of soils from outside the project area.
- Should be closed to public and any other human use/activities.
- Reduce light and noise from vehicles by using earth berms, solid walls, dense vegetation or a combination of these placed on the sides (lateral edges) of the structure.

*Berm on wildlife overpass (Photo: Tony Clevenger).*

## Dimensions – General guidelines

*Overpass Width:*

Minimum: 25–30 m
Recommended: 30–50 m

*Fence/berm height:*

2.4 m

*Soil depth:*

1.0–1.5 m

## Types of construction

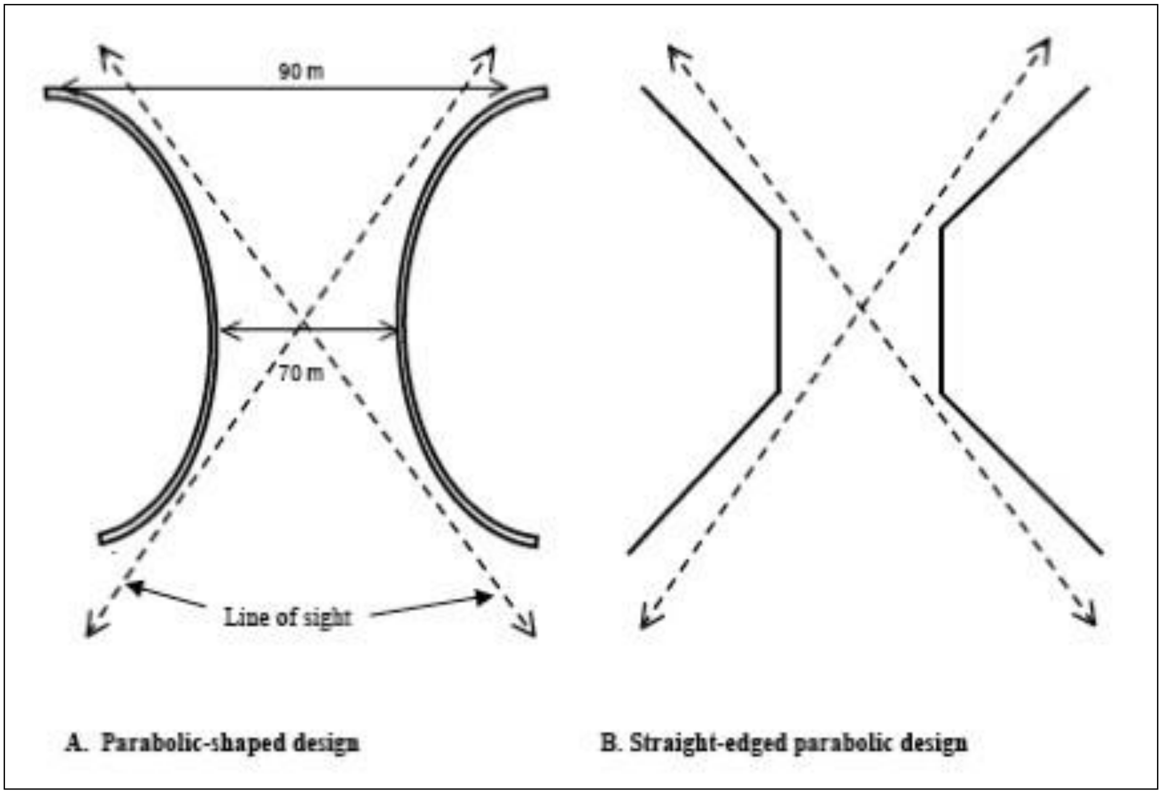
*Span*

Bridge span (steel truss or concrete)

*Arch*

Pre-fabricated cast-in-place concrete arches
Corrugated steel

Parabolic arch design overpass creates better opportunities for wildlife to locate approach ramps; however, costs are higher than rectangular or straight-edged constructions.




*Parabolic-shaped design overpass (A) and straight-edged design (B).*

## Suggested design details

### *Crossing structure*

- Wildlife overpass should be vegetated with native trees, shrubs and grasses. Species that match or are taxonomically close to existing vegetation adjacent to the structure should be employed. Site and environmental conditions (including climate) may require hardy, drought-tolerant species. Composition of trees, shrubs and grasses will vary depending on target species needs.
- Suggested design consists of planting shrubs on edges of the overpass to provide cover and refuge for small- and medium-sized wildlife. The center section of the overpass should be left open with low-lying or herbaceous vegetation. Place piles of shrubs, woody debris (logs) or rock piles in stepping-stone fashion to provide microhabitat and refuge for small, cover-associated fauna. In arid locations, more piles of woody debris and rocks should be used to provide cover for small and medium-sized fauna.
- Soil depth can vary from 25-50 cm to several meters, depending on the landscaping requirements for meeting the habitat requirements for the species that will be using the overpass. For open habitats soil depths can be less than 0.5 m deep. For forested

habitats, soil depths should be sufficient to support 2.4–3.6-m-high trees, i.e., 1.5-2.0 m deep. Regardless of whether the overpass is predominantly open or forested, the structure should be vegetated with mix of grasses and shrubs of varying height. Soil must be deep enough for water retention for plant growth. Structure must have adequate drainage.

- Local topography can be created on the surface with slight depressions and mounding of material used for fill.
- Amphibian habitat can be created in a stepping-stone fashion or by using isolated ponds. Pond habitat may be artificial with impermeable substrates to hold water from rainfall, or landscape designed areas for high water retention.
- Earth berms, solid walls, dense vegetation or a combination of these should be installed as sound- and light-attenuating walls on the sides of the structure. The walls should extend down to approach ramps and curve around to wildlife exclusion fence. The minimum height of walls should be 2.4 m.

