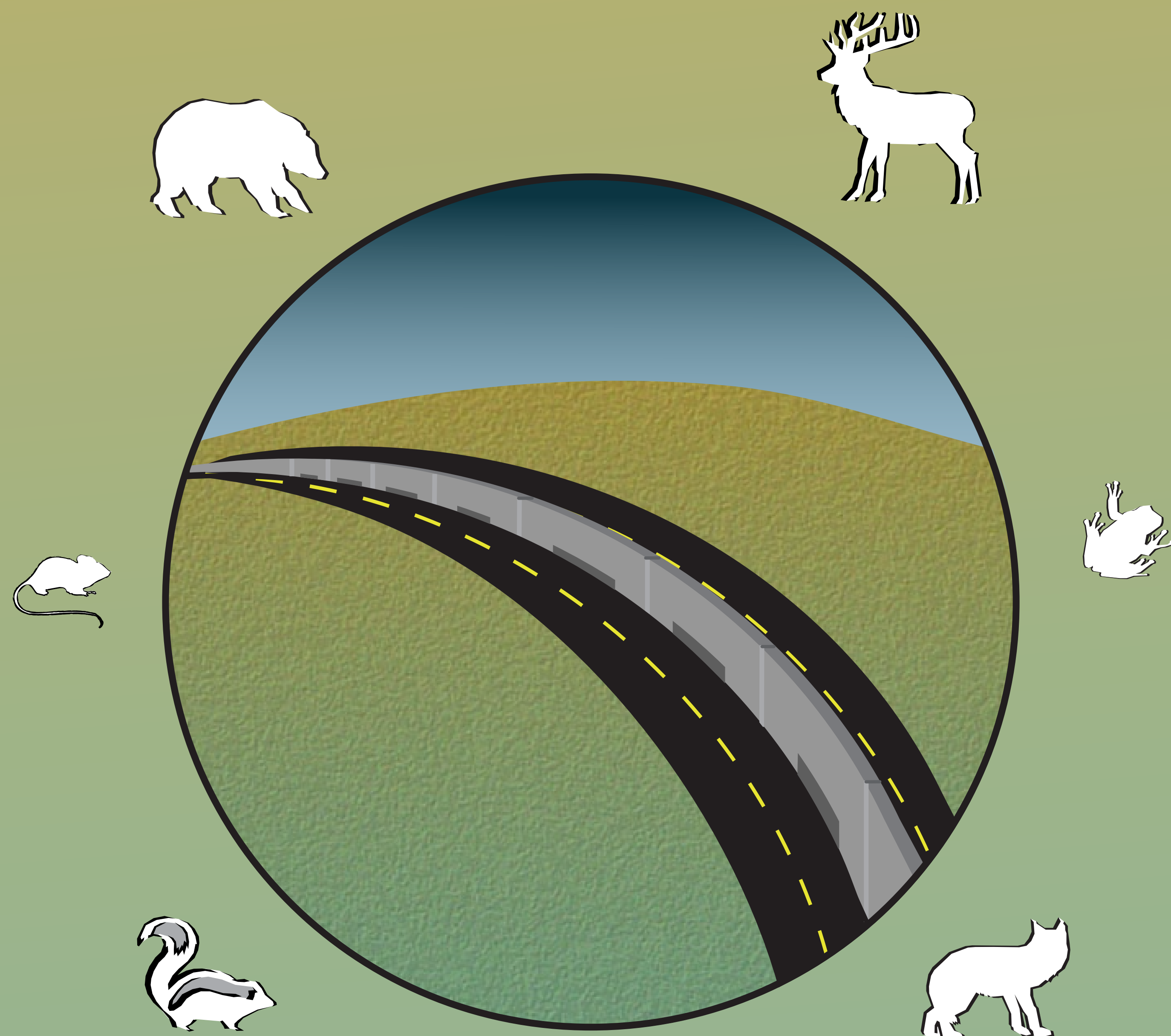
HIGHWAY MEDIAN IMPACTS ON WILDLIFE MOVEMENT AND MORTALITY

State of the Practice Survey and Gap Analysis

Final Report



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HIGHWAY MEDIAN IMPACTS ON WILDLIFE MOVEMENT AND MORTALITY

State of the Practice Survey and Gap Analysis

Final Report

by

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16. Abstract

Highway median barriers are used to separate lanes of traffic and enhance motorist safety on freeways and multi-lane interstate highways. Median barriers of all types have the potential to impede animal movements across highways. Barriers may also increase the risk of road mortality if wildlife becomes trapped or confused while on the road searching for a place to cross.

A recent Transportation Research Board report highlighted the need to better understand the potential impacts of highway barriers. The lack of information to properly assess environmental impacts is causing significant project delays and increasing transportation project costs.
This study includes a state of the practice survey and a review and synthesis of the literature on highway median barriers, their impacts to wildlife movement and performance of mitigative design solutions and provides Caltrans with research recommendations.

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PREFACE

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ACRONYMS LIST

Entities

AASHTO	American Association of State Highway and Transportation Officials
DOT	Department of Transportation
FHWA	Federal Highway Administration
NCHRP	National Cooperative Highway Research Program
NRC	National Research Council
TRB	Transportation Research Board
USDOT	United States Department of Transportation
WTI	Western Transportation Institute

Terms

AADT	Average Annual Daily Traffic
DVC	Deer Vehicle Collision
FAR	Fatal Accident Rate
WVC	Wildlife Vehicle Collision

1. INTRODUCTION

The impacts of roads on wildlife species are well documented (Evink 2002, Forman et al. 2003, National Research Council [NRC] 2005) and have been described in the literature for more than 50 years (Stoner 1925, Haugen 1944, Finnis 1960). Aside from roads benefiting some wildlife as habitats for plants and corridors for travel, they can also create barriers to movements, eliminate and alienate habitat, and be a source of mortality. Of these, road-related mortality is the most visible and direct effect roads have on wildlife. Mortality due to roads can potentially jeopardize the long-term persistence of wildlife populations (see Puglisi et al. 1974, Romin and Bissonette 1996) and is quickly becoming a serious traffic safety problem in North America, Europe and Japan (Conover et al. 1995, Groot Bruinderink and Hazebroek 1996, Hedlund et al. 2003).

Roads represent an obstacle to maintaining ecological connectivity and viable wildlife populations (Bennett 1991, Forman et al. 2003). Reduced landscape connectivity and impeded movements due to roads may result in higher mortality, lower reproduction and ultimately smaller populations and lower population viability. These deleterious effects have underscored the need to maintain and restore essential movements of wildlife species across roads, particularly those with high traffic volumes. In view of their great mobility and extensive spatial requirements for survival, large mammalian carnivores are vulnerable to road effects (Noss et al. 1996; Woodroffe and Ginsberg 2000). However, small taxa with patchy and localized distributions are equally vulnerable to fragmentation effects of roads (Mader 1984, Mansergh and Scotts 1989, Gibbs and Shriver 2002, Gerlach and Musolf 2000,

The barrier or fragmentation effects of roads result when animals within populations are unable to approach or cross roads to connect habitats, access mates or meet other biological requirements. The avoidance of roads or limiting crossing opportunities is generally attributed to road characteristics, such as traffic density, noise, and width of road. Other physical features of roads and adjacent habitat have been shown to limit animal movement or be associated with the occurrence of road-killed animals. Adjacent topography, particularly road alignment with major drainages, strongly influences the movement of ungulates toward roadways and across them (Bellis and Graves 1971, Carbaugh et al. 1975, Mansfield and Miller 1975, Feldhammer et al. 1986, Reeve 1988). Malo et al. (2004) showed collisions rarely occurred where roadsides had high embankments, and Biggs et al. (1999) found ungulates had a tendency to avoid road crossings in areas of steep terrain. Culverts and bridges were locations on roads where animals crossed more frequently (Hubbard et al. 2000, Barnum 2003). Raised highway structures such as concrete median barriers and steel guardrails therefore have the potential to block or limit movement of animals across roads.

Highway median barriers are used to separate lanes of traffic and enhance motorist safety on freeways and multilane interstate highways. Barriers most commonly used in North America are either made of concrete or corrugated galvanized steel. Recently median barriers made of wire cable are gaining popularity in New Zealand and Europe. Median barriers of all types have the potential to impede animal movements across highways given their height, mass, and extent on many highways. Barriers may also increase the risk of motor vehicle accidents by causing wildlife to become trapped or confused while on the road surface searching for a place to cross. From a habitat fragmentation perspective, wildlife may avoid crossing roads altogether where raised median barriers are in place.

Despite these potential impacts, the 2006 American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide (RDG) does not address the effects of highway median barriers on wildlife habitat fragmentation. Resource managers and transportation biologists have identified this as a severe shortcoming that needs immediate attention. A recent Transportation Research Board (TRB) report highlighted the urgent need to better understand how wildlife respond to and are potentially impacted by highway barriers (TRB 2002a). Nationwide, existing highways and transportation projects are being planned to utilize median barriers. The barriers can potentially affect mule deer *(Odocoileus hemionus)* migration across Highway 97 in Oregon; Canada lynx (*Lynx canadensis*) and other wildlife traversing Interstate 70 in Colorado; and grizzly bear (*Ursus arctos*), wolf (*Canis lupus*), lynx and other species movements across Interstate 90 in Montana. Local wildlife biologists believe these structures present formidable barriers for almost all species of wildlife, large and small.

Some median barrier designs have been used to mitigate potential barrier effects on movements, e.g., passages or openings at the bases of concrete Jersey barriers called “scuppers” or “cutouts,” and spacings or gaps between Jersey barrier panels, but they remain virtually untested. The lack of information to properly assess environmental impacts is causing significant project delays and increasing transportation project costs. The California Department of Transportation (hereafter Caltrans) and other state transportation departments are installing highway median barriers in the absence of information on how they affect wildlife movement and mortality, and whether median barriers may adversely, indirectly affect motorist safety.

A state of the practice survey and gap analysis would enable Caltrans to assess effects of median barrier projects on wildlife movements and mortality, meet its obligation to disclose those effects to the public, be a good steward of natural resources by mitigating those effects where warranted, and complete median barrier projects expeditiously. Results from a collective synthesis of this type will produce a solid foundation from which to develop and initiate field studies investigating the effects and performance of a variety of median barrier designs on the movement and mortality of wildlife.

2. BACKGROUND

2.1 Barrier Effects and Wildlife Habitat Fragmentation

2.1.1 Roads and Other Linear Infrastructure

Many landscapes are undergoing extensive and rapid change as a consequence of human activities (Hansson and Angelstam 1991; Houghton 1994). One of the major changes associated with landscape modification is the loss and fragmentation of habitat (Bennett 1999). Less conspicuous than other forms of habitat disturbance, linear features such as road networks can have immense and pervasive impacts on wildlife populations (Forman and Alexander 1998; Rowland et al. 2000; Trombulak and Frissell 2000). In an increasing number of landscapes, the regular movements of animals involve road crossings.

Road networks and systems are vital to today's economy and society (Button and Hensher 2001). Not only do roads provide for safe and efficient movement of goods and people across cities and continents, throughout the world they have become a permanent part of our physical, cultural and social environment (Robinson 1971; Lay 1992). Roads and their networks are one of the most prominent human-made features on the landscape today (Sanderson et al. 2002). Compared to polygonal blocks of built areas, road systems are linear and etched into the landscape to form a woven network of arteries that maintain the pulse of societies. However, as road networks extend across the landscape and their weave intensifies, natural areas become increasingly fragmented and impoverished biologically (Forman et al. 2003).

Despite increasing attention given to the harmful effects of roads (Canters 1997, Evink et al. 1998; Forman and Alexander 1998), road density continues to escalate in North America and Europe, as does motor vehicle travel. Currently there are more than 3.9 million miles [6.2 million km] of public roads in the United States traversed by 200 million vehicles (TRB 1997). As road system networks expand and are upgraded to accommodate an increasing number of vehicles, conflicts between motorists and wildlife are likely to increase.

Although less studied compared to other agents of fragmentation, roads cause changes to wildlife habitat that are more extreme and permanent than other anthropogenic sources of fragmentation (Forman and Alexander 1998; Spellerberg 2002). Road networks and systems not only cause conspicuous changes to physical landscapes, but also alter the patterns of wildlife and the general function of ecosystems within these landscapes (Swanson et al. 1988; TRB 1997; Olander et al. 1998). Busy roads can be barriers or filters to animal movement (Hels and Buchwald 2001; Rondinini and Doncaster 2002; Chruszcz et al. 2003) and in some cases the leading cause of animal mortality (Maehr et al. 1991; Jones 2000; Kaczensky et al. 2003). Sustainable transportation systems must provide effectively for natural processes and biodiversity, and safe and efficient human mobility.

Over the last decade, federal land management and transportation agencies have become increasingly aware of the effects of roads on wildlife. Significant advances in the understanding of these impacts have been made; however, the means to adequately mitigate these impacts have been slower in coming (Clevenger and Wierzchowski in press). Effective wildlife fencing and crossing structures can significantly reduce many harmful impacts of roads on wildlife populations (Falk et al. 1978; Kistler 1998; Clevenger et al. 2001). Yet currently there is limited knowledge on cost-effective mitigation measures that promote sustainable wildlife populations and functioning ecosystems (TRB 2002a). Anticipated population growth and ongoing highway investments in most regions, coupled with the resounding concern for maintaining large-scale landscape connectivity and endangered species protection, have generated increasing interest in mitigation passages as habitat and species conservation tools.

The impact of transportation systems on wildlife ecology and remedial actions to counter these effects is an emerging science. Research remains scarce on the influence of road systems on habitat fragmentation and the conservation value of crossing measures in restoring connectivity (Spellerberg 2002; TRB 2002b; Forman et al. 2003). Moreover, research has primarily focused at the level of individuals and single-species (Guyot and Clobert 1997; Gibbs and Shriver 2002; Ortega and Capen 1999). Key questions remain regarding population- and ecosystem/community-level impacts of roads and the benefits of wildlife crossings to reduce those impacts (Clevenger and Waltho 2000, 2005; Underhill and Angold 2000).

2.1.2 Connectivity

Landscape connectivity is the degree to which the landscape facilitates animal movement and other ecological flows (Forman 1995; Bennett 1999). High levels of landscape connectivity occur when the matrix areas of the landscape comprise relatively benign types of habitats without barriers, thus allowing organisms to move freely (Tischendorf and Fahrig 2000). Reduced landscape connectivity and impeded movements due to roads may result in higher mortality, lower reproduction and ultimately smaller populations and lower population viability (Gerlach and Musolf 2000; Keller and Lagiardèr 2003). These deleterious effects have underscored the need to maintain and restore essential movements of wildlife across roads, particularly those with high traffic volumes.

Fragmentation effects caused by roads begin as individual animals become reluctant to move across roads to access mates or otherwise preferred habitats for food and cover. This aversion to roads is generally attributed to road features (traffic volume, road width) or habitat changes caused by the road. High volume roads have the greatest impact in blocking animal movements (Brody and Pelton 1989; Rondinini and Doncaster 2002; Chruszcz et al. 2003). Yet secondary highways and unpaved roads can impede animal movements as well (DeMaynadier and Hunter 2000; Develey and Stouffer 2001). Ultimately, the barrier effect of a road will impact populations differently depending on species behavior, dispersal ability, and population densities (Lima and Zollner 1996; Cassady St Clair 2003).

The relative permeability of road edge habitat can influence the barrier effect of roads. The severity of this factor is likely dependent on the “hardness” of the edge and habitat needs per species. An open road corridor with grass-covered verges can be a formidable barrier to a forest-specialist small mammal regardless of mortality risks due to vehicles on the roadway. In the last decade, studies have begun assessing barrier permeability and dispersal success of animals in a patch-matrix landscape (Lima and Zollner 1996; Tewksbury et al. 2002). Despite roads being a dominant and permanent landscape feature, relatively few studies have investigated road systems and their role in habitat fragmentation (see Gibbs 1998).

2.1.3 Mitigation of Barrier Effects of Roads

One of the earliest recommendations to arise from studies of habitat fragmentation was that habitat patches linked by a corridor of similar habitat are likely to have greater conservation value than isolated fragments of similar size (Diamond 1975). This early recommendation was based entirely on theory of island biogeography (MacArthur and Wilson 1967). Since then, there has been widespread interest in corridors as conservation measures (Saunders and Hobbs 1991; Beier and Noss 1998; Crooks and Sanjayan in press).

Wildlife crossing systems are designed to link critical habitats and provide safe movement of animals across busy roads. Typically they are combined with high fencing, partial fencing, or no fencing, but nonetheless are proven measures to reduce road-related mortality of wildlife and restore movements (Foster and Humphrey 1995; Clevenger et al. 2001). In recent years there has been an increase of crossings being built in North America and worldwide (McGuire and Morrall 2000; Goosem et al. 2001; Bank et al. 2002). The U.S. Transportation Equity Acts (TEA) of the last decade has enabled numerous highway mitigation projects for restoring wildlife habitat connectivity. Equally important and concurrent with the increased interest and application of the measures have been a National Cooperative Highway Research Program (NCHRP) project 25-27, “Evaluation of the Use and Effectiveness of Wildlife Crossings”, and numerous workshops and training courses specific to mitigating road impacts on barrier effects.

Raised concrete median barriers such as the Jersey and Texas type obviously can limit cross-highway connectivity and genetic interchange of many small and medium-sized fauna. Movements of large mammals can also be impaired when encountering such structures in the central median. Transportation agencies and consulting engineers have been known to install median barriers that meet traffic safety needs while attempting to allow for wildlife habitat connectivity. Caltrans currently has developed three different median barrier designs and applications that enhance cross-highway movements of wildlife. Whether these laudable attempts remediate the negative impacts of median barriers remains to be seen. Ultimately a concerted research effort on the performance of raised median barrier designs in different landscapes with varying taxa will produce a solid foundation to guide transportation practitioners in California and elsewhere.

2.2 A Brief Overview of Median Barriers

Median barriers are longitudinal safety devices used to separate opposing lanes of traffic on divided highways (AASHTO 2006). They are designed to enhance motorist safety by redirecting vehicles that strike either side of the barrier (AASHTO 2006). The relative number of cross-median accidents is low when compared to total accidents, but the proportion of associated fatalities and injuries is substantially higher (FHWA 2006a, Macedo 1999, Lynch et al. 1993).

Collectively, median barriers and similar devices have been shown to be effective countermeasures for reducing injury severity and fatalities. In North Carolina, after the installation of cable median barrier systems, the average crash severity in median crashes decreased by 50% (Lynch 1998). A meta-analysis of 32 studies (n = 232) estimating collision reductions with the use of median barriers, guardrails and crash cushions showed that median barriers reduce severity (but increase crash frequency) while guardrails and cushions reduced both frequency and severity (Elvik 1995 in Strathman et al. 2001). In Sweden, converting wide two lane roads to a 2+1 with median barrier has resulted in an 80% reduction in fatalities and a 50% reduction in severe injuries from head-on or run-off-road collisions on rural state highways (Bergh and Moberg 2005).

Concrete barriers are most commonly used in urban areas, and metal beam and cable barriers are common choices in rural areas (FHWA 2006a). The most commonly used concrete median barrier in the US is the concrete New Jersey shape (Jersey or NJ) barrier (Ray and McGinnis 1997) but unintended costs and potential risks due to installation have been identified for both motorists and wildlife.

In the search for information about the effects of median barriers on wildlife movement and mortality and associated motorist safety, few studies were identified which address the issue specifically. A predominant theme that emerged, however, was the variation in standards for where and when to install median barriers to achieve increased motorist safety and cost effectiveness. This complex, site-specific reality, coupled with the largely unknown impacts of median barriers on wildlife, creates a challenge for transportation agencies concerned with both motorist safety and ecological connectivity. Some median barrier designs and mitigative countermeasures hold promise for meeting safety needs while allowing for wildlife permeability, but the need for empirical research remains.

2.2.1 Installation Guidelines and Historical Trends

On the US freeway system in 2001, crossover median head-on collisions resulted in an estimated 267 human fatalities (FHWA 2006a). Median crossover collisions on interstate highways often result in fatality or severe injury (Monsere et al. 2003) and economic and social losses (Donnell et al. 2002). Median head-on collisions are less frequent but can be three times as severe as other more prevalent highway crashes (North Carolina Department of Transportation in FHWA 2006a). A study of an interstate highway system showed more than 17% of cross-median collisions were fatal and 67% involved injury (Donnell and Mason 2004). For rural two-lane roads, opposing direction crashes account for 20% of fatal crashes and result in 4,500 fatalities annually in U.S. (NHTSA 2003b in Persaud et al. 2004). Collisions involving vehicles that cross over the centerline often are associated with failure to keep in proper lane, inattention, driver fatigue and speeding (Persaud et al. 2004). Options to reduce opposing direction collisions include installing median barriers or widening the roadway (Persaud et al. 2004).

Cable median barriers have been used on US highways since the 1930s (Stasburg and Crawley 2005). The first documented use of concrete median barriers dates back to the 1940-50's in California and New Jersey when the standard was 12 to 18 inches [30 to 46 cm] tall (Kozel 2004). Years of experimentation resulted in a variety of concrete designs (Jersey, Texas, F-shape, and constant-slope) (Kozel 2004, McDevitt 2000) and the 59 inch [150 cm] Ontario Tall Wall high performance concrete barrier (Hubbs and Boonstra 1995).

The most frequently used standard is the Jersey barrier that ranges from 32 inches [81 cm] tall to 57 inches [145 cm] tall (NRC 2005). By 1972, California installed 132 miles [212 km] of Jersey barriers, increasing to 680 miles [1100 km] by 1988 (Kozel 2004). By 1997 California had more than 1,600 miles [2600 km] of concrete and metal freeway median barriers across the state (Caltrans 1997). Over the past decade, the installation of median barriers by departments of transportation (DOTs) has become more widespread in California and elsewhere. Jersey barriers, weighing 600 pounds per linear foot [224 kg per 30 linear cm], are often cast in place or slip-formed (Kozel 2004) making installation so efficient that barriers may stretch continuously for miles. (See photos of median barrier types in Appendix A.)

AASHTO's Roadside Design Guide offers recommendations for placement of median barriers to reduce or eliminate median-encroaching vehicle collisions. The revised excerpt of Chapter 6: Median Barriers (approved by the Technical Committee of Roadside Safety on April 12, 2006) "recommends median barrier on high-speed, fully controlled-access roadways for locations where the median is 30 feet [9 m] in width or less and the average daily traffic (ADT) is greater than 20,000 vehicles per day. For locations with median widths less than 50 feet [15 m] and where the ADT is less than 20,000 vehicles per day, a median barrier is optional."

A one-size-fits-all approach to median barrier guidelines is not appropriate, and case-specific cost/benefit analyses, engineering studies and crash history studies may be required to determine the need for median barrier installation (AASHTO 2006). Each transportation agency has the flexibility to develop its own barrier guidelines and warrants (AASHTO 2006). Some state level policies are more stringent in their median barrier implementation than outlined in the AASHTO guidelines (AASHTO 2006, BMI NCHRP Project in Gabler et al. 2005, Miaou et al. 2004) and suggest that variables other than access control, median width and average daily traffic should be considered (Chanayan et al. 2004, Miaou et al. 2004). Some studies provide recommendations for median barrier guidelines to prevent inappropriate or excessive installation (Miaou et al. 2004, Chanayan et al. 2004) or to encourage more installation (Donnell et al. 2005, Chanayan et al. 2004).

California, Florida, North Carolina, Pennsylvania, Washington and others have adopted more stringent policies for installing median barriers (Miaou et al. 2004). In 1998, Caltrans adopted a policy to install median barriers in medians less than or equal to 75 ft. [23 m] and for new construction whenever a median barrier is anticipated to be needed within five years (Miaou et al. 2004). If the median is less than 20 ft. [~6 m] wide, the policy calls for a concrete barrier; 20 –36 ft. [~ 6-11 m] wide, a concrete or thrie beam barrier; 36-75 ft. [~ 11-23 m] wide, a thrie beam barrier (Miaou et al. 2004). Caltrans and Florida Department of Transportation both have instituted warrants based on crash history (Miaou et al. 2004). In 1998, North Carolina Department of Transportation also adopted a more stringent policy on median barriers on all new construction, reconstruction or resurfacing of roads with medians less than or equal to 70 ft. [~ 21 m] (Miaou et al. 2004).

When determining what type of median barrier should be used, the Federal Highway Administration states a number of factors should be addressed, including: traffic volume and speed, traffic vehicle mix, median width and cross slope, number of lanes, roadway alignment, crash history, and installation/maintenance costs (FHWA 2006a). Raised linear safety structures bisecting roads and landscapes may pose unintended risks to motorists and wildlife alike.

With wildlife-vehicle collisions (WVCs) on the rise and increased development impacts to wildlife and wildlife habitat, ensuring that a safety feature such as the Jersey barrier serves its intended need while not creating another problem is important. The potential, and as yet understudied, environmental impacts of median barriers requires further study. A Transportation Research Board report highlighted the need to better understand the potential impacts of highway barriers on wildlife (TRB 2002a).

2.2.2 Unintended and Potential Impacts of Median Barrier Installation

A survey of the engineering- and safety-focused literature illustrates that there are costs and benefits to utilizing median barriers, which can vary from project to project. This study does not attempt to analyze the complex array of data required for median barrier installation recommendations and warrants but seeks to illustrate that whether or not to install a raised median barrier in the first place is not necessarily a straightforward decision. In Kansas, segments of divided highway with a grassy median were associated with higher deer vehicle collision (DVC) rates than segments with a Jersey barrier, and segments with a Jersey barrier were associated with higher DVC rates than undivided two-lane highways (Meyer and Ahmed 2004). On the other hand, Mok and Landphair's (2002) study showed that parkway sections, characterized by grassy medians, were safer in terms of fatal accident rate (FAR) and had a significantly lower accident cost (AC) when compared to parallel sections of freeways which are characterized by concrete median barriers. Safety performance was particularly significant for urban parkway sections (Mok and Landphair 2002). Gattis et al. (2004) provide conclusions about the safety records of rural low, medium and high access density roads with no, narrow and/or depressed medians.

2.2.2.1 Impacts to Motorists

One way to reduce cross-median collisions is to install median barriers, but an important note is that median barriers do not prevent all crashes (Miaou et al. 2004). The installation of median barriers can transform cross-median collisions into hit-median barrier collisions or they can prematurely force a collision with a barrier when otherwise the motorist and vehicle may have recovered safely (Miaou et al. 2004). A before-and-after study in California showed that median area accidents increased by 10 to 20 percent with median barrier installation (Seamons and Smith 1991). Hunter et al. (2001) found that serious injury and fatalities decreased with median barrier installation but that the frequency of less severe fixed object collisions increased. In the case of deer vehicle collisions, fatal human injuries can occur not only when a motorist strikes a deer, but also when the motorist swerves to avoid the animal and strikes another vehicle or a fixed object instead (Urbitran Associates et al. 2005). Chanayan et al. (2004) references the Seamons and Smith (1991) study that found a total increase of roughly 14% in all injury (including fatal injury) accidents when median barriers were installed at freeway locations.

After installation, general trends indicate that median barrier crashes increase in frequency when posted speed limit increases (Donnell and Mason 2004, Meyer and Ahmed 2004), when the presence of interchange ramps increases, and with curve-associated variables (Donnell and Mason 2004). A count model comparison of road sections with and without median barriers indicated that as the number of curves per mile increased in a section with barriers, the overall crash profile would increase compared to similar sections without median barriers (Chanayan et al. 2004).

To determine the cost-effectiveness of installing a barrier, the benefit of reducing the frequency and severity must be compared with the cost of installing and maintaining a barrier that generates barrier-crashes that otherwise would not have occurred (Miaou et al. 2004). Using Texas data, Miaou et al. (2004) determined, in a 4-lane highway with a posted speed limit of 65 mph [105 km/hr] scenario, installing concrete median barriers in sections that are 1) up to 60 ft. wide [18 m] with 10,000-15,000 average annual daily traffic (AADT), and 2) in sections that range from 60 ft. wide with 15,000 AADT to 125 ft. wide [38 m] with 30,000 AADT, may not be beneficial and perhaps even wasteful. From another perspective, a study using Pennsylvania data showed that approximately 0.7% of median barrier (fixed object) crashes on the Interstate system resulted in fatality, 56% resulted in injury and 43% were property-damage-only crashes while more than 17% of cross-median collisions were fatal, and 67% involved injury (Donnell and Mason 2004).

Median barriers carry a three-fold maintenance cost, direct monetary cost, traffic delays, and risk to road crews (Chanayan et al. 2004) and are not always cost effective (Macedo 1999). Emergency response operators also indicated continuous median barriers lead to delays in responding to events (Srinivasan et al. 2003). Concrete median barriers characteristic of freeways tend to affect the aesthetics of a roadway, but public demand for context sensitive design, such as those featured on parkways, may play a safety benefit (Mok and Landphair 2002). To put a complex process into simple terms, “The decision to install a median barrier is a balancing act” (Hauer 2000 in Miaou et al. 2004). Median barrier installation can produce safety, social, and economic benefits, but it can also incur costs.

2.2.2.2 Impacts to Wildlife

The very nature of median barriers is that of an obstacle which did not previously exist. There is concern that concrete barriers impede small and large animals that attempt to cross highways. Solid concrete structures often extend continuously for many miles creating a wall that can disrupt wildlife movements (Forman et al. 2003, Servheen et al. 1998). Median barriers of all types have the potential to impact wildlife directly and indirectly. AASHTO’s Roadside Design Guide, on which most US transportation agencies rely to some degree, has yet to address this issue (NRC 2005, AASHTO 2006). The general hypothesis is that concrete Jersey barriers may increase the risk of direct vehicle mortality (Basting 2003, NRC 2005, Cooper 1999, Lloyd and Casey 2005, Ontario Ministry of Transportation 2005, Ross 2004, Servheen et al. 2003) or block or otherwise limit animal movement in road sections with the barriers (Barnum 2003, NRC 2005, Cooper 1999, Epps et al. 2005, Jackson and Griffin 2000, Lloyd and Casey 2005, Servheen et al. 2003). Impacts to wildlife carry economic consequences as well as environmental consequences. A review of species-specific studies and responses to median barriers follows in Chapter 3.1.

2.2.3 Current Trends

The Federal Highway Administration has accepted as crashworthy a variety of concrete, metal beam, cable and other median barrier designs that have passed National Cooperative Highway Research Program (NCHRP) 350 Tests (FHWA 2006a and b). The NCHRP Report 350 establishes the framework for the safety performance evaluation of highway features (Gabler et al. 2005).

The US Department of Transportation (USDOT) has stated the need for an alternative to traditional concrete and metal beam barriers because they can be expensive and difficult to install, citing a nationwide goal for each state to identify appropriate projects for deploying cable median barriers as a potential solution (USDOT 2006). FHWA names cable barriers and rumble strips as two priority technologies with proven benefits and which are ready for deployment (Taylor 2005).

Cable barriers have tended to be more popular in Europe and New Zealand; however, some states including Texas, North Carolina, Oklahoma, Iowa, Colorado, Utah (Miaou et al. 2004), Missouri, California, Florida, Wisconsin, Maine, Idaho (Johnson 2006) and Washington (McClanahan et al. 2003) are installing high-tension cable median barriers.

2.3 Study Objectives

The objectives of this study are:

- To collect, review and synthesize literature on highway median barriers to gain an understanding of their impacts on a range of species (from small mammals and herpetiles to wide-ranging fragmentation-sensitive species) and the performance of mitigative design solutions.
- To survey transportation agencies to determine trends and patterns of utilization of the varying median barrier designs, regulatory and practical issues in their deployment, and research being conducted or scheduled.
- To conduct a gap analysis to highlight information needs to provide Caltrans with sound, scientifically defensible information for completing median barrier projects.
- To produce a solid foundation from which to develop and initiate field studies investigating the effects and performance of median barrier designs on the movement and mortality of wildlife.

3. SYNTHESIS OF LITERATURE REVIEW AND SURVEY RESULTS

3.1 Literature Review of the Effects of Median Barriers on Wildlife

A literature review was conducted to gain an understanding of what is known about the effects of median barriers (especially concrete designs) on wildlife mortality and movement. Appendix B lists the indexes, databases and websites that were searched. An updated version of the annotated bibliography originally submitted as an interim report (Task 1 deliverable) is included (Appendix C).

There is documented concern that concrete median barriers, or their placement, may impact wildlife populations by increasing mortality through vehicle collisions and/or by limiting their movement across the landscape (Barnum 2003, Basting 2003, Cooper 1999, Epps et al. 2005, Jackson and Griffin 2000, Lloyd and Casey 2005, Ontario Ministry of Transportation 2005, NRC 2005, Ross 2004, Servheen et al. 2003). As of 1995, there had been no published articles on the impacts of median barriers on wildlife (Hubbs and Boonstra 1995) although Woods (1990) briefly addresses median barriers as part of a fencing-underpass project. Since then, few studies have been conducted in an attempt to determine the actual effects of median barriers on wildlife. The existing knowledge on this topic is sparse and the issue of motorist safety within the context of WVCs in the presence of median barriers appears to be even less explored.

3.1.1 Mortality

Wildlife-vehicle collisions are considered a safety and environmental issue in the United States and around the world. Estimates of 750,000 to 1.5 million automobile collisions with deer (*Odocoileus* sp.) alone occur on US roads each year (Romin and Bissonette 1996, Conover et al. 1995). The annual impact is more than 200 human fatalities, 29,000 injuries and one billion dollars in vehicle damage (Conover et al. 1995). Road-killed animals are also an obvious result of WVCs but the exact magnitude is yet unknown because of inadequate record keeping (Evink 2002).

