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An Evaluation of Wildlife Crossing Design, Placement, Costs, and Funding Opportunities for Corridor Q

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16. Abstract:

Construction is underway along Corridor Q, a 14-mile section of highway in Southwest Virginia that will open to traffic in stages from 2023 to 2027. Preliminary data indicated that a newly established reintroduced herd of elk regularly travels on and alongside the partially constructed road. The purpose of this study was to determine potential design, placement, costs, and funding opportunities for wildlife crossing structures on Corridor Q should the decision be made to pursue this option to reduce the potential risk for elk-vehicle collisions.

A criteria-based method was applied to 0.5-mile road segments to determine suitable locations for a series of crossing structures. Evaluated criteria included elk location data, surrounding land use, landscape features that encourage elk movement, roadside topography for cost-effective structure placement, and structure spacing decisions. Elk location data were obtained from 12 collared female elk in the "Corridor Q herd" (hereinafter "Corridor Q elk"). These locations were evaluated to determine elk use of the road segments, home range sizes and locations relative to the road, and habitat selection probability. Findings indicated that the use of the landscape by the elk herd has been shaped by the construction of Corridor Q. Approximately 38% of the 26,659 locations of the collared elk were within 200 meters of the nearly completed road sections, which provide elk an efficient means of travel to preferred habitat that is abundant along the roadside. Home ranges of all 12 collared elk overlapped with portions of Corridor Q road segments. Home ranges were shaped similarly to the partially constructed sections of Corridor Q, indicating the elk's heavy use of the road to access preferred areas of habitat on both sides of the corridor. Distance to barren land, herbaceous cover, and shrub cover had the largest influence on elk habitat selection, all of which are a product of road construction and are distributed linearly along the roadway.

Construction costs per wildlife crossing structure and associated fencing were estimated to be $5.5 to $5.7 million. If funding were pursued for wildlife crossing construction, contingency costs and inflation would raise the estimate to a range of $8.2 million (for a bid year of 2025) to $9.8 million (for a bid year of 2028). With an average elk crash valued at $80,771 and a deer crash at $41,338, 2.8 elk crashes or 5.4 deer crashes per year would have to be avoided per structure for the crash reduction benefits to begin exceeding the cost of a structure and fencing.

This study demonstrated an effective means of incorporating both quantitative elements and qualitative considerations into wildlife crossing design, placement, and cost considerations. If wildlife crossings are pursued for Corridor Q, the study recommends that the Virginia Department of Transportation consider the structure design and location options provided in this report.

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FINAL REPORT

AN EVALUATION OF WILDLIFE CROSSING DESIGN, PLACEMENT, COSTS, AND FUNDING OPPORTUNITIES FOR CORRIDOR Q

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ABSTRACT

Construction is underway along Corridor Q, a 14-mile section of highway in Southwest Virginia that will open to traffic in stages from 2023 to 2027. Preliminary data indicated that a newly established reintroduced herd of elk regularly travels on and alongside the partially constructed road. The purpose of this study was to determine potential design, placement, costs, and funding opportunities for wildlife crossing structures on Corridor Q should the decision be made to pursue this option to reduce the potential risk for elk-vehicle collisions.

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INTRODUCTION

Virginia Route 460/Corridor Q and U.S. Route 121

Virginia Route 460, or Corridor Q, is associated with U.S. Route 121, which is a designated Congressional High Priority Corridor designed to provide a safe and efficient means of travel in far Southwestern Virginia and southern West Virginia (Virginia Department of Transportation [VDOT], 2022a). The planned Virginia portion of U.S. Route 121 begins at U.S. Route 23 near Pound in Wise County and extends approximately 50 miles through Dickenson and Buchanan counties to the West Virginia state line near Slate.

U.S. Route 121 and Corridor Q are associated with the Appalachian Development Highway System (ADHS). ADHS was created by Congress in 1965 to connect Appalachia to the interstate system and generate economic development in previously isolated areas. Today, generating economic development in Southwest Virginia remains the primary objective for constructing U.S. Route 121 and Corridor Q (Schmidt, 2022). U.S. Route 121 and Corridor Q are regarded as separate but related ADHS transportation initiatives (VDOT, 2022a).

Corridor Q traverses portions of Kentucky, Virginia, and West Virginia, for a total length of 128.7 miles. As illustrated in Figure 1, a portion of Corridor Q overlaps U.S. Route 121 in Virginia. There are approximately 14 miles of Corridor Q to complete, extending from the Kentucky state line to the Town of Grundy, Virginia.

This 14-mile segment of Corridor Q is the focus of this study. The completion of Corridor Q is underway and is being conducted by VDOT in cooperation with the Federal Highway Administration (FHWA). The typical section varies from a four-lane divided roadway to a two-lane undivided roadway with climbing lanes where necessary.

Traffic forecasts for Corridor Q indicate that the 2040 volumes will vary between 5,300 and 6,500 vehicles per day, depending on the road section. The corridor will open to the public in four stages:

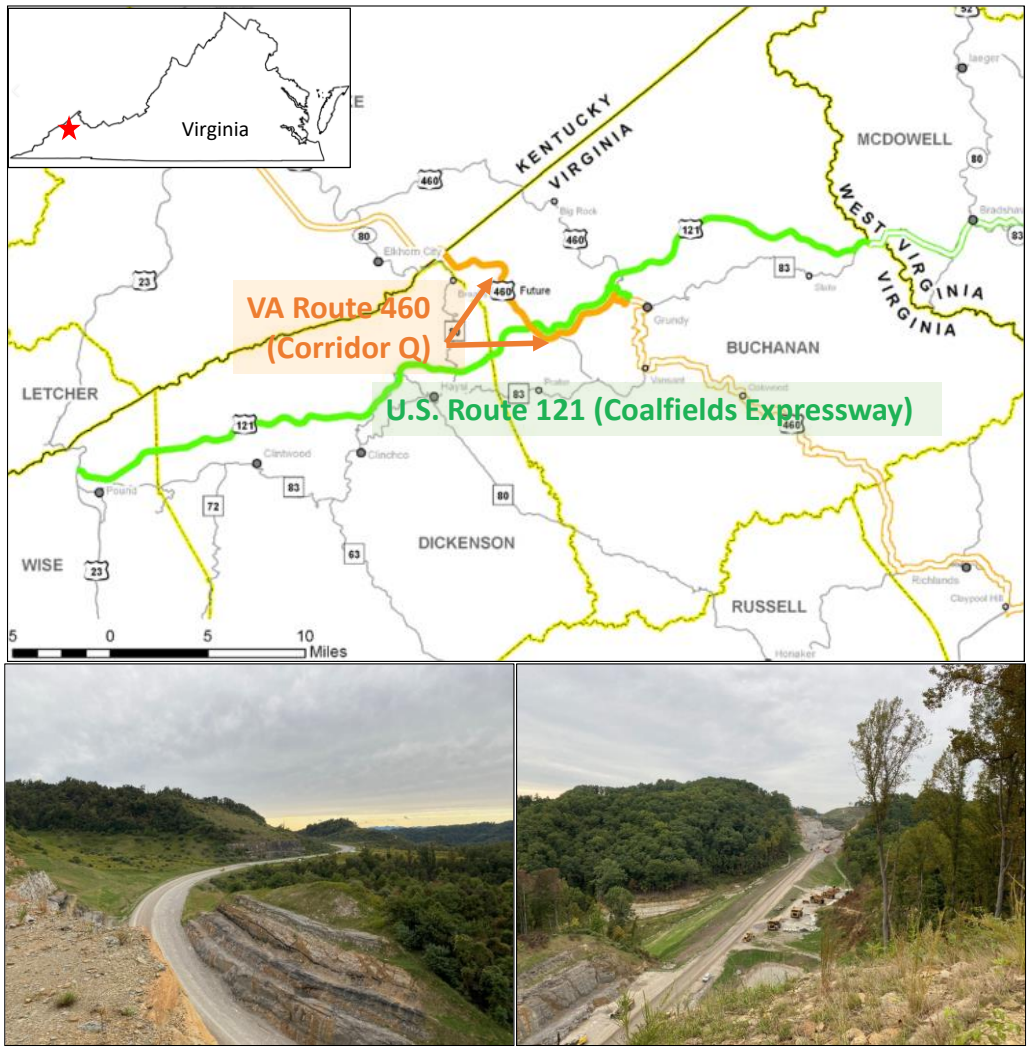

Figure 1. Virginia Route 460 / Corridor Q (*top*), and Corridor Q Under Construction (*bottom*)

1. The westernmost 0.8-mile portion from the Kentucky state line to U.S. Route 744 opened to the public in 2020 and is the only segment currently open to traffic. This section includes Virginia's tallest bridge, over Grassy Creek.

2. The adjoining 8.4-mile segment to the east/southeast is expected to be completed and open to traffic by the fall of 2023.

3. The 2.7-mile section to the east, from Southern Gap, Virginia, to Route 604 at Poplar Creek, Virginia, will be open to traffic in early 2025.

4. The final easternmost 2-mile section that connects to Grundy, Virginia, will be open to the public in 2027.

The landscape comprises mountainous terrain and oak-hickory forests, much of which is characterized as having high ecosystem diversity (Virginia Department of Conservation and Recreation [VDCR], 2021). Common terrestrial wildlife includes white-tailed deer (*Odocoileus virginianus*), black bear (*Ursus americanus*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*), Virginia opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), and groundhog (*Marmota monax*).

Elk in Southwest Virginia

Historically, North American Elk (*Cervus canadensis*) were widely distributed throughout the United States, including in Virginia. Unregulated hunting and habitat loss resulted in their extinction in the eastern United States by the mid-1800s. From 1997 to 2002, 1,541 elk were reintroduced in Kentucky, and by 2000, a number of them had dispersed into adjacent counties in Virginia (Virginia Department of Game and Inland Fisheries [VDGIF], 2019). The Virginia Department of Wildlife Resources (VDWR), formerly the VDGIF, allowed elk hunting in an attempt to prevent elk from becoming established (VDGIF, 2019). Despite this, several small herds found refuge in Virginia. A growing interest in elk in Virginia prompted the development of a plan for elk restoration, and in 2009, the VDGIF board directed the agency to develop a plan to restore and manage a population of elk.

In 2011, elk hunting was prohibited in Buchanan, Dickenson, and Wise counties (VDGIF, 2019). From 2012 to 2014, VDWR relocated 75 elk from Kentucky to reclaimed mined lands in Buchanan County. Buchanan, Dickenson, and Wise counties were designated the Elk Management Zone of Virginia; management of their population includes restricting their expansion beyond this zone (VDGIF, 2019). Buchanan County also borders the elk management zones established by the wildlife agencies in both Kentucky and West Virginia. Today, Virginia's total elk population includes more than 250 animals, of which at least 200 inhabit Buchanan County.

Elk-viewing tourism has become popular in Buchanan County. Breaks Interstate Park, which borders the western end of Corridor Q, provides guided elk-viewing tours in cooperation

with Southern Gap Outdoor Adventure, Southwest Virginia Sportsmen, and the Southwest Virginia Chapter of the Rocky Mountain Elk Foundation (Southern Gap Outdoor Adventure, 2022). VDWR expects further growth in elk-related tourism as a result of their new managed elk hunt program in Buchanan, Dickenson, and Wise counties. VDWR received just over $513,000 from nearly 32,000 applicants for their inaugural elk hunt lottery in 2022, in which five elk licenses were awarded. The Rocky Mountain Elk Foundation generated almost $100,000 from a raffle for the sixth elk license.

Elk Habitat Preferences and Use of Corridor Q

Elk feed opportunistically, grazing on locally abundant resources. Grasses are their primary diet component (Murrow et al., 2009). Elk in the eastern United States have a preference for open areas (such as grasslands or fallow fields) that are partially forested; this allows them to find cover and a means to escape the heat (Murrow et al., 2009; VDGIF, 2019). Given the widespread availability of resources in areas where elk have been reintroduced in the eastern United States, elk populations have not displayed migratory tendencies in the eastern ranges, whereas seasonal migration is the norm for elk in the western United States (Boyce, 1991).

The reintroduced elk in Virginia spend some of their time in forested areas as a refuge from heat and to feed on understory plants. The majority of their diet consists of grasses and forbs available in fields, private lands, and reclaimed mine lands. Some of Buchanan County's forested landscape is interrupted by open reclaimed mine lands and the cleared road corridor for Corridor Q. These openings within the forested landscape serve as prime habitat for the resident elk. According to VDWR, this mixture of forest and open grassy habitat has encouraged Virginia's elk to remain stable within relatively small home ranges of less than 9,000 acres (14 mi^2) (VDWR, 2020). Elk are frequently seen on Corridor Q and grazing along the roadside that has been planted with grass and various forbs to control erosion during and after road construction (Figure 2). White-tailed deer are also commonly observed feeding along the corridor.

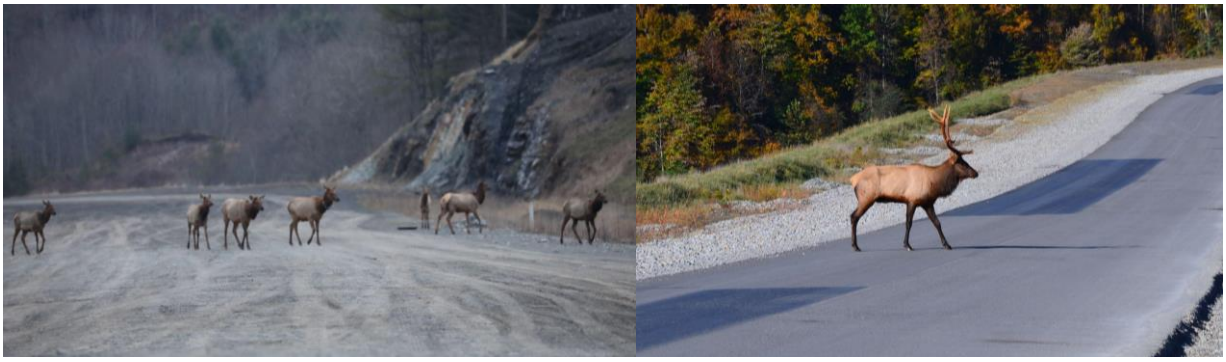

Figure 2. Elk on Corridor Q. Photo credits: Braiden Quinlan (*left*), Nicholas Huff (*right*). Reprinted with permission.

Elk comprise the second largest member of the deer family (*Cervidae*) and are many times larger than white-tailed deer. A female (cow) elk weighs between 375 and 660 pounds, and a male (bull) weighs between 550 and 1,300 pounds (Hudson and Haigh, 2002). Figure 3 illustrates their size relative to vehicles. The large size of elk, the absence of seasonal migration of elk in Virginia, and the abundance of high-quality habitat along and surrounding Corridor Q could present challenges with regard to driver safety when the road opens to traffic.

Figure 3. Elk Crossing a Road, Illustrating Their Large Size Relative to Vehicles. Photo credit: Western Transportation Institute–Montana State University, courtesy of ARC Solutions. Reprinted with permission.

Elk Monitoring and Management

Of the 200 elk in Buchanan County, approximately 100 inhabit the area along Corridor Q near the Kentucky/Virginia state line, through the area referred to as "Southern Gap," and east toward the Town of Grundy. As such, VDWR informally refers to this elk herd as the "Corridor Q herd." In 2019 and 2020, VDWR collared 12 female elk in this herd with GPS-enabled devices that record location data at regular intervals. Four female elk were GPS-collared during January and February 2019, and 8 females were GPS-collared from December 2019 to February 2020. Preliminary evaluations of female elk collar data indicated the female elk's heavy use of Corridor Q and adjacent habitat. Several miles south of the Corridor Q elk, the remaining 100 individuals make up the "Warfork herd" (hereinafter "Warfork elk"). Approximately 50 elk live in Wise County, and additional elk are scattered throughout other areas of Southwest Virginia.

Management of reintroduced elk herds is important, given that unexpected mortality events affect their population sustainability more than they would with larger, more established populations. Researchers who studied the population growth and viability of a 61-member elk herd reintroduced in the Great Smoky Mountains National Park found that the small size of the population made the herd more susceptible to stochastic events (Murrow et al., 2009). The relatively low reproductive rates of elk compared to other ungulates such as white-tailed deer make them especially prone to impacts from road mortality (Rytwinski and Fahrig, 2012).

In Virginia, elk management activities conducted by VDWR include working with private landowners to improve elk habitat. VDWR plans to improve 12 areas (138 total acres) on private lands adjacent to Corridor Q over the next 2 years. This will include controlling invasive plant species on open areas, planting native grasses and forbs for wildlife, and creating

several ponds to provide water sources for elk and other wildlife. An additional 5-acre habitat project is in progress at Breaks Interstate Park.

Wildlife Crash Countermeasures

Under the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users, or SAFETEA-LU (Pub. L. 109-59) (2005 to 2012), the U.S. Department of Transportation (U.S. DOT) was directed to conduct a comprehensive review of research on the effectiveness of measures to reduce wildlife-vehicle collisions (Huijser et al., 2008). An updated review was conducted through a pooled fund study to advance the understanding of effective wildlife crash countermeasures (Huijser et al., 2022). The study included a review of more than 270 research papers and addressed 24 measures with regard to their effectiveness in reducing crashes.

The study found that if reducing collisions with large wild mammals was the only objective, six measures had a "likely high or substantial" effectiveness of greater than 80%. These included wildlife culling (30% to 94% effective), wildlife relocation (30% to 94% effective), anti-fertility treatments (33% to 97% effective), roadside animal detection systems (33% to 97% effective), wildlife fences (80% to 100% effective), and wildlife fences in combination with wildlife crossing structures (80% to 100% effective). If the objectives also included maintaining or improving habitat connectivity for large wild mammals, then wildlife fencing in combination with wildlife crossing structures was most effective (Huijser et al., 2008; Huijser et al., 2022).

The effectiveness of wildlife culling, wildlife relocation, and anti-fertility treatments varies widely, and they can have undesirable side effects that include unsupportive public opinion and logistical difficulties (Huijser et al., 2008; Huijser et al., 2022). For this reason and the fact that these measures would conflict with the management goals for the reintroduced elk population, these three treatments were not considered further.

Fencing Alone

The authors of the 2008 U.S. DOT study and the updated 2022 review stated that properly designed wildlife fencing (unaccompanied by wildlife crossings) is effective at wildlife crash reduction. However, the same authors discouraged practitioners from using fencing alone because of research findings on its adverse effects on wildlife populations (Huijser et al., 2022). This is discussed further later.

Animal Detection Driver Warning Systems

Animal detection driver warning systems are typically intended for discrete crash hotspots along relatively short road segments. They can also be used in combination with wildlife crossings and at fence ends where there is no logical terminus (such as a natural barrier that would prevent elk from circumventing the fence) (Huijser et al., 2006). The systems are designed to sense large animals as they approach the roadway and are intended to warn drivers

about their presence. Once detection is verified, a warning system (such as a flashing warning sign or a changeable message sign that wirelessly communicates with the detection cable) can be used to alert drivers to the danger. The effectiveness of these systems relies on altering driver behavior in response to a warning sign or message; they do not provide a physical barrier that prevents wildlife from entering the roadway.

These systems have reduced elk crashes along S.R. 260 in Arizona by more than 90% (Dodd and Gagnon, 2008). In one study, an animal detection driver warning system was installed to detect elk at one end of a wildlife fence (the other end was tied to a wildlife underpass). The system was intended to modify driver behavior while allowing elk to cross via a dedicated "crosswalk." The detection system installation was associated with reduced vehicle speeds (13%) and increased driver alertness (5.5-fold increase) (Gagnon et al., 2019). Similarly, pilot studies on the Virginia Smart Road and a highway in VDOT's Salem District found that a buried cable animal detection system detected deer with more than 95% reliability (Druta and Alden, 2015). Vehicle speed and brake light application data collected during warning sign activation showed that approximately 80% of drivers either braked or slowed in response (Druta and Alden, 2019).

The Virginia Tech Transportation Institute is conducting an evaluation for VDOT's Bristol District to assess the feasibility of using roadside animal detection systems to reduce the risk of elk crashes on Corridor Q. The study was initiated in December 2022 and will conclude by the end of 2023. The project tasks include (1) reviewing the literature and consulting with vendors with respect to system capabilities, requirements, availability, cost, maintenance, and other relevant operational factors; and (2) identifying potential pilot implementation sites for these systems based on factors such as roadside terrain, access to communication cables, and any potentially considered locations for wildlife crossing structures and fencing. Any pilot installations would be coordinated with the Bristol District project team, the applicable VDOT District Traffic Operations Director or designee, and VDOT's Traffic Operations Division.

Wildlife Crossings With Fencing

Wildlife crossing structures, which are overpasses or underpasses used by wildlife to cross above or beneath a road, have been implemented and evaluated for more than 30 years in the United States. When combined with fencing, they have consistently been found to be an effective measure to reduce animal-vehicle collisions while also providing wildlife a means to access habitat across the road (Huijser et al., 2008; Huijser et al., 2022). For example, seven wildlife crossings with fencing in Colorado resulted in a wildlife crash reduction of 92% (Kintsch et al., 2021). This was an average reduction of 56 vehicle collisions with mule deer per year (or 5.4 per mile per year) over a 10.3-mile mitigated road segment. In Wyoming, the construction of six wildlife underpasses and two wildlife overpasses reduced pronghorn crashes by 100% and mule deer crashes by 78% (Sawyer et al., 2016). This was an average reduction of 69 large animal–vehicle collisions per year (or 5.6 collisions per mile per year) over a 12.4-mile mitigated road segment. Crossing structures and fences on the Trans-Canada Highway reduced collisions involving deer and elk more than 94% (the exact crash numbers were not provided) (Clevenger et al., 2001).

The wildlife fencing component of wildlife crossings serves to prevent wildlife from accessing the road and to guide them toward the crossings. Adding fencing to certain structures, even structures not originally designed for wildlife use, was found to reduce deer crashes by more than 90% on Virginia's I-64 (an average reduction of 8.4 deer crashes per mile per year) (Donaldson and Elliott, 2021) and reduce elk crashes by 97.5% in Arizona (a reduction of 3.5 elk crashes per mile per year) (Gagnon et al., 2015).

There are more than 1,000 dedicated wildlife crossings in the United States today (Einhorn, 2021). For longer stretches of highway where wildlife crash risk is relatively high, wildlife crossings are often constructed in a series with many structures. Montana's U.S. Highway 93 includes one of the highest numbers of wildlife crossings, with 60 structures designed to accommodate passage by a variety of species over 66 miles of road (Montana DOT, n.d.). Nevada has constructed five large overpasses and 18 other new wildlife crossings since 2010 (Einhorn, 2021). Colorado has constructed more than 60 wildlife crossings (American Society of State Highway and Transportation Officials [AASHTO], 2022). Washington has 22 wildlife crossing structures, 11 of which are along a 15-mile segment of I-90 (Clevenger and Vaughn, 2008).

Most large-scale wildlife crossing projects for large animals are in the western United States (Barringer, 2022), despite the fact that the majority of large animal crashes are in the eastern states (Phillips, 2022). According to State Farm's animal crash claims data from July 1, 2021, to June 30, 2022, Virginia has the seventh highest number of animal crashes among states, with an estimated 81,694 (nearly 60,000 of which are deer related). Virginia has two crossing structures dedicated for large animals (in Fairfax County and Chesapeake), both of which were found to be used by the target species for which they were designed (white-tailed deer and black bear) (Donaldson, 2007; Donaldson and Schaus, 2009). In the eastern United States, Florida has one of the highest numbers of dedicated wildlife crossings, with 73 structures, many of which were designed to protect small and/or isolated populations or protected species (Florida Fish and Wildlife Conservation Commission, 2015).

The design and placement of wildlife crossings are critical to the effectiveness of the structure (Clevenger and Waltho, 2003; Forman et al., 2003; Foster and Humphrey, 1995). Gagnon et al. (2011) evaluated the influence of structure design, location, monitoring duration, season, time of day, and day of week associated with successful wildlife crossing use by elk and white-tailed deer. Their results indicated that structural attributes and placement were of primary importance for successful elk and deer passage.

To support the implementation of wildlife crossings in the United States, the recently enacted Infrastructure Investment and Jobs Act (IIJA) (Pub. L. 117-58) established a Wildlife Crossing Pilot Program that dedicated $350 million in federal funding over Fiscal Year (FY) 2022-2026 for these structures. Wildlife infrastructure funding opportunities are also available in more than a dozen additional funding programs in IIJA (Callahan, 2023).

Virginia Wildlife Corridor Action Plan

In 2020, the Virginia General Assembly enacted legislation that directed the creation of a Wildlife Corridor Action Plan (WCAP) for Virginia (*Code of Virginia* § 29.1-579). This legislation directed VDWR, in collaboration with VDOT, VDCR, and the Virginia Department of Forestry, to "[i]dentify wildlife corridors, existing or planned barriers to movement along such corridors, and areas with a high risk of wildlife-vehicle collisions" and to "[p]rioritize and recommend wildlife crossing projects intended to promote driver safety and wildlife connectivity." The final plan was released in May 2023 (VDWR et al., 2023).

A primary objective of WCAP was to advance the mutual benefits of (1) promoting driver safety and (2) identifying and improving wildlife corridors that support the long-term resilience of wildlife biodiversity. To accomplish this, mapping efforts were conducted to identify areas of high wildlife-vehicle conflicts and to identify Wildlife Biodiversity Resilience Corridors. The purpose of Wildlife Biodiversity Resilience Corridors is to maintain wildlife habitat connectivity between biodiverse and natural lands to allow species distribution shifts as the climate changes and the landscape becomes more developed (VDWR et al., 2023).

