The Evolution of Wildlife Exclusion Systems on Highways in British Columbia

Leonard E. Sielecki (250-356-2255, leonard.sielecki@gov.bc.ca), British Columbia Ministry of Transportation, P.O. Box 9850, STN PROV GOVT, 4B - 940 Blanshard Street, Victoria, BC V8W 9T5, Fax: 250-387-7735 Canada

Abstract: Since the mid-1980's, the British Columbia Ministry of Transportation (BCMoT) has been addressing the issue of motor vehicle-related wildlife collisions on Provincial highways with engineered wildlife exclusion systems. As a result of this initiative, the British Columbia has one of the most extensive networks of wildlife exclusion systems, designed to reduce and prevent motor-vehicle-related mortality of terrestrial mammals, in North America.

Typically, wildlife exclusion systems are incorporated as an integral part of new highway development after the potential of wildlife mortality has been identified during highway planning stages. The systems are designed to protect wildlife from motor vehicles and ensure wildlife habitat connectivity. They have been constructed primarily on limited-access, high-speed highways and expressways and designed to protect specific species of wildlife, primarily large ungulates, such as deer, elk, moose and mountain sheep. The systems comprise of specialized fencing and related structures, such as one-way gates, ungulate guards, and crossing structures, designed to safely and effectively protect wildlife by recognizing species-specific behavioral, physical and anatomical characteristics. To date, BCMoT has installed over 470 km of wildlife fencing, incorporating over 100 crossing structures and hundreds of one-way gates.

While the wildlife exclusion systems have been shown to reduce the potential for motor vehicle-related wildlife mortality, BCMoT is continually reviewing the designs of the components of these systems in an ongoing effort to improve them. With each successive project, as the interactions of wildlife with these systems become better understood, BCMoT has refined its fence and crossing structure designs and standards to increase their efficiency, effectiveness and safety for wildlife. BCMoT has also focused its attention on material quality, manufacturing processes and construction techniques to offset the challenges of climate, topography, vegetation and human activity to maximize the effective functional lifespans of wildlife exclusion systems.

Introduction

The diverse climatic, geographic and physiographic characteristics of British Columbia have produced biogeoclimatic or ecological zones that vary from dense rainforests on the west coast and deserts in the southern interior valleys to broad rolling plateaus in the central interior valleys and alpine tundra in the northern mountains (British Columbia Ministry of Forests, 1999). As a result of the exceptional range of wildlife habitats provided by these biogeoclimatic zones, British Columbia has one of the most diverse ranges of large ungulate species in North America. Large mountain ranges transect British Columbia creating numerous valleys providing critical winter habitat for many large ungulates, including deer, elk, moose, and mountain sheep, for up to six months of the year. Historically, most of the British Columbia's major highways were built in the valley bottoms, severing the winter ranges and the migratory corridors of many wild animals. For many years, the wildlife habitat/highway interface was poorly understood. Little was done to assess the impact of highways on wildlife, their migratory corridors and their use of critical ranges. As a consequence, conflicts and collisions between wildlife and motor vehicles were common and wildlife mortality was a seemingly accepted cost of developing highways in British Columbia.

This situation began to change in the mid-1980's, when the British Columbia Ministry of Transportation (BCMoT) started addressing the issue of motor vehicle-related mortality of large ungulates on Provincial highways. The British Columbia Provincial Government has made "environmental stewardship" one of the goals of its administration. In order to support the Provincial Government's environmental objectives, BCMoT has the responsibility of protecting both the motoring public and wildlife within the Province highway system that fell under its jurisdiction. To fulfill its dual obligations, BCMoT has made significant investments in its highway infrastructure to reduce the potential for motor vehicle-related wildlife mortality. Over the last three decades, a major component of these investments has been the development of engineered wildlife exclusion systems. As a result of the continuation of this initiative, the British Columbia has one of the most extensive networks of wildlife exclusion systems, designed to reduce and prevent motor-vehicle-related mortality of terrestrial mammals, in North America.

Wildlife Exclusion Systems in British Columbia

In British Columbia, wildlife exclusion systems are typically incorporated as an integral part of new highway construction to address projected potential wildlife mortality. As part of BCMoT's comprehensive Highway Environmental Assessment Process (British Columbia Ministry of Transportation and Highways, 1997), extensive wildlife identification and monitoring programs conducted by professional biologists and wildlife experts are initiated years before highway construction begins. Particular attention is given to rare and endangered species, especially those subject to the Canadian *Species at Risk Act*. When wildlife population clusters and migration routes are identified during environmental assessments, the habitat fragmenting potential of wildlife exclusion fencing is reduced with crossing structures. In some cases, wildlife exclusion systems are retrofitted on existing highways where problematic wildlife accident locations which have developed over time are identified using BCMoT's Wildlife Accident Reporting System (WARS) (Sielecki, 2004).

Maintaining Wildlife Habitat Connectivity

Given the vast amount of frontier land in British Columbia, highway redevelopment and expansion has occurred in areas of rich wildlife habitat. The fragmenting impact of highways on wildlife habitat is a significant issue. Highways have the potential to sever access to critical breeding, rearing and foraging areas for wildlife. For some, small, slow-moving species, highways can become an impermeable barrier to movement. Maintaining habitat connectivity has become increasingly necessary to provide continued access of wildlife to food, water and shelter for the immediate survival needs of individual animals, and continued genetic diversity necessary for the long-term survival of wildlife species as a whole. This is particularly critical in areas where the habitat of small numbers of rare or endangered species has been severed by highway development. BCMoT strives to maintain habitat connectivity by incorporating crossing structures, such as underpasses, in its wildlife exclusion systems.

To date, approximately 470 km (292 miles) of fencing and 100 crossing structures have been installed on the Coquihalla Highway (Highway 5), the Okanagan Connector Freeway (Highway 97C), Highway 97 and the Vancouver Island Highway (Highway 19). Given their size, complexity, and comprehensive design, BCMoT's wildlife exclusion systems on the Coquihalla and the Okanagan Connector were pioneering efforts for their time. The first wildlife overpass in Canada was built for the Okanagan Connector. The Vancouver Island Highway wildlife exclusion installations were state of the art initiatives at the time of their construction. With each successive project, the Ministry has refined its designs and standards, to improve the efficiency and effectiveness of its wildlife exclusion systems. Both fence and crossing structure designs have evolved over time.

BCMoT has found wildlife exclusion systems that encapsulate highway rights-of-way to be the most effective means of protecting wildlife from motor vehicles (figure 1). BCMoT's experience with regularly maintained, 2.4 m (7.9 ft) high fencing systems, which include one-way gates, ungulate guards and wildlife crossing structures, located on both sides of limited access highways, exceed 90% effectiveness in preventing highway-related wildlife mortality for large ungulates. These results are appear higher than the 80% reductions in wildlife accidents reported when wildlife exclusion fencing was installed along the Trans-Canada Highway in Banff National Park (Clevenger, Chruszez and Gunson, 2001). BCMoT has also found wildlife exclusion fencing appears to be effective when installed on only one side of a highway, if the unfenced side of the highway has pre-existing barriers to animal movement, such as a cliff face.

