COLORADO
Department of Transportation

CDOT Project NO. FBR R200-266
CDOT Subaccount No. 23558

STRUCTURE ALTERNATIVES EVALUATION REPORT

Region 2 Bridge Bundle Design Build Grant Project

Preliminary Design and Procurement Support Services

Structure H-13-N

(Region 2 – US 24 MP 240.686)

Prepared for: Colorado Department of Transportation Region 2
5615 Wills Blvd.
Pueblo, CO 81008

Prepared by: Inna E. Pushkarova, PE
PushkarovaInna@StanleyGroup.com
T:720.460.4742

Stanley Consultants

Stanley Consultants Project No. 29715
January 2021

Table of Contents

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 constrains.

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 prosses:

- 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 will consist of single ALBC 83 Arch Structures by Contech Solutions. The width of the proposed construction must accommodate two 12.0 ft lanes of traffic with 8.0 ft minimum shoulders, and the Colorado current standard Bridge Rail on each side. The proposed length will be 43.0 ft. 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

Existing structure is a one-span treated timber stringer bridge built in 1937 to span a Middle Fork South Platte River. The bridge does not have skew and was based on a CDOT Standard P-117-B-H. The existing bridge consist of one 23.0 ft span, has a curb-to-curb width of 29.0 ft, and out - to-out deck width of 30.0 ft. The existing vertical clearance varies from 6.0 ft to 9.0 ft. The existing bridge framing consists of 14 rows of 6 in x 20 in wood stringers spaced at 2 ft 3.25 in. The bridge deck consists of 3 in x 6 in wood planks.

The abutments consist of 1.0 ft square wood beam abutment caps supported by (7) 1.0 ft diameter timber piles. The abutment piles are spaced at approximately 5.0 ft. There are 4 wood wingwalls at the existing bridge. The wingwalls are 10 ft long and vary in height. Each wingwall is supported by (3) 1.0 ft diameter piles. The existing bridge railing is a steel Bridge Rail Type 10R attached to the outside edge of the deck.

The bridge is located on SH 24, 1.5 miles east of Hartsel, Colorado, at milepost 240.686. Table 1 summarizes bridge information.

National Bridge Structure Number	H-13-N
Year Built	1937
Construction Type	Treated timber stringer
Condition Rating	Poor
Load Restricted	No
Bridge Length	24.4 feet
Bridge Width	30 feet
Number of spans	1
Water Crossing	Middle Fork South Platte River
AADT	3,300
Percent Commercial Traffic	6.8%

Table 1 – Bridge H-13-N Summary Information

Picture 1 – Bridge H-13-N General Location

The replacement of Bridge H-13-N is warranted due to the age and deteriorating conditions. Abutment wood is water stained and shows signs of deterioration. Some of the abutment backing planks are missing and separated. Rock riprap (1 ft to 2 ft diameter) has been placed behind the remaining planks.

Abutment piles are being pushed and are splitting at the tops due to the spikes through the caps which are being held back by the girders. All piles have been retrofitted with steel gusset plate connections at each column bearing point to prevent further movement. Pushing has caused the caps to tip slightly and some loss of bearing between piles and caps. The deck and girders are in decent conditions with some treatment remaining.

Picture 2 – Girders, Abutment Backing and Piles

Picture 3 – Abutment and Wingwall

2.2. RIGHT OF WAY IMPACT

The existing right of way (ROW) is located approximately 50.0 ft from the centerline of the existing road on either side of the road. 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 SH 24. Temporary construction easements may be required for drainage erosion control.

2.3. TRAFFIC DETOUR

As stated by the CDOT grant application, the roadway shall not be closed for construction. Two other alternatives were investigated:

1. Phasing the constructions by incorporating shifting alignment: keep one lane open over the existing structure while portion of the proposed structure is constructed on the new alignment. To meet all typical CDOT roadway phased construction criteria, this alternative can be constructed keeping at least half of the existing bridge open to traffic.

2. Building a one-lane or two-lane shoofly on either side of the existing bridge with a temporary pipe placed for drainage.

Alternative 2 (shoofly) was identified as a preferred traffic alternative for this structure. Both one-lane and two-lane shoofly have been investigated. The preferred option is a one-lane shoofly, constructed south of the existing bridge, which avoids wetland impact.

2.4. UTILITIES

Stanley subcontracted with Lamb-Star Engineering to provide utility location services in the vicinity of the structure. There is an underground fiberoptic line located parallel to ROW line on the north side of the road, approximately 45.0 ft from the centerline of the existing roadway.

There are no other known 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, H-13-N B-1 and H-13-N B-2, were drilled by Yeh in the vicinity of the existing bridge, and two pavement borings, H-13-N P-1 and H-13-N P-2, were drilled along the existing pavement approximately 250 feet from the bridge.

The bridge borings encountered sands, gravels, silt and clay soils in various mixture overlying shale 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)
H-13-N-B-1	1436802.6, 2925066.0	8828.5	25	8803.5	10	8818.5
H-13-N-B-2	1436787.1, 2925031.7	8828.5	30	8798.5	10	8818.5

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. If arch alternative is used, it will be supported on a shallow foundation system such as reinforced concrete strip footing. Design and construction for the shallow foundation system should take into consideration the scour potential at the proposed site. The bottom of the shallow foundation should be a minimum of 36-inches below the exterior ground surface for frost protection and should be founded on a minimum of 2 ft of properly placed CDOT Class 1 Structure Backfill.

2.6. HYDRAULICS SUMMARY

Structure H-13-N crosses over the Middle Fork South Platte River. The Federal Emergency Management Agency (FEMA) has designated the project site as a FEMA Zone A. The design 100-Year flow rate is 14,745 cfs. An SRH-2D model was developed at this location. The results of the hydraulic analysis demonstrate that the existing bridge overtops during the 100-year event. It was also determined that because of the large flows and existing roadway grade, a structure that would convey the 100-year storm with proper freeboard is not feasible at this time. It was agreed that proposed structure would be sized to closely match the current bridge opening, as to not change the floodplain water surface elevations, therefore allowing for a no-rise condition. CDOT will have to develop a Safety Plan for the overtopping that includes signs, maintenance response, etc. that will be reviewed by FHWA.

The proposed CBC alternative is a two-cell 12 ft x 6 ft box. Another option investigated was one-span ALBC 83 corrugated aluminum arch by Contech, with an opening width of 25 ft 2 in and vertical height of 6 ft 2 in. A one-span 24.0 ft long bridge alternative was modeled but not analyzed. Due to the severe roadway overtopping at this location and the likelihood of other changes to this area in the future a bridge option was deemed not viable for this location.

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:

Key Findings

- The Project is located along the Middle Fork of the South Platte River, which the Project bridge spans.

- Surface Waters
    - The Project has the potential to impact 0.70 acres of US Army Corps of Engineers (USACE) jurisdictional wetlands
    - The Project has the potential to impact 0.09 acres (102 linear feet) of USACE jurisdictional surface waters
    - The wetlands within the Project Review Area (PRA) are likely associated with a potential fen wetland located within the same wetland complex, approximately 0.3 miles from Project wetlands
    - Two Avoidance Areas are located on the western extent of the PRA.
- Sensitive Species
    - The Project has no potential to impact species listed under the federal Endangered Species Act
    - The Project has the potential to impact two species listed by Colorado Parks and Wildlife (CPW) as endangered, threatened, or species of concern
        - Boreal toad (Bufo boreas boreas) – State Endangered
        - Burrowing owl (Athene cuniculalria) – State Threatened
    - 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).
    - The Project does not propose to alter the 100-year floodplain. However, the existing bridge does not prevent the 100-year floodplain for overtopping the road, and therefore does not meet the floodplain standards established by CDOT.
    - The hydraulics of the watershed are currently being assessed and further details regarding floodplain design and permitting requirements will be provided in the Bridge Bundle Hydraulics Report.
- Hazardous Waste
    - No know hazardous waste sites occur within or adjacent to the PRA. No further investigations are recommended.
- 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 US 24 is a 2-lane roadway with two-way traffic. The existing east-bound lane is 11.0 ft wide with 2.0 ft shoulder, and the west-bound lane is 12.0 ft wide with 4.0 ft shoulder. There is as existing Type 3 guardrail on both sides of the road within the limits of the structure.

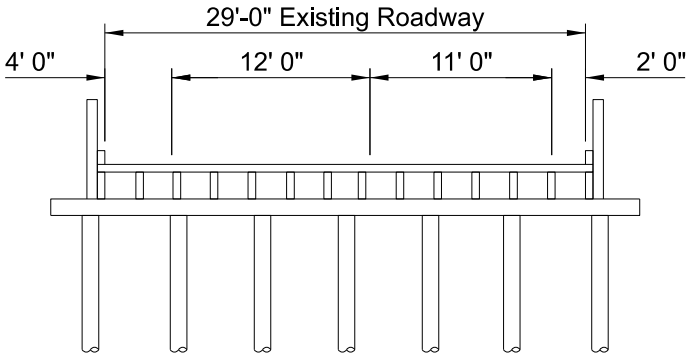


Figure 1 – Existing Section

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.

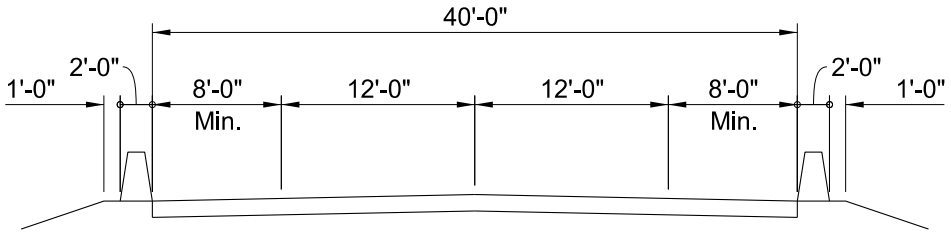


Figure 2 – Proposed Roadway Section

2.8.2. Vertical Alignment

The proposed vertical profile of US 24 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 roadway section beyond the length of the structure.

The proposed vertical profile is on a constant tangent with a slope of -0.11% matching the existing grade. The profile grade is less than 0.5% min recommended by FHWA for bridge

decks. Bridge structure is not a recommended alternative at this location, but if bridge structure is selected, the design team will need to address drainage issues during the final design.

2.8.3. Horizontal Alignment

The existing structure is located along the continuous horizontal tangent and has no skew. 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 skew.