Because most of Corridor Q is not yet open to the public and therefore crash data are lacking, WCAP's identification of existing areas of high wildlife-vehicle conflicts was not applicable to this road. However, Corridor Q traverses an area designated in WCAP as a Wildlife Biodiversity Resilience Corridor (as detailed in the "Benefits" section of this report).

Scenarios Considered in Determining the Study Approach

The research team discussed the implications of four scenarios for Corridor Q (Table 1). These scenarios included three of the six countermeasures described previously as being found to be effective for wildlife crash reduction (wildlife culling, wildlife relocation, anti-fertility treatments, roadside animal detection systems, wildlife fences, and wildlife fences in combination with wildlife crossing structures) (Huijser et al., 2022). The three effective countermeasures not considered for the study approach were wildlife culling, wildlife relocation, and anti-fertility treatments.

Table 1. Implications of Four Scenarios for Corridor Q

Scenario	Potential Benefits		
	Human Crash Avoidance	Elk Crash Avoidance	Habitat Connectivity/Biodiversity and Resilience Value of Area[a]
No action	-	-	-
Wildlife fencing alone	X	X	-
Animal detection driver warning systems	X	X	-
Wildlife crossings with fencing	X	X	X

[a] Because roads are a physical disruption to habitat connectivity, only measures that restore connectivity are considered habitat connectivity improvements (Forman et al., 2003; Huijser et al., 2022).

For the "no action" scenario (Table 1), elk behavior on Corridor Q and research on other elk populations suggest there is some degree of risk to driver safety on the corridor without the implementation of effective countermeasures. VDWR and VDOT staff observed that elk are generally undeterred from their state vehicles, which regularly travel on the unopened sections of the corridor and have approached elk on the nearly completed sections of road on numerous occasions. Research on western elk populations indicated that elk travel on and attempt to cross low-volume roads with traffic volumes similar to those projected for Corridor Q (Dodd et al., 2012; Gagnon et al., 2015; Kintsch et al., 2021). On Arizona and Colorado highways, elk regularly attempted to walk along and across the road, as evidenced by collared elk data (Gagnon et al., 2017) and reported elk crashes (Dodd et al., 2012; Gagnon et al., 2015; Kintsch et al., 2021). On Arizona's S.R. 260, which has an average daily traffic (ADT) of 8,000, there were 4.6 elk crashes per mile per year over an 8-year period (Dodd et al., 2012). In the Canadian Rocky Mountains, elk collisions were negatively correlated with traffic volumes (Gunson et al., 2021). Similarly, Gagnon et al. (2007) found that elk use of roads and adjacent habitat was greater at low traffic volumes. The correlation between elk-vehicle collisions and lower traffic volumes is possibly explained by wildlife's avoidance of roads with high traffic levels (Gagnon et al., 2007). It is important to note that although not all studies referenced in this report made note of the elk population size, western elk herds are typically larger than those in Virginia. This is discussed in further detail later.

The scenario of "wildlife fencing alone" (without the use of crossing structures) (Table 1) can reduce wildlife collisions (Huijser et al., 2008; Huijser et al., 2022), but Huijser et al. discouraged the use of fencing alone because of adverse impacts on wildlife populations. When considering the use of extensive lengths of fencing (several miles or more) without the use of crossing structures, it is important to take into account the context of the surrounding habitat. VDWR is improving elk habitat within 12 areas (138 total acres) on private lands north and south of Corridor Q over the next 2 years. This will include planting native grasses and forbs for wildlife and creating several ponds to provide water sources for elk and other wildlife. The construction of fencing would restrict access to these areas and limit the population's movement within their current range, as has been found with ungulate populations in other areas (McInturff et al., 2020).

In addition, the ConserveVirginia mapping tool, created to identify priority lands for conservation and codified into law in 2021 (*Code of Virginia* § 10.1-104.6:1), categorized the area in which Corridor Q is situated as important with regard to (1) Natural Habitat & Ecosystem Diversity, and (2) Protected Landscapes Resilience (VDCR, 2021). As mentioned previously, the area's high potential for ecosystem resilience is also reflected in WCAP, which identified the area in which Corridor Q is situated as a Wildlife Biodiversity Resilience Corridor (VDWR et al., 2023). When fencing is used without wildlife crossing structures, it counteracts the intended purpose of wildlife corridors, and the barrier it creates to animal movements has been found to impact some species negatively at the population level (Epps et al., 2005; Jaeger et al., 2005). Fencing can inhibit wildlife access to resources and reduce mating opportunities needed for genetic exchange and population viability (Murrow et al., 2009; Rytwinski and Fahrig, 2012). For these reasons, transportation agencies have been reluctant to fence extensive stretches of highways (Dodd et al., 2012).

For the "animal detection driver warning systems" scenario (Table 1), these systems show promise in some applications along short sections of road (i.e., discrete existing or expected crash hotspots). As mentioned previously, their feasibility for certain areas along Corridor Q is currently being evaluated by the Virginia Tech Transportation Institute.

Given that the safety impacts of fencing have been examined and that the feasibility of implementing animal detection driver warning systems on Corridor Q is under evaluation, the technical analysis of this study focused on the use of wildlife crossings with fencing. If agency objectives include improving driver safety and maintaining or improving habitat connectivity for large wild mammals, then "wildlife crossings with fencing" is the most effective scenario shown in Table 1 (Huijser et al., 2008; Huijser et al., 2022). That said, agencies have multiple considerations to weigh and should determine whether this scenario aligns with identified needs, goals, and resources.

Information Gaps

Much of the information applied to this study was based on studies of elk-vehicle collisions and wildlife crossings conducted in western states. There are important differences, however, between western elk populations and the reintroduced elk population in Virginia. Western elk herds are typically larger than those in Virginia. Studies of elk movement and associated elk-vehicle collisions discussed in this report were based on elk populations with 2,500 and 3,000 individuals (Dodd et al., 2012; Gagnon et al., 2017), though the authors noted that not all elk resided in proximity to the evaluated roads.

Another important difference is that the elk in Virginia are not migratory, as are those in many western populations. Elk in Buchanan County have remained in the general area throughout each season, and preliminary reviews of elk collar data indicate that the Corridor Q elk remain along the corridor year-round. This creates difficulty in using elk crash data from western populations to predict elk crash frequencies for the Virginia herds. There is unlikely to be a reliable means of using crash data from larger migratory populations that may travel toward and away from a road on a seasonal basis to predict crash rates for a smaller population that inhabits the Corridor Q area throughout the year.

Finally, since the Virginia elk are a relatively new reintroduced population, their future movement across the landscape may be less predictable than that of western populations. Although the Virginia elk population is increasing (more than tripling in the past decade) and their range is expanding, it is difficult to forecast their use of the landscape with or without wildlife crash countermeasures in place along Corridor Q.

PURPOSE AND SCOPE

The purpose of this study was to determine potential design, placement, approximate costs, and funding opportunities for wildlife crossing structures on Corridor Q should the

decision be made to pursue this option to reduce the potential risk for elk-vehicle collisions. The scope of this study did not include a quantification of risk for these collisions in this corridor.

First, a literature review was conducted and discussions were held with experts to gather information on wildlife crossing structure sizing and spacing considerations specific to elk. Second, a criteria-based evaluation of Corridor Q road segments was conducted to identify suitable locations for wildlife crossings. Although elk were the primary focus of the evaluation, other wildlife species were also considered with regard to minimizing wildlife crash risk and maintaining habitat connectivity. Third, a cost analysis was conducted that compared wildlife crossing and fencing costs with the financial benefits of avoiding crashes with elk and deer. Fourth, potential federal funding sources for wildlife crossings were reviewed and prioritized based on program-specific statutory eligibility requirements.

Designs for wildlife fencing, escape ramps, and wildlife guards are also important components of wildlife crossing implementation. Measures are also needed to prevent unauthorized all-terrain vehicles from accessing structures. The literature provides many examples of successful designs and implementation strategies for these features. Design and location recommendations for these components are not included in this report but will be provided as separate deliverables to VDOT staff if funding for wildlife crossings and fencing is pursued.

METHODS

Information Gathering From the Literature, Wildlife Crossing Experts, and VDOT Engineers

A literature review was conducted to collect information on wildlife crossing projects that aimed to minimize crash risk and maintain or restore habitat connectivity for elk. The literature review focused on the sizing and spacing of wildlife crossing structures specific to elk use of such structures. Spacing considerations were incorporated in the criteria-based evaluation used to determine suitable locations for wildlife crossing structures.

The research team also met with a Nevada Department of Transportation (DOT) engineer with experience in wildlife crossing design and held virtual meetings with four biologists and habitat connectivity specialists from Arizona, Colorado, Utah, and Washington involved in the research and/or implementation of wildlife crossings designed for elk. Topics discussed included wildlife crossing design specifications for elk, optimal distances between crossing structures, and general practical considerations for structure design and construction. VDOT engineers were also consulted to discuss the cost implications of structure sizing options.

Criteria-Based Evaluation to Determine Suitable Locations for Wildlife Crossings

Overview of Study Design

Corridor Q was divided into 0.5-mile (805-meter) segments that served as the basis for a criteria-based evaluation to determine suitable wildlife crossing locations. There were 27 segments labeled from west to east; segment 27 had a length of 0.36 miles (573.4 meters). To provide an additional index of elk use along the roadway, a 0.12-mile (200-meter) buffer was created (Figure 4). ArcMap Version 10.8 software was used for creating road segments (and the 200-meter buffer) and conducting the road segment evaluation. In this report, "road segment" is defined as the 0.5-mile segment of road and its 200-meter buffer on each side of the road.

As described previously, various phases of construction are underway along Corridor Q, ranging from a 0.8-mile section of completed road at the western end of the corridor to completely unconstructed sections on the eastern section of the corridor. In this study, "Phase I" refers to Corridor Q west of S.R. 744; this portion will be open to traffic in 2023 (Figure 4). "Phase II" is east of S.R. 744. The western portion of Phase II will be open to traffic in 2025, and the eastern portion will be open in 2027.

The evaluation method applied to the road segments was based on criteria known to be important for wildlife crossing placement, including wildlife occurrences and habitat use, human land use adjacent to the road, and spacing strategies (Clevenger and Huijser, 2011; Forman et al., 2003). It became apparent during the initial review of elk location data that dividing the corridor into Section A (partially constructed) and Section B (unconstructed) and applying different evaluation methods to each section was necessary because of the strong influence of road construction on elk use of the corridor (Figure 4).

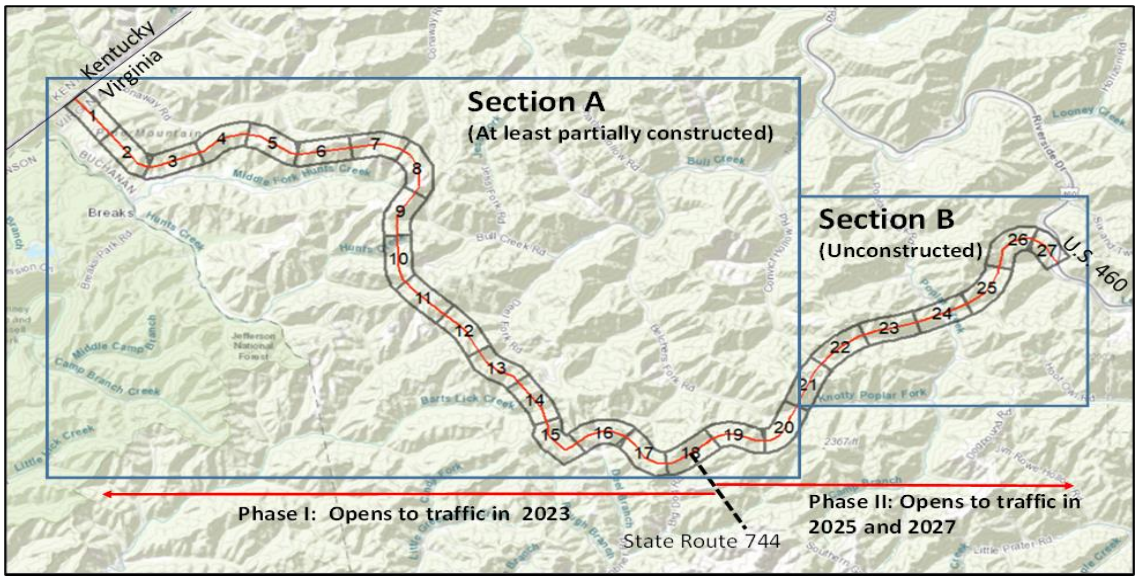

Figure 4. Corridor Q Project Area Separated Into 27 Segments With a 200-m Buffer. For study design purposes, the corridor segments were grouped into Section A and Section B. Phase I and Phase II portions of the corridor are also illustrated, which do not align with Section A and Section B.

Specifically, tree clearing, excavation, grading, and grass planting (for erosion control) created areas of preferred habitat for elk, and these activities were completed in Section A by the time elk collars were deployed in 2019. In Section B, road construction activities were initiated shortly after elk collars were deployed. The elk collar data were therefore not factored into the scoring methods applied to the Section B unconstructed road segments.

To evaluate the segments, Corridor Q was divided into two sections (Figure 4):

- *Section A.* Segments 1 through 20 include the section of the corridor for which road construction (i.e., tree clearing, excavation, grading, and grass planting) had begun to some degree at the time the elk collar data were collected. Section A includes all the segments in Phase I and a small portion of Phase II.

- *Section B.* Segments 21 through 27 include the section of the corridor for which no elements of road construction had begun at the time the elk collar data collection was initiated. All of the segments in Section B are part of the Phase II portion of the corridor.

Each road segment was evaluated by quantitative assessments (with scores assigned for certain criteria) and qualitative assessments (with no assigned score). As illustrated in Figure 5, an "elk use" score (the sum of the elk location score and the home range score) and a "habitat selection probability" score were primary components of the road segment rank for Section A.

For reasons described previously, the elk use score was excluded from the Section B analysis. The roadside topography evaluation was also excluded from the Section B analysis. The topography criterion involved an in-person site evaluation to view the terrain resulting from road construction (i.e., cut and fill sections, steep box cuts) to determine cost-effective structure placement at specific locations; this could not be conducted for Section B since construction had not begun. For Section B, road segment ranks were largely based on the habitat selection probability score. Whereas precise suitable locations could be identified in Section A segments, the identification of any suitable locations determined for Section B segments was generalized to the entire road segment; evaluations of these segments should include an evaluation of elk collar data collected as road construction progresses and on-site scoping to determine specific suitable structure locations.

For both sections, an additional one or two points were given to segments with protected land on one or both sides of the road, respectively (i.e., within the 200-meter buffer). Other criteria that were important considerations in the identification of suitable wildlife crossing placement but were not given a score included (1) landscape features that are navigable and encourage elk movement, (2) structure spacing decisions, and (3) topography that allows for cost-effective structure placement (for Section A segments only). Detailed methods for the evaluation of each criterion are described later.

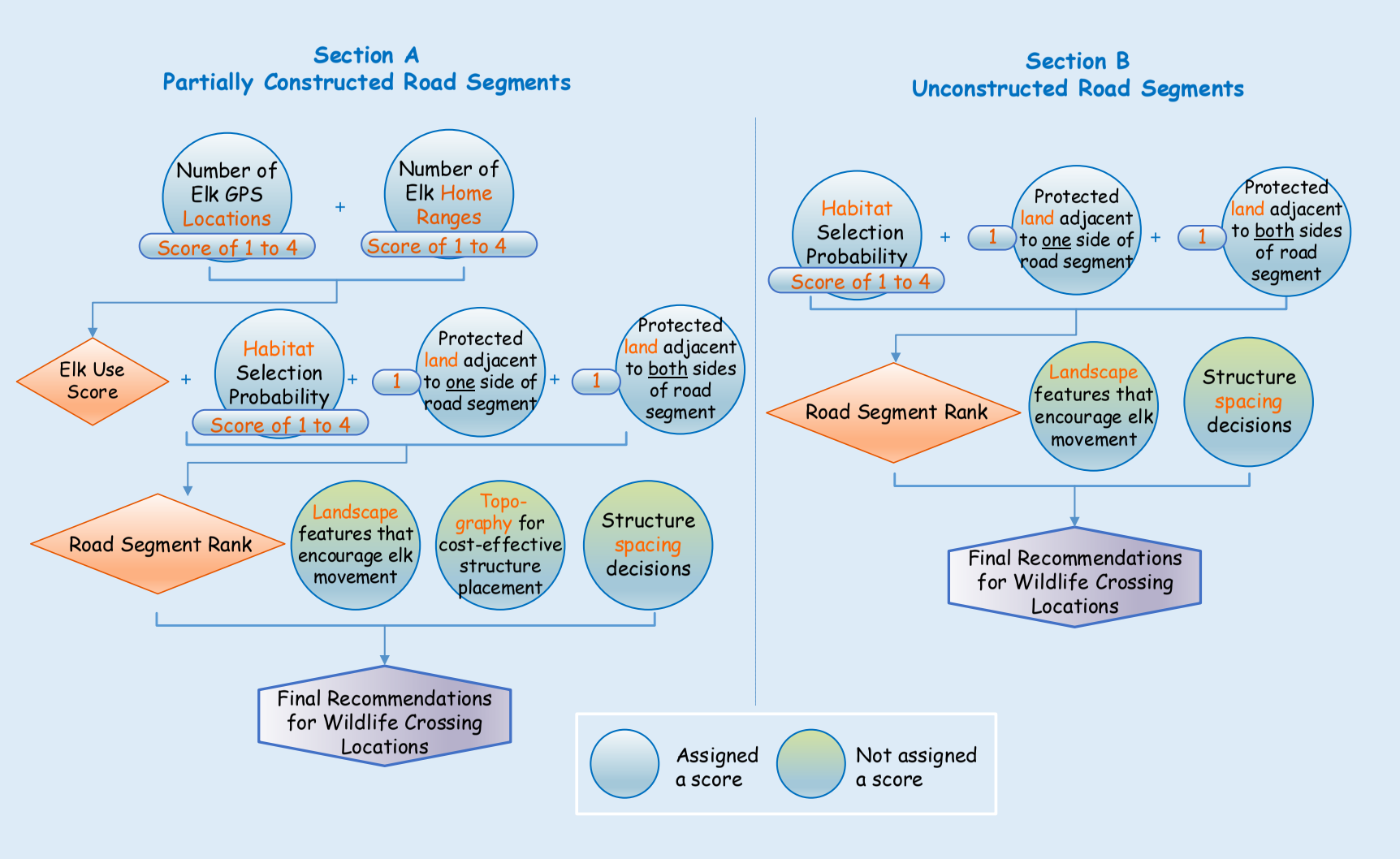

Figure 5. Criteria-Based Evaluation Process for Determining Suitable Wildlife Crossing Locations Within the Corridor Q 0.5-Mile Road Segments

Criteria-Based Evaluation: Elk Locations, Home Ranges, and Habitat Selection

Screening Elk Collar Data

Locations were evaluated from the data from the 12 collared female elk in the Corridor Q herd recorded between February 4, 2019, and December 30, 2021 (Table 2). The GPS collars were programmed to acquire a location fix every 6 hours. Table 2 also includes data from the collared Warfork elk; this information was used for the habitat analysis described later.

The location dataset was uploaded from satellite communication software and screened prior to analysis to remove inaccurate or erroneous data. Obvious location errors from pre- and post-deployment fixes were removed. GPS device location errors are related to location type (i.e., two-dimensional versus three-dimensional fix) and the positional dilution of precision, a measure of satellite geometry. To increase the accuracy of the GPS location data used in the analyses, only three-dimensional fixes with positional dilution of precision values less than 7 were retained (Braunstein et al., 2020; Lewis et al. 2007). For Corridor Q elk, 26,659 locations met these criteria for analysis. The average number of locations per Corridor Q collared elk (n = 12) was 2,221 ± 996.4 (standard deviation [SD]) and ranged from 498 to 4,108 locations per elk (Table 2).

Table 2. GPS Locations for Collared Elk Collected From February 2019 Through December 2021

Corridor Q Herd Elk ID	No. of GPS Locations	Warfork Herd Elk ID	No. of GPS Locations
1	1,112	1	2,330
2	1,034	2	2,177
3	498	3	2,900
4	4,108	4	3,691
5	2,882	5	1,452
6	2,747	6	2,427
7	1,617	7	2,565
8	2,757	8	2,784
9	2,656	9	2,916
10	2,260	10	1,737
11	2,342		
12	2,646		
Total	26,659	Total	24,979

Elk Use Score: Elk Locations and Elk Home Ranges (Section A)

For Section A of Corridor Q, the number of elk locations within each road segment was calculated and used as an index of elk use. Each road segment was scored on a scale of 1 to 4 based on the SD from the mean number of locations (score of 1 or Low ≤ −0.5 SD; score of 2 or Average = −0.5 to 0.5 SD; score of 3 or High = 0.5 to 1.5 SD; score of 4 or Very High = >1.5 SD). The SD was used because the index of elk use is a relative measure where ideally two road segments receive two different scores only if their indices are materially different. The use of the SD is one way to emphasize comparisons based on the difference between the index and the

mean (Longley et al., 2015). As described previously, Section B did not undergo an analysis of elk locations or associated home ranges.

To gain a better understanding of elk home range sizes in the region, and particularly how home range sizes may differ between the Corridor Q elk and the Warfork herd (that lives approximately 4.4 miles south of Corridor Q), elk home ranges were calculated for all collared elk. This included the 10 collared female elk from the Warfork herd in addition to the 12 Corridor Q elk. Home ranges were determined using the R software adehabitatHR package. A kernel density estimator was used to estimate home ranges (Kie et al., 2010; Laver and Kelly, 2010). The total home range area was calculated for each elk, and the resulting polygons were projected in ArcMap. The total number of elk home ranges that intersected each road segment were then calculated and used as an index of elk use by scoring the Section A road segments on a scale of 1 to 4 (score of 1 = 0 to 5 home ranges; score of 2 = 6 to 8 home ranges; score of 3 = 9 to 10 home ranges; score of 4 = 11 to 12 home ranges).

Habitat Selection and Selection Probability (Section A and Section B)

Because landscape features and habitat resources influence the spatial distribution of elk, an evaluation was conducted to determine elk habitat selection in and around Corridor Q. This habitat selection information provided insight into present and future elk use of the corridor. This analysis was applied to Section A and Section B of Corridor Q.

To determine the habitat variables that the elk in Virginia prefer, the habitat selection evaluation was expanded to include all collared elk (i.e., the 10 collared female elk from the Warfork herd and the 12 Corridor Q elk). GPS locations from the Warfork herd elk collars were screened prior to analysis. A total of 51,638 elk locations from both herds were used for the subsequent habitat selection analysis (Table 2).

Elk Habitat Selection. A habitat selection study area was defined by creating a 20-mile (32-kilometer) buffered area centered on the home ranges of all Corridor Q and Warfork elk (Wheatly and Johnson, 2010). To estimate elk habitat selection, resource selection functions were developed using a "use vs. available" design (i.e., second order habitat selection) (Johnson et al., 2006; Manly et al., 2002). For this design, Arc Map was used to pair each elk location ("used" location) with 10 randomly generated "available" locations within the study area.

GIS resource data were extracted from all locations, and the "used" resource data were compared to the "available" data. For all "used" and "available" locations, 10 explanatory variables (topographic and land cover variables) were extracted from GIS raster data that were indicative of landscape conditions that may influence elk habitat selection (Table 3). Topographic rasters were created from 10m-digital elevation models (U.S. Geological Survey, 2019) at a 10 x 10-meter cell resolution; measures of elevation (meters), slope (degrees), and aspect (degrees) were extracted at each location. The National Land Cover Data (Dewitz, 2021; U.S. Geological Survey, 2019) were used to access habitat data; distances were extracted in meters from each location to the habitat resources (forest cover, herbaceous cover, hay/pasture cover, shrub cover, barren land, open water) and human development.

Table 3. Variables Used for Elk Habitat Selection Analysis

Variable	Source and Unit of Measurement
Topographic	**National Elevation Dataset (1/3 arc second resolution) (U.S. Geological Survey, 2019)**
Elevation	Meters
Slope	Degrees
Aspect	Degrees
Land Cover	**National Land Cover Data (30-meter resolution) (Dewitz, 2021; U.S. Geological Survey, 2019)**
Distance to open water	Euclidean distance raster-meters, cell size 10 x 10 meters
Distance to forest	Euclidean distance raster-meters, cell size 10 x 10 meters
Distance to shrub	Euclidean distance raster-meters, cell size 10 x 10 meters
Distance to herbaceous	Euclidean distance raster-meters, cell size 10 x 10 meters
Distance to hay/pasture	Euclidean distance raster-meters, cell size 10 x 10 meters
Distance to barren land	Euclidean distance raster-meters, cell size 10 x 10 meters
Distance to human development	Euclidean distance raster-meters, cell size 10 x 10 meters

"Distance to" measures were used to characterize elk habitat selection better in consideration of linear features and habitat edge effects (Gillies and St. Clair, 2010; Roever et al., 2012). Pairwise correlations were calculated between all 10 variables. Pairs were evaluated to determine whether any were highly correlated ($|r| \geq 0.7$, $p < 0.05$) and should be removed from further analysis (Dormann et al., 2007). No variables were highly correlated; therefore, all 10 variables were retained for further analysis.

