OREGON DEER AND ELK CROSSING PRIORITIZATION PROJECT

Technical Report

SPR 836 – PHASE 2



Oregon Department of Transportation

OREGON DEER AND ELK CROSSING PRIORITIZATION PROJECT

Technical Report
PROJECT SPR836 Phase 2

by

Corrinne O. Dombrowski, Matthew J. Shinderman, Diane L. Popp
Human and Ecosystems Resilience and Sustainability Laboratory
Oregon State University, Cascades

for

Oregon Department of Transportation
Research Section
555 13th Street NE, Suite 1
Salem OR 97301

and

Federal Highway Administration
1200 New Jersey Avenue SE
Washington, DC 20590

November 2026

Technical Report Documentation Page

1. Report No. FHWA-OR-RD-27-09	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Oregon Deer and Elk Crossing Prioritization Project. Technical Report SPR836 Phase 2		5. Report Date November 2026 6. Performing Organization Code
7. Author(s) Corrinne O. Dombrowski, Matthew J. Shinderman (0000-0003-1522-1976); Diane L. Popp;		8. Performing Organization Report No.
9. Performing Organization Name and Address Oregon Department of Transportation Research Section 555 13th Street NE Salem, OR 97301		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Oregon Dept. of Transportation Research Section 555 13th Street NE, Suite 1 Salem, OR 97301 Federal Highway Admin. 1200 New Jersey Avenue SE Washington, DC 20590		13. Type of Report and Period Covered Technical Report 14. Sponsoring Agency Code
15. Supplementary Notes: Project Champion: Cidney Bowman; Project Manager: Kira Glover-Cutter		

16. Abstract: Deer- and elk–vehicle collisions (DEVCs) present a serious risk to human safety and ungulate populations in Oregon. With an estimated 6,000 DEVCs annually, costing Oregonians roughly $135 million per year, the need for strategic mitigation is urgent. To address this challenge, ODOT, in partnership with the Human and Ecosystem Resilience and Sustainability (HERS) Lab at OSU-Cascades, launched the Oregon Deer and Elk Crossing Prioritization Project (ODECPP). The project's goal was to develop a science-based, replicable framework and decision-support tools for identifying high-priority locations for ungulate passage infrastructure with a specific emphasis on human safety. This report outlines the development and use of a matrix-based decision-support tool to guide preliminary planning and site selection. Analyses and decision processes used in tool development followed a precautionary principal approach, wherein inclusion and interpretation of matrix factors utilized empirical information to the greatest extent possible and best-available information where scientific understanding of factors and relationships between factors is incomplete.

17. Key Words: Wildlife Vehicle Collision; Wildlife Crossing Structure; Wildlife Connectivity; Climate And Landscape Resilience; Matrix Based Indexing Method; Analytical Hierarchy Process; Decision Support Tool; Site Prioritization;	18. Distribution Statement Copies available from NTIS, and online at www.oregon.gov/ODOT/TD/TP_RES/		
19. Security Classification (of this report): Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages XXX	22. Price

SI* (Modern Metric) Conversion Factors
Approximate Conversions to SI Units

Physical Quantity	Symbol	When You Know	Multiply By	To Find	Symbol
Length	n	inches	25.4	millimeters	mm
Length	ft	feet	0.305	meters	m
Length	yd	yards	0.914	meters	m
Length	mi	miles	1.61	kilometers	km
Area	in2	square inches	645.2	square millimeters	mm2
Area	ft2	square feet	0.093	square meters	m2
Area	yd2	square yard	0.836	square meters	m2
Area	ac	acres	0.405	hectares	ha
Area	mi2	square miles	2.59	square kilometers	km2
Volume	fl oz	fluid ounces	29.57	milliliters	mL
Volume	gal	gallons	3.785	liters **	L
Volume	ft3	cubic feet	0.028	cubic meters	m3
Volume	yd3	cubic yards	0.765	cubic meters	m3
Mass	oz	ounces	28.35	grams	g
Mass	lb	pounds	0.454	kilograms	kg
Mass	T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
Temperature (exact degrees)	oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	oC
Illumination	fc	foot-candles	10.76	lux	lx
Illumination	fl	foot-Lamberts	3.426	candela/m2	cd/m2
Force and Pressure or Stress	lbf	poundforce	4.45	newtons	N
Force and Pressure or Stress	lbf/in2	poundforce per square inch	6.89	kilopascals	kPa

*SI is the symbol for the International System of Measurement
** Volumes greater than 1000 L shall be shown in m^3

SI* (Modern Metric) Conversion Factors
Approximate Conversions from SI Units

Physical Quantity	Symbol	When You Know	Multiply By	To Find	Symbol
Length	mm	millimeters	0.039	inches	in
Length	m	meters	3.28	feet	ft
Length	m	meters	1.09	yards	yd
Length	km	kilometers	0.621	miles	mi
Area	mm2	square millimeters	0.0016	square inches	in2
Area	m2	square meters	10.764	square feet	ft2
Area	m2	square meters	1.195	square yards	yd2
Area	ha	hectares	2.47	acres	ac
Area	km2	square kilometers	0.386	square miles	mi2
Volume	mL	milliliters	0.034	fluid ounces	fl oz
Volume	L	liters	0.264	gallons	gal
Volume	m3	cubic meters	35.314	cubic feet	ft3
Volume	m3	cubic meters	1.307	cubic yards	yd3
Mass	g	grams	0.035	ounces	oz
Mass	kg	kilograms	2.202	pounds	lb
Mass	Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
Temperature (exact degrees)	oC	Celsius	1.8C+32	Fahrenheit	oF
Illumination	lx	lux	0.0929	foot-candles	fc
Illumination	cd/m2	candela/m2	0.2919	foot-Lamberts	fl
Force and Pressure or Stress	N	newtons	0.225	poundforce	lbf
Force and Pressure or Stress	kPa	kilopascals	0.145	poundforce per square inch	lbf/in2

For More Information see: https://www.fhwa.dot.gov/publications/convtabl.cfm

EXECUTIVE SUMMARY

Deer- and elk–vehicle collisions (DEVCs) present a serious risk to human safety and ungulate populations in Oregon. With an estimated 6,000 DEVCs annually, costing Oregonians roughly $135 million per year, the need for strategic mitigation is urgent. To address this challenge, the Oregon Department of Transportation (ODOT), in partnership with the Human and Ecosystem Resilience and Sustainability (HERS) Lab at OSU-Cascades, launched the Oregon Deer and Elk Crossing Prioritization Project (ODECPP). The project's goal was to develop a science-based, replicable framework and decision-support tools for identifying high-priority locations for ungulate passage infrastructure with a specific emphasis on human safety. This report outlines the development and use of a matrix-based decision-support tool to guide preliminary planning and site selection. Analyses and decision processes used in tool development followed a precautionary principal approach, wherein inclusion and interpretation of matrix factors utilized empirical information to the greatest extent possible and best-available information where scientific understanding of factors and relationships between factors is incomplete. For example, scientific certainty associated with future climate or landscape resilience impacts on wildlife behavior is low, but we assume that locations predicted to exhibit greater landscape resilience to change will fare better under most predicted future conditions. The tool was applied to seven key highways across Oregon, producing prioritization maps that integrate human safety, ecological, and land-use data. These maps are intended to inform strategic investments in ungulate crossing structures and related mitigation efforts.

Methodology Development and Project Highlights:

- *Prioritization Framework*
  - Due to the complex and site-specific nature of environmental, safety, and roadway characteristics, the ODECPP employed a two-stage decision-support framework combining a matrix-based indexing method with the Analytic Hierarchy Process (AHP). This approach produced a structured, data-driven scoring matrix for site prioritization using 11 spatial and ecological parameters, including:
    - Deer- and elk-vehicle (DEVC) collision frequency
    - Road density and traffic volume
    - Proximity to urban growth boundaries
    - Climate and landscape resilience
    - Priority Wildlife Connectivity Areas
  - The indexing method enables integration of diverse, and sometimes conflicting, factors into a transparent and defensible prioritization framework. AHP was used to derive relative weights through pairwise comparisons, followed by normalization to ensure consistency. Widely recognized in transportation and environmental planning, AHP promotes transparency, consistency, and defensibility in multi-criteria decision-making
- *Identification of High-Priority Areas Summary:*
  - The ODECPP's spatial analysis used 0.10-milepost units as the measurement scale. Each milepost across the seven Oregon Highways of Analysis Interest (OHAI) was assigned a value for every matrix factor based on its geographic context (e.g., east or west of the Cascade Mountains). These values were aggregated to generate a composite score, with mileposts in the 99th percentile designated as priority locations.

        - 133 Top 1% Priority Mileposts (TPMs) were identified across the seven highways evaluated.
        - These TPMs were grouped into 81 Priority Highway Segments (PHSs) when located within 1 mile of each other to identify areas suitable for passage projects. Segments were then ranked based on the highest-scoring TPM and the number of TPMs within each segment.
        - Although factor inputs centered on ungulates, 76.5% of PHSs intersected at least one Priority Wildlife Connectivity Area (PWCA) hexagon, reinforcing the habitat connectivity value for a suite of Oregon's native species at these locations.
    - The TPMs and PHSs identified through the ODECPP analysis represent discrete locations appropriate for further evaluation by ODOT to determine suitability for ungulate passage projects.
- *Climate Resilience*:
    - Climate change resilience was identified as an essential factor for inclusion in the decision matrix by the Technical Advisory Committee (TAC). To capture this, the ODECPP incorporated two distinct climate-related spatial layers, Future Climate Resilience and Terrestrial Landscape Resilience, each measuring different aspects of predicted climate resilience at a given site.
        - 31.6% of the TPMs correlated with high Future Climate Resilience.
        - 12% of the TPMs were associated with high Terrestrial Landscape Resilience
    - These findings support considering the long-term viability of ungulate passage projects for these discrete areas, particularly under changing climate conditions. However, the lack of convergence of these factors is likely related to several factors, including the extraction scale, native resolution, and differences in variables included between the models. Future iterations of the ODECPP and similar projects should consider updated climate models, ground-truthing site vegetation conditions, and updated ungulate movement and population data
- *Regional Differences:*
    - Due to variation in statewide ungulate-related data availability, ODECPP applied two distinct AHP frameworks for highways based on their location relative to the Cascade Mountains.
        - Eastern Oregon highways had more robust data (e.g., mule deer winter range, mule deer movement data), allowing for more detailed prioritization for the ungulate species considered.
        - Western Oregon highways lacked equivalent data, leading to recommendations for refinement of the ODECPP model to better incorporate ungulate species native to Western Oregon.
    - Although regional differences in ungulate data influenced some aspects of the analysis, the primary driver of ODECPP priority scores was the DEVC factor, derived from a single ODOT spatial database. This ensured statewide consistency and grounded prioritization in observed collision data rather than predictions, helping direct safety investments to locations with the greatest demonstrated need for reducing ungulate-vehicle collisions.

Recommendations:

- *Site Vetting and Project Design*

    - Each TPM and PHS should undergo site-specific assessments to determine the most appropriate mitigation strategy (e.g., overpass, underpass, fencing, or Roadside Animal Detection Systems).
    - Consider topography, land ownership, and species behavior in final design.
- *Data Expansion and Model Refinement*
    - Prioritize the collection of spatial and population data for western Oregon ungulates, including GPS collaring and population surveys.
    - Develop localized deer- and elk-vehicle collision risk models to improve predictive accuracy.
- *Technology and Innovation*
    - Explore non-invasive genetic sampling to assess wildlife passage effectiveness.
    - Implement AI-powered monitoring systems to track wildlife use of crossing structures.
    - Use spatially explicit modeling tools to predict future collision hotspots.
- *Institutional Collaboration*
    - Integrating findings from the ODECPP alongside other research to inform advisory group decision-making under HB 2978.
    - Encourage municipal partnerships for addressing wildlife-vehicle collisions (WVCs) within urban growth boundaries.

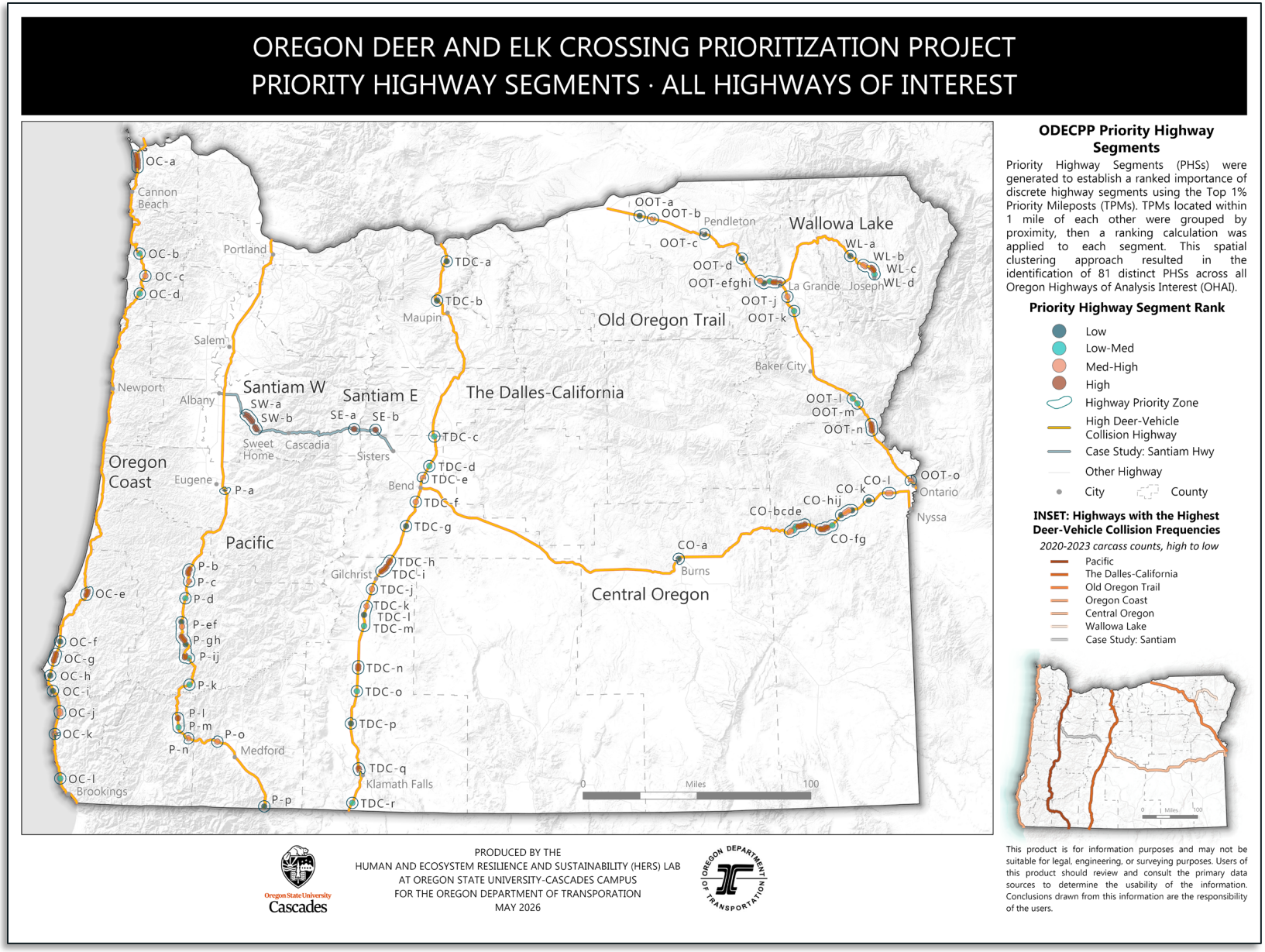
Limitations and Considerations

- *Ungulate Data Gaps:* Western Oregon lacks equivalent ungulate movement data relative to Eastern Oregon, limiting prioritization accuracy in that region.
- *Modeling Constraints:* The initial risk model developed for The Dalles-California Highway in early iterations of the ODECPP had low explanatory power ($R^2_L < 0.10$), leading to a shift toward descriptive statistics.
- *Dynamic Landscapes and Data Availability:* Currently, land use, climate, and wildlife behavior spatial data do not allow for unambiguous interpretation. For example, there is a fair amount of nuance associated with translation of their influence on DEVCs. Future datasets may be offered at a better resolution or scale to streamline and simplify decision-making.