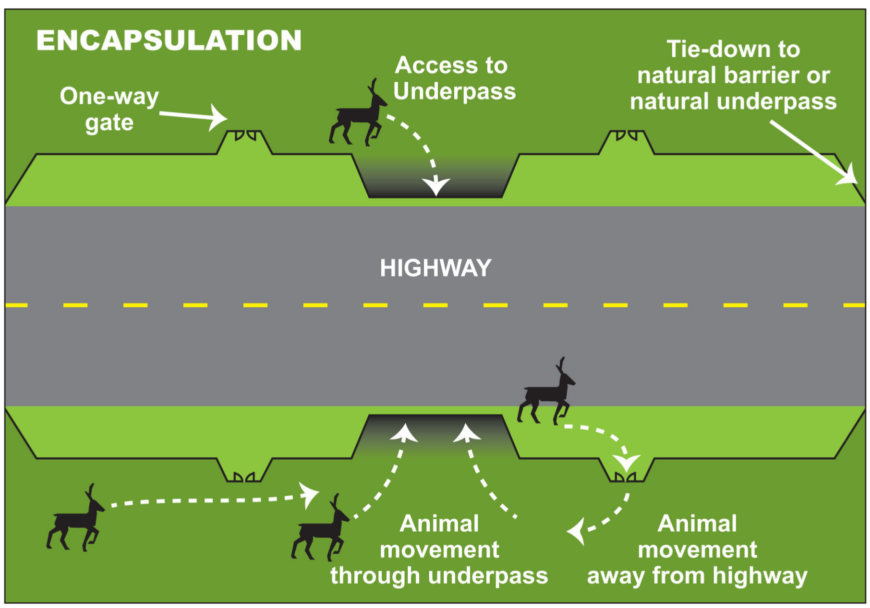

Figure 1. Highway encapsulation with wildlife exclusion system.

Stages of Development

The development of an effective wildlife exclusion system requires detailed, comprehensive planning and evaluation. For BCMoT, there are five main stages in the development of a wildlife exclusion system:

a. historic data analysis,
b. pre-design data collection and analysis,
c. design,
d. materials selection and construction, and
e. post-construction monitoring and evaluation.

(a) Historic Data Analysis

For almost 30 years, highway-related wildlife mortality data has been collected on a daily basis on all numbered Provincial highways that fall under the BCMoT's jurisdiction. The data is entered into the Ministry's Wildlife Accident Reporting System(WARS) database. The WARS database contains a detailed historical record of wildlife mortality and is regularly used as a tool for supporting decision-making with regards to the impacts of existing and planned highways on wildlife. For existing highways, WARS data is used to examine the magnitude and locations of highway-related wildlife mortality to focus wildlife accident mitigation efforts in the most cost-effective manner. For planned highways, WARS data is used as a surrogate data source to assist Ministry engineers and planners and private consultants in their evaluation of potential wildlife accident risks.

(b) Pre-Design Data Collection and Analysis

Preceding the design of a wildlife exclusion system, whether as part of a new highway, or the large-scale redevelopment of an existing one, wildlife biologists are contracted by BCMoT to collect detailed wildlife population and habitat information. Aerial and ground surveys are used to supplement any existing information in an effort to quantify the numbers of wildlife and their movement patterns on lands adjacent to existing and planned highway corridors. Detailed information on the topography, vegetation and other biophysical features of the landscape is used to analyze resident and migratory wildlife movements related to critical life activities, such as breeding, rearing, and seasonal foraging. Data from the WARS database is used to identify locations where the potential for wildlife accident may be high. For new highway development and large-scale redevelopment of existing highways, these activities form an integral part of the environmental assessment process used by BCMoT. Information provided by the wildlife biologists is one of the factors BCMoT's planners and engineers consider for selecting a final highway alignment. Once the alignment has been selected, detailed plans are developed to incorporate the key components of a wildlife exclusion system as necessary to protect those species of animals identified by the wildlife biologists.

(c) Design

Depending on the highway project involved, wildlife exclusion systems can vary greatly in scale and complexity. A wildlife exclusion system can be as simple as a fence for a single species, used to connect existing or planned structures, such as bridges and culverts; or much more complex when multi-species oriented crossing structures, such as underpasses, and wildlife habitat features, such as ponds are integrated into the design. Wildlife exclusion systems are most easily incorporated into the design and construction of new highways. In this way, the designs of major structures, such as bridges and culverts, can be modified to maximize their effectiveness for wildlife passage. Highway traffic closures are not required and significant cost savings can be realized when wildlife exclusion system construction can be integrated with highway infrastructure construction and right-of-way preparation and landscaping. In addition, issues relating to side road access and private property can also be addressed in a systematic and cost-effective manner.

Wildlife biologists provide vital information about the physical and behavioral characteristics of wildlife to BCMoT's engineers so that appropriately sized structures can be designed to meet species-specific wildlife needs and foster their use of structures, such as one-way gates, underpasses and overpasses. Wildlife exclusion systems are usually intended for specific species and their structural components are designed to accommodate and withstand the forces of the largest animals that may be affected by the systems. In British Columbia, large ungulates, such as moose and elk can weigh in excess of 700 kg (1543 lb) and stand in excess of 1.5 m (4.9 ft) in height. While efforts are made to protect the smallest animals by preventing them from accessing the highway right-of-ways, by breaching gaps in the fence, the structural size and strength requirements are designed for the largest specimens of the largest ungulates, typically bull elk or bull moose.

Wildlife Exclusion Fencing

Initially, BCMoT used the wildlife exclusion fencing design developed by Banff National Park (Buckingham, 2007). Over time, the fencing design used by BCMoT has evolved to meet the wildlife and environmental challenges found along highways in British Columbia. Fencing for large ungulates, such as moose and elk, requires more robust designs. This typically involves heavier metal posts or thicker wooden poles, with closer spacing, and heavier fence mesh held onto the posts with heavy clamps. Local climatic conditions can create additional demands on fencing. Heavy snow or ice loading requires heavier metal posts or thicker wooden poles, spaced closely, and heavier fence mesh held onto the posts and poles with heavy clamps. Steep and/or rocky terrain, which prevents the use of heavy equipment and makes the installation of wooden poles difficult, requires the use of metal posts placed in drilled holes. Soft and/or swampy soils require the use of longer posts and posts, and concrete to stabilize them. The spacing of posts and poles can range from 2.5 m (8.2 ft) to 3.5 m (11.5 ft).

A wildlife exclusion system that promotes long term sustainability of the wildlife it protects relies on establishing and maintaining effective habitat connectivity. If animals unexpectedly enter a highway right-of-way, they must be able to exit it as quickly and safely as possible to reach their habitat. To facilitate and expedite the movement of wildlife away from highway rights-of-way, BCMoT has focused considerable effort on the design of one-way gates to accommodate the size, shape and movement characteristics of large ungulates, in particular, deer, moose and elk.

