



**COLORADO**  
Department of Transportation

*CDOT Project NO. FBR R200-266  
CDOT Subaccount No. 23559*

## STRUCTURE ALTERNATIVES EVALUATION REPORT

Region 2 Bridge Bundle Design Build Grant Project  
Preliminary Design and Procurement Support Services

# Structure I-17-X

(Region 2 – US 24 MP 295.442)



Prepared for: Colorado Department of Transportation Region 2  
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*Stanley Consultants Project No. 29715  
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## **1. EXECUTIVE SUMMARY**

### **1.1. PROJECT DESCRIPTION**

The CDOT Region 2 Bridge Bundle Design Build Project consists of the replacement of seventeen (17) rural bridges on essential highway corridors in southeastern and central Colorado. The key corridors (US 350, US 24, CO 239 and CO 9) provide rural mobility, intra- and interstate commerce, movement of agricultural products and supplies, and access to tourist destinations. The 2 other bridges are Additionally Requested Elements (AREs) in the design build project. There is a total of nineteen (19) structures bundled under this project.

This design build project is partially funded by the USDOT FHWA Competitive Highway Bridge Program grant and funds from the Colorado Bridge Enterprise (14 structures, project number 23558). The 5 additional structures are funded solely by Colorado Bridge Enterprise (project number 23559). These projects are combined to form one design-build project.

The nineteen bridges identified to be included in the ‘Region 2 Bridge Bundle’ were selected based on similarities in the bridge conditions, risk factors, site characteristics, and probable replacement type, with the goal of achieving economy of scale. Seventeen of the bridges being replaced are at least 80 years old. Five of the bridges are Load Restricted limiting trucking routes through major sections of the US 24 and US 350 corridors. The bundle is comprised of nine timber bridges, four concrete box culverts, one corrugated metal pipe (CMP), four concrete I-beam bridges, and one I-beam bridge with corrugated metal deck.

### **1.2. PURPOSE OF THE REPORT**

This report presents the findings of the preliminary level multidisciplinary investigation of the existing conditions of the given structure. The objective of this report is not to select a new structure type but to develop guidelines that will be addressed in the Design-Build documents and make recommendations based on the available information. All the information obtained in the survey, geotechnical investigation, hydrology and hydraulics, existing utilities, and environmental investigation is discussed in this report. The study evaluates feasible structure alternatives for the site and identifies all known constraints.

### **1.3. STRUCTURE SELECTION PROCESS**

The following criteria for comparing and evaluating the structural alternatives is discussed below and will need to be considered during design-build processes:

- Hydraulic Opening Requirements
- Roadway alignments
- ROW Impacts
- Constructability
- Construction costs
- Maintenance
- Durability
- Traffic Control

The recommendations of the report are based on the overall consideration of all these elements as appropriate to this site and bridge.

## 1.4. STRUCTURE RECOMMENDATIONS

Based on the subsequent discussion, the recommended proposed overpass structure is a one-span 30.0 ft long bridge with concrete deck over four (4) precast prestressed concrete box girders spaced at 12.0 ft. The proposed substructure consists of tall wall abutments supported by H-piles. The width of the proposed bridge is 43.0 ft to accommodate two 12.0 ft lanes of traffic with 8.0 ft shoulders, and the Colorado current standard Bridge Rail on each side. Wingwalls will be required on all four corners to retain the roadway fill.

The contractor may select a different structure type based on their investigation, meeting the criteria described in this report.

## 2. SITE DESCRIPTION AND DESIGN FEATURES

### 2.1. EXISTING STRUCTURE

The existing I-17-X structure is a two-cell 10 ft x 8 ft, concrete box culvert built in 1965 to allow for the Fountain Creek to cross under turn-around road connecting WB and EB lanes of State Highway 24. US 24 at this location is a 4-lane divided highway with Fountain Creek located between the WB and EB lanes. The turnaround is used by emergency vehicles and provides access to a private entrance to the south of US 24. The existing structure has no skew and is 44.0 ft long. The culvert has four concrete wingwalls at each corner, approximately 12.0 ft long each.

The existing I-17-X structure is located on State Highway US 24, at milepost 295.442, approximately 2.25 miles west of Manitou Springs, Colorado. Table 1 summarizes bridge information.

National Bridge Structure Number	I-17-X
Year Built	1965
Construction Type	Two Cell Box Culvert, (2) 10 ft. x 8 ft.
Condition Rating	Poor
Load Restricted	No
Bridge Length	23 feet
Bridge Width	44 feet
Number of spans	2
Water Crossing	Fountain Creek
AADT	28,000
Percent Commercial Traffic	3.6%

**Table 1 – Bridge I-17-X Summary Information**



**Picture 1 – Bridge I-17-X General Location**

The replacement of Bridge G-12-C is warranted due to the age and deteriorating conditions. There is heavy abrasion on the bottom slab of both cells, with exposed rebar in multiple locations. Some minor spalls and hairline cracks are present in walls, top slab and headwall. Large portion of the CBC and wingwall footings on the downstream side are exposed due to erosion. One of the wingwalls on the downstream side is being pushed and separating from CBC. Large debris block the entrance to one of the CBC cells.



**Picture 2 – Exposed Footing, Erosion, Wingwall Separation**

## 2.2. RIGHT OF WAY IMPACT

The existing right of way (ROW) is located approximately 180.0 ft from the centerline of the existing structure on the west side of the US 24 and 150.0 ft on the east side of the US 24. Any alternative selected by a design-build team shall not make an impact on the existing right of way. No permanent ROW acquisitions are planned on either side of the US 24. Temporary construction easements may be required for drainage erosion control.

## 2.3. TRAFFIC DETOUR

The existing I-17-X structure crosses under the turn-around road connecting WB and EB lanes of State Highway 24. The preferred traffic alternative for this location is to close the turn-around and perform construction without impacts to the US 24 traffic.

## 2.4. UTILITIES

Stanley subcontracted with Lamb-Star Engineering to provide utility location services in the vicinity of the structure.

There is an underground fiber-optics line located 80.0 ft west of the centerline of the existing structure, running parallel to the existing road. Based on the Lamb-Star Engineering investigation, there are no other existing utilities in the vicinity of the structure.

## 2.5. GEOTECHNICAL SUMMARY

Stanley subcontracted with Yeh and Associates, Inc. to perform the geotechnical investigation of all bridges in this project. Full Preliminary Geotechnical Study is provided in the Appendix D.

Two bridge borings, I-17-X-B-1 and I-17-X-B-2 were drilled by Yeh in the vicinity of the existing CBC, and two pavement borings, I-17-X-P-1 and I-17-X-P-2, were drilled along the existing pavement approximately 100 feet from the CBC.

The bridge borings encountered poorly graded sands and gravels overlying granite bedrock. Table 2 provides a summary of the bedrock and groundwater conditions for the bridge borings. The surface elevations, approximate bedrock depths/elevations, and approximate groundwater depths/elevations are presented to the nearest 0.5 feet. The groundwater depths and elevations are based on observations during drilling.

Boring ID	Location (Northing, Easting)	Ground Surface Elevation at Time of Drilling (feet)	Approx. Depth to Top of Competent Bedrock	Approx. Elevation to Top of Competent Bedrock	Approx. Groundwater Depth (feet)	Approx. Groundwater Elevation (feet)
I-17-X-B-1	382852.8 157766.1	7033.0	24	7009.0	19	7014.0
I-17-X-B-2	382851.6 157722.4	7035.0	18	7017.0	15	7020.0

**Table 2 – Summary of Bedrock and Groundwater Conditions**

If a bridge structure is selected, the recommended substructure foundation types for this site include drilled shafts and driven H-piles. If CBC structure is selected, then the structure will be founded on shallow mat foundation. Wingwalls for the bridge and CBC structures will be founded on shallow strip foundations.

## 2.6. HYDRAULICS SUMMARY

Structure I-17-X crosses Upper Fountain Creek. The Federal Emergency Management Agency (FEMA) has designated the project site as a FEMA Zone AE. The design flow rate is 3,143 cfs. An SRH-2D model was developed at this location. The proposed model indicates that there is that a three-cell 12 ft x 8 ft CBC would carry the design flow and prevent overtopping of the roadway. Another alternative that satisfies the proposed hydraulic parameters is two-cell arch



ALBC 59 with an approximate opening of 22 ft x 8.5 ft. A one-span 30.0 ft long bridge alternative was also evaluated and shown to have an adequate opening to carry the design flows.

The channel was identified as having a high potential for debris production. Therefore, if a bridge is selected for the proposed conveyance structure, 4 feet of freeboard would typically be required. However, the existing 100-year floodplain overtops the roadway, and due to funding and site constraints, it is not feasible to raise the bridge enough to obtain this freeboard. The proposed preliminary design, bridge option lowers the water surface elevation to provide 1.69 ft of freeboard.

A Preliminary Hydraulic Report has been completed and can provide more information about the existing and proposed hydraulics conditions.

## 2.7. ENVIRONMENTAL CONCERNS

Based on field investigation performed by Stanley Consultants Environmental team, the area in the vicinity of the existing bridge has the following key findings:

- The Project is located along the Fountain Creek, which the Project bridge spans.
- Potential Waters of the U.S.
  - The Project has the potential to impact 0.20 acres of US Army Corps of Engineers (USACE) jurisdictional tributaries.
- Sensitive Species
  - The Project has potential to impact one species listed under the federal Endangered Species Act:
    - Mexican spotted owl (*Strix occidentalis lucida*) – Threatened
  - The Project is located within Mexican spotted owl designated critical habitat
  - The Project has the potential to impact two (2) species listed as state endangered or threatened:
    - Arkansas darter (*Etheostoma cragini*) – Threatened
    - Southern redbelly dace (*Phoxinus erythrogaster*) – Endangered
  - There is potential for Migratory Bird Treaty Act (MBTA) species and bats to occur.
- Floodplains
  - The Project is located within a Federal Emergency Management Agency (FEMA) Zone A Floodplain (100-year floodplain) and a FEMA Regulatory Floodway.
- Hazardous Waste
  - Metals and petroleum products from the former Colorado Midland Terminal Railroad have the potential to have contaminated the surrounding soils.

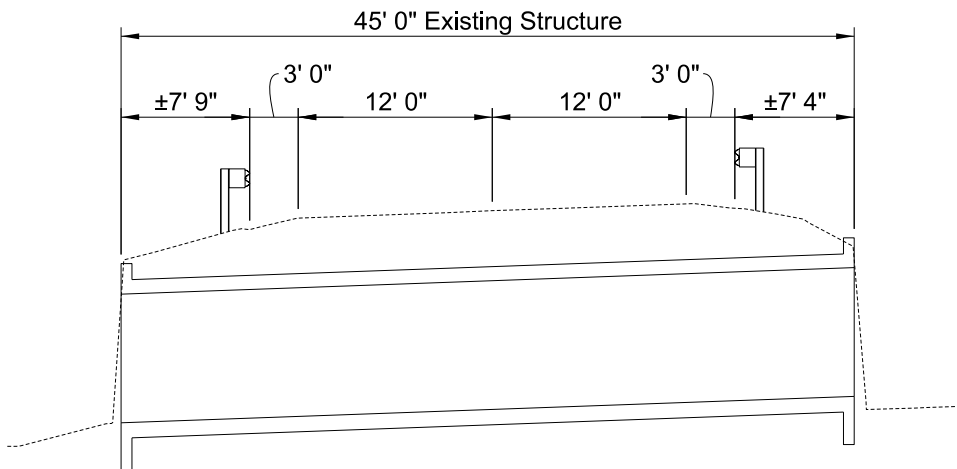
- Archaeological, Historic and Paleontological Resources
  - These resources are being assessed by CDOT and will be provided under separate cover

Refer to Desktop Study and wetland reports for additional information.