There is evidence that the majority (70-88%) of WVCs occur on undivided two-lane roads with a much smaller percentage occurring in the presence of raised median barriers (Elzohairy et al. 2004, Urbitran et al. 2005). Deer and elk (*Cervus* sp.) road-kill locations were found to occur less often than expected in areas with a Jersey barrier in the median (Singleton and Lehmkuhl 2000). Conversely, Gunson et al. (In prep.) found ungulate-vehicle collision sites were closer to concrete median barriers and guardrails than expected by chance. While the relative percentage of WVCs occurring in the presence of a raised median barrier appears quite low, the numbers are likely still substantial enough to constitute a motorist safety concern.

Whether or not a vegetated median, in road sections wide enough to accommodate them, can enhance an animal’s ability to safely cross the roadway (Lloyd and Casey 2005) or whether a divided (with raised barrier) versus an undivided roadway reduces the likelihood of WVCs is unclear. In a 13-county region in New Jersey, 70% (n = 3,524) of deer-vehicle collisions (DVCs) occurred on roads without medians or guardrails, 19% (n = 959) of DVCs occurred in the presence of a grassy median while 6% (n = 309) occurred in the presence of a concrete barrier, 3% (n = 147) in the presence of a guardrail, 1% (n = 36) in the presence of a concrete median and 1% was categorized as “other” (Urbitran et al. 2005). A model of deer-vehicle crash likelihood using roadway characteristics in Kansas also illustrates that highways with grassy medians were associated with higher DVC rates than those with Jersey median barriers, but those with Jersey barriers were associated with higher DVC rates than undivided two-lane highways (Meyer and Ahmed 2004).

A highway-widening project from 2 to 4-lanes did not appear to act as a barrier to dispersing wolves (*Canis lupus lycaon*) in Wisconsin, but whether the mitigation effort of a ballooned median of natural cover actually facilitated crossings of the highway is unknown (Kohn et al. 2000). In Southern Texas, bobcat (*Lynx rufus*) mortality was more frequent in road sections with thornshrub in the median (Cain et al. 2003). On an unfenced, twinned highway in Canada, elk-vehicle collisions were not significantly related to concrete or grassy medians (Woods 1990). A road kill study of small terrestrial vertebrates in Canada found that the number of Jersey barriers along roadways was not a factor in explaining road-kill occurrence of small- and medium-sized vertebrates (birds, mammals, amphibians) but that birds were 85% more likely to be killed on roads with vegetated medians than on roads without medians (Clevenger et al. 2003). Medians vegetated with a fruit-bearing shrub (*Thorny eleagnus*) have been linked to 95% of bird vehicular mortality in one study, with as many as 350 dead birds collected at one location in a single day (Watts 2005).

Anecdotal evidence gathered in an expert-opinion rapid assessment makes a potential link in road-killed beaver (*Castor canadensis*), nutria (*Myocastor coypus*), raccoon (*Procyon lotor*), deer and birds with the presence of a Jersey barrier (Lloyd and Casey 2005). Road kill rates of small- to medium-sized mammals (including weasels (*Mustela* sp.), skunks (*Mephitis* sp.), groundhogs (*Marmota* sp.), opossums (*Didelphis marsupialis*) and foxes (*Vulpes vulpes*) were not higher or significantly different in road sections with concrete median barriers compared to those without concrete median barriers (Armstrong 1994 in Hubbs and Boonstra 1995). An independent unpublished report on a connectivity study on Highway 401 in Ontario suggests that the presence of a continuous concrete median barrier (including the Ontario Tall Wall, measuring 59 in. [150 cm] tall (Hubbs and Boonstra 1995) tends to increase the amount of mammalian road kill (Ross 2004 unpub.). In response to concerns of federal agencies and the public, the Ontario Ministry of Transportation completed a median barrier wildlife mortality field study on mammals, birds, amphibians and reptiles on Highway 401, the results of which should be available in fall 2006 (K. Ogilvie, Ontario Ministry of Transportation, pers. comm.).

Hostick and Styskel (2005) attempted to determine whether the installation of highway dividers would increase the number of animals killed by vehicle collision. Deer kills were not higher than expected in road sections with newly installed guardrail and/or concrete median dividers designed with animal passage in mind (Hostick and Styskel 2005). The results from this study, however, are not conclusive about the relationship between deer kills and highway structures and serve more to highlight management challenges (Hostick and Styskel 2005).

Much of the data above may suggest that raised median barriers may not be correlated with higher than average WVCs levels, however, such barriers appear to play some role in affecting how, and if, different species of wildlife move along and/or across roadways.

3.1.2 Movement

Roadway barriers of all types have the potential to impede wildlife movement for foraging, migration, dispersal and reproduction. Continuous, solid designs are presumed to have a greater impact by preventing an animal from traversing over or under the structure, increasing the time it takes to traverse the barrier, by modifying the behavior of the animal, or by causing some other limitation. In contrast to other barrier types, concrete median barriers are generally impassable to animals, although small animals may pass through drainage holes in Jersey barriers (Hubbs and Boonstra 1995).

A permeability study in the Italian Alps recorded transportation infrastructure and all walls higher than 3 meters [9.8 ft] that might serve as a barrier to brown bears (*Ursus arctos*) (Molinari and Molinari-Jobin 2001). The aforementioned Ontario connectivity study applied a ranking system to the "median" as a highway corridor feature. The concrete median barrier was considered to be insurmountable to all but the largest of mammals and received the lowest ranking behind vegetated and landform divided medians (Ross 2004 unpub). In studies noting the effects of concrete Jersey barriers [32 to 57 inches tall; 81 to 145 cm], guardrails which also measure 32 inches tall (presumably similar to metal or thrie beam barriers) are mentioned and often viewed collectively (Barnum 2003, Hostick and Styskel 2005).

Species-specific biology, behavior, size and physical ability likely affect whether or not a particular animal would attempt to traverse or be repelled by a concrete Jersey or similar barrier. Direct observation of animal crossing behavior can be a chance encounter or a time-consuming and variably productive endeavor. A motorist driving at highway speed sighted a black bear (*Ursus americanus*) climbing (front leg, back leg, back leg, front leg) over a concrete median barrier in Montana. The bear appeared to be experienced since it crossed directly and moved fast, but the median was a hindrance and caused the animal to slow down (K. Sinay, Yellowstone Safari Company, pers. comm.). There are anecdotal sightings of animals milling, or being perceived as "trapped," on roadways with a concrete Jersey barrier as well as sightings of deer moving across the highway in the presence of a Jersey barrier (Lloyd and Casey 2005). Fifty-one 2-hour long observation periods of 31 cumulative highway miles [50 km] over the course of four monitoring seasons (totaling 62 "hour-miles") yielded the sighting of two deer (both before divider installation), ten western gray squirrels (*Sciurus griseus)* (nine before installation, one after installation) and a single golden-mantled ground squirrel (*Spermophilus lateralis)* (before installation) trying to cross the highway; a sample size too small to judge crossing success rates before and after highway divider installation (Hostick and Styskel 2005). Animal behaviorists using captive animals documented that solid roadside barriers have the effect of repelling desert tortoises *(Gopherus agassizii)*, causing them to walk parallel for several minutes then stop or walk away from the highway (Ruby et al. 1994).

Newly installed highway dividers (guardrails and concrete barriers, the latter of which included gaps for animal passage) on an Oregon highway did not appear to block deer from crossing the highway or influence deer preference for crossing locations (Hostick and Styskel 2005). A theory to explain these results includes the possibility that deer did not notice the gaps designed for passage (Hostick and Styskel 2005). The Western gray squirrel population, however, plummeted after the concrete divider installation (Hostick and Styskel 2005). A reduction in the genetic diversity of desert bighorn sheep *(Ovis canadensis nelsoni)* populations in California has been linked to isolation caused by human-made barriers, including a concrete median barrier (Epps et al. 2005).

In some cases, conclusions between median barrier and roadside barrier effects overlap. Track counts of medium- and large-sized mammals indicated that crossing zones of mule deer, elk and coyote were inversely correlated with sections of road that were obstructed by barriers such as

Jersey barriers, guardrails, walls or cliffs on highways in Colorado (Barnum 2003). These species avoided barriers when entering a roadway, rarely walked in the narrow space between the barrier and road surface, but jumped over Jersey barriers and guardrails to exit a roadway (Barnum 2003). Snowdrifts caused by plowing transformed spaced barriers into one continuous barrier (Barnum 2003). In a road section where median and outer-edge barriers are prevalent, animal crossing activity occurred at locations with the fewest barriers, either no barrier at all or just a “median side” barrier, regardless of snow cover (Barnum 2003). On a steep and deeply incised Washington State Interstate 90, marked with a Jersey barrier in the median and variably on one or both shoulders, the absence of road kills served as an indicator of relative impermeability to ungulates (Singleton and Lehmkuhl 2000). Carnivores, however, were detected along the road segment at automatic camera stations and during snow tracking; one coyote crossing of the roadway was documented via snow tracking (Singleton and Lehmkuhl 2000).

Animals sometimes walk hundreds of meters along roadsides without barriers before crossing (Carbaugh et al. 1975, Barnum 2003). On roadways with barriers, there appears to be a strong relationship between animal crossing zones and gaps between and ends of barriers (Barnum 2003, Gunson et al. In prep.). This effect, if left unchecked, can funnel animals onto the roadway and create a potential WVC hotspot where wildlife crossings would otherwise be dispersed (Barnum 2003). In road segments requiring barriers, Jersey barriers and guardrails could serve a double function for safety and for guiding animals to crossing structures (Barnum 2003, Singleton and Lehmkuhl 2000). Extensive library and internet searches yielded no studies of the effects of cable median barriers or centerline rumble strips on wildlife movement and/or mortality. Nonetheless, both are being employed mitigatively for wildlife permeability (V. Izzo, HDR Engineering, pers. comm.).

3.1.3 Mitigation

Barrier effects, such as those resulting from transportation infrastructure, probably have the greatest negative ecological impact because an individual animal’s dispersal ability is key to species survival (Bekker and Iuell 2003). Mitigations addressed at ameliorating this barrier effect generally focus on wildlife crossing structures and exclusion fencing. To mitigate the potential barrier effect of median barriers, specifically, certain types and configurations are being used (cable barriers, thrie-beam, rumble strips, openings or scuppers, spaced concrete median barriers), but these techniques remain virtually untested.

A variety of median safety mitigation techniques have been recommended and might have the potential to serve both motorists and wildlife. These include creating wider roads without barriers that would allow animals to cross at-grade; installing barrier types that prevent vehicle penetration but allow animal movement (at-grade); spacing barriers or providing passages within the barriers to let animals pass (at-grade); installing solid barrier in combination with wildlife exclusion fencing and crossing structures; and utilizing solid barriers along the roadside to funnel animals to crossing structures.

When possible, a wider roadway and median (with no raised barrier) may be one solution to reduce the barrier effect. Wider medians cause an additional loss of natural habitat but may have less ecological impact than a narrow, paved median with a barrier or guardrail (NRC 2005). It is generally accepted that wider medians have lower collision rates (Gabler et al. 2005, Knuiman et al. 1993 in Gattis et al. 2004, Strathman et al. 2001). A mitigation effort for dispersing wolves included a ballooned median section, but there is no evidence that it facilitated wolf crossings of the highway (Kohn et al. 2000). Centerline rumble strips were installed on the Trans-Canada Highway (phase 3B, unfenced, unmitigated section 2-lanes) in Banff National Park in 2001 for motorist safety reasons, after a number of head-on collisions occurred, and no funding was available to upgrade the corridor to 4-lanes with median and fencing/wildlife crossings (T. McGuire, Parks Canada Highway Service Centre, pers. comm.).

A FHWA-approved cable barrier design is being used in a median barrier installation project in Utah (U.S. 6), primarily to mitigate potential wildlife impacts but also to meet other criteria. Simply put, cable barrier was chosen because it is believed to allow wildlife to pass, meets safety requirements, has less of a visual impact, and is less expensive to install and maintain. The final decision to use 3- or 4-strand cable has not yet been made and median rumble strips may also be used (V. Izzo, HDR Engineering, pers. comm.). One median barrier survey respondent remarked that deer avoid road segments with three-strand cable barrier; however, observation is anecdotal and has not been studied (see Section 3.2). In response to concerns raised during an environmental assessment, the Ontario Ministry of Transportation is proposing to install two 100 m [328 ft] segments of a modified thrie-beam type barrier for animal passage in place of a continuous Ontario Tall Wall concrete barrier on Highway 401. However, the final decision regarding which median barrier type will be used is contingent on the outcome of the wildlife mortality study (K. Ogilvie, Ontario Ministry of Transportation, pers. comm.).

Some transportation agencies are installing Jersey barriers with a modified design that allows passage of small- to medium-sized fauna. In a known hotspot for WVCs on SR 52, Caltrans (Caltrans) installed concrete median barriers with 1-meter-wide gaps for deer, foxes, coyotes and small mammals (FHWA, 2006c). Deer have been observed on both sides of the highway since the installation but road-kill monitoring has yielded no record of road-killed deer (FHWA, 2006c). A median barrier project on Highway 1 near San Luis Obispo, California, was noted for environmental excellence by AASHTO for a context-sensitive solution. Semi-circular openings were included at grade to allow small-size animal crossings and for medium-size animals when evident (AASHTO 2005) (Figure 1). The small dimensions of the scuppers and the fact that they are spaced at wide intervals makes it less likely that any except the smallest of creatures that actually succeed in finding the openings will find safe passage (Figure 2). The effectiveness of various gap and scupper dimensions and designs, intervals at which they are spaced, and other factors require further study (Figure 3).

Figure 1: Caltrans included basal openings in the Highway 1 concrete barrier for small animal passage. Photo by A.P. Clevenger

Figure 2: No standards currently exist for spacing of basal openings. Small mammals would be challenged to find passage through this section of median barrier on Highway 1 . Photo by A. P. Clevenger.

Figure 3. Many factors likely affect the effectiveness of median barrier mitigations for wildlife, such as this weed infestation along the barrier of Highway 1. Photo by A. P. Clevenger.

In 2003, Oregon DOT installed 32 inch [81 cm] tall concrete median barriers with an arched cutout (6 in. [15 cm] diameter) in the bottom center of each 11.5 foot [3.5 m] block allowing for small animal passage and drainage of surface water. In addition, every 100 or 500 feet [30 – 152 m], ODOT inserted 20 in. [51 cm] gaps for animal movement and roadway maintenance concerns (Hostick and Styskel 2005). Cooper (1999) also suggests scuppers for the passage of smaller wildlife (e.g., furbearers, rodents, amphibians, reptiles, lagomorphs). The recommendation is 25 cm [~ 9 in] high and 100 cm [~ 39 in] wide cutouts along the bottom, accounting for at least 20% of the barriers or one every 5th barrier (Cooper 1999). Upgrades of an 18-km [11 mile] section (phase 3A) on the Trans-Canada Highway from 2 to 4 lanes in Banff National Park, Alberta, included concrete median barriers with passages for small fauna (see Figure 40, Appendix; McGuire and Morrall 2000). The Banff project used the modified median barriers as recommended above, placing them only on sections of highway where cross-highway connectivity was believed to be important for small- and medium-sized fauna, i.e., where the highway bisects gentle terrain and wildlife habitat. However, there is no information regarding how effective these modified barriers are, and there are no standard guidelines regarding their placement (NRC 2005).

When placed along the roadside, Jersey barriers may serve to funnel animals towards crossing structures (Singleton and Lehmkuhl 2000, Barnum 2003). Others recommend minimizing the use of median barriers (Barnum 2003, Basting 2003, Servheen et al. 2003) or avoiding Jersey barrier installation (and fencing) when not used in conjunction with wildlife passage structures (Jackson and Griffin 2000). It is often difficult to quantify the amount of impact that transportation projects utilizing Jersey and other vertical barriers have on threatened species such as Canada lynx; therefore, assessments and effective mitigation plans must err on the side of caution for the benefit of the species (Barnum 1999, Basting 2003).

Washington State DOT’s Design Manual addresses the impacts of concrete median and roadside barriers on wildlife and provides a flow chart to aid in determining the effect of barrier placement (WSDOT 2005) (Figure 4).

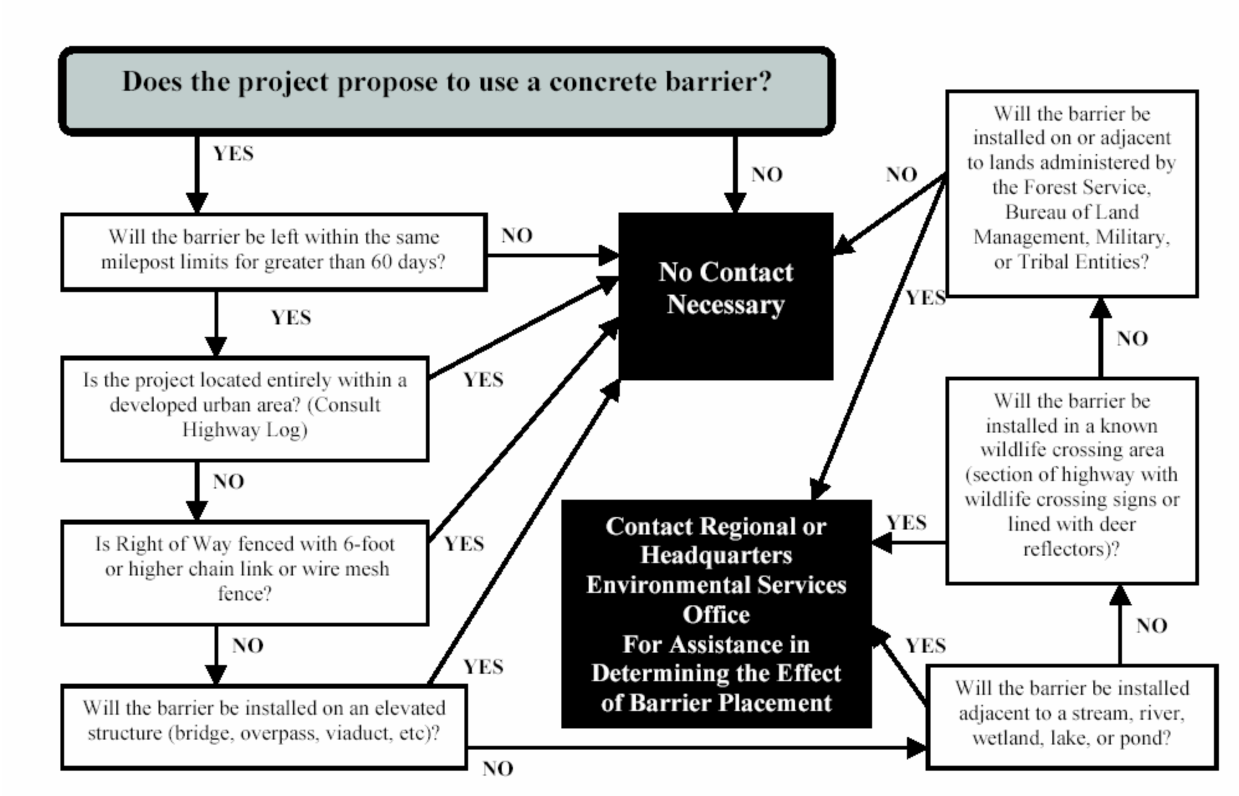

Figure 4. Concrete median barrier placement guidance for assessing impacts to wildlife.

3.1.4 Analysis of Potential Wildlife Impacts

Median barriers are often categorized into three basic groups that relate to their properties and behavior in the event of a collision. Ray and McGinnis (1997) use the following groupings: weak-post-and-beam systems, strong post-and-beam-systems and continuous concrete barriers to discuss the issue of crashworthiness.

For the purposes of determining the effect of median barriers on wildlife attempting to traverse them and the potential associated risks to motorists, other more obvious physical features such as height, width, length and permeability are more applicable (see Appendix A). While it is recognized that certain areas are more likely to sustain wildlife populations and constitute wildlife crossing zones than others, these matrix analyses are conducted with the established assumption that at some point in time each of these species might attempt to cross a road with these median barrier types. In keeping with the main median barrier design types addressed in this report, the following categories are used in a qualitative analysis of potential permeability and potential mortality risk to wildlife.

- Concrete (Jersey, F-shape, Texas constant-slope, etc.)
- Concrete Ontario tall wall
- Concrete with gaps
- Concrete with scuppers
- Concrete with gaps and scuppers.
- Metal beam (steel, W, box, thrie, etc.)
- Cable (3-, 4-strand and proprietary designs)

- Centerline rumble strips
- Vegetated median (center strips of grass, shrubs or trees)

Taxa groups are classified by general size differentiation as follows (Species extinct/not present in California in parentheses):

- 1: mice, shrews / frogs, salamanders, lizards, snakes
- 2: rat families, squirrels, weasels / turtles / young waterfowl and upland birds
- 3: marten, fisher, mink, badger, skunk, fox, opossum
- 4: coyote, bobcat, (lynx), (wolverine), otter, raccoon, (ocelot)
- 5: (grizzly bear), black bear, (wolf), (moose), elk, deer, bighorn sheep, mountain lion

Permeability scores were qualitatively assigned based on the physical size and ability of each taxa group to overcome each barrier type, independent of potential traffic mortality risk. Potential permeability was viewed in absolute terms – whether an animal could traverse, climb over or crawl under a barrier given enough time, that is, if the barrier was in a field, a forest or on a road with no cars, for example. Red, yellow and green were assigned to indicate no to low permeability, moderate permeability or high permeability, respectively. This qualitative analysis is not intended to be a guideline but rather is a starting point for discussion about potential impacts. Concrete barriers (solid and continuous) range in permeability from no/low to high depending on the taxa group. However, even solid concrete barriers often have nominal notches at the base for installation purposes that may serve the smallest-bodied creatures. The Ontario tall wall at almost 5 feet [1.5 m] tall likely allows no or low permeability for all taxa groups. Concrete with gaps, Concrete with scuppers, and Concrete with gaps and scuppers maintains permeability for mid- to large-bodied animals of taxa groups 4 and 5 but still likely poses a challenge for smaller animals depending on the interval spacing of the gaps and scuppers and the size of the scuppers themselves. Depending on the size of the scuppers, mid-sized animals of taxa group 3 may or may not be able to utilize them. The permeability of Metal beam, Cable, Centerline rumble strips and Vegetated median are rated high for all taxa groups (Table 1).

Table 1. Potential permeability of median barriers for taxa groupings of different sizes.

	Taxa Group				
Median Barrier Type	1	2	3	4	5
Concrete					
Ontario Tall Wall					
Concrete with gaps					
Concrete with scuppers					
Concrete with gaps and scuppers					
Metal beam					
Cable					
Centerline rumble strips					
Vegetated median					

no to low	**1**
moderate	**2**
high	**3**

The potential for road mortality in the presence of each median type for the five taxa groupings was also scored. Potential mortality risk was viewed in terms of the extent to which a barrier might limit or impede an animal's ability to clear the barrier and avoid an imminent collision with an oncoming vehicle and to see approaching vehicles on the other side of the median. The score also took into consideration literature references that indicated a higher risk of wildlife-vehicle collision (especially deer) on undivided two-lane roads and on roads with grassy and vegetated medians. This qualitative analysis is not intended to be a guideline but outlines the potential impacts that require further study. Note that color codes are reversed from the matrix above: red signifies high mortality risk, yellow signifies moderate mortality risk and green signifies no to low mortality risk. Concrete barrier (solid and continuous) pose the greatest threat to the small- to mid-sized animals in the taxa 1-3 groupings. Larger animals have an advantage of being able to climb or jump over the barrier while seeing approaching vehicles on the other side of the median; however, the mere presence of the barrier likely hinders the speed at which the animal can cross the road while avoiding collision. The Ontario tall wall likely poses a high mortality risk to all species. Concrete with gaps may enhance crossing opportunities for taxa groups 1-3, but some studies show that gaps can create new WVC hot spots for some species in taxa groups 4 and 5. The intervals at which the gaps exist likely affects whether or not the mortality risk is actually lowered. Concrete with scuppers has a similar score with the exception of mid-sized animals of taxa group 3 that may not easily and quickly pass through a scupper in time to avoid a collision. Concrete with gaps and scuppers likely enhances safe crossing opportunities for small- to mid-sized animals compared to solid concrete barriers but remains equally likely to pose a moderate mortality risk to all species. Metal beam, Cable, Centerline rumble strips and Vegetated median have essentially the same associated mortality risk for animal of taxa group 3 and smaller. Given the similar height of Metal beam and Cable barrier to standard concrete designs, the risk for larger animals (taxa groups 4 and 5) remains unchanged. Based on literature sources, undivided two-lane roads (and likely those with centerline rumble strips) and roads with certain types of vegetated medians can pose a moderate mortality risk to animals in taxa groups 4 and 5 (Table 2).

Table 2. Potential mortality risk of median barriers for taxa of different sizes.

	Taxa Group				
Median Barrier Type	1	2	3	4	5
Concrete	red	red	red	yellow	yellow
Ontario Tall Wall	red	red	red	red	red
Concrete with gaps	yellow	yellow	yellow	red	red
Concrete with scuppers	yellow	yellow	red	yellow	yellow
Concrete with gaps and scuppers	yellow	yellow	yellow	red	red
Metal beam	green	green	green	yellow	yellow
Cable	green	green	green	yellow	yellow
Centerline rumble strips	green	green	green	yellow	yellow
Vegetated median	green	green	green	yellow	yellow

high	**1**
moderate	**2**
no to low	**3**

Scores based on potential permeability and mortality risk were summed for a total potential risk score (Table 3). Based on this matrix model, small- to mid-sized animals (taxa groups 1, 2 and 3) have the greatest range in risk (high with solid, continuous concrete designs; moderate with mitigated concrete designs; low with roads that utilize permeable barrier designs or no raised median barrier at all). Larger-bodied animals (taxa groups 4 and 5) have a moderate risk for all types of median designs with the exception of Ontario Tall Wall which is likely to have a high risk because of its height.

Table 3. Combined risk score based on potential permeability and mortality risk of median barrier type for taxa of different sizes.

	Taxa Group				
Median Barrier Type	1	2	3	4	5
Concrete	2	2	3	5	5
Ontario Tall Wall	2	2	2	2	2
Concrete with gaps	4	4	4	4	4
Concrete with scuppers	4	4	3	5	5
Concrete with gaps and scuppers	4	4	4	4	4
Metal beam	6	6	6	5	5
Cable	6	6	6	5	5
Centerline rumble strips	6	6	6	5	5
Vegetated median	6	6	6	5	5

high risk	**2 or 3**
moderate risk	**4 or 5**
low risk	**6**

3.2 State of the Practice Survey

The Transportation Research Board (TRB 2002a) has stated the need to better understand the potential impacts of highway barriers. Most of the literature available about median barriers focuses on motorist safety. The state of the practice of the use of guardrails and median barriers and their crashworthiness relative to motorist safety has been synthesized (Ray et al. 1997).

This research study represents the only known Median Barrier State of the Practice Survey pertaining to wildlife movement and mortality, and motorist safety within the context of WVCs in the presence of median barriers. The aim of this survey was to obtain the most up-to-date information on the current practices and knowledge of these agencies in planning projects with highway median barriers.

3.2.1. Survey Participation

Ninety-six targeted biological/environmental and engineering specialists in transportation agencies in the U.S. and Canada were invited to participate in this online survey. All fifty U.S. states, the District of Columbia and Canada's thirteen provinces and territories were included. The survey was made available via http://questionpro.com. Targeted specialists were invited to participate on April 12, 2006. Bulk reminders were sent on April 19, April 27, May 5, and May 16. Individual (new referral) invitations and reminder phone calls were also conducted during that time. Survey responses continued to be submitted as of May 24, 2006. The survey remained active until July 30 to ensure the highest rate of participation possible.

Thirty-four individuals representing 28 transportation agencies completed the survey. Twenty of the participants were engineering specialists (including design, traffic, safety and maintenance) and 14 were biologists or environmental specialists (including natural resources and land management). Participating agencies and occupational focus areas are listed in Table 4 and shown in Figure 5. Prince Edward Island representatives emailed to say they did not take the survey because their agency has no median barriers to separate lanes of traffic. The resulting overall agency response rate was 45% (29 of 64 transportation agencies). Participation level may have been affected by another Western Transportation Institute survey conducted less than one month prior to this survey. Multiple attempts were made in order to encourage the highest participation rate possible.

Nine others (representing 8 states and 1 province) responded, did not participate because they lacked the necessary design, technical or historical knowledge required. However, most provided another contact within the agency. The interdisciplinary nature (biology and engineering) of this survey was cited as a challenge because agency personnel are often separated by focus area and associated job tasks.

Survey participation statistics are listed in Table 5. Survey questions as they appeared online are shown in Appendix D.

Table 4. Participating agencies and occupational focus areas.

U.S. State	Agency	Occupational focus	Jurisdiction
Alabama*	Department of Transportation	Engineering & Biology/Environment	State
Alaska	Department of Transportation	Engineering	Region
Florida	Department of Transportation	Biology/Environment	State
Georgia	Department of Transportation	Biology/Environment	State
Idaho	Department of Transportation	Biology/Environment	Region
Illinois*	Department of Transportation	Engineering & Biology/Environment	State
Iowa	Department of Transportation	Engineering	State
Louisiana	Department of Transportation	Engineering	State
Maine	Department of Transportation	Engineering	State
Mississippi	Department of Transportation	Biology/Environment	State
New Hampshire*	Department of Transportation	Engineering & Biology/Environment	Region
New York*	Department of Transportation	Engineering & Biology/Environment	State
North Dakota	Department of Transportation	Biology/Environment	State
Ohio	Department of Transportation	Engineering	State
Oregon	Department of Transportation	Engineering	State
South Dakota	Department of Transportation	Engineering	State
Texas	Department of Transportation	Engineering	State
Virginia	Department of Transportation	Engineering	State
Washington State	Department of Transportation	Biology/Environment	State
West Virginia	Department of Transportation	Engineering	State
Wisconsin	Department of Transportation	Biology/Environment	State
Wyoming	Department of Transportation	Engineering	State
Canadian Province			
Alberta	Infrastructure and Transportation	Biology/Environment	Province
New Brunswick*	Department of Transportation	Engineering & Biology/Environment	Province
Newfoundland & Labrador	Department of Transportation & Works	Engineering	Province
Quebec	Ministry of Transportation	Biology/Environment	Region
Saskatchewan	Department of Highways and Transportation	Engineering	Province
Canadian Territory			
Yukon	Department of Highways & Public Works	Engineering	Territory

* Two or more specialists from the agency participated in the survey.

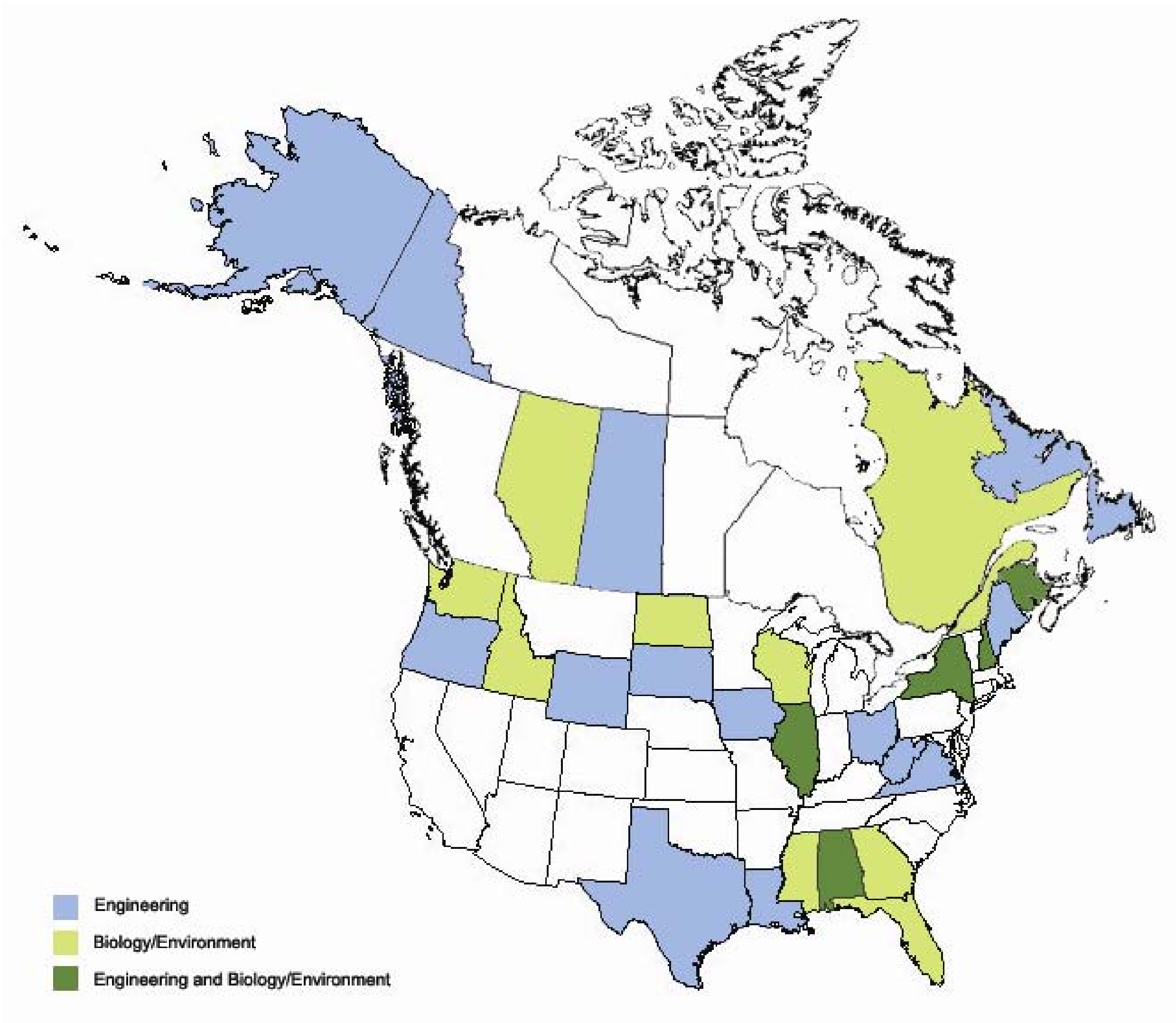

Figure 5. Respondent type by state, province and territory.