One-way Gates

The original one-way gate design used by BCMoT was based on earlier designs developed in Utah by the Utah Department of Transportation (UDoT). Over time, the one-way gate design has evolved as their use by ungulates has been become better understood (figures 2 and 3).

Figure 2. One-way gate designed for moose and deer.

The original "straight" tyne was found to be an impalement hazard for large ungulates. Soon after the installation of the first one-way gates, a moose reversed its direction of movement while passing through a one-way gate and impaled itself. The moose's movement backward in the one-way gate had not been anticipated when the original "straight" tyne design was developed. The second, "improved", version of the one-way gate tyne, the "looped" tyne was also found to be hazardous as the loops became ensnarement hazards when some deer passing through the gates were found to raise their front legs and catch them in the loops. In the late 1990's, the "looped" design was replaced with the "disked" and "ball" tyne designs, which prevent impalement and ensnarement. BCMoT is monitoring the use of the "disked" and "ball" tyne designs to determine if they are operating as designed and do not create a hazard for the wildlife they were designed to protect.

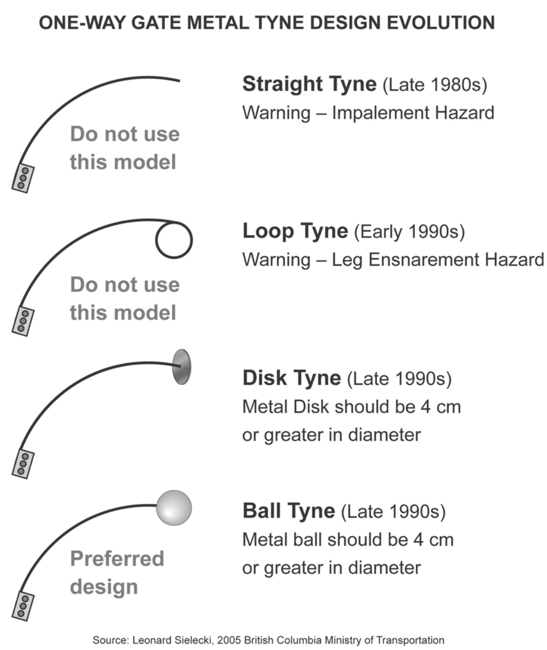

Figure 3. One-way gate metal tyne design evolution.

The BCMoT wildlife exclusion fencing specifications are typically designed to produce a fence with a 20 to 25 year lifespan. The remote and/or physically challenging locations of some wildlife exclusion fencing makes daily inspection and maintenance difficult, if not impossible. As a consequence, design, materials and construction are very important components in the development of effective and reliable wildlife exclusion fencing.

Other structures, such as earthen ramps and jumpouts, are used by other jurisdiction to enable wildlife to exit fenced highway rights-of-way (Ito, 2005). However, BCMoT does not currently use these structures. British Columbia provincial highway rights-of-way in British Columbia are accessible to the public, and although earthen ramps and jumps may be more effective than one-way gates for use by some large ungulates, unresolved safety issues, relating to the activities of mountain bikers, all terrain vehicle (ATV) users and hikers, have delayed their implementation. BCMoT continues to monitor the use of earthen ramps and jumpouts by other jurisdictions in order to ascertain their effectiveness as well as understand their operational and safety limitations and implications.

Grade Separated Wildlife Passage Structures

Grade-separated wildlife passage structures are key to the BCMoT's efforts to minimize habitat fragmentation. Whether these structures are used independently, or incorporated with wildlife exclusion fencing in wildlife exclusion systems, they represent the consistently, safest, and most effective method of allowing wildlife to traverse a highway corridor.

In 1987, BCMoT constructed the first wildlife overpass in Canada. The Trepanier Wildlife Overpass on the Okanagan Connector (Highway 97C) was built following the concept of the first overpass built for deer in Utah by the Utah Department of Transportation (UDoT) (figure 4). The Trepanier Wildlife Overpass was developed from the basic design of a pedestrian highway overpass at a cost of approximately CAN$1 million. Structural advancements were required to accommodate the weight of soil necessary for vegetation used to create a more "natural" environment to foster wildlife use. The decision to construct the overpass on the Okanagan Connector was supported by detailed wildlife studies. These studies also assisted in locating the structure so that it could provide essential passage for critical summer and winter deer habitat.

Figure 4. The Trepanier Wildlife Overpass on Highway 97C.

There are over 100 wildlife crossing structures located on Provincial highways in British Columbia. All, except the Trepanier Wildlife Overpass, are underpasses. They were installed on the Coquihalla Highway (Highway 5), the Okanagan Connector, Highway 97 and the Vancouver Island Highway. Terrain and geologic constraints can make locating wildlife overpasses problematic. However, BCMoT has found, that if designed properly, underpasses can be multi-purpose, meeting the needs of wildlife, adjacent land users and the highway infrastructure. The size and design of the structures has been evolving as the understanding of how wildlife interact at the wildlife habitat/highway interface grows. Underpasses are now typically taller in height , wider in width. They are more species-friendly, with carefully selected flooring materials to suit the target species.

To maximize the use of environmental enhancement funds and improve the effectiveness of passage structures, the Ministry has been focusing its attention to underpasses for multi-species use. Large multi-plate culverts can cost upwards of CAN$500,000 while concrete bridges and box culverts can cost several million dollars. Incorporating natural watercourses into the design of passage structures, enables the movement of aquatic and terrestrial species. Modifications in the design of "bottomless" culverts for the preservation of the passage envelop and trail surfacing, combined with selective riprap armouring and increasing structure clearance heights, allow underpasses to be developed to promote wildlife passage, rather than hinder it.

Underpasses are another significant component of wildlife exclusion systems that have been evolving. Early underpasses were constructed approximately 3.7 m (12.2 ft) in diameter (figure 5). Although monitoring of wildlife tracks indicated these structures were used by deer, larger structures, in excess of 5 m (16.4 ft), were constructed to increase deer use, and better accommodate the needs of elk and moose (figure 6). To make underpasses more suitable for ungulates, BCMoT has been building larger structures and incorporating features to accommodate the needs of more species, including fish, primarily salmonids (figure 7). BCMoT has been working with the United States Forest Service to develop monitoring and assessment techniques to evaluate underpasses and improve ungulate use of them.

Figure 5. Wildlife underpass designed for deer on the Okanagan Connector (early 1990's).

Figure 6. Wildlife underpass designed for elk and deer on the Vancouver Island Highway (1999).

Figure 7. Multi-species wildlife underpass on the Vancouver Island Highway (1999).

(d) Materials Selection and Construction Techniques

Materials and workmanship are critical components of the construction phase for wildlife exclusion systems. Attention to design details and the use of good quality materials help ensure the systems will operate as designed for a prolonged period of time. This is especially important when wildlife exclusion systems are located in remote areas where maintenance is difficult to perform.

BCMoT specifications for materials have been developed to produce fences with an expected design life of 20 to 25 years. To promote system longevity, metal components are either stainless steel or heavily galvanized. Metal fence poles, fence mesh, and high tensile wire are heavily galvanized. In areas where heavy snowfall can occur and/or aggressive large ungulates live, heavy-duty stainless steel or galvanized steel clamps are used to attach fence mesh to the poles. Wooden fence posts are typically 18 cm (7.1 in) to 22 cm (8.6 in) in diameter, and pressure treated for periods in excess of conventional construction standards.

