TABLE 1 : CONNECTIVITY SOLUTIONS

Solution	Species Group	Region	Mitigation Type	Timing Of Solution/ Evaluation	Impact Reduction Benefits	Cost Range	Design Considerations	Source(s)
Shift Alignment - Prevent or reduce impact through alteration to the proposed road alignment such that the connectivity function can be maintained								
Examples:	• Multi-species	VT	Minimization	Project Planning/ Alternatives Analysis			• Shift road alignment at least 100 ft away from edge of Missisquoi River and restore area to functional riparian habitat	Austin, J.M., M. Ferguson, G. Gingras, and G. Bakos. 2003. Strategies for restoring ecological connectivity and establishing wildlife passage for the upgrade of Route 78 in Swanton, Vermont: an overview. IN: Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. C.L. Irwin, P. Garrett, K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 253-259. http://escholarship.org/uc/item/50q5q4m7
INSTALL STRUCTURE - Provide overpass, underpass, or at-grade cross to facilitate wildlife passage over, under or across the roadway								
Overpass: Grade separation structure designed to allow wildlife to cross over an intersecting highway or railroad, usually covered with vegetation								
	Carnivores/large herbivores/small - medium sized mammals/flying animals/reptiles & amphibians	ALL	Minimization/ Compensation	Project Planning/ Alternatives Analysis	Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs	>$1 million	• Size range >40 m wideWidth required increases with length of overpass (width to length ratio should be >0.8) • Designed to resemble natural habitat	Bissonette, J.A. and P.C. Cramer. NCHRP Report 615: Evaluation of the Use and Effectiveness of Wildlife Crossings. Transportation Research Board of the National Academies, Washington D.C., 2008. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_615.pdf
Examples:	Ungulates/multi-species	Alberta	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs	$1,688,993/overpass (2007); IN CONSTRUCTION - $3,290,000 - $3,760,000 for Lake Louise Area of Park including traffic control & detour; fencing $69/m (2007 $) (Huijser et al. 2008)	• 52-m wide x 70 m long overpasses (Huijser et al. 2008) • Openness ratio =5.41 (Clevenger and Waltho 2005) • Planted with native grasses/shrubs/white spruce (Gloyne and Clevenger 2001) • Lake Louise overpass - 60m wide across 2-lane road (Huijser et al. 2008)	Clevenger, A.P. and N. Waltho. 2005. Performance Indices to Identify Attributes of Highway Crossing Structures Facilitating Movement of large Mammals. Biological Conservation 121(3): 453-464 http://biology.ucf.edu/~rnoss/papers/Clevenger%20and%20Waltho%202005.pdf Gloyne, C.C. and A.P. Clevenger. 2001. Cougar (Puma concolor) use of wildlife crossing structures on the Trans-Canada highway in Banff National Park, Alberta. Wildlife Biology 7: 117-124. http://www.wildlifebiology.com/Downloads/Article/326/En/7_2_gloyne.pdf M.P. Huijser, P. McGowen, A.P. Clevenger, and R. Ament. 2008. Wildlife-vehicle collision reduction study: best practices manual. Report to Congress. U.S. Department of Transportation, Federal Highway Administration. http://www.fhwa.dot.gov/environment/hconnect/wvc/index.htm
Underpass: passages that allow for wildlife to cross underneath the roadway								
Bridge underpass: structure (>20') including supports, erected over a depression or obstruction and having a floor for carrying traffic or other moving loads								
Examples:	Carnivores/large herbivores/small - medium sized mammals/flying animals/reptiles & amphibians, aquatic animals	ALL	Minimization/ Compensation	Project Planning/ Alternatives Analysis	Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Location in the landscape influences effectiveness • Light in the underpass will increase openness and therefore, may be helpful for some species	Bissonette, J.A. and P.C. Cramer. NCHRP Report 615: Evaluation of the Use and Effectiveness of Wildlife Crossings. Transportation Research Board of the National Academies, Washington D.C., 2008. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_615.pdf
	• Bighorn sheep	AZ			Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Openness ratios: = 75, 28, 56 (highest was most successful)	Bristow, K. and M. Crabb. 2008. Evaluation of Distribution and Trans-highway movment of desert bighorn sheep: Arizona Highway 68. Final Report 588. Arizona Department of Transporation. http://www.azdot.gov/TPD/ATRC/publications/project_reports/PDF/AZ588.pdf
	• Mountain goat	MT			Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Openness ratio = 25-57 • 12-28 feet h x 90 ft w x 44 ft through • 8-ft fencing	Singer, F.J., W.L. Langlitz, and E.C. Samuelson. 1985. Design and construction of highway underpasses used by mountain goats. Transportation Research Record. 1016:6-10 abstract only

Solution	Species Group	Region	Mitigation Type	Timing Of Solution/ Evaluation	Impact Reduction Benefits	Cost Range	Design Considerations	Source(s)
	• Florida panther/ alligators	FL			Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Openness ratio = 0.92-1.12 • Underpass has 22.3 m median opening • 3 m high fence	Foster, M.L. and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23(1): 95-100 http://www.jstor.org/pss/3783202