## 2.8. ROADWAY FEATURES

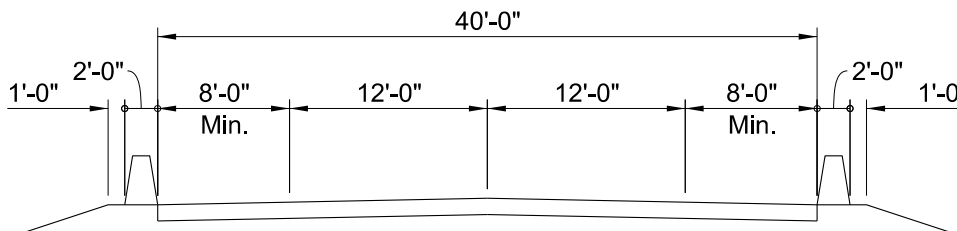
### 2.8.1. Cross Section

Existing turn-around connecting north-bound and south-bound US 24 is a 2-lane roadway with two-way traffic. The existing lanes are 12.0 ft wide with 3.0 ft shoulder. There is an existing guardrail on either side of the road.



**Figure 1 – Existing Section**

The proposed roadway section width is based on the on the current traffic volumes and the requirements of the current CDOT Roadway Design Guide. Lane width is expected to be 12.0 ft in each direction with 8.0 ft shoulders. Total required roadway width over proposed structure is 40.0 ft.



**Figure 2 – Proposed Roadway Section**

### 2.8.2. Vertical Alignment

The proposed vertical profile of US 24 turnaround must be set as close to the existing as allowed by the results of the hydrology study to avoid any ROW acquisitions and to limit impacts to the

existing mainline eastbound and westbound lanes of US 24 roadway section beyond the length of the structure.

The proposed structure profile is on a 96.00 ft vertical sag curve that matches the existing roadway profile. The incoming grade is -6.90%, and outgoing grade is -1.41%. The proposed bridge profile slope is approximately 4.15%.

### 2.8.3. Horizontal Alignment

The horizontal alignment of the existing structure has no skew. The structure is on a continuous horizontal tangent. It is understood that the proposed structure will be constructed in the same location as the existing with no change to the horizontal alignment of the road and no skew.

## 3. STRUCTURAL DESIGN CRITERIA

### 3.1. DESIGN SPECIFICATIONS

- AASHTO LRFD Bridge Design Specifications, 9<sup>th</sup> Edition
- CDOT LRFD Bridge Design Manual
- CDOT Bridge Rating Manual
- CDOT Bridge Detail Manual

### 3.2. CONSTRUCTION SPECIFICATIONS

Colorado Department of Transportation Standard Specifications for Road and Bridge Construction, 2019.

### 3.3. LOADING

*Live Loads:* HL-93 Design Truck or Tandem, Design Lane Load, Colorado Permit Vehicle

*Bridge Barrier:* Bridge Rail Type 9 or Type 10MASH per the Colorado current standard

*Future Wearing Surface:* 36.67 lbs per square foot (3 in minimum)

*Utilities:* per plan details if required at final design

*Collision Load:* the substructure will not require collision loading design. In cases where Bridge Rail is attached to the structure, the effects of vehicular collision on the barrier must be considered in accordance with AASHTO.

*Earthquake Load:* The structure is located within Seismic Zone 1 and must meet the AASHTO connection and detailing requirements.

*Stream Forces and Scour Effects:* stream force effects must be evaluated during final design when applicable. Possible cases include stream forces on the substructure and superstructure in addition to buoyancy from overtopping. Evaluation from scour will be performed per the CDOT Bridge Design Manual and AASHTO.

## **4. STRUCTURE SELECTION**

### **4.1. SELECTION CRITERIA**

The goal of this report is to identify which structural alternatives best meet the project requirements. The following criteria were established as a basis for evaluating the suitability of each structure type: hydraulic opening, constructability, construction cost, maintenance & durability, ROW and roadway impacts. The discussion below expands on these factors as it pertains to each alternative. Summary of Structure Alternatives Evaluation Table can be found at the end of Section 4.

### **4.2. REHABILITATION ALTERNATIVES**

Rehabilitation of I-17-X will not be performed due to the age and type of the bridge. Constructed in 1965, this structure was in service for over 55 years and is showing signs of deterioration and aging that are inconsistent with practical and cost-effective rehabilitation.

### **4.3. STRUCTURE LAYOUT ALTERNATIVES**

Layout of the proposed structure is controlled by the width of the proposed roadway section, stream geometry, hydraulic opening requirements, phased construction considerations and the position of the existing bridge substructure.

The horizontal alignment of the proposed structure will not have skew.

Refer to CDOT Bridge Design Manual and CDOT Drainage Manual for additional clearance requirements information.

Any bridge structure selected for final construction must satisfy the live load deflection requirement for the selected girder types specified in AASHTO LRFD Bridge Design Manual.

### **4.4. SUPERSTRUCTURE ALTERNATIVES**

#### **4.4.1. Concrete Box Culvert Alternative**

Concrete box culverts are a cost-effective solution in both short- and long-term due to ease of construction and maintenance. The benefit of this structure type is that the culverts can be cast-in-place (CIP) or precast off-site and transported to the site for placement to streamline the construction processes. In addition, CBC size can be selected from CDOT M&S Standards that cover wide array of single-cell and multi-cell culvert sizes.

For I-17-X a three-cell 12 ft x 8 ft box culvert is required to carry the design flow. The box can be constructed as CIP or precast. The centerline of the proposed box culvert will be placed inline with the centerline of the existing box culvert. The minimum design cover over the top slab of the proposed CBC is approximately 4.0 ft. The concrete box culvert proposed total length is 61.0 ft. Wingwalls will be provided on all 4 corners of the box culvert. Wingwalls will be per CDOT M-601-20 standard.

Concrete box culvert alternative will require riprap apron on the downstream side of the structure as an energy dissipation countermeasure.

#### 4.4.2. Steel Arch Alternative

In order to provide a structure with a natural river bottom a steel arch alternative was evaluated. This alternative requires two steel arch structures, ALBC 59 by Contech Solutions. The horizontal width of each cell is 21 ft 9 in with a vertical clearance of 8 ft 5 in. Cast in place footings will be required to support the ends of each arch. The footings will be constructed below the natural river bottom. The arches will have approximately 3.0 ft of cover. The steel arch proposed total length is 61.0 ft.

The total width of the proposed arch alternative is 50.0 ft, which is considerably wider than the existing structure. The existing channel slopes will need to be retained using MSE, soil nail or CIP retaining walls on all four corners of the structure. A roadway model was created to estimate the length of the retaining walls required for this alternative and cost of the retaining walls was added to the total cost of the structure to adequately compare it to other alternatives.

#### 4.4.3. Concrete Girder Bridge Alternatives

Selected materials and structure components must exhibit high durability to provide longevity of the bridge. A precast prestressed concrete girder bridge requires minimum maintenance and have been shown to be highly durable under Colorado's harsh conditions. For this project, viable concrete alternatives include precast prestressed box girders or Colorado bulb tee (CBT) shapes.

Proposed girder sizes were selected based on the Table 5B-1 and Figures 5B-1, 5B-2, 5B-4 in the CDOT Bridge Design Manual. Based on this information, (4) BX 18x48 girder section spaced at 12.0 ft was chosen as a cost-effective precast concrete solution for the required 30.0 ft span. A standard 8.0 in deep reinforced concrete deck will be used.

#### 4.4.4. Steel Girder Bridge Alternatives

At this location a concrete box culvert and concrete girder bridge alternatives have been evaluated. Since steel girders are not usually cost effective for short spans, we have not evaluated a steel girder option at this location. Steel girders also require future maintenance and are not a preferred alternative.

#### 4.4.5. Span Configurations

Total length of the proposed concrete box culvert and steel arch alternatives was determined based on the requirements of the proposed roadway section.

A one-span 30.0 ft long bridge length proposed bridge alternative was determined based on the requirements of the hydraulics opening.

### 4.5. SUBSTRUCTURE ALTERNATIVES

The preferred concrete bridge substructure type considered in this study are tall wall abutments supported on H-Piles. Tall wall abutments were selected to provide maximum hydraulic opening

while maintaining short span that avoids additional retaining walls to retail the channel slopes on the upstream and downstream sides of the structure. The stem of the tall wall abutment will be 2.5 ft wide and 11.0 ft tall. The footings will be 8.0 ft wide and 2.0 ft deep and will be supported by (8) HP 12x53 piles arranged in two rows. Wingwalls will be 20.0 ft long integral wingwalls attached to the stem of the tall wall abutment.

Steel arch alternative will have 2.5 ft wide by 1 ft 4 in deep cast in place footings under each leg per Contech Solutions standards.

#### 4.6. ACCELERATED BRIDGE CONSTRUCTION (ABC)

CDOT has developed an Accelerated Bridge Construction (ABC) decision making process. The intent of this process is to apply some form of ABC on most projects. Design-build team is encouraged to use these recourses to evaluate cost efficiency of implementing ABC design.

#### 4.7. CONSTRUCTION PHASING

As discussed in Section 2.3, the turnaround can be closer to traffic during construction. No additional construction phasing considerations are required at this location.

#### 4.8. CONSTRUCTABILITY

Constructing concrete box culvert would require less construction time and using precast sections would further reduce construction time.

Constructing steel arch alternatives would require building retaining walls that are not required for two other alternatives. Shoring will be required to construct the retaining walls parallel to the US 24.

#### 4.9. MAINTENANCE AND DURABILITY

Typical CDOT specified materials and construction methods must be used for the construction of the proposed structure. Following accepted current practice in designing and constructing the structure will provide a durable bridge to meet the required 100-year service life with minimal required maintenance.

Concrete box and steel arch alternatives may require routine cleaning. There is very little maintenance associated with the concrete girder bridge alternative.

#### 4.10. CORROSIVE RESISTANCE

Epoxy coated reinforcing must be used for all reinforced concrete elements. A waterproofing membrane and stone matrix asphalt will be used on top of the concrete deck or CBC to prevent water and salt intrusion.

