TRANS-CANADA HIGHWAY AND DEAD MAN'S FLATS UNDERPASS: IS HIGHWAY MITIGATION COST EFFECTIVE?

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ABSTRACT

A study of a 39 kilometer section of the Trans-Canada Highway (TCH) directly east of Banff National Park in Alberta, Canada evaluated the best locations to mitigate the effect of the TCH on the local wildlife populations and provide for reductions in wildlife-vehicle collisions (WVCs). In addition, the study conducted cost-benefit analyses to show where investments in mitigation may provide a net savings to society. Lastly, the study evaluated the cost savings associated with the development of an underpass and fencing within the study area using 6 years of pre and post construction data.

The total number of WVCs for the study section between 1998 and 2010 was 806 or an average of 62 WVCs per year. This amounts to an average cost-to- society of $640,922 per year due to motorist crashes with large wildlife, primarily ungulates. Results indicate there are ten sites where mitigation measures would address a combination of values: local and regional conservation needs, high WVC rates, land security (can't be developed). Of the 10 mitigation emphasis sites (MES) that were identified, five had average annual costs exceeding $20,000 per year due to WVCs making each of these an excellent candidate for cost effective mitigation measures.

An analysis of a wildlife underpass with fencing at a 3 km section of the TCH within the project area near Dead Man's Flats showed that total WVCs dropped from an annual average of 11.8 preconstruction to an annual average of 2.5 WVCs post-mitigation construction. The wildlife crossings and fencing reduced the annual average cost by over 90%, from an average of $128,337 per year to a resulting $17,564 average per year.

INTRODUCTION

The Bow Valley consists of a complex array of human residential developments and associated land-use activities, a major transportation corridor (Highway 1, the Trans-Canada Highway and the Canadian Pacific railway) and an active rock mining industry. The Trans-Canada Highway (TCH) has been identified as one important barrier to wildlife movement and a source of mortality for wildlife in the region. The purpose of this study is to identify areas along the TCH from the junction of Highway 40 to the Banff National Park (BNP) East Gate where transportation mitigation for wildlife needs to be considered. Transportation mitigation is an important strategy for improving human safety and ensuring connectivity across the TCH for wildlife species. The success of transportation mitigation measures has been well documented as an effective strategy to reduce wildlife-vehicle collisions and facilitate wildlife movement.

Prioritizing highway segments where mitigation needs to be considered is important to assist transportation planners in decision making around mitigation. The species concerned, the nature of the terrain, and the land security (potential for development) all influenced the prioritization of highway segments that could receive mitigation measures. An important concern from transportation planners has been the costs associated with implementing transportation mitigation measures for wildlife. Cost-benefit analyses of mitigation measures allow for insight in the financial aspects of wildlife-vehicle collisions and their mitigation measures. It may also be useful in the potential future decision process on whether to implement mitigation measures.

STUDY AREA

The study area for this project includes a 38 km stretch of the TransCanada Highway (TCH) from the junction of the TCH with Highway 40 to Banff National Park East Gate (Figure 1). This stretch of the TCH runs along a rare east-west corridor, the Bow Valley, within a landscape dominated by north-south mountain ridges in the Canadian Rockies. The Bow Valley represents high quality low elevation wildlife habitat in a mountain landscape where ice and rock are common. The region is both home and a travel corridor for the full complex of Canadian large mammals including grizzly bear, lynx, cougar, wolves, bobcats, wolverine, bighorn sheep, elk, deer and moose.

Much of the Bow Valley is protected, with BNP to the west, and to the east, west and south by the Canmore Nordic Centre, Bow Valley and Spray Valley Provincial Parks. However, in the valley bottom, wildlife in the region competes for space with numerous land uses and activities from the local population and the large urban center of Calgary. The Bow Valley is a beautiful place to live and supports the town of Canmore (17,000 residents and growing) as well as the hamlets of Dead Man's Flats, Lac Des Arcs, Exshaw and Harvie Heights. There is a well development assortment of trails and facilities thorough out the region to support a large recreational tourism industry. Other land-uses include an active rock mining industry, four-lane TCH connecting Canada from the East Coast to the West Coast with annual daily traffic volumes of 21,500 around Canmore and the Canadian Pacific Railway, a two-line railway supporting upward of 40 trains a day. All these activities, changes in land use and natural topography combined to create a complex landscape for wildlife to navigate.

Wildlife research in the area highlights the complexity and limitations of wildlife movement through the Bow Valley due to human activity and natural barriers (Whittington and Forshner 2009, Percy 2003). Therefore reducing WVCs along the TCH and facilitating safe movement across the TCH is an important contribution for maintaining wildlife in the region.

