State Route 154 Wildlife Crossing Opportunities: An Assessment of Existing Road Infrastructure



Prepared by Los Padres ForestWatch

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INTRODUCTION

Los Padres ForestWatch is a nonprofit organization working to protect wildlife and ecosystems in the Los Padres National Forest and surrounding public lands along California's Central Coast. Wildlife depends on connections between the forest and surrounding landscapes, but highways and development increasingly block these movement routes. Maintaining these connections is essential to the long-term survival of wildlife populations.

This report presents the results of a field survey of existing structures along State Route 154 in Santa Barbara County that wildlife may use to cross the highway, including culverts, bridges, and underpasses. Between July and September 2026, ForestWatch inventoried these structures and evaluated how well each one is likely to function as a wildlife crossing.

The goals of this report are to provide agencies, local governments, landowners, and conservation partners with a baseline inventory of potential wildlife crossings, help identify crossings worth protecting and opportunities for improvement, and support planning for safer wildlife movement along the corridor.

PROJECT BACKGROUND

Roads are among the most significant barriers to wildlife movement in Santa Barbara County. Mountain lions, bobcats, deer, coyotes, and many smaller animals have to cross highways to reach food, water, mates, and refuge from fire and drought, and many are killed trying. Where safe passage exists, it is usually by accident: culverts, bridges, and underpasses built to carry water or traffic that animals have learned to use.

California's Room to Roam Act (AB 1889, signed in September 2024) requires cities and counties to address wildlife connectivity in the conservation element of their general plans. At the state transportation level, SB 1250 (signed in September 2026) further directs Caltrans to consider wildlife connectivity in the planning of transportation projects. Fine-scale field information, such as the crossing-level data presented in this report, will be necessary to guide these planning processes and future connectivity-improvement efforts along SR 154.

The sections that follow describe the project setting, survey methods, scoring framework, findings, profiles of the highest-scoring crossings, and recommended next steps.

PROJECT SETTING

State Route 154 (SR 154) is a 32-mile highway in Santa Barbara County that connects Santa Barbara to the Santa Ynez Valley through the San Marcos Pass in the Santa Ynez Mountains.

Additionally, the highway provides a scenic bypass for many commuters, with much of Santa Ynez Valley's rural character still intact.

The highway traverses a landscape characterized by extensive open space, chaparral, oak woodland, riparian habitat, and other natural communities that support a diverse assemblage of wildlife. As a result, the corridor plays an important role in maintaining ecological connectivity between the Santa Ynez Mountains, the Los Padres National Forest, and surrounding habitats.

Despite this ecological importance, the California Department of Fish and Wildlife (CDFW) has identified SR 154 as a barrier to wildlife movement, as it bisects a linkage connecting the Santa Ynez Mountains to a larger section of the Los Padres National Forest through the Cachuma Lake Recreation Area (CDFW, n.d.). Recent studies have also identified portions of SR 154 as hotspots for wildlife-vehicle collisions (WVCs), further increasing the urgency for data on wildlife crossings along the highway (UC Davis Road Ecology Center, 2023).



Figure 1: SR 154 in Santa Barbara County

PROJECT OBJECTIVES

The objective of the Project is to inventory existing infrastructure along SR 154 that may facilitate wildlife movement beneath, alongside, or across the highway, and to evaluate each structure's suitability as a wildlife crossing. In addition to documenting structural characteristics, the Project characterized the environmental conditions that may influence

wildlife use and assessed each structure using a standardized field survey and a scoring framework, the Connectivity Score.

While multiple structure types were included in this assessment, the primary emphasis was placed on culverts and Caltrans drainage infrastructure. Larger structures such as bridges and underpasses are relatively uncommon along SR 154 and are generally easier to identify and characterize, whereas culverts represent the most abundant crossing opportunity available to wildlife throughout the corridor.

METHODS

Survey Development and Design

Prior to initiating field surveys, ForestWatch obtained Caltrans infrastructure records through a California Public Records Act request. These records included GIS datasets documenting culvert locations and associated drainage infrastructure throughout Santa Barbara County. Among the datasets provided were point features representing culvert inlet and outlet locations or culvert openings, as well as line features representing culvert alignments and drainage features.

These GIS datasets served as the foundation for survey development and field planning. Using ArcGIS Online and Survey123, a standardized survey was designed to document structural characteristics, environmental conditions, movement constraints, and other attributes relevant to evaluating wildlife crossing suitability at crossing openings. These openings act as entry points to Caltrans infrastructure; therefore, survey designs were developed around collecting data along these openings. The digital survey format allowed for consistent data collection while streamlining data management and quality control throughout the Project.

Crossing Definition

In this Project, a “crossing” is defined as any human-made structure that may facilitate wildlife movement beneath, alongside, or across a highway or road. This definition specifically refers to culverts, underpasses, and bridges. Every crossing consists of openings on either side that provide access to that structure.

This use of the term differs from other conventional definitions of wildlife crossings, which generally refer to infrastructure specifically designed to facilitate wildlife movement, such as wildlife overpasses or green bridges. The structures assessed during this Project were not originally constructed for wildlife connectivity purposes and instead primarily serve transportation or drainage functions. Nevertheless, many of these structures may provide incidental opportunities for wildlife passage and therefore represent potential connectivity features within the corridor.

Structure Selection Criteria

Caltrans records identified more than 700 culvert openings along SR 154. Surveying every crossing structure and associated openings was not feasible within the scope and timeline of this Project. As a result, minimum dimensional thresholds were established to prioritize structures most likely to provide meaningful wildlife passage opportunities.

Round culverts were required to have a minimum diameter of three feet, while box and arch culverts were required to have a minimum width of four feet. These thresholds were selected to maintain a manageable survey workload while prioritizing structures with greater potential value for wildlife usage.