	• Multi-species	NC			Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Openness ratio = 2.48-4.03 3 m high fencing ≥800 m from underpasses (continued through underpasses to other side) One underpass has a stream	McCollister, M.F. and F.T. Van Manen. 2010. Effectiveness of Wildlife Underpasses and Fencing to Reduce Wildlife-Vehicle Collisions. Journal of Wildlife Management 74(8): 1722-1731. http://onlinelibrary.wiley.com/doi/10.2193/2009-535/abstract
	• Elk	AZ			Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs	$1.5 - 2 million/underpass; video/cameras -$7000	• Openness ratios - 12.3 and 5.5 Minimize length or add atrium Avoid areas with human disturbance Some underpasses with streams	Dodd, N.L., J.W. Gagnon, S. Boe, A. Manzo, and R.E. Schweinsburg. 2007. Evaluation of Measures to Minimize Wildlife-Vehicle Collisions and Maintain Permeability across highways: Arizona Route 260. Final Report 540. Arizona Department of Transportation. http://www.azdot.gov/TPD/ATRC/publications/project_reports/PDF/AZ540.pdf
	• Mountain lions, multi-species	Alberta			Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs	$675,597-965,139 (2007) - 12m w x 30m l underpass; IN CONSTRUCTION - Lake Louise area - $2,350,000 (2007) incl traffic control & detour (16-25m w under-pass); fencing $69/m (2007 $) (Huijser et al. 2008)	• Open span /creek=3m h x 11 m w (Phase 1 &2) 12m w x 5 m high underpass (Phase 3A) (Huijser et al. 2008) Openness ratio =0.4-1.25 minimize human disturbance/use (Clevenger and Waltho 2000)	Gloyne, C.C. and A.P. Clevenger. 2001. Cougar (Puma concolor) use of wildlife crossing structures on the Trans-Canada highway in Banff National Park, Alberta. Wildlife Biology 7: 117-124. http://www.wildlifebiology.com/Downloads/Article/326/En/7_2_gloyne.pdf M.P. Huijser, P. McGowen, A.P. Clevenger, and R. Ament. 2008. Wildlife-vehicle collision reduction study: best practices manual. Report to Congress. U.S. Department of Transportation, Federal Highway Administration. http://www.fhwa.dot.gov/environment/hconnect/wvc/index.htm Clevenger, A.P. and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology 14(1): 47-56. http://www.transwildalliance.org/resources/200884165345.pdf
	• Multi-species	Ontario	Minimizaton/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs	bridge =$1.2 million;	• 81 m open span bridge	Gartshore, R. G., M. Purchase, R.I. Rook,and L. Scott. Bayview Avenue Extension, Richmond Hill, Ontario, Canada Habitat Creation and Wildlife Crossings in a Contenious Environmental Setting: A Case Study (September 2005). Pages 55-76 IN Proceedings of the 2005 International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Paul Garrett, and K.P. McDermott. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University, 2006. http://www.icoet.net/ICOET_2005/proceedings/2005ICOETProceedingWeb.pdf
	• Large herbivores, carnivores, small & medium-sized mammals	MT	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs	$435,340 (2007$); fencing $27-42/m (Huijser et al. 2008)	• Open span bridge 12m w x 30 m l (height unknown) (Huiijser et al. 2008)	M.P. Huijser, P. McGowen, A.P. Clevenger, and R. Ament. 2008. Wildlife-vehicle collision reduction study: best practices manual. Report to Congress. U.S. Department of Transportation, Federal Highway Administration. http://www.fhwa.dot.gov/environment/hconnect/wvc/index.htm Huijser, M.P., T.D.H. Allen, and W.Camel. 2010. US 93 Post-Construction Wildlife-Vehicle Collision and Wildlife Crossing Monitoring and Research on the Flathead Indian Reservation between Evaro and Polson, Montana. Annual Report. Montana Department of Transportation. http://www.mdt.mt.gov/research/docs/research_proj/wildlife_crossing/phaseii/annual_report_oct10.pdf
	• Multi-species	VT	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• 500-ft wide bridge span over wetland/upland habitat complex	Austin, J.M., M. Ferguson, G. Gingras, and G. Bakos. 2003. Strategies for restoring ecological connectivity and establishing wildlife passage for the upgrade of Route 78 in Swanton, Vermont: an overview. IN: Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. C.L. Irwin, P. Garrett, K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 253-259. http://escholarship.org/uc/item/50q5q4m7

Solution	Species Group	Region	Mitigation Type	Timing Of Solution/ Evaluation	Impact Reduction Benefits	Cost Range	Design Considerations	Source(s)
Culvert - covered with embankment around entire perimeter	Carnivores/small - medium sized mammals/flying animals/reptiles & amphibians, aquatic animals	ALL	Minimization/ Compensation	Project Planning/ Alternatives Analysis	Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Location in the landscape influences effectiveness Light in the underpass will increase openness and therefore, may be helpful for some species	Bissonette, J.A. and P.C. Cramer. NCHRP Report 615: Evaluation of the Use and Effectiveness of Wildlife Crossings. Transportation Research Board of the National Academies, Washington D.C., 2008. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_615.pdf
Box culvert - culvert with a square or rectangular cross-sectional profile having 4 sides, including a bottom.								
