Recommendations for Significantly Enhancing Wildlife Connectivity under Five Interstate 40 Bridges Proposed for Replacement along the Pigeon River Gorge, North Carolina

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INTRODUCTION

Over the last decade, roads have been identified as a leading cause of habitat fragmentation and loss of connectivity for wildlife populations in North America (Beckman et al. 2010, Jackson and Fahrig 2011). In addition, wildlife vehicle collisions cause wildlife mortality (Fahrig and Rytwinski 2009, Trombulak and Fressell 2001) and increased risks to human safety (Bissonette et al. 2008, Huijser et al. 2009).

Interstate 40 in the Pigeon River Gorge (PRG) near the Tennessee-North Carolina border bisects Great Smoky Mountains National Park (Park) and Pisgah and Cherokee National Forests. This ecologically diverse and important region is home to a growing and dispersing elk population, a large and robust black bear population, and modest numbers of white-tailed deer. Due to the abundance of wildlife in the region, wildlife vehicle collisions are frequent. To protect both wildlife and roadway users, conservationists and federal/state wildlife resource and transportation agencies are seeking ways to alleviate these impacts and restore connectivity. Existing transportation structures (i.e., vehicle underpasses, bridges, and culverts) that cross perpendicularly under the interstate have the potential to safely pass wildlife but are limited since wildlife passage was generally not considered in construction (Gurrutxaga and Saura 2013). Retrofitting or modifying existing structures during replacement or repairs to promote use by wildlife can be cost-effective ways to reduce the barrier effect of roads (Smith et al 2015, Niemi et al. 2014, Ng et al. 2004) by making them more permeable to animal movements (Van der Ree et al. 2011), thus helping to maintain landscape connectivity and human safety (Huijser et al. 2009).

Modifications to structures to improve wildlife use can be highly dependent upon species-specific needs (Clevenger and Huijser 2011). Because elk, deer, and black bear vehicle collisions impact human safety along the interstate, and modifications to accommodate movement of these animals will also help facilitate safe crossing and connectivity for other wildlife species (Polak et al. 2018), our recommendations focus on improving structures for the passage of these larger mammals. We describe the ecological requirements and make recommendations on how modifications to 5 structures slated for replacement on I-40 would be advantageous to improve human safety and wildlife connectivity (Kintsch and Cramer 2011, Clevenger and Huijser 2011).

Target Species of highest concern with respect to Interstate 40 in the Pigeon River Gorge:

Elk (Cervus elaphus)

The elk population dispersing out of the Park and crossing the interstate pose a large threat to human safety given the animals' size and the severity of elk vehicle collisions. Elk have large area requirements and potential migratory behavior (Dodd et al. 2007a). The proximity of I-40 to the Cataloochee Valley in the Park (< 6.4 km), which is the epicenter of elk activity, puts dispersing animals in direct contact with this specific portion of the interstate where structures are to be replaced (Figure 1). Elk mortality has been reported at both the High Bridge (n=2) and Low Bridge (n=1) where White Oak Road crosses under I-40 (NCWRC biologists). The traffic-related mortality of elk in the region is likely impacting the slow growing population (personal communication Joe Yarkovich, NPS biologist). Costs associated with the average elk-vehicle

collision are extreme, estimated to be $17,483 by Huijser et al. 2009, and there is significant risk of human fatalities resulting from a high-speed collision with a near-thousand pound animal on the interstate. To facilitate successful crossing of underpasses by elk, a pathway free from road traffic on natural substrate (Smith et al. 2015, Kintsch and Cramer 2011), 7-10 m wide x 4 m high is recommended (Clevenger and Huijser 2011). The addition of 2.5 m high fencing to both exclude elk from the roadway and to funnel elk towards crossing structures would increase elk passage and reduce vehicle collisions (Gagnon et al. 2019, Dodd et al. 2007b, Ruediger et al. 2005).

White-tailed deer (Odocoileus virginianus)

White-tailed deer are also a safety concern for motorists (Bissonette et al. 2008). Though smaller in body size, they constitute the majority of wildlife vehicle collisions in the state of North Carolina (~16,000 in 2018). The estimated costs for the average deer-vehicle collision is $6,617 (Huijser et al. 2009). While deer in some urban regions show plasticity in their use of crossing structures, deer (like elk) generally require a large openness ratio and therefore recommendations for crossing structures and mitigation are similar: 7-10 m wide x 4 m high passage free from traffic with natural substrate and fencing (Dodd and Gagnon 2011, Ruediger et al. 2005).

