Spring 2023

Highway 17 Wildlife Crossing

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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ENTITLED

HIGHWAY 17 WILDLIFE CROSSING

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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Department Chair **date**

HIGHWAY 17 WILDLIFE CROSSING

By

Taryn Chisholm, Seema Singh, Justin Uyeno

SENIOR DESIGN PROJECT REPORT

Submitted to

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of

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- Shawn Lockwood - Valley Water Wildlife Biologist

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HIGHWAY 17 WILDLIFE CROSSING

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Department of Civil, Environmental, and Sustainable Engineering

Santa Clara University, Spring 2023

Abstract:

Highway 17 is an essential corridor for people to commute between the Bay Area and the Santa Cruz regions, but this highway also creates a barrier between wildlife territories, fragmenting their habitats and stranding animal populations on either side. The lack of crossing infrastructure along Highway 17 forces wildlife to attempt to cross the highway into oncoming traffic, causing wildlife-vehicle collisions (WVC) which endangers the lives of motorists and animals alike. In order to address this problem, the team designed a precast, concrete culvert crossing underneath Highway 17 to provide a safer passageway to increase habitat connectivity as well as safety for both motorists and wildlife. The design included the general layout of the culvert and retaining structures, construction planning with temporary transportation design, the design of the retaining structures, the foundation selection, and environmental considerations. The team delivered the design package in Spring 2023 along with AutoCAD drawings for the structural and geotechnical aspects of the culvert design, analysis for the environmental impact, and cost estimate of the proposed wildlife crossing.

Keywords: Civil Engineering, Structural Engineering, Geotechnical Engineering, Hydrology, Wildlife Crossing, Concrete Culvert, Construction, Transportation Engineering

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1. Introduction

1.1 Description of Client and Project

The Santa Cruz Mountains are home to many animal species, including mountain lions, bobcats, and deer. Based on the Revised Alternatives Report created by Midpeninsula Regional Open Space District in January of 2019, Highway 17 has dense traffic and no accessible crossings for the wildlife, which puts the motorists and the animals in danger of wildlife-vehicle collisions (WVC) and limits the wildlife's options to find food, mates, and habitats. Highway 17 is already known for being a dangerous passageway based on its winding turns through the Santa Cruz mountains, so the safety of drivers was critical to consider throughout the design.

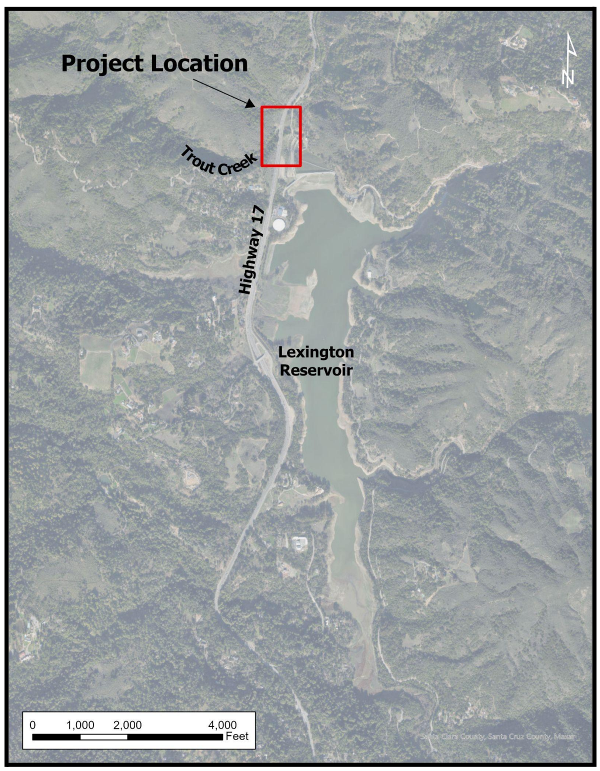

Figure 1: Wildlife crossing project area near Lexington Reservoir.

The goal of this project was to design a wildlife crossing to protect the safety of animals and humans. The approximate location for the wildlife crossing across Highway 17 is shown in Figure 1 near Lexington Reservoir. This project location was identified based on wildlife road fatality data. The design included construction, transportation, structural, geotechnical, hydrological, and environmental considerations.

The client for this project was the Midpeninsula Regional Open Space District (Midpen). Additional stakeholders included the California Department of Transportation (Caltrans), Santa Clara County, City of Los Gatos, and various wildlife and resource agencies.

1.2 Problem Statement

Highway 17 is an essential corridor for people to commute between the Bay Area and Santa Cruz regions. The highway creates a barrier between wildlife migratory routes within the Santa Cruz mountains. Animals have been known to attempt crossing this stretch of highway, which can cause accidents and fatalities for both humans and wildlife. Furthermore, collisions between wildlife and vehicles along this highway span result in delayed travel times, road closures, and vehicular damages.

1.3 Description of Project Requirements

The objective of this project was aligned with the client's long term goal to create links where wildlife habitats already exist to allow the animals to cross Highway 17 safely. Lexington Reservoir was a top priority location where Highway 17 isolates long-ranging species, such as mountain lions and deer. Additional project objectives included improving motorist safety and reducing the potential for wildlife collisions along Highway 17. The goal of the project was to provide an alternative design for a wildlife crossing design near Lexington Reservoir. The existing project is currently in the design process for the Highway 17 Wildlife Passage and Regional Trail Crossings with the Midpeninsula Regional Open Space District.

The following design constraints were required of all alternatives for the Wildlife Crossing project:

- Remain within budget
- Follow design requirements set by the Caltrans Highway Design Manual and the California Manual on Uniform Traffic Control Devices (CA MUTCD)

- Meet the American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway Bridges and the Load and Resistance Factor Design (LRFD) Bridge Design Specifications

- Meet National Pollutant Discharge Elimination System (NPDES) requirements for drainage into waterways

- Meet required loading (dead load, live load of traffic)

- Meet required environmental restrictions set by The California Environmental Quality Act (CEQA) and the California Endangered Species Act (ESA)

- Provide adequate fencing to properly direct the animals to the crossing location and jump outs to provide any animals with a way out from the active highway

- Meet minimum undercrossing dimensions:

    - Width: 15 feet

    - Height: 10 feet

    - Approach ramp slope: 3:1

The end product for this project was a design of the wildlife crossing consisting of construction, geotechnical, structural, and environmental components with drawings, maps, and a report of calculations.

1.4 Description of Project Approach

The project culminated in the Senior Design Conference held in May of 2023 with a presentation and final report. Each scope of work for this project is defined in the following section. Then, the project approach is summarized in Table 1 with the timelines for each task and an overall schedule shown in Figure 2.

Water/Environmental Design

- Estimated rainfall, runoff, and infiltration for preliminary culvert drainage design

- Created ArcGIS maps
  - Watershed basin area and creeks of Lexington Reservoir
  - Topography of the location
- Established necessary environmental considerations for project
  - Organizations to keep in communication
  - Impacts to the health and safety of motorists, residents, and wildlife
- Created environmental considerations cost estimate
  - Fencing
  - Jump outs
  - Storm Water Pollution Prevention Plan (SWPPP)
  - Environmental mitigations

Transportation Design

- Assessed the available design speeds and corresponding curvature radii
- Designed temporary highway lane shifts and associated traffic control device plans
  - Curvature for specific design speeds
  - Tangents between curves for safer driving
  - Speed reductions to design
- Calculated preliminary cut and fill volume required for phase two (2) temporary lane shifts
- Created AutoCAD drawings
  - Plan view of phase one (1) temporary highway lane shift

    - Plan view of phase one (1) traffic control device layout
    - Plan views of phase two (2) temporary highway lane shift alternatives
    - Plan view of phase two (2) traffic control device layout
    - Plan view of phase two (2) cut and fill area
    - Typical cross section of the existing highway conditions
    - Typical cross section of phase one (1) temporary highway lane shift
    - Typical cross section of phase two (2) temporary highway lane shift
- Created transportation cost estimation
    - Asphalt and bases
    - Addition and removal of temporary paint and rails
    - Traffic control devices

Geotechnical Design

- Looked for geotechnical report
    - Soil properties and capacities
- Established the type of foundation that would best suit the culvert and soil properties
    - Piles, shear footings, strip footings
- Determined the connections that would be needed for culvert and foundation
- Created a package of foundation calculations
    - Worked with the culvert loads
- Created AutoCAD drawings of the foundations
    - Cross sections

    - Elevations

Structural Design

- Assessed the constructability of crossing
    - Developed feasible strategy for implementation
    - Assessed construction phasing and extent of highway closures
    - Coordinated temporary transportation strategy during construction with construction phasing
    - Assessed how the constructability impacted the form of the structure
- Generated general layout of culvert and retaining walls
    - Determined final type of culvert structure and retaining structure
    - Determined dimensions for culvert
        - Length
        - Span
        - Height
- Communicated with Contech Engineering Solutions (Contech)
    - Estimated loading for preliminary foundation design
        - Established gravity loads of culvert
            - Dead loads (asphalt, soil, and concrete)
            - Live loads (highway)
    - Designed final culvert elements
        - Size of culvert

        - Determined height for foundation pedestal

- Designed retaining structures
    - Temporary retaining wall utilized during construction
    - Permanent retaining wall
- Created AutoCAD drawings
    - Plan view of culvert
    - Elevation view of culvert
    - Typical Section of culvert
    - Section cut of temporary retaining wall
    - Section cut of permanent retaining wall

Construction Logistics

- Researched equipment and haul loads
    - Flatbed trailers
    - Cranes
    - Dump trucks
- Calculated weight of structures
    - Culvert pieces
    - Soil weight
- Created construction cost estimation
    - Equipment
    - Labor
    - Removal of surrounding materials

    - Delivery and materials of culvert
    - Process of foundation installation
    - Process of temporary and permanent retaining walls

<u>Team</u>

- Created preliminary presentation at the end of Winter Quarter
- Created preliminary report at the end of Winter Quarter
- Created final senior design presentation for conference
    - Added new information, drawings, or maps
    - Finalized slides
    - Practiced presentation
- Created final senior design report

Based on these outlined tasks, the milestones were placed in a Gantt chart to visualize the schedule for the remainder of the senior design project. The project start date for this schedule was January 9th, 2023, the first day of Winter Quarter. The schedule is shown in Figure 2.

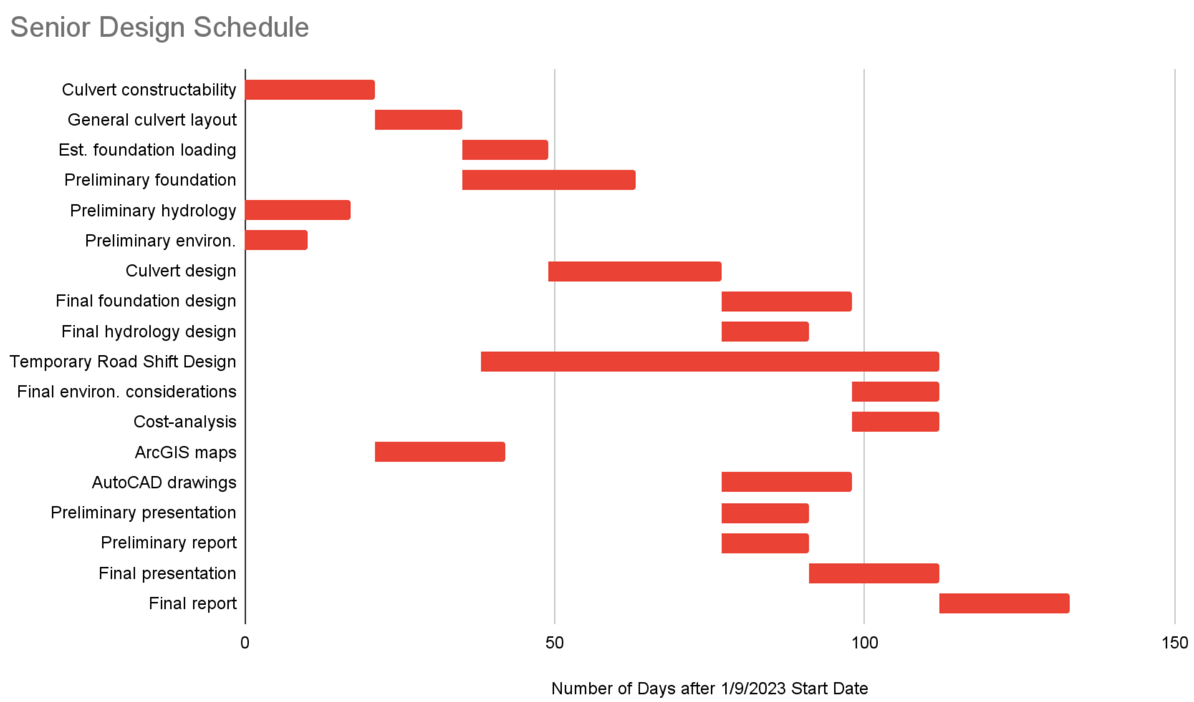

Figure 2: Schedule for Scope of Work Tasks.

The schedule showed an overview of the scope of work. Table 1 shows a more detailed summary of the tasks needed to complete the project. Each task includes the team member(s) working on it and the predicted timeline.

Table 1: Project tasks with assigned team members and timeline.

Task	Activity	Person	Timeline	Must follow
A	Assessing the constructability of culvert	Taryn	3 weeks	N/A
B	Generate general layout of culvert and retaining walls	Taryn	2 weeks	A

C	Estimate loading for preliminary foundation design	Taryn	2 weeks	B
D	Preliminary foundation design	Seema	3 weeks	B
E	Preliminary hydrology design	Justin	2.5 weeks	N/A
F	Preliminary environmental considerations	Justin	1.5 weeks	N/A
G	General culvert design	Taryn	4 weeks	C
H	Final foundation design	Seema	4 weeks	G
I	Final hydrology design	Justin	2 weeks	G
J	Temporary Road Shift Design	Justin	10.5 weeks	N/A
K	Final environmental considerations	Justin	2 weeks	H/I
L	Cost-analysis	Justin	2 weeks	H/I
M	ArcGIS Maps	Justin	3 weeks	A
N	AutoCAD drawings	TEAM	3 weeks	G
O	Preliminary presentation	TEAM	2 weeks	E/F/G
P	Preliminary report	TEAM	2 weeks	E/F/G

Q	Final presentation	TEAM	3 weeks	N
R	Final report	TEAM	3 weeks	P
Task	**Activity**	**Person**	**Timeline**	**Must follow**

Resources Needed

This project relied on the preliminary information and constraints from the existing project with Midpen. The necessary information can be found in the preliminary design alternatives analysis section of this report.

The Engineering Computer Labs were needed to complete the necessary drawings and calculations. This includes the programs of AutoCAD, ArcGIS, MathCAD, and ENERCALC.

2. Alternatives Analysis

Wildlife crossings can take many forms. This alternatives analysis compared five (5) different alternatives for the type of crossing structure based on eight (8) weighted criteria.

2.1 Summary of Alternatives

There were five (5) alternatives for the wildlife crossing on Highway 17. The alternatives considered were a steel bridge, a prefabricated steel bridge, a precast concrete bridge, a precast concrete culvert, and the status quo.

The first alternative was a steel bridge composed of structural steel members with a concrete deck. The steel would be transported to the site. This would involve steel girders, beams, and columns. The connections would be completed both in the shop and at the site for all required welding and bolting. The objective would be to weld as much as possible in the shop in order to speed up the construction process and minimize the time and cost of additional on-site inspections.

The second alternative was a prefabricated steel bridge. A steel bridge would be fabricated offsite to the specifications of the project and brought to the site. The prefabricated bridge would need to be connected to the foundation and checked for seismic compliance, but all other design would be completed by the prefabricated bridge company.

The third alternative was a precast concrete bridge. The elements of the concrete bridge would be created offsite and brought onsite to be placed. The precast concrete bridge would be composed of concrete and steel reinforcement. This is a quicker, more feasible alternative compared to a cast-in-place concrete bridge, which would not be feasible for a project over Highway 17.

The fourth alternative considered was a precast concrete culvert under Highway 17. The precast concrete arch culvert would be provided by Contech Engineering Solution. The design would also include the design of the retaining walls at each end of the culvert.

The final alternative was the status quo. This alternative assumed that there are no changes and the project would not continue. This would assume that no wildlife crossing will be implemented along this span of Highway 17. There would be no additional connectivity for the wildlife, and the danger to both drivers and animals remains.

2.2 Ranking of Criteria

Criteria are the optional parameters that would be beneficial for a project to have, but are not necessary for its success. These criteria can sometimes conflict with one another, so a decision matrix is often required to prioritize the most favorable criteria for the project. The following design criteria were used to develop and evaluate the alternative analysis for the structure types used for the wildlife crossing:

1. Low traffic disturbance during construction
2. Attractiveness to animals of interest
3. Ability to design based on courses taken
4. Constructability based on unstable soil conditions
5. Low construction cost
6. Low maintenance and operation costs
    a. Durability of materials
    b. Sustainability of overall solution
7. Minimal impact of final crossing on highway users
8. Environmental impact of materials

The established criteria for this project were ranked by importance based on how well a given criteria addressed the project objectives. Each criteria was assigned a weight on a scale of one to five (1 to 5), with one (1) signifying a criteria of little importance and five (5) signifying a criteria of great importance in relation to fulfilling the project objectives. The project design criteria and the respective justifications for their attributed weights are summarized in Table 2.

Table 2: List of criteria with the given weights and justifications.

Criteria	**Weight**	**Justification**
Attractiveness to animals of interest	5	The goal of the wildlife crossing was to increase wildlife connectivity. The attractiveness of a crossing was one of the most critical criteria, as that impacted the wildlife's decision to utilize the crossing. Certain wildlife have preferences with regards to the crossing type and shape, which was considered in selecting the ideal crossing alternative.
Ability to design based on courses taken	5	The goal of the wildlife crossing design was to apply the skills and knowledge from the courses at Santa Clara University as the senior capstone project. Therefore, one of the most critical criteria was the ability of the team to design the given alternative based on the courses taken.
Low traffic disturbance during construction	4	This project was located along an important highway for daily commuters. Each crossing alternative would require different construction sequencing processes and traffic control measures that dramatically impact the flow of traffic. Therefore, it was one of the most critical criteria to consider which crossing type will cause minimal disruptions to the traffic flow during construction.
Constructability based on unstable soil conditions	3	This project was located on an important passageway for commuters. Within this region, the soil is considered unstable and must be considered in order to determine feasible structure types for the crossing. Construction

		precautions depended on the interaction with the soils beneath the foundation and in the highway fill where the structure would be placed.
Low construction cost	2	One important goal was to complete the wildlife connection with the minimal cost possible for implementation, primarily since it is publicly funded. The cost was dependent on the materials, transportation, and duration of labor.
Low maintenance and operation costs	2	When looking at the completion of this project it was important to keep the maintenance and operation costs to a minimum for long term costs. Frequent maintenance would disturb the flow of the animals that are comfortable utilizing the crossing by increasing the human and animal interaction. The cost is dependent on the long term upkeep based on the material and structure type.
Minimal impact of final crossing on highway users	1	The goal of the wildlife crossing was to increase wildlife connectivity while improving the safety of the drivers on Highway 17. Once the design is complete, the crossing could impact the drivers on Highway 17 negatively if their vision is blocked or there are additional distractions above or around the highway. Although all designs would follow the Caltrans design standards, it was still important to consider how the different alternatives could impact the drivers. Therefore, one criteria for the alternative analysis was to minimize the impact on highway users once the final crossing was complete.

		This was not the most important criteria in the decision process because the minimum requirements from Caltrans ensured the drivers would still be safe.
Environmental impact of materials	1	One common consideration of all new structures was the environmental impact of the materials in terms of the carbon footprint of the material emissions. The emissions that are generated by a given material are dependent on the amount of material used and the type of material selected.

2.3 Alternative Rating System

The matrix method was utilized to evaluate the top alternative solution based on the established criteria and the proposed crossing alternatives. Based on how well a given alternative met each criteria, a score between one (1) and 10 was attributed to each alternative for that specific criteria. The following list categorizes what each score on the scale represented:

1. The criteria is not met at all. This alternative may be detrimental to move forward with in regards to this criteria.
2. The criteria is not met. This alternative is not favorable in regards to this criteria.
3. The criteria is partially met. This alternative may not be favorable in regards to this criteria.
4. The criteria is close to being met. This alternative is slightly unfavorable and has major drawbacks in regards to this criteria.
5. The criteria is met at the bare minimum.
6. The criteria is met to a slight extent. This alternative is acceptable in regards to this criteria, but has major drawbacks.

7. The criteria is met to a considerable extent. This alternative is acceptable in regards to this criteria, but has some drawbacks.

8. The criteria is met to a great extent. This alternative is strong in regards to this criteria, but has a few drawbacks.

9. The criteria is nearly met to the fullest extent. This alternative is close to ideal in regards to this criteria.

10. The criteria is met to the fullest extent. This alternative is ideal in regards to this criteria.

2.4 Decision Matrix

The five (5) alternatives were assessed in a matrix with the criteria defined with assigned weighting. The matrix assessed each criteria using the rating system described above. The matrix is shown in Table 3.

Table 3: Matrix of established criteria and proposed crossing alternatives.

Criteria	**Weight**	**Steel Bridge**	**Prefab Steel Bridge**	**Precast Concrete Bridge**	**Precast Concrete Culvert**	**Status Quo**
Attractiveness to animals of interest	5	5	5	5	10	1
Ability to design based on courses taken	5	9	7	1	7	1
Low traffic disturbance during construction	4	5	8	8	4	10
Constructability based on unstable soil conditions	3	7	7	5	5	10

Low construction cost	2	2	5	2	7	10
Low maintenance and operation cost	2	6	6	4	5	10
Minimal impact of final crossing on highway users	1	5	5	4	10	8
Environmental impact of materials	1	6	6	3	4	10
	Total Score	138	146	96	154	138

2.5 Comparison of Alternatives

The *attractiveness to the animals of interest* was one critical criteria to assess, as the wildlife must be comfortable with utilizing the crossing in order to increase connectivity. The steel bridge, prefabricated steel bridge, and precast concrete bridge alternatives were all rated a five (5), while the precast concrete culvert was rated at a ten (10). As the primary wildlife served were mountain lions and deer, their preferences were accounted for when selecting a crossing type. In this case, the deer, otherwise referred to as ungulates, do not have a specific preference between a bridge or a culvert. The mountain lions do have a specific preference towards culvert undercrossings as they do not prefer to be in exposed areas, which would apply to a bridge crossing. Both animal species also prefer to have minimal light disturbances and a clear view of the entire crossing. For a bridge, it would be difficult to provide the wildlife with a clear view of the other side of the crossing due to the vertical slopes needed on each end of the structure for ample drainage and highway clearance, and light disturbances would require extra countermeasures to be installed. For a culvert, wildlife would have a clear line of sight of the entire undercrossing passage and light disturbances would not be an issue, as the culvert crosses beneath the highway. Whether steel or concrete, the undercrossing or culvert alternative was much more attractive for the wildlife in the project area. The status quo was rated a one (1) because having no official wildlife crossing was not attractive to the animals. The highway that cuts through their natural territory decreases the wildlife connectivity and heavily deters them from attempting to cross.

Furthermore, it was critical to assess the *ability to design based on the University courses* the team has taken. The steel bridge was very feasible for the team to design because one of the team members has taken structural steel design. This course covered the design of beams, girders, and columns as well as the basic design of both welded and bolted connections. This course covered most of the necessary knowledge, but it was not rated a ten (10) because the course did not consider some of the factors critical to bridge design that would differ from members designed in a building. The prefabricated steel bridge was rated high as well because the fabrication company does the majority of the more complicated design for the actual bridge structure. One of the team members has already taken the seismic engineering course, so the team would be able to check the seismic conditions and design the lateral system to support the loading. This alternative would be more difficult to design because no one on the team has taken the bridge design course, so prefabricated bridges are unfamiliar and would require research and assistance. The precast concrete bridge is rated a one (1) because none of the team members have taken advanced concrete structures which teaches about precast-prestressed concrete. The precast concrete culvert is rated highly at a seven (7) because the precast arches are designed by Contech. Multiple team members are taking the concrete design course, and therefore will be able to design the retaining walls on each end. The remainder of the design relies on the principles the entire team studied in the structural design course, such as different types of loads and reactions. Finally, status quo is rated a one (1) because, although doing nothing is an easy design to do with limited design experience, this alternative does not allow the team to show what they have learned over the course of their Santa Clara University education. Therefore, it would not effectively test the abilities of the students.

As this project was located along an important highway for daily commuters, *low traffic disturbance* during construction was one of the most critical criteria to consider. The steel bridge alternative was rated at a four (4), as it required an extensive amount of work to be completed onsite, such as the welding and bolting of different connections. The installation of the steel bridge alternative would take several months to complete, requiring ample traffic control and disruptions throughout the sequencing process. Some of the connection welding could occur offsite to speed up the staging and reduce the amount of overall disturbances to the traffic. The prefabricated steel bridge as well as the precast concrete bridge alternatives were both highly rated at eight (8), as there was less onsite work required for the construction of these alternatives. The necessary components of either alternative would be fabricated concurrently offsite and shipped to the site as needed. This process helped minimize the typical construction-related traffic disturbances and only would take a few weeks to complete. The precast concrete culvert alternative was rated a six (6) as it required a fair amount of sequencing and traffic disruptions during construction to ensure public safety, but the culvert could be installed within several days. The installation process required rolling lane closures per Caltrans Standard Traffic Control procedures, but offsite fabrication of the necessary components allowed for the culvert units to be placed properly in a short period of time. Finally, the status quo alternative was rated a ten (10), as there would not be any construction to cause traffic disturbances.

When starting construction the first thing that needed to be done were the foundations for a bridge or digging out soil to slide in retaining structures for the culvert. This should be a smooth and thought out process beforehand. When looking at the *constructability of the foundations*, according to the U.S Department of Transportation Federal Highway Association, it was important to keep in mind that steel foundations are lighter compared to concrete foundations. If the soil type is a soft clay, silty clay, soft sandy clay, or soft silty sand then there will have to be piles driven into the ground for better stability. If the soil type is more of a hard clay, gravel and sand, or a rocky solid, then a shallow foundation would be best. The steel and prefabricated steel were both rated a seven (7) because of the lightness that would be easier for construction, including being allowed to use longer spans to be built, limiting the impact on the habitats below. The precast concrete received a five (5) because of the weight of the foundations going into the ground and time it would take due to the heaviness. The culvert was rated a five (5), as the main part of constructing a culvert is removing that area of soil, and having a difficult soil will increase the time and labor trying to dig it out. The preferred soil type for digging out for a culvert is sand and gravel, as it is easy to work with. It does not slide around like a soft clay but is not a hard clay where it would be difficult to break through. The status quo was rated a ten (10) because there would be no reason to disturb the ground.

Bridges tend to cost more than culverts. The materials, time, and labor play into the *construction costs*. Culverts are simpler structures and designs, which requires less time and labor. Prefabricated steel bridges minimize the on-site labor costs, with the structure arriving constructed already, but considering the material cost this was rated a five (5). The steel bridge brings in the girders and decking to be constructed together at the site, increasing the labor costs and time of construction. This was rated two (2) because of materials, time, and labor. The precast concrete was rated a two (2) considering the time of labor and time for assembly. According to the Department of Transportation, a reinforced concrete slab bridge has a typical span of 16 to 44 feet, with a cost of $150 - $450 price per square foot. A steel I girder bridge has a typical span of 60 to 300 feet with a cost range of $325 - $700 price per square foot. Comparing concrete and steel in general, it is shown that steel is faster to build with because of the weight of the material causing the transportation of the material to be longer, including being allowed to use longer spans to be built, limiting the impact on the habitats below. The quality control on site is heightened for concrete compared to a lower quality control with steel, meaning hiring more people to supervise and a longer construction time. The culvert was rated a six (6), as culverts are much quicker to construct compared to any bridge. This cuts the time and labor down. In earthwork the costs required for the culvert construction were higher than a bridge construction, meanwhile the construction costs of the culvert in structural work was less than a bridge. The status quo was rated a ten (10) because the construction costs would be zero since there would not be anything made.

It was important to look into the long term *maintenance and operation costs* when picking a structure that would be best for this project. For the steel bridge or a prefabricated steel bridge there will be a need to repaint this to minimize the rust of the structure, which is usually done every 15 to 25 years. Both of the steel bridges were rated a six (6), making these the least expensive to keep maintained. When looking at a precast concrete bridge, the maintenance cost was relatively low, as this included keeping the concrete sealed to minimize moisture, and minimizing cracking due to drying shrinkage and moisture expansion. The precast concrete bridge was rated a four (4) due to the cost of what the maintenance will demand. Compared to steel, concrete maintenance was seen as more labor intensive, in turn costing more money. Removing sediment, organic debris, trash, and vegetation is all part of the maintenance of a culvert, which is usually done once a year. The precast concrete culvert was rated a five (5) because of the frequency of maintenance, as this allowed more human and animal interaction but was the least labor intensive. With the status quo there was no maintenance because there is no structure to maintain, so it was rated a 10.

Once the final crossing is implemented on Highway 17, the different alternatives would *impact the highway users* in different ways. Ideally, the wildlife crossing has a minimal impact on the highway users, and the crossing would not introduce any new dangers or distractions to the drivers. Highway 17 is a very diverse road with hills and valleys as well as many unpredictable turns. Therefore, visibility is critical in ensuring safe driving conditions for the drivers. Each of the three bridge alternatives could impact the sight distance of the drivers by obstructing the view in the distance. Each alternative would need to comply with the Caltrans standards and the AASHTO specifications. Even though the minimum sight distance and vertical clearance will be maintained, the elements of an overcrossing could impede the vision at far distances and introduce additional distractions. Additionally, lateral clearance is also an important factor to consider. Lateral displacement, as defined by Professor He in transportation design, is the driver's perception of the location of objects along the edge of the roadway. At a critical point, drivers will move laterally instinctually to avoid the perceived object. Each of the bridge alternatives will require supports on the side of the highway which could potentially trigger this instinctive reaction of drivers that would increase the risk of accidents. Using the data from the State of California Department of Transportation's Comparative Bridge Costs, the common span length of different types of bridges are listed. A shorter span length could require a support at the middle of the highway which would require an object very close to the path of the driver with minimal lateral clearance. A reinforced concrete slab bridge has a typical span of 16 to 44 feet, where a reinforced concrete box girder bridge has a typical span of 50 to 120 feet. At the maximum typical span of 120 feet, the reinforced concrete could span the entire highway, but it is possible that the precast concrete would require that center support. The structural steel I girder bridge has a common span range of 60 to 300 feet. A steel bridge will typically allow for a longer span, which allows for more vertical clearance for the drivers. The final precast culvert has virtually no impact on the highway drivers because everything remains under the highway. Finally, even though the status quo would not negatively impact the drivers with anything new, the status quo does not provide any protection from the danger of animals attempting to cross the highway due to the lack of highway connectivity.

The last criteria that was important to consider for this wildlife crossing project is the *environmental impact of the chosen materials*. Steel and concrete both have an associated carbon dioxide equivalent emission per unit weight, and the amount of material used can determine the overall net carbon dioxide equivalent generated. According to a study conducted by the University of Wyoming (Barker et al., 2022), the steel bridge and prefabricated steel bridge alternatives were both rated at six (6), as steel material has the lower environmental impact in terms of carbon dioxide equivalent emissions compared to concrete material. Steel material also requires less energy in order to be formed and has more recyclable material available at the end of its service life. The steel bridge and prefabricated steel bridge alternatives were not rated higher, as they still consume a large amount of natural resources and contribute carbon dioxide equivalent emissions. The precast concrete bridge and precast concrete culvert alternatives were rated at three (3) and four (4), respectively, for the same reasons stated above. Concrete emits more embodied carbon dioxide equivalent, consumes more energy to create, and contains less recyclable material at the end of its life cycle. The concrete culvert is rated one higher than the concrete bridge, as the culvert requires less materials than a bridge of the same span and width. Finally, the status quo was rated a ten (10) as no new materials would be consumed if no construction work was done. Therefore, there would be no resulting environmental impact related to material usage.

2.6 Summary of Top Alternative

Based on the decision matrix found in Table 3, the top alternative for the wildlife crossing design was a precast concrete culvert. The culvert will affect the Highway 17 traffic, but with strategic sequencing the culvert can be implemented without completely stopping traffic. Additionally, using precast concrete elements allows the culvert placement to be done quickly and the highway lanes to open back up while the work under the culvert and off the side of the highway is completed. The culvert alternative is the best option for attracting the animals of interest. Based on conversations with Terry McGuire, a project manager that has been heavily involved in the implementation of wildlife crossings in Canada, mountain lions prefer the culvert to the bridge, so they are not exposed out in the open. Additionally, there is less noise and light disturbances, and the culvert can be designed so the animals can have a clear view through the entire length. The culvert also is a feasible alternative when assessing the design experience of the team. Team members are familiar with the basic structural design and are proficient in concrete design necessary for the retaining walls. Although the team does not have experience with precast concrete, the arches will be provided by Contech and the basic demands were considered by the team. The culvert alternatives will require additional excavation work and retaining structures, but the continuous strip foundations can easily be designed based on the geotechnical conditions and the dead and live loads. Additionally, retaining walls will account for the soil conditions and create stability. Although culverts have lower construction costs, the additional earthwork to tunnel under Highway 17 will increase costs. Therefore, the costs will most likely remain competitive. The culvert will require maintenance both for the concrete and the debris under the culvert, but this can be completed annually. The culvert is the ideal final solution for drivers on Highway 17 because a culvert does not introduce any distractions above the highway, block drivers' vision above the highway, or reduce lateral clearance. Environmentally, concrete releases more carbon dioxide than steel, but the culvert uses less concrete due to the soil fill as opposed to a bridge. Therefore, overall the culvert is the best alternative for the wildlife crossing near Lexington Reservoir.

3. Codes and Regulations

The wildlife crossing will have to conform to multiple codes and regulations throughout the design and construction process. One of the most important resources is the Caltrans Highway Design Manual because the project is within the Caltrans right of way.

Caltrans Highway Design Manual:
https://dot.ca.gov/programs/design/manual-highway-design-manual-hdm

- Chapter 80 - Application of Design Standards
  - Topic 81 - Project Development Overview
    - 81.6 Design Standards and Highway Context
  - Topic 82 - Application of Standards
- Chapter 100 - Basic Design Policies
  - Topic 113 - Geotechnical Design Report
- Chapter 200 - Geometric Design and Structure Standards
  - Topic 208 - Bridges, Grade Separation Structures, and Structure Approach Embankment
    - 208.6 Bicycle and Pedestrian Overcrossings and Undercrossings
    - 208.8 Cattle Passes, Equipment, and Deer Crossings
  - Topic 210 - Reinforced Earth Slopes and Earth Retaining Systems
    - 210.8 Type Selection and Plan Preparation, Sloping Footing, Foundation Investigations
- Chapter 300 - Geometric Cross Section
  - Topic 304 - Side Slopes Standards
  - Topic 306 - Right of Way

- Topic 309 - Clearances
  - 309.2 Vertical Clearances
  - 309.4 Lateral Clearance for Elevated Structures
- Chapter 700 - Miscellaneous Standards
  - Topic 701 - Fences
- Chapter 820 - Cross Drainage
  - Topic 825 - Hydraulic Design of Culverts
  - Topic 827 - Outlet Design
- Chapter 840 - Subsurface Drainage
  - Topic 841 - Subsurface discharge
- Chapter 860 - Roadside Channels
  - Topic 861 - General
  - Topic 866 - Hydraulic Design of Roadside Channels
- Chapter 890 - Storm Water Management
  - Topic 892 Storm Water Management Strategies
- Chapter 900 - Landscape Architecture - Roadsides
  - Topic 904 - Planting Design
  - Topic 906 - Erosion Control

Environmental Regulations:

- California Environmental Quality Act (CEQA)
  - California Code of Regulations (CCR) Title 14, Division 6, Chapter 3

- National Environmental Policy Act (NEPA)
  - Section 102(2)(C) - All agencies of the Federal government to include an environmental statement
  - Section 106 - National Historic Preservation Act (NHPA)
- Clean Air Act (CAA)
  - Sections 108 and 109 - set National Ambient Air Quality Standards (NAAQS)
- California Ambient Air Quality Standards (CAAQS)
  - CCR Title 17, Division 3, Chapter 1

AASHTO LRFD Bridge Design Specifications

- Referenced by Caltrans Highway Design Manual

LRFD Guide Specification for the Design of Pedestrian Bridges

- If designing a pedestrian bridge

American Institute of Steel Construction (AISC) Specifications and Construction Manual

- For steel design

American Concrete Institute (ACI) Codes and Specifications

- For concrete design

The Occupational Safety and Health Administration (OSHA) Standards:

- Protect the safety of construction workers if the project was to go into construction (not applicable within this scope)

4. Preliminary Design

4.1 Preliminary Design Overview

The goal of this preliminary design is to explore key components of the wildlife crossing project. Based on the alternatives analysis, the best solution for the wildlife crossing was a precast concrete culvert under Highway 17. The selected location for the culvert is near Trout Creek shown in Figure 3. The location was selected based on the constructability for a culvert from Midpeninsula Regional Open Space District Revised Alternatives Report on Highway 17 Wildlife Passage and Regional Trail Crossings from January 2019.

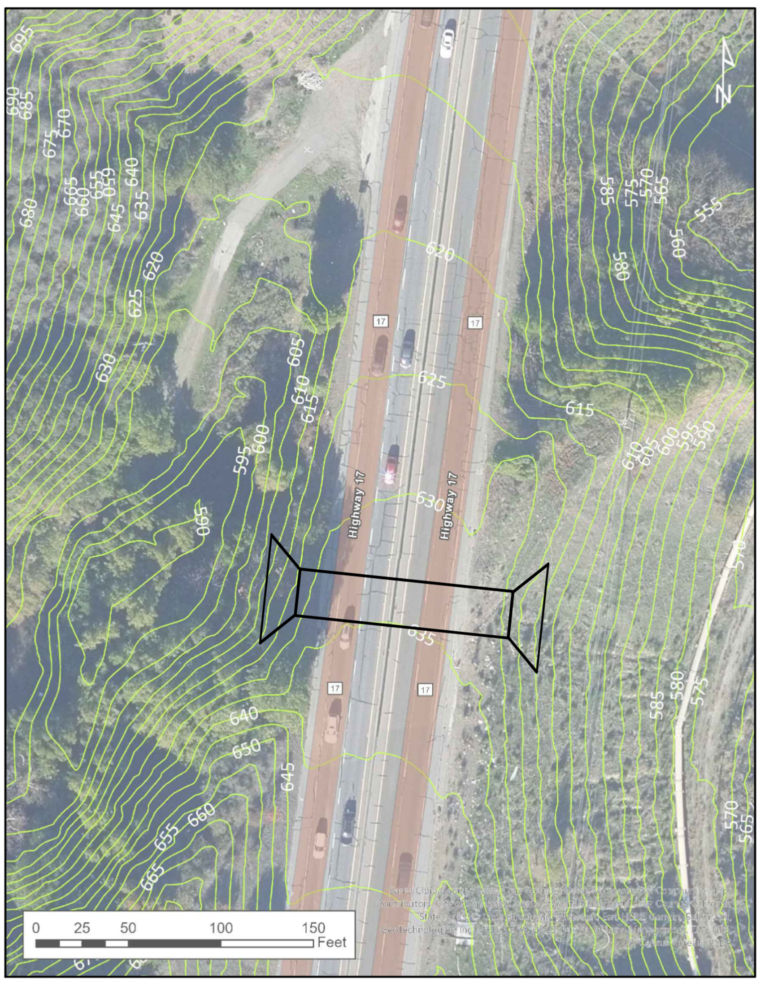

Figure 3: The location of the culvert near Trout Creek along Highway 17.

The design started with the layout of the culvert. The layout defines the critical dimensions for the precast concrete culvert and the height of soil fill above the arch. The critical dimensions that were defined based on the location are shown in Figure 4. The culvert acts as a wildlife connection under Highway 17, so it was important to look at how the animals will access the culvert and analyze how the existing topography impacts wildlife accessibility. The dimensions were compared to the existing conditions to determine the approximate amount of cut and fill required during construction. Finally, the preliminary design included a look into the construction of the culvert. Construction is complicated because the culvert goes under Highway 17, a critical passageway from Santa Cruz County to Santa Clara County, and traffic disruption should be avoided. The preliminary analysis helped determine how the sequencing of the construction can be done.

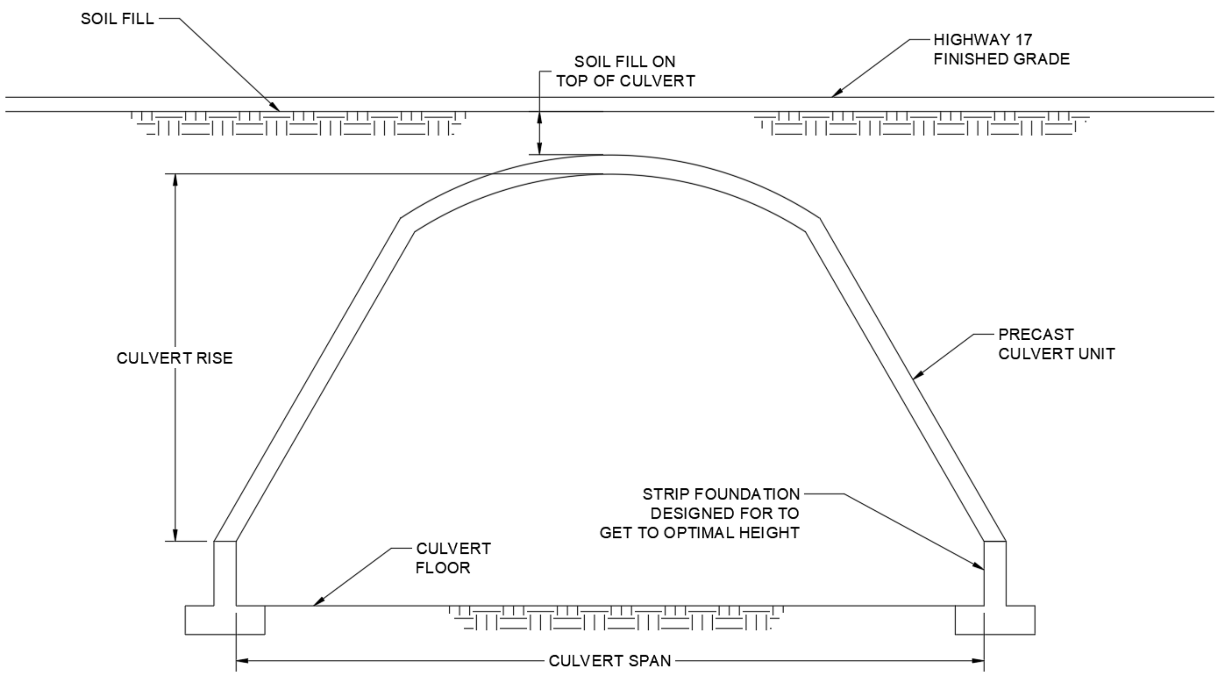

Figure 4: Critical dimensions for the precast concrete culvert to be determined.