Examples: CLASS 1: Small; ≤1.5 m (5 ft)	Some medium-sized mammals, aquatic animals, small mammals, reptiles & amphibians	ALL	Minimization/ Compensation	Project Planning/ Alternatives Analysis	Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs			
	• Spotted salamander/ mole salamanders	MA	Minimization		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Bury drift fence 6-10 cm (Jackson and Tyning 1989) Tunnels 200 m apart (FHWA Critter Crossings website); or 200 ft. apart (Jackson 2003). Min. 2 ft. x 2ft concrete culverts, open grate top and soil bottom (Jackson 2003) Culvert wingwalls and min. 18-inch high vertical walls extend 100 to 200 feet in length (Jackson 2003)	Jackson, S.D. and T.F. Tyning. 1989. Effectiveness of drift fences and tunnels for moving spotted salamanders under roads. Pp. 93-99 In T.E.S. Langton (ed.) Amphibians and Roads. proceedings of the toad tunnel conference. ACO Polymer Products, Shefford, England. http://www.umassextension.org/NREC/images/stories/linked_content/pdf_files/amphibians_and_roads.pdf Jackson, Scott. 2003. Proposed Design and Considerations for Use of Amphibian and Reptile Tunnels in New England. Department of Natural Resources Conservation, University of Massachusetts Amherst. http://www.umass.edu/nrec/pdf_files/herp_tunnels.pdf FHWA Critter Crossings Website http://www.fhwa.dot.gov/environment/wildlifecrossings/salamand.htm
	• Otter, beaver, muskrat, herps	VT	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Concrete wetland box culverts min. 4' wide Open grate, trapezoidal cast concrete amphibian tunnels	Austin, J.M., M. Ferguson, G. Gingras, and G. Bakos. 2003. Strategies for restoring ecological connectivity and establishing wildlife passage for the upgrade of Route 78 in Swanton, Vermont: an overview. IN: Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. C.L. Irwin, P. Garrett, K.P. McDermott. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 253-259. http://escholarship.org/uc/item/50q5q4m7
	• Santa Cruz long-toed salamander	CA	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Five 32cm h x 47cm w and one 21 cm h x 23 cm w tunnels constructed of non-abrasive cement polymer with slots along top Entrances screened with wire mesh (5cm x 10 cm) to reduce predator access Permanent fencing 40 cm h, curved	Allaback, M.L. and D.M. Laabs. 2002-03. Effectiveness of road tunnels for the Santa Cruz long-toed salamander. Transactions of the Western section of the Wildlfie Society 38/39:5-8. http://www.tws-west.org/transactions/Allaback%20Laabs.pdf
	• Small & medium-sized mammals	MT	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs	$70,932 (2007 $); fencing $27-42/m (Huijser et al. 2008)	• Concrete box culverts, 1.2m w x 1.8m h x 27.5m l (Huijser et al. 2008) Openness ratio =0.08	M.P. Huijser, P. McGowen, A.P. Clevenger, and R. Ament. 2008. Wildlife-vehicle collision reduction study: best practices manual. Report to Congress. U.S. Department of Transportation, Federal Highway Administration. http://www.fhwa.dot.gov/environment/hconnect/wvc/index.htm Huijser, M.P., T.D.H. Allen, and W.Camel. 2010. US 93 Post-Construction Wildlife-Vehicle Collision and Wildlife Crossing Monitoring and Research on the Flathead Indian Reservation between Evaro and Polson, Montana. Annual Report. Montana Department of Transportation. http://www.mdt.mt.gov/research/docs/research_proj/wildlife_crossing/phaseii/annual_report_oct10.pdf

Solution	Species Group	Region	Mitigation Type	Timing Of Solution/ Evaluation	Impact Reduction Benefits	Cost Range	Design Considerations	Source(s)
CLASS 2: Medium ; >1.5 m (5 ft) to 2.4 x 2.4 m (8 ft)	Large carnivores, small & medium-sized mammals, reptiles & amphibians, aquatic animals, some flying animals	ALL	Minimization/ Compensation	Project Planning/ Alternatives Analysis	Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs			