The selection criteria for structures surveyed are consistent with research in road ecology pertaining to wildlife usage of road infrastructure. Research has consistently demonstrated that larger crossing dimensions and higher openness are associated with increased use by medium- and large-sized wildlife species (Arizona Game and Fish Department, 2006). While smaller culverts may still provide passage opportunities for reptiles, amphibians, and small mammals, this Project focused on structures most likely to facilitate movement across a wider range of species (Chen et al., 2021).

Underpass and bridge locations, which were not included in the culvert GIS package, were obtained from the publicly available Caltrans statewide bridge GIS dataset (Caltrans, 2024). Bridge and underpass features and their associated attribute data were added to the crossing dataset by ForestWatch prior to field surveys.

Field Data Collection

Field surveys were conducted between July and September 2026. A team consisting of a ForestWatch staff member and a student intern (Surveyors) visited potential crossing locations identified through Caltrans GIS datasets and documented a variety of structural and environmental characteristics at each opening on either side of every crossing. Data collected included structure type, dimensions, substrate composition, vegetation density, visibility through the structure, noise level, presence of riparian habitat, evidence of barriers, adjacent land-use, and general site observations.

Data collection equipment included mobile phones equipped with Survey123, handheld measuring equipment, personal protective equipment (PPE), and a commercial drone for aerial imagery. Survey sheets were also printed to create a physical record for each opening, as well as being the primary recording choice when Surveyors were outside of cellular range. For measuring noise activity, Surveyors used the *NIOSH Sound Level Meter* mobile app to provide a rapid assessment of noise level activity at each opening.

Safety considerations were an important component of field observations due to the wide variety of terrain and environmental conditions encountered along this corridor. Surveyors frequently worked in steep terrain, dense vegetation, active road work, and areas adjacent to roadways with limited shoulder space.



Figure 2: Surveyor assessing culvert conditions

Whenever feasible, both openings were visited in person to document environmental conditions and evaluate the crossing's overall suitability for wildlife usage. Visual conditions were also recorded by collecting photographs of opening conditions and surrounding areas. If in-person surveys were not possible, either due to safety considerations or openings being located on private property, Surveyors would deploy the

drone to collect remote data and aerial imagery. Crossing characteristics were supplemented through Caltrans infrastructure records.

For a list of all data fields collected, please refer to Appendix A for detailed descriptions of the data and data values collected during field surveys.

Data Management and Control

All survey data was collected and managed through ArcGIS Online and Survey123. Digital data collection reduced transcription errors and allowed information to be synchronized directly with the Project database. Simultaneously, data was physically recorded on printed survey sheets, creating a paper copy of the dataset. All data collected on survey sheets was uploaded to a spreadsheet and used for reviewing data.

Following fieldwork, records were reviewed for completeness, consistency, and accuracy. Digital records were cross-referenced to the physical dataset to flag any data discrepancies. Photographs, field notes, and spatial data were used to resolve discrepancies and ensure that opening attributes were accurately represented within the final inventory.

The resulting dataset provides a standardized inventory of crossing structures along SR 154 and serves as a foundation for the analyses and recommendations presented in this report.

Connectivity Score

Decades of research in road ecology have identified a number of structural and environmental characteristics that influence whether wildlife will use or avoid transportation structures as crossings (Arizona Game and Fish Department, 2006; Brudin, 2003; Environmental Policy Innovation Center et al., 2026). Although the specific requirements of wildlife species vary considerably, several key principles consistently emerge in the scientific literature and are widely used to guide wildlife crossing planning and evaluation.

1. Size/Openness: Crossing size must accommodate the size of the animal in question; many studies use the following formula: *Openness Ratio = (Crossing Height x Crossing Width)/Crossing Length*. For medium and large wildlife, a higher Openness Ratio is preferred, meaning wider, taller crossings with a shorter length between openings (Arizona Game and Fish Department, 2006).

2. Natural Substrate: Natural substrate is preferred by wildlife, which can include stream bed material, natural ground, sand, and fine aggregate. Materials that may deter wildlife include plastic, concrete, and metal (Environmental Policy Innovation

Center *et al*., 2026).

3. Visibility & Field of View: Some species of wildlife, such as deer, prefer crossings with visibility of suitable habitat on the other side of the crossing (Brudin, 2003). Visibility through the crossing is achieved when there are no obstructions on the openings, culverts are straight and do not bend in direction, and crossing lengths are shorter as long crossings can create dark spots.

4. Vegetation: While vegetation needs vary by species and trophic roles, large- and medium-sized wildlife will generally prefer higher natural vegetation along a crossing's approach that will provide necessary cover as they traverse towards the opening (Arizona Game and Fish Department, 2006).

5. Suitable Habitat: Crossings should have suitable habitat on both ends and should preferably be located along known movement corridors (Arizona Game and Fish Department, 2006).

6. Stream Considerations: For crossings with creeks or streams, it's recommended that the structure extends past the width of the creek to allow dry strips for traversing or adding dry banks along the length of the crossing so as to allow passage to wildlife that would otherwise avoid deep water (Environmental Policy Innovation Center *et al*., 2026).

Using these principles to guide data analysis, ForestWatch developed a scoring framework referred to as the *Connectivity Score.* The Connectivity Score is intended to function as a rapid assessment tool for comparing inventoried features rather than a direct measure of wildlife use. Openings receiving higher scores possess characteristics generally associated with successful wildlife crossings, while lower-scoring openings exhibit conditions that may restrict movement or reduce crossing suitability.

The score was calculated using the following equation:

Connectivity Score = Openness Score + Ecological Integrity Score + Barrier Score

Where:

- **Openness Score** incorporates the Openness Ratio determined by structural dimensions.
- **Ecological Integrity Score** incorporates substrate conditions, entrance obscurity, vegetation cover, and visibility through the crossing.
- **Barrier Score** accounts for the presence of physical barriers that may impede wildlife access to crossing openings.