4.2 Culvert Layout

The minimum and recommended dimensions of the culvert were taken from the Midpeninsula Regional Open Space District Revised Alternatives Report on Highway 17 Wildlife Passage and Regional Trail Crossings from January 2019 (Midpen Revised Alternatives

Report, 2019). The report summarizes the cross section design criteria for wildlife. For mountain lion and deer, the minimum width for a wildlife undercrossing is 16 feet and the minimum height is 10 feet (Midpen Revised Alternatives Report, 2019). It is recommended that the width is greater than or equal to 25 feet and that the height is 15 feet (Midpen Revised Alternatives Report, 2019). The culvert was sized based on these basic constraints and criteria.

The precast concrete arch for the culvert structure will utilize the Contech Engineered Solution CON/SPAN O-Series Buried Bridge System (Contech, n.d.). Using the Precast Waterway Charts from Contech, the precast concrete culvert will use the O-200 Series with a span of 26 feet and a rise of 12'-9 ⅛" with a self weight of 2.24 ton/ft.

From the Specification for Manufacture and Installation of the CON/SPAN O-Series Bridge Systems, the minimum height from the top of the precast culvert to the finish grade is two (2) feet, as specified on page 13. For the preliminary design, the culvert is covered by a minimum of three (3) feet of fill. A drawing of the cross section of the culvert and the longitudinal elevation of the culvert is included in Figure A-1 in Appendix A.

Once the dimensions of the culvert were set, it was important to consider how the culvert would be implemented and how the animals access the crossing based on the specific location. Looking at the topographic contours on the plan view shown in Figure 5, the existing conditions show that the highway is raised with a drop off of 30 feet on the West side and 20 feet on the East side within 50 feet of the highway on either side. The sharp drop off suggests that there would be a minimal amount of soil removal and need for retaining structures on either side of the highway to allow the animals to access the culvert. The location has existing access points to the undercrossing. The design of the culvert changed to ensure that the traffic on Highway 17 is minimally disturbed. Additionally, depending on the constructability, the culvert was oriented to best account for the existing topography and conditions. Ideally, the animals will have a clear line of vision across the entire culvert.

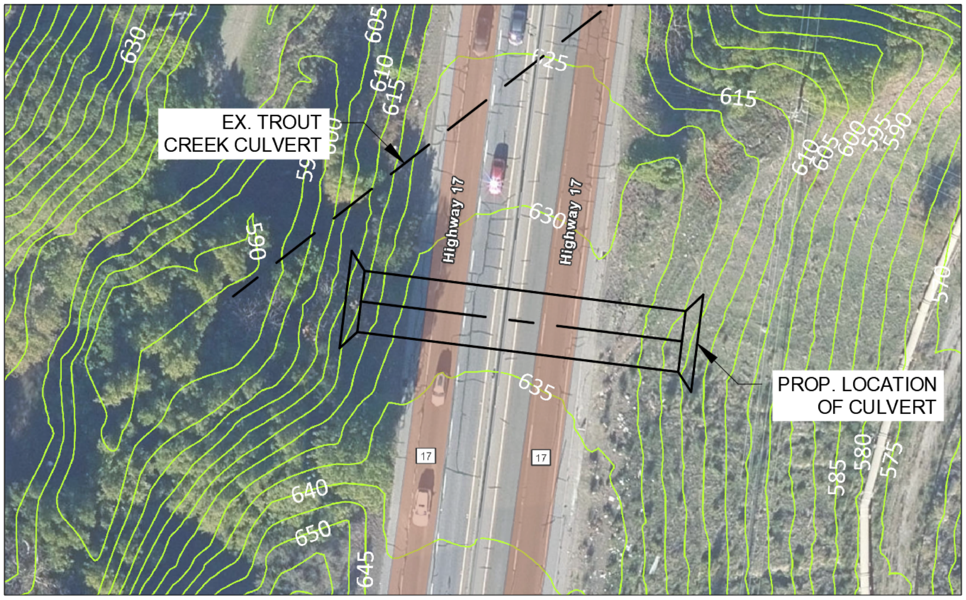

Figure 5: Close-up plan view of culvert layout displaying critical elevations.

4.3 Estimated Cut and Fill

It was essential to consider the required cut and fill for the culvert construction process, because the existing soil under the culvert will need to be removed, and all of the soil above the culvert will be filled to the finished grade of the highway, an accurate cut and fill calculation was required. A sketch of the cut and fill in the cross section of the culvert is shown in Figure 6.

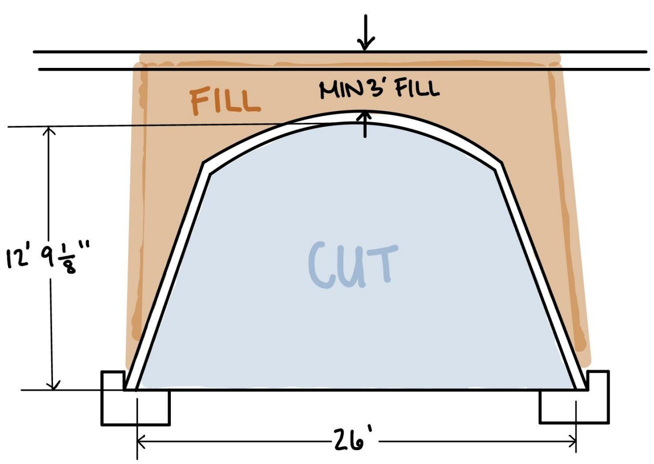

Figure 6: A sketch of the cut and fill for the culvert.

Using the AutoCAD drawings found in Figure A-1 in Appendix A**,** the dimensions of cut and fill for the preliminary design of the culvert were calculated. The area of cut included the area under the precast concrete culvert and the area of the concrete itself. Multiplying the cut area along the cross section by the length of the culvert, the cut volume was calculated using Equation 1:

$$V_{cut} = A_{cut} \times L_{culvert} = 258.19\ ft^2 \times 120\ ft = 30982.8\ ft^3 \quad \text{[Eq. 1]}$$

Assuming the fill over the top of the culvert is three (3) feet, the area of fill was calculated by calculating the total area under the highway and subtracting the area of the cut in Equation 2:

$$A_{fill} = A_{total} - A_{cut} = 409.78\ ft^2 - 258.19 ft^2 = 151.59\ ft^2 \quad \text{[Eq. 2]}$$

Once the area was calculated, the volume of fill was calculated by multiplying the fill area by the length of the culvert:

$$V_{fill} = A_{fill} \times L_{culvert} = 151.59 ft^2 \times 120 ft = 18190.8\ ft^3 \quad \text{[Eq. 3]}$$

These preliminary calculations for the excavation quantities account for the bulk of the cut and fill volumes. Additional volume will result from the construction at the ends of the culvert with the retaining walls and wildlife access paths. These quantities will be developed further throughout the design.

4.4 Construction Considerations

To implement the culvert at the selected location, certain sequences for construction must be followed per Caltrans Standard Traffic Control plans within the California Manual on Uniform Traffic Control Devices (CA MUTCD) (California Department of Transportation, n.d.). There needs to be a minimum serviceability of the road, dependent on the specific times of the day and the traffic flows at that time, along with the proper control measures in place to warn motorists of the ongoing construction. While a detailed construction plan was outside of this project's scope of work, there still must be a general understanding of what construction sequencing would be reasonable to follow and how disruptive the construction could be to motorists.

There were a variety of necessary challenges to consider for the construction of this culvert below Highway 17. Since there is a limited amount of space at the proposed culvert location, a minimum staging area for all equipment, such as excavators or cranes, must be designated. The method of the precast culvert unit installation also must be considered, as they could be either lifted into place via crane or rolled into place along rails. The method of installation may then determine the sequencing in which the highway lanes are closed down for construction and how construction can proceed across the entire highway span. Finally, there needs to be a consideration of how the precast culvert units must be delivered to the project site safely. A large communication and coordination effort must be made with the Contech Engineering precast yard, as the limited amount of staging space may not be sufficient to store all of the precast culvert units on-site for an extended period of time.

5. Detailed Alternative Analysis

After the preliminary design was completed, a detailed alternative analysis was conducted to determine the culvert depth in relation to Trout Creek and the current highway elevation. This started with alternatives and criteria that were taken into account to determine what was best for the wildlife crossing.The team looked into the different scopes that were affected by the different alternatives.

5.1 Summary of Alternatives

The detailed alternative analysis focused on two (2) different culvert depths for the arch culvert under Highway 17. The first alternative was an arch culvert at a lower elevation to include the Trout Creek flow. Trout Creek currently flows through an existing box culvert to the North of the proposed project site. The location of the existing box culvert for Trout Creek flow is shown in Figure 7. The box culvert was not a viable option for wildlife connectivity. This first alternative would replace the existing box culvert diverting all of Trout Creek's flow through the new wildlife crossing culvert. The culvert included the Trout Creek flow would require approximately 30 feet of fill on top of the culvert. The arch culvert would include a channel on the culvert floor for the flow of the creek and the design would include outfall considerations. The second alternative was an arch culvert with minimum fill depth, which was assumed initially to be a fill of three (3) feet above the top of the arch culvert. The two (2) alternatives impacted construction, hydrology, structural, and geotechnical considerations. Each of these scopes are discussed in more detail in section 5.4 through section 5.7.

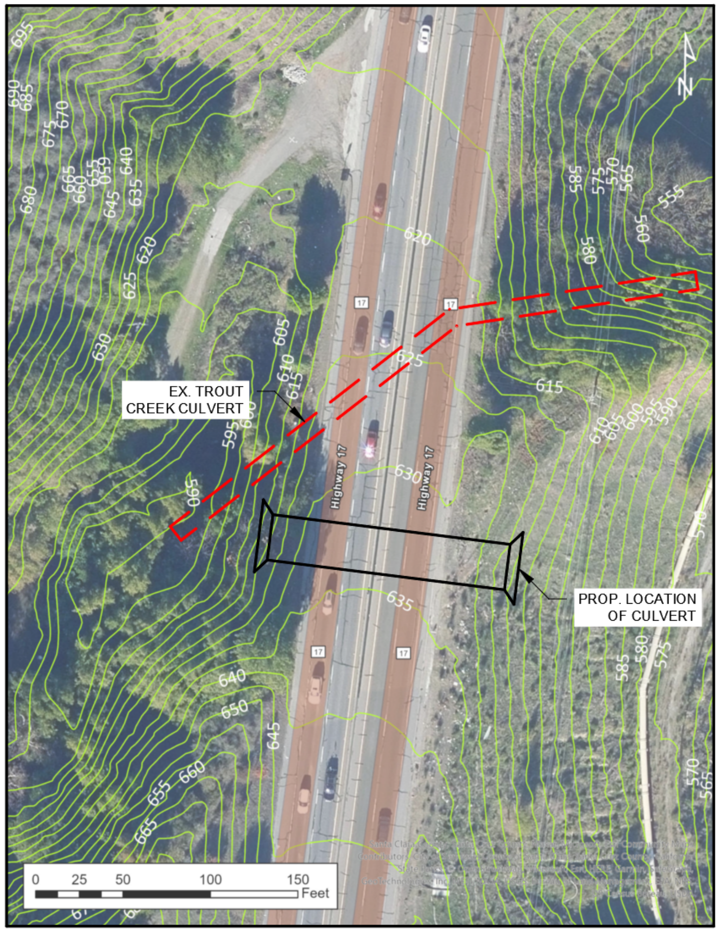

Figure 7: Location of existing Trout Creek box culvert in comparison to proposed location of the wildlife crossing culvert.

5.2 Ranking of Criteria

As defined in the preliminary alternatives analysis, criteria are the optional parameters that would be beneficial for a project to have, but are not necessary for its success. The following design criteria were used to develop and evaluate the alternatives for the detailed alternative analysis:

1. Attractiveness to animals of interest
2. Construction cost
3. Ease of design
4. Impact to environment

5. Conflict with adjacent properties

The established criteria for this project were ranked by importance based on how well a given criteria addressed the project objectives. Each criteria was assigned a weight on a scale of one through five (1 to 5), with one (1) signifying a criteria of little importance and five (5) signifying a criteria of great importance in relation to fulfilling the project objectives. The project design criteria and the respective justifications for their attributed weights are summarized in Table 4.

Table 4: List of criteria with the given weights and justifications.

Criteria	**Weight**	**Justification**
Attractiveness to animals of interest	5	The goal of the wildlife crossing was to increase wildlife connectivity. The attractiveness of a crossing was one of the most critical criteria, as that can impact the wildlife's decision to utilize the crossing. The wildlife species of interest, specifically mountain lions and deer, have preferences with regard to the culvert characteristics, which were considered in selecting the culvert depth.
Construction cost	4	One important goal was to complete the wildlife connection with the minimal cost possible for implementation, primarily since it would be publicly funded. This included the materials and labor cost based on the duration of work.
Ease of design	4	The goal of this design process was to assess the team's abilities within the senior design process. Therefore, the design needed to be feasible for the team to complete within the time allotted. Additionally, the project was

		along an active highway, so a simpler design reduced the impact to the highway users.
Impact to environment	3	Although the goal of the wildlife crossing was to positively impact the wildlife connectivity, it was important to mitigate and understand the residual impact to the environment. One secondary goal of the project was to minimize the harm to the environment surrounding the project implementation.
Conflict with adjacent properties	2	Another secondary goal of the project was to reduce the conflict with adjacent properties to minimize the communication and additional construction precautions required during the project implementation and once the project was complete.

5.3 Alternative Rating System

The matrix method was utilized to evaluate the top alternative solution based on the established criteria and the proposed crossing alternatives. Based on how well a given alternative met each criteria, a score between one (1) and 10 was attributed to each alternative for that specific criteria. The rating system matched the alternative rating system utilized in the preliminary alternative analysis. Each score on the scale was previously defined in section 2.3.

5.4 Constructability Factors

Multiple criteria for this detailed alternative analysis depend on the constructability of each alternative.

One constructability factor that is impacted by the depth of the culvert is the length of the culvert under the highway. The length of the culvert is determined by the existing topography of the region. With minimum fill, the length of the culvert is determined by the construction needs for the temporary transportation plan. At the elevation required for Trout Creek's flow, either the length of the culvert will need to be significantly longer or the retaining structures will be much more complex. Figure 8 shows the preliminary analysis of the culvert length based on the two alternatives.

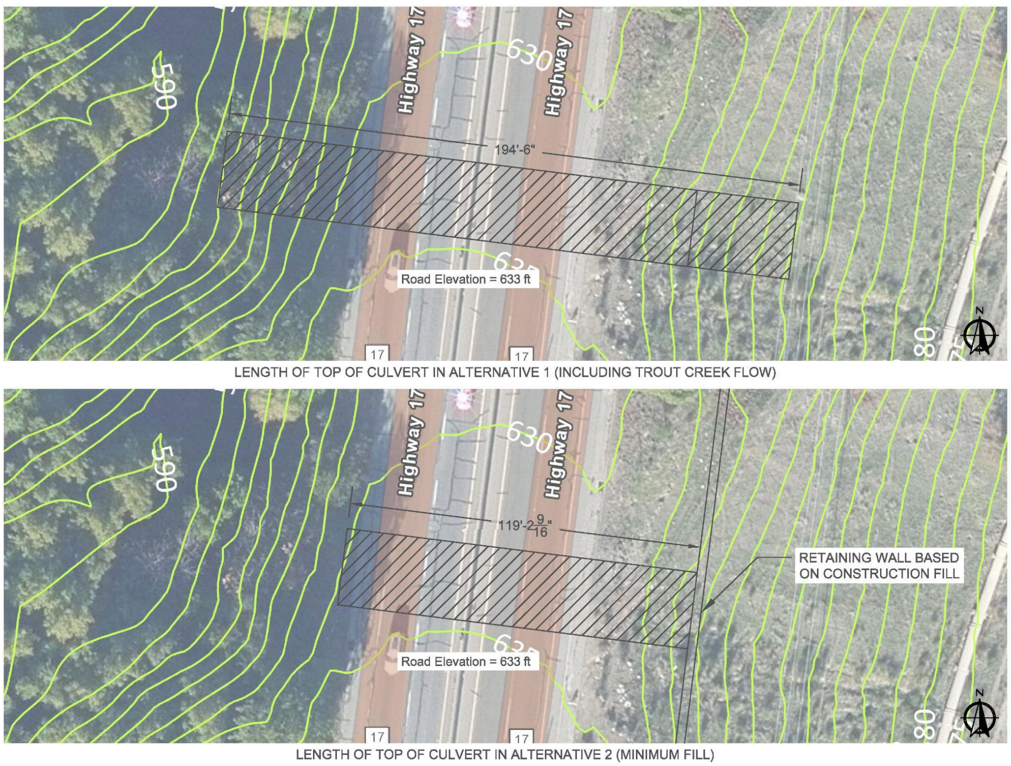

Figure 8: Length of culvert for the two alternatives (at depth of Trout Creek on top and at minimum fill depth on bottom) in the detailed alternative analysis.

The alternatives impact the amount of cut and fill for the site. For a deeper construction for the culvert, the duration of the construction would be increased because of increased excavation. Additionally, the construction would have a larger potential impact to the environment because more soil, foliage, and trees would be displaced and the construction would disrupt the current Trout Creek flow. The increase in duration would have a larger impact on Highway 17 users because the reduced speed for construction would be implemented for longer. The project is neighboring the Lexington Reservoir that has multiple existing facilities and utilities. The Lenihan Dam on the East side of Highway 17 is near the planned culvert. The spillway runs perpendicular to the projected culvert, so it is important to assess the relation between these constraints. There is a large diameter water pipe owned by SJW that runs along the hill (Midpen Revised Alternatives Report, 2019). The locations of the neighboring spillway and above-ground water pipe are shown in Figure 9. Ideally, the culvert design does not impact the existing utilities and neighboring facilities.

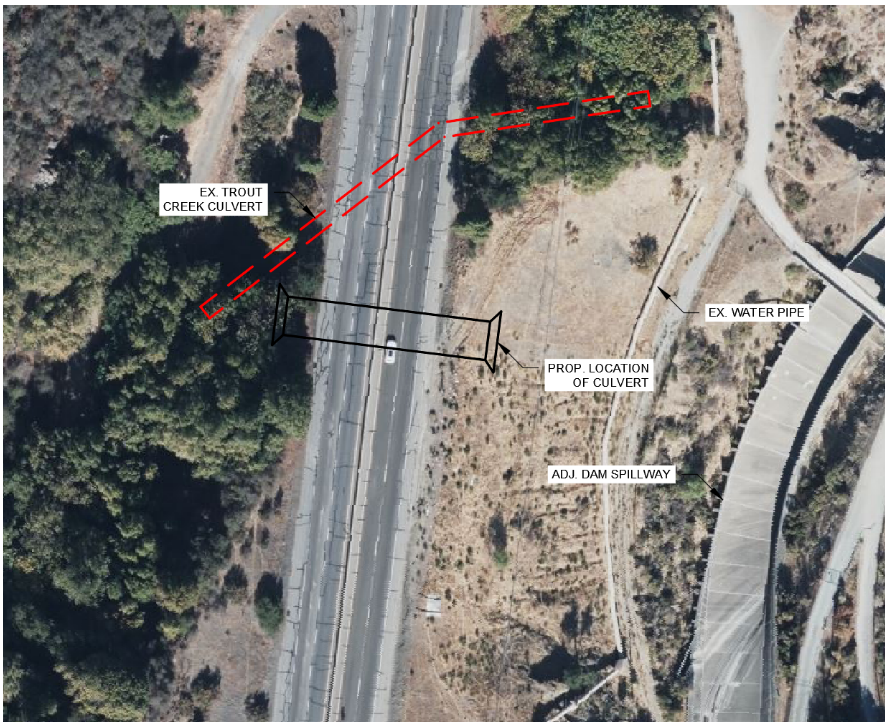

Figure 9: Location of culvert in relation to neighboring utilities and facilities.

The constructability factors can have a significant impact on the cost for construction of the overall project. Ideally, the cost of construction is minimized.

5.5 Hydrology Considerations

As one of the alternatives includes a culvert at a low enough depth below the highway to convey the water flow of Trout Creek, the subwatershed characteristics must be considered in order to design a proper drainage channel. Trout Creek is located to the northwest of Lexington Reservoir and spans 1.8 miles in length. Using the United States Geological Survey (USGS)'s

StreamStats webpage, the yellow outlined area of the subwatershed basin is measured to be 780 acres. The Trout Creek subwatershed is shown in Figure 10, with the location of the proposed culvert shown by the blue marker.

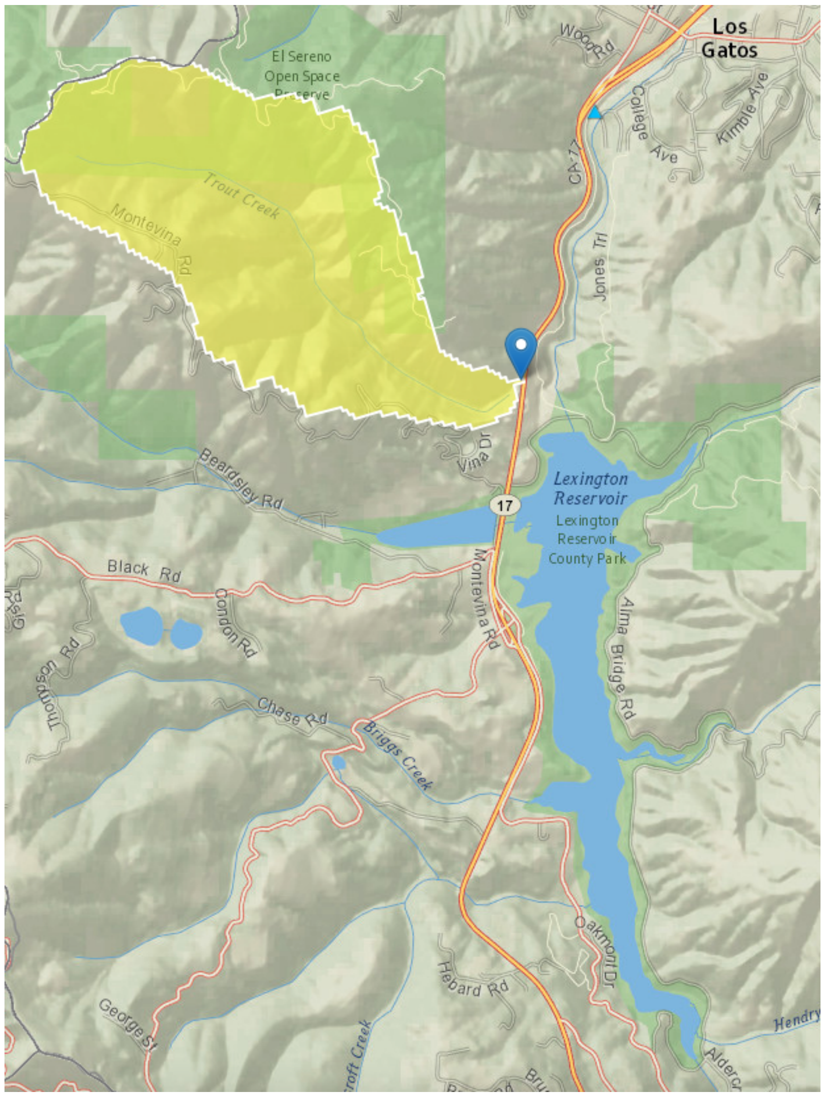

Figure 10: Preliminary estimation of Trout Creek subwatershed.

For a chosen design storm duration of 24 hours and a return period of 10 years, Trout Creek is estimated to have a peak storm flow of 430 cubic feet per second (cfs). The channel would need to be designed to convey this flow through the proposed culvert. The calculated peak flow is a conservative estimate for the channel design as it would assume that all of the Trout Creek peak flow would go through this project's proposed culvert as opposed to the existing

Trout Creek culvert. Furthermore, as Trout Creek is a major tributary to the Los Gatos Creek, there would also need to consider an outfall for the Trout Creek flow. In the event that the drainage would flow into the nearby Lexington Reservoir spillway which connects with Los Gatos Creek, communications would need to be established with nearby landowners in the area such as Santa Clara Valley Water District (SCVWD) and San Jose Water Company (SJWC). The flow is assumed to be redirected from the existing culvert into the proposed culvert, there should be little to no impact on downstream conditions.

For the culvert alternative at a depth of the minimum backfill beneath Highway 17, the culvert floor elevation would be above the top of the bank area for Trout Creek. Therefore, no flow would be conveyed through the culvert, and no drainage channel design through the proposed culvert would need to be considered for this alternative.

5.6 Structural Considerations

The culvert design depends directly on the amount of load applied based on the amount of fill above the top of the culvert. Including the Trout Creek flow in the culvert significantly increases the loading on the culvert. Therefore, the size of the precast culvert pieces would be increased, causing an increase in the cost for materials and construction.

5.7 Geotechnical Considerations

Implementing Trout Creek into the culvert would mean the culvert would be approximately 30 feet below the highway. The fill on top of the culvert below the highway would increase from three (3) feet to 17 feet, increasing the loads on the foundation by about six (6) times. The team found that shallow footing would end up being too large, meaning the team would switch to driven piles down into the earth. This would not be ideal because of the construction time and money. Also because of the depth it would make the culvert length larger, which would require more piles.

5.8 Decision Matrix

The two (2) alternatives were assessed in a matrix based on the weighted criteria. The matrix assessed each criteria using the rating system described above. The matrix is shown in Table 5.

Table 5: Matrix of established criteria and alternatives for culvert depth.

Criteria	**Weight**	**Alternative 1: Culvert at lower elevation**	**Alternative 2: Culvert with minimum cover**
Attractiveness to animals of interest	5	5	8
Construction cost	4	2	7
Ease of design	4	3	8
Impact to environment	3	2	5
Conflict with adjacent properties	2	5	7
	Total Score	61	129

5.9 Comparison of Alternatives

To achieve the primary goal of the wildlife crossing, the *attractiveness to animals of interest* was compared for the two (2) potential culvert depths. The first alternative, the culvert at the lower elevation, was rated a five (5). The first alternative was attractive to the animals of interest because it included Trout Creek through the culvert. Based on conversations with biologists, wildlife tends to utilize waterways as a natural pathway, so the water source would draw wildlife through the wildlife crossing. The first alternative was less attractive because the length of the culvert needed to increase in order to account for the additional depth. Animal species prefer a clear view through the length of the culvert, so the animals can identify that they can safely travel through. The longer culvert length reduced the vision throughout the length and would deter animals from entering into the culvert. Additionally, the channel for Trout Creek would be made of concrete which would create a less natural environment for the animals. The second alternative, the culvert with minimum fill, was rated an eight (8). The second alternative did not include a water source to attract animals, but the culvert would be significantly shorter, so the crossing would appear to have clearer vision through the entire length.

The second criteria considered was the *construction cost* for each alternative. The first alternative was rated a two (2). The culvert at the lower elevation required more materials because the structure and foundations had to be larger. The lower elevation culvert would require significantly more excavation and fill during construction. The first alternative's construction would also need to contain a new budget for the hydrology design implementation, such as the construction of the channel and the outfall considerations. The duration of the construction would also increase, which would increase the cost of labor overall. The second alternative was rated a seven (7). The culvert would require less materials and labor than alternative one (1), but the construction would still require significant funding.

The *ease of design* was compared for the two alternatives. The first alternative was rated a three (3). The design of the foundations was more difficult because pile foundations were needed as opposed to continuous shallow foundations. The design would also include additional hydrology considerations for the sizing of the channel and the outfall considerations. The second alternative was rated an eight (8). The higher elevation culvert could utilize shallow foundations and would not require the design for the Trout Creek flow.

The *impact to the environment* was then assessed. The first alternative was rated a two (2). The culvert would include the Trout Creek flow which will have impacts to the water and the environment in the area of the outfall. Additionally, the lower elevation of the culvert disrupts more natural topography and foliage during construction. The second alternative analysis was rated a five (5) because the culvert would not introduce further environmental impacts but the construction process would still disrupt the surrounding region's natural conditions.

Finally, both alternatives were assessed for *conflict with adjacent properties*. The first alternative was rated a five (5). The length of the culvert extends outside the right of way of Highway 17. The construction would have to consider the interaction with the nearby utilities and facilities, especially with San Jose Water Company and Valley Water. The second alternative was rated a seven (7). The culvert length remains within the right of way of Highway 17. The construction would require coordination with the neighboring landowners and facilities, but the crossing would have little impact on the neighboring properties long-term.

5.10 Summary of Top Alternative

Based on the decision matrix found in Table 5, the culvert with the minimum cover was selected at the ideal culvert depth for the wildlife crossing. The second alternative was more attractive to the animals of interest because the culvert would have the minimal length allowing for the clearest view for animals entering the crossing. Additionally, the construction cost for the second alternative was significantly less than the cost of the first alternative due to the increased materials, construction duration, and design consideration for hydrology that would be required for the first alternative. The design of the second alternative was more applicable to the knowledge of the team and feasible within the design period allotted. The impact to the environment and the conflict with adjacent properties was reduced in the second alternative due to the shorter length of the culvert within the right of way of the highway.

6. Final Design

After the preliminary design and detailed alternatives analysis, the team was able to begin work on the elements of the final design for the wildlife crossing. The final design started with the development of a construction phasing and implementation plan. Following the construction phasing plan, the structural design of the culvert was completed with the expertise of an engineer from Contech Engineering Solutions. The retaining structures and foundation design followed the structural design. Finally, the design considered the environmental impacts and culminated in a cost estimate.

6.1 Construction Phasing

Any project that impacts existing Caltrans highways will have to comply with the Caltrans Highway Design Manual and be approved by Caltrans officials. One of the major concerns with this project was its impact on highway traffic. Highway 17 is known to be a dangerous passageway through the Santa Cruz mountains, so the construction phasing had to carefully consider the impact to the highway users to prevent any additional danger in their commute. This concern affected the required construction phasing for the project design that can further impact the design of the structural elements. Therefore, the design process began with a rigorous analysis of the constructability of the project.

Based on preliminary research and discussions with Caltrans representatives, Highway 17 must remain fully functional with four (4) lanes of traffic for the majority of construction, especially during peak times of traffic flow. All four (4) lanes must be active in case there is a need for emergency evacuation because this highway is a critical evacuation route for the residents in the area. Therefore, a primary criterion for the construction of the wildlife crossing was that four (4) lanes of Highway 17 remain active throughout the peak hours of traffic flow with minimal disruption of traffic overall.

Based on the Caltrans Highway Design Manual, the minimum road width for highway traffic is 12 feet. Additionally, if the two (2) directions of traffic are directly adjacent to each other, there must be a median barrier to prevent head-on collisions of opposing traffic. A simple K-rail barrier has a base width of two (2) feet. The construction phasing alternatives assumed that the entirety of the highway asphalt can be used to support traffic, including the shoulders along the edge of the existing highway. If the traffic runs along an edge of pavement, there needs to be additional space for a barrier on the exterior of the temporary road. To account for the 4 lanes, the K-rail and 3 feet of shoulder width, the minimum width for the active traffic on Highway 17 during construction was 55 feet.

Using the minimum criteria for the highway users, the team developed multiple phasing concepts, analyzed each option, and determined which option is the most feasible. The first phasing concept involved three (3) phases for the highway traffic shown in Figure 11. Each phase includes a minimum of 55 feet for the drivers with construction work in the remaining road area.

Figure 11: The three phases of the first construction alternative.

For this first alternative construction phasing plan, the first phase shifted all of the traffic to the West side of Highway 17 with a minimum width of 25 feet for construction on the East side. The second phase shifted all of the traffic to the East side of Highway 17 with a width of 25 feet for the construction on the West side. The third, and final phase, split the traffic with one direction of traffic on the East side and one direction of traffic on the West side. Each direction of traffic would have a width of 28 feet. This allowed for the construction of the middle of the wildlife crossing with 22 feet of working room. This method involved three shifts in traffic flow which could cause confusion for highway users due to the short term lane shifts. This phasing plan made the most sense for quick construction because there was limited construction area for each phase. This alternative does not require any additional fill to extend the highway and remains within the existing road.

The second alternative construction phasing plan consisted of two (2) phases shown in Figure 12. The new highway would be extended 35 feet past the existing highway edge of pavement to the East for a total highway width of 115 feet.

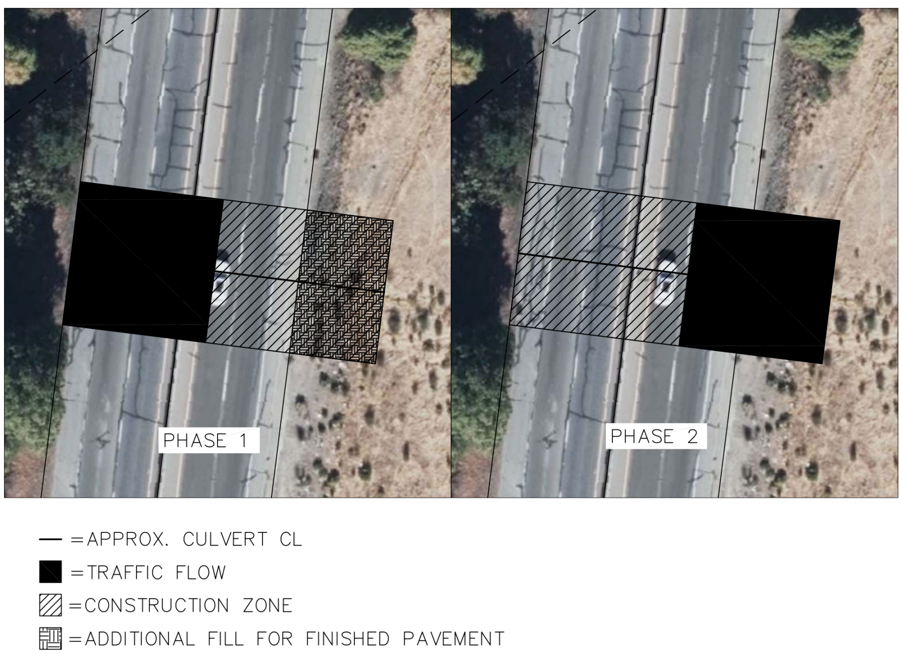

Figure 12: The two phases of the second construction alternative.

The first phase would shift all traffic to the West side of Highway 17 shown in Figure 12. Construction would commence on the East side of the existing highway. During this construction, additional fill would be placed on the East side to extend the road past the existing pavement edge. The culvert would be built on the East side of Highway 17 and extended past the existing highway edge. By the end of the first phase, the East side of the highway would be finished and able to carry traffic onto the newly extended portion of the highway. The second phase would utilize the additional 35 feet built during phase one (1) and shift all traffic onto the East side, giving space for the entire West side construction to be completed. The additional 35 feet to expand the highway surface would be completed in tandem with the construction of the East side, but this will require additional fill.

After analyzing these two alternatives, the team chose the second alternative with two phases for construction. This alternative required additional labor and materials up front due to the additional fill along the East side of Highway 17, but this phasing scheme will be safer for the highway users and construction personnel. With this alternative, there is more room for construction, so the construction can be completed in more continuous intervals. Additionally, the highway users are impacted less than in the first alternative because the traffic route is only changed twice, instead of three (3) times. The East side of Highway 17 at the selected project location has adequate space for the extension.

The final construction phasing plan is detailed in Figure 13 and Figure 14. Each drawing shows the critical dimensions as well as the space for the temporary road and the construction zone.

PHASE 1 - TRAFFIC ON THE WEST SIDE OF HWY 17, CONSTRUCTION ON EAST WITH ADDITIONAL 35' FILL

Figure 13: Phase one (1) for construction phasing with the traffic on the West side and the construction on the East side of Highway 17.

PHASE 2 - TRAFFIC ON THE EAST SIDE OF HWY 17, CONSTRUCTION ON WEST

Figure 14: Phase two (2) for construction phasing with the traffic on the East side utilizing the additional constructed fill and the construction on the West side of Highway 17.

In order to understand the sequencing of construction, Figure 15 shows an elevation of the construction completed during phase one (1). Figure 16 shows an elevation of the construction completed during phase two (2).

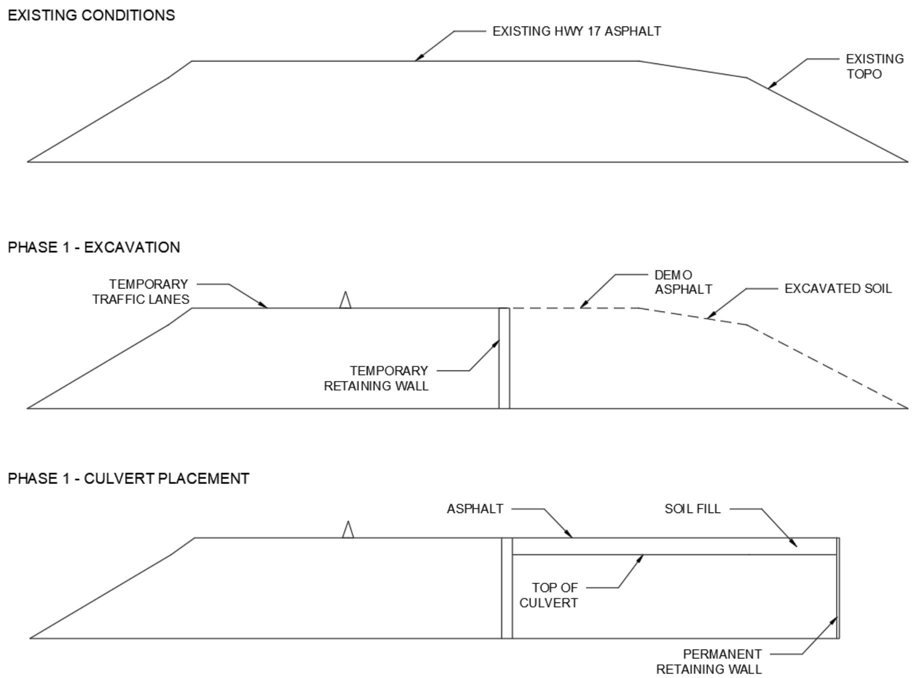

Figure 15: Elevation drawings showing the construction sequencing during phase one (1).

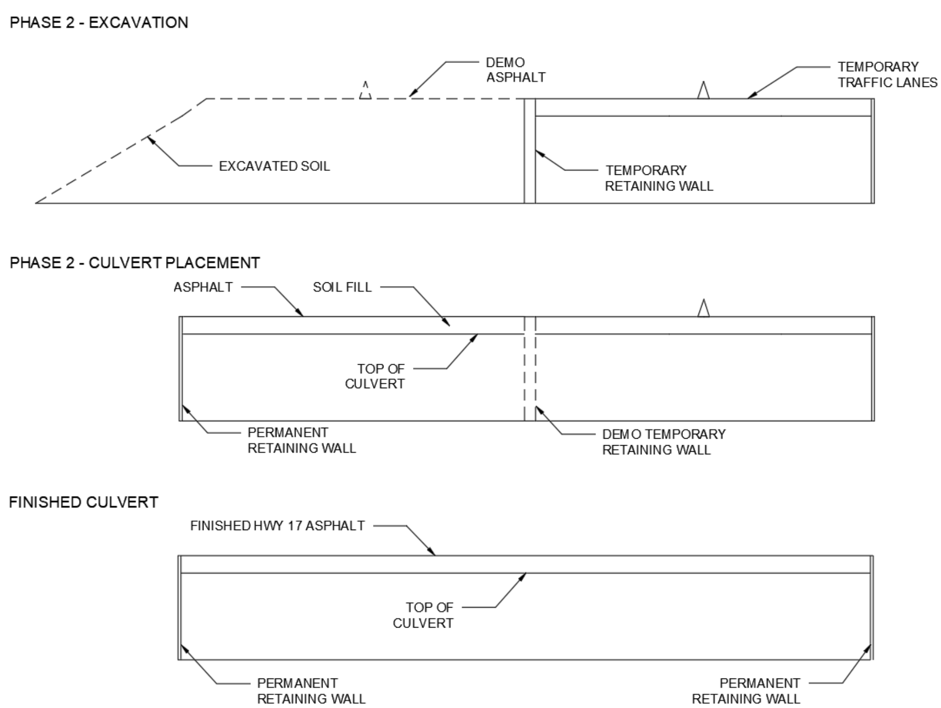

Figure 16: Elevation drawings showing the construction sequencing during phase two (2).

The selected construction phase plan maintained four (4) lanes of active traffic throughout the majority of the implementation of the crossing. The traffic will be reduced to one (1) lane of traffic in each direction when the traffic lanes are shifted in between the construction phases. The lane striping and demo of existing traffic lanes would be conducted outside of peak traffic flow, during the night. This is the only planned night work.

6.2 Design of Temporary Retaining Structures

Temporary retaining structures are required during construction when the construction phase plan defined in Section 6.1 is adopted. A retaining wall was necessary during phase one (1) of construction between the highway traffic on the West side of Highway 17 once demolition and excavation began on the East side. Additionally, during both phases of construction, once the excavation begins retaining walls are required along the length of the excavation for the culvert, running perpendicular to Highway 17. The team aimed to minimize the impact to the highway users, therefore the smallest construction area was utilized. Therefore, retaining walls were designed to maintain the excavation pit, instead attempting to attain stable slopes along the length of the excavation.

Soldier pile walls were chosen as the ideal temporary retaining structure for each of the structures installed temporarily during the construction process. The soldier pile wall was an ideal solution because it is built from the top down as the construction team excavates soil. Steel H piles are driven vertically into the earth at regular intervals and horizontal lagging is placed behind the flanges of the piles. Soldier pile walls are efficient and cost effective for temporary retention of soil because they can be easily removed once they are no longer needed.