	• Multi-species	FL	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• 2.4x2.4m submerged culverts 1.8x1.8m dry culverts Openness ratio <0.6 Concrete barrier wall 1.1 m h, 15.2 cm overhanging lip; wall runs 2.8 km e and 2.5 km w	Dodd, C.K., W.J. Barichivich, and L.L. Smith. 2005. Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biological Conservation 118: 619-631. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V5X-4BG8TPH-1&_user=10&_coverDate=08%2F31%2F2004&_rdoc=8&_fmt=high&_orig=browse&_origin=browse&_zone=rslt_list_item&_srch=doc-info(%23toc%235798%232004%23998819994%23498300%23FLA%23display%23Volume)&_cdi=5798&_sort=d&_docanchor=&_ct=15&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=c2e64825118ceaaf42f6be78c3ed58de&searchtype=a
CLASS 3: Large - 2.4 m x 6.1 m (8x20 ft) or 3.1 x 3.1 m (10x10ft) to open span bridges	Large herbivores, large carnivores, small & medium-sized mammals, reptiles & amphibians, aquatic animals, some flying animals	ALL	Minimization/ Compensation	Project Planning/ Alternatives Analysis	Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs			
	• Florida panther	FL	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Openness ratio = 1.2 2.4 m h x 7.3 m w, 14.6 m l	Land, D. and M. Lotz. 1996. Wildlife crossing designs and use by florida panthers and other wildlife in southwest Florida. In G.L. Evink, P.A. Garrett, D. Zeigler, and J. Berry, eds. Proceedings of the International Conf. on Wildlife Ecology and Transportation. June, 1996. Tallahassee, FL. FL DOT FL-ER 58-96. http://www.icoet.net/downloads/96paper26.pdf
	• Mountain lions; multi-species	Alberta	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs	$217,156-241,285 (2007 $) (4x7); $173,725 (2007 $) (2.5x3); IN CONSTRUC-TION - Lake Louise area 3-4m w and h $940,000 incl traffic control & detour; fenc-ing $69/m (2007 $) (Huijser et al. 2008)	• Metal culvert= 4m h x 7 m w, concrete box culvert= 2.5m h x 3m w; all crossings with dirt substrate (Phase 1&2) (Gloyne and Clevenger 2001) Metal culverts 3.5m h x 4.2m w x 96m l & 4m h x 7m w x 56 l, openness ratio =0.15-0.5 (Clevenger and Waltho 2000)	Gloyne, C.C. and A.P. Clevenger. 2001. Cougar (Puma concolor) use of wildlife crossing structures on the Trans-Canada highway in Banff National Park, Alberta. Wildlife Biology 7: 117-124. http://www.wildlifebiology.com/Downloads/Article/326/En/7_2_gloyne.pdf Clevenger, A.P. and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology 14(1): 47-56. M.P. Huijser, P. McGowen, A.P. Clevenger, and R. Ament. 2008. Wildlife-vehicle collision reduction study: best practices manual. Report to Congress. U.S. Department of Transportation, Federal Highway Administration. http://www.fhwa.dot.gov/environment/hconnect/wvc/index.htm
	• Black bear	FL	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Openness ratio- 1.22 2.4m h x 7.3 m w x 14.3 m l 3 m fence with barbed wire - 0.6 km to west, 1.1 km to east; bury fence	Roof, J. and J. Wooding. 1996. Evaluation of the S.R. 46 wildlife crossing in Lake County, Florida. 7 pp. In G.L. Evink, P. Garrett, D. Zeigler and J. Berry (eds.) Trends in Addressing Transportation Related Wildlife Mortality, proceedings of the transportation related wildlife mortality seminar. State of Florida Department of Transportation, Tallahassee, FL. FL-ER-58-96. http://www.icoet.net/downloads/96paper27.pdf

Solution	Species Group	Region	Mitigation Type	Timing Of Solution/ Evaluation	Impact Reduction Benefits	Cost Range	Design Considerations	Source(s)
Arch culvert - a culvert section forming an arc of a circle and having a natural substrate for its base (bottomless)								