Strict quality control and quality assurance are critical. During construction, inspections occur regularly to ensure correct materials and construction techniques are being used to produce a long, lasting, durable structure that meets design specifications. Upon completion of the projects, careful examination and thorough testing of the structures occurs before the project is accepted.

(e) Post-Construction Monitoring and Evaluation

In mountainous settings, severe climate conditions and aggressive vegetation can create operational problems for wildlife exclusion systems. Consequently, these systems are monitored on a regular basis to ensure they function as designed and deficiencies can be identified and addressed in a timely manner.

The most comprehensive, recent audits of BCMoT's wildlife exclusion systems were conducted for BCMoT by professional wildlife biologists in 2005 (Demarchi, 2005; Harper, 2005; Hartwig and Demarchi, 2005; and Hayward, 2005). These audits were intended to provide a detailed inventory on the fencing, one-way gates, ungulate guards and crossing structures, and to investigate the use of each component of the systems by wildlife. The audits found the wildlife exclusion systems were functioning as designed. Evidence of wildlife use of one-way gates and crossing structures was demonstrated by tracks, hair and fecal droppings. At a number of wildlife underpasses evidence of temporary human occupation was found. The effect of human presence and the remaining discarded food wrappers and packaging on the long-term use of underpasses by wildlife is unknown. However, it is believed wildlife avoid using these structures when humans are present in them.

At a number of one-way gates, the remains of dead deer were found (figure 8). From the orientation of the remains, it appeared these animals may have been using the one-way gates to exit highway rights-of-way. The causes of death could not be determined because the remains were in relatively poor condition. However, further investigation and monitoring is required to determine if the deer are dying after using the one-way gates following a collision with motor vehicles on the highway, or if the deer are being attacked by opportunistic predators when they pass through the one-way gates.

Regular maintenance is essential for ensuring that wildlife exclusion systems operate properly. In British Columbia, roadside fence maintenance is a part of the BCMoT's highway maintenance contracts maintenance specifications. As a consequence, damage done to fencing by falling trees, motor vehicles, vandals and heavy snow loads must be repaired in an expedient manner. In areas where trees are located close to wildlife exclusion fencing, the potential for a treefall on top of the fence is ever present. Where mature trees do not exist, the potential exists for new trees to grow through the fence or block one-way gates. One-way gates must be kept clear of growing trees and broken tynes must be replaced as quickly as possible. In areas subject to heavy snow accumulations, inspections and maintenance earlier in the Spring should reduce the potential for motor vehicle-related ungulate mortality.

Unlike the effects of nature, such as falling trees, ground subsidence and heavy snow, vandalism is a manmade issue that has the potential to become a serious problem. Uncontrolled human access by hunters and poachers, mountain bike enthusiasts, and all terrain vehicles (ATVs) by way of holes cut into fences or the disabling of one-way gates compromise the integrity of wildlife exclusion systems. While such activities are difficult to detect when they occur, regular monitoring and maintenance reduce the potential impact of vandalism.

Figure 8. Deer remains near one-way gate.

Installations

BCMoT has constructed wildlife exclusion systems on both existing and new highways. From the mid-1980's until the mid-1990's, BCMoT designed and built two new, major, high speed, limited access sections of highway transecting large tracts of wildlife habitat in the southern interior of British Columbia. The highways connected the Lower Mainland with Kamloops and Kelowna. Construction occurred in three phases: Coquihalla Highway (Highway 5) Phases I and II, Okanagan Connector (Highway 97C) Phase III.

The wildlife exclusion systems developed on these highways were the first projects of their kind in British Columbia. The installation on the Coquihalla Highway is an example of a retro-fit on an existing highway, while the Okanagan Connector is an example of integrating a wildlife exclusion system as a component of a new highway.

The Coquihalla Highway and Okanagan Connector projects were followed by projects on Highway 97 and the Vancouver Island Highway. In 1999, a collective effort involving the Ministry, the Insurance Corporation of British Columbia and the Summerland Sportsmens' Association and the Peachland Sportsmen's Association, affiliated associations of the British Columbia Wildlife Federation, resulted in the construction of a wildlife exclusion system on Highway 97 near Okanagan Lake. This project was a retrofit on a long-established highway. Between 1999 and 2001, the Ministry constructed four wildlife exclusion systems as integral components of two phases of new highway construction on the Vancouver Island Highway (Highway 19). With each successive project, the Ministry has refined its designs and standards, to improve the efficiency and effectiveness of its wildlife exclusion systems. The Vancouver Island Highway installations are state-of-the art initiatives in British Columbia.

Coquihalla Highway (Highway 5)

The Coquihalla Valley has long served as the major transportation route in British Columbia linking the Lower Mainland with the Interior (figure 9) The origins of the highway network in the valley originate with the Hope-Nicola Trail in 1876. The development of road access culminated with the construction of the Coquihalla Highway (Highway 5).

Figure 9. The Coquihalla Highway in the Coquihalla Valley.

The Coquihalla Highway is a high speed (110 km/hr (68.4 mi/hr)) toll road which extends 195 km (121.2 mi) north from Hope to Kamloops, via Merritt. It is the only toll road in British Columbia. Construction on the Coquihalla Highway between Hope and Merritt started in 1979 and was completed in 1986. Despite the challenges of severe mountainous terrain and winter conditions, the highway became operational in May, 1986, to coincide with provincial and national traffic destined for Expo 86 in Vancouver. Starting north of Hope, at an elevation of approximately 50 m (164 ft), the Coquihalla Highway climbs steadily up the western slopes of the Cascade Mountains. For the first 42 km (26.1 mi), through the Coquihalla Pass, the highway ascends to the Coquihalla Summit at an elevation of 1244 m (4081 ft). Once past the summit, the highway continues another 78 km (48.5 mi) northeast, traversing the top of the Thompson Plateau, then descending to Merritt, which has an elevation of 595 m (1592 ft).

Over its length, the Coquihalla Highway passes through a number of climatic regimes. Near Hope, the highway environment is subject to temperate climate due to warm, moist Pacific Ocean airflows (Pojar and Meidinger, 1991). Here, summers are typically dry and summer temperatures average 25oC (77 oF). Winters are typically wet and mild. Snowfalls are infrequent in low-lying areas, with accumulations melting within a few days. Further north, the Coastal Range acts as a barrier separating the moist Pacific air from the interior of the Province. As the moist ocean air is forced to rise over these mountains, heavy precipitation occurs on the western slopes, with rain at lower elevations and snow at higher ones. Rainfall in Hope can exceed 2 m (6.6 ft) each year. About 80 km (50 mi) east of Hope the interior valleys between the mountain ranges receive considerably less precipitation and experience hot summers. Further north, near Merritt, summer temperatures often exceed 30 oC (86 oF).