Table 5. Survey participation statistics

Survey Participation Statistics	Count/Rate
Individuals invited, accounting for bounced emails and new referrals (Agencies invited)	92 (64)
Individuals who participated in the survey (Participating agencies)	34 (28)
Did not participate because they use no median barriers to separate lanes of traffic (Prince Edward Island)	1
Total individual responses and response rate	35/38%
Total agency responses and response rate	29/45%

3.2.2. Survey Questions and Results

One questionnaire was developed for both engineering and environmental specialists. Questions focused on utilization history, trends, performance evaluation of various median barrier designs, studies of median barrier effects on wildlife and motorist safety, mitigations for wildlife, and implications for transportation planning.

Results from the survey are presented in a question-by-question format unless synthesizing answers from related questions is more elucidating. Responses include open-ended text, multiple choice and ranked values. A discussion follows each question or set of questions and includes the motivation for the question, a summary of responses and additional comments, if applicable.

3.2.2.1 Utilization History

This section establishes the history of median barrier use by each transportation agency. The goal of this set of questions was to gain background information about the types, chronology and uses of median barriers as well as the guidelines consulted for their installation.

1. **What types of median barriers does your agency use on any or all roadway types, i.e. multi-lane interstate, two-lane rural roads, etc.? Please select all that apply.**

Thirty-four participants representing 28 agencies responded to this question. Multiple responses from a single agency were aggregated. Results are presented in Figure 6. Grassy strip, Painted centerline and Centerline rumble strips were included to offer a broad spectrum of median types. Grassy strip and Painted centerline options were used by the greatest number of agencies, 20 and 19 of 28, respectively.

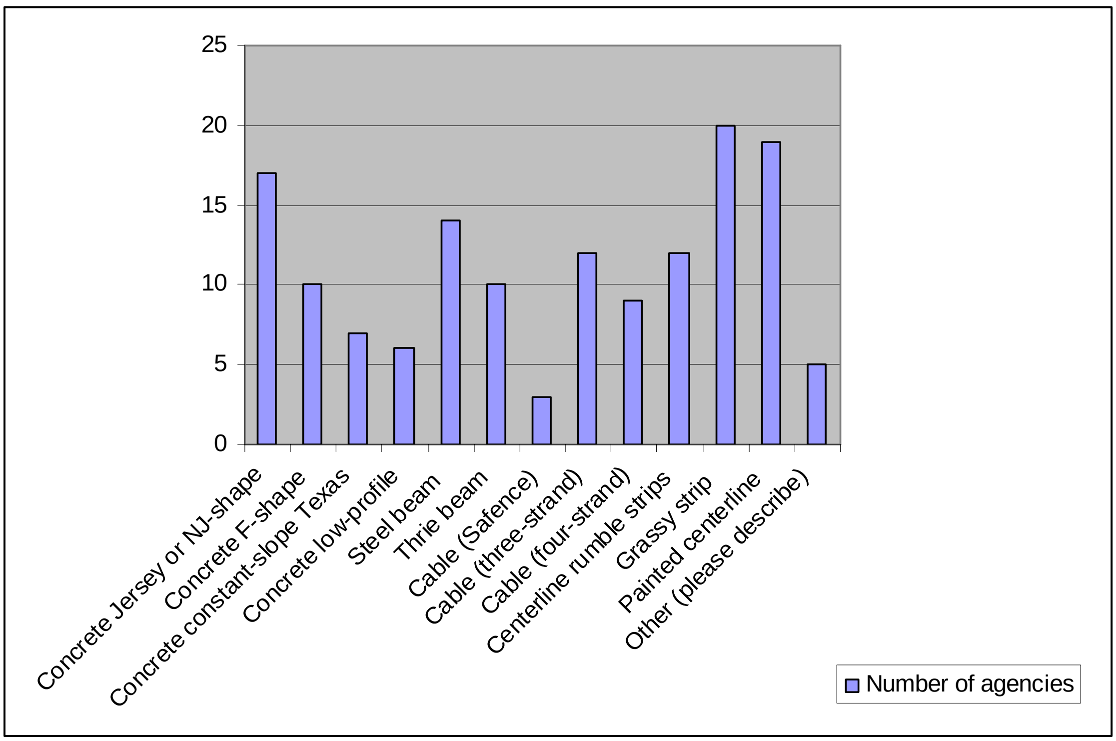

Figure 6. Agency use of different median barrier types.

The most common choice of raised median barrier was Concrete Jersey (n=17), followed by Steel beam (n=14). Three-strand cable and Centerline rumble strips were equally the next most popular choice (n=12). Concrete F-shape, Texas, Low-profile, Thrie beam, Safence,™ Four-strand cable and a variety of others were used by 10 of 28 agencies or less. "Other" barrier types described include Slope curb (6") raised median; Box beam; Earth berm; Curb-gutter; and Curbed median, and flush (2") curbed median.

2. When did your agency…

The following set of questions was aimed at determining the historical use of a variety of median barrier types. Twenty-four agencies responded to this question set. In some instances, multiple respondents from the same agency answered differently to the same question. Since the responses in this section were aggregated, "participants" is meant to carry the same meaning as "participating agencies." If two or more answers from a single agency cited a different number of years, then the more conservative answer (fewer number of years) was used in the analysis. If one response referred to number of years but another said "Not applicable," the answer referring to number of years was used. Such adjustments were necessary in Questions 2b, d, f, g, h, i, and j. Four other survey takers refrained from answering this set of questions entirely (Iowa, North Dakota, Quebec, Washington State).

a. When did your agency BEGIN installing raised median barriers of any type?

Seventy-nine percent of the agencies that responded (19 of 24) began the practice of installing raised median barriers 20 or more years ago. Alaska and Yukon indicated they began the practice 15 and five years ago, respectively. Results are shown in Figure 7. The question may have been confusing for some because three agencies responded that this question was "Not applicable" (Idaho, Saskatchewan, West Virginia) but later answered affirmatively to specific types in use. Saskatchewan only uses grassy medians.

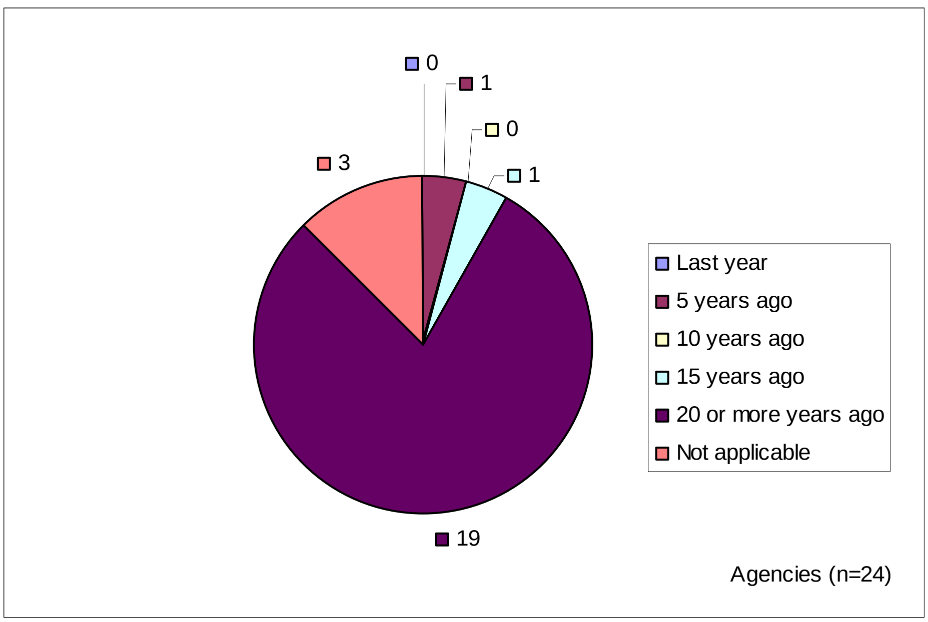

Figure 7. Years since agencies began installing raised median barriers of any type.

b. When did your agency BEGIN installing concrete Jersey or F-shape median barriers?

Approximately 63% of participating agencies (15 of 24) began installing concrete Jersey or F-shape median barriers 20 or more years ago. Three agencies began 15 years ago (Alaska, Mississippi, New Hampshire) and three agencies began five years ago (South Dakota, Virginia, West Virginia). Three indicated this question was “Not applicable” (Saskatchewan, Wyoming, Yukon). Results are shown in Figure 8.

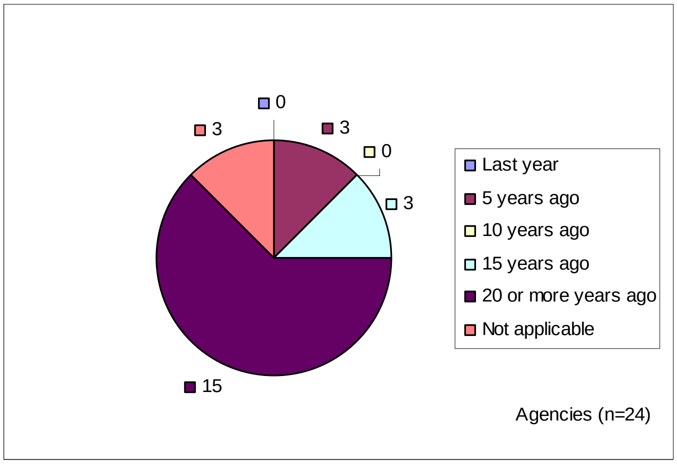

Figure 8. Years since agencies began installing concrete Jersey or F-shape median barriers.

c. When did your agency DISCONTINUE installing concrete Jersey or F-shape median barriers?

Ninety-five percent of participating agencies (20 of 21) chose “Not applicable,” illustrating that most agencies continue to install concrete Jersey or F-shape median barriers. Ohio specified they discontinued installing these concrete designs last year. Results are shown in Figure 9. Three refrained from this particular question (Georgia, Texas, Virginia).

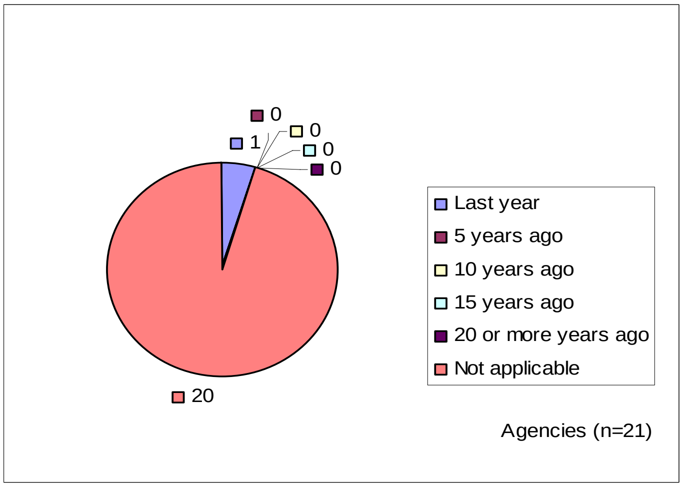

Figure 9. Years since agencies discontinued installing concrete Jersey or F-shape median barriers.

d. When did your agency BEGIN installing concrete constant-slope Texas median barriers?

Concrete Texas median barriers are not applicable to 16 of 22 (73%) of agencies who responded to this question. Three agencies began installing them 15 years ago (Illinois, Oregon, Texas), one began 10 years ago (Alabama) and one began five years ago (New York). In 2c Ohio reported they discontinued installing concrete Jersey barriers last year and also indicated they began installing concrete Texas barriers in the same year. Results are shown in Figure 10. Two agencies did not answer the question (Georgia, Virginia).

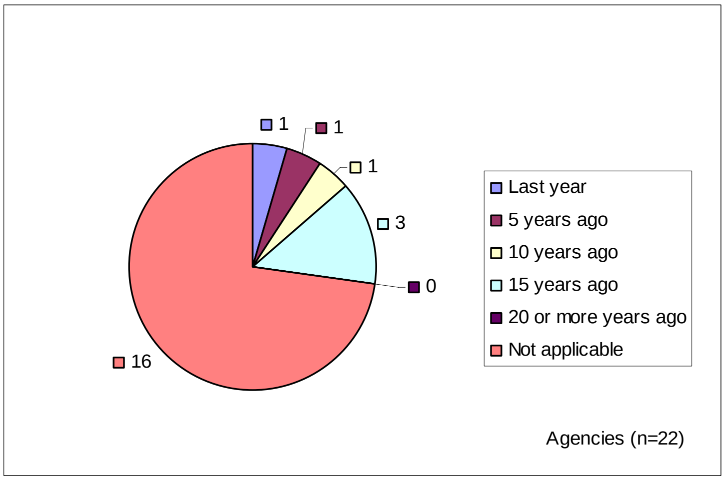

Figure 10. Years since agencies began installing concrete constant-slope Texas median barriers.

e. When did your agency DISCONTINUE installing concrete constant-slope Texas median barriers?

For all but one of the participating agencies this question was not applicable (20 of 21; 95%). Virgina reported they discontinued installing concrete Texas median barriers 10 years ago but refrained from answering Question 2c. Results are shown in Figure 11. Florida, Georgia and Texas refrained from answering this particular question.

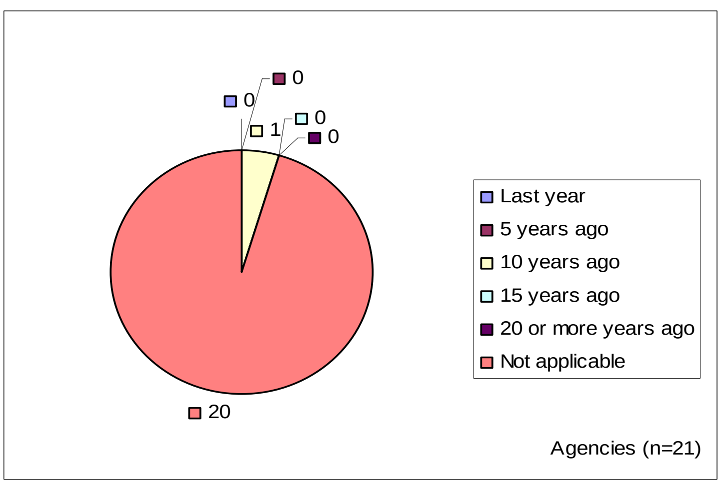

Figure 11. Years since agencies discontinued installing concrete constant-slope Texas median barriers.

f. When did your agency BEGIN installing steel or thrie beam median barriers?

Approximately 64% of agencies that responded to this question (14 of 22) began installing steel or thrie beam median barriers 20 or more years ago. Two agencies began installing this design 15 years ago (Mississippi, Wyoming). For six agencies, this question was not applicable (Alaska, Idaho, Newfoundland & Labrador, Saskatchewan, West Virginia, Yukon). See results in Figure 12. Two participants did not answer this question (Florida, Texas).

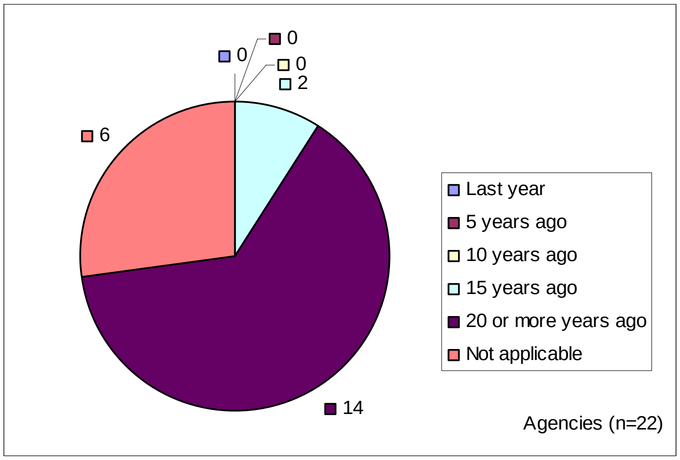

Figure 12. Years since agencies began installing steel or thrie beam median barriers.

g. When did your agency DISCONTINUE installing steel or thrie beam median barriers?

Ninety percent of agencies that responded (18 of 20) indicated this question was not applicable. One agency discontinued installing steel or thrie beam median barriers 10 years ago (Ohio) and another discontinued installing them 20 or more years ago (New Brunswick). New Brunswick also indicated they began installing steel/thrie beam 20 or more years ago in Question 2e. Results are illustrated in Figure 13. Four participants refrained from answering this particular question (Florida, Georgia, Texas, Virginia).

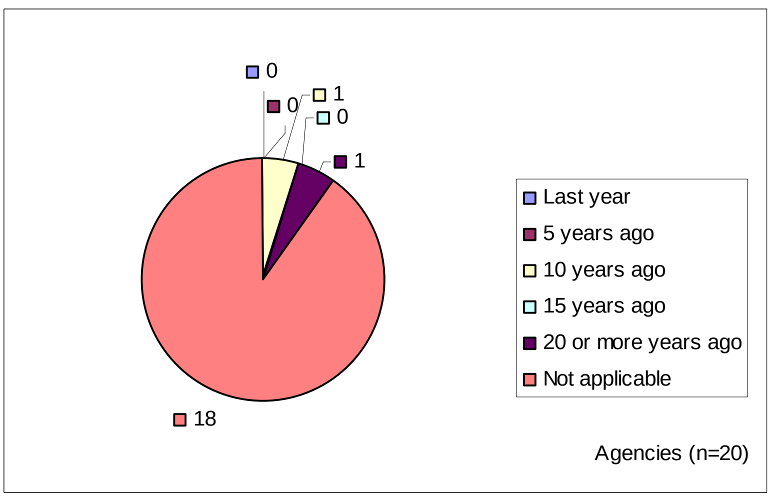

Figure 13. Years since agencies discontinued installing steel or thrie beam median barriers.

h. When did your agency BEGIN installing cable median barriers?

Six of 24 participating agencies began installing cable median barriers as many as 20 years ago (New Brunswick, New Hampshire, New York, South Dakota, Virginia, Wisconsin). Another 25% began installing them last year (Alberta, Georgia, Illinois, Louisiana, Ohio, West Virginia). There was a discrepancy in two responses obtained from one agency. The environmental specialist indicated cable median barriers were installed beginning just last year while an engineer from the same agency reported cable median barriers have been installed for 20 years or more. For consistency, the more conservative (lower) number was used in this analysis. It is likely, however, that the engineer's reply could be more accurate. Two agencies reported they began installing cable barriers in the median five years ago (Alabama, Texas), one began 10 years ago (Oregon) and another began 15 years ago (Florida). Eight others indicated this question was not applicable to their agency. Results are shown in Figure 14.

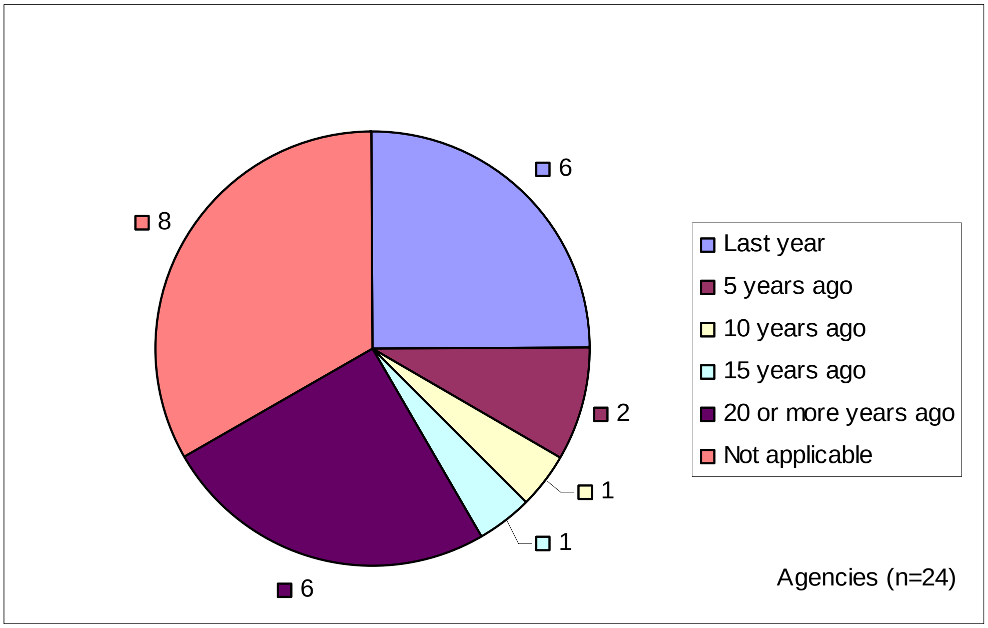

Figure 14. Years since agencies began installing cable median barriers.

i. When did your agency DISCONTINUE installing cable median barriers?

Approximately 90% of participating agencies (19 of 21) reported this question was not applicable. Eight of these indicated the same in the previous question, inferring that 11 of the agencies that utilize cable median barriers have not discontinued installing them. One agency reported discontinuing cable median barrier installation 15 years ago (New Hampshire) while another discontinued their installation 20 or more years ago (New Brunswick). Results are shown in Figure 15. Three participants did not respond to this question (Florida, Texas, Virginia).

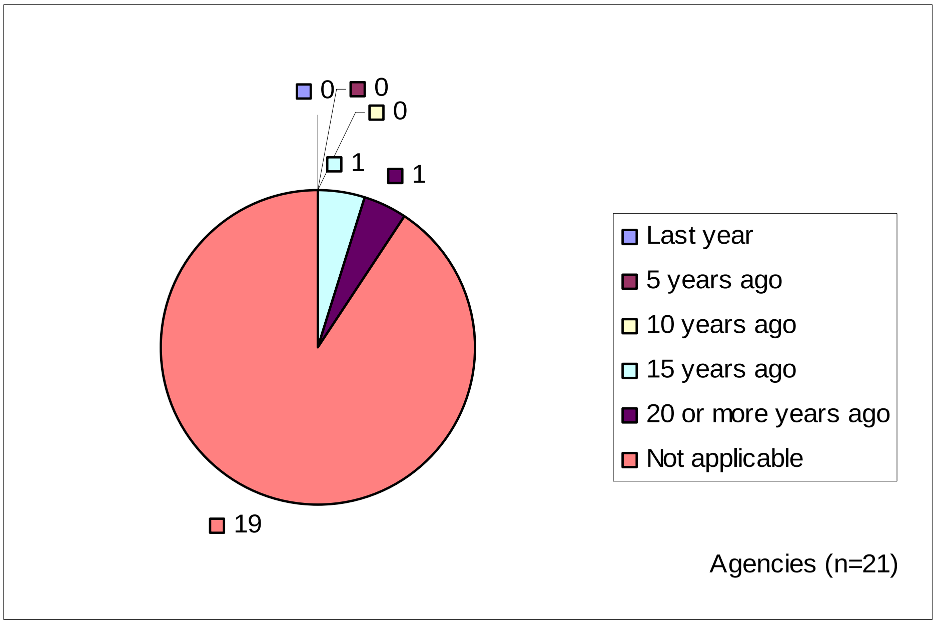

Figure 15. Years since agencies discontinued installing cable median barriers.

j. When did your agency begin installing centerline rumble strips?

Forty-five percent of participating agencies (9 of 20) reported installing centerline rumble strips; three began installing them 10 years ago (Idaho, New Brunswick, Oregon), four began five years ago (Alberta, New Hampshire, West Virginia, Yukon) and two began last year (Illinois, Texas).

Two participants from a single agency (one environmental specialist and one engineer) responded differently to this question. The engineer reported rumble strips have only been installed beginning last year while the environmental specialist reported installation has been occurring for 20 or more years. For consistency, the lower, more conservative number was used in the analysis. Eleven respondents indicated this question was not applicable. Results are illustrated in Figure 16. Four participants abstained from answering this question (Florida, Georgia, Virginia, Wisconsin).

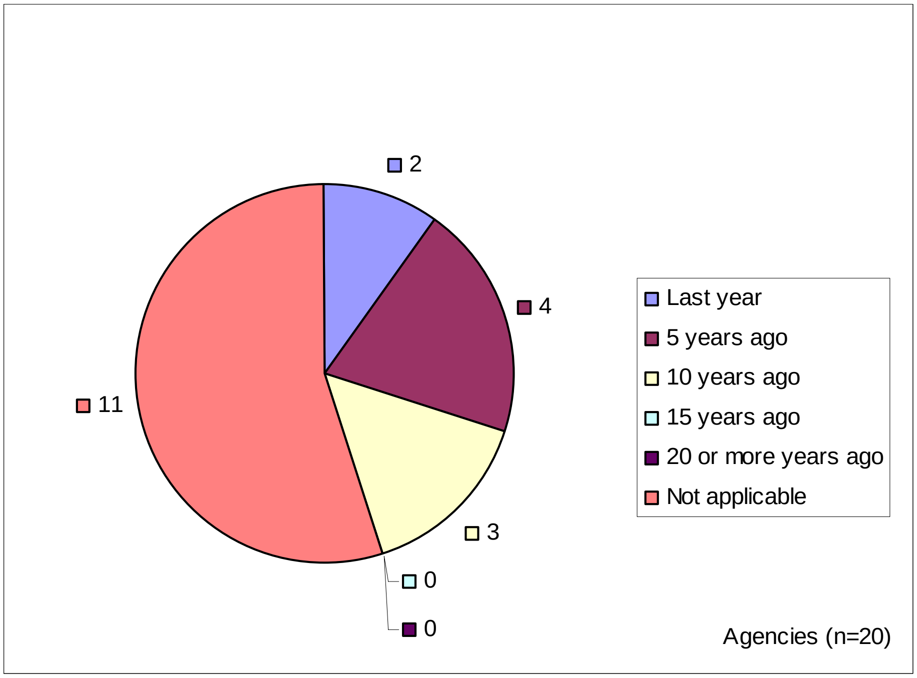

Figure 16. Years since agencies began installing centerline rumble strips.

k. When did your agency DISCONTINUE installing centerline rumble strips?

Nineteen of 20 participating agencies (95%) indicated this question was not applicable, inferring that all nine of the agencies that utilize centerline rumble strips continue their installation. Wisconsin refrained from Question 2j but reported here that they discontinued centerline rumble strip installation 10 years ago. Conversely, Texas reported installing centerline rumble strips beginning last year in Question 2j but refrained from answering this question, presumably because they have not discontinued their use. Results are shown in Figure 17. Florida, Georgia and Virginia also refrained from answering this question.

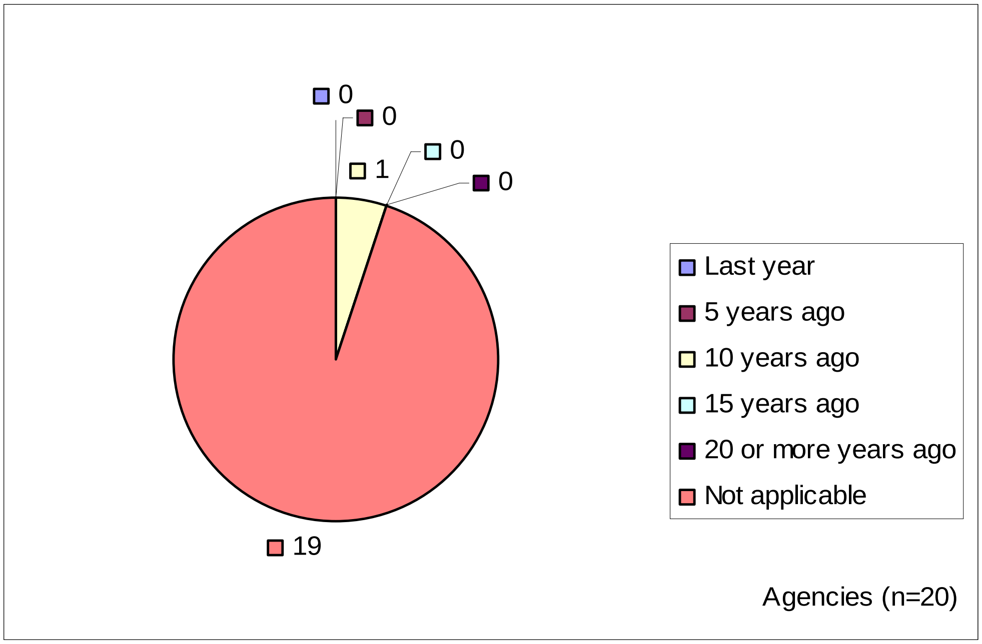

Figure 17. Years since agencies discontinued installing centerline rumble strips.

l. When did your agency BEGIN installing grassy median barriers?

Seventy-five percent of participating agencies (18 of 24) began installing grassy median barriers 20 or more years ago. One began installing them 10 years ago (Idaho). Five indicated this question was not applicable (Alabama, Louisiana, Ohio, Wyoming, Yukon). Results are shown in Figure 18. The wording of this question may have been confusing insofar as a grassy median, in itself, may not be considered as barriers in the same way as raised designs.

m. When did your agency DISCONTINUE installing grassy median barriers?

Nineteen of 20 participating agencies (95%) reported this question was not applicable, effectively inferring that they have not discontinued grassy median barrier installation. One participant (Oregon) who indicated grassy median installation began 20 or more years ago, reported discontinuing such installations five years ago. Results are illustrated in Figure 19. All four that refrained from answering this question reported earlier (in Question 2k) that their agencies began installing grassy median barriers 20 or more years ago (Florida, Georgia, Texas, Virginia).

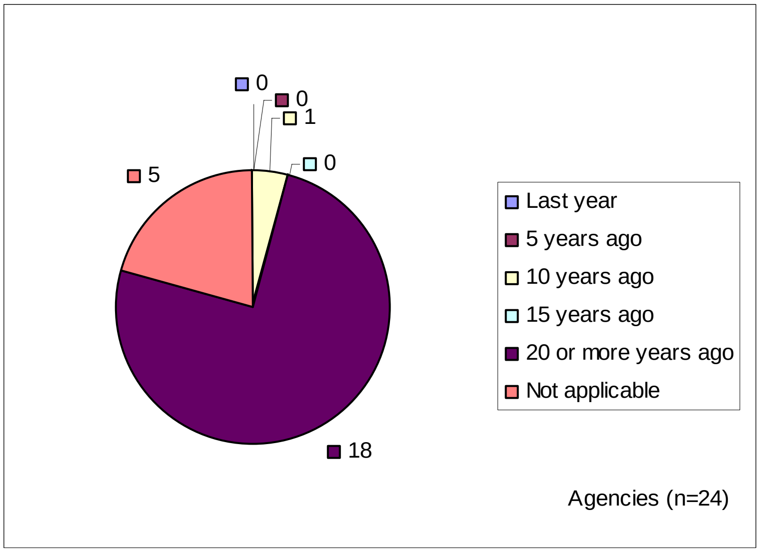

Figure 18. Years since agencies began installing grassy medians.

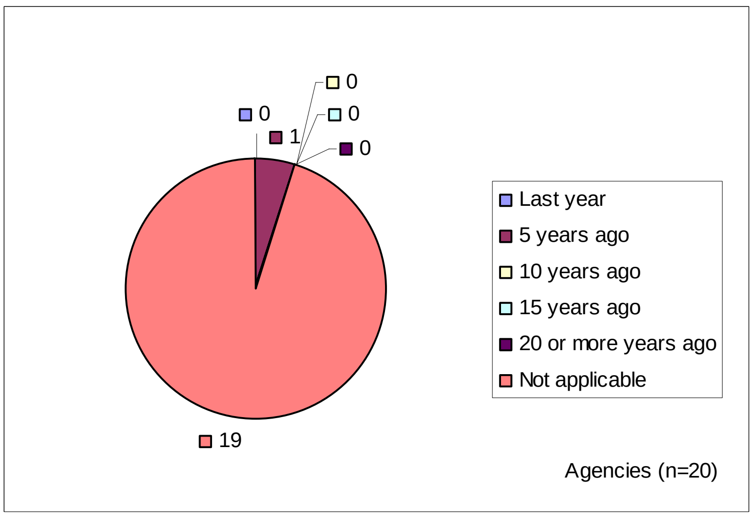

Figure 19. Years since agencies discontinued installing grassy medians.

3. What criteria/variables does your agency use/analyze to determine the need for median barrier installation? Please select all that apply.

Thirty-four participants representing 25 agencies responded to this question. Multiple responses from a single agency were aggregated. Results are shown in Figure 20.

Twenty-one of 25 agencies (84%) chose Historical cross-over collision records and Median width as the top two criteria for determining the need for median barrier installation. At least 68% of agencies that responded also use Traffic factors (n=18) or Average daily traffic (n=17), specifically. Posted speed limit (n=15, 60%), Controlled access and Geometric factors (n=14, 56%), Slope (n=12, 48%) Cost-benefit analyses, Environmental factors, Rural/suburban/urban location (n=10, 40%) and Roadway segment in relation to interchanges or other roadway feature (n=8, 32%) were also used to determine the need for installation. The least chosen criteria was Collision probability models, used by only 4 of 25 agencies that responded (16%). "Other" criteria included Political (n=2), Level of service policy decisions (n=1) and whether the median was Traversable, flushed or depressed (n=1). Three participants refrained from answering the question.

