Appendix A

Project Leadership Team and Technical Team Meeting Minutes

I-70 East Vail Pass Wildlife Crossing Feasibility Study
Project Leadership Team Meeting
January 6, 2020
Meeting Minutes

Attendees:

National Forest Foundation: Emily Olsen
US Forest Service: Ashley Nettles, Anna Bengtson
Colorado Department of Transportation: Grant Anderson, John Kronholm
Rocky Mountain Wild: Paige Singer
Summit County: Kate Berg
Consultant Team: Julia Jung, Julia Kintsch, Colleen Roberts

1. Project Overview
    a. It was stated that the purpose of the study was to build on previous studies to develop a well-defined, constructible, cost-credible solution that leverages stakeholder support.
    b. A brief background of the I-70 Mountain Corridor PEIS and Summit County Safe Passages work was provided.
    c. The scope of the study was discussed, and it was agreed that it included determination of feasibility of the three identified locations, preparation of preliminary cost estimates, identification of critical design and construction issues, and creation of marketing materials
    d. A design schedule showing completion of the project in July with Technical Team meetings in March and June was discussed.
2. I-70 Mountain Corridor Context Sensitive Solutions (CSS) process
    a. The overall concept of the CSS process was presented, and it was stated that following the CSS process for this project is not necessarily required at this stage, but it is prudent nonetheless because it sets the project up for future success.
    b. The role of Project Leadership Team (PLT) was defined as the group that leads/guides the project, enables decision making, and provides an avenue for stakeholder input. It was clarified that the PLT is not a decision-making body.
    c. The role of the Technical Team (TT) was defined as a larger group of stakeholders who want or need to be included have technical expertise or authority relevant to the project, and can provide technical input to assist in decision-making.
    d. Various stakeholders and their appropriate roles were discussed. Additional PLT and TT members were proposed. Please see attached list of stakeholders (under development).

3. Technical Design Issues
    a. Roadway design criteria was discussed. Concepts developed for overpasses will ensure that abutments are located outside of the current clear zone of I-70, and a third lane will not be precluded. Underpasses will be designed to carry 2-lanes of traffic and appropriate shoulders and will not preclude widening to 3-lanes. The wildlife underpasses will be sized based on I-70 being 3-lanes.
    b. It was agreed that wildlife design criteria would evolve with various concepts in order to maximize benefits to wildlife while addressing engineering challenges.
    c. Potential safety issues caused by shading and icing were discussed.
    d. The location of existing wetlands including potential FENs was discussed, including the potential fen around MP 193.5, which may require obtaining a soil sample.
    a. The rest area complex on Vail Pass is being reconstructed / remodeled through a funded project managed by CDOT Region 3. The design of wildlife fencing should take the revised rest area site plan into consideration.
    b. CDOT noted that it was important to communicate accurately about how wildlife criteria are being addressed. If they are listed in the design criteria table, it gives the impression that they are set and cannot be adjusted.
4. Criteria that will be used to evaluate different options were discussed. The team agreed that wildlife and biological considerations, land use considerations, stakeholder support, constructability, cost, safety, maintenance and outreach and education opportunities should all be evaluation criteria.

ACTION ITEMS:

1. **Julia Jung to schedule upcoming Technical Team meeting**
2. **Ashley Nettles to provide contact information for Forest Service wetland specialist**
3. **Julia Jung to coordinate with Chinook on updates to logo**
4. **Julia Jung to investigate location of buried archeological site**
5. **Julia Jung to remove wildlife criteria from the design criteria spreadsheet**
6. **Colleen to provide links to or copies of documentation for the Westbound Twin Tunnels Categorical Exclusion and I-70 Mountain Corridor Design Speed Study**

Stakeholders List

National Forest Foundation (NFF): PLT – Emily Olsen, TT – Emily Olsen

United States Forest Service (USFS): PLT – Ashley Nettles, Anna Bengtson, TT – Ashley Nettles

Colorado Department of Transportation (CDOT): PLT – John Kronholm, Grant Anderson, TT – John Kronholm, Sam Abraham, Stuart Gardner, other specialty units

Summit County: PLT – Kate Berg, TT – Staff at Public Works and Open Space Trails

Rocky Mountain Wild: PLT – Paige Singer, TT – Paige Singer

Eagle County: PLT – Adam Palmer, TT - TBD

I-70 Coalition: PLT – Margaret Bowes

Federal Highway Administration (FHWA): TT - TBD

Colorado Parks and Wildlife (CPW): TT - TBD

United States Fish and Wildlife Service (USFWS): TT -TBD

Copper Mountain: TT - TBD

Vail Resorts: TT - TBD

Arapahoe Basin: TT - TBD

Eagle County Safe Passages: TT - TBD

Center for Large Landscapes Conservation: TT - TBD

Denver Zoo: TT - TBD

Eagle Summit Wilderness Alliance: TT - TBD

Vail Pass Task Force: TT - TBD

I-70 East Vail Pass Wildlife Crossing Feasibility Study
Technical Team Meeting #1
March 30, 2020
Meeting Minutes

Attendees:

National Forest Foundation (NFF): Emily Olsen
US Forest Service (FS): Ashley Nettles, Kate DeMorest
Colorado Department of Transportation (CDOT): John Kronholm, Grant Anderson, Cinnamon Levi-Flinn, Kristin Salamack, and Sam Abraham
Summit County: Brian Lorch
Rocky Mountain Wild: Paige Singer
Federal Highway Administration (FHWA): Jeff Bellen
Colorado Parks and Wildlife (CPW): Elissa Slezak
Vail Resorts: Jim Testin
Denver Zoo: Stefan Ekernas
Eagle Summit Wilderness Alliance: Mike Browning
Center Large Landscape Conservation: Liz Fairbank, Renee Callahan
Consultant Team: Julia Jung, Julia Kintsch, Jon Altschuld, Tyler Bowman, and Mandy Whorton

MINUTES:

1. Overview
    a. It was stated that the purpose of the study was to build on previous studies to develop a well-defined, constructible, cost-credible solution that leverages stakeholder support.
    b. A brief background of the I-70 Mountain Corridor PEIS and Summit County Safe Passages work was provided.
    c. The scope of study was described as determination of feasibility of the three identified locations, preparation of preliminary cost estimates, identification of critical design and construction issues, and creation of marketing materials
    d. A design schedule showing completion of the project in July with Technical Team meetings in March and June was discussed.
    e. It was noted that the project would be administered by the NFF with CDOT and USFS as major partners.
    f. It was noted that the Project Leadership Team (PLT) included the NFF, USFS, Summit County, CDOT, and Rocky Mountain Wild
2. Technical Team Roles and Responsibilities
    a. The role of the Technical Team (TT) was defined as:
        i. Assuring that local context is defined and integrated into the project
        ii. Recommending and guiding methodologies involving criteria, and analysis
        iii. Supporting and providing insight with respect to community and agency issues

iv. Assisting in evaluating, selecting, and refining alternatives and options
v. Coordinating and communicating with respective agencies

3. Wildlife Crossing Preliminary Alternatives
    a. Three underpass alternatives at MP 193.5 and MP 193.0 and 192.3 were presented, all of which assumed a roadway width of 45', which corresponds to a 45' length for the animals to traverse:
        i. Buried precast arches with a maximum opening of 44' and 13.5' of vertical clearance
        ii. Traditional bridges with a maximum opening of 100' and 15' of vertical clearance
        iii. Buried bridges with a maximum opening of 76' and 15' of vertical clearance.
    b. Two overpass alternatives at MP 192.3 were presented:
        i. A straight bridge with angled wingwalls and a 125' width
        ii. An hourglass shaped bridge with a minimum width of 85'
    c. Construction phasing and temporary detour pavement were briefly discussed. It was noted that underpasses required temporary detours, but overpasses could be completed with night closures only.
    d. The wildlife fencing plan was described. Graphics showing the proposed fencing running along both sides of eastbound and westbound I-70 were shown. It was highlighted that the median would be fenced in. It was also noted that access for hunting and recreation needed additional discussion.
4. Alternatives Evaluation Criteria
    a. The criteria the design team developed to evaluate the wildlife crossing options was presented and feedback was requested. There were no comments requesting changes in criteria.
    b. The TT was presented with evaluation matrices for comparing different options at each milepost. The TT agreed with the information presented in the final evaluation matrices *[provided in Appendix B of the final project report]*.
    c. Construction costs were presented by the design team. It was noted that, in order of magnitude, all the underpass options would have a similar cost and overpasses would be about twice as much or more.
    d. Overall, there was a general consensus that any of the options could work in any of the locations. There was not a general consensus that any option was preferred over another.
5. Additional general feedback from the Technical Team included:
    a. One downside of the crossings being visible from the bike path would be that people would be more likely to ski or walk on/under the bridges.
    b. Skewed arches are much more difficult to construct than perpendicular arches.
    c. Snow and sand will get pushed over the side of the underpasses during plowing operations.
    d. Wildlife fencing should be located outside of the clear zone.

e. Foundation and shoring are large cost drivers.
f. CDOT could have difficulty inspecting a buried bridge.
g. Vegetation should be provided on the overpasses for animal cover.
h. The approach slope on the overpass looks steep.
i. The project should be viewed in the context of the whole landscape, not individual sites.
j. Public perception and understanding of wildlife crossings is very different than it was ten years ago, and it is important to create visual projects that pique the curiosity of the public.
k. Crash data could be used to show that the crossings pay for themselves by reducing accidents.
l. There were several requests for additional information to understand the broader view of the project.
    i. The design team clarified that the crossings were proposed for westbound I-70 only, and there are existing bridges that act as animal crossings on eastbound I-70.
    ii. The design team clarified that the bike path was outside of the construction limits.
    iii. The design team clarified that the intent is to construct crossings at all three locations.

I-70 East Vail Pass Wildlife Crossing Feasibility Study
Technical Team Meeting #2
May 4, 2020
Meeting Minutes

Attendees:

National Forest Foundation (NFF): Emily Olsen
US Forest Service (FS): Ashley Nettles, Kate DeMorest
Colorado Department of Transportation (CDOT): John Kronholm, Grant Anderson, Cinnamon Levi-Flinn, Kristin Salamack, and Sam Abraham
Summit County: Brian Lorch, Jordan Mead
Eagle County: Adam Palmer
Rocky Mountain Wild: Paige Singer
Federal Highway Administration (FHWA): Jeff Bellen
Colorado Parks and Wildlife (CPW): Elissa Slezak
US Fish and Wildlife Service (USFWS): Kurt Broderdorp
Denver Zoo: Stefan Ekernas
Center Large Landscape Conservation: Liz Fairbank, Renee Callahan
Consultant Team: Julia Jung, Julia Kintsch, Jon Altschuld, Tyler Bowman, and Mandy Whorton

MINUTES:

1. Overview
    a. It was stated that the purpose of the meeting was to answer additional questions and receive additional feedback from the Technical Team (TT), with the ultimate goal of narrowing down the wildlife crossing options under consideration at each location.
    b. As requested at the last meeting, a slide was presented showing the entire project area and highlighting the bike path, proposed fencing, the existing bridges on eastbound I-70, and the proposed wildlife crossing locations on westbound I-70.
    c. A review of the wildlife crossing options under consideration at each location was provided.
    d. It was stated that the design team understood from the last meeting that there was a general consensus that all of the options could work but additional feedback was required to decide which options to carry forward for detailed preliminary design.
2. TT feedback and discussion on the wildlife crossing alternatives and evaluation:
    a. Concerns were voiced that snow would build up in the underpasses in the winter, reducing the proposed vertical clearance. The design team noted that during the winter only small animals use the crossings (elk and deer do not), so a reduction in vertical clearance could be acceptable.
    b. The importance of approach cover and vegetation on overpasses was stressed. An example of an existing failed structure with steep approach grades, no vegetation, and livestock fence was provided to the design team.

c. It was noted that a buried bridge would be less noisy to wildlife crossing underneath than a traditional bridge.
d. Discussion regarding the hour-glass shaped overpass included the following feedback:
    i. The shape of the approach is more natural from the animal perspective.
    ii. The structure is more aesthetically appealing from the highway.
    iii. The width at the narrowest point should still be wide enough to accommodate all targeted species, including elk.
e. Engineering and constructability items for consideration voiced by the TT included:
    i. Providing adequate work room for constructing precast arches.
    ii. Adding new bridge decks to I-70 creates icing issues and should be avoided.
    iii. Buried bridges could be inspected from the bottom of the bridge.
    iv. Snow build up and the formation of cornices could be an issue for the overpass.
    v. Shading of I-70 from the overpass could create icing issues on I-70.
f. The frequency of wildlife use of underpasses vs overpasses was discussed. The design team noted that greater wildlife connectivity is provided by a diversity of crossing structure types within the landscape. It was further discussed that consideration of an overpass structure was critical for public visibility and education.
g. It was noted that an overpass has a much bigger construction footprint and would cost significantly more than an underpass.
h. It was noted that all species that use a buried bridge would also use a precast arch.
i. As a discussion point, the design team noted that the cost of any of the underpass structures would be similar to each other and similar at all three locations.
j. There was discussion about providing access points through the wildlife fencing for recreational users at key locations. It was pointed out that access for recreation from sanctioned parking areas is provided by existing structures, and parking along I-70 is illegal. It was also noted that the wildlife fence could be cut by recreational users who are used to parking on I-70. The team agreed that it was important to educate recreational users about using sanctioned access points, and that further partnership would be required to change behaviors.

3. The following decision points resulted from feedback and discussion at the meeting:
    a. A holistic approach to the landscape would be most effective for wildlife connectivity, and variability of wildlife crossing structure types is preferred.
    b. An overpass at MP 192.3 should be carried forward for further consideration.
    c. At MP 193.0 and 193.5 different structure types should be considered. Because buried bridges and precast arches do not introduce an icing problem on I-70, they should be carried forward rather than a traditional bridge concept.
4. The following items were discussed regarding potential options for fundraising:
    a. Various types of grants and partnerships need to be explored
    b. CDOT ownership of the project could open up more opportunities for funding
    c. Central Federal Lands – Highway Division (CFLHD) Federal Lands Access Program (FLAP) Grants should be investigated

I-70 East Vail Pass Wildlife Crossing Feasibility Study
Technical Team Meeting #3
August 6, 2020
Meeting Minutes

Attendees:

US Forest Service (FS): Ashley Nettles
Colorado Department of Transportation (CDOT): John Kronholm, Grant Anderson, and Sam Abraham
Summit County: Brian Lorch, Jordan Mead
Eagle County: Adam Palmer
Rocky Mountain Wild: Paige Singer
Federal Highway Administration (FHWA): Jeff Bellen
Colorado Parks and Wildlife (CPW): Elissa Slezak
US Fish and Wildlife Service (USFWS): Kurt Broderdorp
Denver Zoo: Stefan Ekernas
Center Large Landscape Conservation: Liz Fairbank, Renee Callahan
Consultant Team: Julia Jung, Julia Kintsch, Jon Altschuld, Tyler Bowman, and Mandy Whorton

MINUTES:

1. Project Update
    a. The design team presented an updated schedule indicating the final report for the study would be submitted near the end of August.
    b. The design team indicated that they had refined one engineering concept at each location as discussed at Technical Team (TT) Meeting #2:
        i. Area 1: A buried bridge with an 85' wide opening and 15' of vertical clearance
        ii. Area 2: A buried arch with a 44' wide opening and 13.5' of vertical clearance
        iii. Area 3: An hour-glass shaped overpass with an 80' wide opening for I-70 and an 85' wide (at the minimum) platform for animals to cross on
    c. It was noted the design team had considered extending the structure of the buried bridge and arch to prevent plowed snow from being pushed over the edge and building up at the entrance to the crossings. However, it was determined that this would increase the distance wildlife would have to traverse through the structure by 60', so it was decided not to adjust the structures. It was noted that medium sized animals would likely still have enough vertical clearance to use the structures in the winter, and larger animals don't migrate in the winter.
    d. The design noted that the overpass option had a combination noise wall and permeable fence to reduce the likelihood of cornices forming on the overpass. It was noted that more study was needed to confirm the impacts of blowing snow.

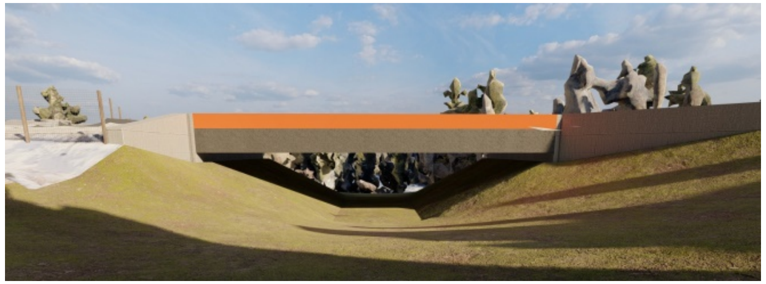
e. The results of a shading simulation for the overpass for February 15 were presented. It was noted that the portions of the area that were in total shade were either directly below the structure or outside of the traveled way.
f. The final configuration for the wildlife fence and fence ends was described.
g. The cost estimate for the project was presented.
    i. Area 1 construction cost: $3.0M
    ii. Area 2 construction cost: $3.5M
    iii. Area 3 construction cost: $8.5M
    iv. Fencing: $4M
    v. Design and administration: $2M
    vi. Total: $21M
h. The project indicated that a final report and marketing materials would be delivered as part of the study.

2. TT feedback and discussion included:
    a. Adding an "awning" in the future to prevent snow build up at the entrance to the underpasses was discussed. It was noted that the designs would not preclude that.
    b. It was stressed that additional outreach and communication was required regarding hunting access and parking along I-70.
    c. The necessity for vegetation, especially on the overpass was discussed. It was noted that larger plants could be placed at the approaches and smaller plants on top of the structure.
    d. It was noted that monitoring and research projects should be included in the project and cost estimates. It was noted that the cost for research was an item covered by a 30% contingency that was applied to the project. It was noted that CDOT and CPW have contributed to monitoring on past projects. It was also noted that environmental documents could call for monitoring as mitigation.
    e. The geotechnical report was briefly discussed. It was noted that nothing unusual was encountered.
    f. The cost of the overpass compared to the underpass was discussed. It was noted that it was more than twice as expensive, but had a lot of value for elk passage, fundraising, and education.
    g. The TT suggested comparing the cost of crashes to the construction cost to help garner support and raise funds.
    h. The team discussed the possibility of building the project in phases as funding becomes available.

Appendix B

Wildlife Crossing Dimensions and Evaluation Matrices

Area 1: MP 193.5



Dimensions (from the perspective of the wildlife)			
	Length	Width (widest point)	Height (at apex for arches)
Underpass: Buried Arch	45’	44’	13.5’
Underpass: Traditional Bridge	45’	100’	15’
Underpass: Buried Bridge	45’	76’	15’

Area 1: MP 193.5

Evaluation Matrix					
	Criteria				
	Wildlife and Biological Considerations	Constructability	Cost	Maintenance	Outreach and Education Opportunities
	opening size, land use conflicts, impacts to wetlands/fens, relation to recreation path, human accessibility, wildlife accessibility	phasing, traffic impacts	construction cost	snow storage, icing, barriers, joints, space for equipment	visibility from roadway, visibility from recreation path, aesthetics fundraising/partnership opportunities
Underpass: Buried Arch	Smallest opening size. No wetland impacts.	Significant shoring. Temp paving to maintain traffic.	$	Least structure maintenance. Introducing additional guardrail.	Rec path educational opportunity.
Underpass: Traditional Bridge	Largest opening of underpasses. No wetland impacts.	Some shoring. Temp. paving to maintain traffic.	$	Roadway icing concerns. Joint repair/bridge maint. Introducing additional guardrail.	Rec path educational opportunity.
Underpass: Buried Bridge	No wetland impacts.	Some shoring. Temp. paving to maintain traffic.	$	Bridge maintenance (unique structure). Introducing additional guardrail.	Rec path educational opportunity.

Area 2: MP 193.0

Dimensions (from the perspective of the wildlife)			
	Length	Width (widest point)	Height (at apex for arches)
Underpass: Buried Arch	45’	44’	13.5’
Underpass: Traditional Bridge	45’	100’	15’
Underpass: Buried Bridge	45’	76’	15’

Area 2: MP 193.0

Evaluation Matrix					
	Criteria				
	Wildlife and Biological Considerations	Constructability	Cost	Maintenance	Outreach and Education Opportunities
	opening size, land use conflicts, impacts to wetlands/fens, relation to recreation path, human accessibility, wildlife accessibility	phasing, traffic impacts	construction cost	snow storage, icing, barriers, joints, space for equipment	visibility from roadway, visibility from recreation path, aesthetics fundraising/partnership opportunities
Underpass: Buried Arch	Smallest opening size. No wetland impacts.	Significant shoring. Temp paving to maintain traffic.	$	Least structure maintenance. Introducing additional guardrail.	Rec path educational opportunity.
Underpass: Traditional Bridge	Largest opening of underpasses. No wetland impacts.	Some shoring. Temp. paving to maintain traffic.	$	Roadway icing concerns. Joint repair/bridge maint. Introducing additional guardrail.	Rec path educational opportunity.
Underpass: Buried Bridge	No wetland impacts.	Some shoring. Temp. paving to maintain traffic.	$	Bridge maintenance (unique structure). Introducing additional guardrail.	Rec path educational opportunity.

Area 3: MP 192.3 (Underpass)

Dimensions (from the perspective of the wildlife)			
	Length	Width (widest point)	Height (at apex for arches)
Underpass: Buried Arch	45’	44’	13.5’
Underpass: Traditional Bridge	45’	100’	15’
Underpass: Buried Bridge	45’	76’	15’

Area 3: MP 192.3 (Overpass)

Dimensions (from the perspective of the wildlife)		
	Length	Width (at narrowest point)
Overpass: Angled Walls	100’ (length of straight section)	125’
Overpass: Hourglass	54’ (distance of roadway to cross)	85’

Area 3: 193.2

Evaluation Matrix					
	Criteria				
	Wildlife, Biological, and Environmental Considerations	Constructability	Cost	Maintenance	Outreach and Education Opportunities
	opening size, land use conflicts, impacts to wetlands/fens, relation to recreation path, human accessibility, wildlife accessibility	phasing, traffic impacts	construction cost	snow storage, icing, barriers, joints, space for equipment	visibility from roadway, visibility from recreation path, aesthetics fundraising/partnership opportunities
Underpass: Buried Arch	Smallest opening size. No wetland impacts.	Significant shoring. Temp paving to maintain traffic.	$	Least structure maintenance. Introducing additional guardrail.	Rec path educational opportunity.
Underpass: Traditional Bridge	Largest opening of underpasses. No wetland impacts.	Some shoring. Temp. paving to maintain traffic.	$	Roadway icing concerns. Joint repair/bridge maint. Introducing additional guardrail.	Rec path educational opportunity.
Underpass: Buried Bridge	No wetland impacts.	Some shoring. Temp. paving to maintain traffic.	$	Bridge maintenance (unique structure). Introducing additional guardrail.	Rec path educational opportunity.
Overpass: Angled Walls	Largest wildlife crossing area. Diversity of structure types. No wetland impacts. Most visual impact.	Short-term closures (night, etc.). Simpler angles.	$$	Roadway icing concerns. Least structure maintenance. Introducing additional guardrail. Noise wall snow concern.	Most visible to public. Most fundraising/partnering opportunities. Less visible from rec path, still edu opp.
Overpass: Hourglass	Diversity of structure types. No wetland impacts. More visual impact than underpasses.	Short-term closures (night, etc.). Complex curves.	$$	Roadway icing concerns. Bridge maintenance (unique). Introducing additional guardrail. Noise wall snow concern.	Most visible to public and aesthetically pleasing. Most fundraising/partnering opportunities. Less visible from rec path, still edu opp.

Appendix C

Geotechnical Feasibility Study

Final Geotechnical Feasibility Study

East Vail Pass Wildlife Crossings

Summit County, Colorado

Yeh Project No.: 219-176

August 28, 2020

Prepared for:

Wood Environment and Infrastructure Solutions, Inc.
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Yeh and Associates, Inc.
Consulting Engineers & Scientists

Final Geotechnical Feasibility Study

East Vail Pass Wildlife Crossings

Summit County, Colorado

Yeh Project No.: 219-176

August 28, 2020

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1. PURPOSE AND SCOPE OF STUDY

This report presents the results of our final geotechnical feasibility study completed for proposed wildlife crossings along US Interstate 70 (I-70), in Summit County, Colorado. The project is located along I-70 between mileposts (MP) 190 and 194 approximately 2.5 miles west of Copper Mountain, on the north side of the west bound lanes as shown in Figure 1.