***Local habitat management***

- Trees and shrubs should be located at the edges of approach ramps to guide wildlife to the structure entrance. The vegetation should integrate with the adjacent habitat. Adjacent lands should be acquired, zoned or managed as reserve or protected area into perpetuity.
- Wildlife overpasses are best situated in areas bordered by elevated terrain, enabling the approach ramps and surface of structure to be at the same level as the adjacent land. If the structure is built on level ground, then approach ramps should have gentle slopes (e.g., 5:1). One or both slopes may be steeper if built in mountainous areas.
- There is a trade-off between slope and retaining vegetative cover on approach ramps. A steep-sloped ramp will retain vegetative cover close to the overpass structure. Gentle slopes (3:1 or 4:1) generally require more fill, which extends the approach ramp farther out away from the structure and will bury vegetation, including trees.
- Wildlife fencing is the most effective and preferred method to guide wildlife to the structure and prevent intrusions onto the right-of-way. Mechanically stabilized earth walls, if high enough, can substitute for fencing and are not visible to motorists.
- Efforts should be made to avoid having roads of any type pass in front of or near the entrance to the wildlife overpass, as it will hinder wildlife use of the structure.
- Large boulders can be used to block any vehicle passage on the overpass.
- Existing or planned human development in adjacent areas must be at a sufficient distance to not affect long-term performance of the overpass. Long-range planning must ensure that adjacent lands will not be developed and the wildlife corridor network is functional.

**Possible variations**

- Vegetation for screening and fence

- Berms on approach ramps
- Berm in middle of overpass

## Maintenance

- Relatively low maintenance. Walls and any fences may need to be checked and repaired.
- During first few years it may be necessary to irrigate vegetation on the structure, particularly if there are extended periods with little rainfall. Sufficient watering (assisted or rainfall) will allow vegetation to settle and take root.
- Monitor and document any human use in the area that might affect wildlife use of the structure and take action necessary to control.

# Wildlife Underpasses SHEET B

## General design

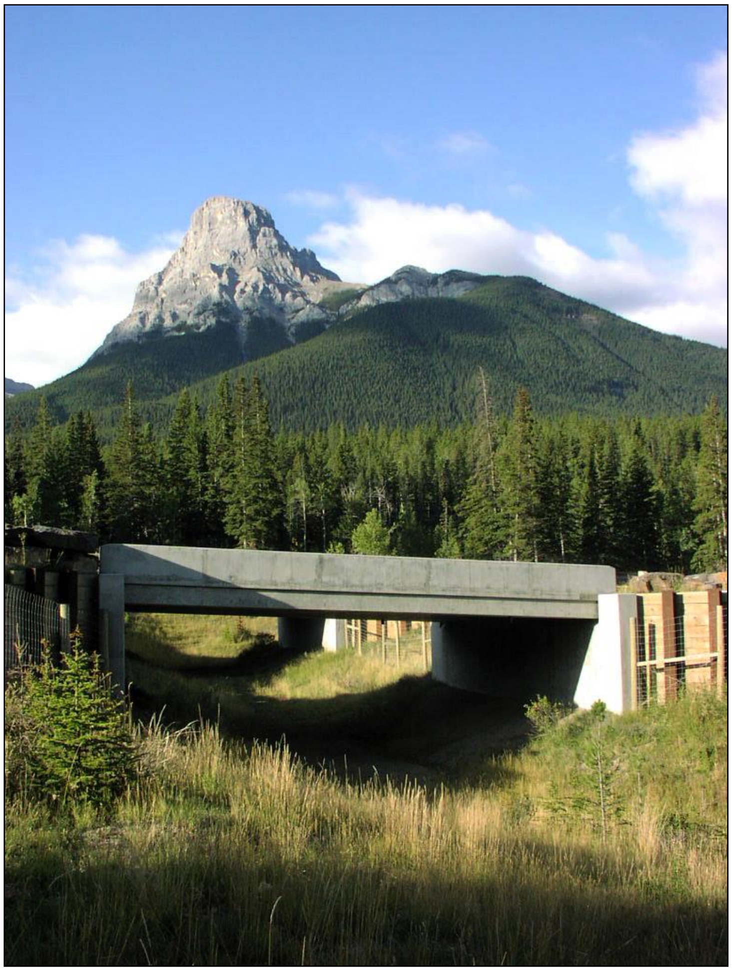
The wildlife underpass is not as large as most viaducts, but is the largest of underpass structures designed specifically for wildlife use. It is primarily designed for large mammals, but use by some large mammals will depend on how it may be adapted for their specific crossing requirements. Small- and medium-sized mammals (including carnivores) generally utilize these structures, particularly if cover is provided along walls of the underpass by using brush or root wads. These underpass structures can be readily adapted for amphibians, semi-aquatic and semi-arboreal species.

## Use of the structure

The wildlife underpass is designed exclusively for use by wildlife.

## General guidelines

- Being generally smaller than a viaduct or flyover, the ability to restore habitat underneath will be limited. Open designs that provide ample natural lighting will encourage greater development of native vegetation.
- To ensure performance and function, wildlife underpasses should be situated in areas with high landscape permeability that are known wildlife travel corridors and that experience only minimal human disturbance.
- Motor vehicle or all-terrain vehicle use should be prohibited. Eliminating public or any other human use, activity or disturbance at the underpass and adjacent area is recommended for its proper function and for maximizing wildlife use.
- Underpasses should be designed to conform to local topography. Design drainage features so flooding does not occur within the underpass. Highway runoff near structure should not be directed toward the underpass.
- Maximize continuity of native soils adjacent to and within the underpass. Avoid importation of soils from outside the project area.