Due to this, the ODECPP framework must be updated regularly as new data sources become available to enhance prioritization efficacy.

Conclusion

The ODECPP provides a robust and adaptable science-based foundation for prioritizing ungulate passage projects across Oregon. By integrating ecological, safety, and land-use data, the project supports ODOT's goals of enhancing public safety and preserving biodiversity. The decision-support tool and maps developed through this process offer a replicable indexing exercise for future planning and investment, positioning Oregon to advance statewide transportation safety through strategic consideration of deer and elk movement patterns and their intersection with highway corridors.



OHAI Priority Highway Segments (PHS). Segments were generated from spatially clustered Top 1% Priority Mileposts (TPMs) and ranked on a per-highway basis, using the ratio of the total number of TPMs in each discrete highway segment to the highest-value TPM within that segment. This process resulted in 81 PHSs across the seven highways analyzed. The Santiam Highway is included in gray to represent its role as a case study in the ODECPP; subsequent maps will display the highway without this distinction.

ACKNOWLEDGEMENTS

The collaborative efforts of the Oregon Deer and Elk Crossing Prioritization Project (ODECPP) were made financially possible by the Oregon Department of Transportation (ODOT).

We are deeply grateful to all who contributed to this project. Special thanks to Kira Glover-Cutter and Cidney Bowman (ODOT) for their invaluable counsel, technical guidance, and resource support throughout the multi-year development of this work. We also thank Jiguang Zhao (ODOT) for their comprehensive review and recommendations for factor analysis improvement and Jennifer Lanzarotta and the ODOT GIS Unit for providing access to their geospatial database.

Don Whittaker (ODFW) and Valerie Hinojoza-Rood (OSU/ODFW/USGS) generously facilitated the incorporation of novel ungulate geospatial data for eastern Oregon and provided oversight for its use. We are also grateful to Rachel Wheat (ODFW) for graciously providing access to statewide ungulate prioritization data.

Pat Basting and Teresa Smithson (Jacobs Environmental) offered thoughtful guidance on the development of the deer- and elk-vehicle collision risk model. Benjamin Padilla and Jessica Wilkes (ODFW) contributed their expertise in considering western Oregon ungulate species within the prioritization model.

We are especially appreciative of our colleagues at the Oregon Department of Transportation and the Technical Advisory Committee for their diverse perspectives and generous counsel throughout the iterative development of the ODECPP.

Finally, sincere gratitude is extended to the reviewers who provided detailed feedback throughout the development of this report. Their contributions undoubtedly enhanced the precision of the final product.

DISCLAIMER

This document is disseminated under the sponsorship of the Oregon Department of Transportation and the United States Department of Transportation in the interest of information exchange. The State of Oregon and the United States Government assume no liability of its contents or use thereof.

The contents of this report reflect the view of the authors who are solely responsible for the facts and accuracy of the material presented. The contents do not necessarily reflect the official views of the Oregon Department of Transportation or the United States Department of Transportation.

The State of Oregon and the United States Government do not endorse products of manufacturers. Trademarks or manufacturers' names appear herein only because they are considered essential to the object of this document.

This report does not constitute a standard, specification, or regulation.

COMMONLY USED ACRONYMS

AADT	ANNUAL AVERAGE DAILY TRAFFIC
AHP	ANALYTIC HIERARCHY PROCESS
BACI	BEFORE-AFTER-CONTROL-IMPACT
CWHP	CATEGORICAL WILDFIRE HAZARD POTENTIAL
DVC	DEER-VEHICLE COLLISION
DEVC	DEER- AND ELK-VEHICLE COLLISION
FCR	FUTURE CLIMATE RESILIENCE
GPS	GLOBAL POSITIONING SYSTEM
HERS LAB	HUMAN AND ECOSYSTEM RESILIENCE AND SUSTAINABILITY LAB
HPZ	HIGHWAY PRIORITY ZONE
HWY	HIGHWAY
MAP	MULTI-ATTRIBUTE POLYGON
MDWR	MULE DEER WINTER RANGE
OCAMP	OREGON CONNECTIVITY ASSESSMENT AND MAPPING PROJECT
ODFW	OREGON DEPARTMENT OF FISH AND WILDLIFE
ODOT	OREGON DEPARTMENT OF TRANSPORTATION
OHAI	ODOT HIGHWAY(S) OF ANALYSIS INTEREST
OSU-C	OREGON STATE UNIVERSITY-CASCADES
ODECPP	OREGON DEER AND ELK CROSSING PRIORITIZATION PROJECT
PHS	PRIORITY HIGHWAY SEGMENT
PWCA	PRIORITY WILDLIFE CONNECTIVITY AREA
RAD	ROADSIDE ANIMAL DETECTION
RD	ROAD DENSITY
TAC	TECHNICAL ADVISORY COMMITTEE
TLR	TERRESTRIAL LAND RESILIENCE
TPM	TOP 1% PRIORITY MILEPOST
UGB	URBAN GROWTH BOUNDARY
WCS	WILDLIFE CROSSING STRUCTURE

Table of Contents

1.0 INTRODUCTION 1

2.0 BACKGROUND 5

3.0 METHODOLOGY 6

3.1 Matrix Factor Selection Process 7
3.2 Factor Value Extraction 8
3.3 Analytic Hierarchy Process (AHP) 10
3.4 Descriptive Statistics 11
3.5 Exclusion of 0.10 Mileposts within Urban Growth Boundaries 11
3.6 Priority Highway Segment Determination 12
3.7 Highway Priority Zone Determination 12
3.8 Sensitivity Analysis 13

4.0 ANALYSIS AND DISCUSSION 14

4.1 Top 1% Priority Mileposts 14
Scope and counts 14
Top 1% Priority Milepost Aggregation and Priority Highway Segment Ranking 14
Geographic Distribution 14
4.2 Priority Highway Segments 14
4.3 Top 1% Priority Mileposts and Matrix Factors 18
4.3.1 Future Climate Resilience 18
4.3.2 Terrestrial Land Resilience 18
4.3.3 Urban Growth Boundaries (UGB) 18
4.3.4 Road Density 18
4.3.5 Distance from Mule Deer Winter Range 18
4.3.6 Annual Average Daily Traffic 18
4.3.7 Deer- and Elk-Vehicle Collisions (DEVCs) 19
4.3.8 Priority Wildlife Connectivity Areas (PWCAs) 19
4.3.9 Multi-Attribute Polygons (MAPs) 19
4.3.10 Existing Wildlife Crossing Structure Projects 19
4.4 Sensitivity Analysis 21
4.5 Discussion 23

5.0 RECOMMENDATIONS AND FUTURE WORK 28

5.1 Recommendations 28
5.1.1 Priority Feature Interpretation & Ungulate Passage Projects 28
5.1.2 Ungulate Spatial Data Solicitation and Procurement 28
5.1.3 Large Mammal Wildlife-Vehicle Collision Spatial Data 29
5.1.4 Advancing Wildlife-Traffic Conflict Mitigation Technologies 29
5.1.5 Statewide Deer- and Elk-Vehicle Collision Risk Modeling 30
5.1.6 Long-Term Wildlife Passage Project Monitoring 31
5.1.7 Statewide Wildlife Passage Project Advisory Group 31
5.2 Future Work 32
5.2.1 Non-Invasive Genetic Sampling 32

5.2.2 Priority Highway Segment Validation 33
5.2.3 Complete Highway System Prioritization 33
5.2.4 Spatially Explicit Deer- and Elk-Vehicle Collision Risk Model 33

6.0 CONCLUSION 34

6.1 PRIORITY LOCATIONS AND CONNECTIVITY POTENTIAL 34
6.2 CLIMATE RESILIENCE 35
6.3 TECHNOLOGICAL ADVANCEMENTS 35
6.4 DECISION-MAKING PROCESS 36
6.5 LEVERAGING SPATIAL TECHNOLOGIES 36
6.6 DECISION-SUPPORT TOOL AND MAPS 37
6.7 RECOMMENDATIONS 37

7.0 REFERENCES 40

DIGITAL APPENDICES: XLIV

APPENDIX A. *OREGON DEER AND ELK CROSSING PRIORITIZATION PROJECT (ODECPP) MAP PRODUCTS* XLIV

APPENDIX B. *OREGON DEER AND ELK PRIORITIZATION PROJECT (ODECPP) TECHNICAL ADVISORY COMMITTEE (TAC) MEMBERS AND AFFILIATION* XLIV

APPENDIX C. *DETAILED MATRIX FACTOR DESCRIPTIONS* XLIV

APPENDIX D. *ANALYTIC HIERARCHY PROCESS* XLIV

APPENDIX E. *OREGON DEER AND ELK CROSSING PRIORITIZATION PROJECT (ODECPP) ODOT HIGHWAYS OF ANALYSIS INTEREST (OHAI) PRIORITY WILDLIFE CONNECTIVITY AREA (PWCA) HEXAGON ANALYSIS* XLIV

APPENDIX F. *OREGON DEER AND ELK CROSSING PRIORITIZATION PROJECT (ODECPP) AND OREGON CONNECTIVITY ASSESSMENT AND MAPPING PROJECT (OCAMP) DATA COMPARISON* XLIV

APPENDIX G. *TOP 1% PRIORITY MILEPOST (TPM) SCORES* XLIV

APPENDIX H. *FREQUENTLY ASKED QUESTIONS (FAQ)* XLIV

APPENDIX I. *ANNOTATED BIBLIOGRAPHY* XLIV

APPENDIX J. *REGIONAL ANALYSIS OF PRIORITY HIGHWAY SEGMENTS (PHSS)* XLIV

APPENDIX K. *OREGON DEER AND ELK CROSSING PRIORITIZATION PROJECT (ODECPP) FECAL DNA ANALYSIS* XLIV

LIST OF TABLES

Table 3-1: The seven ODOT Highways of Analysis Interest (OHAI). These highways were selected for inclusion in the Oregon Deer and Elk Crossing Prioritization Project (ODECPP) due to their increased deer- and elk-vehicle (DEVC) frequency relative to all highways statewide and/or their identification as candidates for wildlife crossing prioritization projects (e.g., Santiam Highway). 6
Table 3-2: Oregon Deer and Elk Crossing Prioritization Project (ODECPP) Matrix factors derived from raster values. Raster values were analyzed in ArcGIS Pro 3.4 to produce a factor value for Top 1% Priority Milepost (TPM) and Priority Highway Segment (PHS) determination. 9
Table 3-3: The Fundamental Analytic Hierarchy Process (AHP) Scale as defined by Saaty (1987). Used to assign importance weights to each factor in the Oregon Deer and Elk Crossing Priority Project (ODECPP) matrix. These weights were equated using a reciprocal pairwise comparison matrix. 11
Table 4-1: Priority Highway Segments (PHSs) on the seven ODOT Highways of Interest (OHAI) analyzed for the Oregon Deer and Elk Crossing Prioritization Project (ODECPP). Priority Highway Segments (PHSs) were identified by selecting the Top 1% Priority Mileposts (TPMs). TPMs located within a 1-mile radius were grouped into clusters, forming the foundation for generating PHSs. Priority scores for PHSs were calculated by dividing the number of 0.10-mileposts in a segment by the total number of TPMs on a given highway, then multiplying by the highest priority milepost in a distinct segment. This generated a composite score, identifying the highest value priority highway segment per OHAI (Figure 4-1). 15
Table 4-3. Percent (%) total of Top 1% Priority Mileposts (TPMs) per factor excluded during sensitivity analysis that remained in original order of distribution despite the factor not contributing to the total score. *Top: Highways East of the Cascades. Bottom: Highways West of the Cascades.* 22
Table 4-4. Percent (%) total Top 1% Priority Mileposts (TPMs) that remained within the top 1% of values upon factor exclusion during sensitivity analysis. *Top: Highways East of the Cascades. Bottom: Highways West of the Cascades.* 22
Table 4-5. Oregon Deer and Elk Crossing Prioritization Project (ODECPP) Matrix Factor Categories and Data Sources. Categories and associated factors evaluated for ungulate passage project placement on the seven ODOT Highways of Analysis Interest (OHAI) (*see*, Appendix C). 24

LIST OF FIGURES

Figure 1-1: Deer-Vehicle Collision (DVC) Frequency on Selected Oregon Highways. The six highways in Oregon with the highest frequency of deer–vehicle collisions (DVCs) from 2020 to 2023, based on carcass counts from the Oregon Department of Transportation Animal–Vehicle Collision Geodatabase. These highways were selected for analysis in the Oregon Deer and Elk Crossing Prioritization Program due to their relatively high DVC frequency compared to other highways statewide. Santiam Highway is included beyond the dashed line to represent its role as a case study in the ODECPP. 2

Figure 1-2: Priority Wildlife Connectivity Areas (PWCAs) surrounding Lava Butte, a prominent feature of Newberry National Volcanic Monument managed by The Deschutes National Forest (U.S. Forest Service) in central Oregon. The figure highlights four primary conservation action recommendations associated with PWCAs: Enhance/Maintain, Protect, Restore, and Transportation Mitigation. 3

Figure 4-1. ODOT Highways of Analysis Interest (OHAI) Priority Highway Segments (PHSs). Segments were generated from spatially clustered Top 1% Priority Mileposts (TPMs) and ranked on a per-highway basis, using the ratio of the total number of TPMs in each segment to the highest-value TPM within that segment. This process resulted in 81 PHSs across the seven highways analyzed. 16

Figure 4-2: Highest-value Priority Highway Segment (PHS) per ODOT Highway of Analysis Interest (OHAI). Each top-value PHS was identified using a prioritization calculation to isolate the segment with the highest relative score on each highway. 17

Figure 4-3. Priority Highway Attribute count per Oregon Highway of Analysis Interest (OHAI) analyzed for the Oregon Deer and Elk Crossing Prioritization Project (ODECPP). Priority Highway Attributes include the Top 1% Priority Mileposts (TPMs), Priority Highway Segments (PHSs), and Highway Priority Zones (HPZs). Highway Priority Zones (HPZs) were established by grouping 0.10-mileposts within a 5-mile proximity. PHSs nested within HPZs were identified by selecting the Top 1% Priority Mileposts (TPMs). TPMs located within a 1-mile radius were grouped into clusters, forming the foundation for generating PHSs. 20

Figure 4-4. Distribution of Top 1% Priority Mileposts (TPMs) across all ODOT Highways of Analysis Interest (OHAI) that remained within the top 1% of values when the Deer- and Elk-Vehicle Collision (DEVC) factor was excluded from contributing to final values for the sensitivity analysis. All OHAI except for Pacific (HWY001) and Wallowa Lake (HWY010) had at least one TPM remain within the Top 1% of values despite DEVC removal from analysis. Top 1% Priority Mileposts have been buffered and merged for visualization. 21

1.0 INTRODUCTION

Interest in the establishment of large mammal wildlife crossing structures (WCS) has increased in the U.S. When implemented with mitigation infrastructure, such as exclusion fencing, these crossings are highly effective at reducing wildlife-vehicle collisions (WVCs), specifically those resulting in vehicle crashes with large-bodied animals like ungulates (e.g., deer and elk), thereby ensuring both human safety and wildlife survival (Huijser et al., 2016). In Oregon, approximately 3% of the total annual statewide crashes involve wildlife, primarily deer and elk species Cramer et al., 2022; HERS Lab, 2024). These crashes cost Oregonians upwards of $135 million annually (Cramer et al., 2022). However, the total number of annual deer- and elk-vehicle collisions (~6,000) is approximately 3.5 times higher than those reported as crashes (Cramer et al., 2022; HERS Lab, 2024).