Black bear (Ursus americanus)

The black bears in this region are especially impacted by I-40 due to their large population in the Park and their expansive home range requirements to accommodate large movements due to seasonal changes in food availability. Black bears require some cover and some openness to see through a passage and prefer less open structures (Clevenger and Waltho 2005). Given their similar size to elk and deer, black bears require similar structures 7-10 m wide x 4 m high, free from traffic with natural substrate and fencing (Dodd and Gagnon 2011, Ruediger et al. 2005).

RECOMMENDED STRUCTURE IMPROVEMENTS:

General Suggestions for NCDOT that apply across bridges:

1. If the potential cost for the recommended improvements we describe below would be a barrier to their implementation by NCDOT, please let us know. We are committed to working with NCDOT and the broader wildlife conservation community to advocate for funding to make these bridge replacements as wildlife-friendly as possible.

2. Ideally, any improvements to wildlife connectivity under the five Interstate 40 bridges planned for replacement would be paired with appropriate wildlife fencing along the highway to funnel large species to the bridge structures (Clevenger et al. 2001). This fencing should extend as far as possible along the highway to avoid creating fence-end effects - ideally the fencing would extend along the entire stretch of highway between potential wildlife crossing opportunities. Incorporating the use of the existing topography such as steep slopes and rock cuts into fencing placement would help to limit the amount of fencing used and facilitate movement in congruence with the landscape (Clevenger and Huijser 2011). If exclusion fencing is used, incorporating jump outs (escape ramps) for animals that enter the fenced right of way will have to be considered and incorporated into designs (See AZDOT-*Wildlife Escape Measures)*.

Even if wildlife fencing is outside the current scope of replacing the I-40 bridges, we ask that any necessary design elements be considered and added now such that it will be easier to

attach 2.5m chain link or wire fencing to the new bridges when they are completed and when funds for fencing become available. In other words, please make sure it will be easy to retrofit the newly replaced bridges with wildlife fencing in both directions to funnel animals to the appropriate spaces under Interstate 40.

3. For the bridges that have Interstate exit and entrance ramps associated with them, if those ramps will be re-worked or repaved as part of the bridge replacement process, please consider adding "cattle guard" type grates across the surface of the ramps at locations that would, when combined with substantial fencing described above, make it much less likely that deer and elk would make it onto the Interstate (Allen et al. 2013). The pairing of extra-wide cattle guards and fencing has been used with good success to prevent ungulate-vehicle collisions in western US states (Ruediger et al. 2005). Various guidelines have been developed for effective "wildlife guard" design, and these guidelines can be reported to NCDOT if the ramps will be part of the bridge replacement process (see Allen et al. 2013).

One interesting improvement on the standard cattleguard design would be to consider making the space under the cattleguard bars into a de facto crossing structure for salamanders and other small animals (the space under the guard bars or grid would need to be deep enough to accommodate small vertebrates). If such a dual purpose structure is in fact feasible, this would allow salamanders, snakes, turtles, and small mammals to cross safely under the entrance and exit ramps, while larger animals would be steered across the ramps into the wildlife-friendly spaces we are suggesting for each bridge (Andrews et al. 2015). Low concrete curbs could be used to steer small animals towards the wildlife guard crossing tunnels (Glista et al. 2009).

4. As recommended by Canadian highway engineer and wildlife road crossing expert Terry McGuire, the new bridge structures should be designed to minimize the generation of noise by vehicles passing over the bridge deck. Such noise can be a significant barrier to wildlife passage under high-traffic bridges such as the ones along Interstate 40. For example, the expansion joints used should be as robust as possible, to minimize noise and reduce bridge maintenance costs as well (Iglesias et al. 2011). The bridge decking surface should be as noise-reducing as possible, while still serving to shed water and providing enough friction to prevent hydroplaning. Solid concrete parapet walls should be used on the sides of the bridge to reduce noise transmission (and visual disturbance) to animals below (Van der Ree 2011).

5. Rip-rap should be used quite sparingly or avoided altogether on bridge embankments and along riparian zones, indeed anywhere where wildlife will be expected to move under the replacement bridges. A jumbled and steep rocky surface poses a significant movement barrier to many species of wildlife, particularly elk and deer. If rip-rap has to be used in a given space to stabilize sloped terrain, then a smooth and level "trail" should be built across the rip-rap, providing a stable natural surface treadway for elk and deer and other species to safely make it across the rocks and under the highway (Smith et al. 2015). This treadway should be at least 2 m wide (within the context of an even wider space under the bridge) and it should be designed to resist erosion to prevent the need for frequent maintenance.