GIS information extracted from used versus available locations was compared using a logistic regression framework where elk locations were represented as a binary response (1 = used; 0 = available). Models were then created that contrasted the explanatory variable composition of the availability domain with the used domain; this was conducted with a conditional logistic regression to infer resource selection and the influence of explanatory variables on used and available locations (Fortin et al., 2005; Signer et al., 2019; Thurfjell et al., 2014). To explain variation in elk habitat selection, multiple models were developed using all variables (listed in Table 3) and different combinations of those variables. Individual elk were used as a random intercept in all models to address issues associated with non-independence and unbalanced sample sizes (Gillies et al., 2006). To identify the model that best explained elk habitat selection, differences in the Akaike information criterion (ΔAICc) values were used to rank models (Burnham and Anderson, 2002). The model with the lowest AICc score was considered the best-performing (most accurate) model, as were models within 2 AICc units from the most accurate model. If maximized log-likelihood estimates were similar, the model with the fewest parameters was considered the most parsimonious (i.e., "best fit") (Burnham and Anderson, 2002) and was evaluated further. To assess the robustness and prediction accuracy of the top-performing model, a k-fold cross validation (k = 10) was performed to calculate the mean cross-validation estimate of accuracy (between 0 and 1) (Boyce et al., 2002; Koper and Manseau, 2009).

Elk Habitat Selection Probability. Model estimates from coefficients in the top-performing elk habitat selection model with significant *p*-values (<0.05) were used to spatially predict the relative probability of elk habitat selection in the study area. Each cell in the

respective coefficient's raster layer was multiplied by its model estimate and added together using the following formula: $w(x) = \exp(\beta_1 X_1 + \beta_2 X^2 + \beta_3 X_3 + \cdots + \beta_{10} X_{10})$ (Johnson et al., 2006) to create a predictive habitat selection probability raster surface (Zeller et al., 2020). It was assumed that pixels with higher probability values afforded higher value to habitat selection than those with lower probability values.

The relative probability of elk habitat selection was examined across the road corridor by calculating the average elk habitat selection probability value for each of the 27 road segments (in both Section A and Section B). The segment average elk habitat selection probability value was used to index and score segments from 1 to 4 based on percentile rank calculation (score of 1 = ≤ 25th percentile, score of 2 = > 25th percentile and ≤ 50th percentile, score of 3 = > 50th percentile and ≤ 75th percentile, score of 4 = > 75th percentile). It is important to note that the sources of the topographic and land cover data listed in Table 3 were from 2019. Because construction, tree clearing, excavation, grading, and grass planting had been completed in Section A of Corridor Q but had not been initiated in Section B, habitat selection probability rank calculations were conducted separately for Section A segments and Section B segments.

Adjacent Land Use (Section A and Section B Road Segments)

Land use of the areas adjacent to Corridor Q was determined by evaluating land ownership information. This was an important factor in determining areas that will likely remain suitable for concentrating the movement of elk and other wildlife across Corridor Q.

Land use considerations were a component of the road segment score. Road segments where protected land managed by The Nature Conservancy was adjacent to one side or both sides of the road were given a score of 1 or 2, respectively (Figure 5).

Topography and Landscape Features (Most Section A Road Segments)

For 18 of the 20 segments in Section A, site visits and map analyses were conducted to evaluate topography and other landscape features on and adjacent to the corridor. For segments 19 and 20 of Section A, road construction had not progressed to the point that the final topographical elements of the roadside could be evaluated during the site visits. Although topography and landscape features were not assigned a numerical score, they were important for the identification of (1) "constructible sites" within the road segments, where topographical characteristics of the roadside lend themselves to a more cost-effective structure design and placement; and (2) the terrain features that are likely to be navigable for elk near the identified constructible sites. This evaluation was conducted with two site visits and analyses of maps, including those illustrating terrain ruggedness and construction maps showing road design elements and as-built contours.

The site visits included the research team and staff from VDOT's Bristol District. These staff included engineers who provided input on areas where cut sections and fill sections of the road might serve as cost-effective locations for overpasses and underpasses, respectively. For example, graded transitions (and costs) can be substantially reduced by the selection of a location

that takes advantage of grades adjacent to the road that are proximate to the height of the structure (McGuire et al., 2021).

Information was documented by the research team and VDOT engineers at all sites identified as being potentially suitable for wildlife crossing structures. Field notes included engineering and construction considerations (i.e., whether the site was a cut or fill section, the degree of tree-clearing required, whether the structure would have to be skewed, etc.) and wildlife use considerations (i.e., whether the adjacent topography would allow unimpeded access to the structure, whether there was evidence of elk tracks or droppings, etc.). Information was also documented on the potential for a structure at a given location to provide a clear line of sight for the animal approaching the entrance. Because an unobstructed view from a structure entrance to the habitat at the other end of a structure has been found to affect elk use of wildlife crossings, the structures should be aligned such that visibility through or across the structures is maximized (Dodd et al., 2012).

Cost Analysis Comparing Wildlife Crossing and Fencing Costs With Financial Benefits of Crash Avoidance

Calculating the Value of Avoided Elk and Deer Crashes

A cost-benefit analysis was conducted to determine the number of elk and deer crashes that need to be avoided per year along a mitigated road segment for wildlife crossings to generate crash reduction benefits in excess of costs. The evaluation required (1) estimated costs of an elk crash and a deer crash, and (2) estimated costs of wildlife crossing structures and fencing.

To quantify the benefits of preventing elk and deer crashes, the value of an elk crash and the value of a deer crash were determined by calculating their average crash severities. This approach (using severity values to quantify crash costs) is used by practitioners in Virginia when calculating the benefit-cost ratio for specific safety treatments (VDOT, 2022b).

In Virginia, deer are the only animal that have a separate field in police report forms. Deer crash severity information (i.e., property damage, injury, or fatality) was obtained from police report records between July 1, 2014, and June 30, 2021. A search of elk crash information in the police reports yielded no information (largely because “elk” is not a field in the police report form). Data on elk-related crashes were therefore gathered by searching other state department of motor vehicle (DMV) websites and contacting DMV personnel. Searches were conducted in nearby states with reintroduced elk populations (i.e., Kentucky, North Carolina, Pennsylvania, Tennessee, and West Virginia) and in western states with sizable elk populations (Arizona, California, Colorado, Idaho, New Mexico, Nevada, Montana, Utah, and Washington). Available police records with information specific to elk-related crashes were evaluated to determine the proportion of these crashes that resulted in property damage, human injury, and human fatality.

Costs attributed to crash severity types were obtained from *Virginia Traffic Crash Costs* (VDOT, 2022b), which uses KABCO crash unit costs to attribute a different cost to each of five levels of crash severity (where K is the unit cost of fatal crashes; A, B, and C are the unit costs of injury crashes that vary in severity; and O is the unit cost of property-damage-only crashes). *Virginia Traffic Crash Costs* was developed for highway safety project evaluations and provides Virginia-specific comprehensive crash costs, which are based on *Crash Costs for Highway Safety Analysis* (Harmon et al., 2018). These values are a combination of economic crash unit costs (tangible impacts) and quality-adjusted life years crash unit costs (monetized pain and suffering).

Using police report records to determine the proportion of crash severities (P) and VDOT crash severity values (VDOT, 2022b) to determine crash costs (CC), the average cost per crash was determined for an elk crash and a deer crash with the following equation:

$$C_{Average} = C_O \times P_O + C_I \times P_I + C_K \times P_K$$

where

$C_{Average}$ = average crash cost for elk (this was also calculated for deer)
C_O = crash cost for property-damage-only crashes
P_O = proportion of crashes resulting in property damage only
C_I = crash cost for injury crashes (for deer crashes, these were broken down into three injury severity types [A/B/C on the KABCO scale] because this information was available in police reports)
P_I = proportion of injury crashes
C_K = crash cost for fatality crashes
P_K = proportion of fatality crashes.

Calculating the Costs of Wildlife Crossing Structures and Fencing

The research team coordinated with VDOT Bristol District engineers to discuss size dimensions and suitable locations for underpass and overpass structures. The engineers used this information to create location-specific cost estimates for new structures (Halloway, 2023). Cost estimates used in the calculations were site-specific and included all construction costs (i.e., concrete, structural and reinforcing steel, mobilization, engineering, traffic control, erosion and sediment work, base and paving, final pavement marking, excavation, centerline shoring, and markup additions). Contingency costs and inflation were also estimated for the purpose of determining a project budget in the event construction was pursued.

Wildlife crossing and fencing costs (including maintenance costs) were annualized to determine the yearly number of crashes that would need to be avoided to equal or exceed the costs of the structures and fencing. Annualized costs assume uniform yearly costs of the structures and fencing throughout their respective service life. These costs were expressed as present discounted values. The present discounted value measures the worth of a future amount

of money in today's dollars adjusted for interest and inflation. The following equation was used to calculate the present discounted value:

where

$$PV = FV\frac{1}{(1+r)^n}$$

where

PV = present value of the future maintenance cost
FV = expected maintenance cost in year n (the future value)
r = discount rate (0.031)
n = year in which the maintenance cost will be incurred.

The annualized structure and fencing costs incorporated a 100-year structure service life (the service life used in bridge models developed by VDOT's Structure and Bridge Division); a 25-year fencing service life; and a 3.1% annual discount rate to adjust for inflation (based on the effective rate for October 2022 federal funds) (Board of Governors of the Federal Reserve System, 2022). Maintenance costs were estimated by calculating 1% of structure construction costs.

The following equation was used to calculate the annualized costs:

$$ACS + ACF = (CS \times r)/(1 - (1 + r)^{-TS}) + (CF \times r)/(1 - (1 + r)^{-TJ})$$

where

ACS = annualized cost of structure
ACF = annualized cost of fencing
CS = cost of structure and maintenance
CF = cost of fencing and maintenance
TS = service life for the structure (100 years)
TJ = service life for the fencing (25 years)
r = discount rate (0.031).

Review and Prioritization of Funding Sources

IIJA authorized nearly $350 billion in federal surface transportation funding over 5 years, including funding for projects aimed at reducing wildlife-vehicle collisions and/or maintaining or improving habitat connectivity. To identify potential funding sources for wildlife crossings, the research team (1) reviewed 15 federal discretionary grant and formula allocation programs for which wildlife infrastructure is expressly eligible under IIJA; and (2) prioritized those programs based on the projected ability of the Corridor Q project to compete successfully for funding given program-specific statutory eligibility requirements, eligible project activities, eligible

applicants, facility ownership, federal share payable, project outcome and merit criteria, and other relevant programmatic eligibilities, including mandatory program set-asides and geographic diversity requirements.

An important component of prioritizing the federal funding programs as a potential funding source was an analysis of Corridor Q project's alignment with the project outcome and merit criteria for federal grant applications. FHWA application evaluation teams attribute a score to each criterion, and these scores are translated into overall rankings such as Strongly Recommended, Recommended, or Not Recommended (U.S. DOT, 2023b). For this study, the research team simulated this process by evaluating each criterion in the context of Corridor Q and providing an anticipated project rating assessment (see Appendices).

RESULTS AND DISCUSSION

Literature Review and Discussions With Experts: Wildlife Crossing Structure Designs

Transportation agencies have constructed wildlife crossings with the explicit goals of reducing large animal crash risk and maintaining or improving habitat connectivity. These agencies include those in western states such as Arizona (Dodd et al., 2012), Colorado (Kintsch et al., 2021), Montana (Huijser et al., 2016), and Washington (Ernest, 2021) and in eastern states such as Florida (Florida Fish and Wildlife Conservation Commission, 2015), North Carolina (Safe Passage, 2021), and Virginia (Donaldson, 2007; Donaldson and Schaus, 2009). Habitat connectivity can be achieved only if wildlife use the structures, and wildlife use is strongly associated with structure design (Clevenger and Huijser, 2011).

Studies have not established a single most effective wildlife crossing design for elk given the numerous factors that can influence structure use and the difficulty in replicating study designs. It has been recognized, however, that larger structures are typically more effective for elk and other ungulate species such as white-tailed deer. In the *Wildlife Crossing Structure Handbook,* Clevenger and Huijser (2011) recommended a minimum width of 130 feet for a large mammal overpass and a minimum width of 125 feet for a large mammal underpass, but these size dimensions are not specific to elk. (With regard to wildlife crossing design, "width" refers to the width at the structure entrances and "length" refers to the distance the animal travels through or over the structure.)

Several states have evaluated the effectiveness of wildlife crossings with regard to elk use of the structures. Table 4 is not a complete list of structures used by elk, but it includes structures for which elk was a primary target species in the design and planning of the structures. For example, Nevada has three wildlife overpasses on I-93 and I-80 (with widths of 100 feet, 150 feet, and 200 feet) designed to accommodate mule deer during migrations, but elk also use the structures (Simpson, 2022).

Table 4. Wildlife Crossing Structure Designs for Which Elk Was a Target Species[a]

State	Road	No. of Structures	Width (ft)	Height (ft)	Length (ft)	Reference
Underpasses						
Arizona	S.R. 260	11	110-135	17-41	174-420	Dodd et al., 2012
Colorado	S.H. 9	5	44	14	66	Kintsch et al., 2021
Montana[b]	I-93N	6	25-197	17-18	72-105	Huijser et al., 2016
Washington[c]	I-90	8	120-900	10-35	118-220	Kalisz, 2022
Overpasses						
Colorado	S.H. 9	2	100	NA	66	Kintsch et al., 2021
Montana	I-93	1	197	NA	207	Huijser et al., 2016
Washington	I-90	1	150	NA	215	Kalisz, 2022

[a] Structure dimensions are listed from the perspective of an animal approaching the structure.
[b] Of the 41 structures on I-93N, only the "Evaro" structures with reported use by elk are included in the table.
[c] Many of the I-90 underpasses were designed with large widths to accommodate rivers in addition to wildlife. The table does not include sizing information for I-90 structures designed for smaller wildlife species.

With the appropriate sizing, underpasses and overpasses have both proven successful for elk passage. Although some research suggests that elk tend to prefer wildlife overpasses to a greater extent than wildlife underpasses (Huijser et al., 2022), monitoring studies in Arizona, Colorado, and Washington have found underpasses to be effective with regard to elk passage (Dodd et al., 2012; Kalisz, 2022; Kintsch et al., 2021). Given the success of both overpasses and underpasses with regard to elk use, the size of the structure may be a more important factor for elk use than whether it spans over or beneath the road. Overpasses maximize visibility across the structure (a factor that is important for elk use) (Clevenger and Huijser, 2011), but adequate visibility can be achieved with sufficient underpass design (Dodd et al., 2012).

Underpasses on Colorado's S.H. 9 were intended to target primarily mule deer but were also designed for use by other species, including elk. With widths of 44 feet (Table 4), these underpasses are among the smaller structures found to be used by elk, and though elk use increased in the first several years following construction, the structures did not receive the degree of elk use found with larger structures in Arizona and Washington (Dodd et al., 2012; Kalisz, 2002; Kintsch et al., 2021). Similarly, Montana's structures on I-93 were designed to accommodate a variety of small to large species, and in the structures used by elk (i.e., structures with maximum widths of only 25 feet) 30 elk crossings were recorded over 5 years (Huijser et al., 2016). In *Wildlife Habitat Connectivity Considerations in Fish Barrier Removal Projects,* the Washington State DOT recommends a minimum width of 60 feet and a minimum height of 15 feet for structures up to 50 feet long (Washington State DOT, 2022). However, the structures designed in part to accommodate elk passage on Washington's I-90 are much larger (Table 4).

The 11 underpasses designed for elk and other species on Arizona's S.R. 260 have minimum widths of 110 feet (Table 4). In discussing Corridor Q wildlife crossings designs, the primary researcher that evaluated the Arizona structures recommended minimum widths of 100 feet (Gagnon, personal communication). It is important to note that the recommended 100-foot width refers to the space between the bridge abutments. However, there is a steep embankment from the abutments to the ground, resulting in a width that is substantially narrower at the ground level where the elk travel beneath the underpass.

Wildlife Crossing Structure Designs for Corridor Q

Given the use of both overpasses and underpasses by elk (Table 4), the research team decided that cost considerations and placement of structures in a manner that maximized elk use should be prioritized over structure type for Corridor Q. With regard to structure sizing, there is no conclusive determination of minimum (and still effective) structure dimensions.

VDOT engineers determined that wildlife crossing structures (both overpasses and underpasses) would require a length of 80 feet to span the travel lanes and shoulders of Corridor Q. Factoring in the 80-foot structure lengths, cost considerations, findings from the literature, and discussions with experts, the research team coordinated with VDOT engineers to determine the appropriate height and width for structures. The following size dimensions were determined to be appropriate for wildlife crossings constructed on Corridor Q (dimensions are listed from the perspective of an animal approaching the structure entrance):

- *For overpasses:* 100-foot width of structure entrances for wildlife (also the structure width when measured along the vehicular traffic direction); 80-foot length of travel for wildlife (or span length of structure as measured perpendicular to the vehicular traffic direction); 18-foot height (vertical clearance where the span length is measured).

  Rationale: Overpasses with a width of 100 feet were found to be successful for accommodating elk passage in Colorado (Kintsch et al., 2021) and, although not as wide as some overpass designs in the United States, were noted as having a sufficient minimum width by wildlife crossing experts in Arizona, Nevada, Utah, and Washington (Simpson, Gagnon, Cramer, Kalisz, personal communications).

- *For underpasses:* 85-foot width of structure entrances for wildlife (or structure span length when measured along the vehicular traffic direction); 80-foot length of travel for wildlife (or width of structure as measured perpendicular to the vehicular traffic direction); 18-foot height (vertical clearance from the bottom of the superstructure to the ground level where elk travel).

  Rationale:
  - An underpass with these dimensions is larger than the minimum width recommended by the Washington State DOT in *Wildlife Habitat Connectivity Considerations in Fish Barrier Removal Projects* (Washington State DOT, 2022); larger than structures used by elk in Colorado (Table 4); similar to some of the structures that are effective for elk and deer on Arizona's S.R. 260; and smaller than those on Washington's I-90 (Table 4).

  - DOT engineers found that a structure with a width of 85 feet is substantially less expensive than a wider structure.

Criteria-Based Evaluation to Determine Suitable Locations for Wildlife Crossings

Elk Locations and Elk Home Ranges (Section A Road Segments)

Of the 26,659 elk locations from the collared Corridor Q elk, 10,113 were within the Section A road segments (37.9%) on both sides of Corridor Q. Of the locations within the Section A road segments, 1,267 were on the road (12.5%). The far western segments of Corridor Q received the least use (Figure 6). The number of elk locations within the 20 segments of Section A ranged from 3 to 1,657, with an average number per road segment of 505.7 (505.7 ± 382.4 [SD]) (Table 5 and Figure 6). Of the segments' elk use scores (the sum of elk location scores and elk home range scores), segment 14 had the highest score of 4 (on a scale of 1 to 4), with 1,657 locations. Eight segments received scores of 3 (range = 613 to 876 locations), 7 segments received scores of 2 (range = 195 to 544 locations), and 4 segments received scores of 1 (range = 3 to 171 locations).

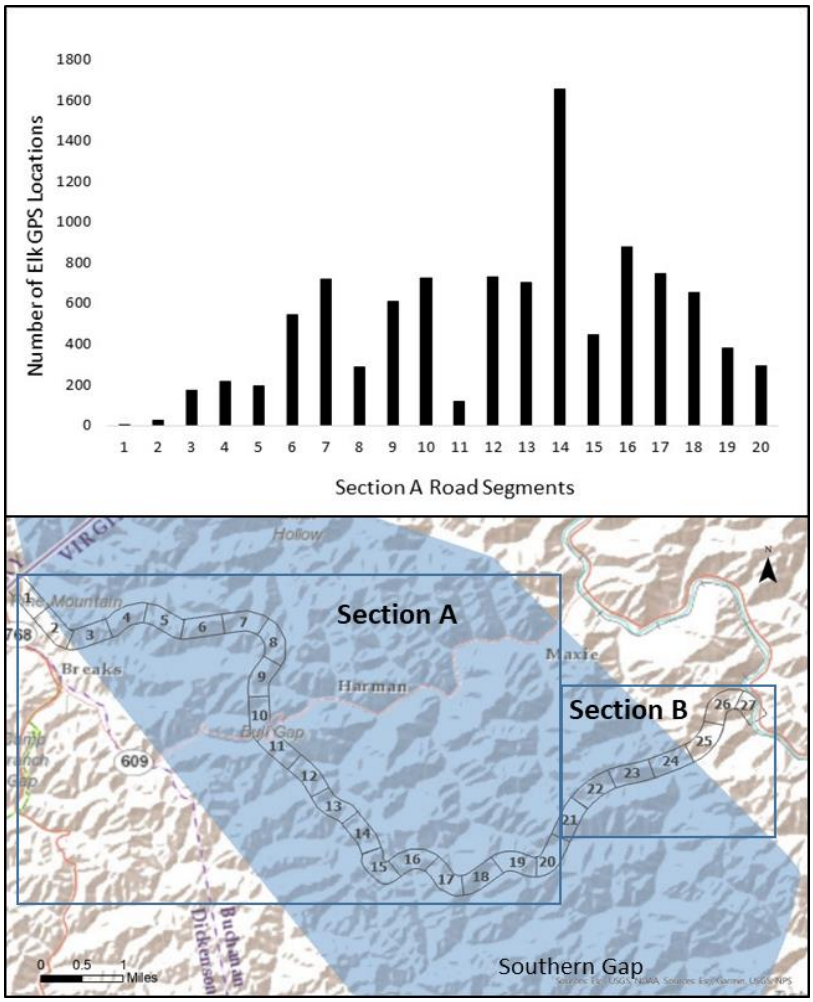

Figure 6. Number of Elk Locations in Each Section A Road Segment (*top*) and Geographic Extent (Blue) of Elk Locations (*bottom*) Recorded for 12 Female Elk From February 4, 2019, to December 30, 2021. Precise elk locations are not illustrated to protect the elk herd from poaching and to protect landowners from associated trespassing.

Table 5. Elk Use Scores for Section A Road Segments Based on Collar Data Collected From February 4, 2019, to December 30, 2021

Segment	Elk Locations		Elk Home Ranges		Elk Use Score
	No. in Segment	Elk Locations Score	No. in Segment	Elk Home Ranges Score	
1	3	1	5	1	2
2	25	1	7	2	3
3	171	1	9	3	4
4	215	2	9	3	5
5	195	2	11	4	6
6	544	2	11	4	6
7	722	3	11	4	7
8	288	2	11	4	6
9	613	3	11	4	7
10	726	3	11	4	7
11	120	1	12	4	5
12	732	3	12	4	7
13	703	3	12	4	7
14	1,657	4	12	4	8
15	446	2	12	4	6
16	876	3	12	4	7
17	750	3	12	4	7
18	652	3	12	4	7
19	381	2	12	4	6
20	294	2	12	4	6

Home ranges of all 12 collared female elk in Corridor Q overlapped with portions of Corridor Q road segments (Figure 7). Home ranges were shaped similarly to those in Section A, indicating the elks' heavy use of the road to access preferred areas of habitat on both sides of the corridor. A review of location data within the home ranges indicated that the collared elk were traveling the full extent of their home ranges over the course of a year. A given Section A road segment overlapped with 5 to 12 elk home ranges. Ten road segments included all 12 overlapping elk home ranges, and 6 segments included 11 overlapping elk home ranges (Figure 7). For score ranking (on a scale of 1 to 4), 18 segments had a score of 4 (range = 11-12), 2 segments had a score of 3 (range = 9), 1 segment had a score of 2 (7 home ranges), and 1 segment had a score of 1 (5 home ranges).

Home range areas for the 12 Corridor Q elk averaged 20.8 $mi^2 \pm 7.0$ (SD) and ranged from 5.8 mi^2 to 27.8 mi^2. Home range areas for the 10 Warfork elk were much smaller, with an average of 3.1 $mi^2 \pm 2.6$ (SD) and a range of 1.0 mi^2 to 8.0 mi^2. These findings, in addition to the 1,267 elk locations on the road itself, suggest that the road has become an established and efficient means of travel (i.e., a larger area can be accessed for resources with less energy expenditure) for the Corridor Q elk herd.