The required height of soil retained was 16 feet and eight (8) inches based on the depth of the foundations for the culvert. A surcharge load of 250 pounds per square foot (psf) was assumed to represent the active traffic along the West side of the highway (Lien, 2017). The soil properties used for the retaining structure design were acquired for the foundation design found in section 6.7. This design assumed a soil density of 100 pounds per cubic foot (pcf) and a soil angle of friction of 30 degrees. ENERCALC, a structural engineering library, was used to find the optimal design of the soldier pile wall based on these conditions. The steel piles were designed using LRFD method and the Rankine lateral pressure method for the soil pressure.

In order to find the optimal solution, three (3) alternative designs were compared in ENERCALC. For each design, the lagging material was timber lagging with a thickness of three (3) inches. The piles were W-sections made of ASTM A36 steel with yield strength of 36 kips per square inch (ksi). The piles were spaced at six (6) feet intervals. The first alternative was a cantilever soldier pile wall with no tie backs or concrete embedment. This alternative used W21x111 piles with an embedment depth of 29 feet. The second alternative used one (1) tie back, four (4) feet from the bottom of the excavation. The height of the tie back was chosen for ease of placement during construction. This alternative used W18x76 piles with an embedment depth of 10 feet. The size of the W-section was controlled by the minimum width of 11 inches for soldier piles. The third alternative used concrete embedment with a drilled diameter of 29 inches. This alternative used W18x119 sections with an embedment depth of 21 feet. A summary of the three (3) alternatives is shown in Table 6. The ENERCALC packages for all three (3) alternatives are included in Appendix B.

Table 6: Summary of the three (3) soldier pile wall alternative designs.

Alternative	**Ties**	**Concrete Embed**	**W-Section**	**Embedment Depth (feet)**	**Moment Utilization**	**Shear Utilization**
1	N	N	W21x111	29	0.98	0.23
2	Y	N	W18x76	10	0.59	0.35
3	N	Y	W18x119	21	0.87	0.22

Soldier pile walls with tie backs or concrete embedment would significantly complicate construction and increase the cost of construction. Ultimately, the first alternative of a cantilever soldier pile wall was chosen for the final design. An elevation drawing of the soldier pile design is shown in Figure 17. A plan drawing of the soldier pile design is shown in Figure 18.

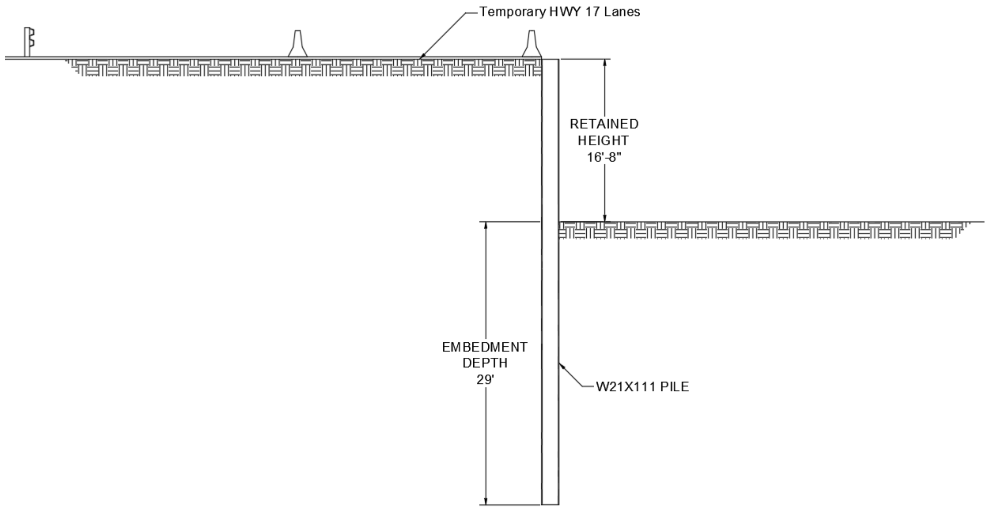

Figure 17: Elevation drawing of final soldier pile design.

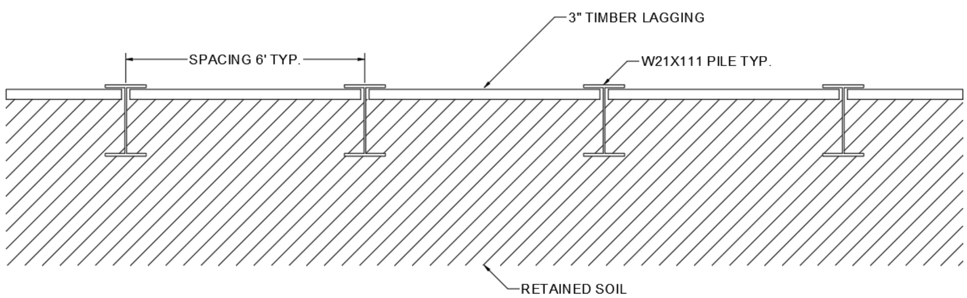

Figure 18: Plan drawing of final soldier pile design.

6.3 Transportation Design for Roads During Construction

Based on the construction phasing from Section 6.1, temporary highway traffic lane shifts were necessary during times of construction. Regulations from the Highway Design Manual and the Federal Highway Administration (FHWA) guided the conceptual horizontal curve design for phases one (1) and two (2). The posted speed limit of this area is 50 miles per hour (mph) and the typical travel lane size is 12 feet (ft) in width. Figure 19 shows a typical cross section cut of the existing Highway 17 lane configuration.

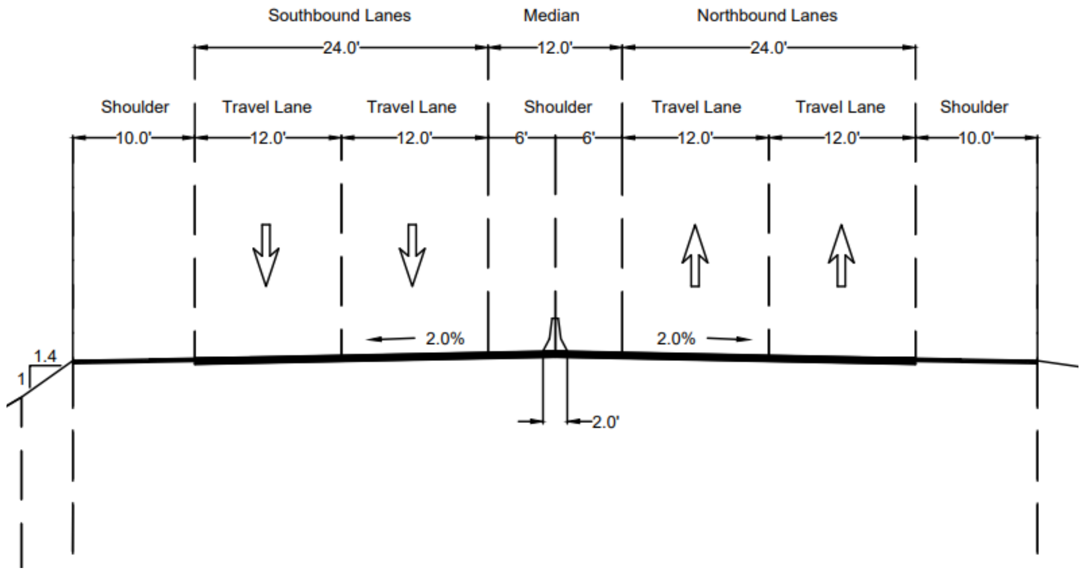

Figure 19: Typical cross section of existing lane configuration on Highway 17.

All four (4) of these lanes must remain open for traffic at all points during the construction. In both phase one (1) and phase two (2), the following criteria were chosen in order to design the temporary phase shifts in each phase:

1. Provide a safe and comfortable driving experience to the users of the road
2. Minimize speed reductions while driving on the temporary lane shifts
3. Minimize the overall highway lane shift length
4. Minimize the environmental impact of the temporary lane shifts

The Transportation Research Board (TRB) provided constraints in regards to allowable access-point density, or the amount of on- and off-ramps per stretch of highway mile, as well as the total lateral clearance, or the available total shoulder lane width. These factors determine the amount of speed reduction required for a given area, which would impact the posted speed limit of the temporary lane shift.

For the first phase of construction, there was one alternative as this design met all of the initial criteria for the temporary lane shift design. The existing concrete median would first be opened and the traffic would be redirected to the new traffic lanes. A proposed design speed of 55 mph was considered in order to develop the temporary road shift curvature necessary for construction on the east of the highway to take place, including the consideration for any speed reductions due to access-point density and total lateral clearance. This resulted in a safe speed for the area of 50 mph, which matched the existing posted speed limit of 50 mph, so no change in signage would be necessary. For this design speed and assuming a side of friction of 0.15, each curve will have a 1550 ft radius. The Institute of Transportation Engineers (ITE) recommended that a straight tangent of at least 100 ft be provided between each curve to create a safe and comfortable driving experience for motorists. Figure 20 shows a plan view engineering drawing of the phase one (1) temporary lane shifts with labeled station points for each curve.

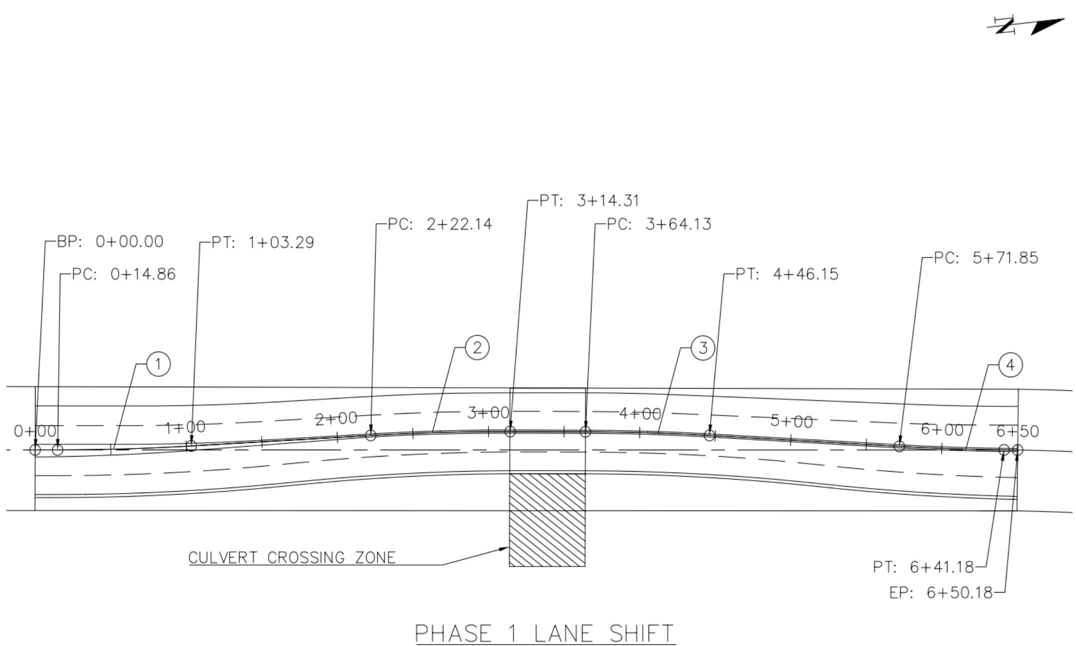

Figure 20: Phase one (1) temporary highway road shift to allow for construction.

This phase one (1) alternative provided tangents greater than 100 feet for providing additional comfort and safety to driving and had no speed reductions for construction. The total highway lane shift length was minimized to 650 ft, and there would be little to no vegetation removal as the lane shifts occurred completely on the existing highway pavement. Figure 21 shows a typical cross section cut of the phase one (1) road section with the proposed lane shifts.

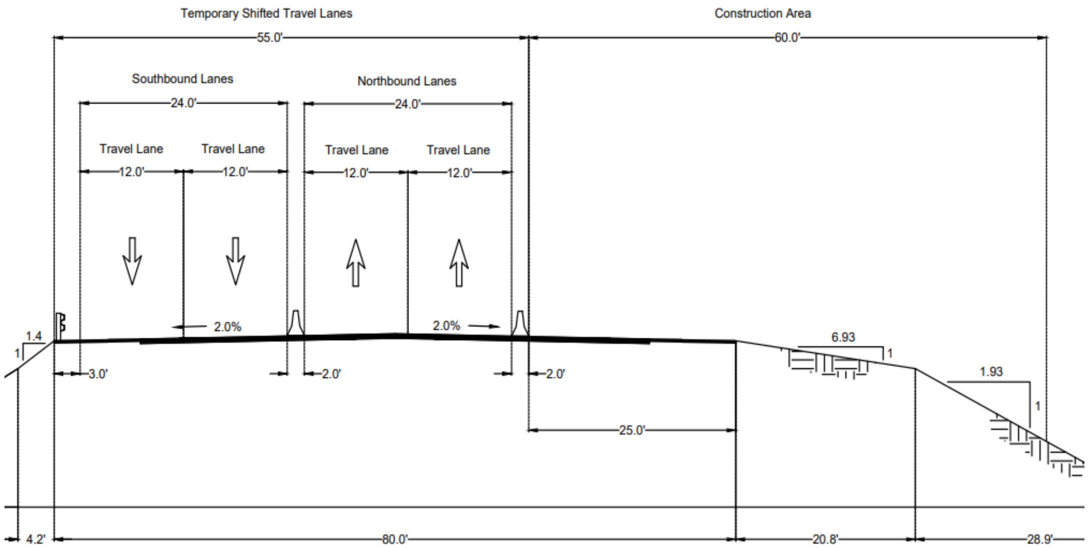

Figure 21: Typical phase one (1) cross section of proposed lane configuration on Highway 17.

Figure 22 shows engineering drawings developed to show the placement of the traffic control devices necessary to warn drivers of the oncoming construction area based on the California Manual on Uniform Traffic Control Devices (CA MUTCD).

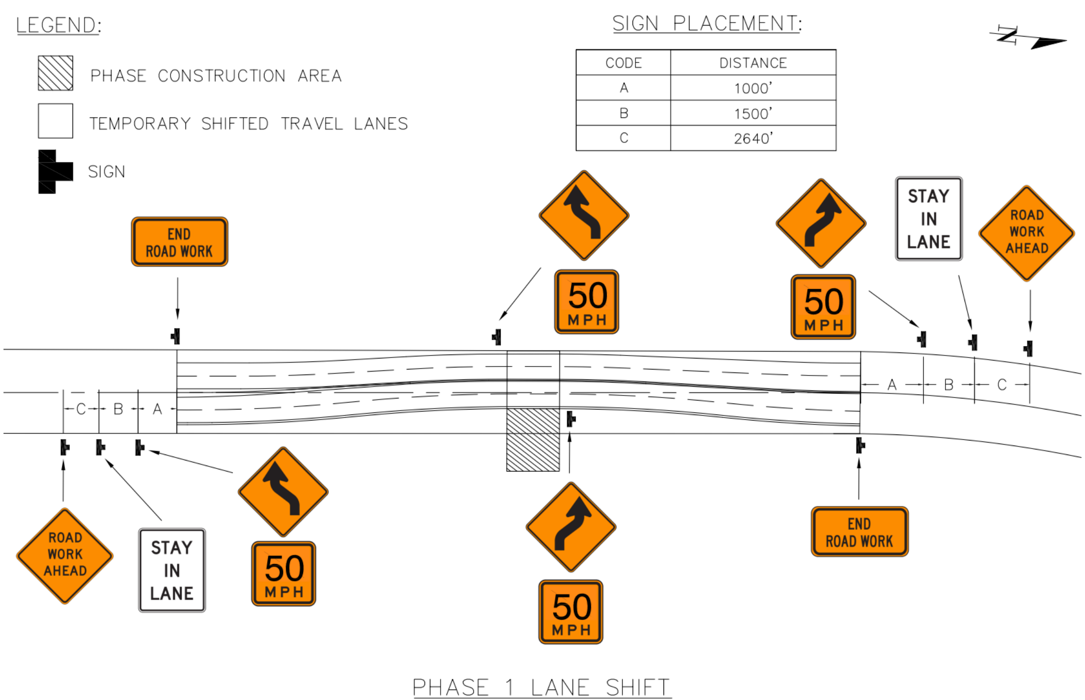

Figure 22: Plan view of phase one (1) traffic control device layout.

During the second phase, the traffic lanes were redesigned to account for the construction to switch from the East to the West side of the highway. Phase two (2) had to consider several different alternatives as no one (1) alternative completely satisfied all of the design criteria requirements. In the first phase two (2) alternative shown in Figure 23, the design was focused on minimizing the overall lane shift length as well as the environmental impact to the area in terms of native vegetation removal. This alternative design failed to provide 100 ft tangents between curves and also had the largest required speed reduction from the posted 50 mph to 30 mph for the construction area.

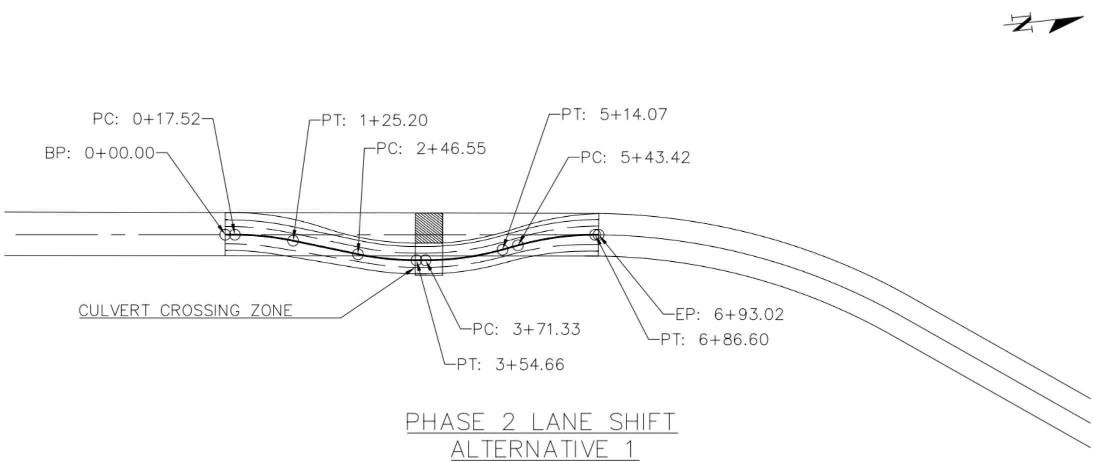

Figure 23: First phase two (2) alternative temporary highway road shift to allow for construction.

In the second phase two (2) alternative, this design focused on providing a comfortable driving experience with minimized speed reductions. The curvature of this alternative included 100 ft tangents between the curves and a large enough radii for each curve so that there would be no speed reduction. In order to accommodate these design choices, the overall length required at least 1750 ft of temporary lane shift length along with significant vegetation removal, as a large portion of the highway would need to be extended out on the East side as shown in Figure 24.

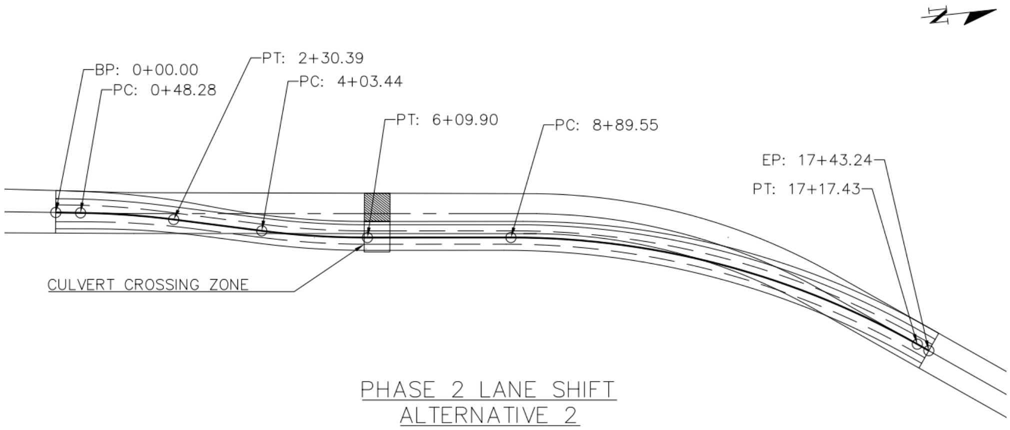

Figure 24: Second phase two (2) alternative temporary highway road shift to allow for construction.

The third alternative provided the best balance of all four (4) design criteria and became the recommended curve design for phase two (2). As shown in Figure 25, the design included 100 ft tangents between the curves for the comfortable driving experience and had minimal impact on the traffic with only a 10 mph speed reduction. The overall lane shift length was minimized to 1516 ft and would require little to no native tree removal based on where the highway needed to be extended on the East side.

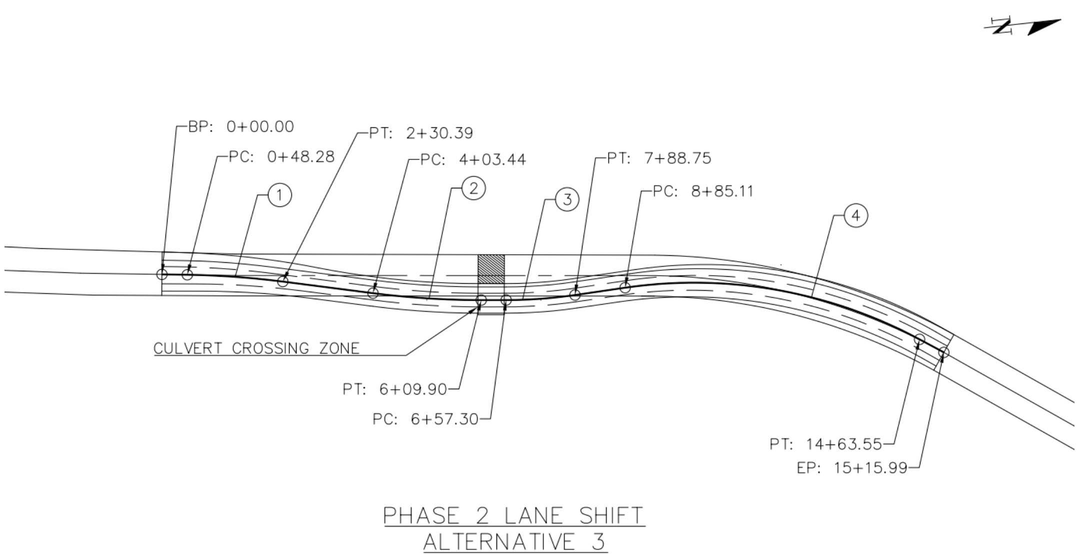

Figure 25: Recommended phase two (2) temporary highway road shift for construction.

Figure 26 shows a typical cross section cut of the recommended phase two (2) road section with the proposed lane shifts.

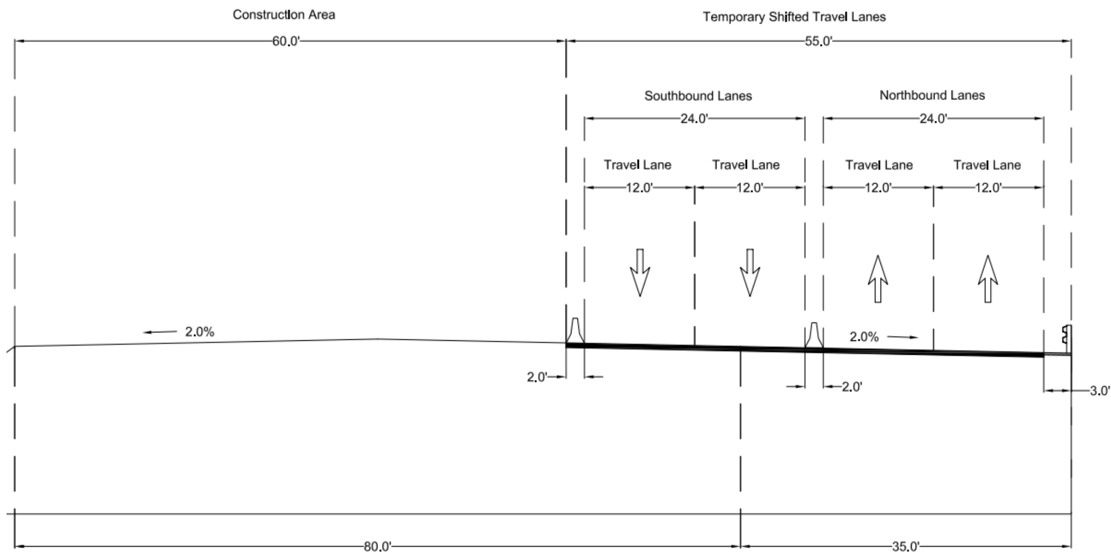

Figure 26: Typical phase two (2) cross section of proposed lane configuration on Highway 17.

Similar to phase one (1), Figure 27 shows the placement layout plan of the traffic control devices necessary to warn drivers of the oncoming construction area based on the CA MUTCD.

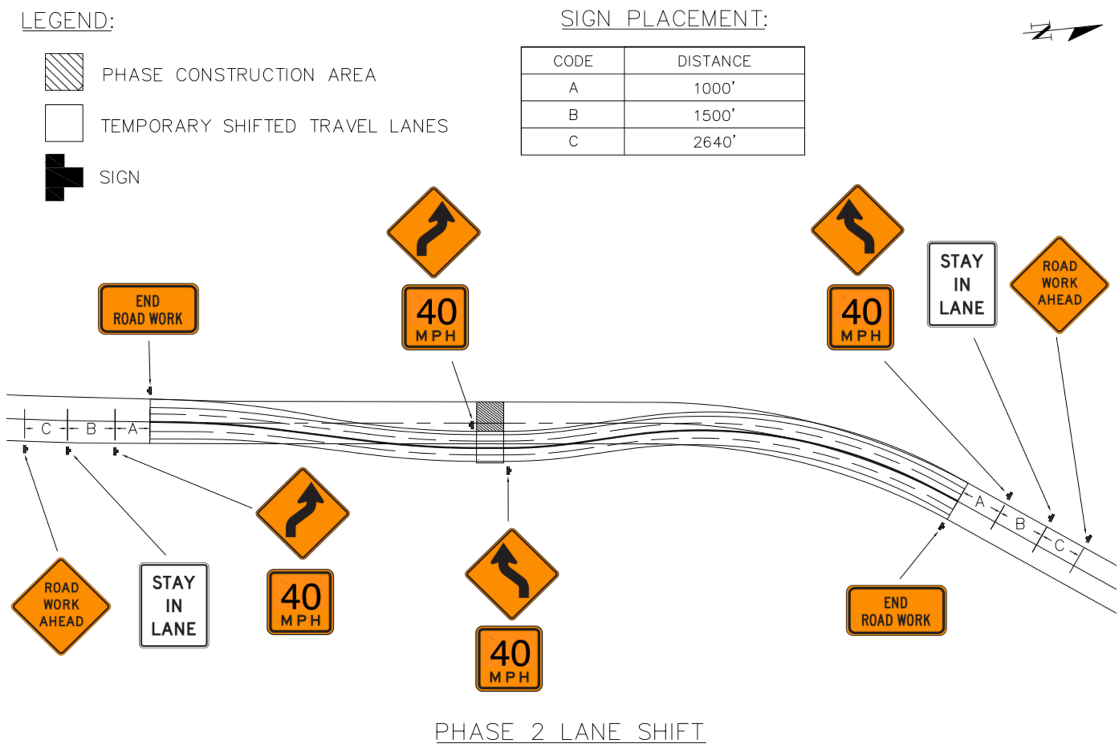

Figure 27: Plan view of phase two (2) traffic control device layout.

6.4 Construction Logistics Plan

The weight and length of the culvert pieces determine the types of trucking and crane used for the transportation. For the transportation of the culvert pieces onto the site, a 30 foot step deck flatbed truck was chosen, which was able to haul 30,000 lbs. The width of each culvert piece is four (4) feet and a span of 26 feet; after considering the weight of each piece the team decided that the truck can haul four (4) pieces at a time. To move the pieces from the flatbed truck to the excavated area of the culvert, the team used a 50 ton crane. There are 5 (five) pick points directly on the culvert which would be connected to a square spreader bar, so no cracking would be experienced throughout the process. The spreader bar was designed for the weight to be distributed equally across the length of the culvert piece. Each culvert piece weighed approximately 6,000 pounds; each pick carried 1,200 pounds.

For the transportation of the cut and fill the team chose articulated dump trucks, which would be able to haul 23 cubic yards. From phase one (1) the team had cut from the excavated area of the culvert which then was used to construct the temporary road. For this the team had to truck in 360 cubic yards of extra fill, which took 16 trips for the articulated dump trucks. From phase two (2) the team had 674 cubic yards of cut from the excavated area of the culvert, which took 30 trips for the articulated dump trucks.

Staging will be critical, as this is a tighter construction site and there will be many moving parts. The entire footprint area of the undercrossing is in Caltrans right of way, although connections to it for construction and access involved lands and facilities of San Jose Water Company and Santa Clara Valley Water District. For the staging, the process was split up into the two (2) phases in reflection of the two (2) phases explained in section 6.1 Construction Phasing. For phase one (1) with the traffic on the West side, there was a required temporary road access for the East side and a bench for the crane to sit on. For phase two (2) because of the Trout Creek flow 30 feet below, dewatering of the creek and installation of a diversion dam had to occur to ensure the water did not get through to the construction site.

6.5 Structural Design of Culvert

The structural design for the culvert consisted of the design of a precast concrete culvert with the company that would provide the culvert units. The goal of using a prefabricated culvert was to streamline the construction process on the site since the work would be conducted along the active highway. The prefabricated elements can be placed on site quicker than cast-in-place concrete elements.

Contech Engineering Solutions (Contech) was determined as the most viable partner to create the prefabricated culvert based on professional advisor recommendations. To initiate the structural design process, the team contacted the internal bridge consultants from Contech to assess the viable solutions.

Based on the wildlife of interest in this region of Highway 17, the optimal dimensions for a wildlife crossing culvert were a span of 25 feet and a height of 15 feet. The length of the culvert under the highway was approximately 120 feet. To minimize environmental impacts and water drainage considerations, the culvert would be placed with the minimum amount of soil fill between the top of the culvert and the highway surface. Based on the research from the preliminary design, the Precast CON/SPAN O-Series was identified as the best solution for the given constraints.

Based on the project constraints defined above, and communication with a consultant from Contech, the optimal culvert was O226 shape with a span of 26 feet and a height of 12 feet 9 1⁄8 inches paired with a pedestal foundation with a stem wall that allowed the culvert to reach the total clear height of 15 feet. The typical minimum cover of one (1) foot for most loading cases was utilized for the design. A sketch of the culvert design proposed is shown in Figure 28. A three-dimensional (3D) rendering of the optimal design created by a Contech engineer is shown in Figure 29. A plan, elevation, and typical section drawing is found in Appendix H.

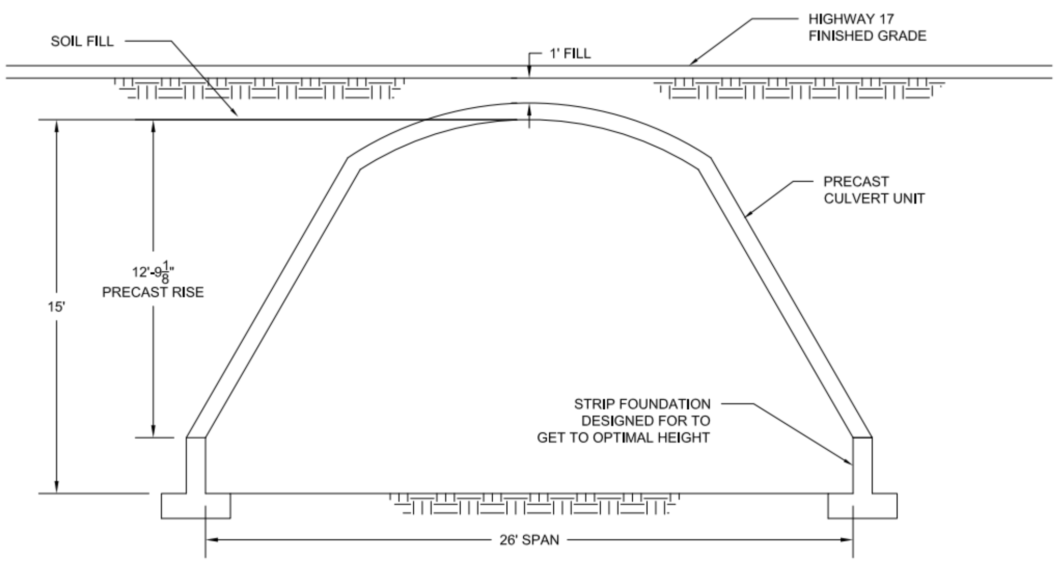

Figure 28: Sketch of precast culvert design.

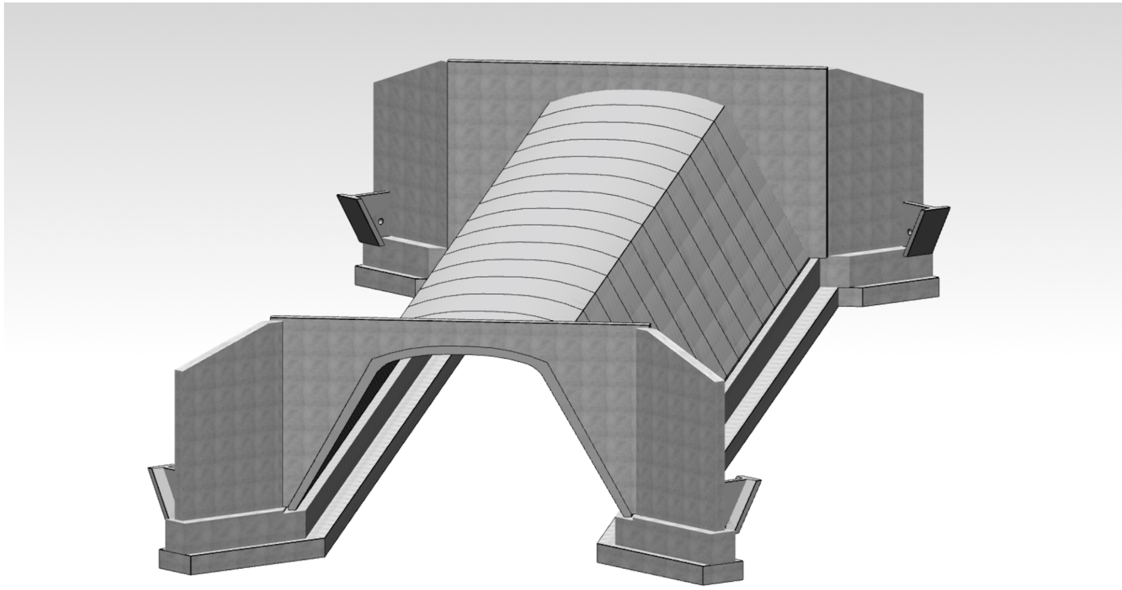

Figure 29: Three-Dimensional rendering of culvert solution from Contech Engineering Solutions.

Once the shape of the culvert was selected, the consultant created a complete design package for the precast culvert based on the constraints of this project. This package includes the detailed drawings of the culvert, as well as the loads applied by the culvert, and the cost estimate. The materials for the culvert design specifically were estimated to sell for $450,000 to $500,000, including delivery of the culvert units to the jobsite. A summary of the culvert reactions transferred to the foundations are shown in Table 7. The complete calculation package can be found in Appendix C.

Table 7: Summary of the support reactions transferred to foundations per leg of culvert.

	Dead Load	**Dead and Live Load**
Vertical Loads (kip/ft)	12.0	17.3
Horizontal Loads (kip/ft)	2.0	4.8

The loads exerted by the culvert based on the culvert shape selected and cover found in Table 7 were used in the foundation design detailed in section 6.6.

6.6 Design of Permanent Retaining Structures

Once the culvert is placed, a permanent retaining structure was needed at each end of the culvert to retain the soil fill placed on top of the culvert. On the West side, the retaining wall was designed to retain the soil at the face of the culvert, then wing walls proposed by Contech extend at a diagonal. On the East side of the highway, the structure was designed to retain the additional fill placed along the length of the highway during phase one (1) of construction for the temporary traffic lanes, extending beyond the face of the culvert itself.

Mechanically Stabilized Earth (MSE) walls were designed for these permanent retaining structures. MSE walls are a retaining structure composed of layers of compacted backfill with soil reinforcement placed at regular intervals and connected to a wall facing. The MSE wall design was completed based on the instructions from Professor Kitch from Cal Poly University in the graduate course on Earth Retaining Structures (Geotechnical Engineering, 2015).

The design began with the preliminary sizing for the embedment of the leveling pad and the minimum reinforcement length. Similar to the process used for the temporary retaining structures in section 6.2, the lateral earth pressure was determined using Rankine's method, and the traffic surcharge was 250 pounds per square foot. The height of the retained soil was 16 feet and eight (8) inches with a soil density of 97.4 pounds per cubic foot and soil friction coefficient of 30 degrees.

The structure was checked for external stability to protect against sliding and overturning moment failure. Within the scope of this project, seismic design was not included. The reinforcement system selected was steel reinforcing strips with a width of two (2) inches and a height of 0.156 inches. Following the standard practices for MSE walls, the steel reinforcing strips were made of ASTM A1011 galvanized grade 65 steel. The steel reinforcing strips will be placed every two (2) feet on center horizontally and vertically. For inextensible reinforcement, the critical failure surface for rupture is a bilinear failure surface based on empirical testing defined in FHWA NHI-00-043 Figure 28, pp. 106 (USDOT FHWA, 2009). Using these conditions, the maximum tensile force at each reinforcement level was checked against the allowable long-term reinforcement capacity. Additionally, the pullout capacity was checked to determine the final required embedment length. Ultimately, the height of the retaining wall including the embedment beneath the floor is 17 feet six (6) inches with an embedment length of 20 feet. The final design is summarized in the drawing shown in Figure 30. The complete calculation package is found in Appendix E.

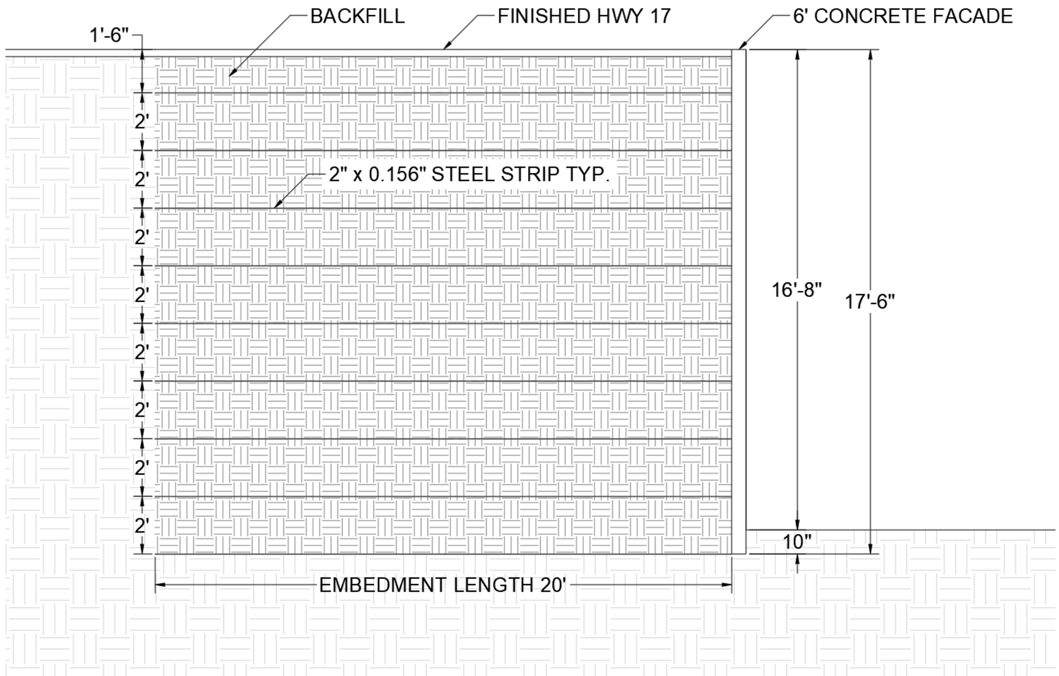

Figure 30: Elevation view of the MSE design for each end of the finished culvert.

6.7 Foundation Design

Once the location was finalized, the next steps were to find the soil properties for the given site. This was found through public property records and the United States Geological Survey (USGS). These records present the different layers of soil at the site. The bottom most layer is sandstone and shale, middle layer of sandstone and mudstone, and the top layer being colluvium. Based on the loads of the culvert and live loads provided by Contech, the team was able to design shallow footings with a width of six (6) feet. The foundation was then calculated for bearing capacity, moment overturning, and sliding forces.

The shallow footing foundation will include a pedestal to get the culvert to the optimal height of 15 feet. The height of this pedestal is two feet, two and seven eighth inches (2’ 2 ⅞”).

This height is needed for the animals to get a clear view of the other side, enhancing the use of the culvert.

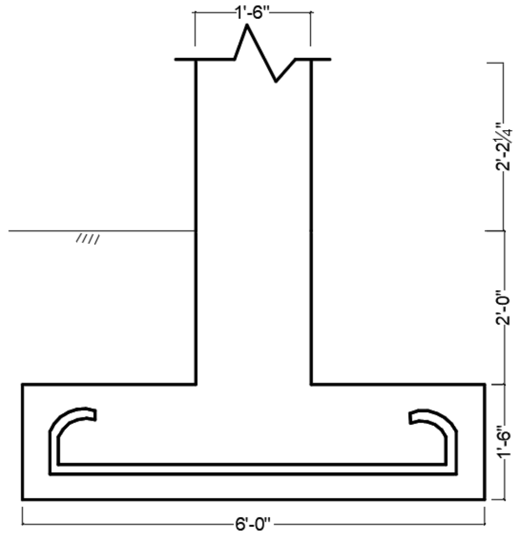

Figure 31: Foundation dimensions.