Figure 1. Project Location Map

Our scope of services consisted of the following:

- Drill three (3) exploratory borings for the proposed structures foundation design, one at the north end of each of the three proposed areas as named on plan view provided by Wood to a depth penetrating dense gravels or bedrock. Drill one boring at the proposed overpass/underpass location at MP 192.3 (Area 3) and drill two borings at the proposed underpass locations at MP 193.0 (Area 2) and MP 193.5 (Area 1) on I-70.

- Laboratory testing to characterize the soil and rock properties as appropriate.
- Geotechnical report including the following:
    - Conduct a subsurface investigation to obtain information on the subsurface conditions.
    - Perform laboratory testing on soil and rock samples obtained during the subsurface investigation to evaluate pertinent soil classification and engineering characteristics of the on-site soils and bedrock. Laboratory testing is to include corrosivity and R-value.
    - Perform engineering analysis and prepare a report that summarizes our evaluation of the field and laboratory data and presents the results of our geotechnical engineering analyses and recommendations for the proposed structures. In accordance with the Statement of Work and RFP for the Vail Pass East Wildlife Passages Feasibility Study, both shallow and deep foundation recommendations are provided for the planned structures.
    - Identify geologic hazards in the vicinity of the project and evaluate any potential impact to construction and discuss mitigation efforts, if necessary.

All borings were drilled on the cut side, or north side, of the westbound lanes of I-70. Since the fill side, or south side, of the westbound lanes was not explored there is considerable uncertainty as to the bedrock depth, fill depth, engineering characteristics and soil composition south of the highway. Additional borings at each of the three areas on the south side are recommended to provide specific geotechnical recommendations for south side foundation design and to mitigate risk pertaining to deep foundation construction for the project.

This report has been prepared in general accordance with the work order from Wood Environment and Infrastructure Solutions, Inc. (Wood) with project number 32783014 issued on April 20, 2020 to Yeh and Associates, Inc. (Yeh) to perform a geotechnical investigation and geologic hazards evaluation. Borings were drilled on the north shoulder of the west bound lanes of I-70 as requested by client. Additional borings at the southern foundation areas were beyond the scope of this investigation. Based on information collected during the investigation, Yeh has completed an evaluation of the surface and subsurface conditions and provided geotechnical recommendations for the proposed structures based on investigations on the north end of foundation areas. The recommendations are based on the proposed construction, subsurface exploration, and site reconnaissance performed as part of the investigation. Foundation and retaining wall design recommendations as well as a discussion of geotechnical engineering considerations for design and construction are also included in this feasibility study.

2. PROPOSED CONSTRUCTION

The proposed construction along the westbound lanes of I-70 will include underpass structures at MP 193.5 (Area 1) and MP 193.0 (Area 2) and either an underpass or overpass structure at MP 192.3 (Area 3). Design for all structures should anticipate a third lane of traffic in the westbound direction for future I-70 expansion possibilities.

2.1 Areas 1 and 2: Wildlife Underpass Crossings

We estimate the proposed wildlife underpass crossings will be located at or near existing natural drainages at Areas 1 and 2, located in the middle and at the east end of the project at approximate MP 193.0 (Area 2) and MP 193.5 (Area 1) respectively. These two areas are north and west of an existing bridge in the eastbound lanes near Copper Mountain Ski Resort as shown in Figure 2. Boring locations were selected near existing natural drainages as shown in Figures 2 and 3. In general, terrain south of the interstate consisted of steep slopes with intermittent terraces down to the valley bottom as shown in Figures 4 and 5. Bedrock outcroppings were observed east of test boring B-1, east of the project area, as shown in Figure 6. It is anticipated the wildlife underpass crossings will have a minimum height of 14 feet and be at least 44 feet wide as discussed in the Summit County Safe Passages for Wildlife document for I-70, Vail Pass, Mileposts 190-194.

We understand the preferred design alternative at Area 1 consists of a buried bridge designed with an integral abutment supported on H-pile foundations. A sloped embankment in front of the abutment will be incorporated in the design. We understand the preferred design alternative at Area 2 consists of a buried arch structure supported on drilled shaft foundations. Reinforced concrete box culverts supported on shallow foundations may also be considered for wildlife underpass crossings at Areas 1 and 2.

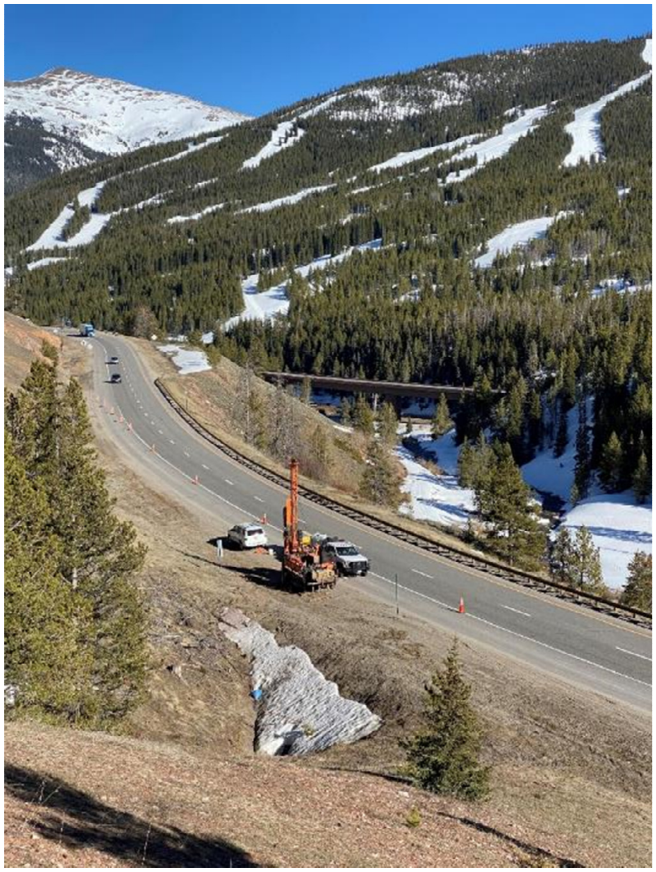

Figure 2. Area 1, Boring B-1 location near existing drainage. Eastbound I-70 bridge near Copper Mountain Ski Area shown in the background, looking southeast.

Figure 3. Area 2, Boring B-2 near existing drainage, looking southeast.

Figure 4. Area 1, Steep hillside and terrace south of boring B-1 looking west.

Figure 5. Area 2, Steep hillside and terrace area south of boring B-2 looking west.

Figure 6. Bedrock outcroppings east of the project site.
Drilling boring B-1 in background, looking west.

2.2 Area 3: Wildlife Overpass/Underpass Crossing

A proposed wildlife overpass or underpass crossing will be located near the west end of the project area in the westbound lanes at approximate MP 192.3 (Area 3) which is north of the Stafford Creek bridge in the eastbound lanes. We understand the preferred design alternative for the Area 3 wildlife crossing is an overpass consisting of a bridge structure designed with an integral abutment and supported on H-pile foundations. In addition, a wall will be constructed in front of the abutment. A reinforced concrete box culvert supported on shallow foundations may also be considered for a wildlife underpass crossing at Area 3. We anticipate selection of the final structure location will depend on type of construction and topography of the hillside south of the interstate. A bedrock outcrop was observed west of the drill location as shown in Figure 7. The hillside south of the interstate at Area 3 consisted of a steeply sloping hillside down to the valley bottom with a bench area as shown in Figure 8.

Figure 7. Bedrock outcropping located west of boring B-3 location.

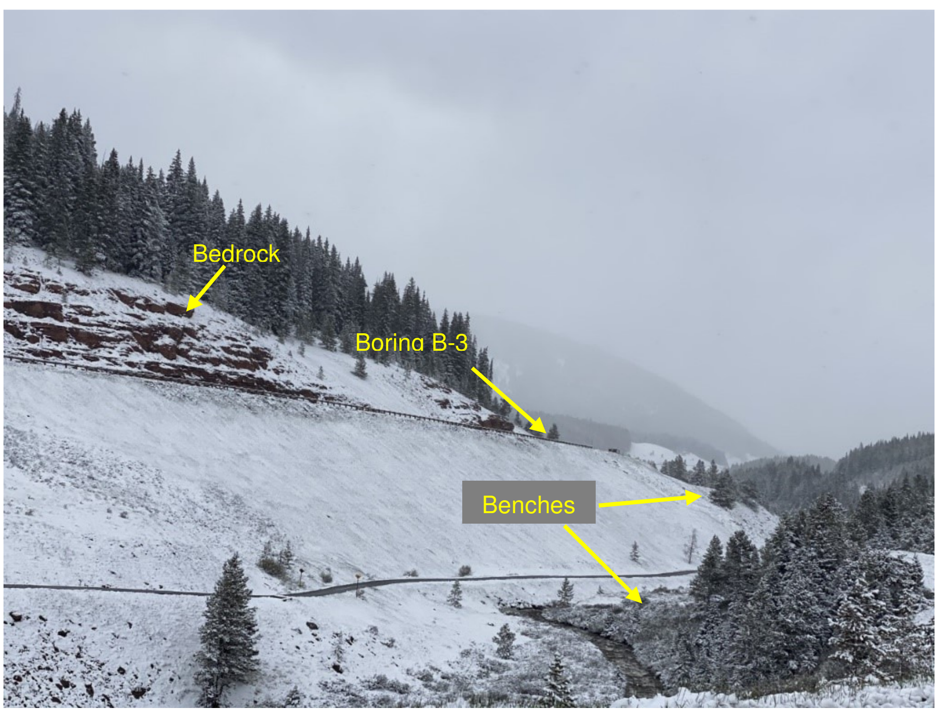

Figure 8. Area 3 bedrock outcropping, boring B-3, steep hillside and bench.

3. SITE CONDITIONS, GEOLOGICAL SETTING, AND GEOLOGIC HAZARD DISCUSSION

The project area was located along the Interstate 70 corridor in the glaciated West Tenmile Creek Valley. Based on the Geologic map of the southwest quarter of the Dillon quadrangle (Bergendahl, 1969), faults have been mapped north and east of the project area in what is generally known as the Gore Fault Zone along the eastern edge of the Gore Mountain Range of the Rocky Mountains. Surficial deposits in the project area include Quaternary age glacial moraine deposits of poorly sorted sand, gravel, cobbles, and boulders. Localized areas of fill typically associated with roadway construction were encountered in the project area. Bedrock outcrops near the west end of the project area have been mapped as the sandstone, mudstone/shale, and conglomerate of the Pennsylvanian-Permian age Maroon Formation and outcrops south of the project area have been mapped as dipping, or tilting, to the east at approximately 10 to 20 degrees. Migmatite, highly metamorphosed rock, is mapped east of the project area.

During our investigation, material associated with debris flow deposits were encountered, especially at the low-lying areas in drainages. Future debris flow occurrences are possible.

According to referenced maps, including the CDOT I-70 Mountain Corridor Final Programmatic Environmental Impact Statement (PEIS), 2011, landslide activity is not mapped in the project area. Rockfall hazards may be present in areas of bedrock outcrops. While some rockfall may be rock that detaches from a larger rock mass, rocks up to boulder in size, in rocky soils, such as surficial glacial deposits can also be mobilized from steep slopes. Minor flooding during rapid spring thaw and snowmelt should be anticipated if structures are constructed near or at drainage areas. Existing drainage features appear to be successful in diverting flow below existing roadways to the valley bottom to the south. A geology and geologic hazard map is provided in Appendix A.

It should be noted that upper silty, clayey sand deposits encountered may have potential for collapse or settlement after loading when water is introduced. Proper construction methods as discussed in this report will reduce these impacts if followed correctly by the contractor.

In our opinion, for the design life of the proposed structures, we do not anticipate large scale geologic hazards or the need for mitigation of such hazards at the project area. The above mentioned cautions of lesser geologic impacts should be considered during design.

4. SUBSURFACE EXPLORATION AND CONDITIONS

4.1 Field Exploration

Yeh subcontracted drilling services from Authentic Drilling, Incorporated of Kiowa, Colorado. During the period of April 29 through May 1, 2020, three borings were advanced to depths ranging from 52.0 to 90.8 feet within the north shoulder of the westbound lanes of I-70 as shown on the Boring Location Plan provided in Appendix B. Borings were drilled with an Acker Renegade, track mounted, drill rig as shown in Figures 2 and 3. Borings B-1 (Area 1) and B-2 (Area 2) were drilled using solid stem auger and ODEX methods. Boring B-3 (Area 3) was drilled with ODEX and HQ core methods.

Borings were advanced to appropriate depths where a Modified California sampler with a 2-inch interior diameter (ID) and 2.5 inch outside diameter (OD), or a standard split spoon sampler with a 1⅜-inch ID and 2 inch OD were used to record blow counts and obtain samples. The sampler was seated at the bottom of the boring, then advanced by a 140-pound hydraulic automatic, or "auto," hammer falling a distance of 30 inches. The average energy transfer ratio for this hammer was 96 percent. The Modified California Sampler 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. The Modified California Sampler drive length is 12 inches and "Penetration Resistance" refers to the sum of all blows. The number of blows required to drive the samplers two 6-inch intervals or a fraction thereof, constitutes the N-value. The N-value, when properly evaluated, is an index of the consistency or relative density of the material tested.

Samples were obtained at 5 feet intervals down to 25 feet below ground surface. Below 25 feet the sampling frequency was reduced as material type became consistent to the maximum depth explored. In boring B-3 rock core was recovered from 28.5 feet to 52 feet. Bulk samples of auger cuttings were also obtained. Samples were collected in general accordance with ASTM D1586 for SPT, and ASTM D3550 for Modified California.

Samples obtained during the field explorations were examined by the project personnel and representative samples were submitted for laboratory testing to evaluate the engineering characteristics of materials encountered. Boring logs and legend are presented in Appendix C.

4.2 Subsurface Conditions

In general, subsurface conditions consisted of 10 to 27 feet of stratified layers of silty, clayey sand over gravel or bedrock. Minor amounts of road base shoulder material were encountered at the surface. Dense to very dense gravel with cobbles and boulders were encountered in borings B-1 and B-2 below 27 feet depth. A stratified silty clay and sand layer with possible cobbles and boulders was encountered in boring B-2 between 48 and 73 feet. Boulders encountered during drilling were estimated to range in size from 1.5 to 3 feet and based on terrain and glacial deposits, larger boulders should be anticipated. Bedrock was encountered in boring B-3 at a depth of 10 feet to the depth explored. Bedrock was not encountered in borings B-1 and B-2 to the depths explored. Borings were backfilled with native cuttings after drilling. Detailed boring logs are provided in Appendix C.

4.3 Laboratory Testing

Samples retrieved during the field explorations were returned to the laboratory for review by the project geotechnical engineer and were classified in accordance with the Unified Soil Classification System (USCS) and American Association of State Highway and Transportation Officials (AASHTO). An applicable program of laboratory testing was developed to evaluate engineering properties of the subsurface materials.

Laboratory soil and rock testing included the following:

- Description and Identification of Soils (Unified Soil Classification System)
- Natural moisture-density
- Unconfined Compressive Strength on selected rock samples
- One Dimensional Swell-Consolidation
- R-Value
- Direct Shear
- Water Soluble Sulfate Content
- Water Soluble Chloride Content
- Resistivity
- pH

Results of the laboratory tests are shown on the boring logs are presented in the Laboratory Summary found in Appendix D.

4.3.1 Clay

Two native clay samples tested had 60 and 74 percent fines, liquid limits of 29 to 32 percent (material passing the No. 200 sieve). Atterberg limit testing on these samples indicated liquid limits of 25 and 28 percent and a plasticity index of 7 percent. One of these samples taken at a depth of 25 feet was tested for swell/consolidation (ASTM 4546) and exhibited collapse of 0.2 percent when wetted under an applied pressure of 1,000 pounds per square foot (psf). A clay sample taken at a depth of 25 feet was tested for direct shear. The clay classified as CL-ML according to the Unified Soil Classification System (USCS) and as A-4 (2) and A-4 (4) based on the American Association of State Highway Transportation Officials (AASHTO).

4.3.2 Sand and Gravel

Twelve sand and gravel samples were subjected to laboratory testing. Eleven sand samples tested had 13 to 49 percent fines, liquid limits of no value to 32 percent and plasticity indices of non-plastic to 10 percent. One gravel sample tested had 23 percent fines, a liquid limit of 19 percent and a plasticity index 4 percent. Three of the sand samples taken at a depths of 15 and 20 feet were tested for swell/consolidation (ASTM 4546) and exhibited collapse of 0.1 percent when wetted under an applied pressure of 1,000 psf. The gravel sample was tested for swell/consolidation (ASTM 4546) and exhibited collapse of 0.1 percent when wetted under an applied pressure of 2,000 psf. A sand sample taken at a depth of 15 feet was tested for direct shear. Two bulk samples of sand taken from depths of between 1 and 5 feet from test borings B-1 and B-2 subjected to Hveem (R-value) testing (ASTM 2844) resulted in R-values of 65 and 57, respectively, at an exudation pressure of 300 (psi). The sand and gravel classified as SC, SC-SM, SM, and GC-GM (USCS), and A-4 (0), A-2-4, and A-1-b (AASHTO).

4.3.3 Bedrock

One sandstone bedrock sample retrieved from boring B-3 at a depth of 29 feet exhibited an unconfined compressive strength of 9,917 pounds per square inch (psi). Bedrock encountered appeared to consist of an upper zone of weathered red sandstone above a more competent red sandstone. Rock Quality Designation (RQD) based on measurements of discontinuities, or joints and cracks in rock, can be used as an indicator of rock quality, with values ranging from very poor at 0 to 25 percent to excellent at 90 to 100 percent. RQD values for the retrieved core of the more competent sandstone at depths of 28 feet to the depth explored in boring B-3 ranged from 51 to 100 percent. Full RQD values can be found in the boring logs in Appendix C and core photographs can be found in Appendix E.

4.4 Groundwater

Groundwater was encountered at depths of 18 feet, 80 feet, and 19 feet during drilling in borings B-1, B-2, and B-3, respectively. The water level in boring B-2 was observed to equilibrate at a depth of 30 feet prior to backfilling boring. The observed groundwater levels and a summary of the borings are presented in Table 4-1. Groundwater readings to establish long term or seasonal fluctuations were outside our scope of services. These observations represent groundwater conditions at the boring location at the time of our exploration and should not be extrapolated to other times or at other locations. Although not encountered during our investigation, previous studies by others (Robinson, 1971) indicate near surface water may be present in the project area, especially in areas of moraine or alluvial deposits. Groundwater conditions often fluctuate and may be influenced by seasonal precipitation, highway maintenance practices, development, or other factors. The magnitude of groundwater variations will be largely dependent upon fluctuations in snowmelt, duration and intensity of precipitation and the surface and subsurface drainage characteristics of the surrounding area.

Table 4-1. Summary of Geotechnical Borings

Boring	I-70 Mile Post	Boring Depth (feet)	Estimated Elevation at Ground Surface (feet)*	Observed Groundwater Depth (feet)	Bedrock Depth (feet)
B-1	193.5 (Area 1)	61.0	9954	18.0	None encountered
B-2	193.0 (Area 2)	90.8	10023	30.0	None encountered
B-3	192.3 (Area 3)	52.0	10139	19.0	10.0

***Based on estimated boring elevations from client.**

5. Seismicity

The seismic site classifications for the project area are displayed below in Table 5-1 in accordance with Table 3.10.3.1-1 of the 2017 AASHTO Guide Specifications for LRFD Bridge Design. The Peak Ground Acceleration (PGA), and the short- and long-period response spectral acceleration coefficients (S_S and S_1 respectively) for the reference site were obtained using the USGS Design Maps tool for an event with a 7% Probability of Exceedance (PE) in 75 years and a Site Class B (reference site). An event with the above probability of exceedance has a return period of about 1,000 years. At Areas 1 and 2 the site classification (Class D) is different from the reference site

(Class B, Table 5-1), therefore site specific value adjustments are necessary. The seismic design parameters for the site are shown in Table 5-2. These values may be used to construct the Design Response Spectrum for use in the seismic design of bridge structures.

Table 5-1. Seismic Parameters for Reference Site Class B

Site Class	PGA (0.0 sec)	S_S (0.2 sec)	S_1 (1.0 sec)
B	0.078 g	0.159 g	0.040 g

Table 5-2. Seismic Design Parameters for I-70 WB Wildlife Crossings

Area	Site Class	A_S (0.0 sec)	S_{DS} (0.2 sec)	S_{D1} (1.0 sec)
1 and 2	D	0.124 g	0.255 g	0.097 g
3	B	0.078 g	0.159 g	0.040 g

6. STRUCTURE FOUNDATIONS

The proposed construction along the westbound lanes of I-70 will include underpass structures at MP 193.5 (Area 1) and MP 193.0 (Area 2) and either an overpass or underpass structure at MP 192.3 (Area 3). Additionally, wing walls may be constructed at the ends of underpass and/or overpass structures.

We understand the preferred design alternative for the Area 1 underpass structure consists of a buried bridge designed with an integral abutment supported on H-pile foundations. A sloped embankment in front of the abutment will be incorporated in the design. Similarly, we understand the preferred design alternative for the Area 2 underpass crossing consists of a buried arch structure supported on drilled shaft foundations. Deep foundations should be considered to support an arch type underpass structure at Area 2 given the relatively large abutment loads, low to moderate support characteristics of the near surface soils and the presence of dense bearing gravels near foundation levels. Alternatively, the buried arch structure could be supported on shallow foundations provided some ground improvement (i.e., removal of roughly 3 feet of in-situ soils and replacement with aggregate base course material) is performed. We understand that reinforced concrete box culverts bearing on shallow foundations may also be considered for wildlife underpass crossings at Areas 1, 2 and 3.

For the Area 3 overpass crossing, we understand the preferred design alternative consists of a bridge structure designed with an integral abutment supported on H-pile foundations. In addition, a wall will be constructed in front of the abutment at this location. An arch type overpass structure bearing on shallow foundations was considered for the overpass at Area 3; however, due to the large anticipated abutment loads, low to moderate support characteristics of the near surface soils, and the presence of bedrock approximately 10 feet or less below the ground surface (at our boring location), deep foundations are preferred.

Borings at each location were drilled on the cut side, or north side, of the westbound lanes of I-70. Since the fill side, or south side, of the westbound lanes was not explored there is considerable uncertainty as to the bedrock depth, fill depth and soil composition south of the highway. Deeper fill extents and longer driven pile and drilled shaft lengths should be expected towards the south side of the highway embankment. Additional borings at each of the three areas on the south side are recommended to sufficiently characterize the variable subsurface conditions along the length of the proposed structures, to provide specific geotechnical recommendations for south side foundation design, and to mitigate risk pertaining to deep foundation construction for the project. Should additional borings not be performed, we recommend that only driven steel H-piles be utilized for deep foundations on the project in conjunction with an increased frequency of dynamic testing on the south side of the roadway to ensure bearing resistance requirements for deep foundations are satisfied.

Recommendations for deep and shallow foundations, in accordance with AASHTO LRFD (2017), are presented in the following report sections. Our recommendations are based on the soil and rock properties encountered in our borings and the results of laboratory testing.

6.1 Driven H-pile Foundations

Based on the results of our subsurface investigation, we recommend H-pile foundations for the Area 1 underpass bridge structure be driven into the dense gravel, cobbles and boulders that range between approximately 27 feet below ground surface at estimated elevation 9927 feet and the maximum explored depth of 61 feet on the north side of the roadway. Estimated elevations at surface were provided by client. The depth to this bearing layer on the south end of the structure is unknown. Bedrock was not encountered to the maximum explored depth of 61 feet, or estimated elevation 9893 feet. Based on information provided to us by the client, estimated top of pile elevation for the Area 1 structure is 9928.0 feet.

H-pile foundations for the Area 3 overpass bridge structure should be driven to refusal into hard, unweathered sandstone bedrock at a depth of approximately 28 feet on the north side of the roadway near an elevation of 10,111 feet based on an estimated surface elevation of 10,139 feet provided by client. The depth to bedrock is unknown on the south side of the roadway. Based on information provided to us by the client, estimated top of pile elevation for the Area 3 overpass structure is 10121.9 feet. Piles should be driven to refusal into the underlying bedrock as defined in Section 502.05 of the CDOT (2017). Wave equation analysis using the Contractor's pile driving equipment is necessary to estimate pile drivability when the pile driving equipment is selected and submitted for review.

Boulders encountered in overburden materials should be expected and may require pre-drilling at pile locations. Pile tip protection should be utilized due to the dense nature of the bearing gravels that includes cobbles and boulders at Area 1 and the weathered bedrock at Area 3. We recommend a Pile Driving Analyzer (PDA) be used to evaluate acceptance criteria for piles. The effects of scour, if any, should be estimated by others. Water loading and reduction of soil support, should be accounted for in the horizontal and axial design of the driven piles. Recommendations for driven piles are presented below.