*Open span wildlife underpass (Photo: Tony Clevenger).*

## Dimensions – General guidelines

*Width:*

Minimum: 7 m

Recommended: >12 m

*Height:*

Minimum: 4 m

Recommended: >4.5 m

## Types of construction

*Span*

Concrete bridge span (open-span bridge)

Steel beam span

*Arch*

Concrete bottomless arch

Corrugated steel bottomless arch

Elliptical multi-plate corrugated steel culvert

*Box culvert*

Prefabricated concrete

## Suggested design details

***Crossing structure***

- Structures should be designed to meet the movement needs of the widest range possible of species that live in the area or might be expected to re-colonize the area, e.g., high- and low-mobility species.
- Attempt to mirror habitat conditions found on both sides of the road and provide continuous habitat adjacent to and within the structure.
- Maximize microhabitat complexity and cover within the underpass using salvage materials (logs, root wads, rock piles, boulders, etc.) to encourage use by semi-arboreal mammals, small mammals, reptiles and species associated with rocky habitats.
- It is preferable that the substrate of the underpass is of native soils. If construction type has a closed bottom (e.g., concrete box culvert), a soil substrate $\geq$ 6 in (15 cm) deep must be applied to interior.
- Revegetation is possible in areas of the underpass closest to the entrance. Light conditions tend to be poor in the center of the structure.
- Design underpass to minimize the intensity of noise and light coming from the road and traffic.

***Local habitat management***

- Protect existing habitat. Design with minimal clearing widths to reduce impacts on existing vegetation. Where habitat loss occurs, reserve all trees, large logs, and root wads to be used adjacent to and within the underpass.
- Wildlife fencing is the most effective and preferred method to guide wildlife to the structure and prevent intrusions onto the right-of-way. Mechanically stabilized earth walls, if high enough, can substitute for fencing and are not visible to motorists.
- Encourage use of underpass by either baiting or cutting trails leading to the structure, if appropriate.
- Avoid building underpass in locations where a road runs parallel and adjacent to entrance, as it will affect wildlife use.
- If traffic volume is high on the road above the underpass it is recommended that sound attenuating walls be placed above the entrance to reduce noise and light disturbance from passing vehicles.


*Brush and root wads placed along underpass wall to provide cover for mammals (Photo: Nancy Newhouse).*

- Underpass must be within cross-highway habitat linkage zone and connect to larger corridor network.
- Existing or planned human development in adjacent area must be at sufficient distance to not affect long-term performance of underpass. Long-range planning must ensure that adjacent lands will not be developed and the wildlife corridor network is functional.

## Possible variations

Divided road (two structures)
    In-line
    Off-set:

Undivided road (one structure)

## Maintenance

- If wildlife underpass is not being monitored on a regular basis, periodic visits should be made to ensure that there are no obstacles or foreign matter in or near the underpass that might affect wildlife use.
- Fence should be checked, maintained and repaired periodically (minimum once per year, preferably twice per year).

# Fencing SHEET C

## General purpose

Wildlife exclusion fencing keeps animals away from roadways. However, fencing alone can isolate wildlife populations, thus creating a barrier to movement, interchange and limiting access to important resources for individuals and affecting the long-term survival of the population. Fencing is one part of a two-part mitigation strategy—fencing *and* wildlife crossing structures.

Fences keep wildlife away from the roadway and lead animals to wildlife crossings, thus allowing them to travel safely under or above the highway. Fences need to be impermeable to wildlife movement in order to keep traffic-related mortality to a minimum and ensure that wildlife crossings will be used. Defective or permeable fences result in reduced use of the wildlife crossings and increased risk of wildlife–vehicle collisions. Little research and best management practices exist regarding effective fence designs and other innovative solutions to keep wildlife away from roads.


*Wildlife exclusion fencing and culvert design wildlife underpass (Photo: Tony Clevenger).*

## Configurations

Fencing configuration used to mitigate road impacts will depend on several variables associated with the specific location, primarily adjacent land use and traffic volumes. Both sides of the road must be fenced (not only one side) and fence ends across the road need to be symmetric and not offset or staggered.

- *Continuous fencing* – Most often associated with large tracts of public land with little or no interspersed private property or in-holdings. <u>Advantages:</u> Long stretches of continuous fencing have fewer fence ends and generally few problems of managing wildlife movement ("end-runs") around multiple fence ends, as with discontinuous fencing (below). <u>Disadvantages:</u> Access roads with continuous fencing will need cattle guards, electro-mats, or gates to block animal access to roads (see Sheet C).
- *Partial (discontinuous) fencing* – More common with highway mitigation for wildlife in rural areas characterized by mixed land use (public and private land). Generally installed when private lands cannot be fenced. Partial fencing is recommended in locations like MRG where it is not feasible or there is a need to fence long sections of highway. <u>Advantages:</u> Generally accepted by public stakeholders. Few benefits to wildlife and usually the only alternative when there is mixed land use. <u>Disadvantages:</u> Results in multiple segments of fenced and unfenced sections of road, each fenced section having two fence ends. Additional measures need to be installed and carefully monitored to discourage end-runs at fence ends and hasten wildlife use of new crossing structures (see Terminations below). Earthen ramps or "jump-outs" are also needed in close proximity to fence ends in order to allow animals escape the fenced once inside (see Sheet C).

## Interceptions

Fences invariably intersect other linear features that allow for movement of people or transport materials. This can include access roads, but also recreational trails (people) and water (creeks, streams). These breaks or interceptions in the fence require special modifications in order to limit the number of wildlife intrusions into the right-of-way.