Individual openings are graded using this scoring framework to receive a Connectivity Score ranging from 0 to 16, with higher values indicating greater potential suitability for wildlife usage.

Crossing structures are then graded by averaging the mean of both openings' Connectivity Scores to get the resulting *Structure Connectivity Score*, where:

Structure Connectivity Score = (Opening A Connectivity Score + Opening B Connectivity Score)/2

Crossing structures and their associated openings are all assigned a Connectivity Class, which provides a simplified categorical interpretation of the Connectivity Score for all features. Features are assigned to one of four categories: Low, Medium, High, or Very High. These classes are derived directly from the calculated Connectivity Scores and are intended to facilitate interpretation, mapping, and prioritization.

This scoring rubric and the relative weight assigned to each component reflect assumptions informed by general road ecology principles rather than empirically derived values; future planning projects should therefore refine these criteria based on the species-specific requirements of target wildlife.

Additionally, because the Structure Connectivity Score is a mean, it may not reflect differences between openings. A structure with one high-scoring and one low-scoring opening can receive the same score as a structure with two moderately scoring openings, although the two likely function differently for wildlife. To account for this, individual opening scores are retained in the Project's GIS layers, where each opening is represented as a separate feature in the SR154_Endpoints layer and both opening scores are recorded for each structure in the SR154_Crossings layer.

A detailed breakdown of scoring criteria and point assignment is provided in Appendix B.

FINDINGS AND DISCUSSIONS

Distribution of Openings

A total of 194 openings to crossing structures were assessed throughout the duration of the Project. Of these openings, 86 were categorized as "not_surveyed" and were excluded from subsequent analyses.

Openings received a "not_surveyed" designation for one or more of the following reasons:

1. Opening locations were identified through Caltrans layers, but no openings were located or verified in the field.
2. Dense vegetation prevented effective evaluation through aerial surveys, limiting the ability to confirm opening characteristics.

3. An opening was verified through the survey process, but the structure was determined to be unsuitable for wildlife movement and therefore does not function as a crossing access point (e.g., small grated drainage inlets, vertical pipe drainage features, etc.).

These openings were categorized into a separate ArcGIS layer and were removed from subsequent analyses and thus did not receive a Connectivity Score.

Openings surveyed break down by structure type as follows:

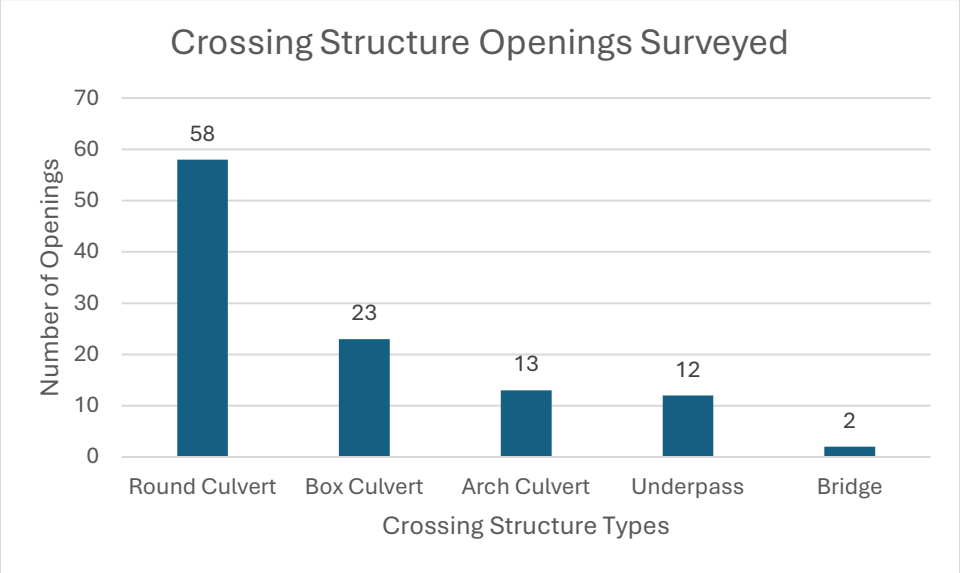


Figure 3: Bar graph of crossing structure openings assessed

Number of Crossings

A total of 47 crossings were identified and inventoried following completion of field surveys and data analyses. To be included in the final inventory, a crossing was required to have both openings surveyed and evaluated using the Connectivity Score framework. Crossings for which one or both openings could not be assessed were excluded from the inventory and subsequent analyses. This approach ensured that all reported scores were derived from complete datasets and that conclusions were based only on fully evaluated crossing structures.