6.1.1 Driven Steel H-Pile General Recommendations

Driven piles should be installed in accordance with the requirements in Section 502 of the CDOT Standard Specifications for Road and Bridge Construction (2017). Driven piles should also comply with all applicable requirements and guidelines listed in AASHTO (2017). At Area 1, driven piles should be installed to penetrate fill material (anticipated on the south side of the roadway embankment), native soils and into dense gravel, cobbles and boulders. Piles should be driven to design tip elevation within dense gravels to achieve the required nominal bearing resistance at this location. Once design pile sections and loads are determined for the Area 1 structure, the designer should use the geotechnical design parameters presented in steps 2 and 3 below to determine the design tip elevation. At Area 3, piles should be driven to penetrate native soils, fill material (anticipated on the south side of the roadway embankment), weathered bedrock and refuse in hard, unweathered bedrock. PDA should be used to confirm bearing resistance for all pile installation on the project. To facilitate installation, we recommend pile foundations be designed using a larger section such as an HP12x74. The following recommendations can be used for pile design:

1. The Nordlund/Thurman method described in section 10.7.3.8.6f in AASHTO (2017) can be used to estimate axial capacity for H-pile foundations at the Area 1 underpass structure.

2. Using Load Resistance Factor Design (LRFD) criteria for axial compression design, the nominal unit side resistance (q_s) for Area 1 piles installed on the north side of the roadway can be computed using equation 10.7.3.8.6f-1 together with Figures 10.7.3.8.6f-1 through 10.7.3.8.6f -6. An effective unit weight of 67 pounds per cubic foot (pcf) for wet conditions, and internal friction angle (φ_f) = 38 degrees can be used for the gravel with cobbles and boulders along the full length of the pile. For H-piles, the perimeter or "box" area should generally be used to compute the surface area of the pile side. The upper 4 feet of side resistance should be neglected to account for construction disturbance.

3. The nominal unit tip resistance (q_p) for Area 1 piles on the north side of the roadway can be computed using equation 10.7.3.8.6f-2 together with Figures 10.7.3.8.6f-7 through -9. Again, an effective unit weight of 67 pcf and φ_f = 38 degrees can be used for the gravel with cobbles and boulders at Area 1.

4. Using Load Resistance Factor Design (LRFD) criteria for axial compression design, steel H-piles driven to virtual refusal into unweathered bedrock at Area 3 may be designed for a maximum combined tip resistance and side resistance nominal bearing resistance of 33 ksi for Grade 50 steel, multiplied by the cross sectional area of the pile.

5. Driven piles should be installed per CDOT Standard Specifications for Road and Bridge Construction, Section 502 (Piling) dated 2017. The piles at Area 3 should be driven without damage to virtual refusal as determined by interpretation of the PDA, at or below the estimated driven pile tip elevations specified below. Previous CDOT refusal criteria were defined as 10 blows per inch into bedrock, but vary depending on the PDA results. It should be noted that the piles are assumed to be driven to the Estimated Pile Tip Elevation. Driving the piles to elevations higher than the Estimated Pile Tip elevation may result in unsatisfactory pile performance. Conversely, piles that are driven to elevations significantly lower than the estimated tip elevation should be noted and Yeh and Associates, Inc. should be contacted.

Estimated bedrock and pile tip elevations at Area 3 are shown in Table 6-1. It is estimated that the piles will penetrate approximately 5 feet into bedrock. The final tip elevations will depend on bedrock conditions encountered during driving and the conditions and types of the driving equipment.

Table 6-1. Estimated Bedrock and Pile Tip Elevations at Area 3

Location	Unweathered Bedrock Approximate Elevation (feet)*	Approximate Pile Tip Elevation (feet)*
Area 3, north side of roadway	10,111	10,106

* Based on estimated ground surface elevation of 10,139 ft at Boring No. B-3.

6. The factored bearing resistance is the product of the nominal bearing resistance and the resistance factor. A resistance factor of 0.65 may be used provided that a minimum number of piles are dynamically monitored according to AASHTO Table 10.5.5.2.3-1. The monitoring shall be conducted using a PDA (Pile Driving Analyzer) per CDOT Standard Specifications for Road and Bridge Construction, Section 502 (Piling) dated 2017. Resistance Factors for Driven Piles and the driving criteria is established by signal matching at the beginning-of-restrike (BOR). The maximum factored resistance should be checked against the structural strength limit state for the selected piling size and type. Section 502.05 of the CDOT Standard Specifications (2017) stipulates that a minimum of two piles be PDA tested per structure to determine the condition of the pile, efficiency of the hammer, static bearing resistance of the pile, and to establish pile driving criteria.

7. A PDA analysis should be used to develop virtual refusal criteria prior to production. Tip elevations will likely depend on soil and rock conditions encountered while driving. If additional geotechnical borings are not performed on the south side of the roadway, we recommend that PDA be performed on 10 percent (or a minimum of 3, whichever is less) production piles on the south side of the roadway (at each area) to confirm bearing resistance requirements are satisfied.

8. Section 10.7.3.9 in AASHTO (2017) provides recommendations for resistance of pile groups.

9. Steel reinforcement pile tips are recommended on the ends of the steel HP sections for protection.

10. Input parameters provided in Table 6-2 are recommended for use with the computer program LPILE to develop the soil models for determining the driven pile response to lateral loading. Section 10.7.3.12 of AASHTO (2017) provides recommendations for lateral resistance of piles and also recommendations for group effects. The soils prone to future disturbance, such as from utility excavations or frost heave, should be neglected in the lateral loading analyses to the depth of disturbance, which may require more than but should not be less than 4 feet.

11. Groups of piles will also require appropriate reductions of the lateral capacities based on "shadowing" and other group effects. The minimum spacing requirements between piles should be five diameters from center to center. For lateral loading, recommended P multipliers should comply with AASHTO LRFD Table 10.7.2.4-1 to account for lateral group effects.

12. Based on the results of our field exploration, laboratory testing, and experience with similar properly constructed driven pile foundations, we estimate individual pile settlement will be less than ½ inch when designed according to the criteria presented in this report.

13. A qualified representative of the geotechnical engineer should observe pile-driving activities on a full-time basis. Piles should be observed and checked for crimping, buckling, and alignment. Also, a record should be kept of embedment depths and penetration resistances for each pile.

Table 6-2. LPILE Parameters

Soil/Rock Description	Depth From Pile Top (ft)	p-y Curve Model	Effective Unit Weight (pcf)	Undrained Shear Strength (psf)	Angle of Internal Friction (deg)	ε_{50}	k_{static} (pci)
Area 1							
(neglect)	0 to 4	-	-	-	-	-	-
Gravel with Cobbles, Boulders	4 to 35	Sand (Reese)	67	-	38	-	125
Area 2							
(neglect)	0 to 4	-	-	-	-	-	-
Gravel with Cobbles, Boulders	4 to 24	Sand (Reese)	67	-	38	-	125
Silty Clay	24 to 30	Stiff Clay w/ Free Water (Reese)	67	2500	-	0.005	750
Silty Sand	30 to 49	Sand (Reese)	67	-	32	-	125
Gravel, Cobbles, Boulders	49 to 66	Sand (Reese)	67	-	38	-	125

Soil/Rock Description	Depth From Pile Top (ft)	p-y Curve Model	Effective Unit Weight (pcf)	Uniaxial Compressive Strength (psi)	Initial Modulus Rock Mass (psi)	RQD (%)	Strain Factor, k_{rm}
Area 3							
(neglect)	0 to 4	-	-	-	-	-	-
Weathered Sandstone	4 to 11	Weak Rock (Reese)	145	1000	490,000	0	0.0005
Sandstone	11 to 35	Weak Rock (Reese)	145	9000	640,000	60	0.0005

6.2 Drilled Shafts

Based on the results of our subsurface investigation, we recommend drilled shaft foundations for the Area 2 buried arch underpass structure bear in the variable soils consisting of dense gravel with cobbles and boulders, and dense sand that range between approximately 27 feet below ground surface at an estimated elevation of 9996 feet and the maximum explored depth of approximately 91 feet at an estimated elevation of 9932 feet on the north side of the roadway. A 6-ft thick layer of silty clay was encountered at a depth of 48 feet in boring B-2. Bedrock was not encountered in the boring at Area 2. Elevations are based on estimated ground surface elevations for borings provided by client.

Drilled shafts at this location will develop bearing resistance in side shear. Due to the clay layer encountered within the soil boring at this location, end bearing should be neglected. The depth and lateral extent of this clay layer is unknown. The depth to the dense bearing layer on the south end of the structure is also unknown. Based on information provided to us by the client, estimated top of shaft elevation for the Area 2 structure is estimated at 9998.7 feet. Should an additional boring not be performed at Area 2 we recommend driven steel H-piles with PDA monitoring be utilized in lieu of drilled shafts to ensure bearing resistance requirements for deep foundations are met.

Boulders should be expected during installation of drilled shafts. The effects of scour, if any, should be estimated by others. Water loading and reduction of soil support, should be accounted for in the horizontal and axial design of the drilled shafts. Recommendations for drilled shafts are presented below.

6.2.1 Drilled Shaft General Recommendations

Drilled shafts should be installed in accordance with the requirements in Section 503 of the CDOT Standard Specifications for Road and Bridge Construction (2017). Drilled shafts should also comply with all applicable requirements and guidelines listed in AASHTO (2017). At Area 2, drilled shafts should be installed to penetrate fill material (anticipated on the south side of the roadway embankment), native silty sand material and terminate in dense strata of gravel, sand, cobbles and boulders below. The following recommendations can be used for drilled shaft design and construction:

1. The Contractor shall construct the drilled shafts using means and methods that maintain a stable hole without compromising the soil/concrete bond providing the side resistance.

2. Using Load Resistance Factor Design (LRFD) criteria, a nominal side resistance of 3.2 ksf may be used along the full length of the shaft. We recommend a resistance factor of 0.55 for side shear. Settlement of the structure should be checked against loadings obtained based on service limit state and LRFD methodology.

3. Inefficiencies of group resistance due to closely spaced shafts should be considered in the design. The group reduction factor will be dependent on the spacing and configuration of the drilled shaft group. The appropriate group reduction factor (η) from table 10.8.3.6.3-1 in AASHTO (2017) can be used to estimate the bearing

resistance for a group of shafts. The group reduction factor selected for design is dependent on the spacing and configuration of the drilled shaft group.

4. Input parameters provided in Table 6-2 are recommended for use with the computer program LPILE to develop the soil models for determining the drilled shaft response to lateral loading at Area 2. The upper 4 feet of drilled shaft penetration should be neglected for lateral load resistance calculation. 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 10.7.2.2 of AASHTO (2017). The P_m value will depend on the direction of the applied load, center-to-center spacing, and location of the shaft within the group.

5. The presence of groundwater in boring B-2 indicates casing and/or dewatering equipment will be required. In no case should concrete be placed in more than 2 inches of water unless the tremie method is used. A drilled hole may be considered dry at the time of concrete placement if, without dewatering, the water depth at the bottom of the hole is not in excess of 2 inches. If water cannot be removed or prevented with the use of casing and/or dewatering equipment prior to placement of concrete, the tremie method, as described in the CDOT's 2017 Standard Specifications for Road and Bridge Construction, should be used.

6. Boulders may be encountered during excavation of drilled shafts. The contractor should mobilize equipment of sufficient size and operating condition to achieve the required design shaft penetration.

7. Based on estimated size of cobbles and boulders, we would anticipate a shaft diameter of at least 2.5 feet or greater. Rock drilling methods may be necessary.

8. Integrity testing of drilled shafts should be performed in accordance with CDOT requirements. This should consist of Crosshole Sonic Log (CSL) testing performed in accordance with ASTM D 6760.

9. A representative of the soils engineer should observe drilled shaft drilling operations on a full-time basis.

6.3 Shallow Foundations

Shallow foundations may be used to support reinforced concrete box culverts (CBC) and associated wing walls for the wildlife underpass crossings at Areas 1, 2 and 3 provided the recommendations below are incorporated into design and construction of the foundation. In consideration of the uncertain fill depths to the south and to mitigate associated differential settlement concerns, foundations should bear on the recommended thickness of aggregate base course (ABC) overlying native soils along their entire length.

6.3.1 Concrete Box Culvert

CBC structures at Areas 1, 2 and 3 are expected to bear approximately 20 feet below the traveled road surface. Structures should bear on imported ABC as described below to provide a uniform bearing surface.

6.3.2 Wing Walls

Wing walls adjacent to CBC structures founded on shallow foundations or that are designed to be structurally independent from adjacent structures supported on deep foundations may bear on shallow foundations a minimum of 5 feet below the lowest adjacent finished grade for frost heave protection. Footings should bear on imported ABC as described below to provide a uniform bearing surface.

6.3.3 General Shallow Foundation Recommendations

1. All loose, disturbed, or otherwise unstable soils including fill should be removed. CBC structures and/or wingwall footings should bear on a minimum of 2 feet of imported ABC material. The thickness of ABC beneath a CBC structure at Area 3 may be reduced to 12 inches provided weathered sandstone bedrock is encountered upon excavation.

2. Following subgrade excavation, ABC material meeting CDOT Class 6, defined in Table 703-2 CDOT (2017), should be placed below foundations as follows. ABC should be placed in loose lifts not to exceed 8 inches and compacted within 2 percent of optimum moisture and to at least 95 percent maximum density based on ASTM 1557 (modified Proctor).
3. Backfill against the sides of CBC structures or wingwalls should consist of CDOT Class 1 Structural Backfill.

4. Shallow foundations constructed as described above may be designed using a nominal bearing resistance of 10 ksf.

5. The bearing resistance factor for shallow foundations is 0.45 in accordance with AASHTO LRFD (2017) Table 10.5.5.2.2-1.

6. An unfactored coefficient of friction of 0.67 may be used for the calculation of sliding resistance when performing an external stability check in accordance with AASHTO (2017) Section 10.6.3.4. The recommended sliding resistance factor is 0.80 for shallow foundations per AASHTO (2017) Table 10.5.5.2.2-1. Passive pressures against the vertical face of foundations should be neglected in sliding resistance calculations.

7. The permeability of the predominantly coarse grained in-situ foundation soils is expected to be sufficiently high to dissipate excess pore pressures generated during construction. Total settlement of shallow foundations is estimated to be less than 1 inch when constructed as discussed above. Differential settlement, as measured along a horizontal distance of 30 feet, is estimated to be ½ to ¾ of the total settlement. The project designer should review the estimated settlement and evaluate potential impacts to structures.

8. Foundation movements could occur if water from any source infiltrates the foundation soils. Therefore, proper drainage should be provided in the final design and during construction.

9. All foundation excavations should be observed by a representative of the geotechnical engineer prior to placement of concrete.

7. LATERAL EARTH PRESSURE

This section presents results of our geotechnical analyses and recommendations for lateral earth pressure on proposed CBC walls and structure wing walls. Our evaluations were based solely on soil types as no detailed plans or drawings were presented at the time of this report. Our engineering analysis and geotechnical recommendations for this feasibility study are based on our understanding of the proposed construction, the subsurface conditions encountered at our boring locations and the provisions and requirements outlined in the limitations section of this report.

Since the roof of the CBC will act to restrain lateral movement of the side walls we recommend using at-rest earth pressures for design of the side walls of the CBC. If the structures are backfilled with CDOT Class 1 Structure Backfill an at-rest lateral earth pressure coefficient (k_o) of 0.44 may be used. Free standing wing walls can be designed using an active earth pressure coefficient (k_a) of 0.28 and a passive earth pressure coefficient (k_p) of 3.5. CDOT Class 1 Structure Backfill properties include a unit weight of 135 pounds per cubic foot (pcf) and an angle of internal friction of 34 degrees. Soils encountered in the soil borings have relatively high fines content but on-site soil may be used that conform to the Class 1 specifications as per CDOT, 2017.

All foundation and retaining structures should be designed for appropriate hydrostatic and surcharge pressures resulting from adjacent roadways, traffic, construction materials and equipment. Hydrostatic (seepage) pressures should not be allowed to develop in the active soil wedge zone. We recommend that the wall designer include appropriate drainage elements that are typically installed near the back and bottom of retaining walls, such as geocomposite strip drains, perforated pipes, filter materials and/or weep holes to control surface and ground water flows.

8. SITE GRADING

Soil slope cut and fill grading for the proposed improvements should follow the procedures of the CDOT Standard Specifications for Road and Bridge Construction (2017). Most of the native soils encountered are suitable for use in compacted embankment fill. Some soils may have high moisture contents and require moisture conditioning prior to use as fill. Fill should be placed and compacted in accordance with Section 203.07 of the Standard Specifications for compaction and moisture content. Fill should not contain organic matter or other deleterious material.

Site grading will be necessary to complete the earthwork around the wildlife crossings and roadway. Permanent un-retained cut and fill slopes in the project area should not be steeper than 3:1 (horizontal: vertical). The risk of slope instability will be increased if seepage is encountered in cuts and fills. If seepage is encountered in permanent excavations, an investigation should be conducted to evaluate if the seepage will adversely affect the stability of the slope. Additional drainage elements such as strip drains, piped outlets, and/or horizontal drains may be necessary to contain the seepage. Based on existing conditions encountered in our investigation a global stability analysis may be beneficial for the project and can be performed by Yeh at each location for an additional fee.

The ground surface underlying all fills should be carefully prepared by removing all organic material or other deleterious materials, scarifying to a minimum depth of 6 inches and compacting to 95 percent of standard Proctor density at a moisture content within 2 percent of optimum. Embankment placed on existing slopes should be benched in accordance with Subsection 203.06 of the Standard Specifications (CDOT, 2017). Good surface drainage should be provided around all permanent cuts and fills to direct surface runoff away from the slope faces. Fill slopes, cut slopes, and other stripped areas should be protected from erosion by re-vegetation or other methods of stabilization.

Groundwater was encountered at depths of 18 feet, 30 feet, and 19 feet in borings B-1, B-2 and B-3, respectively. The contractor should anticipate seepage of groundwater into temporary excavations for CBC structures and associated wing walls and implement dewatering measures such as sumps and pumps as necessary. Furthermore, seepage quantities may be considerable given the relatively permeable nature of the overburden soils.

Based upon the subsurface conditions encountered, subgrade soils exposed during construction are anticipated to be relatively stable. However, the stability of the subgrade may be affected by drainage and precipitation, especially in the underpass structure locations. The base of excavations should be slightly sloped during construction to promote positive drainage. If unstable conditions are encountered or develop during construction, stability may be improved by scarifying and drying the subgrade soils or with other ground improvement techniques (e.g. geogrid).

8.1 Construction in Wet or Cold Weather

During construction, the site should be graded such that surface water can drain readily away from the structural and pavement areas. Promptly pump out or otherwise remove water that accumulates in excavations or on subgrade surfaces and allow these areas to dry before resuming construction. The use of berms, ditches, and similar means may be used to prevent stormwater from entering the work area and to convey water off site efficiently. Allowing water to pool or build-up behind retaining wall structures, such as wing walls associated with a box culvert underpass, during construction may lead to failure of the wall. Erosion of soil during precipitation events may also impact wall integrity. Therefore, construction operations and regular inspection should be implemented during construction.

Grading fill, structural fill or other fill should not be placed on frosted or frozen ground, nor should frozen material be placed as fill. Frozen ground should be allowed to thaw or be completely removed prior to placement of fill. Additionally, foundations or other concrete elements should not be constructed on frozen soil. Frozen soil should be completely removed from beneath the concrete elements, or thawed, scarified, and re-compacted. The amount of time passing between excavation or subgrade preparation and placing concrete should be minimized during freezing conditions to prevent the prepared soils from freezing. Blankets, soil cover, or ground heaters may be utilized to help protect subgrade soils.

9. EXCAVATION

Excavations will encounter a variety of conditions. All excavations must comply with the applicable local, State, and Federal safety regulations, and particularly with the excavation standards of the Occupational Safety and Health Administration (OSHA). Construction site safety, including excavation safety, is the sole responsibility of the Contractor as part of its overall responsibility for the means, methods, and sequencing of construction operations. Yeh and Associates recommendations for excavation support are provided for the Client's sole use in planning the project, in no way do they relieve the Contractor of its responsibility to construct, support, and maintain safe slopes. Under no circumstances should the following recommendations be interpreted to mean that Yeh and Associates is assuming responsibility for either construction site safety or the Contractor's activities.

We believe the overburden silty sand and gravel encountered on this site will classify as Type C material and the sandstone bedrock as "stable rock" using OSHA criteria. OSHA requires that unsupported cuts be no steeper than 1½:1 for Type C, and near vertical for stable rock for unbraced excavations up to 20 feet in height. In general, we believe that these slope ratios will be temporarily stable under unsaturated conditions. Flattened slopes may be required if excavations extend into the groundwater or the slopes will be exposed for an extended period of time. Please note that an OSHA-qualified "competent person" must make the actual determination of soil type and allowable sloping in the field.

Weathered sandstone, as encountered in boring B-3 to a depth of about 28 feet below the existing ground surface, is expected to be rippable with conventional earth moving equipment such as a D-7 dozer. More competent, less weathered bedrock below this depth may require other means, such as blasting to facilitate excavation.

The soils and bedrock encountered by the proposed excavations may vary significantly across the site. The preliminary classifications presented above are based solely on the materials encountered in widely spaced exploratory test borings. The contractor should verify that similar conditions exist throughout the proposed area of excavation.

As a safety measure, it is recommended that all vehicles and soil stockpiles be kept a lateral distance equal to at least the depth of the excavation from the crest of the slope. The exposed slope face should be protected against the elements and monitored by the contractor on at least a daily basis.

10. CORROSIVITY

The concentrations of water-soluble sulfates measured in five samples obtained from the exploratory borings varied from less than 0.001 to 0.002 percent. This concentration of water-soluble sulfates represents a Class 0 degree of sulfate attack on concrete exposed to these soils. The degree of attack is based on a range of Class 0 (negligible) to Class 3 (very severe) as described in the American Concrete Institute (ACI) Standard 201.2R, “Guide to Durable Concrete” and as presented in Table 601-2, CDOT (2017).

The pH, electrical resistivity and water-soluble chloride concentration were also determined for the same samples. Test results measured pH values of 7.3 to 8.3. The resistivity measurements were 1006 to 6192 ohm-centimeters, and the water-soluble chloride concentrations were 0.0002 to 0.0302 percent. A qualified corrosion engineer should review this data to determine the appropriate level of corrosion protection.

11. PAVEMENT CONSIDERATION

We recommend that the pavement section be replaced to match existing conditions at each project site. Drilling within I-70 pavement areas was not feasible due to utilities and limited closure restrictions. Pavement section evaluation and/or recommendations were beyond our scope of service. R-value testing was performed on select samples for informational purposes and for future pavement evaluation should a need become necessary.

12. LIMITATIONS

The findings and recommendations presented in this report are based upon data obtained from borings, field observations, laboratory testing, our understanding of proposed construction, and other sources of information referenced in this report. It is possible that subsurface conditions may vary between or beyond the locations explored. The nature and extent of such variations may not become evident until construction. If during construction conditions appear to be different from those described herein, Yeh should be advised and provided the opportunity to observe and evaluate those conditions and provide additional recommendations, as necessary. Yeh should also be contacted if the scope of construction changes from that generally described within this report. The conclusions and recommendations contained in this report shall not be considered valid unless Yeh reviews all proposed construction changes and either verifies or modifies the conclusions of this report in writing.

This report was prepared in substantial accordance with the generally accepted standards of practice for geotechnical engineering as exist in the site area at the time of our investigation. No warranties, expressed or implied, are intended or made.

13. REFERENCES

AASHTO, 2017, 8th edition LRFD Bridge Design Specifications, American Association of State Highway and Transportation Officials, Washington, D.C.

American Concrete Institute: Guide to Durable Concrete, 2016, https://www.concrete.org/Portals/0/Files/PDF/Previews/201.2R-16_preview.pdf.

Bergendahl, M., 1969, Geologic map and sections of the southwest quarter of the Dillon quadrangle, Eagle and Summit counties, Colorado: U.S. Geological Survey Miscellaneous Geologic Investigations, MAP I-563, scale 1:24,000.

Colorado Department of Transportation (CDOT), 2017, Standard Specifications for Road and Bridge Construction.

Colorado Department of Transportation, 2011, I-70 Mountain Corridor Final Programmatic Environmental Impact Statement, Section 3.5 Geologic Hazards, pp. 3.5-1 to 3.5-6.