In recognition of this issue, the Oregon Department of Transportation (ODOT) established seven large mammal wildlife crossing structures on state-managed highways beginning in 2012, with the most recent structure established in 2022. These structures, with all but two located on U.S. South Highway 97 in central Oregon, have provided safe passage for many species crossing the highway, including deer and elk, which pose the greatest risk to human safety statewide (Bliss-Ketchum L., Parker C., 2015; Thompson et al,. 2018). However, additional state highways would benefit from large-mammal crossing infrastructure as evidenced by the total number DEVCs reported statewide (Cramer et al., 2022; ODFW, 2024) (Figure 1-1).

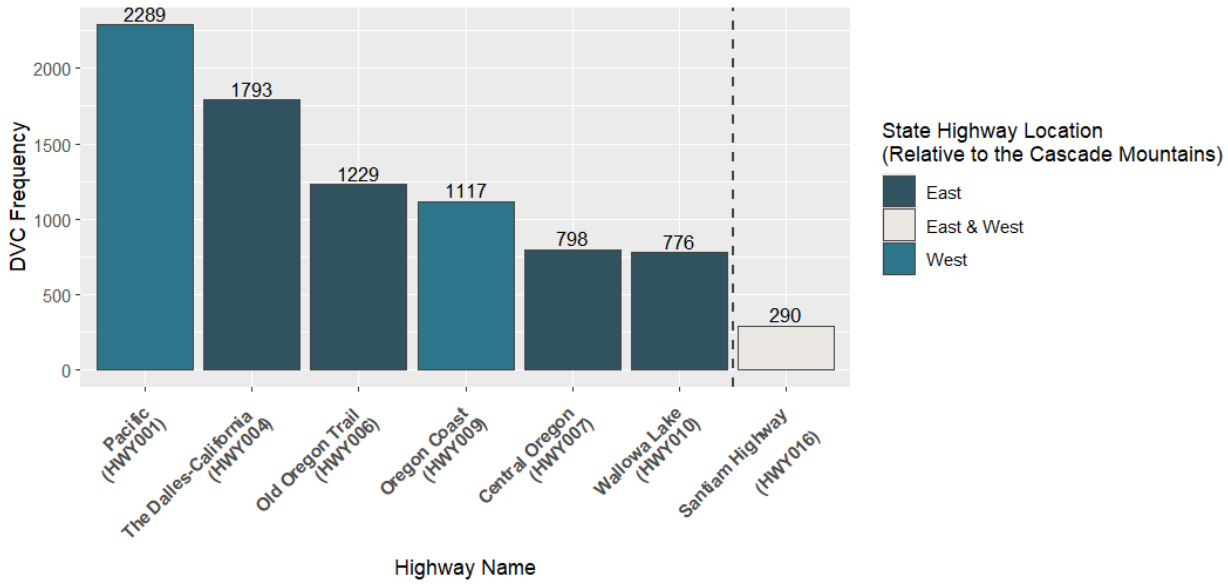


Figure 1.1: Deer-Vehicle Collision (DVC) Frequency on Selected Oregon Highways. The six highways in Oregon with the highest frequency of deer–vehicle collisions (DVCs) from 2020 to 2023, based on carcass counts from the Oregon Department of Transportation Animal–Vehicle Collision Geodatabase. These highways were selected for analysis in the Oregon Deer and Elk Crossing Prioritization Program due to their relatively high DVC frequency compared to other highways statewide. Santiam Highway is included beyond the dashed line to represent its role as a case study in the ODECPP.

Over the past two and a half decades, federal and state legislative momentum to enhance and protect wildlife habitat connectivity throughout the western U.S. has facilitated transdisciplinary efforts to establish corridors and crossings employing the best available science (US DOI, 2018; Stio E., Christian L., 2024). In Oregon, House Bill 2834 (80th Leg. Assemb. 2019) introduced Or. Rev. Stat § 496.272, establishing the Wildlife Corridor Action Plan (ORS, 2019). One of the outcomes of Or. Rev. Stat. § 496.272 was the completion of the Oregon Connectivity Assessment and Mapping Project (OCAMP), a collaborative effort aimed at identifying priority habitats and connectivity for a diversity of species native to the state. The resultant product from this work was the development of a collection of spatial products highlighting the combined top 1% of priority habitats of 54 surrogate species for facilitating wildlife movement, designated as Oregon's Priority Wildlife Connectivity Areas (PWCAs) (Stio E., Christian, L., 2024; ODFW, 2023a) (Figure 1-2).



Figure 1.2: Priority Wildlife Connectivity Areas (PWCAs) surrounding Lava Butte, a prominent feature of Newberry National Volcanic Monument managed by The Deschutes National Forest (U.S. Forest Service) in central Oregon. The figure highlights four primary conservation action recommendations associated with PWCAs: Enhance/Maintain, Protect, Restore, and Transportation Mitigation.

The PWCAs, symbolized as a network of 40-acre hexagons, contain important information for state planners, state and federal resource managers, and non-governmental organizations concerning primary and secondary conservation action recommendations, including transportation mitigation (ODFW, 2023a). In total, there are > 400,000 PWCA hexagons, approximately 700 of which include transportation mitigation as the primary conservation action recommendation (HERS, 2023). PWCA hexagons attributed with a conservation action recommendation of transportation mitigation are areas of the network that are particularly susceptible to fragmentation from roadways, as determined both by the value of the surrounding habitat for facilitating movement as well as known areas of high densities of vehicle collisions with large-bodied wildlife (ODFW, 2023b; ORS, 2019). Ungulate-specific (e.g., deer, elk, pronghorn, and bighorn sheep) connectivity data layers delivered to ODOT by the Oregon Department of Fish and Wildlife (ODFW) indicate areas within the PWCA network where highway-based improvements for ungulate species may be beneficial (ODFW, 2023b).

Or. Rev. Stat. § 496.272 established cooperation between ODOT and ODFW to limit WVCs and enhance public safety in the corridors identified through the OCAMP process (ORS, 2019). While the PWCAs provide a critical assessment of areas suitable for transportation-related mitigation based on wildlife-related factors, they are not ranked by the magnitude of need. Given the number of PWCA hexagons identified for ungulate-specific and surrogate species through

OCAMP, and the absence of a ranking framework among the primary conservation recommendations within those hexagons, ODOT initiated the Oregon Deer and Elk Crossing Prioritization Project (ODECPP). This research effort, conducted in partnership with the Human and Ecosystem Resilience and Sustainability (HERS) Lab at Oregon State University – Cascades (OSU-C) was undertaken to identify PWCA hexagon locations that intersect with highways experiencing elevated DEVCs relative to the statewide highway network, as well as other highway segments that may warrant interventions to reduce vehicle-ungulate conflict in alignment with ODOT's safety and ecological priorities.

More specifically, the ODECPP was established to develop a defensible and replicable indexing approach to enhancing traffic safety decision-making with the objective of minimizing conflict with deer and elk, using the best available science. By applying authoritative spatial layers and other relevant data, the ODECPP aims to create a decision support tool and prioritization maps that identify potential ungulate passage areas based on a suite of weighted environmental and biological factors and the summation of their scores. These resources are designed for Oregon's transportation and natural resource managers, as well as other stakeholders, to pinpoint areas best suited for ungulate crossing projects, both now and in the context of Oregon's evolving ecological and economic landscape.

In this report, we discuss the development of an indexing-based decision-support tool and prioritization maps focused on seven of Oregon's highways. This product serves as a foundation for a statewide process to identify high-priority areas for ungulate crossing infrastructure in Oregon. The products presented aim to enhance highway safety for the traveling public and connectivity for ungulates, specifically, deer (*Odocoileus spp.*) and elk (*Cervus spp.*), due to their economic importance and potential for vehicle collisions (Romin, L.A., Bissonett, J.A., 1996). Additionally, wildlife crossing infrastructure developed for ungulates may provide connectivity benefits for many of Oregon's other native wildlife species.

2.0 BACKGROUND

While wildlife crossing structures are not a new tool for mitigating wildlife-human conflict, the methods for determining their placement have evolved significantly since their establishment. Initially, decisions for mitigating wildlife traffic conflicts, including WCS placement, were primarily based on transportation improvement project planning that coincided with increased wildlife-vehicle collision frequency (Kintsch et al., 2019; Donaldson, 2017; Shilling F.M., Waetien D.P., 2015). This methodology is still applied broadly across the U.S. However, states like Colorado, Washington, and others have now adopted connectivity model-based approaches that incorporate an additional prioritization structure, considering various factors to identify optimal locations for wildlife crossings (Kintsch et al., 2019, 2022; WSDOT, 2023). This stepwise, multi-factor approach allows for the incorporation of local and regional data, which may not be suitable for the connectivity modeling phase, thereby enhancing the granularity and focus on potential priority areas.

The PWCAs generated by OCAMP under Or. Rev. Stat. § 496.272 (ORS, 2019) position ODECPP to leverage contemporary connectivity models, supplemented with research-based strategies similar to those adopted by the previously mentioned states. This approach supports the integration of supplementary factors that influence ungulate movement patterns and behavior, with a primary emphasis on human safety. By applying this methodology, the ODECPP can also evaluate the suitability of potential passage project locations based on projected safety benefits and the durability of investment in the context of climate change impacts on deer and elk movement and their implications for the highway segments analyzed.

3.0 METHODOLOGY

The tools and methods described were applied to seven Oregon highways located on both the east and west side of the state, referred to as the ODOT Highways of Analysis Interest (OHAI) (Table 3-1). Highways were selected for inclusion in the ODECPP based on elevated DEVC frequency, with the exception of the Santiam Highway, which was included as a case study based on local interest as a candidate for future wildlife crossing prioritization efforts. As such, the methods are designed to be adaptable for a region-specific analysis. Importantly, regionally specific spatial layers should be used to enhance the ODECPP analysis and substantiate priority locations along Oregon Highways of Analysis Interest. These factors should be updated regularly using the best available data to support accurate and effective decision-making.

Table 3.1: The seven ODOT Highways of Analysis Interest (OHAI). These highways were selected for inclusion in the Oregon Deer and Elk Crossing Prioritization Project (ODECPP) due to their increased deer- and elk-vehicle (DEVC) frequency relative to all highways statewide and/or their identification as candidates for wildlife crossing prioritization projects (e.g., Santiam Highway).

Highway Name	Highway Number	Geographic Orientation
Pacific	001	West
The Dalles-California	004	East
Central Oregon	006	East
Old Oregon Trail	007	East
Oregon Coast	009	West
Wallowa Lake	010	East
Santiam	016	East & West

3.1 MATRIX FACTOR SELECTION PROCESS

The matrix factor selection process was grounded in a review of primary source literature (see Appendix I). This review encompassed various topics, including wildlife crossing structure effectiveness and siting, land-use change, climate change, prediction and validation of wildlife corridors, ungulate movement, and disturbance. After summarizing these topics and identifying key themes, authoritative spatial layers, considered to be accurate, verified, and regularly updated, were assembled and transformed for analysis (Elsevier, n.d.).

Initial factor weights, derived from the selected spatial layers, were evaluated based on the immediacy and magnitude of each factor and then presented to a Technical Advisory Committee (TAC). Final factors and weights were established following a multi-week open comment period during which TAC members provided responses and final recommendations.

Following the multi-week open comment period and the incorporation of feedback from the TAC, the final factors and their respective weights were determined. These factors represent agreed upon elements influencing ungulate crossing projects for a majority of Oregon's highways and are essential for guiding the decision-making process. The final factors are as follows with detailed descriptions in Appendix C:[1]

- Future Climate Resilience (FCR)
- Terrestrial Landscape Resilience (TLR)
- Distance from Urban Growth Boundary (UGB)
- Road Density (RD)
- Categorical Wildfire Hazard Potential (CWHP)
- Distance from Mule Deer Winter Range* (MDWR)
- Annual Average Daily Traffic (AADT)
- Deer- and Elk-Vehicle Collision Count (DEVC)
- OCAMP Priority Wildlife Connectivity Area Hexagons – All Species & Conservation Recommendation Categories (PWCA)
- Multi-Attribute Polygons* (MAP)
- Existing Wildlife Crossing Structure Project (WCS)

**Spatial layer availability varies across the state. As a result, these factors and their corresponding scores differ between the east and west of the Cascade Mountains. See Appendix C for detailed descriptions and final values of each factor.*

[1] Complete factor descriptions and their corresponding justifications and weights are available in Appendix C.

3.2 FACTOR VALUE EXTRACTION

ArcGIS Pro 3.4 (ESRI, 2024, hereafter, ArcGIS Pro) was utilized to extract values from authoritative spatial layers at each 0.10-milepost on the ODOT Highways of Analysis Interest (OHAI). Careful attention was given to spatial properties, with analyses conducted within each raster's original coordinate system. Raster layer categories were transformed and reclassified based on the type of analysis selected to assign factor values (Table 3-2). Results were subsequently converted to ODOT's NAD 1983 Oregon Statewide Lambert (Intl Feet) coordinate system (WKID 2992).

To support spatial analysis, a variety of geoprocessing tools were employed to assign values to individual factors according to their granularity. To reflect the average daily movement of mule deer, the species most frequently involved in wildlife-vehicle collisions statewide, factor values were extracted from 1.5 km (0.93 mi) circular buffers centered on the 0.10 mileposts (Madelon, 2021). Although mule deer movement varies by herd and seasons, this buffer size also constrained data extraction to areas in close proximity to the highway, where transportation agencies may be better positioned to implement wildlife passage infrastructure.

The 1.5 km (0.93-mi) buffer was applied to the following raster data:

- Terrestrial Landscape Resilience
- Road Density
- Categorical Wildfire Hazard Potential

Future Climate Resilience was extracted from mileposts due to the layer's 10 km x 10 km spatial resolution (Table 3-2).

Table 3.2: Oregon Deer and Elk Crossing Prioritization Project (ODECPP) Matrix factors derived from raster values. Raster values were analyzed in ArcGIS Pro 3.4 to produce a factor value for Top 1% Priority Milepost (TPM) and Priority Highway Segment (PHS) determination.

Factor Name	Raster Layer	Native Resolution	Geoprocessing Tools	Value Extraction	Factor Value Range
Future Climate Resilience	Historical and 21st century soil temperature and moisture data for drylands of the western U.S. and Canada	10 km	Spatial Join	Resilience value associated with a given milepost	Low [-1] Moderate [0] High [1]
Terrestrial Landscape Resilience	Resilient Sites (Terrestrial and Coastal)	30 m	Reclassify & Zonal Statistics	Percent resilient sites within 1.5 km (0.93 mi) buffer	<50% Resilient [0] >50% Resilient [1]
Road Density	Urban Imperviousness	30 m	Reclassify & Zonal Statistics	Percent all road density within 1.5 km (0.93 mi) buffer	<25% Road Density [1] >25% Road Density [0]
Categorical Wildfire Hazard Potential	Wildfire Hazard Potential, Version 2023 Classified	270 m	Reclassify & Zonal Statistics	Categorical wildfire hazard potential within 1.5 km (0.93 mi) buffer	Very Low – Moderate [1] High – Very High [0]

As with rasters, various GIS tools and methods were employed to determine factor values from point and polygon spatial layers, depending on the metric required to evaluate priority at a specific milepost. Multi-Attribute Polygon (MAP) factor values were generated based on the intersection of multiple characteristics at a given milepost (see Appendix C).