### *Roads*

*Texas Gates* – Transportation and land management agencies commonly install Texas Gates (also called cattleguards or cowcatchers) where fences intersect access roads. Many different designs have been used, but few have been tested for their effectiveness with wildlife. Designs of Texas Gates vary in dimension, grate material (flat or cylindrical steel grates), and grate adaptations for safe passage by pedestrians and cyclists. Recently a grate pattern was developed that was 95 percent effective in blocking Key deer movement and was safe for pedestrians and cyclists. Work by Allen et al. (2013) on fenced sections of US-93 in Montana showed that Texas gates were >85% effective in keeping deer from accessing the road and 93.5% of deer used the crossing structure instead of the adjacent wildlife guard when crossing the road (Allen, Huijser, and Willey 2013). The gates were less effective in keeping black bear and coyotes from accessing the road (33–55%). However, all black bears and 94.7% of coyotes used the crossing structure instead of the adjacent wildlife guard when crossing the road.

*Cattle guard (Texas gate) in road (Photo: Tony Clevenger).*

- *Electro-mats* – These electrified mats act like electric Texas Gates to discourage wildlife from crossing at the gap in the fence. Pedestrians wearing shoes and bicyclists can cross the mats safely, but dogs, horses and people without shoes will receive an electric shock. The electro-mats are generally 2-3 m wide, but can be designed to any width, and built into access roads where they breach fences. Cross-Tek® has been the lead company developing the e-mas and has had great success in high snowfall areas (Anchorage, Alaska) and dry areas (Arizona). They are currently designing and testing e-mats in Banff National Park.
- *Painted crosswalks* – Highway crosswalk structures have been used to negotiate ungulates across highways at grade level. White crosswalk lines are painted across the road to emulate a cattle guard. The painted crosswalk serves as a visual cue to guide ungulates directly across the highway. Painted crosswalks have not been tested, but if effective, they would be an inexpensive alternative to the more costly cattle guards. See Lenhert and Bissonette (1998) for more detail.

***Trails***

- *Swing gates (for fishermen, hikers)* – Where fences impede public access to popular recreation areas, swing gates can be used to negotiate fences. Gates must have a spring-activated hinge that ensures that even if the gate is left open it will spring back and close. In areas of high snowfall, gates may be elevated and steps built to keep the bottom of the gate above snow.

*Step gate with spring-loaded door situated at trailhead in Banff National Park, Alberta (Photo: Tony Clevenger).*

- *Canoe/kayak landings* – There are no known simple gate solutions for transporting canoes/kayaks through fences. The swing gate described above is one solution, although the gate should be slightly wider than normal to allow a wide berth suitable for moving canoes/kayaks. Gates must have a spring-activated hinge that ensures they remain closed after use.

### ***Watercourses***

- *Rubber hanging drapes* – Watercourses pose problems for keeping fences impermeable to wildlife movement, as their flow levels tend to fluctuate throughout the year. When water levels are low, gaps may appear under the fence material allowing wildlife to easily pass beneath. Having fencing material well within watercourses will cause flooding problems, as debris being transported will not pass through the fence and can eventually obstruct water flow. A solution to this problem would require having a device on the bottom of the fence that moves up and down with the water levels. This could be done by attaching hinged strips of rubber mat-like material, draping down from the bottom of the fence material into the water. The rubber strips are hinged, so they float on top of the water and move in the direction of flow.

## **Suggested design details**

### ***Mesh type, gauge and size***

Fence material may consist of woven-wire (page-wire) or galvanized chain-link fencing. Fence material must be attached to the back (non-highway) side of the posts, so impacts will only take down the fence material and not the fence posts.

- *Woven- or page-wire fencing* – Woven-wire fences consist of smooth horizontal (line) wires held apart by vertical (stay) wires. Spacing between line wires may vary from 8 cm at the bottom for small animals to 15–18 cm at the top for large animals. Wire spacing generally increases with fence height. Mesh wire is made in 11, 12, 12 ½, 14, and 16 gauges and fences are available in different mesh and knot designs. The square-shaped mesh may facilitate climbing by some wildlife, such as bears. If climbing is a concern then use of a smaller mesh is recommended.
  Wildlife fences along the Trans-Canada Highway in Banff National Park consist of 12 ½ gauge line wires with tensile strength of 1390 N/sq. mm. Stay wires have a tensile strength of 850 N/sq. mm. All wires had Class III zinc galvanized coating (see below) at a minimum of 260 gms/sq. m.
- *Chain-link fencing* – Chain-link fence is made of heavy steel wire woven to form a diamond-shaped mesh. It can be used in various industrial, commercial and residential applications. Chain-link was used for highway mitigation fencing along I-75 and SR 29 in Florida. There have been agency and public concerns about the visual aesthetics of chain-link fencing compared to woven-wire as it is less attractive and does not blend into the landscape. Steel posts are always used with chain-link fencing. Chain-link fence fabrics can be galvanized mesh, plastic-coated galvanized mesh or aluminum mesh.

- Most wire sold today for fencing has a coating to protect the wire from rust and corrosion. Galvanizing is the most common protective coating. The degree of protection depends on thickness of galvanizing and is classified into three categories; Classes I, II, and III. Class I has the thinnest coating and the shortest life expectancy. Nine-gage wire with Class I coating will start showing general rusting in 8 to 10 years, while the same wire with Class III coating will show rust in 15 to 20 years.
- *Electrified fencing* – Electric fences are a safe and effective means to deter large wildlife from entering highway right-of-ways, airfields and croplands. The 2-m-high fence will deliver a mild electric shock to animals that touch it, discouraging them from passing through. It is made of several horizontal strands of rope-like material about 1 cm in diameter that can deliver a quick shock that is enough to sting, but not seriously harm humans. Wildlife respond differently to standard electric fences; high voltage fences are generally required to keep bears away. There are public safety issues of having electrified fencing bordering public roads and highways as there is high likelihood that people will come into contact with the fence (fishermen, hikers, motorists that run into fence).