#### 4.11. CONSTRUCTION COST

Construction costs are one of the most important factors in the structure type selections. Preliminary construction cost estimates are prepared for all selected structure alternatives to be compared as discussed above. High level construction cost for each structure type is summarized in the table below. Detailed calculations of the cost can be found in the Appendix C of this report. Individual items cost was obtained from recent CDOT Cost Data Books. A 30% contingency multiplier was used in cost calculations.

<b>Alternative</b>	<b>Construction Cost (30% Contingency)</b>	<b>Area</b>	<b>Cost per sf</b>	<b>Cost Rating</b>
Concrete Box Culvert	\$ 696,950.00	2399 sf	\$ 290	1.2
Steel Arch (including retaining walls)	\$ 867,882.00	3172 sf	\$ 274	1.0
Concrete Bridge	\$ 654,425.00	1398 sf	\$ 468	1.3

**Table 3 – Construction Cost Summary**

#### 4.12. CONCLUSIONS AND RECOMMENDATIONS

Table below provides a summary of feasible alternatives evaluation based on the established selection criteria

<b>Criteria</b>	<b>CBC</b>	<b>Steel Arch</b>	<b>Concrete Bridge</b>
Hydraulic Opening	Satisfies the requirements, but does not provide natural channel	Satisfies the requirements. Provides natural channel favorable for fish and wildlife	Satisfies the requirements. Provides natural channel favorable for fish and wildlife
Constructability	Can be precast to streamline the construction	Requires construction of the retaining walls and shoring. Delivered to site in ready to install sections	May require longer construction time than CBC or Arch but avoids retaining walls
Construction Cost Rating	1.2	1.0	1.3
Maintenance & Durability	May require routine cleaning	May require routine cleaning	Concrete girders require minimal maintenance
ROW and Roadway Impacts	No ROW impacts	No ROW impacts	No ROW impacts

**Table 4 – Summary of Structure Alternatives Evaluation**

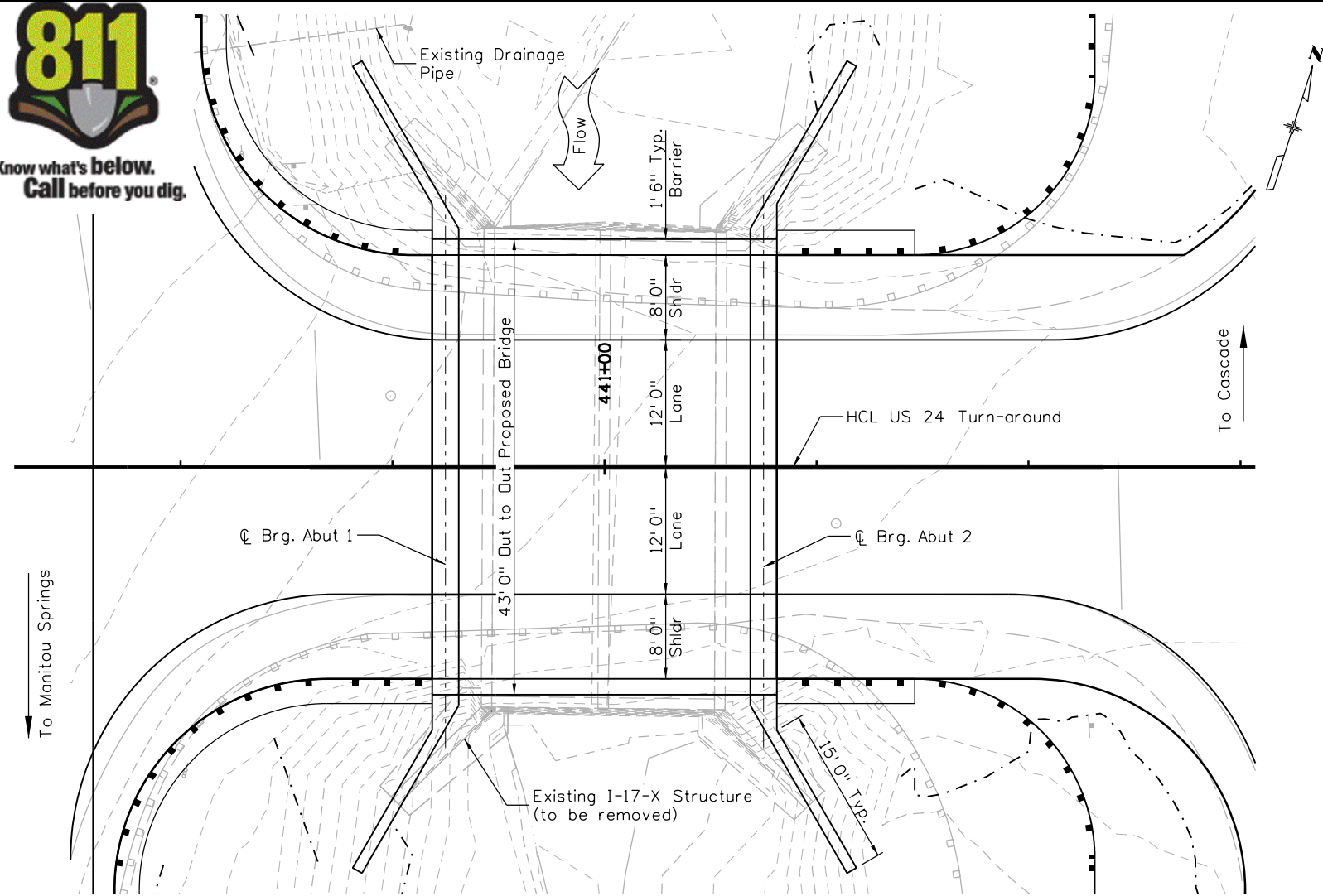
Based on the criteria discussed above, the concrete bridge alternative is the recommended alternative to replace existing I-17-X structure. The contractor may select a different structure type based on their investigations, meeting the criteria described in this report. See Appendix A for the selected General Layout and Typical Section.



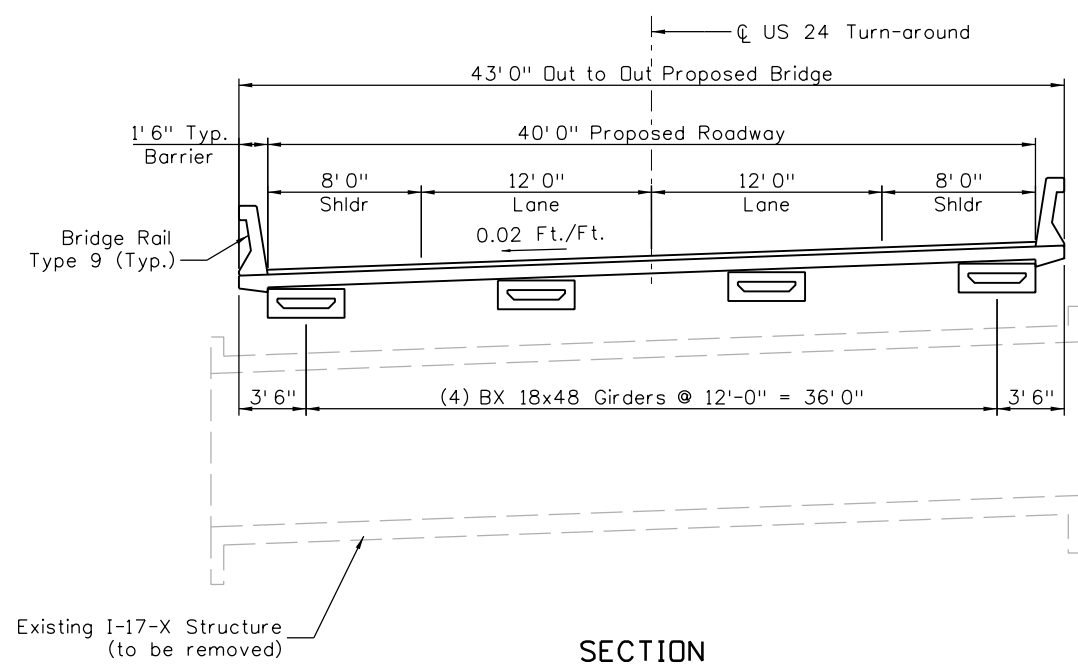
# **APPENDIX A**

General Layout and Typical Section

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**PLAN**

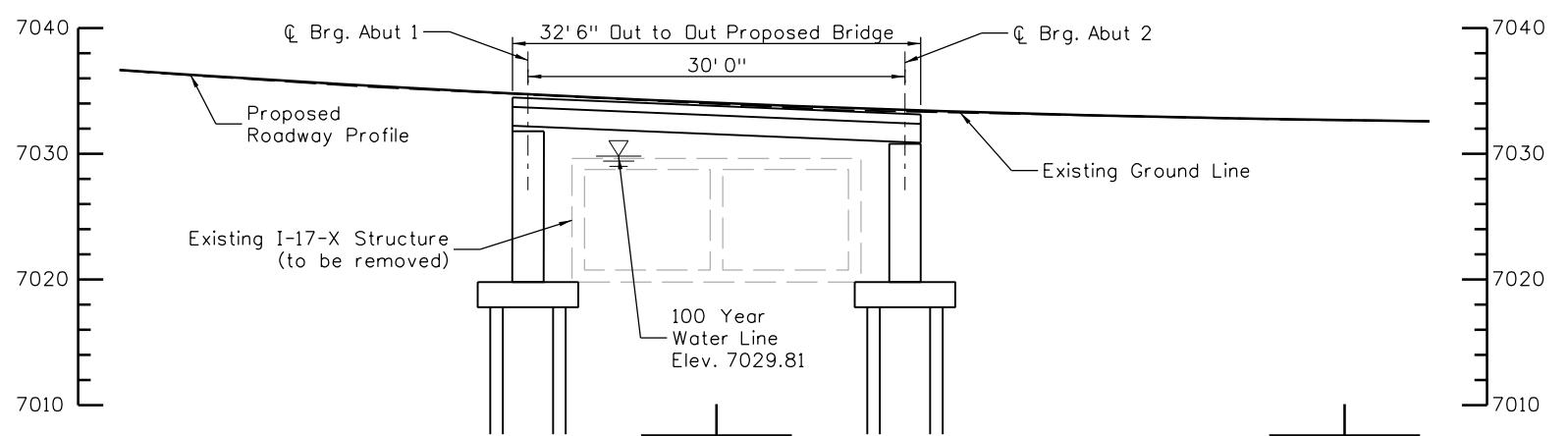


**SECTION**

(Taken Normal to HCL US 24 Turn-around)

**Notes:**

- Dimensions are based on recent survey and existing as-built drawings.