The steep terrain at the southern portion of the highway combined with heavy snowfalls has created a challenging environment for highway construction. The Coquihalla Highway can experience severe winter conditions. Snow accumulations of over 12 m (39.4 ft) are not uncommon, and in years of heavy snowfall, snow depths have reached 15 m (Shewchuk, 1998). In January, 2006, almost 50 cm (1.6 ft) snow fell during a 15 hour period stopping traffic (Public Safety and Emergency Preparedness Canada, 2006). A number of avalanche tracks have been identified along this portion of the highway. On average, about 100 avalanches occur per year along the Coquihalla Highway southwest of the summit. Most avalanches are small and pose no threat to motorists as they usually do not reach the highway.

At lower elevations, the Coquihalla Higwhay passes through large stands of Douglas fir and ponderosa pine. As the highway climbs to higher elevations, it passes through large stands of Engelmann spruce, lodgepole pine, and subalpine fir. Once past the Coquihalla Summit, the highway traverses the top of the Thompson Plateau and then descends through expansive rolling countryside with many small lakes. Extensive grasslands are found closer to Merritt.

Despite challenging terrain and seasonal climatic conditions, the Coquihalla Valley contains prime wildlife habitat. The primary large ungulate species found throughout the area are mule deer and smaller numbers of moose. Small concentrations of elk are found in the southern reaches of the valley. Mountain goats are widespread but restricted to rugged areas in the Coast Mountains Black bears occur throughout this area. Fewer numbers of wolves, cougars and grizzly bears are also found here. Between 1979 and 1981, prior to the construction of the Coquihalla Highway, winter wildlife studies were conducted (Kent, 2005). The studies indicated few resident deer and moose resided in the area. Limiting the studies to the winter periods resulted in a serious shortfall in information regarding migratory animals. The winter tracking studies were unable to identify the annual Spring/Summer and Fall movements of large herds of deer from the Tulamene Valley to the Coldwater Valley and down to Boston Bar across the proposed highway alignment. The lack of information became apparent just after the highway opened. In 1986, when between May and July and between October and November, unexpectedly large numbers of deer were killed during their seasonal migrations. The combination of large ungulates and high speed vehicle traffic prompted BCMoT to construct its first wildlife exclusion system to protect wildlife and motorists.

BCMoT initially installed wildlife reflectors in response to these deer-related accidents,. When it became apparent the reflectors alone would not be able to reduce the high numbers of accidents on the highway, BCMoT began the design and construction of wildlife exclusion fencing on Phase I of the highway (figure 10).

Figure 10. Wildlife exclusion fencing on the Coquihalla Highway.

By improving on the designs originally developed by Public Works Canada for Banff National Park, BCMoT was able to develop effective fencing and one-way gates (Kent, 2005). Wildlife exclusion fencing was constructed for a distance of approximately 70 km (43.5 mi) on both sides of the highway, between the toll booth and Merritt (figure 11).

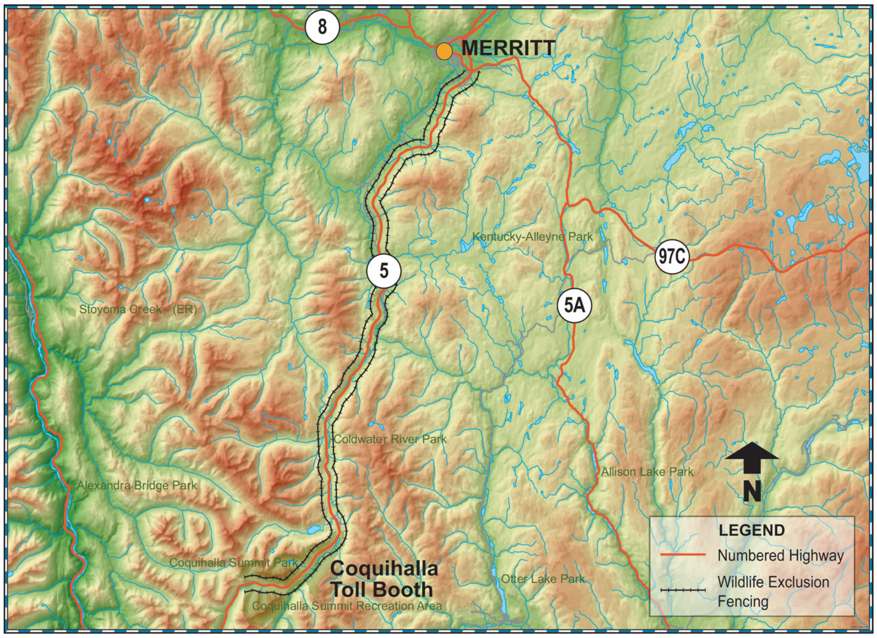

Figure 11. Location of wildlife exclusion fencing on the Coquihalla Highway.

Fencing on the Coquihalla Highway was constructed to control deer primarily because of their numbers in the area, but was designed to handle moose because of their more significant potential accident severity risk. Wildlife exclusion fencing has proven very effective in reducing wildlife accidents on the Coquihalla Highway (Highway 5) located between Hope and Merritt. On the 35 km (21.7 mi) portion of the Coquihalla Highway, between Dry Gulch Bridge and Kingsvale Bridge, wildlife exclusion fencing reduced wildlife accidents by 100%. Data from the WARS database indicates the number of wildlife accidents declined from 74, in the 1989 to 1993 period, to 0, in the 1994 to 1998 period.

Okanagan Connector (Highway 97C)

The Coquihalla Connector (Highway 97C) is a high speed freeway (110 km/hr (68.4 mi/hr) posted speed limit) that links the Coquihalla Highway (Highway 5) at Merrit to Highway 97 and the Okanagan communities of Kelowna and Peachland (figure 12). The highway is approximately 108 km (67.1 mi) long and provides a vital link in the Province's highway network, connecting Vancouver and the Fraser Valley to the Okanagan Valley via the Coquihalla Highway. This highway is one of the highest elevation highways in Canada. At Pennask Summit, the Okanagan Connector reaches an elevation of 1,740 m (5708.6 ft).

Figure 12. Okanagan Connector.

The Okanagan Connector lies east of the crest of the Coast and Cascade mountain ranges and west of the Columbia Mountains (Ministry of Sustainable Resource Management, 2006). This area is located in the Southern Interior Ecoprovince of British Columbia, which includes the Thompson Plateau, the Pavilion Ranges, the eastern portion of the Cascade Ranges, and the western margin of the Shuswap and Okanagan Highlands.

The leeward portion of the Coast and Cascade ranges and the drier portion of the highlands share much the same climate as the Thompson Plateau (Pojar and Meidinger, 1991). Lying in the rain shadow of the coastal mountains, this area has some of the warmest and driest areas of the Province in summer. By the time the Pacific Ocean airflows move into this area, they have already lost most of their moisture on the west facing slopes of the coastal mountains. Periodically in the summer, hot and dry air advances from the United States to the south. This produces clear skies and very warm temperatures. Since there is no effective physical barrier in the north, in the winter and early spring there are frequent outbreaks of cold, dense Arctic air. These events are less frequent in this area than on the plateaus further north. At higher elevations, the western portion of the highway is subject to cold winter temperatures and heavy snowfalls. At lower elevations, nearer Okanagan Lake, the eastern portion of the highway experiences warmer winters with considerably less snowfall.

