CalPolyPomona

I-15 WILDLIFE CROSSING

CALIFORNIA MOUNTAIN LION

Cal Poly Pomona

Wildlife Crossings

Design for I-15

California Polytechnic State University, Pomona

Department of Civil Engineering

Senior Project 2018-19

Table of Contents

Lists of Figures

Lists of Tables

1. Introduction

A 7-mile stretch along the I-15 in the Temecula, CA region is being looked at in regards to its impact on mountain lion preservation. This area of urbanization serves as a main cutoff between two populations of mountain lions: one on the east side of the freeway, and one approximately 10 miles northwest of that population. Figure 1.1 shows the GPS collar tracking data of the two aforementioned mountain lions that are separated by the I-15. The yellow dots represent the movement of the mountain lions within their respective regions.

Winston Vickers from University of California, Davis, has been leading a team in the gathering of data regarding the Santa Ana Mountain Lion population. For the past 15 years, the population of mountain lions in the Santa Ana mountain regions and the Eastern Peninsula Mountains has been dwindling due to a variety of reasons. The Nature Conservancy, and other supporting Ecologists, believe that depredation permits, vehicle strikes, fires, and urbanization are some of the key factors that contribute to the unsuccessful reproduction rates found within these populations. After looking at the studies, along with evidence from the professionals, it was determined that the urbanization of the surrounding area was the most impactful towards the separation of the lions, as well as the greatest potential for improvement.

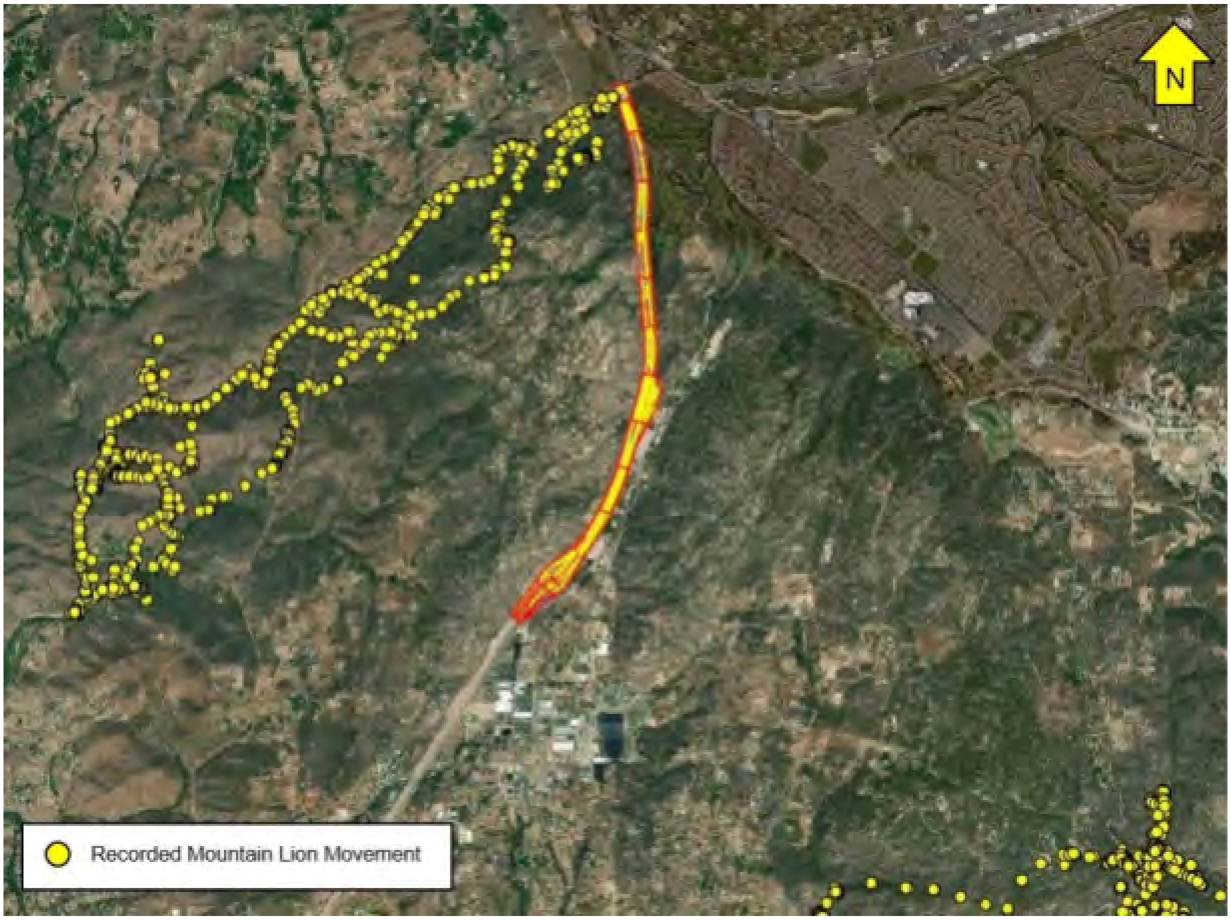


Figure 1.1. Recorded mountain lion movement through GPS collar data.

The urbanization within the city of Temecula, and the installation of Interstate 15, removes the connectivity within the species. The loss in connectivity has resulted in numerous issues such as inbreeding, vehicle to mountain lion strikes, and population isolation. Recent research conducted by UC Davis Wildlife Health Center and The Nature Conservancy, using several methods such as the use of trail cameras and global position system collars, has led to the creation of mountain lion movement corridors in the areas shown in Figure 1.1.

The main purpose of the Wildlife Crossing Design for I-15 was to find engineering solutions to promote mountain lion crossing utilizing the information provided by the biologists. The project was led by three civil engineering advisors at California Polytechnic State University, Pomona and a group of 16 civil engineering students. For the purpose of analyzing a wider range of options for solutions, the students were divided into three teams. The first team consisted of eight students that were tasked with analyzing the site to find the best location for the construction of an overpass and to design the most feasible wildlife bridge design. The second team, a group of four students, were similarly tasked with analyzing the site to find the best fit location and to design a feasible wildlife crossings culvert. And lastly, a group of four students were assigned with producing plans for improving the existing Temecula Creek Underpass. This paper will include the processes for which the locations of each passageway had been chosen, the processes for designing each passageway, and the final designs.

2. Background

The research on mountain lions in Southern California began approximately 20 years ago. Since then, a variety of organizations and concerned individuals have gotten involved with project, including the likes of California Department of Fish and Wildlife, San Diego County Association of Governments, The Nature Conservancy, California State Parks, and the Western Riverside County Regional Conservation Authority. For the duration of this project, which is focused in the Temecula area, the main points of contact for biologic or ecologic data has been through the University of California, Davis, The Nature Conservancy, and Caltrans. Professionals were also contacted in regards to an engineering approach to encourage the sustainability of the mountain lions. The organizations and the professionals have had experience with the installations and implementation of wildlife passageways in other regions.

University of California, Davis has been the leading authority in the study of these mountain lions. The methods used when studying these animals include attaching GPS Collars with satellite technology to them, baiting the mountain lions with road-killed deer, using cage traps, tracking skills, and images from trail cameras like the one shown in Figure 2.1. The data of movement corridors and habitats of the species were compiled by a team of collaborating professional researchers.

Figure 2.1. Trail Camera Image

Through the research led by Winston Vickers, it has been determined that the urbanization of the Temecula area has created extensive threats to mountain lions and their survival rates. Habitat loss and fragmentation of the animals has a variety of long-term, detrimental effects to the mountain lions and other native species. Mountain lion's nature requires that they have access to large territories to explore, hunt, and mate. This requirement has led to the need for crossing the I-15 for territory expansion. Most of the data collected of their attempts at crossing the I-15 show results of unsuccessful crossings, i.e. serious injury to or even death of mountain lions. In fact, just this past December, a mountain lion was struck by a car and died along the 7 mile stretch of the project scope. It is also hypothesised that the urbanization of the area traps the mountain lions during fires. After large fires, there have been dead mountain lions that have signs of trying to escape the fire, in example burnt paws, but are ultimately unsuccessful in trying to flee the disaster. The issuance of depredation permits also decreases the chance for survival of the animals. These permits authorize the killing of mountain lions that have trespassed onto private property. The increase in infrastructure has also led to population isolation. The isolation of mountain lion populations causes the mountain lions to inbreed, resulting in unhealthy offspring with low survival rates. This is called inbreeding depression, which means that the biological fitness of the population decreases with each generation. This continuous cycle of mountain lions being killed by vehicle strikes, fires, or inbreeding is a pertinent issue in the Temecula area. The biologists that have been working in the area believe that these issues may soon lead to extirpation, which means local extinction.

Since this discovery, more efforts have been directed towards the mountain lions to get a clearer understanding of how to help them. Researches at the University of California, Davis, have determined that there are certain highways that are 'hot spots' for animal fatalities.

Since the initiation of this effort in 2001, 88 pumas have been collared in the area and genetic data has been collected from 139 individual mountain lions. This conglomerate of information has allowed the professionals to more accurately explain the issue that the mountain lions face, as well as provide information that is easily understood by the public.

Since the research began, a few potential projects have been brought to attention. Some of these projects include wildlife designed fencing or the installation of a passageway. The wildlife fencing was created with the intention of being able to stop mountain lions from crossing. In order to accomplish this, the fencing was modified with an overhang to prevent the mountain lions from jumping as well as deep foundations with the intention of blocking the lions and other wildlife from digging under the barrier. According to Caltrans roadkill data, the installation of fencing for the SR 241 project resulted in an approximate 95% reduction in wildlife/vehicle strikes and deaths. The area went from hundreds of animals being killed by failed attempts to cross the roadway, to only two coyotes in a year. Figure 2.2 is a visual of the roadkill in the area before and after the installation of the fencing. The green dots represent the roadkill locations before the installation of the fencing and the red dots display the roadkill events after the installation of fencing. From this figure we can see that there are less red dots than green which demonstrate a decrease in roadkill after the installation of fencing.

Although fencing has proved effective in the past, it is best used to complement more comprehensive designs in preserving wildlife. In the case of the Santa Ana mountain lions, one of the most important goals of the project is to create a connection between the separated populations, therefore installing fencing alone may not be the best way to address the issue of inbreeding and lack of genetic diversity. A physical connection between the east and west side of the I-15 may be needed in order to effectively achieve this goal. Throughout the report, the alternative solutions and the logic behind each design will be discussed. These passageways are fit to address the issues of the mountain lions, as well as serve to help other wildlife in the area.

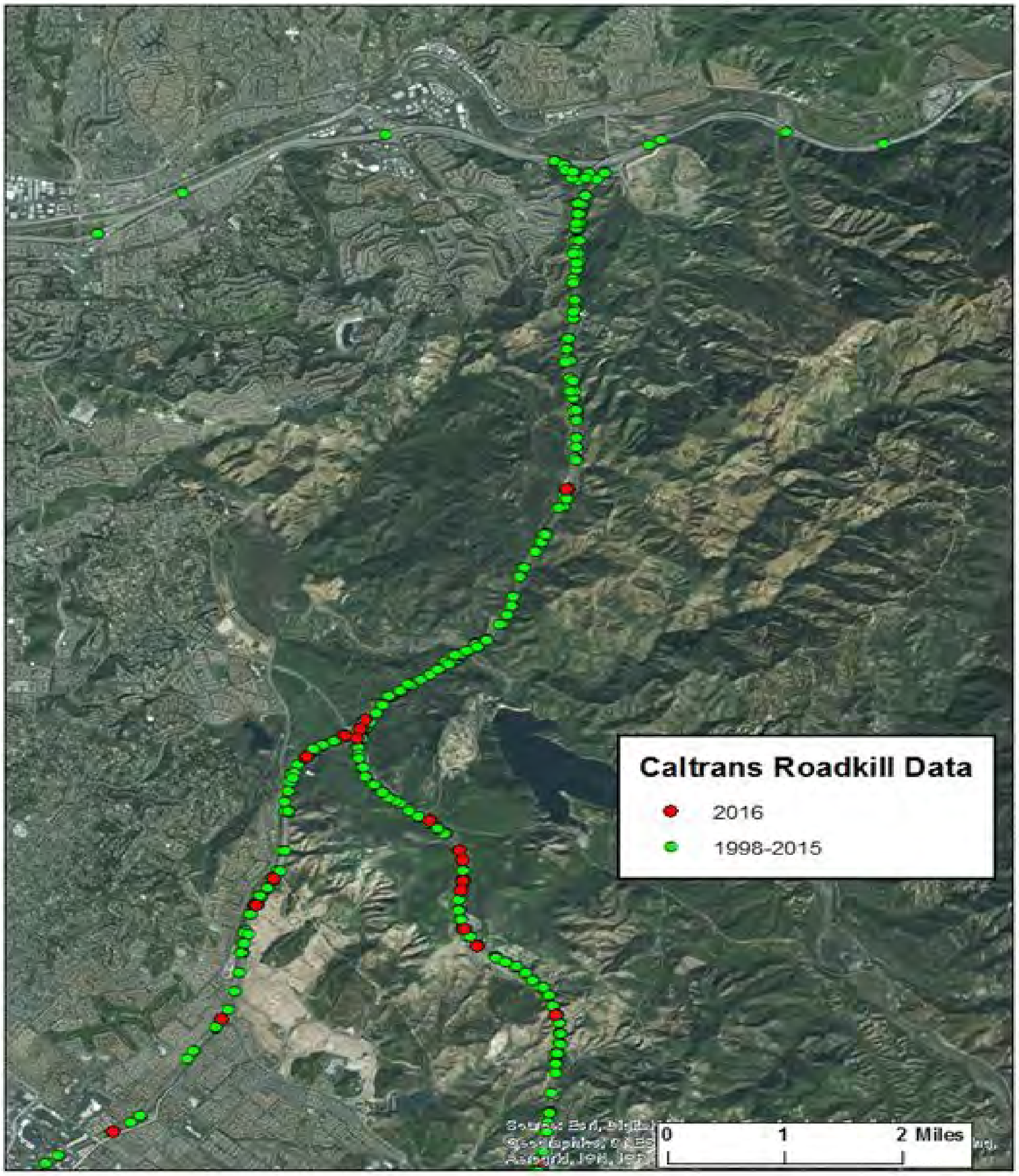


Figure 2.2. *Caltrans Roadkill Data.*

3. Site Investigation

Portions of undeveloped land on both sides of the 7 mile stretch are owned by The Nature Conservancy who are interested in the preservation of the land and promoting wildlife crossings. Some of this land can be accessed by foot north of the Temecula Creek by means of a parking lot for a small shopping center. There is also current construction just south of the parking lot.

The team visited the project site on various occasions. Within the project site, the existing underpass, culverts, and plateaus were inspected and analyzed for possible issues, as well as their existing conditions.

Figure 3.1. *Temecula Creek Aerial Image*

The area near the existing Jack in the Box is level and makes the Temecula Creek Underpass accessible to the public by dirt path. There is also construction occurring adjacent to the Jack in the Box which creates another access point for human traffic. Figure 3.1 shows the Jack in the Box and the surrounding dirt path that leads to the Temecula Creek underpass.

This land is protected by the ecological reserve, however from the field visits it is clear that there is consistent human presence. This was determined after the multiple human interactions during the team's field visits, as well as the presence of footprints found beneath the bridge. A visual of these footprints found on one of the field visits are shown in Figure 3.2.

Figure 3.2. *Temecula Creek Site Photo.*

Beyond the discovery of the footprints and the interactions with people, there was also significant presence of graffitti along the bridge columns. It was also documented that the creek located further east tends to discharge through this passageway. The site was observed before the rainy season in which the stream was narrow and slow-moving, but still with a consistent current. After the rain, the Temecula Creek Underpass experienced a heightened discharge rate underneath the bridge. However, this discharge rate did not impact the accessibility to cross the bridge. The impacting factor that was observed and prevented potential crossing was the increase in vegetation and cover that was in the area. Figure 3.3 shows the dense vegetation and presence of graffitti underneath the existing Temecula Creek Underpass. It was also observed, that after the rain, there seemed to be a controlled fire that changed the vegetation layout and decreased the density. The team researched for evidence, but found no record of how frequent this is performed in the area, nor the exact purpose of this case.

Another key factor in the investigation of the Temecula Creek Underpass was the intense noise created by the traffic overhead. The columns underneath the bridge created an observable echo which increased in volume underneath the Underpass. The initial predictions that the team made was that the riprap located on the edges of the bridge and the spacing of the columns could have increased the observable noise underneath the Underpass.

These restraints within the Underpass were identified as possible deterrents. They were explored by the team and then presented on in multiple workshops. These workshops allowed the team to understand different professional perspectives on how these deterrents could efficiently and effectively be mitigated for.

Figure 3.3. *Temecula Creek Site Photo 2.*

Afterwards, the team's advisors and professional contributors went to visit the existing culvert. The existing culvert is located south of the Temecula Creek Underpass. It is smaller than the ones discussed in the report. Based on research, it is recommended to have a visual of the other side of the culvert, known as an openness ratio. However, in this case, since the culvert is skewed and the length of the culvert exceeds 200’, it is very difficult to get the desired openness ratio.

This culvert was approximately 4’ in diameter and made of concrete. It is also located near canyons which, according to the report, can serve as natural funnels for a variety of wildlife. Figure 3.4 shows a visual of the existing culvert.

Figure 3.4. *Existing Culvert.*

There have been cameras set up in the vicinity of this culvert, but very little mountain lion activity has been recorded.