Robinson, C., and Cochran, D., 1971, Intermediate Geologic Investigations Big Horn Creek to Wheeler Junction, Vail Pass, Colorado Department of Highways Project No. I 70-2 (19). Map scale 1:2,400.

Summit County Safe Passages for Wildlife, I-70, Vail Pass MP 190-194, p. 71-75

United States Geologic Survey. 2015. Earthquake Hazards Program U.S. Seismic Design Maps. Retrieved June 8, 2020, from http://earthquake.usgs.gov/designmaps/us/application.php

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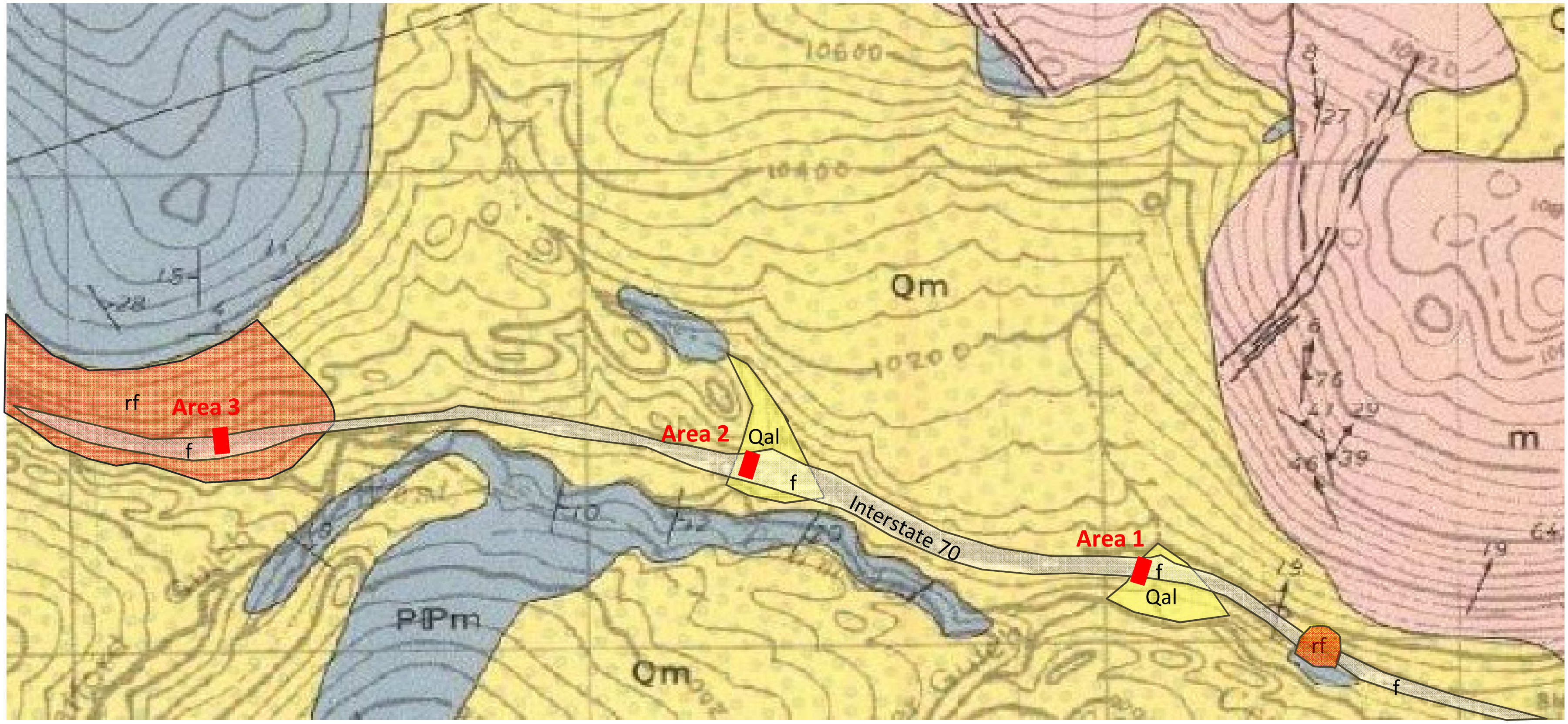
Appendix A

GEOLOGY AND GEOLOGIC HAZARD MAP



rf	Potential rockfall zone
f	Fill (unknown material type and depth)
Qal	Alluvial Fan/ Debris Flow Deposits
Qm	Glacial Moraine Deposits
PIPm	Maroon Formation
m	Migmatite with gneiss

North

Note: Based on field observations, geology maps by Bergendahl 1969 and Robinson and Cochran 1971, and I-70 Mountain Corridor Final PEIS; see reference section of report

Print Date: 08/27/2020 File Name: East Vail Pass Wildlife Crossings Scale: Not to scale	**Geology and Geologic Hazard Map Interstate 70 East Vail Pass Wildlife Crossings**		SHEET NUMBER: **A-1**
Yeh and Associates, Inc. Geotechnical - Geological - Construction Services	Drawn by: SAW Checked by: SWR	Yeh and Associates Project No. 219-176	

Appendix B

BORING LOCATION MAP

LEGEND

B-1

Indicates approximate location of test borings

NOTES:
1. Base map from client.
2. Borings located using hand methods in field by Yeh and Associates; no survey provided for boring locations.

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DRAWN BY: SAW	DATE: 06/04/2020	PROJECT: Interstate 70 East Vail Pass Wildlife Crossings Summit County, Colorado	
CHECKED BY: SWR	DATE: 06/04/2020		
DESIGNED FOR: Wood			SHEET
PROJECT NUMBER: 219-176		**Approximate Test Boring Location Map**	B-1
SCALE: 1"=600'			

0 300' 600' 1200'

Appendix C

BORING LOGS

Legend for Symbols Used on Borehole Logs

Sample Types

- Auger Cuttings
- Standard Penetration Test (ASTM D1586)
- Rock Core
- Modified California Sampler (2.5 inch OD, 2.0 inch ID)
- ODEX/Downhole Hammer

Other Symbols

- Water level at time of investigation, April/May 2020

Lithology Symbols (see Boring Logs for complete descriptions)

- Fill Road Base
- CLAY, silty
- SAND, clayey
- SAND, silty, clayey
- SAND, silty
- GRAVEL, clayey
- GRAVEL, silty
- Boulders
- Weathered Bedrock
- Sandstone

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/Consolidation (ASTM D4546)
UCCS	Unconfined Compressive Strength (ASTM D2166)
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. "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 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.
2. 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.

Boring Began: 4/29/2020
Boring Completed: 4/29/2020
Drilling Method(s): Solid-Stem Auger / ODEX
Driller: Authentic Drilling
Drill Rig: Acker Renegade Track
Hammer Type: Automatic (hydraulic)

Total Depth: 61.0 ft
Ground Elevation:
Coordinates: N: 1.0 E: 3.0
Location: MP 193.5
Logged By: S. Richards
Final By: S. White

Weather Notes: Sunny, mild
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels:

Symbol	▽		
Depth	18.0 ft	-	-
Date	4/29/20	-	-

Elevation (feet)	Depth (feet)	Blows per 6 in	Penetration Resistance	Material Description	Moisture Content (%)	Dry Density (pcf)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Liquid Limit	Plasticity Index	AASHTO & USCS Classifications	Field Notes and Other Lab Tests
	0.0			**0.0 - 1.5 ft.** dark brown, (road base).									
	1.5			**1.5 - 27.0 ft. silty SAND** clayey with gravel, no to low plasticity, damp to wet, loose to very dense, intermittent cobbles and boulders.	5.5		12	63	25	NV	NP	A-2-4 (0) SM	R-Value=65
	5	9-15	24		8.1	118.0	25	58	17	NV	NP	A-1-b (0) SM	
	10	2-3-5	8		18.9		8	43	49	22	5	A-4 (0) SC-SM	pH=7.6 S=0.001% Chl=0.0081% Re=2798ohm·cm
	15	25-30	55		14.2	112.0	15	59	26				S/C=-0.1%
		8-18-20	38										
	18 ▽												
	20	17-36	53										
	25	10-10	20		13.4	113.0	12	28	60	25	7	A-4 (2) CL-ML	pH=8.3 S=0.002% Chl=0.0007% S/C=-0.2% DS (C)=737psf Re=5688ohm·cm
		9-12-20	32										
	27.0			**27.0 - 36.0 ft. silty GRAVEL** with sand to silty SAND with gravel; with cobbles, boulders, red, no plasticity, wet, dense to very dense.									
	30												

Elevation (feet)	Depth (feet)	Sample Type/ Advancement 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
						36.0 - 39.0 ft. BOULDERS.									
	40		20-33-42	75		**39.0 - 48.0 ft. silty GRAVEL** with sand to silty SAND with gravel; with cobbles, boulders, red, no plasticity, wet, dense to very dense.	12.1		23	44	33	NV	NP	A-2-4 (0) SM	
	45														
						48.0 - 49.0 ft. BOULDERS.									
	50					**49.0 - 52.0 ft. silty GRAVEL** with sand to silty SAND with gravel; with cobbles, boulders, red, no plasticity, wet, dense to very dense.									
						52.0 - 53.5 ft. BOULDERS.									
	55					**53.5 - 61.0 ft. silty GRAVEL** with sand to silty SAND with gravel; with cobbles, boulders, red, no plasticity, wet, dense to very dense.									
	60		70 for 8 inches	70 for 8 inches											
						Bottom of Hole at 61.0 ft.									**61.0 ft** - ODEX refusal at 61 feet on rock

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Project Name: East Vail Pass Wildlife Crossings

Project Number: 219-176

Boring No.: **B-2**

Boring Began: 4/30/2020

Boring Completed: 4/30/2020

Drilling Method(s): Solid-Stem Auger / ODEX

Driller: Authentic Drilling

Drill Rig: Acker Renegade Track

Hammer Type: Automatic (hydraulic)

Total Depth: 90.8 ft

Ground Elevation:

Coordinates: N: 1.0 E: 2.0

Location: MP 193.0

Logged By: S. Richards/K. Dye

Final By: S. White

Weather Notes: Sunny, mild

Inclination from Horiz.: Vertical

Night Work: ☐

Groundwater Levels:			
Symbol	∇		
Depth	30.0 ft	-	-
Date	5/13/20	-	-

Elevation (feet)	Depth (feet)	Sample Type/ Advancement 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
						0.0 - 1.2 ft. (road base).									
			9-24-33	57		**1.2 - 10.0 ft. silty SAND** clayey with gravel, low plasticity, moist, dense to very dense.									pH=7.7 S=0.002% Chl=0.0302% Re=1006ohm·cm
	5		28-25-30	55			5.4		32	45	23	22	5	A-1-b (0) SC-SM	**5.0 ft** - Change from solid stem auger to ODEX drilling
	10		13-14-18	32		**10.0 - 20.0 ft. silty SAND** with clay, red, moist, medium dense to dense.									
	15		10-10	20			9.4		8	57	35				S/C=-0.1% DS (C)=1154psf
	20		3-3	6		**20.0 - 23.0 ft. clayey SAND**, brown, low plasticity, moist, loose, with organics.	13.5		6	55	39	32	9	A-4 (0) SC	pH=7.3 S=0.001% Chl=0.0023% S/C=-0.1% Re=6192ohm·cm
			3-3-2	5											
						23.0 - 27.0 ft. silty SAND, red, moist, medium dense.									
	25		7-7	14											
						27.0 - 48.0 ft. clayey GRAVEL silty, with cobbles and boulders, red with gray-brown, low plasticity, moist to wet, dense to very dense, gray-light brown igneous gravels mixed in red sedimentary gravel.									
	∇30														

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Elevation (feet)	Depth (feet)	Sample Type/ Advancement 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
			22-35	57		**27.0 - 48.0 ft. clayey GRAVEL** silty, with cobbles and boulders, red with gray-brown, low plasticity, moist to wet, dense to very dense, gray-light brown igneous gravels mixed in red sedimentary gravel.									
			20-25-32	57			6.1		39	38	23	19	4	A-1-b (0) GC-GM	S/C=-0.1%
	40														
	45														
						48.0 - 54.0 ft. silty CLAY with sand, red, low plasticity, moist to wet, very stiff, micaceous.									
	50		14-20	34			18.2	111.0	2	24	74	28	7	A-4 (4) CL-ML	pH=8.2 S=0.002% Chl=0.0002% Re=5236ohm·cm
			7-11-15	26											
						54.0 - 56.0 ft. BOULDERS, no plasticity, very dense.									
	55														
						56.0 - 73.0 ft. SAND with silt to silty, with gravel, red with white, moist to wet, dense to very dense, varicolored gravel.									
	60														
	65														
	70		100 for 10 in,	100 for 10 in,			5.1		34	53	13				**70.0 ft** - Inner bit stuck in casing and retrieved.
						73.0 - 75.0 ft. BOULDERS, damp, very dense.									**73.0 ft** - Drilling slowed on cobbles, boulders between 73 and 75 feet
	75					**75.0 - 90.8 ft. silty GRAVEL** with sand, red, wet, very dense.									**75.0 ft** - Driller struggled to separate inner bit

Elevation (feet)	Depth (feet)	Sample Type/ Advancement 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
	80					**75.0 - 90.8 ft. silty GRAVEL** with sand, red, wet, very dense.									from head **80.0 ft** - Driller noted water
	85														
	90		98 for 10 in.	98 for 10 in.											

Bottom of Hole at 90.8 ft.

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Project Name: East Vail Pass Wildlife Crossings

Project Number: 219-176 *Boring No.:* **B-3**

Boring Began: 5/1/2020
Boring Completed: 5/1/2020
Drilling Method(s): ODEX / HQ Coring
Driller: Authentic Drilling
Drill Rig: Acker Renegade Track
Hammer Type: Automatic (hydraulic)

Total Depth: 52.0 ft
Ground Elevation:
Coordinates: N: 1.0 E: 1.0
Location: MP 192.3
Logged By: K. Dye
Final By: S. White

Weather Notes: Sunny, mild
Inclination from Horiz.: Vertical
Night Work: ☐

Groundwater Levels:			
Symbol	⊻		
Depth	19.0 ft	-	-
Date	5/1/20	-	-

Elevation (feet)	Depth (feet)	Sample Type/ Advancement Method	Rock: Recovery (%)	Rock: RQD (%)	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							**0.0 - 1.0 ft.** (road base).									
	1.0							**1.0 - 10.0 ft. silty SAND** clayey with gravel, red, low plasticity, moist, medium dense, micaceous.									
	5				9-13-7	20			10.4		27	53	20	20	4	A-1-b (0) SC-SM	
	10				50 for 1 in. 50 for 1 in.	50 for 1 in. 50 for 1 in.		**10.0 - 28.0 ft. WEATHERED SANDSTONE**, red, decomposed to predominantly decomposed, soft to medium hard.									
	15				50 for 3 in. 50 for 2 in.	50 for 3 in. 50 for 2 in.			8.7	129.0							
	19.0 (⊻)																
	20				50 for 3 in. 50 for 2 in.	50 for 3 in. 50 for 2 in.											
	25				95 for 10 in.	95 for 10 in.			6.1								
	28.0							**28.0 - 52.0 ft. SANDSTONE**, red with white, green, moderately weathered to fresh, medium hard to very hard, micaceous.									**28.5 ft** - Change from ODEX drilling to HQ coring UCCS=9917psi
	30		98	71													
			100	51													

Elevation (feet)	Depth (feet)	Sample Type/ Advancement Method	Rock: Recovery (%)	Rock: RQD (%)	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
	40		100	89													
	45		100	92													
	50		100	100													

Bottom of Hole at 52.0 ft.

Appendix D

LABORATORY TEST RESULTS

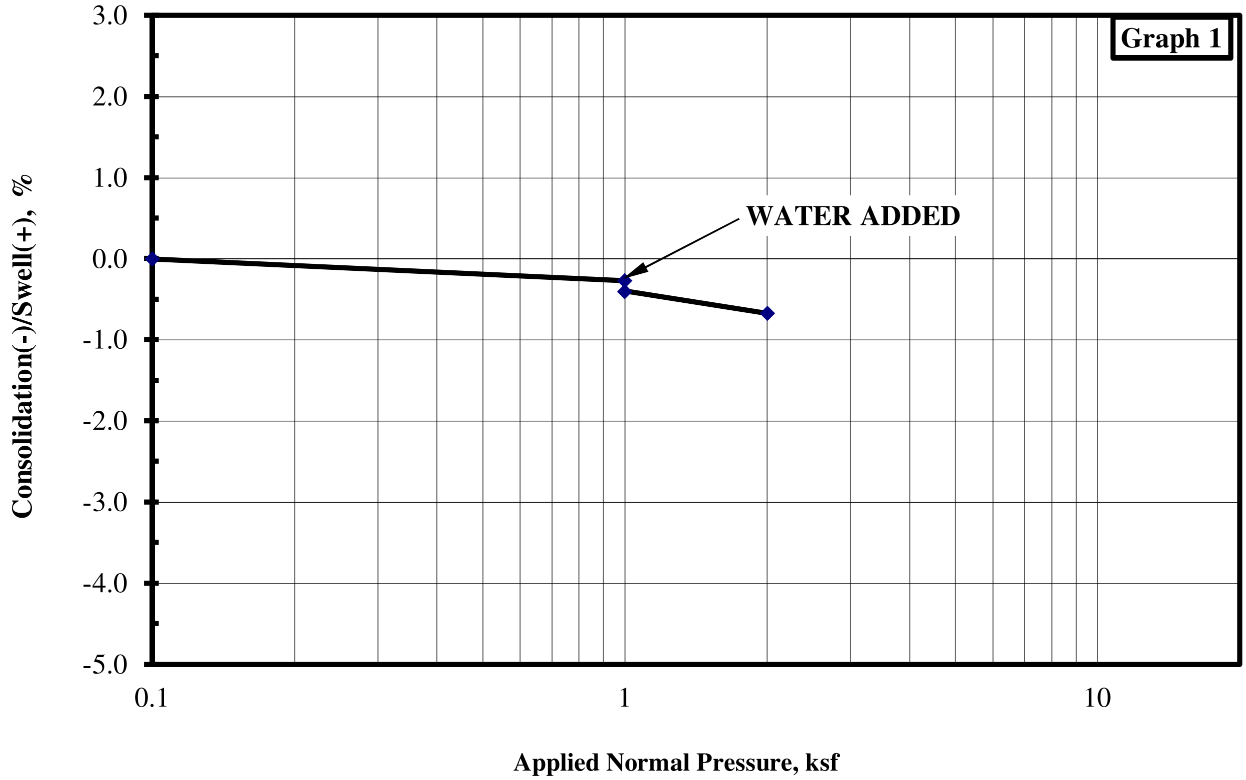
YEH & ASSOCIATES, INC

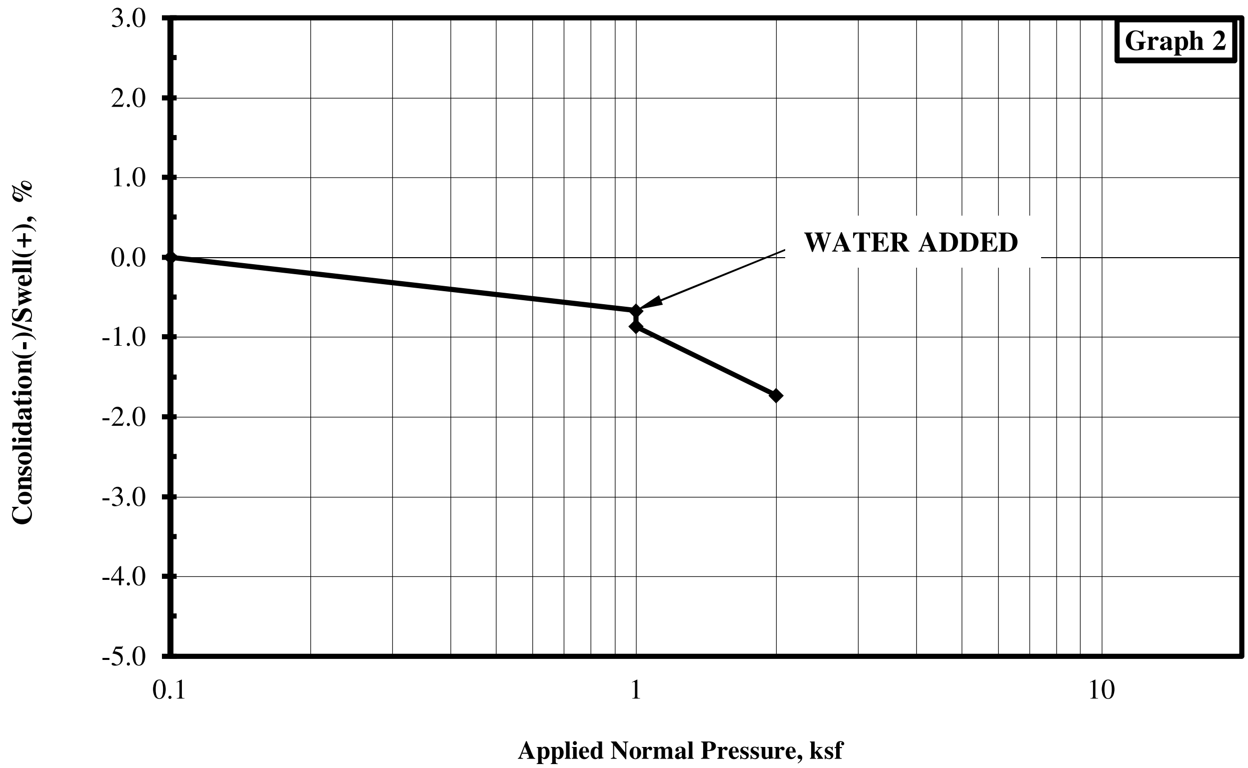
Summary of Laboratory Test Results

Project No: 219-176   Project Name: East Vail Pass Wildlife Crossings

Sample Location			Moisture Content (%)	Dry Density (pcf)	Grain Size Analysis			Atterberg Limits			Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	pH	Swell/ Consolidation		Unconfined Compressive Strength (psi)	Direct Shear (psf)	R-Value	AASHTO	USCS	Material Description
Test Boring	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI					%	psf						
B-1	2 to 5	Bulk	5.5		12	63	25	NV	NP	NP									65	A-2-4 (0)	SM	SAND, silty
	5	MC	8.1	118	25	58	17	NV	NP	NP										A-1-b (0)	SM	SAND, silty with gravel
	10	SPT	18.9		8	43	49	22	17	5	<0.001	0.0081	2798	7.6						A-4 (0)	SC-SM	SAND, silty, clayey
	15	MC	14.2	112	15	59	26								-0.1	1,000						SAND, silty, clayey with gravel
	25	MC	13.4	113	12	28	60	25	18	7	0.002	0.0007	5688	8.3	-0.2	1,000		737		A-4 (2)	CL-ML	CLAY, silty with sand
	40	SPT	12.1		23	44	33	NV	NP	NP										A-2-4 (0)	SM	SAND, silty with gravel
B-2	1 to 4	Bulk	3.5		11	55	34	24	17	7	0.002	0.0302	1006	7.7					57	A-2-4 (0)	SC-SM	SAND, silty, clayey
	5	SPT	5.4		32	45	23	22	17	5										A-1-b (0)	SC-SM	SAND, silty, clayey with gravel
	15	MC	9.4	124	8	57	35	22	17	5					-0.1	1,000		1,154		A-4 (0)	SC-SM	SAND, silty, clayey
	20	MC	13.5	114	6	55	39	32	23	9	<0.001	0.0023	6192	7.3	-0.1	1,000				A-4 (0)	SC	SAND, clayey
	36	MC	6.1	133	39	38	23	19	15	4					-0.1	2,000				A-1-b (0)	GC-GM	GRAVEL, silty, clayey with sand
	50	MC	18.2	111	2	24	74	28	21	7	0.002	0.0002	5236	8.2						A-4 (4)	CL-ML	CLAY, silty with sand
	70	MC	5.1	128	34	53	13	28	21	7										A-2-4 (0)	SC-SM	SAND, silty, clayey with gravel
B-3	5	SPT	10.4		27	53	20	20	16	4										A-1-b (0)	SC-SM	SAND, silty, clayey with gravel
	15	MC	8.7	129																		WEATHERED SANDSTONE BEDROCK
	25	SPT	6.1																			WEATHERED SANDSTONE BEDROCK
	29	CORE	0.4	162													9,917					SANDSTONE BEDROCK

BULK - Indicates auger cuttings
MC - Indicates modified California sampler
SPT - Indicates split spoon sampler/Standard Penetration Test
NV - Indicates no value
NP - Indicates non-plastic