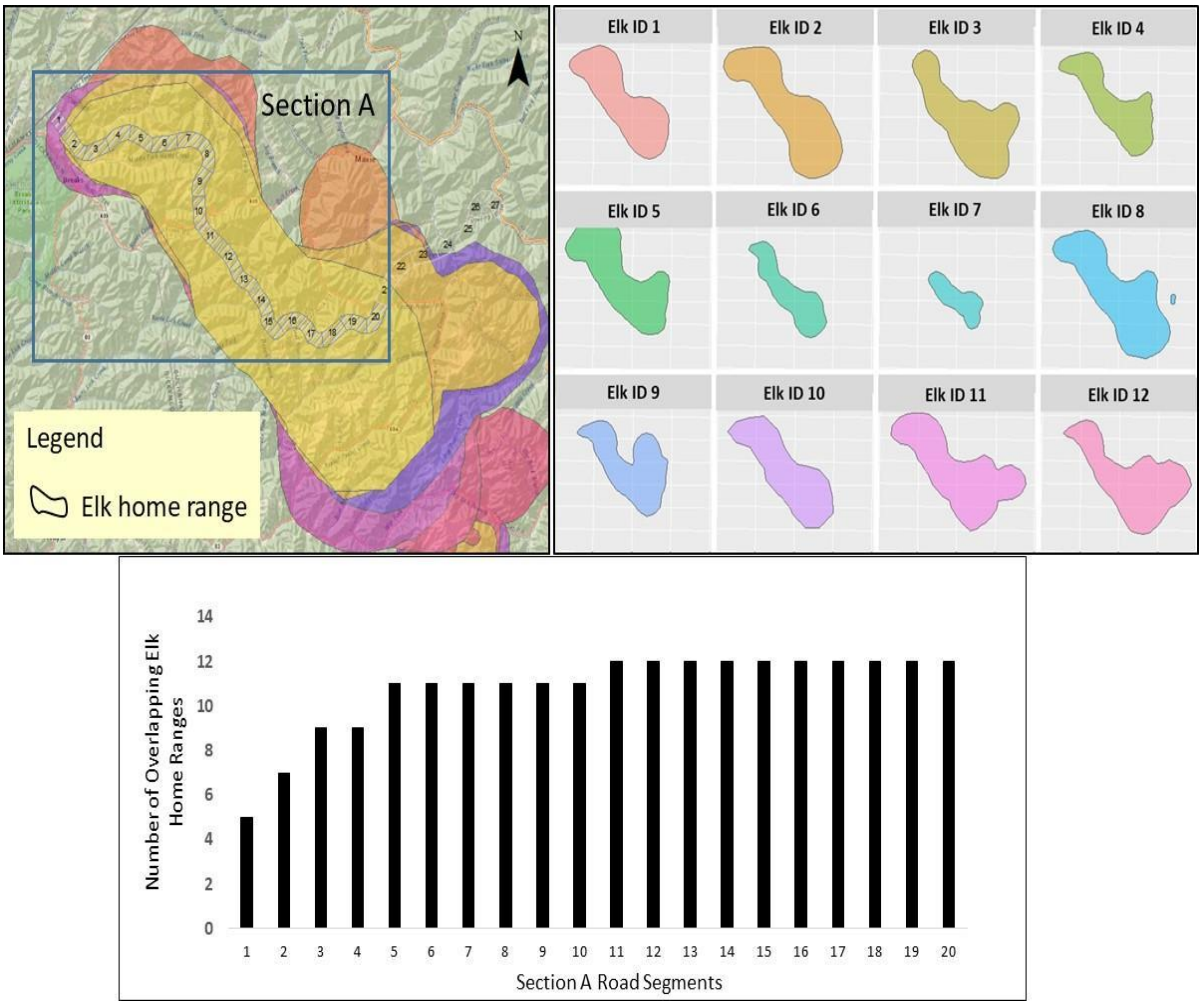

Figure 7. Corridor Q Elk Home Range Information. ***Top left:*** **combined home ranges illustrating their locations relative to Corridor Q.** ***Top right:*** **individual home ranges.** ***Bottom:*** **number of elk home ranges that overlapped Section A road segments.**

Habitat Selection (Corridor Q Elk and Warfork Elk)

The top elk habitat selection model with the lowest AICc score (ΔAICc of next top-performing model = 58.1) included all 10 explanatory variables: elevation, slope, aspect, distance to forest cover, distance to herbaceous cover, distance to shrub cover, distance to hay/pasture, distance to barren land, distance to open water, and distance to human development. The relative probability of elk habitat selection increased significantly ($p < 0.05$) in areas with relatively flatter slopes, higher elevations, and southern aspects and in areas closer to herbaceous cover, shrub cover, hay/pasture cover, and forest cover. This is consistent with research that found elk tend to choose habitat that contains preferred grass forage and cover (i.e., shelter) in the form of trees and shrubs (Christianson and Creel, 2007) and that elk avoid steep slopes due to high energetic movement costs (Frair et al., 2005; Fryxell et al., 2008). Elk selection for more southern aspects is likely due to the available sunlight and associated vegetative conditions on south-facing slopes.

The relative probability of elk habitat selection increased significantly ($p < 0.05$) in areas farther from human development and open water (Table 6). Distance to barren land, herbaceous cover, and shrub cover had the largest influence on elk habitat selection in the study area, with almost twice as much influence as the next highest influential covariates (slope and distance to hay/pasture).

Table 6. Coefficient Estimates (β), Standard Error (SE), and Z-Values (Zb) From the Top Model Used to Evaluate the Influence of Land Cover and Topographic Variables on Habitat Selection

Variable[a]	β	SE	Zb
Intercept	-5.595	0.107	-51.69
Distance to open water	0.716	0.007	92.85
Distance to barren land	-1.716	0.0148	-110.65
Distance to forest	-0.053	0.0058	-9.65
Distance to shrub	-1.460	0.0164	-88.27
Distance to grass/herbaceous	-1.321	0.0162	-79.29
Distance to hay/pasture	-0.761	0.0138	-109.59
Distance to human development	0.240	0.0077	71.11
Elevation	0.684	0.0095	-54.34
Slope	-0.856	0.007	28.88
Aspect	0.067	0.007	7.75

[a] All variables listed were found to have a significant influence on elk habitat selection ($p < 0.05$).

Habitat Selection Probability (Sections A and B)

The average elk habitat selection probability value in Section A road segments ranged from 3% to 63%, with the average elk habitat selection probability per road segment of 30% (±20.4% [SD]) (Table 7 and Figure 8).

Table 7. Habitat Selection Probability

Section A Road Segments			Section B Road Segments		
Segment	Habitat Selection Probability	Habitat Selection Score	Segment	Habitat Selection Probability	Habitat Selection Score
1	6.2%	1	21	13.4%	3
2	9.9%	1	22	16.9%	4
3	8.5%	1	23	15.3%	4
4	2.7%	1	24	1.1%	2
5	13.4%	2	25	0.9%	1
6	34.1%	2	26	1.1%	2
7	53.9%	3	27	2.3%	3
8	38.7%	3			
9	40.0%	3			
10	60.5%	3			
11	37.9%	4			
12	8.4%	3			
13	7.2%	3			
14	22.3%	3			
15	28.1%	3			
16	50.0%	2			
17	55.6%	2			
18	62.7%	4			
19	46.9%	4			
20	13.4%	3			

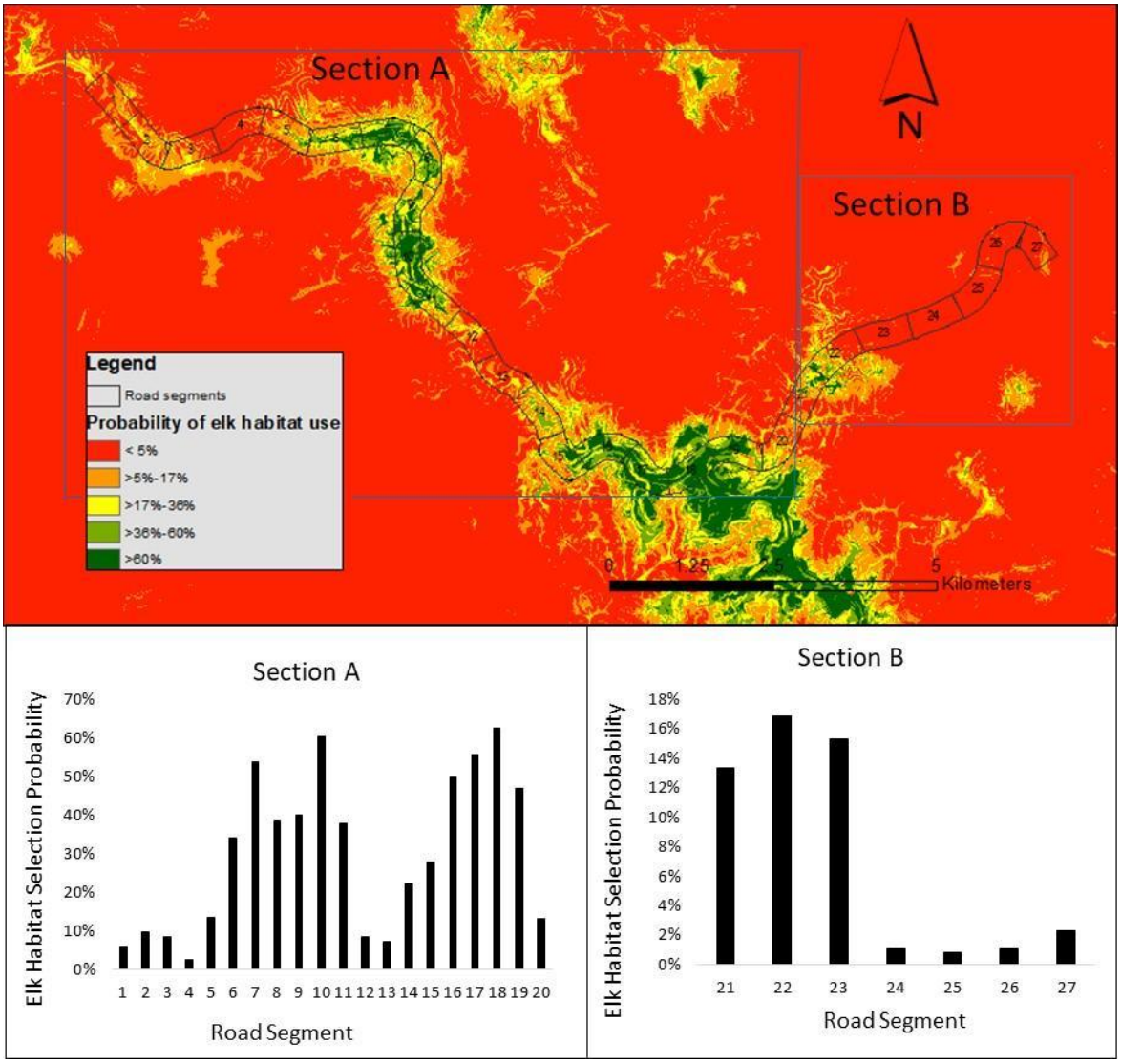

Figure 8. Elk Habitat Selection Probability Along Corridor Q

For the percentile ranking score (on a scale of 1 to 4), three segments received a score of 4 (range = 56% to 63%), seven segments received a score of 3 (range 34% to 54%), four segments received a score of 2 (range = 13% to 28%), and six segments received a score of 1 (range = 3% to 10%). The average elk habitat selection probability value for road segments in Section B ranged from 1% to 17%, with an average elk habitat selection probability percentage per road segment of 5% (±7.4% [SD]) (Figure 8).

Given the importance of the habitat types created by road construction, habitat selection probability values are expected to increase in Section B as road construction progresses. The availability of herbaceous cover and shrub cover (which includes early successional vegetation that establishes after a forested area is cleared) (Swanson et al., 2010) are main drivers of elk habitat selection in the region. In Section A, herbaceous cover, shrub cover, and flattened slopes are a product of road construction and are distributed linearly along the roadway. As these

conditions that drive elk habitat selection are created in Section B, elk use is expected to increase at levels comparable to those in Section A.

The habitat selection analysis confirms that the use of the landscape by this newly established elk population has been shaped by road construction. Although their movement in relation to the road would have been difficult to predict during the planning of Corridor Q, using new knowledge to implement adaptive management strategies such as wildlife crossings and fencing has been found to influence elk movement in a manner that reduces risks to driver safety (Dodd et al., 2012; Hamr et al., 2022). For example, when researchers in Arizona determined there was an increased risk of elk crashes after reconstruction of a highway section with three wildlife underpasses but only limited wildlife fencing, they implemented adaptive management strategies in two ways: (1) retrofitted an existing 1-meter right-of-way fence to 2.4 meters in height and tied it into underpasses at the project's east end, and (2) installed an animal detection driver warning system at the end of the fencing to prevent collisions when animals crossed. This resulted in a 97% decrease in elk crashes (a crash reduction of 3.6 per mile) (Gagnon et al., 2019).

Adjacent Land Use (Sections A and B)

Corridor Q is situated in a rural mountainous area with limited development. Privately owned land and land owned by Cumberland Forest Highlands, LLC (CFH) and managed by The Nature Conservancy) each comprise approximately one-third of the land area within a 200-meter area on either side of the corridor (Figure 9). CFH lands overlap most of the Section A segments (Figure 10). Eight road segments were given a score of 1 for overlapping CFH land on one side of the road segment, and six were given a score of 2 for overlapping CFH land on both sides. Corridor Q is also within 0.5 miles of Breaks Interstate Park and within 2 miles of the Jefferson National Forest (Figure 10).

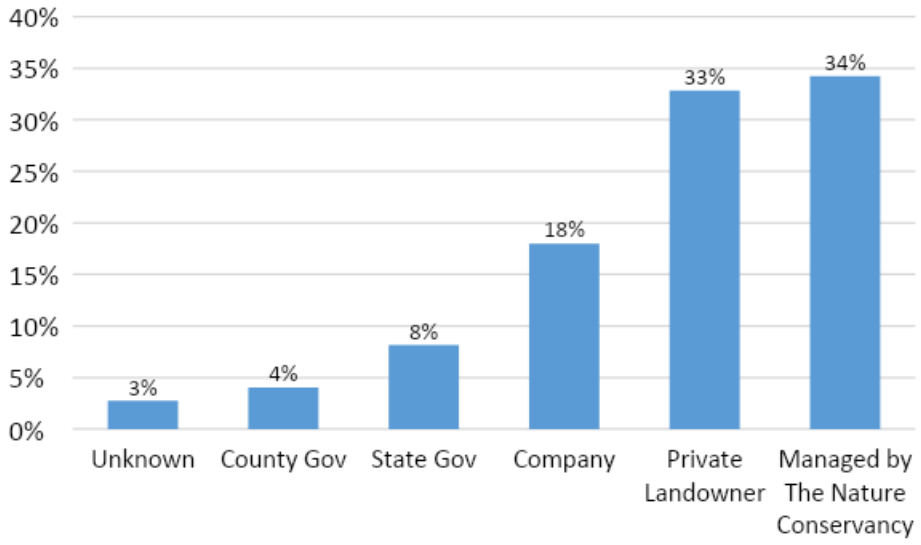

Figure 9. Land Ownership or Management Within a 200-Meter Area Bordering Corridor Q

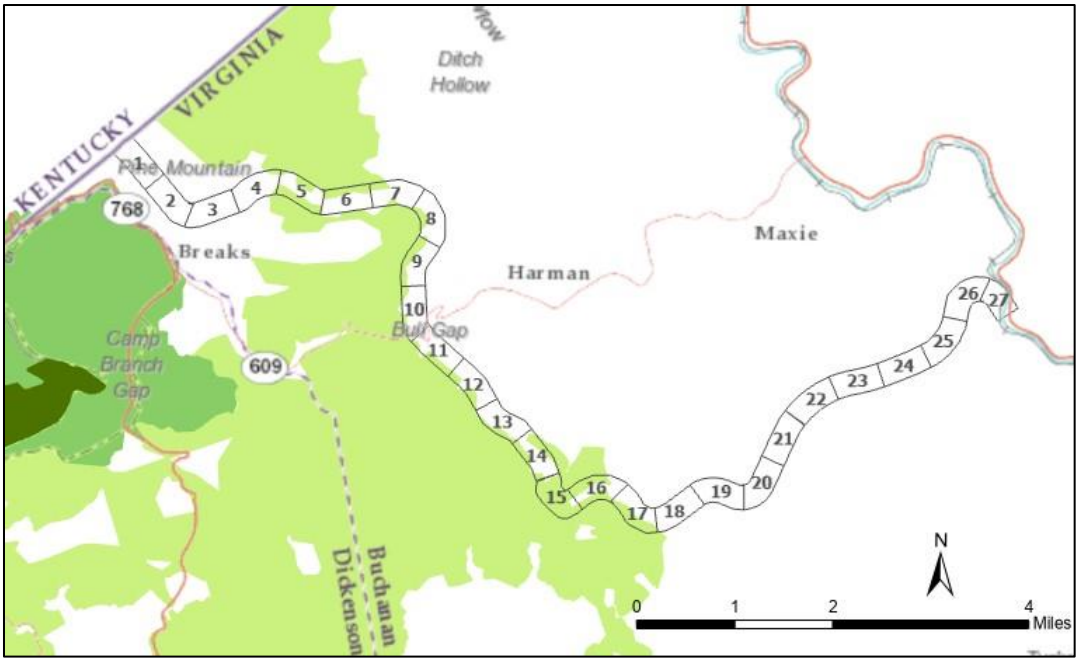

Figure 10. Corridor Q Road Segments Relative to Land Owned by Cumberland Forest Highlands, LLC (Managed by The Nature Conservancy) (light green); Breaks Interstate Park (medium green); and the Jefferson National Forest (dark green).

VDWR has agreements with five landowners whose properties intersect the Corridor Q right of way. VDWR may use the properties for public access and to conduct habitat and infrastructure work related to wildlife and recreation. VDWR currently has almost 9,000 acres associated with the five cooperating landowners and is working to add additional properties along the corridor.

Road Segment Ranks

As listed in Table 8 and Table 9, the total scores were the sum of the elk use score (for Section A segments), the habitat selection probability score, and the adjacent land use score (all of which were scored from 1 to 4). A road segment rank was created based on the percentile rank of the total score. The road segment rank was categorized into four categories (with 1 considered low and 4 considered high) (Figure 11).

Thirteen of the 27 road segments had medium-high or high ranks of 3 or 4 (Table 8 and Table 9, Figure 11). As noted previously, the final determination of suitable wildlife crossing placement was not based solely on road segment scores but also incorporated analyses of landscape features that encourage elk movement, evaluations of roadside topography, and spacing decisions.

Table 8. Road Segment Ranks for Section A of Corridor Q

Section A Road Segment	1. Elk Use Score	2. Habitat Selection Probability Score	3. Land Use Score	Total Score (1.+2.+3)	Road Segment Rank
1	2	1	0	3	1
2	3	1	0	4	1
3	4	1	0	5	1
4	5	1	1	7	1
5	6	2	2	10	2
6	6	2	2	10	2
7	7	3	2	12	4
8	6	3	1	10	2
9	7	3	1	11	3
10	7	3	1	11	3
11	5	4	1	10	2
12	7	3	1	11	3
13	7	3	1	11	3
14	8	3	2	13	4
15	6	3	2	11	3
16	7	2	2	11	3
17	7	2	1	10	2
18	7	4	0	11	3
19	6	4	0	10	2
20	6	3	0	9	1

Ranks (1-4, low to high) were based on percentile ranks of the total score.

Table 9. Road Segment Ranks for Section B of Corridor Q

Section B Road Segments	1. Habitat Selection Probability	2. Land Use	Total Score (1.+2.)	Road Segment Rank
21	3	0	3	3
22	4	0	4	4
23	4	0	4	4
24	2	0	2	2
25	1	0	1	1
26	2	0	2	2
27	3	0	3	3

Ranks (1-4, low to high) were based on percentile ranks of the total score.

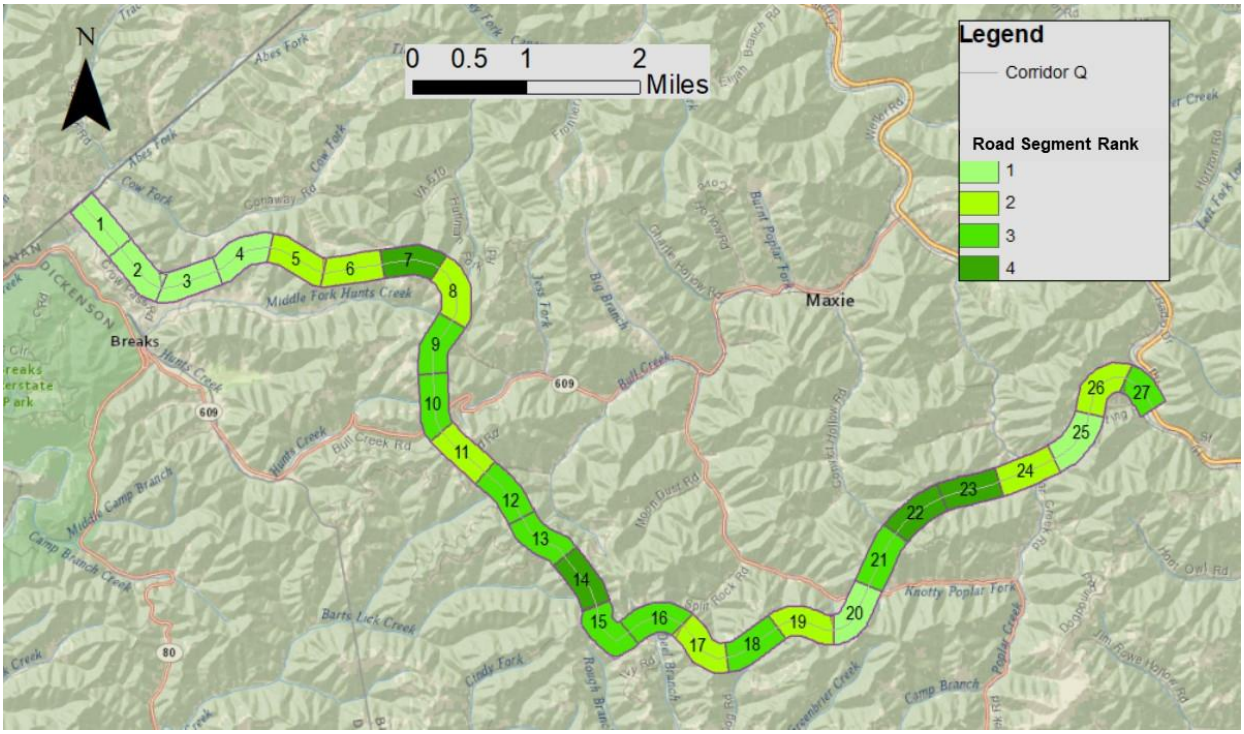

Figure 11. Road Segment Ranks for Corridor Q. Road segment ranks range from 1 (lowest) to 4 (highest). The numbers within road segments indicate segment numbers. Road segment ranks are designated by color.

Topography and Landscape Features (Section A Road Segments)

During the site visits, two main characteristics of a site were evaluated to determine its potential suitability for a wildlife crossing: (1) cost-effective constructability, and (2) adjacent landscape features that are compatible with elk movement (e.g., terrain that elk can easily navigate as they approach the structure entrances). Sites with both of these characteristics were considered suitable for a wildlife crossing. More sites were considered suitable for underpasses than for overpasses. For underpasses, 11 sites had both characteristics. For overpasses, although 9 were suitable with regard to constructability, only 3 were also suitable with regard to landscape features.

From a constructability/cost-effectiveness standpoint, overpasses were considered most suitable on certain cut sections, specifically in areas where road construction created areas of high rock walls on both sides of the road. These high points may help serve as the foundation for an overpass, with the bridge deck spanning from one rock wall to the other. However, on Corridor Q, some of these high points are associated with steep slopes on the back side (the side not facing the road), which elk would have to navigate to access an overpass entrance. As determined by the habitat selection model and supported by other studies (Frair et al., 2005; Fryxell et al., 2008), elk tend to avoid steep slopes compared to flatter terrain. Even if the Corridor Q elk are accustomed to navigating the areas of steep terrain (and these elk have often been observed on relatively steep slopes), landscape features that provide an easily navigable pathway to a wildlife crossing comprise an important element of structure placement (Clevenger and Huijser, 2011).

An evaluation of topographic rasters (U.S. Geological Survey, 2019) illustrates an example of a steep slope adjacent to what otherwise would be considered a suitable overpass location (Figure 12). Elk would have to traverse a steep slope immediately behind the cut section to access an overpass; this type of terrain also provides elk no clear line of sight toward and across a structure. Sites with steep slopes adjoining the top of a cut section of road were therefore not considered suitable overpass locations.

Locations identified as suitable underpass locations were on fill sections of road, where the land slopes downward on both roadsides (Figure 13). Sites were considered potentially suitable for underpasses on fill sections of the road adjacent to areas where the landscape contours provide easily navigable pathways for wildlife and where the position of the structure would be along a clear line of sight for an approaching animal (Clevenger and Huijser, 2011).

Figure 12. Illustrations of a Steep Slope Adjacent to a Cut Section of Road That Could Decrease the Likelihood of Elk Accessing an Overpass

Figure 13. Example of a Fill Section of Road That Would Serve as a Suitable Underpass Location

Wildlife Crossing Structure Spacing

Structure spacing decisions were important in determining suitable crossing locations for Corridor Q. For example, two adjacent road segments may have a high road segment rank and may include several sites where the topography lends itself to cost-effective structure placement,

but a suitable site can be selected or eliminated based on the targeted spacing interval between structures.

Decisions regarding how far to space wildlife crossing structures along a road are typically based on several factors, including movements of the target species, existing wildlife crash hotspots (or areas with an expected high risk of crashes), important habitat areas on either side of the road, and cost considerations (Bissonette and Adair, 2008; Clevenger and Huijser, 2011; Dodd et al., 2012). Another consideration is the number of animals (or the proportion of a species' population) that would need to move across a road to maintain population viability, but this is difficult to determine and is not commonly evaluated for wildlife crossing projects.