The team also went out to investigate the overpass site locations to gather data on the existing plataus shown in Figure 3.5. Since the areas surrounding these plateaus are not accessible by foot without a permit, the team drove past these plateaus along the I-15 to see the surrounding area and how that might impact the effectiveness of a possible overpass.

It was observed that there was an existing golf course surrounded by chain link fence. In addition, there was a truck stop area that had many lights surrounding it and consistent traffic flow nearby. These observations were significant due to their possible impact on attractiveness of a wildlife crossing structure to animals. In this area, there were also visible canyons and natural paths that could help the mountain lions discover the overpass. The GPS data from Figure 1.1 shows that the mountain lions tend to travel along the natural canyons and pathways when moving about in their respective areas.

Figure 3.5. *Existing Plateaus.*

Ultimately, it was through our site investigation that the team was capable of identifying possible problems or benefits of the natural landscape, as well as the layout and locations of businesses and residential areas.

4. Needs and Purpose

The project's needs include lack of genetic diversity in the local mountain lion population and prevention of vehicle/mountain lion collisions. The purpose of the project is to provide safe passageways to promote mountain lion crossing.

Below are Figures 4.1 and 4.2 which show the separation of mountain lion population in yellow GPS position points, and another image with red triangles which represent the vehicle/mountain lion strikes along the project's focus area.

Figure 4.1. *Santa Ana Mountain Lion GPS points.*

Figure 4.2. *Mountain Lion Vehicle Strikes.*

5. Overpass

Overview

One of the most commonly used means of animal crossings is the use of overpass bridges. Overpasses are well suited for large, herd-type species of animals which prefer open pathways such as deer and mountain goats. Although our target species of mountain lions do not typically live in herds, their target preys do. The belief is that by giving those species an area to cross, the mountain lions will follow their path as well. The existing plateaus in the area create an opportunity for a feasible overpass design.

One of the notable examples of this type of structure is the recently constructed Yoho wildlife overpass. This overpass is located in the Rocky Mountains west of Calgary in the province of Alberta, Canada. The main species target for this overpass is mountain goats, however bears, cougars and other species of animals are expected to use this overpass. Some aspects and ideas used in the design of our overpass have taken notes from the Yoho overpass, such as usage of lightweight fill and berms.

Site Selection Criteria

First step in designing any crossing passageway involves picking a sustainable and constructable site. For the purposes of picking the best location for the overpass, the team created a few criteria items and ranked each using a point system matrix. The decision matrix and the weighted categories are as shown in Table 5.1.

Table 5.1. *Site Selection Criteria for Overpass.*

Site Selection Criteria	Weight
Land Conservation	20%
Natural Movement Corridors for Lions	20%
Biologists' Data	15%
Wildlife Accessibility	15%
Light Pollution	9%
Adjacency to other Crossings	7%
Constructability	7%
Human Activity	4%
Noise	3%
Total Score	100%

The first category in the criteria is Land Conservation. Land conservation is ranked very highly for many reason. For one, if the proposed passageway is to be constructed on private land, much more influence is going to be needed to use private property as a pathway for the species. There could also be a conflict of interest in the use of the land in future. The private owner might decide to use the land and develop the area into a neighbourhood, or any other land use which could attract human beings. This will inevitably result in fall of usage of the overpass. Therefore, a land that is used for conservation purposes would be a tremendous positive factor for location purposes. The second criteria is Natural movement corridors. Since mountain lions natural habitat is in the mountain sides and higher altitudes, the canyons existing in these mountain sides can be used as a movement corridor to lead the lions and other species towards the pathways. The GPS recorded data could also be used to better determine where the natural corridors reside. Biologist's data was also chosen as one of the criterias. This data included the GPS locations, trail camera footage, and behavioral factors that has been studied for years. Light and noise pollution are also part of the table. The belief is that the noise and light of the cars using the busy interstate freeway act as a deterrent for most of the mountain lion population and keeps the animals away from expanding their territory. Adjacency and constructibility are also part of the criteria. Since more than one type of passageway is being proposed, and it is possible to construct all three as a part of a pathway system, constructing each at a greater distance would be a positive. However, based on research found, it is understood that adjacency of these pathways would not hinder their effectiveness. Lastly, human activity which is one of the main points of deterrence for the animals. Due to the distance of the possible locations for the overpass to the nearest communities, this criteria was ranked lower than others. Once the criteria table was created, it was shown to a panel of wildlife and engineering experts who helped rearrange the order and weight of each category.

Site Comparison

The site selection criteria allowed the team to narrow down possible locations for the overpass. Two sites were determined to have the most potential in meeting the needs of the mountain lions. These two were compared based on the site selection criteria.

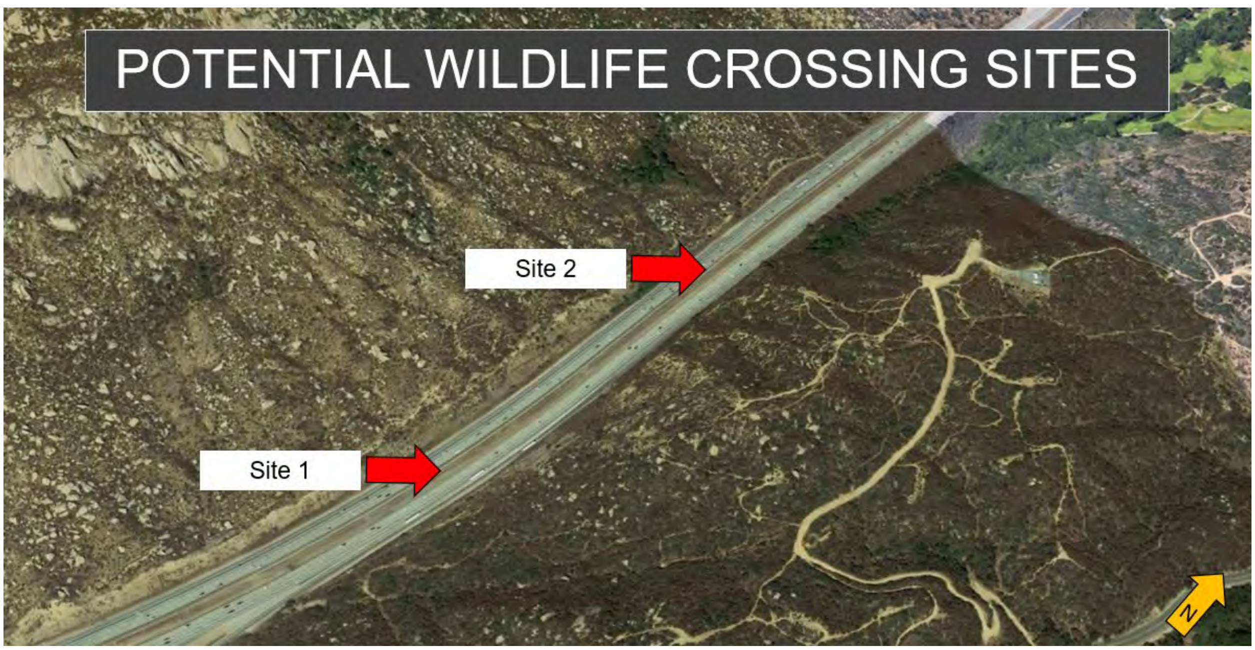


Figure 5.1. *Potential Wildlife Crossings Sites.*

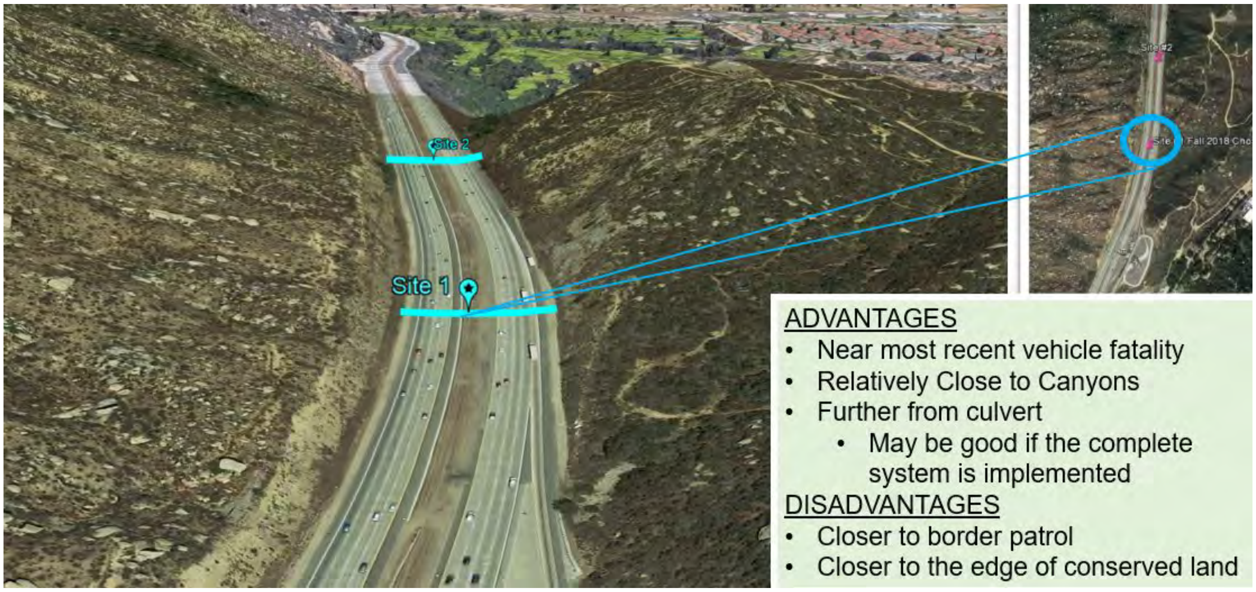


Figure 5.2. *Advantages and Disadvantages of Site 1.*

The first site studied is more southerly than the other and closer to the border patrol. Some of the advantages of this site include its closeness to some recent fatal vehicle to mountain lion collisions. Another advantage of this site is its closeness to the canyons, which as mentioned before, are going to be used as natural funnels to guide the animals toward our overpass. The third advantage of the first site is its distance from the proposed culvert location. Some of the disadvantages of this site is its closeness to the border patrol which could increase noise and light pollution at nighttime. This site is also closer to the edge of the conserved land, meaning that there could be changes made to the nearby land that affect the usage of the overpass.

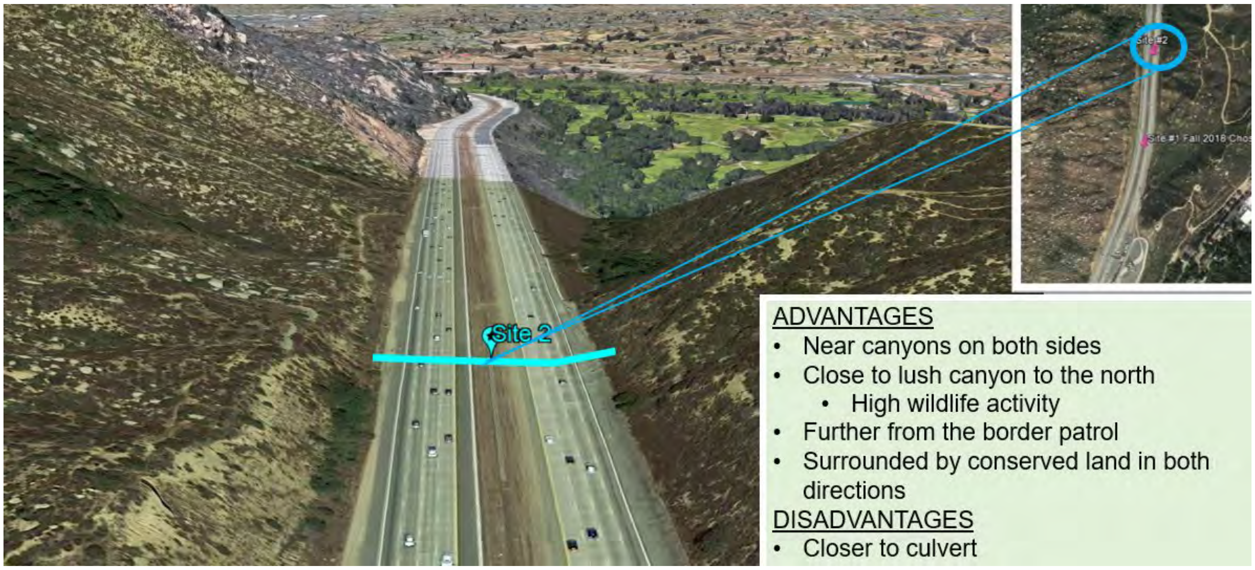


Figure 5.3. *Advantages and Disadvantages of Site 2.*

The second studied site is more northerly, closer to the proposed culvert site and the Temecula Creek Inn. Some of the advantages of this site include its inclusion of canyons on both sides of the freeway. Its closeness to lush canyon to the north which means a higher wildlife activity. Lastly, the site is located in conserved land which is a top priority. Its biggest disadvantage is its closeness to the proposed culvert site. Though as mentioned before, based on the research studied, adjacency is not a big factor in reduction of passageway use.

Once both sides were studied and compared to one another, they were put through the criteria table and ranked. As shown in Table 5.2, the second site, more northerly and closer to the culvert, is the higher ranked site and therefore chosen as the preferred location.

Table 5.2. *Rankings for Site 1 and Site 2 based on Site Selection Criteria.*

Site Selection Criteria	Weight	Site 1		Site 2	
		Rating	Weighted Score	Rating	Weighted Score
Land Conservation	20%	5	1	5	1
Natural Movement Corridors for Lions	20%	3	0.6	4	0.8
Biologists' Data	15%	4	0.6	3.5	0.5
Wildlife Accessibility	15%	3	0.5	4.5	0.7
Light Pollution	9%	3	0.27	4.5	0.41
Adjacency to other Crossings	7%	5	0.35	3	0.21
Constructability	7%	5	0.4	4	0.3
Human Activity	4%	3	0.1	5	0.2
Noise	3%	3	0.1	4	0.1
Total Score	100%	3.8		4.2	
Chosen Alternative	Site 2 is the Chosen Location				

Design Alternatives

There were a few design considerations developed for the overpass. Orientation of the bridge, whether straight across or diagonal positioning, materials used, geotechnical layer, and innovation were a few design aspects considered.

A diagonal orientation for this site would be preferential from a wildlife usage standpoint, placed most closely to the edge of the canyons. A straight across design at our preferred location is still a viable choice for use of the canyons. However, this design will be less accessible. Due to notable raise in cost, and with the straight across design still using the canyons, the decision was made to continue with a straight across design.

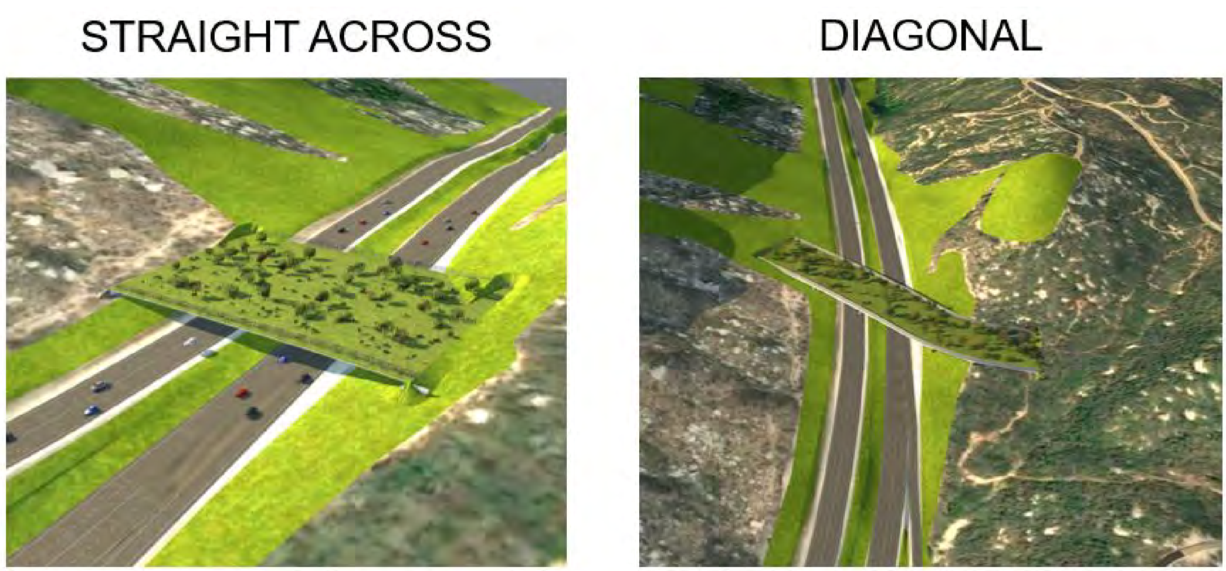


Figure 5.4. *Infraworks Models of a Straight Across and a Diagonal Design.*

The overpass team decided to study two different design alternatives. The first alternative is a traditional beam bridges with foundations on either sides and median of the freeway. The second is a innovative design inspired from the Hypar Nature design by HTNB and Michael Van Valkenbugh which was a finalist at ARC international design competition.

Figure 5.5. *Design Alternatives.*

Structural Analysis

After careful site selection was done, we performed structural analysis to prove the the feasibility of both the traditional and the innovative design. The whole point of structural analysis is to see if the structure can withstand its own weight and any additional loads when being applied. Some of the loads that were achieved after calculations are dead load, live load, and ultimate bearing capacity. The preliminary structural analysis calculations were performed in order to size the slab, girders, columns, and foundation.