3. STRUCTURAL DESIGN CRITERIA

3.1. DESIGN SPECIFICATIONS

- AASHTO LRFD Bridge Design Specifications, 9th 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 H-13-N will not be performed due to the age and type of the bridge. Constructed in 1937, this structure was in service for over 80 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 structure selected must provide natural channel bottom to satisfy environmental requirements.

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 prosses. In addition, CBC size can be selected from CDOT M&S Standards that cover vide array of single-cell and multi-cell culvert sizes.

For H-13-N a two-cell 12 ft x 6 ft box culvert is required to maintain a no-rise conditions. However, to provide a natural channel bottom, a two-cell 12 ft x 8 ft CBC with bottom slab buried 2 ft under the channel bottom will be evaluated. The box can be constructed as CIP or precast. The centerline of the proposed box culvert will be placed approximately in line with the

centerline of the existing bridge. The design cover over the top slab of the proposed CBC varies from 1.0 ft to 1.25 ft.

Both headwalls will be placed in-line with the proposed Type 3 guardrail and have Bridge Rail Type 10MASH attached to them. The concrete box culvert proposed total length is 43.0 ft.

Wingwalls will be provided on all four corners if 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. Additionally, a riprap will be provided inside the CBC to protect natural channel bottom and washing out of provided soil cover.

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 single steel arch structures, ALBC 83 by Contech Solutions. The width of proposed arch is 25 ft 2 in and vertical height of 7.0 ft. 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 design cover over the proposed arches varies from 1.0 ft to 1.25 ft.

Similarly to the CBC alternative, both arch headwalls will be placed in-line with the proposed Type 3 guardrail and have Bridge Rail Type 10MASH attached to them. The steel arch proposed total length is 43.0 ft.

4.4.3. Concrete Girder Bridge Alternatives

Due to the severe roadway overtopping at this location and the likelihood of other changes to this area in the future a bridge option was deemed not viable for this location and was not analyzed.

4.4.4. Span Configurations

Total length of the proposed concrete box culvert and steel arch alternatives was determined based on the requirements of the proposed roadway width, and the existing bridge dimensions. Only one span alternative was analyzed.

4.5. SUBSTRUCTURE ALTERNATIVES

Steel arch alternative will have 3.0 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

The existing wood bridge structure does not provide adequate width to allow for a one lane phasing option. And, as stated by grant application, the roadway should not be closed for construction.

The proposed option for phasing is construction of a shoofly. Refer to Section 2.3 for more information.

4.8. CONSTRUCTABILITY

All the alternatives are proposed to be constructed in phases. Shoring will be required to construct any of the proposed alternatives. Constructing concrete box culvert or steel arch would require less construction time and using precast sections would further reduce construction time.

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.

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.

Alternative	Construction Cost (30% Contingency)	Area	Cost per sf	Cost Rating
Concrete Box Culvert	$ 455,920.00	1140 sf	$ 400	1.0
Steel Arch	$ 439,280.00	1849 sf	$ 238	1.1

Table 3 – Construction Cost Summary

4.12. CONCLUSIONS AND RECOMMENDATIONS

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

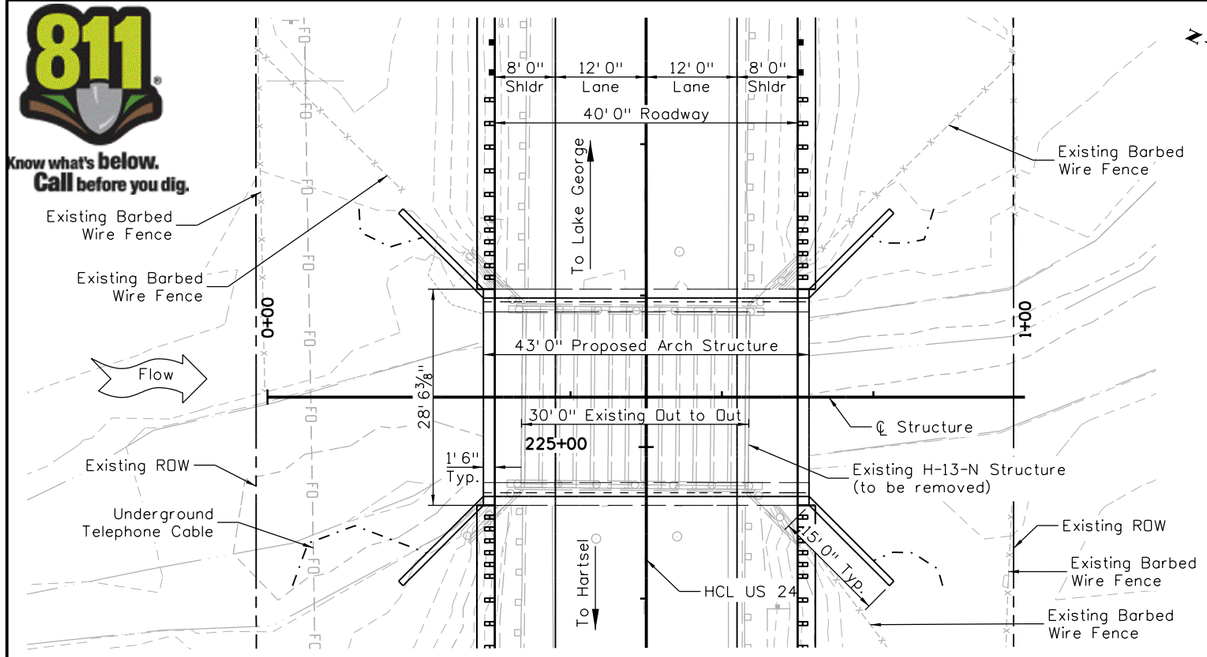
Criteria	CBC	Steel Arch
Hydraulic Opening	Satisfies the requirements. Provides natural bottom by burying bottom slab.	Satisfies the requirements. Provides natural bottom.
Constructability	Can be precast to streamline the construction	Delivered to site in ready to install sections
Construction Cost Rating	1.0	1.1
Maintenance & Durability	May require routine cleaning	May require routine cleaning
ROW and Roadway Impacts	No ROW impacts	No ROW impacts

Table 4 – Summary of Structure Alternatives Evaluation

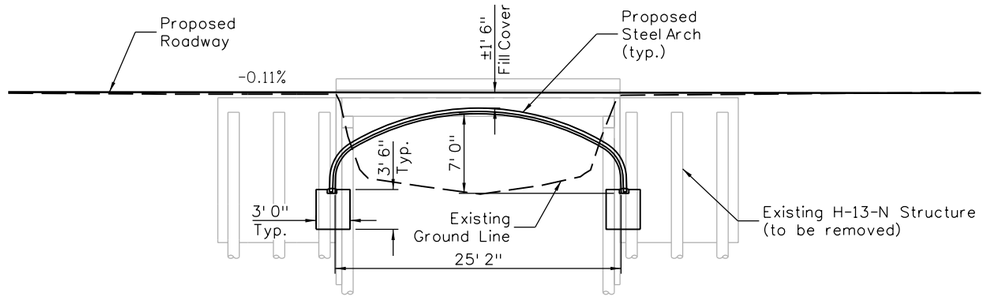
Based on the criteria discussed above, the steel arch alternative is the recommended alternative to replace existing H-13-N structure. The contractor may select a different structure type based on their investigations, meeting the criteria described in this report. See Appendix A for the selected General Layout and Typical Section.

APPENDIX A

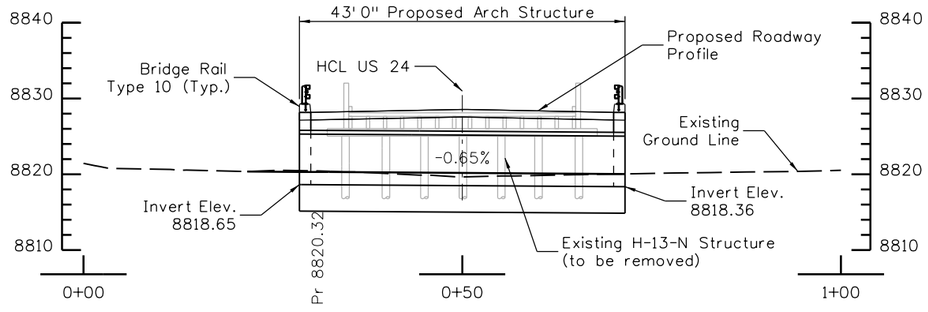
General Layout and Typical Section



PLAN



SECTION
(Taken Normal to ℄ Structure)



PROFILE
(Taken Along ℄ Structure)

Notes:

1. Dimensions are based on recent survey and existing as-built drawings.
2. Shallow foundation system must be placed on a minimum of 2'-0" of properly placed CDOT Class 1 Structure Backfill.
3. The bottom of the shallow foundation must be a minimum of 3'-0" below the final ground surface for frost protection.

Print Date: 2/3/2021 File Name: 23558STR_General Layout H-13-N_US24 MP 240.68.dgn.dgn	Sheet Revisions: Date / Comments / Init.	Colorado Department of Transportation, 5615 Wills Blvd, Pueblo, CO 81008, Phone: 719-546-5753, FAX: 719-546-5402	As Constructed	REGION 2 BRIDGE BUNDLE US 24 OVER SEASONAL DRAW GENERAL LAYOUT AND TYP. SECTION	Project No./Code
Horiz. Scale: Vert. Scale: As Noted		Region 2 JLS	No Revisions:	Designer: I. Pushkarova; Structure No. H-13-N	
Stanley Consultants INC. 8000 South Chester St. Suite 500 Centennial, CO 80112 Phone: 303-799-6806			Revised:	Detailer: I. Pushkarova; M.P. US 24 240.686	
			Void:	Sheet Subset: STR; Subset Sheets: 1 of 1	Sheet Number

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
  - ☐ Steel Girder Alternatives
  - ☐ Span Configurations
- ☐ Substructure Alternatives:
  - ☐ Abutment Alternatives (GRS, Integral, Semi-integral, etc.)
  - ☐ Pier Alternatives
- ☐ Wall Alternatives
- ☐ Construction Phasing
- ☐ Possible Future Widenings
- ☐ 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

* CBC Alternative

* RCP Alternative

Other

_____

_____

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

_____

_____

_____

_____

_____

If you need more space, use an additional sheet(s) of paper.

List of Variances

_____

_____

_____

_____

_____

If you need more space, use an additional sheet(s) of paper.

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.