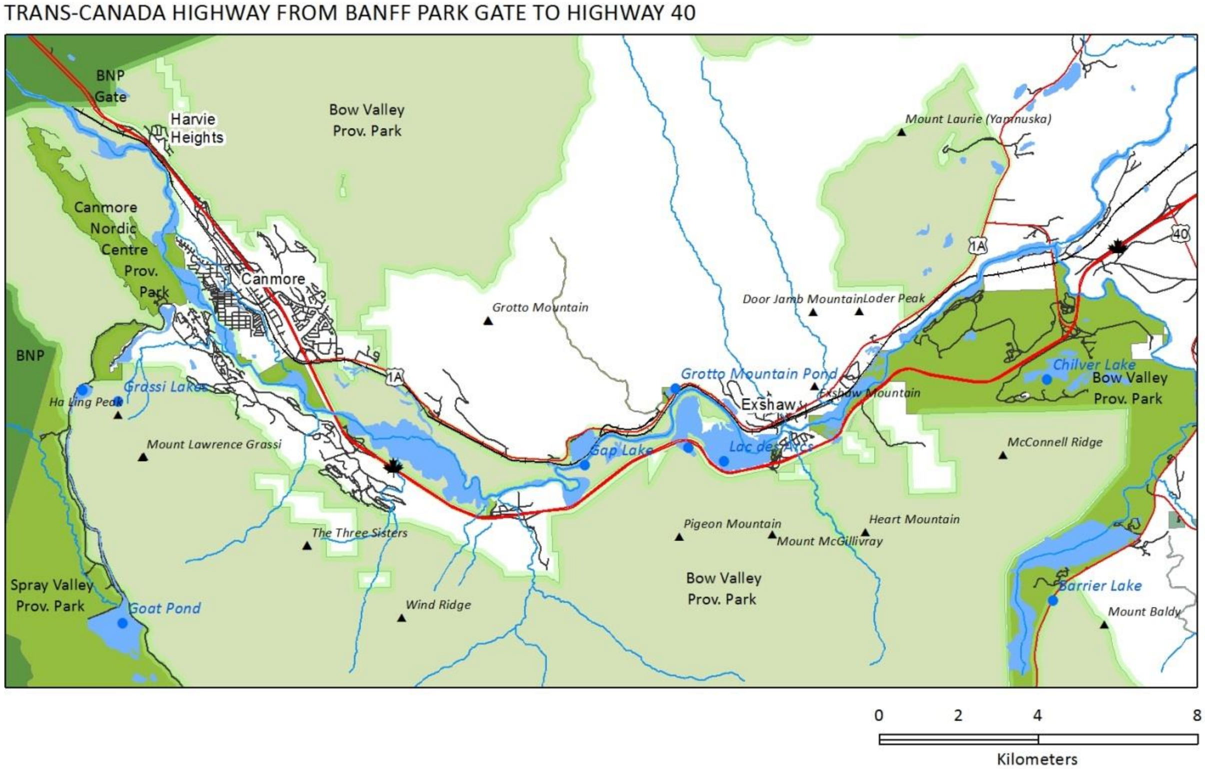

FIGURE 1: Map of study area.

WILDLIFE VEHICLE COLLISION ASSESSMENT

In this section we highlight the current state of knowledge of wildlife-vehicle collisions (WVCs) along the TCH from the junction with Highway 40 to BNP's East Gate. We identify highway segments (units are in one kilometer sections) where there are high numbers of WVCs. This information was one aspect that was used to help select the highway segments where mitigation should be considered, the project uses the term mitigation emphasis site (MES).

One of the complexities of quantifying the rate of wildlife mortality from collisions with vehicles along the TCH is the lack of a systematic and standardized data collection system. The data used in this analysis is from 1998-2010, and was acquired from five sources; Table 1 describes the different data collection systems and the years in which the data was collected using these different systems. In addition many of the records where not confirmed by Alberta Environment and Sustainable Resource Development (AESRD) staff and the accuracy of the location is therefore unknown.

TABLE 1 Sources of wildlife-vehicle collision data for the project area.

Year	Data sources
1998	Clevenger[1]
1999	Clevenger, ENFOR[2]
2000	Clevenger, ENFOR
2001	Clevenger, ENFOR
2002	Clevenger, ENFOR,
2003	Clevenger, ENFOR, WOD[3]
2004	Clevenger, WOD
2005	Clevenger, WOD
2006	KES[4], ENFOR, Logbook[5]
2007	KES, ENFOR, Logbook
2008	KES, ENFOR, Logbook
2009	KES, ENFOR, Logbook
2010	KES, ENFOR, Logbook

[1] Clevenger – Data collected by Tony Clevenger systematically from April to October 1998 to 2002. Other months (Nov-March) and from 2003 to 2005 data were collected by Alberta Environment and Sustainable Resource Development (AESRD) Fish and Wildlife.
[2] ENFOR - Enforcement Occurrence Record database, information collected by AESRD Fish and Wildlife Officers and Parks Conservation Officer. When they encounter road kill or respond to a public call about a WVC, the officer is required to fill out an ENFOR Occurrence record.
[3] WOD - Wildlife Observation Database, includes records from public calling in a road kill either directly to Kananaskis Emergency Services (KES) or to the AESRD office. Officers and other staff will also on occasion call in road kill information to KES.
[4] KES - Kananaskis Emergency Services database replaced WOD in 2006.
[5] Logbook - a logbook of road kill information maintained in the AESRD office of records of wildlife sightings and moralities witnessed by staff.