All of our designs used a strength of concrete at 4000 psi and a strength of steel of 60,000 psi. We first assumed a certain number for the thickness of the slab. Next, we calculated the self weight of concrete and added that to the weight of the soil which makes up the total dead load. For the live load, we are using the typical live load of 20 psf. From this, we were to calculate the maximum negative and positive bending moments. We also determined the appropriate number of rebars of reinforcement for this particular slab. From here, we performed calculations to see if the DCR falls within the typical range of 0.9 to 1, which in our case, it was 0.94. A lower number DCR means overdesign while a higher number indicates underdesign. The summary of the slab can be found in Table 5.3**.**

Slab	
Strength of Concrete (f'c)	4,000 psi
Strength of Steel Rebar (Fy)	60,000 psi
Length	10 ft
Height	0.5 ft
Chosen Rebar	#4
Soil Layer Depth	3 ft
Dead Load	353 lb/ft
Live Load	20 lb/ft

Table 5.3. *Summary of Slab Analysis.*

For the girders, we follow the similar procedure from the slab and apply it to the girders. Since the span length of our bridge was 234 feet, we decided to divide it up into two even span of 117 feet. In other words, this is the span length of our girders. We are designing a rectangular beam since that's conservative, which then can be translated into an "I" beam if needed. Our first step was to come up with reasonable numbers for the height and width of the girder. Once again, we calculated the self weight of the girders and added to the total dead load from the slabs. Then, the negative and positive bending moments are calculated along with reinforcement rebar and stirrups. Lastly, we checked if the DCR falls within the typical range of 0.9 to 1, which in our case, it was 0.97. The summary of the girders can be found in Table 5.4**.**

Girder	
Girder Spacing	10 ft
Span Length	117 ft
Width	20 in
Height	82 in
Chosen Rebar	#11
Chosen Stirrup	#4
Dead Load	2,061 lb/ft
Live Load	200 lb/ft

Table 5.4. Summary of Girder Analysis.

Third, we determined the amount of columns needed to provide support for our Traditional Overpass design. Using the above mentioned assumed strength of concrete and reinforcement steel, along with the summation of the dead loads from the slab, girder, and soil the area of concrete was determined and the diameter of the columns. Through calculations from our lectures on reinforced concrete design, the diameter of

8 feet at 25 feet on-center spacing, giving the design eight round spiral columns in total to support the 165 foot width of the overpass. Using calculations to determine seismic effect the area of steel was found to be 26 inches squared. This area of steel reinforcement can achieved using 22 #10 bars on one side of each column. After the general design of the columns was determined the needed checks of the design were followed and the assumption of 22 #10 bars, the area of steel (As), and diameter of the column were found to be sufficient. A summary of the column design was generated for presentations and is shown in Table 5.5**.**

Column	
Type of Column	Round Spiral
Diameter	8 ft
Height	24 ft
Spacing	25 ft
Chosen Rebar	#10
# of Bars	22/side
Size of Ties	#4
Dead Load	2,915 lb/ft
Live Load	20 lb/ft

Table 5.5. *Summary of Column Design.*

Vegetation

The overpass design comprises a vegetation design. Used to imitate the feel of natural surroundings and create a pathway for wildlife, vegetation will also assist with mitigating traffic noise and light. Berms are another element of our vegetation design. Placed on each side of the bridge they will act as a natural barrier for the wildlife; with lightweight geofoam at the center to reduce the amount of topsoil needed our berm design will also be relatively light. To mitigate cost, the bridge layers will be smaller, therefore the vegetation will also need to have shallow roots. This is why we are focused on Coastal Sage Scrub which is native to the Temecula area while having shallow rooting. Some examples of the vegetation we are planning on using is Black Sage, California Buckwheat, and California Poppy; there are eight plant types in total in the design. Fencing for the outermost edges of the overpass will also be implemented to act as a barrier for any humans that may be able to climb onto the overpass. Shown in Figure 5.6 below is the layout of the vegetation design for the overpass.

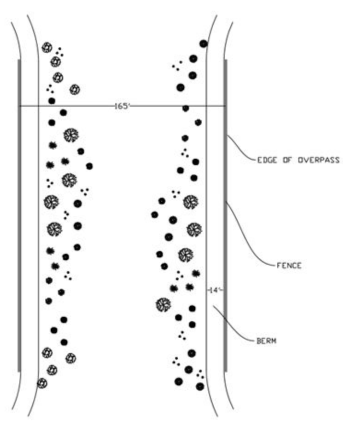


Figure 5.6. *Vegetation Design Layout.*

Artwork & Community Outreach

The overpass has a distinction from the other two crossing types in that is the only crossing that is easily visible by the public. This gives the overpass an important opportunity to connect with the public. Due to this we are proposing the use of artwork along our overpass design as a way to educate and gain interest from the public. We propose to implement paintings and carvings along the columns and the visible foundations, similar to those shown in Figure 5.7 below.

Figure 5.7. *Paintings and/or carvings examples to be placed on visible foundations and columns.*

We are also proposing metal cut-outs to be placed on the lightweight fencing similar to the artwork in figure 5.8. below.

Figure 5.8. *Metal cut-out art example to be placed on the lightweight fencing.*

All of these artwork pieces will tell the public that this overpass is being used for wildlife, they will highlight some of the specific species that the overpass is helping, and it will elicit public interest in the project. We are also proposing that signage be placed on a nearby street that will inform the public about this project and alo educate them about wildlife issues in the area.

Construction Staging

For the alternative 1 design, we prepared a construction staging plan. Our plans are preliminary, there's need to be a traffic study done in the area to determine how big of a work area the construction crew will have. The traffic study is also essential to determine if bottlenecking traffic is possible or if a freeway closure is required therefore detours will need to be providing. Construction was split into seven stages. The first stage is the mobilization of the construction crew and equipment to the site. In addition, at the ends and median of the work area, there will be excavation and compaction of the soil with the appropriate cut or fill.

Figure 5.9. *Construction Stage One.*

For stage two, the abutments will be poured at the ends of the overpass and the columns will be placed at the median.

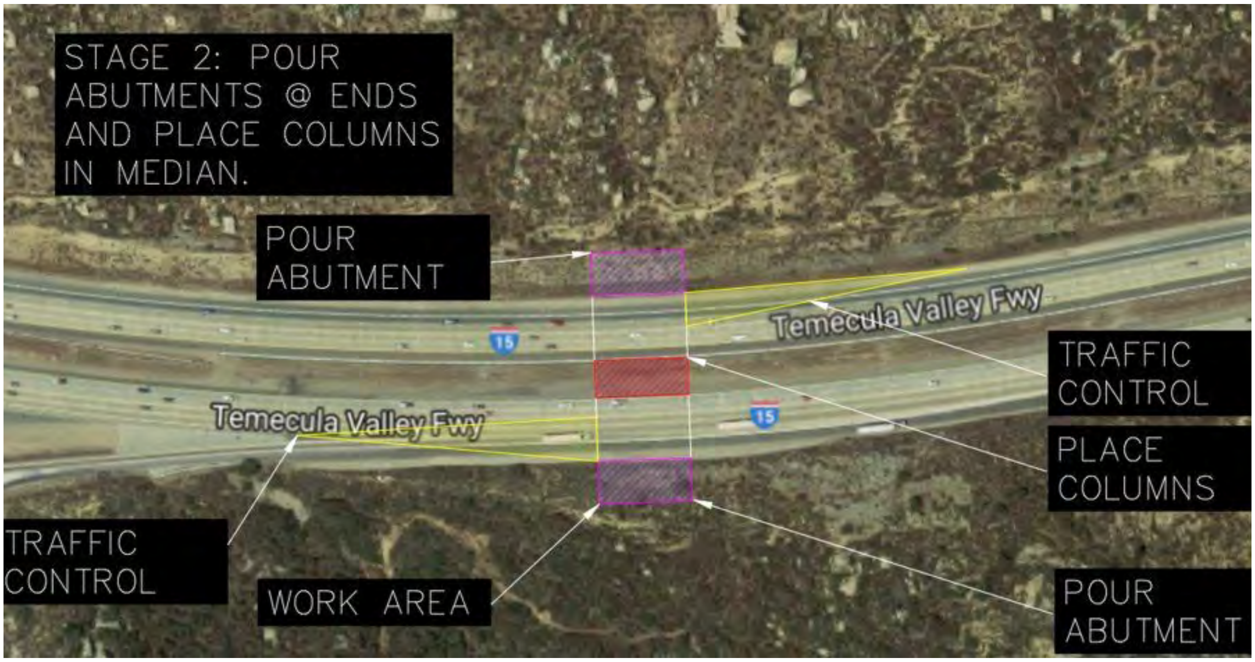


Figure 5.10. *Construction Stage Two.*

In stage three, we will install temporary scaffolding and foam work throughout the entire work area.

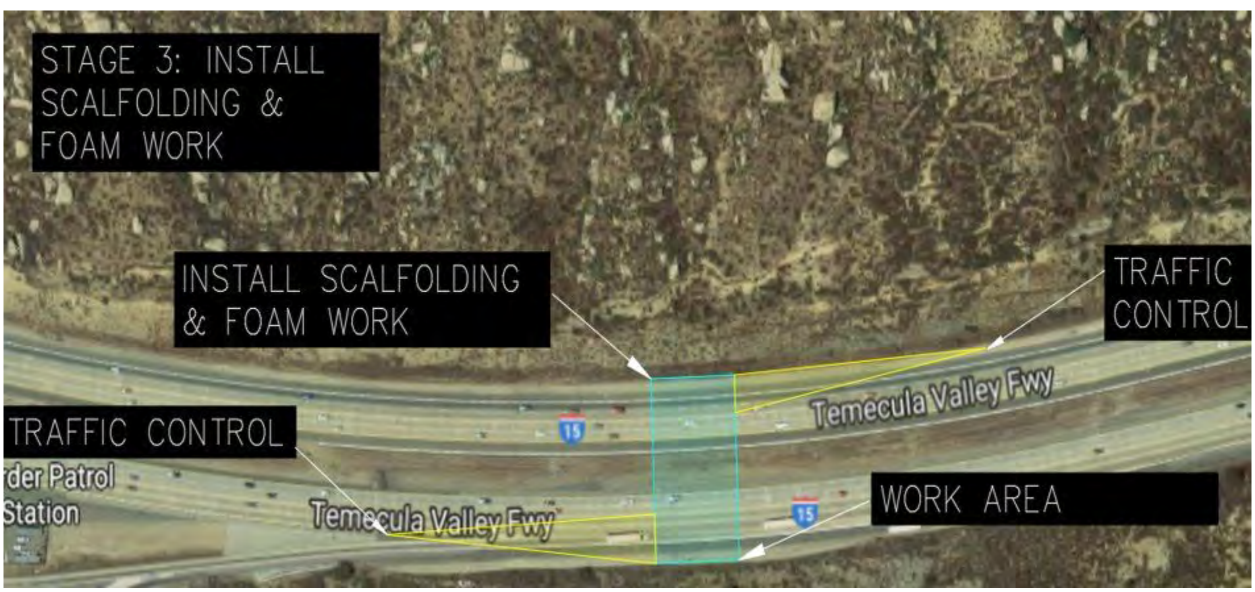


Figure 5.11. *Construction Stage Three.*

After the scaffolding and foam-work have been installed, we will move into stage four and place girders on the one side of the overpass work area at a time depending on what is more efficient to the construction crew, stage five will be a mirror of stage four.

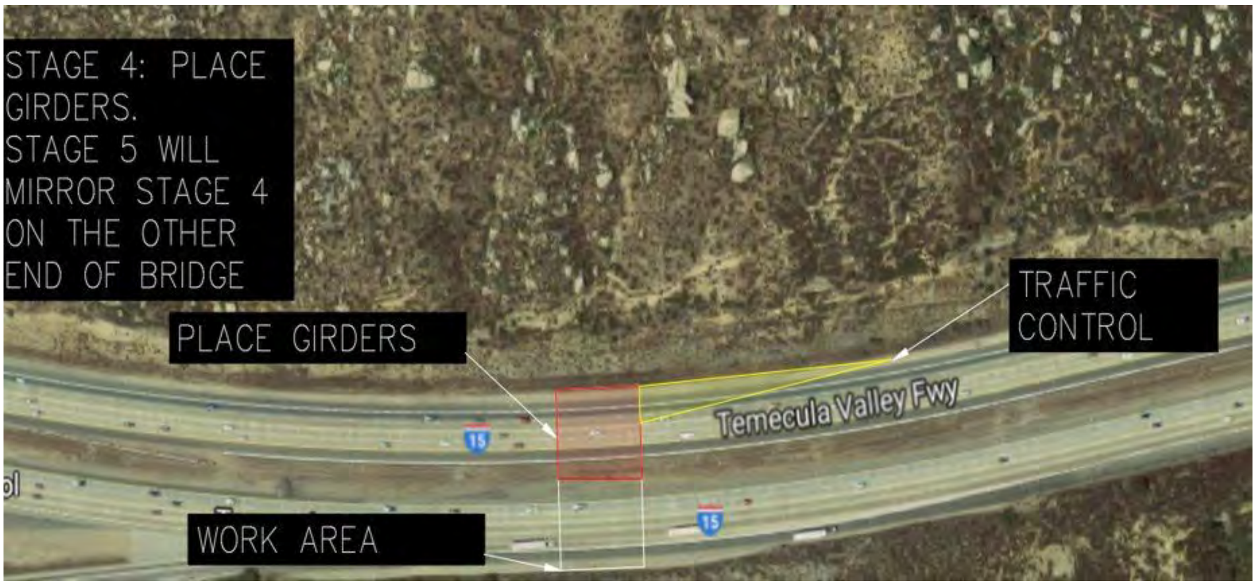


Figure 5.12. *Construction Stages Four and Five.*

In stage six, the mobilization of the precast slab will take place and it will be placed on top of the girders.

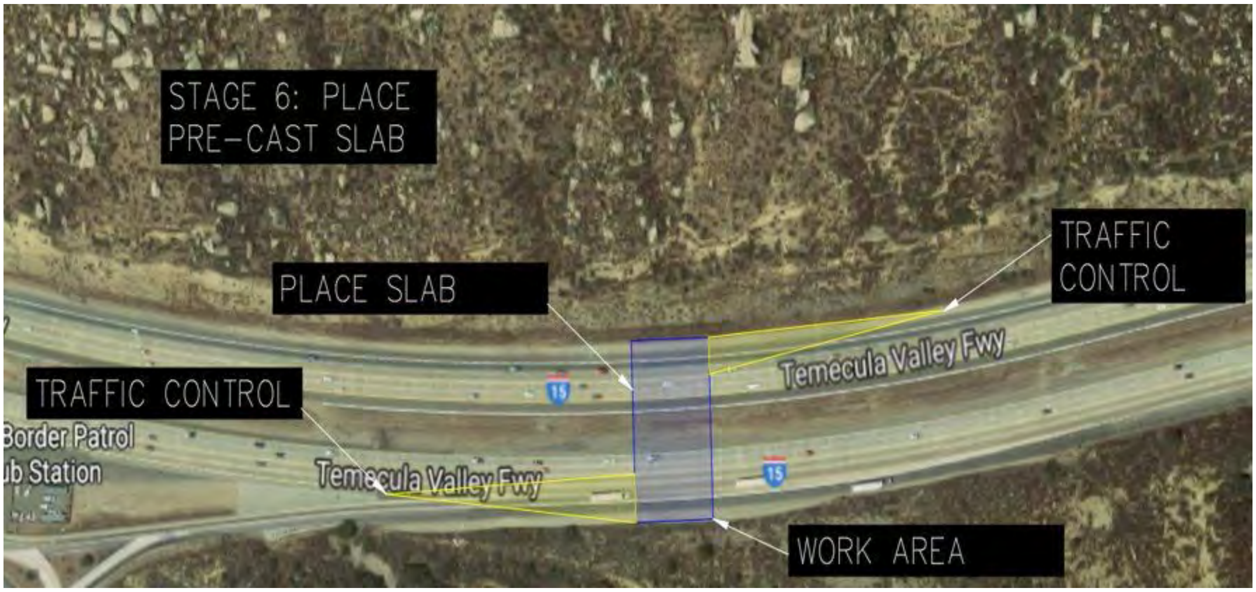


Figure 5.13. *Construction Stage Six.*

Finally, in stage seven, the finishing touches, testing, and artwork will take place. On the foundation of the foam work there will be paintings and carvings. Throughout the metal fencing, there will be metal artwork be implemented. The finishing touches includes adding soil and vegetation on top of the overpass, along with fencing and our vegetative layout. We prepared this construction staging plan to the best of our ability, but look forward to further work with professionals and get their insights and advice.

Figure 5.14. *Construction Stage Seven.*

Cost Estimate

For our overpass, we did a preliminary level cost estimate based on the criteria that Caltrans specifies in Chapter 20 of their Project Development Procedures Manual (PDPM). Section 2 of the document gave us a format for how our preliminary level project cost estimate should look and which items are typically included.

To calculate approx earthwork costs, our team used CAD to generate a Cut/Fill Volume Report. This report allowed us to determine unit costs via Caltrans Contract Cost Database. The Cost Database stores the unit costs for all of Caltrans' projects and allowed us to search for recent prices of bid items such as "Roadway Excavation" by district /volume to obtain an accurate unit cost.

We had multiple factors to take into account for our overcrossing that we estimated at $209 per SQFT. This cost takes into account the girders, the lightweight native fill, sand, and imported topsoil.

