PASSAGE ENHANCEMENT TOOLBOX FOR IMPROVING PERMEABILITY OF EXISTING STRUCTURES FOR TERRESTRIAL WILDLIFE

PASSAGE ENHANCEMENT SOLUTION	SPECIES MOVEMENT GUILDS	STRUCTURE FUNCTIONAL CLASS	PHOTOS & LINKS	NOTES & REFERENCES
Remove Obstacles to Wildlife Passage				
Remove obstruction or barrier at one or both structure entrances, inside the structure, or in the approaches to the structure (e.g.,cattle fencing across structure entrances; trash or debris).	Low Mobility Small Fauna Moderate Mobility Small Fauna Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	ALL	CO US 13 culvert	
Clear debris and install sediment traps and/or regularly maintain to prevent structure from being blocked, filled or clogged.	Low Mobility Small Fauna Moderate Mobility Small Fauna Adaptive High Mobility Fauna	Class 1, 2	CO I70 sediment-filled culvert	Yanes, M., J.M. Velasco, and F. Suárez. 1995. Permeability of roads and railways to vertebrates: the importance of culverts. Biological Conservation 71:217-222.
Keep culvert enterances clear of heavy vegetation growth that could block wildlife passage.		Class 1, 2, 3		Clevenger, A.P., B. Chruszcz, and K. Gunson. 2001. Drainage culverts as habitat linkages and factors affecting passage by mammals. Journal or Applied Ecology 38:1340-1349.
Facilitate Movement and Create Pathways				
Add a dry, natural pathway through structure, on both sides of waterway if a stream or river is present.	Adaptive Ungulates Very High Openness Fauna	Class 3, 4, 5	MN crossing with natural pathways UT dry pathway under bridge with deer AZ desert tortoise culvert ramp	Forman, R. T., Sperling, D., Bissonette, J. A., Clevenger, A. P., Cutshall, C. D., Dale, V. H., et al. 2003. Mitigation for wildlife. Pages 139-167 in: Road Ecology: Science and Solutions. Island Press, Washington, D.C.
Minimize or cover riprap on side-slopes with dirt to create a dry, smooth pathway.	Adaptive Ungulates Very High Openness Fauna	Class 3, 4, 5	CA I80 path through riprap under bridge	

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Install interlocking brick to support slopes instead of riprap toopen up a pathway and facilitate wildlife passage.	Adaptive Ungulates Very High Openness Fauna	Class 3, 4, 5	MN wildlife path	
Install a raised shelf through water-filled culverts to provide a dry pathway for small mammals; Include a shelf tube to provide protective cover for voles.	Low Mobility Small Fauna	Class 1, 2	MT US93 wildlife shelf	
			MT US 93 wildlife shelf and vole tube	
Add baffles to culvert floor to retain sediment on artifical culvert floor (where water flows occasionally through the culvert).	Moderate Mobility Small Fauna Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Class 1, 2, 3	NW I40 Tijeras Canyon culvert baffles	
			CO I70 Dowds Junction baffles	
Install woody debris (e.g., down logs) through a structure for small species requiring cover from predators.	Low Mobility Small Fauna Moderate Mobility Small Fauna	Class 2, 3, 4, 5	European Overpass with woody debris	Ehinger, W., P. Garvey-Darda, R. Gersib, K. Halupka, P. McQueary, W. Meyer, R. Schanz and P. Wagner. 2006. Interstate 90 Snoqualmie Pass East Mitigation Development Team: Recommendation package. Submitted to: U.S. Department of Transportation, Federal Highway Administration and Washington State Department of Transportation.
			VT Bennington Bypass logs and stumps	
Maintain natural streambanks through the structure.	Low Mobility Small Fauna Moderate Mobility Small Fauna (riparian species)	Class 2, 3, 4	MN crossing with natural pathways	
Add a strip of natural substrate and vegetation along one or both sides of a road through a structure.	Low Mobility Small Fauna Moderate Mobility Small Fauna	Class 3	UT I80 natural pathway next to road	
			European road with natural shoulders	