6.8 Environmental Considerations

For this project, there were large environmental factors to consider, two of which included providing adequate directional fencing for the wildlife of the region that would utilize the crossing as well as jump out opportunities along Highway 17 for wildlife within the highway by mistake. Directional fencing extends a few miles out from the crossing location in order to properly funnel wildlife into the crossing and dissuade them from entering the highway. A study conducted by the Western Transportation Institute at Montana University recommends a few miles of wildlife fencing for short stretches of roadway, especially if there is a nearby suburb or urban area (Huijser et al., 2015). For the proposed Trout Creek crossing, there would need to be at least 2.4 miles of this fencing along the highway, or 1.2 miles in either direction of the crossing site which covered the distance from the edge of the Los Gatos border and the South end of Lexington Reservoir. The project would also have to consider the removal of some existing fencing for the nearby Los Gatos Creek trail to increase the connectivity of the West and East sides of the highway. In addition to directional fencing, jump outs should be to increase the effectiveness of this project for the wildlife of interest. Jump outs are mulch embankments that lead to a break within the wildlife fencing to assist the animals that wandered onto the existing highway by mistake. These jump out escapes are typically several feet tall to ensure that animals can leave the highway, but cannot re-enter from outside of the highway.

Because the project location is in a riparian area, there would be heavy restrictions on the work that could be performed in this area. Any work done within the riparian area must first gain approval from the State Water Resources Control Board (SWRCB), the California Department of Fish and Wildlife (CDFW) and Valley Water. The following permits and reports would need to be obtained to begin any construction work in this area:

- Clean Water Act (CWA) 404 Permit to regulate fill material discharge into US waters from the Army Corps of Engineers
- CWA 401 Permit to protect the water quality of federally regulated waters from the Regional Water Quality Control Board
- Lake and Streambed Alteration Agreement which would be required when any project activity may adversely impact fish and wildlife resources or when diverting or obstructing any regulated water flow from CDFW
- Incidental Take Permit which is required by CDFW for the take of an endangered or threatened species to monitor any potential impacts
- CEQA Environmental Impact Report (EIR) sent to the City of Santa Clara which describes the potential environmental impacts of a proposed project along with the mitigation efforts that would be employed

With their approval and proper documents, several native trees would need to be removed from both the West and East sides of the highway to allow for proper staging and construction zone space. For the West side, native trees would need to be removed in order to provide a large enough staging area for the construction equipment as well as for the actual construction area of the culvert. After dewatering a portion of Trout Creek, a diversion dam and bypass would then be required in order to continue to convey the flow of Trout Creek through the existing Trout Creek culvert during construction. Based on negotiations with SWRCB and CDFW, the project would also have to mitigate the removal of these native trees by committing to a revegetation ratio to replant more native trees within the same watershed.

Additionally, the California Department of Forestry and Fire Protection (CAL FIRE) identified the Trout Creek location as a critical anchor point to prevent catastrophic wildfires from ravaging the Santa Cruz mountains along with the residents and wildlife that live within them. Certain invasive species, such as the French broom, have spread widely unchecked and could serve as a major fuel source for wildfire outbreaks in the region. Thus, the project considered the removal of these species for the health and safety of the wildlife, the Santa Cruz mountain residents, and the ecosystem as a form of sustainable forest management.

With the removal of all the various vegetation in the area as well as the construction of the culvert, there would be a large mobilization of sediment that would occur as a result. Thus, the project accounted for using various erosion control methods such as soil blankets or silt fences to reduce the amount of erosion that would occur. A SWPPP would also be created to include the plans for protecting the water quality of Trout Creek.

Finally, a wildlife study would need to be conducted in the area for protected species such as nesting bald eagles and tiger salamanders, as their presence would delay or suspend the construction work from occurring.

6.9 Cost Estimate

For the construction cost estimation the team looked into the Caltrans Construction Manual. The Caltrans Construction Manual provided Caltrans biddings from projects throughout the years, which allowed the team to use similar project numbers. For structural, the team considered the delivery and materials of the culvert and the process of the retaining walls, which included excavation and the equipment needed. The removal of surrounding materials, included objects such as the down drainage and fencing from the construction site. With a 20% contingency, the construction cost was estimated to be a total of nine million dollars ($9 million).

The RSMeans Manual was used to estimate the labor and equipment costs. The labor and equipment were listed for each task that needed to be done on the construction site, which included the excavation, pouring of the concrete for the foundations, and the piles for the retaining structures. With a 20% contingency, the total for the labor and equipment was estimated to be a total of $1.3 million.

The Caltrans contract cost online database with project bidding data was used to estimate the temporary lane shift phasing costs. Major costs of this portion of the project included the new hot mix asphalt and aggregate bases, excavation of the existing pavement, removal of existing paint, and the installation of temporary paint stripes, Type K railings, Midwest guardrails, retroreflective pavement markers, and traffic control devices. With a 20% contingency, the total transportation cost was estimated to be approximately $800,000.

Finally, the Caltrans contract cost online database along with unit cost values from the Midpen Preliminary Alternatives Analysis Report were used to estimate the environmental consideration costs. The team considered the costs of directional fencing, jump outs, environmental mitigation efforts, invasive species control, and a SWPPP creation. With a 20% contingency, the total environmental consideration cost was estimated to be $1.9 million.

7. Non-technical Considerations

Although the technical elements of the project are critical, there are many non-technical considerations that need to be carefully evaluated. This section will look at the ethical, environmental, social, political, and health and safety considerations of the project.

7.1 Ethics - Rules, Rights, and Duties

After further researching social change, rights of people, and the ASCE Code of Ethics, there is a list of considerations to keep in mind. The ASCE Code of Ethics describes in depth the duty of the engineer to protect the rights to health, safety, and welfare of the public, all of which is to be kept in mind during the design and construction process. Aside from decreasing the rate of wildlife-vehicle collisions, this crossing is also meant to help eliminate fatalities for both animals and humans.

The ASCE Code of Ethics states the engineer's duty to acknowledge the diverse historical, social, and cultural needs of the community, including the animals. The culvert will be made with keeping both the animals and public in mind, making the space safer for all that are occupying the area. It is important, while constructing, to mitigate adverse societal, environmental, and economic effects, which include using resources wisely while minimizing resource depletion and minimizing carbon footprint. During construction, it will be important to keep certain things in mind, including the time of day and the amount of traffic flow so that construction does not impact the travelers' commutes especially since the highway is only four (4) lanes wide. The noise level is to be minimized for the owners of the land surrounding the construction site. The construction site and workers will need to follow OSHA regulations through the process, ensuring the safety of the project.

As an engineer, there is a duty to practice engineering in compliance with all legal requirements in the jurisdiction of practice, which entails following all codes and regulations for that region. During the design process for the project, it is important to comply with the California standards and regulations. During the construction process, it is important to follow requirements for inspections and safety checks. If the various checks are not met, the project could be set back and require additional funding from the various federal, state, and private organizations contributing to the project.

7.2 Ethics - Consequences

For any project, it is important to carefully consider the consequences of the project and look at the ethical considerations of these consequences.

The design must carefully consider the safety of both the animals and humans once the wildlife crossing is implemented. Increasing the connectivity for wildlife could negatively impact the people using the trails in the Los Gatos region. The team will place directional fencing and make sure to educate the trail users about the impacts of the wildlife crossing. Positively, this project will reduce the number of vehicular accidents. It is important to ensure that the animals are safe during crossing as well, so the team will make sure they cannot access the highway and have appropriate jump outs over the directional fencing if they end up on the wrong side.

A potential consequence of the crossing is that the construction could impact the neighbors and environment around the site. The construction impacts must be controlled, such as the isolation of hazardous materials, the reduction of construction noise, and the strategic staging of equipment and materials. These consequences of these temporary conditions could be significant.

Since this project is publicly funded it raises the question of whether this is the best use of taxpayer dollars. This project will decrease the number of fatalities and the amount of lane closures due to the accidents, so this will immensely help the public with time and funds.

7.3 Sustainability Impacts

Sustainability is defined as the ability to be maintained at a certain rate or level. For this wildlife crossing project, the two main sustainability issues that the team considered include selecting materials that have reasonable life cycles and designing a crossing that is capable of withstanding various unstable soil conditions.

When designing the wildlife crossing, material selection is an important consideration with respect to the sustainability of the structure. It is best to select materials that have longer lifespans or adequate resistance to weathering so that the overall structure will require less repair and maintenance over its design service life. This will reduce the amount of resources used over the lifespan of the structure. When choosing the materials for the project, the team needed to evaluate the site conditions and required loadings in order to determine which materials best suit the design needs in the long run.

Another important sustainability consideration relates to the structural design of the wildlife crossing and its potential factor of safety. The various codes and regulations set out minimum requirements that must be met in the structural design, but additional resilience can be added by designing for a greater factor of safety. This increased resilience may lengthen the overall lifespan of the structure, but may also require an additional amount of resources to achieve that factor of safety. Balancing these two facets will be crucial in determining a recommendation for the proposed factor of safety and overall project sustainability of the structural design.

Additionally, the sustainability of the crossing can be improved by designing the structure and foundations appropriately for the difficult soil conditions in the region. The soils in the Santa Cruz mountains can be prone to landslides and difficult to build on. The team will choose the final location considering the complex topography surrounding Highway 17 and design the structure to withstand the various unstable soil conditions. Therefore, the crossing will have a longer lifespan and be more sustainable.

7.4 Environmental Impacts

All projects must consider the various environmental impacts that are associated with their design and construction. For this wildlife crossing project, the team considered the drainage of water out from the structure and the selected resource emissions and usage.

Proper drainage from the structure to a specific location is a crucial factor to consider for a wildlife crossing, regardless if the crossing is designed for above or below the highway. For environmental considerations, drainage for under crossings is especially important as runoff from the highway could enter the system and contaminate the body of water that receives the water from the outfall. Furthermore, additional water drained from the crossing could impact the conditions of the receiving system. Whether that be the nearby reservoir, a downstream point of Los Gatos Creek, or the stormwater drainage system, those systems may not have been designed to handle additional inflows which could potentially cause flooding. The team must be cognizant of the effects that the crossing drainage could have on existing systems and evaluate if there would be any significant impact on water quality or on design flow capacities.

7.5 Social, Political, and Health & Safety Impacts

Every project has numerous social impacts that must be carefully considered at all points of design and construction. For this wildlife crossing project, it is important to analyze the path that animals will use to access the crossing because this could impact the neighboring facilities and residences. In choosing the final location of the crossing, the team needed to predict what paths the animals will take and assess if the wildlife will put any neighboring facilities in additional danger. The team mitigated any impacts by strategically placing directional fencing in both directions of the wildlife crossing to prevent animals from crossing into highly populated regions or having access to the highway.

Another important social impact of the wildlife crossing is how the implementation affects the commuters using Highway 17. Highway 17 is an essential passageway that is critical to many people's commute. During the alternative analysis stage, it was important to consider how each alternative will be constructed, how much the construction process will disrupt traffic, and how the driver's safety will be maintained during construction. The team needed to ask how long the construction will take and if all lanes will need to be closed or if it can be done with only partial lane closures to address the issues of traffic disruption and driver safety. Additionally, it will be important to minimize the impact of the wildlife crossing once the construction is complete. An overcrossing could limit the visibility for drivers, and the design must consider how to ensure animals, soil, and vegetation stay on the crossing.

Furthermore, every project must address the political concerns that are associated with design and construction. One major political impact of this wildlife crossing that needs to be considered would be the project cost and funding. With both public and private organizations being stakeholders in the funding of this crossing, the team must be able to justify the reasoning of the design choices and be transparent about the various costs associated with the crossing construction. The stakeholders need to understand why this project is worth the investment and how it will be beneficial to the community in order to garner adequate funding and support. Additionally, it is important to consider what else the funding can be used for, such as supporting the growing homeless population, and ensure the crossing remains within a reasonable budget and does not take away from other essential needs in the community.

Another important political issue that must be addressed in regards to the construction of a large crossing beneath Highway 17 is how traffic disruptions will be minimized. A large volume of commuters travel between the Bay Area and Santa Cruz every day and massive traffic disturbances cannot be allowed for the sake of the drivers, as well as the respective local economies of each region. The team needs to consider how to best minimize any traffic congestion due to construction processes to maintain a relatively healthy traffic flow along the highway, especially during commute times for work.

Finally, every project must consider the health and safety impacts associated with its construction and final implementation. For this wildlife crossing project, the health and safety of both wildlife and motorists is one of the most important impacts to consider. Implementing crossing infrastructure for Highway 17 allows the wildlife in the area to be protected when migrating from one side to the other, eliminating the risk of these animals attempting to cross the highway into oncoming traffic. Additional safety measures must be used during construction to further protect the safety of the motorists. Temporary traffic control signs and procedures must be utilized to signify the upcoming construction area to drivers and to ensure the stability of the highway in the construction area. Additionally, there will be precautions on the staging of materials and equipment to prevent any injuries during the construction process to the drivers or the construction team.

Another health and safety issue to consider is the impact of the new crossing on nearby communities and local trails. As this crossing aims to serve deer and mountain lions, there must be a consideration of the amount of new connectivity that these animals will have. The team must be aware of the likelihood of increased wildlife-human interactions in neighboring areas and on local trails, and potentially propose alternatives that reduce or mitigate any potential for interaction to both people and animals alike.

8. Conclusion

After the considerations taken regarding traffic control, safety of the public, and the protection of the animals, an arched culvert under Highway 17 was determined to be the best option for the given location. This project is able to be completed in phases, with the proper structures in place to keep normalcy for the users. The concerns for the animals are addressed with the arched culvert, which is designed by a structural and geotechnical engineer. The thought of water entering the culvert is analyzed by the hydrology engineer. In the end, if this project is built, it will create a space for both animals and the public to use for their own benefits.

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Appendix A: AutoCAD Drawings of Culvert Preliminary Design

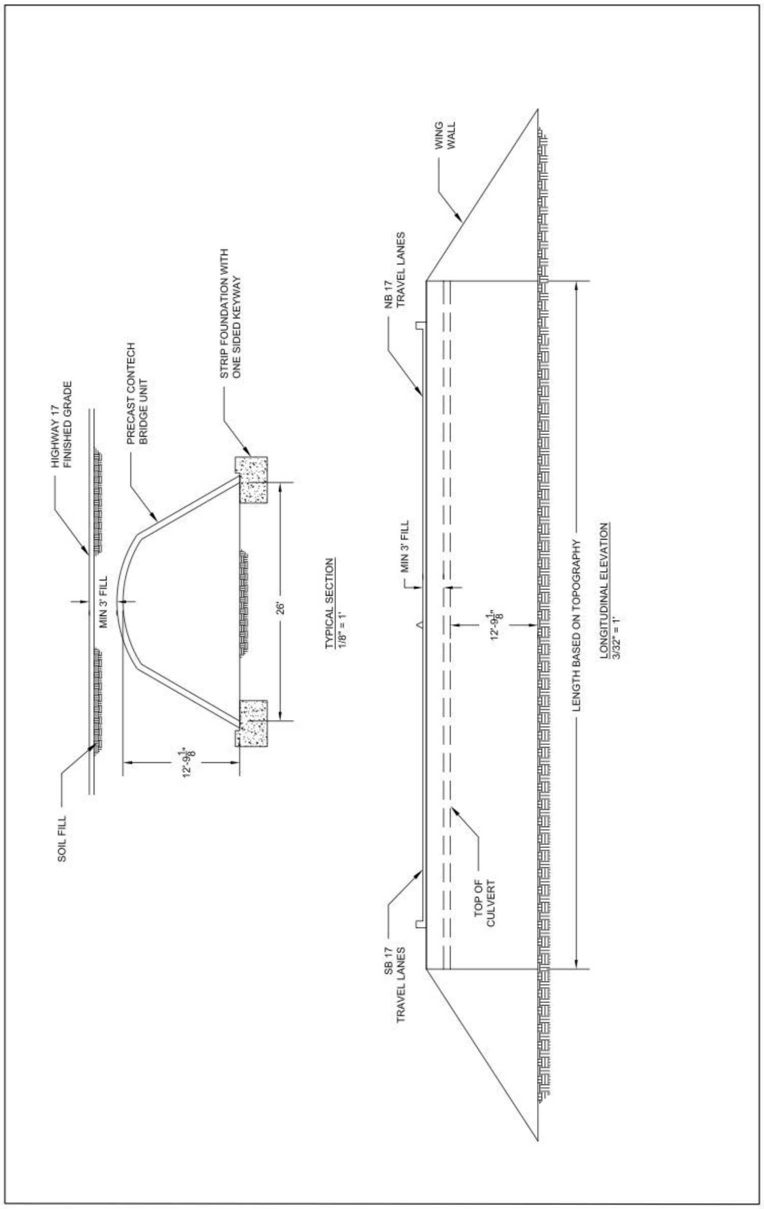


Figure A-1: Longitudinal elevation and cross section views of the proposed precast concrete culvert from Contech Engineered Solutions.

Appendix B: Soldier Pile Wall Design Alternatives

Summary of Design Options (using ENERCALC)

For all alternatives:

- Retained height is 16 feet 8 inches
- Timber lagging Thickness = 3 inches
- Arching factor = 2.4
- Steel ASTM A36 Fy = 36 ksi
- Spacing 6 feet

Alternative	Ties	Concrete Embed	W-Section	Embedment Depth (feet)	Moment Utilization	Shear Utilization
1	N	N	W21x111	29	0.98	0.23
2	Y (4 feet from bottom of excavation)	N	W18x76 (controlled by min width of 11 in)	10	0.59	0.35
3	N	Y (Dia = 29.11 in)	W18x119	21	0.87	0.22

Alternative	**Ties**	**Concrete Embed**	**W-Section**	**Embedment Depth (feet)**	**Moment Utilization**	**Shear Utilization**
1	N	N	W21x111	29	0.98	0.23
2	Y	N	W18x76	10	0.59	0.35
3	N	Y	W18x119	21	0.87	0.22

Project Title:
Engineer:
Project ID:
Project Descr:

Soldier Pile Retaining Wall

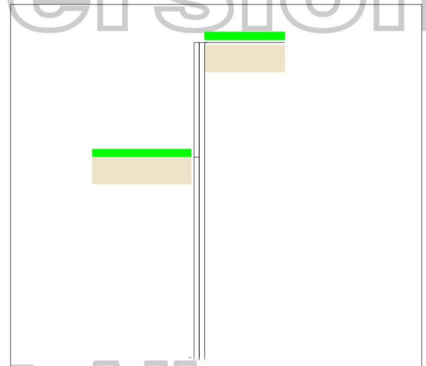
Project File: soldierpile.ec6

LIC# : KW-06090157, Build:20.22.6.12 - Educational Version Licensed User : SANTA CLARA UNIVERSITY, CIVIL ENGINEERING (c) ENERCALC INC 1983-2022

DESCRIPTION: No Tieback - Soldier pile design for temporary retaining walls during construction of wildlife crossing along

Design Parameters

Wall height (retained height)	16.670	ft
Backfill slope		deg
Soil Density	100.0	pcf
Soil Phi angle	30	deg
Ka (horizontal)	0.333	
Kp (Rankine):	3.0	
Surcharge top of soil @ retained	250.0	psf
Allow. Passive	300.00	psf / ft
Apply S.F. to Passive	1.0	
Pile Spacing	6.0	ft
Flange Width, in.	12.30	in
Multiplier to Passive Wedge	2.40	
Required Embedment		ft
Total Pile Embedment	29.0	ft
Soldier Beam Selection	lx111	
Steel Design Method	**LRFD**	
Lateral Presure Method	Rankine	
Passive Pressure to Neglect	12	in
Number of Tiebacks	-1	
Tieback Location	None	
Steel Fy	36	ksi



Thumbnail

Lagging

Lagging Depth	16.670	ft
Lagging Pressure @ Depth	639.0	psf
Lagging Mom. @ Depth	2,300.40	ft-lbs
Lagging Shear @ Depth	1,917.0	lbs/vert. ft
Lagging Selection	Timber 3 in	

Design Results

Required embedment	28.78	ft	28.78ft = 27.78 + 1 ft neglecte
	29.0	ft	
Deflection at top of pile	0.30	in	
Pile Pa	27,788.9	lb	
Pile Pw	8,335.0	lb	
Pile Total Lateral	36,123.9	lb	
Depth to Max M	8.735	ft	
Mmax in Pile (Service)	433,767	ft-lbs	
Vmax in Pile (Service)	36,124	lb	
Mmax in Pile (factored)	694,027	ft-lbs	
Vmax in Pile (factored)	57,798	lb	

Status Checks

					Ratio	Status
Mu	694,027 ft-lbs	PhiMn	706,117	ft-lbs	0.98	OK
Vu	57,798 lb	PhiVn	255,420	lb	0.23	OK
Embedment Required						OK

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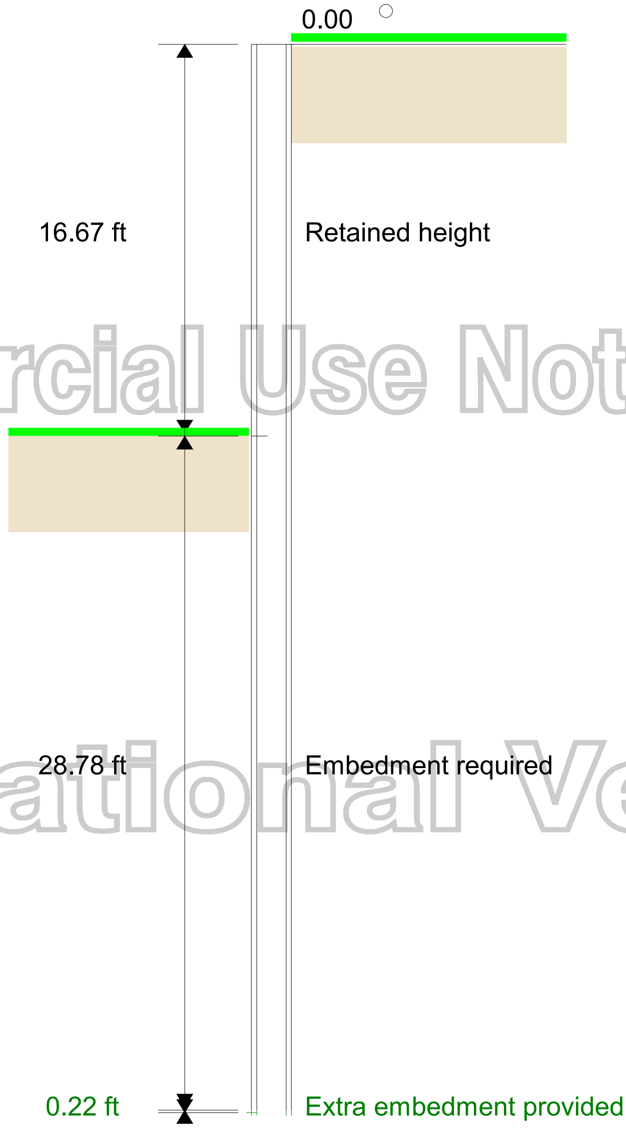
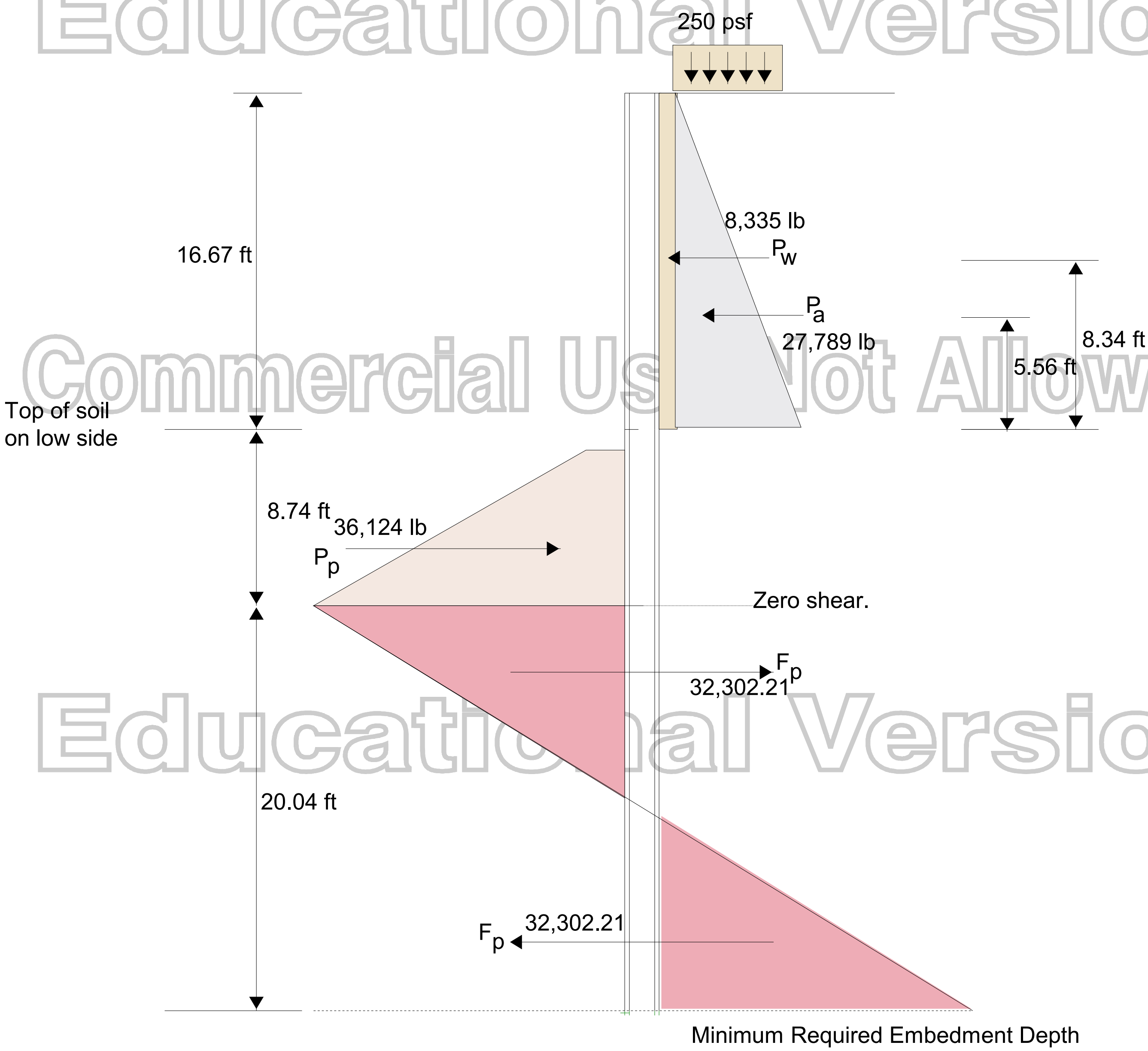


Soldier Pile Retaining Wall

DESCRIPTION: No Tieback - Soldier pile design for temporary retaining walls during construction of wildlife crossing along



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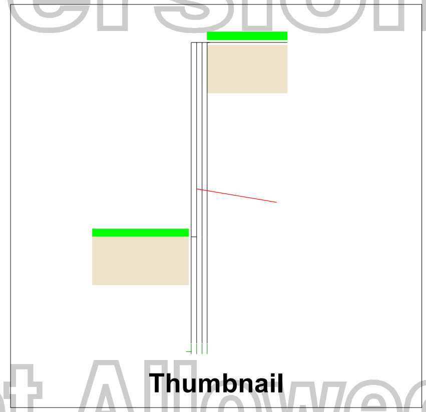
DESCRIPTION: Tieback - Soldier pile design for temporary retaining walls during construction of wildlife crossing along

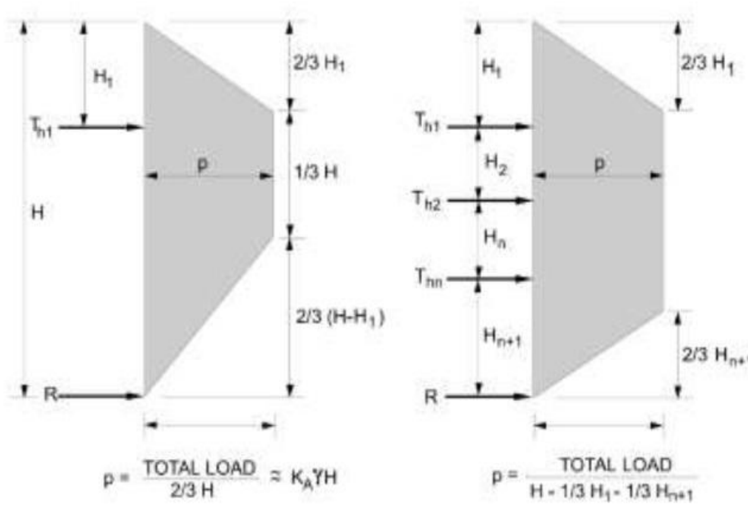
Design Parameters

Wall height (retained height)	16.670	ft
Backfill slope		deg
Soil Density	100.0	pcf
Soil Phi angle	30	deg
Ka (horizontal)	0.333	
Kp (Rankine):	3.0	
Surcharge top of soil @ retained	250.0	psf
Allow. Passive	300.00	psf / ft
Apply S.F. to Passive	1.0	
Pile Spacing	6.0	ft
Flange Width, in.	11.00	in
Multiplier to Passive Wedge	2.40	
Required Embedment		ft
Total Pile Embedment	10.0	ft
Soldier Beam Selection	W18x76	
Steel Design Method	**LRFD**	
Lateral Presure Method	Rankine	
Passive Pressure to Neglect	12	in
Number of Tiebacks	1	
Tieback Location	12.670 ft	
Steel Fy	36	ksi



Lagging

Lagging Depth	16.670	ft
Lagging Pressure @ Depth	639.0	psf
Lagging Mom. @ Depth	2,300.40	ft-lbs
Lagging Shear @ Depth	1,917.0	lbs/vert. ft
Lagging Selection	Timber 3 in	



Design Results

Tieback #1 Reaction	68,522	lb
Base Reaction	27,191	lb
Required embedment	9.13	ft 9.13 ft Em
Embedment Used	10.0	ft
Deflection at top of pile	0.35	in
Extreme Deflection	0.35	in

Extreme Deflection Occurs at level_2 (as defined on Solver I

P (See Pressure Diagram)	3,834	plf
Total Lateral Force	41,331	lb
Mmax in Pile (Service)	148,168	ft-lbs
Vmax in Pile (Service)	36,137	lb
Mmax in Pile (factored)	237,069	ft-lbs
Vmax in Pile (factored)	57,820	lb

Status Checks

				Ratio	Status
Mu	237,069 ft-lbs	PhiMn	398,933 ft-lbs	0.59	OK
Vu	57,820 lb	PhiVn	167,076 lb	0.35	OK
Embedment Required					OK

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Engineer:
Project ID:
Project Descr:

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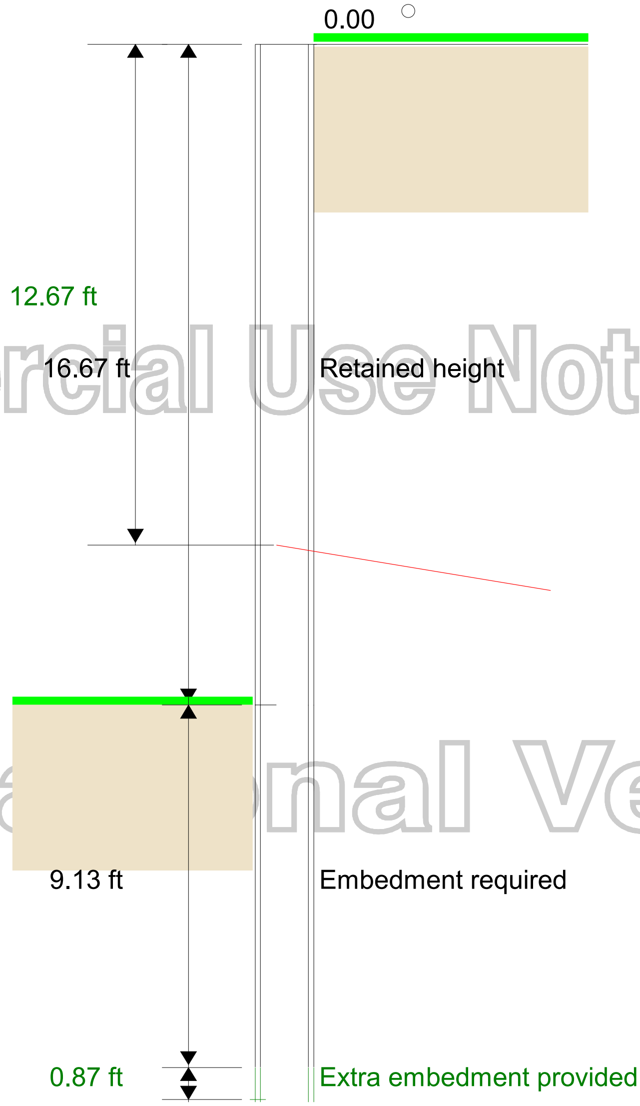
DESCRIPTION: Tieback - Soldier pile design for temporary retaining walls during construction of wildlife crossing along



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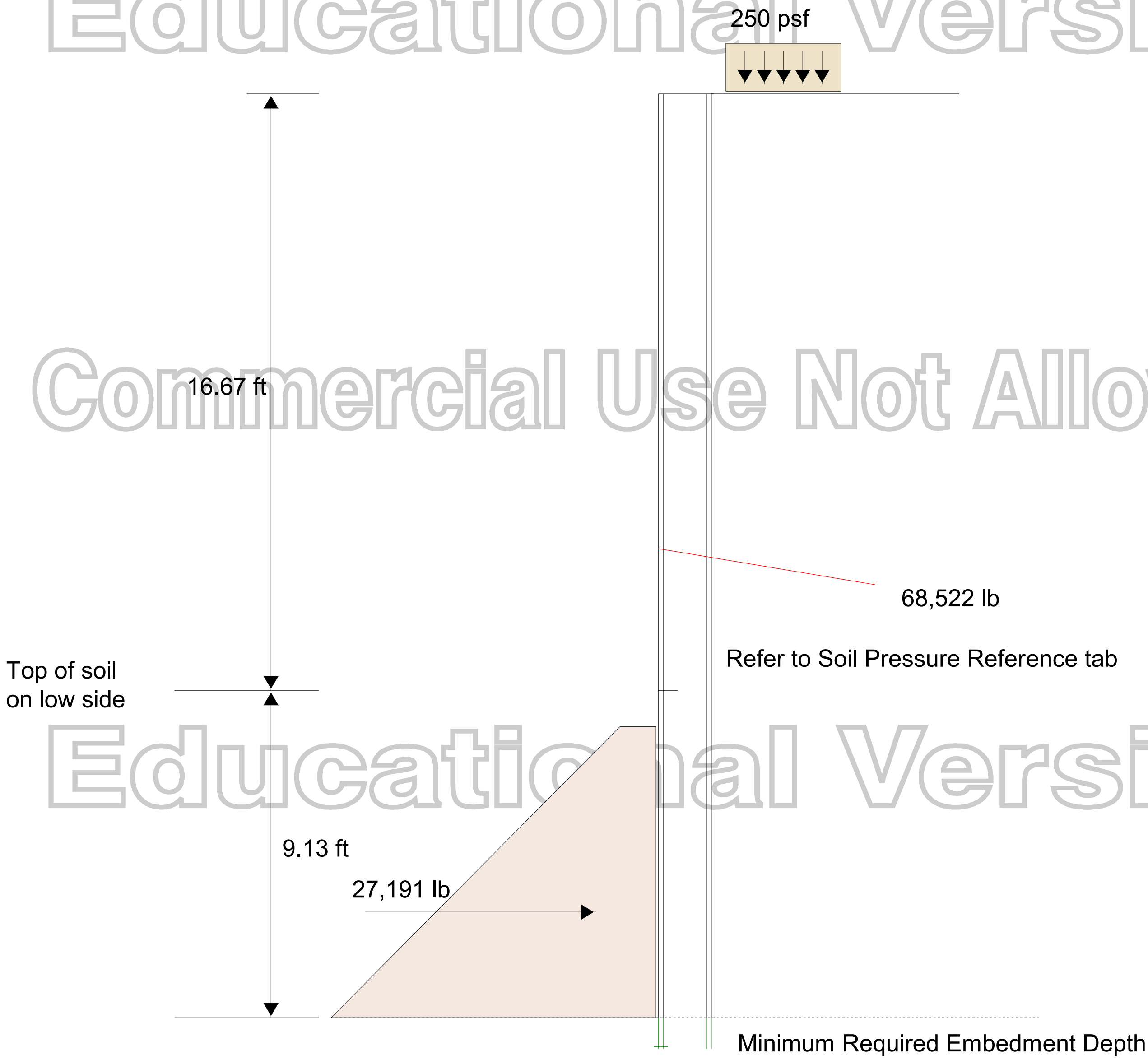

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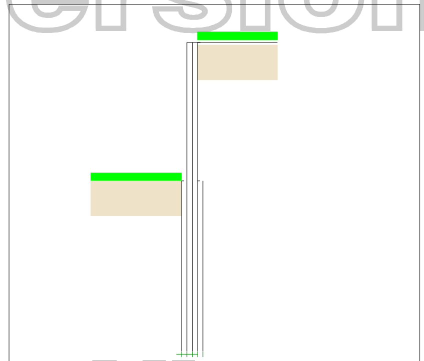
DESCRIPTION: Soldier pile design for temporary retaining walls during construction of wildlife crossing along Highway 17.

Design Parameters

Wall height (retained height)	16.670	ft
Backfill slope	0.0	deg
Soil Density	100.0	pcf
Soil Phi angle	30	deg
Ka (horizontal)	0.333	
Kp (Rankine):	3.0	
Surcharge top of soil @ retained	250.0	psf
Allow. Passive	300.00	psf / ft
Apply S.F. to Passive	1.0	
Pile Spacing	6.0	ft
Drilled Diameter, in.	29.11	in
Multiplier to Passive Wedge	2.40	
Required Embedment		ft
Total Pile Embedment	21.0	ft
Soldier Beam Selection	8x119	
Steel Design Method	**LRFD**	
Lateral Presure Method	Rankine	
Passive Pressure to Neglect	12	in
Number of Tiebacks	-1	
Tieback Location	None	
Steel Fy	36	ksi



Thumbnail

Lagging

Lagging Depth	16.670	ft
Lagging Pressure @ Depth	639.0	psf
Lagging Mom. @ Depth	2,300.40	ft-lbs
Lagging Shear @ Depth	1,917.0	lbs/vert. ft
Lagging Selection	Timber 3 in	

Design Results

Required embedment	20.41	ft 20.41ft = 19.41 + 1 ft neglecte
	21.0	ft
Deflection at top of pile	0.36	in
Pile Pa	27,788.9	lb
Pile Pw	8,335.0	lb
Pile Total Lateral	36,123.9	lb
Depth to Max M	5.729	ft
Mmax in Pile (Service)	360,999	ft-lbs
Vmax in Pile (Service)	36,124	lb
Mmax in Pile (factored)	577,598	ft-lbs
Vmax in Pile (factored)	57,798	lb

Status Checks

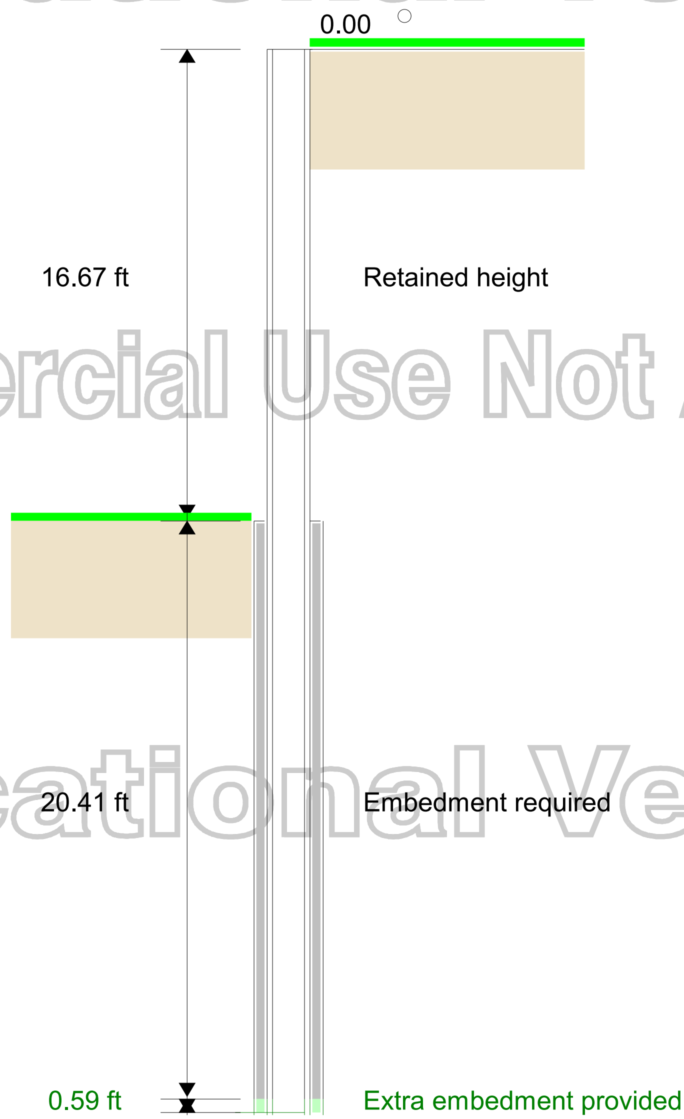
				Ratio	Status
Mu	577,598 ft-lbs	PhiMn	663,892 ft-lbs	0.87	OK
Vu	57,798 lb	PhiVn	268,812 lb	0.22	OK
Embedment Required					OK

Project Title:
Engineer:
Project ID:
Project Descr:

Soldier Pile Retaining Wall

Project File: soldierpile.ec6

DESCRIPTION: Soldier pile design for temporary retaining walls during construction of wildlife crossing along Highway 17.