The structure and earthwork were applicable items in the procedure manual for our overpass that were used for a total project cost (TPC). All other items were determined as percentages of the total project cost since they were not as significant for our project, and did not vary the results for each of our alternatives. The following are all costs and their percentage of TPC: Drainage at 20% , Environmental at 10%, Traffic at 10%, Mobilization at 5%, Staging at 25%, Electrical at 5%, and Aesthetics at 5%.

Finally, we included a Contingency of 20% and an additional 20% for Support Costs. For our project, we did a cost estimate for both alternatives (traditional and modular) and used that information in our Weighted Decision Matrix. The cost for each alternative is as shown in the tables below. The calculated cost for the first alternative, the traditional design overpass, is an estimated sum of 18 million dollars, not including the cost of labor. The calculated cost for the second alternative, Hypar-Nature designed by HNTB, is a sum total of 26 million dollars also not including labor costs.

Table 5.6. *Cost Estimate for Alternative 1.*

Item	Cost in Millions
Excavation	$0.15
Structure	$7.00
Drainage	$1.40
Environmental	$0.70
Traffic	$0.70
Construction Mobilization	$0.35
Construction Staging	$1.80
Aesthetics Cost	$0.35
Support Costs (20%)	$2.50
Contingency (20%)	$2.50
Total Cost	$17.60

Table 5.7. *Cost Estimate for Alternative 2.*

Item	Cost in Millions
Excavation	$0.40
Structure	$10.40
Drainage	$2.10
Environmental	$1.00
Traffic	$1.00
Construction Mobilization	$0.50
Construction Staging	$2.60
Aesthetics Cost	$0.50
Support Costs (20%)	$3.70
Contingency (20%)	$3.70
Total Cost	$25.90

6. Culvert

Overview

In order to combat the pressing issue of the sustainability of the Santa Ana Mountain Lion population, a connection needs to be made between the existing mountain lion populations located on the eastern and western sides of the mountain ranges. Due to urbanization and the inherent territorial characteristics of mountain lions, infrastructure needs to implemented or modified to provide safe access routes to wildlife. The primary focus is on the preservation of mountain lions; however, the proposed solutions are long term proposals designed to stimulate all wildlife inhabitants native to the region.

Caltrans currently uses culverts to help with the diversion of stormwater runoff to prevent damage by redirecting water. In the attempt to both positively impact the communities stormwater dispersion system and address the depreciation of the Santa Ana Mountain Lion population, the installation of a larger culvert is proposed to create a passageway for wildlife as well as water runoff. The goal is to time the installment of the culvert with the maintenance requirements of the existing culverts. In that way, Caltrans can absorb the design costs, and the construction costs can be covered by private donors that have an interest in the preservation of wildlife. When considering the installation of a new culvert, the location, hydraulic condition, surrounding topography, culvert design, and other details of the proposed culvert are analyzed to see their influence on the culvert's effectiveness as a wildlife passageway . In order to design for the purpose and needs of this project, the best solution was based off of the historical mountain lion data, wildlife expert input, engineering official recommendations, and innovative designs of Cal Poly Pomona students. These were all taken into consideration in the design and implementation plan of the proposed culvert.

Site Selection Criteria

The first factor that was investigated was the site itself. The investigation of the location site considered 9 different site conditions. The first was the natural movement corridors, research shows that canyon-like topography can serve as a natural passage and guide for animals. If the culvert was placed near these natural corridors this could bring more wildlife to it. It was important that the land surrounding both ends of the culvert be conserved so that the animals would be safe entering and exiting the structure. The location had to be suitable for the installation and maintenance of the culvert. The culvert location needed to have downward slopes on both ends of the I-15 to accommodate both exit and entrance points which would also reduce constructability costs for grading. Next, the existing biologist data was looked at, a combination of GPS tracking, SCAT data, as well as vehicle strikes to see where the highest activity was. The presence and accessibility of humans was also considered to ensure that the animals would feel safe around this passageway. The surrounding vegetation was also a factor in the location criteria to analyze the existing conditions as to how that might attract or deter wildlife. Finally, light and noise pollution was considered as a possible deterrent for wildlife because of the presence of the freeway.

Table 6.1. *Site Selection Criteria for Culvert.*

Site Selection Criteria	Weight
Natural Movement Corridors for Lions	20%
Land Conservation	20%
Constructability	16%
Biologists' Data	13%
Wildlife Accessibility	10%
Human Activity	10%
Landscape	5%
Artificial Lighting	3%
Noise	3%
Total Score	100%

Site Comparison

First chosen location is the more northerly of the two closer to the Temecula Creek Inn and golf course. The current culvert in that location has a steep slope of 25 degrees and there is little to no light at the location. At this location there is private land to the East and conserved land to the west of the freeway. The second location is more located about 1 mile to the south of the first with a slight slope of 7 degrees for the existing culvert and little light from the eastern side of the freeway. The land on both sides of this location is conserved. Once vetted through our site selection criteria, site 2 is clearly the better choice scoring much higher than site 1 as shown in the figure below.

Figure 6.1. *Site 1 and Site 2 location for Culvert.*

Within the 7 mile stretch of the focus area, site 2 is recommended as the most advantageous when looking at the criteria, the ‘focus site’. This focus site was ranked based on the criteria and discussed with the UC Davis Wildlife Health Center and is consistent with their findings and needs.

Table 6.2. *Ratings of Site 1 and Site 2 based on the Site Selection Criteria.*

Site Selection Criteria	Weight	Site 1		Site 2	
		Rating	**Weight Score**	**Rating**	**Weight Score**
Natural Movement Corridors	20%	3	0.6	5	1.0
Land Conservation	20%	1	0.2	4	0.8
Constructibility	16%	2	0.3	3.5	0.6
Biologist's Data	13%	3	0.4	4.5	0.6
Wildlife Accessibility	10%	3	0.3	4.5	0.5
Human Activity	10%	2	0.2	3	0.3
Landscape	5%	3	0.2	4	0.2
Artificial Lighting	3%	3	0.1	5	0.2
Noise	3%	5	0.2	4	0.1
Total Score	100%	**2.4**		**4.2**	
Choosen Alternative		**SITE 2 IS THE CHOSEN ALTERNATIVE**			

Design Considerations

For the design of the culvert a few design considerations were considered. First design consideration is a study of the hydrological behavior of the area. Rainfall intensity data was required to run the hydrology analysis to insure the proposed culvert is capable of handling the discharge in the surrounding area. Rainfall intensity data was collected from the National Oceanic and Atmospheric Administration (NOAA) for the considered area. Once the data was collected, discharge calculation were performed and a design flow for a 50 year storm return interval was considered. Once the design flow was calculated, hydrology analysis was performed on the proposed culvert using a program called HY-8 provided by the Federal Highway Administration (FHWA). Several parameters were obtained such as the normal depth, critical depth, inlet control depth, and outlet control depth. A critical depth of 1 feet was calculated, and therefore both of our design alternatives, the concrete box culvert as well as he corrugated steel pipe met the minimum depth requirement.

Moreover, in order to construct the proposed culvert, earthwork needed to be performed on both east and west sides of I-15. Due to the high elevation terrain and steep slopes on the west side of I-15, cutting and excavation of the land was required. On the other hand, the east side of I-15 needed to be filled to create a smoother terrain for mountain lions to pass as well as to ease the construction process. The earthwork calculated amounts to about 30,000 cubic yards of cut on the west and 10,000 cubic yards of fill on the eastern side of the freeway. The cut on the western side is necessary to make it simpler for the mountain lions to approach the culvert from the western side and to leave it towards the mountains if approached from the eastern side. The fill on the eastern side is necessary to accomodate for the steep slopes. Other design consideration included Geogrid to accomodate for erosion control and keeping the natural soil at the bottom of the culvert from washing off. Riprap design is also considered for the design in order to control the velocity of the flow exiting the culvert, however accomodations need to be made for wildlife entering and exiting the culvert. Another consideration is use of textured concrete to prevent graffiti artists on coming to the site and deterring the wildlife from passing through.

Design Alternatives

Two different alternative has been considered for the selected location. The first alternative is a 12 feet by 12 feet concrete box culvert. Its design has been inspired by Caltrans Standard Plans 2018.

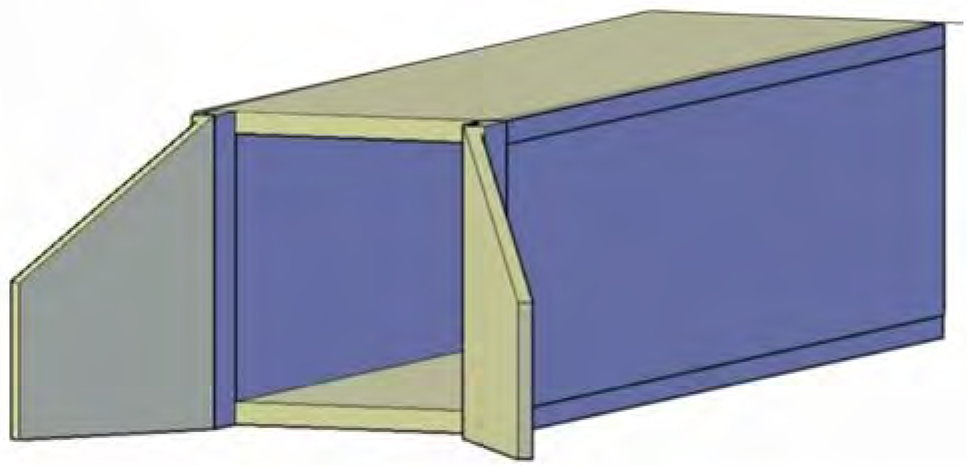


Figure 6.2. *Concrete Box Culvert Design.*

The height and span of the opening of the culvert amount to 12 feet each, with a wall thickness of 1 feet. Reinforcing design of the culvert is also calculated based on the Caltrans Standards Plans. For this alternative there is also a footing design calculated. The footing is a 16 feet by 1.5 feet and 210 feet long. The reinforcing used for this culvert is #4 rebars at 7” off center. The pressure applied on the foundation and the soil bearing capacity allowed we calculated and it has been determined that the footing design is feasible.

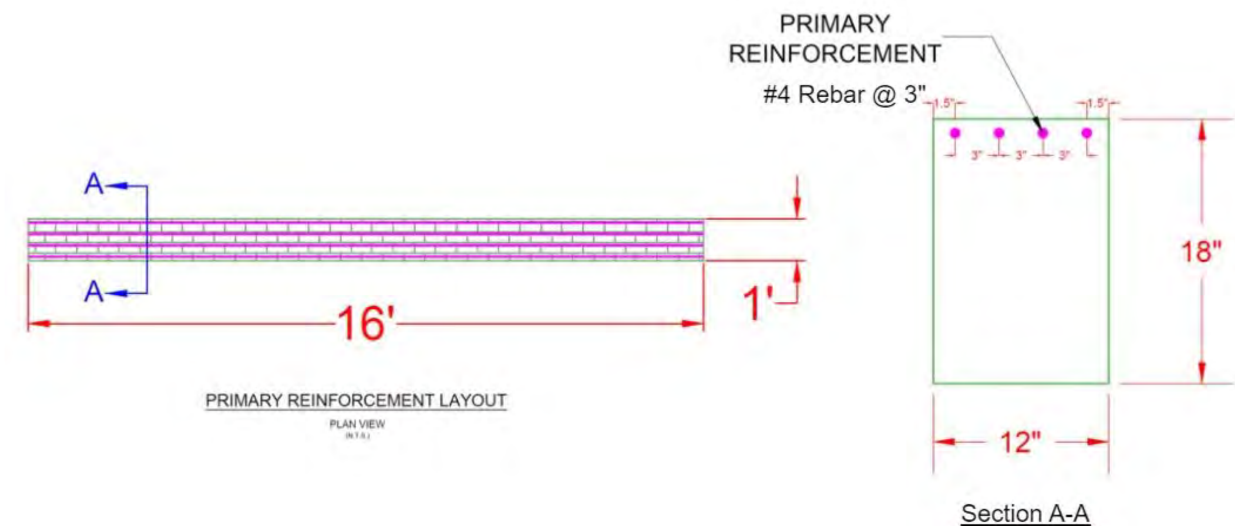


Figure 6.3. *Foundation Design for Concrete Box Culvert.*

For this design there is also a consideration made for the mitigating hydrological aspects deterring animal usage. Approaching the culvert from the western side where the watershed is located, there is a slope of two percent guiding the water to the left of the culvert (towards north) where a gutter with a width of 6 feet is placed. The purpose of said slope and gutter is to separate the water pathway from the animal crossing pathway which is covered by familiar soil. At the end of the culvert on the eastern side there will be riprap present on the water pathway to prevent erosion. Below is a cross-section of what the structural layout of the design is to be. For this alternative a construction method of manual tunneling is considered. Due to the constraints in closing a major freeway such as interstate 15, the ways are constructions are limited to trenchless methods. For a box shaped culvert, methods such as pipe ramming or pipe jacking are unavailable, therefore the best method selected for this alternative is the manual tunneling method where laborers will dig segment by segments and use temporary reinforcement to hold the soil in place, afterwhich the concrete culvert is placed segment by segment. This method of construction brings its own constraints and pitfalls. One of the biggest pitfalls would be the cost of this method. Due to the big number of manual labor needed, the cost is surely to increase. Another negative aspect of this construction method is the safety worries. Due to presence of laborers in dangerous conditions, there will be increasing concerns.

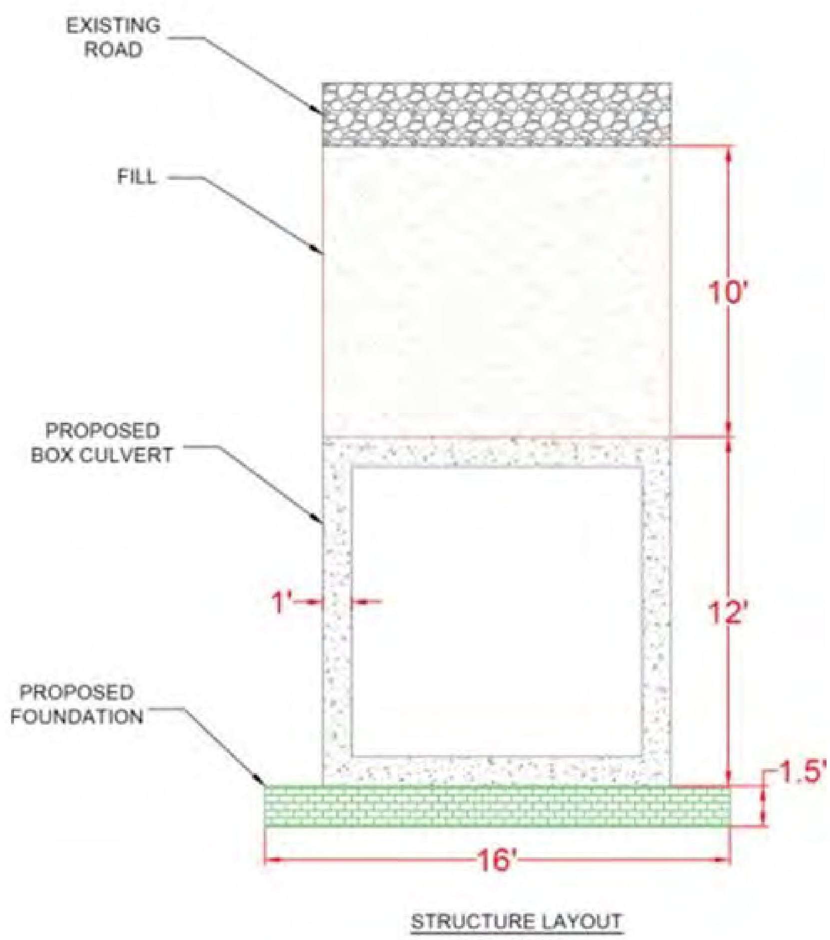


Figure 6.4. *Structural Layout of Concrete Box Culvert.*

The second design alternative is a corrugated steel pipe. Corrugated steel pipes come in various sizes and shapes. For our project, we selected an arch shape with a span of 11 feet and 10 inches, and a height of 7 feet and 9 inches. In addition, these pipes come in different thicknesses depending on the needs of the project. The thickness used to meet the requirements of our project was 8 gage for steel thickness and 0.168 inches for galvanized thickness. The maximum amount of earth cover for this specific size of a steel pipe is 16 feet. Since corrugated steel pipes are not as heavy as concrete box culverts, they do not require foundation to be placed on. This factor is one of the positive attributes of the corrugated steel pipe as it will require less cost and an easier construction process. The method of construction chosen for this alternative is called pipe ramming. Pipe ramming or pipe jacking is another trenchless construction method for culvert which involves a launch shaft from which the pipe is driven through the soil in the desired direction and angle.

Figure 6.5. *Corrugated Steel Pipe Culvert Design.*

Construction Staging

The construction staging plan for the culverts consists of 3 main stages. These stages include, Mobilization, Pipe ramming or manual tunneling depending on the alternative, and demobilization. Mobilization, the initial stage in our construction plan, escorting the equipment, machinery, and facilities to the site. Since the construction is to begin at the East side of the freeway, there will need to be some fill and leveling work done on the area to the side of the freeway to station all the equipment. Once the equipment is settled, we can move to the second phase of the construction. Due to construction procedures there will be need for temporary closure of shoulders and right lanes of the freeways. A summary of the first stage of construction is shown below.