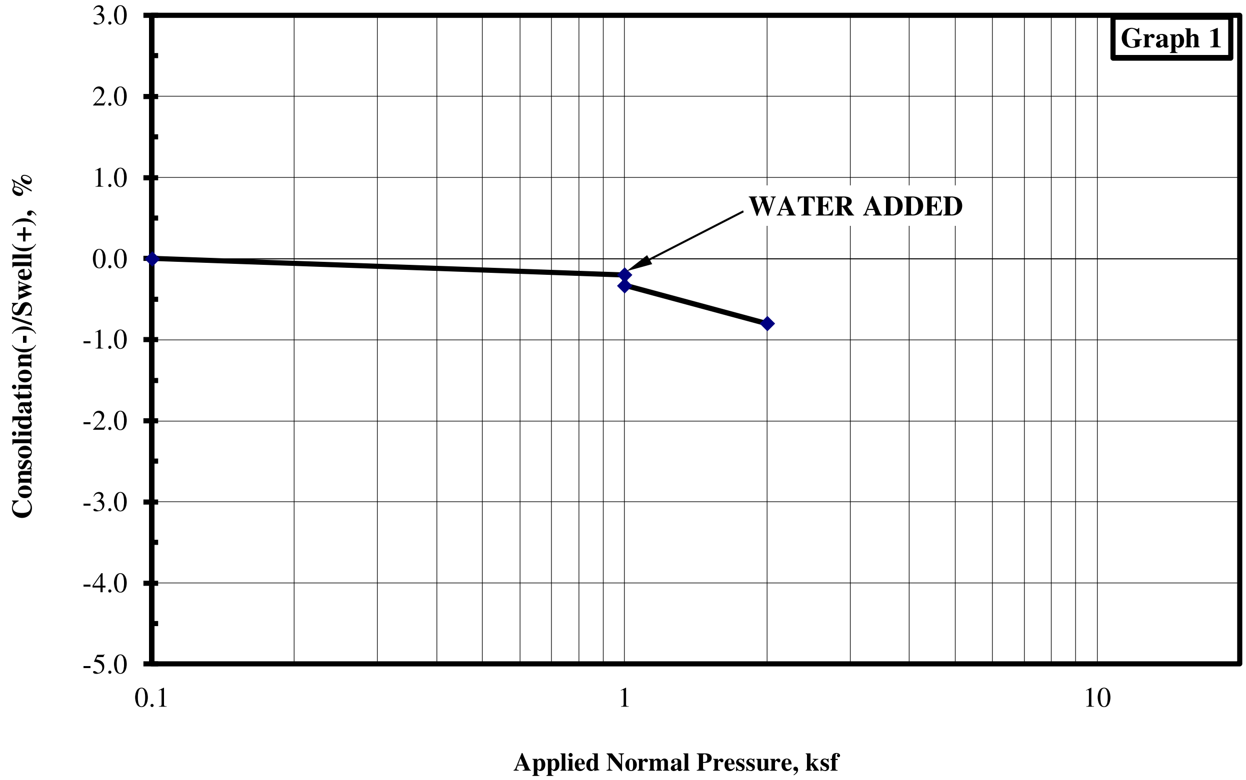


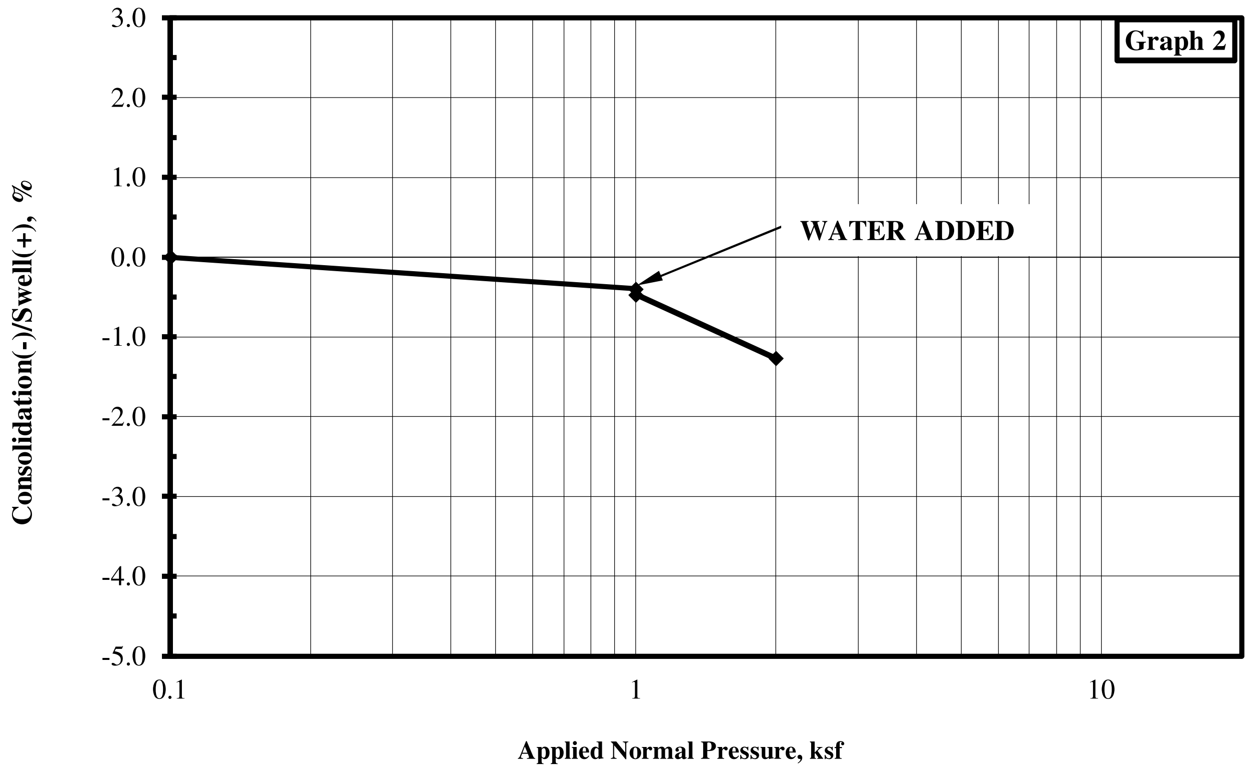
Graph Number	Boring Number	Depth (ft)	Natural Dry Density (pcf)	Moisture Content (%)	Swell(+) / Consolidation(-) (%)	Soil Description	SWELL / CONSOLIDATION GRAPH
1	B-1	15	112	14.2	-0.1	SAND, silty, clayey with gravel	Drawn By: SAW
2	B-1	25	113	13.4	-0.2	CLAY, silty with sand (CL-ML)	Checked By: SWR

Job No:	219-176	Project Name:	East Vail Pass Wildlife Crossings

YEH & ASSOCIATES, INC.

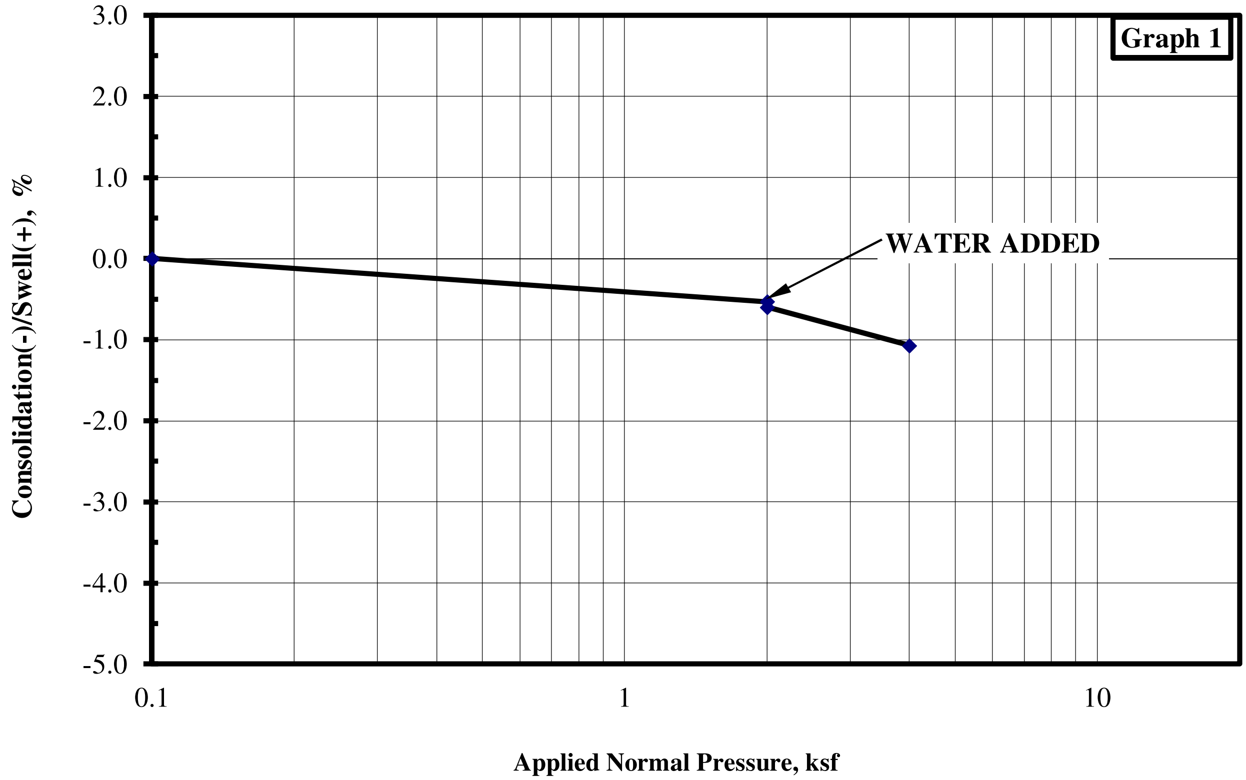
Figure No. D-1

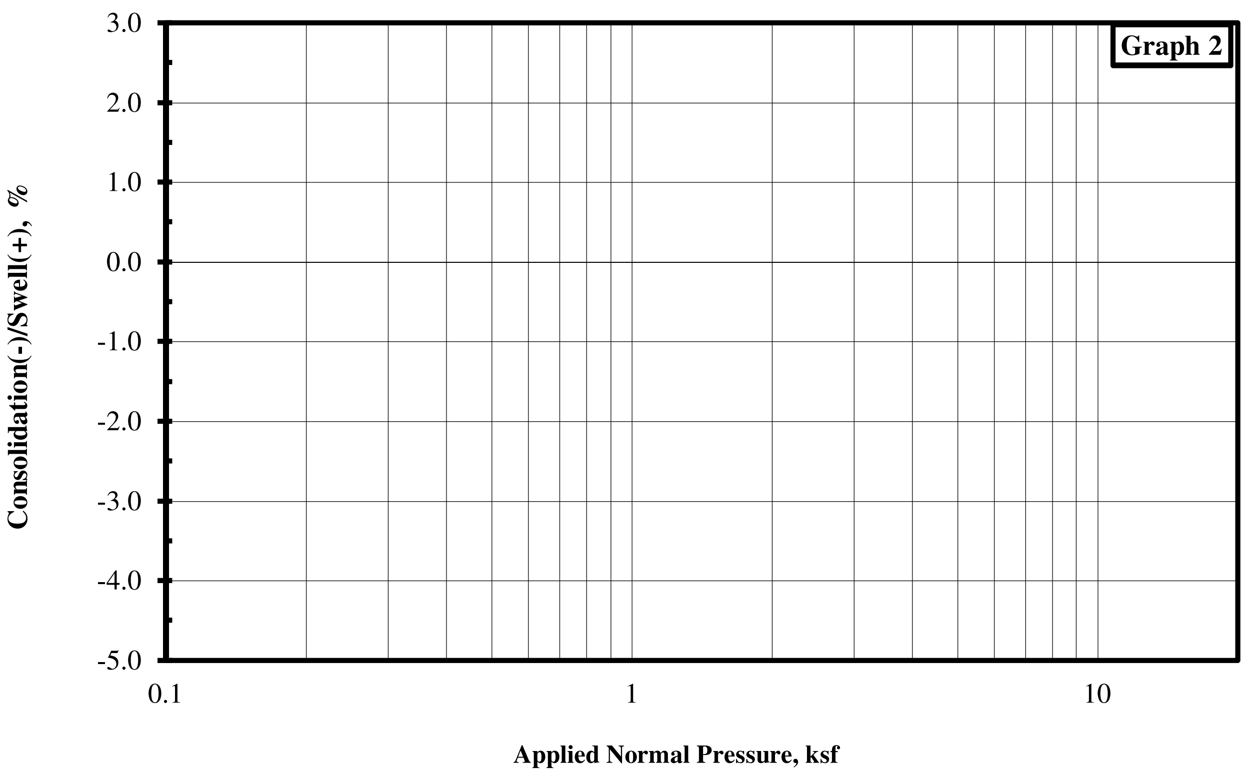




Graph Number	Boring Number	Depth (ft)	Natural Dry Density (pcf)	Moisture Content (%)	Swell(+) / Consolidation(-) (%)	Soil Description	SWELL / CONSOLIDATION GRAPH	
1	B-2	15	124	9.4	-0.1	SAND, silty, clayey	Drawn By:	SAW
2	B-2	20	114	13.5	-0.1	SAND, clayey (SC)	Checked By:	SWR
Job No:	219-176	**Project Name:**	East Vail Pass Wildlife Crossings				Figure No. D-2	

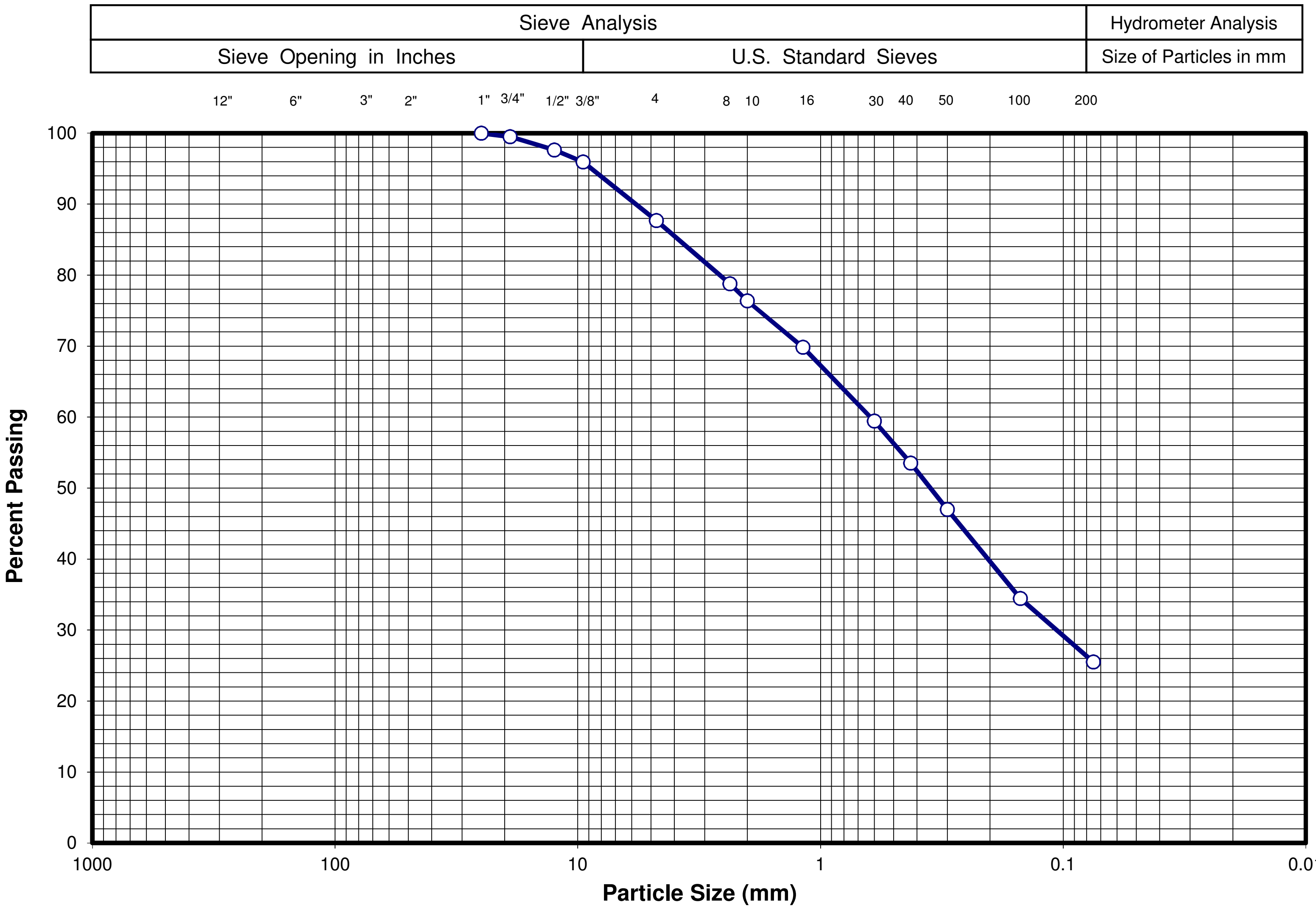
YEH & ASSOCIATES, INC.





Graph Number	Boring Number	Depth (ft)	Natural Dry Density (pcf)	Moisture Content (%)	Swell(+) / Consolidation(-) (%)	Soil Description	SWELL / CONSOLIDATION GRAPH
1	B-2	36	133	6.1	-0.1	GRAVEL, silty, clayey with sand (GC-GM)	Drawn By: SAW
2							Checked By: SWR
Job No:	219-176	Project Name:	East Vail Pass Wildlife Crossings				Figure No. D-3

YEH & ASSOCIATES, INC.



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	-
1"	100
¾ "	99
½"	98
⅜"	96
#4	88
#10	76
#40	54
#200	25

Gravel (%)	12	LL	NV	Project Name:	I-70 East Vail Pass Wildlife Crossings, Summit County, CO
Sand (%)	63	PL	NP	Sample ID:	B-1
Fines (%)	25	PI	NP	Sample Depth (ft.):	2 to 5
Sample Description:	SAND, silty (SM)				

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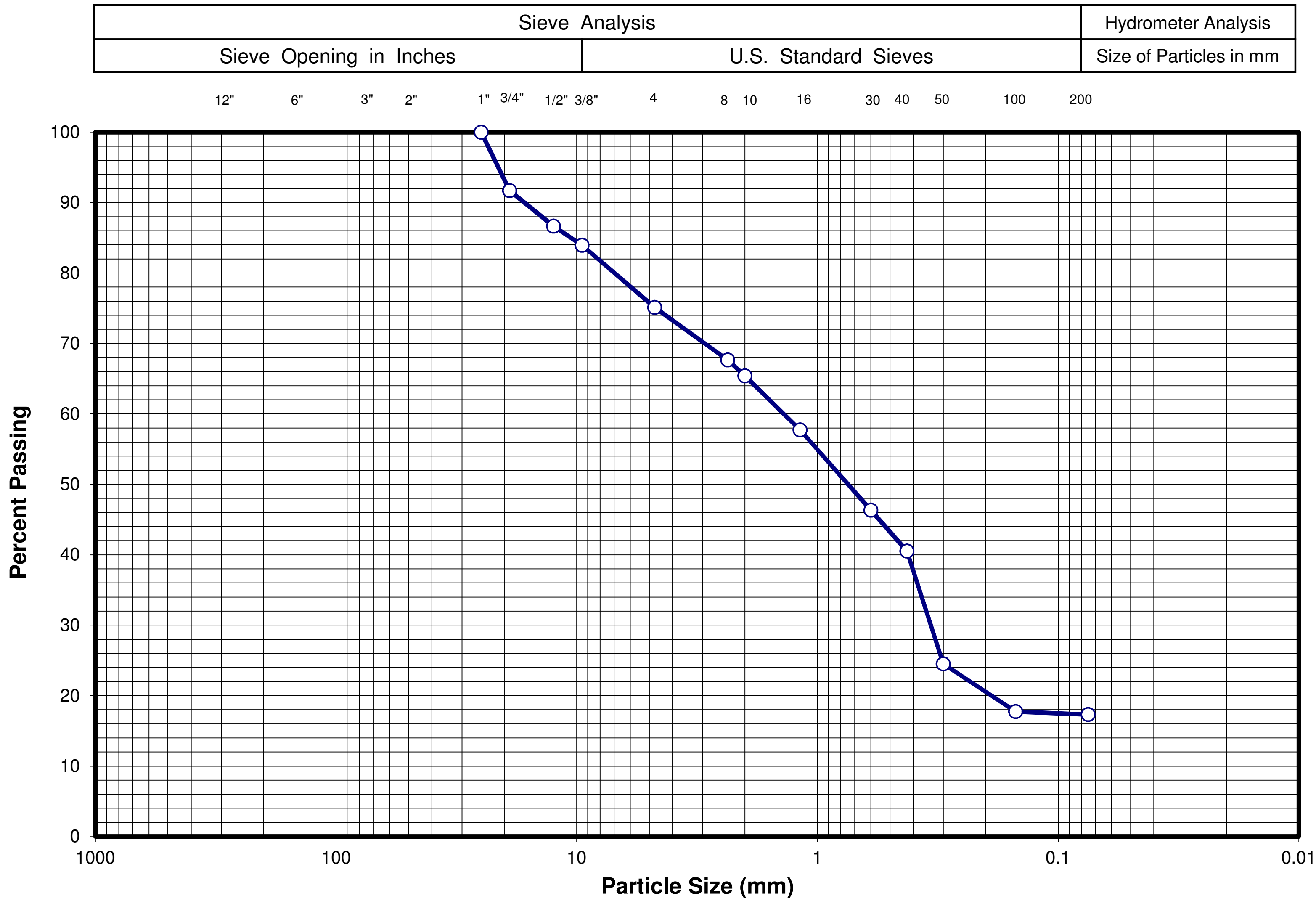
SIEVE ANALYSIS

Drawn By:	SAW	Project No.:	219-176
Checked By:	SWR	Figure No.:	D-4



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	-
1"	100
¾ "	92
½"	87
⅜"	84
#4	75
#10	65
#40	41
#200	17

Gravel (%)	25	LL	NV	Project Name:	I-70 East Vail Pass Wildlife Crossings, Summit County, CO
Sand (%)	58	PL	NP	Sample ID:	B-1
Fines (%)	17	PI	NP	Sample Depth (ft.):	5
Sample Description:	SAND, silty with gravel (SM)				

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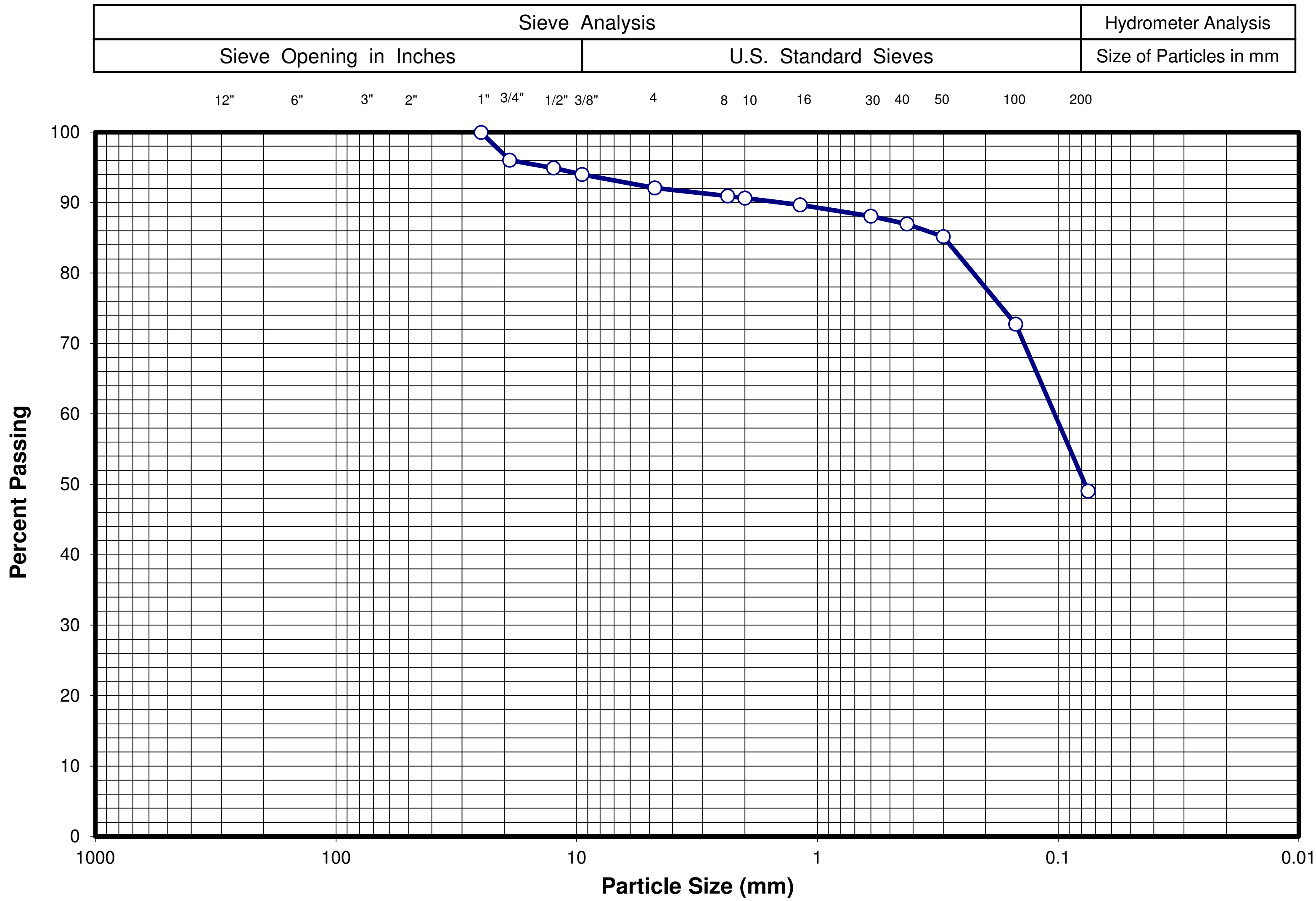
SIEVE ANALYSIS