**ELEVATION**

(Taken Along HCL US 24)

Print Date: 2/1/2021	File Name: 23559STR_GeneralLayout I-17-X_SH24_MP_295.45.dgn	<b>Sheet Revisions</b>		<b>Colorado Department of Transportation</b> 5615 Wills Blvd Pueblo, CO 81008 Phone: 719-546-5753 FAX: 719-546-5402	As Constructed	<b>REGION 2 BRIDGE BUNDLE</b>		Project No./Code
Horiz. Scale:	Vert. Scale: As Noted	Date:	Comments:		Init.:	No Revisions:	<b>US 24 OVER FOUNTAIN CREEK</b>	
8000 South Chester St. Suite 500 Centennial, CO 80112 Phone: 303-799-6806		<b>Region 2</b>		JLS	Revised:	Designer: I. Pushkarova	Structure No. I-17-X	Sheet Number
					Void:	Detailer: I. Pushkarova	M.P. US 24 295.442	
						Sheet Subset: STR	Subset Sheets: 1 of 1	

# **APPENDIX B**

## Structure Selection Report Checklist

# Structure Selection Report QA Checklist

This checklist is to serve as a general guideline for structure selection process. It is to be filled out by the project Engineer of Record or designee to indicate all items that are to be discussed in the Structure Selection Report. This checklist is to be included as an appendix to the Structure Selection Report and must be signed by Staff Bridge Unit Leader or designee prior to submittal of FIR documents to the Region.

Project Name \_\_\_\_\_

Project Location \_\_\_\_\_

Project Number \_\_\_\_\_ Subaccount \_\_\_\_\_

Structure Number(s) \_\_\_\_\_

Engineer of Record \_\_\_\_\_ Date \_\_\_\_\_

## Cover Sheet

- Name of the Project and Site Address
- Structure(s) Number
- Property Owner Name and Contact Information
- Report Preparer Name and Contact Information
- Seal and Signature of the Designer
- Submittal and Revision Dates as Applicable

## Executive Summary

- Project Description
- Purpose of the Report
- Structure Selection Process
- Structure Recommendations

## Site Description and Design Features

- Existing Structures
- ROW Impact
- Traffic Detour
- Utilities
- Geotechnical Summary
- Hydraulics Summary
- Environmental Concerns
- Roadway Design Features
  - Cross Section
  - Vertical Alignment
  - Horizontal Alignment

## Structural Design Criteria

- Design Specifications
- Construction Specifications
- Loading
  - Collision Load
  - Earthquake Load
- Software to be used by the Designer
- Software to be used by the Independent Design Checker

## Structure Selection

- Selection Criteria
- Rehabilitation Alternatives
- Structure Layout Alternatives:
  - Vertical Clearances
  - Horizontal Clearances
  - Deflection
  - Skew

- Superstructure Alternatives:
  - Concrete Girder Alternatives \* CBC Alternative
  - Steel Girder Alternatives \* RCP Alternative
  - Span Configurations
- Substructure Alternatives:
  - Abutment Alternatives (GRS, Integral, Semi-integral, etc.)
  - Pier Alternatives
- Wall Alternatives
- Construction Phasing
- Possible Future Widening
- Use of Existing Bridge in Phasing / Partial Configuration
- ABC Design
- Constructability
- Aesthetic Design
- Maintenance and Durability
- Corrosive Resistance
- Load Testing Requirements
- Use of Lightweight Concrete
- Construction Cost
- Life Cycle Cost Analysis

**Other**

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**Figures and Appendices**

- Vicinity Map
- Alternative Typical Sections
- General Layout of the Selected Structure
- Summary of Structure Type Evaluation Table
- Summary of Quantities and Cost Estimate Tables
- Inspection Report
- Hydraulics Investigation Results
- Geotechnical Investigation Results

**Recommendations**

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**List of Variances**

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**CDOT Staff Bridge Quality Assurance Sign-off**

By signing this checklist Staff Bridge Unit Leader or designee acknowledges approval of the Structure Selection Report findings, recommendations, and all design deviations from the CDOT Structural Standards and design criteria.

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Print Name Signature Date

# **APPENDIX C**

## Construction Cost Estimate









# **APPENDIX D**

Geotechnical Report



February 11, 2021

Project No. 220-063

Mr. Ron Gibson, P.E.  
Stanley Consultants  
8000 South Chester Street, Suite 500  
Centennial, Colorado 80112

**Subject: Preliminary Geotechnical Study  
Structure I-17-X  
23558/23559 Region 2 Bridge Bundle  
CDOT Region 2, Colorado**

Dear Mr. Gibson:

This memorandum presents the results of Yeh and Associates, Inc.'s (Yeh) preliminary geotechnical engineering study for the proposed replacement of the Structure I-17-X as part of the CDOT Region 2 Bridge Bundle Design-Build Project.

The CDOT Region 2 Bridge Bundle Design-Build Project consists of the replacement of a total of 19 structures bundled together as a single project. These structures are rural bridges on essential highway corridors (US 350, US 24, CO 239, and CO 9) in southeastern and central Colorado. These key corridors provide rural mobility, intra- and interstate commerce, movement of agricultural products and supplies, and access to tourist destinations. The design-build project consists of 17 bridges and two Additionally Requested Elements (ARE) structures.

This design-build project is jointly funded by the USDOT FHWA Competitive Highway Bridge Program grant (14 structures, Project No. 23558) and the Colorado Bridge Enterprise (five structures, Project No. 23559). These projects are combined to form one design-build project. The two ARE structures are part of the five bridges funded by the Colorado Bridge Enterprise.

The 19 bridges identified to be included in the Region 2 Bridge Bundle were selected based on similarities in the bridge conditions, risk factors, site characteristics, and probable replacement type, with the goal of achieving economy of scale. Seventeen of the bridges being replaced are at least 80 years old. Five of the bridges are load-restricted, limiting trucking routes through major sections of the US 24 and US 350 corridors. The bundle includes nine timber bridges, four concrete box culverts, one corrugated metal pipe (CMP), four concrete I-beam bridges, and one I-beam bridge with corrugated metal deck.

## **1 PROJECT UNDERSTANDING**

Structure I-17-X is part of the Region 2 Bridge Bundle Design-Build Project. Our preliminary geotechnical study was completed to support the 30% design level that will be included in the design-build bid package. We understand the existing structure is a concrete box culvert (CBC) and will be replaced with either a CBC or a bridge structure. The new structure will be constructed along the current roadway alignment and existing

roadway grade will be maintained. No significant cut or fills are required for construction of the proposed replacement structure.

## 2 SUBSURFACE CONDITIONS

Two bridge borings, I-17-X-B-1 and I-17-X-B-2 were drilled by Yeh in the vicinity of the existing CBC, and two pavement borings, I-17-X-P-1 and I-17-X-P-2, were drilled along the existing pavement approximately 100 feet from the CBC. The approximate boring locations are shown on the engineering geology sheet in Appendix A. The legend and boring logs are included in Appendix B. Laboratory test results are provided in Appendix C and are shown on the boring logs.

The bridge borings encountered poorly graded sands and gravels overlying granite bedrock. Table 1 provides a summary of the bedrock and groundwater conditions for the bridge borings. The surface elevations, approximate bedrock depths/elevations, and approximate groundwater depths/elevations are presented to the nearest 0.5 feet. The groundwater depths and elevations are based on observations during drilling.

**Table 1. Summary of Bedrock and Groundwater Conditions**

Boring ID	Location <sup>1</sup> (Northing, Easting)	Ground Surface Elevation at Time of Drilling <sup>1</sup> (feet)	Approx. Depth to Top of Competent Bedrock <sup>1</sup> (feet)	Approx. Elevation to Top of Competent Bedrock <sup>1</sup> (feet)	Approx. Groundwater Depth <sup>1, 2</sup> (feet)	Approx. Groundwater Elevation <sup>1, 2</sup> (feet)
I-17-X-B-1	382852.8, 157766.1	7033.0	24.0	7009.0	19.0	7014.0
I-17-X-B-2	382851.6, 157722.4	7035.0	18.0	7017.0	15.0	7020.0

Notes:

(1) Surface elevations, approximate bedrock depths/elevations, and approximate groundwater depths/elevations are presented to the nearest 0.5 feet. Location and elevation are provided by project surveyor.

(2) Groundwater depths and elevations are based on observations during drilling.

## 3 BRIDGE FOUNDATION RECOMMENDATIONS

We understand that the replacement structure will consist of either a new bridge structure or a concrete box culvert structure (CBC). If a bridge structure is selected, then the abutments and piers will be supported on driven H-piles or drilled shafts. If a CBC structure is selected, then the structure will be founded on a shallow mat foundation. Wing walls for the bridge and CBC structures will be founded on shallow strip foundations.

Based on the subsurface conditions encountered during our preliminary study, our engineering analysis, and our experience with similar projects, it is our opinion that driven H-pile and drilled shaft foundations are suitable for support of the bridge structure. Shallow foundations are suitable for support of the CBC and wing wall structures. Recommendations for the drilled shafts are presented in Section 3.2, driven H-pile recommendations are provided in Section 3.3, and CBC foundation recommendations are presented in Section 3.4.

The soil and bedrock properties were estimated from penetration resistance, material descriptions, and laboratory data. The design and construction of the foundation elements should comply with all applicable requirements and guidelines listed in AASHTO (2020) and the CDOT Standard Specifications (CDOT 2019).



### 3.1 Shallow Foundation Recommendations

Based on the depth to competent bedrock and the anticipated loading requirements, it is our opinion that shallow foundations are not suitable to support the bridge abutments. Bedrock is anticipated up to about 10 to 20 feet below the existing channel bottom, and the relatively loose sands observed above the bedrock are not suitable for support of shallow foundations.

### 3.2 Drilled Shaft Recommendations

#### 3.2.1 Drilled Shaft Nominal Axial Resistance

The estimated bearing resistance should be developed from the side and tip resistance in the underlying competent bedrock. The resistance from the overburden soil should be neglected. We used unconfined compressive strength (UCS) and Standard Penetration Test (SPT) values to evaluate side and tip resistances in accordance with AASTHO LRFD (2020). The design approach in Abu-Hejleh et al. (2003) provides recommendations for the use of an updated Colorado SPT-based (UCSB) design method. In this design method, the nominal side and tip resistance of a drilled shaft in bedrock is proportional to the driven sampler penetration resistance. This approach was generally used to estimate the axial resistance in the bedrock where UCS test results were unavailable. Based on local practice, the modified California penetration resistance is considered to be equivalent to SPT penetration resistance, i.e. N value, in bedrock.

Table 2 contains the recommended values for the nominal side and tip resistance for drilled shafts founded in the underlying competent bedrock. The upper three feet of competent bedrock penetration shall not be used for drilled shaft resistance due to the likelihood of construction disturbance and possible additional weathering. To account for axial group effects, the minimum spacing requirements between drilled shafts should be three diameters from center-to-center.