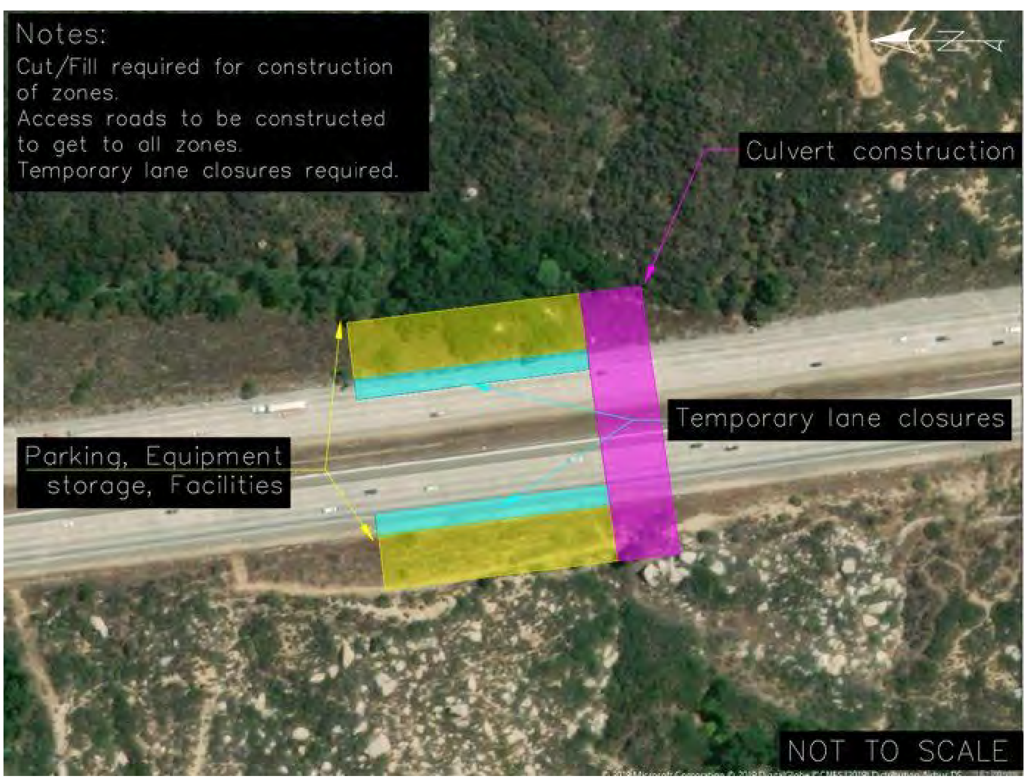


Figure 6.6. *Construction Stage One.*

The second stage of the construction is dependent on the alternative used. For the first alternative, concrete box culvert, a method of manual tunneling is utilized. For this method, construction crews will dig segments under the freeway at a time and use temporary reinforcement to keep the site stable. Once segments are cut and soil is taken out, the concrete box culvert is placed in segments at a time.

As shown in the figure below, some area is needed for crane equipment to assist with placing of the culvert segments. Temporary lane closures are also necessary to ensure construction crew and public safety.

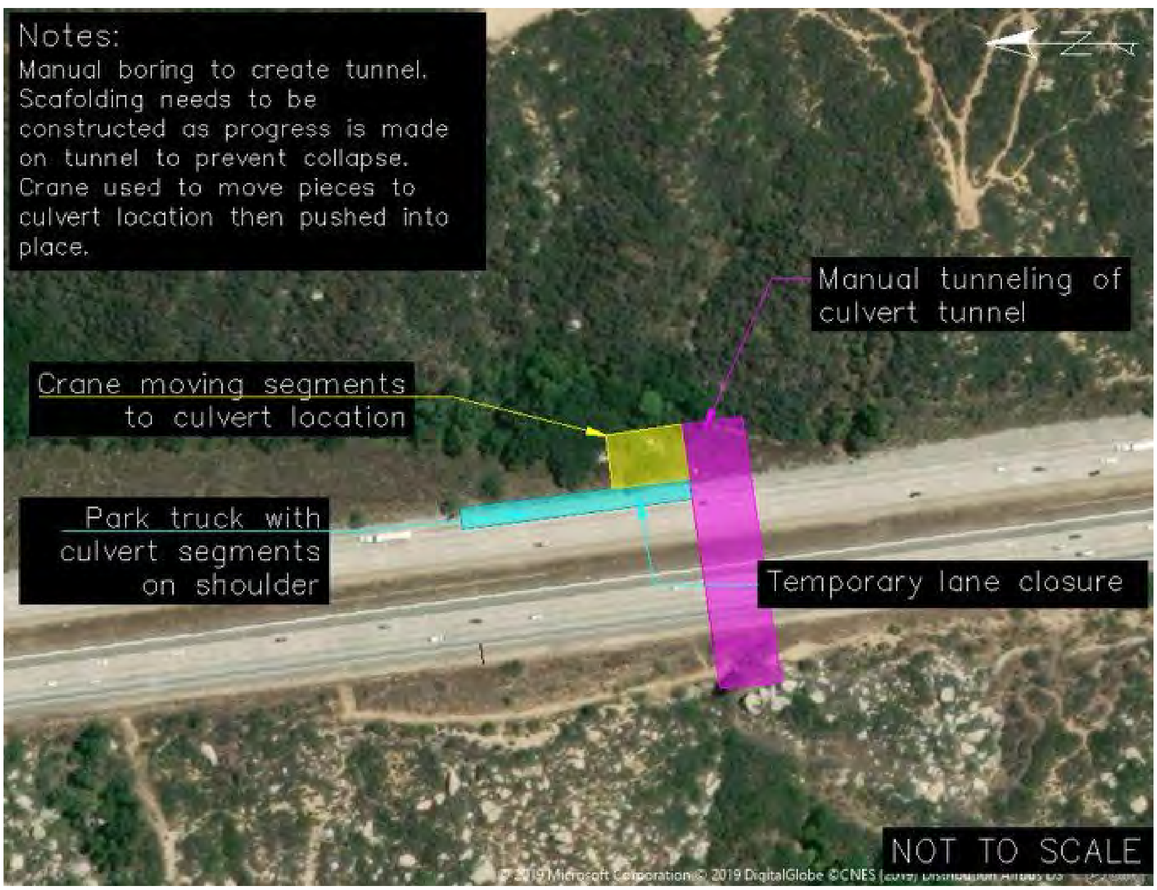


Figure 6.7. *Construction Stage Two - Concrete Box.*

For the second alternative, corrugated steel pipe, a method of pipe ramming, or pipe jacking can be used. For this method, after clearing out the site area, a pipe ramming machine is placed in the desired direction and angle for which the culvert is to be placed. Once placement is finalized, a machine will ram the culvert through the soil and as the pipe is rammed through the soil, the cut soil is cleared out. A sample figure of how pipe ramming is used is shown below.

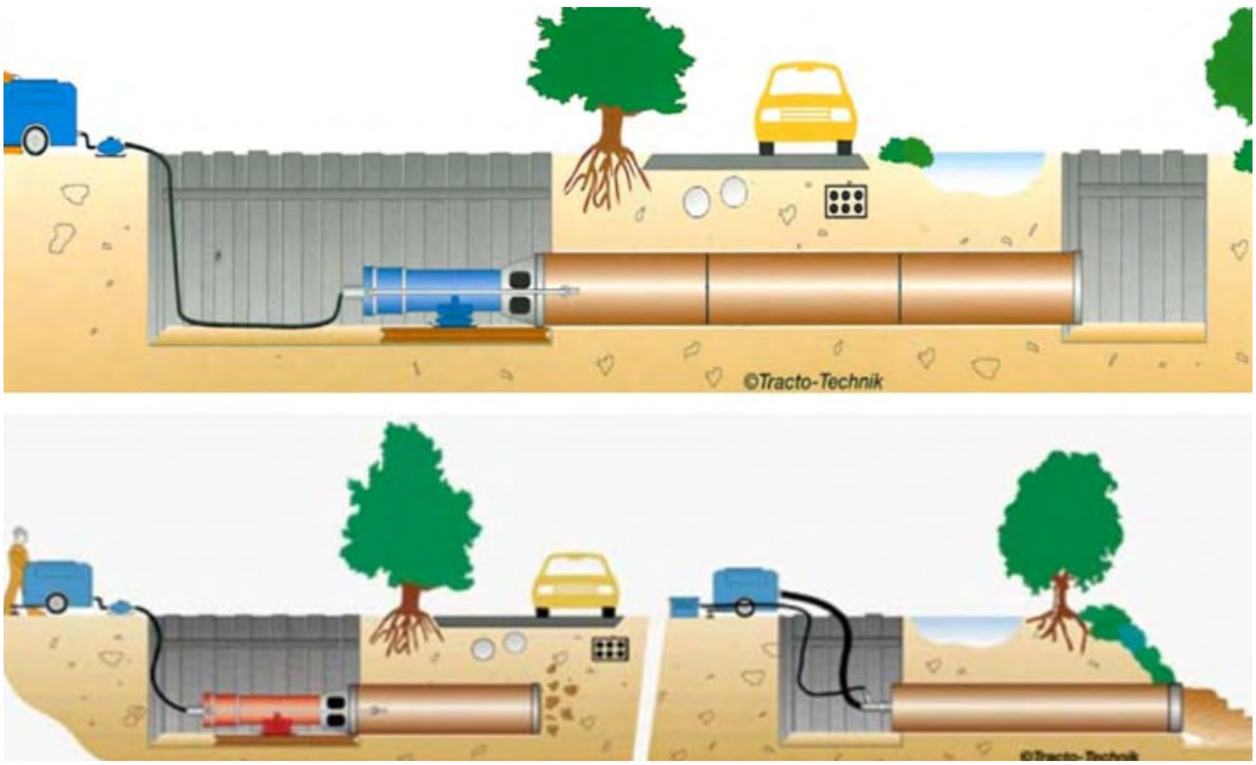


Figure 6.8. *Sample of Pipe Ramming.*

As shown in the figure below, pipe ramming will begin from the eastern side of the freeway. Some area is needed for the crane to move the corrugated steel pipe to the location and temporary lane closures on the Northbound side of interstate 15 are necessary to ensure the safety of construction crew and the public.

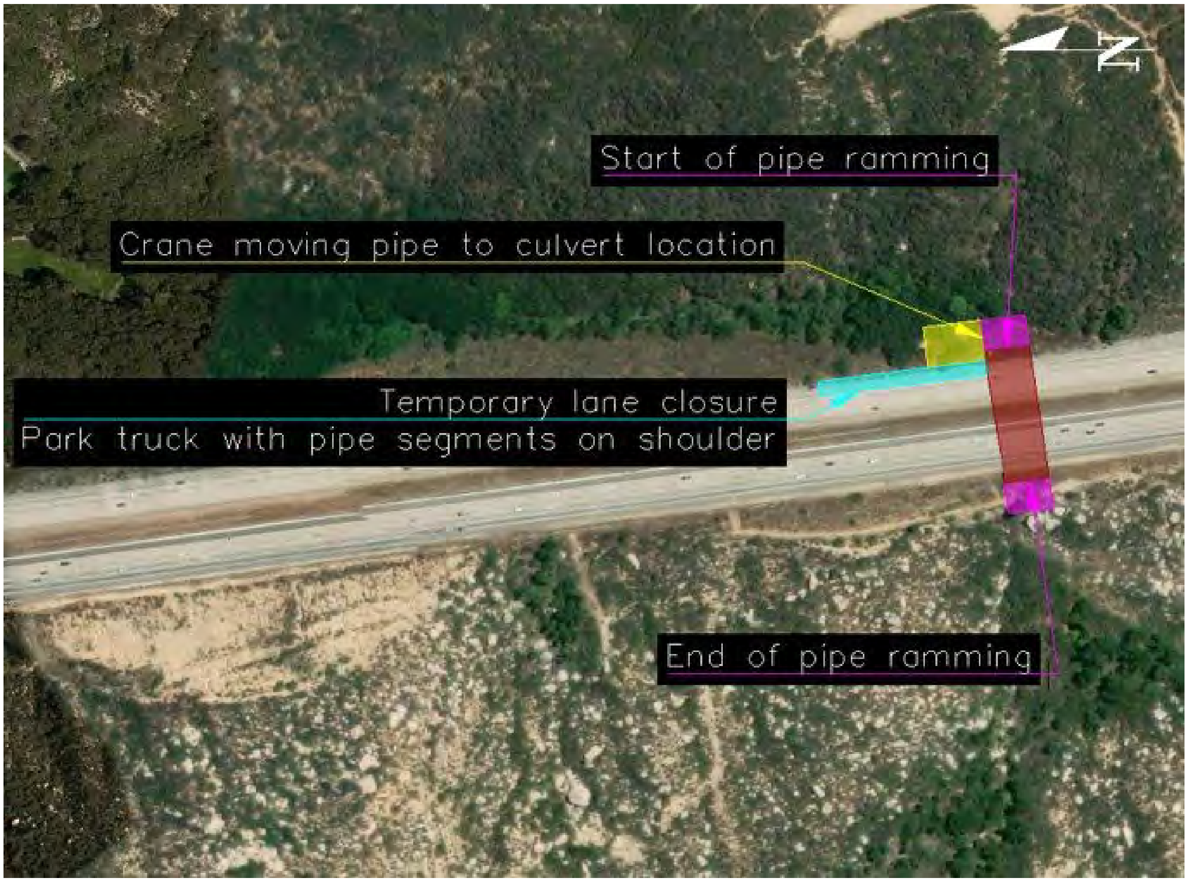


Figure 6.9. *Construction Stage Two - Corrugated Steel Pipe.*

The final stage of the construction phasing is the demobilization. For this final stage clearing and grubbing will take place, along with removal of facilities and equipment.

Figure 6.10. *Construction Stage Three.*

Cost Estimate

The cost estimate of the project consisted of 5 categories: earthwork, materials, environmental impacts, traffic staging, and mobilization. In each of the alternatives, both cost estimates did not include the cost of labor. The California Department of Transportation, CalTrans, had provided a document accessible on the web that details the Preparation Guidelines for Project Development Cost Estimates. The guideline helped create the cost estimate for this project by considering all elements of work without accounting for the labor. CalTrans also provided a cost database from previous years that list each item and the average unit cost. With the help of all these references and the data from our location site, the cost estimate for alternative 1: concrete box culvert is estimated to be around $10,000,000 and is shown in Table 6.3. The cost estimate for alternative 2: corrugated steel pipe is estimated to be around $9,000,000 and is shown in Table 6.4.

Table 6.3. *Cost Estimate for Alternative 1.*

Item	Unit	Cost	Total
Excavation	30,000 CY	$108.56	$ 3,256,800
Backfill	10,000 CY	$121.93	$ 1,219,300
Reinforced Steel Bars	56,481 LB/LF	$1.48	$ 83,592
Structural Concrete	563 CY	$1,776.64	$ 1,000,248
Geogrid	450 SQYD	$65.00	$ 29,250
Environmental	10%		$ 558,919
Traffic	10%		$ 558,919
Mobilization	5%		$ 279,460
Staging	25%		$ 1,397,298
Contingency	20%		$ 1,676,757
Total			$ 10,060,542

For the cost estimate for Alternative 1, the 5 main items were: excavation, backfill, reinforced steel bars, structural concrete, and geogrid. The excavation and backfill quantities were accumulated from the earthwork data collected during the pre-design phase. Once the design of the concrete box culvert was established, it was then obtainable to calculate the amount reinforcement and concrete is needed to carry out the project. The amount of geogrid is consistent between both alternative 1 and 2 as the geogrid is to be placed on the bottom layout of the 210' culvert.

Table 6.4. *Cost Estimate for Alternative 2.*

Item	Unit	Cost	Total
Excavation	30,000 CY	$108.56	$ 3,256,800.00
Backfill	10,000 CY	$121.93	$ 1,219,300.00
Corrugated Steel Pipe	210 LF	$2,387.00	$ 501,270.00
Geogrid	450 SQYD	$65.00	$ 29,250.00
Environmental	10%		$ 500,662.00
Traffic	10%		$ 500,662.00
Mobilization	5%		$ 250,331.00
Staging	25%		$ 1,251,655.00
Contingency	20%		$ 1,501,986.00
Total			$ 9,011,916.00

For Alternative 2, the cost estimate consists of 4 main components, the excavation, backfill, corrugated steel pipe, and geogrid. The main difference between the cost of alternative 1 and alternative 2 is that the price of the corrugated steel pipe is less than the material for the box culvert.

7. Temecula Creek Underpass

Overview

The Temecula Creek Bridge or the “Underpass” is an existing structure located at the northernmost portion of the seven-mile stretch of the I-15 freeway that applies to this project. It is adjacent to a residential neighborhood to the east and a shopping center located approximately half a mile north of the bridge. Although a crossing is already provided by the underpass, data from collar-tracking technology has shown that mountain lions often congregate in this area, but none have crossed. This is due to the existing conditions at this site that discourage mountain lions from passing through, one of which is human presence. Thus, most of the proposed work for this passageway will be focused on human deterrence. Proposed work will consist of the following design components to be implemented in phases: signs, vegetation, fencing, and sound baffles. If modified successfully, the underpass could provide a safe passageway for mountain lions that would be the least expensive and fastest to implement.

Existing Conditions

The existing conditions of the vegetation in the underpass varies from season to season. There are three major conditions that currently exist at the creek: human presence, dense vegetation, and slow water flow through the creek. Proposed work for the underpass was developed based on these conditions.