***Post types***

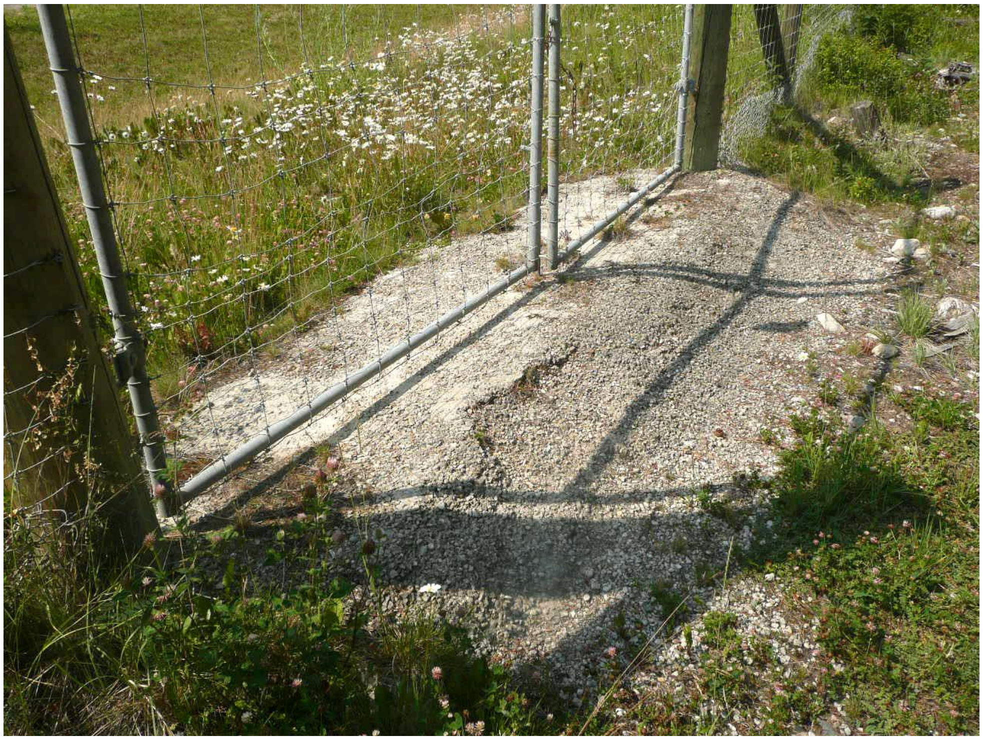
- *Wood* – Wood posts are commonly used and can be less expensive than other materials if cut from the farm woodlot or if untreated posts are purchased. Post durability varies with species. For example, osage orange and black locust posts have a lifespan of 20 to 25 years whereas southern pine and yellow poplar rot in a few years if untreated.
- The life expectancy of pressure-treated wooden posts is generally 20 to 30 years depending on the type of wood. Softwoods are the most common wood used for posts when fencing highways. Lodgepole pine and Jack pine are common tree species for fence posts. For Trans-Canada Highway wildlife fences, all round fence posts were pressure treated with a chromate copper arsenate (CCA) wood preservative.
- Wood posts are highly variable in size and shape. For typical 2.4-m-high fencing, non-sharpened wooden posts 3.7 m and 4.2 m long are used. Fence posts are sharpened and then installed by preparing a pilot hole approximately 125 mm in diameter, vibrating the post down to specified post height and backfilling around the post with a compacted non-organic material to ground level. The strength of wood posts increases with top diameter. Post strength is especially important for corner and gate posts, which should have a top diameter of at least 16 cm. Line posts can be as small as 13 cm and should not need to be more than 14 cm on top diameter, although larger diameter posts make fences stronger and more durable.
- *Steel* – Steel posts are used to support fences when crossing rock substrate. They weigh less and last longer than wood posts; the main disadvantage is they are more expensive than wood posts. Steel posts are supplied in 3.7 m lengths and installed in concreted 1000-mm-long sleeves for the 3 m x 8 cm steel posts.

- Tension – Tension between posts can consist of metal tubing on metal posts and reinforced cable on wooden posts.

## Reinforcements

- *Unburied fence* – Unburied fences are used in areas where resident wildlife are not likely to dig under the fence. The fence material should be flush with the ground to minimize animals crawling beneath the fence and reaching the right-of-way.
- Buried fence – This is strongly recommended in areas with wildlife capable of digging under the fence (e.g., bears, canids, badgers, wild boar). Buried fence in Banff National Park significantly reduced wildlife intrusions to the right-of-way compared to unburied fence (Clevenger et al. 2002). Buried fence consists of a 1- to 1.2-m-wide section of galvanized chain-link fence spliced to the bottom of unburied fence material. The chain-link section is buried at a 45-degree angle away from the highway and is approximately 1.1 m below ground. Swing gates should have a concrete base to discourage digging under them.
- Cable (protective) – Trees blown onto fences can not only damage fence material but provide openings for wildlife to enter the right-of-way. This is typically a problem during the initial years after construction, but can continue over time. A high-tensile cable strung on top of fence posts to help break the fall of trees onto the fence material should reduce fence damage, repair costs and maintenance time.