**Table 2. Recommended Drilled Shaft Axial Resistance**

Reference Boring	Approximate Top of Competent Bedrock Elevation (feet)	Tip Resistance (ksf)		Side Resistance, (ksf)	
		Nominal	Factored ( $\Phi=0.5$ )	Nominal	Factored ( $\Phi=0.55$ )
I-17-X-B-1	7009.0	150	75	15	8.2
I-17-X-B-2	7017.0	150	75	15	8.2

#### 3.2.2 Drilled Shaft Lateral Resistance

The input parameters provided in Table 3 are recommended for use with the computer program LPILE to develop the soil models used to evaluate the drilled shaft response to lateral loading. Table 3 provides the estimated values associated with the soil types encountered in the borings. They can also be used for driven H-piles, which will be described in Section 3.3. The nature and type of loading should be considered carefully. Individual soil layers and their extent can be averaged or distinguished by referring to the boring logs at the locations of the proposed bridge. The soils and/or bedrock materials prone to future disturbance, such as from utility excavations or frost heave, should be neglected in the lateral load analyses to the depth of disturbance, which may require more than but should not be less than three feet.



Recommendations for p-y multiplier values ( $P_m$  values) to account for the reduction in lateral capacity due to group effects are provided in Section 10.7.3.12 of AASHTO (2020). The  $P_m$  value will depend on the direction of the applied load, center-to-center spacing, and location of the foundation element within the group.

**Table 3. LPILE Parameters**

Material Type	LPILE Soil Criteria	Effective Unit Weight (pcf)		Friction Angle, (deg.)	Unconfined Compressive Strength (psi)	Strain Factor, $\epsilon_{50}$	p-y modulus kstatic (pci)	
		AGT <sup>1</sup>	BGT <sup>2</sup>				AGT <sup>1</sup>	BGT <sup>2</sup>
Class 1 Structure Backfill	Sand (Reese)	130	67.5	34	-	-	90	60
Sand and Gravel	Sand (Reese)	125	62.5	33	-	-	90	60
Granite Bedrock	Strong Rock (Vuggy Limestone)	140	140	-	4,000	0.004	-	-

Note: <sup>1</sup>Above Groundwater Table  
<sup>2</sup>Below Groundwater Table

### 3.2.3 General Drilled Shaft Recommendations

The following recommendations can be used in the design and construction of the drilled shafts.

- Groundwater and potentially caving soils may be encountered during drilling depending on the time of year and location. The Contractor shall construct the drilled shafts using means and methods that maintain a stable hole.
- Bedrock may be very hard at various elevations. The contractor should mobilize equipment of sufficient size and operating condition to achieve the required design bedrock penetration.
- Drilled shaft construction shall not disturb previously installed drilled shafts. The drilled shaft concrete should have sufficient time to cure before construction on a drilled shaft within three shaft diameters (center to center spacing) begins to prevent interaction between shafts during excavation and concrete placement.
- Based on the results of the field investigation and experience with similar properly constructed drilled shaft foundations, it is estimated that foundation settlement will be less than approximately ½ inch when designed according to the criteria presented in this report.
- A representative of the Contractor’s engineer should observe drilled shaft installation operations on a full-time basis.

### 3.3 Driven H-Pile Recommendations

#### 3.3.1 Driven H-Pile Axial Resistance

Steel H-piles driven into bedrock may be designed for a nominal axial resistance equal to 34 kips per square inch (ksi) multiplied by the cross-sectional area of the pile for piles composed of Grade 50 ksi steel for use with LRFD Strength Limit State design. Piles should be driven to refusal into the underlying bedrock as defined in Section 502.05 of CDOT (2019). A wave equation analysis using the Contractor’s pile driving equipment is necessary to estimate pile drivability.



Based on the strength of the granite bedrock encountered during our investigation, it is likely that refusal will be met within the upper 1 to 2 feet of bedrock. Holes may need to be pre-drilled to meet the requirement for pile design tip elevations.

### 3.3.2 Driven H-Pile Axial Resistance Factors

Assuming a pile driving analyzer (PDA) is used to monitor pile driving per Section 502 of CDOT (2019), a resistance factor of 0.65 may be used per AASHTO (2020) Table 10.5.5.2.3-1. Section 502.05 of CDOT (2019) stipulates that if PDA is used, a minimum of one PDA monitoring per bridge bent be performed to determine the condition of the pile, efficiency of the hammer, static bearing resistance of the pile, and to establish pile driving criteria. Per AASHTO (2020) recommendations, a resistance factor of 0.5 can be used for wave equation analysis only without pile dynamic measurements such as PDA monitoring. Per AASHTO (2020) recommendations, a resistance factor of 0.75 may be used if a successful static load test is conducted per site condition.

### 3.3.3 Driven H-Pile Lateral Resistance

The information provided previously in Section 3.2.2 may be used to evaluate H-pile lateral resistance.

### 3.3.4 General Driven H-Pile Recommendations

The following recommendations are for the design and construction of driven H-piles.

1. Based on the results of the field exploration and our experience with similar properly constructed driven pile foundations, it is estimated that settlement will be less than approximately  $\frac{1}{2}$  inch when designed according to the criteria presented in this report.
2. A minimum spacing requirement for the piles should be three diameters (equivalent) center to center.
3. Driven piles should be driven with protective cast steel pile points or equivalent to provide better pile tip seating and to prevent potential damage from coarse soil particles, which may be present at the site.
4. A qualified representative of the Contractor's engineer should observe pile-driving activities on a full-time basis. Piles should be observed and checked for crimping, buckling, and alignment. A record should be kept of embedment depths and penetration resistances for each pile.
5. It is estimated that the piles will penetrate approximately 1 to 2 feet into competent bedrock (see Table 1 for the estimated elevation for the top of competent bedrock). The final tip elevations will depend on bedrock conditions encountered during driving.
6. If the pile penetration extends below the estimated pile penetration into bedrock by 10 feet or more, the pile driving operations should be temporarily suspended for dynamic monitoring with PDA. We recommend that the subject pile be allowed to rest overnight or longer before restriking and monitoring the beginning-of-restrike with a PDA. The data collected with the PDA shall then be reduced using the software CAPWAP to determine the final nominal pile resistance. The pile driving criteria may be modified by CDOT's or the Contractor's engineer based on the PDA/CAPWAP results.

## 3.4 CBC Foundation Recommendations

Shallow bedrock was encountered in I-17-X-B-2. Bedrock encountered within 2 feet of the bottom of the foundations should be over-excavated to allow for a minimum of 2-feet of structural fill below the CBC and wing wall foundations extending to the top of bedrock. To assure adequate foundation support and to minimize the potential for differential settlement, we recommend that the exposed subgrade soils should be scarified a



minimum of 6 inches, moisture conditioned, and re-compacted in accordance with Section 203.07 of the CDOT Standard Specifications (2019) before the placement of structural elements or structural backfill. If unsuitable or soft materials are encountered after the excavation, the materials may be removed and replaced with CDOT Class 1 Structure Backfill in accordance with Section 203.07 of the CDOT Standard Specifications (2019). Visual inspection of the foundation excavations should be performed by a qualified representative of the Geotechnical Engineer of record to identify the quality of the foundation materials prior to placement of backfill and the CBC. Groundwater may be encountered during excavation for the subgrade preparation. Groundwater control systems may be required to prevent seepage migrating into the construction zone by creating groundwater cut-off and/or dewatering systems.

The recommended nominal bearing resistance using Strength Limit State for the CBC and associated wing walls for both moist and saturated conditions are provided in Table 4. We assume the materials in contact with the bottom of the proposed CBC and wing walls will consist of native sandy soils or CDOT Class 1 Structure Backfill placed in accordance with Section 203.07 of the CDOT Standard Specifications (2019). The reduced footing width due to eccentricity can be calculated based on the recommendations in Sections 11.6.3.2 and 11.10.5.4 of AASHTO (2020). A bearing resistance factor of 0.45 may be used for shallow foundations based on the recommendations in Table 10.5.5.2.2-1 of AASHTO (2020).

**Table 4. Bearing Resistance for CBC and Wing Walls on Shallow Foundation**

Soil Conditions	Nominal Bearing Resistance (ksf) <sup>1, 2</sup>
Moist	$3.5 + 2.1 * B'$
Saturated	$1.7 + 1.1 * B'$

<sup>1</sup> B' is the footing width in feet reduced for eccentricity (e).  $B' = B - 2e$ , where B is the nominal foundation width.  
<sup>2</sup> The calculated nominal bearing resistance is based on a minimum 12 inches of embedment and shall be limited to 15 ksf.

The proposed CBC will be at the location of the existing CBC, and as needed, a portion of the CBC will be in a cut area, therefore it is estimated that the total settlement of the structure will be minimal and will occur during construction. The structure settlement is partially controlled by the weight of the adjacent embankment fill. Thus, it is recommended that the embankment fill on both sides of the CBC be placed at a relatively uniform elevation.

Resistance to sliding at the bottom of foundations can be calculated based on a coefficient of friction at the interface between the pre-cast concrete and the existing native soils or compacted CDOT Class 1 Structure Backfill. The recommended nominal coefficients of friction and the corresponding resistance factors for Class 1 Structure Backfill and native soils are provided in Table 5.

**Table 5. Coefficients of Friction for CBC and Wing Walls on Shallow Foundation**

Foundation Soil Type	Coefficient of Friction	Resistance Factor
Class 1 Structure Backfill	0.53	0.9
Native Sand/Gravel	0.36	0.8





Backfill adjacent to the CBC should be Class 1 Structure Backfill, compacted with moisture density control. Backfill materials shall have a Class 0 for severity of sulfate exposure. Fill should be tested for severity of sulfate exposure prior to acceptance.

The passive pressure against the sides of the foundation is typically ignored; however, passive resistance can be used if long-term protection from disturbance, such as frost heave, future excavations, etc., is assured. Table 6 presents recommendations for the passive soil resistances for the encountered soil conditions. The passive resistance estimates are calculated from Figure 3.11.5.4-1 in AASHTO (2020) where a portion of the slip surface is modeled as a logarithmic spiral, the backslope is horizontal and the passive soil/concrete interface friction angle is equal to 60 percent of the soil’s friction angle.

The recommended passive earth pressure resistances are presented in terms of an equivalent fluid unit weight for moist and saturated conditions. The recommended passive earth pressure values assume mobilization of the nominal soil/concrete foundation interface shear strength. A suitable resistance factor should be included in the design to limit the strain, which will occur at the nominal shear strength, particularly in the case of passive resistance. The resultant passive earth force, calculated from the equivalent fluid unit weight, should be applied at a point located 1/3 of the height of the soil (in contact with the foundation) above the base of the foundation, directed upward at an angle of 20 degrees from the horizontal.

**Table 6. Passive Soil Resistance for CBC**

Passive Soil Resistance	Soil Type	Nominal Resistance	Resistance Factor
	Moist	424 psf/ft	0.50
	Saturated	212 psf/ft	0.50

**3.5 Lateral Earth Pressures**

External loads used in the analyses of the bridge abutments and wing walls should include earth pressure loads, traffic loads, and any other potential surcharge loads. Typical drainage details consisting of inlets near the abutments, geocomposite strip drains, and perforated pipes shall be included in the design to properly contain and transfer surface and subsurface water without saturating the soil around the abutments and walls.