Examples: CLASS 1: Small; ≤1.5 m (5 ft)	Some medium-sized mammals, aquatic animals, small mammals, reptiles & amphibians	ALL	Minimization/ Compensation	Project Planning/ Alternatives Analysis	Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs			
CLASS 2: Medium; >1.5 m (5 ft) to 2.4 x 2.4 m (8 ft)	Large carnivores, small & medium-sized mammals, reptiles & amphibians, aquatic animals, some flying animals	ALL	Minimization/ Compensation	Project Planning/ Alternatives Analysis	Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs			
CLASS 3: Large - 2.4 m x 6.1 m (8x20 ft) or 3.1 x 3.1 m (10x10ft) to open span bridges	Large herbivores, large carnivores, small & medium-sized mammals, reptiles & amphibians, aquatic animals, some flying animals	ALL	Minimization/ Compensation	Project Planning/ Alternatives Analysis	Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs			
	• Some large herbivores, carnivores, small & medium-sized mammals	MT	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs	$223,076 (2007 $); fencing $27-42/m (Huijser et al. 2008)	• Metal arch underpass (Huijser et al. 2008) 7-8m w x 5m h x 18.3-21.9 l (Huijser et al. 2008) Openness ratio = 1.6-1.9 (Huijser et al. 2008)	M.P. Huijser, P. McGowen, A.P. Clevenger, and R. Ament. 2008. Wildlife-vehicle collision reduction study: best practices manual. Report to Congress. U.S. Department of Transportation, Federal Highway Administration. http://www.fhwa.dot.gov/environment/hconnect/wvc/index.htm Huijser, M.P., T.D.H. Allen, and W.Camel. 2010. US 93 Post-Construction Wildlife-Vehicle Collision and Wildlife Crossing Monitoring and Research on the Flathead Indian Reservation between Evaro and Polson, Montana. Annual Report. Montana Department of Transportation. http://www.mdt.mt.gov/research/docs/research_proj/wildlife_crossing/phaseii/annual_report_oct10.pdf
Round/elliptical culvert - a culvert unbroken (entire in cross-section								
Examples: CLASS 1: Small; ≤1.5 m (5 ft)	Some medium-sized mammals, aquatic animals, small mammals, reptiles & amphibians	ALL	Minimization/ Compensation	Project Planning/ Alternatives Analysis	Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs			
	• Herps/sm mammals	Ontario	Minimizaton/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs	Migration study - $71,000; 5 amphibian tunnels = $360,000; monitoring - $14,500/year	• Round pipes: two concrete 1.2m diameter, two corrugated steel 1.2m diameter One 1m x 1.7m elliptical concrete Openness ratio = <0.6 (0.04-0.05)	Gartshore, R. G., M. Purchase, R.I. Rook,and L. Scott. Bayview Avenue Extension, Richmond Hill, Ontario, Canada Habitat Creation and Wildlife Crossings in a Contenious Environmental Setting: A Case Study (September 2005). Pages 55-76 IN Proceedings of the 2005 International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Paul Garrett, and K.P. McDermott. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University, 2006. http://www.icoet.net/ICOET_2005/proceedings/2005ICOETProceedingWeb.pdf

Solution	Species Group	Region	Mitigation Type	Timing Of Solution/ Evaluation	Impact Reduction Benefits	Cost Range	Design Considerations	Source(s)
	• Herps, small mammals	FL	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Round 0.9m culverts Openness ratio <0.6 Concrete barrier wall 1.1 m h, 15.2 cm overhanging lip; wall runs 2.8 km e and 2.5 km w	Dodd, C.K., W.J. Barichivich, and L.L. Smith. 2005. Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biological Conservation 118: 619-631. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V5X-4BG8TPH-1&_user=10&_coverDate=08%2F31%2F2004&_rdoc=8&_fmt=high&_orig=browse&_origin=browse&_zone=rslt_list_item&_srch=doc-nfo(%23toc%235798%232004%2399881999 4%23498300%23FLA%23display%23Volume)&_cdi=5798&_sort=d&_docanchor=&_ct=15&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=c2e64825118ceaaf42f6be78c3ed58de&searchtype=a