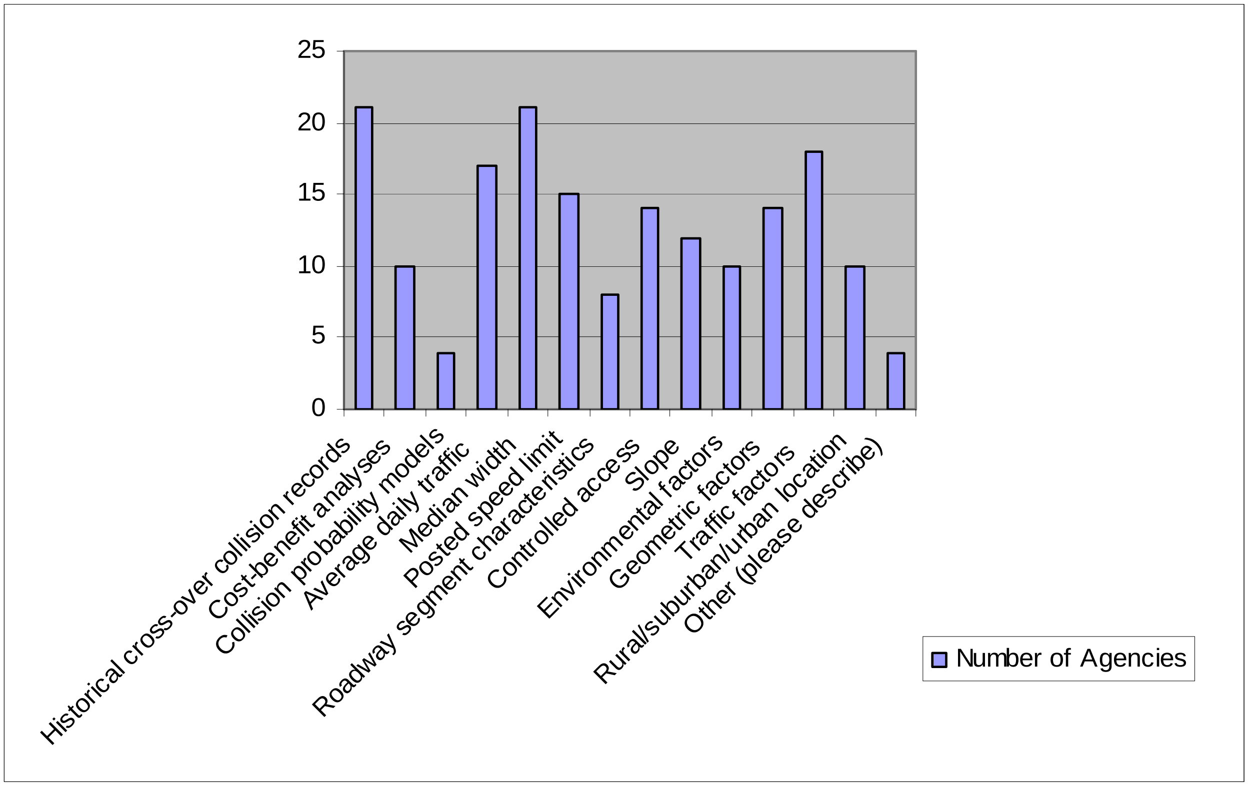

Figure 20. Criteria for determining need for median barrier installation.

4. **What guidelines does your agency use to determine the type and location of median barrier installations? Please select all that apply.**

Twenty-one of 26 agencies (81%) that responded to this question reported using AASHTO's Roadside Design Guide (RDG). Cumulatively, 25 of 26 (96%) utilize their own state/province or agency guidelines. Two reported using another agency's guidelines. Three indicated they employ an ad hoc approach, two of which also utilize guidelines and one of which also indicated this question was "Not applicable; no need for median barrier installation guidelines." Results from multiple respondents from a single agency were aggregated. Most (65%, 17 of 26) utilized both AASHTO's RDG as well as other governmental or agency guidelines. Five participants reported using only ASSHTO's RDG while two reported using only governmental/agency guidelines. Results are shown in Figure 21 and Figure 22. Nine of the 27 agencies that reported using guidelines other than AASHTO's Roadside Design Guide, provided the name of the document. The listing can be found in Table 6. Given that this survey was sent to Canadian transportation agencies, it was an oversight not to include Transportation of Canada's Guidelines as an option.

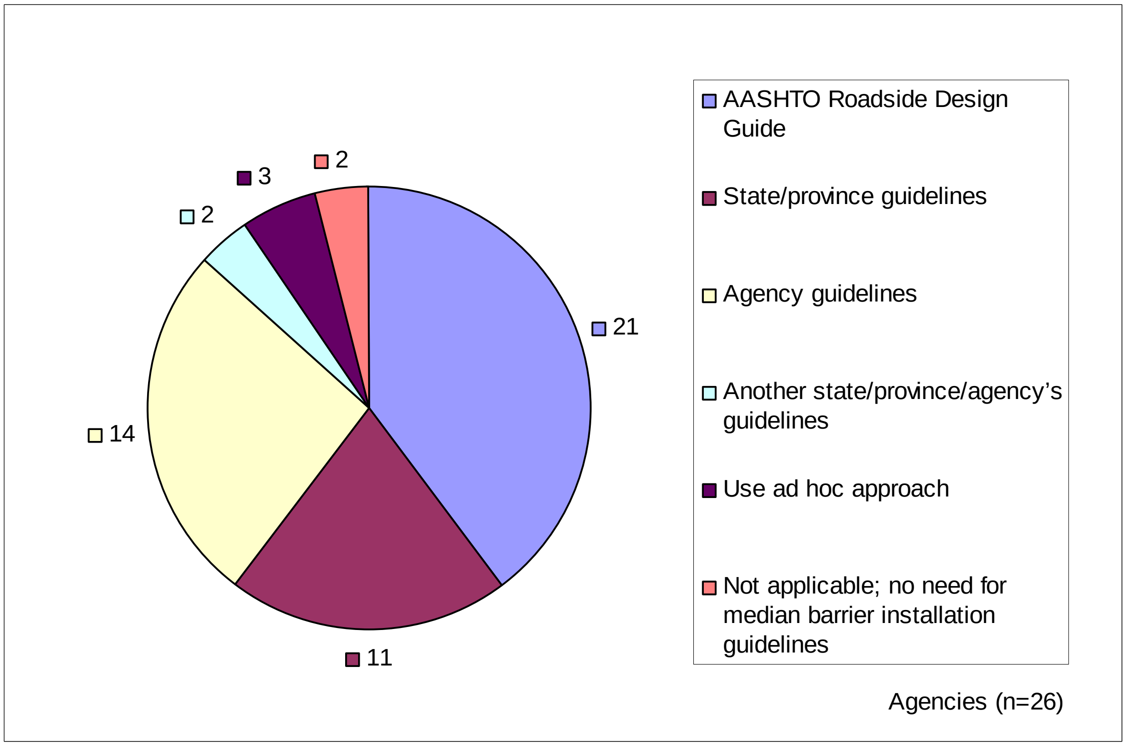

Figure 21. Median barrier placement guidelines/approaches used by agencies.

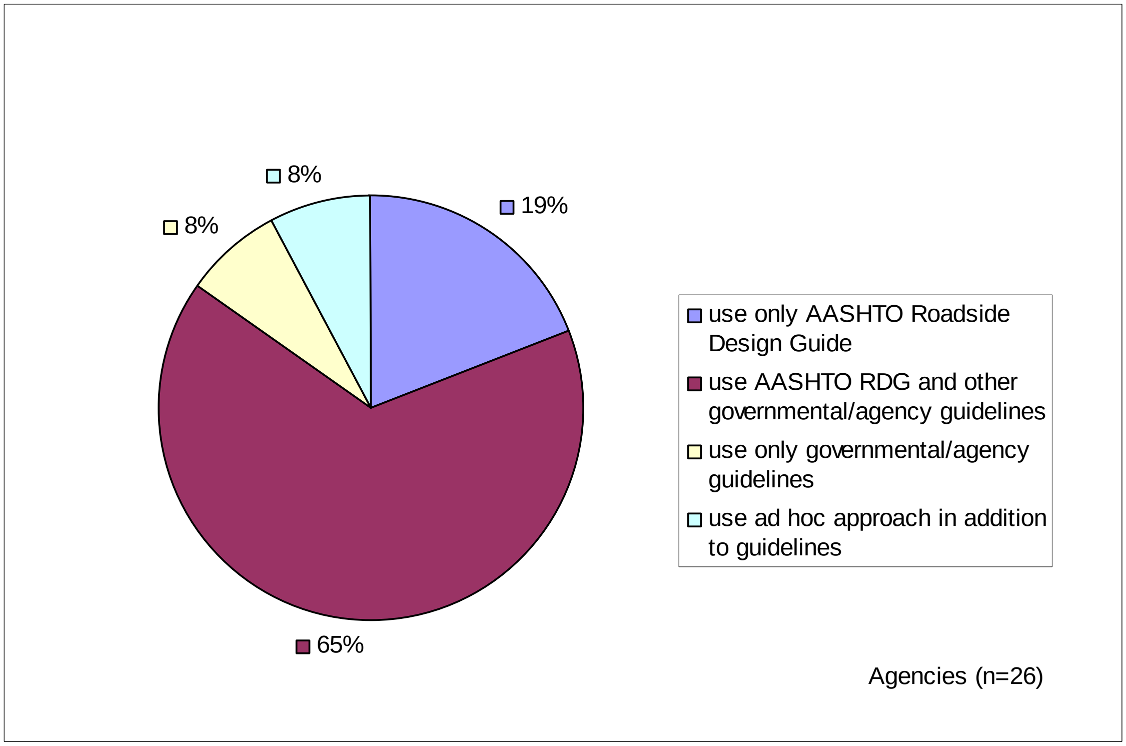

Figure 22. Relative percentage of agencies that use a single set or a combination of guidelines/approaches.

Table 6. Other documents used by agencies for median barrier guidance.

Agency	Document
Alberta	Alberta Geometric Design Guidelines
Illinois	Bureau of Design and Environment Manual www.dot.il.gov/desenv/bdemanual.html
New Brunswick	Transportation Association of Canada Guidelines
New Hampshire	NHDOT Policy for Design Criteria
New York	NYSDOT Highway Design Manual
Newfoundland & Labrador	Manual of Geometric Design Standards for Canadian Roads by the Transportation Association of Canada
Ohio	ODOT Location and Design Manual, Roadway Design
Oregon	I am in process of writing policy for our Highway Design Manual.
Virginia	AASTHO'S Geometric Design of Highways and Streets

5. **Please describe any specific uses for barrier types utilized by your agency, i.e. as median barrier versus edge barrier, in high snow areas versus snow-free areas, etc.**

The intention of this question was to determine if certain types of barriers are better suited for specific situations or conditions. Participants representing five agencies responded. An edited version of the open-ended text responses are included in Table 7.

3.2.2.2 Trends

This section was aimed at determining current and future transportation agency trends as they pertain to median barrier installation.

6a. Please characterize your agency/state/province's installation trends for each of the following median barrier types.

A maximum of 24 agencies were represented in this analysis. In some instances, participants made no selection for particular barrier types. For Concrete constant-slope Texas, Steel or thrie beam, Centerline rumble strips, n=22. For Cable and Grassy median, n=23. For Concrete Jersey or F-shape, n=24.

The number of concrete Jersey or F-shape, Steel or thrie beam and Grassy median installations appear to be stable among most participating agencies that use them. An increasing trend towards Cable median barrier installation is the case for 11 of 17 agencies (65%) that use them. Among those agencies that utilize Centerline rumble strips, installation trends are either stable or increasing. Comparative results are shown in Figure 23. Four agencies refrained from answering entirely.

Table 7. Specific uses of certain barrier types.

Barrier type	Specific use
Concrete Jersey	Divided rural high-speed highways with narrow right-of-way that precludes a common median ditch or separate roadways (NB) Divided and two-way roads edge protection where deflection is not acceptable (NB)
Concrete F-shape concrete	In urban areas (NH) Turnpike systems (NH)
Steel or thrie beam guardrail	In rural areas (NH) In urban areas – (specified Thrie beam) (NH) Edge barrier ('Strong Post' (wood) double beam guardrail) (NH) Median barrier ('Strong Post' (wood) with double-sided beam guardrail) (NH) Divided and two-way roads edge protection (W-section steel rail on wooden posts at 12'-6' [3.7- 1.8 m] spacing (closer spacing at structures)) (NB)
Cable	Remaining open medians in excess of 75 feet [23 m] in width (OR)
Pertaining to grassy median	Proprietary median barriers are being used for grassy medians of 40 to 80 feet [12-24 m] when warranted by benefit/cost from crash history. (IL)
Pertaining to barrier choice in general	Preventing cross over crashes on the Interstate (WY) Use median and edge barriers (NB) Snow drifting typically is not a factor in choice of barrier (NB)

(Illinois =IL, New Brunswick = NB, New Hampshire = NH, Oregon = OR, Wyoming =WY)

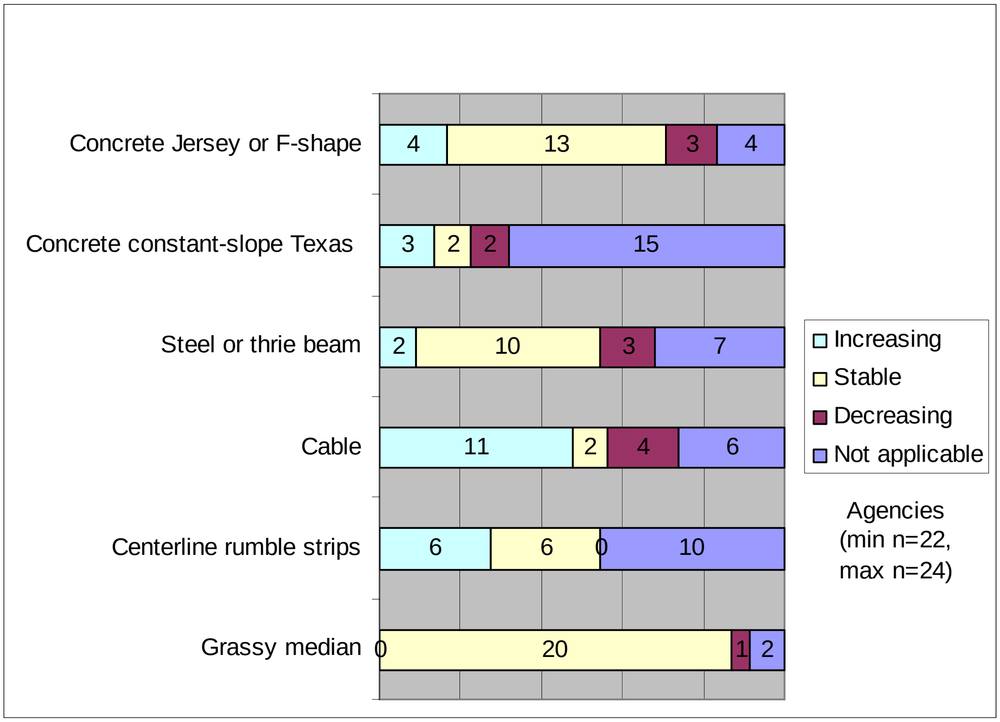

Figure 23. Comparison of median barrier installation trends by type.

b. Please describe any other trends in the use of median barriers by your agency/state/province.

Five participants provided further information regarding other median barrier trends within their agencies. Open-ended comments are listed in Table 8.

Table 8. Other median barrier trends.

Agency	Comments regarding other median barrier trends
New Brunswick	NBDOT uses shoulder rumble strips on its divided highways and on some high volume two-way arterials, but is not using centerline rumble strips, pending Transportation Association of Canada issuing guidelines for same. I am not familiar with the constant-slope Texas barrier, unless it's the 20' high precast barrier with straight, out-leaning slopes designed primarily for use on construction sites to separate opposing traffic. We've considered that barrier type for the viaduct portion of a new four-lane urban arterial proposed to connect NB Route 1 to the port facilities of Saint John, but will probably opt for Jersey barrier because of the high percentage of heavy trucks.
New Hampshire	In urban or rural two lane systems, we use a slope curb median with a 6 foot to18 foot [1.8-5.5 m] width grass median. In high-speed LA ROW facilities (Interstate) w/ grade separation, we would install median barrier if median width is less than 60 feet [18m].
Newfoundland & Labrador	Increased protection at end treatments by installing crash barriers etc.
Wyoming	We are looking at cable systems. We will be letting several contracts in the near future with cable systems.
Yukon	We have approximately 500m [.3 miles] of centerline rumble strip in the Yukon. Located in an urban canyon area where a number of run off road and cross over collisions have occurred.

7. Please select the median barrier type your agency is most likely to use for each of the following roadway types.

A maximum of twenty-seven participants representing 23 agencies answered this question set. For Suburban 2-lane, Suburban 4-lane, Rural 2-lane and Rural 4-lane, n=27. For Suburban > 4-lane, Urban 2-lane and Urban 4-lane, n=26. For Urban > 4-lane, n= 25. Two agencies (Alaska and Saskatchewan) did not make a median barrier type choice for Suburban > 4-lane, Urban 2-lane, Urban 4-lane and/or Urban > 4-lane roadway types, presumably because the question was not applicable to them. Results are shown in Figure 24. Five others refrained from answering this question set entirely.

The qualitative nature of this question set does not lend itself to aggregating, therefore, all of the individual representatives' responses were included. Most participants (22 of 27; 81%) indicated their agencies use only Painted centerlines on Rural 2-lane roads. Nineteen of 27 (70%) reported utilizing Grassy medians for Rural 4-lane roads. Twenty-three of 27 (85%) indicated their agencies use only Painted centerlines on Suburban 2-lane roadways. The majority was split for median types used on Suburban 4-lanes, with roughly 41% (11 of 27) choosing Grassy median or Painted centerline. For Suburban > 4-lane roadways, the most common choices were Grassy median (9 of 26; 35%) or Concrete Jersey/F-shape (8 of 26; 31%). Eighty-five percent of participants (22 of 26) indicated their agencies use only Painted centerlines for Urban 2-lane roads. For Urban 4-lane roads, Painted centerlines (9 of 26), Grassy median (8 of 26) and

Concrete Jersey/F-shape (5 of 26) were the most common choices. Most participants reported utilizing Concrete Jersey/F-shape median barriers on Urban > 4-lane roads (14 of 25; 56%).

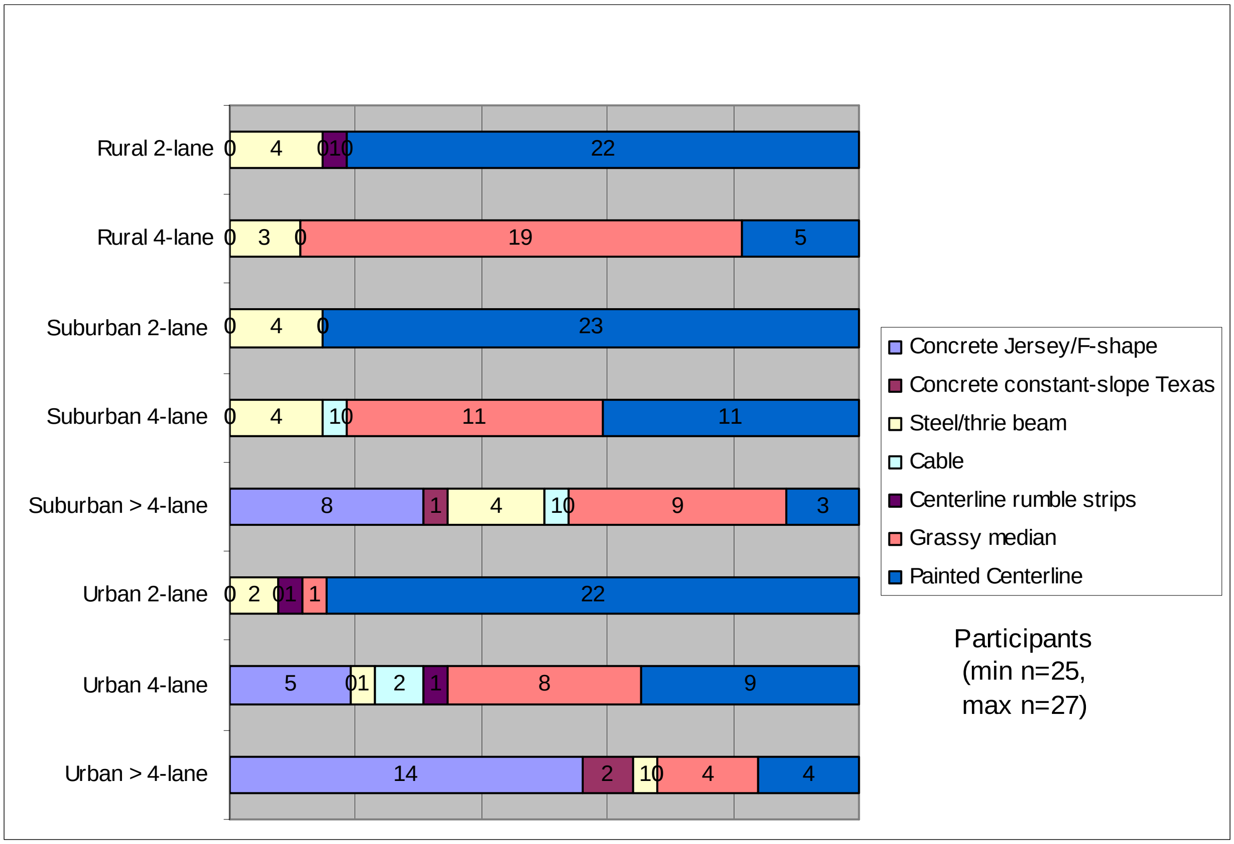

Figure 24. Median barrier types used by roadway type.

In some instances multiple representatives from a single agency responded differently for certain roadway types. Discrepancies are summarized in Table 9.

Table 9. Differing intra-agency responses for median types used for particular roadway types.

Roadway type	Differing responses from multiple participants representing a single agency
Rural 2-lane	Steel/thrie beam and Painted centerline
Rural 4-lane	Grassy median and Painted centerline Steel/thrie beam and Grassy median
Suburban 2-lane	Steel/thrie beam and Painted centerline
Suburban 4-lane	Cable and Painted centerline Steel/thrie beam and Grassy median
Suburban > 4-lane	Concrete Jersey/F-shape and Grassy median Concrete Jersey/F-shape and Painted centerline Concrete Jersey/F-shape, Streel/thrie beam and Grassy median
Urban 2-lane	Centerline rumble strips and Painted centerline Steel/thrie beam and Painted centerline
Urban 4-lane	Cable and Centerline rumble strips Concrete Jersey/F-shape, Grassy median and Painted centerline
Urban > 4-lane	Concrete Jersey/F-shape and Painted centerline Concrete Jersey/F-shape and Grassy median

3.2.2.3 Performance Evaluation

The purpose of this section was to obtain information about whether and what types of median barrier studies have been conducted relative to motorist safety and wildlife movement and mortality. Measures of effectiveness, goals and the prevalence of unforeseen negative impacts are also addressed.

8a. Has your agency studied the effectiveness of installed median barriers for motorist safety?

Twenty-eight participants representing 24 agencies responded to this question. Of those able to provide a conclusive response, almost half reported that their agency has studied the effectiveness of median barriers relative to motorist safety. In one case, representatives from a single agency had contrasting responses (Yes and No). Since no example was provided (Question 8b) to support the positive response, the negative response (No) was included in the analysis. Results are shown in Table 10.

8b. If yes, what type of median barrier(s) was studied?

Eight of nine who responded affirmatively provided more detailed information about the motorist safety studies. Table 11 lists the median barrier types that were studied by particular agencies.

Table 10. Agency responses regarding median barrier motorist safety studies.

Response	Number of agencies	Relative percentage
Yes	9	37.5%
No	10	41.7%
I don’t know	5	20.8%
Total	24	100%

Table 11. Motorist safety/median barrier type studies by participating agencies.

Agency	Median barrier type studied
Alabama	Concrete Barriers and double-faced guardrail
Alaska	F-shape, w-beam, thrie beam
Idaho	With Jersey barrier and without
Ohio	One high tension cable installation (Brifen)
Oregon	All
Virginia	Concrete, cable
West Virginia	Cable
Wisconsin	Jersey barrier

8c. If yes, what were the measures of effectiveness? Please select all that apply.

Of the nine agencies that conducted median barrier studies related to motorist safety, eight responded to this question about measures of effectiveness. Reduction of cross-over collisions, Reduction of cross-over collision fatalities and Lives saved ranked equally high (6 of 8; 75%), followed by Reduction of injury severity (3 of 8) and Dollars saved (2 of 8). Participants provided no other measures of effectiveness. Results are illustrated in Figure 25. Some agencies used a combination of measures; those sets are shown in Figure 26.

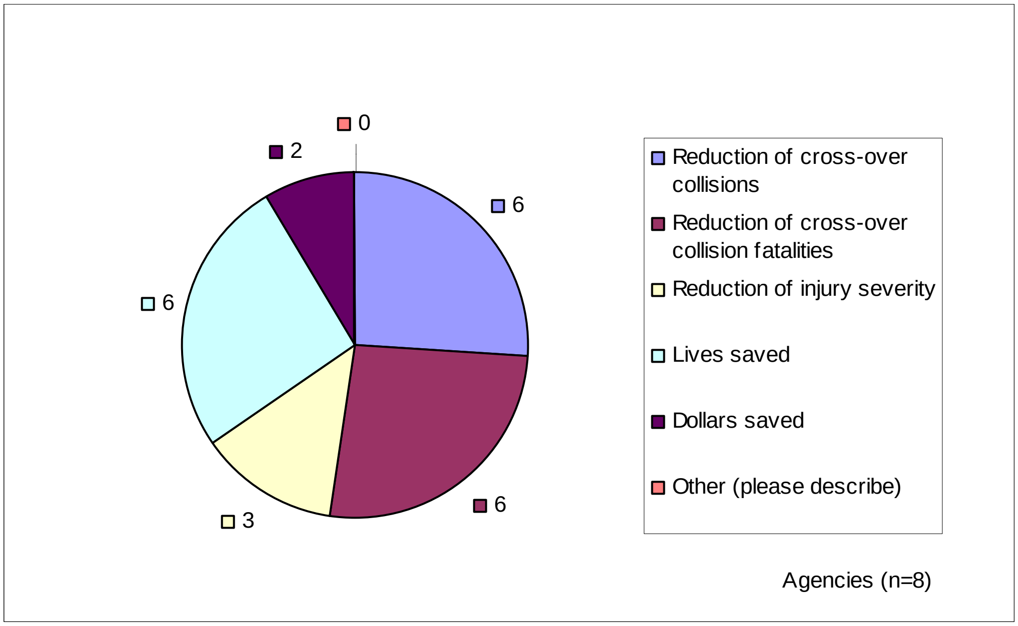

Figure 25. Measures of effectiveness used by agencies in motorist safety/median barrier studies.

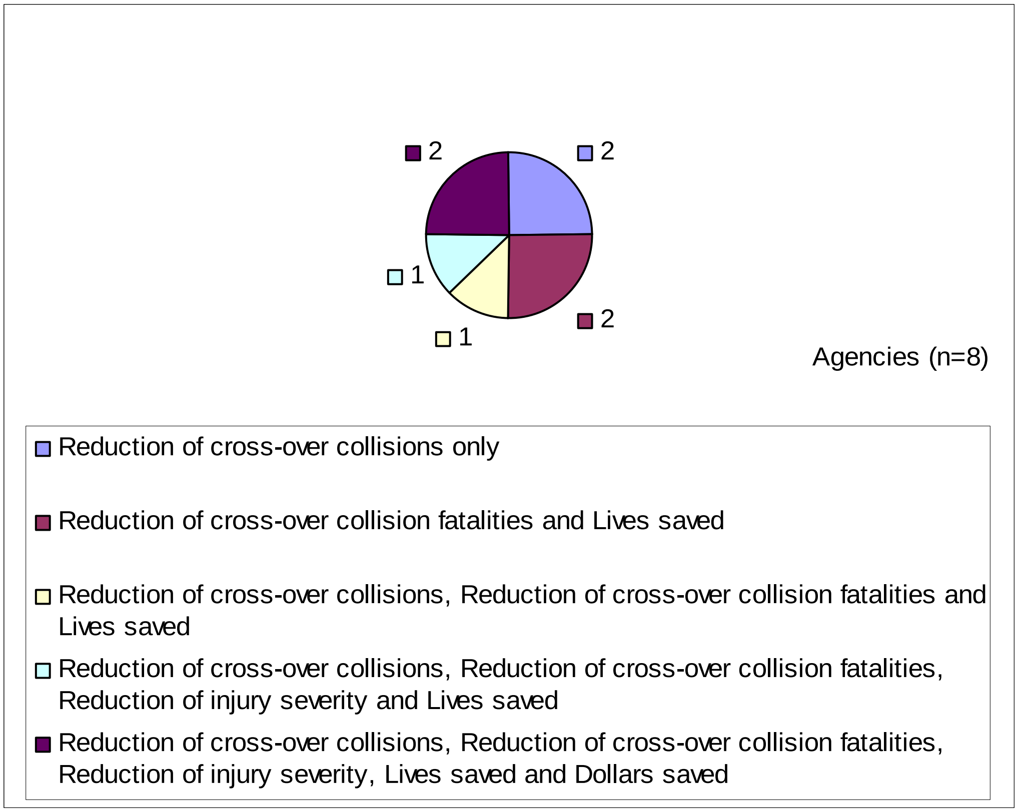

Figure 26. Sets of measures of effectiveness used by agencies in motorist safety median barrier studies.

9. Did the installation of median barriers enable your agency to achieve its a priori goal(s) for increasing motorist safety?

Of those able to provide a conclusive response to Question 8, most (14 of 15; 93%) indicated their agencies' median barrier installations met a priori goals for increasing motorist safety. In two cases, individuals from the same agency responded differently (Yes and I don't know). In both cases, the conclusive response (Yes) was used in the analysis. Results are shown in Table 12.

Table 12. Agency a priori goal achievement for increasing motorist safety.

Response	Number of agencies	Relative percentage
Yes	14	58.3%
No	1	4.2%
I don't know	9	37.5%
Total	24	100%

10a. Has your agency studied the effects of median barriers on wildlife movement and/or mortality?

Thirty respondents representing 25 agencies answered this question. Responses from two or more participants from a single agency were aggregated. There were differing answers from individuals representing the same agency in two cases (No and I don't know). In both cases the conclusive response (No) was used in the analysis. Sixteen percent (4 of 25) reported that their agency has studied the effects of median barriers on wildlife movement and/or mortality. Most (19 of 25; 76%) indicated that their agency has not conducted such studies. Results are shown in Table 13. Three agencies refrained from answering this question.

Table 13. Agency responses regarding the study of median barrier effects on wildlife.

Response	Number of agencies	Relative percentage
Yes	4	16%
No	19	76%
I don't know	2	8%
Total	25	100%

10b. If yes, please explain general findings and provide report citation(s).

All four of the participants who responded in the affirmative provided a description of the study. Oregon DOT's study is cited in this report as Hostick and Styskel 2005. Follow up queries revealed that the other three studies are not directly related to median barriers. See Table 14 for original descriptions of studies and follow up information in *italics*.

Table 14. Wildlife movement and/or mortality median barrier studies by participating agencies.

Agency	Description of median barrier wildlife study
Alaska	I think central region and Moose program.
Oregon	Wildlife study was conducted on section of US 97, south of the City of Bend. We needed median barrier to save human lives, created openings in barrier for wildlife. I have not seen a research report of the outcome.
Texas	The overall effects of road construction / reconstruction on Threatened and Endangered Ocelots and Houston Toads have been studied as part of Endangered Species Act consultations with USFWS. Barriers were a minor inclusion, not a significant consideration. Much more thought was given to 'critter crossings.' In response to Question 10c: It is very likely that TxDOT will study impacts on species in depth as part of the Trans Texas Corridor 35 Tier II EIS which is likely to start sometime in FY 07.
Virginia	If rare species, pipe/box culvert access provided. In response to Question 10c: Early stages of project development, environmental documents. Targeted species based on environmental document? *I am not aware of any studies or projects VDOT is currently working on regarding wildlife crossings on highways involving median barriers.*

10c. If no, is any such research being considered or planned for the future?

Twenty-six participants representing 21 agencies responded to this question, including two who indicated that their agency did conduct such research in Question 10a. Most participating agencies (16 of 21; 76.2%) indicated they have no plans for such research. Texas was the only agency to indicate they have future study plans. (See Table 15.) If answering yes to this question, participants were also asked to briefly explain scope/type of planned study, projected date, stage of the project, targeted species, and other relevant details. Responses are included above in Table 15. Seven agencies did not answer this question.

Table 15. Agency responses concerning plans for future wildlife/median barrier research.

Response	Number of agencies	Relative percentage
Yes	1	4.8%
No	16	76.2%
I don't know	4	19%
Total	21	100%

10d. If no, please rank your agency's reasons for not studying the effects of median barriers on wildlife movement and/or mortality. (1 = Highest, 5 = Lowest)

This question targets the perceptions of agency personnel regarding the lack of median barrier studies pertaining to wildlife. Nineteen participants representing 17 agencies responded to this question. Due to the subjective nature of the question, all participant responses are reflected in the analysis. Most (12 of 19) ranked highest No perceived need to conduct such research. The most common reason ranked #2 was No mandate to conduct such research (9 of 19). No specialized personnel to conduct the study was ranked third by most (10 of 19). Too time consuming was the most common fourth ranked choice (10 of 19). Too expensive ranked fifth in 7 of 19 responses. Results are shown in Figure 27. Fifteen participants refrained from answering this question.