All abutment and wing wall backfill materials should meet the requirements for CDOT Structure Backfill Class 1 in accordance with CDOT (2019). All backfill adjacent to the abutments and walls shall be placed and compacted in accordance with CDOT (2019). It is recommended that compaction of backfill materials be observed and evaluated by an experienced Contractor’s engineer or Contractor’s engineer’s representative.

A lateral wall movement or rotation of approximately 0.1 to 0.2 percent of the wall height may be required to mobilize active earth pressure for the recommended backfill materials. If the estimated wall movement is less than this amount, an at-rest soil pressure should be used in design. In order to mobilize passive earth pressure, lateral wall movement or rotation of approximately 1.0 to 2.0 percent of the wall height may be required for the recommended backfill materials. It should be carefully considered if this amount of movement can be accepted before passive earth pressure is used in the design.

Earth pressure loading within and along the back of the bridge abutments and wing walls shall be controlled by the structural backfill. We recommend that active, at-rest, and passive lateral earth pressures used for the design of the structures be based on an effective angle of internal friction of 34 degrees, and a unit weight of



135 pounds per cubic foot (pcf) for CDOT Structure Backfill Class 1. The following can be used for design assuming a horizontal backslope:

- Active earth pressure coefficient ( $k_a$ ) of 0.28
- Passive earth pressure coefficient ( $k_p$ ) of 3.53
- At-rest earth pressure coefficient ( $k_0$ ) of 0.44

Lateral earth pressures for a non-horizontal backslope can be estimated using section 3.11 in AASHTO (2020).

### 3.6 Bridge Scour Parameters

A bulk sample of the creek bed soils/rock below the existing structure was collected for gradation analysis. The results of the grain size analysis are presented in Appendix C.

## 4 BRIDGE APPROACH PAVEMENT

Pavement borings were located approximately 100 feet beyond the existing CBC on each side. Prior to drilling, the existing pavement was cored with a 4-inch nominal diameter core barrel. Photos of the pavement core, logs of the subsurface soils/rock, and results of geotechnical and analytical laboratory testing are presented in the appendices. Bulk soil samples were collected from the pavement borings and combined for classification, strength (R-value), and analytical testing. The asphalt pavement thicknesses, aggregate base thicknesses (if present), subgrade soil classifications, and subgrade R-values are presented in Table 7. Analytical test results are presented in Table 8. Preliminary pavement design will be completed by CDOT Staff Materials.

**Table 7. Existing Pavement Section and Subgrade Properties**

Boring ID	Existing Asphalt Concrete Thickness (in)	Aggregate Base Thickness (in)	Subgrade Soil Classification (AASHTO) <sup>1</sup>	R-Value <sup>1</sup>
I-17-X-P-1	10.0	Not Encountered	A-1-b (0)	76
I-17-X-P-2	8.0	Not Encountered		

Note: <sup>1</sup> Subgrade Classification and R-value test results based on combined bulk sample from each pavement boring

## 5 ANALYTICAL TEST RESULTS

Analytical testing was completed on representative samples of soils encountered in the borings. The test results can be found in Appendix C and are summarized in Table 8. The Analytical results should be used to select the proper concrete type for the project in accordance with CDOT Standard Specifications (2019). A qualified corrosion engineer should review the laboratory data and boring logs to determine the appropriate level of corrosion protection for materials in contact with these soils.

**Table 8. Analytical Test Results**

Boring ID	Material	Water Soluble Sulfates, %	Water Soluble Chlorides, %	pH	Resistivity, ohm-cm
I-17-X-P-1/P-2	Silty Sand (Fill)	0.004	0.0130	-	-
I-17-X-B-1	Silty Sand	0.012	0.0094	8.5	2053



## 6 SEISMIC CONSIDERATIONS

No active faults are known to exist in the immediate vicinity of the proposed structure location. Based on the site class definitions provided in Table 3.10.3.1-1 of AASHTO LRFD (2020), the site can be categorized as Site Class C. Also based on the recommendations in Table 3.10.6-1 of AASHTO LRFD (2020), the bridge site can be classified as Seismic Zone 1.

The peak ground acceleration (PGA) and the short- and long- period spectral acceleration coefficients ( $S_s$  and  $S_1$ , respectively) for Site Class B (reference site class) were determined using the seismic design maps from the USGS website. The seismic design parameters for Site Class C are shown in Table 9.

**Table 9. Seismic Design Parameters**

PGA (0.0 sec)	$S_s$ (0.2 sec)	$S_1$ (1.0 sec)
0.059 g	0.127 g	0.036 g
$A_s$ (0.0 sec)	$S_{DS}$ (0.2 sec)	$S_{D1}$ (1.0 sec)
0.071 g	0.153 g	0.062 g

## 7 LIMITATIONS

Our scope of services was performed, and this report was prepared in accordance with generally accepted principles and practices in this area at the time this report was prepared. We make no other warranty, either express or implied.

The classifications, conclusions, and recommendations submitted in this report are based on the data obtained from published and unpublished maps, reports, and geotechnical analyses. Our conclusions and recommendations are based on our understanding of the project as described in this report and the site conditions as interpreted from the explorations. This data may not necessarily reflect variations in the subsurface conditions and water levels occurring at other locations.

The nature and extent of subsurface variations may not become evident until excavation is performed. Variations in the data may also occur with the passage of time. If during construction, fill, soil, rock, or groundwater conditions appear to be different from those described in this report, this office should be advised immediately so we could review these conditions and reconsider our recommendations. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed because of natural forces or construction operations at or adjacent to the site, we recommend that this report be reviewed to determine the applicability of the conclusions and recommendations concerning the changed conditions or time lapse. We recommend on-site observation of foundation excavations and foundation subgrade conditions by an experienced geotechnical engineer or engineer's representative.

The scope of services of this study did not include hazardous materials sampling or environmental sampling, investigation, or analyses. In addition, we did not evaluate the site for potential impacts to natural resources, including wetlands, endangered species, or environmentally critical areas.



## 8 REFERENCES

AASHTO LRFD, 9<sup>th</sup> Edition. AASHTO Load Resistance Factor Design (LRFD) Bridge Design Specifications, Eight Edition. Washington, DC: American Association of State Highway and Transportation Officials. 2020.

Abu-Hejleh, N., O'Neill, M.W., Hanneman, Dennis, Atwooll, W.J., 2003. Improvement of the Geotechnical Axial Design Methodology for Colorado's Drilled Shafts Socketed in Weak Rocks, Final Report: Colorado Department of Transportation Research Branch, July 2003, Report No. CDOT-DTD-R-2003-6.

Colorado Department of Transportation, 2019. CDOT Standard Specifications for Road and Bridge Construction. 2019 Edition.

Respectfully Submitted,  
**YEH AND ASSOCIATES, INC.**

Prepared by:



Cory S. Wallace, EIT, GIT  
Staff Engineer

Reviewed by:



JG T. McCall, PE  
Senior Project Engineer

Independent Technical Review by:



Hsing-Cheng Liu, PE, PhD  
Senior Project Manager

Attachments:

- Appendix A
- Appendix B
- Appendix C

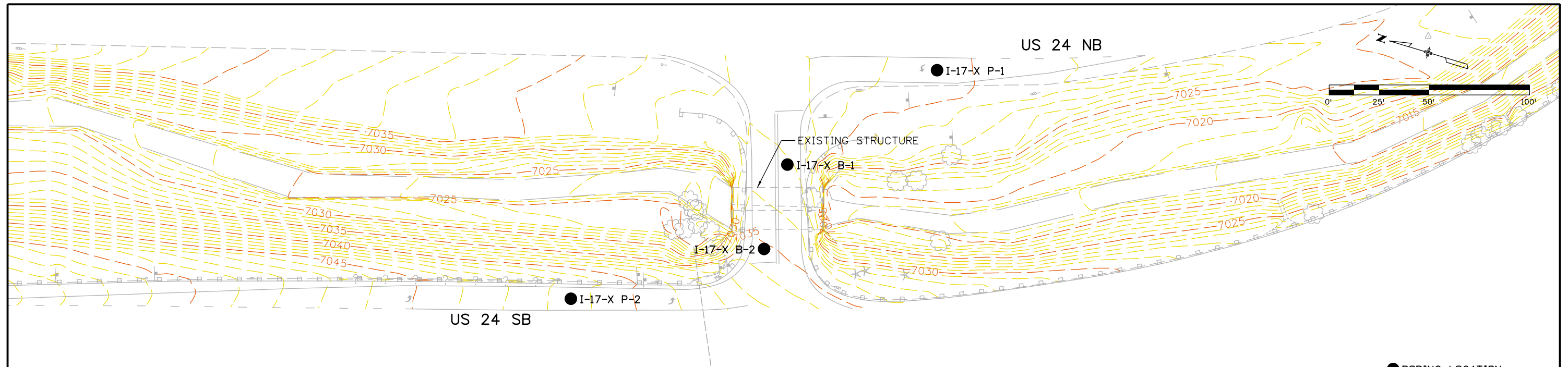
## APPENDIX A

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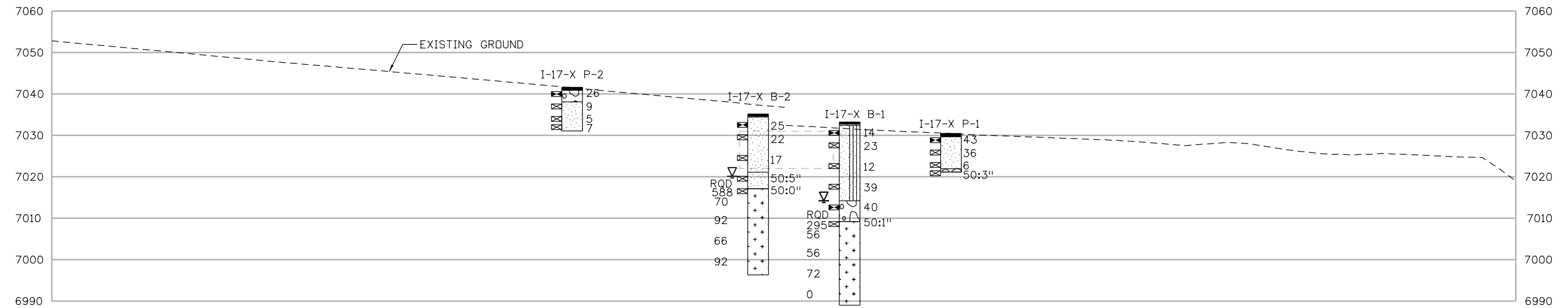
## ENGINEERING GEOLOGY SHEET



mwalz 7:43:07 AM pw:\cdot-pw-bentley.com\dot-pw-01P\Documents\01 Major Projects\R2B2 (REGION 2 BRIDGE BUNDLE)\Legacy Data\23559 - R2B2 (REGION 2 BRIDGE BUNDLE)\NON-GRANT\Materials\_Geotechnical\Drawings\23558GDOT\_Engineering\_Geology



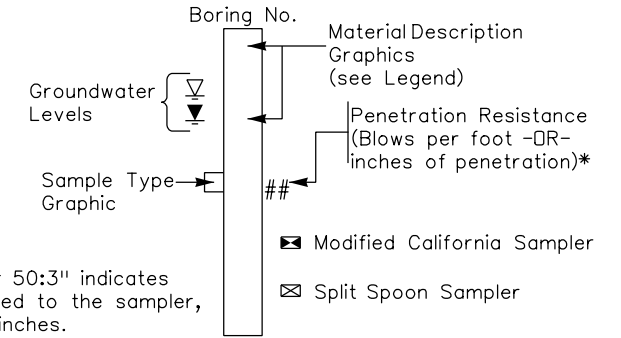
● BORING LOCATION



**LEGEND**

- Asphalt
- USCS Poorly-graded Sand with Silt
- Cobbles and gravel
- Fill with Gravel as major soil
- USCS Poorly-graded Gravel
- Granite
- Fill
- USCS Poorly-graded Sand

**TYPICAL BOREHOLE LOG**



\*e.g. A value of 50/3 or 50:3" indicates that 50 blows were applied to the sampler, with a penetration of 3 inches.