Human presence at the underpass is one of the most prevalent and most deterring conditions for wildlife. Evidence of human activity can be seen through graffiti on the walls of the bridge. At all three site visits to the Temecula Creek Bridge, people were encountered underneath the bridge, and multiple footprints could be seen on the dirt paths leading to the site. The site is also very easily accessible by the local neighborhood, as well as by the nearby shopping center, which has trails connecting it to the underpass.

The vegetation around the underpass varies throughout the seasons. During fall and winter, the vegetation is much thinner due to the plants losing their leaves, making the vegetation easier to walk through. During spring and summer, the vegetation grows back very densely, and is much more difficult to walk through. However, mountain lions will not be affected by the density of the vegetation, so it will not be modified to accommodate the wildlife. The creek in the underpass also varies. For most of the year, the creek is dry or has very low water levels. During large rain events, the water levels of the creek may rise and start to flow faster. This condition is not a major concern, because we do not believe that the creek will ever reach a state the will prevent wildlife from crossing.

Phasing Plan

Initially the plan was to install all the human-deterring and animal-attracting aspects of our project at once to see the drastic transformation, in attempt to create a large impact. However, after various meetings with professionals, it was determined that a phasing plan was the most cost effective route to take. There was a shared expressed interest in using this project as a method to determine which components would be most effective at deterring humans and promoting wildlife access and eventually animal crossing. Since this option is the most cost-effective approach, it was recommended to test the boundaries further by phasing the project in such a way that utilized less expensive tactics first and follow those up by installing more expensive tactics.

The first phase was chosen to be warning signs. The signs would display warnings for danger of rattlesnakes, which are also native to the area, as well as mountain lion signs, both shown in the figures below.

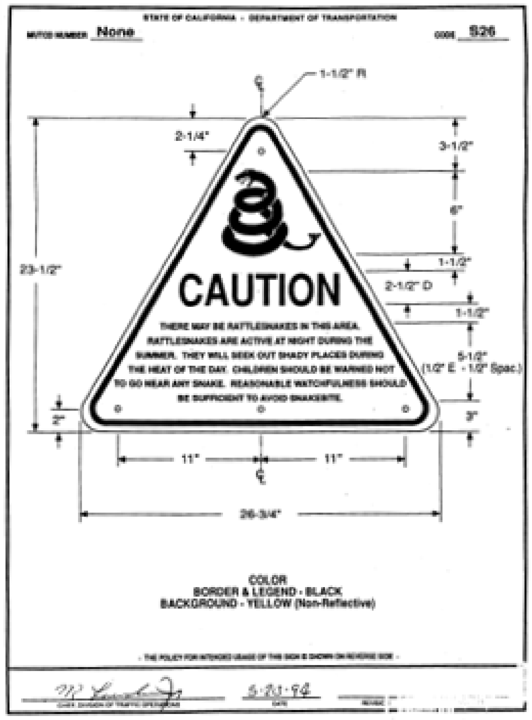


Figure 7.1. *S26(CA) sign from MUTCD.*

The rattlesnake sign above is a standard sign that can be purchased and placed on posts throughout the area. These signs are more familiar to the public and can be found on a variety of different hiking trails in the surrounding area. The mountain lion sign would be similar to the one pictured below. This sign would serve as a “danger” warning sign, as well as an educational sign of the presence of these animals in the area. In Phase 1 of this project, these signs would also be placed on posts throughout the underpass. The first phase would be installed and observed for 2 months before proceeding to the following phase. During this time the traffic in the underpass would be recorded with the help of the ecological reserve to determine the effectiveness of this phase. It is expected that this phase have a small effect on human traffic since it is anticipated that people inhabiting this area are already familiar with the wildlife species present and will not be easily deterred by this. Thus, these signs are intended to be more effective at deterring new trespassers or community members who are exploring the area.

Figure 7.2. *Caution Mountain Lion Sign.*

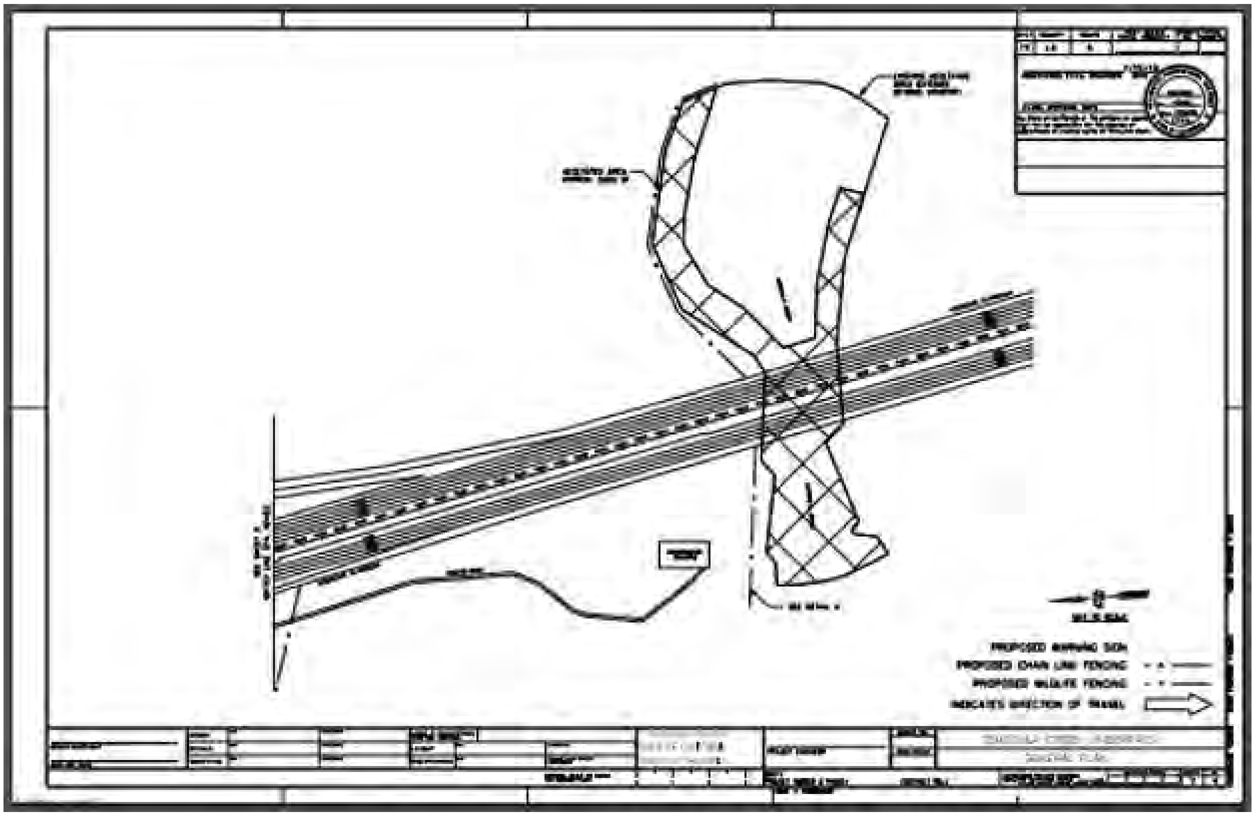


Figure 7.3. *APS of Vegetation Layout.*

In Phase 2 of the Underpass renovation, it is proposed that vegetation be planted to make the area uncomfortable for humans. The figure above shows the area that will be modified to include this vegetation, which includes native species such as California roses and stinging nettles. Research was conducted to determine how this vegetation would impact wildlife; ecologists and nature experts confirmed that these species would not affect the wildlife and would not be a deterrence. Pictures of these species can be found below in the figures. When looking at the types of vegetation to be implemented, it was important to look for vegetation that had an immediate effect on the people trespassing onto conserved land.

Figure 7.4. *Stinging Nettles.*

The spiky texture and coating on the the stinging nettles makes being in contact with this plant very uncomfortable. The California Rose has many thorns located along the stems of the plant that make it uncomfortable to move around. Since these plants have this effect on people in contact with them, it is believed that they will serve as a deterrent to humans and make the this site less appealing.

Figure 7.5. *California Rose.*

Initially poison oak was considered, although, in the workshop hosted in November it was determined that the delayed response that poison oak has would not produce the best results and could have long-lasting results on the community health. Therefore, the choices in vegetation were made due to their immediate response by people, the fact that they are native to the area, as well as their ability to prosper in the climate conditions of the site. This phase would serve as a active measure to ensure humans do not inhabit the area temporarily or permanently. Part of the vegetation plan will be to clear some vegetation which has been encroaching on the native species of the area. These two parts of the vegetation phase will serve as methods of determining humans and maintaining the authenticity of the habitat by protecting the conserved land and ensure that wildlife feel safe in the area.

This phase will be installed and observed for 6 months- 1 year or until the vegetation has a chance to grow into the area and sustain on its own. This phase will be monitored with the help of the ecological reserve to determine how effective the planting of these species will deter humans and impact wildlife crossing.

Once this phase has gone through its process and the vegetation has grown in and the other intruding vegetation has been removed, we will proceed to phase 3. Phase 3 is the installation of fencing. The key to this phase is out partnership with the ecological reserve which will ensure the maintenance and repair of any fencing that has been tampered with or destroyed. At a workshop, one professional had expressed that the most important aspect of successful fencing is the presence of an active party maintaining the fencing. Therefore, we predict that the duration of this phase be between 6 months and 1 year to ensure that the presence of maintenance be observed by those who are vandalizing or obstructing the fencing. This phase will consist of a combination of Caltrans, chainlink fencing along the access points of people, as well as a tailored, wildlife fencing for the mountain lions. Two alternatives for the fencing layout were created based on selection criteria; this will be discussed further in the next section of this paper. In this phase, we also propose to move the warning signs to the fencing; this is shown in the figure by the blue dots along the fencing layout. In phase, 1 the sign distribution will be within the fencing layout area and the goal is to make the signs visible to passing traffic before they enter the area.

The final, and most expensive phase is the installation of sound baffles along the walls of the underpass. It was recommended by conservancy professionals to install sound baffles in the Underpass section. Various companies were contacted to give quotes and estimates of the effectiveness of their materials. It was determined that the sound baffles would provide a noticeable difference in the sound volume as well as the echoing produced and therefore a meaningful addition to the proposal. The sound baffles would be placed with a 1' offset along the walls of the underpass. This is also the last phase because it was determined that sound is the least likely deterrence for the mountain lions because of their consistent exposure to it.

Figure 7.6. *Sound Baffle Layout.*

Below is a visual of what the sound baffles may look like once installed on the walls of the underpass. The installation of these sound baffles is estimated to reduced the volume within this area by 10 decibels. It was also observed by a group of the professionals that the sound was varied depending on what openign you went through in the underpass. Therefore, the intention of the sound baffle phase is to reduce the presence of this echoing.

The intention of the phasing is to see the most effective form of encouraging wildlife to cross as well as creating the most cost effective solution to the need. Our phasing succession takes into consideration the cost of each phase, starting with the most minimal environmental impact and most cost effective phase, the installation of signs, until the most expensive phase. Ideally, if at any point during the phase our target wildlife begin to cross the underpass then it is possible that we stop the phasing because we have successfully addressed the purpose. In this way we also ensure to make the smallest impact possible on the wildlife while focusing on their sustainability.

Fencing Layout

The layout of the fencing is the most important component of this passageway, because we believe it will be the most effective modification of the area that will encouraging mountain lions to cross. Because the primary purpose of the fencing is to restrict human access, most of the proposed fencing will be a chain-link fence per Caltrans' standards; Figure 7.7 shows a detail of this fence below. However, in areas where more mountain lion activity is seen based on biologists' data, a fence specifically designed for mountain lions will be used. This fence was used in the award-winning State Route 241 Wildlife Protection Project and features an overhang to prevent mountain lions from jumping over the fence, as well as deeper footings to prevent mountain lions from digging underneath the fence to get across. Refer to Figure 7.7 below for a detail of this fence.

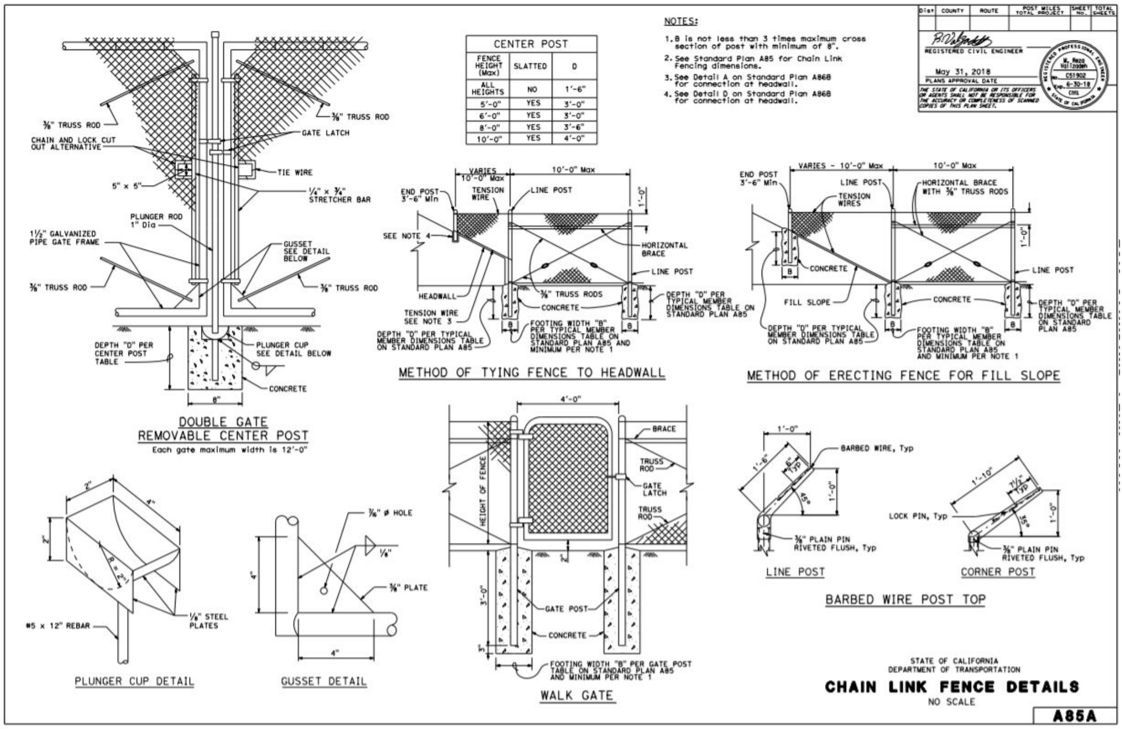


Figure 7.7. *Caltrans Standard Detail for Chain-link Fences.*

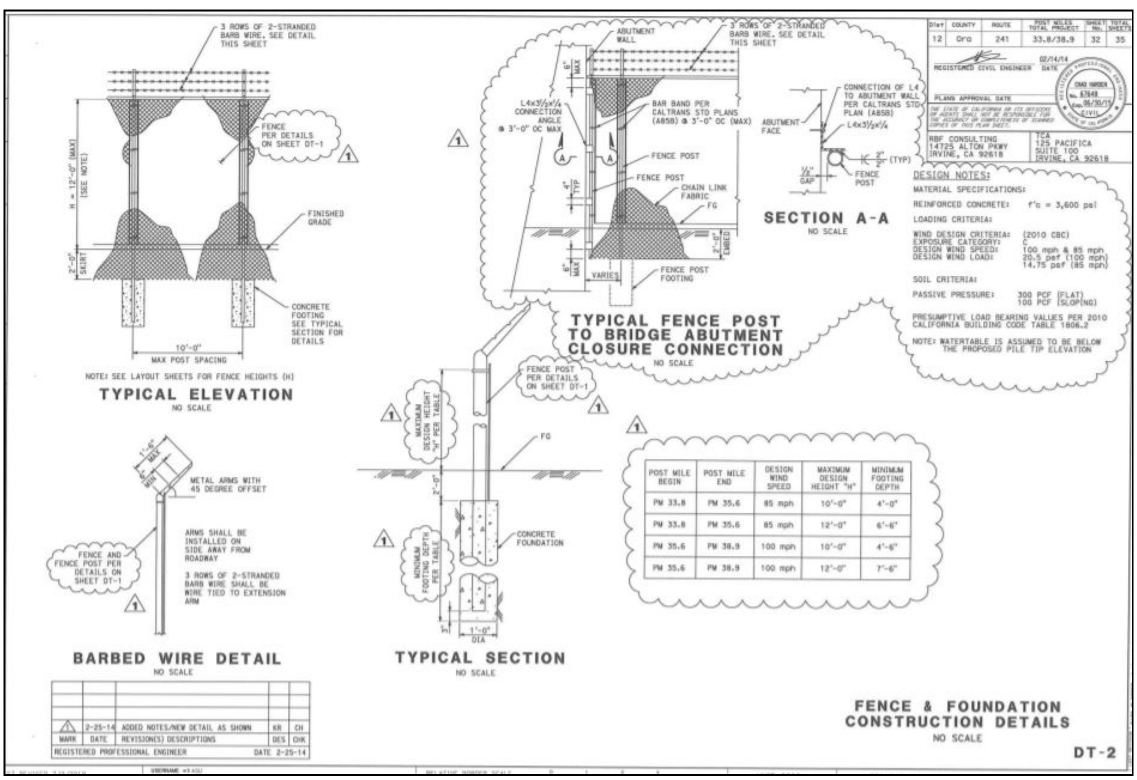


Figure 7.8. *Detail for Wildlife Fencing.*

Criteria for the fencing layout was created and consists of three factors: how effective the layout its at human deterrence, the cost to implement the layout, and how easy it is to maintain. See Table 7.1 for the criteria and the weights assigned to each criteria.