_____	_____	_____
Print Name	Signature	Date

APPENDIX C

Construction Cost Estimate

Project No.: CDOT #23558 (Stanley #29715) Date: 2/3/2021

Project Name: Region 2 Bridge Bundle Design Build Grant Project

Subject: Quantity Calculations - H-13-N ARCH Alternative

Client: CDOT Region 2

ARCH Alternative

Contract Item No.	Item Description	Unit	Estimated Unit Cost	TOTAL	
				Approx Quantities	Estimated Total Cost
202-00400	Removal of Bridge	EACH	**$ 90,000.00**	**1**	$ 90,000
206-00000	Structure Excavation	CY	**$ 20.00**	**339**	$ 6,780
206-00100	Structure Backfill (Class 1)	CY	**$ 35.00**	**369**	$ 12,915
420-00102	Geotextile (Erosion Control) (Class 1)	SY	**$ 7.00**	**646**	$ 4,522
506-00000	Riprap	CY	**$ 120.00**	**482**	$ 57,840
510-20100	Structural Plate Arch (Special)	LF	**$ 1,700.00**	**43**	$ 73,100
601-04550	Concrete Class G	CY	**$ 900.00**	**70**	$ 63,000
601-40300	Structural Concrete Coating	SY	**$ 14.00**	**68**	$ 952
602-00020	Reinforcing Steel (Epoxy Coated)	LB	**$ 1.50**	**11079**	$ 16,619
606-11035	Bridge Rail Type 10 MASH	LF	**$ 210.00**	**58**	$ 12,180
				Subtotal of accounted construction items =>	$ 337,908
				Contingency Multiplier =>	30%
				Subtotal of construction items =>	**$ 439,280**
				Deck area (SF) =>	1849.00
				Cost per SF =>	**$ 238**

Project No.: CDOT #23558 (Stanley #29715) Date: 1/15/2021

Project Name: Region 2 Bridge Bundle Design Build Grant Project

Subject: Quantity Calculations - H-13-N CBC Alternative

Client: CDOT Region 2

CBC Alternative

Contract Item No.	Item Description	Unit	Estimated Unit Cost	TOTAL	
				Approx Quantities	Estimated Total Cost
202-00400	Removal of Bridge	EACH	**$ 90,000.00**	**1**	$ 90,000
206-00000	Structure Excavation	CY	**$ 20.00**	**372**	$ 7,440
206-00100	Structure Backfill (Class 1)	CY	**$ 35.00**	**280**	$ 9,800
506-00000	Riprap	CY	**$ 120.00**	**139**	$ 16,680
515-00120	Waterproofing (Membrane)	SY	**$ 22.50**	**151**	$ 3,398
601-04550	Concrete Class G	CY	**$ 900.00**	**163**	$ 146,700
601-40300	Structural Concrete Coating	SY	**$ 14.00**	**93**	$ 1,302
602-00020	Reinforcing Steel (Epoxy Coated)	LB	**$ 1.50**	**42839**	$ 64,259
606-11035	Bridge Rail Type 10 MASH	LF	**$ 210.00**	**53**	$ 11,130
	Subtotal of accounted construction items =>				$ 350,708
	Contingency Multiplier =>				30%
	Subtotal of construction items =>				**$ 455,920**
	Deck area (SF) =>				1139.50
	Cost per SF =>				**$ 400**

APPENDIX D

Geotechnical Report

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

2000 Clay Street, Suite 200
Denver, CO 80211
(303) 781-9590
www.yeh-eng.com

February 10, 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 H-13-N
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 Bridge Structure H-13-N 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

Bridge H-13-N 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 will be replaced with either an arch structure, concrete box culvert (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, H-13-N B-1 and H-13-N B-2, were drilled by Yeh in the vicinity of the existing bridge, and two pavement borings, H-13-N P-1 and H-13-N P-2, were drilled along the existing pavement approximately 250 feet from the bridge. 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 sands, gravels, and clays overlying decomposed shale and shale 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[1] (Northing, Easting)	Ground Surface Elevation at Time of Drilling[1] (feet)	Approx. Depth to Top of Competent Bedrock[1] (feet)	Approx. Elevation to Top of Competent Bedrock[1] (feet)	Approx. Groundwater Depth[1, 2] (feet)	Approx. Groundwater Elevation[1, 2] (feet)
H-13-N-B-1	1436802.6, 2925066.0	8828.5	40	8788.5	10	8818.5
H-13-N-B-2	1436787.1, 2925031.7	8828.5	35	8793.5	10	8818.5

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 an arch or CBC structure is selected, then the structure will be founded on shallow foundations. Wing walls for the 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 arch, 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 Arch Structure Foundation Recommendations

We understand the arch structure will be supported on a shallow foundation system such as reinforced concrete strip footings. Design and construction for the shallow foundation system should take into consideration the scour potential at the proposed bridge site. The bottom of the foundations should be a minimum of 36-inches below the exterior ground surface for frost protection.

We anticipate that the bearing resistance of the shallow foundations will meet the project loading requirements provided that the shallow foundations are founded on a minimum of 2 feet of properly placed CDOT Class 1 Structure Backfill.

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 construction of the foundation. 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.

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 bedrocks 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 (Φ=0.5)	Nominal	Factored (Φ=0.45)
H-13-N-B-1	8788.5	110	55	12.5	5.6
H-13-N-B-2	8793.5	110	55	12.5	5.6

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.)	Undrained Cohesion, (psf)	Strain Factor, ε50	p-y modulus kstatic (pci)	
		AGT[1]	BGT[2]				AGT[1]	BGT[2]
Class 1 Structure Backfill	Sand (Reese)	130	67.5	34	-	-	90	60
Sand and Gravel	Sand (Reese)	125	62.5	32	-	-	90	60
Clay/Decomposed Shale	Stiff Clay [3] (Reese)	120	57.5	-	2,000	0.005	-	-
Shale Bedrock	Stiff Clay w/o Free Water (Reese)	130	130	-	8,000	0.004	-	-

Note: [1]Above Groundwater Table
[2]Below Groundwater Table
[3]Stiff Clay w/ Free Water (Reese) for clay below groundwater table and Stiff Clay w/o Free Water (Reese) for clay above groundwater

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 32 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.

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 ½ 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 3 to 5 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

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 sand or gravel 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) [1, 2]
Moist	3.0 + 1.7 * B'
Saturated	1.5 + 0.9 * B'

[1] B' is the footing width in feet reduced for eccentricity (e). B' = B - 2e, where B is the nominal foundation width.
[2] The calculated nominal bearing resistance is based on a minimum 12 inches of embedment and shall be limited to 10 ksf.

The proposed CBC will be at the location of the existing bridge and as needed, 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 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 existing 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
Fill/Native Sand/Gravel	0.35	0.8
Native Clay	0.31	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

	Soil Type	Nominal Resistance	Resistance Factor
Passive Soil Resistance	Moist	406 psf/ft	0.50
	Saturated	203 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 bridge 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 250 feet beyond the existing bridge abutments 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)[1]	R-Value[1]
H-13-N-P-1	9.5	Not Encountered	A-2-6 (1)	19
H-13-N-P-2	8.0	Not Encountered		

Note: [1] 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
H-13-N-P-1/P-2	Clayey Sand (Fill)	0.091	0.0039	-	-
H-13-N-B-1	Decomposed Shale	0.080	0.0005	8.2	1035
H-13-N-B-2	Sandy Lean Clay	0.112	0.0006	8.0	634

6 SEISMIC CONSIDERATIONS

No active faults are known to exist in the immediate vicinity of the proposed bridge 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 D. 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 D are shown in Table 9.

Table 9. Seismic Design Parameters

PGA (0.0 sec)	S_S (0.2 sec)	S_1 (1.0 sec)
0.075 g	0.155 g	0.042 g
A_s (0.0 sec)	S_{DS} (0.2 sec)	S_{D1} (1.0 sec)
0.119 g	0.248 g	0.100 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, 9th 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:

COLORADO LICENSED
THOMAS MCCALL
56485
2-10-2021
PROFESSIONAL ENGINEER

JG T. McCall, PE
Senior Project Engineer

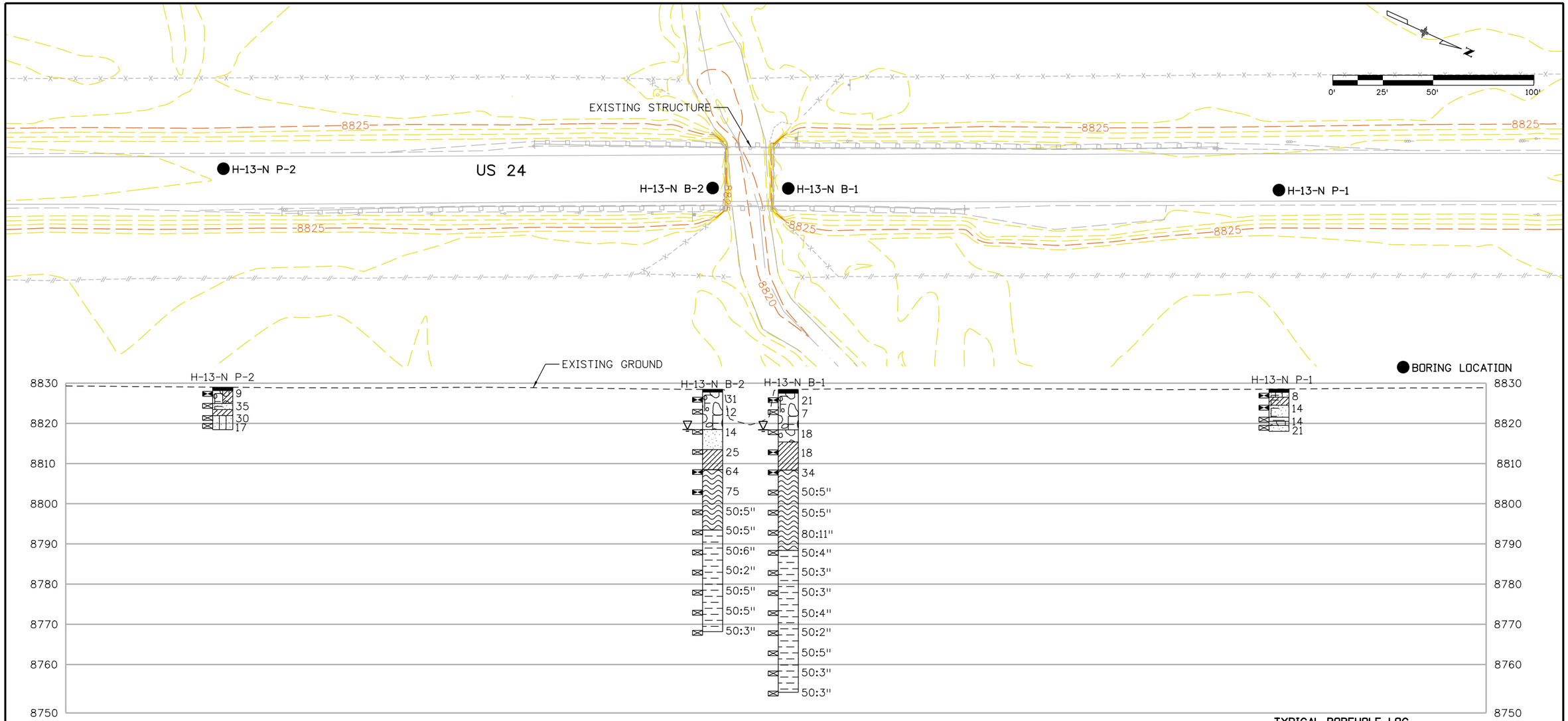
Independent Technical Review by:

Hsing-Cheng Liu, PE, PhD
Senior Project Manager

Attachments:
Appendix A
Appendix B
Appendix C

APPENDIX A

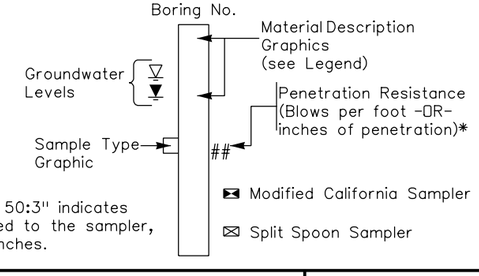
ENGINEERING GEOLOGY SHEET



LEGEND

- Asphalt
- Low Plasticity Sandy Clay
- USCS Low Plasticity Organic silt or clay
- USCS Poorly-graded Gravel
- USCS Poorly-graded Sand
- USCS Poorly-graded Gravel with Clay
- Fill
- USCS Silty Sand
- Shale

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	Sheet Revisions	Colorado Department of Transportation	As Constructed
File Name: 23558GEOT_Engineering Geology H-13-N.dgn	Date: / Comments / Init.	1480 Quail Lake Loop, Suite A Colorado Springs, CO 80906 Phone: 719-634-2323 FAX: 719-227-3298	No Revisions:
Horiz. Scale: 1:50 Vert. Scale: As Noted		Region 2	Revised:
Unit Information Unit Leader Initials			Void:
Yeh and Associates, Inc. Geotechnical · Geological · Construction Services			

R2 BRIDGE BUNDLE ENGINEERING GEOLOGY				Project No./Code
Designer: JTM	Structure Numbers	H-13-N		STM R200-262
Detailer: MJW				23558
Sheet Subset: Geology	Subset Sheets:	1 of 1		Sheet Number

APPENDIX B

KEY TO BORING LOGS

BORING LOGS

PAVEMENT CORE PHOTOS

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

Project: CDOT Region 2 Bridge Bundle

Project Number: 220-063

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.

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

Project Name: CDOT Region 2 Bridge Bundle

Project Number: 220-063 *Boring No.:* **H-13-N P-1**

Boring Began: 9/28/2020
Boring Completed: 9/28/2020
Drilling Method(s): Coring / Hollow-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: 80%

Total Depth: 10.5 ft
Ground Elevation: 8828.5
Coordinates: N: 1436903.5 E: 2925288.3
Location: US 24, westbound outside lane
Logged By: C. Wallace
Final By: J. McCall

Weather Notes: Clear, 60s
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels: Not Observed

Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
							0.0 - 0.8 ft. ASPHALT (9.5 inches).									
				5-3	8		**0.8 - 2.0 ft. Silty SAND (SM) (Fill)**, brown, moist, loose.									
8825							**2.0 - 4.0 ft. Sandy lean CLAY (CL) (Fill)**, light brown, moist, medium stiff.									
	5			7-7	14		**4.0 - 7.0 ft. Poorly graded SAND (SP) with silt (Fill)**, brown, moist, medium dense.	3.4	102.6		93.4	6.6	NV	NP	A-1-b (0)	S/C=-1.9%
				5-6-8	14		**7.0 - 8.0 ft. Organic CLAY (OL)**, black, moist, stiff.									
8820							**8.0 - 9.0 ft. Poorly graded GRAVEL with sand (GP)**, gray-brown, moist, medium dense.									
	10			5-9-12	21		**9.0 - 10.5 ft. Poorly graded SAND with gravel (SP)**, dark brown, moist to wet, medium dense.									
							Bottom of Hole at 10.5 ft.									
8815																
8810																
8805																

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

Project Name: CDOT Region 2 Bridge Bundle

Project Number: 220-063 *Boring No.:* **H-13-N P-2**

Boring Began: 9/28/2020
Boring Completed: 9/28/2020
Drilling Method(s): Coring / Hollow-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: 80%

Total Depth: 10.5 ft
Ground Elevation: 8828.94
Coordinates: N: 1436694.5 E: 2924806.5
Location: US 24, eastbound outside lane
Logged By: C. Wallace
Final By: J. McCall

Weather Notes: Clear, 60s
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels: Not Observed

Symbol			
Depth	-	-	-
Date	-	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
							0.0 - 0.7 ft. ASPHALT (8 inches).									
				5-4	9		**0.8 - 4.0 ft. Clayey GRAVEL with sand (GC) (Fill)**, yellowish brown, moist, loose.	7.8		56.0	21.7	22.3	28	12	A-2-6 (0) GC	
8825	5			8-27-8	35		**4.0 - 5.5 ft. Poorly graded SAND with gravel (SP) (Fill)**, brown, moist, dense.									
							5.5 - 7.0 ft. Sandy lean CLAY (CL), dark brown to black, low plasticity, moist, medium stiff.									
8820				7-15-15	30		**7.0 - 10.5 ft. Silty SAND with gravel (SM)**, yellowish brown, moist to wet, medium dense.									
	10			4-5-12	17											

Bottom of Hole at 10.5 ft.

8815
8810
8805

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE FIXED FORMATTING 12-11-2020.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 1/21/21

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

Project Name: CDOT Region 2 Bridge Bundle

Project Number: 220-063 *Boring No.:* **H-13-N B-1**

Boring Began: 9/28/2020
Boring Completed: 9/28/2020
Drilling Method(s): Hollow-Stem Auger
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: 80%

Total Depth: 75.3 ft
Ground Elevation: 8828.5
Coordinates: N: 1436802.6 E: 2925066.0
Location: US 24, westbound outside lane
Logged By: C. Wallace
Final By: J. McCall

Weather Notes: Clear, 40s
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels:			
Symbol	▽		
Depth	10.0 ft	-	-
Date	9/28/20	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
							0.0 - 0.9 ft. ASPHALT (11 inches).									
							0.9 - 10.0 ft. Poorly graded GRAVEL with sand (GP) (Fill), tan, moist, loose to medium dense, sandstone gravels.									
				6-15	21											
8825	5			17-3-4	7											
8820	▽10			7-9-9	18		**10.0 - 13.0 ft. Poorly graded GRAVEL with sand (GP)**, gray to brown, moist to wet, medium dense.									
8815							**13.0 - 20.0 ft. Sandy lean CLAY (CL)**, gray, medium plasticity, dry to moist, very stiff, visible rock structure (shale residuum).									
	15			7-11	18			13.2	119.6	0.0	24.3	75.7	33	15	A-6 (10) CL	S/C=0.3%
8810																
	20			14-20	34		**20.0 - 40.0 ft. DECOMPOSED SHALE**, gray, medium hard to very hard, thinly laminated, locally sandy.	14.8					NV	NP		UCCS=62.8 psi
8805																

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
				50:5"	50:5"											pH=8.2 S=0.08% Chl=0.0005% Re=1035ohm·cm
8800	30			28-50:5"	50:5"											
8795	35			45-30-50:5"	80:11"											
8790	40			40-50:4"	50:4"		**40.0 - 75.3 ft. SHALE**, gray, very hard, thinly laminated, locally sandy.									
8785	45			50:3"	50:3"											
8780	50			50:3"	50:3"											
8775	55															

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

Project Name: CDOT Region 2 Bridge Bundle

Project Number: 220-063 *Boring No.:* **H-13-N B-1**

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
8770				45-50:4"	50:4"											
	60			50:2"	50:2"											
8765																
	65			50:5"	50:5"											
8760																
	70			50:3"	50:3"											
8755																
	75			50:3"	50:3"											
8750							Bottom of Hole at 75.3 ft.									
8745																

BORING LOG 2019 - SPT CDOT STYLE 220-063 R2 BRIDGE BUNDLE FIXED FORMATTING 12-11-2020.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 1/21/21

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

Project Name: CDOT Region 2 Bridge Bundle

Project Number: 220-063 *Boring No.:* **H-13-N B-2**

Boring Began: 9/29/2020
Boring Completed: 9/29/2020
Drilling Method(s): Hand Auger / Mud Rotary
Driller: Vine Laboratories
Drill Rig: CME 750X Buggy
Hammer: Automatic (hydraulic), ER: 80%

Total Depth: 60.3 ft
Ground Elevation: 8828.5
Coordinates: N: 1436787.1 E: 2925031.7
Location: US 24, eastbound outside lane
Logged By: C. Wallace
Final By: J. McCall

Weather Notes: Clear, 40s
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels:			
Symbol	▽		
Depth	10.0 ft	-	-
Date	9/29/20	-	-

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
							0.0 - 0.7 ft. ASPHALT (7.5 inches).									
				14-17	31		**0.7 - 10.0 ft. Poorly graded GRAVEL with silt and sand (GP-GM) (Fill)**, gray to reddish brown, moist, loose to medium dense.									
8825	5			22-8-4	12			0.2		46.0	42.9	11.1	NV	NP	A-1-b (0) GP-GM	
8820	▽10			6-5-9	14		**10.0 - 15.0 ft. Poorly graded SAND with gravel (SP)**, brown, wet, medium dense.									
8815	15			8-12-13	25		**15.0 - 20.0 ft. Sandy lean CLAY (CL)**, gray, moist, very stiff, weakly cemented.	14.0		9.0	32.0	59.0	30	11	A-6 (4) CL	pH=8.0 S=0.112% Chl=0.0006% Re=634ohm·cm
8810	20			22-42	64		**20.0 - 35.0 ft. DECOMPOSED SHALE**, gray, hard to very hard, thinly laminated, locally sandy.									
8805																