Drawn By: SAW		Project No.:	219-176
Checked By: SWR		Figure No.:	D-5



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	-
1"	100
¾ "	96
½"	95
⅜"	94
#4	92
#10	91
#40	87
#200	49

Gravel (%)	8	LL	22	Project Name:	I-70 East Vail Pass Wildlife Crossings, Summit County, CO
Sand (%)	43	PL	17	Sample ID:	B-1
Fines (%)	49	PI	5	Sample Depth (ft.):	10

Sample Description: SAND, silty, clayey (SC-SM)

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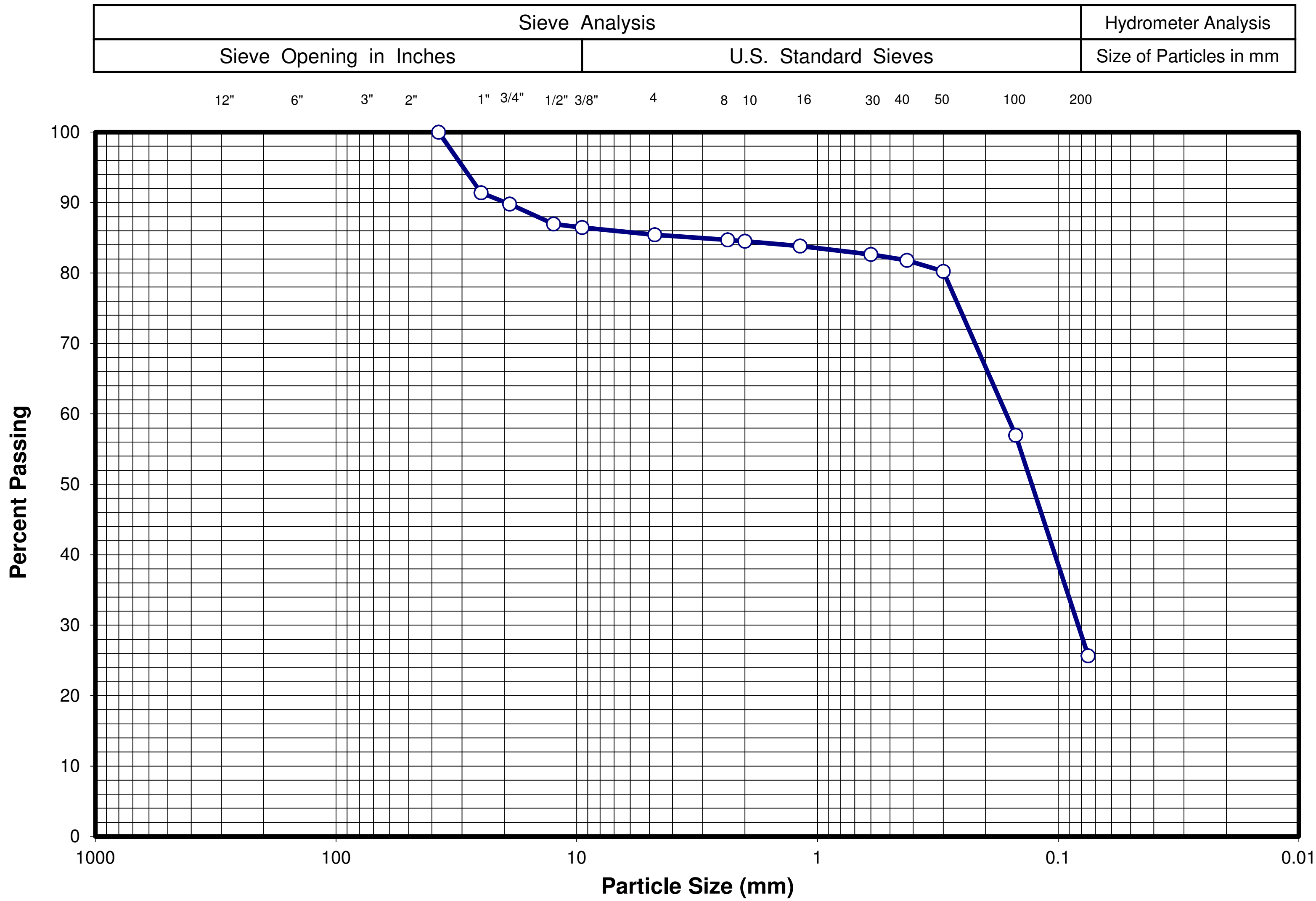
SIEVE ANALYSIS

Drawn By:	SAW	Project No.:	219-176
Checked By:	SWR	Figure No.:	D-6



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	100
1"	91
¾ "	90
½"	87
⅜"	86
#4	85
#10	84
#40	82
#200	26

Gravel (%)	15	LL	-	Project Name:	I-70 East Vail Pass Wildlife Crossings, Summit County, CO
Sand (%)	59	PL	-	Sample ID:	B-1
Fines (%)	26	PI	-	Sample Depth (ft.):	15
Sample Description:	SAND, silty, clayey with gravel				

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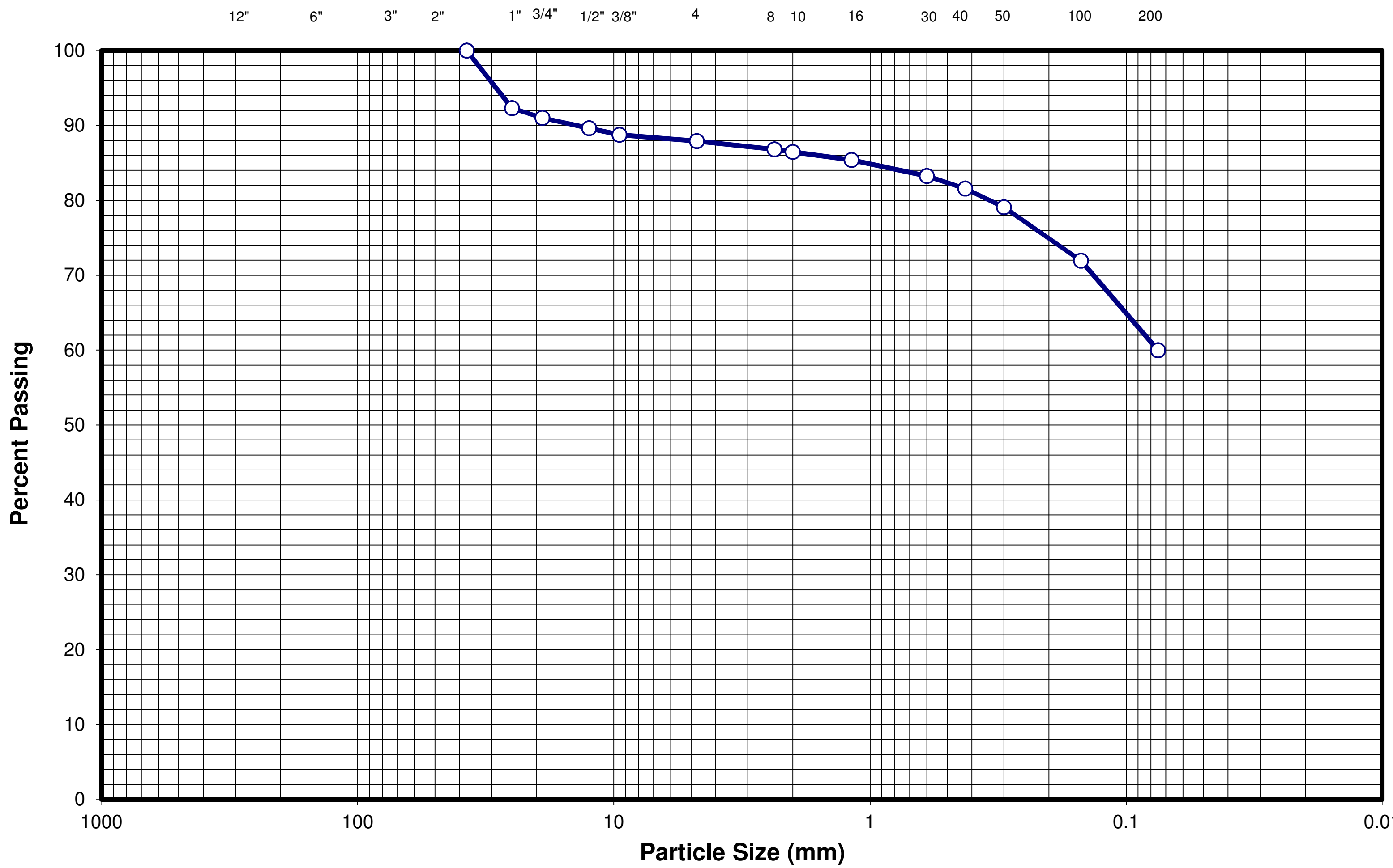
SIEVE ANALYSIS

Drawn By:	SAW	Project No.:	219-176
Checked By:	SWR	Figure No.:	D-7

Sieve Analysis		Hydrometer Analysis
Sieve Opening in Inches	U.S. Standard Sieves	Size of Particles in mm



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	100
1"	92
¾ "	91
½"	90
⅜"	89
#4	88
#10	86
#40	82
#200	60

Gravel (%)	12	LL	25	Project Name:	I-70 East Vail Pass Wildlife Crossings, Summit County, CO
Sand (%)	28	PL	18	Sample ID:	B-1
Fines (%)	60	PI	7	Sample Depth (ft.):	25
Sample Description:	CLAY, silty with sand (CL-ML)				

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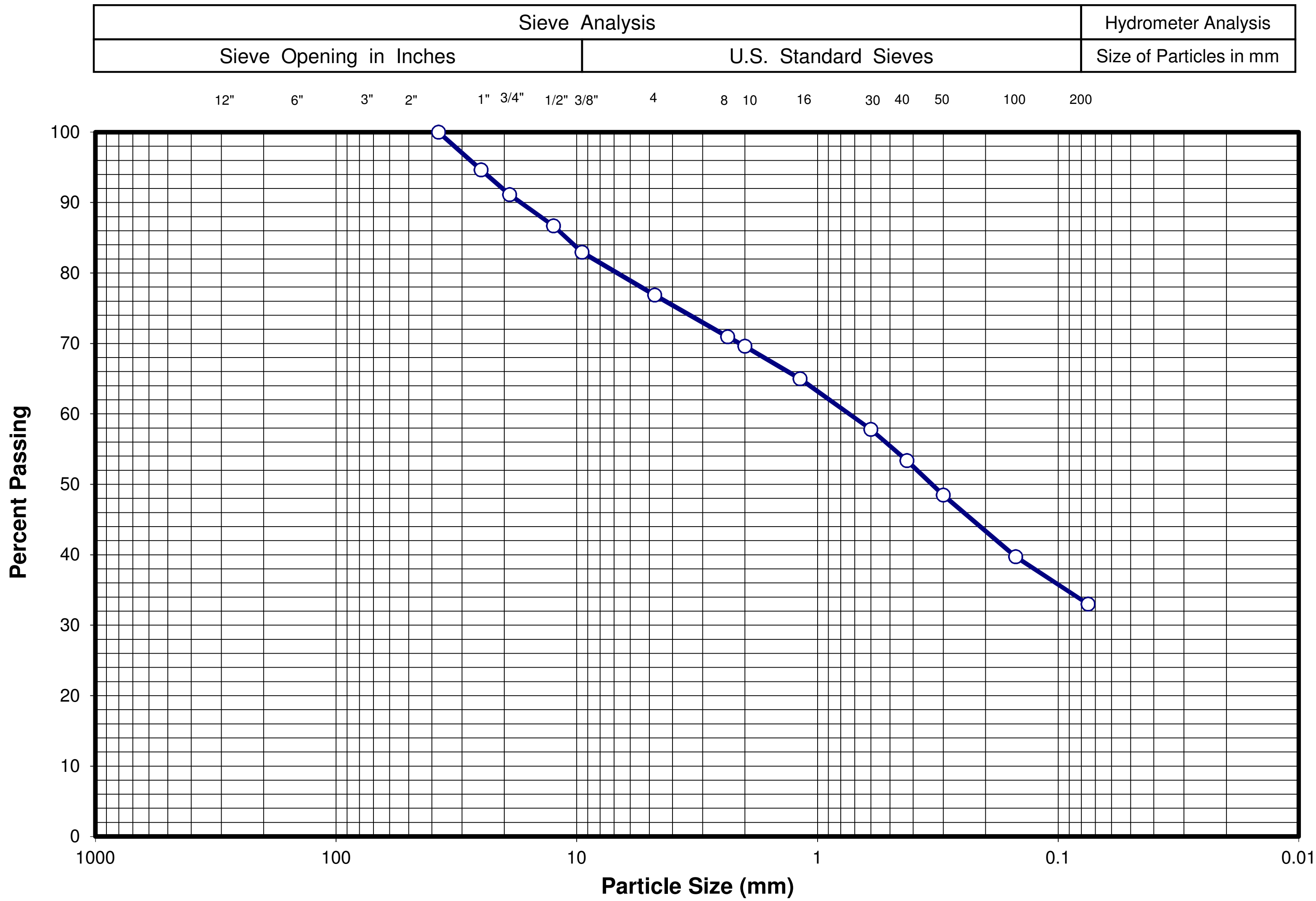
SIEVE ANALYSIS

Drawn By:	SAW	Project No.:	219-176
Checked By:	SWR	Figure No.:	D-8



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	100
1"	95
¾ "	91
½"	87
⅜"	83
#4	77
#10	70
#40	53
#200	33

Gravel (%)	23	LL	NV	Project Name:	I-70 East Vail Pass Wildlife Crossings, Summit County, CO
Sand (%)	44	PL	NP	Sample ID:	B-1
Fines (%)	33	PI	NP	Sample Depth (ft.):	40
Sample Description:	SAND, silty with gravel (SM)				

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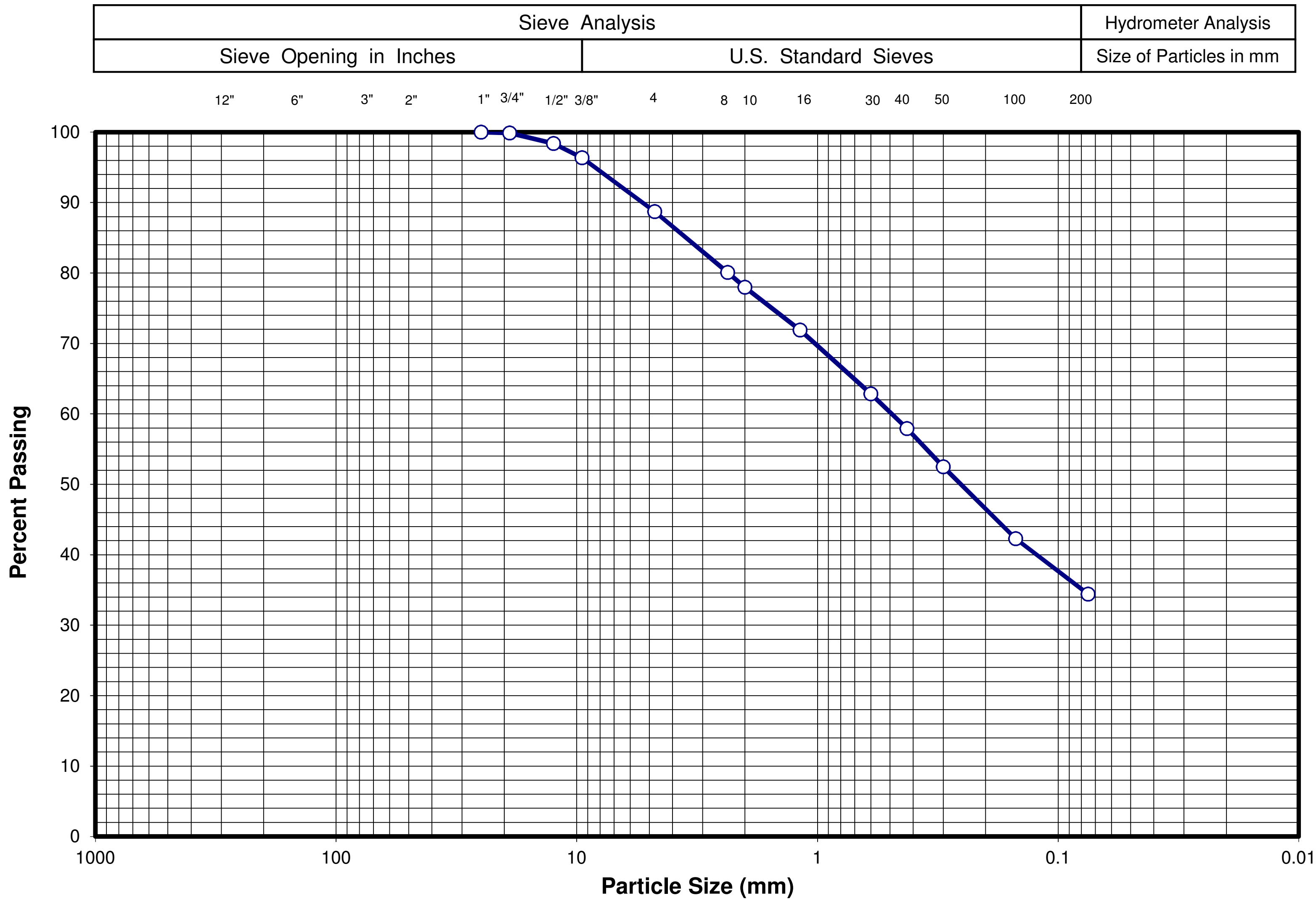
SIEVE ANALYSIS

Drawn By:	SAW	Project No.:	219-176
Checked By:	SWR	Figure No.:	D-9



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	-
1"	100
¾ "	100
½"	98
⅜"	96
#4	89
#10	78
#40	58
#200	34

Gravel (%)	11	LL	24
Sand (%)	55	PL	17
Fines (%)	34	PI	7

Project Name: I-70 East Vail Pass Wildlife Crossings, Summit County, CO

Sample ID: B-2

Sample Depth (ft.): 1 to 4

Sample Description: SAND, silty, clayey (SC-SM)

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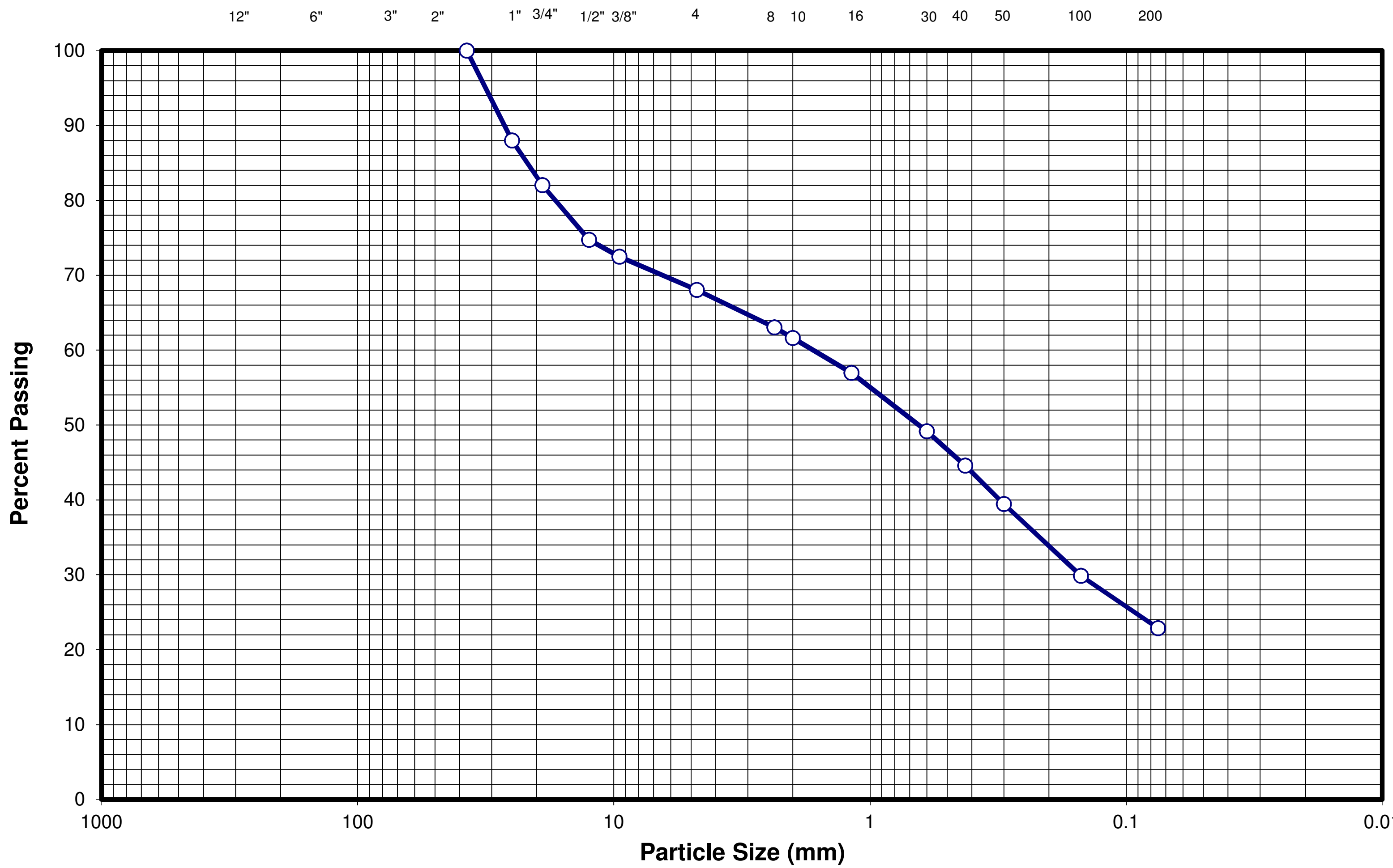
SIEVE ANALYSIS

Drawn By:	SAW	Project No.:	219-176
Checked By:	SWR	Figure No.:	D-10

Sieve Analysis		Hydrometer Analysis
Sieve Opening in Inches	U.S. Standard Sieves	Size of Particles in mm



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	100
1"	88
¾ "	82
½"	75
⅜"	72
#4	68
#10	62
#40	45
#200	23

Gravel (%)	32	LL	22	Project Name:	I-70 East Vail Pass Wildlife Crossings, Summit County, CO
Sand (%)	45	PL	17	Sample ID:	B-2
Fines (%)	23	PI	5	Sample Depth (ft.):	5

Sample Description: SAND, silty, clayey with gravel (SC-SM)