The *Wildlife Crossing Handbook* does not provide a recommended structure spacing distance specific to elk but notes that landscapes that are relatively intact and less fragmented will require relatively more wildlife crossings than highly fragmented landscapes with little natural habitat bisected by roadways (Clevenger and Huijser, 2011). Spacing wildlife crossings at shorter distances apart increases an animal's chance of encountering the structure during its routine movements (Bissonette and Adair, 2008). Spacing structures too far apart may not only risk decreasing the use of the structure by wildlife but can also increase the likelihood that animals that do not encounter the structure will find their way through or around the end of fencing and create crash hotspots in those locations (Huijser et al., 2008).

Using the radius or diameter of the home range for the target species has been thought to be a useful means of balancing structure spacing decisions and cost implications (Bissonette and Adair, 2008; Donaldson and Elliott, 2021; Huijser et al., 2015). Bissonette and Adair (2008) calculated spacing distances for several large animal species using the square root of their home range sizes ($HR^{0.5}$, or $\sqrt{HR}$). The authors used home range information from Harestad and Bunnell (1979) to propose a spacing calculation of 2.2 miles for elk, 0.9 mile for white-tailed deer, and 3.1 miles for black bear. Although their study did not evaluate the effectiveness of implementing this recommendation, the theory was tested by researchers in Arizona.

Arizona researchers (Dodd et al., 2012) evaluated Bissonette and Adair's (2008) home range ($\sqrt{HR}$) theory by evaluating elk use of 11 wildlife underpasses along a 17-mile road segment in Arizona. Dodd et al. (2012) applied the home range sizes of elk in the S.R. 260 area to the home range calculation ($\sqrt{HR}$). This resulted in a spacing of 1.6 miles. For each of the 11 wildlife underpasses, the researchers calculated the elk passage rate (i.e., the number of elk crossings through a structure per the number of elk approaches to the structure). In general, findings indicated an inverse relationship between structure spacing and elk use; elk use of structures decreased as the average spacing increased. The close (0.6-mile) spacing of structures promoted a high level of elk permeability (0.81 crossings/approach), whereas spacing that was twice that distance promoted only one-third the level of permeability (0.27). The 1.5-mile spacing resulted in one-tenth the permeability (0.09). The mean structure spacing of 1.0 mile across all evaluated structures resulted in an intermediate level of elk use (0.44 elk crossings per approach). To balance cost considerations and elk use, the researchers therefore recommended a "preferred target" of 1.0 mile (Dodd et al., 2012). In a follow-up discussion with one of the study's authors (and the author of other studies on the S.R. 260 wildlife crossings), spacing

distances of no more than approximately 1.5 miles was recommended (Gagnon, personal communication).

Researchers in Washington have monitored the use of wildlife crossings by elk and other species following the construction of 10 wildlife underpasses and 1 overpass on I-90. Structures that are large enough for elk are spaced at an average of 0.9 mile, but 2 years of elk crossing data indicate that there is more use of structures that are closer together (0.1 mile to 0.4 mile) (Kalisz, 2022). As no reports or publications are available regarding these findings, it is important to note that these preliminary findings were based on a simple review of crossing data and do not account for the many other factors that affect structure use.

Table 10 includes information on average spacing intervals for several large-scale mitigation projects designed for large mammals, including elk. Structures were variably spaced in each project but had a 1.1-mile spacing interval on average.

Table 10. Spacing Distances Between Wildlife Crossings Designed for Large Mammals Including Elk

Location (Reference)	No. of Crossings	Road Length (mi)	Average Spacing Distance Between Structures (mi)			
			0.5	1.0	1.5	2.0
Arizona S.R. 260 (Dodd et al., 2012)	17	17		X (1.0)		
Trans-Canada Highway (cited in Clevenger and Huijser, 2011)[a]	24	27			X (1.2)	
Trans-Canada Highway (cited in Clevenger and Huijser, 2011)[b]	8	7.5		X (0.9)		
Montana U.S. 93[c]	60	81			X (1.4)	
Washington I-90 (Kalisz, 2022)[d]	8	6.2		X (0.8)		

[a] Phases 1, 2, and 3A reconstruction.
[b] Phase 3B reconstruction.
[c] Includes structures designed for large and small mammals on U.S. 93N and U.S. 93S.
[d] Washington's I-90 includes additional wildlife crossings along a longer segment of road, but the information in the table is specific to crossings used by elk.

Wildlife Crossing Structure Spacing for Corridor Q Elk

As detailed in previous sections, Corridor Q elk location data indicated elk use of every Corridor Q segment that was at least partially constructed (Section A). Structure spacing and fencing considerations should factor in the likelihood (as determined by the elk location and habitat selection analyses) that elk use of Section B road segments will increase as road construction progresses. The optimal strategy therefore includes minimizing elk access to both Sections A and B of Corridor Q. Constructing structures and fencing along only a portion of the corridor risks the possibility that elk will seek access to the unfenced road segments and create crash risks in those areas (Clevenger and Huijser, 2011; Huijser et al., 2016).

Although Dodd et al. (2012) found that Bissonette and Adair's (2008) √HR structure spacing strategy was ineffective for elk structure use on Arizona's S.R. 260, the √HR method was one of the spacing strategies considered for Corridor Q. Applying this to the 20.8-mi^2 home range of Corridor Q elk would result in a structure spacing interval of 4.6 miles. It is important to note that the average home range of Corridor Q elk was more than 6 times larger than that of the Warfork elk (20.8 mi^2 compared to 3.1 mi^2). This considerable difference in home range sizes is likely explained by the Corridor Q herd's use of the road. As indicated previously in Figure 7, their home range is influenced by Corridor Q. Of the 10,113 locations within the Section A road segments, 12.5% were on the road itself. The road is an efficient and easy means of travel compared to the adjacent habitat with steep topography; elk can travel greater distances on the road because it requires less energy expenditure to access resources. Because the purpose of using home size in spacing decisions is to ensure that structures are accessible for the target species, it would be necessary to consider that home range sizes of Corridor Q elk would likely decrease if their access to the road was blocked with fencing and crossing structures. Because of this complicating factor with the Corridor Q herd (i.e., the sizes and shapes of their home ranges have been shaped by the road, a situation that has not been reported in other elk studies), using √HR was determined to be an unsuitable strategy upon which to base structure spacing decisions. In addition, a 4.6-mile spacing interval is more than 3 times greater than the largest average spacing interval applied in other elk crossing projects (Table 10), and its use would risk creating a barrier to wildlife movement for species with smaller home ranges.

For the Corridor Q elk, a maximum distance of approximately 1.5 miles between structures was determined to provide a balance between costs and the likelihood of elk and other large animals encountering and using the structures. The following considerations summarize the factors used to determine this spacing strategy. (It is recognized, however, that the variety of other considerations agencies must weigh with regard to implementation may allow for increased flexibility in spacing decisions.)

- Spacing the structures as far apart as possible without sacrificing the effectiveness of the structures is needed to accommodate cost considerations.

- Elk researchers in Arizona, who have conducted the most extensive research on wildlife crossing use by elk, recommended a spacing distance of 1 mile (Dodd et al., 2012) not to exceed approximately 1.5 miles (Gagnon, personal communication) to balance the likelihood of elk use of the structure and costs.

- Although structures spaced less than 1 mile apart have been found to be associated with higher elk use of structures, spacing structures 1 mile apart or less on Corridor Q would add to the number of wildlife crossings and thereby substantially increase costs.

- Spacing structures substantially greater than 1.5 miles apart risks a low use of the structures and a higher chance that elk will be motivated to break through any weak points (damaged sections) in the fencing or around the fence ends (potentially creating crash hotspots in those areas) (Huijser et al., 2008).

- Spacing structures substantially greater than 1.5 mile apart may adversely affect the ability of other wildlife in the area to move across the landscape. A maximum distance of 1.5 miles is likely sufficient for black bears, who have large home ranges, and possibly sufficient (though perhaps not ideal) for white-tailed deer. Home range sizes of black bears are highly variable throughout Virginia; average male home range sizes have varied from 15.4 mi^2 to 90.1 mi^2 and average female home range sizes have varied from 3.6 mi^2 to 15.7 mi^2 (VDWR, 2012). White-tailed deer have a smaller home range size; the average annual home range of this species is considered to be approximately 1 mi^2 (VDGIF, 2015).

Suitable Wildlife Crossing Locations for Corridor Q

As a result of the criteria-based evaluation process applied to the 0.5-mile road segments, suitable locations for 10 new wildlife crossing structures were identified along Corridor Q: two overpasses and eight underpasses (Figure 14). In addition to new structures, an existing large bridge underpass at the western end of the corridor is expected to be used by wildlife if fencing is extended to the structure. Eight-foot-high woven wire wildlife fencing should extend between any constructed crossing structures.

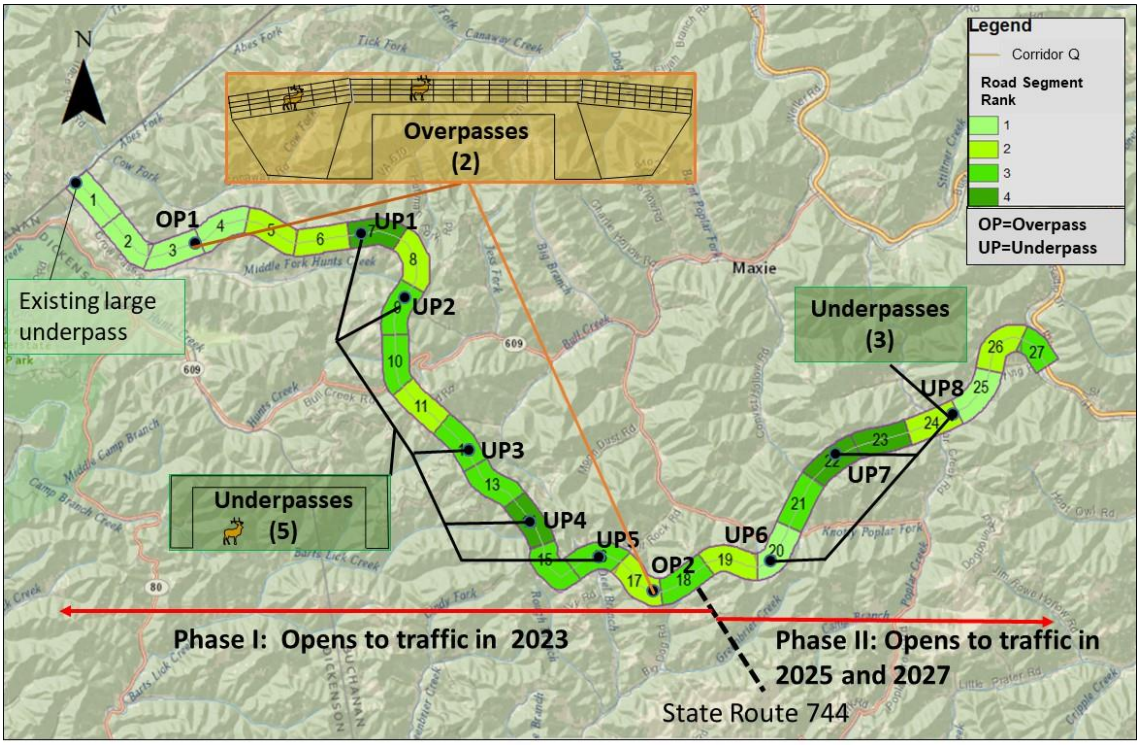

Figure 14. Wildlife Crossing Structure Types and Identified Suitable Structure Locations Along Corridor Q. Fencing should extend between any constructed structures. Numbers within road segments indicate segment numbers; road segment ranks are designated by color (1 is a low rank and 4 is a high rank). Because site visits were not conducted on segments 20, 22, and 24, further evaluation will be needed to determine precisely where to place underpasses within those road segments.

In Section A, the identified structure locations are within both of the highest-scoring road segments (with ranks of 4) and three of the next highest-scoring road segments (with ranks of 3). Although the two identified locations in lower ranked segments (with ranks of 1 and 2) were selected in part to avoid fenced sections substantially longer than 1.5 miles, structures in these lower ranked sections are still expected to be used by elk. For example, although segment 3 has the lowest road segment rank of 1, the home ranges of 9 of the 12 collared elk included segment 3. Elk locations extend north and south of Corridor Q along the western end of the corridor. In addition, two VDWR observational findings indicated that elk are increasingly using the areas near the western portion of the corridor: (1) uncollared male elk are observed annually from December through March in the western portion of the corridor; elk are expanding their range in this area, as evidenced by their presence in Breaks Interstate Park for the first time in 2023; and (2) ear-tagged elk from Kentucky have been found near the western portion of the corridor, indicating that individuals from the Kentucky population are continuing to enter Virginia through Buchanan County.

Spacing distances between the identified locations ranged from 0.7 mile to 1.8 mile, with an average distance of 1.2 miles (Table 11). Wildlife crossing locations are spaced closer together between segments 12 and 18 because of consistently high road segment ranks between these segments. Because site visits were not conducted on segments 20, 22, and 24, further evaluation will be needed to determine precisely where to place underpasses 6, 7, and 8 within the road segments (and where to end fencing in segment 27).

It is important to note that S.R. 744 and S.R. 609 intersect Corridor Q. Because fencing cannot extend across these intersections, warning signs or animal detection driver warning systems could be considered as a means to alert drivers about the risk of elk entering these areas. In the event elk enter these openings, escape ramps should be placed in the adjacent fencing near these intersections. These measures will be discussed with VDOT staff if funding for wildlife crossings and fencing is pursued.

Table 11. Wildlife Crossing Structure Types and Suitable Locations Along Corridor Q

Structure	Study Design			Distance to Next Structure (mi)	VDOT Construction Phase
	Section	Road Segment	Road Segment Score		
Existing underpass	A	1	NA	1.5	I
Overpass (OP1)	A	3	1	1.7	I
Underpass (UP1)	A	7	4	0.9	I
Underpass (UP2)	A	9	3	1.8	I
Underpass (UP3)	A	12	3	1.0	I
Underpass (UP4)	A	14	4	0.7	I
Underpass (UP5)	A	16	3	0.7	I
Overpass (OP2)	A	17	2	NA[a]	I
Underpass (UP6)	A	20	1	NA[a]	II
Underpass (UP7)	B	22	4	NA[a]	II
Underpass (UP8)	B	24	2	NA[a]	II

[a] Spacing distances are not available for these structures because identified wildlife crossing locations are broadly applied to road segments 20 (UP6), 22 (UP7), and 24 (UP8). Further evaluation will be needed to identify precise locations.

Cost Analysis and Savings

Wildlife Crossing Structure Costs

Site-specific costs were estimated for each of the 10 proposed structures listed in Table 11. Cost estimates were adapted from WSP USA (Halloway, 2023; WSP USA, 2023) and include concrete, structural and reinforcing steel, mobilization, engineering, traffic control, erosion and sediment work, base and paving, final pavement marking, excavation, centerline shoring, and markup additions. Construction costs for underpasses and overpasses were similar and ranged from $4.9 million to $5.1 million. When fencing was included, the average construction cost per site was estimated to be approximately $5.5 million to $5.7 million. Estimated annual maintenance costs per structure and associated fencing are $55,000 to $57,000 (1% of the structure and fencing construction costs).

For the purpose of setting a future project budget if funding were to be pursued for wildlife crossing construction, contingency costs and inflation were also estimated. Contingency costs account for risks that may affect the project's cost, such as changing field conditions that are not seen in the preliminary engineering stage or unforeseen circumstances that cause the cost to exceed the estimate. When contingency costs and inflation were included, the order of magnitude estimate for each structure based on the year of construction ranged from $8.2 million (for a bid year of 2025) to $9.8 million (for a bid year of 2028).

Structures Costs Compared to Savings From Prevented Elk and Deer Crashes

Virginia police report forms contain a specific field for deer-related collisions, but there are no such fields for other species. Finding information on other animal-related collisions can be done only if the police officer noted the species in the "Comments" column on the form. A search for "elk" in the comments column of police reports evaluated between July 2014 and June 2021 yielded no information. The elk crash information in Table 12 is based on the 5 states (of the 14 states contacted) with police report records that (1) were publicly accessible, (2) separated elk-related crashes from other wildlife crash types, and (3) provided crash severity information. Crash cost calculations for elk crashes were based on crash severity proportions from the 3,421 elk crash records obtained from these 5 states (Table 12).

As Table 12 indicates, the calculated costs for an elk crash and a deer crash were $80,771.49 and $41,338.28, respectively. Figure 15 illustrates the number of elk crashes or deer crashes that would need to be avoided per year for wildlife crossing construction, fencing, and maintenance costs to generate monetized crash reduction benefits in excess of the estimated construction costs. Approximately 2.8 elk crashes or 5.4 deer crashes would need to be avoided per year per structure (and its associated fencing) over the lifetime of the structure for crash reduction benefits to begin exceeding construction and maintenance costs.

Table 12. Crash Severity Information Used to Calculate the Average Cost of an Elk Crash and a Deer Crash

Elk					
			Crash Severity Proportion (%)		
State	Date Range	No. of Crashes	Property Damage	Injury	Fatalities
California[a]	5/2015-11/2020	171	88.3	11.7	0
Colorado	2016-2020	1,874	86.0	13.8	0.2
New Mexico	2016-2020	1,311	86.1	13.7	0.2
North Carolina	2012-2021	40	89.5	10.5	0
Tennessee	2009-2021	25	92.0	8.0	0
Average proportionate crash severity (weighted average)			86.2	13.6	0.2
Average elk crash cost[c]			$80,771.49		
Deer					
			Crash Severity Proportion (%)		
State	Date Range	No. of Crashes	Property Damage	Injury	Fatalities
Virginia	July 2014-June 2021	45,915	91.5	8.47[b]	0.004
Average deer crash cost[c]			$41,338.28		

Crash severity proportions were obtained from police records, and costs attributed to crash severity types were obtained from VDOT (2022b).

[a] Of 171 elk-related crash records from California, 60 were classified as resulting in no injuries (property damage only) and 7 were classified as injury crashes (11.7%). The remainder had no crash severity information; these crashes were treated as property-damage-only crashes.

[b] Records obtained from Virginia police reports included injury severity information separated into the following categories and proportions: incapacitating injury (0.9%), non-incapacitating injury (4.63%), and possible injury (2.94%).

[c] Costs associated with crash severities were obtained from *Virginia Traffic Crash Costs* (VDOT, 2022b), which are Virginia-specific comprehensive crash costs based on *Crash Costs for Highway Safety Analysis* (Harmon et al., 2018). These values are a combination of economic crash unit costs (tangible impacts) and quality-adjusted life years crash unit costs (monetized pain and suffering).

Research on western elk populations provides the best available information on elk crash reductions following the construction of wildlife crossings and fencing. However, there is unlikely to be a reliable means of using existing crash data from western populations (larger herds that typically travel across and away from a highway during specific seasons) to predict crash frequencies for the Corridor Q elk (a small herd that uses the road on a year-round basis with home ranges that have become centered on the road).

With that kept in mind when considering the 2.8 elk crash reductions needed to offset structure and fencing costs on Corridor Q (Figure 15), the research team considered two cases of elk crash reductions in Arizona:

1. On Arizona's S.R. 260, which has an ADT of 8,000 (similar to Corridor Q traffic projections), there were 4.6 elk crashes per mile per year over an 8-year period (2001-2008). Following the construction of 11 wildlife underpasses and fencing along a 17-mile road segment, such crashes decreased by 3.5 per mile per year, a 76% reduction (Dodd et al., 2012). For comparison with Corridor Q's average of 1.2 miles of fencing associated per structure, this would be an equivalent crash reduction of 4.2 elk per year.

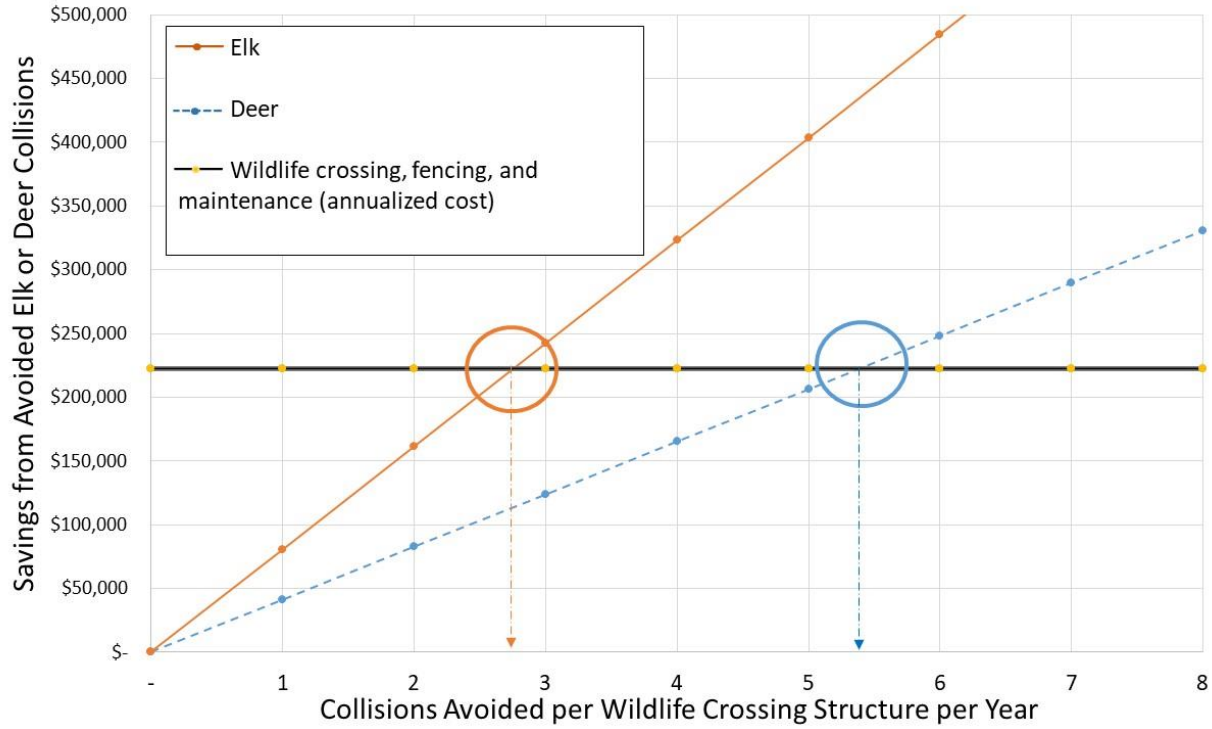

Figure 15. Number of Avoided Collisions Required per Wildlife Crossing per Year for the Monetized Impacts From Crash Reductions to Exceed Structure and Fencing Costs. Circled areas signify the break-even point at which the costs of a structure equal the savings from an avoided elk or deer crash. The monetized impacts of crashes avoided begin exceeding the installation and maintenance cost of a structure and fencing when 2.8 elk crashes or 5.4 deer crashes are avoided per structure per year.

2. There were similar findings along Arizona I-17 (with an ADT of 17,000). Elk crashes decreased from a mean of 3.6 elk crashes per mile per year from 2007 to 2010 to 0.09 crashes per mile per year (a reduction of 97%, or 3.5 elk crashes per mile per year) (Gagnon et al., 2015). For comparison with Corridor Q's average of 1.2 miles of fencing associated per structure, this would be an equivalent crash reduction of 4.3 elk per year.

Another important consideration is the point at which the number of elk killed by vehicle collisions exceeds the number required to maintain the viability of the population. Although determining this threshold was outside the scope of this study, it is possible that along an unmitigated road that receives continual use by elk, the number of elk crashes over time could result in the weakening and/or decline of the population. Conversely, it is possible that the number of any elk crashes that might occur would not be significant enough to affect their population viability adversely.

Because Corridor Q has not been completed and opened to the public, the number of wildlife collisions is simply not known. With that kept in mind, when the research team considered the 5.4 deer crash reduction needed to offset structure and fencing costs on Corridor Q (Figure 15), a project conducted on I-64 in Virginia provided insight into potential deer crash

reductions from underpasses and fencing. Donaldson and Elliott (2022) compared deer crash frequencies before and after the installation of fencing to two existing underpasses near Charlottesville. Following fencing installation, there was an average reduction of 8.4 deer vehicle collisions per mile per year at the evaluated sites. For comparison with Corridor Q's average of 1.2 miles of fencing associated per structure, this would be an equivalent crash reduction of 10.1 deer per year.

Suitable Funding Sources

Based on a review of 15 programs for which wildlife infrastructure is expressly eligible under IIJA (Callahan, 2023), the research team identified the Rural Surface Transportation Grant Program (hereinafter "Rural") as the most suitable source of funding for the wildlife crossing structures and fencing identified in this study (see Appendix B for details). In addition to Rural, pursuing supplemental funding from the Rebuilding American Infrastructure With Sustainability and Equity (RAISE) program and/or the Wildlife Crossing Pilot Program (WCPP) was determined to be the next most suitable alternative funding option to consider. The following summarizes the funding options deemed most suitable for Corridor Q wildlife crossings and fencing:

- Rural (full federal funding / no match requirement)

- Rural (full federal funding / no match requirement) supplemented with RAISE (partial) and/or WCPP (partial).

The team also identified the following five programs as additional potential funding sources for this project, which are analyzed in more detail in Appendix A:

1. Nationally Significant Freight and Highway Program (INFRA)
2. Highway Safety Improvement Program
3. Surface Transportation Block Grant Program
4. Federal Lands Access Program
5. Transportation Alternative Set-Aside.