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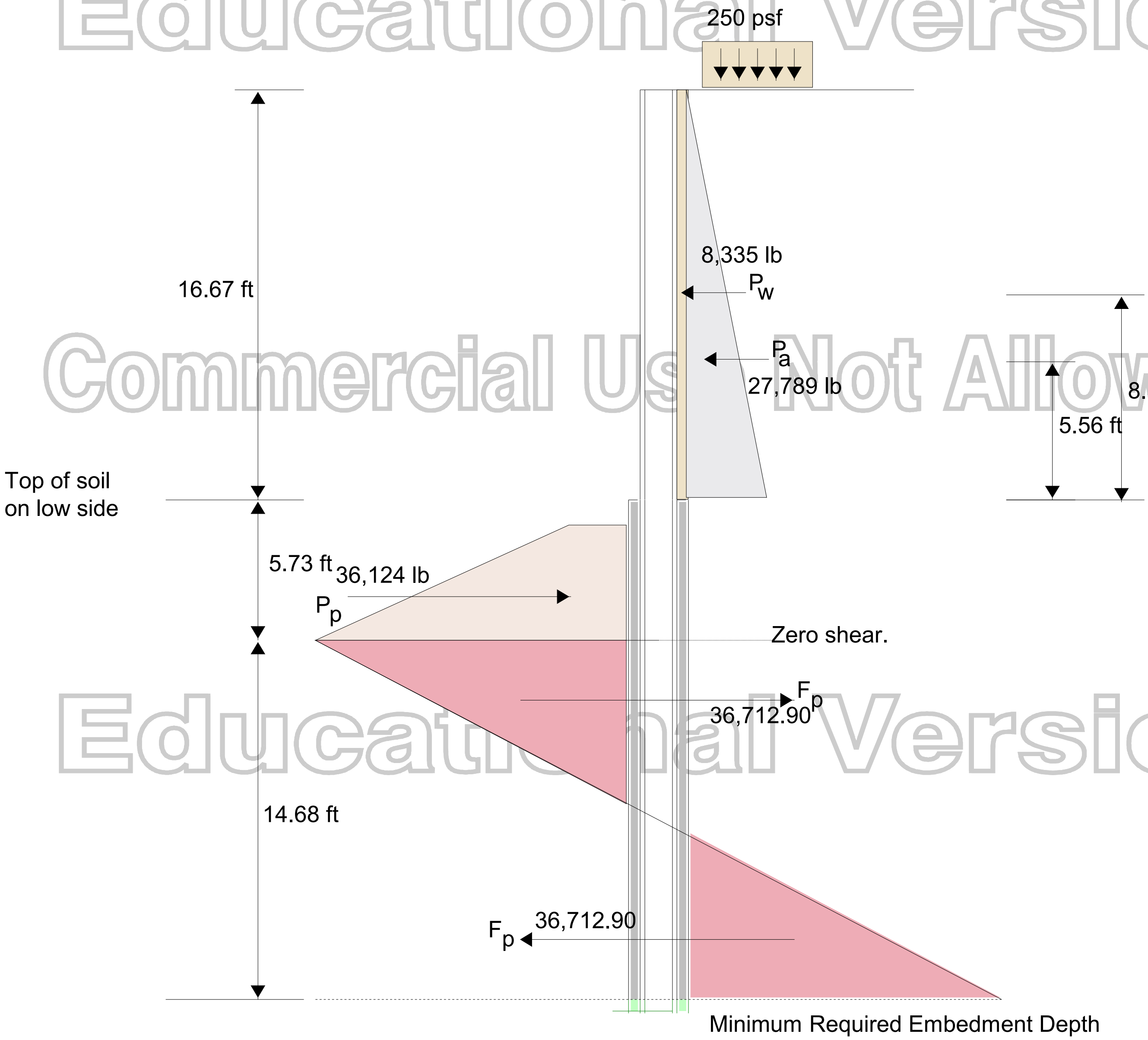
Project File: soldierpile.ec6

DESCRIPTION: Soldier pile design for temporary retaining walls during construction of wildlife crossing along Highway 17.



Appendix C: Cut and Fill Calculations

Table C-1: Cut and fill calculations required for the Phase 2 Lane Shifts.

From	To	Area (ft^2)	Elev 1 (ft)	Elev 2 (ft)	Elev 3 (ft)	Elev 4 (ft)	Elev Avg (ft)	Actual Avg (ft)	Average Difference (ft)	Cut and Fill (cy)
610	610	162.3	610	608	610	–	610	609.33	0.67	4.01
610	615	590.6	610	608	615	608	612.5	610.25	2.25	49.22
615	620	1140.72	615	608	620	609	617.5	613	4.5	190.12
620	625	1703.54	620	609	625	622	622.5	619	3.5	220.83
625	630	2065.38	625	622	630	628	627.5	626.25	1.25	95.62
630	635	2504.12	630	628	635	627	632.5	630	2.5	231.86
635	640	2106.64	635	627	640	635	637.5	634.25	3.25	253.58
640	645	1898.01	640	635	645	645	642.5	641.25	1.25	87.87
645	650	1586.92	645	645	650	656	647.5	649	-1.5	-88.16
650	655	754.49	650	656	655	658	652.5	654.75	-2.25	-62.87
655	660	218.16	655	658	660	–	656.7	657.67	-1	-8.08

Table C-2: Total cut and fill calculations in cubic yards.

Road Cut and Fill	973.99
Cut from Culvert	-674.04
Total Cut and Fill	299.95
Total with Contingency	359.93

Appendix D: Contech Engineering Solutions Calculation Package

3/6

Howdy Taryn,

Thank you for the time and interest! Based upon the parameters in your message I think you are on the right track with your selection of the CON/SPAN O-series for a number of reasons. If you require the full 15’ rise as part of your clearance box for the target species, a foundation with a stem wall is a good choice. I will work up a sketch and those reactions for you in the next couple of days. In regards to your other questions, here are my replies:

For the recommended culvert type, what is the minimum recommended amount of fill? Typical minimum cover is 1’ for most loading cases
What are the vertical and horizontal reactions that we could assume for our foundation design? I will have them calculated and transmit with the sketch and budget estimate
Do the reactions include dead and live loads and are they factored or unfactored? Yes, both dead and live loads. Typically they are unfactored
Any additional resources or information on the cost or constructability of the culverts would also be appreciated. I will work up a budget estimate based upon the sketch. I will also take a crack at the installed costs making a few assumptions on unit pricing.

Thank you again for the time and interest! I will have something for you in the next couple of days.

Regards,

Matthew D. Houser, PE (OR, WA, MO)
Internal Bridge Consultant

CONTECH Engineered Solutions, LLC
11815 NE Glenn Widing Dr Portland, OR 97220
(503) 784 - 5026
matthew.houser@conteches.com
www.ContechES.com

3/10

Taryn,

Thank you again for the time and interest! I have attached a preliminary sketch and reactions for your consideration. In regards to the cost of the structure, I am estimating the materials to sell for $450k to $500k which included delivery to the jobsite. All the other work (excavation, foundations, setting the pieces, backfill, traffic control, etc) is by others than CONTECH.

I also copied you on the project I created in our Design Center so that you can edit and adjust the sketch that is attached. You should have another email in your inbox from our Design Center with a link you can click on to access.

Best of luck on your project, please let me know how else I can be of service.

Regards,

Matthew D. Houser, PE (OR, WA, MO)
Internal Bridge Consultant

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11815 NE Glenn Widing Dr Portland, OR 97220
(503) 784 - 5026
matthew.houser@conteches.com
www.ContechES.com

CON/SPAN O-SERIES REACTIONS

JOB #: XXXXXX
NAME: Hwy 17 Animal Undercrossing
DATE: 9-Mar-23
BY: MDH

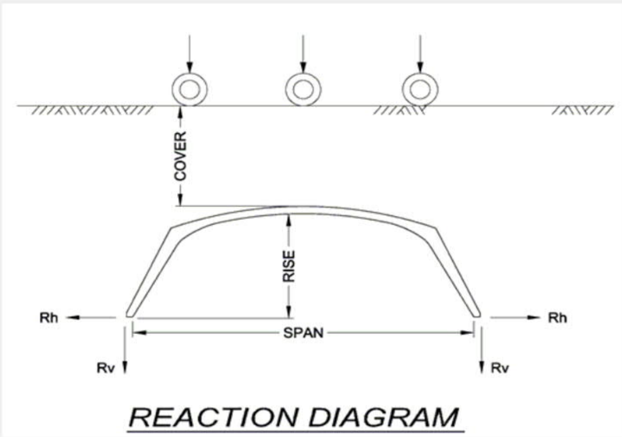
BRIDGE DATA:

Bridge type = **CON/SPAN O-SERIES**

cover, at structure center = 1.00 ft, max
Shape ID O226
bridge span = 26 ft
bridge rise = 12.8 ft
live load = HL93

LOADS:

vertical load (dead load), per leg, RvDL	12.0 k/f
vertical load (dead + live load), per leg, RvDL+LL	17.3 k/f
horizontal load (dead load), per leg, RhDL	2.0 k/f
horizontal load (dead + live load), per leg, RhDL+LL	4.8 k/f



Notes:
1) Axle load positions are varied to produce critical reactions shown here.
2) Reactions are unfactored loads.
3) Impact is not included.
4) Horizontal reactions includes effects of lateral earth pressure above top of foundation.
5) Units are kips/ft.
6) Soil Weight = 120 pcf.
7) reactions are based on spread foundations.

CON/SPAN O-Series DYO
CON/SPAN O-Series

PROJECT SUMMARY

LOCAL BRIDGE CONSULTANT

- NAME = Alex Keenan
- EMAIL = Alex.Keenan@conteches.com
- PHONE NUMBER = 303-817-4198

STRUCTURE DETAILS

- SPAN = 26' - 0"
- PRECAST RISE = 12' - 9 1/8"
- LENGTH = 120 FT.

HEADWALLS

- INLET HEADWALL HEIGHT = 2 FT.
- OUTLET HEADWALL HEIGHT = 2 FT.

FOUNDATIONS

- FOUNDATION TYPE = PEDESTAL

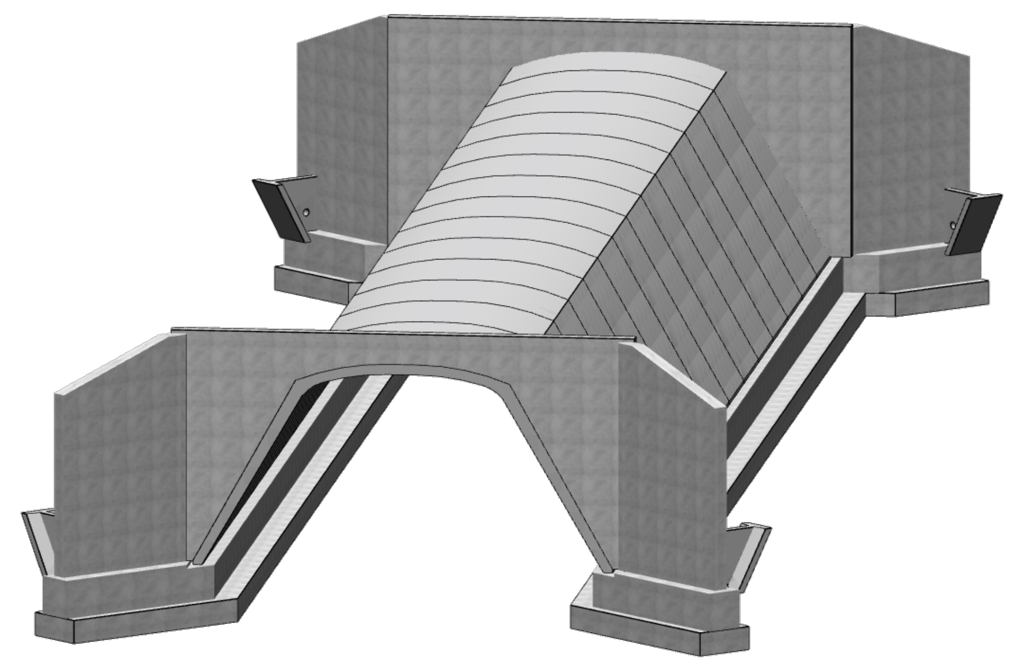
WINGWALLS

- WW 1 ANGLE = 45 DEG.
- WW 1 LENGTH = 10 FT.
- WW 1 HIGH HEIGHT = 14.93 FT.
- WW 1 LOW HEIGHT = 12 FT.

- WW 2 ANGLE = 45 DEG.
- WW 2 LENGTH = 10 FT.
- WW 2 HIGH HEIGHT = 14.93 FT.
- WW 2 LOW HEIGHT = 12 FT.

- WW 3 ANGLE = 45 DEG.
- WW 3 LENGTH = 10 FT.
- WW 3 HIGH HEIGHT = 14.93 FT.
- WW 3 LOW HEIGHT = 12 FT.

- WW 4 ANGLE = 45 DEG.
- WW 4 LENGTH = 10 FT.
- WW 4 HIGH HEIGHT = 14.93 FT.
- WW 4 LOW HEIGHT = 12 FT.



NOTES

1. THIS BRIDGE HAS BEEN DESIGNED FOR GENERAL SITE CONDITIONS. THE PROJECT ENGINEER SHALL BE RESPONSIBLE FOR THE STRUCTURE'S SUITABILITY TO THE EXISTING SITE CONDITIONS AND FOR THE HYDRAULIC EVALUATION -- INCLUDING SCOUR AND CONFIRMATION OF SOIL CONDITIONS.
2. PRIOR TO CONSTRUCTION, CONTRACTOR MUST VERIFY ALL ELEVATIONS SHOWN THROUGH THE ENGINEER.
3. ONLY CONTECH ENGINEERED SOLUTIONS LLC, THE CONSPAN APPROVED MANUFACTURER IN THE PROJECT STATE MAY PROVIDE THE STRUCTURE DESIGNED IN ACCORDANCE WITH THESE PLANS.
4. THIS DYOB DRAWING IS A CONCEPTUAL DESIGN. PLEASE WORK WITH YOUR LOCAL BRIDGE CONSULTANT FOR FURTHER SOLUTION DEVELOPMENT AND PRICING.
5. THE USE OF ANOTHER PRECAST STRUCTURE WITH THE DESIGN ASSUMPTIONS USED FOR THE CON/SPAN® STRUCTURE MAY LEAD TO SERIOUS DESIGN ERRORS. USE OF ANY OTHER PRECAST STRUCTURE WITH THIS DESIGN AND DRAWINGS VOIDS ANY CERTIFICATION OF THIS DESIGN AND WARRANTY. CONTECH ENGINEERED SOLUTIONS ASSUMES NO LIABILITY FOR DESIGN OF ANY ALTERNATE OR SIMILAR TYPE STRUCTURES.

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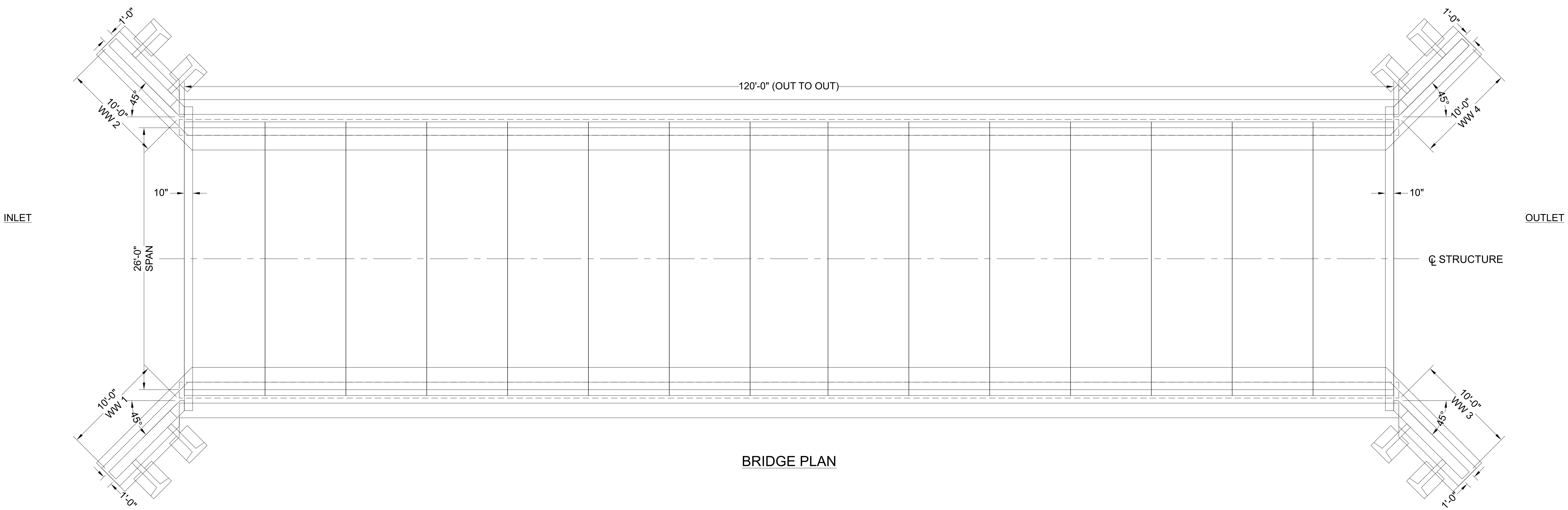
800-338-1122 513-645-7000 513-645-7993 FAX

CON/SPAN O-SERIES

DYOB DRAWING

DYO28424, Hwy 17 Animal Undercrossing
CON/SPAN O-Series
Los Gatos, CA
O Series, 26' Span x 12'-9 1/8" Rise

PROJECT No.: 19032	DYO No.: 28424	DATE: 03/10/2023
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.: D1 OF D9		



BRIDGE PLAN

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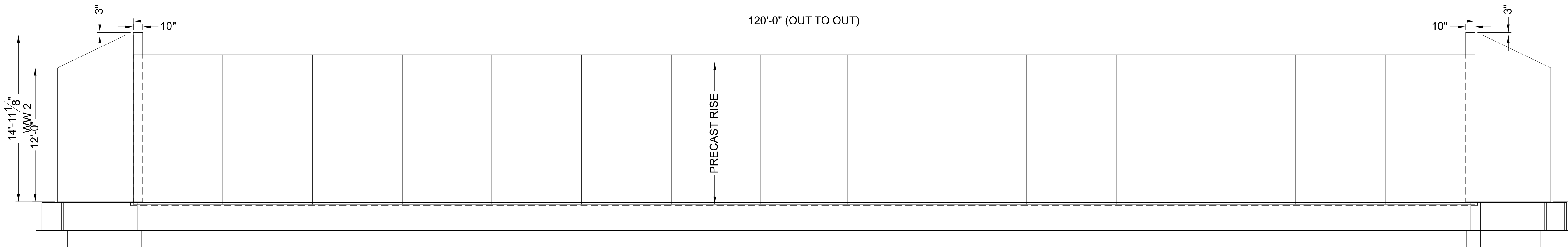
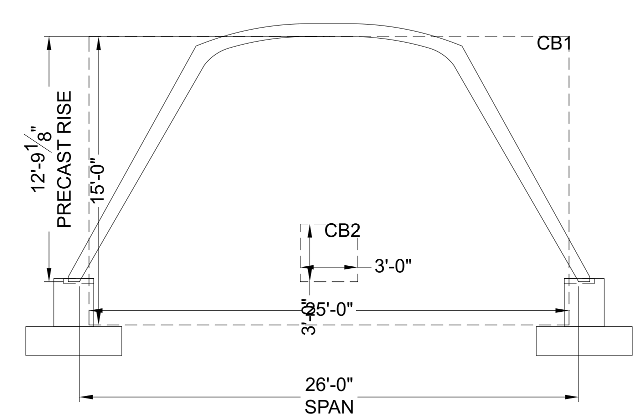
CHECKED: DYO	APPROVED: DYO	
SHEET NO.: D2 OF D9		



LONGITUDINAL SECTION



CROSS SECTION

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DESIGNED: DYO		DRAWN: DYO
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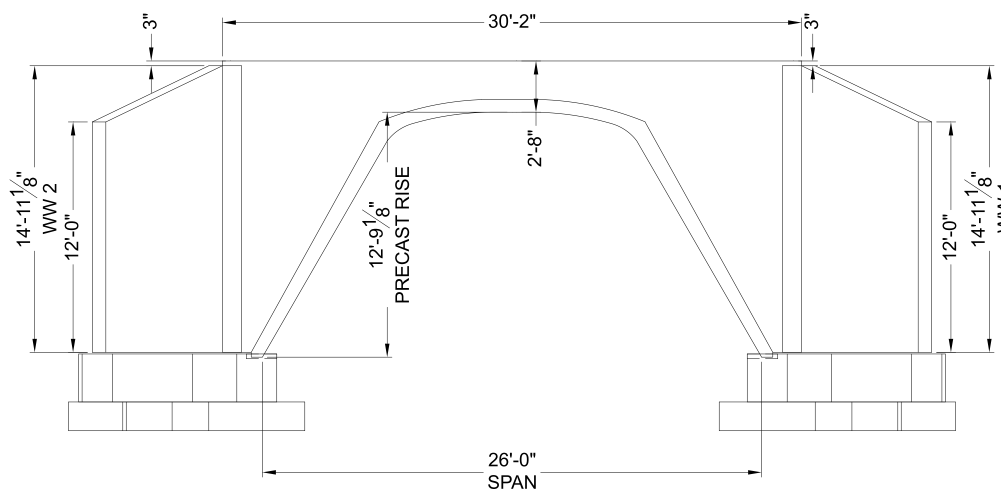
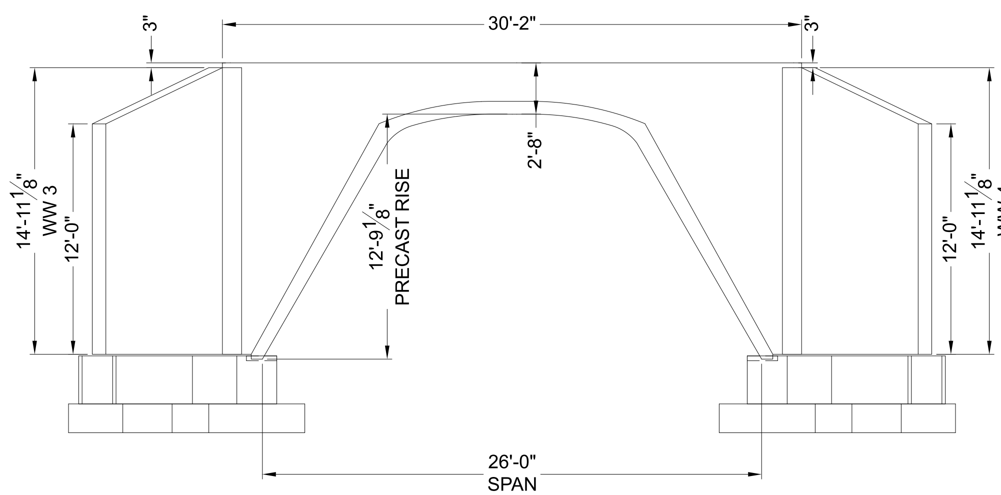
SHEET NO.: D3 OF D9		



INLET END ELEVATION



OUTLET END ELEVATION

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CON/SPAN O-SERIES

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DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
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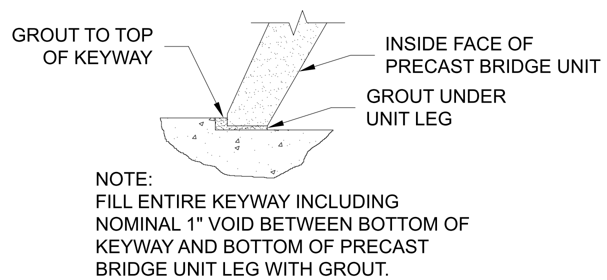
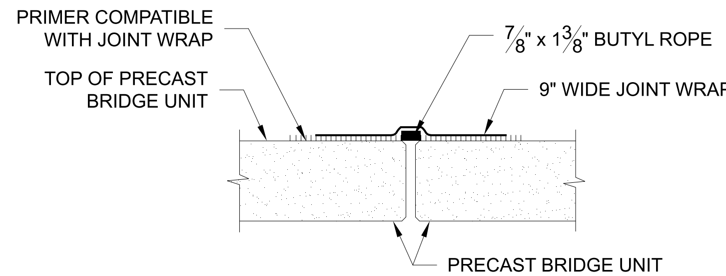


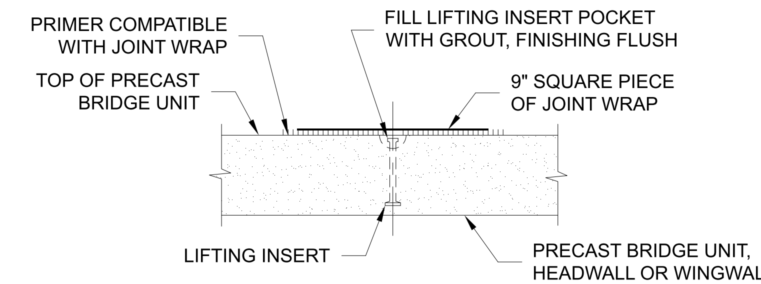
TYPICAL BRIDGE UNIT GROUT DETAIL

NOT TO SCALE



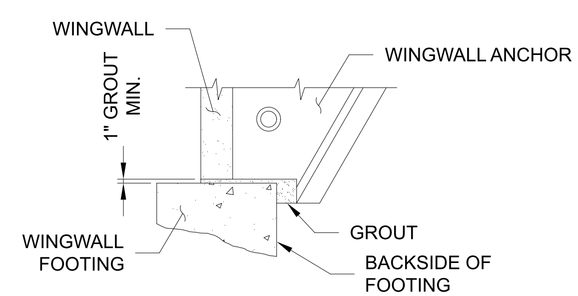
TYPICAL JOINT SEAL DETAIL

NOT TO SCALE



TYPICAL LIFT INSERT SEALING DETAIL

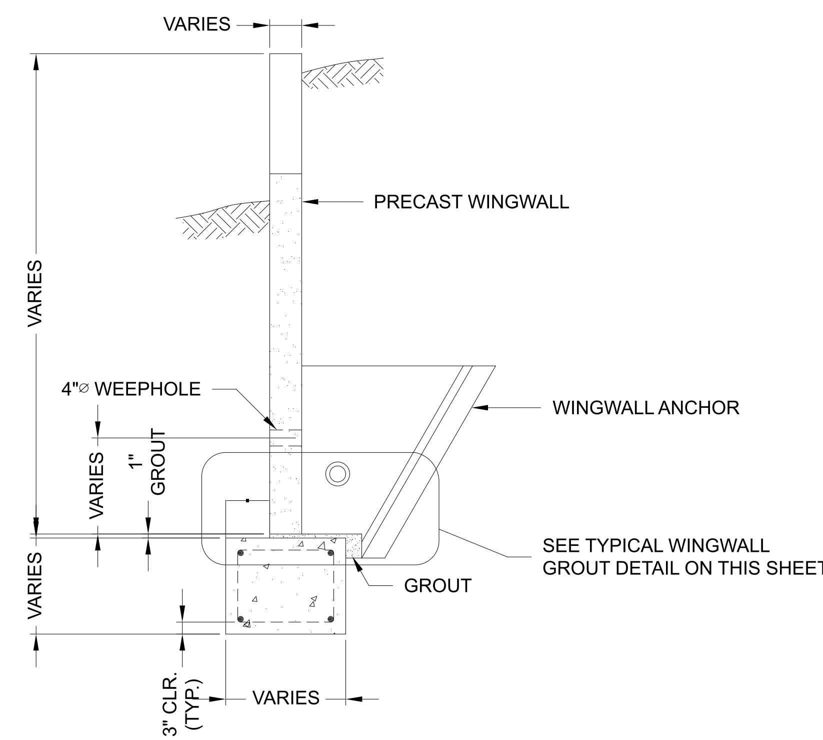
NOT TO SCALE



NOTES:
- MINIMUM 1" GROUT UNDER WINGWALL LEG & ANCHOR STEM.
- AREA BETWEEN WINGWALL FOOTING AND WINGWALL ANCHOR SHALL BE GROUTED SOLID BEFORE BACKFILL.
- FORM BACKSIDE OF FOOTING TO DIMENSIONS SHOWN ON FOUNDATION PLAN.

TYPICAL WINGWALL GROUT DETAIL

NOT TO SCALE



TYPICAL WINGWALL SECTION

NOT TO SCALE

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CON/SPAN O-SERIES

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PROJECT No.: 19032	DYO No.: 28424	DATE: 03/10/2023
DESIGNED: DYO	DRAWN: DYO	
CHECKED: DYO	APPROVED: DYO	
SHEET NO.: D5 OF D9		

SPECIFICATIONS FOR MANUFACTURE AND INSTALLATION OF CON/SPAN® O-SERIES BRIDGE SYSTEMS

1. DESCRIPTION
   1.1. TYPE - THIS WORK SHALL CONSIST OF FURNISHING AND CONSTRUCTING A CON/SPAN® O-SERIES BRIDGE SYSTEM IN ACCORDANCE WITH THESE SPECIFICATIONS AND IN REASONABLY CLOSE CONFORMITY WITH THE LINES, GRADES, DESIGN AND DIMENSIONS SHOWN ON THE PLANS OR AS ESTABLISHED BY THE ENGINEER. IN SITUATIONS WHERE TWO OR MORE SPECIFICATIONS APPLY TO THIS WORK, THE MOST STRINGENT REQUIREMENTS SHALL GOVERN.
   1.2. DESIGNATION - PRECAST REINFORCED CONCRETE CON/SPAN® O-SERIES BRIDGE UNITS MANUFACTURED IN ACCORDANCE WITH THIS SPECIFICATION SHALL BE DESIGNATED BY SPAN AND RISE. PRECAST REINFORCED CONCRETE WINGWALLS AND HEADWALLS MANUFACTURED IN ACCORDANCE WITH THIS SPECIFICATION SHALL BE DESIGNATED BY LENGTH, HEIGHT, AND DEFLECTION ANGLE. PRECAST REINFORCED CONCRETE EXPRESS™ FOUNDATION UNITS MANUFACTURED IN ACCORDANCE WITH THIS SPECIFICATION SHALL BE DESIGNATED BY LENGTH, HEIGHT AND WIDTH.

2. DESIGN
   2.1. SPECIFICATIONS - THE PRECAST ELEMENTS ARE DESIGNED IN ACCORDANCE WITH THE "AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS" 8TH EDITION, ADOPTED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS, 2017. A MINIMUM OF ONE FOOT OF COVER ABOVE THE CROWN OF THE BRIDGE UNITS IS REQUIRED IN THE INSTALLED CONDITION. (UNLESS NOTED OTHERWISE ON THE SHOP DRAWINGS AND DESIGNED ACCORDINGLY.)

3. MATERIALS
   3.1. CONCRETE - THE CONCRETE FOR THE PRECAST ELEMENTS SHALL BE AIR-ENTRAINED WHEN INSTALLED IN AREAS SUBJECT TO FREEZE-THAW CONDITIONS, COMPOSED OF PORTLAND CEMENT, FINE AND COARSE AGGREGATES, ADMIXTURES AND WATER. AIR-ENTRAINED CONCRETE SHALL CONTAIN 6 ± 2 PERCENT AIR. THE AIR- ENTRAINING ADMIXTURE SHALL CONFORM TO AASHT0 M154. THE MINIMUM CONCRETE COMPRESSIVE STRENGTH SHALL BE AS SHOWN ON THE SHOP DRAWINGS.
      3.1.1. PORTLAND CEMENT - SHALL CONFORM TO THE REQUIREMENTS OF ASTM SPECIFICATIONS C150-TYPE I, TYPE II, OR TYPE III CEMENT.
      3.1.2. COARSE AGGREGATE - SHALL CONSIST OF STONE HAVING A MAXIMUM SIZE OF 1 INCH. AGGREGATE SHALL MEET REQUIREMENTS FOR ASTM C33.
      3.1.3. WATER REDUCING ADMIXTURE - THE MANUFACTURER MAY SUBMIT, FOR APPROVAL BY THE ENGINEER, A WATER-REDUCING ADMIXTURE FOR THE PURPOSE OF INCREASING WORKABILITY AND REDUCING THE WATER REQUIREMENT FOR THE CONCRETE.
      3.1.4. CALCIUM CHLORIDE - THE ADDITION TO THE MIX OF CALCIUM CHLORIDE OR ADMIXTURES CONTAINING CALCIUM CHLORIDE WILL NOT BE PERMITTED.
      3.1.5. MIXTURE - THE AGGREGATES, CEMENT AND WATER SHALL BE PROPORTIONED AND MIXED IN A BATCH MIXER TO PRODUCE A HOMOGENEOUS CONCRETE MEETING THE STRENGTH REQUIREMENTS OF THIS SPECIFICATION. THE PROPORTION OF PORTLAND CEMENT IN THE MIXTURE SHALL NOT BE LESS THAN 564 POUNDS (6 SACKS) PER CUBIC YARD OF CONCRETE.
   3.2. STEEL REINFORCEMENT
      3.2.1. THE MINIMUM STEEL YIELD STRENGTH SHALL BE 60,000 PSI, UNLESS OTHERWISE NOTED ON THE SHOP DRAWINGS.
      3.2.2. ALL REINFORCING STEEL FOR THE PRECAST ELEMENTS SHALL BE FABRICATED AND PLACED IN ACCORDANCE WITH THE DETAILED SHOP DRAWINGS SUBMITTED BY THE MANUFACTURER.
      3.2.3. REINFORCEMENT SHALL CONSIST OF WELDED WIRE REINFORCING CONFORMING TO ASTM SPECIFICATION A 1064, OR DEFORMED STEEL BARS CONFORMING TO ASTM SPECIFICATION A 615, GRADE 60. LONGITUDINAL DISTRIBUTION REINFORCEMENT MAY CONSIST OF WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS.
   3.3. STEEL HARDWARE
      3.3.1. BOLTS AND THREADED RODS FOR WINGWALL CONNECTIONS SHALL CONFORM TO ASTM A 307. NUTS SHALL CONFORM TO AASHTO M292 (ASTM A194) GRADE 2H. ALL BOLTS, THREADED RODS AND NUTS USED IN WINGWALL CONNECTIONS SHALL BE MECHANICALLY ZINC COATED IN ACCORDANCE WITH ASTM B695 CLASS 50.
      3.3.2. STRUCTURAL STEEL FOR WINGWALL CONNECTION PLATES AND PLATE WASHERS SHALL CONFORM TO AASHTO M 270 (ASTM A 709) GRADE 36 AND SHALL BE HOT DIP GALVANIZED AS PER AASHTO M111 (ASTM A123).
      3.3.3. INSERTS FOR WINGWALLS SHALL BE 1" DIAMETER TWO-BOLT PRESET WINGWALL ANCHORS AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700 AND SHALL BE ELECTRO GALVANIZED IN ACCORDANCE WITH ASTM B633 SC-1.
      3.3.4. FERRULE LOOP INSERTS SHALL BE F-64 FERRULE LOOP INSERTS AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700 AND SHALL BE ELECTRO GALVANIZED.
      3.3.5. HOOK BOLTS USED IN ATTACHED HEADWALL CONNECTIONS SHALL BE ASTM A307.
      3.3.6. INSERTS FOR DETACHED HEADWALL CONNECTIONS SHALL BE AISI TYPE 304 STAINLESS STEEL, EXPANDED COIL INSERTS AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700. COIL RODS AND NUTS USED IN HEADWALL CONNECTIONS SHALL BE AISI TYPE 304 STAINLESS STEEL. WASHERS USED IN HEADWALL CONNECTIONS SHALL BE EITHER AISI TYPE 304 STAINLESS STEEL PLATE WASHERS OR AASHTO M270 (ASTM A709) GRADE 36 PLATE WASHERS HOT DIP GALVANIZED AS PER AASHTO M111 (ASTM A123).
      3.3.7. MECHANICAL SPLICES OF REINFORCING BARS SHALL BE MADE USING THE DOWEL BAR SPLICER SYSTEM AS MANUFACTURED BY DAYTON SUPERIOR CONCRETE ACCESSORIES, MIAMISBURG, OHIO, (800) 745-3700, AND SHALL CONSIST OF THE DBDI SPLICE SYSTEM (DOWEL BAR SPLICER AND DOWEL-IN), OR AS MANUFACTURED BY BARSPLICE PRODUCTS INC, DAYTON, OHIO, (937)-275-8700, AND SHALL CONSIST OF BARSPLICER XP TYPE 2 SYSTEM.