Only one of the systems for a short period of time, collected data systematically, the others are all based on opportunistic sightings and rely on the observations and reporting by concerned local citizens or government staff. This data analysis therefore has the following limitations;

- True rates of WVCs occurring along the TCH in the study area and within each highway segment is unknown; and
- Location error for many of the WVC records is unknown.

Data was provided by Alberta Environment and Sustainable Resource Development (AESRD), Fish and Wildlife and Alberta Parks in 2 datasets; 1998-2005 and 2006-2010. The data sets were cleaned (duplicates removed and locations added) by AESRD or Alberta Parks personal.

Data was processed to generate the average number of WVCs for this 39 km stretch of TCH, as well for each species including both known and unknown locations. These numbers (known and unknown) were used to calculate an annual rate of WVCs, species involved in WVCs and a conservative estimate of the total costs of ungulate vehicle collisions for this the section of the TCH in the project area.

The total number of WVCs along the average number of WVCs recorded on the TCH from Highway 40 to BNP East Gate, a 39 km stretch, is approximately 62 wildlife mortalities annually. The actual mortality rate is likely higher due to a number of factors reducing observer's ability to record all mortalities associated with WVCs. For example, injured wildlife may move away from the road, vegetation may obscure the carcass, a predator or human may remove the carcass from the roadway before it is recorded. It is therefore likely that the datasets used in this analysis are in-accurate in terms of magnitude of the number of wildlife mortalities occurring along the TCH.

Mortality Clusters

To identify highway segments where WVCs mortality clusters occur, the TCH was divided into one kilometer (km) segments. Known WVC location data was enumerated to each km section along TCH. A moving window approach was used to calculate a mortality value for each segment, where by each segment was equated to a sum of itself and its two neighbouring segments. Therefore, the wildlife mortality value was representative of a 3-km long section "moving window".

Mortality values were classified using a quintile approach, whereby segments with zero were removed from the analysis and segments with mortality values were categorized into percentiles where "very high" represents the 81-100 percentile (top 20% of WVCs), "high" represents the 61-80 percentile and "medium" are WVC annual rates within the 41-60 percentile.

The method to identify mortality clusters is simply based on identifying the highway segments that have the highest frequency of wildlife-vehicle crashes. The mortality clusters that are identified do not necessarily meet a national standard or provincial norm. The procedure described above only identifies the road sections with most wildlife vehicle collisions for the highway segments along the TCH included in the analysis. Wildlife-vehicle collisions also occur outside of the mortality clusters, but less frequently.

The identification of highway segments (1-km in length) classified into percentiles of very high, high and medium wildlife mortality rates are displayed in Figure 4. Along the TCH, seven kilometers of the highway were classified as *very high* mortality clusters, representing 18% of the study area, while 15 km of the highway were classified as *high* mortality clusters and represented 22% of the Highway in the study area (Figure 2).

It is difficult to compare the rates of WVCs along this section of the TCH with other areas in the province of Alberta's transportation system due to inconsistencies in data collection across the province. Alberta Transportation may want to consider developing a consistent data collection methodology for the province that would enable a review of the very high to medium wildlife vehicle collision zones from a provincial perspective and enable planners and decision makers to better prioritize transportation mitigation strategies across the province. Only highway segments within the top 40% percentile (high and very high) of WVC's were considered in the identification of site specific mitigation sites along this stretch of the TCH.