Table 7.1. *Fencing Layout Criteria*

Fencing Layout Criteria	**Weight**
Human Deterrence	40%
Cost	30%
Maintenance	30%
TOTAL	**100%**

Cost Estimate

The cost estimate for this project consisted of five items. The five items are: signs, vegetation, human fencing, animal fencing, and sound mitigation. There were two alternatives for the underpass, but the only difference came in the amount of human and animal fencing that would be layed out. The amount of signs being placed, amount of vegetation being used, and amount of sound baffles being used were kept the same for both alternatives. What was not took into consideration in our cost estimates were permit costs, and manual labor cost for the underpass.

For both alternatives the amount of signs that would be used will be ten, five beware of mountain lion signs and five bewars of rattlesnake signs. Each sign would cost roughly $20 and the total cost for this would come up to be $200. Both alternatives would have the same amount of vegetation placed, and the unit cost would come out to be $7000. The final cost that would come out the same are the sound baffles. The sound baffles are the most expensive part of the project which is why it is the final phase. There would be sixty sound baffles placed on the underpass to reduce the noise caused by the freeway.

The amount of human fencing and animal fencing varies for both alternatives. For the first alternative there would be more fencing placed for alternative one which means the cost of the fencing will be more for the first alternative. The second alternative has less fencing placed and this caused for the price to be less that the first alternative. The total price for alternative one came out to be $620,000 without taking into consideration labor costs. The total price for alternative two came out to be $570,000 without taking into consideration labor costs. The phases can be stopped at anytime once there is a visible decrease in the amount of human activity in the underpass.

Table 7.2. *Underpass Fencing Alternative 1 Cost Estimate.*

Alternative 1			
Item	**Unit**	**Unit Cost**	**Total**
Signs	10	20	$ 200
Vegetation	1	7000	$ 7,000
Human Fencing	4100	20	$ 82,000
Animal Fencing	650	75	$ 48,750
Sound Baffles	8,000	60	$ 480,000
Total			$ 620,000

Table 7.3. *Underpass Fencing Alternative 2 Cost Estimate.*

Alternative 2			
Item	**Unit**	**Unit Cost**	**Total**
Signs	10	20	$ 200
Vegetation	1	7000	$ 7,000
Human Fencing	1950	20	$ 39,000
Animal Fencing	540	75	$ 40,500
Sound Baffles	8,000	60	$ 480,000
Total			$ 570,000

Appendix

Overpass

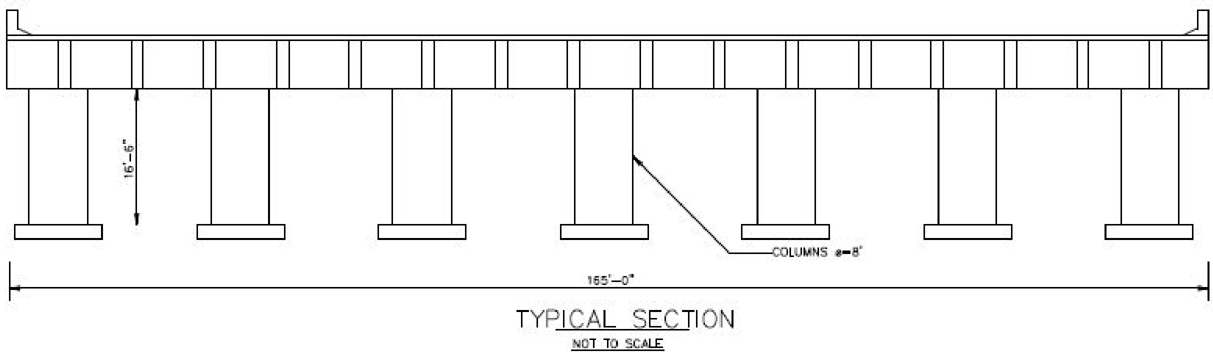
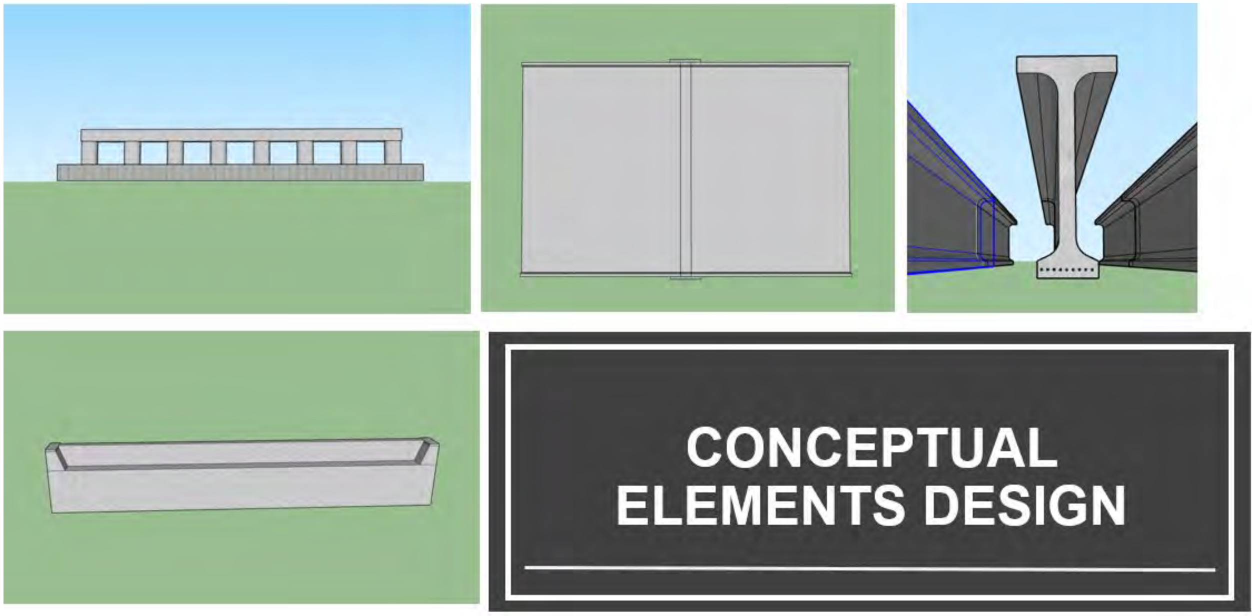


Figure 5.15. *Typical Section of Traditional Design.*

Slab		Girder		Column		Foundation Slab	
Strength of Concrete (fc)	4,000 psi	Girder Spacing	10 ft	Type of Column	Round Spiral	Width	25 ft
Strength og Steel Rebar (fy)	60,000 psi	Span Length	117 ft	Diameter	8 ft	Length	165 ft
Length	10 ft	Width	20 in	Height	24 ft	Depth	8 ft
Height	0.5 ft	Height	82 in	Spacing	25 ft	Ult. Bearing Capacity	50,000 psf
Chosen Rebar	#4	Chosen Rebar	#11	Num. of Column	8		
Soil Layer Depth	3 ft	Chosen Stirrup	#4	Chosen Rebar	#10		
Dead Load	353 lb/ft	Dead Load	2,061 lb/ft	Num. of Bars	22/ side		
Live Load	20 lb/ft	Live Load	200 lb/ft	Size of Ties	#4		
				Dead Load	2,915 lb/ft		
				Live Load	20 lb/ft		

Table 5.8. *Structural Analysis Summary of Traditional Overpass Design*



.***Figure 5.16.*** *Conceptual Structural Elements of Traditional Overpass*

Culvert

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**1.57** (1.32-1.90)	**2.05** (1.73-2.47)	**2.71** (2.27-3.26)	**3.28** (2.72-4.00)	**4.08** (3.26-5.15)	**4.74** (3.71-6.11)	**5.42** (4.14-7.19)	**6.17** (4.56-8.41)	**7.22** (5.11-10.3)	**8.09** (5.62-12.0)
10-min	**1.13** (0.948-1.36)	**1.47** (1.24-1.77)	**1.94** (1.63-2.35)	**2.35** (1.95-2.86)	**2.93** (2.34-3.69)	**3.40** (2.66-4.38)	**3.89** (2.96-5.15)	**4.42** (3.27-6.03)	**5.18** (3.67-7.39)	**5.80** (3.96-8.57)
15-min	**0.912** (0.764-1.10)	**1.19** (0.996-1.43)	**1.57** (1.31-1.89)	**1.90** (1.57-2.31)	**2.36** (1.89-2.98)	**2.74** (2.14-3.53)	**3.14** (2.39-4.15)	**3.56** (2.64-4.86)	**4.18** (2.96-5.96)	**4.67** (3.19-6.91)
30-min	**0.686** (0.576-0.824)	**0.894** (0.752-1.08)	**1.18** (0.990-1.43)	**1.43** (1.18-1.74)	**1.78** (1.42-2.24)	**2.06** (1.61-2.66)	**2.36** (1.80-3.13)	**2.69** (1.99-3.66)	**3.15** (2.23-4.49)	**3.52** (2.41-5.21)
60-min	**0.522** (0.439-0.627)	**0.681** (0.572-0.820)	**0.900** (0.753-1.09)	**1.09** (0.901-1.32)	**1.35** (1.08-1.71)	**1.57** (1.23-2.02)	**1.80** (1.37-2.38)	**2.04** (1.51-2.79)	**2.39** (1.70-3.41)	**2.68** (1.83-3.97)
2-hr	**0.376** (0.316-0.452)	**0.490** (0.410-0.589)	**0.644** (0.538-0.776)	**0.773** (0.641-0.941)	**0.955** (0.764-1.21)	**1.10** (0.861-1.42)	**1.25** (0.954-1.66)	**1.41** (1.05-1.93)	**1.64** (1.16-2.34)	**1.82** (1.24-2.69)
3-hr	**0.306** (0.257-0.368)	**0.399** (0.335-0.480)	**0.523** (0.438-0.632)	**0.627** (0.520-0.764)	**0.773** (0.618-0.975)	**0.887** (0.695-1.15)	**1.01** (0.768-1.33)	**1.13** (0.838-1.55)	**1.31** (0.927-1.87)	**1.45** (0.990-2.14)
6-hr	**0.222** (0.186-0.267)	**0.289** (0.243-0.348)	**0.379** (0.317-0.457)	**0.453** (0.376-0.552)	**0.556** (0.445-0.702)	**0.637** (0.498-0.822)	**0.720** (0.549-0.954)	**0.808** (0.598-1.10)	**0.929** (0.658-1.33)	**1.03** (0.700-1.52)
12-hr	**0.148** (0.125-0.178)	**0.194** (0.163-0.233)	**0.253** (0.212-0.306)	**0.303** (0.251-0.369)	**0.371** (0.297-0.468)	**0.424** (0.332-0.547)	**0.478** (0.365-0.633)	**0.535** (0.396-0.730)	**0.613** (0.434-0.874)	**0.675** (0.461-0.998)
24-hr	**0.097** (0.085-0.111)	**0.127** (0.112-0.147)	**0.167** (0.147-0.194)	**0.200** (0.175-0.234)	**0.246** (0.208-0.296)	**0.281** (0.233-0.346)	**0.318** (0.257-0.400)	**0.356** (0.281-0.460)	**0.408** (0.310-0.550)	**0.450** (0.330-0.626)
2-day	**0.057** (0.050-0.065)	**0.076** (0.067-0.088)	**0.102** (0.090-0.119)	**0.125** (0.109-0.146)	**0.156** (0.132-0.189)	**0.182** (0.151-0.224)	**0.208** (0.169-0.262)	**0.237** (0.187-0.306)	**0.277** (0.210-0.373)	**0.310** (0.227-0.431)
3-day	**0.040** (0.035-0.046)	**0.054** (0.048-0.063)	**0.074** (0.065-0.086)	**0.091** (0.080-0.107)	**0.116** (0.098-0.140)	**0.137** (0.113-0.168)	**0.159** (0.129-0.200)	**0.183** (0.144-0.236)	**0.217** (0.165-0.292)	**0.246** (0.180-0.342)
4-day	**0.032** (0.029-0.037)	**0.045** (0.039-0.051)	**0.062** (0.054-0.071)	**0.076** (0.067-0.089)	**0.098** (0.083-0.118)	**0.116** (0.096-0.143)	**0.135** (0.110-0.171)	**0.157** (0.124-0.203)	**0.188** (0.143-0.253)	**0.214** (0.157-0.298)
7-day	**0.022** (0.019-0.025)	**0.030** (0.026-0.035)	**0.042** (0.037-0.048)	**0.052** (0.045-0.061)	**0.067** (0.057-0.081)	**0.080** (0.066-0.098)	**0.093** (0.076-0.118)	**0.109** (0.086-0.140)	**0.131** (0.099-0.176)	**0.150** (0.110-0.208)
10-day	**0.016** (0.015-0.019)	**0.023** (0.020-0.026)	**0.032** (0.028-0.037)	**0.040** (0.035-0.047)	**0.052** (0.044-0.062)	**0.062** (0.051-0.076)	**0.072** (0.059-0.091)	**0.084** (0.066-0.109)	**0.102** (0.077-0.137)	**0.116** (0.085-0.162)
20-day	**0.010** (0.009-0.012)	**0.014** (0.013-0.017)	**0.020** (0.018-0.024)	**0.026** (0.022-0.030)	**0.033** (0.028-0.040)	**0.040** (0.033-0.049)	**0.047** (0.038-0.059)	**0.055** (0.043-0.071)	**0.067** (0.051-0.090)	**0.077** (0.056-0.107)
30-day	**0.008** (0.007-0.009)	**0.012** (0.010-0.013)	**0.016** (0.015-0.019)	**0.021** (0.018-0.024)	**0.027** (0.023-0.033)	**0.033** (0.027-0.040)	**0.038** (0.031-0.048)	**0.045** (0.035-0.058)	**0.055** (0.041-0.073)	**0.063** (0.046-0.087)
45-day	**0.006** (0.006-0.007)	**0.009** (0.008-0.011)	**0.013** (0.011-0.015)	**0.016** (0.014-0.019)	**0.021** (0.018-0.026)	**0.026** (0.021-0.032)	**0.030** (0.025-0.038)	**0.036** (0.028-0.046)	**0.043** (0.033-0.058)	**0.050** (0.036-0.069)
60-day	**0.006** (0.005-0.006)	**0.008** (0.007-0.009)	**0.011** (0.010-0.013)	**0.014** (0.012-0.017)	**0.019** (0.016-0.022)	**0.022** (0.019-0.027)	**0.026** (0.021-0.033)	**0.031** (0.024-0.040)	**0.037** (0.028-0.050)	**0.043** (0.031-0.060)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Figure 6.11. *NOAA data used to calculate discharge.*

Table 6.5. *Watershed Results based on Design flow calculation based on a 50 storm interval.*

Storm Return Interval (yrs.)	Overland Flow Travel Time (min)	Shallow Concentrated Flow Time (min)	Channel Flow Time (min)	Time of Concentration (min)	Design Storm Intensity (iph)	Design Flow (cfs)
2	8.2	0	2.5	10.7	1.42	23.5
5	7.1	0	2.3	9.4	1.99	32.9
10	6.5	0	2.1	8.6	2.51	41.4
25	5.8	0	1.9	8	3.23	53.3
50	5.4	0	1.8	8	3.75	61.8
100	5.1	0	1.8	8	4.29	70.7

Table 6.6. *Hydrological analysis results based on HY-8 program.*

Storm Return Interval (yrs.)	Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)
25	53.3	53.3	1242.07	1.24	-4.15
50	61.8	61.8	1242.21	1.38	-5.06