4. MANUFACTURE OF PRECAST ELEMENTS - SUBJECT TO THE PROVISIONS OF SECTION 5, BELOW, THE PRECAST ELEMENT DIMENSION AND REINFORCEMENT DETAILS SHALL BE AS PRESCRIBED IN THE PLAN AND SHOP DRAWINGS PROVIDED BY THE MANUFACTURER.
   4.1. FORMS - THE FORMS USED IN MANUFACTURE SHALL BE SUFFICIENTLY RIGID AND ACCURATE TO MAINTAIN THE REQUIRED PRECAST ELEMENT DIMENSIONS WITHIN THE PERMISSIBLE VARIATIONS GIVEN IN SECTION 5 OF THESE SPECIFICATIONS. ALL CASTING SURFACES SHALL BE OF A SMOOTH MATERIAL.
   4.2. PLACEMENT OF REINFORCEMENT
      4.2.1. PLACEMENT OF REINFORCEMENT IN PRECAST BRIDGE UNITS - THE COVER OF CONCRETE OVER THE OUTSIDE CIRCUMFERENTIAL REINFORCEMENT SHALL BE 2" MINIMUM. THE COVER OF CONCRETE OVER THE INSIDE CIRCUMFERENTIAL REINFORCEMENT SHALL BE 1½" MINIMUM, UNLESS OTHERWISE NOTED ON THE SHOP DRAWINGS. THE CLEAR DISTANCE OF THE END CIRCUMFERENTIAL WIRES SHALL NOT BE LESS THAN 1" NOR MORE THAN 2" FROM THE ENDS OF EACH SECTION. REINFORCEMENT SHALL BE ASSEMBLED UTILIZING SINGLE OR MULTIPLE LAYERS OF WELDED WIRE FABRIC (NOT TO EXCEED 3 LAYERS), SUPPLEMENTED WITH A SINGLE LAYER OF DEFORMED BILLET-STEEL BARS, WHEN NECESSARY. WELDED WIRE FABRIC SHALL BE COMPOSED OF CIRCUMFERENTIAL AND LONGITUDINAL WIRES MEETING THE SPACING REQUIREMENTS OF 4.3, BELOW, AND SHALL CONTAIN SUFFICIENT LONGITUDINAL WIRES EXTENDING THROUGH THE BRIDGE UNIT TO MAINTAIN THE SHAPE AND POSITION OF THE REINFORCEMENT. LONGITUDINAL DISTRIBUTION REINFORCEMENT MAY BE WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS AND SHALL MEET THE SPACING REQUIREMENTS OF 4.3, BELOW. THE ENDS OF THE LONGITUDINAL DISTRIBUTION REINFORCEMENT SHALL BE NOT MORE THAN 3" AND NOT LESS THAN 1½" FROM THE ENDS OF THE BRIDGE UNIT.
      4.2.2. BENDING OF REINFORCEMENT FOR PRECAST BRIDGE UNITS - THE OUTSIDE AND INSIDE CIRCUMFERENTIAL REINFORCING STEEL FOR THE CORNERS OF THE BRIDGE SHALL BE BENT TO SUCH AN ANGLE THAT IS APPROXIMATELY EQUAL TO THE CONFIGURATION OF THE BRIDGE'S OUTSIDE CORNER.
      4.2.3. PLACEMENT OF REINFORCEMENT FOR PRECAST WINGWALLS AND HEADWALLS - THE COVER OF CONCRETE OVER THE LONGITUDINAL AND TRANSVERSE REINFORCEMENT SHALL BE 2" MINIMUM. THE CLEAR DISTANCE FROM THE END OF EACH PRECAST ELEMENT TO THE END OF REINFORCING STEEL SHALL NOT BE LESS THAN 1½" NOR MORE THAN 3". REINFORCEMENT SHALL BE ASSEMBLED UTILIZING A SINGLE LAYER OF WELDED WIRE FABRIC, OR A SINGLE LAYER OF DEFORMED BILLET-STEEL BARS. WELDED WIRE FABRIC SHALL BE COMPOSED OF TRANSVERSE AND LONGITUDINAL WIRES MEETING THE SPACING REQUIREMENTS OF 4.3, BELOW, AND SHALL CONTAIN SUFFICIENT LONGITUDINAL WIRES EXTENDING THROUGH THE ELEMENT TO MAINTAIN THE SHAPE AND POSITION OF THE REINFORCEMENT. LONGITUDINAL REINFORCEMENT MAY BE WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS AND SHALL MEET THE SPACING REQUIREMENTS OF 4.3, BELOW.
      4.2.4. PLACEMENT OF REINFORCEMENT FOR PRECAST FOUNDATION UNITS - THE COVER OF CONCRETE OVER THE BOTTOM REINFORCEMENT SHALL BE 3 INCHES MINIMUM. THE COVER OF CONCRETE FOR ALL OTHER REINFORCEMENT SHALL BE 2 INCHES MINIMUM. THE CLEAR DISTANCE FROM THE END OF EACH PRECAST ELEMENT TO THE END OF REINFORCING STEEL SHALL NOT BE LESS THAN 2 INCHES NOR MORE THAN 3 INCHES. REINFORCEMENT SHALL BE ASSEMBLED UTILIZING A SINGLE LAYER OF WELDED WIRE FABRIC OR A SINGLE LAYER OF DEFOREMED BILLET-STEEL BARS. WELDED WIRE FABRIC SHALL BE COMPOSED OF TRANSVERSE AND LONGITUDINAL WIRES MEETING THE SPACING REQUIREMENTS OF 4.3, BELOW, AND SHALL CONTAIN SUFFICIENT LONGITUDINAL WIRES EXTENDING THROUGH THE ELEMENT TO MAINTAIN THE SHAPE AND POSITION OF THE REINFORCEMENT. LONGITUDINAL REINFORCEMENT MAY BE WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS AND SHALL MEET THE SPACING REQUIREMENTS OF 4.3, BELOW.
   4.3. LAPS, WELDS, SPACING
      4.3.1. LAPS, WELDS, AND SPACING FOR PRECAST BRIDGE UNITS - TENSION SPLICES IN THE CIRCUMFERENTIAL REINFORCEMENT SHALL BE MADE BY LAPPING. LAPS MAY BE TACK WELDED TOGETHER FOR ASSEMBLY PURPOSES. FOR SMOOTH WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5B AND 5.10.8.5.2. FOR DEFORMED WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5A AND 5.10.8.5.1. THE OVERLAP OF WELDED WIRE FABRIC SHALL BE MEASURED BETWEEN THE OUTER-MOST LONGITUDINAL WIRES OF EACH FABRIC SHEET. FOR DEFORMED BILLET-STEEL BARS, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.1 FOR SPLICES OTHER THAN TENSION SPLICES, THE OVERLAP SHALL BE A MINIMUM OF 1'-0" FOR WELDED WIRE FABRIC OR DEFORMED BILLET-STEEL BARS. THE SPACING CENTER TO CENTER OF THE CIRCUMFERENTIAL WIRES IN A WIRE FABRIC SHEET SHALL BE NOT LESS THAN 2" NOR MORE THAN 4". THE SPACING CENTER TO CENTER OF THE LONGITUDINAL WIRES SHALL NOT BE MORE THAN 8". THE SPACING CENTER TO CENTER OF THE LONGITUDINAL DISTRIBUTION STEEL FOR EITHER LINE OF REINFORCING IN THE TOP SLAB SHALL BE NOT MORE THAN 1'-4".
      4.3.2. LAPS, WELDS, AND SPACING FOR PRECAST WINGWALLS, HEADWALLS AND FOUNDATIONS - SPLICES IN THE REINFORCEMENT SHALL BE MADE BY LAPPING. LAPS MAY BE TACK WELDED TOGETHER FOR ASSEMBLY PURPOSES. FOR SMOOTH WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5B AND 5.10.8.5.2. FOR DEFORMED WELDED WIRE FABRIC, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.5A AND 5.10.8.5.1. FOR DEFORMED BILLET-STEEL BARS, THE OVERLAP SHALL MEET THE REQUIREMENTS OF AASHTO 5.10.8.2.1. THE SPACING CENTER-TO-CENTER OF THE WIRES IN A WIRE FABRIC SHEET SHALL BE NOT LESS THAN 2" NOR MORE THAN 8".
   4.4. CURING - THE PRECAST CONCRETE ELEMENTS SHALL BE CURED FOR A SUFFICIENT LENGTH OF TIME SO THAT THE CONCRETE WILL DEVELOP THE SPECIFIED COMPRESSIVE STRENGTH IN 28 DAYS OR LESS. ANY ONE OF THE FOLLOWING METHODS OF CURING OR COMBINATIONS THERE OF SHALL BE USED:
      4.4.1. STEAM CURING - THE PRECAST ELEMENTS MAY BE LOW-PRESSURE STEAM CURED BY A SYSTEM THAT WILL MAINTAIN A MOIST ATMOSPHERE.
      4.4.2. WATER CURING - THE PRECAST ELEMENTS MAY BE WATER CURED BY ANY METHOD THAT WILL KEEP THE SECTIONS MOIST.
      4.4.3. MEMBRANE CURING - A SEALING MEMBRANE CONFORMING TO THE REQUIREMENTS OF ASTM SPECIFICATION C309 MAY BE APPLIED AND SHALL BE LEFT INTACT UNTIL THE REQUIRED CONCRETE COMPRESSIVE STRENGTH IS ATTAINED. THE CONCRETE TEMPERATURE AT THE TIME OF APPLICATION SHALL BE WITHIN +/- 10 DEGREES F OF THE ATMOSPHERIC TEMPERATURE. ALL SURFACES SHALL BE KEPT MOIST PRIOR TO THE APPLICATION OF THE COMPOUNDS AND SHALL BE DAMP WHEN THE COMPOUND IS APPLIED.
   4.5. STORAGE, HANDLING & DELIVERY
      4.5.1. STORAGE - PRECAST CONCRETE BRIDGE ELEMENTS SHALL BE LIFTED AND STORED IN "AS-CAST" POSITION. PRECAST CONCRETE HEADWALL AND WINGWALL UNITS ARE CAST, STORED AND SHIPPED IN A FLAT POSITION. THE PRECAST ELEMENTS SHALL BE STORED IN SUCH A MANNER TO PREVENT CRACKING OR DAMAGE. STORE ELEMENTS USING TIMBER SUPPORTS AS APPROPRIATE. THE UNITS SHALL NOT BE MOVED UNTIL THE CONCRETE COMPRESSIVE STRENGTH HAS REACHED A MINIMUM OF 2500 PSI (3000 PSI FOR SPANS >48 FEET), AND THEY SHALL NOT BE STORED IN AN UPRIGHT POSITION.
      4.5.2. HANDLING - HANDLING DEVICES SHALL BE PERMITTED IN EACH PRECAST ELEMENT FOR THE PURPOSE OF HANDLING AND SETTING. SPREADER BEAMS MAY BE REQUIRED FOR THE LIFTING OF PRECAST CONCRETE BRIDGE ELEMENTS TO PRECLUDE DAMAGE FROM BENDING OR TORSION FORCES.
      4.5.3. DELIVERY - PRECAST CONCRETE ELEMENTS MUST NOT BE SHIPPED UNTIL THE CONCRETE HAS ATTAINED THE SPECIFIED DESIGN COMPRESSIVE STRENGTH, OR AS DIRECTED BY THE DESIGN ENGINEER. PRECAST CONCRETE ELEMENTS MAY BE UNLOADED AND PLACED ON THE GROUND AT THE SITE UNTIL INSTALLED. STORE ELEMENTS USING TIMBER SUPPORTS AS APPROPRIATE.
   4.6. QUALITY ASSURANCE - THE PRECASTER SHALL DEMONSTRATE ADHERENCE TO THE STANDARDS SET FORTH IN THE NPCA QUALITY CONTROL MANUAL. THE PRECASTER SHALL MEET EITHER SECTION 4.6.1 OR 4.6.2
      4.6.1. CERTIFICATION - THE PRECASTER SHALL BE CERTIFIED BY THE PRECAST/PRESTRESSED CONCRETE INSTITUTE PLANT CERTIFICATION PROGRAM OR THE NATIONAL PRECAST CONCRETE ASSOCIATION'S PLANT CERTIFICATION PROGRAM PRIOR TO AND DURING PRODUCTION OF THE PRODUCTS COVERED BY THIS SPECIFICATION.
      4.6.2. QUALIFICATIONS, TESTING AND INSPECTION
         4.6.2.1. THE PRECASTER SHALL HAVE BEEN IN THE BUSINESS OF PRODUCING PRECAST CONCRETE PRODUCTS SIMILAR TO THOSE SPECIFIED FOR A MINIMUM OF THREE YEARS. HE SHALL MAINTAIN A PERMANENT QUALITY CONTROL DEPARTMENT OR RETAIN AN INDEPENDENT TESTING AGENCY ON A CONTINUING BASIS. THE AGENCY SHALL ISSUE A REPORT, CERTIFIED BY A LICENSED ENGINEER, DETAILING THE ABILITY OF THE PRECASTER TO PRODUCE QUALITY PRODUCTS CONSISTENT WITH INDUSTRY STANDARDS.
         4.6.2.2. THE PRECASTER SHALL SHOW THAT THE FOLLOWING TESTS ARE PERFORMED IN ACCORDANCE WITH THE ASTM STANDARDS INDICATED. TESTS SHALL BE PERFORMED AS INDICATED IN SECTION 6 OF THESE SPECIFICATIONS.
            4.6.2.2.1. AIR CONTENT: C231 OR C173
            4.6.2.2.2. COMPRESSIVE STRENGTH: C31,C39,C497
         4.6.2.3. THE PRECASTER SHALL PROVIDE DOCUMENTATION DEMONSTRATING COMPLIANCE WITH THIS SECTION TO CONTECH® ENGINEERED SOLUTIONS AT REGULAR INTERVALS OR UPON REQUEST.
         4.6.2.4. THE OWNER MAY PLACE AN INSPECTOR IN THE PLANT WHEN THE PRODUCTS COVERED BY THIS SPECIFICATION ARE BEING MANUFACTURED.
      4.6.3. DOCUMENTATION - THE PRECASTER SHALL SUBMIT PRECAST PRODUCTION REPORTS TO CONTECH® ENGINEERED SOLUTIONS AS REQUIRED.

5. PERMISSIBLE VARIATIONS
   5.1. BRIDGE UNITS
      5.1.1. INTERNAL DIMENSIONS - THE INTERNAL DIMENSION SHALL VARY NOT MORE THAN 1% FROM THE DESIGN DIMENSIONS NOR MORE THAN 1½" WHICHEVER IS LESS.
      5.1.2. SLAB AND WALL THICKNESS - THE SLAB AND WALL THICKNESS SHALL NOT BE LESS THAN THAT SHOWN IN THE DESIGN BY MORE THAN ¼". A THICKNESS MORE THAN THAT REQUIRED IN THE DESIGN SHALL NOT BE CAUSE FOR REJECTION.
      5.1.3. LENGTH OF OPPOSITE SURFACES - VARIATIONS IN LAYING LENGTHS OF TWO OPPOSITE SURFACES OF THE BRIDGE UNIT SHALL NOT BE MORE THAN ½" IN ANY SECTION, EXCEPT WHERE BEVELED ENDS FOR LAYING OF CURVES ARE SPECIFIED BY THE PURCHASER.
      5.1.4. LENGTH OF SECTION - THE UNDERRUN IN LENGTH OF A SECTION SHALL NOT BE MORE THAN ½" IN ANY BRIDGE UNIT.
      5.1.5. POSITION OF REINFORCEMENT - THE MAXIMUM VARIATION IN POSITION OF THE REINFORCEMENT SHALL BE ±½". IN NO CASE SHALL THE COVER OVER THE REINFORCEMENT BE LESS THAN 1½" FOR THE OUTSIDE CIRCUMFERENTIAL STEEL OR BE LESS THAN 1" FOR THE INSIDE CIRCUMFERENTIAL STEEL AS MEASURED TO THE EXTERNAL OR INTERNAL SURFACE OF THE BRIDGE. THESE TOLERANCES OR COVER REQUIREMENTS DO NOT APPLY TO MATING SURFACES OF THE JOINTS.
      5.1.6. AREA OF REINFORCEMENT - THE AREAS OF STEEL REINFORCEMENT SHALL BE THE DESIGN STEEL AREAS AS SHOWN IN THE MANUFACTURER'S SHOP DRAWINGS. STEEL AREAS GREATER THAN THOSE REQUIRED SHALL NOT BE CAUSE FOR REJECTION. THE PERMISSIBLE VARIATION IN DIAMETER OF ANY REINFORCEMENT SHALL CONFORM TO THE TOLERANCES PRESCRIBED IN THE ASTM SPECIFICATION FOR THAT TYPE OF REINFORCEMENT.
   5.2. WINGWALLS & HEADWALLS
      5.2.1. WALL THICKNESS - THE WALL THICKNESS SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".
      5.2.2. LENGTH/HEIGHT OF WALL SECTIONS - THE LENGTH AND HEIGHT OF THE WALL SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".
      5.2.3. POSITION OF REINFORCEMENT - THE MAXIMUM VARIATION IN THE POSITION OF THE REINFORCEMENT SHALL BE ±½". IN NO CASE SHALL THE COVER OVER THE REINFORCEMENT BE LESS THAN 1½".
      5.2.4. SIZE OF REINFORCEMENT - THE PERMISSIBLE VARIATION IN DIAMETER OF ANY REINFORCING SHALL CONFORM TO THE TOLERANCES PRESCRIBED IN THE ASTM SPECIFICATION FOR THAT TYPE OF REINFORCING. STEEL AREA GREATER THAN THAT REQUIRED SHALL NOT BE CAUSE FOR REJECTION.
   5.3. FOUNDATION UNITS
      5.3.1. WALL THICKNESS - THE WALL THICKNESS SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".
      5.3.2. LENGTH/ HEIGHT/WIDTH OF FOUNDATION SECTIONS - THE LENGTH, HEIGHT AND WIDTH OF THE FOUNDATION UNITS SHALL NOT VARY FROM THAT SHOWN IN THE DESIGN BY MORE THAN ½".
      5.3.3. POSITION OF REINFORCEMENT - THE MAXIMUM VARIATION IN THE POSITION OF THE REINFORCEMENT SHALL BE ±½". IN NO CASE SHALL THE COVER OVER THE REINFORCEMENT BE LESS THAN 1½".
      5.3.4. SIZE OF REINFORCEMENT - THE PERMISSIBLE VARIATION IN DIAMETER OF ANY REINFORCING SHALL CONFORM TO THE TOLERANCES PRESCRIBED IN THE ASTM SPECIFICATION FOR THAT TYPE OF REINFORCING. STEEL AREA GREATER THAN THAT REQUIRED SHALL NOT BE CAUSE FOR REJECTION.

6. TESTING/ INSPECTION
   6.1. TESTING
      6.1.1. TYPE OF TEST SPECIMEN - CONCRETE COMPRESSIVE STRENGTH SHALL BE DETERMINED FROM COMPRESSION TESTS MADE ON CYLINDERS OR CORES. FOR CYLINDER TESTING, A MINIMUM OF 4 CYLINDERS SHALL BE TAKEN FOR EACH BRIDGE ELEMENT. FOR CORE TESTING, A MINIMUM OF 2 CORES SHALL BE TAKEN FOR EACH BRIDGE ELEMENT. EACH ELEMENT SHALL BE CONSIDERED SEPARATELY FOR THE PURPOSE OF TESTING AND ACCEPTANCE.
      6.1.2. COMPRESSION TESTING - CYLINDERS SHALL BE MADE AND TESTED AS PRESCRIBED BY THE ASTM C39 SPECIFICATION. CYLINDERS SHALL BE CURED IN THE SAME ENVIRONMENT AS THE BRIDGE ELEMENTS. CORES SHALL BE OBTAINED AND TESTED FOR COMPRESSIVE STRENGTH FROM EACH ELEMENT IN ACCORDANCE WITH THE PROVISIONS OF THE ASTM C42 SPECIFICATION.
      6.1.3. ACCEPTABILITY OF CYLINDER TESTS - WHEN THE AVERAGE COMPRESSIVE STRENGTH OF ALL CYLINDERS TESTED IS EQUAL TO OR GREATER THAN THE DESIGN COMPRESSIVE STRENGTH, AND NOT MORE THAN 10% OF THE CYLINDERS TESTED HAVE A COMPRESSIVE STRENGTH LESS THAN THE DESIGN CONCRETE STRENGTH, AND NO CYLINDER TESTED HAS A COMPRESSIVE STRENGTH LESS THAN 90% OF THE REQUIRED CONCRETE STRENGTH, THEN THE ELEMENT SHALL BE ACCEPTED. WHEN THE COMPRESSIVE STRENGTH OF THE CYLINDERS TESTED DOES NOT CONFORM TO THESE ACCEPTANCE CRITERIA, THE ACCEPTABILITY OF THE ELEMENT MAY BE DETERMINED AS DESCRIBED IN SECTION 6.1.4, BELOW.
      6.1.4. ACCEPTABILITY OF CORE TESTS - THE COMPRESSIVE STRENGTH OF THE CONCRETE IN A BRIDGE ELEMENT IS ACCEPTABLE WHEN EACH CORE TEST STRENGTH IS EQUAL TO OR GREATER THAN THE DESIGN CONCRETE STRENGTH. WHEN THE COMPRESSIVE STRENGTH OF A CORE TESTED IS LESS THAN THE DESIGN CONCRETE STRENGTH, THE PRECAST ELEMENT FROM WHICH THAT CORE WAS TAKEN MAY BE RE-CORED. WHEN THE COMPRESSIVE STRENGTH OF THE RE-CORE IS EQUAL TO OR GREATER THAN THE DESIGN CONCRETE STRENGTH, THE COMPRESSIVE STRENGTH OF THE CONCRETE IN THAT BRIDGE ELEMENT IS ACCEPTABLE.
         6.1.4.1. WHEN THE COMPRESSIVE STRENGTH OF ANY RECORE IS LESS THAN THE DESIGN CONCRETE STRENGTH, THE PRECAST ELEMENT FROM WHICH THAT CORE WAS TAKEN SHALL BE REJECTED.
         6.1.4.2. PLUGGING CORE HOLES - THE CORE HOLES SHALL BE PLUGGED AND SEALED BY THE MANUFACTURER IN A MANNER SUCH THAT THE ELEMENTS WILL MEET ALL OF THE TEST REQUIREMENTS OF THIS SPECIFICATION. PRECAST ELEMENTS SO SEALED SHALL BE CONSIDERED SATISFACTORY FOR USE.
         6.1.4.3. TEST EQUIPMENT - EVERY MANUFACTURER FURNISHING PRECAST ELEMENTS UNDER THIS SPECIFICATION SHALL FURNISH ALL FACILITIES AND PERSONNEL NECESSARY TO CARRY OUT THE TEST REQUIRED.
   6.2. INSPECTION - THE QUALITY OF MATERIALS, THE PROCESS OF MANUFACTURE, AND THE FINISHED PRECAST ELEMENTS SHALL BE SUBJECT TO INSPECTION BY THE PURCHASER.

7. JOINTS
   THE BRIDGE UNITS SHALL BE PRODUCED WITH FLAT BUTT ENDS. THE ENDS OF THE BRIDGE UNITS SHALL BE SUCH THAT WHEN THE SECTIONS ARE LAID TOGETHER THEY WILL MAKE A CONTINUOUS LINE WITH A SMOOTH INTERIOR FREE OF APPRECIABLE IRREGULARITIES, ALL COMPATIBLE WITH THE PERMISSIBLE VARIATIONS IN SECTION 5, ABOVE. THE JOINT WIDTH BETWEEN ADJACENT PRECAST UNITS SHALL NOT EXCEED ¾".

8. WORKMANSHIP/ FINISH
   THE BRIDGE UNITS, WINGWALLS, HEADWALLS AND FOUNDATION UNITS SHALL BE SUBSTANTIALLY FREE OF FRACTURES. THE ENDS OF THE BRIDGE UNITS SHALL BE NORMAL TO THE WALLS AND CENTERLINE OF THE BRIDGE SECTION, WITHIN THE LIMITS OF THE VARIATIONS GIVEN IN SECTION 5, ABOVE, EXCEPT WHERE BEVELED ENDS ARE SPECIFIED. THE FACES OF THE WINGWALLS AND HEADWALLS SHALL BE PARALLEL TO EACH OTHER, WITHIN THE LIMITS OF VARIATIONS GIVEN IN SECTION 5, ABOVE. THE SURFACE OF THE PRECAST ELEMENTS SHALL BE A SMOOTH STEEL FORM OR TROWELED SURFACE. TRAPPED AIR POCKETS CAUSING SURFACE DEFECTS SHALL BE CONSIDERED AS PART OF A SMOOTH, STEEL FORM FINISH.

9. REPAIRS
   PRECAST ELEMENTS MAY BE REPAIRED, IF NECESSARY, BECAUSE OF IMPERFECTIONS IN MANUFACTURE OR HANDLING DAMAGE AND WILL BE ACCEPTABLE IF, IN THE OPINION OF THE PURCHASER, THE REPAIRS ARE SOUND, PROPERLY FINISHED AND CURED, AND THE REPAIRED SECTION CONFORMS TO THE REQUIREMENTS OF THIS SPECIFICATION.

10. REJECTION
   THE PRECAST ELEMENTS SHALL BE SUBJECT TO REJECTION ON ACCOUNT OF ANY OF THE SPECIFICATION REQUIREMENTS. INDIVIDUAL PRECAST ELEMENTS MAY BE REJECTED BECAUSE OF ANY OF THE FOLLOWING:
   10.1. FRACTURES OR CRACKS PASSING THROUGH THE WALL, EXCEPT FOR A SINGLE END CRACK THAT DOES NOT EXCEED ONE HALF THE THICKNESS OF THE WALL.
   10.2. DEFECTS THAT INDICATE PROPORTIONING, MIXING, AND MOLDING NOT IN COMPLIANCE WITH SECTION 4 OF THESE SPECIFICATIONS.
   10.3. HONEYCOMBED OR OPEN TEXTURE.
   10.4. DAMAGED ENDS, WHERE SUCH DAMAGE WOULD PREVENT MAKING A SATISFACTORY JOINT.

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CON/SPAN. O-SERIES

DYOB DRAWING

CON/SPAN O-SERIES SPECIFICATIONS

PROJECT No.:	SEQ. No.:	DATE:
DESIGNED: DYO		DRAWN: DYO
CHECKED: DYO		APPROVED: DYO
SHEET NO.: D6 OF D9		

SPECIFICATIONS FOR MANUFACTURE AND INSTALLATION OF CON/SPAN® O-SERIES BRIDGE SYSTEMS (CONT'D)

11. MARKING
EACH BRIDGE UNIT SHALL BE CLEARLY MARKED BY WATERPROOF PAINT. THE FOLLOWING SHALL BE SHOWN ON THE INSIDE OF THE VERTICAL LEG OF THE BRIDGE SECTION:
BRIDGE SPAN x BRIDGE RISE
DATE OF MANUFACTURE
NAME OR TRADEMARK OF THE MANUFACTURER

12. INSTALLATION PREPARATION
TO ENSURE CORRECT INSTALLATION OF THE PRECAST CONCRETE BRIDGE SYSTEM, CARE AND CAUTION MUST BE EXERCISED IN FORMING THE SUPPORT AREAS FOR BRIDGE UNITS, HEADWALL, AND WINGWALL ELEMENTS. EXERCISING SPECIAL CARE WILL FACILITATE THE RAPID INSTALLATION OF THE PRECAST COMPONENTS.

12.1. FOOTINGS
DO NOT OVER EXCAVATE FOUNDATIONS UNLESS DIRECTED BY SITE SOIL ENGINEER TO REMOVE UNSUITABLE SOIL.

THE SITE SOILS ENGINEER SHALL CERTIFY THAT THE BEARING CAPACITY MEETS OR EXCEEDS THE FOOTING DESIGN REQUIREMENTS, PRIOR TO THE CONTRACTOR POURING OF THE FOOTINGS.

THE BRIDGE UNITS AND WINGWALLS SHALL BE INSTALLED ON EITHER PRECAST OR CAST-IN-PLACE CONCRETE FOOTINGS. THE SIZE AND ELEVATION OF THE FOOTINGS SHALL BE AS DESIGNED BY THE ENGINEER. A KEYWAY SHALL BE FORMED IN THE TOP SURFACE OF THE BRIDGE FOOTING AS SPECIFIED ON THE PLANS. NO KEYWAY IS REQUIRED IN THE WINGWALL FOOTINGS, UNLESS OTHERWISE SPECIFIED ON THE PLANS.

THE FOOTINGS SHALL BE GIVEN A SMOOTH FLOAT FINISH AND SHALL REACH A COMPRESSIVE STRENGTH OF 2,000 PSI BEFORE PLACEMENT OF THE BRIDGE AND WINGWALL ELEMENTS. BACKFILLING SHALL NOT BEGIN UNTIL THE FOOTING HAS REACHED THE FULL DESIGN COMPRESSIVE STRENGTH.

THE FOOTING SURFACE SHALL BE CONSTRUCTED IN ACCORDANCE WITH GRADES SHOWN ON THE PLANS. WHEN TESTED WITH A 10'-0" STRAIGHT EDGE, THE SURFACE SHALL NOT VARY MORE THAN 1/4" IN 10'-0".

IF A PRECAST CONCRETE FOOTING IS USED, THE CONTRACTOR SHALL PREPARE A 4" THICK BASE LAYER OF COMPACTED GRANULAR MATERIAL THE FULL WIDTH OF THE FOOTING PRIOR TO PLACING THE PRECAST FOOTING.

THE FOUNDATIONS FOR PRECAST CONCRETE BRIDGE ELEMENTS AND WINGWALLS MUST BE CONNECTED BY REINFORCEMENT TO FORM ONE MONOLITHIC BODY. EXPANSION JOINTS SHALL NOT BE USED.

THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE CONSTRUCTION OF THE FOUNDATIONS PER THE PLANS AND SPECIFICATIONS.

13. INSTALLATION
13.1. GENERAL - THE INSTALLATION OF THE PRECAST CONCRETE ELEMENTS SHALL BE AS EXPLAINED IN THE PUBLICATION CON/SPAN BRIDGE SYSTEMS INSTALLATION HANDBOOK.
13.1.1. LIFTING - IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO ENSURE THAT A CRANE OF THE CORRECT LIFTING CAPACITY IS AVAILABLE TO HANDLE THE PRECAST CONCRETE UNITS. THIS CAN BE ACCOMPLISHED BY USING THE WEIGHTS GIVEN FOR THE PRECAST CONCRETE COMPONENTS AND BY DETERMINING THE LIFTING REACH FOR EACH CRANE UNIT. SITE CONDITIONS MUST BE CHECKED WELL IN ADVANCE OF SHIPPING TO ENSURE PROPER CRANE LOCATION AND TO AVOID ANY LIFTING RESTRICTIONS. THE LIFT ANCHORS OR HOLES PROVIDED IN EACH UNIT ARE THE ONLY MEANS TO BE USED TO LIFT THE ELEMENTS. THE PRECAST CONCRETE ELEMENTS MUST NOT BE SUPPORTED OR RAISED BY OTHER MEANS THAN THOSE GIVEN IN THE MANUALS AND DRAWINGS WITHOUT WRITTEN APPROVAL FROM CONTECH® ENGINEERED SOLUTIONS.
13.1.2. CONSTRUCTION EQUIPMENT WEIGHT RESTRICTIONS - IN NO CASE SHALL EQUIPMENT OPERATING IN EXCESS OF THE DESIGN LOAD (HL-93) BE PERMITTED OVER THE BRIDGE UNITS UNLESS APPROVED BY CONTECH® ENGINEERED SOLUTIONS.
13.1.2.1. IN THE IMMEDIATE AREA OF THE BRIDGE UNITS, THE FOLLOWING RESTRICTIONS FOR THE USE OF HEAVY CONSTRUCTION MACHINERY DURING BACKFILLING OPERATIONS APPLY:
- NO CONSTRUCTION EQUIPMENT SHALL CROSS THE BARE PRECAST CONCRETE BRIDGE UNIT.
- AFTER THE COMPACTED FILL LEVEL HAS REACHED A MINIMUM OF 4" OVER THE CROWN OF THE BRIDGE, CONSTRUCTION EQUIPMENT WITH A WEIGHT OF LESS THAN 10 TONS MAY CROSS THE BRIDGE.
- AFTER THE COMPACTED FILL LEVEL HAS REACHED A MINIMUM OF 1'-0" OVER THE CROWN OF THE BRIDGE, CONSTRUCTION EQUIPMENT WITH A WEIGHT OF LESS THAN 30 TONS MAY CROSS THE BRIDGE.
- AFTER THE COMPACTED FILL LEVEL HAS REACHED THE DESIGN COVER, OR 2'-0" MINIMUM, OVER THE CROWN OF THE PRECAST CONCRETE BRIDGE, CONSTRUCTION EQUIPMENT WITHIN THE DESIGN LOAD LIMITS FOR THE ROAD MAY CROSS THE PRECAST CONCRETE BRIDGE.

13.2. LEVELING PAD/SHIMS - THE BRIDGE UNITS AND WINGWALLS SHALL BE SET ON HARDBOARD SHIMS CONFORMING TO ASTM D1037 OR PLASTIC SHIMS (DAYTON SUPERIOR P-80, P-81 OR APPROVED EQUAL) MEASURING 5" x 5", MINIMUM, UNLESS SHOWN OTHERWISE ON THE PLANS. A MINIMUM GAP OF 1/2" SHALL BE PROVIDED BETWEEN THE FOOTING AND THE BOTTOM OF THE BRIDGE'S VERTICAL LEGS OR THE BOTTOM OF THE WINGWALL. ALSO, A SUPPLY OF 1/4", 1/2" AND 1/8" THICK HARDBOARD OR PLASTIC SHIMS FOR VARIOUS SHIMMING PURPOSES SHALL BE ON SITE.
13.3. PLACEMENT OF BRIDGE UNITS - THE BRIDGE UNITS SHALL BE PLACED AS SHOWN ON THE ENGINEER'S PLAN DRAWINGS. SPECIAL CARE SHALL BE TAKEN IN SETTING THE ELEMENTS TO THE TRUE LINE AND GRADE. THE JOINT WIDTH BETWEEN ADJACENT PRECAST UNITS SHALL NOT EXCEED 3/4".

13.4. IT IS THE CONTRACTOR'S RESPONSIBILITY TO MAINTAIN THE STRUCTURE SPAN DURING ALL PHASES OF INSTALLATION. DUE TO THE ARCH SHAPE, BRIDGE ELEMENTS WILL TEND TO SPREAD UNDER SELF-WEIGHT. IT IS IMPERATIVE THAT ANY LATERAL SPREADING OF THE BRIDGE ELEMENTS BE AVOIDED DURING AND AFTER THEIR PLACEMENT. GENERALLY, HORIZONTAL CABLE TIES OR TIE RODS ARE SHIPPED IN THE LARGER BRIDGE ELEMENTS TO ASSIST IN PREVENTING THIS SPREADING. CABLE TIES/TIE RODS SHALL NOT BE REMOVED UNTILL BRIDGE UNITS ARE GROUTED AND GROUT HAS CURED. IT IS RECOMMENDED THAT TEMPORARY HARDWOOD BLOCKS BE USED IN CONJUNCTION WITH THE CABLE TIES/TIE RODS TO MAINTAIN SPAN. IF, HOWEVER, DUE TO SITE RESTRICTIONS, THESE CABLE TIES/TIE RODS MUST BE REMOVED PRIOR TO PLACEMENT OF THE BRIDGE ELEMANTS, THE CONTRACTOR MUST NOTIFY CONTECH (MANUFACTURER) AND REQUEST A SUGGESTED INSTALLATION PROCEDURE.

IN ADDITION, IF THE CABLE TIES/TIE RODS MUST BE REMOVED PRIOR TO SETTING ARCH UNITS, THE FOLLOWING QUALITY CONTROL PROCEDURE MUST BE FOLLOWED:
1) FIND "MEASURED SPAN" UPON ARCH UNIT'S DELIVERY TO SITE, PRIOR TO LIFTING FROM TRUCK AND REMOVING CABLE TIES/TIE RODS. "MEASURED SPAN" SHALL BE THE AVERAGE OF (3) SPAN MEASUREMENTS ALONG THE LAY LENGTH OF THE ARCH UNIT.
2) AFTER SETTING OF BRIDGE UNIT ON THE FOUNDATION, VERIFY THE SPAN. THIS "INSTALLED SPAN MEASUREMENT" SHALL NOT EXCEED THE MAXIMUM OF:
A) THE NOMINAL SPAN +1/2" OR
B) THE "MEASURED SPAN"
IF THE "INSTALLED SPAN MEASUREMENT" EXCEEDS THIS AMOUNT, THE ARCH UNIT SHALL BE LIFTED AND RE-SET UNTIL THE "INSTALLED SPAN MEASUREMENT" MEETS THE LIMITS.

13.5. PLACEMENT OF WINGWALLS, HEADWALLS AND FOUNDATION UNITS - THE WINGWALLS, HEADWALLS AND FOUNDATIONS SHALL BE PLACED AS SHOWN ON THE PLAN DRAWINGS. SPECIAL CARE SHALL BE TAKEN IN SETTING THE ELEMENTS TO THE TRUE LINE AND GRADE.
13.6. JOINT PROTECTION AND SUBSURFACE DRAINAGE
13.6.1. EXTERNAL PROTECTION OF JOINTS - THE BUTT JOINT MADE BY TWO ADJOINING BRIDGE UNITS SHALL BE COVERED WITH A 7/8" x 1 3/8" PREFORMED BITUMINOUS JOINT SEALANT AND A MINIMUM OF A 9" WIDE JOINT WRAP. THE SURFACE SHALL BE FREE OF DIRT BEFORE APPLYING THE JOINT MATERIAL. A PRIMER COMPATIBLE WITH THE JOINT WRAP TO BE USED SHALL BE APPLIED FOR A MINIMUM WIDTH OF 9" ON EACH SIDE OF THE JOINT. THE EXTERNAL WRAP SHALL BE CS212 BY CONCRETE SEALANTS INC., EZ-WRAP RUBBER BY PRESS-SEAL GASKET CORPORATION, SEAL WRAP BY MAR MAC MANUFACTURING CO. INC. OR APPROVED EQUAL. THE JOINT SHALL BE COVERED CONTINUOUSLY FROM THE BOTTOM OF ONE BRIDGE SECTION LEG, ACROSS THE TOP OF THE BRIDGE AND TO THE OPPOSITE BRIDGE SECTION LEG. ANY LAPS THAT RESULT IN THE JOINT WRAP SHALL BE A MINIMUM OF 6" LONG WITH THE OVERLAP RUNNING DOWNHILL.
13.6.2. IN ADDITION TO THE JOINTS BETWEEN BRIDGE UNITS, THE JOINT BETWEEN THE END BRIDGE UNIT AND THE HEADWALL SHALL ALSO BE SEALED AS DESCRIBED ABOVE. IF PRECAST WINGWALLS ARE USED, THE JOINT BETWEEN THE END BRIDGE UNIT AND THE WINGWALL SHALL BE SEALED WITH A 2'-0" STRIP OF FILTER FABRIC. ALSO, IF LIFT HOLES ARE FORMED IN THE BRIDGE UNITS, THEY SHALL BE PRIMED AND COVERED WITH A 9" x 9" SQUARE OF JOINT WRAP.
13.6.3. DURING THE BACKFILLING OPERATION, CARE SHALL BE TAKEN TO KEEP THE JOINT WRAP IN ITS PROPER LOCATION OVER THE JOINT.
13.6.4. SUBSOIL DRAINAGE SHALL BE AS DIRECTED BY THE ENGINEER.

13.7. GROUTING
13.7.1. GROUTING SHALL NOT BE PERFORMED WHEN TEMPERATURES ARE EXPECTED TO GO BELOW 35° FOR A PERIOD OF 72 HOURS. GROUTING SHOULD BE COMPLETED AS SOON AS PRACTICAL AFTER PRECAST ARCHES HAVE BEEN INSTALLED. FILL THE BRIDGE-FOUNDATION KEYWAY WITH CEMENT GROUT (PORTLAND CEMENT AND WATER OR CEMENT MORTAR COMPOSED OF PORTLAND CEMENT, SAND AND WATER) WITH A MINIMUM 28-DAY COMPRESSIVE STRENGTH OF 3000 PSI. VIBRATE AS REQUIRED TO ENSURE THAT THE ENTIRE KEY AROUND THE BRIDGE ELEMENT IS COMPLETELY FILLED. IF BRIDGE ELEMENTS HAVE BEEN SET WITH TEMPORARY TIES (CABLES, BARS, ETC.) GROUT MUST ATTAIN A MINIMUM COMPRESSIVE STRENGTH OF 1500 PSI BEFORE TIES MAY BE REMOVED.
13.7.2. ALL GROUT SHALL HAVE A MAXIMUM AGGREGATE SIZE OF 1/4".
13.7.3. LIFTING AND ERECTION ANCHOR RECESSES SHALL BE FILLED WITH GROUT.
13.7.4. AFTER GROUT HAS REACHED ITS DESIGN STRENGTH THE TEMPORARY HARDWOOD WEDGES SHALL BE REMOVED AND THEIR HOLES FILLED WITH GROUT.
13.8. BACKFILL
13.8.1. DO NOT PERFORM BACKFILLING DURING WET OR FREEZING WEATHER.
13.8.2. NO BACKFILL SHALL BE PLACED AGAINST ANY STRUCTURAL ELEMENTS UNTIL THEY HAVE BEEN APPROVED BY THE ENGINEER.
13.8.3. BACKFILL SHALL BE CONSIDERED AS ALL REPLACED EXCAVATION AND NEW EMBANKMENT ADJACENT TO THE PRECAST CONCRETE ELEMENTS. THE PROJECT CONSTRUCTION AND MATERIAL SPECIFICATIONS, WHICH INCLUDE THE SPECIFICATIONS FOR EXCAVATION FOR STRUCTURES AND ROADWAY EXCAVATION AND EMBANKMENT CONSTRUCTION, SHALL APPLY EXCEPT AS MODIFIED IN THIS SECTION.
13.8.4. BACKFILL ZONES:
- IN-SITU SOIL
- ZONE A: CONSTRUCTED EMBANKMENT OR OVERFILL.
- ZONE B: FILL THAT IS DIRECTLY ASSOCIATED WITH PRECAST CONCRETE BRIDGE INSTALLATION.
- ZONE C: ROAD STRUCTURE.

13.8.5. REQUIRED BACKFILL PROPERTIES
13.8.5.1. IN-SITU SOIL - NATURAL GROUND IS TO BE SUFFICIENTLY STABLE TO ALLOW EFFECTIVE SUPPORT TO THE PRECAST CONCRETE BRIDGE UNITS. AS A GUIDE, THE EXISTING NATURAL GROUND SHOULD BE OF SIMILAR QUALITY AND DENSITY TO ZONE B MATERIAL FOR MINIMUM LATERAL DIMENSION OF ONE BRIDGE SPAN OUTSIDE OF THE BRIDGE FOOTING.
13.8.5.2. ZONE A - ZONE A REQUIRES FILL MATERIAL WITH SPECIFICATIONS AND COMPACTING PROCEDURES EQUAL TO THAT FOR NORMAL ROAD EMBANKMENTS.
13.8.5.3. ZONE B - GENERALLY, SOILS SHALL BE REASONABLY FREE OF ORGANIC MATTER, AND, NEAR CONCRETE SURFACES, FREE OF STONES LARGER THAN 3" IN DIAMETER SEE CHARTS FOR DETAILED DESCRIPTIONS OF ACCEPTABLE SOILS.
13.8.5.4. ZONE C - ZONE C IS THE ROAD SECTION OF GRAVEL, ASPHALT OR CONCRETE BUILT IN COMPLIANCE WITH LOCAL ENGINEERING PRACTICES.
13.8.5.5. GEOTECHNICAL ENGINEER SHALL REVIEW GRADATIONS OF ALL INTERFACING MATERIALS AND, IF NECESSARY, RECOMMEND GEOTEXTILE FILTER FABRIC (PROVIDED BY CONTRACTOR)

13.8.6. PLACING AND COMPACTING BACKFILL
DUMPING FOR BACKFILLING IS NOT ALLOWED ANY NEARER THAN 3'-0" FROM THE BRIDGE LEG.

THE FILL MUST BE PLACED AND COMPACTED IN LAYERS NOT EXCEEDING 8". THE MAXIMUM DIFFERENCE IN THE SURFACE LEVELS OF THE FILL ON OPPOSITE SIDES OF THE BRIDGE MUST NOT EXCEED 2'-0".

THE FILL BEHIND WINGWALLS MUST BE PLACED AT THE SAME TIME AS THAT OF THE BRIDGE FILL. IT MUST BE PLACED IN PROGRESSIVELY PLACED HORIZONTAL LAYERS NOT EXCEEDING 8" PER LAYER.

THE BACKFILL OF ZONE B SHALL BE COMPACTED TO A MINIMUM DENSITY OF 95% OF THE STANDARD PROCTOR, AS REQUIRED BY AASHTO T-99.

SOIL WITHIN 1'-0" OF CONCRETE SURFACES SHALL BE HAND-COMPACTED. ELSEWHERE, USE OF ROLLERS IS ACCEPTABLE. IF VIBRATING ROLLER-COMPACTORS ARE USED, THEY SHALL NOT BE STARTED OR STOPPED WITHIN ZONE B AND THE VIBRATION FREQUENCY SHOULD BE AT LEAST 30 REVOLUTIONS PER SECOND.

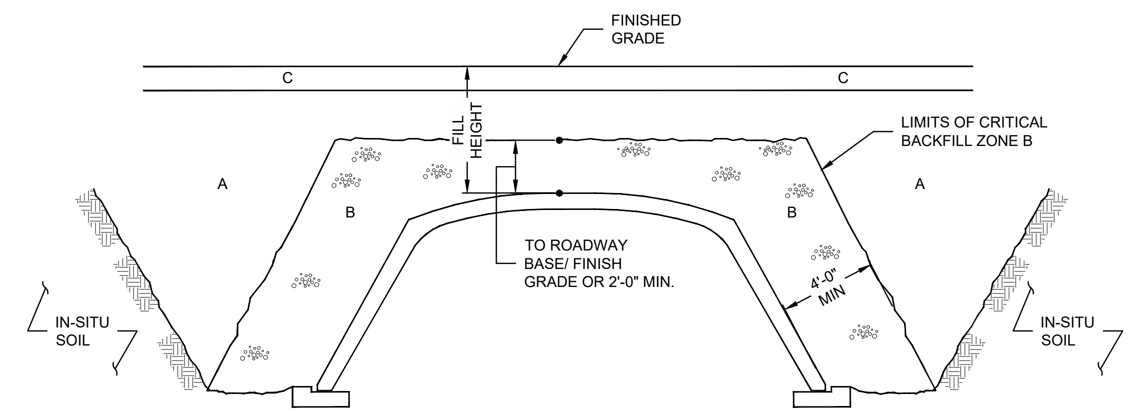
THE BACKFILL MATERIAL AND COMPACTING BEHIND WINGWALLS SHALL SATISFY THE CRITERIA FOR THE BRIDGE BACKFILL, ZONE B.

BACKFILL AGAINST A WATERPROOFED SURFACE SHALL BE PLACED CAREFULLY TO AVOID DAMAGE TO THE WATERPROOFING MATERIAL.
13.8.7. BRIDGE UNITS
FOR FILL HEIGHTS OVER 12 FEET (AS MEASURED FROM TOP CROWN OF BRIDGE TO FINISHED GRADE), NO BACKFILLING MAY BEGIN UNTIL A BACKFILL COMPACTION TESTING PLAN HAS BEEN COORDINATED WITH AND APPROVED BY CONTECH® ENGINEERED SOLUTIONS.
13.8.8. WINGWALLS
BACKFILL IN FRONT OF WINGWALLS SHALL BE CARRIED TO GROUND LINES SHOWN IN THE PLANS.
13.8.9. MONITORING
THE CONTRACTOR SHALL CHECK SETTLEMENTS AND HORIZONTAL DISPLACEMENT OF FOUNDATION TO ENSURE THAT THEY ARE WITHIN THE ALLOWABLE LIMIT PROVIDED BY THE ENGINEER. THESE MEASUREMENTS SHOULD GIVE AN INDICATION OF THE SETTLEMENTS AND DEFORMATIONS ALONG THE LENGTH OF THE FOUNDATIONS.