	• Small mammals	Alberta	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• 0.3 m dia metal drainage culverts Vegetative cover important	McDonald, W. and St Clair, C. C. (2004), Elements that promote highway crossing structure use by small mammals in Banff National Park. Journal of Applied Ecology, 41: 82–93. http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2004.00877.x/full
	• Red-sided garter snake	Manitoba	Minimization		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs		• Drift fencing Pipes 6-12 inches; 20 cm polymer concrete channel covered by slotted iron gate	Carcnet website http://www.carcnet.ca/english/tunnels/snake_mortality.php
CLASS 2: Medium; >1.5 m (5 ft) to 2.4 x 2.4 m (8 ft)	Large carnivores, small & medium-sized mammals, reptiles & amphibians, aquatic animals, some flying animals	ALL	Minimization/ Compensation	Project Planning/ Alternatives Analysis	Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs			
	• Bats	Wales	Minimization		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs	Bat tunnel installation = $180,000 (unsure if per tunnel or total)	• 2.2 m and 1.8 m - diameter corrugated steel ellipitcal culverts installed on flight path/hedgerow lines Funnel leading to tunnels was planted to help continue hedgerow corridor effect	Wray, S., D. Wells., W. Cresswell, and H. Walker. Design, Installation, and Monitoring of Safe Crossing Points for Bats on a New Highway Scheme in Wales. Pages 369-379 IN Proceedings of the 2005 International Conference on Ecology and Transportation, edited by C. Leroy Irwin, Paul Garrett, and K.P. McDermott. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University, 2006. http://www.icoet.net/ICOET_2005/proceedings/2005ICOETProceedingWeb.pdf
	• Some large herbivores, carnivores, small & medium-sized mammals	MT	Minimization/ Compensation		Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs	$70,932 (2007 $); fencing $27-42/m (Huijser et al. 2008)	• Elliptical culvert; 2m w x 1.5m h x 27.5m l (Huijser et al. 2008) Openness ratio =0.11 (Huijser et al. 2008)	M.P. Huijser, P. McGowen, A.P. Clevenger, and R. Ament. 2008. Wildlife-vehicle collision reduction study: best practices manual. Report to Congress. U.S. Department of Transportation, Federal Highway Administration. http://www.fhwa.dot.gov/environment/hconnect/wvc/index.htm Huijser, M.P., T.D.H. Allen, and W.Camel. 2010. US 93 Post-Construction Wildlife-Vehicle Collision and Wildlife Crossing Monitoring and Research on the Flathead Indian Reservation between Evaro and Polson, Montana. Annual Report. Montana Department of Transportation. http://www.mdt.mt.gov/research/docs/research_proj/wildlife_crossing/phaseii/annual_report_oct10.pdf
CLASS 3: Large - 2.4 m x 6.1 m (8x20 ft) or 3.1 x 3.1 m (10x10ft) to open span bridges	Large herbivores, large carnivores, small & medium-sized mammals, reptiles & amphibians, aquatic animals, some flying animals	ALL	Minimization/ Compensation	Project Planning/ Alternatives Analysis	Maintain connectivity between core habitats; maintain biodiversity; reduce WVCs			

Solution	Species Group	Region	Mitigation Type	Timing Of Solution/ Evaluation	Impact Reduction Benefits	Cost Range	Design Considerations	Source(s)
At-grade crossing: designated areas for wildlife to cross the roadway								
At-grade crossing	Large herbivores, reptiles & amphibians	ALL	Minimization		Reduce WVCs			
Examples:	• Mule deer	UT	Minimization	n/a	Reduce WVCs	4-lane crosswalk - $28,000/2-lane crosswalk =$15,000; fencing	• 2.3 m high fence 1 m fence at funnel Cattle guard lines on road surface	Lehnert, M.E. and J.A. Bissonette. 1997. Effectiveness of highway crosswalk structures at reducing deer-vehicle collisions. Wildlife Society Bulletin 25(4):809-818. http://www.jstor.org/pss/3783727