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Where scour has resulted in perched culverts, build up scour resistant materials to create a navigable pathway into the culvert. Use natural materials; if riprap is used to build up the entrance pathway, it should be covered with natural substrate.	Low Mobility Small Fauna Moderate Mobility Small Fauna	Class 1, 2,	Idaho perched culverts before retrofit	
Rerrange substrate material around inlet/outlet of small culverts to allow greater visibility through structures.	Low Mobility Small Fauna Moderate Mobility Small Fauna	Class 1		
Add salamander ramps at curbs.	Low Mobility Small Fauna			
Add grates to existing culverts to allow light/moisture/temperature penetration into the culvert.	Low Mobility Small Fauna	Class 1, 6	FL culvert grate	Carr, T., R. Dacanay, K. Drake, C. Everson, A. Sperry and K. Sullivan. 2003. Wildlife Crossings: Rethinking Road Design to Improve Safety and Reconnect Habitat. Portland State University Planning Workshop, Prepared for Metro. 111 pp.
Modify existing trenched drains to allow animals to enter.	Low Mobility Small Fauna	Class 6		Bank, F.G., C.L. Irwin, G.L. Evink, M.E. Gray, S. Hagood, J.R. Kinar, A. Levy, D. Paulson, B. Ruediger, and R.M. Sauvajot. 2002. Wildlife Habitat Connectivity Across European Highways. Federal Highway Administration. Alexandria, VA. URL: http://international.fhwa.dot.gov/wildlife_web.htm
For Multi-chambered structures with waterflow, divert waterflow so that one chamber remains dry for terrestrial wildlife.	Moderate Mobility Small Fauna Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Class 2, 3, 4	CO I25 multichamber bridge	
Promote waterflow through culverts to prevent standing water from inhibiting passage through a culvert or detering entry into the culvert.	Moderate Mobility Small Fauna Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Class 1, 2, 3	CO I-70 pool obstructing culvert outlet	
Prevent polluting agents and road sediment from being flushed through culverts.	Low Mobility Small Fauna Moderate Mobility Small Fauna	Class 1, 6		
Reduce Intimidation				
Replace steep abutment slopes or walls with natural 2:1 slopes.	Adaptive Ungulates Very High Openness Fauna	Class 2, 3, 4		Dodd, N.L., J.W. Gagnon, A.L. Manzo, and R.E. Scheinsburg. 2007. Video surveillance to assess highway underpass use by elk in Arizona. Journal of Wildlife Management 71(2):637-645.
Remove fill predator perches - ledges or places where prey species may be fearful of unseen predators.	Adaptive Ungulates Very High Openness Fauna	Class 2, 3, 4	AZ US260 bridge with ledge	Little, S.J., R.G. Harcour, A.P. Clevenger. 2002. Do wildlife passages act as prey-traps? Biological Conservation 107:135-145.

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Add median skylights or openings. [This measure is not appropriate for all culvert situations. Avoid creating very high contrast conditions inside the culvert; Avoid where there is a narrow median that would result in a large increase in traffic noise inside the culvert; Avoid allowing precipitation to enter the culvert where winter temperatures could cause the creation of ice mounds inside the culvert, thereby inhibiting wildlife passage].	Adaptive Ungulates Very High Openness Fauna	Class 2	CO I70 culvert skylight	Reed, D.F., T.N.Woodard, T.M. Pojar. 1975. Behavioral Response of Mule Deer to a Highway Underpass. J. Wild Manage. 39(2):361-367.
			UT I70 culvert skylight	
Avoid/remove highway lighting near structure entrances.	ALL	ALL		Jackson, S. D. (2000). Overview of Transportation Impacts on Wildlife Movement. Wildlife and Highways: Seeking Solutions to an ecological and Socio-economic Dilemma. T. A. Messmer and B. West, The Wildlife Society.
Implement measures to reduce traffic noise inside culvert and/or at structure entrances (e.g., concrete shoulder barriers placed above the structure)	ALL	ALL		Jackson, S. D. (2000). Overview of Transportation Impacts on Wildlife Movement. Wildlife and Highways: Seeking Solutions to an ecological and Socio-economic Dilemma. T. A. Messmer and B. West, The Wildlife Society.
To the extent possible, avoid laying trails or other human access through crossing structures. Where trails do pass through a structure, separate human trails from wildlife pathways through the structure.	High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Class 2, 3, 4, 5	Netherlands greenstrip on overpass I-70 bridge and bike path	Hartmann, M. (2003). Evaluation of Wildlife Crossing Structures: Their Use and Effectiveness.
Install signs near crossing structures or where trails cross through structures to limit human activity in and around wildlife crossings [Avoid drawing attention to unobtrusive crossing structures with unnecessary signage]	ALL	ALL	CO US40 wildlife crossing structure sign	Clevenger, A. and N. Waltho. 2005. Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biological Conservation 121:453-464.
Install barriers (e.g., large boulders) to prevent motorized travel through crossing structures.	High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Class 3, 4, 5		
Enhance Structure Approaches				
Enhance/maintain native vegetation cover in front of structure entrances.	ALL	ALL	FL bear crossing with tree seedlings planted	Ng, S., J. Dole, R. Sauvajot, S. Riley, and T. Valone. 2004. Use of highway undercrossings by wildlife in southern California. Biological Conservation 1115:499-507.