The integration of driver and wildlife safety infrastructure into the U.S. highway network is becoming increasingly widespread, as illustrated by the following examples of projects paid for in part using federal funding:

- In 2022, the I-70 Floyd Hill to Veterans Memorial Tunnels Improvements Project in Clear Creek County, Colorado, was awarded a $100 million FY22 INFRA grant to increase safety along the I-70 Mountain Corridor by adding a third westbound travel lane, a frontage road connection, and a new on-ramp for U.S. Highway 6. In addition to using innovative technologies, the multimodal project will use the funding to restore nearby creek and wetland areas and to integrate wildlife crossings and associated fencing (U.S. DOT, 2022c).

- In 2019, the State of Wyoming was awarded $14.5 million in BUILD (RAISE's predecessor) funding for the Dry Piney Creek Wildlife Habitat Connectivity Project, which entailed construction of a network of wildlife crossings and associated fencing, jump-outs, and other improvements along a 19-mile stretch of U.S. 189 between La Barge and Big Piney, Wyoming (U.S. DOT, 2019).

- In 2015, the State of Colorado broke ground on a network of 24 planned wildlife crossings to reduce crashes involving elk and mule deer along a 20-mile segment of U.S. Highway 160 near Durango, Colorado. Eighty percent of funding for the first structure—a $7 million underpass—was paid for by the Highway Safety Improvement Program, supplemented by a 20% state match (Pace, 2015).

- An additional wildlife overpass and underpass were constructed along a different 2-mile segment of U.S. Highway 160 in 2022, at a total cost of $12 million. Funding support included $8.6 million from the Colorado DOT; $1.3 million from the Southern Ute Indian Tribe; $750,000 from Colorado Parks and Wildlife; $317,000 from the National Fish and Wildlife Foundation; $100,000 from the Mule Deer Foundation (via a private donor); and $75,000 from the Rocky Mountain Elk Foundation (Burney, 2022).

Rural Surface Transportation Grant Program: Identified as the Most Suitable Funding Option for Corridor Q Wildlife Crossings

Newly established under IIJA, the Rural Surface Transportation Grant Program (i.e., Rural) makes available up to $2 billion in discretionary grant funds over 5 years to improve and expand surface transportation infrastructure in rural areas. The goal of the program is to increase transportation connectivity, improve the safe and reliable movement of people and freight, generate regional economic growth, and improve quality of life. Rural provides funding for projects that are otherwise eligible under several existing federal highway programs including the Highway Safety Improvement Program and the Surface Transportation Block Grant Program. Eligible activities include projects to construct new or retrofitted wildlife crossing structures; other measures or strategies to reduce wildlife-vehicle collisions, including project-related planning, design, monitoring and preventative maintenance; and environmental mitigation aimed at reducing wildlife mortality due to vehicles or restoring and maintaining habitat connectivity.

To receive a Rural grant, projects are required to meet five statutory requirements. Specifically, the project must (1) generate national or regional economic, safety, or mobility benefits; (2) be cost-effective; (3) aid in meeting national performance goals; (4) be based on preliminary engineering; and (5) be expected to begin construction within 18 months of funding. Twenty-five percent of Rural funding is reserved for projects that further completion of designated segments of ADHS, which are eligible for up to 100% federal funding. At least 90% of Rural funds must be for grant awards of at least $25 million, with up to 10% available for grant awards of less than $25 million (U.S. DOT, 2022b). Assuming future Rural notices make available the same amount of funding as in FY22 ($300 million), then at least 25%, or $75 million, will be available for ADHS routes during forthcoming award cycles.

Application Review and Rating

In addition to conducting an economic analysis of the anticipated costs and benefits of the project (compared to a no-build scenario) and demonstrating project readiness, the proposal will be evaluated based on the following project outcome criteria:

1. safety
2. state of good repair
3. economic impacts, freight movement, and job creation
4. climate change, resiliency, and the environment
5. equity, multimodality, and quality of life
6. use of innovative technologies, project delivery practices, or financing.

Each criterion will receive a rating from 0 to 3 and an overall project outcome rating of High, Medium-High, Medium, Medium-Low, or Low based on the number of 3s and 0s scored. Although projects are not required to score highly on each criterion, projects that are able to demonstrate clear, direct, data-driven, and significant benefits for the greatest number of categories will score the highest rating. After assessment of the project outcome criteria, economic analysis, and project readiness, each eligible project will be assigned an overall rating of Highly Recommended, Recommended, or Not Recommended. In addition to scoring well on the ranking system, an exemplary project may receive a Highly Recommended rating because it is determined to generate significant national or regional benefits in one of the project outcome areas.

Once all eligible projects have been assigned an overall rating, a list of Highly Recommended" projects for consideration will be generated. This list will be reviewed to determine whether a project meets the requirements for the set-asides (e.g., 25% for ADHS) and geographic diversity, including whether a project is located within a federally designated community development zone (e.g., a qualified Opportunity Zone, Empowerment Zone, Promise Zone, or Choice Neighborhood). In the event these additional requirements are not met by the initial list of Highly Recommended projects, similarly Recommended projects may be added to the list until the required set-asides and geographic diversity requirements are met. The U.S. Secretary of Transportation then selects award recipients from the final list of projects for consideration (U.S. DOT, 2022b).

Program Relevance to Corridor Q Wildlife Crossings

The mitigation measures for both Sections A and B appear to satisfy all five Rural statutory requirements, including that the project is cost-effective and reasonably expected to begin construction no later than 18 months after grant funds are obligated. As summarized in Appendix B, the project appears to be well-positioned to score a numerical rating of 2 or 3 on the project outcome criteria, thereby potentially achieving an overall project outcome rating of Highly Recommended or Recommended.

The recent award of a $25 million FY22 Rural grant for the Coalfields Expressway, a related project that overlays a portion of the Corridor Q ADHS route near the Town of Grundy, Virginia, is also worth noting. The funding award will support construction of an approximately 15-mile segment of the Coalfields Expressway near the City of Mullens, West Virginia, located within an area of persistent poverty in Wyoming County, West Virginia. Although an anticipated reduction in wildlife-vehicle conflicts is not expressly mentioned, the project will flatten and lengthen vertical and horizontal curves, thereby reducing conflict points and improving safety for residents and businesses along this mountainous route. Other benefits include reduced travel times, improved access to tourist destinations and public lands, and increased broadband access (U.S. DOT, 2022e).

In sum, because of (1) the required set-aside of 25% of Rural funds for ADHS segments; (2) the potential for 100% federal funding; (3) the project's apparent location within a preferred geographic Opportunity Zone; and (4) its nexus with the Coalfields Expressway Project (a successful applicant to the FY22 Rural program), project proponents could consider a grant proposal for 100% of future project costs from the Rural program.

Rebuilding American Infrastructure With Sustainability and Equity (RAISE): Identified as an Alternative Suitable Funding Option for Corridor Q Wildlife Crossings

IIJA authorizes $7.5 billion in funding over 5 years for the Local and Regional Project Assistance Program (49 U.S.C. § 6702(j)), which is known as the Rebuilding American Infrastructure With Sustainability and Equity, or RAISE, grant. Funding is available for highway and bridge planning and capital projects, as well as a host of other project types. Since its inception, the program has received more than 11,000 applications requesting close to $200 billion in funding for a variety of road, rail, transit, and port projects and has awarded more than $12 billion to 769 projects during 14 rounds of competitive grant applications (U.S. DOT, 2022d).

The primary goal of the RAISE program is to fund transportation infrastructure improvements that will have a significant local or regional impact (49 U.S.C. § 6702(b)(2)). The FY23 Notice of Funding Opportunity included two separate potential funding sources: the first, under IIJA, authorized a total of $1.5 billion in funding, with a maximum award size of $25 million for capital projects; and the second, included in the FY23 appropriations package, authorized an additional $800 million in funding, with a maximum award size of $45 million, for a total of $2.3 billion in available funding for both sources. Urban and rural areas may each receive up to 50% of the total funding made available, and no single state may receive more than 15% ($345 million in FY23). At least $35 million will be awarded for projects in historically disadvantaged communities or areas of persistent poverty. The U.S. DOT seeks to fund projects that target at least 40% of benefits and resources toward low-income, disadvantaged, overburdened, or underserved communities. Rural areas, historically disadvantaged areas, and areas of persistent poverty are also eligible to use RAISE funds to pay for up to 100% of total project costs (U.S. DOT, 2023a).

Application Review and Rating

In addition to meeting applicable cost-effectiveness and project readiness requirements, projects will be assessed based on the following merit selection criteria:

1. safety
2. environmental sustainability
3. quality of life
4. mobility and community connectivity
5. economic competitiveness and opportunity
6. state of good repair
7. partnerships and collaboration
8. innovation.

As set forth in the RAISE Notice of Funding Opportunity, capital projects will receive a rating of High, Medium, Low, or Non-Responsive, with the High rating reserved for instances in which (1) the merit criterion is a primary project purpose (and is not an incidental or ancillary purpose except for Criterion 7, partnerships and collaboration, and Criterion 8, innovation); (2) the application includes clear, direct, data-driven, and significant benefits; and (3) those benefits align with at least one of the benefits identified in the High rating column of the merit criteria rubric set forth in the Notice of Funding Opportunity. A rating of Medium occurs when (1) the criterion is not a primary project purpose or (2) the project benefits do not have at least one of the benefits required to receive a High rating. Individual merit criterion rankings are then combined to form an overall merit rating. Highly Recommended and Exceptional Recommended projects are advanced to a second-tier review involving a cost-benefit and project readiness analysis. Following completion of this analysis, the U.S. Secretary of Transportation selects award recipients from the final list of highly rated projects, consistent with the merit criteria and statutory geographic and modal diversity requirements (U.S. DOT, 2023a).

Program Relevance to Corridor Q Wildlife Crossings

In addition to demonstrating cost-effectiveness and project readiness, the project appears to be well-positioned to score a rating of High or Medium on the eight merit criteria, based on anticipated project benefits, as summarized in Appendix C.

Although one project to reduce wildlife-vehicle collisions with ungulates (mule deer, pronghorn, moose) has previously secured $14 million in funding under RAISE's predecessor, BUILD (U.S. DOT, 2019), the sheer breadth of eligible projects, coupled with an applicant pool that has averaged approximately 800 proposals and resulted in about 55 awards per round—roughly a 7% success rate—for each of the past 14 funding cycles, underscores the stiff competition for RAISE funding (U.S. DOT, 2022d).

Despite being highly competitive, RAISE remains an especially desirable funding source because it allows for up to 100% federal funding for rural projects. To be considered for project support from the total RAISE funding pot, the maximum grant request may not exceed $25

million (U.S. DOT, 2023a). Accordingly, potential federal funding for Corridor Q may be optimized by submitting two grant requests: (1) a Rural application for 100% of total estimated project costs, and (2) a RAISE application for up to $25 million.

Wildlife Crossing Pilot Program (WCPP): Identified as an Alternative Suitable Funding Option for Corridor Q Wildlife Crossings

For the first time, IIJA includes $350 million in dedicated federal funding over 5 years to reduce motorist crashes involving wildlife and improve habitat connectivity for terrestrial or aquatic species (U.S. DOT, 2023b). The following applicants are eligible to apply for the WCPP: federal land management agencies, tribes, states, metropolitan planning organizations, and local governments. Eligible project partners include all eligible applicants plus foundations; non-governmental organizations; universities; federal, tribal, regional, or state governmental entities; and groups of these applicants (23 USC § 171; U.S. DOT, 2023b).

The primary merit criteria for the WCCP are (1) protect motorists and wildlife by reducing wildlife-vehicle collisions, and (2) improve terrestrial and aquatic habitat connectivity. Secondary merit criteria are (1) leveraging non-federal investments (including through public-private partnerships), (2) supporting local economies and visitation opportunities, (3) incorporating innovative technologies and advanced design techniques, (4) providing education and outreach opportunities, (5) monitoring and research activities aimed at identifying best practices, and (6) survival of species (U.S. DOT, 2023b). At least 60% of pilot funds each year are to be awarded to projects in rural areas (23 U.S.C. § 171). Although there is no minimum or maximum award size, FHWA encourages eligible entities to submit applications with total project costs of $200,000 or more and anticipates awarding 15 to 50 grants with awards ranging from $200,000 to $20 million (U.S. DOT, 2023b).

Application Review and Rating

In addition to demonstrating project readiness, the proposal will be evaluated based on the primary and secondary merit criteria. A Technical Evaluation Team will first assess the project's alignment with the two primary merit criteria and assign a rating of Strong Alignment, Alignment, or No Alignment based on the data and information provided in the application. Individual criterion ratings will be translated into an overall primary merit criteria ranking of Strongly Recommended, Recommended, or Not Recommended. Applications that receive a ranking of Strongly Recommended or Recommended for the primary merit criteria will be assessed against each of the six secondary merit criteria and assigned a rating of Strong Alignment, Alignment, or No Alignment. Individual criterion scores will then be translated into an overall secondary merit criteria ranking of Strongly Recommended, Recommended, or Not Recommended. Applications that are Strongly Recommended or Recommended from the primary merit criteria and Strongly Recommended or Recommended from the secondary merit criteria will undergo a project readiness review and receive an overall project readiness rating of High, Medium, or Low (U.S. DOT, 2023b). Based on the rankings for the primary merit criteria, secondary merit criteria, and project readiness, the Technical Evaluation Team will assign each application an overall rating of Highly Recommended, Recommended, or Not Recommended.

All Highly Recommended and Recommended applications will be forwarded to FHWA's Senior-Level Review Team, which will advance as many Highly Recommended applications as possible to the FHWA Administrator for potential grant awards, consistent with the statutory requirement that 60% of available funds be awarded to projects in rural areas. The FHWA Administrator will make final project selections from the list of applications provided by the Senior-Level Review Team, with the goal of identifying the applications that best address the goals of the pilot program, the Administration's priorities, and geographic diversity and best ensures the effective use of federal funding (U.S. DOT, 2023b).

Program Relevance to Corridor Q Wildlife Crossings

The project appears to be well-positioned to meet the project readiness criteria and achieve a ranking of Strong Alignment with the WCPP's two primary goals. As summarized in Appendix D, the project similarly appears to have a Strong Alignment or Alignment with at least four of the six secondary merit criteria including (1) preservation of the elk population, which is expected to accrue local economic and tourism benefits without compromising the project's safety and connectivity benefits (Criterion 2.2); (2) inclusion of at least one innovation in the form of an experimental animal detection system (Criterion 2.3); (3) enhanced education and outreach opportunities (Criterion 2.4); and (4) the ability to integrate monitoring and research aimed at identifying best practices for what may be the first animal detection system deployed in the eastern United States (Criterion 2.5).

Despite the potential to score highly on four secondary merit criteria, the project would presumably be at a competitive disadvantage vis-à-vis other projects with respect to the leveraging of non-federal investments (Criterion 2.1) and the survival of federally listed threatened, endangered, proposed, or candidate species (Criterion 2.6), which may result in a finding of No Alignment. Even if, however, the Corridor Q project was deemed to have No Alignment with one or more secondary merit criteria, it would nonetheless remain eligible for an overall rating of Highly Recommended given its anticipated Strong Alignment with one or both primary merit criteria, thereby ensuring the project would be advanced to the FHWA Administrator for a potential grant award.

Because WCPP funding is dedicated, the pilot is likely to attract a large number of highly competitive applicants. Moreover, since the pilot is a new program, it is not possible to review prior awards to gauge how the Corridor Q project compares to other projects that have successfully competed for funding in the past. Although FHWA is not prohibited from awarding grants outside its anticipated range ($200,000 to $20 million) (U.S. DOT, 2023b), it seems prudent to assume that Corridor Q would, at most, secure a WCPP award of $20 million, which would presumably require a non-federal match of $4 million. Because of these factors, coupled with the prospect of the Corridor Q project being well-positioned to secure up to 100% federal funding from the Rural and/or RAISE programs, project proponents could consider applying to the WCPP in addition to, rather than in lieu of, Rural and RAISE as a pathway to maximizing the likelihood of securing full funding for measures to mitigate the anticipated effects of Corridor Q on motorists and wildlife.

SUMMARY OF FINDINGS

The following summarizes the key findings from the evaluation of wildlife crossing sizing, placement, costs, and funding opportunities:

- *Structure Sizing*: The following structure sizes were determined by balancing cost considerations, information from the literature, and discussions with experts:

  — *Overpass dimensions:* 100-foot width of structure entrances for wildlife (or structure length when measured along the vehicular traffic direction); 80-foot length of travel for wildlife (or span length of structure as measured perpendicular to the vehicular traffic direction); 18-foot height (vertical clearance where the span length is measured)

  — *Underpass dimensions:* 85-foot width of structure entrances for wildlife (or structure span length when measured along the vehicular traffic direction); 80-foot length of travel for wildlife (or width of structure as measured perpendicular to the vehicular traffic direction); 18-foot height (vertical clearance from the bottom of the superstructure to the ground level where wildlife travel).

- *Suitable wildlife crossing locations were identified through a criteria-based evaluation of Corridor Q road segments. Key findings include:*

  — *Elk locations:* Approximately 38% of the 26,659 elk locations from the collared Corridor Q elk were within 200 meters of the partially constructed portions of Corridor Q, and elk use of the unconstructed portions is expected to continue to increase as construction progresses.

  — *Elk home ranges:* Home ranges of all 12 collared Corridor Q elk overlapped with portions of Corridor Q road segments. Home ranges were shaped similarly to those of Section A of Corridor Q, indicating heavy use by the elk of the partially constructed road to access preferred areas of habitat on both sides of the corridor.

  — *Elk habitat selection probability:* Distance to barren land, herbaceous cover, and shrub cover had the largest influence on elk habitat selection, all of which are a product of road construction and are distributed linearly along the roadway. Elk habitat selection probability in partially constructed road segments ranged from 3% to 63%, with an average of 30% per segment.

  — *Adjacent land use:* Land use is compatible with wildlife crossing placement along Corridor Q; the surrounding area has little development and land managed by The Nature Conservancy overlaps most of the Section A segments.

  — *Topography and landscape features:* From an evaluation of locations identified as potentially suitable for wildlife crossings, there were stronger candidate locations

for underpasses (n = 11) than for overpasses (n = 4) with respect to both cost-effective structure design and landscape characteristics that would encourage structure use by wildlife.

— *Spacing:* Aiming for a maximum distance of approximately 1.5 miles between structures was determined to provide a balance between costs and the likelihood of elk and other large animals encountering the structures.

- *Structure Placement:* Suitable locations for two overpass and eight underpass structures were identified for Corridor Q. Spacing between structure locations ranges from 0.7 mile to 1.8 miles, with an average distance of 1.2 miles.

- *Structure Costs:* Wildlife crossing and fencing cost estimates averaged approximately $5.5 to $5.7 million per structure. If funding is pursued for structures and an estimated project budget is desired, the addition of contingency costs and inflation would raise the cost estimate to $8.2 million (for a bid year of 2025) to $9.8 million (for a bid year of 2028). Non-monetized benefits of crossing structures are described later.

- *Costs Versus Benefits From Elk and Deer Crash Avoidance:* With calculated values of $80,771 and $41,338 for an elk crash and a deer crash, respectively, approximately 2.8 elk crashes per year or 5.4 deer crashes per year over the lifetime of the structure must be avoided for the monetized crash reduction benefits to begin exceeding the costs of a structure and its associated fencing.

- *Funding Sources:* From a review of potential federal funding opportunities for a Corridor Q wildlife crossing project and an analysis of the project's alignment with the project outcome and merit criteria of funding programs, a project appears to be well-positioned to achieve an overall outcome rating of Highly Recommended or Recommended for the Rural Surface Transportation Grant Program. The following program benefits are of particular relevance to this project: (1) a required set-aside of 25% of Rural funds for ADHS segments; (2) the potential for 100% federal funding; (3) Corridor Q's apparent location within a federally designated Opportunity Zone; and (4) its nexus with the Coalfields Expressway Project, a successful applicant to the FY22 Rural program.

CONCLUSIONS

- *The use of the landscape by the newly established elk population has been shaped by the construction of Corridor Q, which provides elk an efficient means of travel to preferred habitat that is abundant along the roadside and adjacent areas*. The average home range size of the elk that use Corridor Q is approximately 6 times greater than that of a nearby herd that does not access the corridor. Thus, the movement of the newly established Corridor Q

elk population in relation to the road would have been difficult to predict during the planning of Corridor Q.

- *Agencies have constructed wildlife crossings with the explicit goals of reducing crash risk and maintaining or improving habitat connectivity, which requires structures that are properly designed and located.* The wildlife crossing designs and locations provided in this report were more conservative (i.e., smaller designs and longer spacing intervals) than those of some other wildlife crossing structures designed for elk; this was intended to balance structure costs and the habitat connectivity benefits that would be realized from use of the structures by elk and other wildlife. These benefits align with the WCAP's designation of the area as a Wildlife Biodiversity Resilience Corridor.

- *Several federal funding programs have financed a variety of wildlife crossing projects in the United States that were found to meet program objectives.* A wildlife crossing construction project along Corridor Q meets the objectives of the Rural Surface Transportation Grant Program, which is the most suitable source of funding given the program requirements (e.g., a required set-aside of certain sets of funds) and Corridor Q's characteristics (e.g., Corridor Q lies within a federally designated Opportunity Zone).

RECOMMENDATION

1. *If wildlife crossings are pursued for Corridor Q, VDOT should consider the wildlife crossing design and location options provided in this report.*

BENEFITS

Monetized Benefits

If VDOT pursues and is awarded funding for wildlife crossings, the "Cost Analysis and Savings" section of this report describes the estimated savings from avoided elk and deer collisions and the number of collisions that would need to be avoided to offset the construction and maintenance costs of wildlife crossings and fencing. As mentioned previously, with calculated values of $80,771 and $41,338 for an elk crash and a deer crash, respectively, approximately 2.8 elk crashes per year or 5.4 deer crashes per year over the lifetime of the structure must be avoided for the monetized crash reduction benefits to begin exceeding the costs of a structure and its associated fencing.

Non-Monetized Benefits

The following sections describe the non-monetized benefits of wildlife crossing implementation.

Alignment With National and State Roadway Safety Strategies

The U.S. Secretary of Transportation recently released a National Roadway Safety Strategy to address roadway fatalities and serious injuries (U.S. DOT, 2022a). The first principle listed in the U.S. DOT's approach prioritizes the elimination of crashes that result in death and serious injuries. The safety strategy introduces new priority actions that support the federal government's expectation that the transportation system be designed and operated in a proactive manner that prevents these incidents.

The *Virginia Strategic Highway Safety Plan: 2022-2026* (VDOT, 2022c) describes Virginia's adoption of the U.S. DOT's "zero deaths" goal. The plan describes a "Safe System" approach, which includes reducing the risks of driving mistakes by focusing on proper design and management of road infrastructure. The plan notes that from 2016 to 2020, roadway departures accounted for 51% of Virginia's fatalities and 39% of Virginia's serious injuries. Speeding is a major contributing factor to roadway departures, and rural roads are the greatest problem with regard to speeding and roadway departures (VDOT, 2022c). Implementing the elk crash reduction safety measures on Corridor Q, particularly given its rural location where safety incidents can affect a relatively higher proportion of the population than in other areas, adheres to these and other principles outlined in the National Roadway Safety Strategy. Specifically, the strategy states that highways "that serve rural communities and small towns face outsized safety impacts relative to their population and number of miles traveled, and have unique design considerations such as how to minimize collisions with large animals" (U.S. DOT, 2022a).

VDWR management plans also address the importance of large animal crash reduction strategies in Virginia. Minimizing elk-vehicle collisions (in addition to deer- and bear-vehicle collisions) is a VDWR management objective in support of the agency's mission "[t]o protect people and property by promoting safe outdoor experiences and managing human-wildlife conflicts" (VDGIF, 2019).

Public Opinion, Local Economy, and Outdoor Recreation

Wildlife crossings would contribute to the preservation of the elk population and the associated benefits elk provide to the public and the local economy. Elk and other large ungulates are typically viewed as valuable resources for the state they inhabit (Miller, 2022). Survey results reported in the Virginia Elk Management Plan (VDGIF, 2019) indicated a positive public opinion toward the reintroduced elk in Southwest Virginia. A survey of Virginia residents found that 86% (n = 2,755) of respondents supported having elk in Southwest Virginia and 89% (n = 2,858) appreciated knowing that elk have been restored in Southwest Virginia. Most respondents indicated that the number of elk should increase in the Southwest Virginia region, in the county in which they live, and in their immediate neighborhood (cited in VDGIF, 2019).

Elk have generally been embraced by the residents of Buchanan County, who are striving to diversify their local economy from one that has historically relied on coal mining (Taylor, 2022; Southwest Virginia Sportsmen, personal communication). The Buchanan County Board

of Supervisors supported elk restoration and continues to support the elk program (VDGIF, 2019).

Elk have recently expanded their range to include Breaks Interstate Park, which is adjacent to the western section of Corridor Q. The park provides guided elk-viewing tours in cooperation with Southern Gap Outdoor Adventure, Southwest Virginia Sportsmen, and the Southwest Virginia Chapter of the Rocky Mountain Elk Foundation (Southern Gap Outdoor Adventure, 2022). As illustrated previously in Figure 10, Corridor Q is also within 2 miles of the Jefferson National Forest. Public access to these areas will be greatly enhanced when the corridor opens to traffic. Breaks Interstate Park offers activities such as wildlife watching, hiking, rock climbing, whitewater rafting, and zip lining. The national forest provides hiking, hunting, and fishing opportunities. VDWR is working with Breaks Interstate Park to improve 5 acres of elk habitat and to develop a parking lot, an elk-viewing shelter, and trail maintenance to improve public elk-viewing opportunities for visitors.