	• Mule deer	WY	Minimization	n/a	Reduce WVCs	Utilized a deer-sensing warning system	• Warning signs 300 m e & w of migratory route crossing 2.4 m high fence	Gordon, K.M., M.C. McKinstry, and S.H. Anderson. 2004. Motorist response to a deer-sensing warning system. Wildlfie Society Bulletin 32(2): 565-573. http://www.jstor.org/pss/3784997
	• Mule deer	West US	Minimization	n/a	Reduce WVCs	Temporary/seasonal warning signs; 6.5 -km strech of rd - $1,740 (lg signs=$400; small signs=$90; lights=$40)	• Signs at mile intervals in migration corridors	Sullivan, T.L., A.F. Williams, T.A. Messmer, L.A. Hellings, S.Y. Kyrychenko. 2004. Effectiveness of temporary warning signs in reducing deer-vehicle collisions during mule deer migrations. Wildlife Society Bulletin 32(3): 907-915. http://www.jstor.org/pss/3784815
	• Amphibians	ME	Minimization	n/a	Reduce WVCs	Temporary/seasonal warning signs	• Use standard roadway sign material Signs deployed seasonally to avoid “sign fatigue”	Maine Department of Inland Fisheries and Wildlife http://www.maine.gov/ifw/atv_snowmobile_watercraft/news_events/pressreleases/2009/07-10a-09.htm
	• Ungulates	All	Minimization	n/a	Reduce WVCs	Animal detection system; cost- $9,000 - 350,000; Cost of installation: $3,000 - 60,000	• Overview of implemented systems throughout North America/Europe	Huijser, M.P. and P.T. McGowen. 2004. Overview of animal detection and animal warning systems in North America and Europe. IN: Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. Irwin CL, Garrett P, McDermott KP. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 368-382. http://escholarship.org/uc/item/2cc2s81w
RETROFIT STRUCTURE - modify an existing structure or roadway corridor to better facilitate wildlife passage over, under or across								
Add ROW fencing to direct wildlife towards an existing structure								
Examples:	• Moose	Quebec	Minimization		Reduce WVCs; maintain access between core habitats	Approx. $617,000; maintenance Approx: $12,780	• Bridge underpass w/1.5 m high electric fence Openness ratio of existing bridge underpass = 4.87 (23 l x 16 w x 7 h) Also included an at-grade crossing	LeBlond, M., C. Dussault, J.P. Ouellet, M. Poulin, R. Courtois, and J. Fortin. 2007. Electric Fencing as a Measure to Reduce Moose-Vehicle Collisions. Journal of Wildlife Management 71 (5): 1695-1703 http://www.jstor.org/pss/4496252
	• Desert Tortoise	CA	Minimization		Reduce WVCs; maintain access along corridor		• 0.9-1.5 m diameter corrugated steel pipe 1.4m diameter concrete, 3-3.6 x 1.8-3m concrete box culverts Openness ratio = <0.6 24 km long fence, 45 cm high, buried, mesh/ hardware cloth	Boarman, W. I. and M. Sazaki. 1996. Highway Mortality in Desert Tortoises and Small Vertebrates: Success of Barrier Fences and Culverts. Pp. 169-173 In G.L. Evink, P. Garrett, D. Zeigler and J. Berry (eds.) Trends in Addressing Transportation Related Wildlife Mortality, Proceedings of the Transportation Related Wildlife Mortality Seminar. State of Florida Department of Transportation, Tallahassee, Florida. FL - ER - 58 - 96 Discussed IN : http://fishandgame.idaho.gov/cms/wildlife/manage_issues/collision/amphi-bRep.pdf
	• Turtle	NY	Minimization	Project Planning Post-construction	Reduce WVCs; maintain access between core habitats	$15,250 for 2000 meters of fencing	• 50 x 100mm 12 ga. PVC coated fencing or mesh Platic UV resistent cable ties	Langen, Tom and John Falge. 2011 Design Considerations, Construction and Effectiveness of Fencing for Turtles. : Northern New York State Highway Traspostation Case Studies. New York State Wetlands Forum. April 2011.