Mule deer are the most abundant large ungulate in this area, although the white-tailed deer has been extending its range westward from the Okanagan Basin and the Okanagan and Shuswap highlands. Moose are not originally native to this area, but migrated southward from the centre of the Province as forests of the north Cariboo were opened up by farming, logging and roadbuilding activities (Shewchuk, 1998). Moose are now dispersed throughout the area and can been seen in both open grasslands and upland swamps (Shewchuk, 1998). Bighorn sheep, both native California bighorn and the introduced Rocky Mountain bighorn, occur on the rugged grasslands throughout the Thompson and Okanagan valleys and in the Clear Ranges. Smaller mammals characteristic of the area include: spotted bats, pallid bats, Nuttall's cottontails, white-tailed jack rabbits, Great Basin pocket mice, and western harvest mice.

The Okanagan Connector was opened in 1990. It is a controlled access free way with no "at grade" intersections. Prior to its construction, the seasonal ranges and movements of moose were extensively studied between 1987 and 1989. Fourteen cow moose were radio-collared and relocated a total of 1212 times during this period (Gyug and Simpson, 1989). A fixed wing aircraft and helicopter were used to estimate population numbers. The studies were able to identify migration behavior that varied from some moose remaining in one location all year round; other moose had distinct winter ranges, but combined summer fall ranges; while, yet other moose had distinct winter, summer, and fall ranges. Moose were found to pass through a 7 m (diameter culvert. Tracking counts showed the passage rate by moose was 17%. Moose were found to migrate away from higher elevation habitats where snow depths exceeded 70 cm. Moose preferred lower elevation riparian or mixed deciduous-evergreen habitats where forage was abundant and thermal or security cover was available in nearby forests.

Underpasses for critical moose passage in winter range were determined to be 6.5 m (21.3 ft) by 7.4 m (24.3 ft) (Abrams, 1986). Deer underpasses were determined to be 4.2 m (13.8 ft) by 3.7 m (12.1 ft). The installed cost in 1989 for wildlife mitigation for the Okanagan Connector was estimated to be CAN$7 million. For this project, BCMoT spent CAN$500,000 on wildlife and mitigation studies (Stuart, 1989). Annual wildlife-vehicle collisions for the entire alignment were estimated to at 500 deer and 100 moose. A total of 40 moose collisions were estimated for the 30 km (18.6 mi) section of highway annually. There are approximately 82 km (51 mi) of wildlife exclusion fencing constructed on the Okanagan Connector on both sides of the highway. The fencing was designed to control moose, as the primary species, based on the size and weight of these animals, and deer, as the secondary species, based on their large population in the area (figure 13).

Figure 13. Location of the wildlife exclusion system between Aspen Grove and Drought Hill.

As part of the exclusion system, a wildlife overpass was constructed near Trepanier Creek. It was the first wildlife overpass constructed in Canada (figure 1). The overpass was closely modeled after the wildlife overpass built in Utah, the first wildlife overpass built in North America. Since the wildlife exclusion system was constructed on the Coquihalla Connector Freeway (Highway 97C) in 1990 to 1998, no wildlife accidents were recorded in either the westbound or eastbound lanes of the highway which are protected by wildlife exclusion fencing.

Highway 97

Extending almost 3,200 km, Highway 97 is one of the longest north-south highways in North America. It connects the City of Weed, in northern California to the Town of Watson Lake and the Alaska Highway, in the southeastern Yukon. From the late-1900's, in southern British Columbia, Highway 97 evolved on the terraces and benches above the western shores of Okanagan Lake.

The section of Highway 97 located between Peachland and Summerland is located in the Southern Interior Ecoprovince of British Columbia, the only ecoprovince in the Province that is part of the Dry and Semi-arid Steppe Highland ecodivisions. The southern end of the Okanagan Valley in British Columbia represents the northernmost extension of the Western Great Basin of North America. The area is located between the leeward ranges of the Coast Mountains, and the western side of the Okanagan and Shuswap highlands. Winters are cold and the summers are often very hot. This is one of the warmest and driest areas of the Province in summer. The Coast Mountains act as a barrier to the moist westerly air flow (Tourism British Columbia, 2006). Periodically, there are hot, dry air arrives from the United States, to the south, in the summer. This produces clear skies and very warm temperatures. The southern portions of the Interior Plateau, including the Okanagan, Similkameen, and Thompson River Valleys, experience the Province's hottest summers, with temperatures often in the 30oC (86 oF), occasionally rising above 40°C (104°F). In the winter and early spring, outbreaks of cold, dense Arctic air are common because there is no effective physical barrier in the north.

The area is very arid as it receives an average of 25 cm (8.9 in) to 40 cm (15.7 in) of precipitation and 2,000 hours of sunshine annually. (British Columbia Ministry of Environment, 2007). Low annual rates of precipitation, hot summers, and very mild winters create a number of different of semi-arid habitats. The dry grasslands and open pine forests in this area provide a vital landscape corridor between the shrub-steppe habitats of the Columbia Basin in Washington State in the south and the grasslands of the Thompson and Nicola valleys to the north and west.

The South Okanagan and Lower Similkameen has long been recognized as a providing a variety of habitats for unique species, many of which are found nowhere else in British Columbia or in the rest of Canada (British Columbia Ministry of Environment, 2007a, 2007b, 2007c, 2007d). The Okanagan Valley also has more species of plants and animals living here than in most areas of both British Columbia and Canada. The dry shrub grasslands of this area support a great variety of wildlife, including many of British Columbia's most rare and endangered species. There area is primarily habitat for mule deer but includes white-tailed deer, moose and mountain goats (Hope et. al., 1991). While mule deer are the most abundant large ungulate, the white-tailed deer has been extending its range westward from the Okanagan Basin and the Okanagan and Shuswap highlands. Bighorn sheep, both native California bighorn and the introduced Rocky Mountain bighorn, occur on the rugged grasslands throughout the Okanagan Valley and in the Clear Ranges. Spotted bats, pallid bats, Nuttall's cottontails, white-tailed jack rabbits, Great Basin pocket mice, and western harvest mice are characteristic small mammals.

From the late 1980's to the mid-1990's, the number of deer-related motor vehicles accidents occurring between Summerland and Peachland began increasing. In 1999, BCMoT partnered with the Insurance Corporation of British Columbia (ICBC) and Summerland Sportsmens' Association and the Peachland Sportsmen's Association, affiliated associations of the British Columbia Wildlife Federation, to construct a wildlife exclusion fence on the west side of Highway 97 between Bentley Road and Deep Creek. While BCMoT supplied fencing materials, ICBC contributed CAN$128,000 and the sportsmen's associations provided construction labour and on-going maintenance. Most Ministry wildlife exclusion installations involve the construction of fencing on both sides of a highway. However, due to the topography of this area, with steep banks on the east side of the highway, a decision was made to construct fencing on only the west side of the highway (figure 14).