3.3 ANALYTIC HIERARCHY PROCESS (AHP)

The Analytic Hierarchy Process (AHP) is a structured decision-making methodology that facilitates the evaluation of subjective and potentially conflicting criteria (Saaty, 1987). In this context, many of the factors included in the decision matrix are measured on discrete scales, with categorical scores assigned based on their presumed influence on DEVCs and deer and elk movement along highway corridors. Due to the inherent subjectivity in assigning categorical weights, AHP was employed to systematically compare the relative importance of each factor, enabling a transparent and replicable prioritization process.

To normalize matrix factor values, importance weights were assigned using the standard AHP scale of 1 to 9 (Table 3-3) (Saaty, 1987). Criteria were established from the final matrix factors and assessed in relation to each other based on importance on a fundamental scale from one to nine, with one representing equal importance and nine indicating utmost importance (Saaty, 1987). This process established importance values for each factor juxtaposed to another matrix factor in a reciprocal pairwise comparison matrix. After calculating the pairwise comparisons, a geometric mean was applied to each criterion to normalize the values and establish the importance weights for each distinct factor. A consistency check was performed on the pairwise comparison matrix to ensure the comparisons were logically consistent. The consistency ratios for both matrices were found to be <0.10, indicating that the pairwise comparisons were consistent. Final factor scores were derived from the product of the criteria being examined at a given 0.10-milepost and its importance weight. Final values for distinct 0.10-mileposts were derived from the summation of all factor values for that location.

Table 3.3: The Fundamental Analytic Hierarchy Process (AHP) Scale as defined by Saaty (1987). Used to assign importance weights to each factor in the Oregon Deer and Elk Crossing Priority Project (ODECPP) matrix. These weights were equated using a reciprocal pairwise comparison matrix.

Importance Weight Intensity	Explanation
1	Equal importance of compared factors.
2	Intermediate compromise value between 1 & 3.
3	Moderate importance relative to compared factor.
4	Intermediate compromise value between 3 & 5.
5	Strong importance relative to compared factor.
6	Intermediate compromise value between 5 & 7.
7	Very strong importance relative to compared factor.
8	Intermediate compromise value between 7 & 9.
9	Extreme importance relative to compared factor.

3.4 DESCRIPTIVE STATISTICS

To support pattern identification between associated factors and priority locations, descriptive statistics were used to evaluate the relationships between the Top 1% Priority Mileposts (TPMs) and their corresponding factor value. Specifically, we used measures of central tendency, relative frequency, and proportions to describe the contribution of each matrix factor's value and importance weight to the aggregated TPM score in the results. Attribute tables containing the matrix factor value category, importance weight, and aggregate score for each TPM were extracted from ArcGIS Pro, cleaned in RStudio (R Core Team, 2024) using the tidyverse package suite (Wickham et al., 2019), and organized into pivot tables in Microsoft Excel (v. 2410). Measures of central tendency and proportions were used in the sensitivity analysis to verify the contribution of matrix factors to the distribution of TPMs within the top 1% of values for each ODOT Highway of Analysis Interest (OHAI). Additionally, we developed Annual Average Daily Traffic and Road Density categories (numerical ranges) using the distribution of deer- and elk-vehicle collision counts. A complete explanation of how descriptive statistics guided the development of these factors is provided in Appendix C. R code and Excel files utilized in this analysis are available upon request from corrinne.dombrowski@osucascades.edu.

3.5 EXCLUSION OF 0.10 MILEPOSTS WITHIN URBAN GROWTH BOUNDARIES

To prioritize potential ungulate crossing structure locations further from areas subject to elevated human disturbance, 0.10-mileposts located within Urban Growth Boundaries (UGBs) were

removed from the OHAI spatial datasets for analysis in the ODECPP. This allowed the analysis to focus on areas more likely to receive attention from state agencies and traditional funding sources due to their traveler safety and habitat connectivity value.

However, we recognize that high-traffic volume highways within UGBs may play an important role in facilitating human-wildlife conflict. Therefore, points within UGBs also received priority scores based on the sum of importance weights established in the Analytic Hierarchy Process.

These points are made available to ODOT to provide to municipal governments intending to work with the agency to establish an ungulate passage program within community boundaries. Municipalities wanting to work with state agencies (ODOT and ODFW) to reduce deer- and elk-vehicle interactions on highways within UGBs can review the prioritized 0.10-mileposts as focal areas for ungulate passage to enhance connectivity for commuters and urban wildlife while reducing deer- and elk-vehicle collision risk on highways within incorporated communities.

3.6 PRIORITY HIGHWAY SEGMENT DETERMINATION

The Top 1% Priority Mileposts (TPMs), derived from the ODECPP analysis, correspond to discrete 0.10-mile intervals exhibiting the highest aggregated factor scores. A substantial number of these TPMs occur in close proximity, often within a one-mile span, allowing for their aggregation into contiguous, high-priority highway segments, referred to as Priority Highway Segments (PHS).

Priority Highway Segments were identified by extracting and summing normalized factor values to generate a final prioritization score for each 0.10-milepost on a given highway. Mileposts within the top 1% of final score values (Top 1% Priority Mileposts) were identified using conditional formatting in Excel and selected for PHS development. Mileposts located within 1-mi of each other were identified using the *Group by Proximity* tool in ArcGIS Pro (ESRI, 2024) and organized into distinct clusters.

These clusters were converted to continuous linear features using the *Point to Line* tool in ArcGIS Pro (ESRI, 2024), facilitating segment-level analysis. Each segment was further ranked and categorized by dividing the number of mileposts allocated to each cluster by the total number of TPMs for a given highway. This result was then multiplied by the highest ranked milepost within the segment. This methodology allowed segments to receive a weighted relative importance. Quartiles from the output weights were identified for each segment and categorized as “Low Priority” to “High Priority.”

3.7 HIGHWAY PRIORITY ZONE DETERMINATION

Due to the statewide scale of the selected highways, Highway Priority Zones (HPZs) were established to enhance the visual communication of proximal Priority Highway Segments (PHSs). An HPZ was created if a Top 1% Priority Milepost was within five miles of another. Milepost proximity was determined with the *Group by Proximity* tool in ArcGIS Pro (ESRI, 2024). If an HPZ was less than 3 km from another HPZ, they were combined into a single zone due to the degree of feature overlap. This process resulted in the creation of 57 distinct zones across the OHAI. Maps for these spatial features are available in Appendix A.

Similar to the establishment of the PHS, priority mileposts associated with the HPZ were converted to segments using the *Point to Line* tool in ArcGIS Pro, aligned to the highway, and buffered at 3 km for visualization (ESRI, 2024). Unlike the PHS, no ranking or categorization system was established for the HPZs as they were established to represent spatial clustering of Priority Highway Segments.

3.8 SENSITIVITY ANALYSIS

Due to the exploratory nature of this indexing exercise, the ODECPP analysis did not employ a statistical model to predict locations suitable for ungulate passage placement. Instead, site-level composite scores for a given 0.10-milepost were calculated based on the product of the importance weight from the Analytic Hierarchy Process and the factor value extracted from the exact milepost of interest. Consequently, a non-model sensitivity analysis was conducted to evaluate the influence of each individual factor on the distribution of the TPMs across all OHAI.

Factor values for each 0.10-milepost per OHAI were stored in attribute tables, obtained from ArcGIS Pro, and exported to Excel using the *Table to Excel* tool (ESRI, 2024). Excel sheets were organized by OHAI and contained multiple columns representing the final 0.10-milepost values excluding a given factor, along with the corresponding milepost label. Value columns and their labels were sorted in descending order. Conditional formatting highlighted the top 1% of values for each factor. One-tenth milepost labels were then used to evaluate the percent shift in TPM distribution from the full factor analysis values compared to the values when each factor was excluded, while holding all other factor values constant. This procedure also assessed whether the initial TPMs remained within the top 1% of values, albeit in a different ranked order than the full factor analysis.

4.0 ANALYSIS AND DISCUSSION

4.1 TOP 1% PRIORITY MILEPOSTS

Scope and counts

A total of 13,271 distinct 0.10 mileposts (μ = 1,658.86 ± 990.09 SD) were analyzed for prioritization across the OHAI included in this analysis. Of these, 133 mileposts (μ = 16.63 ± 9.47 SD) fell within the top 1% of matrix scores and were designated Top 1% Priority Mileposts (TPMs) (Table 4-1). Final milepost scores and priority values were evaluated on a per highway basis, which produced unique value ranges by highway. The minimum inclusion value for a TPM was 1.53 on the Santiam Highway West, and the maximum was 10.61 on the Pacific Highway.

Top 1% Priority Milepost Aggregation and Priority Highway Segment Ranking

TPMs that were spatially clustered were aggregated into 81 Priority Highway Segments (PHSs) (Table 4-1) (Figure 4-1). Segments were ranked based on the ratio of the total count of TPMs within each segment to the highest value TPM in that segment (Figure 4-2).

Geographic Distribution

Of the 133 TPMs, 78 TPMs (58.7%) were distributed across highways east of the Cascades (μ = 15.6 ± 10.6 SD) and 55 TPMs (41.4%) were located on highways west of the Cascades (μ = 18.0 ± 9.07 SD). The Central Oregon Highway and the Oregon Coast Highway had the highest counts, with 26 and 25 TPMs, respectively.

4.2 PRIORITY HIGHWAY SEGMENTS

A total of 51 PHSs (μ = 10.2 ± 6.94 SD) were established on the eastern OHAI, and 30 PHSs (μ = 10.0 ± 7.21 SD) were identified on the western OHAI (Figure 4-3). The Dalles-California Highway had the highest number of PHSs east of the Cascades (n = 18), while the Pacific Highway produced the most west of the Cascades (n = 16). Santiam East had the fewest, with two segments.

Table 4.1: Priority Highway Segments (PHSs) on the seven ODOT Highways of Interest (OHAI) analyzed for the Oregon Deer and Elk Crossing Prioritization Project (ODECPP). Priority Highway Segments (PHSs) were identified by selecting the Top 1% Priority Mileposts (TPMs). TPMs located within a 1-mile radius were grouped into clusters, forming the foundation for generating PHSs. Priority scores for PHSs were calculated by dividing the number of 0.10-mileposts in a segment by the total number of TPMs on a given highway, then multiplying by the highest priority milepost in a distinct segment. This generated a composite score, identifying the highest value priority highway segment per OHAI (Figure 4-1).

Highway Name	Highway Number	TPM Count	PHS Count	Highest Value PHS	PHS Composite Score Prioritization
Pacific	001	22	16	**P g**	**1.12**
The Dalles-California	004	24	18	**TDC i**	**0.57**
Old Oregon Trail	006	19	15	**OOT n**	**0.94**
Central Oregon	007	26	12	**CO f**	**0.78**
Oregon Coast	009	25	12	**OC a**	**1.65**
Wallowa Lake	010	7	4	**WL c**	**3.28**
Santiam East	016	2	2	**SE b**	**0.92**
Santiam West	016	8	2	**SW a**	**0.84**
	Total	**133**	**81**		

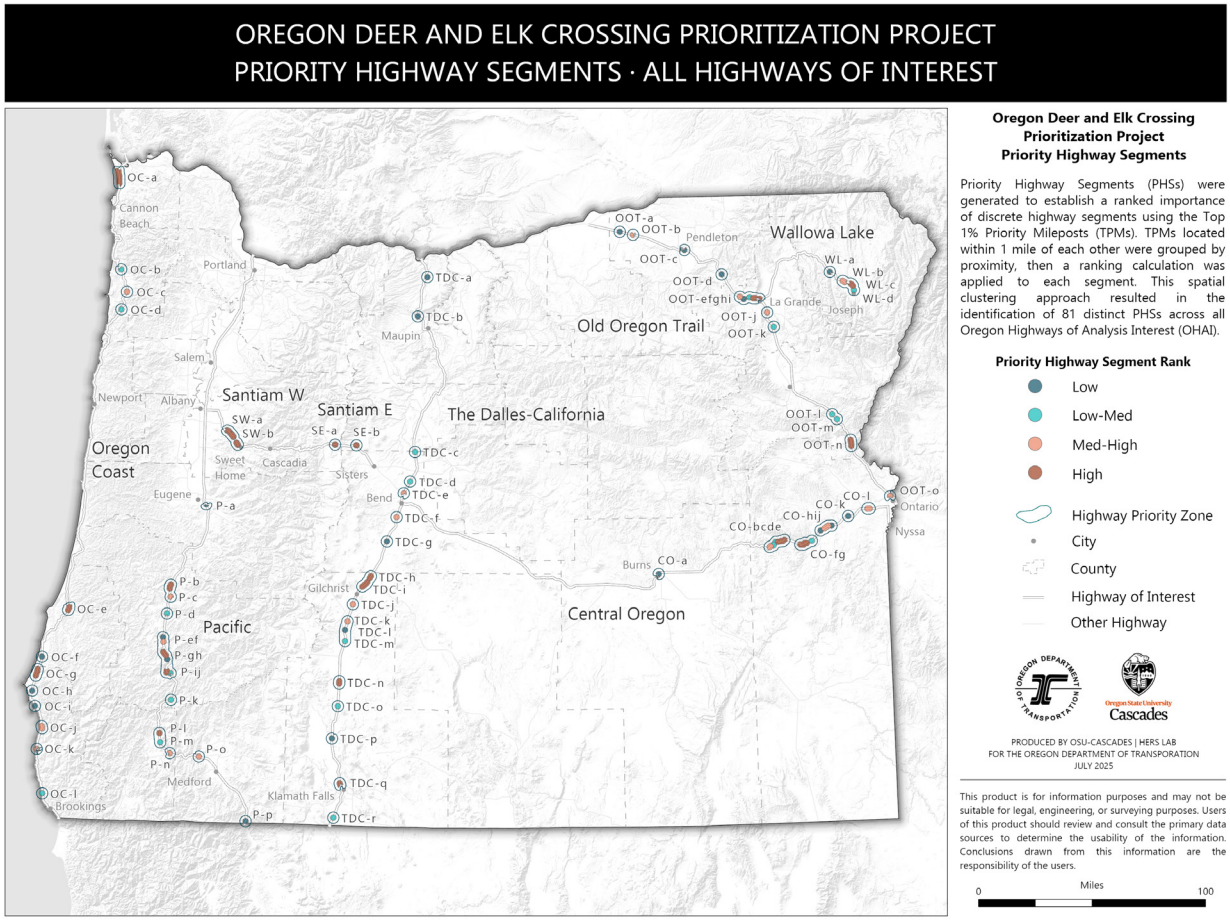


Figure 4.1. ODOT Highways of Analysis Interest (OHAI) Priority Highway Segments (PHSs). Segments were generated from spatially clustered Top 1% Priority Mileposts (TPMs) and ranked on a per-highway basis, using the ratio of the total number of TPMs in each segment to the highest-value TPM within that segment. This process resulted in 81 PHSs across the seven highways analyzed.