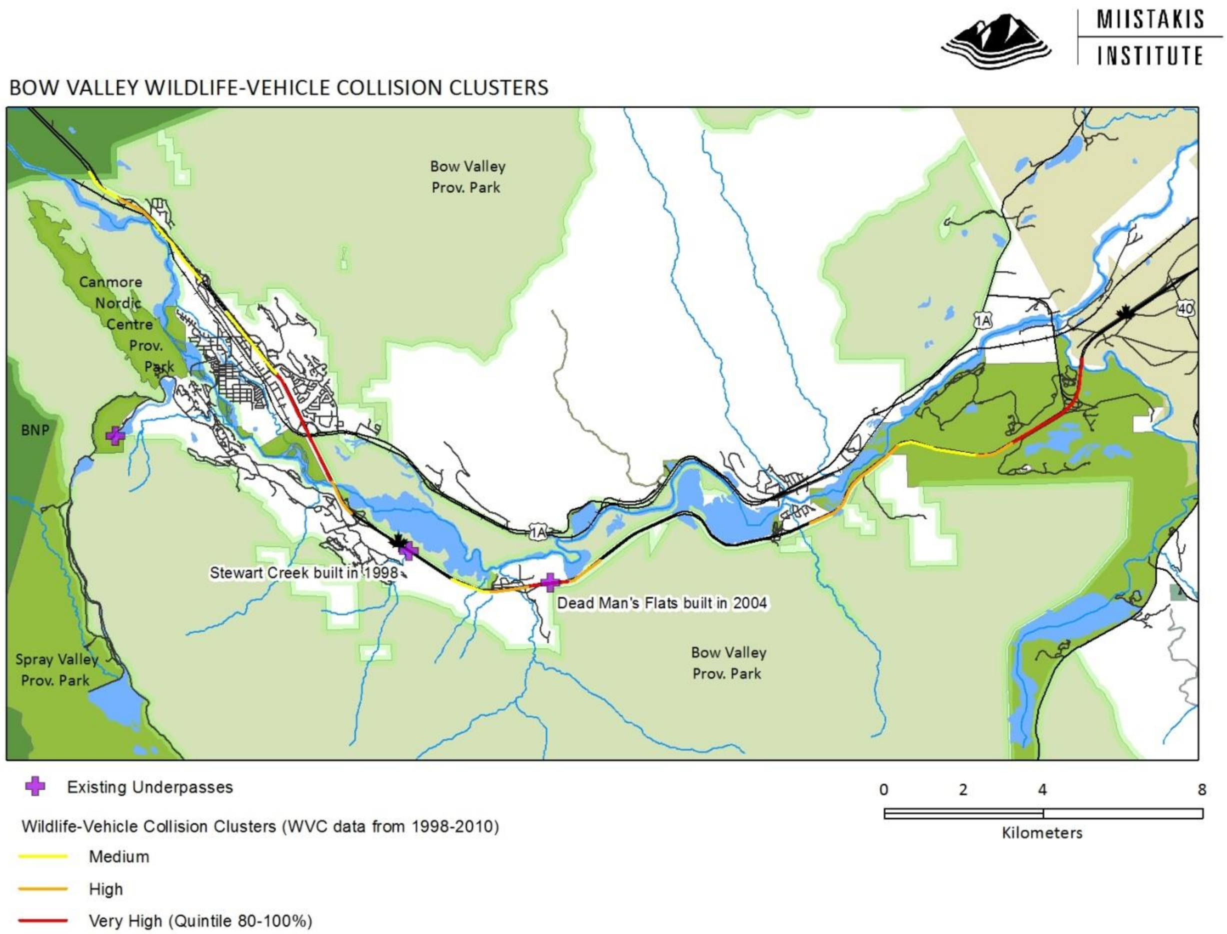

FIGURE 2 Wildlife-vehicle collision clusters of medium, high to very high crash rates (those in the 41-60, 61-80 and 81-100 percentile groups, respectively) on the TransCanada Highway within the project area.

IDENTIFYING MITIGATION EMPHASIS SITES

One of the objectives of this project was to identify sites within the study area that are important for wildlife conservation; such as wildlife movement corridors, areas of high mortality due to WVCs and areas where land-use was compatible with investments to mitigate the highway to increase permeability for wildlife. A review of morality clusters and a synthesis of research on wildlife connectivity sites were assessed by the research team and 10 mitigation emphasis sites (MESs) were identified (Figure 3). Each MES was appraised for its appropriate location and then tested for its inclusion into the study via a field review.

To determine where wildlife connectivity is important along the TCH, we used the existing wildlife corridors and habitat patches developed by the Bow Corridor Ecosystem Advisory Group (BCEAG) (Figure 2) (BCEAG 1998). In addition, the following reports were considered when identifying the location of MESs;

- Whittington, J. and A. Forshner. 2009. An analysis of wildlife snow tracking, winter transect, and highway underpass data in the eastern Bow Valley. 27pp.
- Heuer K. and T. Lee. 2010. Private land conservation opportunities in the Bow Valley. Prepared for the Yellowstone to Yukon Conservation Initiative (Y2Y), Bow Valley Land Conservancy and Nature Conservancy of Canada. Y2Y offices, Canmore, AB.
- Golder Associates. 2002. Final report: assessment of wildlife corridors within in DC site 1, DC site 3, and District R. Prepared for Three Sisters Resort, Inc. and the Town of Canmore.
- Lee, T., Managh, S. and N. Darlow 2010. Spatial-temporal patterns of wildlife distribution and movement in Canmore's benchland corridor. Prepared for Alberta Tourism, Parks and Recreation, Canmore, Alberta.