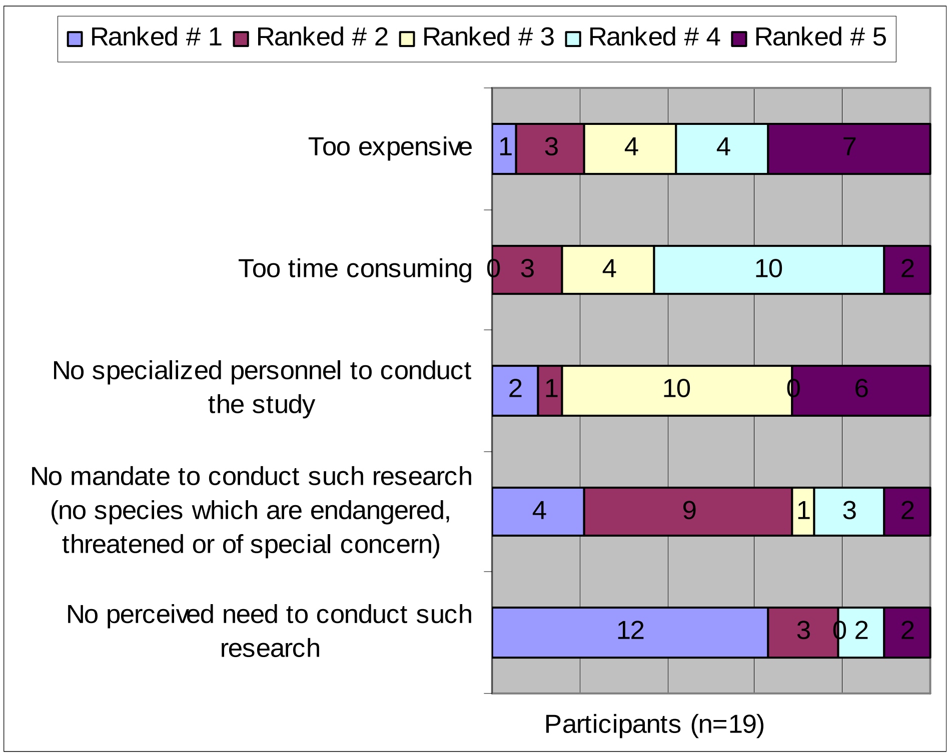

Figure 27. Ranked reasons for not studying the effects of median barriers on wildlife.

10e. If there are other reasons not listed above, please describe.

Some provided further information, see Table 16.

Table 16. Other reasons for not studying the effects of median barriers on wildlfie.

Agency	Reason for not studying effects of median barriers on wildlife
Alabama	Barriers are installed when there is a specific need for the safety of people.
New Hampshire	No plans for study currently but probably will in the future.
New York	Related research underway regarding highway permeability for reptiles and amphibians.

11. Have any unforeseen negative impacts resulted from different types of median barrier installations by your agency/state/province? Please select all that apply.

The aim of this question was to gain insight into agencies' experiences with unintended negative impacts (listed in Figs. 23-28) after installing different median barrier types. For each of the negative impacts, participants were given the opportunity to mark the median barrier types (Concrete Jersey/F-shape, Concrete constant slope Texas, Steel/thrie beam, Cable, Centerline rumble strips or Grassy median) with which they experienced the problem.

Sixteen agencies (57% of all 28 participating agencies) responded to this question set, an indication that they have experienced unforeseen negative impacts after the installation of one or more of these median barrier types. Twelve agencies did not respond to this question set either because they have not experienced any of these particular unforeseen negative impacts after installing any of these median barrier types, or for some other reason.

The number of agencies that marked responses for each sub-question (each listing a different negative impact) varied, presumably according to their experience. For example, of the 16 agencies that responded to this question set, seven agencies responded to the sub-question regarding Increase in fixed object (median barrier) collisions. Of those seven, five indicated that they experienced an Increase in fixed object collisions with the Concrete Jersey/F-shape barrier type (Figure 23). The number of agencies (n=X; out of 16 maximum who responded to this question set) that had an experience with each negative impact is noted in Figures 23-28. Multiple responses from a single agency were aggregated.

Collectively, participating agencies that have installed Concrete Jersey/F-shape median barriers have experienced nine unforeseen negative impacts (out of 10 possible choices). Results are shown in Figure 28. Recall from Question 1 that out of 28 participating agencies, 17 reportedly use Concrete Jersey and ten use Concrete F-shape median barriers.

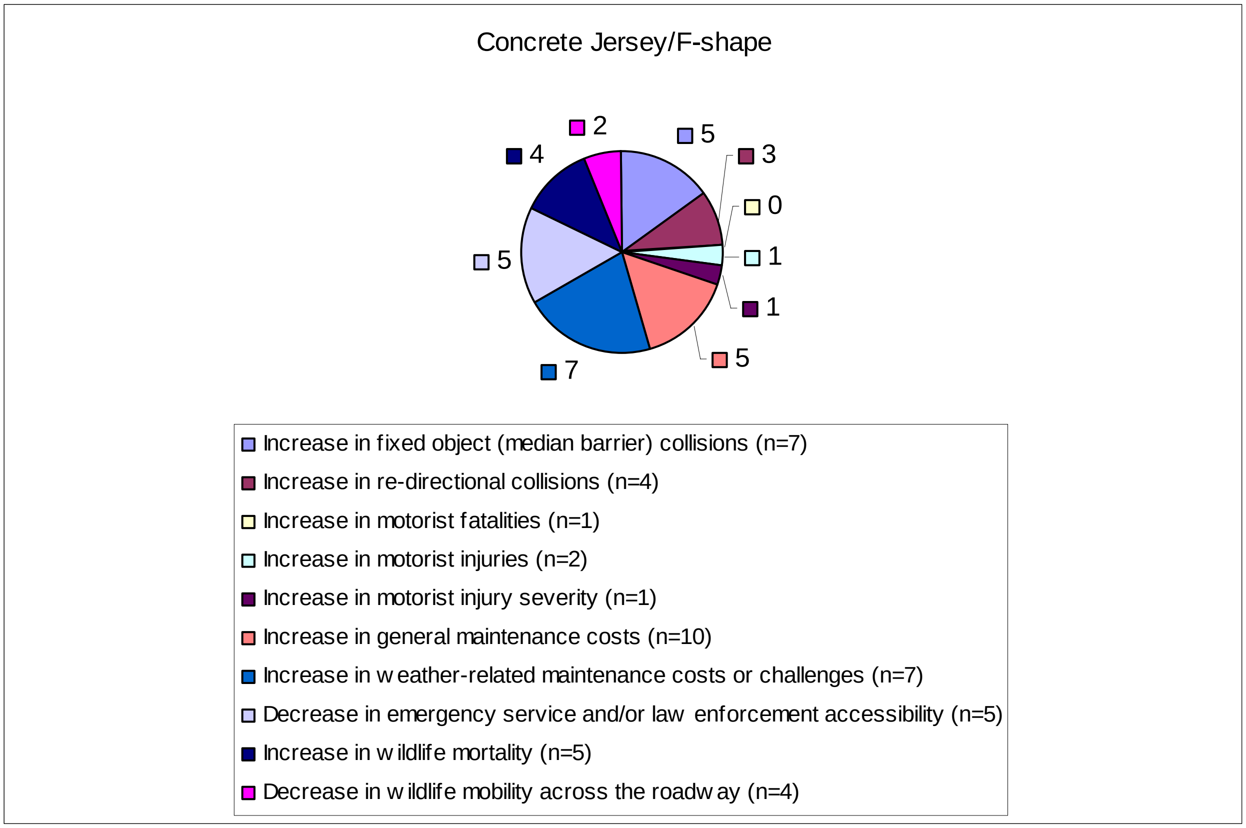

Figure 28. Unforeseen negative impacts associated with concrete Jersey/F-shape median barriers.

As a whole, participating agencies that have installed Concrete constant-slope Texas median barriers have experienced three unforeseen negative impacts (out of 10 possible choices). Results are shown in Figure 29. Seven of 28 participating agencies indicated they use constant-slope Texas median barriers (see Question 1.)

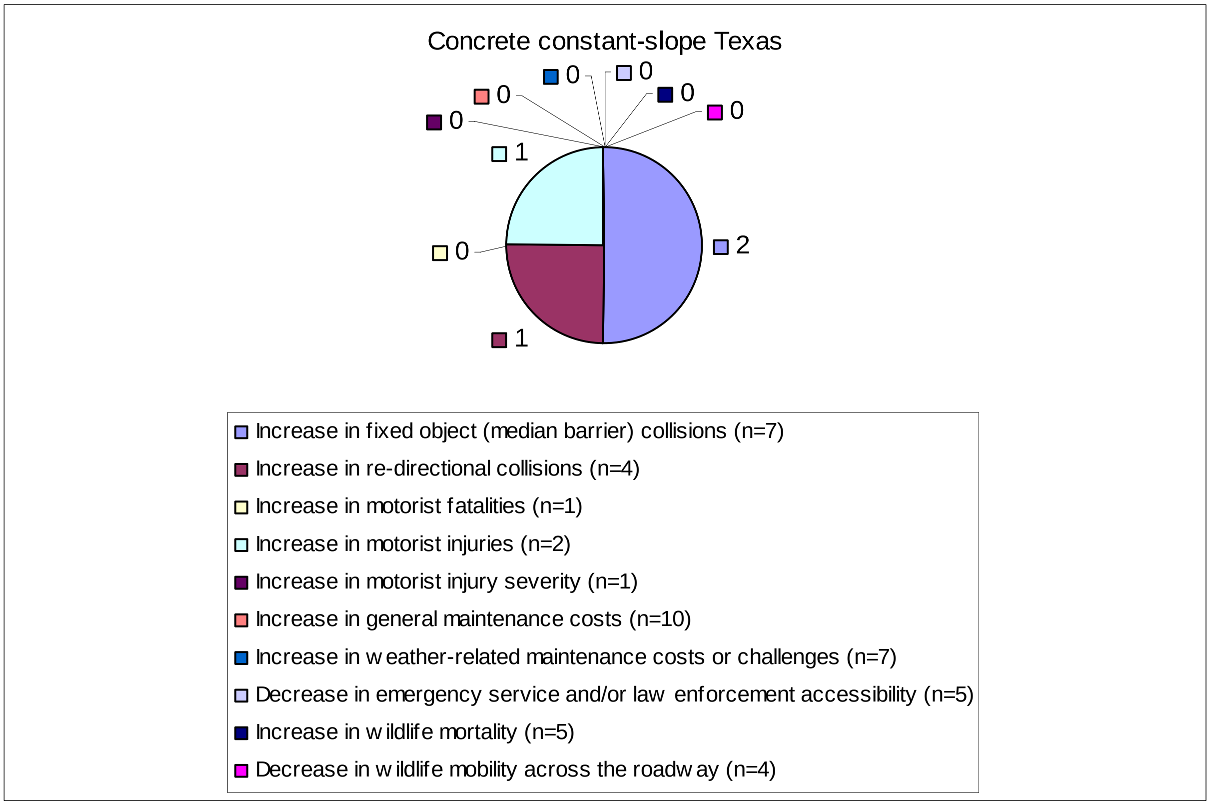

Figure 29. Unforeseen negative impacts associated with concrete constant-slope Texas median barriers.

Collectively, participating agencies that have installed Steel/thrie beam median barriers have experienced eight unforeseen negative impacts (out of 10 possible choices). Results are shown in Figure 30. Recall from Question 1, ten of 28 participating agencies reportedly use Steel/thrie beam barriers.

As a group, participating agencies that have installed Cable median barriers have experienced six unforeseen negative impacts (out of 10 possible choices). Results are shown in Figure 31. Fifteen of 28 participating agencies indicated they use some form of Cable barrier.

Collectively, participating agencies that have installed Centerline rumble strips have experienced one unforeseen negative impact (out of 10 possible choices). Results are shown in Figure 32. Twelve of 28 participating agencies reported they use Centerline rumble strips (see Question 1).

As a whole, participating agencies that have installed Grassy medians have experienced seven unforeseen negative impacts (out of 10 possible choices). Results are shown in Figure 33. Twenty of 28 participating agencies indicated they install Grassy medians (see Question 1).

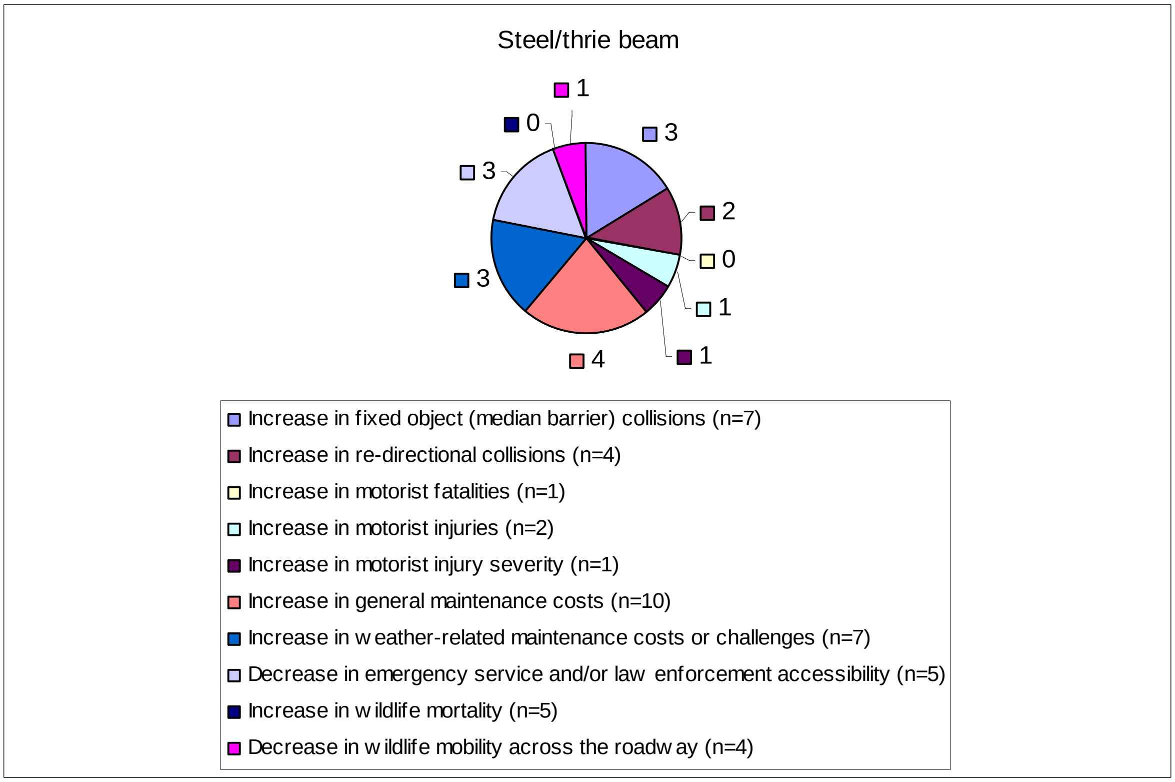

Figure 30. Unforeseen negative impacts associated with steel/thrie beam median barriers.

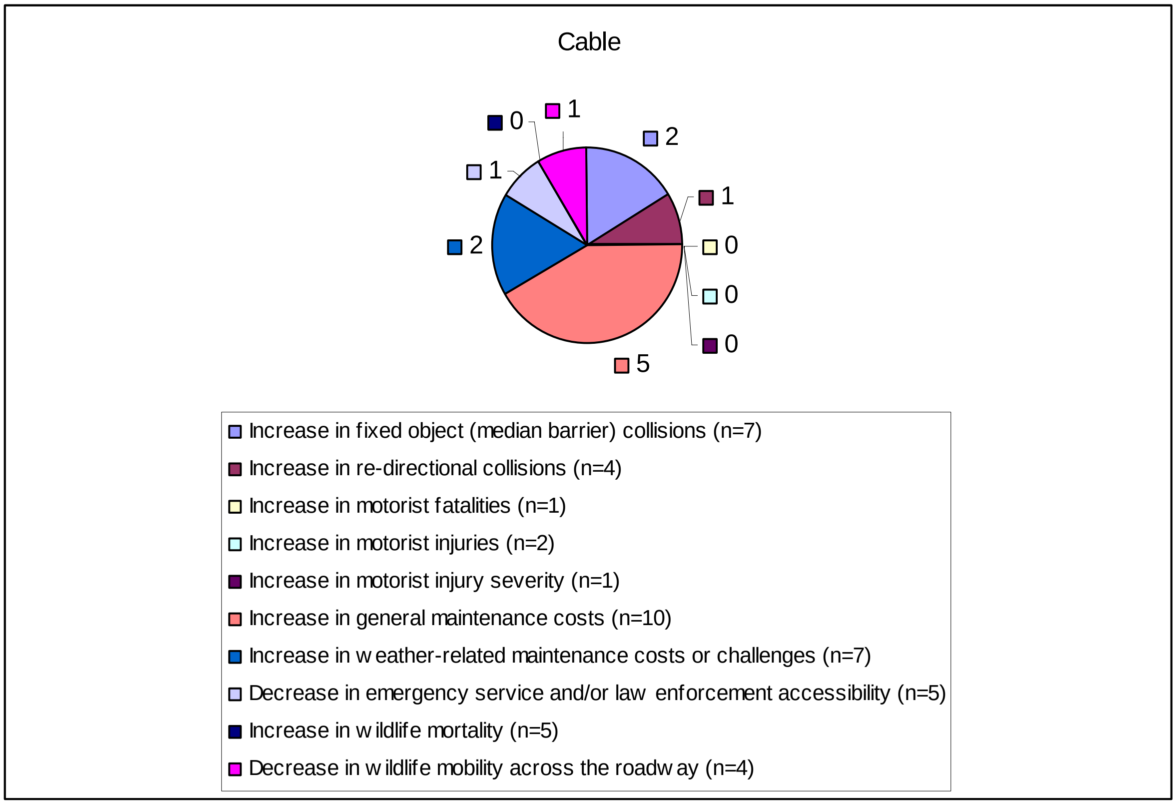

Figure 31. Unforeseen negative impacts associated with cable median barriers.

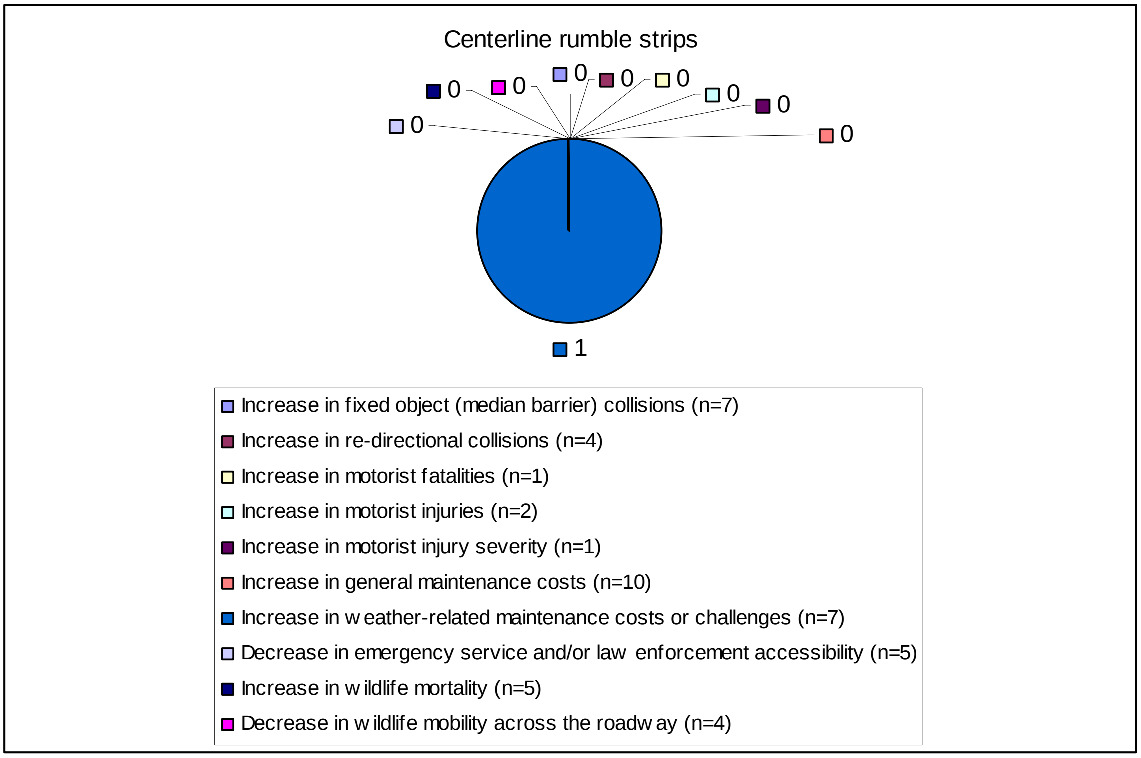

Figure 32. Unforeseen negative impact associated with centerline rumble strips.

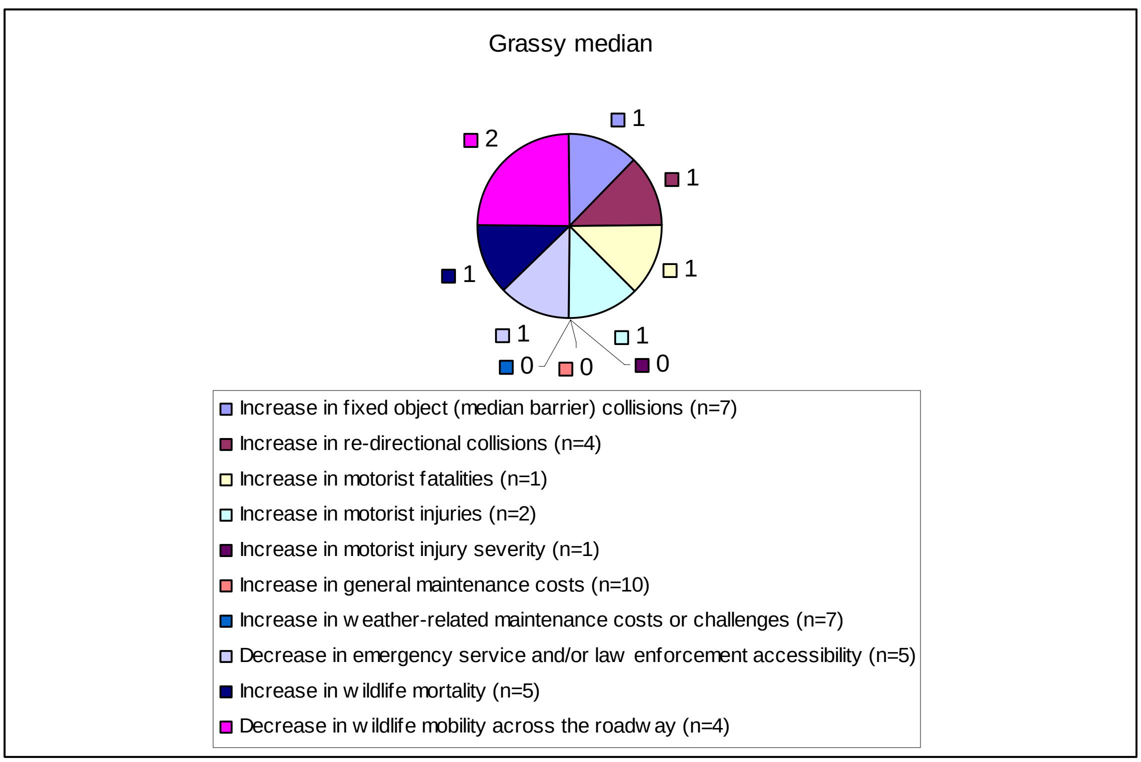

Figure 33. Unforeseen negative impacts associated with grassy medians.

Due to the similar solid nature of Concrete Jersey/F-shape and constant-slope Texas median barriers, the number of negative impacts associated with these were aggregated and compared to other median barrier types in Figure 34.

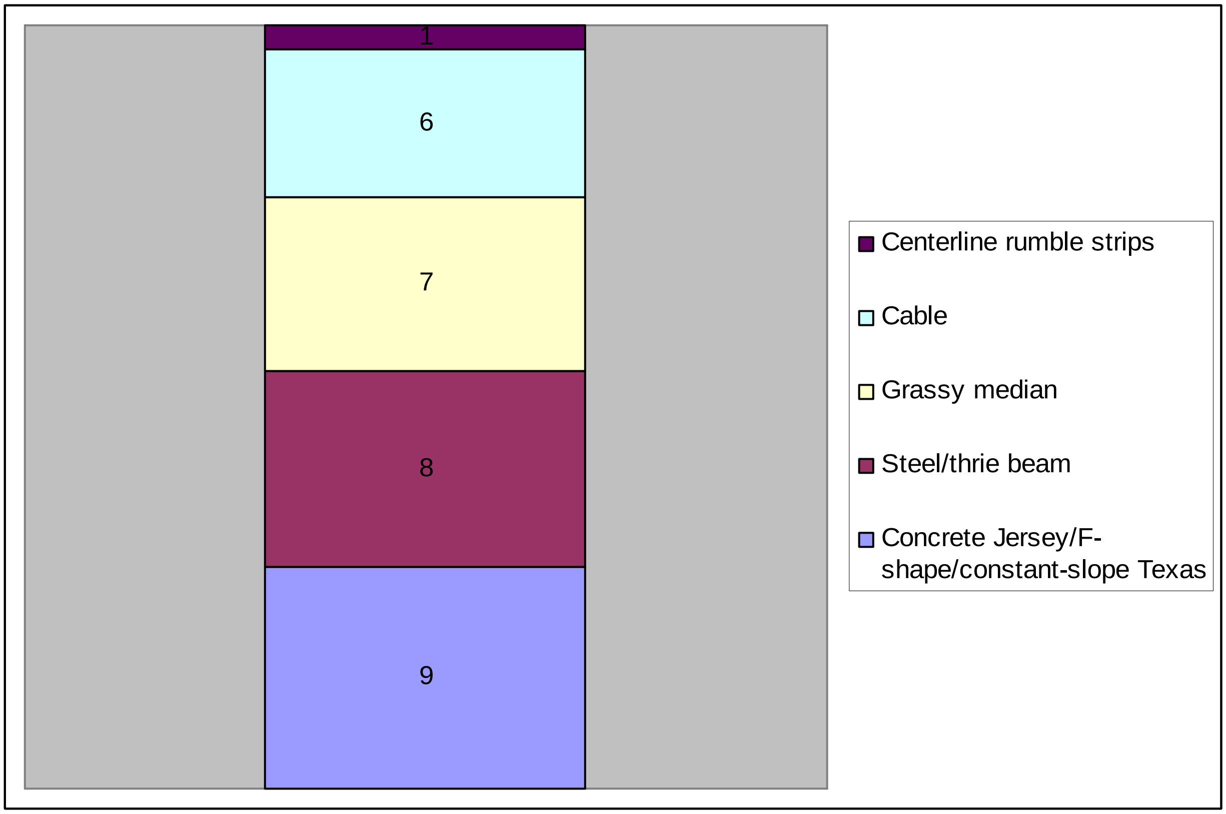

Figure 34. Number of unforeseen negative impacts by median barrier type.

3.2.2.4 Mitigations for Wildlife

This section focuses on wildlife species that might be affected by median barriers and the likelihood of agencies to consider or employ mitigative actions.

12. **What species (deer, bears…) or groupings (small mammals, reptiles/amphibians…) of wildlife appear to be most affected by roadways with raised median barriers in your jurisdiction?**

Twenty four agencies answered this question; multiple responses from a single agency were aggregated. Four agencies refrained from answering this question. Eight of 24 (33%) indicated that they have no or few median barriers, there is no wildlife impact or it is unknown whether median barriers have a negative impact on wildlife. The other 17 agencies (71%) provide information about species or groups that appear or are assumed to be affected by median barriers. See potentially affected wildlife listing in Table 17.

Agencies that contributed to this listing include Georgia, Idaho, Illinois, New Brunswick, New Hampshire, New York, Newfoundland & Labrador, North Dakota, Ohio, Oregon, Quebec, South Dakota, Texas, Virginia, Washington State, Wisconsin, West Virginia.

Table 17. Combined agency listing of wildlife potentially affected by median barriers.

Reptiles and amphibians toads (*Bufo* sp.), turtles
Small to medium-sized mammals squirrels, muskrat, possums, raccoons, porcupines, ocelots
Large mammals deer, moose *(Alces alces)*, bear
Birds ducks, other waterfowl
Younger animals of all types

13. **How frequently does your agency/state/province *consider* mitigative design solutions to median barrier impacts on wildlife movement and/or mortality? (e.g. spacing of barriers, scuppers, passages…)**
14. **How frequently does your agency/state/province *employ* mitigative design solutions to median barrier impacts on wildlife movement and/or mortality?**

Thirty-one respondents representing 27 agencies answered Questions 13 and 14. In two cases multiple individuals from a single agency responded differently. These responses were aggregated either by taking the average value and applying the corresponding frequency or, if adjacent values, by taking the lower (more frequent) value. Agencies for which this method was applied are marked with an asterisk below (*). Five agencies indicated these questions were Not applicable. Of the remaining 22 agencies that answered these questions, results to these two questions were similar; 68% rarely or never *consider* mitigative design solutions and 77% rarely or never *employ* them. See comparative results in Figure 35.

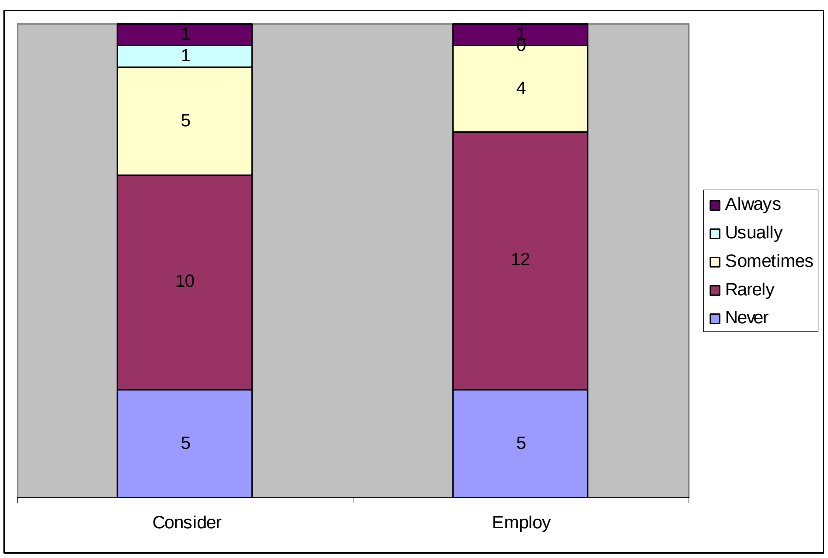

Figure 35. Frequency with which agencies consider or employ designs to mitigate impacts to wildlife.

Virginia reported that they **always** *consider* and *employ* mitigative design solutions to median barrier impacts on wildlife movement and/or mortality. New Hampshire* **usually** *considers* such mitigations. New Brunswick,* New York, Texas, West Virginia and Wyoming **sometimes** *considers* and New Brunswick,* New Hampshire,* West Virginia and Wyoming **sometimes** *employs* such mitigations.

3.2.2.5 Implications for Transportation Planning

15. Has your agency encountered any practical or regulatory issues regarding the use of median barriers in your state/province?

16a. Does your agency know of any practical or regulatory issues regarding the use of median barriers across states/provinces/the country?

These questions attempt to learn what issues may exist with median barriers and whether they deal with motorist safety or wildlife. Twenty-seven agencies responded to this question; multiple responses from a single agency were aggregated. One agency refrained from answering this question. Note, in response to Question 16, respondents from a single agency provided contrasting answers and were omitted from the analysis for Question 16.

Few (3 of 27, 4 of 26) knew of any practical or regulatory issues within their own states/provinces or across other states/provinces/country, respectively. Most (16 of 27; 59%) reported that their agency did not encounter any such issues in their own state or province and (12 of 26; 46%) did not know of any such issues in other states/provinces across the country. Eight of 27 (30%) and 10 of 26 (38%) were not able to answer the question conclusively. Results are shown in Figure 36.

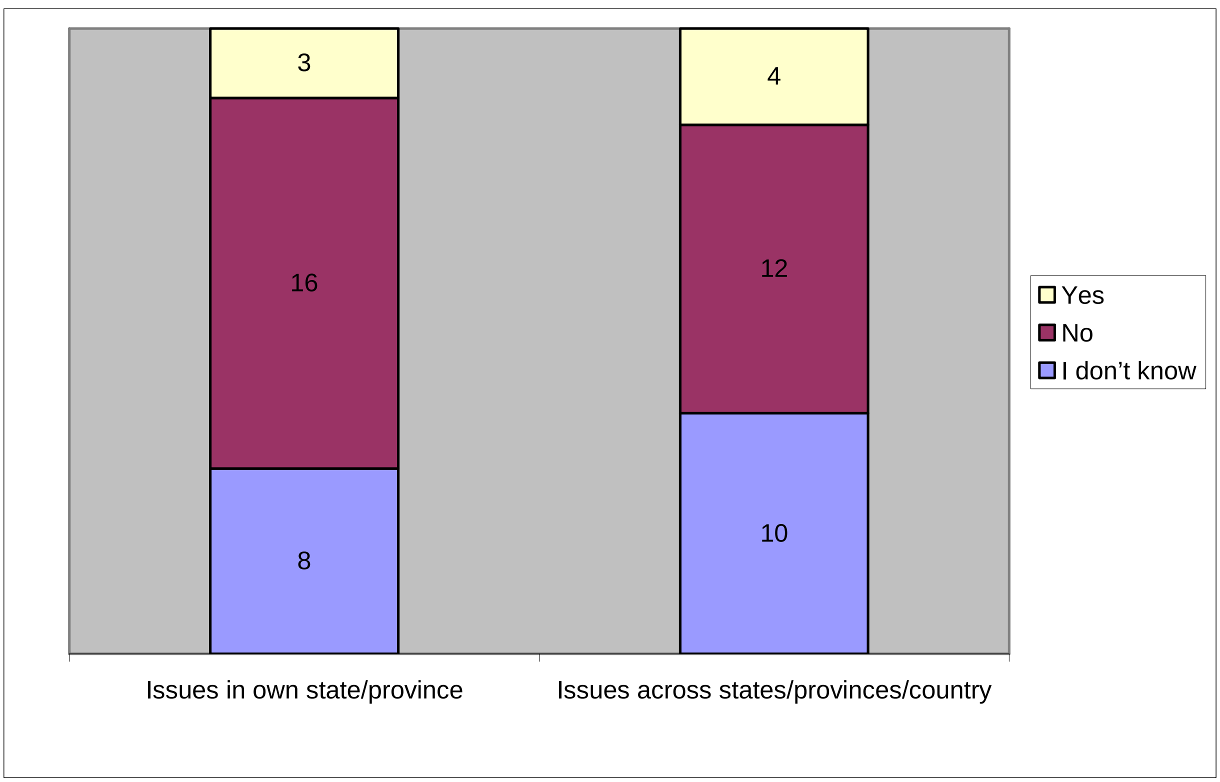

Figure 36. Agency experience with or knowledge of practical or regulatory issues with median barriers.