THE FIRST MEASUREMENT SHOULD TAKE PLACE AFTER THE ERECTION OF ALL PRECAST BRIDGE SYSTEM ELEMENTS, A SECOND AFTER COMPLETION OF BACKFILLING, AND A THIRD BEFORE OPENING OF THE BRIDGE TO TRAFFIC. FURTHER MEASUREMENTS MAY BE MADE ACCORDING TO LOCAL CONDITIONS.

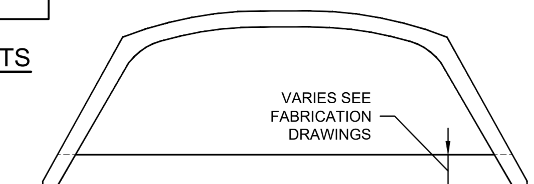
ACCEPTABLE SOILS FOR USE IN ZONE B BACKFILL

TYPICAL USCS MATERIALS	AASHTO GROUP	AASHTO SUBGROUP	PERCENT PASSING US SIEVE NO.			CHARACTER OF FRACTION PASSING NO. 40 SIEVE		SOIL DESRIPTION
			#10	#40	#200	LIQUID LIMIT	PLASTICITY INDEX	
GW, GP, SP	A1	A-1a	50 MAX	30 MAX	15 MAX		6 MAX	LARGELY GRAVEL BUT CAN INCLUDE SAND AND FINES
GM, SW, SP, SM	A1	A-1b		50 MAX	25 MAX		6 MAX	GRAVELLY SAND OR GRADED SAND, MAY INCLUDE FINES
GM, SM, ML, SP, GP	A2	A-2-4			35 MAX	40 MAX	10 MAX	SANDS, GRAVELS WITH LOW-PLASTICITY SILT FINES
SC, GC, GM	A2	A-2-5			35 MAX	41 MIN	10 MAX	SANDS, GRAVELS WITH PLASTIC SILT FINES
SP, SM, SW	A3			51 MIN	10 MAX		NON-PLASTIC	FINE SANDS
ML, SM, SC	A4				36 MIN	40 MAX	10 MAX	LOW-COMPRESSIBILTY SILTS

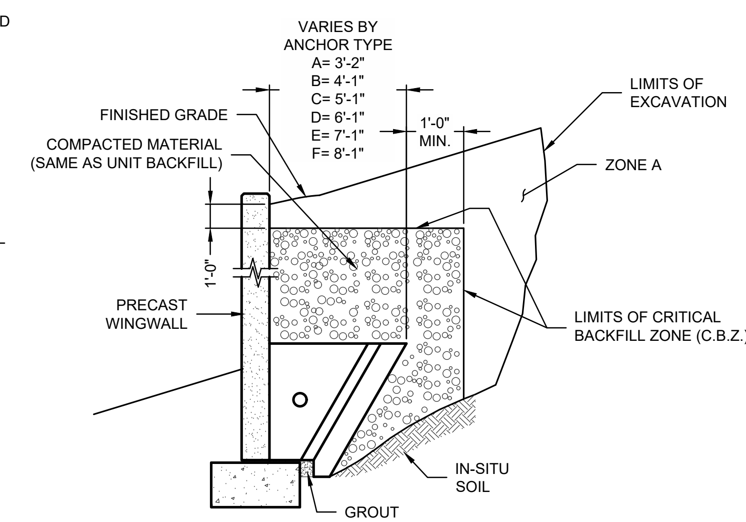


SPAN	FILL HEIGHT	ACCEPTABLE MATERIAL INSIDE ZONE B
≤ 24'-0"	≥ 12'-0"	A1, A3
≤ 24'-0"	< 12'-0"	A1, A2, A3, A4
> 24'-0"	ALL	A1, A3

BACKFILL REQUIREMENTS



TIE RODS



WALL BACKFILL REQUIREMENTS

MARK	DATE	REVISION DESCRIPTION	BY

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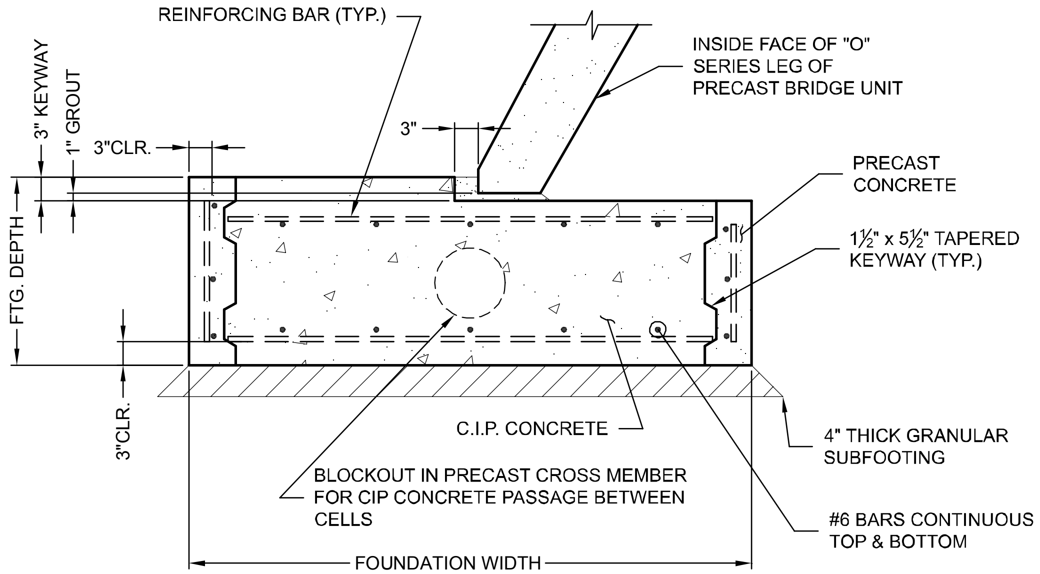
CON/SPAN. O-SERIES

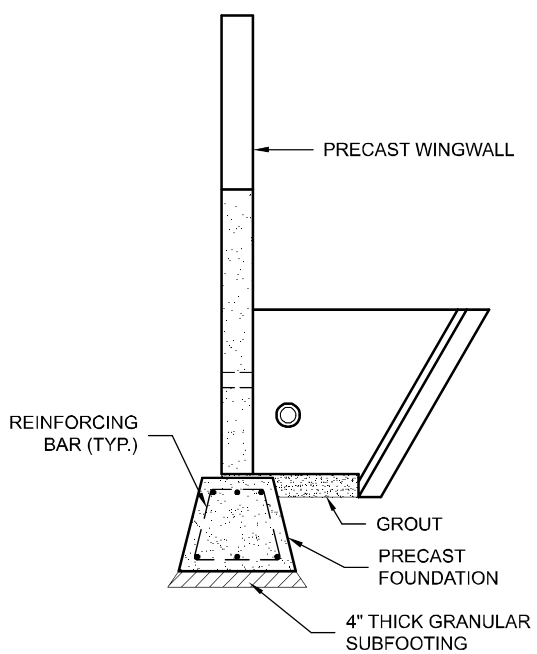
DYOB
DRAWING

CON/SPAN O-SERIES
SPECIFICATIONS

PROJECT No.:	SEQ. No.:	DATE:
DESIGNED: DYO		DRAWN: DYO
CHECKED: DYO		APPROVED: DYO
SHEET NO.: D7 OF D9		



SECTION (A)
(NOT PROJECT SPECIFIC)



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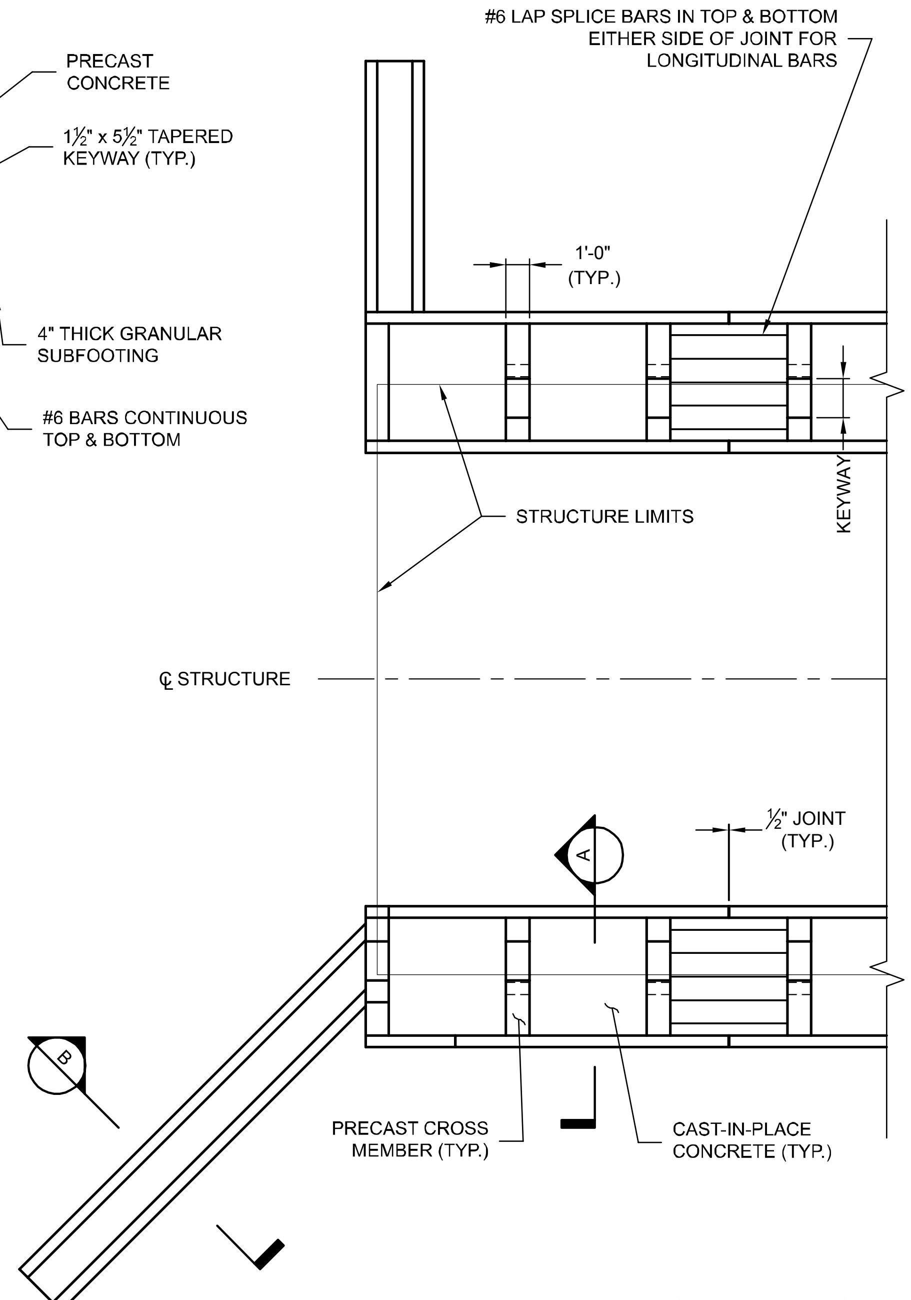

SAMPLE PARTIAL FOUNDATION PLAN
(NOT PROJECT SPECIFIC)

EXPRESS FOUNDATIONS

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DYOB DRAWING

CON/SPAN O-SERIES EXPRESS FOUNDATION SAMPLES

PROJECT No.:	DATE:
DESIGNED: DYO	DRAWN: DYO
CHECKED: DYO	APPROVED: DYO
SHEET NO.: D8 OF D9	

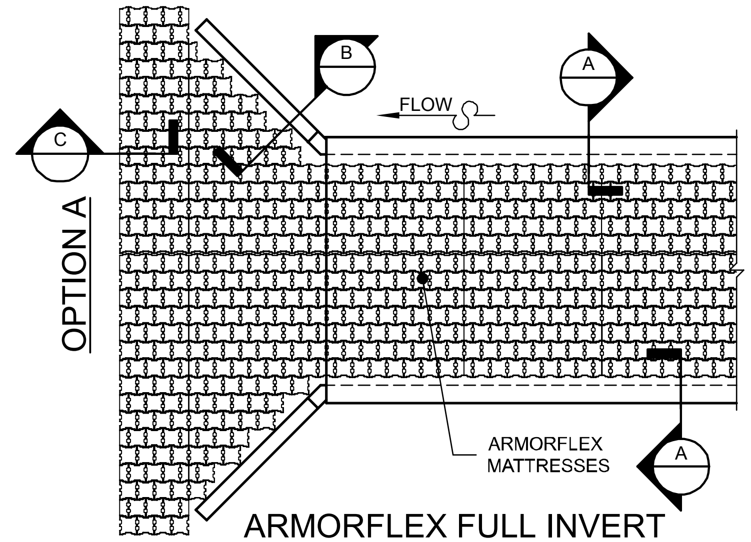
SAMPLE DRAWING ONLY

CONSIDER A COMPLETE SYSTEM WITH ARMORTEC REVETMENT

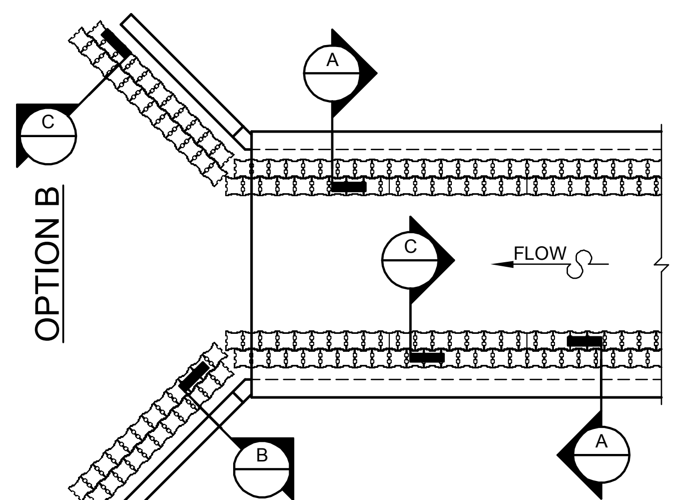
ARMORFLEX FULL INVERT - CLOSED CELL
N.T.S.

ARMORFLEX PARTIAL INVERT
N.T.S.

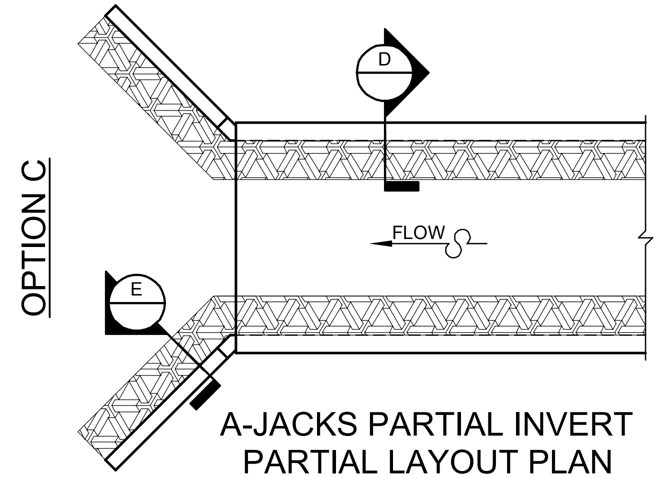
A-JACKS PARTIAL INVERT
N.T.S.



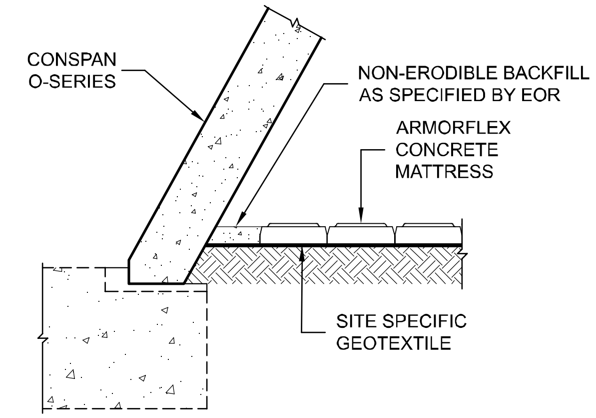
ARMORFLEX FULL INVERT PARTIAL LAYOUT PLAN
N.T.S.



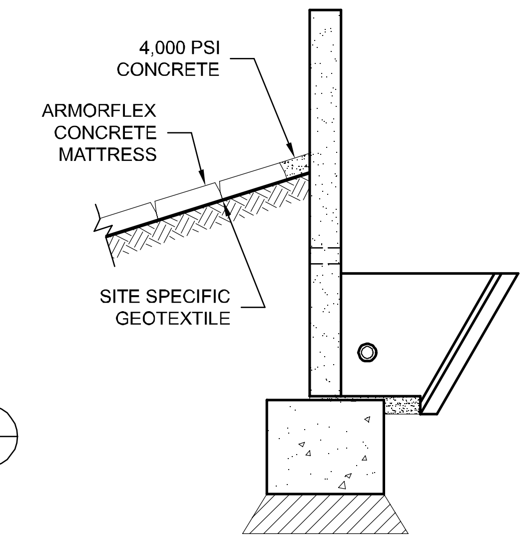
ARMORFLEX PARTIAL INVERT PARTIAL LAYOUT PLAN
N.T.S.



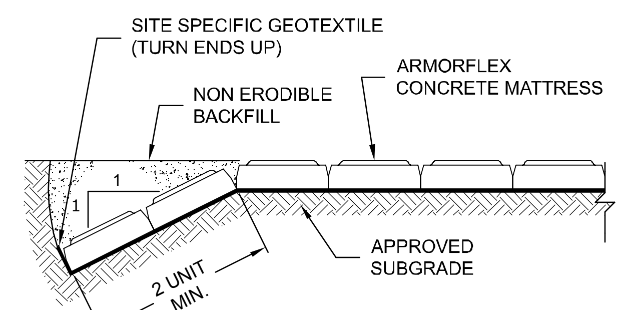
A-JACKS PARTIAL INVERT PARTIAL LAYOUT PLAN
N.T.S.



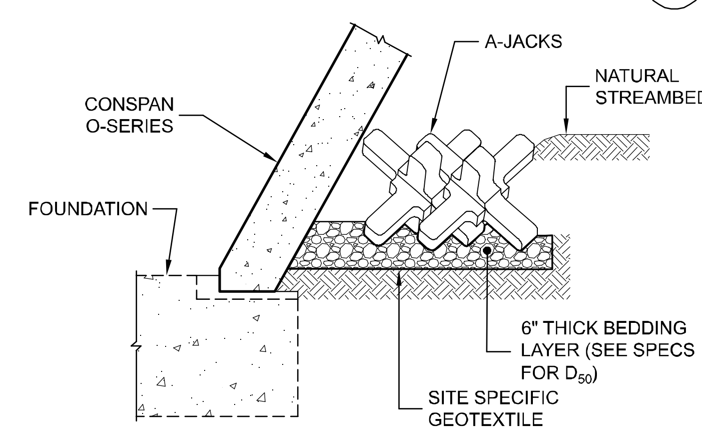
ARMORFLEX STRUCTURE TERMINATION (A)
N.T.S.



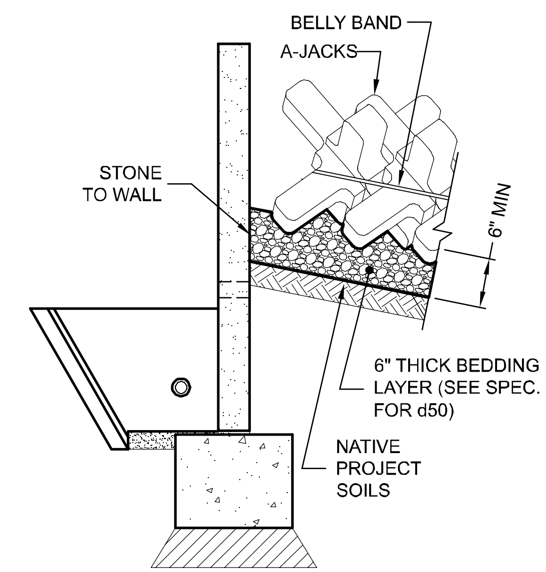
ARMORFLEX WINGWALL TERMINATION (B)
N.T.S.



STANDARD TERMINATION (C)
N.T.S.



A-JACKS STRUCTURE TERMINATION (D)
N.T.S.



A-JACKS WINGWALL TERMINATION (E)
N.T.S.

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DYOB
DRAWING

CON/SPAN O-SERIES
ARMORTEC EXAMPLES

PROJECT No.:	DATE:
DESIGNED: DYO	DRAWN: DYO
CHECKED: DYO	APPROVED: DYO
SHEET NO.: D9 OF D9	

Appendix E: Calculations for MSE Wall

MSE Wall Design:

Performance Criteria:

External stability:

Eccentricity: Within middle 1/3

Sliding: $FS_{sliding} \geq 1.5$

Bearing Capacity: $FS_{bearing} \geq 2.5$

Global Failure: $FS_{global} \geq 1.3$

Seismic stability: $FS_{seismic} \geq 75\%\ static$

Internal stability:

Reinforcement pullout: $FS_{pull} \geq 1.5$

Reinforcement rupture: $FS_{rupture.strips} \geq 0.55 \cdot F_y$

$FS_{rupture.grids} \geq 0.48 \cdot F_y$

$FS_{rupture.geosynthetics} \geq T_{all}$

Settlement: Varied dependent on project

Project Information:

Retained Height:

$H := 16.67\ ft$

Soil Density:

$\gamma := 97.39\ pcf$

Soil Friction Coefficient:

$\phi := 30\ deg$

Traffic Surcharge:

$S := 250\ psf$

Preliminary Sizing:

Embedment:

For horizontal walls minimum top of leveling pad (see FHWA NHI-00-043 pp.38):

$$D_{embed} := \frac{H}{20} = 0.834\ ft$$

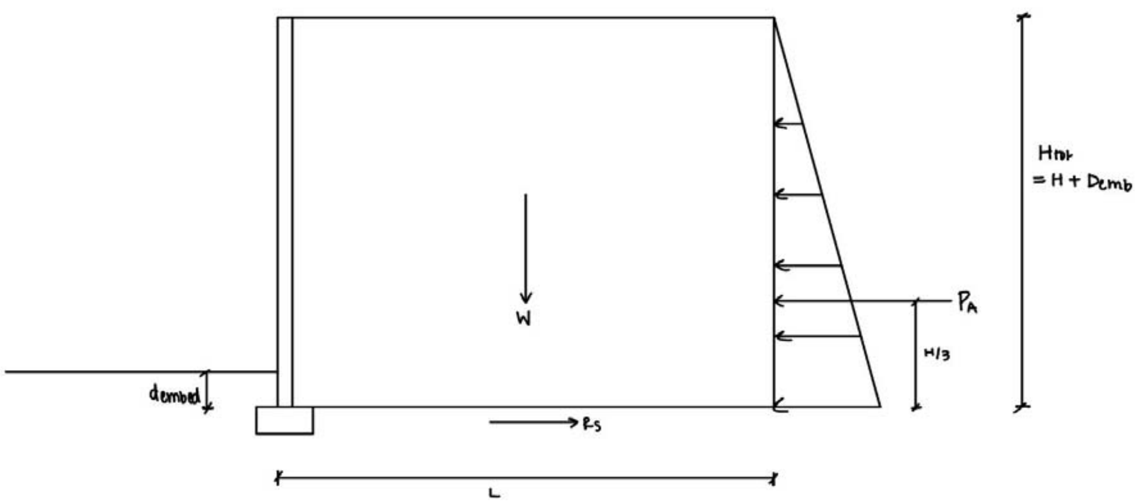
$$h_{tot} := H + D_{embed} = 17.504\ ft$$

Reinforcement length:

$$L_{min} := \max\left(0.7 \cdot h_{tot}, 8\ ft\right) = 12.252\ ft$$

Note: For walls with significant surcharge loads, increase to 0.8H to 1.1H.

$$L := 13\ ft$$



Earth pressure:

Taken at the back of the reinforced soil

Rankine's earth pressure:

Active pressure:

$$K_A := \left(\tan\left(45\ deg - \frac{\phi}{2}\right)\right)^2 = 0.333$$

$$P_A := \frac{1}{2} \cdot K_A \cdot \gamma \cdot H^2 = 4.511\ \frac{kip}{ft}$$

Resultant force for earth pressure

Passive pressure:

$$K_P := \left(\tan\left(45\ deg + \frac{\phi}{2}\right)\right)^2 = 3$$

Surcharge pressure:

$$S := 250\ psf$$

$$h_{surcharge} := \frac{S}{\gamma} = 2.567\ ft$$

Using the typical surcharge for highway traffic, assume an additional height of 2.6 feet for the lateral earth pressure.

Earth pressure with surcharge:

$$H_{tot} := h_{tot} + h_{surcharge} = 20.07\ ft$$

$$P_A := \frac{1}{2} \cdot K_A \cdot \gamma \cdot {H_{tot}}^2 = 6.539\ \frac{kip}{ft}$$

External Stability:

Check sliding, overturning, bearing capacity, global failure, and settlement.

Sliding:

Disturbing force:

$$P_A = 6.539\ \frac{kip}{ft}$$

Resisting force:

$$A_{active} := H_{tot} \cdot L$$

$$W_{active} := \gamma \cdot A_{active} = 25.411\ \frac{kip}{ft}$$

$$P_{friction} := W_{active} \cdot \tan(\phi) = 14.671\ \frac{kip}{ft}$$

Actual Factor of Safety:

$$FS_{sliding} := \frac{P_{friction}}{P_A} = 2.244$$

$$FS_{sliding} \geq 1.5$$

Overturning Moment:

The disturbing moment is generated by the active pressure active at 1/3*H. The resisting moment is generated by the weight of the active soil at half of the reinforcement length.

Disturbing moment:

$$M_{disturb} := P_A \cdot \left(\frac{1}{3} \cdot H_{tot}\right) = 43.744\ \frac{kip \cdot ft}{ft}$$

Resisting moment:

$$M_{resisting} := W_{active} \cdot \left(\frac{1}{2} \cdot L\right) = 165.169\ \frac{kip \cdot ft}{ft}$$

Actual Factor of Safety:

$$FS_{overturning} := \frac{M_{resisting}}{M_{disturb}} = 3.776$$

$$FS_{overturning} \geq 1.5$$

Seismic Design:

Earthquake induced forces behind wall: P_{AE} (50% at 0.6*H))

Inertial acceleration of reinforced soil within wall: P_{IR} (Zone with length 0.5*H)

Design maximum acceleration, Am:

$A_m = (1.45 - A)\ A$ A = AASHTO site accel. coeff.

Horizontal ground surface:

$P_{IR} = 0.5 \cdot A_m \cdot \gamma \cdot H^2$

$P_{AE} = 0.375 \cdot A_m \cdot \gamma \cdot H^2$ (Only use 50% of P_{AE})

Add in seismic forces to static forces and recheck sliding, overturning, and bearing are all greater than 75% of the static factor of safety.

The Seismic Design is not within the scope of this project.

Internal Stability:

Select reinforcement system:

Start by assuming an **steel reinforcing strip**. Cross-section dimensions:

$w_{strip} := 2\ in$

$h_{strip} := 0.156\ in$

GALVANIZED GRADE 65 - ASTM A1011 $F_y := 65\ ksi$

Determine critical failure surface (for Rupture):

Depends on the function of relative stiffness of reinforcement and the soil & if the MSE system is inextensible (metallic) or extensible (geosynthetic).

For extensible reinforcement, use Coulomb failure surface: $45 + \frac{\phi}{2}$

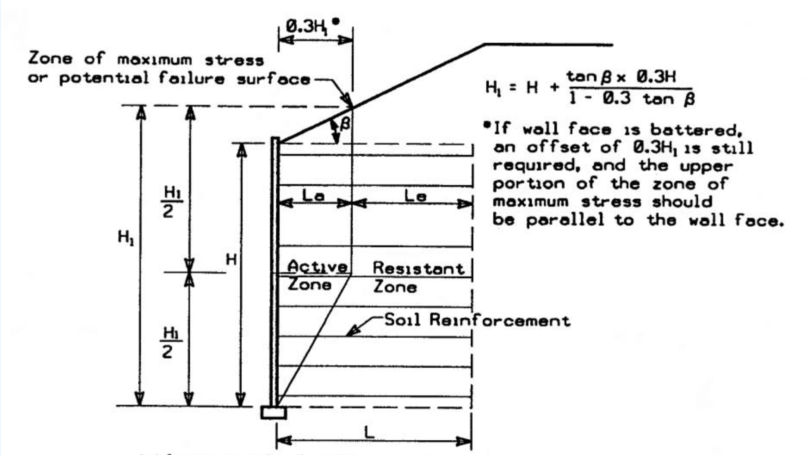
For inextensible reinforcement, use bilinear failure surface based on empirical testing (see FHWA NHI-00-043 Figure 28, pp.106):

For half of the height of the wall (from base to H/2):

Slope: Follows close to coulomb failure surface

For upper half of the height of the wall (from base to H/2):

Vertical rupture at $0.3 \cdot H_1$



(a) Inextensible Reinforcements

$\beta := 0$

$$H_1 := H_{tot} + \frac{\tan(\beta) \cdot 0.3 \cdot H_{tot}}{1 - 0.3 \cdot \tan(\beta)} = 20.07\ ft$$

$W_{failure} := 0.3 \cdot H_1 = 6.021\ ft$ The distance to the vertical failure.

$H_{slope} := \frac{H_1}{2} = 10.035\ ft$ The height from the bottom of the MSE wall to the location where the failure surface is vertical.

Computing horizontal reinforcement stress:

$\sigma_x = K_r \cdot \sigma_z$

K_r is reinforcement earth pressure coefficient

For extensible reinforcement:

Determine from figure with slope if less than 6m tall. At least 20% higher than active earth pressure.

For metal strips:

$K_{r.max} = 1.7 \cdot \sigma_z$

$K_{r.min} = 1.2 \cdot \sigma_z$

Select preliminary spacing (typically controlled by system):

For simplicity sake: Use 2 foot spacing vertically uniformly. Spaced at 2 feet horizontally.

$S_v := 2\ ft$

$S_h := 2\ ft$

Calculate the maximum tensile force at each reinforcement level:

Using tributary area:

For sheets:

$T_{max} = \sigma_x \cdot S_v$

For strips or grids:

$$T_{max} = \frac{\sigma_x \cdot S_v}{R_e}$$

$T_{max} < T_{all}$

Determine reinforcement coverage ratio (strips do not cover the entire area of soil):

$A_c := h_{strip} \cdot w_{strip} = 0.312\ in^2$

$$R_e := \frac{w_{strip}}{S_h} = 0.083$$

Calculate the reinforcement load at each level of reinforcement:

At topmost level (1.5' from surface):

$K_{r.top} := 1.64 \cdot K_A = 0.547$ (from Kr/Ka diagram)

$\sigma_{z.top} := K_A \cdot \gamma \cdot (1.5\ ft) = 48.695\ psf$

$\sigma_{x.top} := K_{r.top} \cdot \sigma_{z.top} = 26.62\ psf$

$$T_{max.top} := \frac{\sigma_{x.top} \cdot S_v}{R_e} = 0.639\ \frac{kip}{ft}$$

At bottom level (20.07' from surface):

$K_{r.bottom} := 1.2 \cdot K_A = 0.4$ (from Kr/Ka diagram)

$\sigma_{z.bottom} := K_A \cdot \gamma \cdot (H) = 541.164\ psf$

$\sigma_{x.bottom} := K_{r.bottom} \cdot \sigma_{z.bottom} = 216.466\ psf$

$$T_{max.bottom} := \frac{\sigma_{x.bottom} \cdot S_v}{R_e} = 5.195\ \frac{kip}{ft}$$

Compare to the allowable long-term reinforcement capacity:

$$T_{all} := \frac{A_c \cdot F_y}{w_{strip}} = 121.68\ \frac{kip}{ft}$$

$T_{all} > T_{max}$

Calculate the pullout capacity and check required embedment length:

Unanchored length: L_a

Required anchored length: L_e

$L = L_a + L_e$

Pullout capacity:

$P_r = F_{friction} \cdot \alpha \cdot \sigma'_v \cdot L_e \cdot C$

$C := 2$

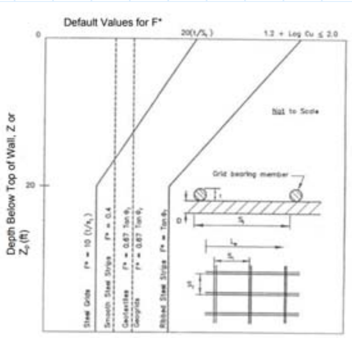
Solve for L_e:

$$L_e = max\left(\frac{T_{max}}{F_{friction} \cdot \alpha \cdot \sigma'_v \cdot C} \cdot FS_{pull}, 1\ m\right)$$

Check pullout capacity at bottom of MSE wall:

For standard backfill materials as defined in AASHTO LRFD Bridge Construction Specifications, Article 7.3.6.3, with the exception of uniform sands (Cu < 4), it is acceptable to use conservative default values:

$\alpha := 1.0$ (default for metal reinforcement)



$F_{friction} := 0.4$ (default for smooth steel strips)

$L_a := 0$

$\sigma'_v := K_A \cdot \gamma \cdot (H_{tot}) = 651.555\ psf$

$FS_{pull} := 1.5$

$L_e := \max\left(\frac{T_{max.bottom}}{F_{friction} \cdot \alpha \cdot \sigma'_v \cdot C} \cdot FS_{pull}, 1\ m\right) = 14.95\ ft$

$L := L_a + L_e = 14.95\ ft$ $\qquad 15\ ft > L_{min}$

Increase the embedment length to 15 feet

Check pullout capacity at location with maximum stress and maximum unanchored length (at point where vertical failure surface is reached):

$L_a := W_{failure} = 6.021\ ft$

$\alpha = 1$
$F_{friction} = 0.4$
$FS_{pull} = 1.5$

$\sigma'_v := K_A \cdot \gamma \cdot (H_{tot} - H_{slope}) = 325.778\ psf$

Determine the tension in the steel:

At 6 ft from top of MSE wall:

$K_{r.6} := 1.45 \cdot K_A = 0.483$ (from Kr/Ka diagram)

$\sigma_{z.6} := K_A \cdot \gamma \cdot (6\ ft) = 194.78\ psf$

$\sigma_{x.6} := K_{r.6} \cdot \sigma_{z.6} = 94.144\ psf$

$T_{max.6} := \frac{\sigma_{x.6} \cdot S_v}{R_e} = 2.259\ \frac{kip}{ft}$

$L_e := \max\left(\frac{T_{max.6}}{F_{friction} \cdot \alpha \cdot \sigma'_v \cdot C} \cdot FS_{pull}, 1\ m\right) = 13.004\ ft$

$L := L_a + L_e = 19.025\ ft$ $\qquad 19.025\ ft > 15\ ft$

Increase the embedment length to 20 feet

Check pullout capacity the top layer of reinforcement:

$L_a := W_{failure} = 6.021\ ft$

$\alpha = 1$

$F_{friction} = 0.4$

$FS_{pull} = 1.5$

$\sigma'_v := K_A \cdot \gamma \cdot (1.5\ ft + 2.57\ ft) = 132.126\ psf$

Determine the tension in the steel:

At 1.5 ft from top of MSE wall:

$K_{r.top} := 1.64 \cdot K_A = 0.547$ (from Kr/Ka diagram)

$\sigma_{z.top} := K_A \cdot \gamma \cdot (1.5\ ft) = 48.695\ psf$

$\sigma_{x.top} := K_{r.top} \cdot \sigma_{z.top} = 26.62\ psf$

$$T_{max.top} := \frac{\sigma_{x.top} \cdot S_v}{R_e} = 0.639\ \frac{kip}{ft}$$

$$L_e := \max\left(\frac{T_{max.top}}{F_{friction} \cdot \alpha \cdot \sigma'_v \cdot C} \cdot FS_{pull}, 1\ m\right) = 9.066\ ft$$

$L := L_a + L_e = 15.087\ ft$ $\quad 15.087\ ft < 20\ ft$

Use embedment length of 20 feet.

Check seismic loads:

Internal seismic force P_I:

$$P_I = W_A \cdot A_m$$

W_A = weight of active wedge

$A_m = (1.45 - A)\ A$ A = AASHTO site accel. coeff.

Distribute to compute for each reinforcement layer based on the anchored length:

$$(T_{md}) = P_I \cdot \frac{L_e}{\Sigma L_e}$$

Compute the total reinforcement load on an element:

$$T_{total} = T_{max} + T_{md}$$

Check rupture using 75% reduction of total load:

$$0.75 \cdot T_{total} < T_a$$

Check pullout using 80% of apparent friction:

$$L_e = \frac{0.75 \cdot T_{total}}{0.8 \cdot F_{friction} \cdot \alpha \cdot \sigma'_v \cdot C} \cdot FS_{pull}$$

Check facing connection strength:

Typically allowable strength specified by manufacturer.

The Seismic Design is not within the scope of this project.

Summary of design:

$h_{tot} = 17.504\ ft$ Height of retaining wall, not including surcharge load height

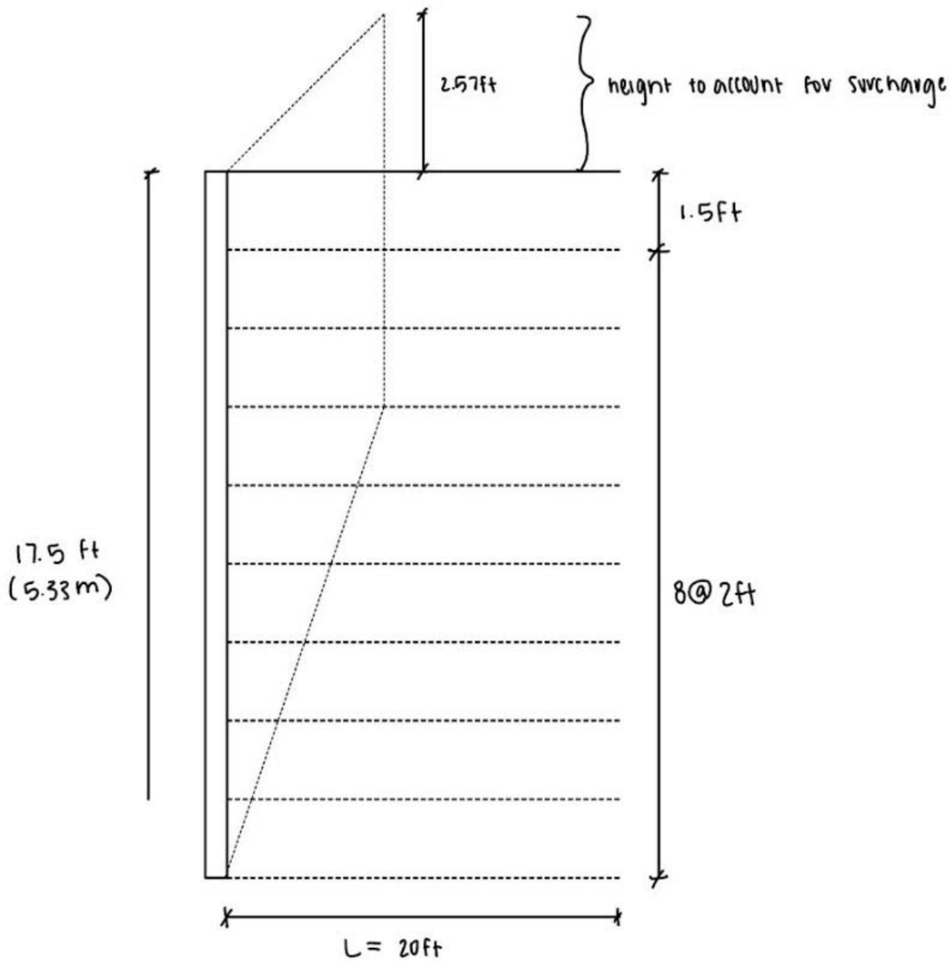
$L := 20\ ft$ Required embedment length of steel strips

MSE Wall:

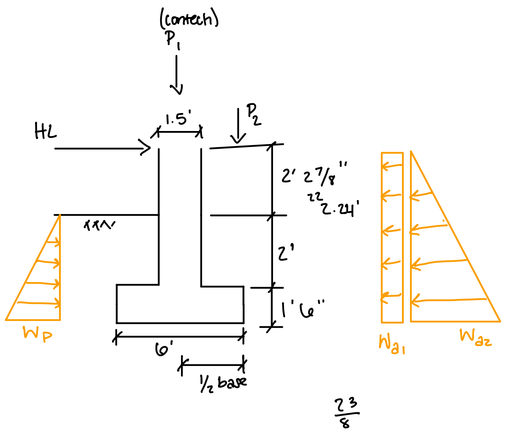
steel reinforcing strip: ASTM A1011 Galvanized Gr. 65

$w_{strip} := 2\ in$

$h_{strip} := 0.156\ in$



Appendix F: Foundation Design



$P_2 = (H_T)(\gamma)(w)$

H_T = top of culvert to top of footing

W = center of pedestal to outter edge of footing

Allowable bearing pressure

1) All vertical loads

$q_n = c' N_c + \sigma'_{z0} N_q + 0.5\gamma' B N_\gamma$

$\phi = 30^\circ$ $c' = 18.5$ $\qquad \sigma'_{z0} = \gamma D \Rightarrow (97.63 lb/ft^3)(3.5') = 341.71 lb/ft^2$

$\gamma = 97.63$ pcf

$N_c = 37.2$

$N_q = 22.5$

$N_\gamma = 20.1$

$q_{ult} = (18.5)(37.2) + (22.5)(341.71 lb/ft^2) + (0.5)(97.63 pcf)(4 ft)(20.1) = 688.2 + 7688.475 + 3924.726 = \frac{12301.401}{3} = 4100.467$

$q_{actual} = \frac{F}{A} \Rightarrow \frac{17300 lb/ft + 1125 lb/ft}{9 ft} = 3070.83 lb$

$W_f/b = (7.5 ft^2)(150 lb/ft^3) = 1125 lb/ft$

Footing Weight = $[(6 \times 1.5') + (4.24' \times 1.5')]$ 100 pcf = 3132 lb/ft

+ 6.36

Passive Pressure

$K_p = \frac{1+\sin\phi}{1-\sin\phi} = \frac{1+\sin 30^\circ}{1-\sin 30^\circ} = \frac{\frac{3}{2}}{\frac{1}{2}} = \frac{3}{2} \cdot \frac{2}{1} = \frac{6}{2} = 3$

$K_p = 3$

$\gamma = 97.63$ pcf

$(97.63 pcf)(3) = 292.89$ pcf

Active Pressure

K_o = Coefficent at rest pressure

$K_o = 1 - \sin 30^\circ = \frac{1}{2}$

$K_o \sigma_v'$ = at rest pressure

$\sigma_v' = \gamma d - u = (97.63 lb/ft^3)(3.5 ft) = 341.71$ psf

no ground water → u=0

lateral surcharge = $(\frac{1}{2})(341.71 psf) = 170.85$ psf

$$P_1 = (97.63\text{ pcf})\left[(3')(12.8') + \tfrac{1}{3}(12.8')(12.8')\right] = 9{,}080.89\text{ lb/ft}$$

$$P_2 = (17.04')(97.63\text{ pcf})(2) = 4990.85\text{ lb/ft}$$

$$W_{a1} = (170.8\text{ psf})(17.04') = 2910.43\text{ lb}$$

$$W_{a2} = (170.8\text{ psf})(5.74') = 980.39\text{ lb}$$

$$W_p = (292.89\text{ pcf})(3.5') = 1025.12\text{ psf}$$

$$M_{overturning} = (2910.43\text{ lb})(5.74') + (980.39\text{ lb})\left(\frac{5.74'}{2}\right)\left(\frac{5.74'}{3}\right) = 17956.65 = 17.956\text{ k-ft/ft}$$

$$M_{resisting} = (9080.89)(1.5') + (4990.85)(2.24') + (1461\text{ lb})(1.5') + (1052.12)(3.5')(1/2) =$$

$$13621.335 + 11179.5 + 2191.5 + 1841.21 = 28.8\text{ k·ft/ft}$$

$$\text{Overturning Safety Factor} = \frac{M_R}{M_{OT}} = \frac{28.8}{17.9} = 1.61 < 1.5 \checkmark \text{ ok}$$

Appendix G: Cost Estimate Breakdown

Table G-1: Cost estimation for construction activities.