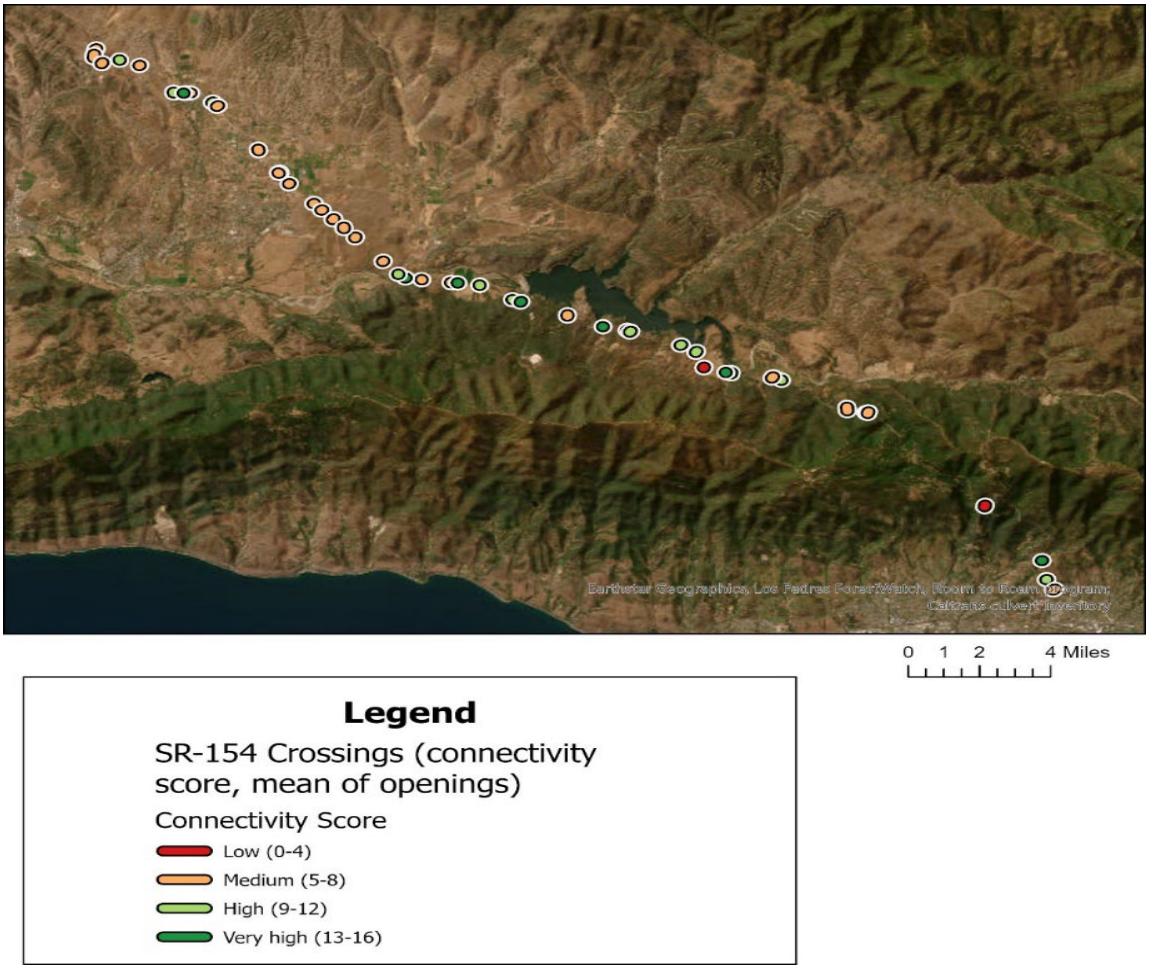


Figure 4: Crossing structures distributed along SR 154

High-Scoring Crossings

The following section highlights a subset of crossings that represent the best crossing opportunities in the Project Area. These crossings were selected because they possess characteristics commonly associated with effective wildlife usage. Each crossing profile includes a brief assessment of existing conditions, factors contributing to the crossing's score, and recommendations for potential improvements that could further enhance functionality for wildlife.

CUL_15.54

Structure ID	Opening A	Opening A Score	Opening B	Opening B Score	Structure Connectivity Score (Mean Score)
CUL_15.54	CUL_15.54_N	16	CUL_15.54_S	14	15

Figure 5: Scoring table for CUL_15.54

This crossing received one of the highest Connectivity Scores possible within the inventory and exemplifies many of the characteristics generally considered favorable for wildlife movement. The crossing's large dimensions, combined with a relatively short structure length, produce a high Openness Ratio, indicating a highly accessible crossing environment that is likely suitable for a wide range of sizes of wildlife species.

Along both openings, visibility conditions are excellent, with no obstructions blocking either side and maintaining a clear line of sight through the crossing structure. Dense vegetation surrounding the approach on both sides provides cover for wildlife entering the crossing. The substrate is generally natural throughout the crossing, though the structure's concrete bottom is exposed along the south-facing opening, potentially discouraging usage of the crossing for some wildlife.

Recommendations: Although the crossing offers excellent overall passage conditions, standing water or saturated substrate may discourage use by some terrestrial species. Installation of dry passage shelves or raised ledges along the margins of the crossing could improve accessibility for terrestrial wildlife while maintaining the structure's primary drainage function (Environmental Policy Innovation Center *et al*., 2026).



Figure 6: CUL_15.54_S or south aspect view

UND_2.55

Structure ID	Opening A	Opening A Score	Opening B	Opening B Score	Structure Connectivity Score (Mean Score)
UND_2.55	UND_2.55_N	15	UND_2.55_S	15	15

Figure 7: Scoring table for UND_2.55

This crossing received one of the highest scores due to its favorable structural and environmental characteristics along both openings. The crossing's substantial width and height, coupled with its relatively short length, result in a high Openness Ratio. This is readily apparent in the field, where the open span beneath the bridge provides an expansive field of view and allows wildlife to maintain visual contact with habitat on the opposite side.

The crossing benefits from unobstructed openings and complete visibility through the structure, both factors commonly associated with increased wildlife usage. Dense vegetation near the approaches provides cover for wildlife, while the natural substrate creates suitable crossing conditions for a variety of species. The absence of barriers further enhances the accessibility and allows wildlife to enter and exit the crossing without being impaired.

Recommendations: Vegetation levels were appropriate at the time of the survey; however, riparian vegetation can rapidly change and eventually obscure portions of the crossing if left unmanaged. Periodic vegetation monitoring and clearing may help maintain visibility and accessibility (Arizona Game and Fish Department, 2006). Additionally, because this crossing is within a more developed and residential landscape, future studies could evaluate how the crossing contributes to wildlife movement at a broader landscape scale and assess its relationship to nearby habitat linkages and movement corridors.