Although the financial benefits of elk viewing have not been calculated for the elk in Virginia, wildlife watching and other types of wildlife-associated recreation (also known as "nature tourism") have brought substantial benefits to local economies (Texas Parks and Wildlife, 2022). In a study calculating the economic value of wildlife, an individual elk in Yellowstone National Park was valued at $17,227 for its elk-viewing benefits alone (Duffield and Neher, 2019).

Buchanan County Tourism, the Buchanan County Chamber of Commerce, and Southern Gap Outdoor Adventure feature elk in their logos, an indication of the importance of the elk population to the area and to the local economy. Tourists visiting Buchanan County to view elk during both public and private tours positively contribute to the local economy through monies spent on lodging, food, gasoline, and items from other local businesses. In 2022, 473 people attended these tours through park reservations, 84% of whom were not residents of Southwest Virginia. VDWR also provided multiple elk-viewing tours for the public in 2022, with 135 people attending from an average distance of 171 miles. Many private tours are also provided each year by Breaks Interstate Park, Southwest Virginia Sportsmen, The Nature Conservancy, and VDWR. In addition, an elk-themed festival is held at Southern Gap Outdoor Adventure every October in cooperation with Buchanan County Tourism, the Buchanan County Chamber of Commerce, Southwest Virginia Sportsmen, VDWR, and the Southwest Virginia Chapter of the Rocky Mountain Elk Foundation (Cardinal Staff, 2022). The festival includes food, entertainment, and craft vendors and features multiple elk-viewing tours.

In October 2022, VDWR held the first elk hunt in Buchanan County. Twenty landowners in Buchanan County allowed access for six licensed elk hunters. Revenue from the lottery for five of the elk licenses totaled approximately $513,000, and proceeds from the Rocky Mountain Elk Foundation's raffle for the sixth elk license was approximately $93,000. As a consequence, each bull elk license was worth roughly $100,000. Five of the six hunters were not local, indicating the value of the elk to the outside hunting community and the associated effects on the local economy. VDWR expects elk hunting opportunities to increase as the elk population continues to grow.

Preserving the Conservation and Landscape Resilience Values of the Corridor Q Area

Where roads cross areas of important habitat, implementing measures to maintain habitat connectivity and minimize wildlife crashes helps maintain the area's conservation value. Wildlife crossings have been found not only to significantly reduce direct mortality of wildlife but also to positively affect the genetic structure of populations by minimizing the barrier effect that roads can have on their movement (Sawaya et al., 2014).

As noted previously, The Nature Conservancy manages 34% of the 200-meter buffered area evaluated along Corridor Q. The land was purchased in 2019 through Cumberland Forest Highlands, LLC, as part of the organization's largest single investment to protect a portion of the Appalachians, which some consider to be North America's most critical climate migration corridor. The Nature Conservancy considers this land a migration area for wildlife and a home for climate change–resilient forests. The Nature Conservancy allows sustainable logging practices to continue on the land it manages in the Corridor Q area to allow residents to continue to earn a living (McKenzie, 2019).

The Virginia WCAP (*Code of Virginia* § 29.1-579, 2020) indicates that Corridor Q is situated within a Wildlife Biodiversity Resilience Corridor (an area ranked as a primary resilience priority in Virginia). The purpose of the resilience corridors is to maintain connectivity between biodiverse and natural lands to allow species distribution shifts as the climate changes and the landscape becomes more developed (VDWR et al., 2023). As there are no crash data available for Corridor Q, the road is not an area in the Virginia WCAP identified as having a high occurrence of wildlife crashes.

Similarly, much of the area surrounding Corridor Q is categorized as having high conservation value in the ConserveVirginia mapping tool developed to guide land management decisions and land conservation investments in Virginia. ConserveVirginia was created by the VDCR and was codified into law in 2021 (*Code of Virginia* § 10.1-104.6:1). It identifies priority lands for conservation based on seven categories, each representing a different conservation value (VDCR, 2021). Figure 16 illustrates two of these categories in which Corridor Q intersects: Natural Habitat & Ecosystem Diversity, and Protected Landscapes Resilience.

The Natural Habitat & Ecosystem Diversity category includes large patches of important land with regard to habitat quality and species diversity. As illustrated in Figure 16, the western half of Corridor Q intersects land within this category.

The Protected Landscapes Resilience category includes areas that represent climate-resilient sites and species movement areas (corridors). These areas include key habitats and the space for nature to adapt and change in the face of a changing climate (VDCR, 2021). Corridor Q is centered within one of the largest areas with the Protected Landscapes Resilience designation in Virginia.

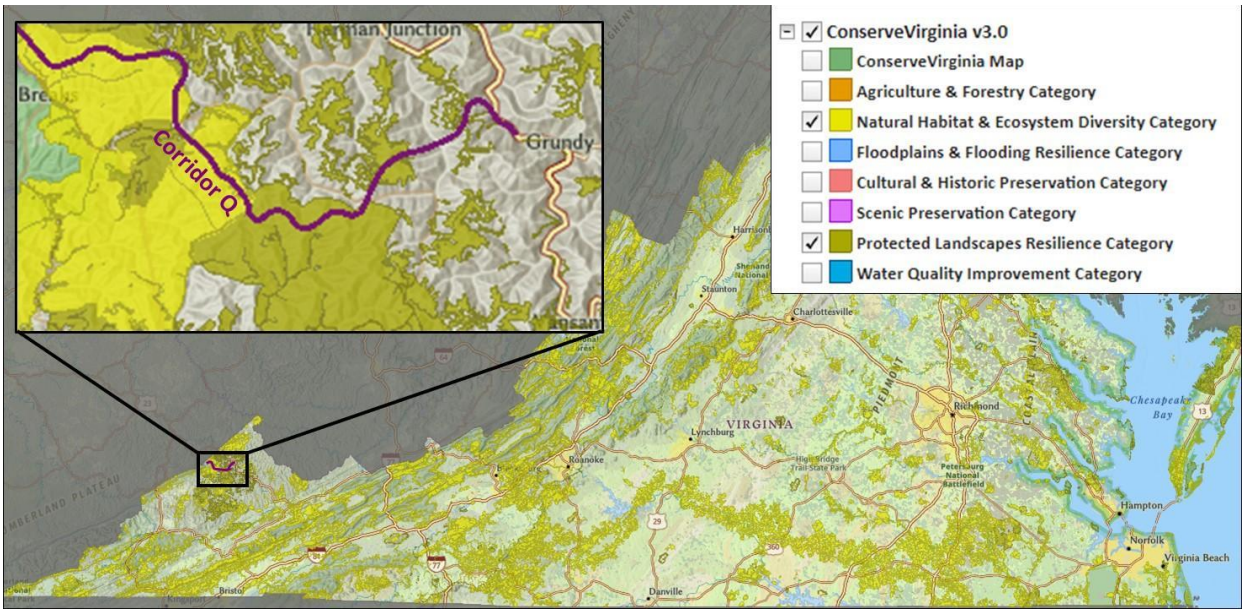

Figure 16. Illustration of Corridor Q Relative to the Natural Habitat & Ecosystem Diversity and Protected Landscapes Resilience Categories of ConserveVirginia, Version 3.0 (Virginia Department of Conservation and Recreation, 2021).

There is a growing interest by policy makers to address transportation infrastructure and ecosystem resilience (Skroch and Duncan, 2023), and wildlife crossings have been recognized as an important means of providing wildlife movement needed to deal with the effects of climate change (Einhorn, 2021; Skroch and Duncan, 2023).

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APPENDIX A

OTHER RELEVANT IIJA FUNDING SOURCES

Nationally Significant Multimodal Freight and Highway Program (INFRA)

IIJA authorized up to $8 billion in funding over 5 years for the Nationally Significant Multimodal Freight and Highway Program (INFRA), which provides federal funding for projects of regional or national significance, including wildlife crossing structures. Program goals vary and include (1) improving the safe, efficient, and reliable movement of people and freight; (2) generating economic benefits; (3) reducing congestion; (4) improving intermodal freight connectivity; (5) enhancing critical infrastructure resiliency and environmental protection; (6) improving national energy security; and (7) addressing the effects of population growth on moving people and freight (23 U.S.C. § 117).

To receive an INFRA grant, projects are required to meet seven statutory requirements. Specifically, the project must (1) generate national or regional economic, safety, or mobility benefits; (2) be cost-effective; (3) aid in meeting national performance goals; (4) be based on preliminary engineering; (5) demonstrate that one or more dependable sources of associated non-federal funding and financial commitments are available to construct, operate, and maintain the project, including contingency funding to cover any unanticipated cost increases; (6) show that the project cannot be efficiently or easily completed without additional federal funding; and (7) establish that construction is expected to begin within 18 months of funding.

INFRA funds may be used to pay for up to 60% of future project costs.

Up to 85% of annual INFRA funding is reserved for Large Projects; Large Projects in the State of Virginia must (1) have total project costs of at least $100 million, and (2) seek a minimum grant award of $25 million or more. At least 25% of Large Project funds must be awarded in rural areas, which are defined as outside urbanized areas that have a population over 200,000. Assuming the FY23 notice makes available the same amount as FY22 ($1.55 billion), up to 85%, or ~$1.3 billion, will be available for Large Projects, with at least 25%, or ~$330 million, set aside for rural areas.

A minimum of 15% of annual INFRA funding is reserved for Small Projects; Small Projects must (1) have total project costs of less than $100 million, and (2) seek a minimum grant award of $5 million or more. A minimum of 30% of Small Project funds must be awarded in rural areas. If the FY23 notice makes available the same amount as in FY22 ($1.55 billion), at least 15%, or $232.5 million, will be available for Small Projects, with at least 30%, or $70 million, set aside for rural areas (U.S. DOT, 2022b).

Application Review and Rating

In addition to conducting an economic analysis of the anticipated costs and benefits of the project and demonstrating project readiness, INFRA proposals share a common application with the Rural grant and will be evaluated based on the same six project outcome criteria, including:

1. safety
2. state of good repair
3. economic impacts, freight movement, and job creation
4. climate change, resiliency, and the environment
5. equity, multimodality, and quality of life
6. use of innovative technologies, project delivery practices, or financing.

Selection considerations for INFRA Small Projects also include cost-effectiveness, which is assessed based on the cost-benefit economic analysis; the project's effect on state and regional mobility, which is considered as part of project outcome Criteria 3 and 5; and the project's effect on freight corridor safety hazards, including "high winds, heavy snowfall, flooding, rockslides, mudslides, wildfire, wildlife crossing onto the roadway, or steep grades," which is considered as part of project outcome Criteria 1, 3, and 4 (U.S. DOT, 2022b).

Program Relevance to Corridor Q Wildlife Crossings

The recommended mitigation measures for both Sections A and B appear to satisfy all seven of the INFRA statutory requirements, including being cost-effective and reasonably expected to begin construction no later than 18 months after funding is obligated. As summarized in Appendix B, the project is projected to score either 2s or 3s and no 0s on the project outcome criteria, thereby potentially achieving an overall project outcome rating of Highly Recommended or Recommended. In addition, as noted, the project appears to be located within an Opportunity Zone (an additional geographic diversity factor that results in the project being more competitive than similar projects not located within such a zone). Unlike Rural, however, an INFRA award may be used to satisfy up to only 60% of a project's anticipated future costs. Although other federal funds may be used to meet the non-INFRA cost share requirement, the total amount of federal project assistance (including INFRA and non-INFRA) may not exceed 80%. Because INFRA would require securing an additional 40% in non-INFRA funding, including at least 20% in non-federal (state/local/private) funding, the INFRA program is significantly less attractive than either Rural or RAISE, which each allows for up to 100% federal funding for this project.

State and Federal Formula Allocation Programs and Funding

In addition to federal discretionary grant programs, IIJA allocates significant funding via a formula to states that may be used to pay for wildlife crossings and other similar wildlife-related mitigation countermeasures. These programs include (1) the Highway Safety Improvement Program, which may be used to pay for adding or retrofitting structures or other

measures to improve safety by eliminating or reducing crashes involving vehicles and wildlife; (2) the Surface Transportation Block Grant Program, which may be used to pay for construction of wildlife crossing structures and other projects and strategies designed to reduce the number of wildlife-vehicle collisions, including project-related planning, design, construction, monitoring, and preventative maintenance; (3) the Transportation Alternatives Set-Aside, which may be used to pay for environmental mitigation activities aimed at reducing wildlife mortality due to roads or restoring and maintaining terrestrial or aquatic habitat connectivity; and (4) the Federal Lands Access Program, which may be used to pay for environmental mitigation to improve public safety and reduce wildlife mortality due to roads while maintaining habitat connectivity (Callahan, 2023).

Program Relevance to Corridor Q Wildlife Crossings

Given the substantial lead time required to budget funding for new projects, it is likely that VDOT has already programmed its federal formula allocation funds, including those for the Highway Safety Improvement Program, the Surface Transportation Block Grant Program, and the Transportation Alternatives Set-Aside. In addition, the FY23-26 call for Virginia Federal Lands Access Program projects opened in February 2022 and closed in May 2022 (U.S. DOT, 2022f); as a result, the Federal Lands Access Program is not currently a viable source of funding for the recommended mitigation measures. It thus does not appear that these formula allocation programs would be suitable sources of funding.

APPENDIX B

RURAL SURFACE TRANSPORTATION GRANT PROGRAM (RURAL)

Application Review and Rating

In addition to an economic cost-benefit analysis and the demonstration of project readiness, Rural proposals will be evaluated based on the following project outcome criteria:

1. safety
2. state of good repair
3. economic impacts, freight movement, and job creation
4. climate change, resiliency, and the environment
5. equity, multimodality, and quality of life
6. use of innovative technologies, project delivery practices, or financing.

Each criterion will receive a rating from 0 to 3 based on the following guidelines:

- *Rating of 0:* The project negatively affects the outcome area *or* the application contains insufficient information to assess the outcome area.

- *Rating of 1:* The project's claimed benefits in the outcome area are plausible but minimal *or* the project's claimed benefits are not plausible.

- *Rating of 2:* The project has clear and direct benefits in the outcome area stemming from the adoption of common practices for planning, designing, or building infrastructure.

- *Rating of 3:* The project has clear and direct, data-driven, and significant benefits in the outcome area that are well supported by evidence presented in the application.

An overall project outcome rating of High, Medium-High, Medium, Medium-Low, or Low will be assigned based on the following:

- *High:* To receive a rating of High, the project must receive a score of at least three 3s and no 0s.

- *Medium-High:* To receive a rating of Medium-High, the project must receive a score of at least one 3 and no 0s.

- *Medium:* To receive a rating of Medium, the project must receive a score of no 3s and no 0s.

- *Medium-Low:* To receive a rating of Medium-Low, the project must receive no more than one 0.

- *Low:* To receive a rating of Low, the project must receive a score of two or more 0s.

Although projects are not required to score highly on each project outcome criterion, projects that are able to demonstrate clear, direct, data-driven, and significant benefits for the greatest number of categories will score the highest rating. Upon completion of the project outcome criteria, economic analysis, and project readiness assessments, each eligible project will be assigned an overall rating of Highly Recommended, Recommended, or Not Recommended, as summarized here:

1. *A rating of Highly Recommended will be assigned to a project that:*
   a. Meets all the statutory requirements for an award; *and*
   b. Receives a High rating for (1) all project outcome criteria; (2) economic analysis; and (3) project readiness; *or*
   a. Meets all the statutory requirements for an award; *and*
   b. Is otherwise determined to be an exemplary project of national or regional significance that generates significant benefits in one of the project outcome areas.

2. *A rating of Recommended will be assigned to a project that:*
   a. Meets all the statutory requirements for an award; *and*
   b. Is not otherwise assigned a Highly Recommended or Not Recommended rating.

3. *A rating of Not Recommended will be assigned to a project that:*
   a. Does not meet one or more statutory requirements for an award or additional information is required for one or more statutory requirements; *or*
   b. Receives a Low rating for one or more of the project outcome criteria, economic analysis, or project readiness; *or*
   c. Is otherwise identified as not suitable for a grant award based on its weakness within a project outcome area.

Once all eligible projects have been assessed and assigned an overall rating, a list of Highly Recommended projects for consideration will be generated and reviewed to determine whether sufficient projects are included to meet the required program set-asides (e.g., 25% for ADHS) and geographic diversity requirements (e.g., rural-urban). In the event these additional set-aside and diversity requirements are not met by the list of Highly Recommended projects, Recommended projects may be added to the list of projects for consideration until the required program set-asides and geographic diversity requirements are met. The addition of such Recommended projects to the list can occur only (1) if the project directly addresses an identified program deficiency regarding set-asides or geographic diversity requirements, *or* there are insufficient Highly Recommended projects to distribute all available funds, *and* all similarly situated Recommended projects are treated the same. The final list of projects for consideration is presented to the U.S. Secretary of Transportation, who selects the final projects (U.S. DOT, 2022b).

Program Relevance to Corridor Q Wildlife Crossings

The recommended mitigation measures for both Sections A and B appear to satisfy all five of the Rural statutory requirements, including being cost-effective and reasonably expected to begin construction no later than 18 months after funds are obligated. As summarized in Table A1, the project also appears to be well-positioned to score a numerical rating of 2 or 3 on most if not all of the six project outcome criteria, thereby potentially achieving an overall project outcome rating of Highly Recommended or Recommended.

Table A1. Preliminary Analysis of Project Outcome Criteria for Rural and INFRA (Proposals That Share a Common Application)

Project Outcomes	Rating Scale (0 to 3) Assessment Considerations	Preliminary Project Rating Assessment Based on Anticipated Benefits
Criterion 1: Safety	• Targets a known safety problem and seeks to protect motorized and non-motorized travelers and communities, including vulnerable users, from health and safety risks. • Provides estimated impacts on the number, rate, and consequences of crashes, fatalities, and serious injuries. • Addresses vulnerable roadway users. • Addresses inequities in crash victims. • Incorporates roadway design and technology proven to improve safety. • Activity is identified in The National Roadway Safety Strategy. • Addresses long-term parking shortage for commercial motor vehicles on the National Highway System.	• **Projected Rating of 3:** Safety is a primary purpose of this project, which targets a known, documented safety problem of elk on the highway. Integrated wildlife safety countermeasures will provide significant safety benefits by reducing WVCs and associated fatalities and serious injuries by up to 97%. • This project aligns with the National Roadway Safety Strategy's recognition that highways "that serve rural communities and small towns face outsized safety impacts relative to their population and number of miles traveled, and have unique design considerations such as how to minimize collisions with large wildlife" (emphasis added). (U.S. DOT, 2022a). • In addition, given the project's location adjacent to multiple Census Tract Areas of Persistent Poverty and Historically Disadvantaged Communities, integration of wildlife safety crossings will likely reduce fatalities and/or serious injuries along the corridor compared to the statewide average for other underserved communities.
Criterion 2: State of Good Repair	• Is consistent with relevant plans to maintain transportation facilities or systems in a state of good repair, including Department-required asset management plans, and addresses current and projected vulnerabilities that if left unimproved will threaten efficient and accessible movement of goods and people or economic growth.	• **Projected Rating of 2 or 3:** The project will create new infrastructure in a remote community that will be maintained in a state of good repair. • In addition, the project both improves the safety of existing transportation infrastructure (via retrofits in Section A) and addresses projected motorist

	• Includes a plan to maintain the infrastructure in a state of good repair. • Ensures a good infrastructure condition and supports economic growth and commerce. • Improves the condition and safety of existing transportation infrastructure within the right of way.	vulnerabilities due to wildlife crossing onto the highway (by integrating crossings into Section B). • Failure to address this known safety issue would otherwise threaten the ability of Corridor Q to achieve its goal of ensuring the safe, efficient, and cost-effective movement of people, goods, and services along this critical economic development corridor. • In addition, it is anticipated that the installation of wildlife crossings will reduce maintenance costs incurred for removal and disposal of carcasses along Corridor Q and will provide potential cost savings due to avoided collisions.
Criterion 3: Economic Impacts, Freight Movement, and Job Creation	• Improves system operations to increase travel time reliability and manage travel demand for goods movement, especially strengthening the resilience and expanding the capacity of critical supply chain bottlenecks to promote economic security and improve local and regional freight connectivity to the national and global economy. • Decreases transportation costs and improves access through reliable and timely access to employment centers and job opportunities. • Improves regional and national economic strength by increasing the economic productivity of land, capital, or labor and improving the economic strength of regions and cities. • Enhances recreational and tourism opportunities by providing access to federal land, national parks, national forests, national recreation areas, national wildlife refuges, wilderness areas, or state parks. • Creates high-quality jobs by supporting good-paying jobs with a free and fair choice to join a union in project construction and in on-going operations and maintenance, and incorporates strong labor standards. • Creates workforce opportunities for historically underrepresented groups, such as through the use of local hire provisions or other workforce strategies targeted at or jointly developed with historically underrepresented groups. • Fosters economic growth and development while creating long-term high-quality jobs and addressing acute challenges, such as	• **Projected Rating of 3:** Improved economic opportunity is a primary goal of the Corridor Q project. Absent integration of the recommended mitigation measures, motorists will experience heightened vulnerability to wildlife crossing onto the roadway, which will threaten the ability of Corridor Q to achieve its essential goal of ensuring the safe, efficient, and cost-effective movement of people, goods, and services along this critical economic development corridor. • Among other potential benefits within this category, a mitigated Corridor Q will promote wealth building through long-term economic growth and other broader economic and fiscal benefits to Buchanan County; promote economic security by improving travel time reliability; enhance access to job opportunities; facilitate efficient and reliable movement of goods; and support the creation of good-paying, high-quality jobs. • A mitigated Corridor Q will provide improved tourism opportunities and enhanced access to the nearby Breaks Interstate Park and George Washington and Jefferson National Forests. • The newly established elk population has been an important draw to the area, and elk-viewing tourism is

	energy sector job losses in energy communities. • Supports integrated land use, economic development, and transportation planning to improve the movement of people and goods and local fiscal health. • Facilitates greater public-private investment in land-use productivity, including rural main street revitalization or increased production or preservation of location-efficient housing. • Helps the United States compete globally by encouraging the location of important industries and future innovations and technology in the United States and facilitating efficient, reliable freight movement.	becoming increasingly popular. In addition, VDWR expects tourism to grow as a result of the first managed elk hunt last fall in Buchanan, Dickenson, and Wise counties and future anticipated elk hunts.
Criterion 4: Climate Change, Resiliency, and Environment	• Considers climate change and environmental justice in the planning stage and in project delivery. • Reduces air pollution and greenhouse gas emissions; increases use of lower-carbon travel modes or construction materials; improves resilience of at-risk infrastructure; or addresses environmental impacts of transportation on disadvantaged communities. • Prevents stormwater runoff detrimental to aquatic species. • Promotes energy efficiency, incorporates electric vehicle or zero emission infrastructure, increases resiliency, and recycles or redevelops brownfield sites. • Utilizes demand management strategies to reduce congestion, induced travel demand, and greenhouse gas emissions. • Serves renewable energy supply chains. • Improves disaster preparedness and resilience. • Avoids adverse environmental impacts to air or water quality, wetlands, and endangered species, such as through reduced pollutants and greenhouse gases, improved stormwater management, or improved habitat connectivity. • Proposes recycling of materials, use of materials known to reduce or reverse carbon emissions, or both.	• **Projected Rating of 2 or 3:** Environmental sustainability is a primary purpose of integrating wildlife safety mitigation measures into this project. Inclusion of the recommended mitigation measures will result in clear, direct, data-driven, and significant environmental benefits by reducing WVCs while maintaining habitat connectivity that would otherwise be harmed or severed for resident elk populations and other wildlife species. • Corridor Q is situated within an area categorized by the Virginia Wildlife Corridor Action Plan as a Wildlife Biodiversity Resilience Corridor. In addition (as shown in Figure 16), Corridor Q intersects Natural Habitat & Ecosystem Diversity and Protected Landscapes Resilience lands that not only provide rich habitat for a range of species today but will also serve as climate refugia and enduring movement corridors in the future. By providing safe passage within this important wildlife area, this project will help ensure stable wildlife populations today and in the future.
Criterion 5: Equity, Multimodality, and Quality of Life	• Increases affordable and accessible transportation choices and equity for individuals, including disadvantaged communities. • Improve access to emergency care, essential services, healthcare providers, or drug and alcohol treatment and rehabilitation centers.	• **Projected Rating of 3:** Improved quality of life is a primary purpose of the Corridor Q project, which will proactively increase equity, access to goods, and job opportunities for local residents, including underserved HCD/APP populations, by increasing

	• Reduces transportation and housing cost burdens. • Increases walkability and accessibility for pedestrians and encourages thriving communities. • Enhances the unique characteristics of the community. • Proactively addresses equity or other disparities and barriers to opportunity through the planning process or through incorporation of design elements. • Engages, or will engage, diverse people and communities and demonstrates that equity considerations and community input and ownership, particularly among disadvantaged communities, are meaningfully integrated into planning, development, and implementation. • Demonstrates collaboration and support among a broad range of stakeholders, including community organizations, other public or private entities, and labor unions. • Supports a local/regional/state equitable development plan. • Benefits a historically disadvantaged community or area of persistent poverty. • Proactively addresses equity and barriers to opportunity. • Includes new or improved freight access to underserved communities to increase access to goods and job opportunities.	transportation affordability; reducing transportation burdens; improving transportation access; and lowering vehicle miles traveled to emergency care, healthcare providers, treatment centers, jobs, and other essential and daily destinations. • This project would support and engage a wide diversity of community members and interested stakeholders to ensure meaningful integration of equity considerations for this underserved community including Buchanan County, community residents, and adjacent landowners, including private and public landowners such as The Nature Conservancy–Virginia. Other organizations that have expressed support for wildlife crossings and fencing on Corridor Q are identified in Table 12.
Criterion 6: Use of Innovative Technologies, Project Delivery Practices, or Financing	• Incorporates technological design solutions. • Enhances the environment for connected, electric, and automated vehicles. • Uses technology to improve the detection, mitigation, and documentation of safety risks. • Utilizes innovative practices in contracting (such as public-private partnerships and single contractor design-build arrangements), congestion management, asset management, or long-term operations and maintenance. • Utilizes innovative financing.	• **Projected Rating of 2 or 3:** The project may incorporate an experimental animal detection system and associated monitoring, which will improve detection, documentation, and mitigation of the risk to motorists of crashes involving wildlife while at the same time refining best practices with respect to use of this innovative technology.