Description	Source	Item Code	Quantity	Units	Cost per unit	Total Unit Cost
Structure Excavation (culvert)	Caltrans	192025	973	CY	$30.92	$30,085.16
Structure Retaining (excavation)	Caltrans	192037	1044	CY	$101.19	$105,642.36
Piles for Retaining walls	Caltrans	499010	87	LF	$636.77	$55,398.99
Remove Fence	Caltrans	803040	600	LF	$3.65	$2,190.00
Structural concrete, retaining wall	Caltrans	510060	1050	CY	$978.09	$1,026,994.50
Structural concrete, box culvert	Caltrans	510090	4012	CY	$1,200.66	$4,817,047.92
12" Steel pipe downdrain	Caltrans	690110	100	LF	$255.19	$25,519.00
Structural Concrete Footing	Caltrans	510051	1080	CY	$833.45	$900,126.00
Removal of Downdrain	Caltrans	710138	1	EA	$2,023.42	$2,023.42
					Total	$6,965,027.35
					Total with contingency (20%)	$8,358,032.82

Table G-2: Cost estimation for laborers.

Excavation	Daily Rate	Duration	Total	Inflation
1 equipment operator	$459.60	15	$6,894.00	
1 laborer	$328.40	15	$4,926.00	
1 Hyd. Excavator, 3.5 C.Y	$2,256.00	15	$33,840.00	
Total Excavation Price			$45,660.00	$52,266.29
Foundation				
1 carpenter foreman	$429.20	30	$12,876.00	
16 carpenters	$6,611.20	30	$198,336.00	

4 rodmen	$1,755.20	30	$52,656.00	
2 laborers	$656.80	30	$19,704.00	
2 cement finishers	$782.40	30	$23,472.00	
1 equipment operator	$440.80	30	$13,224.00	
1 gas engine vibrator	$26.55	30	$796.50	
1 concrete pump	$844.05	30	$25,321.50	
Total Foundation Price			$346,386.00	$396,502.63
Soldier Pile Wall				
2 skilled worker foremen	$886.40	4	$3,545.60	
8 skilled workers	$3,417.60	4	$13,670.40	
.375 equipment operator (crane)	$172.35	4	$689.40	
.375 hybrid crane, 80 ton	$557.63	4	$2,230.52	
Total Soldier Wall Installation			$20,135.92	$23,049.25
Piles for Retaining Walls				
1 pile driver foreman	$433.20	4	$1,732.80	
4 pile drivers	$1,668.80	4	$6,675.20	
2 equip. oper. (crane)	$919.20	4	$3,676.80	
1 equip. oper. (oiler)	$393.60	4	$1,574.40	
1 crawler crane, 75 ton	$1,734.00	4	$6,936.00	
1 lead, 90' high	$134.60	4	$538.40	
1 hammer, diesel, 41k ft-lb	$565.45	4	$2,261.80	
Total piles for retaining walls			$23,395.40	$26,780.35
Excavation for piles				
1 equipment operator	$459.60	2	$919.20	
1 laborer	$328.40	2	$656.80	
1 Hyd. Excavator, 3.5 C.Y	$2,256.00	2	$4,512.00	
Total Excavation Price			$6,088.00	$6,968.84
Crane uses for culvert pieces	$459.60	15	$6,894.00	
1 equipment operator (crane)	$459.60	15	$6,894.00	
1 equipment operator (oiler)	$393.60	15	$5,904.00	

1 hyd. crane, 55 ton (daily)	$1,299.00	15	$19,485.00	
1 P/U truck, 3/4 ton (daily)	$140.45	15	$2,106.75	
Total for crane			$41,283.75	$47,256.81
Culvert pieces and delivery				
From Contech			$475,000	
Total			$475,000	$475,000
MSE Walls				
2 skilled worker foremen	$886.40	10	$8,864.00	
8 skilled workers	$3,417.60	10	$34,176.00	
.375 equipment operator (crane)	$172.35	10	$1,723.50	
.375 hybrid crane, 80 ton	$557.63	10	$5,576.30	
Total Soldier Wall Installation			$50,339.80	$57,622.27
		80	days	$1,085,446.44
Total		6.667	months	$1,356,808.05

Table G-3: Cost estimation for temporary lane shifts.

Description	**Source**	**Item Code**	**Quantity**	**Units**	**Cost per Unit**	**Total Unit Cost**
Hot Mix Asphalt (Type A)	Caltrans	390132	355.89	Tons	$147.15	$52,369.43
Class 2 Aggregate Base	Caltrans	260203	351.50	CY	$127.47	$44,805.42
Class 2 Aggregate Subbase	Caltrans	250201	527.25	CY	$243.83	$128,558.55
Roadway Excavation (Type A)	Caltrans	190112	236.11	CY	$135.19	$31,919.86
Remove Painted Traffic Stripe	Caltrans	846020	16890	LF	$2.57	$43,407.30
Temporary Pavement Paint	Caltrans	120159	12990	LF	$0.54	$7,014.60
Paint Traffic Stripe (1-Coat)	Caltrans	840655	3900	LF	$0.57	$2,223.00
Midwest Guardrail System	Caltrans	832005	2215	LF	$42.06	$93,162.90
Remove Guardrail	Caltrans	839752	50	LF	$7.68	$384.00
Temporary Railing (Type K)	Caltrans	129000	865	LF	$14.53	$12,568.45
Relocate Concrete Barrier (Type K)	Caltrans	152372	1950	LF	$3.91	$7,624.50

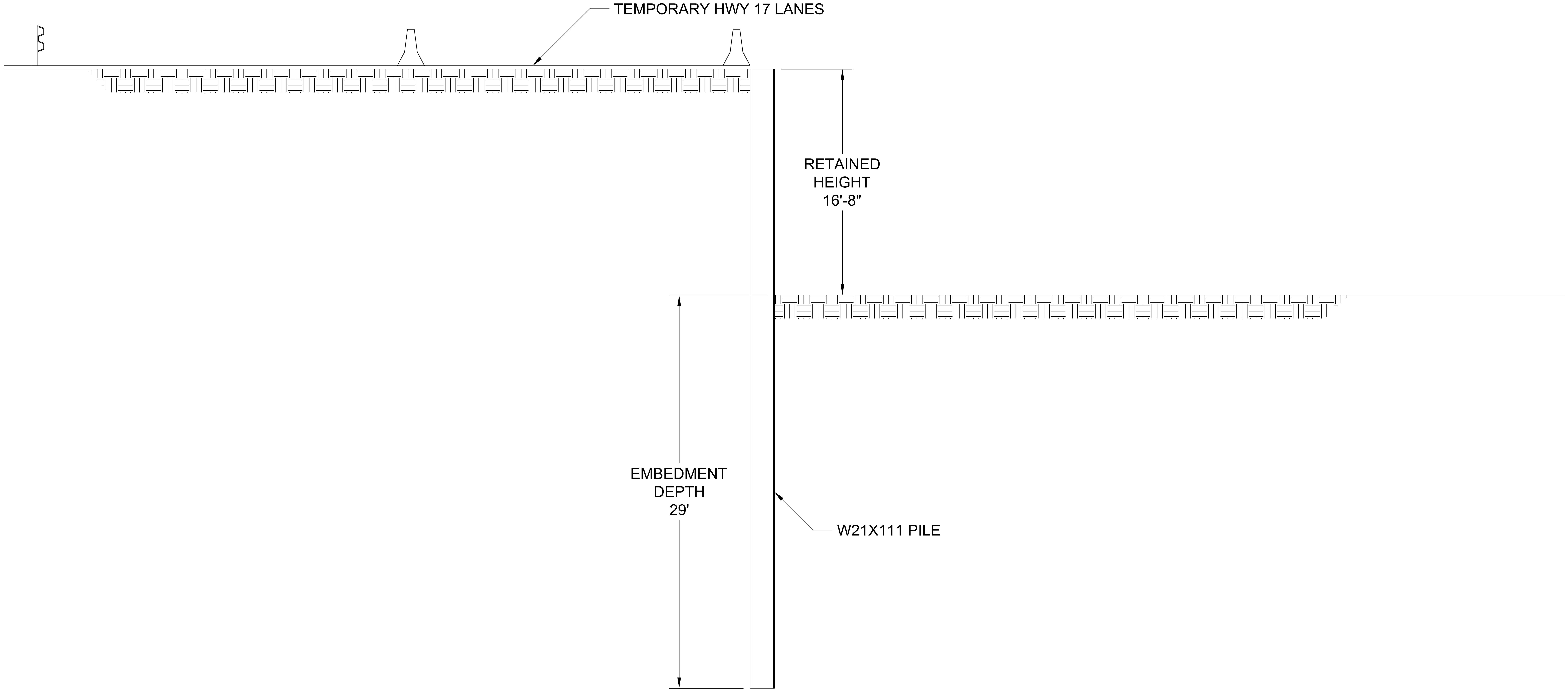
Pavement Marker (Retroreflective)	Caltrans	810230	170	EA	$6.82	$1,159.40
Remove Concrete Barrier (Type K)	Caltrans	839775	865	LF	$28.01	$24,228.65
Traffic Control System	Caltrans	120100	1	LS	$218,997.52	$218,997.52
					Total Cost:	$668,423.59
					Total with Contingency (20%):	$802,108.31

Table G-4: Cost estimation for environmental considerations.

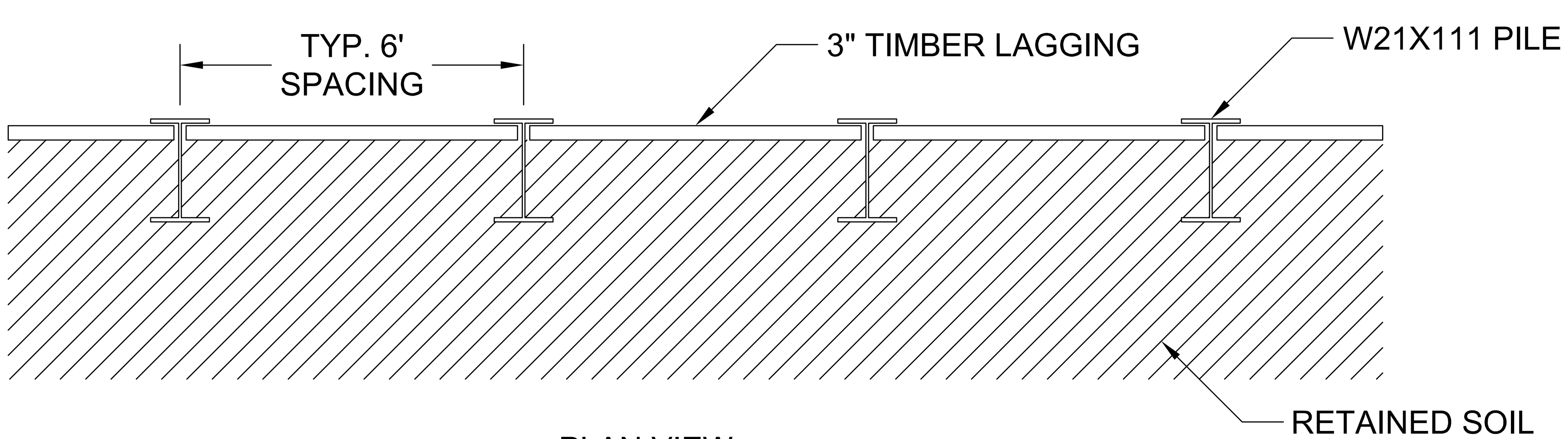
Description	**Source**	**Item Code**	**Quantity**	**Units**	**Cost per Unit**	**Total Unit Cost**
Fencing	Midpen Report		12672	LF	$103.42	$1,310,481.17
Jump Out	Midpen Report		10	EA	$9,733.22	$97,332.23
Invasive Species Control	Caltrans	146007	1	LS	$10,974.17	$10,974.17
Clearing and Grubbing	Caltrans	170103	1	LS	$34,271.90	$34,271.90
Move-In/Move-Out (Erosion Control)	Caltrans	130505	2	EA	$901.04	$1,802.08
Prepare Storm Water Pollution Prevention Plan	Caltrans	130300	1	LS	$4,134.65	$4,134.65
Environmental Mitigation	Midpen Report		1	LS	$73,000.00	$73,000.00
					Total Cost:	$1,531,996.21
					Total with Contingency:	$1,912,436.12

Appendix H: Detailed Design Drawings

List of Detailed Design Drawings



ELEVATION VIEW
1/4" = 1'



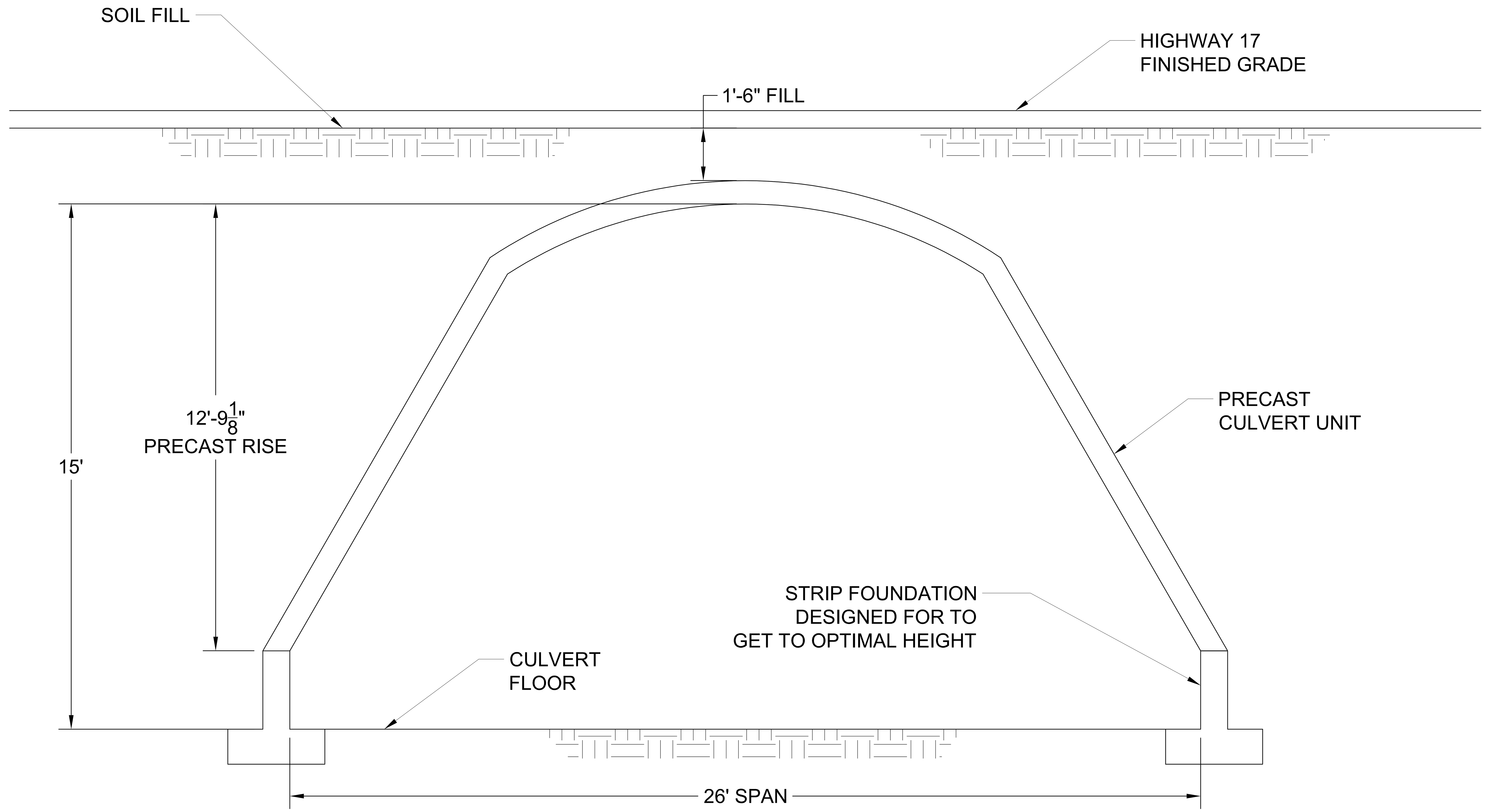
PLAN VIEW
1/2" = 1'

PROJECT NAME:

HIGHWAY 17
WILDLIFE CROSSING

DRAFTER: TARYN CHISHOLM | DATE: 05/26/2023

DRAWING NAME: SOLDIER PILE WALL | SHEET NUMBER: S1 | SCALE: AS NOTED



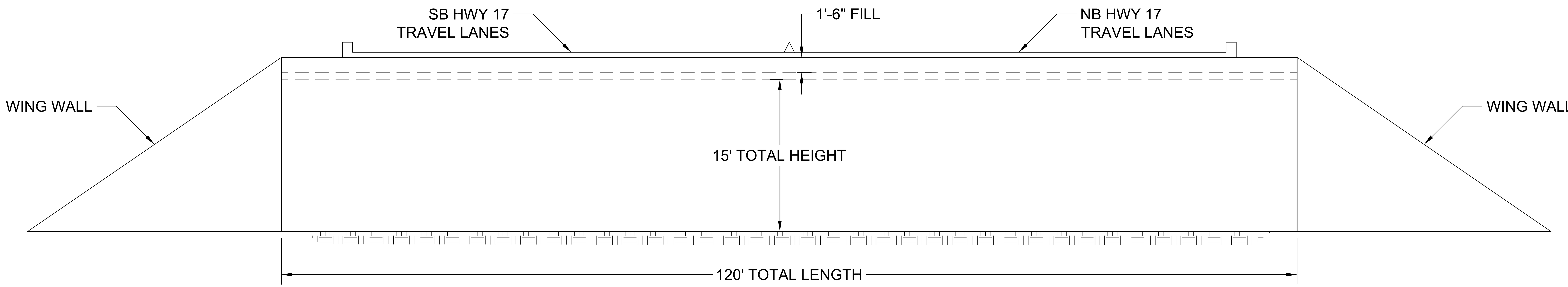
PROJECT NAME:
HIGHWAY 17 WILDLIFE CROSSING

DRAFTER: TARYN CHISHOLM | DATE: 05/26/2023

DRAWING NAME: CULVERT CROSS-SECTION

SHEET NUMBER: S2

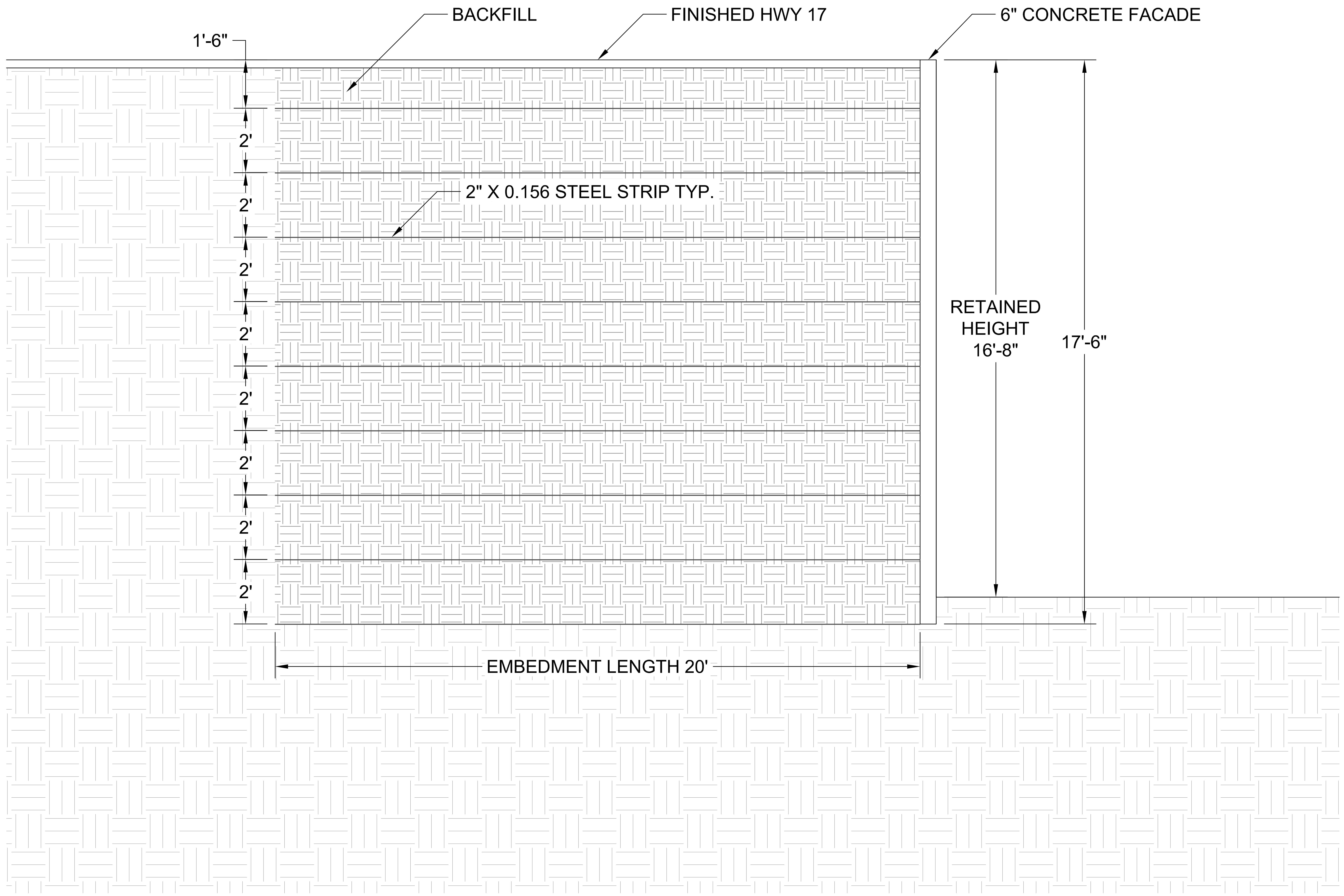
SCALE: $\frac{1}{2}$" = 1'-0"



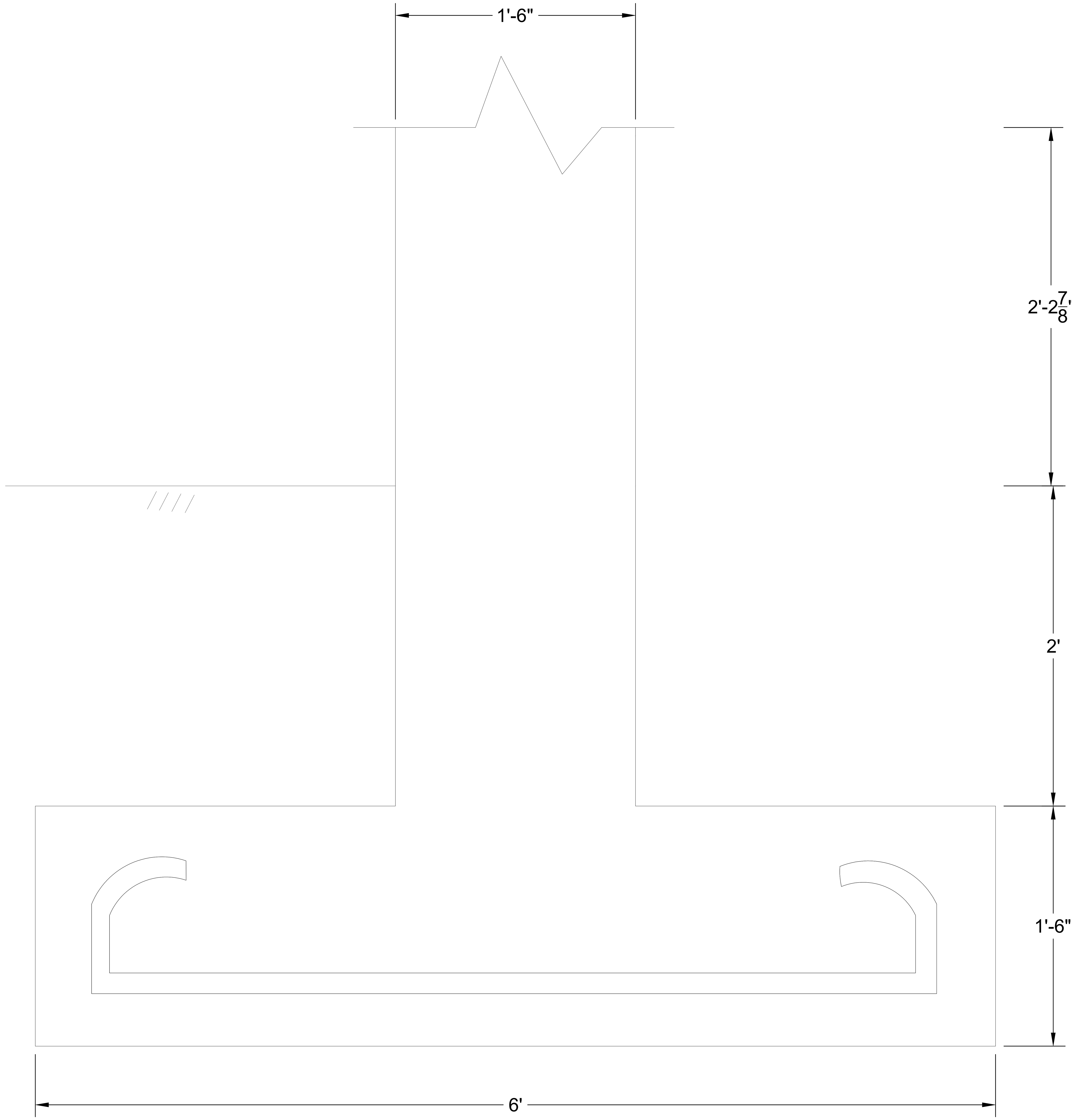
PROJECT NAME:

HIGHWAY 17 WILDLIFE CROSSING

DRAFTER: TARYN CHISHOLM	DATE: 05/26/2023	
DRAWING NAME: CULVERT ELEVATION	SHEET NUMBER: S3	SCALE: $\frac{3}{16}$" = 1'-0"



PROJECT NAME: HIGHWAY 17 WILDLIFE CROSSING		
DRAFTER: TARYN CHISHOLM	DATE: 05/26/2023	
DRAWING NAME: MSE WALL ELEVATION	SHEET NUMBER: S4	SCALE: $\frac{1}{2}$" = 1'-0"



PROJECT NAME:

HIGHWAY 17 WILDLIFE CROSSING

DRAFTER: SEEMA SINGH

DATE: 05/26/2023

DRAWING NAME:

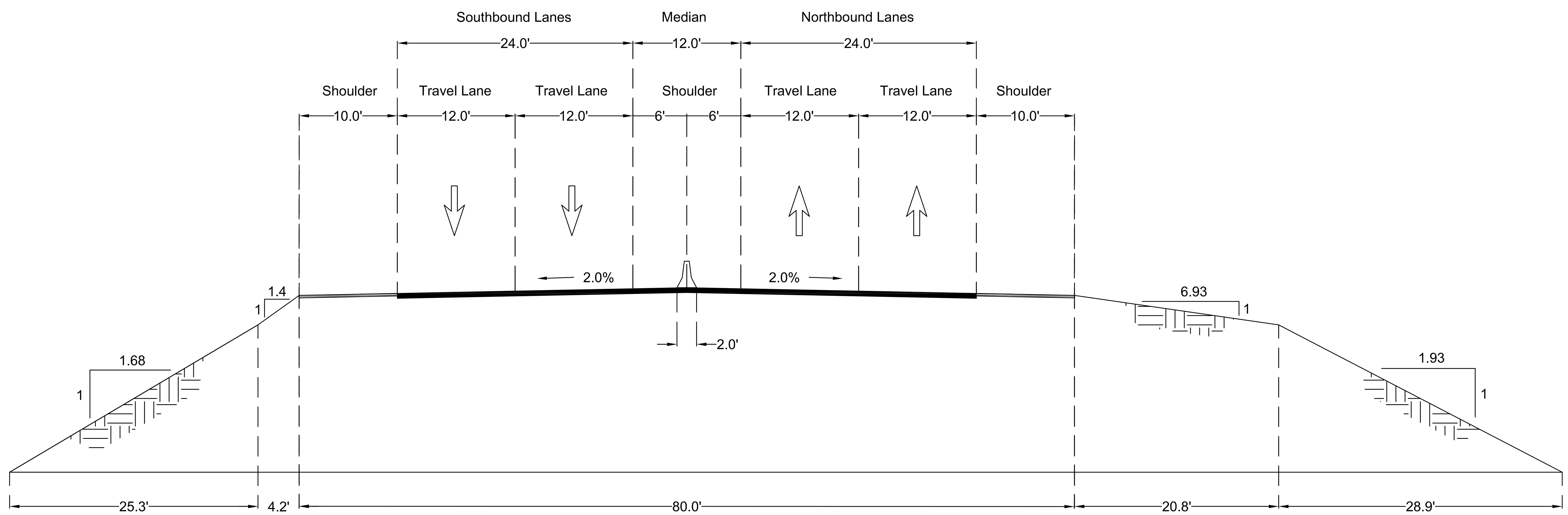
FOUNDATION DIMENSIONS

SHEET NUMBER:

S5

SCALE:

1" = 5"



PROJECT NAME: HIGHWAY 17 WILDLIFE CROSSING		
DRAFTER: JUSTIN UYENO	DATE: 06/04/2023	
DRAWING NAME: EXISTING HIGHWAY CROSS SECTION	SHEET NUMBER: C1.1	SCALE: 1 1/2" = 1'-0"

CURVE DATA:

No. (#)	L	R	△	SAFE SPEED
1	88.43'	1551.28'	3d15'59"	50 mph
2	92.16'	1551.28'	3d24'14"	50 mph
3	82.02'	1551.28'	3d1'46"	50 mph
4	69.34'	1551.28'	2d33'39"	50 mph

PHASE 1 LANE SHIFT

LEGEND:

PHASE CONSTRUCTION AREA

TEMPORARY SHIFTED TRAVEL LANES

PROJECT NAME:
HIGHWAY 17 WILDLIFE CROSSING

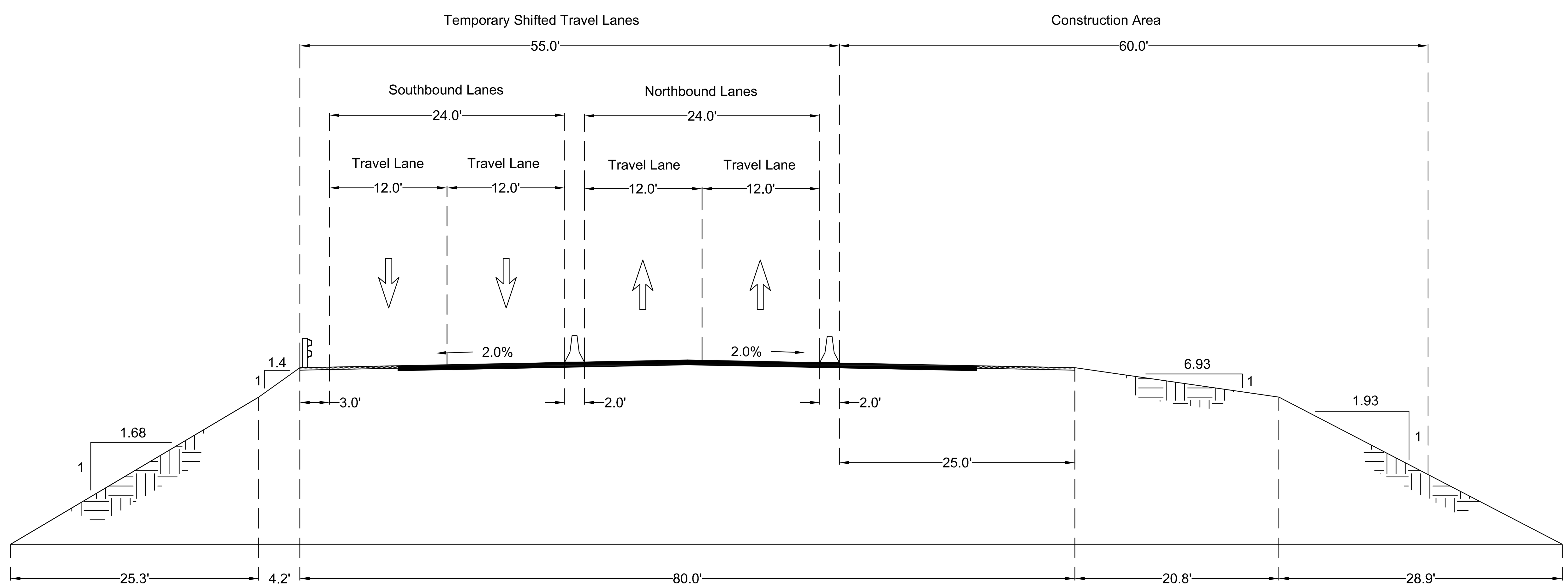
DRAFTER: JUSTIN UYENO

DATE: 06/04/2023

DRAWING NAME: PHASE 1 LANE SHIFTS

SHEET NUMBER: C2.1

SCALE: 1" = 30'-0"



TYPICAL CROSS SECTION
PHASE 1

PROJECT NAME: HIGHWAY 17 WILDLIFE CROSSING		
DRAFTER: JUSTIN UYENO	DATE: 06/04/2023	
DRAWING NAME: PHASE 1 HIGHWAY CROSS SECTION	SHEET NUMBER: C2.2	SCALE: $1\frac{1}{2}$" = 1'-0"

LEGEND:

- PHASE CONSTRUCTION AREA (hatched)
- TEMPORARY SHIFTED TRAVEL LANES
- SIGN

SIGN PLACEMENT:

CODE	DISTANCE
A	1000'
B	1500'
C	2640'

PHASE 1 LANE SHIFT

PROJECT NAME: HIGHWAY 17 WILDLIFE CROSSING		
DRAFTER: JUSTIN UYENO	DATE: 06/04/2023	
DRAWING NAME: PHASE 1 MUTCD	SHEET NUMBER: C2.3	SCALE: NTS

CURVE DATA:

No. (#)	L	R	△	SAFE SPEED
1	107.68'	525.13'	11d44'56"	30 mph
2	108.11'	525.13'	11d47'46"	30 mph
3	142.74'	525.13'	15d34'25"	30 mph
4	143.17'	525.13'	15d37'16"	30 mph

LEGEND:

PHASE CONSTRUCTION AREA

TEMPORARY SHIFTED TRAVEL LANES

PROJECT NAME:
HIGHWAY 17
WILDLIFE CROSSING

DRAFTER: JUSTIN UYENO
DATE: 06/04/2023

DRAWING NAME:
PHASE 2 LANE
SHIFT ALT 1

SHEET NUMBER:
C3.1

SCALE:
1" = 40'-0"

CURVE DATA:

No. (#)	L	R	△	SAFE SPEED
1	182.11'	1608.21'	6d29'17"	50 mph
2	206.92'	1608.21'	7d22'20"	50 mph
3	827.88'	1608.21'	29d29'42"	50 mph

LEGEND:

PHASE CONSTRUCTION AREA

TEMPORARY SHIFTED TRAVEL LANES

PROJECT NAME: HIGHWAY 17 WILDLIFE CROSSING		
DRAFTER: JUSTIN UYENO	DATE: 06/04/2023	
DRAWING NAME: PHASE 2 LANE SHIFT ALT 2	SHEET NUMBER: C3.2	SCALE: 1" = 60'-0"

CURVE DATA:

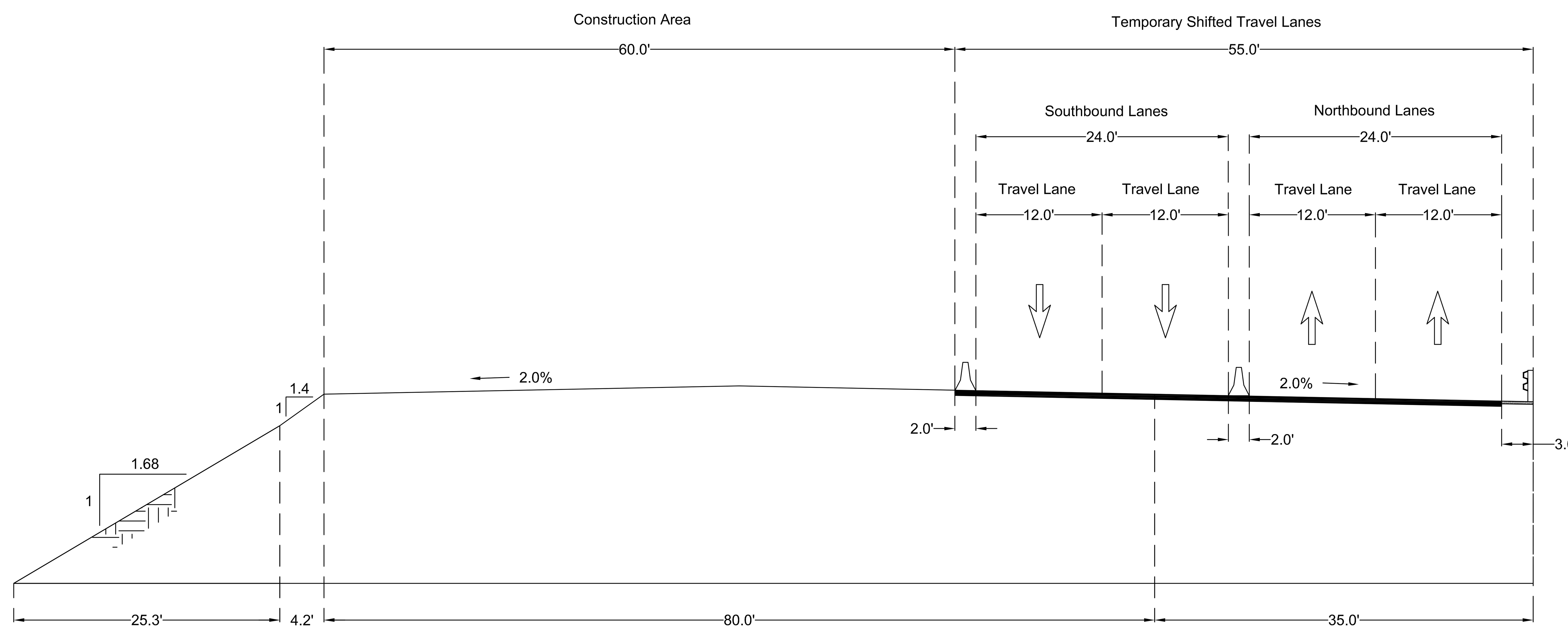
No. (#)	L	R	△	SAFE SPEED
1	182.11'	1608.21'	6d29'17"	50 mph
2	206.46'	1608.21'	7d21'20"	50 mph
3	131.45'	904.62'	8d19'31"	40 mph
4	578.44'	904.62'	36d38'11"	40 mph

LEGEND:

PHASE CONSTRUCTION AREA

TEMPORARY SHIFTED TRAVEL LANES

PROJECT NAME: HIGHWAY 17 WILDLIFE CROSSING	
DRAFTER: JUSTIN UYENO	DATE: 06/04/2023
DRAWING NAME: PHASE 2 LANE SHIFT ALT 3	SHEET NUMBER: C3.3 — SCALE: 1" = 50'-0"



TYPICAL CROSS SECTION
PHASE 2

PROJECT NAME:
HIGHWAY 17
WILDLIFE CROSSING

DRAFTER: JUSTIN UYENO	DATE: 06/04/2023	
DRAWING NAME: PHASE 2 HIGHWAY CROSS SECTION	SHEET NUMBER: C3.4	SCALE: $1\frac{1}{2}$" = 1'-0"

LEGEND:

PHASE CONSTRUCTION AREA

TEMPORARY SHIFTED TRAVEL LANES

SIGN

SIGN PLACEMENT:

CODE	DISTANCE
A	1000'
B	1500'
C	2640'

PHASE 2 LANE SHIFT

PROJECT NAME: HIGHWAY 17 WILDLIFE CROSSING		
DRAFTER: JUSTIN UYENO	DATE: 06/04/2023	
DRAWING NAME: PHASE 2 MUTCD	SHEET NUMBER: C3.5	SCALE: NTS