Print Date: 2/4/2021	0000
File Name: 23558GDOT_Engineering Geology I-17-X.dgn	
Horiz. Scale: 1:50      Vert. Scale: As Noted	
Unit Information      Unit Leader Initials	

Sheet Revisions		
Date:	Comments	Init.

**Colorado Department of Transportation**

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Phone: 719-634-2323  
FAX: 719-227-3298

<b>As Constructed</b>
No Revisions:
Revised:
Void:

<b>R2 BRIDGE BUNDLE ENGINEERING GEOLOGY</b>			
Designer:	JTM	Structure Numbers	I-17-X
Detailer:	MJW	Subset Sheets:	1 of 1

<b>Project No./Code</b>
STM R200-262
23559
Sheet Number

## **APPENDIX B**

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**KEY TO BORING LOGS**

**BORING LOGS**

**PAVEMENT CORE PHOTOS**

**ROCK CORE PHOTOS**



# Legend for Symbols Used on Borehole Logs

## Sample Types



Bulk Sample of auger/odex cuttings



Rock core



Modified California Sampler (2.5 inch OD, 2.0 inch ID)



Standard Penetration Test (ASTM D1586)

## Drilling Methods



CORING



HOLLOW-STEM AUGER

## Lithology Symbols (see Boring Logs for complete descriptions)



Asphalt



Cobbles and gravel



USCS Fat/High Plasticity Clay



USCS Lean/Low Plasticity Clay



Fill



Fill with Clay as major soil



Fill with Gravel as major soil



USCS Clayey Gravel



USCS Silty, Clayey Gravel



USCS Poorly-graded Gravel



USCS Poorly-graded Gravel with Clay



Low Plasticity Gravelly Clay



USCS Silt



USCS Low Plasticity Organic silt or clay



High Plasticity Sandy Clay



Poorly-graded Sandy Gravel



Low Plasticity Sandy Clay



USCS Clayey Sand



USCS Silty Sand



USCS Poorly-graded Sand



Cobbles and gravel



Diorite



Gneiss



Granite



Limestone



Sandstone



Shale



Weathered Bedrock

## Lab Test Standards

Moisture Content	ASTM D2216
Dry Density	ASTM D7263
Sand/Fines Content	ASTM D421, ASTM C136, ASTM D1140
Atterberg Limits	ASTM D4318
AASHTO Class.	AASHTO M145, ASTM D3282
USCS Class.	ASTM D2487
(Fines = % Passing #200 Sieve)	
Sand = % Passing #4 Sieve, but not passing #200 Sieve)	

## Other Lab Test Abbreviations

pH	Soil pH (AASHTO T289-91)
S	Water-Soluble Sulfate Content (AASHTO T290-91, ASTM D4327)
Chl	Water-Soluble Chloride Content (AASHTO T291-91, ASTM D4327)
S/C	Swell/Collapse (ASTM D4546)
UCCS	Unconfined Compressive Strength (Soil - ASTM D2166, Rock - ASTM D7012)
R-Value	Resistance R-Value (ASTM D2844)
DS (C)	Direct Shear cohesion (ASTM D3080)
DS (phi)	Direct Shear friction angle (ASTM D3080)
Re	Electrical Resistivity (AASHTO T288-91)
PtL	Point Load Strength Index (ASTM D5731)

## Notes

1. Visual classifications are in general accordance with ASTM D2488, "Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)".
2. "Penetration Resistance" on the Boring Logs refers to the uncorrected N value for SPT samples only, as per ASTM D1586. For samples obtained with a Modified California (MC) sampler, drive depth is 12 inches, and "Penetration Resistance" refers to the sum of all blows. Where blow counts were > 50 for the 3rd increment (SPT) or 2nd increment (MC), "Penetration Resistance" combines the last and 2nd-to-last blows and lengths; for other increments with > 50 blows, the blows for the last increment are reported.
3. The Modified California sampler used to obtain samples is a 2.5-inch OD, 2.0-inch ID (1.95-inch ID with liners), split-barrel sampler with internal liners, as per ASTM D3550. Sampler is driven with a 140-pound hammer, dropped 30 inches per blow.
4. "ER" for the hammer is the Reported Calibrated Energy Transfer Ratio for that specific hammer, as provided by the drilling company.







**Boring Began: 9/2/2020**

**Total Depth: 44.2 ft**

**Weather Notes: Sunny, 67F**

**Boring Completed: 9/2/2020**

**Ground Elevation: 7033**

**Inclination from Horiz.: Vertical**

**Drilling Method(s): Hollow-Stem Auger / Wireline Coring**

**Coordinates: N: 382852.8 E: 157766.1**

**Location: US 24, westbound turn lane**

**Night Work:**

**Driller: Vine Laboratories**

**Logged By: B. Lykins**

**Drill Rig: CME 750X Buggy**

**Final By: J. McCall**

**Hammer: Automatic (hydraulic), ER: 80%**

**Groundwater Levels:**

Symbol	▽		
Depth	19.0 ft	-	-
Date	9/2/20	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Rock		Soil Samples		Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits		AASHTO & USCS Classifications	Field Notes and Other Lab Tests
				Recovery (%)	RQD (%)	Blows per 6 in	Penetration Resistance								Liquid Limit	Plasticity Index		
7030	5					8-6	14		0.0 - 0.5 ft. ASPHALT (6 inches).									
									0.5 - 0.8 ft. AGGREGATE BASE COURSE (3 inches) (Fill).									
						9-13-10	23		0.8 - 19.0 ft. Poorly graded SAND with silt and gravel (SP-SM), dark brown with gray, moist, medium dense to dense.									
7025	10					6-6-6	12											
7020	15					5-11-28	39			9.2	37.0	47.5	15.5					
7015	20					18-22	40		19.0 - 24.0 ft. Poorly graded GRAVEL with sand (GP), reddish brown, wet, dense, granite fragments.									
7010						50:1"	50:1"		24.0 - 44.2 ft. GRANITE, pink, strong; highly fractured 24-27.7									pH=8.5 S=0.012% ChI=0.0094% Re=2053ohm:cm

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 12/10/20









Boring:	P-1	AC:	10"
Roadway:	US 24	PCC:	-
Direction:	Westbound	Base:	-
Lane:	Turn Lane	Notes:	-



Boring:	P-2	AC:	8"
Roadway:	US 24	PCC:	-
Direction:	Eastbound	Base:	-
Lane:	Turn Lane	Notes:	-



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**Pavement Core Photographs**

FIGURE

PROJECT NO. 220-063 DATE: 12/7/2020  
 FIGURE BY: BHL YEH OFFICE: Colorado Springs  
 CHECKED BY: JTM

CDOT Region 2 Bridge Bundle  
 Structure I-17-X

**B-1**



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PROJECT NO.	220-063	DATE:	12/6/2020
FIGURE BY:	BHL	YEH OFFICE:	BHL
CHECKED BY:	JTM		

**Rock Core Photos**  
**Boring: B-1**  
**Depth: 24' - 34.6'**

CDOT Region 2 Bridge Bundle  
 Structure I-17-X

FIGURE

**B-2**





**Yeh and Associates, Inc.**

Geotechnical • Geological • Construction Services

PROJECT NO.	220-063	DATE:	12/6/2020
FIGURE BY:	BHL	YEH OFFICE:	Colorado Springs
CHECKED BY:	JTM		

**Rock Core Photos**  
**Boring: B-1**  
**Depth: 34.6' - 44.2'**

CDOT Region 2 Bridge Bundle  
 Structure I-17-X

FIGURE

**B-3**

## APPENDIX C

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### SUMMARY OF LABORATORY TEST RESULTS