APPENDIX C

REBUILDING AMERICAN INFRASTRUCTURE WITH SUSTAINABILITY AND EQUITY (RAISE)

Application Review and Rating

In addition to meeting applicable cost-effectiveness and project readiness requirements, projects will be assessed based on the following merit selection criteria:

1. safety
2. environmental sustainability
3. quality of life
4. mobility and community connectivity
5. economic competitiveness and opportunity
6. state of good repair
7. partnerships and collaboration
8. innovation.

As set forth in the RAISE Notice of Funding Opportunity, projects will receive a rating of High, Medium, Low, or Non-Responsive based on the following rubric:

- *High:* To receive a High rating, "the criterion must be addressed as a primary project purpose (not an ancillary or incidental consideration, except for the Partnership and Collaboration and Innovation criteria), must include clear, direct, data-driven (capital projects only), and significant benefits, and must align with at least one of the benefits described in the high column of the merit criteria rubric."
- *Medium:* To receive a Medium rating, "the criterion may not be a primary project purpose, or the project benefits do not meet at least one of the requirements for a 'high' rating, as described in the merit criteria rubric."
- *Low:* To receive a Low rating, the application must contain "insufficient information to assess that criterion's benefits."
- *Non-Responsive:* To receive a Non-Responsive rating, either the project negatively affects the criterion or the application does not address the criterion.

Individual merit criterion rankings are combined to form an overall merit rating of Highly Recommended, Recommended, Acceptable, or Unacceptable, as detailed here:

- *Highly Recommended* if six or more of the eight merit criteria ratings are High and none of the merit criteria ratings are Non-Responsive.

- *Recommended* if at least one, but no more than five, of the merit criteria ratings are High, no more than three of the merit criteria ratings are Low, and none are Non-Responsive.

- *Acceptable* if there is a combination of High, Medium, Low, or Non-Responsive ratings that do not fit within the definitions of Highly Recommended, Recommended, or Unacceptable.

- *Unacceptable* if there are three or more Non-Responsive ratings (U.S. DOT, 2023a).

Program Relevance to Corridor Q Wildlife Crossings

In addition to satisfying cost-effectiveness and project readiness, the project appears to be well-positioned to score a rating of High or Medium on most if not all of the eight merit criteria based on anticipated project benefits (Table C1).

Table C1. Preliminary Analysis of Merit Criteria for RAISE

Project Outcomes	Rating Scale (High/Medium) Assessment Considerations	Preliminary Project Rating Assessment Based on Anticipated Benefits
Criterion 1: Safety	**HIGH:** Safety is a primary project purpose AND the project has clear, direct, data-driven (for capital projects only), and significant benefits that target a known, documented safety problem by doing one or more of the following: • Protects non-motorized travelers and communities from safety risks; or • Reduces fatalities and/or serious injuries to bring them below the statewide average for underserved communities; or • Incorporates and cites specific actions and activities identified in the National Roadway Safety Strategy. **MEDIUM:** The project has one or more of the following safety benefits, but safety may not be a primary project purpose, or the project does not meet the description(s) of a High rating: • Protects non-motorized or motorized travelers or communities from safety risks; or • Reduces any number of fatalities and/or serious injuries.	• **Projected Rating of HIGH:** Safety is a primary purpose of this project, which targets a known, documented safety problem of elk on the highway. Integrated wildlife safety countermeasures will provide significant safety benefits by reducing WVCs and associated fatalities and serious injuries by up to 97%. • Inclusion of such unique design considerations "to minimize collisions with large wildlife" on rural highways like Corridor Q is recommended in the National Roadway Safety Strategy as a strategy to make our nation's rural highways safer for motorists (U.S. DOT, 2022a). • In addition, given the project's adjacency to several Census Tract Areas of Persistent Poverty and Historically Disadvantaged Communities, it is likely that the project will directly result in a reduction in fatalities and/or serious injuries compared to the statewide average for these underserved communities.

Criterion 2: Environmental Sustainability	**HIGH:** Environmental sustainability is a primary project purpose AND the project has clear, direct, data-driven (for capital projects only), and significant benefits that explicitly consider climate change and environmental justice by doing one or more of the following: • Reduces transportation-related air pollution and greenhouse gas emissions in underserved communities; or • Addresses the disproportionately negative environmental impacts of transportation on underserved communities such as by reducing exposure to elevated levels of air, water, and noise pollution; or • Aligns with the state, regional, county, or city decarbonization plan; or • Implements transportation-efficient land use and design, such as drawing on the features of historic towns and villages that have a mix of land uses, compact walkable development patterns, green space, and neighborhood centers; or • Reduces vehicle miles traveled specifically through modal shift to transit or active transportation; or • Reduces emissions specifically by shifting freight to lower-carbon travel modes; or • Incorporates energy-efficient investments, such as electrification or zero emissions vehicle infrastructure; or • Improves resilience of at-risk infrastructure to withstand extreme weather events and natural disasters caused by climate change; or • Removes, replaces, or restores culverts to improve aquatic passage; or • Avoids adverse environmental impacts to air or water quality, wetlands, and endangered species. **MEDIUM:** Project has one or more of the following environmental sustainability benefits, but environmental sustainability may not be a primary project purpose or the project does not meet the description(s) of a High rating: • Reduces transportation-related air pollution and greenhouse gas emissions; or • Reduces vehicle miles traveled; or • Incorporates lower-carbon pavement/construction materials; or • Redevelops brownfield sites; or • Improves resilience of infrastructure to current and future weather and climate risks; or • Makes basic stormwater improvements.	• **Projected Rating of HIGH or MEDIUM:** Environmental sustainability is a primary purpose of integrating wildlife safety mitigation measures into this project. Inclusion of the recommended mitigation measures which will result in clear, direct, data-driven, and significant environmental benefits by reducing WVCs while maintaining habitat connectivity that would otherwise be harmed or severed for resident elk populations and other wildlife species. • As shown in Figure 16, Corridor Q intersects Natural Habitat & Ecosystem Diversity and Protected Landscapes Resilience lands, which not only provide rich habitat for a range of species today but will also serve as climate refugia and enduring movement corridors in the future. By providing safe passage within this important wildlife area, this project will help ensure stable wildlife populations today and in the future.

Criterion 3: Quality of Life	**HIGH:** Quality of life is a primary project purpose AND the project has clear, direct, data-driven (for capital projects only), and significant benefits by doing one or more of the following: • Increases affordable transportation choices by improving and expanding active transportation usage or significantly reducing vehicle dependence, particularly in underserved communities; or • Reduces transportation and housing cost burdens by integrating mixed-use development and a diversity of housing types, including affordable housing, with multimodal transportation infrastructure; or • Coordinates and integrates land use, affordable housing, and transportation planning to create more livable communities and expand travel choices; or • Improves access to daily destinations such as jobs, healthcare, grocery stores, schools, places of worship, recreation, or parks through transit and active transportation; or • Implements transit-oriented development that benefits existing residents and businesses and low-income and disadvantaged communities and minimizes displacement; or • Improves public health by adding new facilities that promote walking, biking, and other forms of active transportation; or • Mitigates urban heat islands to protect the health of at-risk residents, outdoor workers, and others; or • Proactively addresses equity. **MEDIUM:** Project has one or more of the following quality-of-life benefits but quality of life may not be a primary project purpose or the project does not meet the description(s) of a High rating: • Increases affordability for travelers; or • Reduces vehicle dependence.	• **Projected Rating of HIGH or MEDIUM:** Improved quality of life is a primary purpose of the Corridor Q project, which will proactively address equity by increasing affordability for travelers within an HCD/APP by improving access and lowering vehicle miles traveled to jobs, healthcare, and other daily destinations.
Criterion 4: Mobility & Community Connectivity	**HIGH:** Mobility and community connectivity is a primary project purpose AND the project has clear, direct, data-driven (for capital projects only), and significant benefits by doing one or more of the following: • Improves system-wide connectivity with access to transit, micro-mobility, and mobility on-demand; or • Implements plans, based on community participation and data, that identifies and addresses gaps in the existing network; or	• **Projected Rating of HIGH:** Mobility and community connectivity comprise a primary project purpose, and Corridor Q provides clear, direct, data-driven, and significant benefits by filling a gap in the Appalachian Development Highway System based on community participation and data.

	• Removes physical barriers for individuals by reconnecting communities to direct, affordable transportation options; or • Includes transportation features that increase the accessibility for non-motorized travelers for underserved communities, such as through a Complete Streets approach; or • Incorporates Universal Design that exceeds ADA requirements; or • Directly increases intermodal and multimodal freight movement; or • Considers last-mile freight plans in a Complete Streets and multimodal approach. **MEDIUM:** Project has one or more of the following mobility and community connectivity benefits, but mobility and community connectivity may not be a primary project purpose or the project does not meet the description(s) of a High rating: • Increases accessible transportation choices; or • Includes ADA improvements.	
Criterion 5: Economic Competitiveness & Opportunity	**HIGH:** Economic competitiveness is a primary project purpose AND the project has clear, direct, data-driven (for capital projects only), and significant benefits by doing one or more of the following: • Improves intermodal and/or multimodal freight mobility, especially for supply chain bottlenecks; or • Facilitates tourism opportunities; or • Fosters inclusive economic development such as the utilization of Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses, and Veteran Owned Businesses; or • Promotes wealth building; or • Promotes long-term economic growth and other broader economic and fiscal benefits; or • Promotes robust job creation by supporting good-paying jobs directly related to the project with free and fair choice to join a union, expand training programs, and implement policies such as targeted hiring preferences that will promote the entry and retention of underrepresented populations into those jobs including women, people of color, and people with convictions; or • Promotes greater public and private investments in land-use productivity, including rural main street revitalization or locally driven density decisions that support equitable commercial and mixed-income residential development.	• **Projected Rating of HIGH:** Improved economic competitiveness and opportunity is a primary goal of the Corridor Q project. Among other potential benefits within this category, a mitigated Corridor Q will directly result in improved tourism opportunities; promote wealth building through long-term economic growth and other broader economic and fiscal benefits to Buchanan County; promote economic security by improving travel time reliability; and facilitate efficient movement of goods. • The newly established elk population has been an important draw to the area, and elk-viewing tourism is becoming increasingly popular. In addition, VDWR expects tourism to grow as a result of the first managed elk hunt last fall in Buchanan, Dickenson, and Wise counties and anticipated elk hunts in the future.

	MEDIUM: Project has one or more of the following economic competitiveness and opportunity benefits, but economic competitiveness and opportunity may not be a primary project purpose or the project does not meet the description(s) of a High rating: • Improves travel time reliability; or • Improves movement of goods; or • Creates jobs related to the project's delivery and on-going operations.	
Criterion 6: State of Good Repair	**HIGH:** State of good repair is a primary project purpose AND the project has clear, direct, data-driven (for capital projects only), and significant benefits by doing one or more of the following: • Restores and modernizes (such as through road diets and Complete Streets approaches) the existing core infrastructure assets that have met their useful life; or • Reduces construction and maintenance burdens through efficient and well-integrated design; or • Creates new infrastructure in remote communities that will be maintained in a state of good repair; or • Addresses current or projected system vulnerabilities for underserved communities; or • Prioritizes improvement of the condition and safety of existing transportation infrastructure within the existing footprint. **MEDIUM:** Project has one or more of the following state of good repair benefits but state of good repair may not be a primary project purpose or the project does not meet the description(s) of a High rating: • Routine or deferred maintenance; or • Creates new infrastructure (not in a remote community) that will be maintained in a state of good repair; or • Identifies the party responsible for maintenance and describes how the new or improved asset(s) will be maintained in a state of good repair; or • Resolves current or projected system vulnerabilities.	• **Projected Rating of HIGH:** State of good repair is a primary project purpose, and the project will create new infrastructure in a remote community that will be maintained in a state of good repair. • In addition, by retrofitting Section A, the project prioritizes improvement of the condition and safety of Corridor Q within its existing footprint, thereby addressing current vulnerabilities for adjacent underserved communities. • Similarly, by integrating wildlife safety countermeasures within Section B, the project addresses projected motorist vulnerabilities due to wildlife crossing onto the highway for those same underserved communities. • Failure to address this known safety issue would otherwise threaten the ability of Corridor Q to achieve its goal of ensuring the safe, efficient, and cost-effective movement of people, goods, and services along this critical economic development corridor. • In addition, it is anticipated that the installation of wildlife crossings will reduce maintenance costs incurred for removal and disposal of carcasses along Corridor Q as well as provide other potential cost savings due to avoided collisions.
Criterion 7: Partnership & Collaboration	**HIGH:** Project has, or demonstrates or plans to support and engage diverse people and communities that go above and beyond by doing one or more of the following • Engages residents and community-based organizations to ensure that equity considerations for underserved communities are meaningfully integrated throughout the	• **Projected Rating of HIGH:** A collaboration between VDOT and VDWR, this project supports and engages a wide diversity of community members and interested stakeholders to ensure meaningful integration of equity considerations for this underserved community

	lifecycle of the project, for example, by citing and describing how the project aligns with the Department's *Promising Practices for Meaningful Public Involvement in Transportation Decision-Making Guide*; or • Coordinates with other types of projects such as economic development, commercial or residential development near public transportation, power/electric infrastructure projects, or broadband deployment; or • Partners with Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses, and Veteran Owned Businesses; or • Partners with high-quality workforce development programs with supportive services to help train, place, and retain underrepresented communities in good-paying jobs or registered apprenticeships; or • Partners and engages with unions and/or worker organizations in the development of the project and the lifecycle of the project, including the maintenance or operation of the project; or • Partners with communities or community groups representative of historically underrepresented groups to develop workforce strategies; or • Establishes formal public-private partnerships or joint ventures to expand or create infrastructure or economic development capacity; or • Participates in a non-DOT federal capacity-building program. **MEDIUM:** Project has one or more of the following partnership and collaboration benefits but partnership and collaboration may not be a primary project purpose or the project does not meet a High rating: • Collaborates with public and/or private entities; or • Documents support from local, regional, or national levels.	including Buchanan County, community residents, and adjacent landowners, including private and public landowners such as The Nature Conservancy–Virginia. Other organizations that have expressed support for wildlife crossings and fencing on Corridor Q are identified in Table 13.
Criterion 8: Innovation	**HIGH:** Project has, or demonstrates plans for, one or more of the following innovative benefits. • Innovative Technologies — Enhance the environment for electric, connected, and automated vehicles to improve the detection, mitigation, and documentation of safety risks; or — Uses low-carbon materials; or — Uses caps, land bridges, or underdecks. • Innovative Project Delivery	• **Projected Rating of HIGH or MEDIUM:** The project incorporates an experimental animal detection system and associated monitoring, which will improve detection, documentation, and mitigation of the risk to motorists of crashes involving wildlife and aid in refining best practices with respect to use of this innovative technology.

	— Uses practices that facilitate accelerated project delivery such as single contractor design-build arrangements, congestion management, asset management, or long-term operations and maintenance. • Innovative Financing — Secures TIFIA, RRIF, or private activity bond financing; or — Uses congestion pricing or other demand management strategies. **MEDIUM:** Project has one or more of the following innovation benefits but does not meet the description(s) of a High rating: • Deploys technologies, project delivery, or financing methods that are new or innovative to the applicant or community.	

APPENDIX D

WILDILFE CROSSING PILOT PROGRAM (WCPP)

Application Review and Rating

In addition to demonstrating project readiness, the proposal will be evaluated based on the following primary and secondary merit criteria (U.S. DOT, 2023b):

Primary Merit Criteria

- Criterion 1.1: Reduction of wildlife-vehicle collisions (WVCs).
- Criterion 1.2: Improvement of terrestrial or aquatic habitat connectivity.

Secondary Merit Criteria

- Criterion 2.1: Leveraging Investments, including public-private partnerships.
- Criterion 2.2: Economic Development and Visitation Opportunities.
- Criterion 2.3: Innovation, including innovative technologies, advanced design techniques, and other innovative strategies to reduce WVCs and improve habitat connectivity.
- Criterion 2.4: Education and Outreach, including how the project will effectively and equitably engage and educate the public on WVCs, motorist safety, and habitat connectivity.
- Criterion 2.5: Monitoring and Research, including a plan to effectively monitor, evaluate, and report on the project's effect on WVCs and/or habitat connectivity.
- Criterion 2.6: Survival of Species, including whether the project is expected to significantly benefit federally listed threatened or endangered species or proposed or candidate species for listing.

FHWA's Technical Evaluation Team will first assess the project's alignment with the primary merit criteria and assign a rating of Strong Alignment, Alignment, or No Alignment based on the data and information provided in the application. Individual criterion ratings will be translated into an overall primary merit criteria ranking of Strongly Recommended, Recommended, or Not Recommended (U.S. DOT, 2023b).

Applications that receive a rating of Strongly Recommended or Recommended in the primary merit criteria will then be assessed against each of the six secondary merit criteria. Individual ratings will be translated into an overall secondary merit criteria ranking of Strongly Recommended, Recommended, or Not Recommended based on the following rubric (U.S. DOT, 2023b):

- *Strongly Recommended applications have*
  (1) Strong Alignment with two or more of the six secondary merit criteria; *and*
  (2) Alignment with all the remaining secondary merit criteria.

- *Recommended applications are*
  (1) applications that are not evaluated as Strongly Recommended *and*
  (2) that have Alignment or Strong Alignment with at least three of the six secondary merit criteria.

- *Not Recommended applications have No Alignment with four or more of the six secondary merit criteria.*

Applications that are Strongly Recommended or Recommended from the primary merit criteria and Strongly Recommended or Recommended from the secondary merit criteria will undergo a project readiness review and receive an overall project readiness rating of High, Medium, or Low (U.S. DOT, 2023b).

Based on the rankings for the primary merit criteria, secondary merit criteria, and project readiness, the Technical Evaluation Team will assign each application an overall rating, based on the following rubric (U.S. DOT, 2023b):

- *Highly Recommended applications will have ratings of:*
  (1) Strongly Recommended in primary merit criteria;
  (2) either Strongly Recommended or Recommended in secondary merit criteria; *and*
  (3) either High or Medium in project readiness.

- *Recommended applications will have ratings of:*
  (1) Recommended in primary merit criteria;
  (2) either Strongly Recommended or Recommended in secondary merit criteria; *and*
  (3) either High or Medium in project readiness.

- *Not Recommended applications will have ratings of:*
  (1) Not Recommended in primary merit criteria;
  (2) Not Recommended in secondary merit criteria; *or*
  (3) Low in project readiness.

The Technical Evaluation Team then forwards all Highly Recommended and Recommended applications to FHWA's Senior-Level Review Team. The Senior-Level Review Team is charged with advancing as many Highly Recommended applications as possible to the FHWA Administrator for potential grant awards, consistent with the statutory requirement that 60% of available funds be awarded to projects in rural areas. The Senior-Level Review Team may also advance Recommended applications, or advance a Recommended project over a Highly Recommended project based on (1) how the application meets one or more of the U.S. DOT Administration's priorities discussed in Section A.2, including Safety; Climate Change and Sustainability; Equity; and Workforce Development, Job Quality, and Wealth Creation; (2) rankings on individual primary and secondary merit criterion; (3) project readiness; and (4) geographic diversity (consistent with the requirement that 60% of funds go to projects in rural

areas). The Senior-Level Review Team may also offer guidance on options for reduced awards (U.S. DOT, 2023b).

The FHWA Administrator will make final project selections from the list of applications advanced by the Senior-Level Review Team, with the goal of identifying the applications that best address the goals of the pilot program, the Administration's priorities, geographic diversity, and ensuring the effective use of federal funding (U.S. DOT, 2023b).

Program Relevance to Corridor Q Wildlife Crossings

The project appears well-positioned to achieve a ranking of Strong Alignment with the WCPP's two primary goals of (1) protecting motorists and wildlife by reducing wildlife-vehicle collisions, and (2) improving habitat connectivity. As summarized in Table D1, the project similarly appears at this time to have a Strong Alignment or Alignment with up to four of the six secondary merit criteria.

Table D1. Preliminary Analysis of Secondary Merit Criteria for WCPP

Project Outcomes	Rating Scale Assessment Considerations	Preliminary Project Rating based on Anticipated Benefits
Criterion 2.1: Leveraging Investments	• **Strong Alignment:** The application documents substantial dedicated non-federal contributions. • **Alignment:** The application documents dedicated non-federal contributions. • **No Alignment:** The application does not document or poorly documents the inclusion of dedicated non-federal contributions.	• **Projected Rating of Alignment or No Alignment:** The project is not currently able to document dedicated non-federal contributions. It is thus projected at this time to earn a rating of Alignment or No Alignment for this criterion.
Criterion 2.2: Economic Development and Visitation Opportunities	• **Strong Alignment:** The application describes how the project will improve visitation and improve the local economy. • **Alignment:** The application describes how the project will provide visitation opportunities and support the local economy. • **No Alignment:** The application does not demonstrate or poorly demonstrates inclusion of visitation opportunities and support for local economic development.	• **Projected Rating of Strong Alignment or Alignment:** The local community is striving to diversify its economy from one that has historically relied on coal mining, and revenues generated from elk viewing, elk hunting, and other associated elk-tourism activities are expected to substantially contribute to local economic and visitation opportunities.
Criterion 2.3: Innovation	• **Strong Alignment:** The application describes how the proposed project will employ at least one new technology or innovation that is expected to substantially enhance the project's efficiency and effectiveness in reducing WVCs or improving habitat connectivity. • **Alignment:** The application describes how the proposed project will employ at least one new technology or innovation that is expected to enhance the project's efficiency and effectiveness in reducing WVCs or improving habitat connectivity.	• **Projected Rating of Strong Alignment or Alignment:** The project may incorporate an experimental animal detection system and associated monitoring, which will improve detection, documentation, and mitigation of the risk to motorists of crashes involving wildlife while at the same time refining best practices with respect to use of this innovative technology.

	• **No Alignment:** The application does not demonstrate or poorly demonstrates incorporation and application of new or innovative technologies that are expected to enhance the proposed project's efficiency and effectiveness in reducing WVCs and improving habitat connectivity.	
Criterion 2.4: Education and Outreach	• **Strong Alignment:** The application describes how the proposed project will effectively and equitably engage and educate the public on WVCs, motorist safety, and habitat connectivity. • **Alignment:** The application describes the proposed project's plan to engage the public on WVCs, motorist safety, or habitat connectivity. • **No Alignment:** The application does not demonstrate or poorly demonstrates a plan for public engagement on WVCs, motorist safety, or habitat connectivity.	• **Projected Rating of Strong Alignment or Alignment:** A variety of public and private activities are expected to substantially contribute to enhanced education and outreach opportunities, including but not limited to (1) public and private elk-viewing tours, (2) a local elk-themed festival, which occurs annually in October, and (3) a VDWR–Breaks Interstate Park project to improve 5 acres of elk habitat and develop an elk-viewing shelter.
Criterion 2.5: Monitoring and Research	• **Strong Alignment:** The application demonstrates that the proposed project includes an effective plan to monitor, evaluate, and report on WVCs or habitat connectivity. • **Alignment:** The application demonstrates that the project includes data collection and monitoring efforts for WVCs or habitat connectivity. • **No Alignment:** The application does not demonstrate or poorly demonstrates data collection or monitoring efforts for WVCs or habitat connectivity.	• **Projected Rating of Strong Alignment or Alignment:** The project may incorporate an experimental animal detection system and associated monitoring, which will improve detection, documentation, and mitigation of the risk to motorists of crashes involving wildlife while at the same time refining best practices with respect to use of this innovative technology for what may be the first animal detection system deployed in the eastern United States.
Criterion 2.6: Survival of Species	• **Strong Alignment:** The application demonstrates that the proposed project is expected to significantly benefit one or more federally listed threatened or endangered species or species that are proposed or candidate for listing. • **Alignment:** The application demonstrates that the proposed project is expected to moderately benefit one or more federally listed threatened or endangered species or species that are proposed or candidate for listing. • **No Alignment:** The application does not demonstrate or poorly demonstrates a benefit to any threatened or endangered species or species that are proposed or candidate for listing.	• **Projected Rating of Alignment or No Alignment:** The project is not currently able to demonstrate that it will benefit any threatened and endangered, proposed or candidate species for listing. It is thus projected at this time to earn a rating of Alignment or No Alignment for this criterion.