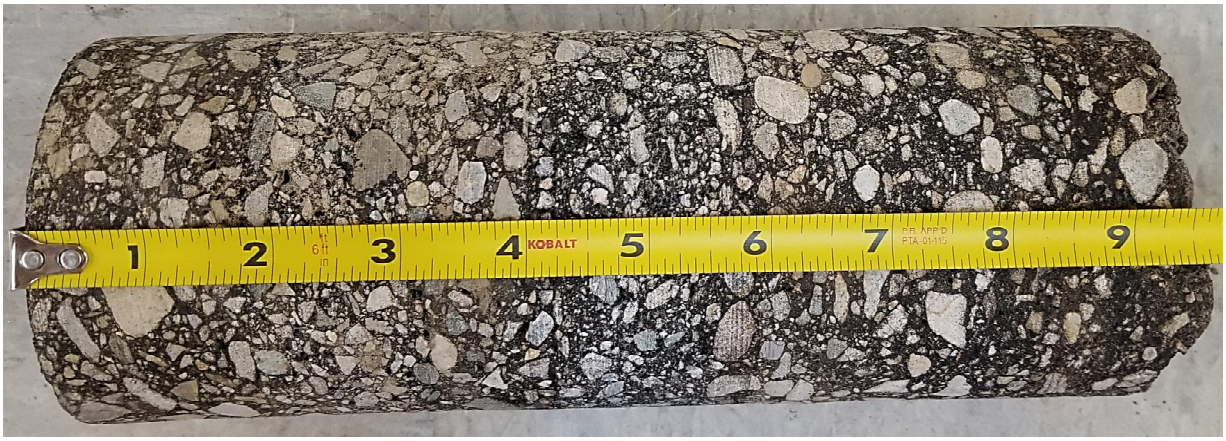
Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
				32-43	75			7.3		0.0	20.9	79.1	33	16	A-6 (11) CL	UCCS=61 psi
8800	30			25-50:5"	50:5"											
8795	35			50:5"	50:5"		**35.0 - 60.3 ft. SHALE**, gray, very hard, thinly laminated, locally sandy.									
8790	40			50:6"	50:6"											
8785	45			50:2"	50:2"											
8780	50			50:5"	50:5"											
8775	55															

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

Project Name: CDOT Region 2 Bridge Bundle

Project Number: 220-063 *Boring No.:* **H-13-N B-2**

Elevation (feet)	Depth (feet)	Sample Type/Depth	Drilling Method	Soil Samples: Blows per 6 in	Soil Samples: Penetration Resistance	Lithology	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Atterberg Limits: Liquid Limit	Atterberg Limits: Plasticity Index	AASHTO & USCS Classifi-cations	Field Notes and Other Lab Tests
8770				50:5"	50:5"											
	60			50:3"	50:3"		Bottom of Hole at 60.3 ft.									
8765																
8760																
8755																
8750																
8745																



Boring:	**P-1**	AC:	**9.5"**
Roadway:	**US 24**	PCC:	**-**
Direction:	**Westbound**	Base:	**-**
Lane:	**Outside**	Notes:	**-**

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

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

Pavement Core Photographs

FIGURE

B-1

PROJECT NO.	220-063	DATE:	12/14/2020
FIGURE BY:	BHL	YEH OFFICE:	Colorado Springs
CHECKED BY:	JTM		

CDOT Region 2 Bridge Bundle
Structure H-13-N

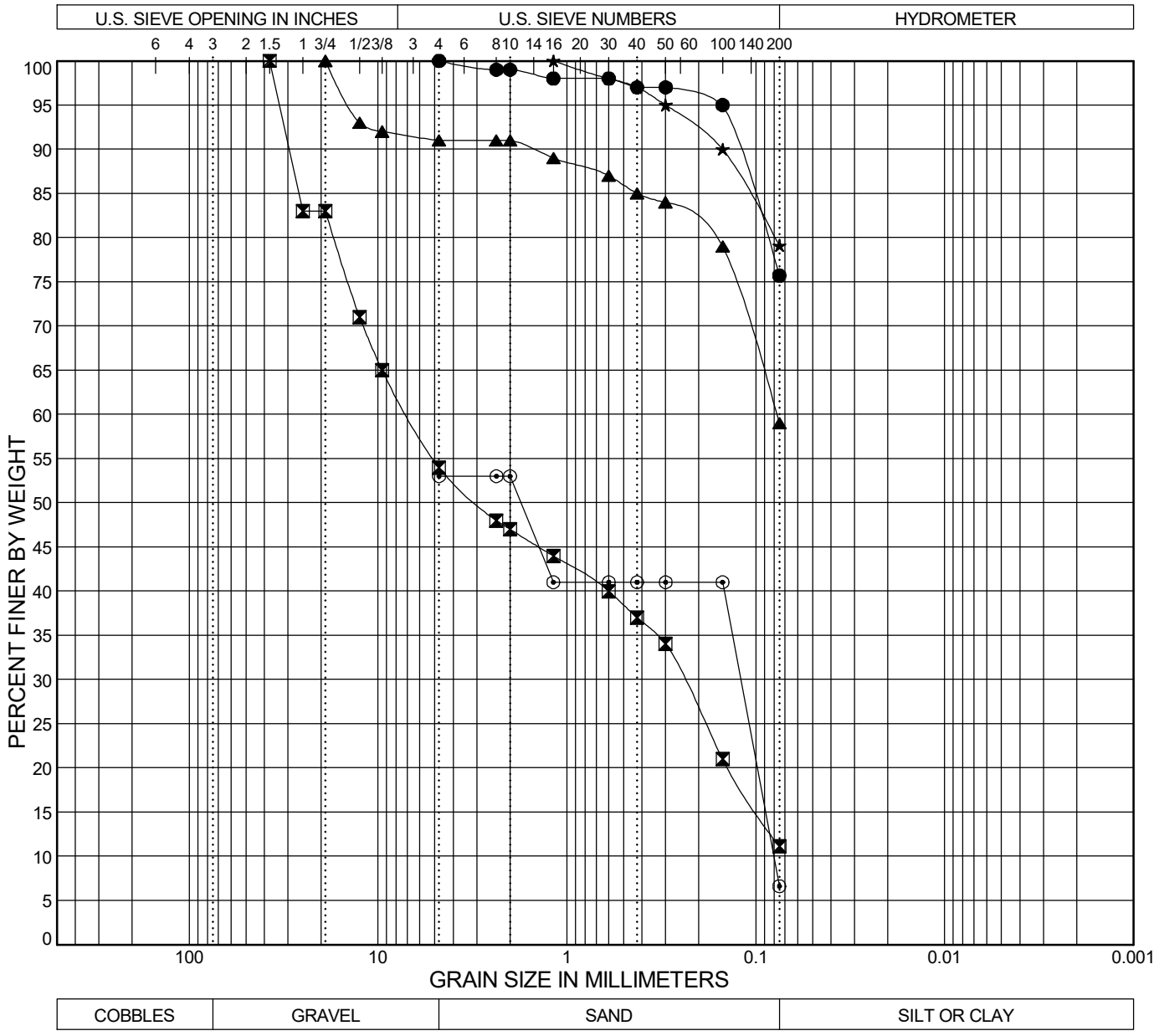
APPENDIX C

SUMMARY OF LABORATORY TEST RESULTS

Summary of Laboratory Test Results

Project No: 220-063 Project Name: CDOT Region 2 Bridge Bundle Date: 12-17-2020

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
H-13-N B-1	15.0	MC	13.2	119.6	0.0	24.3	75.7	33	18	15					0.3 @ 1500			A-6 (10)	CL
H-13-N B-1	20.0	MC	14.8					NV	NP	NP						62.8			
H-13-N B-1	25.0	SPT									8.2	0.08	0.0005	1035					
H-13-N B-2	5.0	SPT	0.2		46.0	42.9	11.1	NV	NP	NP								A-1-b (0)	GP-GM
H-13-N B-2	15.0	SPT	14		9.0	32.0	59.0	30	19	11	8.0	0.112	0.0006	634				A-6 (4)	CL
H-13-N B-2	25.0	MC	7.3		0.0	20.9	79.1	33	17	16						61		A-6 (11)	CL
H-13-N P-1	4.0	MC	3.4	102.6		93.4	6.6	NV	NP	NP					-1.9 @ 200			A-1-b (0)	
H-13-N P-1/P-2	2.5	BULK	6.7		5.0	61.0	34.0	30	13	17		0.091	0.0039				19	A-2-6 (1)	SC
H-13-N P-2	1.0	MC	7.8		56.0	21.7	22.3	28	16	12								A-2-6 (0)	GC
H-13-N Scour	0	BULK	5		0.0	60.0	40.0	NV	NP	NP								A-4 (0)	SM



BOREHOLE		DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
										%Silt	%Clay
●	H-13-N B-1	15.0	A-6 (10)	CL	33	18	15	0.0	24.3	75.7	
⊠	H-13-N B-2	5.0	A-1-b (0)	GP-GM	NV	NP	NP	46.0	42.9	11.1	
▲	H-13-N B-2	15.0	A-6 (4)	CL	30	19	11	9.0	32.0	59.0	
★	H-13-N B-2	25.0	A-6 (11)	CL	33	17	16	0.0	20.9	79.1	
⊙	H-13-N P-1	4.0	A-1-b (0)		NV	NP	NP		46.4	6.6	