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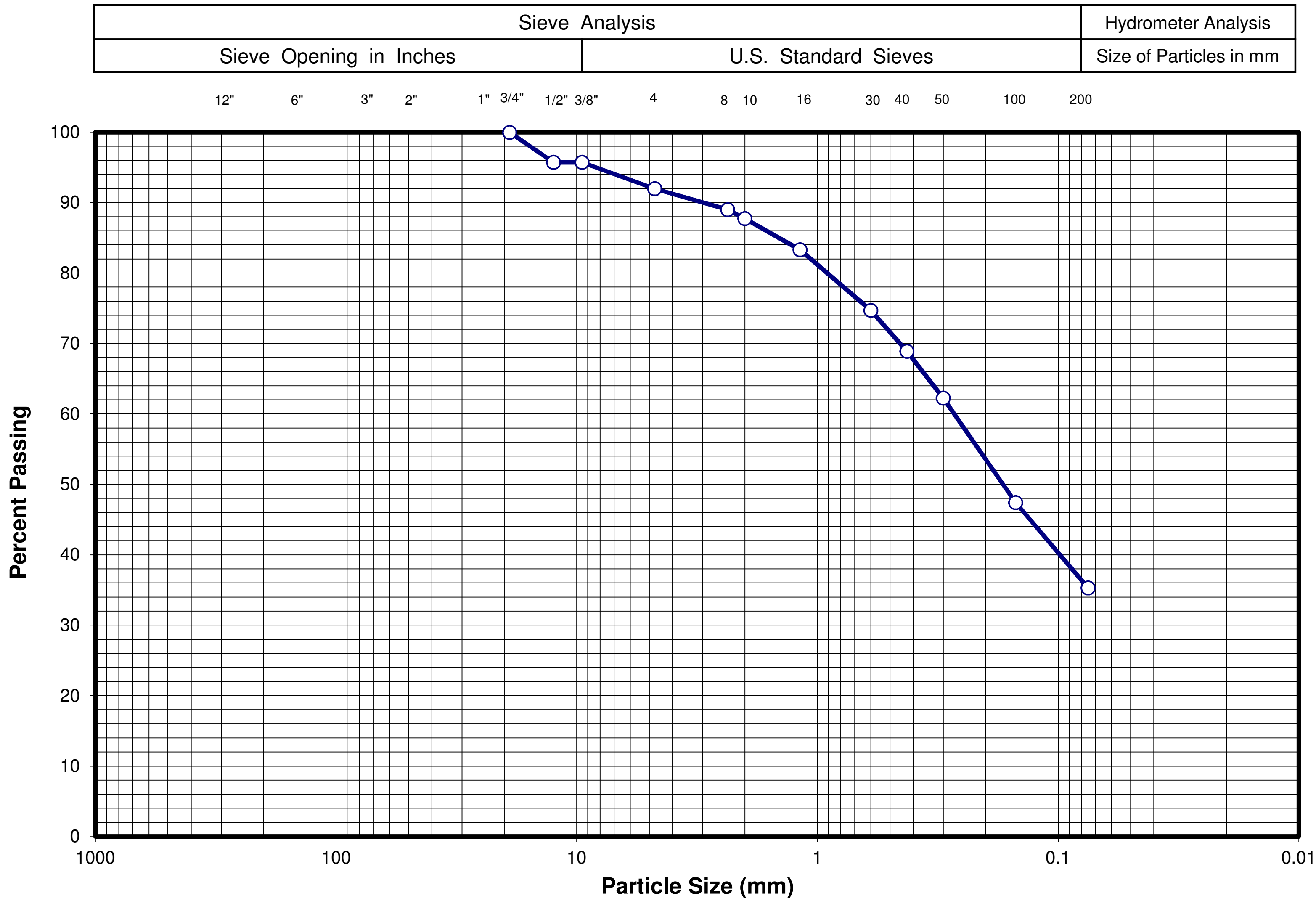
SIEVE ANALYSIS

Drawn By:	SAW	Project No.:	219-176
Checked By:	SWR	Figure No.:	D-11



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	-
1"	-
¾ "	100
½"	96
⅜"	96
#4	92
#10	88
#40	69
#200	35

Gravel (%)	8	LL	22	Project Name:	I-70 East Vail Pass Wildlife Crossings, Summit County, CO
Sand (%)	57	PL	17	Sample ID:	B-2
Fines (%)	35	PI	5	Sample Depth (ft.):	15
Sample Description:	SAND, silty, clayey (SC-SM)				

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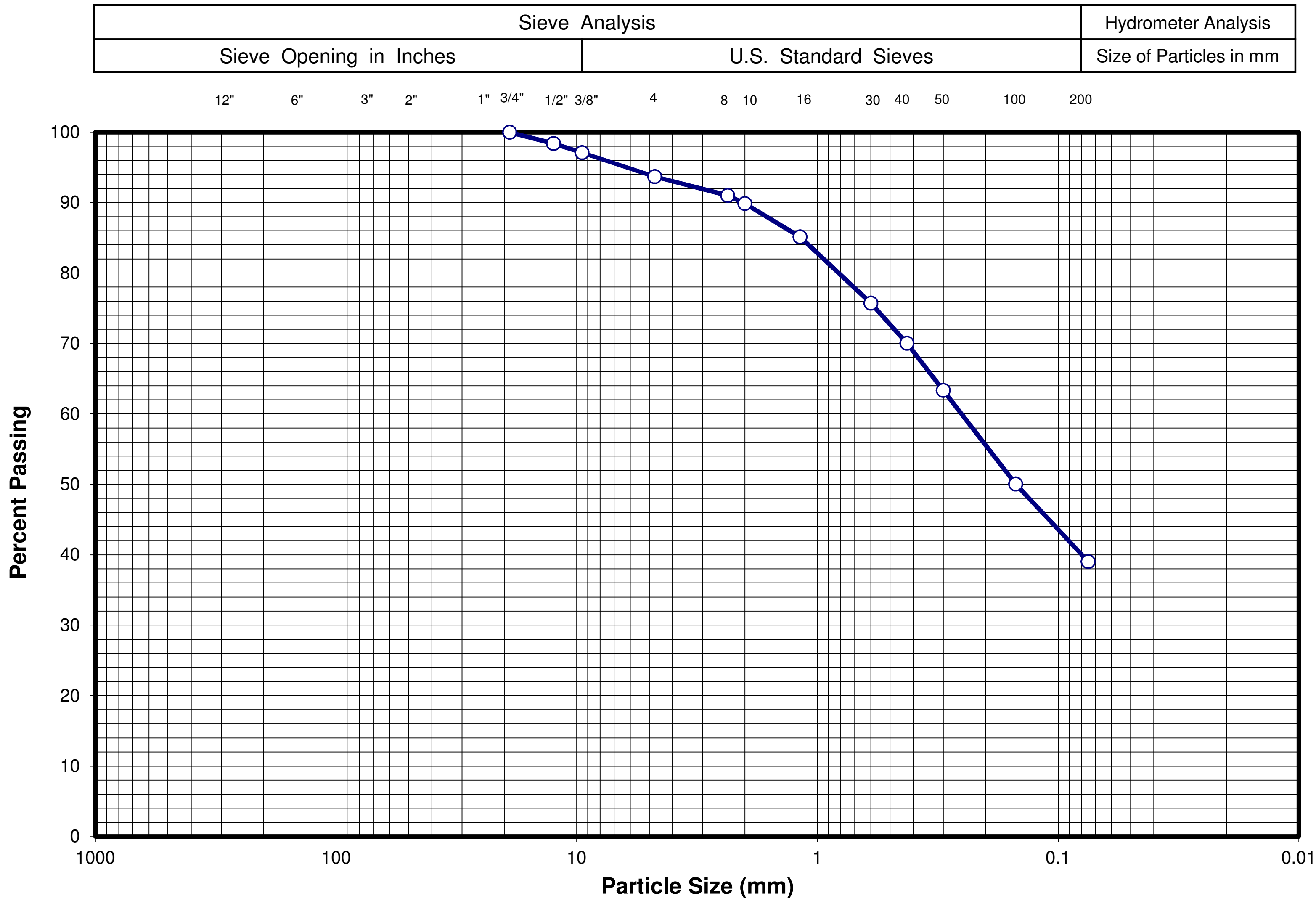
SIEVE ANALYSIS

Drawn By:	SAW	Project No.:	219-176
Checked By:	SWR	Figure No.:	D-12



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	-
1"	-
¾ "	100
½"	98
⅜"	97
#4	94
#10	90
#40	70
#200	39

Gravel (%)	6	LL	32	Project Name:	I-70 East Vail Pass Wildlife Crossings, Summit County, CO
Sand (%)	55	PL	23	Sample ID:	B-2
Fines (%)	39	PI	9	Sample Depth (ft.):	20
Sample Description:	SAND, clayey (SC)				

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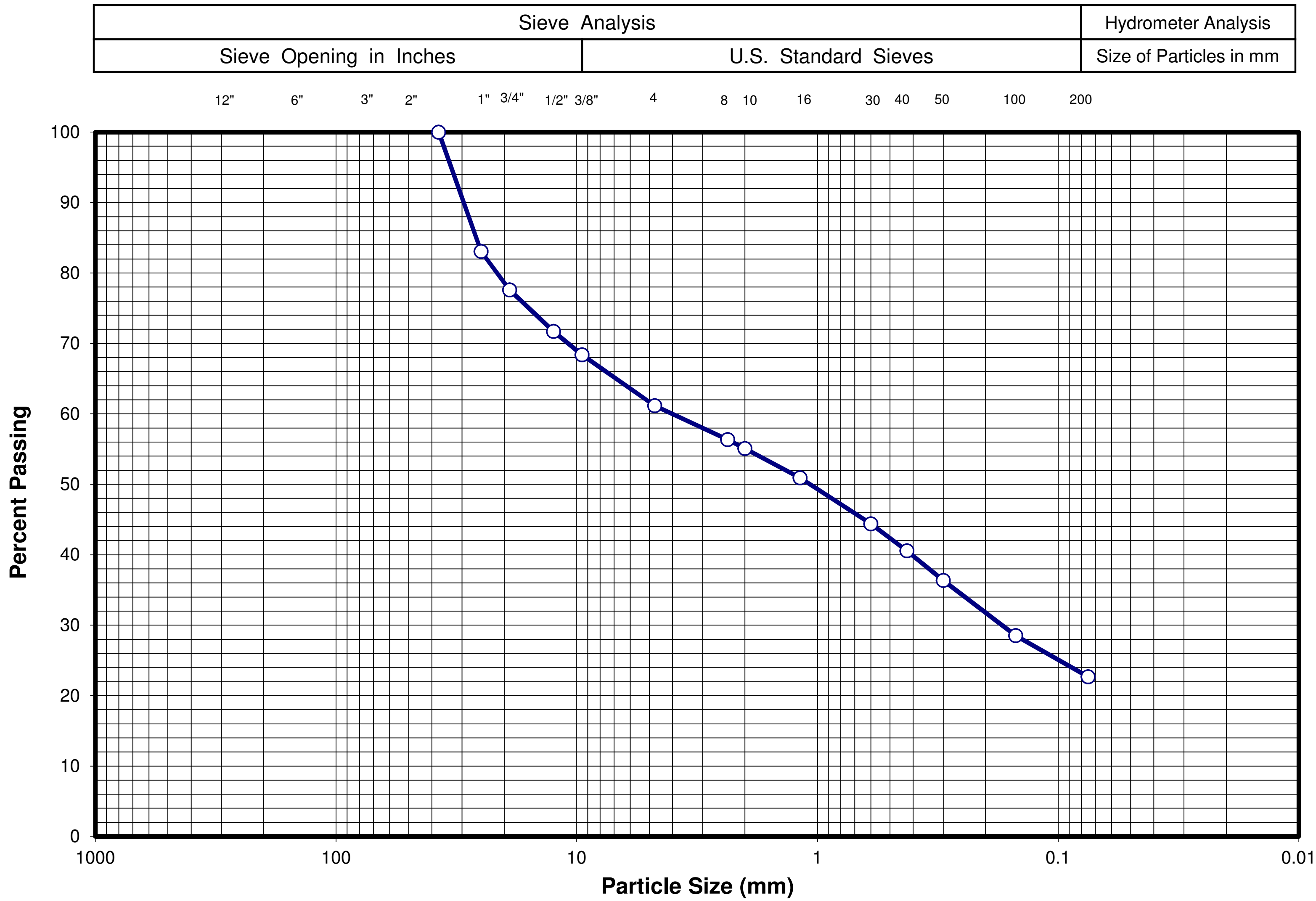
SIEVE ANALYSIS

Drawn By:	SAW	Project No.:	219-176
Checked By:	SWR	Figure No.:	D-13



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	100
1"	83
¾ "	78
½"	72
⅜"	68
#4	61
#10	55
#40	41
#200	23

Gravel (%)	39	LL	19	Project Name:	I-70 East Vail Pass Wildlife Crossings, Summit County, CO
Sand (%)	38	PL	15	Sample ID:	B-2
Fines (%)	23	PI	4	Sample Depth (ft.):	36

Sample Description: GRAVEL, silty, clayey with sand (GC-GM)

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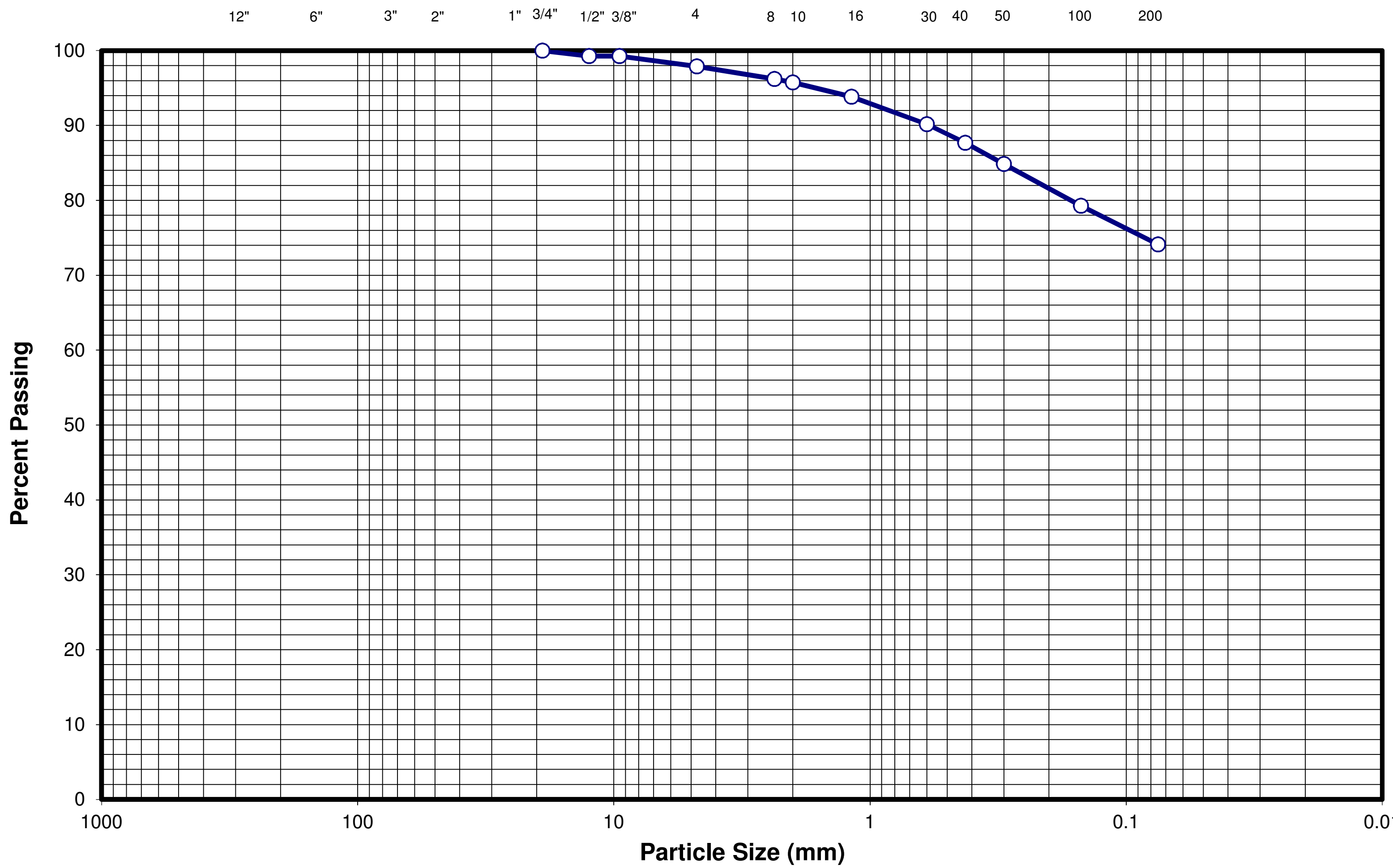
SIEVE ANALYSIS

Drawn By:	SAW	Project No.:	219-176
Checked By:	SWR	Figure No.:	D-14

Sieve Analysis		Hydrometer Analysis
Sieve Opening in Inches	U.S. Standard Sieves	Size of Particles in mm



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	-
1"	-
¾ "	100
½"	99
⅜"	99
#4	98
#10	96
#40	88
#200	74

Gravel (%)	2	LL	28	Project Name:	I-70 East Vail Pass Wildlife Crossings, Summit County, CO
Sand (%)	24	PL	21	Sample ID:	B-2
Fines (%)	74	PI	7	Sample Depth (ft.):	50
Sample Description:	CLAY, silty with sand (CL-ML)				

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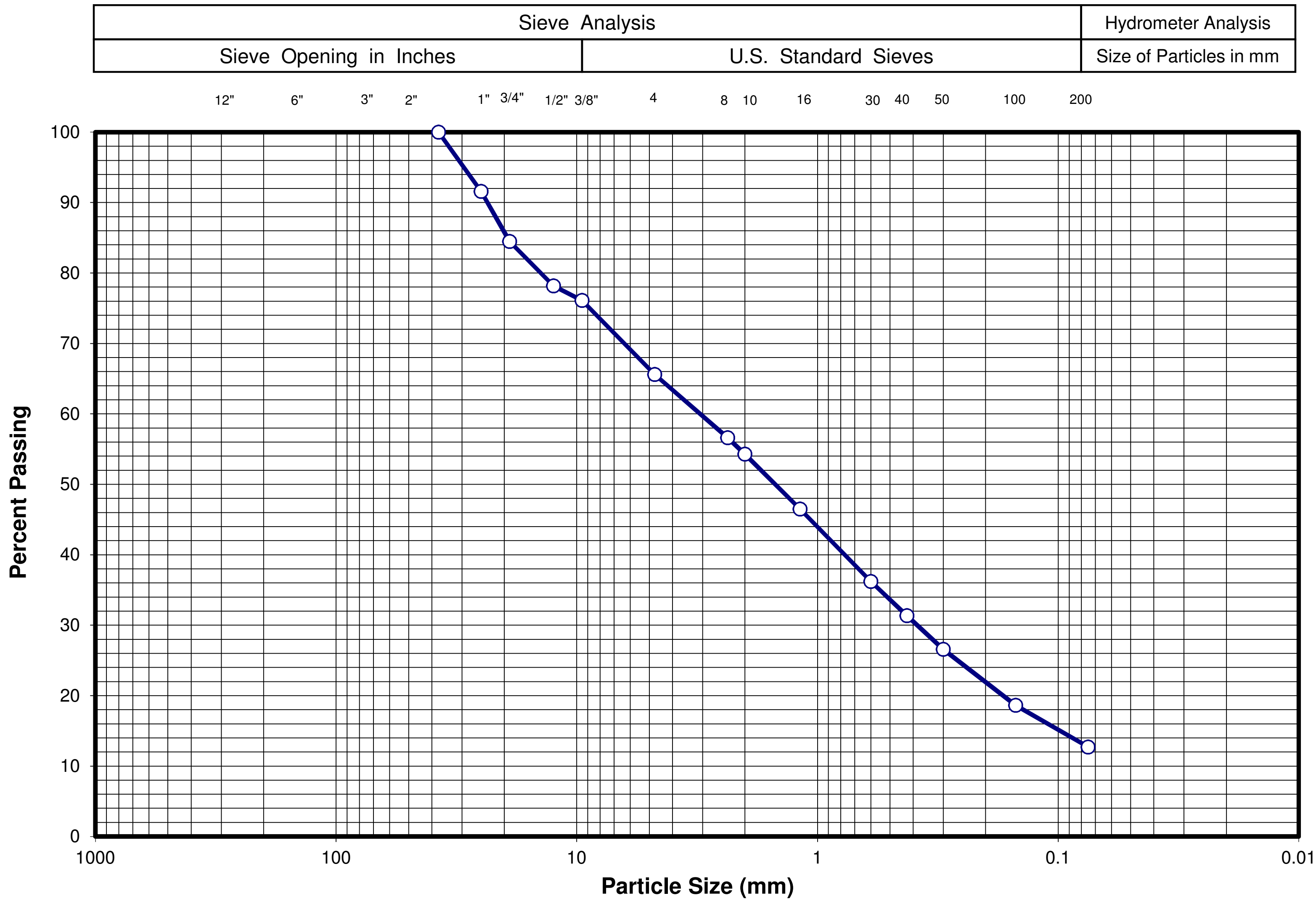
SIEVE ANALYSIS

Drawn By:	SAW	Project No.:	219-176
Checked By:	SWR	Figure No.:	D-15



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	100
1"	92
¾ "	84
½"	78
⅜"	76
#4	66
#10	54
#40	31
#200	13

Gravel (%)	34	LL	28
Sand (%)	53	PL	21
Fines (%)	13	PI	7

Project Name: I-70 East Vail Pass Wildlife Crossings, Summit County, CO

Sample ID: B-2

Sample Depth (ft.): 70

Sample Description: SAND, silty, clayey with gravel (SC-SM)

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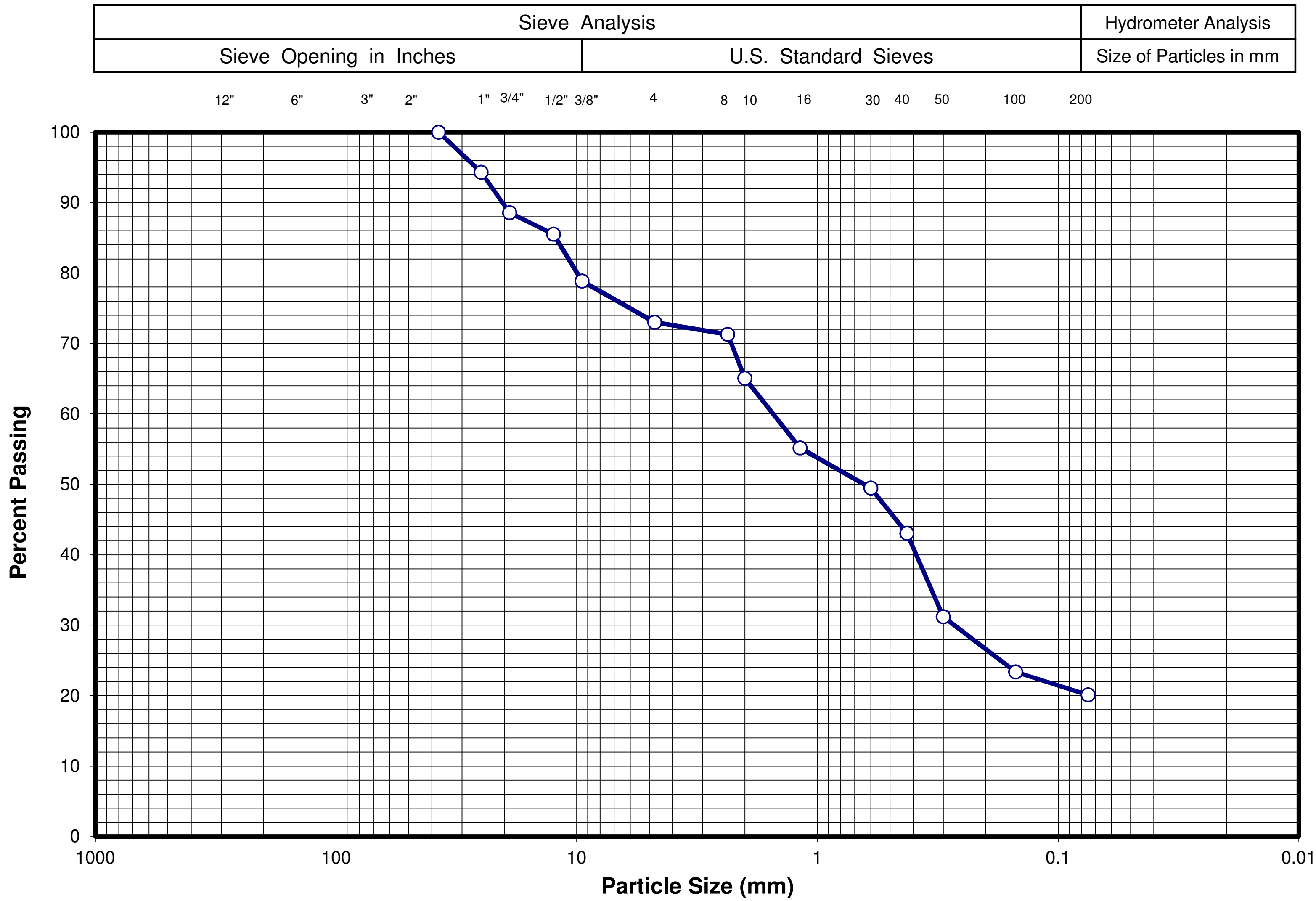
SIEVE ANALYSIS