*Wildlife exclusion fence with buried apron (Photo: Tony Clevenger).*



*Concrete base of swing gate to prevent animal digging under wildlife fence (Photo: Tony Clevenger).*

*High tensile cable designed to break fall of trees onto fence material (Photo: Tony Clevenger).*

## Terminations

Fence ends are notorious locations for wildlife movements across roads and, thus, for accidents with wildlife. The problem is more acute soon after fence installation as wildlife are confused, unsure where to cross the road, and tend to follow fences to their termination, and then make end-runs across the road or graze inside the fence.

Each mitigation situation is different and will require a site-specific assessment, but as a general rule, fence ends should terminate at a wildlife crossing structure.
If a wildlife crossing cannot be installed at the fence ends, then fences should be designed to terminate in the least suitable location or habitat for wildlife movement—i.e., places wildlife are least likely to cross roads. Some examples are:

- Steep, rugged terrain such as rock-cuts (bighorn sheep and mountain goats excluded).
- Habitats that tend to limit movement, e.g., open areas for forest-dwelling species.
- Human-altered habitats and areas with frequent human activity and disturbance.

Placing animal-detection systems (see Sheet A) at fence ends has been an effective method of alerting motorists of wildlife approaching or crossing roads at fence terminations. The most rigorous testing of the system took place over a 3-year period in Arizona. Overall, the animal-detection system and associated warning signs met their objective of modifying driver behavior by reducing speeds between 14-18%, (8-10 mph), thereby reducing the risk of collision with wildlife (J.W. Gagnon et al. 2010). They encountered few instances when their roadside animal-detection system and signs were inoperable; overall, their "crosswalk" system performed properly on 93% of their test visits. Motorist warning signs activated 98% of the time for both species at some point following the presence of animals in the detection zone. Overall, the system exhibited a relatively minimal amount of false positives or false negatives; following final modifications to the system, the amount of time the system was not operable was negligible (J.W. Gagnon et al. 2010).

## Dimensions – General guidelines

Highway fencing for large mammals, including most native ungulate species of moose, elk, deer, and bighorn sheep, should be a minimum of 2.4 m high with post separation on average every 4.2 to 5.4 m. In some cases the fence height may not need to be designed for large ungulates. Alternate fence design and specifications will need to reflect not only requirements for species present, but also species that may re-colonize or disperse into the area in the future.
Fencing is an important component of a successful and functional mitigation scheme. However, in high snowfall areas standard fencing guidelines have been modified to address snow-load problems with fence posts and material (mesh type). These issues are a concern throughout many parts of the MRG study area, but less so in lower sections.

For previous work planning mitigation on highways in high snowfall areas we consulted colleagues working for the Norwegian Directorate of Transportation (Oslo, Norway) who have worked with mitigation fencing for wildlife in areas with high snowfall. Bjørn Iuell prepared some guidelines currently being used in Norway with regard to fence mesh size, poles, distance between poles and fence height (see Appendix C). We have included those guidelines as an Appendix to this report. Colleagues working for the Swedish Road Administration and Norwegian Directorate of Transportation (Oslo, Norway) will be able to provide valuable information on fence designs for parts of the Trans-Canada Highway in MRG. Raised mechanically stabilized earth (MSE) walls may be an option in places where the walls function as fences to block animal movement onto the highway and guide animals to crossing structures (see photo of MSE wall in Sheet E).

## Maintenance

- Fences are not permanent structures, nor are they indestructible. They are subject to constantly occurring damage from vehicular accidents, falling trees, and vandalism. Natural events also cause damage and threaten the integrity of the fence. Soil erosion, excavation by animals, and flooding can loosen fence posts and collapse portions of fencing.
- Fences must be checked every six months by walking entire fence lines, identifying gaps, breaks and other defects caused by natural and non-natural events.

# Gates and Ramps SHEET D

## General purpose

If wildlife become trapped inside the fenced area, they need to be able to safely exit the highway area. The most effective means of escape are through a steel swing gate or an earthen ramp or "jump-out". The number, type and location of escape structures will depend on the target species, terrain and habitat adjacent to the highway fence.

*Escape ramp (jump-out) for wildlife trapped inside highway right-of-way (Photo: Tony Clevenger).*

## Application

- *Swing gates* are generally used (with or without ramps) in areas where highways are regularly patrolled by wardens/rangers. As part of their job, if wildlife are found inside the fence, the nearest gates are opened and animals are moved towards the opened gate. Double swing gates are more effective than single swing gates, especially for larger mammals such as elk or moose. Swing gates are used to remove ungulates and large carnivores (e.g., bears). In high snowfall areas swing gates will be rendered ineffective until snow melts and gates can swing open and closed.

*Single swing gate in wildlife exclusion fence (Photo: Tony Clevenger).*

- *Earthen ramps or jump-outs* allow wildlife (large and small) to safely exit right-of-ways on their own without the aid of wardens or rangers. Typically wildlife find the ramps and exit by jumping down to the opposite side of fence. Deer and elk are the most common users, but moose, bighorn sheep, bears and cougars use these structures as well. The outside walls of the escape ramp must be high enough to discourage wildlife from jumping up onto the ramp and accessing the right-of-way. However, the walls should not be so high they discourage wildlife from jumping off. The landing spot around the outside wall must consist of loose soil or other soft material to prevent injury to animals. The outside walls must be smooth to prevent bears or other animals from climbing up. For best use, escape ramps should be positioned in a setback in the fence, in an area protected with dense vegetative cover, so animals can calm down and look over the situation before deciding to use the jump out or continue walking along the fence. A right-angle jog in the fence is recommended for positioning the escape ramp but not necessary.