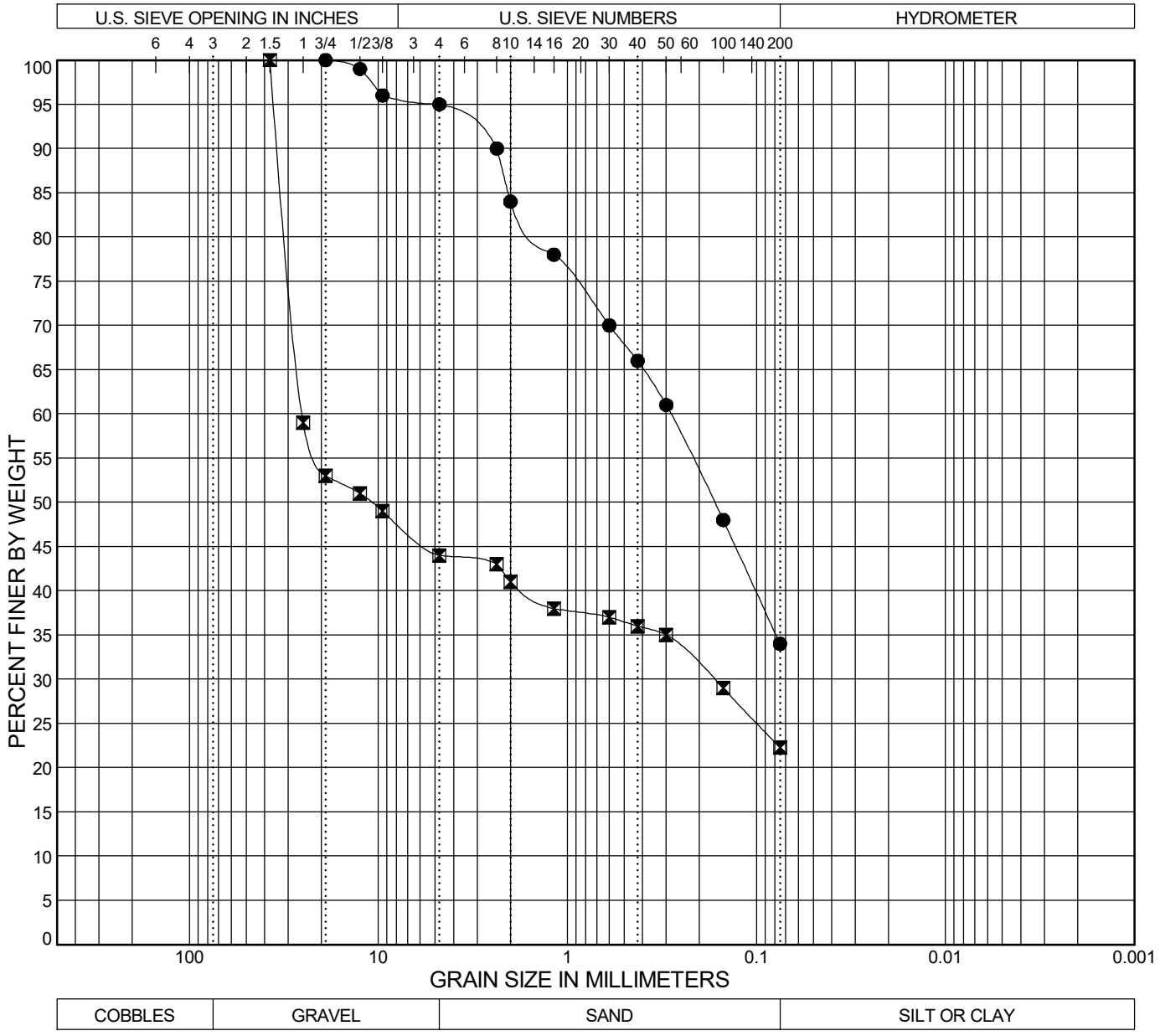
Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

SIEVE ANALYSIS

FIGURE
C- 1

Project No. 220-063 Date: 12-12-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Structure H-13-N



	BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
										%Silt	%Clay
●	**H-13-N P-1/P-2**	**2.5**						**5.0**	**61.0**	**34.0**	
⊠	**H-13-N P-2**	**1.0**	**A-2-6 (0)**	**GC**	**28**	**16**	**12**	**56.0**	**21.7**	**22.3**	

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

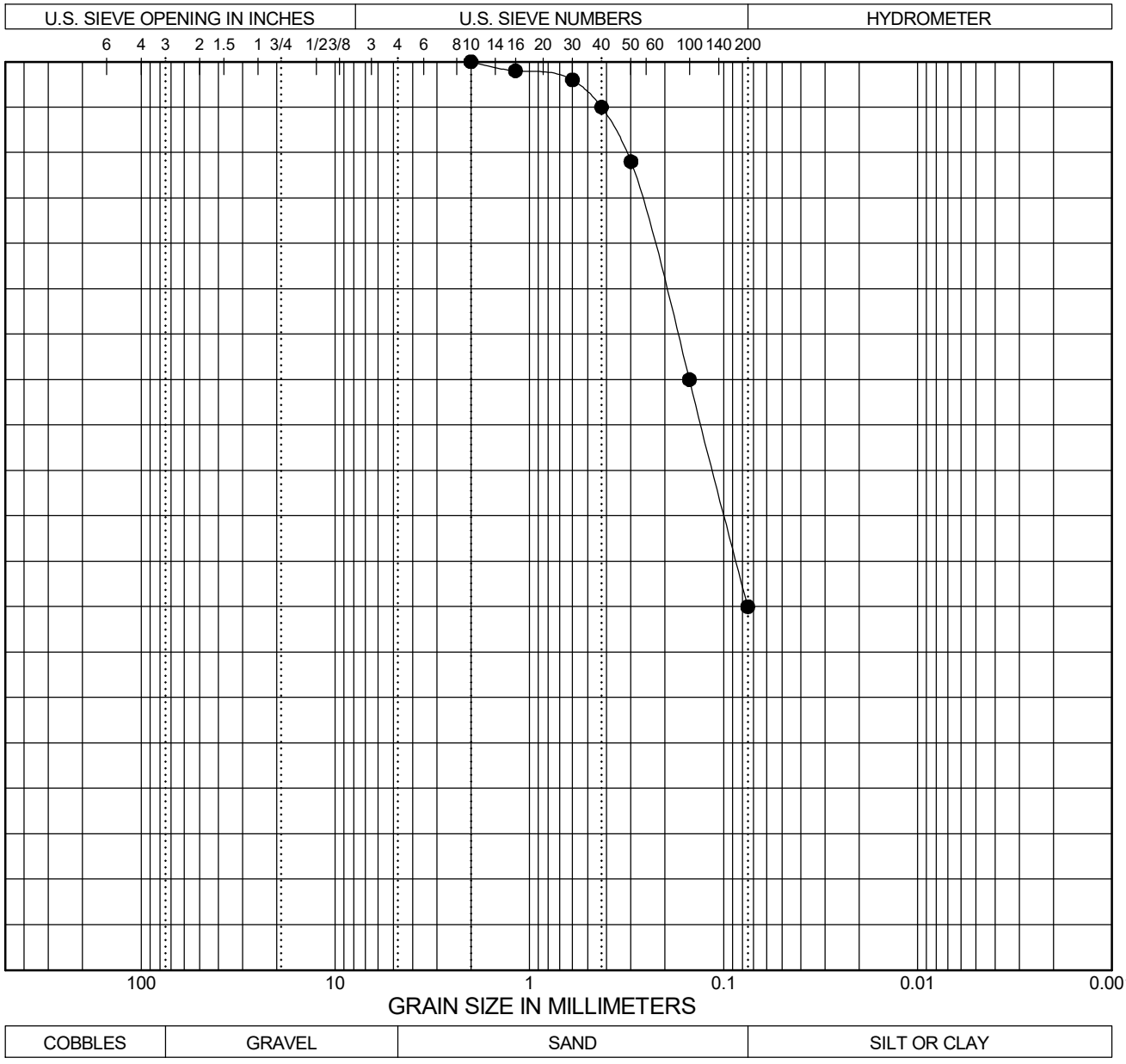
SIEVE ANALYSIS

FIGURE

C- 2

Project No. 220-063 Date: 12-12-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Structure H-13-N



BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
									%Silt	%Clay
● **H-13-N Scour**	**0.0**	**A-4 (0)**	**SM**	**NV**	**NP**	**NP**	**0.0**	**60.0**	**40.0**	

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

SIEVE ANALYSIS

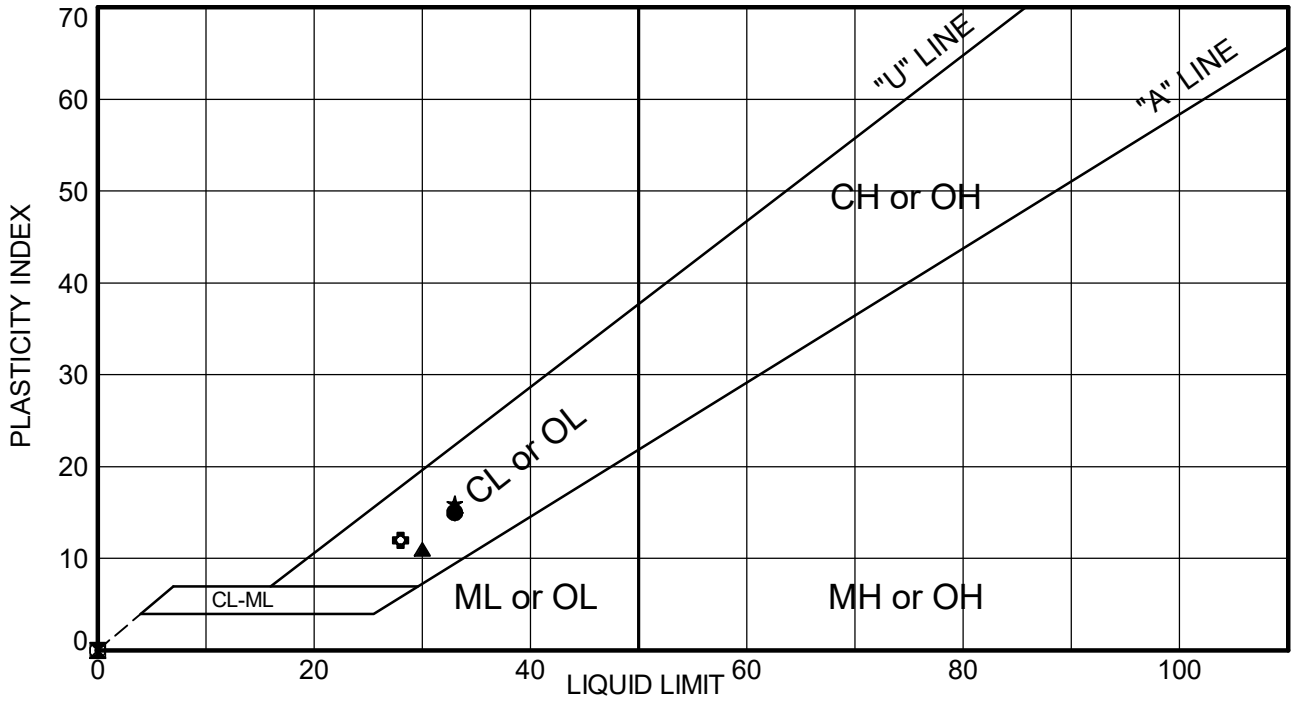
FIGURE

C- 3

Project No. 220-063 Date: 12-12-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Structure H-13-N