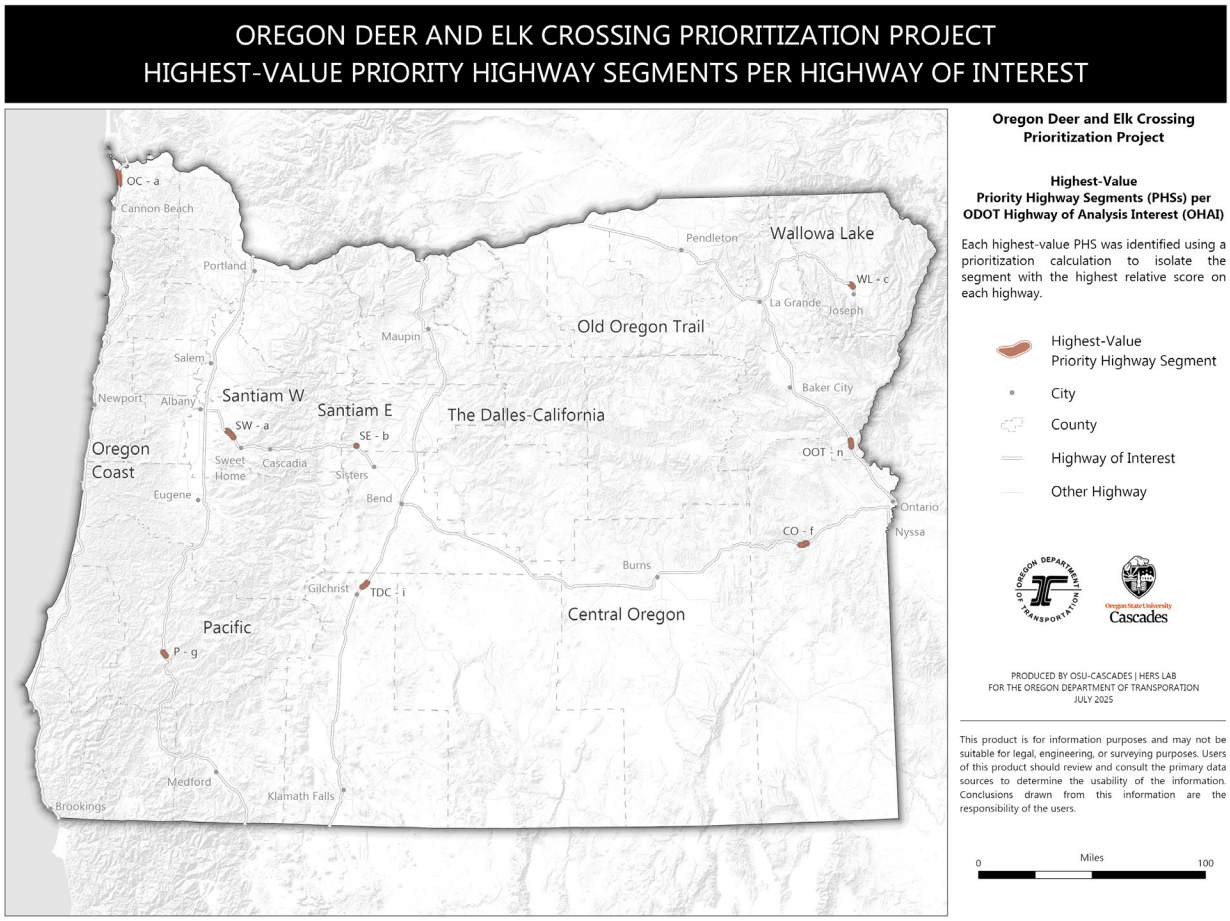


Figure 4.2: Highest-value Priority Highway Segment (PHS) per ODOT Highway of Analysis Interest (OHAI). Each top-value PHS was identified using a prioritization calculation to isolate the segment with the highest relative score on each highway.

4.3 TOP 1% PRIORITY MILEPOSTS AND MATRIX FACTORS

4.3.1 Future Climate Resilience

Thirty-eight percent of TPMs on the eastern OHAI (n = 30, μ = 10.0 ± 6.56 SD) and 21.8% on the western OHAI (n = 12, μ = 4.0 ± 3.6 SD) were associated with the highest factor value for Future Climate Resilience. All TPMs on the Santiam West Highway were associated with this highest value. The Dalles-California Highway and the Wallowa Lake Highway each had over 70% of TPMs in the high category (n = 17 and n = 5, respectively). A majority of TPMs on the Pacific, Central Oregon, and Oregon Coast highways were associated with the lowest factor value for this metric.

4.3.2 Terrestrial Land Resilience

Most TPMs on highways east and west of the Cascades were associated with the lowest factor value for Terrestrial Land Resilience. On the eastern OHAI, 16% of TPMs (μ = 4.33 ± 5.99 SD) had more than 50% of cells within a 1.5 km (0.93 mi) buffer classified as more or most resilient, corresponding to a higher factor value. Of these, 11 occurred on the Central Oregon Highway. The Santiam West Highway was the only western OHAI with TPMs associated with this factor.

4.3.3 Urban Growth Boundaries (UGB)

Eighty-three percent of TPMs on the eastern OHAI (n = 65, μ = 13.0 ± 10.37 SD) and 71% on the western OHAI (n = 39, μ = 13.0 ± 7.55 SD) were located more than 1.5 km (0.93 mi) from a UGB, corresponding to the highest factor value for this metric. Similarly, 80% or more of TPMs on the Santiam East, Central Oregon, and Oregon Coast Highways were associated with this highest value.

4.3.4 Road Density

Only one TPM across all evaluated OHAI segments, located on the Old Oregon Trail Highway, was associated with a road density greater than 25%, corresponding to a lower factor value. All other TPMs were associated with the highest factor value for this metric (<25%).

4.3.5 Distance from Mule Deer Winter Range

Among TPMs evaluated for this factor (eastern OHAI only), 97.4% were located less than 34.1 km from ODFW's spatially delineated winter range, corresponding to the highest factor value for this metric.

4.3.6 Annual Average Daily Traffic

Eighty-eight and a half percent of TPMs in the eastern OHAI (n = 69, μ = 13.8 ± 10.03 SD) were associated with the highest factor value for AADT (see, Appendix C). For the western OHAI, 70.9% of TPMs (n = 39, μ = 13.0 ± 11.4 SD) were associated with the same factor value.

4.3.7 Deer- and Elk-Vehicle Collisions (DEVCs)

A total of 919 DEVCs ($\mu = 183.8 \pm 105.81$ SD) were recorded from 2020 to 2023 at TPMs on the eastern OHAI, and 719 DEVCs ($\mu = 239.7 \pm 200.8$ SD) were recorded on the western OHAI. The Pacific Highway accounted for the most carcasses associated with TPMs west of the Cascades (n = 450), while the Old Oregon Trail Highway accounted for the most on the eastern OHAI (n = 274) during the same period.

4.3.8 Priority Wildlife Connectivity Areas (PWCAs)

Thirty-seven of the 79 TPMs on the eastern OHAI (47.4%, $\mu = 7.4 \pm 6.4$ SD) and 11 TPMs on the western OHAI (20.0%, $\mu = 3.7 \pm 2.5$ SD) intersected PWCA all-species, all-recommendations hexagons, corresponding to a higher factor value. Additionally, most TPMs were within 1.5 km (0.93 mi) of these PWCA hexagons on both the eastern OHAI (93.6%) and western OHAI (83.6%).

4.3.9 Multi-Attribute Polygons (MAPs)

Just over 30% of TPMs on the eastern OHAI (n = 24, $\mu = 4.8 \pm 4.8$ SD) corresponded with a MAP, assigning a higher factor value for this metric. For the western OHAI, more than 50% of TPMs (n = 29, $\mu = 9.7 \pm 2.1$ SD) were associated with this factor. The Central Oregon Highway had the highest percentage of TPMs associated with a MAP (42.31%) across the OHAI, while both the Pacific Highway and Oregon Coast Highway had more than 40% of TPMs corresponding to MAPs.

4.3.10 Existing Wildlife Crossing Structure Projects

The Dalles-California Highway was the only OHAI with wildlife crossing structure monitoring data; therefore, results are reported for this highway only. Three of the 21 TPMs (12.5%) were associated with an existing wildlife crossing project area, corresponding to a higher factor value for this metric.

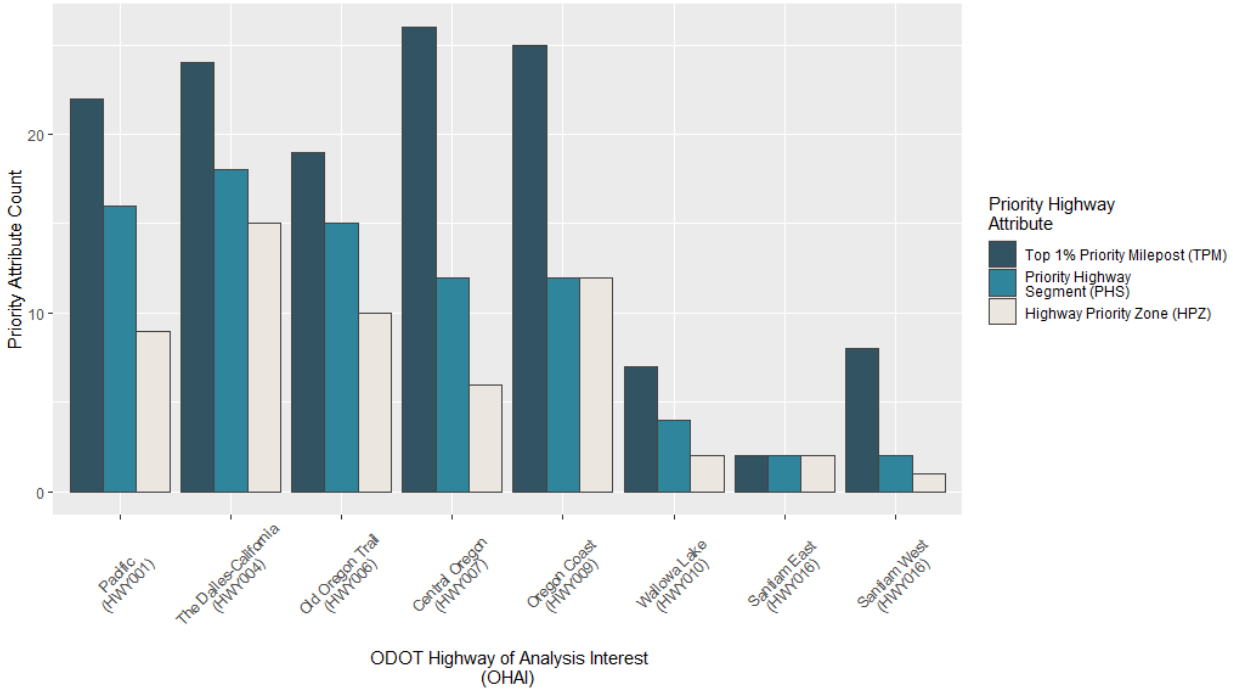


Figure 4.3. Priority Highway Attribute count per Oregon Highway of Analysis Interest (OHAI) analyzed for the Oregon Deer and Elk Crossing Prioritization Project (ODECPP). Priority Highway Attributes include the Top 1% Priority Mileposts (TPMs), Priority Highway Segments (PHSs), and Highway Priority Zones (HPZs). Highway Priority Zones (HPZs) were established by grouping 0.10-mileposts within a 5-mile proximity. PHSs nested within HPZs were identified by selecting the Top 1% Priority Mileposts (TPMs). TPMs located within a 1-mile radius were grouped into clusters, forming the foundation for generating PHSs.

4.4 SENSITIVITY ANALYSIS

The exclusion of Deer- and Elk-Vehicle Collisions and Multi-Attribute Polygon factors had the greatest influence on the distribution of TPMs across all OHAI. When DEVCs were excluded from the factor analysis, 100% of the TPMs across all OHAI areas shifted their distribution. On average, 10.37% (SD ± 16.86) of the DEVC TPMs from the full factor analysis remained in the top 1% of values (Figure 4-4). Similarly, the removal of the MAP factor caused an average shift of 50.63% (SD ± 42.92) of the TPMs, with 95.18% (SD ± 5.74) of the full factor analysis TPMs remaining in the top 1% of values.

Other factors, including Annual Average Daily Traffic, Priority Wildlife Connectivity Area Hexagons, Future Landscape Resilience, Terrestrial Landscape Resilience, Urban Growth Boundaries, and Categorical Wildfire Hazard Potential, also influenced the distribution of the original TPMs when removed from the factor analysis. However, these factors did not alter the distribution of the full factor analysis TPMs by more than 10% (Table 4-3 & Table 4-4).

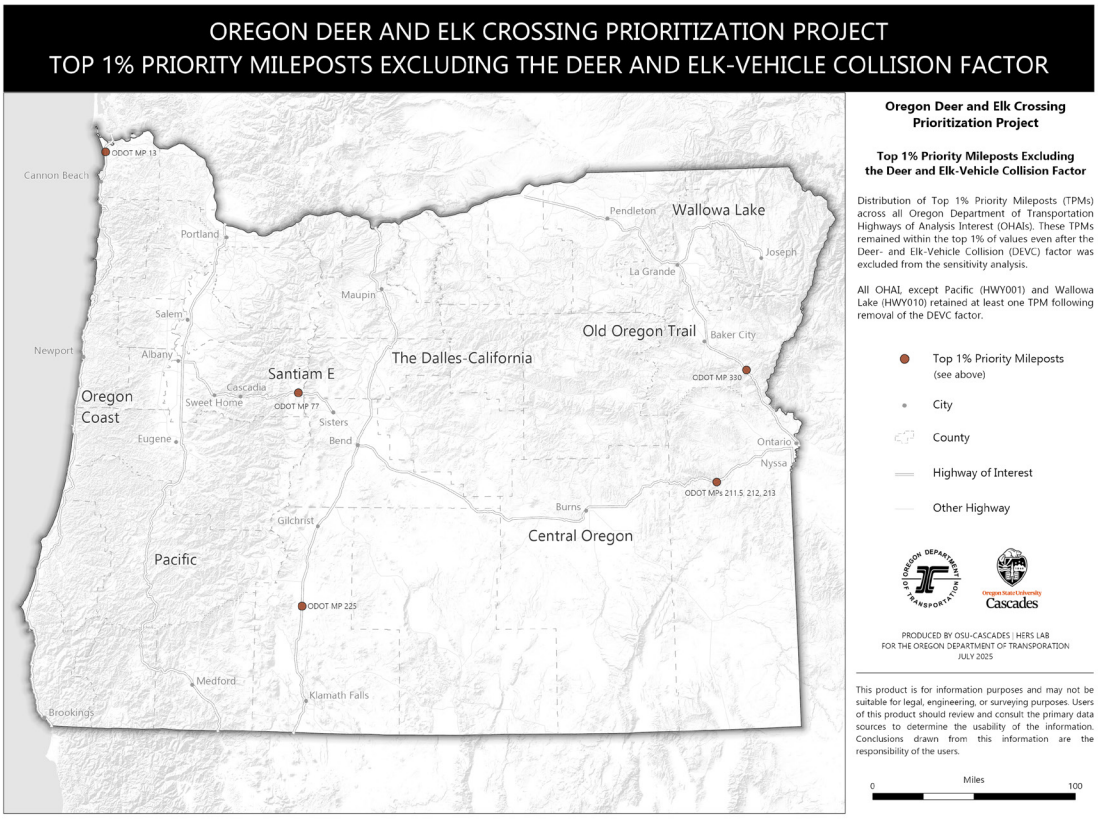


Figure 4.4. Distribution of Top 1% Priority Mileposts (TPMs) across all ODOT Highways of Analysis Interest (OHAI) that remained within the top 1% of values when the Deer- and Elk-Vehicle Collision (DEVC) factor was excluded from contributing to final values for the sensitivity analysis. All OHAI except for Pacific (HWY001) and Wallowa Lake (HWY010) had at least one TPM remain within the Top 1% of values despite DEVC removal from analysis. Top 1% Priority Mileposts have been buffered and merged for visualization.