16b. If yes, are these issues related to motorist safety?

16c. If yes, are these issues related to wildlife movement and/or mortality?

Please explain.

Eight agencies responded, five of which indicated the known practical or regulatory issues are safety-related and four of which indicated known issues are wildlife-related. Five provided explanations which follow in Table 18.

Table 18. Known practical or regulatory median barrier issues.

Agency	Explanation
New Hampshire	Median barrier considered for interstate medians less than 60 feet in width. Any solid barrier near the travel way is a concern for motorist safety. If barrier is solid (e.g. Jersey barrier), small animals can't get through and usually end up as road kill.
Oregon	The only sure way to get wildlife safely across a major highway is to construct a wildlife crossing. Unfortunately, the cost thereof makes the bean counters shy away. We need practicality.
Virginia	Addressed in environmental document!
Washington State	Lack good direction of where to employ these and how.
Wisconsin	Almost all of our barriers occur in very urban areas where very little wildlife exists except small animals and herpetiles, e.g., turtles, frogs.

17. Is your agency planning any changes in its approach to using median barriers? (e.g. type of barrier, placement, etc.)

Twenty-two agencies replied to this question; seven of which answered No or I don't know. Fifteen participants provided details (see Table 19). Six did not answer this question.

Table 19. Agency plans for changing approach to median barrier use.

Agency	Explanation
Illinois	The trend is to cable.
Maine	We are looking to install cable median GR along several corridors where we have recently experienced an increase in cross median crashes and fatalities.
Quebec	Actually we are in the first step of the sensibilisation about this problem in our agency.
New Brunswick	See answers to Question #6. Repeated: NBDOT uses shoulder rumble strips on its divided highways and on some high volume two-way arterials, but is not using centerline rumble strips, pending Transportation Association of Canada issuing guidelines for same. I am not familiar with the constant-slope Texas barrier, unless it's the 20' high precast barrier with straight, out-leaning slopes designed primarily for use on construction sites to separate opposing traffic. We've considered that barrier type for the viaduct portion of a new four-lane urban arterial proposed to connect NB Route 1 to the port facilities of Saint John, but will probably opt for Jersey barrier because of the high percentage of heavy trucks.
New Hampshire	Consideration of high-tension cable median barriers.
New York	Not from a wildlife perspective. Where critical focus species or habitat is identified, median barrier type is considered and potential wildlife impacts assessed. For example, Jersey barrier would not be utilized in occupied bog turtle *(Clemmys muhlenbergii)* habitat unless passage issues are adequately addressed. Increased use of cable on wide medians. Decreased use of w-Beam. Use Box Beam in rural areas/concrete in developed areas or high volume settings.
Ohio	More emphasis on cable barrier for cross median accident mitigation (not as device used for barrier warrants - continue to use concrete for that).
Oregon	See answer to #5. Repeated: We are utilizing more cable rail now, since the remaining open medians are mostly in excess of 75 feet in width, and cable rail is a viable candidate in wide medians.
Saskatchewan	Plan to study the use of cable barriers in the median.
South Dakota	We are looking at potentially using more high tension 4- cable barrier.
Texas	More guidance on cable barrier placement.
Virginia	Continuous safety updates!
Washington State	Being considered.
Wisconsin	No, not regarding animal crossings. We are planning significant changes regarding animal crossings such as bridge extensions with built-in features for animals to cross under.
Wyoming	As noted above, we are planning on installing cable barrier on several projects.

18a. What suggestions or comments do you have regarding median barriers, motorist safety and wildlife movement and/or mortality that might not have been addressed in this survey?

Eight participants had substantive responses. Suggestions and comments are listed in Table 20.

Table 20. Participant comments about median barriers and this survey.

Suggestion and comments about this survey
In regard to wildlife, we provide fencing and/or passage structures along sections of rural divided highways where deer yarding and movements are known.
Median barriers are only a small segment of conflicts. Longitudinal barriers along rural and urban systems create greater barrier obstacles for wildlife mobility while creating higher potential for reduced roadway safety because barrier is close to travel lanes
Relationship between whitetail deer/vehicle collisions and presence of Jersey barrier, 3-strand cable, box beam and W-beam guardrail median barriers. Effectiveness of Jersey barrier 'openings' on highway permeability for small mammals and herpetiles.
Their use may mostly be on urban highways, but I'm not well versed in this area to answer questions above regarding our use of them.
There is not a single environmentalist in this organization that was willing to take this on, because they had no idea of any answers. It was dumped on me, sorry if you don't like my answers.
The European people have made many studies on this problem. I think they are a good source of information.
TRB's Task Force on Ecology and Transportation is focused on the much broader aspects of transportation corridor impacts on flora and fauna. Median barriers play a role, but all aspects of the whole transportation corridor need to be examined together.
Suggest better targeting of participants and questions. I could not answer many of the questions related to the specifics of barrier use, history and design considerations.

18b. If you would like to receive a report of the survey results, please check here.

Twenty respondents representing 15 agencies requested survey results.

3.2.3. Follow-up Request for Mitigation Techniques

Twenty participating agencies that were deemed most likely to be able to provide further information were emailed regarding median barrier mitigations for wildlife. The follow-up email request sought more specific information regarding any mitigation techniques agencies use to lessen potential impacts of median barriers on wildlife movement or mortality. For example,

- in cases where known wildlife crossing issues or WVCs exist, the type of median barrier or mitigations used
- in concrete barriers, the dimensions of basal openings or scuppers for wildlife crossings
- in concrete barriers, the distance between scuppers
- in concrete barriers, the width and interval distance of spacings between barrier ends for larger wildlife crossings
- the target species for which these scuppers or spacings were created
- how these dimensions and distances were determined
- the effectiveness of these mitigations/documented utilization by wildlife

Emailed responses to this request are listed in Table 21.

Table 21. Follow-up responses regarding median barrier mitigation for wildlife.

Agency	Response regarding median barrier mitigations for wildlife
Georgia	Sorry to say – none.
Iowa	After checking this out with a couple people, we're not aware of any mitigation techniques that have been specifically implemented to address this wildlife movement/mortality issue in Iowa.
New Hampshire	We use concrete barrier sparingly because of its small animal impacts. There is none up here other than for temporary use. We have never done anything that I know of to make openings for small mammals. I haven't seen concrete barrier with openings for small mammals used in NH although we use Jersey Barriers on most of our construction sites and even some permanent places.
New York	To the best of my knowledge, we base median barrier selection entirely on traffic safety issues. Typically, this works out OK for wildlife, because we mainly use concrete median barriers on high-volume, high-speed highways and our high-volume highways tend to be in developed areas where little wildlife is at risk. In rural areas, we tend to have wider medians and use rail and post barriers that are not a challenge to wildlife movement. Any openings we provide are for drainage purposes. In general, the only large wildlife in areas where we would use concrete barrier are deer, and they are unimpeded by any normal height concrete barrier. We have made several underpasses that are intended primarily for deer, but have been seen to be used by other species as well. Rather than protection of wildlife, however, I believe the motivation for these underpasses was to reduce the large number of vehicle-deer collisions that occur in New York each year. It may be worth mentioning that, unlike some drier states, New York does not tend to have well-developed, distinct animal crossing sites. Animals can be expected just about anywhere. (Several years ago, my mother-in-law hit a deer near JFK airport.) If the animals were limited to specific crossing locations, such as following a stream bed, or a direct trail between water holes, we might be inclined to worry more about median barriers and animal movements.
North Dakota	I am sorry to report that we have no additional information. Currently in North Dakota, median barriers are used primarily in urbanized areas, only during construction of projects. Because we have lower traffic volumes on both primary and secondary roads, head to head traffic, separated by cones, is acceptable.
Wisconsin	Unfortunately, most of the questions below can be answered with "We do nothing", or we do not account for animal crossings. However, for the first question, we never place median structures in KNOWN wildlife crossing areas, but we know of only a few crossings in the state. By putting no structures in these areas, it is not because we have the welfare of animals in mind but rather there is not heavy traffic in known crossing areas, therefore no structures are needed. Decisions are traffic based, not crossing based. The dimensions of the basal openings are just enough to get fork lift tines under, e.g., an inch or two high. Distance between basal openings is 3-4 feet. Distance between barrier ends is 2-3 inches, or whatever is convenient for fork lift operators. We have no target species for scuppers or spacings.

3.2.4. Survey Summary

The Median Barrier State of the Practice Survey (Appendix D) had a 45% agency response rate (Table 5). The final survey results represent 28 transportation agencies distributed across rural and urban regions of the U.S. and Canada (Table 4; Figure 5). The agency personnel who took the survey were somewhat balanced between environmental (14) and engineering (20) backgrounds. Most participants seemed better versed in the cross-over safety aspect of median barriers than the impact these barriers may have on wildlife, or motorists within the context of WVCs. It is evident that there is little interdisciplinary overlap between biologists and engineers who often were unable to answer cross-discipline questions. It should be noted that in many cases, multiple follow-up responses from as many as three staffers from one agency were combined with the comments of those who actually participated in the survey.

Most participating agencies (84%) indicated they rely on AASHTO's Roadside Design Guide either singly or in combination with other guidelines (Figure 22). Concrete Jersey and metal beam barriers are the most commonly used median barriers currently in use in urban and some suburban areas and after 20 or more years of installations, the trend remains stable. The historical onset for cable median barrier installation has been more variable among agencies but both closed and open-ended responses confirm that current and projected installations are increasing among transportation agencies. Centerline rumble strip installations also appear to be on the rise (Section 3.2.2.1).

Several survey takers had knowledge about the importance of wildlife crossings and of addressing barriers as a whole, but few had much to say specifically about the potential impacts and mitigation of median barriers. One state, Oregon, has studied the specific impacts of median barriers on deer (Hostick and Styskel 2005, reviewed in Section 3.1 and Appendix C). Texas has plans for future research but the extent to which median barriers will be studied remains unclear. The most common highest ranked reason agency personnel chose for not conducting wildlife/median barrier studies was "No perceived need to conduct such research" followed by "No mandate to conduct such research" (Figure 27). When asked which species or groupings of animals may be affected, however, the collective agency-generated list included a range of species: herpetiles (reptiles and amphibians), birds and small- to large-sized mammals (Table 17). The majority of agencies also indicated they rarely employ (77%) or consider (68%) mitigative median barrier designs (Figure 35).

3.3 Gap Analysis

Based on the results of the literature review, the verifiable effects of highway median designs on wildlife movement and/or mortality remain largely understudied and unknown. Twenty-six literature sources that specifically address this topic to some degree were found. The information contained therein ranged from documenting concern about the potential impact of median barriers on wildlife; postulating what those potential impacts are; studying some aspect of the relationship between highway medians and wildlife; or offering mitigative recommendations. See synthesized literature review in Section 3.1 and Annotated Bibliography in Appendix C.

The Median Barrier State of the Practice Survey illustrates that the effects of median barriers on wildlife are not a major concern for transportation agencies at this time. Twenty-eight agencies were represented in the survey responses. See complete state of the practice survey results in Section 3.2.

The following list of knowledge gaps is based on literature reviewed, survey results and questions that arose during the course of the study. Survey responses are in **bold**. Limitations or qualifying information are in *italics*.

Do concrete median barriers affect rates of wildlife-vehicle collisions?

<u>Support that concrete median barriers are associated with increased wildlife mortality:</u>

- Mammalian road mortality is higher in areas with concrete median barrier. *(Only one season of data)* (Ross 2004)

- Western gray squirrel population plummeted after installation of concrete median barrier. *(Exact reason unknown)* (Hostick and Styskel 2005)
- Concrete medians are barriers and increase mortality. *(Rapid assessment, anecdotal)* (Lloyd and Casey 2005)
- The distance to concrete median barriers and guardrails had a negative correlation on ungulate-vehicle collisions, being closer to barriers and guardrails than expected by chance. (Gunson et al. In prep.)
- Barriers are formidable obstacles to small- and large-animal movement across highways; can block animals when they attempt to cross the highway making them vulnerable to traffic mortality. *(Documented concern by experts, no study*) (NRC 2005)
- The presence of concrete roadside and median barriers may exacerbate the potential for WVCs because they partially conceal animals from motorist's view and animals jumping over might do so directly into the path of oncoming traffic. *(Mitigation recommendation; theoretical)* (Cooper 1999)
- **Wildlife mortality increases with concrete median barriers. (4 out of 5 survey responses)**
- **There are wildlife related issues with the use of median barriers. (4 out of 5 survey responses)**
- Wildlife conflict zones may coincide with highway sections with Jersey barriers. (*Based on literature review and professional experience*) (Ontario Ministry of Transportation 2005)

<u>Support that concrete median barriers are associated with lower relative rates of wildlife mortality:</u>

- Grassy medians had higher animal vehicle collision (AVC) rates than concrete medians; concrete medians had higher AVC rates than painted centerline. *(Modeling study)* (Meyer and Ahmed 2004)
- 70 percent of deer-vehicle crashes occurred on roads with neither guardrails nor medians, 19% with grassy medians, 6% with a concrete barrier, 3% with a guardrail, 1% with a concrete median, (1% other). *(No associated wildlife study)* (Urbitran Associates et al 2005)
- 88% of WVCs occur on undivided two-lane roads with a much smaller percentage occurring in the presence of raised median barriers. (Elzohairy et al. 2004)

<u>Support that concrete median barriers are not associated with a difference in wildlife mortality:</u>

- Dividers did not cause higher than expected deer kill. *(Not conclusive, more work needed to correlate track counts, deer population estimates and kills*) (Hostick and Styskel 2005)
- Road kill rates of small to medium sized mammals (including weasels, skunks, groundhogs, opossums and foxes) were not higher or significantly different in road sections with concrete median barriers compared to those without concrete median barriers. (Armstong 1994 in Hubbs and Boonstra 1995)

- Increased traffic or medians remove incentive for animals to cross thereby mortality decreases. *(Theoretical*) (Hubbs and Boonstra 1995)
- Deer and elk road-kills occurred less often than expected in areas with Jersey barriers in the median. *(Indicative of permeability issue*) (Singleton and Lehmkuhl 2000)
- Number of elk-vehicle collisions was not higher along roadway segments with concrete median barriers. (Woods 1990)
- Concrete median barrier may explain road mortality of bighorn sheep (*Other factors also involved*). (Woods 1990)
- The number of Jersey barriers along roadways was not a factor in explaining road-kill occurrence of small- and medium-sized vertebrates (birds, mammals, amphibians). (Clevenger et al. 2003)

<u>Support that median barriers may increase risk to motorists during wildlife vehicle conflicts:</u>

- Fatal human injuries can occur not only when a motorist strikes a deer, but also when the motorist swerves to avoid the animal and strikes another vehicle or a fixed object instead. (Urbitran Associates et al. 2005)
- Road kills occurred closer to Jersey barriers and guardrails. (Gunson et al. In prep.)

What are the limitations in wildlife vehicle collision data collection methodology?

- There is no way of correlating Washington State DOT AVC data to median barrier presence. (M. Carey, Washington State Department of Transportation, pers. comm.)
- The current method of AVC location data collection is not useful because of imprecise scale (nearest mile marker). (Barnum 2003)
- Call for study of relationship of traffic volume and AVC rate. (Meyer and Ahmed 2004)
- Lack of systematic AVC data collection limits ability to compare data. (Ross 2004)
- Animal in the road is listed as "other" in driver-related factors in a vehicle collision study (lumped with pedestrians, bright sunlight, blackout). (Mok and Landphair 2002)

Do concrete median barriers limit or redirect wildlife movement across the road? Do they affect the ability to meet ecological needs and allow for gene flow?

<u>Support that concrete median barriers affect wildlife movement:</u>

- Dividers can produce confusion and increased milling at highway. *(Theoretical*) (Hostick and Styskel 2005)
- Wildlife crossing zones are not correlated with barriers such as Jersey barriers *(natural and human-made barriers viewed collectively*); deer, elk and coyotes avoided barriers; there is a strong relationship between crossing zones and gaps or ends of barriers; barriers can act as funnels to roadway or crossing structures. (Barnum 2003)
- A reduction in genetic diversity of desert bighorn sheep in California is linked to isolation caused by human-made barriers, including a concrete barrier. (Epps et al. 2005)

- Lack of ungulate road kill indicates certain road sections with concrete median barriers are impermeable; propose that installation of extra-tall Jersey barriers or concrete walls may help to redirect animal movement to crossing structures. (Singleton and Lehmkuhl 2000)
- Road kills occurred closer to Jersey barriers and guardrails and suggests that animals are funneled towards road crossing points by landscape features. (Gunson et al. In prep.)
- **Wildlife mobility decreases with concrete and grassy medians. (2 out of 6 survey responses)**
- Barrier effects, such as those resulting from transportation infrastructure, probably have the greatest negative ecological impact because an individual animal's dispersal ability is key to species survival. (Bekker and Iuell 2003)
- **There are wildlife related issues with the use of median barriers. (4 out of 5 survey responses)**

<u>Support that concrete median barriers do not affect wildlife movement:</u>

- Dividers did not influence preference of crossing locations; deer might not notice tiny gaps designed for passage. *(All concrete treatments included gaps and scuppers for passage and were studied in combination with guardrails*) (Hostick and Styskel 2005)
- Deer, elk and coyotes would readily jump over concrete barriers to exit roadway. (Barnum 2003)
- There is no difference if animal needs to backtrack versus cross over a median barrier; increased traffic or medians remove incentive for animals to cross. *(Theoretical)* (Armstong 1994 in Hubbs and Boonstra 1995)

Do concrete median barriers affect certain species more than others? What size, physical, and/or behavioral factors determine the response?

<u>Ungulates</u>

- Deer were not road killed more often than expected in areas with concrete barriers. (Hostick and Styskel 2005)
- Deer, elk and coyote avoid concrete barriers but can jump over. (Barnum 2003)
- **Deer avoid crossing roadways at locations of Jersey barrier. *(*survey response; *anecdotal, not studied*)**
- The distance to concrete median barriers and guardrails had a negative correlation on ungulate-vehicle collisions, being closer to barriers and guardrails than expected by chance. (Gunson et al. In prep.)

<u>Carnivores</u>

- Concrete barrier likely to adversely affect lynx (potential effects - block passage, increased stress, prolonged time in roadway, increased mortality) and wolf (prolonged time in roadway, increased mortality). *(Potential effects difficult to ascertain, theoretical; erred on side of caution*) (Basting 2003)

- High-speed highways and barriers along or between lanes can have a serious impact on grizzly bear survival. (Servheen et al. 1998)
- Carnivores were detected, and one coyote crossed a median barrier where ungulates were notably absent. (Singleton and Lehmkuhl 2000)

Medium-sized mammals

- Beaver, nutria, raccoon are frequently killed in collisions with motor vehicles at hot spot with Jersey barrier. *(Anecdotal; not studied*) (Lloyd and Casey 2005)
- The number of Jersey barriers along roadways was not a factor in explaining road-kill occurrence of medium-sized mammals. (Clevenger et al. 2003)

Small-sized mammals

- Western gray squirrel population plummeted with concrete barrier installation. (Hostick and Styskel 2005)
- Small mammals do not cross roads as part of their standard daily activities, irrespective of the width of the road or the traffic volume; biggest deterrent to movement across the road is probably not traffic but other factors, such as, lack of cover or the road surface itself. (Underhill 2002*)*
- For furbearers, rodents and lagomorphs, concrete median and roadside barriers impede movements across the highway. *(No study)* (Cooper 1999)
- **Small mammal movement is restricted by Jersey barriers; increased mortality at these locations. *(*survey response*; anecdotal, not studied*)**
- The number of Jersey barriers along roadways was not a factor in explaining road-kill occurrence of small- sized mammals. (Clevenger et al. 2003)

Birds

- Birds are frequently killed in collisions with motor vehicles at hot spot with Jersey barrier. *(Anecdotal; not studied*) (Lloyd and Casey 2005)
- The number of Jersey barriers along roadways was not a factor in explaining road-kill occurrence of birds. (Clevenger et al. 2003)

Herpetiles

- For amphibians and reptiles, concrete median and roadside barriers impede movements across the highway. *(No study)* (Cooper 1999)
- **Herpetile movement is restricted by Jersey barrier; increased mortality at these locations. *(*survey response*; anecdotal, not studied*)**
- Solid concrete roadside barriers repel desert tortoises, causing them to walk parallel for several minutes then stop or walk away from the highway. (Ruby et al. 1994)
- The number of Jersey barriers along roadways was not a factor in explaining road-kill occurrence of amphibians. (Clevenger et al. 2003)

Do scuppers and spacing minimize the impact of concrete median barriers? What designs are most effective?

- There is no information about the effectiveness of modified barriers. (NRC 2005)
- **There is a need for more information about the effectiveness of Jersey barrier 'openings' on highway permeability for small mammals and herptiles. (survey response)**
- For smaller wildlife (e.g., furbearers, rodents, amphibians, reptiles, lagomorphs), scuppers large enough to facilitate passage should be incorporated into the design of the barrier. Scuppers, with cutouts along the bottom of 25 cm high and 100 cm wide would be appropriate; scuppers should account for at least 20% of the barriers or 1 every 5th barrier. (Cooper 1999)
- Oregon DOT installed 32 in. tall concrete median barriers with an arched cutout (6 in. [15 cm] diameter) in the bottom center of each 11.5 foot [3.5 m] block allowing for small animal passage as drainage of surface water and every 100 or 500 feet [30 – 152 m], inserted 20 in. gaps for animal movement. (Hostick and Styskel 2005)

Do transportation agencies recognize/mitigate the potential impacts of concrete median barriers on wildlife?

- **76% of agencies have not studied median barriers and wildlife.**
- **1 out of 21 agencies said such research is being considered/planned for future.**
- **In response to “Please rank your agency’s reasons for not studying the effects of median barriers on wildlife movement and/or mortality,” the top three ranking answers out of five were:**

    1. **No perceived need to conduct such research.**
    2. **No mandate to conduct such research (no species which are endangered, threatened or of special concern).**
    3. **No specialized personnel to conduct the study.**

    (*Other choices were time and money*)

- **In response to “How frequently does your agency/state/province consider mitigative design solutions to median barrier impacts on wildlife movement and/or mortality? (e.g. spacing of barriers, scuppers, passages),” 10 of 22 agencies responded rarely or never.**
- **In response to “How frequently does your agency/state/province employ mitigative design solutions to median barrier impacts on wildlife movement and/or mortality? (e.g. spacing of barriers, scuppers, passages),” 12 of 22 agencies responded rarely or never.**
- **Biologists tend not to have information about median barrier use, history and designs. (survey responses and email correspondence agency personnel who were invited but did not participate in the survey)**

Do cable barriers have less of an effect on wildlife movement and mortality? Are they more, less or equally effective as modified concrete medians? Can cable barriers be a countermeasure for improving motorist safety while mitigating impacts to wildlife?

- Cable barriers save lives, are cost effective and are ready for deployment; NCDOT is the lead in this technology. (Stasburg and Crawley 2005, Hunter et al 2001, Miaou et al . 2004, Monsere 2003, Taylor (FHWA) 2005, Zeitz (FHWA) 2003)
- **Trend is toward cable barriers. (survey responses)**
- **Deer avoid crossing roadways at locations of 3-strand cable. (survey response, *anecdotal, not studied*)**
- **Cable median barriers used primarily because of wildlife considerations but also because of safety and cost factors. (*Based on common sense approach*) (V. Izzo pers. comm.)**

Are there situations where centerline rumble strips can improve motorist safety while minimizing impacts to wildlife?

- Centerline rumble strips are effective in reducing fatal cross over crashes. (Agent et al. 2001, Delaware DOT 2003, Outcalt 2001, Persaud et al. 2004)
- For highways with low traffic volume, where AVCs are not a significant safety hazard to animals or motorists, the most cost- and biologically-effective strategy for reducing wildlife/highway conflicts is simply to encourage animals to cross freely at-grade. (Barnum 2003)
- In linkage zones, “Minimize the use of barriers such as concrete medians that can block crossing by wildlife and increase mortality risk for those animals that do venture onto the highway.” (Servheen et al. 2003)

Do wider or grassy medians have less of an effect on wildlife movement and mortality?

- A grassy median may enhance an animal’s ability to cross a roadway. *(Anecdotal)* (Lloyd and Casey 2005)
- Might be better to have a wider median (even with more habitat loss) than a median barrier. (NRC 2005)
- Elk-vehicle collisions were not significantly related to grassy medians. (Woods 1990)
- Highway-widening did not appear to act as a barrier to dispersing wolves but whether the mitigation effort of a ballooned median of natural cover actually facilitated crossings of the highway is unknown. (Kohn et al. 2000)
- Bobcat mortality was more frequent in road sections with thornshrub in the median (Cain et al. 2003).
- Medians vegetated with a fruit-bearing shrub have been linked to 95% of bird vehicular mortality in one study. (Watts 2005)
- Birds were 85% more likely to be killed on roads with vegetated medians than on roads without medians. (Clevenger et al. 2003)

What guidelines and tools are needed for agencies to make informed choices about median barrier installation to reduce impacts to wildlife?

- There are no guidelines for spacing of scuppers for different species or placement of modified median barriers. (NRC 2005)
- Evaluation tools need to be developed for engineers and ecologists to plan and construct infrastructure and prevent or mitigate environmental impacts. (Seiler 2001)
- **Agencies lack good direction of where and how to employ median barriers. (survey response)**
- No practical strategy currently exists for facilitating the incorporation of wildlife mitigation into highway design and permitting decisions. (Jackson and Griffin 2000)
- Systematic approach is needed to identify high risk segments of highway. (Meyer and Ahmed 2004)

What further research is needed?

- What are the effects of different median barrier types on wildlife movement and mortality?
- What mitigative designs are most effective in reducing median barrier impacts?
- What median barrier types best serve the needs of motorists and wildlife?
- Further research in context sensitive design is needed in addressing fatal crashes. (Mok and Landphair 2002)
- **The relationship between whitetail deer-vehicle collisions and presence of Jersey barrier, 3-strand cable, box beam and w-beam guide rail median barriers requires study. (survey response)**
- For certain median barrier types, height over a certain range can have an increase in adverse vehicle trajectories. (Hiss and Bryden 1992 in Ray et al. 2003)
- Is there a difference between with/without versus before/after studies? Do animals learn to avoid areas with median barriers over time?

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The end product of this contract was to provide a collective synthesis of the available literature and institutional information (using real and anecdotal data, field experience, professional intuition) through literature searches and an agency survey to gain a better understanding of the impact of median barriers on wildlife. In doing so, historical and current use of highway median barriers by transportation agencies in North America were summarized along with knowledge of how these structures may fragment wildlife habitat or increase the risk of traffic-related mortality. There is increasing concern among transportation agencies about how median barriers may affect animal movement and mortality on highways. The need to know how median barriers affect wildlife is particularly acute when their presence or planned installation may affect threatened or endangered species (Basting 2003). The lack of information to properly assess environmental impacts can cause significant project delays and increase transportation project costs. Median barrier projects in California were recently delayed six months due to wildlife crossing concerns in Morro Bay and San Juan Bautista (D. Hacker, Caltrans, San Luis Obispo, pers. comm.).

This study represents the first attempt ever in North America to bring together information about highway median barriers and wildlife. Through exhaustive bibliographic and internet-related searches, no similar effort or synthesis of information among transportation agencies at any geographic scale elsewhere outside of North America was discovered. The survey and gap analysis did prove that there is an enormous amount of information about different median barrier designs, their cost-benefits, and collision reduction potential. In contrast, there is a glaring lack of information about how the ubiquitous median barriers on our roadways impact wildlife. The dearth of information is consistent throughout the taxonomic ranks, from small herpetiles to wide-ranging and fragmentation-sensitive species. There was an equally obvious knowledge gap about any real or perceived risks of vehicle collisions with wildlife as a result of median barriers on roads. This scarcity of information coincides with a general absence of field research on how different median barrier designs in varying landscapes may influence animal movements and habitat connectivity. As a result, even the most basic or cursory guidelines to help transportation agencies when working on median barrier projects do not exist. A concerted effort to research the interactions between vehicles, median barriers, and wildlife will serve to narrow the wide information gap and structure a foundation from which to begin setting agency standards and guidelines.

4.1.1 Knowledge Base

The review, survey and gap analysis highlighted what knowledge has been acquired about median barriers and wildlife, and where conspicuous information gaps lie. The <u>knowledge base</u> can be summarized in 6 points.

1. **Median barriers do have an effect on movements of a wide range of wildlife from large to small**. Although this statement has largely come from anecdotal data and unscientific means, there was agreement within the literature and among survey

respondents that barriers can result in increased wildlife mortality and decreased wildlife movements. Key information lacking about the ‘effect’, however, is outlined below in the section describing information deficiencies.

2. **Raised concrete median barriers continue to be installed on highways today**. Raised concrete median barriers (e.g., Jersey or Texas) do have the greatest impacts on wildlife movement. These impacts are intuitive (given their height, mass and extent on most highways) and also perceived (see Tables 1, 2 and 3). Their continued use (in some states/provinces increasing) should be of concern in areas where they bisect areas of ecological importance and wildlife populations of biological value.
3. **There is an increasing use of cable barriers and rumble-strips**. The survey results demonstrated that these alternative, more wildlife-friendly forms of median barriers are gaining popularity among transportation agencies. The survey data and literature concur that these techniques are proven measures to increase motorist safety, are less costly than other median barrier applications, and intuitively allow greater wildlife movement compared to raised median barriers. These are all benefits for wildlife. However, a more reliable assessment of the efficacy of cables and rumble-strips to increase motorist safety while maintaining habitat connectivity will come from research designed to address those transportation needs.
4. **Mitigative design solutions for median barriers are rarely used by transportation agencies**. The survey results shown in Figure 35 clearly bear out the current practice by transportation agencies employing mitigative solutions for median barriers that address wildlife and habitat connectivity concerns. In extremely rare cases do agencies ‘employ’ mitigative designs and only occasionally do they even ‘consider’ them. Lacking a clear mandate to address wildlife and habitat connectivity concerns (other than when threatened and endangered species are potentially affected) and guidelines of any sort to aid in decision-making undoubtedly helps explain why there is little agency experience mitigating the impacts of median barriers.
5. **There is a need for more study**. The literature review, survey and gap analysis demonstrate the urgent need for study, as respondents in particular had conflicting opinions of cost-benefits, impacts to wildlife, and performance of mitigative design solutions.
6. **The survey sample size was not large**. Therefore, the results may not provide adequate representation of agency practices, concerns, and knowledge. For example, there was no survey input from Caltrans which is an agency obviously concerned with median barrier effects on wildlife.

4.1.2 Information Deficiencies

This report highlights the unknowns and uncertainties with regard to median barriers and wildlife. These deficiencies can be summarized in 3 main points having to do with data needs that can only be obtained from rigorous research aimed at clarifying the current knowledge gaps.

1. **What traditional median barrier types are most effective in allowing for animal movement and reduced traffic mortalities?** A common thread throughout the report was the consistent lack of quality information (from field experiments, empirical research data, observational data, etc.) about the effect of median barriers on wildlife. This suggests an urgent need for study, as respondents in particular had conflicting opinions of cost-benefits, impacts to wildlife, and performance of mitigative design solutions. Key information lacking is (1) the determination of exactly how wildlife are impacted by traditional median barrier designs (mortality versus barrier effects and connectivity; individuals and/or population-level effects; demographic and genetic consequences; long-term population persistence), and (2) how different median barrier designs affect movement and mortality of a wide range of California fauna within the varied state ecoregions ranging from the Klamath-North Coast to Mojave.
2. **What mitigative median barrier designs are most effective in allowing animal movement?** Similar to traditional median barriers, there is scant information about the performance of median barriers currently being developed to provide greater cross-highway movement and connectivity for wildlife. The reason lies in that presently there are few instances where mitigative designs have been employed by transportation agencies, and where they have been used, rarely is rigorous monitoring and performance assessments part of the project. The key information lacking above can be said for mitigative median barrier designs.
3. **Guidelines for installation of median barriers on roadways.** How to determine where, when and what type of median barrier to use on transportation projects will require information that can feed into a multi-criteria decision-support framework. The cost of different median barrier types (construction and installation; long-term maintenance) in relation to the expected benefits from reduced accidents (with and without wildlife), streamlined projects, habitat and species conservation gains, are all factors that need to be taken into consideration. Research that investigates the interactions between vehicles, median barriers, and wildlife is long overdue and will help develop a more reliable knowledge base from which to begin drafting agency guidelines. The following section provides a framework for researching the impact of median barriers on wildlife movement and mortality.

4.2 Research Recommendations

4.2.1 Building Scientific Support

During the last 30 years a substantial amount of time and energy has been spent devising strategies that meet the dual needs of allowing animals to cross roads with reduced hazard to wildlife and motorists (Spellerberg 2002, Forman et al. 2003). A growing number of studies are assessing the efficacy of these measures (Woods 1990, Foster and Humphrey 1995, Romin and Bissonette 1996, Jackson and Griffin 2000, McGuire and Morrall 2000). These studies currently provide a basis for emerging concepts and principles regarding multiple scale, wildlife and habitat connectivity for landscapes fragmented by transportation infrastructure (Evink 2002, Forman et al. 2003, Bekker and Iuell 2003).

Like any developing or nascent area of applied science, initial concepts arrive from theoretical investigations (e.g., island biogeography or habitat fragmentation theory; see

MacArthur and Wilson 1967); the strength and validity of these concepts are tested and compared with results from empirical research that help to incrementally refine the concepts and form basic principles. These concepts and principles are generally the basis from which managers and practitioners evaluate their objectives and goals, and ultimately make their decisions regarding a specific project or management scheme.