	• Herps	FL	Minimization	n/a	Maintain access between core habitats	Low (until permanent design can be implemented)	• 0.6 m temporary erosion control fence, buried 20 cm (0.4m above ground) Metal drainage culvert -3.5 m diameter x 46.6 m long Openness - 0.2	Aresco, M.J. 2005. Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a North Florida lake. Journal of Wildlife Management 69 (2): 549-560. http://www.jstor.org/stable/3803725
	• Lg herbivores	MT	Minimization/ Compensation	Project Planning	Reduce WVCs	Estimated costs from Huijser et al 2008 - jumpouts = $6,425-13,241; wildlife guards - $30,840	• Bridge underpass w/ 8’ fence w/ jumpouts (6-8’h) & cattle guards at fence ends (Craighead et al. 2010)	Craighead, L. A. Craighead, and L. Oechsli. 2010. Bozeman Pass Post-Fencing Wildlife Monitoring Project. Montana Department of Transportation. ftp://161.7.16.40/research/OTHER/BOZEMAN_PASS/FINAL_REPORT-10-18-10.DOC. M.P. Huijser, P. McGowen, A.P. Clevenger, and R. Ament. 2008. Wildlife-vehicle collision reduction study: best practices manual. Report to Congress. U.S. Department of Transportation, Federal Highway Administration. http://www.fhwa.dot.gov/environment/hconnect/wvc/index.htm

Solution	Species Group	Region	Mitigation Type	Timing Of Solution/ Evaluation	Impact Reduction Benefits	Cost Range	Design Considerations	Source(s)
Retrofit underpass structure with ledges or pathways to facilitate passage								
Examples:	• Mountain lions	CA	Minimization/ Compensation	Post-construction	Maintain access between core habitats	$1.4-1.6 million (revegetation/fence reconfig)	• Bridge underpass, pavement removal, re-vegetation $53 million (land acquisition) to restore patches on either side of crossing	Koelle, Alexandra. Cougar Corridors: Restoring the Missing Link in California's Chino Hills. The Road-RIPorter - Quarterly Newsletter of Wildlands Center for Preventing Roads. Spring 2003. Vol 8. www.wildlandscpr.org http://www.wildlandscpr.org/files/uploads/RIPorter/rr_v8-1.pdf
	• Bobcats/ ocelots	TX	Minimization	Project Planning	Maintain access between core habitats		• Box culverts modified with "catwalks" - 18- x 12- inch concrete elevated walkways through the length of culvert and along wing walls.	Hewitt, D.G., A. Cain, V. Tuovila, D. Shindle, and M.E. Tewes. 1998. Impacts of an expanded highway on ocelots and bobcats in southern Texas and their preferences for highway crossings. Page 126-134, In Evink, G.L., et al eds. Proceedings of the International Conference on Wildlife Ecology and Transportation. http://www.icoet.net/downloads/98paper16.pdf
	• Small mammals	MT	Minimization/ Compensation	Project Planning	Maintain access between core habitats		• Round culverts - added 25" w shelves to culverts & vole tube Culverts 3 & 4' diameter (material unknown) Added vole tube (similar to gutter drainage pipe)	Foresman KR. 2004. Small mammal use of modified culverts on the Lolo South project of Western Montana - an update. IN: Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. Irwin CL, Garrett P, McDermott KP. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 342-343. http://escholarship.org/uc/item/7cw8043j
	• Small mammals	CO	Minimization/ Compensation	Project Planning	Maintain access along corridor		• Wooden ledges (2.54 x 15.24 cm cedar planks, 1.83 m l attached end to end), glued blocks of wood (5x10.16cm, 30.48 cm l) to culvert wall at 1.83 m intervals with Liquid Nails Ramps same size as planks, attached at ends All culverts openness ratio <0.6	Meaney, C., M. Bakeman, M. Reed-Eckert, and E. Wostl. 2007. Effectiveness of ledges in culverts for small mammal passage. Report No. CDOT-2007-9. Final Report. Colorado Department of Transportation, Denver, CO. http://www.coloradodot.info/programs/research/pdfs/2007/smallmammal.pdf
Alter landscape: designing and managing habitats alongside roads with the aim of reducing collisions and/or facilitating safe passage across the roadway								
Examples:	• Pygmy owl	Mexico/ SW	Minimization	Project Planning	Reduce WVCs		• Plant/maintain lg trees close to roadway and in median Drop road surface below surrounding elevations	Flesch, A.D. and R.J. Steidl. 2007. Association Between Roadways and Cactus Ferruginous Pygmy-owls in Northern Sonora, Mexico. Final Report for Arizona Department of Transportation, Environmental Planning Group, Tuscon, AZ. http://aaronflesch.com/Publications/Reports/Flesch%20and%20Steidl.%20%202007.%20%20Pygmy-owls%20and%20roadways%20Final%20ADOT%20Report.pdf
	• Royal terns	FL	Minimization	Project Planning	Reduce WVCs	10-day pole installation = $5,900 (materials + labor) (1994 $)	• Installed 122, 3m long silver-colored metal poles, 5.1 cm diameter, attached vertically, 3.7m apart on both sides of bridge	Bard, A.M, H.T. Smith, E.D. Egensteiner, R. Mulholland, T.V. Harber, G.W. Heath, W.J.B. Miller, and J.S. Weske. 2002. A simple structural method to reduce road-kills of royal terns at bridge sites. Wildlife Society Bulletin 30(2):603-605. http://www.jstor.org/pss/3784522