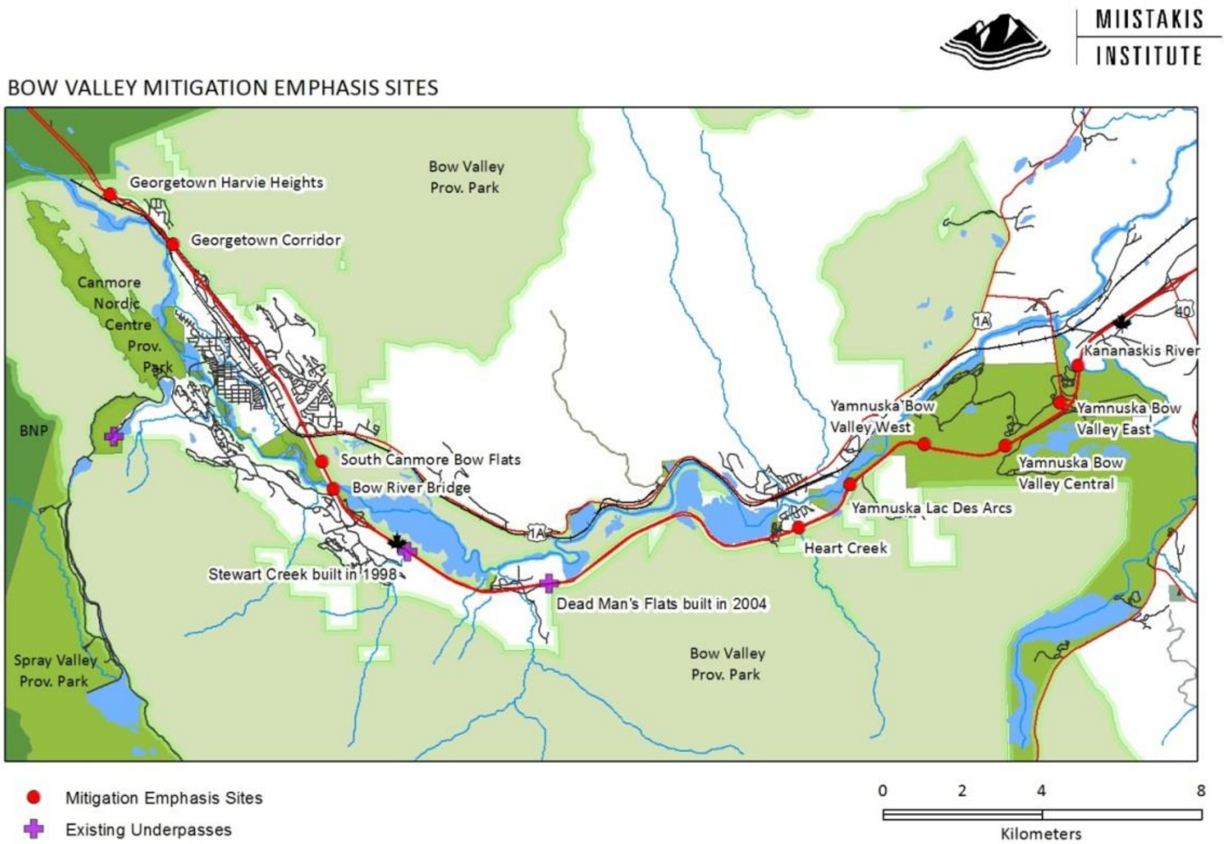

FIGURE 3 The ten mitigation emphasis sites (red dots) that were selected along the TransCanada Highway within the project area.

COSTS OF WILDLIFE-VEHICLE COLLISIONS WITH LARGE UNGULATES

Huijser et al. (2009) summarize the costs of the most prevalent group of large mammals—deer, elk, moose—that are involved in over 90 percent of the WVCs in North America (Table 2). All three species are ungulates and are present along the TCH corridor in the project area and have been recorded in the mortality databases. Although Huijser et al. (2009) developed monetary costs in 2007 U.S. dollars, for the purposes of this report it is reported at a par exchange rate in 2007 Canadian dollars. For the purposes of this project's cost analyses, we used the cost of an average collision of deer as representative of bighorn sheep since the two species have relatively similar body sizes and they are more comparable in size than to elk or moose. This is a conservative estimate of the monetary value as the hunting value of bighorn sheep is much higher than for deer.

There have been no average costs of collisions estimated for large carnivores, such as bears or cougars, *Puma concolor*. Therefore our costs to society for the collisions with large mammals at each of the TCH mitigation emphasis sites and across the entire project area are definitely lower than actual monetary costs of WVCs.

TABLE 2 Average costs of wildlife-vehicle collisions for 3 common ungulates (from Huijser et al. 2009).

Description	Deer Dollars (2007)	Elk Dollars (2007)	Moose Dollars (2007)
Vehicle repair costs per collision	$2,622	$4,550	$5,600
Human injuries per collision	$2,702	$5,403	$10,807
Human fatalities per collision	$1,002	$6,683	$13,366
Towing, accident attendance, and investigation	$125	$375	$500
Hunting value animal per collision	$116	$397	$387
Carcass removal and disposal per collision	$50	$75	$100
Total average cost per collision	$6,617	$17,483	$30,760

Costs of Wildlife Vehicle Collisions for the Ten MESs

The average collisions rates for the four ungulate species in the project area were calculated for each of the mitigation emphases sites. The totals for each MES are based on the recorded WVCs by species within the kilometer section that the MES is located. Based on the average WVC rates and the average costs to society for each species from Table 3, the average annual costs of ungulate-vehicle collisions (UVCs) at each MES are calculated and reported in Table 4.