Table 4.2. Percent (%) total of Top 1% Priority Mileposts (TPMs) per factor excluded during sensitivity analysis that remained in original order of distribution despite the factor not contributing to the total score. ***Top: Highways East of the Cascades. Bottom: Highways West of the Cascades.***

OHAI	HWY NUM	TPM Count	FCR	TLR	UGB	RD	CWHP	MDWR	AADT	DEVC	PWCA	MAP
DCH	**004**	24	70.8	100	100	100	100	54.2	62.5	0.0	62.5	20.8
OOT	**006**	19	68.4	100	100	100	89.5	100	68.4	0.0	57.9	26.3
COH	**007**	26	84.6	88.5	100	100	100	100	100	0.0	76.9	0.0
WLH	**010**	7	100	100	100	100	100	100	100	0.0	28.6	100
SEH	**016**	2	100	50.0	100	100	100	100	100	0.0	100	100
		Mean (%)	84.8	87.7	100	100	97.9	90.8	86.2	0.0	65.2	49.4
		SD (%)	15.2	21.7	0.0	0.0	4.7	20.5	19.0	0.0	26.2	47.2

OHAI	HWY NUM	TPM Count	FCR	TLR	UGB	RD	CWHP	AADT	DEVC	PWCA	MAP
PH	**001**	22	90.9	100	100	100	100	81.8	0.0	100	31.8
OCH	**009**	25	80.0	100	84.0	100	84.0	56.0	0.0	76.0	16.0
SWH	**016**	8	100	100	100	100	100	100	0.0	100	100
		Mean (%)	90.3	100.0	94.7	100.0	94.7	79.3	0.0	92.0	49.3
		SD (%)	10.0	0.0	9.2	0.0	9.2	22.1	0.0	13.9	44.6

Table 4.3. Percent (%) total Top 1% Priority Mileposts (TPMs) that remained within the top 1% of values upon factor exclusion during sensitivity analysis. ***Top: Highways East of the Cascades. Bottom: Highways West of the Cascades.***

OHAI	HWY NUM	TPM Count	FCR	TLR	UGB	RD	CWHP	MDWR	AADT	DEVC	PWCA	MAP
DCH	**004**	24	100	100	100	100	100	95.8	95.8	8.3	100	87.5
OOT	**006**	19	100	100	100	100	100	100	100	5.3	94.7	89.5
COH	**007**	26	100	100	100	100	100	100	100	15.4	100	88.5
WLH	**010**	7	100	100	100	100	100	100	100	0.0	85.7	100
SEH	**016**	2	100	50.0	100	100	100	100	100	50.0	100	100
		Mean (%)	100	90.0	100	100	100	99.0	99.2	15.8	96.1	93.1
		SD (%)	0.0	22.4	0.0	0.0	0.0	1.9	1.9	19.9	6.2	6.3

OHAI	HWY NUM	TMP Count	FCR	TLR	UGB	RD	CWHP	AADT	DEVC	PWCA	MAP
PH	**001**	22	100	100	100	100	100	100	0.0	100	100
OCH	**009**	25	100	100	96.0	100	100	100	4.0	96.0	96.0
SWH	**016**	8	100	100	100	100	100	100	0.0	100	100
		Mean (%)	100	100	98.7	100	100	100	1.3	98.7	98.7
		SD (%)	0.0	0.0	2.3	0.0	0.0	0.0	2.3	2.3	2.3

4.5 DISCUSSION

The objective of the Oregon Deer and Elk Crossing Structure Prioritization Project (ODECPP) was to develop a rigorous and adaptable decision-support tool for prioritizing wildlife passage projects that improve driver safety and support habitat connectivity on Oregon's highways. The ODECPP methodology was designed to provide an efficient foundation for transportation agencies with limited wildlife passage infrastructure resources to identify and prioritize locations for further planning and investment. This GIS-based analysis, delivered to the Oregon Department of Transportation, emphasizes human safety and ungulate-traffic conflict mitigation by identifying areas of overlap between the multifactor indexing results and locations modeled for wildlife connectivity (e.g., OCAMP PWCA hexagons).

The ODECPP is comparable to processes implemented by states such as Colorado and Washington, which use multi-factor indexing approaches to inform the siting of wildlife crossing projects (Kintsch et al., 2019, 2022; WSDOT, 2023). These approaches integrate state-specific wildlife connectivity models and available spatial data to support prioritization. In line with these methods, the framework described here strengthens the case for using structured prioritization to identify high-value areas for ungulate passage projects. This is achieved through the incorporation of multiple authoritative spatial layers, transformed into matrix factors representing environmental and climate resilience, land use and development, traffic safety and deer- and elk-vehicle collision risk, wildlife connectivity and ungulate migration, and existing passage infrastructure (Table 4-5).

Several methods applied in the ODECPP were informed by comparable efforts, particularly Colorado's Western Slope and Eastern Slope and Plains Wildlife Prioritization Studies (Kintsch et al., 2019, 2022). For example, those studies recommended using point feature classes to address analytical challenges associated with highway line segments, a strategy the ODECPP also adopted. However, while there are methodological parallels, we intentionally diverged in our choice of analysis units to better support environmental raster value extraction, ensure uniform sampling, and preserve the spatial attributes of DEVC records. We used 0.1-mileposts as the unit of analysis, in contrast to the 0.5-mile line segments used in the Colorado frameworks. Like the Colorado studies, we implemented a ranking system to identify high-priority areas; however, we focused on 0.1-mileposts within the 99th percentile, rather than the 95th percentile threshold applied in Colorado. This approach enabled us to highlight specific locations with the greatest transportation mitigation need at a finer spatial scale, supporting statewide prioritization and resource allocation.

Table 4.4. Oregon Deer and Elk Crossing Prioritization Project (ODECPP) Matrix Factor Categories and Data Sources. Categories and associated factors evaluated for ungulate passage project placement on the seven ODOT Highways of Analysis Interest (OHAI) (*see*, Appendix C).

Category	Factor Name	Authoritative Data Source
Environmental and Climate Resilience Factors	Future Climate Resilience	U.S. Geological Survey
	Terrestrial Landscape Resilience	The Nature Conservancy
	Categorical Wildfire Hazard Potential	U.S. Forest Service Rocky Mountain Research Station
Land Use and Development Impact	Distance from Urban Growth Boundary	State of Oregon GEOHub
	Road Density	Multi-Resolution Land Characteristics Consortium
Traffic Safety and Wildlife-Vehicle Collision Risk	Annual Average Daily Traffic	Oregon Department of Transportation TransGIS
	Deer- and Elk-Vehicle Collision Counts	Oregon Department of Transportation TransGIS
Wildlife Connectivity and Migration Routes	Distance from Mule Deer Winter Range	Oregon Department of Fish and Wildlife
	ODFW PWCA Hexagons – All Species and Conservation Levels	Oregon Department of Fish and Wildlife
	Multi-Attribute Polygon	Oregon Department of Transportation, Oregon Department of Fish and Wildlife, OSU-Cascades HERS Lab
Road Infrastructure and Mitigation Projects	Existing Wildlife Crossing Structure Project	Oregon Department of Transportation, OSU-Cascades HERS Lab

The ODECPP further diverged from the Colorado studies in its approach to developing matrix factor scores (Kintsch et al., 2019, 2022). In those projects, statistical models were used to estimate ungulate-vehicle collision risk based on roadway and adjacent environmental variables, with resulting coefficients informing factor weights in the prioritization framework. For this Oregon-based project, the ODECPP opted to apply a non-statistical matrix approach, enabling

transparent integration of multiple spatial factors during the matrix weighting process (Kintsch, 2022).

Following a similar trajectory, the ODECPP initially developed a deer-vehicle collision risk model for The Dalles-California Highway to evaluate the level of influence of environmental and roadway characteristics on DEVCs. However, the model accounted for less than 10% of the variance in observed carcass counts ($R^2_L < 0.10$), suggesting limited explanatory power. This may be due to the relative uniformity of independent variables along the highway, such as consistent posted speed limits and mean traffic volumes, which constrained the model's ability to detect spatial variation in collision risk (Denneboom et al., 2024; Inman et al., 2024; Bissonette JA and Kassar CA, 2008).

Given these limitations, the ODECPP instead relied on descriptive statistics that examined the relationship between DEVCs and selected factors to establish categories and subsequent weights where appropriate. For factors not informed by DEVCs, weights were assigned based on the TAC's assessment of each factor's magnitude and immediacy. To further refine the prioritization framework, an Analytic Hierarchy Process (AHP) was used to compare factors and generate normalized values (Rozann, 1987). These values were multiplied by the initial weights at each milepost to produce prioritization scores. The AHP process enabled transparent evaluation of the relative importance of each factor, with safety-related factors receiving the highest valuations, consistent with the purpose and goals of the ODECPP. This method supports adaptability in future project iterations and repeatability for similar efforts by other state transportation departments, as the relative importance of each factor can be adjusted based on project-specific objectives, improved data availability, and input by subject area experts.

By integrating a suite of committee-agreed matrix factors identified through primary source literature review and authoritative data sources and leveraging previously established connectivity information for a subset of Oregon's native species, we identified 133 Top 1% Priority Mileposts, establishing 81 Priority Highway Segments. Each segment consists of at least one 0.10-milepost, with 0.10-mileposts situated less than 1 mile apart, located within 57 distinct Highway Priority Zones on a selection of Oregon's most traveled highways with elevated DEVC risk. Priority Highway Segments (PHS) for each OHAI were categorized from low to high priority based on an evaluation metric that considered the number of 0.10-milepoints in a PHS and the highest scored 0.10-milepost within the segment. All OHAI had one or more "High" category PHS, except Santiam East and Santiam West. Santiam East had two PHS of equal value, while Santiam West had a single PHS.

The matrix factor approach effectively addressed the objectives of ODOT and the HERS Lab by providing a methodology to prioritize locations for ungulate passage projects on Oregon's highways. This included identifying areas where TPMs and PHSs intersected with Oregon's statewide connectivity model, specifically the PWCA hexagons. Because PWCA hexagons were included as one of several input factors, some degree of spatial alignment was anticipated. Notably, 36.1% of TPMs intersected with a PWCA hexagon (47.4% and 20% of OHAI east and west of the Cascades, respectively), and approximately 89.5% were located within one mile of a hexagon. Additionally, 62 of the 81 (76.5%) PHSs intersected with at least one PWCA hexagon. Inversely, 402 PWCA hexagons overlapped with PHSs, with the majority (~53%) classified as Regions, indicating high-value contiguous habitat. 'Protect' (n = 167) was the most common

conservation action recommendation, with 'Transportation Mitigation' (n = 120) being the second most frequent. These patterns reflect areas where multiple prioritization factors, including modeled connectivity, converged, independent of analogous data sources like DEVCs. While PWCA hexagons were included as a factor, the ODECPP is best understood as a complementary resource focused on transportation mitigation needs based on a human-safety perspective, rather than a validation of the PWCA framework, which centers on habitat connectivity for Oregon's native wildlife.

Maintaining and increasing habitat connectivity is hypothesized to contribute to climate-change resilience across taxonomic groups (Mayer et al., 2016; Keeley et al., 2018). Climate change resilience was also identified as a top priority for matrix inclusion by several TAC members, including ODOT and ODFW, and has been recently labeled as a critical consideration of future wildlife passage projects (Littlefield et al., 2024). Forty-two (31.6%) of the total TPMs overlapped with areas projected to be climate-resilient, based on modeled ecosystem water balance at the 10 km site level (Bradford et al., 2019). Twelve percent (n = 16) of TPMs were associated with Terrestrial Land Resilience. Differences in the association of TPMs with resilience-based factors are likely due to the scale at which each raster was extracted and measured as well as its native resolution. For example, the Future Climate Resilience Layer had a native resolution of 10 km with four categories of resilience, whereas the Terrestrial Land Resilience Layer had a 30 m resolution and seven resilience classes. Values extracted from the cells within the 1.5 km (0.93 mi) buffer surrounding 0.10-mileposts from the Terrestrial Land Resilience layer were informed by highways, automatically imparting a proportion of "Average" to "Least"-resilience cells representing four of the classes. These classes received a value of zero in the ODECPP analysis, with only "Slightly" to "Most" resilient sites receiving a value of one, contributing to increases in the 0.10-milepost score.

Thirty-three percent and 68.8% of TPMs were associated with either Future Climate Resilience or Terrestrial Land Resilience *and* intersected with a PWCA hexagon, respectively. However, only four TPMs, all located on the Santiam Highway, corresponded with both resilience factors, with one located west of the Cascade Crest also overlapping with a PWCA hexagon. TPMs identified as having a relationship with Terrestrial Land Resilience intersected with a PWCA more than half of the time, and with Future Climate Resilience more than a quarter of the time.

While many practitioners and policy makers agree that climate change should be incorporated into wildlife crossing structure planning, doing so involves several challenges. First, no single data source offers sufficient resolution and spatial scale to inform statewide planning efforts with a high degree of confidence, particularly where animal response to predicted changes is concerned. New models to address that concern are in development, and they can be incorporated into future iterations of the decision support approach we've introduced here. Additionally, how wildlife respond to changing climate conditions is dependent on several other factors at the site and landscape scales, some of which will likely mediate, moderate, or exacerbate impacts of climate change on animal behavior in a given location. Addressing these challenges will likely require thoughtful weighting of climate data sources, ground-truthing vegetation conditions at proposed crossing locations during secondary vetting processes, and regular incorporation of updated animal population and movement information.

A non-model sensitivity analysis revealed that a limited number of selected matrix factors had a strong influence on the distribution of TPMs across OHAI. However, Deer- and Elk-Vehicle Collisions (DEVCs) and the Multi-Attribute Polygon (MAP) factors altered the distribution of TPMs by an average of 100% and 49.4%, respectively. Only an average of 10.4% of the original TPMs remained in the top 1% of values when DEVCs were removed (Figure 4-4). Both factors are heavily weighted by ungulate carcass counts derived from ODOT's roadkill database and had the highest raw values before being factored by the normalized value. Human safety and collision reduction for ungulates were established as the focal consideration for this effort to prioritize ungulate crossing structure placement statewide. However, as described above, a majority of TPMs are less than a mile from PWCA hexagons that represent all species and conservation recommendations, thus providing potential connectivity value for many of Oregon's native wildlife species.

Certain factors that influenced the prioritization scores on OHAI east of the Cascade Mountains are unique to eastern Oregon and lack equivalent data for other highways in the state, particularly those west of the Cascades. For example, one of the three data sources used to construct the Multi-Attribute Polygon is only available for eastern Oregon mule deer herds (ODFW, 2024c). Additionally, winter range data from the Oregon Department of Fish and Wildlife (ODFW) is only available for eastern Oregon ungulates (ODFW, 2024c; Cowin, 2013). Due to the absence of spatially available data concerning ungulate distribution west of the Cascades, the MAP factor was adjusted for the Pacific, Oregon Coast, and Santiam West Highways to include the intersection of two of the three factors: Optimized Hotspots and 'Ungulate Only' PWCAs.

Western Oregon ungulate species, such as Columbian black-tailed deer (*Odocoileus hemionus columbianus*), Columbian white-tailed deer (*Odocoileus virginianus leucurus*), and Roosevelt elk (*Cervus canadensis roosevelti*), have dissimilar movement patterns compared to eastern Oregon species like mule deer and Rocky Mountain elk (*Cervus canadensis nelsoni*) (Padilla, 2025). Moreover, the spatial data for available for western Oregon species is currently insufficient for decision-making due to the limited number animals included in radio and GPS-collar surveys (Padilla, 2025). Additionally, a single 0.93-mi (1.5-km) buffer representing the average daily distance of mule deer travel was employed to extract raster values to convert and assign values to factors (van de Kerk et al., 2021). While mule deer are the most frequently associated species with wildlife-vehicle collisions statewide, the single buffer does not incorporate the movement patterns for the suite of Oregon's ungulates considered. To address these limitations, we plan to introduce species-specific buffer zones in future versions of the ODECPP, habitat attributes known to influence the movement patterns of western Oregon ungulates, and other ODFW recommended data sources for these species as primary and secondary matrix factors on a highway-by-highway basis as part of anticipated ODECPP version updates and validation process offered in the second phase of this project.