Figure 8: UND_2.55_N or north aspect view

CUL_13.23

Structure ID	Opening A	Opening A Score	Opening B	Opening B Score	Structure Connectivity Score (Mean Score)
CUL_13.23	CUL_13.23_N	13	CUL_13.23_S	14	13.5

Figure 9: Scoring table for CUL_13.23

This crossing received a high Connectivity Score due to structural and environmental conditions that are highly conducive to wildlife crossing usage. The wide openings and tall arch height make the crossing accessible to a variety of medium- and large-bodied species. However, its greater length results in a lower Openness Ratio than some of the highest-scoring crossings. This is evident in the field, as visibility is maintained between both openings, though the extended crossing distance creates areas of complete darkness that may discourage use by some species.

Additional factors contributing to the high score include the absence of obstructions at either opening, substantial vegetation cover along the approaches on both ends, and a lack of barriers that would impede access to this crossing.

Recommendations: Road ecology literature suggests that introducing natural light into particularly long culverts can improve crossing conditions for wildlife. One potential approach could be the installation of grated openings above the culvert, which would allow natural light to enter the structure while also maintaining drainage functionality (Arizona Game and Fish Department, 2006). Substrate conditions could also be improved through the installation of baffles along the bottom of the culvert. Baffles encourage the accumulation of sediment over time, creating more natural substrate conditions preferred by wildlife while maintaining the culvert's drainage functionalities (Environmental Policy Innovation Center *et al*., 2026).



Figure 10: CUL_13.23_N or north aspect view

CUL_13.02

Structure ID	Opening A	Opening A Score	Opening B	Opening B Score	Structure Connectivity Score (Mean Score)
CUL_13.02	CUL_13.02_N	10	CUL_13.02_S	11	10.5

Figure 11: Scoring table for CUL_13.02



Figure 12: CUL_13.02_N or north aspect view

This crossing received a relatively high Connectivity Score, though it ranked notably lower than the highest-scoring crossings in this inventory. While the crossing dimensions are sufficient to accommodate medium-sized wildlife, its smaller diameter and relatively long length resulted in a lower Openness Ratio, reducing its suitability for larger species. Additionally, debris surrounding both openings partially obscures their view and limits visibility through the structure, factors that may further discourage wildlife use. The crossing also received a lower score due to the artificial substrate.

Recommendations: Selective vegetation management around both openings could reduce obstructive views and improve visibility through the crossing while maintaining sufficient cover for wildlife approaching the structure (Arizona Game and Fish Department, 2006). Substrate conditions could also be enhanced through the addition of packed soil or fine aggregate material, creating a more natural surface throughout the length of the crossing (Environmental Policy Innovation Center *et al*., 2026).

Complete datasets, including survey photographs, are available as KMZ data packages upon contacting ForestWatch.

Geography of Crossings

Caltrans' GIS datasets indicate that transportation and drainage infrastructure are distributed throughout the entire 32-mile length of SR 154. The placement of culverts and other drainage features generally reflects the hydrologic needs, flood-control requirements, topographic constraints, and construction considerations. Based solely on the distribution of infrastructure, one might expect wildlife crossing opportunities to be relatively evenly distributed throughout the corridor. However, results from this inventory suggest that crossing opportunities are not uniformly distributed across the highway.

Survey results indicate that the majority of identified crossing opportunities occur within the northern half of the SR 154 corridor, with both the number and average Connectivity Scores generally increasing north of Cold Spring Canyon Arch Bridge and toward the Lake Cachuma and Santa Ynez Valley regions. Crossings receiving higher Connectivity Scores were also more frequently concentrated within this portion of the highway.

One possible explanation for this pattern is the influence of topography on the types of infrastructure present along different sections of the highway. Beginning in Santa Barbara, SR 154 gains considerable elevation as it traverses the Santa Ynez Mountains through San Marcos Pass before descending into the Santa Ynez Valley. During field surveys, direct crossing structures such as box culverts and round culverts appeared to be less common throughout portions of the mountainous landscape. Instead, Surveyors frequently encountered infrastructure designed primarily for drainage purposes, including vertical drainage pipes and similar features. While these structures fulfill important hydrologic functions, they generally provide limited value as wildlife crossings due to their size, configuration, or lack of accessible openings for wildlife usage.



Figure 13: Example of a vertical drainage feature

Another potential explanation relates to differences in survey accessibility and data-collection conditions throughout the corridor. Relatively flat, open portions of the highway near Los Olivos and the Santa Ynez Valley provided safer and more efficient conditions for conducting field surveys. In contrast, sections south of the San Marcos Pass and portions adjacent to Lake Cachuma are characterized by steep slopes, dense vegetation, and rugged terrain. These conditions limited access to some structures and increased reliance on remote surveys using the drone.

Although drone-based surveys proved highly effective for documenting many entry points, their effectiveness was occasionally reduced by dense canopy cover, steep topography, and signal limitations. As a result, some openings located in the most challenging terrain may have been more difficult to identify and fully evaluate. Consequently, the geographic distribution observed in this inventory may reflect a combination of both actual differences in crossing availability and practical limitations with surveying complex terrain.

FUTURE PROJECTS

The results of this Project provide an important baseline inventory of structures that may provide wildlife crossing opportunities along the SR 154 corridor. While this assessment characterizes structural and environmental conditions associated with wildlife passage, additional research is needed to better understand how different species actively use these crossings.

One potential next step could be implementing a wildlife camera-trap study to assess wildlife use at high-scoring crossings in this inventory. Camera trapping would provide valuable information regarding species presence, crossing frequency, and ecological patterns, and could help guide site-specific improvement projects and management actions.

The survey design and methodology developed for this Project can also be replicated to evaluate transportation infrastructure along other identified wildlife barrier segments throughout California's Central Coast. While SR 154 has been identified by CDFW as a wildlife barrier, additional priority corridors include portions of State Routes 1, 166, and 246. Developing similar crossing inventories along these roadways would expand regional connectivity data and support broader wildlife conservation and transportation-planning efforts.