03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE FIXED FORMATTING 12-11-2020.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 12/12/20



	BOREHOLE	DEPTH (ft)	LL	PL	PI	Passing #200	USCS Sample Description and Symbol	AASHTO Class.
●	**H-13-N B-1**	**15.0**	**33**	**18**	**15**	**75.7**	**LEAN CLAY with SAND (CL)**	**A-6 (10)**
⊠	**H-13-N B-2**	**5.0**	**NV**	**NP**	**NP**	**11.1**	**POORLY GRADED GRAVEL with SILT and SAND (GP-GM)**	**A-1-b (0)**
▲	**H-13-N B-2**	**15.0**	**30**	**19**	**11**	**59.0**	**SANDY LEAN CLAY (CL)**	**A-6 (4)**
★	**H-13-N B-2**	**25.0**	**33**	**17**	**16**	**79.1**	**LEAN CLAY with SAND (CL)**	**A-6 (11)**
⊙	**H-13-N P-1**	**4.0**	**NV**	**NP**	**NP**	**6.6**		**A-1-b (0)**
✿	**H-13-N P-2**	**1.0**	**28**	**16**	**12**	**22.3**	**CLAYEY GRAVEL with SAND (GC)**	**A-2-6 (0)**
○	**H-13-N Scour**	**0.0**	**NV**	**NP**	**NP**	**40.0**	**SILTY SAND (SM)**	**A-4 (0)**

Yeh and Associates, Inc.
Geotechnical • Geological • Construction Services

ATTERBERG LIMITS

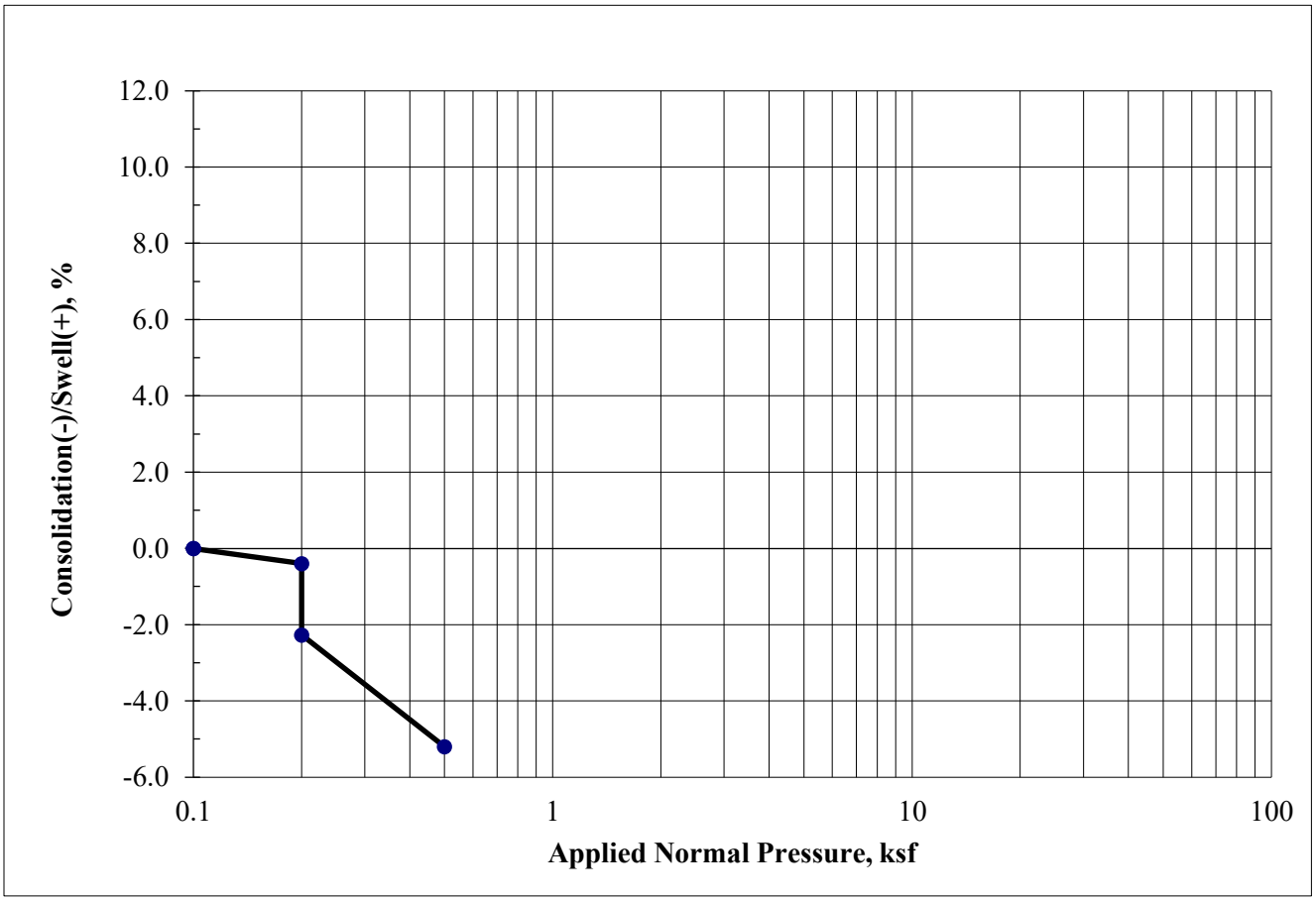
FIGURE

C - 4

Project No. 220-063 Date: 12-12-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Structure H-13-N

SWELL/CONSOLIDATION TEST - ASTM D 4546

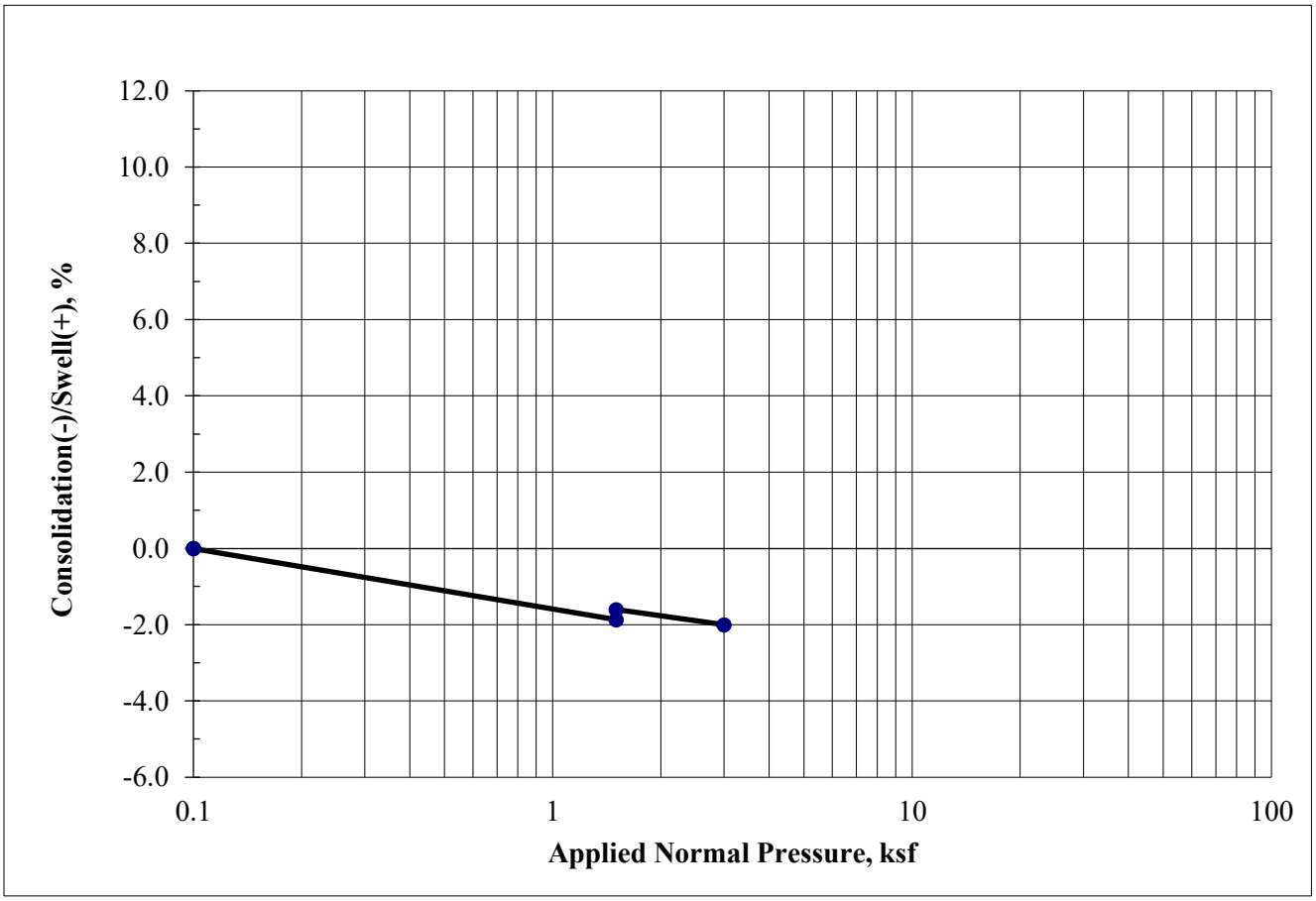


Boring ID	P-1
Sample Depth (ft)	4.0
Date Sampled	9/28/2020

Swell/ Consolidation (%)	-1.9
Natural Moisure Content (%)	3.4
Saturated Moisture Content (%)	18.9
Dry Density (pcf)	102.6

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services		**SWELL/ CONSOLIDATION TEST RESULTS**	**FIGURE**
Project No. 220-063	Date: 12/14/2020	CDOT Region 2 Bridge Bundle Structure H-13-N	**C-5**
Report By: DG	Yeh Lab: Colorado Springs		
Checked By: JTM			

SWELL/CONSOLIDATION TEST - ASTM D 4546



Boring ID	B-1
Sample Depth (ft)	15.0
Date Sampled	9/28/2020

Swell/ Consolidation (%)	0.3
Natural Moisure Content (%)	13.2
Saturated Moisture Content (%)	14.6
Dry Density (pcf)	119.6