In line with this approach, the decision-support tool and spatial products produced by the ODECPP are designed to be updated regularly as new and relevant data become available, including data specific to regional and individual highway systems. This site-specific methodology ensures that the best available science is applied accurately to the appropriate locations, aiming to increase motorist safety by reducing vehicle-ungulate conflicts in areas of greatest benefit to both humans and ungulates, now and into the future.

5.0 RECOMMENDATIONS AND FUTURE WORK

5.1 RECOMMENDATIONS

5.1.1 Priority Feature Interpretation & Ungulate Passage Projects

The Top 1% Priority Mileposts (TPMs) and Priority Highway Segments (PHSs) generated from the ODECPP process offer an initial assessment of potential sites for ungulate passage projects in Oregon, including ungulate crossing structures. However, these priority areas should not be directly interpreted as locations for formal crossing structures, as structures may not be appropriate given site characteristics. Instead, the TPMs and PHSs may be viewed as areas of opportunity to enhance ungulate passage and transportation safety through the implementation of alternative technologies that alter driver behavior and account for target species movement patterns. Vetting each TPM within a PHS is necessary to determine the appropriate passage project type based on site characteristics and target species. As such, we advocate for:

- Vetting each Top 1% Priority Milepost within a Priority Highway Segment during the ODECPP project second phase to determine site characteristics that influence the suitability of mitigation measures, such as topography, roadway characteristics, landownership patterns, and target species movement and behavior.

5.1.2 Ungulate Spatial Data Solicitation and Procurement

One of the primary challenges in mapping and prioritizing ungulate passage projects in Oregon is the inconsistency of available authoritative data between the western and eastern regions of the state. For example, winter range data for eastern Oregon ungulates are readily available (Kauffman et al., 2024; 2025). Additionally, ODFW is working towards mapping Rocky Mountain elk and pronghorn (*Antilocapra americana*) herd distributions based on GPS-collared animals in central and eastern Oregon. However, comparable spatial data are not available for western Oregon ungulate species due to logistical constraints (Padilla, 2025). Similar challenges also limit efforts in collecting population data for these species. Nevertheless, these data are important in vehicle-ungulate conflict decision making, as they provide information on the locations and estimated numbers of animals within a given area. Therefore, we endorse state agencies and universities work together to:

- Strengthen statewide efforts to generate spatial data for western Oregon ungulate herds.
- Extend statewide big game population survey data to include novel population estimates for Columbian black-tailed deer and all white-tailed deer subspecies as they become available.

5.1.3 Large Mammal Wildlife-Vehicle Collision Spatial Data

In most decision-making contexts, wildlife-vehicle collisions describe the consequence resulting from the interactions between large-bodied animals, primarily ungulates, and road networks. Two primary data sources measure these types of WVCs on roadways: crash data and carcass data (Knapp, 2007; Yang et al., 2019). While similar, these sources provide different estimates about WVC frequency at a given location.**Error! Bookmark not defined.** Many states use crash data, typically recorded by law enforcement or insurance agencies, for transportation mitigation decision-making.**Error! Bookmark not defined.** Alternatively, carcass data may be collected by transportation agency maintenance crews, hired contractors, or roadkill salvage permit holders (Knapp et al., 2007; Yang et al., 2019; ODFW, 2023c; Olson, 2013). Critically, both crash and carcass data are frequently underreported (Knapp et al., 2007; Yang et al., 2019; ODFW, 2023c). In Oregon, WVCs used for decision-making are measured as carcass counts. However, both data sources, when collected systematically and consistently, are necessary for comprehensive decision-making concerning ungulate passage projects statewide (Knapp et al., 2007). Therefore, we propose the following:

- Implement a systematic and consistent reporting system for large mammal WVCs, supported by a centralized database that includes spatially referenced crash and carcass data from all reporting sources.
- Include data from diverse reporting sources, such as:
    - ODOT TransGIS Animal Incidents Geodatabase
    - ODOT Crash Data
        - ODFW Roadkill Salvage Data
        - Roadkills of Oregon supported by the iNaturalist platform
- Ensure comprehensive species identification during data collection to better incorporate species-specific movement patterns, particularly for those with high collision risk at both local and landscape scales.
- Encourage widespread adoption of incident reporting to ODFW's Roadkills of Oregon page supported by the iNaturalist platform to help identify areas of frequent vehicle-collision overlap between ungulates and other taxa.

5.1.4 Advancing Wildlife-Traffic Conflict Mitigation Technologies

As discussed in 5.1.1 ***Priority Feature Interpretation & Ungulate Passage Projects***, priority areas represent potentially suitable locations for ungulate-vehicle collision mitigation. This includes novel strategies and technologies such as Roadside Animal Detection Systems (RADS) and at-grade crossings. These systems can be effectively implemented in areas with elevated wildlife mortality over long roadway sections; however, due to site-specific constraints, the location may not be suitable for full ungulate crossing structure projects (Gagnon et al., 2019; Huijer et al.; 2015; Huijser et al., 2006). Roadside Animal Detection Systems alert drivers to the presence of animals near the roadway, and rely on behavioral changes, such as reduced speed and increased vehicle braking, to reduce collision risk (Gagnon et al., 2019; Huijser et al.; 2006; Grace et al., 2017).

These systems are determined to be most effective in regions with lower traffic volumes, providing immediate alerts to drivers about the presence of animals on or near the roadway

(Gagnon et al., 2019; Huijser et al., 2015). This approach allows for an alternative mitigation strategy to ungulate crossing structures and exclusion fencing. Roadside Animal Detection Systems may be beneficial across large segments of roadways, in areas with increased landownership density where a full passage project may not be feasible, or due to landscape or financial constraints (Gagnon et al., 2019; Huijser et al., 2006). Despite the potential benefits, it is important to emphasize that RADS do not address the barrier effect of roads, especially for smaller species, but rather center on a human-safety ideology (Huijser et al., 2015). Additionally, RADS do not have the capabilities to eliminate wildlife-vehicle collisions entirely. As such, identifying project objectives is critical prior to the implementation of RADS as a vehicle-collision mitigation tool. For these reasons, we recommend:

- Identify the primary challenge and goal for mitigation at the site, such as increased habitat permeability for a species, or reduced ungulate-traffic conflict.
- Establish a protocol for the use of RADS within a buffer of project terminus points to warn drivers of potential increases in large-bodied wildlife on the road.
- Determine potential constraints to ungulate crossing structure feasibility at Priority Highway Segments during site vetting in second phase of project.
- Develop a list of traffic-mitigation alternatives to ungulate crossing structures (e.g., RADS) if constraints to ungulate crossing construction are identified.

5.1.5 Statewide Deer- and Elk-Vehicle Collision Risk Modeling

Deer- and elk-vehicle collision risk modeling has been used in projects like the Colorado Western and Eastern Slope and Plains Prioritization Studies to predict suitable areas for ungulate-vehicle conflict mitigation (Kintsch et al., 2019; 2022). These models typically use various environmental, sociodemographic, and roadway factors to assess their impact on ungulate-vehicle collisions, usually measured as presence-absence or counts (Ha H., Shilling F., 2018).

In the initial phase of the ODECPP, an ungulate-vehicle collision risk model was included. However, it was found that the model's ability to explain the variance in carcass counts along the entire The Dalles-California Highway was low ($R^2_L < 0.10$). This low explanatory power may reflect the relative uniformity of independent variables, such as annual average daily traffic and posted speed limit. Consequently, no inferences were drawn from the model results, and the modelling process was abandoned in favor of descriptive statistics. Despite this, ungulate-vehicle collision risk models are useful for identifying factors driving WVCs, especially when variables are selected at local scales. As a result, we encourage:

- Establishment of an ungulate-vehicle collision risk model for short to moderate-length geographically similar highway segments that considers local site characteristics as explanatory variables.
- Integration of advanced statistical techniques like Structural Equation Modeling (SEM) and/or Maxent in ArcGIS Pro, to better analyze the influence and strength of environmental, sociodemographic and roadway factors on collision probability at a given site.
- Inclusion of regular updates and validation of the model to ensure it remains relevant and accurate over time.

5.1.6 Long-Term Wildlife Passage Project Monitoring

Long-term monitoring is essential for providing decision-makers with insights into project effectiveness and opportunities for improvement (Gagnon et al., 2011). Monitoring both before and after project implementation offers critical context on species presence and animal movement patterns at a given site, as well as potential changes in wildlife distribution, abundance, and wildlife-vehicle collision rates following project establishment (Soanes et al., 2024; van der Ree et al., 2015).

Implementing a Before-After-Control-Impact (BACI) design is particularly effective in this context, especially when study design includes appropriate benchmarks (Soanes et al., 2024; van der Ree et al., 2015). Importantly, BACI designs allow for evaluation of project outcomes by comparing conditions before and after implementation, and between impacted and control sites (van der Ree et al., 2015).

Additionally, monitoring wildlife crossing structure passage rates by target species and other wildlife provides an alternative analysis of project success. This can help identify changes in animal use patterns, crossing behavior, and abundance and site-specific factors that may influence these alterations (ODOT, 2024). We recommend the following actions:

- Implement long-term monitoring of all structures and project termini before and after implementation, using a systematic protocol tailored to wildlife crossing structure planning and monitoring in Oregon.
- Apply AI-powered object detection models trained on imagery from Oregon's wildlife crossing structures to automate animal detection and counting, streamlining monitoring workflows and results generation.
- Use habitat connectivity assessments and DNA analysis to evaluate the degree of habitat linkage and functional connectivity provided by wildlife crossing structures for target species.

5.1.7 Statewide Wildlife Passage Project Advisory Group

In recent years, numerous transdisciplinary working groups have been established across Oregon, bringing together members from non-governmental organizations, universities, tribal nations, and state and federal agencies (ODOT, 2024). These groups share a common goal: enhancing wildlife connectivity and improving traveler safety on Oregon's highways. Their collaborative efforts are often focused on specific locations where reducing wildlife-vehicle conflicts is a priority. Many stakeholders participate in multiple initiatives statewide, enabling the exchange of lessons learned, successful strategies, and emerging opportunities.

Newly introduced House Bill 2978 (Oregon, 2025) supports the formation of a memorandum of understanding between the Oregon Department of Transportation and the Oregon Department of Fish and Wildlife. This agreement establishes an advisory group designed to integrate diverse perspectives from a broad array of stakeholders. Such collaboration is essential for addressing complex interdisciplinary challenges and achieving planning and implementation outcomes that would be difficult for any single entity to accomplish alone (Cutcher-Gershenfeld et al., 2025).

The advisory group is tasked with identifying priority locations for wildlife-vehicle collision mitigation, leveraging shared research findings and resources from regional working groups. It will also help identify grant funding sources, support adaptation to changes in state and federal laws, and provide other relevant guidance. For these reasons we suggest:

- Integrating findings from the ODECPP alongside other research to inform advisory group decision-making under HB 2978.

5.2 FUTURE WORK

The matrix approach employed by the ODECPP identified several Priority Highway Segments (PHSs) across the seven Oregon Highways of Analysis Interest (OHAI) as candidates for future wildlife passage projects. However, the primary ODECPP analysis did not incorporate elements that validate the effectiveness of existing wildlife crossing structures or factors that could enhance site-specific suitability assessments. These exclusions were primarily due to limitations in source data, such as insufficient spatial resolution at discrete locations.

Accordingly, future work will be initiated to validate the effectiveness of current wildlife crossing structures using non-invasive genetic sampling. Additional phases will introduce a multi-step, iterative process to ensure that PHS standing is based on relevant and contemporary information, as well as verify and incorporate locally available characteristics for scoring PHSs. Finally, an ungulate-vehicle collision risk model will be generated to predict areas susceptible to increased deer- and elk-vehicle collisions.

5.2.1 Non-Invasive Genetic Sampling

While multiple iterations of long-term wildlife crossing structure monitoring have occurred at Oregon's five wildlife crossings on The Dalles-California Highway between mileposts 145-185, the degree of connectivity provided for migratory ungulates by the crossings has yet to be assessed. The most recent monitoring iteration indicates successful passage rates of 73% for mule deer and 93% for elk. However, it is unknown whether these success rates are influenced by repeat visits of individuals (e.g., resident animals) or by animals migrating to winter or summer ranges.

To address this, a non-invasive genetic sampling project led by the OSU-Cascades HERS Lab has been initiated. This project will use fecal pellets for DNA analysis to determine the primary movement behavior of ungulates using the structures (resident or migratory), establish a local population estimate, determine the proportion of the population that crosses the highway using the underpasses, and generate a corrected passage rate for mule deer and elk at each structure.

Submatrix Development for Priority Highway Segments

ODECPP personnel and TAC committee members identified several site-specific factors, including landownership, landowner density, recreational trail density, and energy development, that could enhance the prioritization process. However, due to their granularity, availability, and source, these factors were not included in the primary matrix. Nevertheless, because of their potential influence on passage project success, they will be considered in a submatrix to assist

with site validation during the Priority Highway Segment Vetting process. This submatrix will provide a systematic review and score of each site, enhancing the ODECPP process by providing supplementary scoring of the PHS.

5.2.2 Priority Highway Segment Validation

As discussed above, PHSs will be vetted to determine the quality of each site based on a systematic review of site-specific characteristics. In addition to providing supplementary scoring of the PHS, the site visits will offer a primary assessment of the suitable passage project type for the area. The initial evaluation will be performed on The Dalles-California Highway and refined for statewide efforts.

5.2.3 Complete Highway System Prioritization

ODECPP analysis was initiated on The Dalles-California Highway and expanded to six additional OHAI (Pacific (HWY001), Old Oregon Trail (HWY006), Central Oregon (HWY007), Oregon Coast (HWY009), Wallowa Lake (HWY010), Santiam (HWY016)) due to the magnitude of need and highway suitability for additional passage projects. However, wildlife-vehicle collisions are a statewide issue, and many additional highways in Oregon necessitate traveler safety improvements and habitat connectivity. During the subsequent phases of the ODECPP, all highways will be analyzed, starting with the highways with the greatest number of average annual DEVCs.

5.2.4 Spatially Explicit Deer- and Elk-Vehicle Collision Risk Model

To enhance road safety and ungulate conservation, a spatially explicit deer- and elk-vehicle collision risk model is being developed by the OSU-Cascades HERS Lab for all Oregon highways. This model integrates site-specific factors to predict potential collision hotspots, considering environmental, sociodemographic, biological, and roadway characteristics. Additionally, a custom tool for ODOT TransGIS department is being created. This tool, developed using ModelBuilder and Python, utilizes a decision tree methodology to guide operators through a series of questions relevant to target species, thereby improving the accuracy of collision predictions.

6.0 Conclusion

Wildlife passage projects are vital components of modern transportation infrastructure. They can reduce wildlife-vehicle collisions when implemented thoughtfully and support safe movement for diverse species across roadways, benefiting both ecological systems and public safety.

- **Infrastructure Integration:** Wildlife passage projects are integral to transportation planning and infrastructure development in Oregon where ungulate-vehicle collisions impact human safety.
- **Ecological and Safety Benefits:** When appropriately placed and designed, passage projects support wildlife movement for a variety of species and reduce wildlife-vehicle collisions, benefiting both ecosystems and the traveling public.

6.1 PRIORITY LOCATIONS AND CONNECTIVITY POTENTIAL

The ODECPP identified 133 Top 1% Priority Mileposts (TPMs) and 81 Priority Highway Segments (PHSs) across seven highways. These locations were selected based on multiple environmental and safety factors, with a focus on deer and elk due to their collision risk and ecological importance.