Figure 14. Highway 97 between Peachland and Summerland.

The fence along this section of Highway 97 is only 15 km (9.3 mi) long and represents the BCMoT's shortest wildlife exclusion installation (figure 15). However, the installation has proven to be very effective, dramatically reducing the incidence of deer-related motor vehicle accidents. The installation also demonstrates how a fence installed on one side of a highway can be successful, if suitable physical landscape features can be incorporated into the design.

Figure 15. Location of the wildlife exclusion system between Peachland and Summerland.

Vancouver Island Highway (Highway 19)

The Vancouver Island Highway (Highway 19) runs for most of the length of the eastern coast of Vancouver Island. From Victoria to Port Hardy, the highway extends over 500 km (310 mi). Between 1989 and 2002, after extensive planning and preliminary, functional and detailed design stages, major upgrades to the highway were made. The longest section of the Vancouver Island Highway Project (VIHP), the Inland Island Highway, stretches from Parksville to Campbell River through an environmentally-sensitive area. The route includes new freeway and expressway alignments with numerous connectors and interchanges. The longest bridge on Vancouver Island, the Tsable River Bridge, was built on this section. The Inland Island Highway included the construction of 150 km (93 mi) of new 4-lane, limited access, divided highway between Victoria and Campbell River.

The Inland Island Highway is located on the leeward side of the Vancouver Island Ranges. After passing eastward over the Vancouver Island Mountains, Pacific Ocean surface air flow descends producing clearer and drier conditions than those found on the west side of the island. As a consequence, this area has the greatest annual amounts of sunshine in British Columbia (Pojar, Klinka and Demarchi, 1991a, 1991b). The moderating influence of the waters of the Strait of Georgia also produces local temperatures among the mildest in Canada. The climate on the East coast of the island is characterized by mild winters and warm summers. Precipitation ranges from 0.8 m (2.6 ft) to 2.5 m (8.2 ft) per year and rainfall is greatest between October and March. Large accumulations of snow on the Vancouver Island Mountains produce some of the lowest treelines in the British Columbia. However, at sea level, while winters are usually wet, snow is not common every year. Typically, summers tend to be dry, especially between June and August. Summer droughts often last 5 to 6 weeks.

The temperate coniferous forests of Vancouver Island provide among the richest habitats in North America for mammals, amphibians and birds. Mule deer ("black-tailed") are the predominant ungulate. From wild and rural areas to urban golf courses and suburban developments, they are ubiquitous. Although relatively few in number in comparison to mule deer, a number of growing herds of Roosevelt elk are found at scattered locations. Although there have been sporadic reports of Grizzly bear, the primary large carnivores on the island are cougar and black bear. Smaller carnivores include river otters, mink and raccoons. These animals tend to be found near water, either along ocean shorelines and in estuaries, or along lake shores and river banks. Small mammals in the area include the Virginia opossum, marsh shrew, Trowbridge's shrew, shrew-mole, Townsend's mole, coast mole, Douglas' squirrel, and creeping vole. The highest diversity of birds in British Columbia are also found in this area. Of all species known in the Province, approximately 90% occur on Vancouver Island. Reptiles found in the area include the sharptail snake while the ensatina and Pacific giant salamander are the predominant amphibians. A number of alien species are also found here. These include the western pond turtle, eastern cottontail rabbit, bullfrog and green frog.

In 1999, the Mud Bay-Courtenay section of the Inland Island Highway was completed. Two years later, the highway was extended to Campbell River. Finally, in 2001, Highway 19 was extended from Courtenay along the last section of the new inland highway to the Campbell River Bypass. The new sections of the Inland Island Highway were constructed through or near, one of the world's most diverse ecosystems, ranging from rainforests, marshes, meadows, beaches, mountains, oceans, rivers and lakes creating habitats for many wildlife species. Special care was taken to ensure the footprint of the new sections of highway were as small as possible and measures were implemented to compensate for lost wildlife habitat. Extensive efforts were also made to protect the Roosevelt elk. At four locations along the Inland Island Highway, where alignment transected elk habitat, wildlife exclusion systems were constructed. Wildlife exclusion fencing and associated structures were installed on both sides of three sections of highway and on one side of one section (figure 16). A total of 148 km (92 mi) of fencing was installed over 84 km (52 mi) of highway (figure 17).

Figure 16. Wildlife exclusion fencing on Vancouver Island Highway (Highway 19).

Figure 17. Location of wildlife exclusion systems on the Vancouver Island Highway.

Ongoing Advancements

It is becoming evident that approaching the issue of wild accident mitigation from a single species perspective does not provide the maximum benefit for wildlife. For BCMoT, integrated wildlife accident management is becoming a greater component of new construction and rehabilitation projects. While, for over 20 years, BCMoT projects have largely focused on highway-related mortality involving larger ungulates, such deer, elk and moose, new projects are increasingly becoming more responsive to the needs of smaller mammals, such as badgers, and amphibians, such as salamanders.

Wildlife exclusion systems are being designed and integrated with larger scale structures and alignment drainage schemes to protect an increasing number of animal species. The construction of larger underpasses, such as bridges and culverts, and the retention of natural watercourses, vegetation and landforms under these structures, increases their effectiveness for wildlife and fish passage. High quality wildlife habitat ponds are developed along highway alignments to lessen the impact of highways on wildlife habitat. On the Vancouver Island Highway Project, wildlife crossing structures and wildlife habitat ponds were carefully integrated with natural topography and drainage systems, to reduce the potential for highway-related wildlife mortality and limit the wildlife habitat fragmenting effects of highways (figure 18).

Figure 18. Man-made wildlife habitat pond adjacent to the Vancouver Island Highway.

Summary

BCMoT has found its wildlife exclusion systems to be very effective in reducing motor vehicle-related mortality on high speed highways for ungulates, in particular deer, elk and moose. Whether these systems are incorporated into the designs of new highways or retrofitted into existing ones, they are becoming an increasingly integral component on BCMoT's approach to reducing the potential for wildlife mortality on British Columbia highways.

Wildlife exclusion systems are most easily incorporated into new highways during the early planning and design stages. This allows major structures, such as bridges and culverts, to be designed to maximize their effectiveness for wildlife passage. Exclusion systems have been found to be the most effective means of keeping wildlife off highway rights-of-way when installed in conjunction with well-designed, well-located, wildlife crossing structures. Clevenger and Waltho (2000) found underpasses increase the success of exclusion fencing by increasing the permeability and habitat connectivity across highways.

BCMoT's experience with wildlife exclusion systems properly designed for specific species, that are well maintained, and strategically located, and that incorporate 2.4 m (7.9 ft) high fencing on both sides of rights-of-way and components, such as one-way gates, ungulate guards, underpasses and overpasses, can be more than 90% effective in preventing highway-related wildlife mortality. Improvements in the effectiveness of wildlife exclusion systems have been the result of system design evolution as the dynamics of the highway/wildlife habitat interface and the behavioral, physical and anatomical characteristics of specific species of wildlife have become better known.