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Thin heavy vegetation that may obstruct wildlife passage at structure entrances.	Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Class 2, 3	FL vegetation blocking culvert enterance	Maintain a balance between enough cover for prey species to feel safe entering a culvert, but not so much that animals cannot enter or have good visibility into and through the culvert.
Avoid the use of herbicides around structure entrances.	Low Mobility Small Fauna	ALL		
Plant bushes in the median to provide better cover and insulation from highway traffic noise and lights.	High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	Wherever open median is present	AZ US260 tree plantings in median	
Avoid the use of erosion netting in landscaping around crossing structures, which may ensnare snakes.	Moderate Mobility Small Fauna	ALL	MN snake ensnared in netting	
Convert cattle fencing near structure approaches to wildlife-friendly rail fencing to allow young to pass through to access structures.	Adaptive Ungulates Very High Openness Fauna	Class 2, 3, 4	UT I-70 wildlife friendly cattle fence in front of new crossing culverts	
Fencing and Barriers				
Add wildlife fencing and/or guide walls to existing suitable structures - do not install extensive fencing where there are no suitable crossing structures.	ALL - type, design & height of fencing or guide wall depends on species (see notes)	N/A	MT US93 crossing, fence and escape ramp FL Paynes Prairie wall and box culvert Toronto turtle fencing	For guidance on different types of wildlife fencing, see: http://www.azdot.gov/highways/EPG/EPG_Common/PDF/Technical/Wildlife_Connectivity/Wildlife_Funnel_Fencing/Wildlife_Funnel_Fencing_Summary.pdf
Modify existing right-of way fencing by adding height to convert it to wildlife fencing.	High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	N/A	UT at junction of standard fence and wildlife fence AZ US260 fence height extension	FHWA. Keeping it Simple - Arizona. http://www.fhwa.dot.gov/environment/wildlifeprotection
Angle fence ends away from roadway to prevent 'end-arounds'.	ALL		ID US 95 rocks at fence end	Clevenger, A. P., B. Chruszcz, and K. E. Gunson. 2001. Highway mitigation fencing reduces wildlife–vehicle collisions. Wildlife Society.
Do not end fencing in good wildlife habitat; end in transitional areas (e.g., steep terrain, change in habitat or land use).				Hardy, A.R., J. Fuller, M.P. Huijser, A. Kociolek and M. Evans. 2006. Evaluation of wildlife crossing structures and fencing on US Highway 93, Evaro to Polson. Phase I: Preconstruction data collection and finalization of evaluation plan. Final report. Western Transportation Institute, College of Engineering, Montana State University.

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Place large boulders at fence ends to prevent animals at-grade crossings at fence ends.	Adaptive Ungulates Very High Openness Fauna	N/A		Clevenger, A.P., B. Chruszcz, K. Gunson, K. and M. Brumfit. 2002. Highway mitigation monitoring: Three Sisters Parkway interchange. Final report, August 1999 - July 2002. Prepared for Alberta Sustainable Resource Development, Canmore, Alberta, Canada.
Install wildlife fencing across a median to adjacent structures.	ALL	N/A	AZ US260 median fencing	
Install escape ramps along fenced sections.	Adaptive Ungulates Very High Openness Fauna	N/A	WY escape ramp with perpendicular fencing	Bissonette, J.A. and M. Hammer. 2000. Effectiveness of earthen ramps in reducing big game highway mortality in Utah: Final Report. Utah Cooperative Fish and Wildlife Research Unit Report Series 2000 (1): 1-29. http://www.azdot.gov/highways/EPG/EPG_Common/PDF/Technical/Wildlife_Connectivity/Wildlife_Connectivity/Description_of_Wildlife_Escape_Measures.pdf
			Alberta, Canada flat jump out	
Replace one-way gates with escape ramps.	Adaptive Ungulates Very High Openness Fauna	N/A	CO US160 rusted one-way deer gate	Bissonette, J.A. and M. Hammer. 2000. Effectiveness of earthen ramps in reducing big game highway mortality in Utah: Final Report. Utah Cooperative Fish and Wildlife Research Unit Report Series 2000 (1): 1-29.
Maintain fencing to prevent gaps in fence.	Adaptive Ungulates Very High Openness Fauna	N/A	UT hole in fence	
Install Electromat at gaps in fencing, such as highway on/off ramps, driveways.	Adaptive Ungulates Very High Openness Fauna	N/A	UT US 6 Electromat	http://www.electrobraid.com/wildlife/highway_fence.html Dodd, N. and J. Wise. The Nation's Most Advanced Game Crossing System. IMSA Journal 45(2); T.W. Seamans, Z.J. Patton, and K.C. VerCauteren. ElectroBraid Fencing for Use as a Deer Barrier. http://www.itre.ncsu.edu/cte/icoet
			Tijeras Canyon NM ElectroBraid	
Construct crosswalk at controlled gap in fencing to allow animals to cross at-grade.	Adaptive Ungulates Very High Openness Fauna	N/A		Gagnon, J.W., N.L. Dodd, S.C. Sprague, K. Ogren, and R.E. Schwuinsburg. 2010. Preacher Canyon Fence and Crosswalk Enhancement Project Evaluation. Report No. JPA 04-088. Arizona Department of Transportation, Phoeniz, AZ. http://www.azgfd.gov/w_c/StateRoute_260_Elk_Crosswalk.shtml