Data from this inventory can also strengthen landscape-scale connectivity analyses by showing where wildlife may be able to cross SR 154, rather than treating the highway as a uniform barrier. In turn, these analyses can help agencies and partner organizations prioritize crossings for protection and improvement, with structures located within modeled habitat linkages generally warranting higher priority. Priority sites could then be targeted for site-specific evaluations, restoration, re-wilding, and crossing enhancements such as vegetation management, barrier removal, wildlife-friendly fencing, or retrofitting existing structures.

Ultimately, the successful implementation of future wildlife connectivity initiatives will depend on continued collaboration among transportation agencies, conservation organizations, landowners, and other stakeholders. The inventory developed through this Project provides a foundation for those partnerships and establishes a framework for future planning efforts aimed at improving habitat connectivity and reducing wildlife-vehicle collisions along the SR 154 corridor.

Appendix A: Data Dictionary

Table A-1: SR154_Endpoints Layer

SR154_Endpoints layer displays surveyed crossing structure openings as point features. Data fields shared with other GIS layers are cross-referenced to this table.

Field Name	Field Label	Description	Possible Values
OBJECTID	OBJECTID	A unique, system-maintained sequential integer that identifies each feature in an ArcGIS dataset.	32-bit integer.
structure_id	Structure ID	A label identifying a crossing structure based on its structure type and postmile. Two or more entry points associated with the same crossing structure share a Structure ID.	Structure type (CUL, UND, or BRID) + postmile (e.g., CUL_15.54). Structures sharing a postmile receive a letter suffix (e.g., CUL_15.54A, CUL_15.54B), with "A" assigned to the northernmost or easternmost structure, dependent on highway orientation.
crossing_id	Crossing ID	A unique label identifying an individual opening. The ID indicates the structure type, postmile, and opening aspect.	Structure type (CUL, UND, or BRID) + postmile + opening aspect (e.g., CUL_15.54_N). Structures sharing a postmile receive a letter suffix (e.g., CUL_15.54A_N, CUL_15.54B_S), with "A" assigned to the northernmost or easternmost structure, dependent on highway orientation.
SYSNO	Caltrans SYSNO	A numbering system used by Caltrans to inventory culvert infrastructure. All openings associated with the same culvert system share this value.	Numeric value.
ETNO	Caltrans ETNO	A numeric identifier unique to each Caltrans opening. Combines the Caltrans SYSNO with an additional numbering sequence unique to the individual feature.	Numeric value.

Field Name	Field Label	Description	Possible Values
Postmile	Postmile	A location reference system used by Caltrans for state and federal highways to measure and track distances along a route.	Continuous numeric value.
crossing_type	Type of Crossing	The type of crossing structure or individual opening.	**box_culvert:** A culvert with a rectangular entrance. **round_culvert:** A culvert with a circular entrance. **arch_culvert:** A culvert with a semicircular entrance. **underpass:** A bridge underpass that passes beneath the highway. **bridge:** A bridge that passes over the highway. **mixed:** The crossing contains a combination of two different opening types.
Diameter	Diameter (ft)	The diameter (ft) of a circular or round crossing.	Numeric value (ft).
Width	Width (ft)	The width (ft) of a non-circular crossing.	Numeric value (ft).
Height	Height (ft)	The height (ft) of a non-circular crossing.	Numeric value (ft).
Length	Length (ft)	The length (ft) of a crossing, measured from one opening to the other.	Numeric value (ft).
substrate_type	Substrate Type	The composition of the substrate within the crossing where wildlife would travel.	**natural:** The substrate consists of natural materials, such as soil, vegetation, aggregate, or creek bed material. **artificial:** The substrate consists of artificial materials, such as concrete, plastic, or metal. **combination:** The substrate consists of a combination of natural and artificial materials.

Field Name	Field Label	Description	Possible Values
entrance_obscured	Entrance Obscured	The extent to which vegetation, debris, or other physical obstructions obscure the crossing's openings.	**yes:** Vegetation or debris completely or mostly obscures the entrance, significantly limiting visibility. **partial:** Vegetation or debris partially obscures the opening, limiting visibility from certain viewpoints. **no:** Entrance is not significantly obscured and is fully or mostly visible.
vegetation_cover	Vegetation Cover	The amount of vegetation cover available for wildlife within 50 ft of the crossing opening.	**high:** Dense vegetation cover is present. Scrub habitat is plentiful, with gaps that allow smaller wildlife to travel through, and tree cover provides shelter for larger wildlife. **medium:** Moderate vegetation cover is present. Scrub habitat is less dense, gaps between vegetation are wider, and some trees provide cover. **low:** Sparse vegetation cover is present. Few shrubs or trees provide limited cover, and the area surrounding the entrance is relatively exposed. **none:** No vegetation cover is available for wildlife to use. Opening approach is entirely exposed.
visibility_crossing	Visibility Through Crossing	Indicates whether the opposite opening is visible when looking through the crossing from the entrance.	**yes:** The opposite side of the crossing is entirely visible, with no obstructions in the middle or at the exit that limit visibility. **partial:** The opposite side of the crossing is partially visible, with some sunlight or habitat visible beyond the crossing. **no:** The opposite side of the crossing is not visible, potentially due to obstructions, crossing length, or a change in direction.