Biographical Sketch: Leonard Sielecki is a registered professional biologist and a registered professional land use planner working under the Chief Engineer of the British Columbia Ministry of Transportation (BCMoT). Since the mid-1990's, Leonard has been the Government of British Columbia's expert on wildlife collision monitoring and mitigation. He manages BCMoT's Wildlife Accident Reporting System (WARS) and is actively involved in both the operational and research aspects of Provincial wildlife collision mitigation initiatives. He supervises and directs the work of wildlife consultants for BCMoT and is responsible for the design and development of the Ministry's wildlife exclusion systems. Leonard is involved in wildlife-related policy development and acts as the Ministry's liaison with Canadian federal and provincial agencies on wildlife-related transportation issues. He provides consulting services to Transport Canada and expert advice to BCMoT staff and consultants involved in major transportation projects in British Columbia. In 2005, the United States National Academies of Science appointed Leonard to the Transportation Research Board (TRB) expert panel overseeing the ongoing National Cooperative Highway Research Program (NCHRP) study on animal collisions in North America. Leonard has a B.Sc. in Biology and Geography, a Masters in Geography, and is currently completing a Ph.D. on natural hazard risk management at the University of Victoria.

References

Abrams, A.,1986, British Columbia Ministry of Transportation and Highways Communication to D.G. Johnson, Senior Design Engineer, Special Project, British Columbia Ministry of Transportation and Highways.

British Columbia Ministry of Environment, 2007a, Grassland Ecosystems, http://wlapwww.gov.bc.ca/sir/fwh/wld/atlas/ecosystems/ecosystems_index.html, accessed April 6, 2006

British Columbia Ministry of Environment, 2007b, Forest Ecosystems, http://wlapwww.gov.bc.ca/sir/fwh/wld/atlas/ecosystems/ecosystems_index.html, accessed April 20, 2007

British Columbia Ministry of Environment, 2007c, Riparian and Wetland Ecosystems, http://wlapwww.gov.bc.ca/sir/fwh/wld/atlas/ecosystems/ecosystems_index.html, accessed April 20, 2007

British Columbia Ministry of Environment, 2007d, Rugged Terrain Ecosystems, http://wlapwww.gov.bc.ca/sir/fwh/wld/atlas/ecosystems/ecosystems_index.html, accessed April 20, 2007

British Columbia Ministry of Forests, 1999, Biogeographic Zones of British Columbia Map, Research Branch, Victoria, British Columbia, Canada

British Columbia Ministry of Sustainable Resource Management, 2007, Ecoregions of British Columbia Home, http://srmwww.gov.bc.ca/ecology/ecoregions/index.html, Accessed April 20, 2007

British Columbia Ministry of Transportation, 2004, Quick Facts Book, October 2004, Victoria, B.C. 32 pp.

Buckingham, A.F., 2007, British Columbia Ministry of Transportation Communication to L.E. Sielecki, Environmental Issues Analyst, British Columbia Ministry of Transportation

Clevenger, A.P., Chruszez B. and Gunson, K.E., 2001, Highway mitigation fencing reduces wildlife-vehicle collisions, *Wildlife Society Bulletin*, 29(2): 646-653.

Demarchi, M., 2005, Wildlife Exclusion Fencing Audit: Coquihalla Highway (No. 5): Dry Gulch to Inks Lake Interchange, LGL Limited, Sidney, BC. 17pp.

Gyug, L. and Simpson K., 1989, Okanagan Connector Ungulate Telemetry and Inventory Progress Report, Seasonal Ranges and Movements of Moose, Keystone Bioresearch, Surrey, B.C. 32 pp.

Harper, W.L., 2005, Wildlife Exclusion Fencing on the Okanagan Connector Freeway (Highway 97C) Audit and Evaluation of Structures and Materials and Recommendations for Maintenance, Osiris Wildlife Consulting, Victoria, B.C., 48pp.

Hope, G.D., W.R. Mitchell, D.A. Lloyd, W.R. Erickson, W.L. Harper, and B.M. Wikeem, 1991, Interior Douglas-fir Zone, Chapter 3 in in Meidinger, D. and J. Pojar (Eds.), Ecosystems of British Columbia, British Columbia Ministry of Forests, pp. 153-166.

Ito, T., 2005, Wildlife-oriented measures against road kill accidents in Japan and their evaluation on Shari Eco-Road, IX International Mammalogical Congress, Proceedings of the Symposium on Wild animals and traffic accidents: Monitoring, analysis, prevention measures, and measure evaluation, Sapporo, August 2, 2005, pp.111-121

Hartwig C.L. and Demarchi R.A., 2005, Wildlife Exclusion Fencing Audit: Vancouver Island Highway No.19., Ecodomain Consulting, Duncan, B.C., 19pp.

Hayward, D., 2005, Highway 97 Wildlife Exclusion Fence Audit, Summit Environmental Consultants Ltd., Vernon, B.C., 33pp.

Hope, G.D., W.R. Mitchell, D.A. Lloyd, W.R. Erickson, W.L. Harper and B.M. Wikeem, Interior Douglas Fir Zone, Chapter 10 in Meidinger, D. and J. Pojar (Eds.), Ecosystems of British Columbia, British Columbia Ministry of Forests, pp. 153-166.

Kent, M., 2005, British Columbia Ministry of Transportation Communication to L.E. Sielecki, Environmental Issues Analyst, British Columbia Ministry of Transportation

Nuszdorfer, F.C., K. Klinka and D.A. Demarchi, 1991a, Coastal Douglas-fir Zone, Chapter 5 in Meidinger, D. and J. Pojar (Eds.), Ecosystems of British Columbia, British Columbia Ministry of Forests, pp. 81-93

Nuszdorfer, F.C., K. Klinka and D.A. Demarchi, 1991b, Coastal Western Hemlock Zone, Chapter 6 in Meidinger, D. and J. Pojar (Eds.), Ecosystems of British Columbia, British Columbia Ministry of Forests, pp. 95-111

Pojar, J. and D. Meidinger, 1991, British Columbia: The Environmental Setting, Chapter 3, in Meidinger, D. and J. Pojar (Eds.), Ecosystems of British Columbia, British Columbia Ministry of Forests, pp. 39-67

Public Safety and Emergency Preparedness Canada, 2007, Keeping Canadians Safe, http://www.psepc.gc.ca/dob/dob06-021-en.asp, Accessed April 20, 2007

Sielecki, L.E., 2004, WARS 1983 – 2002: Wildlife Accident Reporting and Mitigation in British Columbia: Special Annual Report, British Columbia Ministry of Transportation, Environmental Management Section, British Columbia, Canada, 222pp.

Stuart, K., 1989, British Columbia Ministry of Environment, Communication to Mike Kent, Senior Environmental Coordinator, British Columbia Ministry of Transportation and Highways

Shewchuk, M., 1998, Coquihalla Country, Sonotek Publishing, Merritt, British Columbia, 224 pp.

Tourism British Columbia, 2007, Climate and Weather, http://www.hellobc.com/en-CA/AboutBC/ClimateWeather/BritishColumbia.htm, accessed April 20, 2007