Some ecological effects of roads consist of reduced landscape connectivity and impeded animal movements, which may result in higher mortality, lower reproduction and ultimately smaller populations and lower population viability (NRC 2005). These deleterious effects have underscored the need to maintain and restore essential movements of species of special concern, e.g., game, threatened or endangered, or focal species (see Hubbs and Boonstra 1995; Bennett 1999).

4.2.2 Biological Functions and Median Barriers

Median barriers that effectively function to maintain wildlife movements across highways and population connectivity should allow for the following: (1) reduced mortality and increased movement within populations and genetic interchange; (2) fulfillment of biological requirements (food, cover and mates); (3) dispersal from maternal ranges and recolonization after long absences; (4) redistribution of populations in response to environmental changes and natural disasters; and (5) long term maintenance of metapopulations, community stability, and ecosystem processes. Note the sliding scale criteria from (1) to (5), that increases in complexity, in addition to the monitoring costs and time needed to properly assess performance. Not all of these functions may be considered management criteria for transportation and natural resource agencies for a given project, particularly the functions at the more complex end of the scale. Nonetheless, the above functions encompass four levels of biological organization, e.g., *genes, species-population, community-ecosystem, landscape* (see Noss 1990) which form the basis for developing natural resource management and conservation schemes.

4.2.3 Guidelines for Monitoring and Assessment

The recurring theme throughout the report is the concerned need for research, even basic exploratory research, to begin investigating the relationships between median barriers and wildlife populations. Measuring the conservation value of different median barrier designs is a complex and time-consuming task. Nonetheless, it is important to have clear goals and objectives for proper assessment. Up until now, there have been few monitoring efforts and of those, few were designed to test specific hypotheses (Forman et al. 2003). Hypothesis testing will aid in better understanding whether median barrier designs enhance or diminish the population viability of species.

We suggest using a hierarchical approach to provide guidelines and decision support regarding the selection, configuration, location, monitoring, evaluation, and maintenance of median barriers on highways. Roads and traffic affect wildlife at multiple levels of biological organization (e.g. genes, population, ecosystem, landscape), and different questions or problems require different types of research or sets of mitigation measures. Before anything else it is important to formulate the question or define the problem carefully. Certain questions can be "big" or general and may require answers from several scales and perspectives. Big picture research is not necessarily general in nature. General principles have to be well founded, and they are often based on intensive studies of the life histories of wildlife species in local environments. Another value of the hierarchy concept is the recognition that effects of environmental stresses from roads and traffic can reverberate through other levels, often in unpredictable ways, as secondary and cumulative effects.

We provide an example of how a monitoring and assessment project might be implemented using the following 7 steps. These guidelines can be used to design monitoring schemes to evaluate the conservation value and efficacy of median barriers in reducing wildlife mortality, restoring animal movement and maintaining their populations over the long term. A framework that can be used to formulate research questions, select methodologies, and design studies to measure performance of median barriers in mitigating road impacts is shown in Table 22.

1. <u>Establish goals and objectives</u>. What are the mitigation goals? With regard to wildlife, generally the goals are to reduce wildlife-vehicle collisions and/or reduce barrier effects to movement and maintain genetic interchange (Evink 2002). With regard to motorist safety, the goal is usually to improve road safety by reducing the number of injury-related accidents (Persaud et al. 2004, Taylor 2005). The proposed framework is prepared with the aim of reducing wildlife impacts, thus the aspects of measuring traffic safety and benefit-costs will not be addressed in Table 22, however, it can be applied to the same traffic-related research questions.

2. <u>Establish baseline conditions</u>. To develop a mitigation scheme it will be important to determine the extent, distribution and intensity of road and traffic impacts to wildlife in the area of concern. The impacts of installing median barriers may consist of mortality, habitat fragmentation (reduced movements) or some combination thereof. In most cases, the conditions occurring pre-installation will comprise the baseline or control.

3. <u>Identify specific questions to be answered by monitoring</u>. These questions will be formulated from the goals and objectives identified in Step 1 and conditions identified in Step 2. Some questions might include: Is road-related mortality increasing or decreasing as a result of the median barriers? Is animal movement across the road increasing or decreasing? Are animals able to disperse and are populations able to carry out migratory movements? Are populations residing in the transportation corridor stable and reproducing? Before implementing a monitoring program it will help if transportation and land managers can agree on specific benchmarks and thresholds at which management actions may or may not intervene. For example, ≥50% reduction in road-kill would be acceptable, but <50% reduction would initiate additional management actions to improve mitigation performance, e.g., highway-related (reinforcing fencing, installing below-grade passage structures) or driver-related actions (reducing traffic speed, installing animal detection systems and variable message signage, increasing motorist awareness).

4. <u>Select indicators</u>. Identify indicators at the appropriate levels of biological organization that correspond to goals and objectives identified in Step 1 and questions in Step 3. For example: *Genetic*, gene flow and genetic structure; *Population-species*, population distribution and abundance, demographic processes

such as dispersal, survivorship, mortality; *Community-ecosystem*, herbivory and predation rates.

5. Identify control and treatment areas. If pre-installation data are not available, then adjacent 'control' areas may be used to compare indicators with treatments (i.e., road sections with median barriers). It will be important to control for differences in habitat type and population abundance between treatment and control areas. Therefore similar habitats should be used and some means of obtaining population abundance indices (e.g., transects).
6. Design and implement a monitoring plan. Apply principles of experimental design, select sites for monitoring the identified goals and objectives from Step 1 and questions in Step 3. Although treatments and controls should be replicated, that may not always be possible.
7. Validate relationships between indicators and benchmarks. Detailed research carried out over the long-term will be needed to determine how well the selected indicators or success criteria correspond to the mitigation goals and objectives.

4.2.4 A Framework for Designing Research

The first and foremost information need related to median barrier projects is how they impact wildlife in terms of increased mortality and reduced movements or connectivity. Several research avenues can be developed from that initial research question.

A second level of inquiry would ask what is being impacted – *individuals or populations*? This addresses the level of biological organization at which the median barrier impacts may be occurring. Because most transportation and natural resource agencies work within the first two levels of biological organization (*genes-individuals* and *species-populations*) those will be the focus here. Within the second level of inquiry it will be critical to know what are the specific impacts of median barriers – (1) mortality and barrier effects to (a) individuals and (b) populations; (2) how that affects demographics and the genetic consequences to the population.

The third level of research will ask how all of the above affects the long-term persistence of the focal population(s)?

All of the above are found within the framework provided in Table 22. The management question(s) that needs to be answered by empirical research generally concerns the effect of median barriers on road mortality and barrier effects, and how these two impacts influence population viability over the long term.

Table 22. A suggested framework for designing studies to measure performance of median barriers in mitigating road impacts. Numbers relate to one another across columns.

Wildlife Impacts	Research question	Methods	Study Design	Success criteria
Mortality	1. How do median barriers influence mortality rates (increase, no effect, decrease)? 1a. Compared to baseline levels of road mortality 1b. Compared to adjacent 'control' areas post-installation 2. Compared to other sections of highway without median barriers 3. What is the incidence of mortality among a marked sample?	Road-kill data collection: 1 & 2. Road-kill surveys on highway sections with and without median barriers. Surveys must be extensive in length (see Hubbs & Boonstra 1995) and systematically conducted at frequent intervals (e.g., daily) Mark-recapture: 3. Standard capture-mark-recapture techniques. Marking may consist of physical tags Radiotelemetry: 3. Standard capture-mark-release techniques. Transmitters may consist of VHF transmitters or global positioning system (GPS) transmitters; the latter providing more spatial accuracy in identifying how and where animals cross highways.	Road-kill data collection: 1a. Pre- vs post-installation comparison of mortality rates on 'treatment' areas (barriers) with 'controls' (BACI design) 1a. Pre- vs post- installation comparison of mortality rates on 'treatment' areas (barriers) without 'controls' 1b. Post-installation comparison of mortality rates using 'treatment' (barriers) section vs adjacent section without barriers 2a. Multivariate logistic regression analysis 2b. Comparison of mortality rates on section with and without median barriers, standardized by highway length Mark-recapture: 3. Proportion of marked sample killed on highway Radiotelemetry: 3. Proportion of marked sample killed on highway	1 & 2. Mortality rates are reduced compared to baseline conditions (i.e., without median barriers). Reductions should either be significant statistically or biologically. 3. Significant (statistical or biological) proportion of the marked sample survives and reproduces in highway environment with median barriers
Barrier effects (connectivity)	1. What is the frequency of movement across highway with median barriers and without? 2. What are factors that influence crossing activity? 3. Do animals cross above-grade vs below-grade? 4. What are the locations where animals cross	Mark-recapture: See above Radiotelemetry: See above Observational data: 1, 2, 3 & 4a. Cameras that detect and record animal activity in highway environment over 24-hr period. Infrared digital 35mm or videocameras installed on	Mark-recapture: 1. Frequency of marked animal movements across highway sections (treatment, control) 3. Monitor below-grade passage structures Radiotelemetry: 1. Frequency of radio-marked animal movements across highway sections (treatment, control)	1. Significant (statistically or biologically) greater number of marked individual movements occur on treatment sections (median barriers) 2. Traffic volume, intra-group behavior and time of day may help explain movement behavior and crossing success 3 & 4. Significant (statistically or biologically) greater number of individual movements of

Wildlife Impacts	Research question	Methods	Study Design	Success criteria
		preferably straight and level sections of highway. Some videocameras detect and record animal activity on sections up to 1 Km in length 1 & 4b. Sand traps on right-of-way 3 & 4c. Flourescent dye marking. Method allows for follow-up 'tracking' of small animal using UV light at night	2. Frequency of radio-marked animal movements across highway related to traffic volumes and time of day 3 & 4. Radiomonitor closely movements in highway environment and below-grade passage structures <u>Observational data:</u> 1. Frequency of observed movements across vs attempts to cross highway sections (treatment, control)	radiomarked individuals occur on treatment sections (median barriers) <u>Observational data:</u> 1. Significant (statistically or biologically) greater number of observed individuals movements occur on treatment sections (median barriers) compared to control sections
Population viability	5. Do median barriers increase the risk of population extinction (local) over the short and long term?	<u>Spatially-explicit population viability modeling:</u> 5. User-developed or commercially available software. Good data on species demographic parameters and habitat suitability indices should be used in the model	<u>Spatially-explicit population viability modeling</u>: 5. Modeling of population viability under a. baseline conditions, b. highway without median barriers, c. highway with median barriers	5. Models forecast viable populations over the short- and long-term (as defined a priori by management and/or stakeholders)

4.2.5 Mortality

There are several ways to test whether median barriers have an effect on animal mortality. These generally depend upon whether data can be collected prior to installation (to obtain baseline information from a 'control') to compare to mortality levels after installation, or data collection occurs only post-installation. Regardless of the approach, it is important to be able to make comparisons between a 'treatment' (highway section with median barriers) and 'control' (section without median barriers). The type of habitat found in the treatment and control areas must be controlled for, i.e. sites must be as similar as possible to minimize confounding effects of different habitat conditions, which can result in incomparable population distributions and abundances. The analysis with the most statistical power is the Before-After-Control-Impact (BACI) design, where prior to installation a treatment and control area are studied and then compared to data obtained from a treatment and control after installation. Slightly less powerful analyses would be a (1) post-installation comparison of a treatment and control area (adjacent sections of highway) or (2) pre- vs post-installation treatment comparison without a control area.

Data can be obtained several ways; however, the most promising method for evaluating mortality impacts would be using road-kill data collected systematically over a relatively long stretch of highway with treatment and control areas (see Hubbs and Boonstra 1995). Mark-recapture and radiotelemetry techniques do not provide adequate information on mortality occurrence on treatment and control areas. Success criteria can be devised several ways and adapted to the specific landscape, focal species and management question needing answers. In essence mortality rates should decrease. 'How much' should be determined a priori by agency stakeholders. What is statistically significant may not be biologically significant. For example, statistically significant declines in a common and abundant species may be of little biological or conservation significance due to the large size and status of the population. However, the decline in road mortality within a small population, although not statistically significant, may be of great biological importance in maintaining a healthy population.

4.2.6 Barrier Effects

Like evaluating mortality impacts of median barriers, information on how barriers affect movements and population connectivity can be obtained several ways. Again pre- vs post-installation comparisons using a treatment and control (BACI) design are the most compelling and rigorous statistically. The types of analyses and study designs to address potential barrier effects are much the same as that described for the mortality analyses above. Those include a post-installation comparison of a treatment and control area (adjacent sections of highway) or conducting a pre- versus post-installation treatment comparison without a control area.

Unlike quantifying road mortality, this research question asks if animals are able to cross the highway, and if so, then where, how, and with what frequency. To obtain reliable data to answer those questions requires close monitoring of animal movements in the highway environment. Close monitoring of animal movements and activities historically has been difficult for field researchers due to the lack of adequate technologies, and the inherent difficulties of following wildlife at a distance when one can observe activity without influencing it. For the most part, global positioning system (GPS) collars have allowed researchers to closely track animal movements remotely, particularly large-bodied mammals that can carry large transmitters. Recent improvements in GPS technology now allow transmitters to be attached to small- and medium-sized mammals, record movements at relatively frequent intervals, during anywhere from a month to nearly a full year. Because highways are narrow linear features within an animal's home range, crossing a highway may literally happen in seconds; much faster than GPS collars can fix a location. Therefore, GPS transmitters, like the traditional VHF radiotransmitters, can provide information whether the marked individual crossed the highway, but not likely where or how the crossing took place. A highway lined with mitigated (passages or basal openings) Jersey barriers, below-grade drainage culverts and stream crossings, can offer wildlife many ways to safely cross above or under the road. Monitoring of the below-grade passages will be necessary to identify actual routes of animal travel and utility of median barriers.

Mark-recapture is the least promising of techniques, given the fact that animals need to be recaptured to provide data on crossings. The lack of recaptures does not indicate road mortality has occurred. Radiotelemetry (GPS or VHF) is a valid technique but animal movements must be closely monitored along with any alternative means to cross under or over the highway. Cameras can be effective means of collecting critical information on crossing rates and behaviors, in association with other environmental variables (traffic volume, time of day, intra-group behaviors, weather, etc). However, their disadvantages are cost (some are relatively expensive), range of data collection (100 m or up to 1000 m for some infrared videocameras), and types of terrain they work effectively (straight and level roads). Other techniques such as sand traps and fluorescent marking of animals can be promising for study of some specific taxa, but have their own set of challenges to work properly.

4.2.7 Population Viability

Once field research has been conducted on the impacts of median barriers on animal mortality and movement (population connectivity), the empirical information can be used to forecast the long-term persistence of a given wildlife population. Ultimately this will be important for managers dealing with species of concern that may be affected by a median barrier project. How median barriers influence the risk of local population extinctions over the short and long term is critical information for management and complying with regulatory agency issues, concerns, and potential solutions for mitigating impacts on Threatened and Endangered species.

4.2.8 Conclusions

Field research designed to investigate how different median barrier designs in varying landscapes may influence animal movements and habitat connectivity will be a challenging task. There is an unambiguous information gap with regard to median barriers on our roadways and how they impact wildlife populations. Developing a solid knowledge foundation that will enable sound decision-making regarding median barrier designs and placement on highways will require time and a concerted investment by transportation agencies. Research will need to address different taxa and different median barrier designs (mitigated and traditional) in a variety of landscapes to ascertain performance and cost-benefits.

The review of available methodologies provides some guidelines for designing future research. Costs can range from the more expensive approaches using remote camera systems or GPS transmitters on wildlife to relatively less expensive means relying on road-kill data collection. Each methodology has advantages and disadvantages, and ultimately what methodology is most suitable will need to be customized by transportation agencies to the specific transportation project and research question(s).

The research framework reviewed above suggests that in most instances a combination of methods will be the most promising for acquiring sound field data to test median barrier effects and performance. A comprehensive review by Hubbs and Boonstra (1995) came to the same conclusion. Their report specifically addresses different study designs to assess the effects of highway median barriers on wildlife and is a valuable reference for planning a field study.

Lastly, there will need to be agency support for research addressing median barrier impacts to wildlife. This may result from previous experiences with project delays and cost increases due to a lack of information or come from within an agency organically by taking a more proactive approach to project development. From the agency survey it was clearly identifiable that the information needs are not geographically-specific but widespread in North America. Given the prevalent need for information to guide project design and planning cooperative funding mechanisms that share the burden of costs will be more attractive and provide greater cost-benefits than single-agency research. The Transportation Pooled Fund Program allows federal, state, and local agencies and other organizations to combine resources to support transportation research studies. Collaborative research of this type has the distinct benefit of allowing for multiple studies of varied taxa in differing landscapes across North America. The value of replicating studies in multiple study sites is huge and will provide for more rigorous research results that will ultimately help guide transportation projects locally and elsewhere in North America.

5. IMPLEMENTATION

The effects of median barriers on wildlife are understudied and not clearly understood. Popular and scientific opinion is that median barriers (1) do have a potential impact on wildlife movement across roadways and (2) can influence traffic mortality. Therefore when raised median barriers are used on highways that bisect wildlife habitat some form of mitigation is necessary.

The primary implementation recommendation is to conduct a rigorous field study to test the effects of different median barrier types and associated mitigative strategies on a variety of taxa. Before any specific and conclusive implementation standards can be recommended, further field-based research is required (see Research Recommendations Section 4.). In the interim, however, some designs and practices may hold promise and help transportation agencies meet the needs of motorist safety and wildlife movements.

- Mitigative designs for raised median barriers should be used where barriers bisect natural or semi-natural areas that harbor populations of wildlife ranging from small fauna to large mammals.
- In areas where raised median barriers are warranted, funnel animals toward wildlife underpasses, engineered or non-engineered (e.g., the latter being bridge spans over creeks and rivers).
- In areas where continuous concrete designs are warranted, provide scuppers (basal cutouts) at intervals that correspond to the movement requirements of focal taxa or the least mobile species in area, thus meeting the passage and connectivity needs of small- to large-sized taxa (Section 3.1.4)
- In areas where concrete, metal or cable barriers are options, opt for the more permeable metal or cable designs for the benefit of primarily small- to mid-sized taxa, and secondarily large wildlife species.
- In areas where centerline rumble strips are an option on undivided two-lane roads, consider their use to improve motorist attentiveness, reduce risk of WVCs, and increase permeability of roads to wildlife movements.
- In areas with vegetated medians, minimize shrubbery that have been shown to attract wildlife and increase vehicle-caused mortality.

APPENDICES

A. Median Barrier Characteristics

Three main classes of median barrier types (concrete, metal beam and cable) in addition to centerline rumble strips and vegetated medians are described below. Dimensional and permeability characteristics provide the basis for the motorist- and wildlife-related summaries that follow. Information included is drawn from Ray and McGinnis (1997) and Sections 2.1 and 3.1 of this report. Matrices of permeability potential and mortality risks for each of these median barrier types and associated mitigative designs on a broad spectrum of taxa are included in Section 3.1.4.

Concrete

Description

Solid, heavy concrete panels, e.g., New Jersey shape, F-shape, Texas constant-slope and Ontario tall-wall.

Dimensions

Height: ranges from standard 32 in. [81 cm] to as tall as 59 in. [150 cm]

Length: may align end to end continuously for miles or may have gaps at intervals

Width at top: < 8 in. [~20 cm]

Permeability: generally solid for entire height but may have scuppers or cutouts at base for animal access and drainage (6 to 39 in. [15 -100 cm]; may have gaps or spacings for large animal access

Figure 37: Solid continuous concrete barrier. Photo by A. P. Clevenger.

Figure 38: Solid concrete barriers often stretch continuously for miles. Photo by A.P. Clevenger.

Motorist-related

A relatively small percentage of WVCs occur in roads with concrete barriers.

If an animal is in road, the chance for collision may be higher than with other more permeable median barrier types.

If a barrier collision occurs in an effort to avoid animal, there is a higher risk of redirection at high speed into traveled way.

Wildlife-related

Some species avoid roads with concrete barriers which may reduce potential for WVCs but cause populations to become isolated.

Some larger species can readily jump over concrete barriers, others may be thwarted if no spacings or scuppers/cutouts exist.

There is documented concern that concrete barriers increase wildlife mortality but more study is needed.

While gaps may allow animals to pass, these sites may become wildlife-vehicle collision hotspots.

Figure 39: Solid concrete barrier with white-tailed deer carcass. Photo by A. P. Clevenger.

Figure 40: Concrete barriers with scuppers for small to mid-sized animal passage. Photo by A. P. Clevenger.

Other considerations

Relatively expensive to install compared to other designs.

Figure 41: Metal beam barrier and guardrail. Photo by A. P. Clevenger.

Metal beam

Description

Post and beam designs, including weak and strong posts and W-, box, or thrie shaped beams; sometimes called guardrails whether in the median or roadside

Dimensions

Height: range from 27 to 34 in. [68.5 – 86.4 cm] depending on design

Length: may run continuously for miles

Width: if doubled, some designs may be as wide as 1 foot [~30 cm] or more

Permeability: solid beams connect with posts at regularly-spaced intervals; ~12-18 in [30 – 46 cm] gaps exist between the ground and lower edge of beam making this barrier semi-permeable

Motorist-related

A relatively small percentage of WVCs occur in roads with raised median barriers and guardrails.

If a barrier collision occurs in an effort to avoid animal, there is a higher risk of lateral deflection or penetration of the barrier.

Wildlife-related

Some species avoid roads with guardrails which may reduce potential for WVCs but cause populations to become isolated.

Most species can probably crawl under or jump over this semi-permeable design although less agile species that cannot crawl under may have trouble climbing over doubled beam designs.

Figure 42: Doubled metal beam median barrier and guardrail. Photo by A.P. Clevenger.

Cable

Description

Wire rope design consisting of three or four strands attached to posts; proprietary designs include Safence ™ and Brifen; also called cable guard.

Dimensions

Height: posts are approximately 4 feet tall [123 cm];wire ropes are stretched horizontally slightly below post height

Length: may run continuously for miles

Width: neglible

Permeability: post spacings are generally no less than 6.5 feet [2 m]; the lowest cable is set 1 to 2 feet [~3 - 6 m] above the ground making this the most permeable of the raised median barrier designs

Motorist-related

The relative rate of WVCs in the presence of cable barriers is unknown.

If a barrier collision occurs in an effort to avoid an animal, the risk of penetrating or rebounding back into traffic is greatly reduced with cable guards.

Figure 43: Cable median barrier. Photo courtesy of NCDOT.

Wildlife-related

Whether species avoid roads with cable barriers is unknown.

Streamlined designs allows wildlife to clearly see other side of the road but may also not be easily visible if the animal is moving fast.

Most species can probably crawl under or jump over this permeable design.

Other considerations

Relatively low-cost compared to other median barrier designs.

Does not act as snow fence because snow is easily plowed under cable strands.

Cable barriers are not popular among motorcyclists.

Centerline rumble strips

Figure 44: Centerline rumble strips. Photo by Minnesota Department of Transportation.

Description

Grooves cut into road surface

Dimensions

Height: not applicable

Depth: negligible

Length: may run continuously for miles, alternating between grooves and flats

Width: ~7 in [18 cm] grooves, may occur in two parallel lines

Permeability: completely permeable minus the effect of the road itself

Motorist-related

The majority of WVCs occur on roads not divided by median barriers.

The rumble effect aids motorists in staying alert which will also help reduce the possibility of a wildlife-vehicle collision.

Wildlife-related

For animals crossing at-grade, centerline rumble strips would have the same effect as an undivided roadway.

Any barrier effect from the rumble strips themselves is essentially negligible to all but the smallest of wildlife species.

Noise pollution from cars driving on rumble strips may cause wildlife to avoid the roadway.

Other considerations

Centerline rumble strips can be hazardous to motorcyclists.

Vegetated median

Description

Island median of varying width supporting grass, shrubs and trees.

Dimensions

Height: may be slightly mounded, flushed or depressed

Length: may run continuously for miles

Width: variable, generally tens of feet

Motorist-related

It is debatable whether roads divided with grassy medians are safer or less safe than barrier-divided roadways.

Roads with vegetated medians may have higher rates of WVCs than those with solid concrete Jersey barriers.

Vegetated medians are often more aesthetically pleasing than raised median barrier designs.

Wildlife-related

A wider roadway equates to more habitat loss but also more permeability because there are fewer barriers to cross.

Certain species may avoid crossing wide exposed roadcuts.

When used alone, grassy medians pose no vertical barrier to wildlife of any size or taxa.

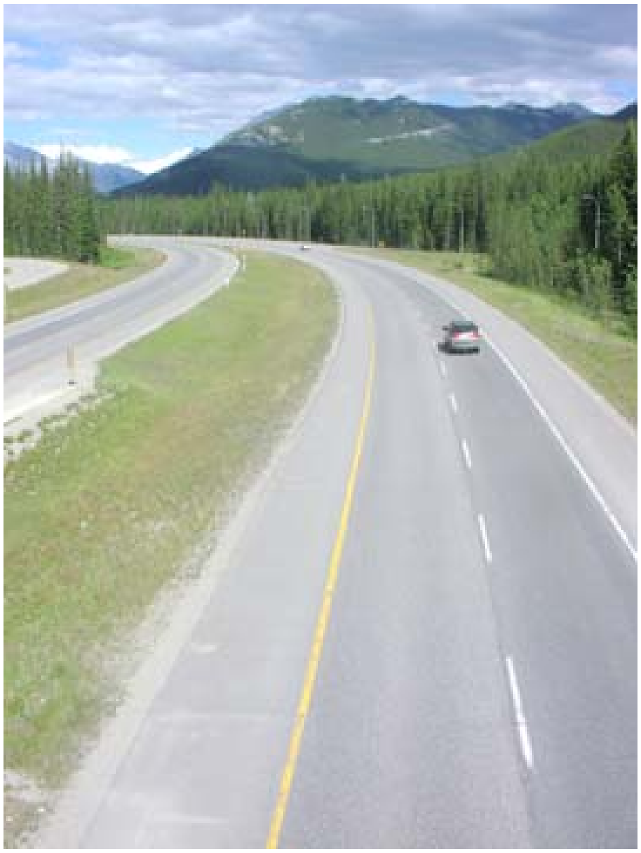

Figure 45: Grassy median. Photo by A. P. Clevenger.

Vegetated medians may serve as refugia for small animals that cross the road.

Some species (bobcats, birds) may have a higher likelihood of being road-killed in areas with vegetated medians.

B. Indexes, Databases & Websites Searched

WTI's In-house ProCite Database

Biological Abstracts

Dissertation Abstracts

Ecology Abstracts

TRIS Online

FHWA Critter Crossings

Wildlife Crossings Toolkit

Wildlife and Ecology Studies Worldwide

Applied Science & Technology Abstracts

InfoTrac OneFile (multidisciplinary index)

Academic Search Premier (multidisciplinary index)

Compendex

Web of Science

Government Publications

International Conference on Ecology and Transportation (ICOET proceedings)

FHWA Environmental Research Database

Wildlife, Fisheries and Transportation Research

Road Ecology Center at UC-Davis

Infra Eco Network Europe

Deercrash.com

Google Scholar

Google

C. Annotated Bibliography: Summary of Median Barrier Effects on Wildlife Movement and Mortality and Motorist Safety

This is an updated version of the annotated bibliography delivered for completion of Task 1.

This report identifies and briefly summarizes documents (articles, organizational reports, policies, management plans, dissertations, etc.), which were perused in the literature search for known effects of median barriers on wildlife movement and mortality and motorist safety. Documents are organized into three topic headings (some are referenced under more than one topic heading): 1. Studies of median barrier effects on wildlife, 2. Recommendations for mitigation of median barriers effects on wildlife, 3. Related ecological research, and 4. Alternatives to concrete median barriers.

A companion excerpted version of this bibliography links individual titles to source material (in PDF or html).

IMPORTANT NOTE: Few studies have been conducted to address the potential effects of median barriers on wildlife. The existing knowledge on this topic is sparse and the issue of motorist safety within the context of wildlife-vehicle collisions in the presence of median barriers appears to be even less explored. In the course of the literature search, documents pertaining to the costs and benefits of various median barrier designs were encountered. Those which show some relevance to median barrier installation decisions with regard to wildlife and correspondent motorist safety are included here.

1. Studies of Median Barrier Effects on Wildlife

1.) Barnum, S.A. 2003. Identifying the Best Locations Along Highways to Provide Safe Crossing Opportunities for Wildlife: A Handbook for Highway Planners and Designers. Report No. CDOT-DTD-UCD-2003-9 Final Report. Colorado Department of Transportation. 69 pp.

> This handbook is intended to aid highway planners and designers in new roadway, major improvement, and wildlife impact mitigation projects. The author states “both the design of a highway and its placement in the landscape should be considered when creating mitigation projects to help wildlife safely cross a highway.”
>
> Barnum discusses the distinction between conflict zones and crossing zones. Conflict zones (landscape scale) were those > 2km long highway segments that were crossed by animals most often. Crossing zones, or crossing hotspots, (local scale) were those 30-600 m segments that had the highest rates of crossing relative to the rest of the segment. Animal-vehicle collision (AVC) data can help identify conflict zones but is not useful for identifying crossing zones. This is because location data are usually only estimated to the nearest milepost.
>
> Barnum conducted a study to determine if the locations where animals cross the highway are different from random locations. The study area consisted of road segments with and without median barriers and with variations in snow cover.
>
> Variables from the roadside that were significantly correlated to crossing zone location included aspect, cover type, distance to the nearest drainage, and

distance to the forest boundary. Conversely, crossing zones were not located along portions of the road that were obstructed by barriers such as Jersey barriers, guardrails, or cliffs. Animals focused crossing activity on locations with either no barrier at all, or just a "median side barrier." However, the association of crossing zones with barrier ends appeared strong, despite some inconsistencies in the study sub-areas. Barnum's discussion of barriers is shown here in its entirety: "Deer, elk, and coyotes avoided barriers (Jersey barrier, guardrails, walls, and steep road cuts) when entering a roadway, although they readily jumped Jersey barrier and guardrail to exit. Animals commonly entered the roadway at the ends of barriers, and rarely wandered along between the barrier and the road before crossing, if the space was narrow. However, animals sometimes walked hundreds of meters along roadsides before crossing if a barrier did not confine them."

For highways with low traffic volume, where AVCs are not a significant safety hazard to animals or motorists, the author suggests, "The most cost- and biologically-effective strategy for reducing wildlife/highway conflicts is simply to encourage animals to cross freely at-grade. Limiting steep cuts and fills, Jersey barrier, guardrails, retaining walls, and the width of the road will minimize the barrier effect of the roadway. Where barriers are required, keep in mind that barrier ends can funnel animals onto the roadway. This effect may create a crossing zone in a highway segment where crossing would otherwise be diffuse. Therefore, if barriers are required, the ends should be located where there is a good line of sight to give motorists adequate time to avoid animals that enter the roadway at these locations." In those segments requiring barriers (e.g., Jersey barriers, guardrails), Barnum proposes that, in addition to meeting safety requirements, these project features may also serve a wildlife mitigation need, if extended and properly placed, by guiding animals to a crossing structure.

2.) Basting, P. 2003. Biological Assessment of the Ongoing Effects of Median Barriers relative to Canada Lynx and Gray Wolves near Lookout Pass in Mineral County, Montana. Prepared for Montana Department of Transportation. 27 pp.

This Biological Assessment, in conjunction with USFWS consultation, determines that installing a concrete median rail (Texas style, 42" height) along 14 miles of Interstate 90 "may affect and are likely to adversely affect the threatened Canada Lynx, and the threatened Gray wolf." Increased habitat fragmentation and other indirect effects "are difficult to ascertain thus caution errs on the side of the species."

Potential indirect effects of installing the concrete median rail on lynx include discouraging or blocking dispersing animals from suitable habitat on the other side of the interstate; separating females and kittens trying to cross; prolonging time spend on the roadway; and increasing stress levels. The installation of the tall median also poses an increased risk of vehicle collision for both lynx and gray wolf.

3.) Cain, A.T., V.R. Tuovila, D.G. Hewitt and M.E. Tewes. 2003. Effects of a highway and mitigation projects on bobcats in Southern Texas. Biological Conservation 114(2):189-197.

The authors studied the impacts of a 4-lane divided highway on bobcats in southern Texas. Mortalities were more frequent in road sections with thornshrub in the median. They discuss wildlife crossings and fencing and the competing nature of wildlife mitigation techniques.

4.) Clevenger, A.P., B. Chruszcz and K. Gunson 2003. Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. Biological Conservation 109:15-26.

The authors studied the spatial patterns and factors influencing road-killed vertebrates on two roadway types. Jersey barriers and vegetated medians were two of the variables considered. They found that the number of Jersey barriers along roadways was not a factor in explaining road-kill occurrence of small- and medium-sized vertebrates (birds, mammals, amphibians). They did determine that birds were 85% more likely to be killed on roads with vegetated medians than on roads without medians.

5.) Elzohairy, Y.M., C. Janusz and L. Tasca. 2004. Characteristics of Motor Vehicle-Wild Animal Collisions: An Ontario Case Study. Submitted to TRB for presentation at The TRB 83rd Annual Meeting, January 11-15, 2004. Washington D.C. 16 pp. (No electronic file, hard copy of full report available from WTI.)

This Ministry of Transportation document reports on an Ontario case study of motor vehicle -wild animal collisions.

In Ontario, 88.7% (n = 9,802) of WVCs occurred along undivided two-way roads. Approximately 6% (n = 657) of all WVCs happened on roads classified as divided and 3.3% (n = 361) occurred on divided roadways with a restraining barrier.

6.) Epps, C.W., P.J. Palsbøll, J.D. Wehausen, G.K. Roderick, R.R. Ramey and D.R. McCullough. 2005. Highways block gene flow and cause a rapid decline in genetic diversity of desert bighorn sheep. Ecology Letters 8: 1029–1038.