Field Name	Field Label	Description	Possible Values
noise_level	Noise Level	The noise level measured at the crossing opening.	Continuous numeric value, measured in decibels (dB).
crossing_notes	Crossing Notes	Additional notes about the crossing.	Any text value.
left_land_use forward_land_use right_land_use	Aspect Land Use	The dominant land use(s) surrounding the crossing opening, recorded from three aspects: Left, Forward, and Right.	**open_space:** Land use is dominated by open space or largely undeveloped land that is not used for crop production or cultivation. May include land primarily used for grazing. **agriculture:** Land use is dominated by agricultural activities, including row crops, orchards, and viticulture. **residential:** Land use is dominated by houses, apartments, and other infrastructure associated with residential development. **industrial:** Land use is dominated by industrial activities, including manufacturing, resource extraction, warehousing, and assembly. **commercial:** Land use is dominated by commercial activities and associated business infrastructure. May include outdoor recreation.
left_barriers_present forward_barriers_present right_barriers_present	Aspect Barriers	Indicates whether barriers that could impede wildlife movement are present within 50 ft of the opening. Observations are recorded from three aspects: Left, Forward, and Right.	**yes:** Barriers are present that could impede wildlife movement toward or through the crossing. **no:** No barriers are present that could impede wildlife movement toward or through the crossing.
left_notes forward_notes right_notes	Aspect Notes	Notes describing any barriers observed. Observations are recorded from three aspects: Left, Forward, and Right.	Any text value.

Field Name	Field Label	Description	Possible Values
riparian_present	Riparian Habitat Present?	Indicates whether riparian habitat or an inventoried creek or stream is present and traverses through the crossing.	**yes:** Riparian habitat or an inventoried creek or stream is present and traverses through the crossing. **no:** Riparian habitat or an inventoried creek or stream is not present. **unsure:** The presence of riparian habitat or an inventoried creek or stream could not be determined.
creek_width	Width of Creek	The width (ft) of the creek where it traverses through the crossing.	Numeric value (ft).
creek_name	Creek Name	The recorded or known name of the creek, if available.	Any text value.
survey_method	Survey Method	The method used to survey the opening.	**in_person:** The opening was surveyed in person, and Surveyors were able to physically access it. **drone:** The opening was surveyed remotely using a drone.
survey_status	Survey Status	Indicates whether the opening survey was completed based on accessibility and the possibility of drone surveying.	**completed:** The opening survey was completed. **not_surveyed:** The opening could not be surveyed, or a survey was completed but the feature was removed from the inventory.
survey_datetime	Date & Time of Survey	The date and time when the opening was surveyed.	Date and time in MM-DD-YYYY HH:MM format.
connectivity_score	Connectivity Score	A numerical score assigned to assess the structural and environmental conditions of an opening and its value for wildlife crossing connectivity.	Numeric score ranging from 0 to 16, with 0 representing the lowest score and 16 representing the highest score.

Field Name	Field Label	Description	Possible Values
connectivity_class	Connectivity Class	A categorical classification based on the Connectivity Score assigned to an opening. Non-whole numbers are rounded up.	**Low (0–4):** The opening has low value for wildlife crossing connectivity. **Medium (5–8):** The opening has moderate value for wildlife crossing connectivity. **High (9–12):** The opening has high value for wildlife crossing connectivity. **Very High (13–16):** The opening has very high value for wildlife crossing connectivity.
structure_connectivity_score	Structure Connectivity Score (mean of openings)	A crossing-level Connectivity Score calculated using the scores assigned to its two openings.	Numeric score ranging from 0 to 16, with 0 representing the lowest score and 16 representing the highest score.
GlobalID	GlobalID	A 36-character Esri-specific unique identifier automatically assigned to a feature.	36-character GUID string.

Table A-2: SR154_Crossings Layer

SR154_Crossings layer displays crossing structures as line features. Data fields shared with other GIS layers are cross-referenced to Table A-1. Fields unique to the layer are defined below.

Field Name	Field Label	Description	Possible Values
OBJECTID	OBJECTID	See *OBJECTID* in Table A-1.	See *OBJECTID* in Table A-1.
structure_id	Structure ID	See *Structure ID* in Table A-1.	See *Structure ID* in Table A-1.
SYSNO	Caltrans SYSNO	See *Caltrans SYSNO* in Table A-1.	See *Caltrans SYSNO* in Table A-1.
crossing_type	Type of Crossing	See *Type of Crossing* in Table A-1.	See *Type of Crossing* in Table A-1.
Postmile	Postmile	See *Postmile* in Table A-1.	See *Postmile* in Table A-1.
Diameter	Diameter (ft)	See *Diameter (ft)* in Table A-1.	See *Diameter (ft)* in Table A-1.
Width	Width (ft)	See *Width (ft)* in Table A-1.	See *Width (ft)* in Table A-1.
Height	Height (ft)	See *Height (ft)* in Table A-1.	See *Height (ft)* in Table A-1.
Length	Length (ft)	See *Length (ft)* in Table A-1.	See *Length (ft)* in Table A-1.

Field Name	Field Label	Description	Possible Values
endpoint_a	Opening A	Identifies the first of the two openings associated with a crossing structure.	Corresponds to the Crossing ID value of the associated opening in the SR154_Endpoints layer.
aspect_a	Opening A Aspect	Identifies the direction or aspect faced by Opening A.	**north:** Opening A faces north. **south:** Opening A faces south. **east:** Opening A faces east. **west:** Opening A faces west.
score_a	Opening A Score	The score assigned to Opening A representing its individual contribution to crossing connectivity.	Corresponds to the score assigned to the associated opening in the SR154_Endpoints layer.
endpoint_b	Opening B	Identifies the second of the two openings associated with a crossing structure.	Corresponds to the Crossing ID value of the associated opening in the SR154_Endpoints layer.
aspect_b	Opening B Aspect	Identifies the direction or aspect faced by Opening B.	**north:** Opening B faces north. **south:** Opening B faces south. **east:** Opening B faces east. **west:** Opening B faces west.
score_b	Opening B Score	The score assigned to Opening B representing its individual contribution to crossing connectivity.	Corresponds to the score assigned to the associated opening in the SR154_Endpoints layer.
connectivity_score	Connectivity Score	A crossing-level score derived from the mean of the scores assigned to Opening A and Opening B.	Corresponds to the Structure Connectivity Score in the SR154_Endpoints layer.
score_class	Connectivity Class	See *Connectivity Class* in Table A-1.	See *Connectivity Class* in Table A-1.
creek_name	Creek Name	See *Creek Name* in Table A-1.	See *Creek Name* in Table A-1.
riparian_present	Riparian Habitat Present?	See *Riparian Habitat Present?* in Table A-1.	See *Riparian Habitat Present?* in Table A-1.
survey_method	Survey Method	Identifies the method used to survey the crossing structure.	**in_person:** The crossing was surveyed in person. **drone:** The crossing was surveyed remotely using a drone. **mixed:** A combination of in-person and drone survey methods was used.
survey_date	Date & Time of Survey	See *Date & Time of Survey* in Table A-1.	See *Date & Time of Survey* in Table A-1.