Yeh and Associates, Inc. Geotechnical • Geological • Construction Services	**SWELL/ CONSOLIDATION TEST RESULTS**	**FIGURE**
Project No. 220-063 Date: 12/14/2020 Report By: DG Yeh Lab: Colorado Springs Checked By: JTM	CDOT Region 2 Bridge Bundle Structure H-13-N	**C-6**

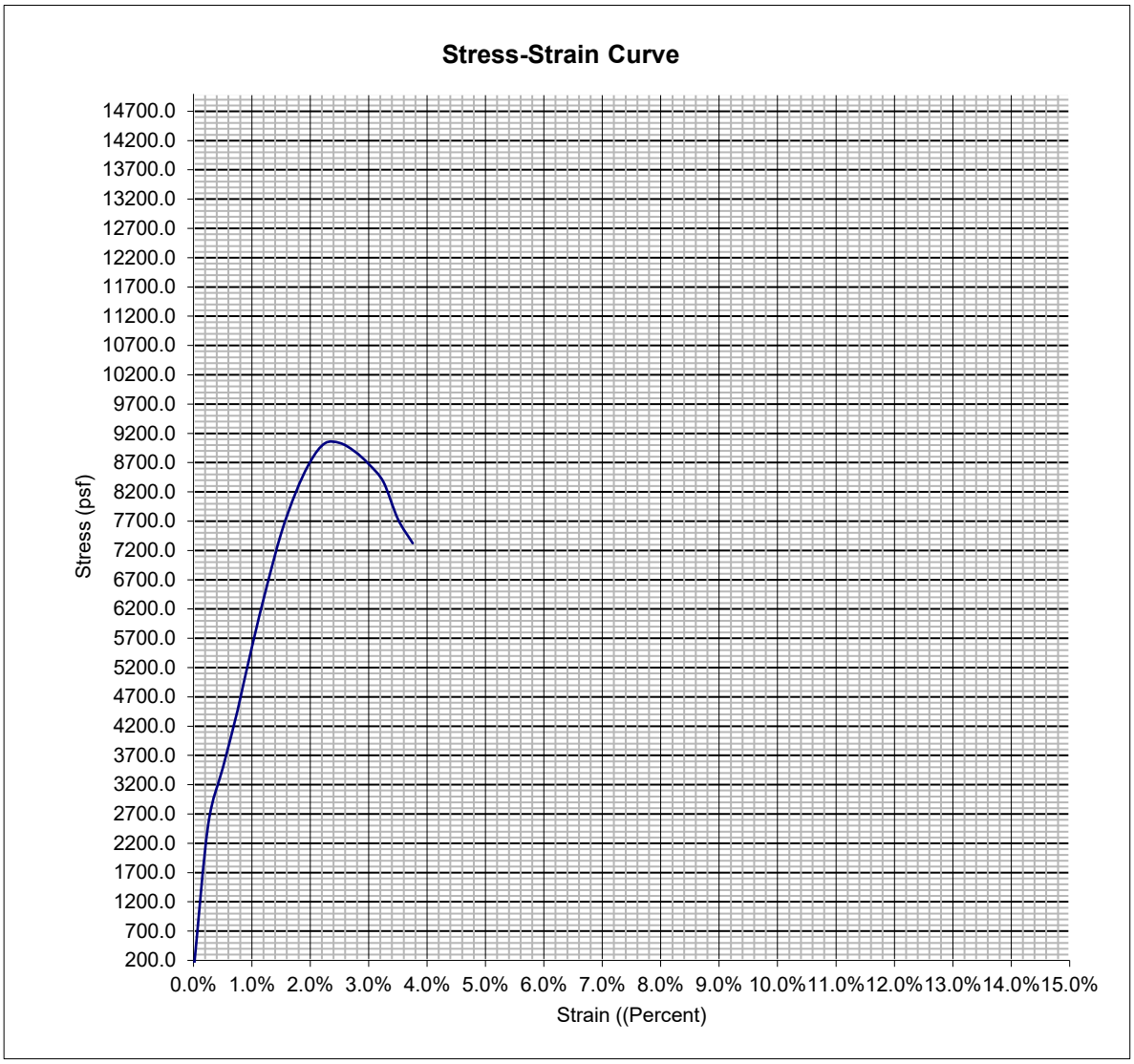
Yeh and Associates, Inc.
Consulting Engineers & Scientists

Clay- Lab Denver

STRESS-STRAIN CURVE
OF COHESIVE SOIL (ASTM D 2166)

Project No:	220-063	Project Name:	CDOT Region 2 Bridge Bundle H-13-N		
Sampled b	CW	Date Sampled:	11/18/2020	Date Tested:	11/18/20
Boring No:	B-1	Depth (ft):	20	Blow Counts:	14-20
Tested by:	M.A	Checked by:	JTM		
Soil Classification:		-			

Axial Strain (%)	Axial Stress (psf)
0.0%	0.0
0.3%	2522.6
0.5%	3489.3
0.8%	4465.9
1.0%	5554.8
1.3%	6574.8
1.5%	7497.1
1.8%	8201.1
2.0%	8727.2
2.3%	9033.2
2.5%	9039.0
2.8%	8900.5
3.0%	8671.6
3.3%	8367.3
3.5%	7735.6
3.8%	7325.8



Unconfined Compressive Strength (q_u) = 9039 psf @ 2.5% Strain
%

Natural Moisture:	14.8	%
Natural Density(Dry):	114.1	pcf
Average Diameter (D):	1.927	inches
Average High (L):	3.998	inches
L/D Ritio:	2.07	

Yeh and Associates, Inc.
Consulting Engineers & Scientists

Clay- Lab Denver

STRESS-STRAIN CURVE
OF COHESIVE SOIL (ASTM D 2166)

Project No:	220-063	Project Name:	CDOT Region 2 Bridge Bundle H-13-N		
Sampled b	CW	Date Sampled:	11/18/2020	Date Tested:	11/18/20
Boring No:	B-2	Depth (ft):	25	Blow Counts:	32-43
Tested by:	M.A	Checked by:	JTM		
Soil Classification:		A-6 (11) / CL			

Axial Strain (%)	Axial Stress (psf)
0.0%	0.0
0.3%	392.8
0.5%	744.4
0.8%	801.2
1.0%	1427.8
1.3%	1949.1
1.5%	2724.8
1.8%	3448.1
2.0%	4346.2
2.3%	6081.6
2.5%	7064.3
2.8%	7960.5
3.0%	8603.7
3.3%	8791.0
3.5%	8507.1
3.8%	7679.6
4.0%	6913.1
4.3%	5990.2

Unconfined Compressive Strength (q_u) = 8791 psf @ 3.3% Strain %

Natural Moisture:	7.3	%
Natural Density(Dry):	125.5	pcf
Average Diameter (D):	1.930	inches
Average High (L):	4.000	inches
L/D Ritio:	2.07	

ADVANCED TERRA TESTING

R Value

ASTM D2844

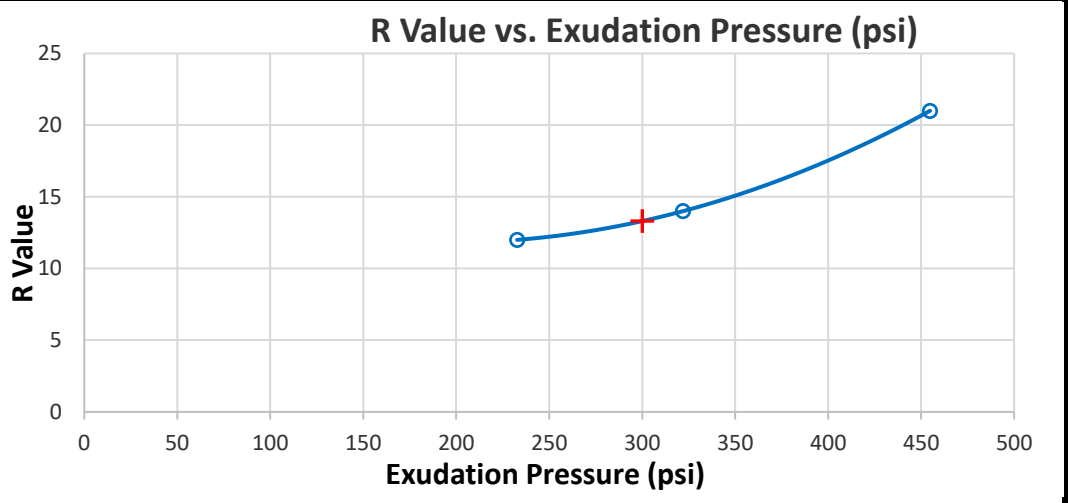
CLIENT	Yeh & Associates	BORING NO.	H-13-N
JOB NO.	2546-128	DEPTH	Combined Bulk
PROJECT	--	SAMPLE NO.	P-1/P-2
PROJECT NO.	220-063	DATE SAMPLED	--
LOCATION	--	SAMPLED BY	--
DATE TESTED	11/18/20	DESCRIPTION	--
TECHNICIAN	ALH		

Sample Conditions

Mass of Wet Soil & Pan (g):	1159.3	1145.8	1110.5
Mass of Dry Soil & Pan (g):	1042.5	1038.9	1003.6
Mass of Pan (g):	14.1	14.0	14.3
Mass of Wet Soil & Mold (g):	3260.9	3235.1	3197.0
Mass of Mold (g):	2114.4	2101.0	2096.2
Sample Height (in):	2.53	2.49	2.44
Wet Density (pcf):	137.4	138.1	136.8
Dry Density (pcf):	123.4	125.0	123.4
Wet Density (kg/m³):	2201	2212	2191
Dry Density (kg/m³):	1976	2003	1977
Moisture (%):	11.4	10.4	10.8

R Value Data

Exudation Pressure (lbs):	2925	5715	4045
Exudation Pressure (psi):	232.8	454.8	321.9
2000 lbs. Dial Reading (psi):	126	107	120
Displacement Turns:	4.98	4.53	4.72
Uncorrected R Value:	12	21	15
Corrected R Value:	12	21	14



Corrected R Value at 300 psi Exudation Pressure

13

NOTES:

Data entry by:	ALH	Date:	11/20/20
Checked by:	KMS	Date:	11/23/20
File name:	2546128__R Value ASTM D2844_0.xlsm		