  Earthen ramps or jump-outs have an important function at fence terminations. Fence ends are typically problematic as wildlife occasionally perform “end runs”, which may lead to having wildlife inside the fenced right-of-way. Fence end problems can be corrected by ensuring that there are at least two jump-outs (one on each side of highway) near each fence end. If wildlife get inside the fenced section of a highway they typically travel close to the fence searching for an exit. By having a jump-out in close proximity to the fence end maximizes the chances that the animal will find the jump-out and exit the right-of-way.

*Wildlife"junp-out" escape ramp (Photo: Tony Clevenger).*

## Maintenance

- Like fences, gates and ramps are not permanent structures, nor are they indestructible. They are subject to constantly occurring damage from vehicular accidents, falling trees, and vandalism. Natural events also can cause damage, obstruct gates and affect how well they perform.
- Like fences, escape structures must be checked every six months to ensure that they are functioning properly and that they perform when needed. Maintenance checks should take place at the same time as fence inspections.

# Animal Detection Systems SHEET E

## General purpose

Animal detection systems use sensors to detect large animals that approach the road. Once a large animal is detected, warning signals are activated to inform the drivers that a large animal may be on or near the road at that time. The warning signals are time specific—that is, they warn of specific detection events rather than warn of the possibility that animals may be in the area. These systems have been installed in more than 50 locations in North America and Europe.


*Animal detection system along Highway 191 in Yellowstone National Park, Montana (Photo: Marcel Huijser, WTI).*

## System types

There are two broad categories commonly used in animal detection systems: area-cover systems and break-the-beam systems.

*Break-the-beam sensors* detect large animals when their body blocks or reduces a beam of infrared, laser or microwave radio signals sent by a transmitter to a receiver.

*Area-cover systems* detect large animals within a certain range of a sensor. Area coverage systems can be passive or active. Passive systems detect animals by only receiving signals. The two most common systems are passive infrared and video detection. These systems require algorithms that distinguish between, e.g., moving vehicles with warm engines and moving pockets of hot air, and movements of large animals. Active systems send a signal over an area and measure its reflection. The primary active area coverage system uses microwave radar.

Area-cover systems are radar-based and contain four key components, solar panel array, the radar, a control enclosure and flashing signage.

The radar is the sensing component that detects and tracks the animals until it leaves the predetermined tracking area. It is pole mounted at various heights and spaced at approximately 350 meters between adjacent radars. The radar will operate in any environment and is not affected by snow, ice, rain, etc.

The radar has a relay output that actuates when an animal is present in the defined tracking area.
The relay closure condition is sent wirelessly to the flashing beacons, which house a controller for adjusting the flash conditions.

The radar also has an internal log that can be retrieved via Ethernet on site at the control enclosure of the radar. All of the time-stamped data from system operation can be downloaded via Ethernet or wirelessly. When coupled with video cameras it is possible to analyze system performance, i.e., proportion of false negative and false positives compared to true operation.

The radar is controlled by a small-embedded computer located in the control enclosure. The battery bank is charged by the solar panel array and charge controller and has been designed to provide approximately 3 days of operation without sunlight before the batteries will be depleted beyond 50% of their charge. In areas without sufficient sunlight the system can be tied into existing power typically running alongside the highway, as is the case in MRG.

## Effectiveness

The effectiveness of animal detection systems has been investigated with regard to a potential reduction in vehicle speed and a potential reduction in animal–vehicle collisions. Previous studies with earlier models have shown variable results: substantial decreases in vehicle speed, minor decreases in vehicle speed, and no decrease or even an increase in vehicle speed. This variability in the results appeared to be related to various conditions, namely, type of warning signal and signs, whether the warning signs are accompanied with advisory or mandatory speed limit reductions, road and weather conditions, whether the driver is a local resident, and perhaps also cultural differences that may cause drivers to respond differently to warning signals in different regions.

Some work in Switzerland has been done reporting on the number of animal–vehicle collisions before and after seven infrared area cover detection systems were installed. These systems reduced the number of animal–vehicle collisions by 82 percent on average. Similar results in collision reductions were found for radar-based systems installed by the Ministry of Transportation in Ontario to reduce moose-vehicle collisions. The radar-based system is proving more reliable and effective at reducing wildlife-vehicle collisions. This system is recommended for use on the Trans-Canada Highway in MRG to reduce collision rates: 1) with mountain goats at locations where goats lick salt on the highway (snow sheds and areas not associated with snow sheds) and 2) at fence ends.

While the data on the effectiveness of animal detection systems are encouraging, animal detection systems should still be regarded as an experimental mitigation measure rather than a measure that will reduce wildlife–vehicle collisions in the short term with a high degree of certainty.

*Information on testing radar-based animal-detection systems in Canada were published in a New York Times article in 2013 (November 1, 2013; “Canada Tests Animal Detectors”).

## Case studies and contacts

For a general overview of technology, reliability and effectiveness, contact Marcel Huijser, Western Transportation Institute, PO Box 174250, Bozeman, Montana 59717-4250, (406)543-2377, mhuijser@coe.montana.edu.

For information about a field study on the effectiveness of animal detection systems, contact Christa Mosler-Berger, Wildtier Schweiz, Strickhofstrasse 39, 8057 Zürich, Switzerland, wild@wild.unizh.ch.

For more information about the animal detection system and wildlife fencing along State Route 260 in Arizona, contact Norris Dodd, Wildlife Connectivity Program Coordinator, Arizona Department of Transportation, 1611 W. Jackson Street MD EM04, Phoenix, Arizona 85007, (480) 271-4334, NDodd@azdot.gov.