TABLE 4 Average annual costs of ungulate-vehicle collisions at the ten mitigation emphasis sites on the TransCanada Highway within the project area.

	Annual Average Ungulate-Vehicle Collision Costs (in 2007 Canadian Dollars)				
Mitigation Emphasis Site Name	Elk	Deer	Bighorn Sheep	Moose	Total
Kananaskis River Bridge	$0	$2,051			$2,051
Yamnuska Bow Valley East Corridor	$28,322	$17,337		$2,460	$48,119
Yamnuska Bow Valley Center Corridor	$16,084	$4,566			$20,650
Yamnuska Bow Valley West Corridor	$13,462	$6,088		$4,614	$24,164
Yamnuska-Lac de Arcs Corridor	$9,441	$7,610		$2,461	$19,512
Heart Creek	$4,021	$10,190	$529		$14,740
Bow River Bridge	$6,644	$2,514			$9,158
South Canmore-Bow Flats Corridor	$22,903	$6,088			$28,991
Georgetown Corridor	$4,021	$6,617			$10,638
Georgetown-Harvie Heights	$22,903	$9,131	$993		$33,027

Table 4 indicates that many of the MESs have elevated annual costs of crashes with wildlife due to the high rates of crashes with ungulates. The most expensive site is Yamnuska Bow Valley East Corridor, with a total exceeding $48,000 per year. Of the ten MES, only two are less than $10,000 per year. One half of the ten sites exceed $20,000 per year. These relatively high monetary values indicate that mitigation measures, such as wildlife underpasses with fencing, could prove to be not only biologically effective in reducing WVCs, but could easily be cost effective as well.

Costs of Wildlife-Vehicle Collisions for the Project Area

The cumulative WVCs for the project area are summarized in Table 5 for the six large mammals that were in the various data sets. These totals include both MESs and highway segments outside the MESs. A total of 806 dead wildlife were recorded in the data sets for the 39 kilometers of the TCH area over a 13-year period, from 1998-2010. These WVCs result in an average of 62 collisions (includes only WVCs of known location) with large mammals per year in the project area (Table 5). Since only the average annual costs to society for UVCs can be calculated, the large number of UVCs results in an average cost of $640,922 per year for these crashes within the project area. A decadal conservative value would put the cost of UVCs at nearly 6 ½ million dollars for this 39 km stretch of the TCH.

TABLE 5 Annual rates of wildlife-vehicle collisions by species and costs of ungulate-vehicle collisions on thirty-nine kilometers of the TransCanada Highway within the project area.

Annual wildlife-vehicle collisions and costs (based on crash data from 1998-2010)	Species						Total
	Deer	Elk	Moose	Bighorn sheep	Black bear	Cougar	
Total number of collisions	467	267	15	17	32	8	806
Annual wildlife-vehicle collision rates	35.9	20.5	1.2	1.3	2.5	0.6	62
Annual wildlife-vehicle collision costs	$237,703	$359,074	$35,492	$8,653	0 [1]	0 [1]	$640,922

[1] The average costs for carnivore-vehicle collisions have not been determined

A MITIGATION SUCCESS STORY: DEAD MAN'S FLATS

The Dead Man's Flats underpass and exclusionary fencing was completed in 2004. Figure 4 displays the number of WVCs per year occurring within a 1.5 km stretch east and 1.5 km west of the underpass site. The average number of WVCs prior to the construction of the underpass was 11.8 annually based on six years of the dataset (1998-2003). After completion of the underpass and fencing mitigation in 2004, the average number of WVCs dropped significantly to 2.5 per year based on 6 years of the data (2005-2010).

WVCs Pre- and Post-construction around the Dead Man's Flats Wildlife Underpass Structure and Fencing

In 2004, the Dead Man's Flats underpass and wing fencing (purple cross located on Figure 3) was completed on the TCH. The mortality cluster analysis identified a very high mortality cluster on the highway segment where the Dead Man's Flat's underpass is located (Figure 3). To assess the effectiveness of the underpass and fencing in reducing WVCs at this location, data was divided into pre-construction of the underpass (1998-2003) and post- construction of the underpass (2005-2010) for the one kilometer of highway where the underpass is located and both neighbouring one kilometer sections, for a total of 3 kilometers of the TCH surrounding the Dead Man's Flats wildlife underpass. Data from 2004 was removed as the underpass was built in 2004. A t-test was run to determine if the number of WVCs pre- and post-construction are statistically different. In addition, for the rest of the TCH, excluding Dead Man's Flats 3 km section was statistically compared for the number of WVCs between the two time spans. This will enable us to determine if changes at Dead Man's Flats in the number of WVCs is due to an overall reduction in number of WVCs occurring along the TCH. In addition, pre- and post-construction costs of UVCs were compared using the average monetary costs of UVCs by species, from Table 2.

Figure 4 summarizes the total number of WVCs per year for the 3 kilometer section of the TCH surrounding the Dead Man's Flats underpass, from a high of 19 WVCs in 2002 to a low of zero WVCs in 2005.