- **High DEVC Risk Corridors:** TPMs and PHSs reflect areas of elevated ungulate-vehicle collision risk, centering priority on human safety.
- **Proximity to PWCA Hexagons:** Most TPMs and PHSs are within 1.5 km (0.93 mi) of a Priority Wildlife Connectivity Area (PWCA) hexagon, suggesting potential for multi-species connectivity benefits.
- **Connectivity Potential:** The proximity of TPMS and PHSs to PWCA hexagons suggests broader connectivity benefits for Oregon's native species.

6.2 CLIMATE RESILIENCE

Just over one-third of TPMs were located in areas projected to be climate-resilient, and 12% exhibited strong Terrestrial Landscape Resilience. Notably, 68% of TPMs associated with Terrestrial Landscape Resilience intersected with PWCA hexagons, reinforcing their long-term value for connectivity and safety.

- **Climate Resilient Locations:** Approximately one-third of TPMs were located in areas resilient to climate change, and 12% aligned with terrestrial resilience indicators.
  Intersection with PWCA Hexagons: TPMs with high Terrestrial Landscape Resilience intersected with PWCA hexagons 68% of the time.
- **Biodiversity and Connectivity:** Prioritizing passage projects near movement corridors in climate-resilient landscapes supports long-term ecological connectivity.
  Future Data Integration: Future iterations of the ODECPP should incorporate updated regional climate resilience datasets as they become available.

6.3 TECHNOLOGICAL ADVANCEMENTS

Recent improvements in geospatial monitoring and mapping, combined with increased legislative support for wildlife connectivity, have significantly enhanced the siting and design of passage projects. These advancements enable a more comprehensive planning approach that incorporates environmental and roadway factors.

- **Spatial Technology Integration:** Advances in geospatial tools have improved the precision of wildlife passage project siting.

- **Policy Momentum:** Legislative support has accelerated development and prioritization of wildlife connectivity projects.

- **Multifactor Planning Framework:** Passage projects now incorporate a range of environmental and road-based factors, including:

    - Animal behavior and movement
    - Spatial use of regions by target species
    - Anticipated climate change patterns

6.4 DECISION-MAKING PROCESS

The ODECPP employed a matrix-based approach that systematically integrated ecological, safety, and land-use data as an initial step in the decision-making process. This method enables transportation departments and stakeholders to develop an informed view of the roaded landscape from both human safety and ecological perspectives. By identifying tangible site locations, the framework provides a starting point for evaluating site feasibility for a potential passage project, ultimately supporting prioritization verification.

- **Matrix-Based Approach:** Integrating comprehensive information as an initial step in decision-making.
- **Informed View:** Establishing an informed perspective of the roaded landscape from both human safety and ecological viewpoints.
- **Project Design Alignment:** Promoting suitable wildlife passage project designs based on site-specific characteristics.

6.5 LEVERAGING SPATIAL TECHNOLOGIES

By integrating environmental and safety spatial data layers with habitat connectivity models and other authoritative datasets, transportation agencies and stakeholders can strategically site ungulate passage projects. This approach enhances both habitat connectivity and public safety.

- **Data-Driven Passage Siting Approaches:** Planning relies on spatial technologies, including habitat connectivity models, to identify priority areas.
- **Collaboration:** Agencies and stakeholders play a key role in ensuring passage projects meet ecological and safety goals.
- **Integrated Data Sources:** Combining diverse datasets strengthens siting decisions and supports long-term ecological outcomes.

6.6 DECISION-SUPPORT TOOL AND MAPS

The decision-support tool and corresponding maps produced by the ODECPP identified 133 Top 1% Priority Mileposts (TPMs) and 81 Priority Highway Segments (PHSs) for ungulate passage project consideration. These areas were evaluated based on various factors influencing ungulate movement behavior at highways, with a specific focus on Oregon's deer and elk species due to their ecological and economic importance and vehicle-collision risk. Passage projects in the priority areas identified could provide enhanced connectivity for a variety of Oregon's native wildlife as a majority of TPMs and PHSs are located within 1.5 km (0.93 mi) of a PWCA hexagon.

- **Evaluation Factors:** Multiple environmental and safety factors were applied to the matrix to help determine priority areas for passage project placement on seven of Oregon's highways, with a focus on deer and elk.
- **Priority Area Identification:** 133 Top 1% Priority Mileposts (TMPs) contained within 81 Priority Highway Segments (PHSs) were highlighted for ungulate passage project consideration across the seven ODOT Highways of Analysis Interest.
- **Connectivity for Native Wildlife:** A majority of the TPMs and PHSs identified during analysis are within 1.5 km (0.93 mi) of a PWCA hexagon, potentially offering connectivity for a variety of Oregon's native wildlife species if a project is planned in one of these locations.

6.7 RECOMMENDATIONS

The following recommendations were identified to help guide future phases of the ODECPP and support statewide efforts to improve wildlife passage planning. These actions emphasize site-level feasibility, data enhancement, modeling refinement, long-term monitoring, and collaborative implementation, each contributing to more effective and adaptive mitigation strategies across Oregon's transportation network.

- **Site Feasibility:** Assess physical and logistical constraints at Top 1% Priority Mileposts and Priority Highway Segments to determine appropriate mitigation strategies.
- **Alternative Mitigation:** Identify traffic safety tools such as RADS for use where crossing structures are not feasible.
- **Data Improvements:** Expand spatial and population data for western Oregon ungulates and improve species-specific WVC reporting.
- **Wildlife Vehicle-Collision Risk Modeling:** Develop localized models using advanced techniques to better understand factors driving WVCs.
- **Monitoring:** Implement long-term monitoring using AI tools and connectivity assessments to evaluate project effectiveness.
- **Consortium Development:** Establish a statewide wildlife passage consortium to support collaboration, funding, and implementation.

The Oregon Deer and Elk Crossing Prioritization Project (ODECPP) provides a replicable, data-driven framework for identifying highway segments with elevated ungulate-vehicle collision risk and potential for improved habitat connectivity. By integrating spatial technologies, authoritative environmental datasets, and committee-informed weighting methods, the project highlights areas

where targeted mitigation efforts may offer both public safety and ecological benefits. The inclusion of climate resilience and connectivity modeling supports long-term planning, though further refinement and validation are needed to address regional data gaps and evolving landscape conditions. Continued development of decision-support tools like the ODECPP will help guide transportation infrastructure investments that balance safety and sustainability across Oregon's highways.

7.0 REFERENCES

Bissonette, J. A., & Kassar, C. A. (2008). Locations of deer-vehicle collisions are unrelated to traffic volume or posted speed limit. *Human–Wildlife Conflicts, 2*, 122.

Bliss-Ketchum, L., & Parker, C. (2015). *Lava Butte wildlife crossing monitoring project: Final report*. Portland State University.

Bradford, J. B., et al. (2019). Climate-driven shifts in soil temperature and moisture regimes suggest opportunities to enhance assessments of dryland resilience and resistance. *Frontiers in Ecology and Evolution, 7*, 358.

Cramer, P., et al. (2022). *The strategic integration of wildlife migration into transportation procedures: A manual for agencies and partners* (Nevada DOT Research Report No. 700-18-803).

Cowin, C. (2013). *Deer and elk winter range for eastern Oregon*. Oregon Department of Fish & Wildlife Data Clearinghouse. https://nrimp.dfw.state.or.us/DataClearinghouse/default.aspx?p=202&XMLname=885.xml

Cutcher-Gershenfeld, J., et al. (2025). Consortia and global challenges. In J. Cutcher-Gershenfeld et al. (Eds.), *The consortia century* (Vol. 7).

Denneboom, D., Bar-Massada, A., & Shwartz, A. (2024). Wildlife mortality risk posed by high and low traffic roads. *Conservation Biology, 38*, e14159.

Donaldson, B. M. (2017). *Improving animal-vehicle collision data for strategic mitigation* (Virginia DOT Research Report No. FWA/VTRC 18-R1C).

Environmental Research Systems Institute (Esri). (2024). *ArcGIS Pro* (Version 3.4.0).

Elsevier. (2025). *Authoritative source*. ScienceDirect. https://www.sciencedirect.com/topics/computer-science/authoritative-source

Gagnon, J. W., et al. (2011). Factors associated with use of wildlife underpasses and importance of long-term monitoring. *Journal of Wildlife Management, 75*, 1477.

Gagnon, J. W., et al. (2019). Animal-activated highway crosswalk: Long-term impact on elk-vehicle collisions, vehicle speeds, and motorist braking response. *Human Dimensions of Wildlife, 24*, 132.

Grace, M. K., Smith, D. J., & Noss, R. F. (2017). Reducing the threat of wildlife-vehicle collisions during peak tourism periods using a roadside animal detection system. *Accident Analysis and Prevention, 109*.

Ha, H., & Shilling, F. (2018). Modelling potential wildlife-vehicle collision locations using environmental factors and human population density. *Ecological Informatics, 43*, 212.

Human and Ecosystem Resilience and Sustainability (HERS) Lab. (2023). *Analysis of priority wildlife connectivity areas*.

Human and Ecosystem Resilience and Sustainability (HERS) Lab. (2024). *Analysis of ODOT animal crash data*.

Huijser, M. P., et al. (2006). *Animal vehicle crash mitigation using advanced technology* (Report SPR-3(076), Western Transportation Institute).

Huijser, M. P., et al. (2015). Wildlife warning signs and animal detection systems aimed at reducing wildlife-vehicle collisions. In R. van der Ree et al. (Eds.), *Handbook of Road Ecology* (p. 198).

Huijser, M. P., et al. (2016). Effectiveness of short sections of wildlife fencing and crossing structures along highways. *Biological Conservation, 197*, 61.

Inman, R. D., et al. (2024). Estimating traffic volume and road age in Wyoming to inform resource management planning. *Ecological Indicators, 166*, 112410.

Kauffman, M., et al. (2024). *Ungulate migrations of the western United States* (USGS SIR 2024-5006).

Kauffman, M., et al. (2025). *Ungulate migrations of the western United States* (USGS SIR 2024–5111).

Keeley, A. T. H., et al. (2018). New concepts, models, and assessments of climate-wise connectivity. *Environmental Research Letters, 13*, 073002.

Kintsch, J., et al. (2019). *Western Slope wildlife prioritization study* (CDOT Report CDOT-2019-01).

Kintsch, J., et al. (2022). *Eastern Slope and Plains wildlife prioritization study* (CDOT Report CDOT-2022-03).

Knapp, K. K., et al. (2007). Crash or carcass data: Critical definition and evaluation choice. *Transportation Research Record, 2019*, 189.

Littlefield, C. E., et al. (2024). Evaluating and elevating the role of wildlife road crossings.

Mayer, A. L., et al. (2016). How landscape ecology informs global land-change science and policy. *BioScience, 66*, 458.

ODFW, Oregon Department of Fish and Wildlife. (2013). *Deer and elk winter range for eastern Oregon*.

ODFW, Oregon Department of Fish and Wildlife. (2023a). *Oregon connectivity assessment and mapping project: Technical report*.

ODFW, Oregon Department of Fish and Wildlife. (2023b). *Priority wildlife connectivity area highway overlap – ungulate species*.

ODFW, Oregon Department of Fish and Wildlife. (2023c). *Roadkill salvage permits*. https://myodfw.com/articles/roadkill-salvage-permits

ODFW, Oregon Department of Fish and Wildlife. (2024a, October 16). *Watch for wildlife: Vehicle collisions with deer, elk, peak this time of year*. https://www.dfw.state.or.us/news/2024/10_Oct/101624.asp

ODFW, Oregon Department of Fish and Wildlife. (2024b). *Mule deer herd movement data* [Provisional; not public].

ODOT, Oregon Department of Transportation. (2024). *Wildlife crossing HB 2834 legislative report*.

ORS, Oregon Revised Statutes § 496.272 (2019).

Olson, D. D. (2013). *Assessing vehicle-related mortality of mule deer in Utah* (Doctoral dissertation, Utah State University).

Padilla, B. J. (2025, January 8). *Virtual meeting*.

R Core Team. (2024). *R: A language and environment for statistical computing*.

Romin, L. A., & Bissonette, J. A. (1996). Deer-vehicle collisions. *Wildlife Society Bulletin, 24*, 276.

Saaty, R. W. (1987). The analytic hierarchy process – What it is and how it is used. *Mathematical Modelling, 9*, 161.

ScienceDirect. (2025). *Authoritative source*. https://www.sciencedirect.com/topics/computer-science/authoritative-source

Shilling, F. M., & Waetjen, D. P. (2015). Wildlife-vehicle collision hotspots. *Nature Conservation, 11*, 41.

Soanes, K., et al. (2024). Do wildlife crossing structures mitigate the barrier effect of roads? *Journal of Applied Ecology, 61*, 417.

Stio, E., & Christian, L. (2024). *State of the states: Trends and insights report*. Wildlands Network & NCEL.

Thompson, J., Moser, B., & Starcevich, L. A. (2018). *Lava Butte wildlife crossing effectiveness: Final report*. Western EcoSystems Technology, Inc.

U.S. Department of the Interior. (2018). *Order on wildlife conservation* (Secretarial Order No. 3362).

van de Kerk, M., et al. (2021). Variation in movement patterns of mule deer. *Movement Ecology, 9*, 1.

van der Ree, R., et al. (2015). Good science and experimentation are needed in road ecology. In *Handbook of Road Ecology* (p. 71).

Washington Department of Transportation. (2023). *WSDOT aims to increase habitat connectivity and decrease wildlife-vehicle collisions*. https://wsdot.wa.gov/about/data/gray-notebook/gnbhome/environment/wildlifehabitatconnectivity/default.htm

Wickham, H., et al. (2019). Welcome to the tidyverse. *Journal of Open Source Software, 4*, 1686.

Yang, X., et al. (2019). Comparative analysis of animal-vehicle collision and carcass data. *Journal of Advanced Transportation, 2019*, 1.

DIGITAL APPENDICES:

The following appendices have been published alongside the report as supplementary documents. If the distributor you have acquired this report from did not include them, please find them at the ODOT statewide research website or contact ODOTNewResearch@ODOT.Oregon.gov

APPENDIX A. *OREGON DEER AND ELK CROSSING PRIORITIZATION PROJECT (ODECPP) MAP PRODUCTS*
APPENDIX B. *OREGON DEER AND ELK PRIORITIZATION PROJECT (ODECPP) TECHNICAL ADVISORY COMMITTEE (TAC) MEMBERS AND AFFILIATION*
APPENDIX C. *DETAILED MATRIX FACTOR DESCRIPTIONS*
APPENDIX D. *ANALYTIC HIERARCHY PROCESS*
APPENDIX E. *OREGON DEER AND ELK CROSSING PRIORITIZATION PROJECT (ODECPP) ODOT HIGHWAYS OF ANALYSIS INTEREST (OHAI) PRIORITY WILDLIFE CONNECTIVITY AREA (PWCA) HEXAGON ANALYSIS*
APPENDIX F. *OREGON DEER AND ELK CROSSING PRIORITIZATION PROJECT (ODECPP) AND OREGON CONNECTIVITY ASSESSMENT AND MAPPING PROJECT (OCAMP) DATA COMPARISON*
APPENDIX G. *TOP 1% PRIORITY MILEPOST (TPM) SCORES*
APPENDIX H. *FREQUENTLY ASKED QUESTIONS (FAQ)*
APPENDIX I. *ANNOTATED BIBLIOGRAPHY*
APPENDIX J. *REGIONAL ANALYSIS OF PRIORITY HIGHWAY SEGMENTS (PHSS)*
APPENDIX K. *OREGON DEER AND ELK CROSSING PRIORITIZATION PROJECT (ODECPP) FECAL DNA ANALYSIS*