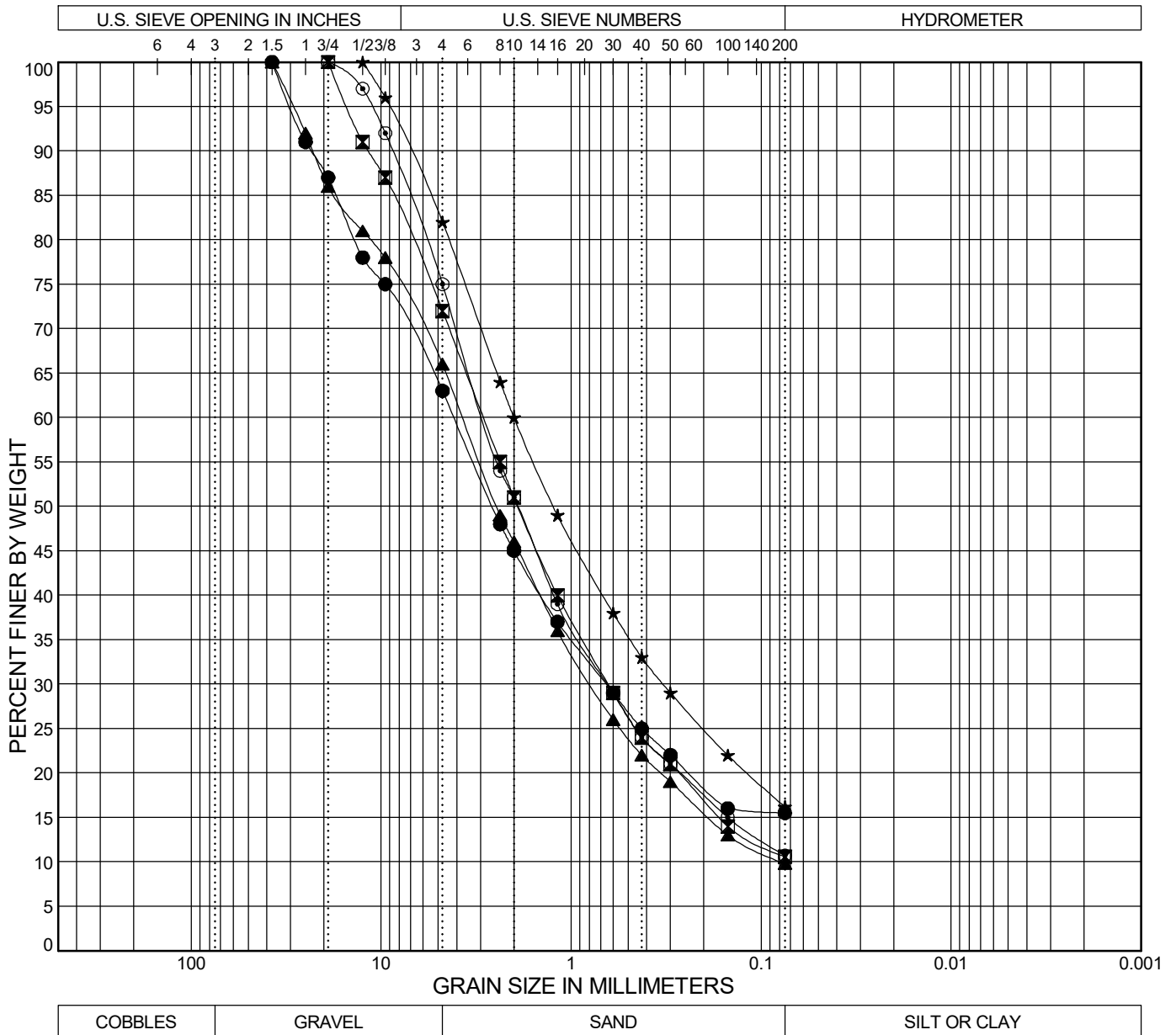


## Summary of Laboratory Test Results


Project No: 220-063      Project Name: CDOT Region 2 Bridge Bundle      Date: 12-06-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
I-17-X Scour	0	BULK	0.4		55.0	44.3	0.7	NV	NP	NP								A-1-a (0)	GW
I-17-X-B-1	15.0	SPT	9.2		37.0	47.5	15.5				8.5	0.012	0.0094	2053					
I-17-X-B-1	25.7	CORE													8930				
I-17-X-B-2	15.0	SPT	8.6		28.0	61.4	10.6												
I-17-X-B-2	18.7	CORE													4040				
I-17-X-P-1	1.0	MC	3.1		34.0	56.2	9.8												
I-17-X-P-1/P-2	2.5	BULK	1.4		18.0	65.8	16.2	24	22	2		0.004	0.0130			76		A-1-b (0)	SM
I-17-X-P-2	4.0	SPT	1.2		25.0	64.3	10.7												

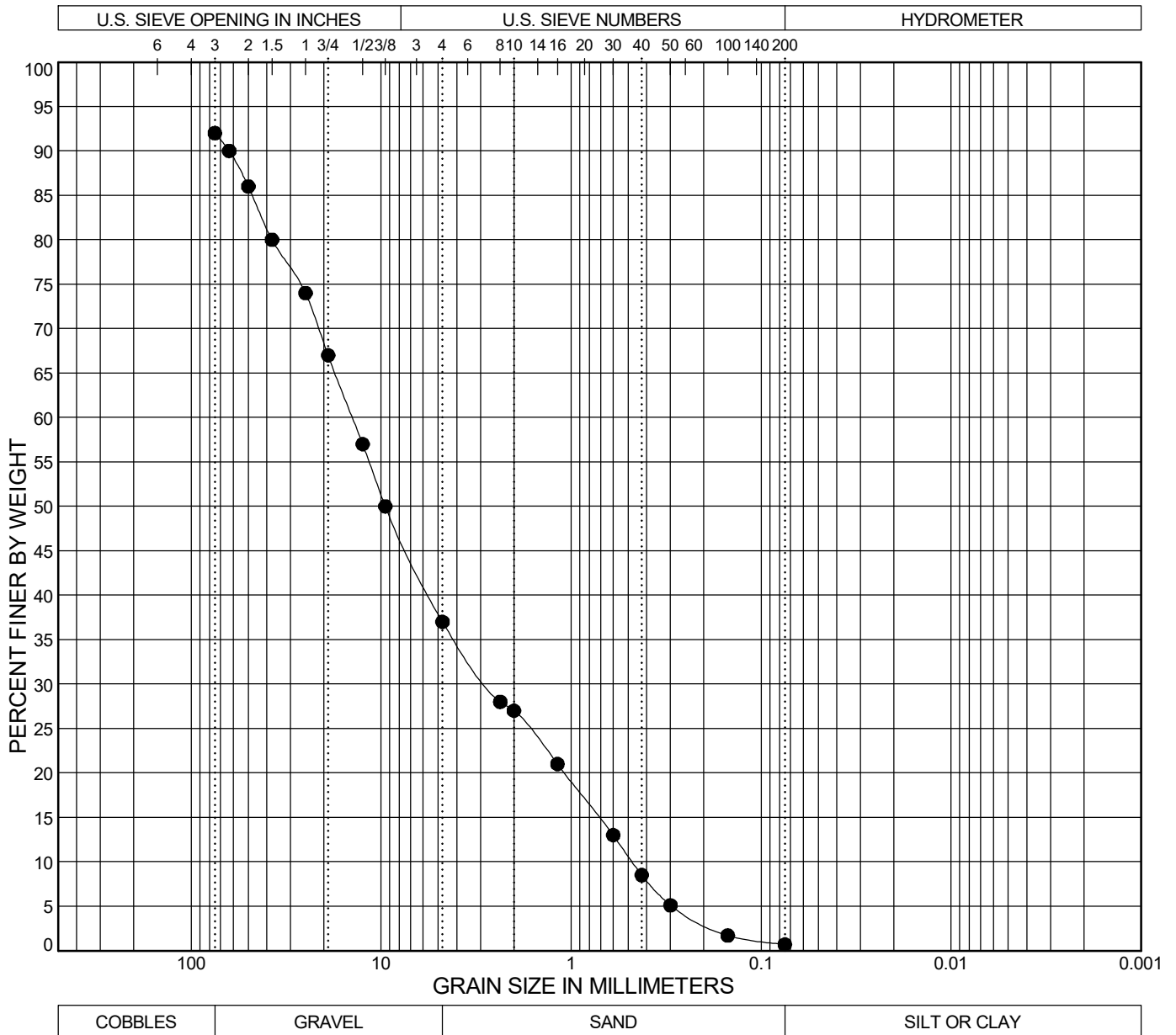
03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE GP.J 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 12/6/20




BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
									%Silt	%Clay
● I-17-X-B-1	15.0						37.0	47.5	15.5	
■ I-17-X-B-2	15.0						28.0	61.4	10.6	
▲ I-17-X-P-1	1.0						34.0	56.2	9.8	
★ I-17-X-P-1/P-2	2.5	A-1-b (0)	SM	24	22	2	18.0	65.8	16.2	
◎ I-17-X-P-2	4.0						25.0	64.3	10.7	

 <b>Yeh and Associates, Inc.</b> Geotechnical • Geological • Construction Services	<h2>SIEVE ANALYSIS</h2>	<h2>FIGURE</h2>
Project No. 220-063      Date: 12-06-2020 Report By: D. Gruenwald      Yeh Lab: Colorado Springs Checked By: J. McCall		

03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 12/6/20



BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
									%Silt	%Clay
● I-17-X Scour	0.0	A-1-a (0)	GW	NV	NP	NP	55.0	36.3	0.7	

 <b>Yeh and Associates, Inc.</b> Geotechnical • Geological • Construction Services	<h2>SIEVE ANALYSIS</h2>	<h2>FIGURE</h2>
Project No. 220-063      Date: 12-06-2020 Report By: D. Gruenwald      Yeh Lab: Colorado Springs Checked By: J. McCall	CDOT Region 2 Bridge Bundle Structure I-17-X	





## R Value ASTM D2844

CLIENT	Yeh & Associates	BORING NO.	I-17-X
JOB NO.	2546-128	DEPTH	Combined Bulk
PROJECT	--	SAMPLE NO.	P-1/P-2
PROJECT NO.	220-063	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	11/18/20	DESCRIPTION	--
TECHNICIAN	ALH		

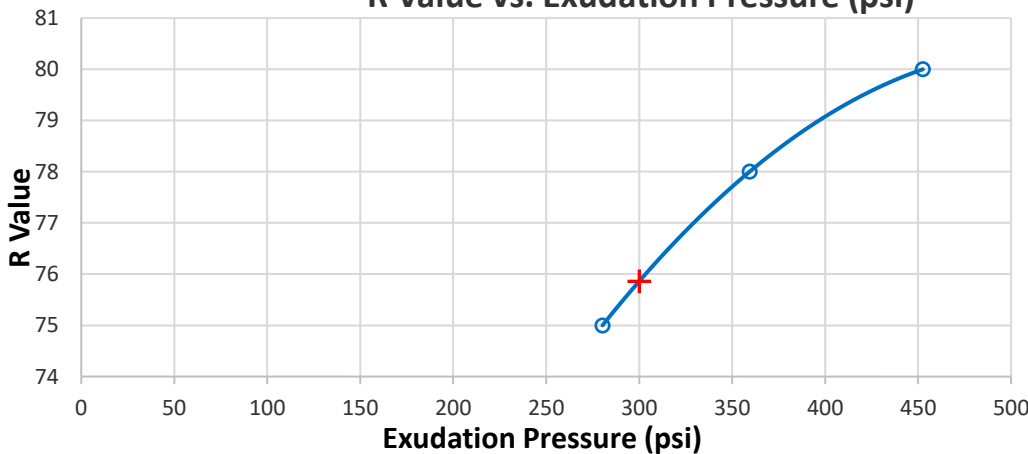
### Sample Conditions

Mass of Wet Soil & Pan (g):	1289.4	1201.0	1438.5
Mass of Dry Soil & Pan (g):	1212.3	1124.0	1361.5
Mass of Pan (g):	114.5	14.4	260.2
Mass of Wet Soil & Mold (g):	3284.9	3294.3	3279.9
Mass of Mold (g):	2110.8	2104.4	2101.8
Sample Height (in):	2.52	2.53	2.54
Wet Density (pcf):	141.2	142.6	140.6
Dry Density (pcf):	132.0	133.3	131.4
Wet Density (kg/m³):	2263	2284	2252
Dry Density (kg/m³):	2114	2136	2105
Moisture (%):	7.0	6.9	7.0

### R Value Data

Exudation Pressure (lbs):	5687	3522	4516
Exudation Pressure (psi):	452.6	280.3	359.4
2000 lbs. Dial Reading (psi):	19	24	21
Displacement Turns:	4.54	4.66	4.56
Uncorrected R Value:	80	75	78
Corrected R Value:	80	75	78

**R Value vs. Exudation Pressure (psi)**



Corrected R Value at 300 psi  
Exudation Pressure

**76**

**NOTES:**

Data entry by: ALH  
 Checked by: KMS  
 File name: 2546128\_R Value ASTM D2844\_1.xlsm

Date: 11/20/20  
 Date: 11/23/20