Notes on Specific Bridges:

Pigeon River Bridge

The Pigeon River Bridge is a large, well-elevated span that nevertheless has limited current opportunities for terrestrial wildlife to pass underneath. On the north end of the bridge, there is an unfortunate constriction where the land surface under the bridge is steeply slanted up to the bottom edge of the highway, and only a narrow and quite steep gap exists between the bridge and the ground underneath (photo above, upper left).

This passageway is likely inadequate for elk and deer use and seems marginal for many other species - indeed it was difficult for humans to climb through that gap and down the slope under the highway. The same side of the bridge is further constrained by the steep rock cut or rock face where the land surface slopes into the river (photo above).

On the South end of the Pigeon River Bridge, there does not seem to be much existing room for wildlife passage either. However, NCDOT staff indicated an access road would be constructed under this end of the bridge to facilitate the bridge replacement process (photo below, far side of river).

Our Recommendations:
1. After the bridge replacement construction has finished, maintain the access road on the south side of the bridge as a passageway for terrestrial wildlife. Ideally this passageway would be closed to motor vehicles but maintained in a semi-open state for wildlife.
2. In the upper corner of the north end of the bridge, excavate the existing narrow gap in such a way as to create an 4m-high passageway for wildlife to enter underneath the bridge. It would also be necessary to smooth and contour the soil/rock surface from the excavation at that side of the highway down to the other side of highway, in order to create an easier pathway for elk and deer to navigate under the bridge. We suggest a 7-10 m wide by 4 m tall pathway under the north end of the bridge would be adequate for elk and most other species.

Fines Creek Road Underpass

The bridge where I-40 passes over Fines Creek Rd does not currently provide much room on either side of Fines Creek Rd for terrestrial wildlife to move underneath. The embankments under both ends of the bridge slope down steeply to the support columns/piers (photo above).

While the Fines Creek Rd bridge is not located in an area surrounded by substantial protected forests, it needs to be acknowledged that the fields, pastures, lawns, and even the revegetated portions of the White Oak landfill all provide excellent foraging habitat for elk and deer in this

region. Indeed, ongoing elk GPS collar studies (including our own project) reveal significant use of this area by elk, as shown in this photo showing the tracks of two elk near the highway.

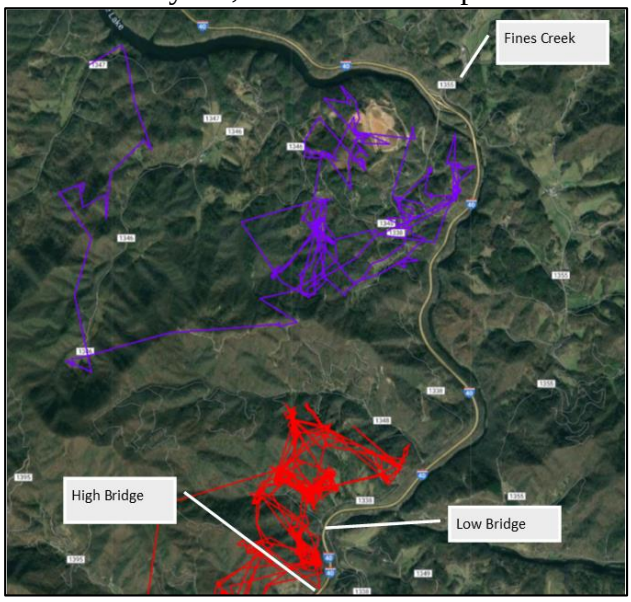


Figure 1. Elk movements (April-May 2019) from 2 GPS collared elk near the High Bridge, Low Bridge, and Fines Creek structures, I-40, Haywood County, NC.

This portion of the I-40 corridor also interferes with wildlife movement from the National Park to the significant acreage of protected conservation easement lands in the "Sandy Mush" area north of Canton, NC. Therefore, from the standpoint of preventing collisions between ungulates and motorists on I-40 it is important to maintain as many safe routes under the highway as possible in this area. Such routes would include wildlife passageways under the Fines Creek Rd bridge, through the Fines Creek culvert (already a substantial concrete structure), under the High and Low White Oak Rd bridges, and under the bridge where I-40 crosses over the Pigeon River.