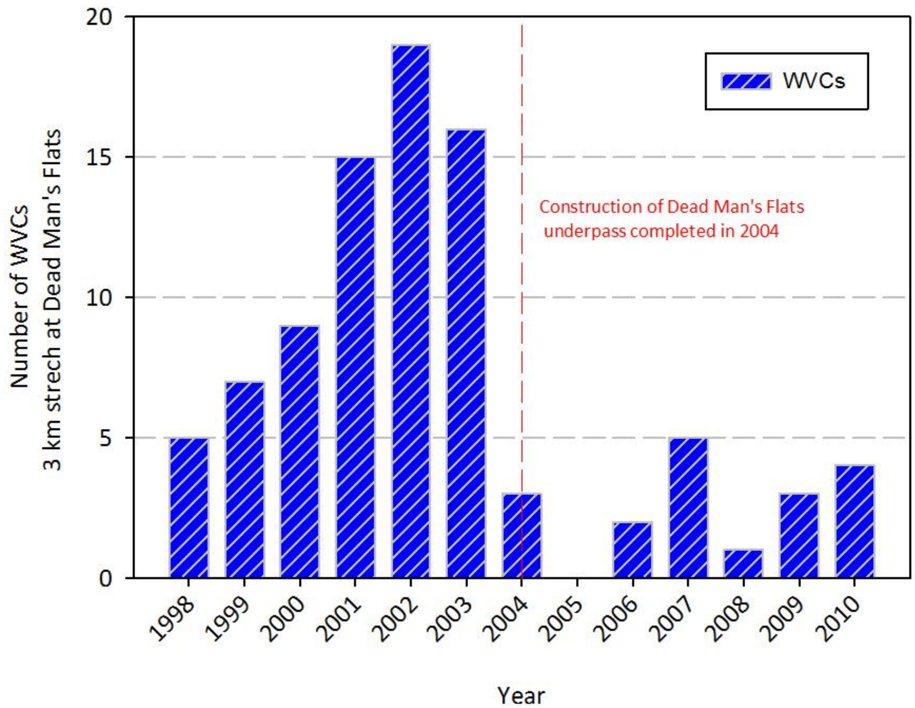

FIGURE 4 Number of wildlife-vehicle collisions per year along the three kilometers of the TransCanada Highway centered at the Dead Man's Flats wildlife underpass.

Statistically Significant Reduction in WVCs

The WVC numbers are very stark at Dead Man's Flats before the underpass was built and after the underpass was constructed with fencing. No single year previous to the mitigation had less than five WVCs, while after the mitigation was implemented, no single year exceeded five WVCs (Figure 4). This represents a 78.8% reduction in WVCs in the TCH segment with the underpass and fencing installed at Dead Man's Flats. A t-test of the pre- and post-construction data confirmed that the WVCs post-construction were significantly less statistically (results of two-tailed t-test, P value= 0.0075) than the pre-construction WVCs.

The rest of the TCH study area where there was not mitigation (excluding three km at Dead Man's Flats) was analysed (Figure 5). There was no statistical difference in the number of WVCs (results of two-tailed t-test, P value = 0.2540) between the 1998-2003 and 2005-2010 time spans. Therefore, statistical results highlight the reduction in WVCs at Dead Man's Flats underpass is the highly probable result of the construction of the underpass with wildlife fencing.

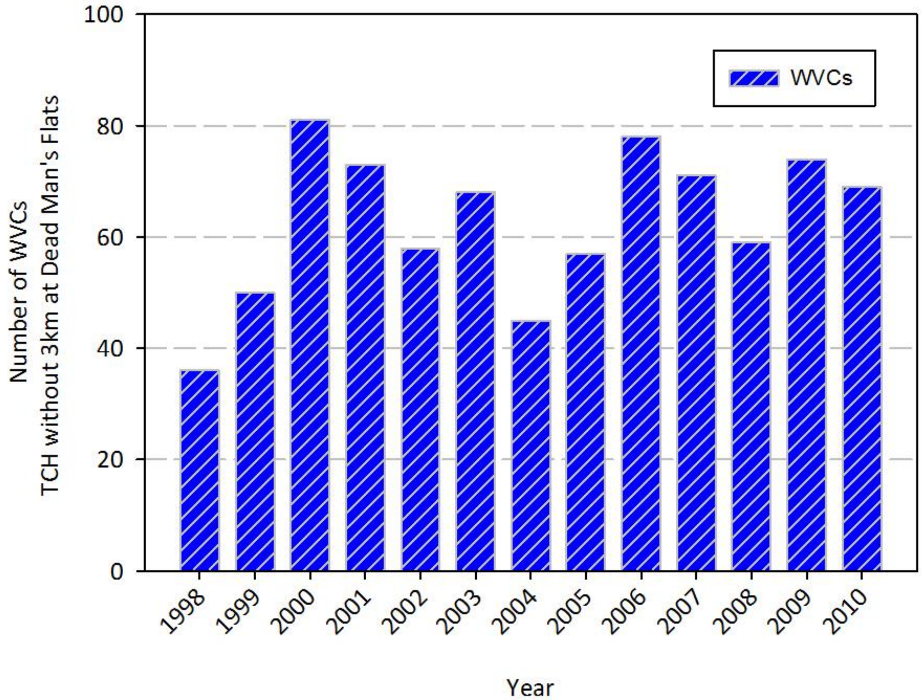

FIGURE 1: Summary of total number of recorded wildlife-vehicle collisions per year along the TransCanada Highway in the project area, excluding the 3 km section at Dead Man's Flats.