The researchers examined genetic variation across desert bighorn sheep populations in California to assess whether human-made barriers significantly affect dispersal and genetic diversity. Part of the study area included a concrete median barrier. Their findings link a reduction in genetic diversity to isolation caused by human-made barriers. Their analyses pointed to the conclusion that human-made barriers may greatly reduce stability of the system as a whole especially the persistence of fragmented populations.

7.) Gunson, K., A.P. Clevenger, B. Chruszcz, C. Mata and F. Caryl. In prep. Spatial error and scale influence on ungulate-vehicle collisions in a forested mountain ecosystem.

The authors aimed to assess the spatial error of reported WVC locations, identify risk factors and examine variables associated with WVCs at different landscape scales. Two of the 24 variables measured at each ungulate-vehicle collision location were Number of Jersey barrier and guardrails at the site and Distance to nearest Jersey barrier or guardrail. Road kills occurred closer to these barriers more often than would be expected by chance. Results also suggest that animals are funneled toward barrier ends but this requires further study.

8.) Hostick, G.A. and E.W. Styskel. 2005. Completion Report: Baker-to-Cottonwood Road Deer Monitoring ODOT PSC # 23928. Prepared by Ecological Services, Bend, OR for Oregon Department of Transportation, Bend, OR. 21 pp.

> This report details a study aimed at determining whether highway (concrete median and guardrail) dividers increase number of animals killed; block deer from crossing; and or change preferences for crossing locations. The authors put forward that median dividers did not cause higher than expected deer kill rates but that these results are not conclusive; dividers with gaps did not block deer from crossing highway; and dividers did not influence preference of crossing locations. Hostick and Styskel explore the theory that dividers can produce confusion and increased milling at highway and that deer might not notice tiny gaps designed for passage.
>
> The authors note that the Western gray squirrel population plummeted after divider installation.
>
> Concrete median dividers were configured to allow for animal passage. Twenty-inch wide gaps were spaced 100 or 500 feet apart. Each 11.5 feet long divider had a 6-inch diameter arched cutout for small animal passage and drainage. No gaps were installed for the guardrail structure, however, each 32-inch tall panel had a clearance of 20 inches above the ground.
>
> The report outlines specific recommendations for conducting deer population estimates and road kill surveys.

9.) Hubbs, A. and R. Boonstra. 1995. Study design to assess the effect of highway median barriers on wildlife. Ontario Ministry of Transportation. 57 pp. (Abstract only, hard copy of full report available from WTI.)

> This report explores numerous methodologies for studying the effects of concrete median barriers on wildlife. The report primarily deals with the controversial 401 Highway project in Ontario for which a wildlife mortality study report is due in 2006. The authors suggest that there is no difference in road mortality between road segments with and without concrete barriers.
>
> An appended study concludes that Jersey barriers, and possibly other impassable designs, do not result in an increase in small animal kills (with sizes ranging from weasel to fox and others with unidentifiable remains) when installed on 4- or 6-lane highways in Ontario (Armstrong, J.J. 1994. Dead Animal Observations on Ontario Highways. Ontario Ministry of Transportation.).

10.) Kohn, B.E., J.L. Frair, D.E. Unger, T.M. Gehring, D.P. Shelley, E.M. Anderson and P.W. Keenlance. 2000. Impact of the US Highway 53 Expansion Project on Wolves in Northwestern Wisconsin: Final Report. Prepared by Wisconsin Department of Natural Resources for Wisconsin Department of Transportation. 55 pp.

> This report summarizes the findings related to the impacts of widening a 2-lane road to a 4-lane road on wolves. The authors found no evidence that the highway project acted as a barrier to dispersing wolves but were not able to determine if the mitigation effort of “ballooned (median) sections” actually facilitated wolf

crossings of the highway. The authors recommend a comprehensive multi-state approach to future development of highways.

11.) Lloyd, J. and A. Casey. 2005. Wildlife Hot Spots along Highways in Northwestern Oregon Prepared by Mason, Bruce & Girard, Inc., Portland, OR for Oregon Department of Transportation Central Geo-Environmental Unit, Salem, OR. 64 pp.

This report details an expert-opinion rapid assessment of conflict areas (hot spots) between wildlife movement and highway operation. The study area consisted of 757 miles of state-maintained roads in the Oregon Department of Transportation's (ODOT) Region 1.

Twenty two percent of the roads analyzed were identified as conflict areas. The authors posit that determining the locations of conflict areas is an essential first step in making highways safer for motorists and animals. In addition to identifying those areas with frequent animal-vehicle collisions (AVCs), the team also found hot spots that did not have frequent AVCs.

The authors divide the study area into eight subregions and identify hot spot sections by mileposts. The following are excerpts of the hot spot notations which reference the presence of Jersey barriers:

"Beaver, nutria, raccoon and birds are frequently killed in collisions with motor vehicles at this hot spot; the Jersey barrier that runs through this section likely represents a significant barrier to most species that attempt to cross, and may increase the risk of collision for animals that attempt to cross over the roadway."

"One major issue throughout almost the entire corridor (with a notable exception around a delta) is the presence of Jersey barriers in the median. Presently the Jersey barrier is 37 inches tall, but whenever it is replaced, 42-inch tall barrier is used. Most participants noted having seen animals trapped on the roadway by the Jersey barrier."

"Deer move across the highway, and the presence of a Jersey barrier was thought to raise the frequency of collisions. Topography (steep bluff/rock southeast of highway) may drive some movement here, but deer-vehicle collisions are still quite infrequent. There is a road underpass at West Cliff Drive, but it was not believed to be used extensively by deer."

"The area was nominated based on occasional deer-vehicle collisions and frequent sightings. Steep topography along the south side forces east-west movement; the open flats north of the road provide good foraging and bedding locations. Currently, this hot spot doesn't have Jersey barriers but instead has a fairly large grass median strip. The median strip may enhance the ability of deer to safely cross the highway."

12.) Meyer, E. and I. Ahmed. 2004. Modeling of deer-vehicle crash likelihood using roadway and roadside characteristics. Submitted to TRB for 2004 Annual meeting. (No electronic file, hard copy of full report available from WTI.)

This study compares deer-vehicle collision rates related to three different types of medians. Results indicate that grassy medians have the highest rate, followed by concrete Jersey barrier and pavement markings (undivided two lane).

13.) Ontario Ministry of Transportation. 2005. Wildlife and Transportation Reference for the Oak Ridges Moraine - Part of the Standard Environmental References. Provincial and Environmental Planning Office. 112 pp.

The purpose of this document is to advise highway proponents on potential wildlife mitigation strategies in light of "increased recognition that highway design and landscape ecology are intertwined…" Using a literature review and professional experience as the basis, the report states that wildlife conflict zones may coincide with highway sections with Jersey barriers. The authors recognize that these structures can form a complete barrier to wildlife movement while enhancing motorist safety. They refer to a current study on Hwy 401 near Kingston, Ontario that is testing the effects of median barriers on wildlife mortality.

14.) National Research Council. 2005. Assessing and Managing the Ecological Impacts of Paved Roads, Ch2. History and Status of the US Road System, p. 37-61. & Ch. 4 Ameliorating the Effects of Roads, p. 98-116. The National Academies Press.

These book excerpts establish the current concern that barriers are formidable obstacles to small- and large-animal movement across highways. Barriers can block animals when they attempt to cross the highway, making them vulnerable to traffic mortality.

The authors discuss the alternatives to concrete median barriers. Guardrails normally provide space beneath and above the rail that allows movement of wildlife. Wider medians cause an additional loss of natural habitat but may have less ecological impact than a narrow, paved median with a barrier or guardrail.

The committee speaks of the trend among states to make barriers more permeable to wildlife but points out that there is no information regarding how effective these modified barriers are, and there are no standard guidelines regarding their placement.

15.) Ross, D. 2004. Analyzing the Resistance Values of the 401 Highway to Wildlife Movements in the Thousand Islands Section of the Algonquin to Adirondack Corridor and Thousand Islands Frontenac Arch Biosphere Reserve. (Unpublished) Prepared for Algonquin to Adirondack Conservation Association, Ontario. 65 pp.

This unpublished report (permission received) details a study that examined the porosity of the highway with specific observations on the effects of median barriers on wildlife mortality. Road kill was recorded one-time only but results suggested that the presence of a continuous concrete median barrier tended to increase the amount of mammalian road kill in this study. These results did not concur with the Ministry of Transportation of Ontario study (Hubbs and Boonstra 1995). The author points out that the lack of systematic collection of road kill data limits the ability to compare these data.

16.) Ruby, D.E., J.R. Spotila, S.K. Martin and S.J. Kemp. 1994. Behavioral responses to barriers by desert tortoises: Implications for wildlife management. Herpetological Monographs 8(144-160).

The researchers used captive animals to study the effect of various barriers on desert tortoise movement. Solid concrete roadside barriers repel desert tortoises, causing them to walk parallel for several minutes then stop or walk away from the highway. The authors discuss tortoise use of culverts and tunnels and the merits of mesh to funnel animals towards passageways.

17.) Singleton, P.H. and J.F. Lehmkuhl. 2000. I-90 Snoqualmie Pass Wildlife Habitat Linkage Assessment Final Report. U.S. Department of Agriculture Forest Service Pacific Northwest Research Station, Wenatchee Forestry Sciences Lab. 78 pp.

This report assesses the habitat connectivity of Interstate 90, a high-volume, high-speed roadway with 2 or 4 lanes in each direction, separated by a broad forested median or concrete median barrier, respectively. Average daily traffic is approximately 24,400 vehicles.

Results include specifics about road kill in relation to different types of median barriers. Deer road-kills occurred less often than expected on hillsides and in areas with Jersey barriers in the median. Elk road-kill locations occurred more often than expected in areas with grassy or forested medians, and less often than expected in areas with jersey barriers in the median. The lack of road kill on a highway with Jersey median and roadside barriers in Washington, served as an indicator of relative impermeability to ungulates, although at least one coyote crossing was documented via snow tracking. The authors discuss possible causes of impermeability of certain road sections and propose that installation of extra-tall Jersey barriers or concrete walls may help to redirect animal movement to crossing structures.

18.) Urbitran Associates, Cambridge Systematics and Howard/Stein-Hudson Associates. 2005. Strategies for Addressing Deer-Vehicle Crashes. Prepared for North Jersey Transportation Planning Authority - Development of Regional Safety Priorities.

This strategy paper address human fatalities as a result of “deer events” whether the motorists strikes a deer or swerves to avoid collision and hits a fixed object. The authors analyze the parameters of deer-vehicle crashes, including road type and presence or absence of medians and other safety barriers. Within in a 13-county region in New Jersey in 2003, 70 percent (n = 3,524) of deer-vehicle collisions (DVCs) occurred on roads without medians or guardrails, 19% (n = 959) of DVCs occurred in the presence of a grassy median, 6% (n = 309) in the presence of a concrete barrier, 3% (n = 147) in the presence of a guardrail, and 1% (n = 36) in the presence of a concrete median.

19.) Watts, B. Center for Conservation Biology. Virginia Cedar Waxwing Highway Median Planting Removal. Wildlife Crossings Toolkit. http://www.wildlifecrossings.info (Keyword: Cedar Waxwing) Last updated August 2005. Last accessed 28 July 2006.

This project listing discusses the effect of Thorny elaeagnus roadside and median plantings on fruit-eating birds. The author details a mortality study and offers mitigation recommendations. About 95% of the vehicular bird mortality, representing 19 species, was linked to feeding on the fruit. More than 97% of all dead birds collected were associated with medians containing shrubs with viable fruit. More than 350 dead birds were collected at one location in a single day and more than 1600 cedar waxwings were collected along 2 segments of highway. The distance of the shrubs from the roadside was suspected as a possible factor in bird/vehicle collisions. The author suggested non-vegetative structures can be used to divide highways such as concrete or cinder block.

20.) Woods, J.G. 1990. Effectiveness of Fences and Underpasses on the Trans-Canada Highway and their Impact on Ungulate Populations in Banff National Park, Alberta. Canada Parks Service, Calgary. (No electronic file, hard copy available upon request.)

This book is referenced by numerous road ecology articles. It includes results of a study which did not find a larger number of elk-vehicle collisions along roadway segments with concrete median barriers or grassy medians.

2. Recommendations for Mitigation of Median Barrier Effects on Wildlife

1.) Barnum, S.A. 2003. Identifying the Best Locations Along Highways to Provide Safe Crossing Opportunities for Wildlife: A Handbook for Highway Planners and Designers. Report No. CDOT-DTD-UCD-2003-9 Final Report. Colorado Department of Transportation. 69 pp.

See annotation in Studies of Median Barrier Effects on Wildlife

21.) Chambers, M. 2005. Animal Profiler using DNA-fingerprinting for Gruesome Crime Scenes, Trent University Researchers are Collecting New Information about Canada's Wildlife Population and Conservation of Endangered Species. InnovationCanada.CAISSUE Issue 14. 6 pp.

The web-based article reports on Trent University's non-traditional use of a DNA-fingerprinting database. The researchers are using the tool to assess the impacts of urbanization and further road development on wildlife. The researchers were quoted as being "intrigued with what the 401 (Highway project) and the median wall from Toronto to Brockville are doing to isolate populations,…"

22.) Cooper, J.M. 1999. Mitigation of Impacts to Wildlife and Wildlife Habitat for Advanced Construction Candidate Package 1 (SNC-Lavalin LTd. Donald to Roth Creek Segment of Cache Creek to the Rockies Program). Prepared by Manning, Cooper and Associates, Sidney, BC for Cache Creek to the Rockies Program, Vancouver Island Highway Project, Victoria, BC. 18 pp.

This report identifies key wildlife issues and provides recommendations to mitigate impacts to wildlife and habitat related to a road improvement project along the Trans Canada Highway corridor. Draft design included east and westbound passing lanes being added to an existing 2-lane highway.

Construction plans included a symmetrical widening, with a narrow median. Design highway speed was 100 km/h.

The author states the primary wildlife-related issue (for the project) was the risk of collision with large mammals and the larger scale impact on movements of large mammals. The construction site was situated in an area with relatively high numbers of road-killed animals; was located within ungulate and carnivore winter and summer range; and within a broad movement corridor for ungulates, bears and other wildlife.

Given that AVCs are primarily a function of three factors: density of animals, traffic volume, and traffic speed, Cooper believed that this project would continue to yield an increase in the frequency and severity of animal-vehicle collisions (AVCs) unless mitigation measures were taken.

The author discusses mitigation recommendations, with discussion of median barriers: "The presence of concrete roadside and median barriers may exacerbate the potential for collisions between wildlife and vehicles because they partially conceal animals from motorist's view, may act as a barrier to animal movement, and animals jumping over the barrier might do so directly into the path of oncoming traffic. For smaller wildlife (e.g., furbearers, rodents, amphibians, reptiles, lagomorphs), concrete median and roadside barriers impede movements across the highway. For these species, scuppers large enough to facilitate passage should be incorporated into the design of the barrier. Scuppers, with cutouts along the bottom of 25 cm high and 100 cm wide would be appropriate. Preliminary design (for the project) includes placement of concrete roadside barriers with scuppers on the south side of the alignment. To facilitate passage of small wildlife, CRBS (assumed to be concrete roadside barriers) with scuppers should account for at least 20% of the barriers or 1 every 5th barrier. Median barriers are not forecast to be needed until about 2020."

23.) Jackson, S.D. and C.R. Griffin. 2000. A Strategy for Mitigating Highway Impacts on Wildlife. Pp. 143-159 Messmer, T.A. and B. West (eds.) Wildlife and Highways: Seeking Solutions to an Ecological and Socio-economic Dilemma. The Wildlife Society. 16 pp.

This book chapter addresses the effects of road and highway construction on wildlife and the view that no practical strategy currently exists for facilitating the incorporation of mitigation into highway design and permitting decisions. The authors suggest it is impractical to design mitigation projects that account for the specific requirements of all species affected by a highway, but that it may be possible to develop a generalized strategy for making highways more permeable to wildlife passage for a larger number of species.

The authors explore many factors which influence the effectiveness of wildlife passage structures. They emphasize the importance of first focusing on the landscape scale to maintain "connectivity zones" and ecological processes followed by implementing specific strategies on the local scale. They name Jersey barriers in particular, "In our opinion, a practical strategy for mitigating highway impacts on wildlife should include: Avoidance of highway fencing and Jersey barriers when not used in association with wildlife passage structures,…"

14.) National Research Council. 2005. Assessing and Managing the Ecological Impacts of Paved Roads, Ch2. History and Status of the US Road System, p. 37-61. & Ch. 4 Ameliorating the Effects of Roads, p. 98-116. The National Academies Press.

See annotation in Studies of Median Barrier Effects on Wildlife

24.) Servheen, C., J.S. Waller and W. Kasworm. 1998. Fragmentation effects of high-speed highways on grizzly bear populations shared between the United States and Canada. The International Conference on Wildlife Ecology and Transportation. .

This paper proposes a three-phase approach to address the impacts of high-speed highways (including associated fencing and other barriers along or between highway lanes) on grizzly bear populations. The authors emphasize the need to understand the characteristics of grizzly bear habitat in association with highways to predict likely crossing sites; identify mitigation designs that will facilitate crossing and monitor ongoing highway impacts. Without a plan of action, the authors believe, high-speed highways (in combination with other human activities) can have a serious impact in grizzly bear survival.

25.) Servheen, C., J.S. Waller and P. Sandstrom. 2003. Identification and Management of Linkage Zones for Wildlife Between the Large Blocks of Public Land in the Northern Rocky Mountains. A U.S. Fish and Wildlife Service Linkage Zone Report Update. 83 pp.

This report evaluates the extent of habitat fracture and potential for wildlife linkage in the Northern Rockies. The authors provide possible crossing management ideas for highways in linkage zones, including one reference to median barriers: “Minimize the use of barriers such as concrete medians that can block crossing by wildlife and increase mortality risk for those animals that do venture onto the highway.”

17.) Singleton, P.H. and J.F. Lehmkuhl. 2000. I-90 Snoqualmie Pass Wildlife Habitat Linkage Assessment Final Report. U.S. Department of Agriculture Forest Service Pacific Northwest Research Station, Wenatchee Forestry Sciences Lab. 78 pp.

See annotation in Studies of Median Barrier Effects on Wildlife

26.) Washington State Department of Transportation. 2005. Design Manual M22-01, Chapter 710, Traffic Barriers. 28 pp.

This agency manual provides information about a variety of traffic barriers and makes note that such barriers are obstacles and should only be used when justified. It includes a brief section on Assessing Impacts to Wildlife with a Concrete Barrier Placement Guidance flow chart.

3. Other Related Ecological Research

27.) Seiler, A. 2001. Ecological Effects of Roads: A Review. Introductory Research Essay No 9. Department of Conservation Biology, Swedish University of Agricultural Sciences. 40 pp.

This is a review of the scientific literature on the known ecological effects of transport infrastructure, with special focus on roads. The author suggests that there is increasing public demand for prevention and mitigation of these environmental impacts, requiring the development of evaluation tools for ecologists and civil engineers.

28.) Underhill, J. 2002. Roads and Wildlife: A study of the effects of roads on mammals in roadside habitats. Dissertation. School of Geography and Environmental Science, The University of Birmingham.

This study does not address median barriers specifically but is included because it explores other road factors which may deter animal movement. The author supports the proposition that small mammals do not cross roads as part of their standard daily activities, irrespective of the width of the road or the traffic volume. The author suggests that the biggest deterrent to movement across the road is probably not traffic but other factors, such as, lack of cover or the road surface itself.

29.) Molinari, P. and A. Molinari-Jobin. 2001. Identifying passages in the southeastern Alps for brown bears and other wildlife. Ursus. 12:131-134. (Abstract only.)

This permeability study attempts to quantify and categorize existing wildlife passages. The authors examine barriers including transportation infrastructure, walls and fences.

4. Alternatives to Concrete Median Barriers

30.) Agent, K.R., J.G. Pigman and N. Stamatiadis. 2001. Countermeasures for fatal crashes on two-lane rural roads. Kentucky Transportation Center

This research report provides a detailed analysis for a random sample of 150 fatal crashes/sites on 2-lane rural road. The highest reduction estimates for roadway related countermeasures, which did not involve reconstruction, were adding shoulder or centerline rumble strips and installing chevron signs.

31.) Chayanan, S., V. Shankar, S. Sittkariya, G. Ulfarsson, M. Shyu and N.K. Juvva. 2004. Median crossover accident analyses and the effectiveness of median barriers. Washington State Transportation Center Research Report prepared for WSDOT.

This research report explores the use of count models to determine design and weather factors correlated with median crossover crashes on Washington State highways. The authors conclude it is not beneficial to install median barriers everywhere on the road network because the frequency of other types of accidents tends to increase in the presence of barriers. A comparison of sections with and without barriers indicated that as the number of curves per mile increased in a section with barriers, the overall crash profile on those sections would increase compared to similar sections with no barriers.

The authors discuss costs associated with median barriers and make recommendations for evaluating sections for installation.

32.) Delaware DOT. 2003. Centerline Rumble Strips: The Delaware Experience Fact Sheet.

> This fact sheet describes a "before-after" study of centerline rumble strip effectiveness. Average yearly head-on collisions decreased by 95 percent after the installation of centerline rumble strips. A benefit-to-cost analyses determined the cost effectiveness of the centerline rumble strip application was approximately 110.

33.) Hunter, W. W., J.R. Stewart, K.A. Eccles, H.F. Huang, F.M. Council and D.L. Harkey. 2001. Three-strand cable barrier in North Carolina: In-service evaluation. Transportation Research Record. (Abstract only)

> The authors used historical crash data to estimate the effects of the installation of cable median barrier on crash rates. Analyses indicate that several types of crashes increased on the sections where cable median barrier was installed. However, overall severity index values were greatly reduced after cable barrier installation.

34.) Miaou, S., R. Bligh and D. Lord. 2004. Developing median barrier installation guidelines: A benefit/cost analysis using Texas data. TRB 2005 Annual Meeting CD-ROM. (No electronic file, hard copy of full report available from WTI.)

> This paper seeks to determine the average annual daily traffic zone where installing concrete median barriers may not be beneficial and perhaps even wasteful. The authors consider median barriers as obstacles and propose that their installation transform cross-median crashes into hit-median barrier crashes. They detail a "with/without" study comparing concrete and high-tension cable barriers. A cost-benefit analysis related to median-related crashes is included.

35.) Mok, J. and H.C. Landphair. 2002. Parkways or freeways: Safety performance linked to corridor landscape types. TRB 2003 Annual Meeting CD-ROM.

> This paper compares medians and other roadway design features of freeways and parkways and their relationship to fatal crashes. The authors call for further research in context sensitive design.

36.) Monsere, C.M., B. Sposito and S. Johnston. 2003. Safety effectiveness and operating performance of a three-cable median barrier on Interstate 5 in Oregon. Institute of Transportation Engineers Annual Meeting. (Abstract only)

> This study indicates that the cable barrier system has been effective in reducing the severity of crashes but has resulted in an increase of reportable minor injury and property damage crashes.

14.) National Research Council. 2005. Assessing and Managing the Ecological Impacts of Paved Roads, Ch 2. History and Status of the US Road System, p. 37-61. & Ch. 4 Ameliorating the Effects of Roads, p. 98-116. The National Academies Press.

> See annotation in Studies of Median Barrier Effects on Wildlife

37.) Outcalt, W. 2001. Centerline Rumble Strips. Report No. CDOT-DTD-R-2001-8 Interim Report, CODOT Research Branch. 15 pp.

This report evaluates the installation of centerline rumble strips in an effort to reduce the number and severity of crossover accidents. Comparison of traffic reports showed a decrease in accidents after installation. The author determined the only drawbacks associated with centerline rumble strips are the potential of increased danger to motorcyclists and bicyclists, increased noise, and increased wear on the pavement marking stripes.

38.) Persaud, B.N., R.A. Retting and C.A. Lyon. 2004. Crash reduction following installation of centerline rumble strips on rural two-lane roads. Accident Analysis and Prevention Vol. 36 p. 1073–1079.

This journal article proposes centerline. rumble strips as a potential engineering countermeasure for preventing vehicles from crossing the centerline. The researchers analyzed data for 210 miles of treated roads in 7 states in a "before-after" study. Results indicate that crashes at treated sites were reduced 12% and that all injury crashes were significantly reduced by 14%. The authors discuss weaknesses of the study but suggest centerline rumble strips are effective while incurring a relatively low installation cost.

39.) Stasburg, G. and L.C. Crawley. 2005. Keeping Traffic on the Right Side of the Road. Public Roads. US Department of Transportation Federal Highway Administration. www.tfhrc.gov/pubrds/pubrds.htm Last updated April 2006. Last accessed 28 July 2006.

This article describes a cross-median study in North Carolina with the objective to reduce number and severity of crashes by establishing a warrant for median barrier placement on roadways with cross-median crash histories. The authors describe a cost-benefit analysis comparing three-cable median barriers to concrete Jersey barriers and suggests that other states are following North Carolina's lead in this median barrier technology.

40.) Strathman, J.G., K.J. Duecker, J. Zhang and T. Williams. 2001. Analysis of design attributes and crashes on the Oregon highway system. Final report SPR 321 #1712. Prepared by Center for Urban Studies, Portland State University for Oregon Department of Transportation and Federal Highway Administration. 65 pp.

This report describes a meta-analysis of crash frequency and severity relative to median barriers and guard rails. The authors discuss crash reduction factors and the states in which they are employed.

41.) Taylor, H.W. 2005. Preventing Roadway Departures. Public Roads. US Department of Transportation Federal Highway Administration. www.tfhrc.gov/pubrds/pubrds.htm Last updated April 2006. Last accessed 28 July 2006.

This article explores six demonstrated or potential countermeasures to mitigate lane and roadway departures, including rumble strips/stripes, median cable barriers and raised median islands. The author weighs costs and benefits and tells of trends among states in each of these technologies. Taylor names cable barriers and rumble strips as two of FHWA's priority technologies with proven benefits and which are ready for deployment.

42.) Zeitz, R. November/December 2003. Low-Cost Solutions Yield Big Savings. Public Roads. US Department of Transportation Federal Highway Administration. www.tfhrc.gov/pubrds/pubrds.htm Last updated April 2006. Last accessed 28 July 2006.

This article describes the effectiveness of the three-strand cable system, in conjunction with other measures, in reducing human fatalities in South Carolina.

D. Median Barrier State of the Practice Survey

Questions marked with a * are required

100%

I. Background Information

Last name *

First name *

State/Province *

Agency *

Position title

Area in your charge (i.e. state/province, region, district...)

Number of years in the transportation field

Responsibilities (brief)

Email

Phone number

In some cases, we may ask to follow up with you for further information. What is the best way to reach you?

- Email
- Phone
- Prefer not to be contacted

II. Survey questions

Utilization History

1. What types of median barriers does your agency use on any or all roadway types, i.e. multi-lane interstate, two-lane rural roads, etc.? Please select all that apply.

- Concrete Jersey or NJ-shape
- Concrete F-shape
- Concrete constant-slope Texas
- Concrete low-profile
- Steel beam
- Thrie beam
- Cable (Safence)
- Cable (three-strand)
- Cable (four-strand)
- Centerline rumble strips
- Grassy strip
- Painted centerline
- Other (please describe)

2. When did your agency...

	Last year	5 years ago	10 years ago	15 years ago	20 or more years ago	Not applicable
BEGIN installing raised median barriers of any type?						
BEGIN installing concrete Jersey or F-shape median barriers?						
DISCONTINUE installing concrete Jersey or F-shape median barriers?						
BEGIN installing concrete constant-slope Texas median barriers?						
DISCONTINUE installing concrete constant-slope Texas median barriers?						
BEGIN installing steel or thrie beam median barriers?						
DISCONTINUE installing steel or thrie beam median barriers?						
BEGIN installing cable median barriers?						
DISCONTINUE installing cable median barriers?						
BEGIN installing centerline rumble strips?						
DISCONTINUE installing centerline rumble strips?						
BEGIN installing grassy median barriers?						
DISCONTINUE installing grassy median barriers?						

3. What criteria/variables does your agency use/analyze to determine the need for median barrier installation? Please select all that apply.

- Historical cross-over collision records
- Cost-benefit analyses

- [ ] Collision probability models
- [ ] Average daily traffic
- [ ] Median width
- [ ] Posted speed limit
- [ ] Roadway segment in relation to interchanges or other roadway feature
- [ ] Controlled access
- [ ] Slope
- [ ] Environmental factors
- [ ] Geometric factors
- [ ] Traffic factors
- [ ] Rural/suburban/urban location
- [ ] Other (please describe)

4. What guidelines does your agency use to determine the type and location of median barrier installations? Please select all that apply.

- [ ] AASHTO (American Association of State Highway and Transportation Officials) Roadside Design Guide
- [ ] State/province guidelines
- [ ] Agency guidelines
- [ ] Another state/province/agency's guidelines
- [ ] Use ad hoc approach
- [ ] Not applicable; no need for median barrier installation guidelines

If using a document other than AASHTO's Roadside Design Guide, please provide citation

5. Please describe any specific uses for barrier types utilized by your agency, i.e. as median barrier versus edge barrier, in high snow areas versus snow-free areas, etc.

Trends

6. Please characterize your agency/state/province's installation trends for each of the following median barrier types.

	Increasing	Stable	Decreasing	Not applicable
Concrete Jersey or F-shape	○	○	○	○
Concrete constant-slope Texas	○	○	○	○
Steel or thrie beam	○	○	○	○
Cable	○	○	○	○
Centerline rumble strips	○	○	○	○
Grassy median	○	○	○	○

Please describe any other trends in the use of median barriers by your agency/state/province.

7. Please select the median barrier type your agency is most likely to use for each of the following roadway types.

	Concrete Jersey/F-shape	Concrete constant-slope Texas	Steel/thrie beam	Cable	Centerline rumble strips	Grassy median	Painted Centerline
Rural 2-lane	○	○	○	○	○	○	○
Rural 4-lane	○	○	○	○	○	○	○
Suburban 2-lane	○	○	○	○	○	○	○
Suburban 4-lane	○	○	○	○	○	○	○
Suburban > 4-lane	○	○	○	○	○	○	○
Urban 2-lane	○	○	○	○	○	○	○
Urban 4-lane	○	○	○	○	○	○	○
Urban > 4-lane	○	○	○	○	○	○	○

Performance Evaluation

8. Has your agency studied the effectiveness of installed median barriers for motorist safety?

○ Yes ○ No ○ I don't know

If **yes**, what type of study was conducted?

○ Before-after comparison ○ With/without comparison ○ Other (please describe)

If **yes**, what type of median barrier(s) was studied?

If **yes**, what were the measures of effectiveness? Please select all that apply.

- [ ] Reduction of cross-over collisions
- [ ] Reduction of cross-over collision fatalities
- [ ] Reduction of injury severity
- [ ] Lives saved
- [ ] Dollars saved
- [ ] Other (please describe) ______

9. Did the installation of median barriers enable your agency to achieve its a priori goal(s) for increasing motorist safety?

○ Yes ○ No ○ I don't know

10. Has your agency studied the effects of median barriers on wildlife movement and/or mortality?

○ Yes ○ No ○ I don't know

If **yes**, please explain general findings and provide report citation(s).

If **no**, is any such research being considered or planned for the future?

○ Yes ○ No ○ I don't know

If **yes**, please briefly explain scope/type of planned study, projected date, stage of the project, targeted species, etc…

If **no**, please rank your agency's reasons for not studying the effects of median barriers on wildlife movement and/or mortality.

(1 = Highest, 5 = Lowest)

Too expensive

Too time consuming

No specialized personnel to conduct the study

No mandate to conduct such research (no species which are endangered, threatened or of special concern)

No perceived need to conduct such research

Rank values must be between 1 and 5

If there are other reasons not listed above, please describe.

11. Have any unforeseen negative impacts resulted from different types of median barrier installations by your agency/state/province? Please select all that apply.

	Concrete Jersey/F-shape	Concrete constant-slope Texas	Steel/thrie beam	Cable	Centerline rumble strips	Grassy median
Increase in fixed object (median barrier) collisions						
Increase in re-directional collisions						
Increase in motorist fatalities						
Increase in motorist injuries						
Increase in motorist injury severity						
Increase in general maintenance costs						
Increase in weather-related maintenance costs or challenges						
Decrease in emergency service and/or law enforcement accessibility						
Increase in wildlife mortality						
Decrease in wildlife mobility across the roadway						

Mitigations for Wildlife

12. What species (deer, bears…) or groupings (small mammals, reptiles/amphibians…) of wildlife appear to be most affected by roadways with raised median barriers in your jurisdiction?

13. How frequently does your agency/state/province **consider** mitigative design solutions to median barrier impacts on wildlife movement and/or mortality? (e.g. spacing of barriers, scuppers, passages…)

- Always
- Usually
- Sometimes
- Rarely
- Never
- Not applicable

14. How frequently does your agency/state/province **employ** mitigative design solutions to median barrier impacts on wildlife movement and/or mortality?

- Always
- Usually
- Sometimes
- Rarely
- Never
- Not applicable

Implications for Transportation Planning

15. Has your agency encountered any practical or regulatory issues regarding the use of median barriers in your state/province?

- Yes
- No
- I don't know

16. Does your agency know of any practical or regulatory issues regarding the use of median barriers across states/provinces/the country?

- Yes
- No
- I don't know

If yes, are these issues related to:

	Yes	No	I don't know
motorist safety?			
wildlife movement and/or mortality?			

Please explain.

17. Is your agency planning any changes in its approach to using median barriers? (e.g. type of barrier, placement, etc.)

18. What suggestions or comments do you have regarding median barriers, motorist safety and wildlife movement and/or mortality that might not have been addressed in this survey?

If there is someone else in your agency who can provide further information, please provide their contact information.

If you would like to receive a report of the survey results, please check here.

☐

Continue

Please contact swang@coe.montana.edu if you experience any problems with this web based survey.

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