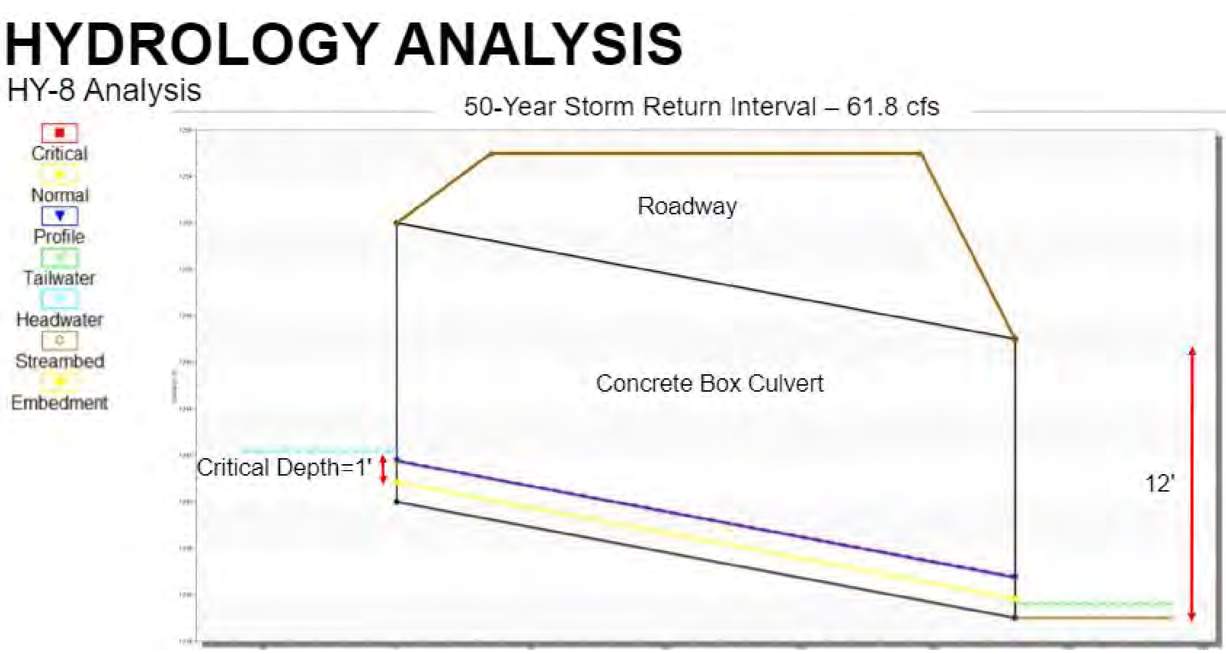


Figure 6.12. *Hydrological analysis results for culvert designs.*

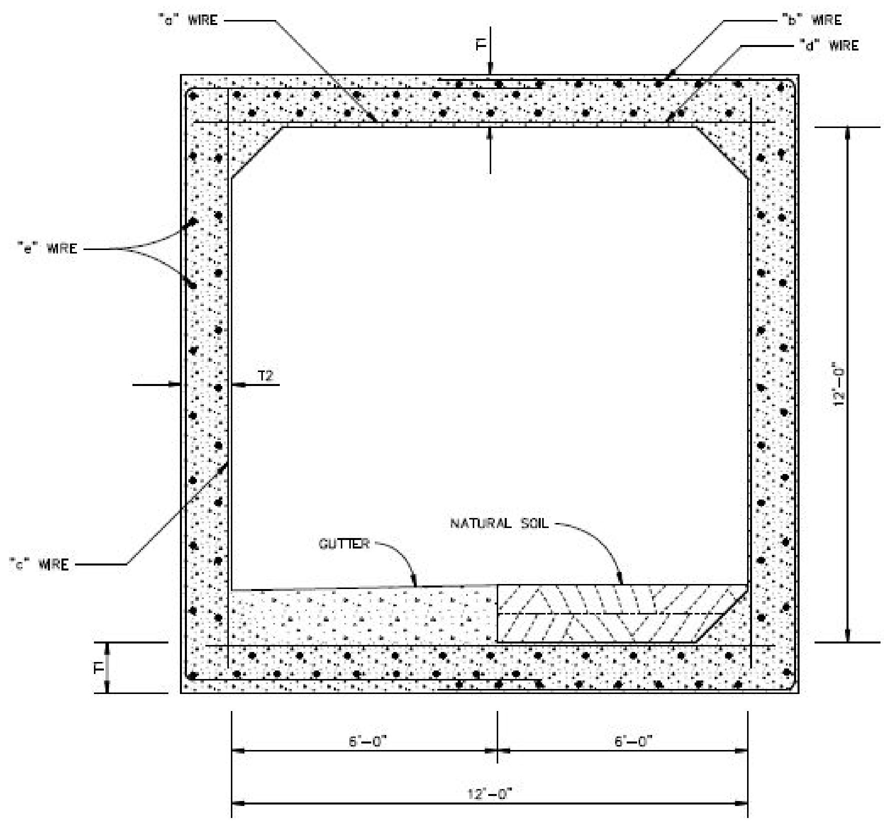


Figure 6.13. *Typical cross-section of proposed box culvert.*

Table 6.7. *Concrete Box Culvert specifications in accordance to Caltrans Standard Plans.*

SPAN, S			12′
HEIGHT, H			
MAXIMUM EARTH COVER			10′
CONCRETE (INCH)	ROOF	T_1	12″
	SIDE WALL	T_2	12″
	INVERT	T_3	12″
MINIMUM WELDED WIRE FABRIC (inch^2/ft)		"a"	1.29
		"b"	.74
		"c"	.42
		"d"	.22
		"e"	.11
* QUANTITY	Conc	CY/LF	2.00
	Reinf	LB/LF	281
** SOIL PRESSURE (ksf)			3.8

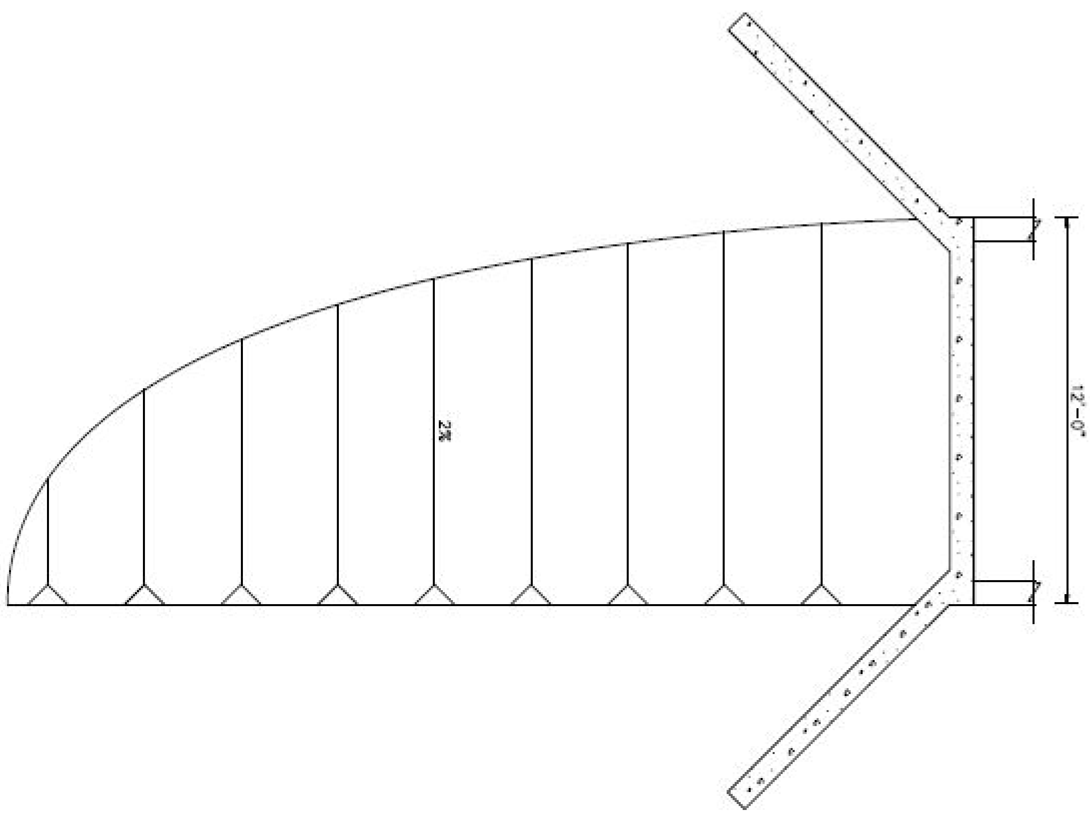


Figure 6.14. *Demonstrates slope approaching the culvert on the western side to lead water towards the gutter inside.*

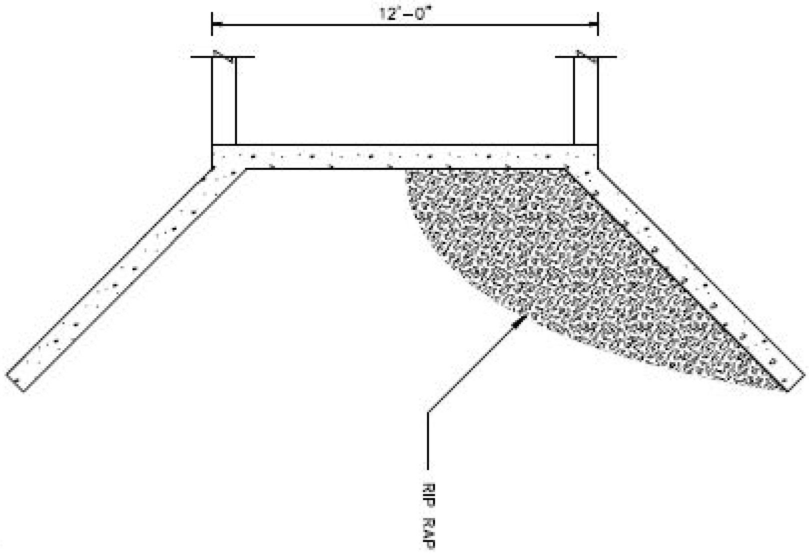


Figure 6.15. *Demonstrates the Riprap on the eastern side to mitigate for erosion.*

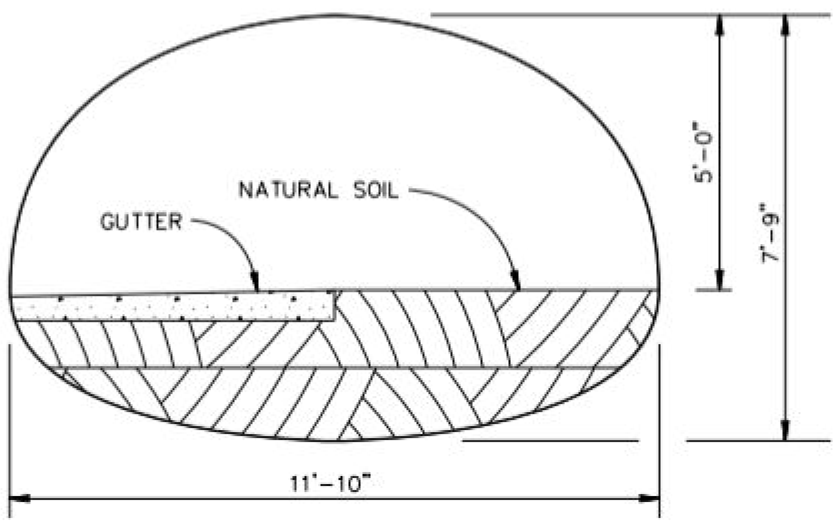


Figure 6.16. *Cross-section of Alternative 2: Corrugated Steel Pipe.*

Underpass

Figure 7.9. *Signs of Human Presence.*

Figure 7.10. *Existing Vegetation to be Removed.*

Figure 7.11. *Existing Vegetation, August - December.*

Figure 7.12. *Existing Vegetation, August - December.*

Figure 7.13. *Existing Vegetation, February - May.*

Figure 7.14. *Graffiti in the Underpass.*

Figure 7.15. *Underpass Wildlife Fencing.*

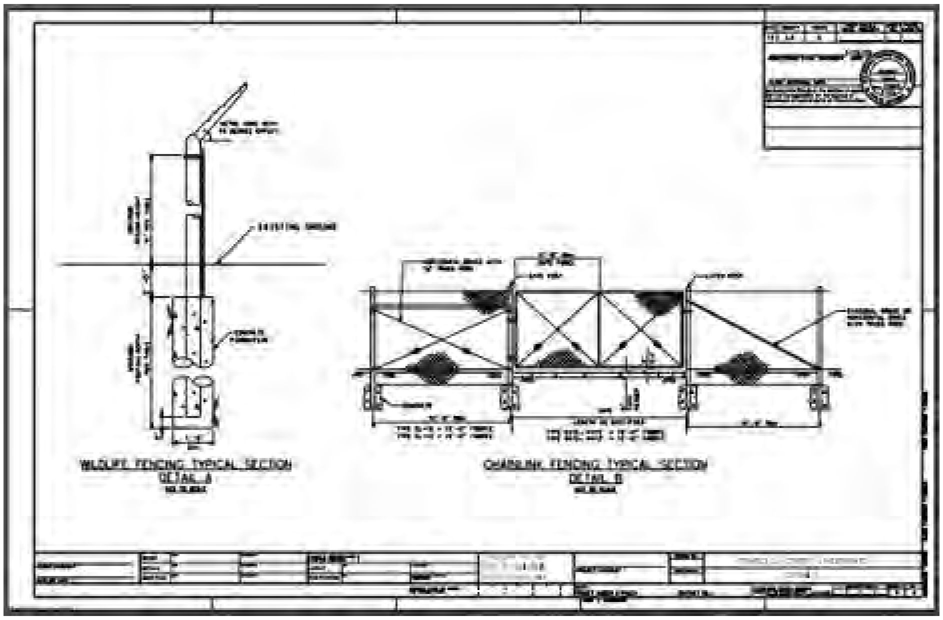


Figure 7.16. *Underpass Human Fencing, Caltrans.*

Table 7.4. *Fencing Layout Alternative Evaluation.*

Criteria	Weight	Alt 1*	Weighted Score	Alt 2*	Weighted Score
Human Deterrence	40%	3	1.2	2	0.8
Cost	30%	1	0.3	2	0.6
Maintenance	30%	2	0.6	3	0.9
Total	100%		2.1		2.3
Chosen Alternative	Alternative 2 is Chosen				

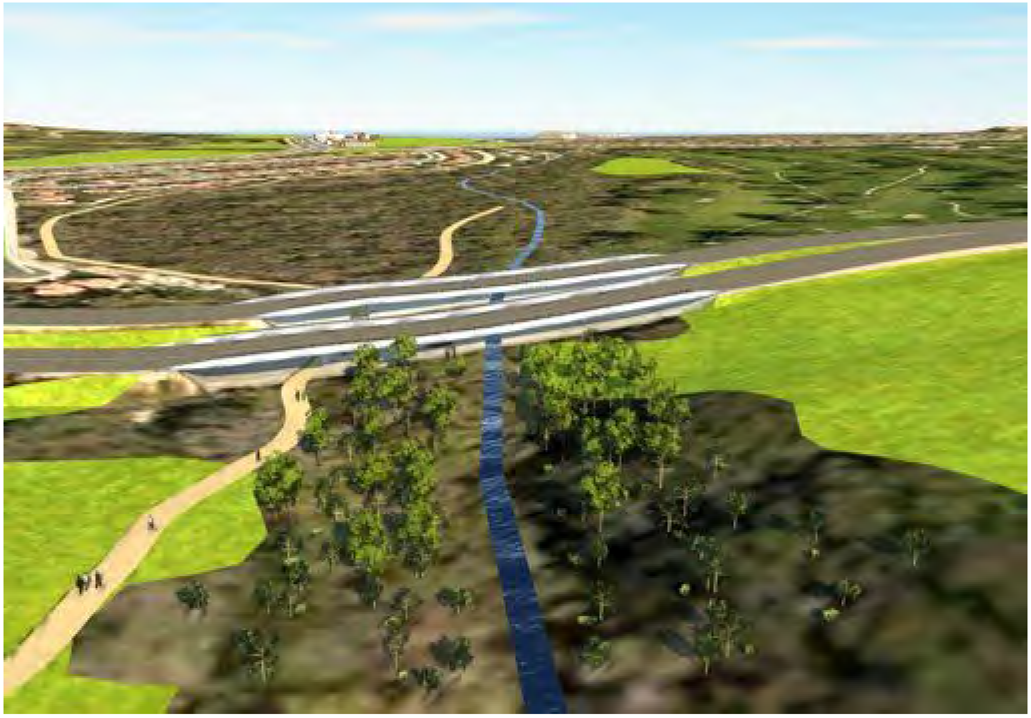


Figure 7.17. *Underpass Infraworks 'Before' Rendering.*

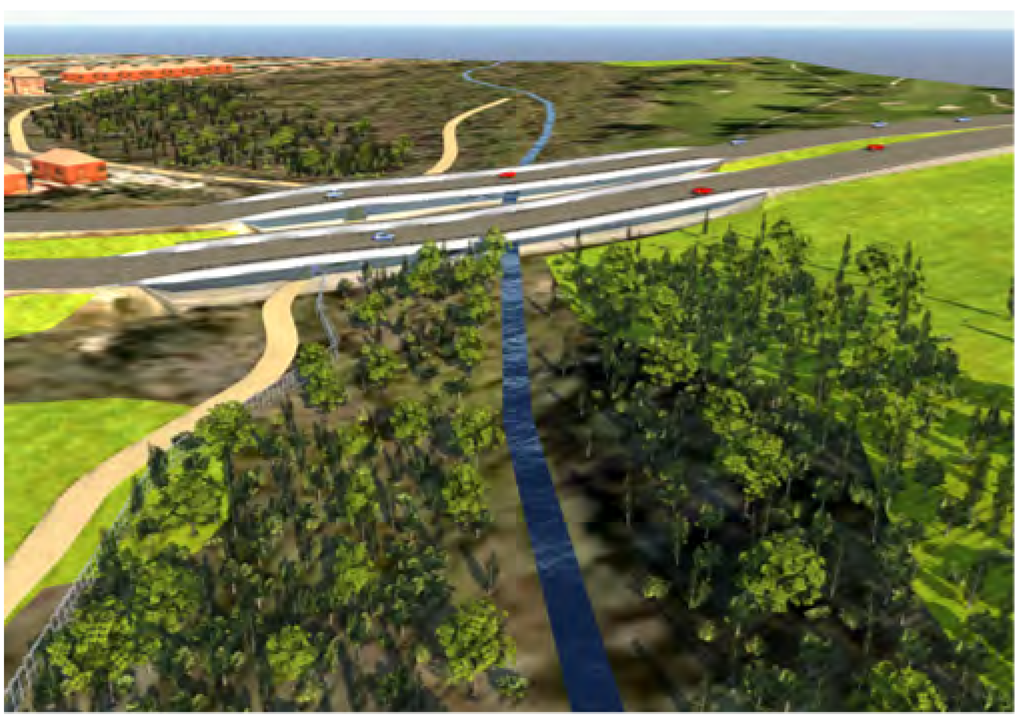


Figure 7.18. *Underpass Infraworks 'After' Rendering.*

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