Significant Cost Savings from WVC Reductions

To determine a very conservative estimate of the cost savings due to the reduction in WVCs occurring at this site, the monetary value of ungulate species was calculated pre- and post-construction of the Dead Man's Flats underpass. The annual monetary cost of WVCs associated with crashes before construction was $128,300 annually. This was reduced to annual monetary costs of $17,500 in WVCs following the construction of the Dead Man's Flats underpass (Table 6).

TABLE 6: Costs of ungulate-vehicle collisions (UVCs) before and after construction of a wildlife underpass and fencing of the TransCanada Highway at Dead Man's Flats.

Species	Pre-construction WVCs 1998-2003	Cost of UVCs[1]	Post-construction WVCs 1005-2010	Cost of UVCs[1]
Deer	30	$198,510	8	52,936
Elk	22	$384,626	3	52,449
Moose	5	$153,800	0	0
Bighorn Sheep	5	$33,085	0	0
Coyote	5	$0	0	0
Wolf	2	$0	0	0
Cougar	1	$0	0	0
Black Bear	0	$0	2	0
Beaver	0	$0	2	0
Unknown	1	$0	0	0
Total WVCs and Costs of the UVCs	71	$770,021	15	$105,385
Annual WVC Rates and Costs	11.8	$128,337	2.5	$17,564

[1] Only the average costs of vehicle collisions with ungulate species have been determined, estimations for carnivores have not been derived and thus do not have a monetary value in this analysis (see Huijser et al. 2009).

In 2004, the Dead Man's Flats underpass was built using G8 Legacy Funds. It was possible to evaluate the effectiveness and costs savings of the underpass. WVC data was available at the location for six years, both pre- and post-construction. Total WVCs dropped from an annual average of 11.8 pre-construction to a six year annual average of 2.5 WVCs post-mitigation construction. From a cost-to-society perspective, mitigation reduced the annual average cost by over 90%, from an $128,337 average per year to a resulting $17,564 average per year. This 3 km section of the highway within the project area provides local evidence of the effectiveness and cost benefit potential for the ten MESs in this study.

BIOGRAPHICAL SKETCHES

Tracy Lee, M.Sc., Senior Project Manager, Miistakis Institute – Mount Royal University. Miistakis is a research institute affiliated with the Mount Royal University; the institute brings people and ideas together to promote healthy communities and landscapes. Tracy acquired her BSc from University of Victoria in biology and environmental design and her MSc from the University of Calgary, Resources and the Environment Program. Tracy's graduate work, in association with the Miistakis Institute, focused on the development and assessment of a citizen science project to monitor wildlife movement across a major highway

Rob Ament, M.Sc., Road Ecology Program Manager, Western Transportation Institute - Montana State University (WTI). Rob has more than 30 years of experience in ecology, natural resource management, environmental policy and organizational development. At WTI, Rob leads efforts to research, monitor and develop solutions to minimize the impacts of roads on the natural environment - in areas as diverse as wildlife, aquatics, vegetation, climate change and new technologies. He is the principal investigator of several research projects while managing nine staff in four locations in western North America that are working on 20 active projects. He is on the Steering Committee for the International Conference on Ecology and Transportation, is a member of the Stakeholders Advisory Group for the Western Governors' Association's Wildlife Corridor Initiative, was elected and serves on Montana State University's Sustainability Council. He served as a panelist for the National Cooperative Highway Research Program's synthesis on new technologies for environmental surveys and as a judge to select FHWA's Environmental Excellence Awards in 2013.

Tony Clevenger has carried out research since 1996, assessing the performance of mitigation measures designed to reduce habitat fragmentation on the Trans-Canada Highway (TCH) in Banff National Park, Alberta. Since 2002, he has been a research wildlife biologist for the Western Transportation Institute (WTI) at Montana State University. Tony is currently a member of the U.S. National Academy of Sciences Committee on *Effects of Highways on Natural Communities and Ecosystems*. He has published over 60 articles in peer-reviewed scientific journals and has co-authored three books including, *Road Ecology: Science and Solutions* (Island Press, 2003) and *Safe Passages: Highways, Wildlife and Habitat Connectivity* (Island Press, 2010). Tony is a graduate of the University of California, Berkeley, has a Master’s degree from the University of Tennessee, Knoxville and a Doctoral degree in Zoology from the University of León, Spain.

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