Our Recommendations:

1. If possible, the best solution for wildlife connectivity would be to extend the length of the Fines Creek Rd bridge so as to provide a 7-10 m wide by 4 m tall extension space for animals to cross under the interstate, on one side or the other of Fines Creek Rd. The space would ideally be level and easy for elk and deer to traverse, and have a mix of native grass vegetation and bare dirt/fine gravel, depending on the level of sunlight reaching the ground to support the growth of plants. No rip-rap or large boulders should be used along the floor of the wildlife passageway.

Thus there would be one space under the bridge for cars and an adjacent space under the bridge (separated from the road by a row of support columns and potentially a tall fence as well) for wildlife. The side of Fines Creek Rd chosen for the wildlife passageway should be the one that provides the easiest access to the most gently-sloped natural habitats on either side of I-40. Given more time we would be happy to consult on this aspect of the design phase for the different bridges. Grassland vegetation appropriate for attracting elk and deer should be used to demarcate the likely pathway that those species would use to access the bridge extension.

2. Guardrails, curbs, and other impediments to animal movement should be removed or at least partly gapped or lowered in such a way as to promote wildlife movement from one side of the

relevant exit ramp on one side of I-40, to the far side of the other exit ramp on the other side of I-40. Even though elk, deer, and bear are capable of jumping over a typical metal guardrail, their use of the bridge extension would likely be enhanced if they did not have to make such exertions to cross under the highway. At the same time, care should be taken not to block the movement pathways for smaller species such as box turtles, snakes, and salamanders. High curbs or low solid walls should be avoided except as a means to funnel smaller species towards appropriate pathways under the bridge.

3. If NCDOT instead chooses to replace the Fines Creek bridge with a culvert structure of some kind, then we request that a second culvert (ideal minimum dimensions 7-10 m wide by 4 m tall) be provided for wildlife, sharing one wall with the road culvert. Again, the side for the wildlife culvert placement should be chosen as described above, and appropriate vegetation (and eventually fencing) provided to guide animals to use the correct culvert.

High Bridge over White Oak Road

This large bridge appears to provide substantial existing amounts of wildlife connectivity along Jonathan Creek, especially in the riparian area on the south end of the bridge (photo above).

Elk using the north western end of the High Bridge to cross under I-40 (April 22, 2019).

The embankment under the north end of the High Bridge is steeply sloped (photo above, left), but we have records of elk using the slope to cross under I-40. The elk appear to forage just east of the bridge but return and exit the bridge (where they entered) on the western side (both GPS locations data and cameras confirm this, photo above, right).

Our Recommendations:
1. Fully maintain the extensive riparian pathways for terrestrial wildlife to move under the south end of the bridge.
2. On the north end of the bridge, create a level path (~2 m wide) traversing the embankment under the bridge, to facilitate easy movement of elk and other species under the interstate. This may involve removing rip-rap or at least filling in rip-rap with a well-secured layer of soil (using additional rocks to stabilize the soil path).

Low Bridge over White Oak Road

This bridge is similar in most respects to the Fines Creek Rd bridge, with the exception that there are no exit ramps to complicate wildlife passage routes. Again, steep embankments on both sides of White Oak Road leave little level ground for wildlife to pass safely under Interstate 40 (photo above).

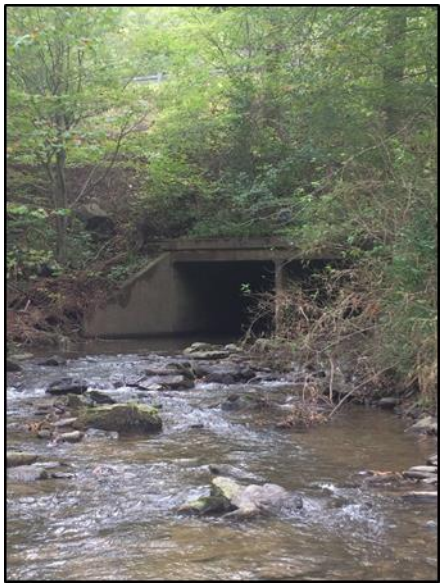
Our recommendations:
1. As for the Fines Creek Rd bridge (please see details above): either extend the length of the bridge to provide a 7-10 m wide by 4 m high space for wildlife on one side of White Oak Rd or the other, or, if the bridge is to be replaced with a culvert, provide a second culvert space of that size (7-10 m W x 4 m H) for wildlife.