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Install shoulder or median barriers with scuppers (at least 25cm high and 100cm wide) every 5th barrier to faciliate small animal passage through the barrier.	Moderate Mobility Small Fauna	N/A	Median barrier passage for small mammals	Clevenger, A.P. and A.V. Kociolek. 2006. Highway median impacts on wildlife movement and mortality: state of the practice survey and gap analysis. Report No. F/CA/MI-2006/09. California Department of Transportation, Sacramento, CA.
Arrange shoulder or median barriers with intermittent gaps to faciliate wildlife passage at-grade.	Moderate Mobility Small Fauna Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna		CA median gap	Clevenger, A.P. and A.V. Kociolek. 2006. Highway median impacts on wildlife movement and mortality: state of the practice survey and gap analysis. Report No. F/CA/MI-2006/09. California Department of Transportation, Sacramento, CA.
Replace concrete shoulder and median barriers with cable median barriers where it is desirable to facilitate at-grade wildlife passage [cable barriers are considered more permeable for all species guilds than box-beam barriers, though more research is needed].	Moderate Mobility Small Fauna Adaptive High Mobility Fauna High Openness High Mobility Carnivores Adaptive Ungulates Very High Openness Fauna	N/A	UT US 189 cable median barrier	Clevenger, A.P. and A.V. Kociolek. 2006. Highway median impacts on wildlife movement and mortality: state of the practice survey and gap analysis. Report No. F/CA/MI-2006/09. California Department of Transportation, Sacramento, CA.
			CO I70 cable shoulder barrier	
Install double cattle-guards and convert existing flat-bar cattle guards with round bars at controlled gaps in wildlife fencing, e.g., driveways or county roads. [May not be effective for all species]	Adaptive Ungulates Very High Openness Fauna	N/A	WY double cattle guard	Hardy, A.R., J. Fuller, M.P. Huijser, A. Kociolek and M. Evans. 2006. Evaluation of wildlife crossing structures and fencing on US Highway 93, Evaro to Polson. Phase I: Preconstruction data collection and finalization of evaluation plan. Final report. Western Transportation Institute, College of Engineering, Montana State University.
			US91 wildlife guard	
Avoid gaps in wildlife fencing or walls.	ALL	N/A	WY gap between fence and wildlife guard	
			CO US550 bike path gap in wildlife fence	
Add or Adjust Structural Features				
Fix perched outlets to allow access into culvert.	Moderate Mobility Small Fauna	Class 1	CO US13 perched culvert	
Add a gutter pipe for small mammals.	Moderate Mobility Small Fauna	Class 1		Foresman, K.R. 2004. The effects of highways on fragmentation of small mammal populations and modifications of crossing structures to mitigate such impacts. Final Report. FHWA/MT-04-005/8161.
Bore new dry culverts adjacent to innundated culverts to promote wildlife passage through drainages.	Low Mobility Small Fauna Moderate Mobility Small Fauna	Class 1		

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Add bat boxes.	Aerial Fauna (bats)	Classes 3, 4, 5		
Install poles placed on bridge edges to help birds perceive the barrier and avoid colliding with vehicles.	Aerial Fauna	Animal-vehicle collision prevention mechanisms at roadway bridges bisecting flyways	OK SH80 eagle perches	FHWA. Keeping it Simple - Oklahoma. http://www.fhwa.dot.gov/environment/wildlifeprotection
Install aerial bridges across highways between poles to facilitate arboreal crossings.	Arboreal Fauna	Class 6		NCDOT flying squirrel platforms Rope bridges over roads
Decommission old roads through a structure and restore natural landscape features to convert to a wildlife crossing.	ALL	Class 3	Coal Canyon, CA UT I-15 planned overpass decomission	