Manufacturer: Blake Dickson, VP Sales and Marketing, Rotalec, 177 Blossom Avenue East, Unit A, Brantford, Ontario N3T 5L9, (519) 753-5100 ext 427, Blake.Dickson@rotalec.com, http://www.rotalec.com/.

## Direct benefits

The available data on the effectiveness of animal detection systems show a reduction in collisions with large animals of 82 percent, which is substantial. This percentage may change as systems improve over time and more data become available from testing systems in place.

## Indirect benefits

Animal detection systems do not restrict animal movements when deployed over long distances.

## Undesirable effects

Animal detection systems can reduce collisions with large animals, but the presence of poles and equipment in the right-of-way can be a potential hazard to vehicles that run off the road.

## Costs

Estimated costs of these systems range from $ 100,000 - $300,000 per km excluding installation costs (unpublished data, Marcel Huijser, Western Transportation Institute – Montana State University). The costs for the equipment will be higher if the road section concerned has curves or slopes, or if the line of sight in the right-of-way is blocked by objects.

# Wildlife Underpasses with Water Flow SHEET F

## General design

This is an underpass structure designed to accommodate dual needs of moving water and wildlife. Structures are generally located in wildlife movement corridors given their association with riparian habitats; however, some may be only marginally important. Structures aimed at restoring proper function and connection of aquatic and terrestrial habitats should be situated in areas with high landscape permeability, that are known wildlife travel corridors and that experience only minimal human disturbance. These underpass structures are frequently used by several large mammal species, yet use by some large mammals will depend on how it may be adapted for their specific crossing requirements. Small- and medium-sized mammals (including carnivores) generally utilize these structures, particularly if riparian habitat is retained or cover is provided along walls of the underpass by using logs, brush or root wads. These underpass structures can be readily adapted for amphibians, semi-aquatic and semi-arboreal species.

*Wildlife underpass designed to accommodate water flow (Photo: Tony Clevenger).*

## Use of the structure

Exclusively for wildlife, but may have some human use.

## General guidelines

- Underpass structure should span the portion of the active channel migration corridor of unconfined streams needed to restore floodplain, channel and riparian functions.
- If underpass structure covers a wide span, support structures should be placed outside the active channel.
- Design underpass structure with minimal clearing widths to reduce impacts on existing vegetation.
- Even with large span structures the ability to restore habitat underneath will be limited. Open designs that provide ample natural lighting will encourage greater development of important native riparian vegetation.
- Maximize the continuity of native soils adjacent to and within the underpass. Avoid importation of soils from outside project area.
- Motor vehicle or all-terrain-vehicle use should be prohibited. Eliminating public or any other human use, activity or potential disturbance at the underpass and adjacent area is recommended for proper function and maximizing wildlife use.
- Underpass should be designed to conform to local topography. Design drainage features so flooding does not occur within underpass. Run-off from highway near structure should not end up in underpass.

## Dimensions – General guidelines

Dimensions will vary depending on width of active channel of water flow (creek, stream, river). Guidelines are given below for dimensions of wildlife pathway alongside active channel and height of underpass structure.

*Minimum:*

Width: 3 m pathway
Height: 3 m

*Recommended:*

Width: >3 m pathway
Height: >4 m

## Types of construction

Concrete bridge span (open-span bridge)
Steel beam span
Concrete bottomless arch

## Suggested design details

### *Crossing structure*

- Structures should be designed to meet the movement needs of widest range possible of species that live in the area or might be expected to re-colonize the area—e.g., high- and low-mobility species.
- Attempt to mirror habitat conditions found on both sides of the road and provide continuous riparian habitat adjacent to and within the structure.
- Maximize microhabitat complexity and cover within underpass using salvage materials (logs, root wads, rock piles, etc.) to encourage use by semi-arboreal mammals, small mammals, reptiles and species associated with rocky habitats.
- Preferable that the substrate of underpass is of native soils.
- Revegetation will be possible in areas of underpass closest to the entrance, as light conditions tend to be poor in the center of the structure.
- Design underpass to minimize the intensity of noise and light coming from the road and traffic.

***Local habitat management***

- Protect existing habitat. Design with minimal clearing widths to reduce impacts on existing vegetation. Where habitat loss occurs, reserve all trees, large logs, and root wads to be used adjacent to and within the underpass.
- Wildlife fencing is the most effective and preferred method to guide wildlife to structure and prevent intrusions to the right-of-way. Mechanically stabilized earth walls, if high enough, can substitute for fencing and is not visible to motorists.
- Encourage use of underpass by either baiting or cutting trails leading to structure, if appropriate.
- Avoid building underpass in a location with road running parallel and adjacent to entrance, as it will affect wildlife use.
- If traffic volume is high on the road above the underpass it is recommended that sound attenuating walls be placed above the entrance to reduce noise and light disturbance from passing vehicles.
- Underpass must be within cross-highway habitat linkage zone and connect to larger corridor network.
- Existing or planned human development in adjacent area must be at sufficient distance to not affect long-term performance of underpass. Long-range planning must ensure that adjacent lands will not be developed and the wildlife corridor network is functional.

*Mechanically stabilized earth (MSE) wall serving as wildlife exclusion "fence" (Photo: Tony Clevenger).*

## Possible variations

Divided road (two structures)

In-line:

Undivided road (one structure)

## Maintenance

- If the wildlife underpass is not being monitored on a regular basis, periodic visits should be made to ensure that there are no obstacles or foreign matter in or near the underpass that might affect wildlife use.
- Fence should be checked, maintained and repaired periodically (minimum once per year, preferably twice per year).