2. Alternatively, if moving the bridge support piers on one side of the bridge ~7-10 m closer to the end of the bridge would be an option, that would create a sufficient space for wildlife movement along the side of this relatively low-traffic road. The corresponding embankment would have to be trimmed back (and stabilized) to provide sufficient level ground along the side of White Oak Rd for elk and other species to traverse under the bridge. This could be an option

for the Fines Creek Rd bridge as well (see above), if indeed it is feasible to extend the unsupported length of the interstate bridge in such a way.

Cold Springs Creek/Harmon Den Bridge

Of the 5 structures along I-40 under review this summer for replacement by NCDOT, this bridge has the potential to be the most important for wildlife habitat connectivity, not just for the large target mammal species but for the full range of southern Appalachian biodiversity as well. The Cold Springs Creek/Harmon Den bridge provides a potential opportunity for wildlife to cross under the interstate in a location where extensive and significant protected public natural lands exist on both sides of the highway (e.g. the Harmon Den Wildlife Management Area and Max Patch on the north side of I-40, and Great Smoky Mountains National Park on the south).



The situation for wildlife movement under the existing bridge is complicated (but also potentially enhanced) by the presence of Cold Springs Creek, which passes under the respective interstate exit and entrance ramps via a pair of box culverts (photos above). The culverts are large enough to allow some wildlife to pass underneath, but they do not have dryland space for more terrestrial species that require dry passage. The relatively dark box culverts also do not appear to be tall or wide for elk use.

Our Recommendations:

1. It is not clear to us at present whether the exit and entrance ramps would need to be modified as part of the bridge replacement process. But if the ramps will be re-worked to any substantive degree, we propose that the existing small box culverts for Cold Springs Creek be replaced with larger underpass structures under the ramps. These structures should be wide enough to include substantial amounts of dry land on both sides of the creek (4+ m on each side ideally), and they should be as tall as possible (4 m ideally, but as high as possible given any constraints posed by the height of the ramp road surfaces). The underpass structures should have a natural surface along the bottom (for both the creek and the dry riparian zone), to promote natural erosion patterns in the creek, and to avoid the creek undercutting the downstream side of an enclosed culvert and creating a barrier to fish and salamander migration. Such enhanced structures would provide a robust route for many species of wildlife large and small to migrate along Cold Springs Creek, from Harmon Den to the Pigeon River and other locations beyond. The larger structures would also serve to significantly reduce the risk of Cold Springs Creek itself exceeding the capacity of the existing smaller culverts and causing damage to I-40 during a major flood.

The Google Maps screen shot above provides a visual reference for the potential of the Cold Springs Creek valley to funnel wildlife towards a sequence of crossing structures under the access ramps and I-40 itself. The falsely-distorted depressions in the road surfaces indicate the locations of the wildlife crossing opportunities at this location (the Pigeon River is in the foreground).

If putting substantial underpass structures or larger culverts along both entrance and exit ramps (for Cold Springs Creek) is not an option at this time, we still predict it will be a high priority for wildlife connectivity improvement along I-40 in the near future. So we ask that NCDOT keep such future plans in mind and make sure that any changes to the I-40 bridge structure at this location are compatible with the idea of making a significant terrestrial wildlife movement corridor along Cold Springs Creek under the highway.

2. If the creek culverts cannot be significantly improved at this time, we request, as for the Fines Creek and Low White Oak Rd bridges described above, that the overall bridge span be lengthened enough to provide a 7-10 m wide by 4 m tall extension space for wildlife on the side of Cold Springs Rd opposite of the creek (south side). Alternatively, if the roadbed of Cold Springs Rd can be moved 7+ m further away from the creek (southward), this would help provide an enhanced wildlife movement space along level ground at some height above the creek, which would work well with the creek bridge/culvert extensions described above when they are installed. Moving Cold Springs Rd away from the creek would also potentially serve to allow increased height within the creek structures by virtue of providing more room to slope the freeway ramps down to the smaller road.

Note on units: One meter = ~3.28 feet, so 7-10 m wide works out to roughly 23 to 33 feet wide, and 4 m high works out to roughly 13 feet high.

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(Note: most of these references can be easily shared as pdf's upon request to liz@wildlandsnetwork.org; book chapters may take longer to scan)

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