Field Name	Field Label	Description	Possible Values
n_segments	Caltrans Segments Merged	The number of Caltrans map features merged to represent the crossing structure during the analysis.	Numeric value.
crossing_notes	Crossing Notes	Additional observations or information regarding the crossing structure and its associated entry points.	Corresponds to the Crossing Notes field in the SR154_Endpoints layer.
Shape__length	Shape__Length	An automatically generated value in an ArcGIS layer that records the geometric length of a line feature.	Numeric value.

Table A-3: SR154_Other_Openings Layer

SR154_Other_Openings layer displays openings and other point features that were removed from the analysis. Data fields shared with other GIS layers are cross-referenced to Table A-1. Fields unique to the layer are defined below.

Field Name	Field Label	Description	Possible Values
OBJECTID	OBJECTID	See *OBJECTID* in Table A-1.	See *OBJECTID* in Table A-1.
crossing_id	Crossing ID	See *Crossing ID* in Table A-1.	See *Crossing ID* in Table A-1.
SYSNO	Caltrans SYSNO	See *Caltrans SYSNO* in Table A-1.	See *Caltrans SYSNO* in Table A-1.
ETNO	Caltrans ETNO	See *Caltrans ETNO* in Table A-1.	See *Caltrans ETNO* in Table A-1.
Postmile	Postmile	See *Postmile* in Table A-1.	See *Postmile* in Table A-1.
crossing_type	Type of Crossing	See *Type of Crossing* in Table A-1.	See *Type of Crossing* in Table A-1.
crossing_aspect	Crossing Aspect	Identifies the direction or aspect associated with the crossing opening.	**north:** Opening faces north. **south:** Opening faces south. **east:** Opening faces east. **west:** Opening faces west.
survey_status	Survey Status	See *Survey Status* in Table A-1.	See *Survey Status* in Table A-1.
opening_status	Opening Status	Indicates whether neither or only one of the two openings associated with a crossing structure could be surveyed.	**Not surveyed:** Neither opening could be surveyed. **Partially surveyed:** Only one of the two openings could be surveyed.
survey_method	Survey Method	See *Survey Method* in Table A-1.	See *Survey Method* in Table A-1.
survey_datetime	Date & Time of Survey	See *Date & Time of Survey* in Table A-1.	See *Date & Time of Survey* in Table A-1.

Field Name	Field Label	Description	Possible Values
opening_score	Opening Score (single opening, not comparable to paired scores)	The Connectivity Score assigned to an individual opening associated with a crossing structure for which only one opening was surveyed. A structure-level mean score cannot be calculated.	Numeric score ranging from 0 to 16, with 0 representing the lowest score and 16 representing the highest score.
Diameter	Diameter (ft)	See *Diameter (ft)* in Table A-1.	See *Diameter (ft)* in Table A-1.
Width	Width (ft)	See *Width (ft)* in Table A-1.	See *Width (ft)* in Table A-1.
Height	Height (ft)	See *Height (ft)* in Table A-1.	See *Height (ft)* in Table A-1.
Length	Length (ft)	See *Length (ft)* in Table A-1.	See *Length (ft)* in Table A-1.
crossing_notes	Crossing Notes	See *Crossing Notes* in Table A-1.	See *Crossing Notes* in Table A-1.

Appendix B: Connectivity Score

Table B-1: Point Distribution for Connectivity Score

Category	Condition	Points
Openness Score	Openness Ratio is < 0.10	0
	Openness Ratio is 0.10 to < 0.25	1
	Openness Ratio is 0.25 to < 0.50	2
	Openness Ratio is ≥ 0.50	3
Substrate Type	artificial	0
	combination	1
	natural	2
Entrance Obscurity	yes	0
	partial	1
	no	3
Vegetation Cover	none or low	0
	medium	1
	high	2
Visibility Through Crossing	no	0
	partial	1
	yes	3
Barrier Conditions	Barriers on Three Sides	0
	Barriers on Two Sides	1
	Barriers on One Side	2
	No Barriers Present	3

Note: Entrance Obscurity and Visibility Through Crossing are weighted more heavily than other Ecological Integrity components (maximum of 3 points rather than 2), reflecting the importance of an unobstructed line of sight through crossing structures identified in road ecology literature. For these categories, an unobstructed condition receives 3 points rather than 2 to reflect this added weight.

Table B-2: Maximum Points per Formula Component

Formula Component	Maximum Points
Openness Score	3
Substrate Type	2
Entrance Obscurity	3
Vegetation Cover	2
Visibility Through Crossing	3
Barrier Conditions	3
Total Possible Score	16

Table B-3: Score Range and Connectivity Class

Score Range	Connectivity Class
0–4	Low
5–8	Medium
9–12	High
13–16	Very High

Appendix C: Literature Cited

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