Drawn By: SAW
Checked By: SWR

Project No.:	219-176
Figure No.:	D-16



Sieve Size	% Passing
3"	-
2 ½"	-
2"	-
1 ½"	100
1"	94
¾ "	89
½"	85
⅜"	79
#4	73
#10	65
#40	43
#200	20

Gravel (%)	27	LL	20	Project Name:	I-70 East Vail Pass Wildlife Crossings, Summit County, CO
Sand (%)	53	PL	16	Sample ID:	B-3
Fines (%)	20	PI	4	Sample Depth (ft.):	5

Sample Description: SAND, silty, clayey with gravel (SC-SM)

Yeh & Associates, Inc.
Geotechnical Engineering Consultants

SIEVE ANALYSIS

Drawn By:	SAW	Project No.:	219-176
Checked By:	SWR	Figure No.:	D-17

ADVANCED TERRA TESTING

Unconfined Compressive Strength
ASTM D7012 Method C

CLIENT	Yeh & Associates	JOB NO.	2546-120
PROJECT	Vail Pass Wildlife Crossing	LOCATION	--
PROJECT NO.	219-176		

BORING NO.	B-3
DEPTH	29.0-29.6
SAMPLE NO.	
DATE SAMPLED	
DATE TESTED	05/19/20
TECHNICIAN	BFUTCH
ROCK TYPE	
Diameter (in):	2.377
Height (in):	5.235
Mass of Wet Rock (g):	994.5
Wet Density (lbs/ft³):	163.1
Wet Density (g/cm³):	2.61
Peak Load (lbs):	44006
Compressive Strength (psi)	9917
Compressive Strength (MPa)	68
Failure Type:	Fracture / Shear

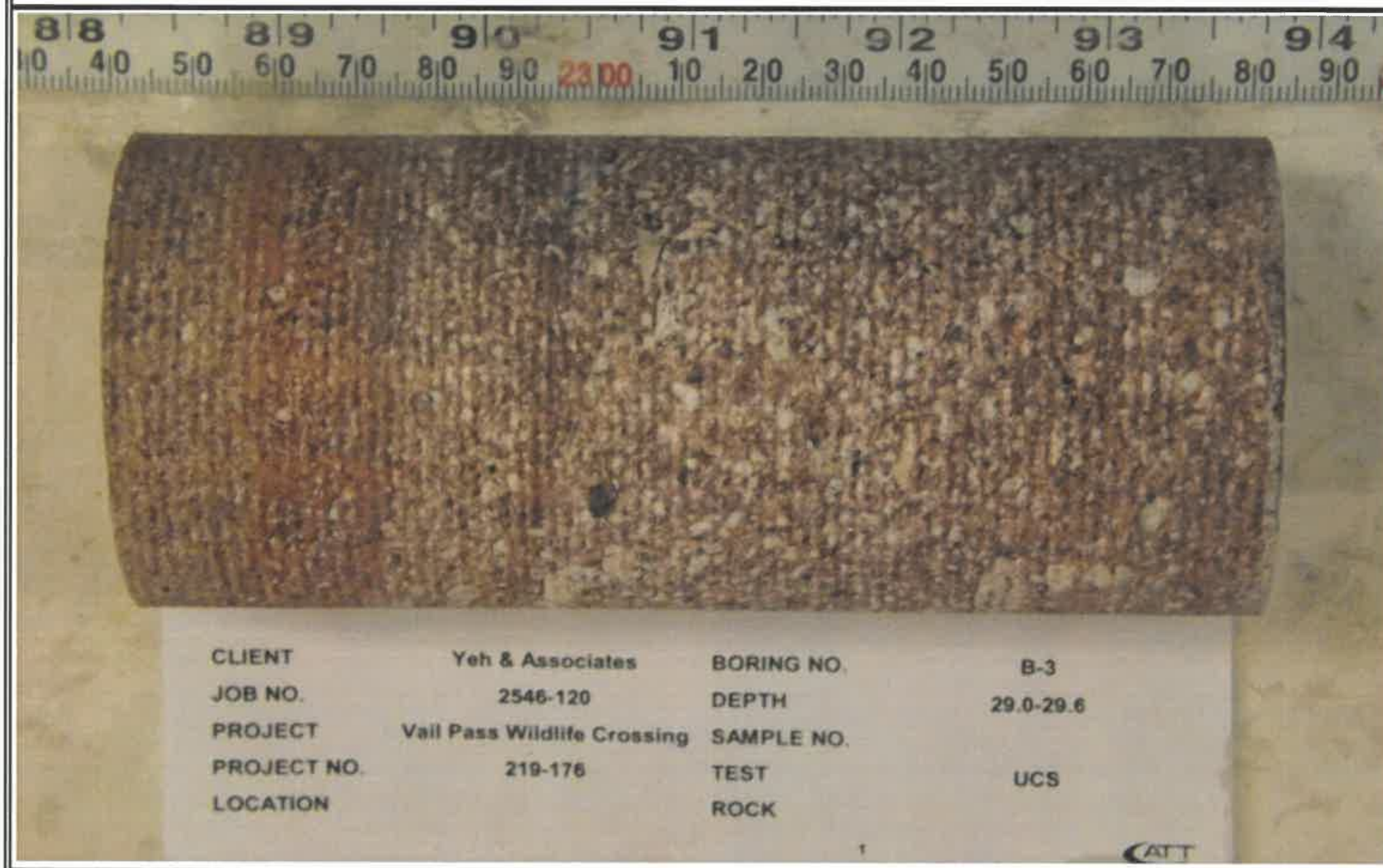
BORING NO.	
DEPTH	
SAMPLE NO.	
DATE SAMPLED	
DATE TESTED	
TECHNICIAN	
ROCK TYPE	
Diameter (in):	
Height (in):	
Mass of Wet Rock (g):	
Wet Density (lbs/ft³):	
Wet Density (g/cm³):	
Peak Load (lbs):	
Compressive Strength (psi)	
Compressive Strength (MPa)	
Failure Type:	
NOTES	

Data entry by:	BFUTCH	Date:	5/19/2020
Checked by:	HN	Date:	5/20/20
File name:	2546120__Rock UCS-TCS ASTM D7012 Method A and C_0.xlsm		

Image Attachment

ADVANCED TERRA TESTING

CLIENT	Yeh & Associates	BORING NO.	B-3
JOB NO.	2546-120	DEPTH	29.0-29.6
PROJECT	Vail Pass Wildlife Crossing	SAMPLE NO.	
PROJECT NO.	219-176	TEST TYPE	UCS
LOCATION	--	ROCK TYPE	



NOTES

File name: 2546120__Image_20_05_19_19_42_35

Image Attachment

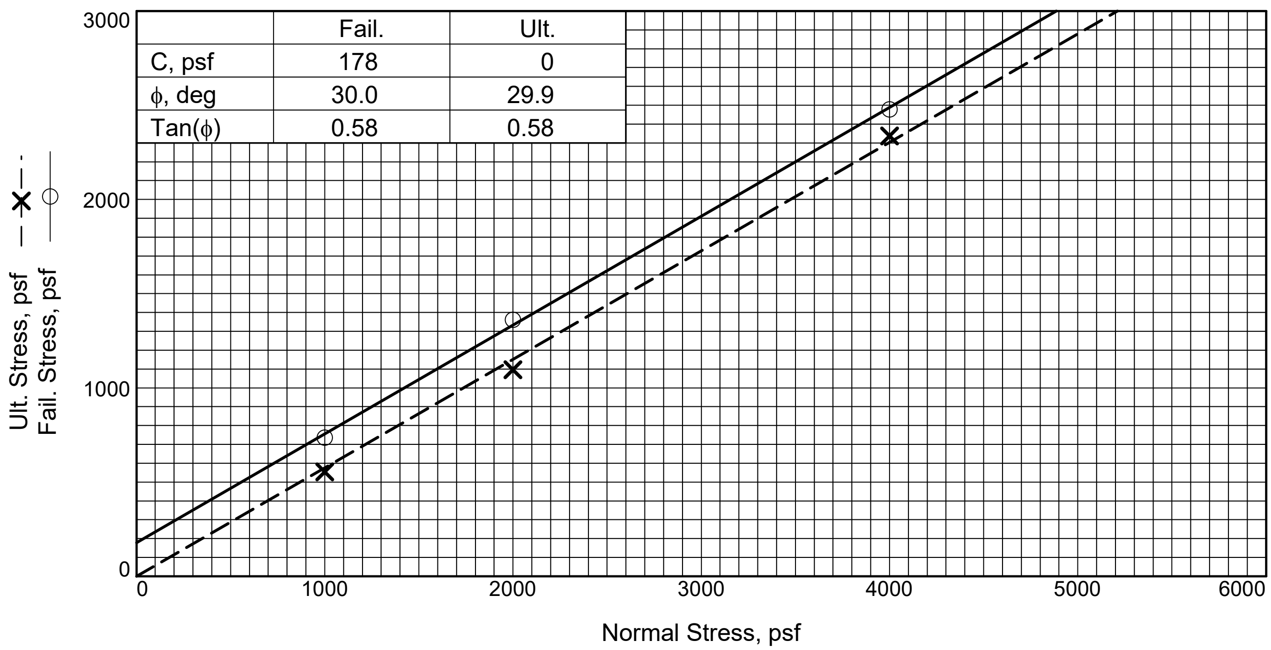
ADVANCED TERRA TESTING

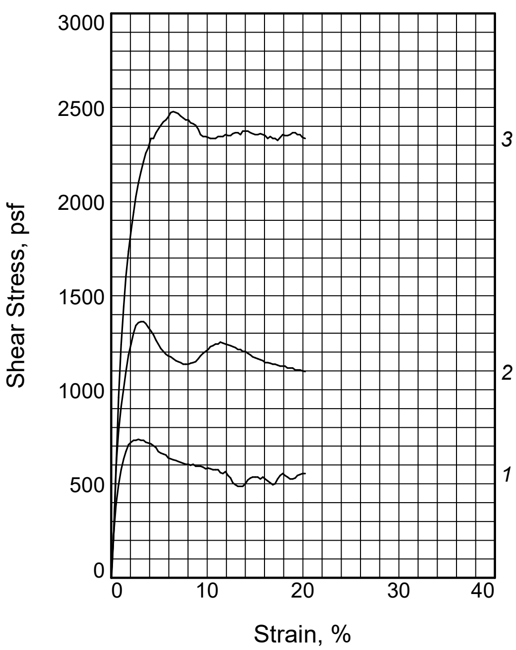
CLIENT	Yeh & Associates	BORING NO.	B-3
JOB NO.	2546-120	DEPTH	29.0-29.6
PROJECT	Vail Pass Wildlife Crossing	SAMPLE NO.	
PROJECT NO.	219-176	TEST TYPE	UCS
LOCATION	--	ROCK TYPE	

NOTES

File name: 2546120__Image_20_05_19_19_43_06

	Fail.	Ult.
C, psf	178	0
ϕ, deg	30.0	29.9
Tan(ϕ)	0.58	0.58





Specimen No.		1	2	3
Initial	Water Content, %	18.4	18.9	19.1
	Dry Density, pcf	110.8	110.9	106.1
	Saturation, %	95.3	98.2	87.5
	Void Ratio	0.5214	0.5194	0.5892
	Diameter, in.	1.93	1.93	1.93
	Height, in.	1.00	1.00	1.00
At Test	Water Content, %	18.2	17.6	18.9
	Dry Density, pcf	113.1	114.2	111.6
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.4910	0.4754	0.5097
	Diameter, in.	1.93	1.93	1.93
	Height, in.	0.98	0.97	0.95
Normal Stress, psf		1000	2000	4000
Fail. Stress, psf		737	1361	2479
Strain, %		2.8	3.1	6.5
Ult. Stress, psf		555	1096	2336
Strain, %		20.2	20.2	20.2
Strain rate, %/min.		0.05	0.05	0.05

Sample Type: Intact

Description: P200=78.5%

Assumed Specific Gravity= 2.7

Remarks: Failure chosen at peak shear stress and 20% strain. Test was inundated.

Figure ________

Client: Yeh & Associates, Inc.

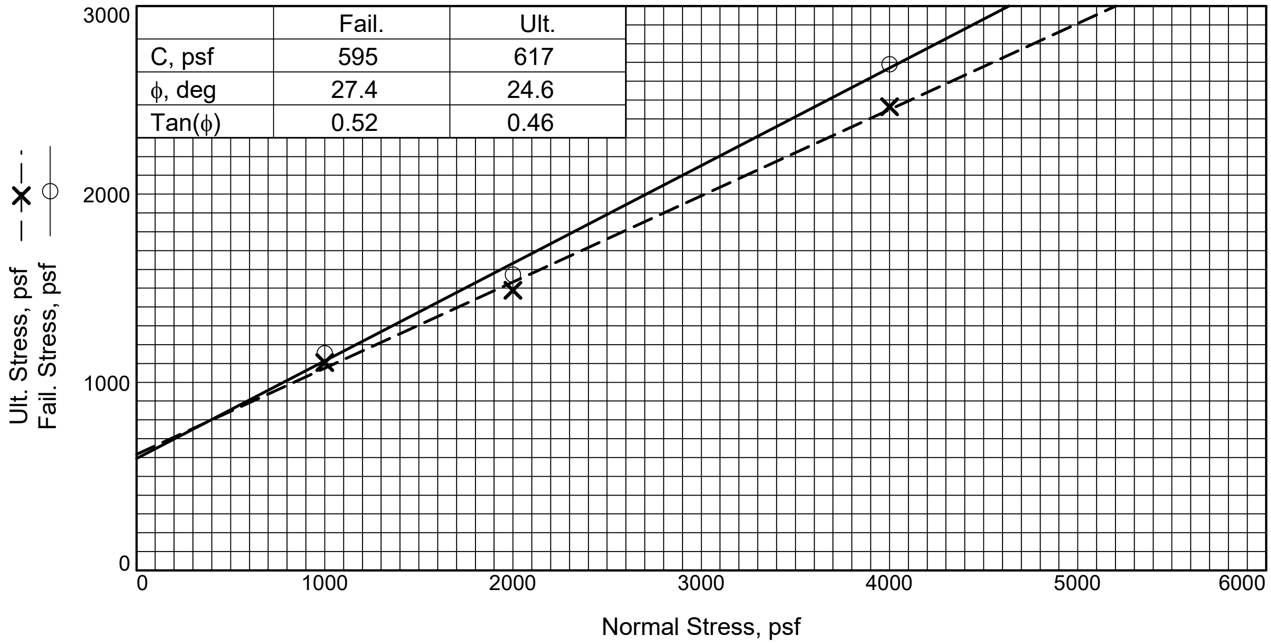
Project: Vail Pass Widlife Crossing
Y&A #219-176

Sample Number: B-1 **Depth:** 25'

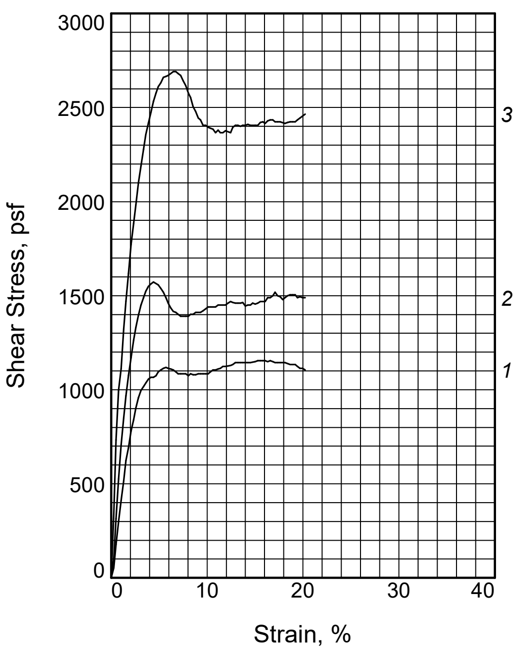
Proj. No.: DV108-129/12 **Date Sampled:** 5/12/20

Knight Piésold CONSULTING

Tested By: ICloud **Checked By:** JBruce



	Fail.	Ult.
C, psf	595	617
ϕ, deg	27.4	24.6
Tan(ϕ)	0.52	0.46



	Specimen No.	1	2	3
Initial	Water Content, %	9.2	9.7	9.6
	Dry Density, pcf	118.5	117.1	119.2
	Saturation, %	58.6	59.6	62.8
	Void Ratio	0.4230	0.4390	0.4142
	Diameter, in.	1.93	1.93	1.93
	Height, in.	1.00	0.99	1.03
At Test	Water Content, %	13.9	14.0	12.8
	Dry Density, pcf	122.5	122.4	125.1
	Saturation, %	100.0	100.0	100.0
	Void Ratio	0.3761	0.3767	0.3469
	Diameter, in.	1.93	1.93	1.93
	Height, in.	0.97	0.95	0.98
	Normal Stress, psf	1000	2000	4000
	Fail. Stress, psf	1154	1573	2691
	Strain, %	15.3	4.4	6.5
	Ult. Stress, psf	1105	1489	2464
	Strain, %	20.2	20.2	20.2
	Strain rate, %/min.	0.05	0.05	0.05

Sample Type: Intact
Description: P200=36.6%

Assumed Specific Gravity= 2.7
Remarks: Failure chosen at peak shear stress and 20 % strain. Test was inundated.

Figure ________

Client: Yeh & Associates, Inc.

Project: Vail Pass Widlife Crossing
Y&A #219-176
Sample Number: B-2 **Depth:** 15'

Proj. No.: DV108-129/12 **Date Sampled:** 5/12/20

Knight Piésold CONSULTING

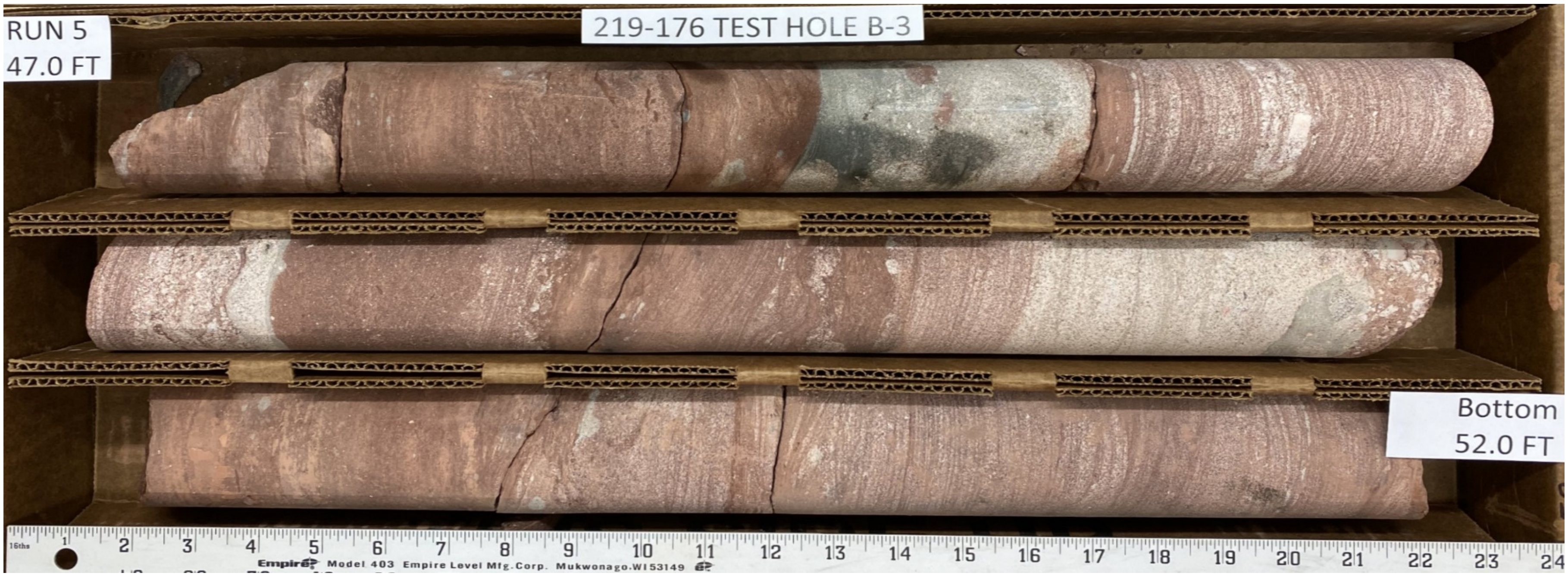
Tested By: ICloud **Checked By:** JBruce

Appendix E

CORE PHOTOGRAPHS

PROJECT NO.	**Rock Core Photos**	FIGURE	
219-176	**Boring B-3**		
DRAWN BY: SAW	**Depth: 28.5 to 37.0 feet**		**E-1**
CHECKED BY: SWR	East Vail Pass Wildlife Crossings		

PROJECT NO.	**Rock Core Photos**	FIGURE
219-176	**Boring B-3**	
DRAWN BY: SAW	**Depth: 37.0 to 47.0 feet**	**E-2**
CHECKED BY: SWR	East Vail Pass Wildlife Crossings	



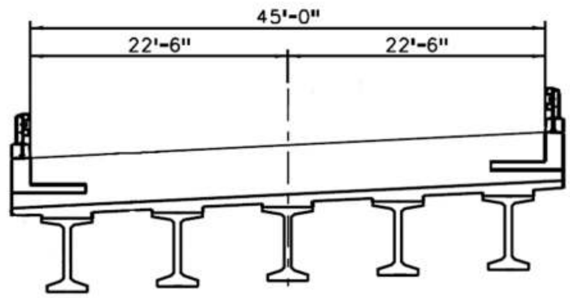
PROJECT NO.	Rock Core Photos Boring B-3 Depth: 47.0 to 57.0 feet	FIGURE
219-176		
DRAWN BY: SAW		E-3
CHECKED BY: SWR	East Vail Pass Wildlife Crossings	

Appendix D

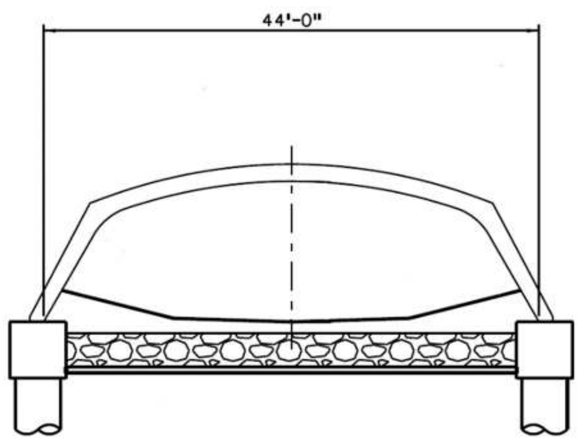
Typical Sections

East Vail Pass Wildlife Crossing Typical Sections

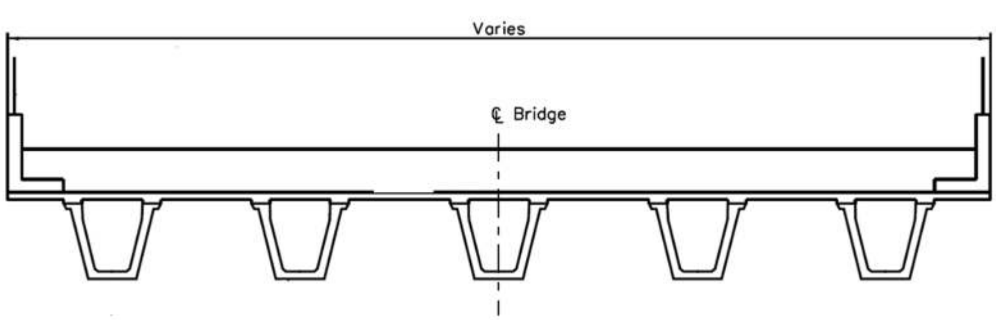
Area 1: Buried Bridge



Areas 2: Burined Arch



Areas 3: Houglass-Shaped Overpass



Appendix E

Wetland Mapping

Stream Channel
Potential Fen
Riparian
Potential Wetland
Interstate 70

N

SCALE:1 inch = 500 feet
0 1,000 Feet

NATIONAL FOREST FOUNDATION

East Vail Pass
Summit County, CO

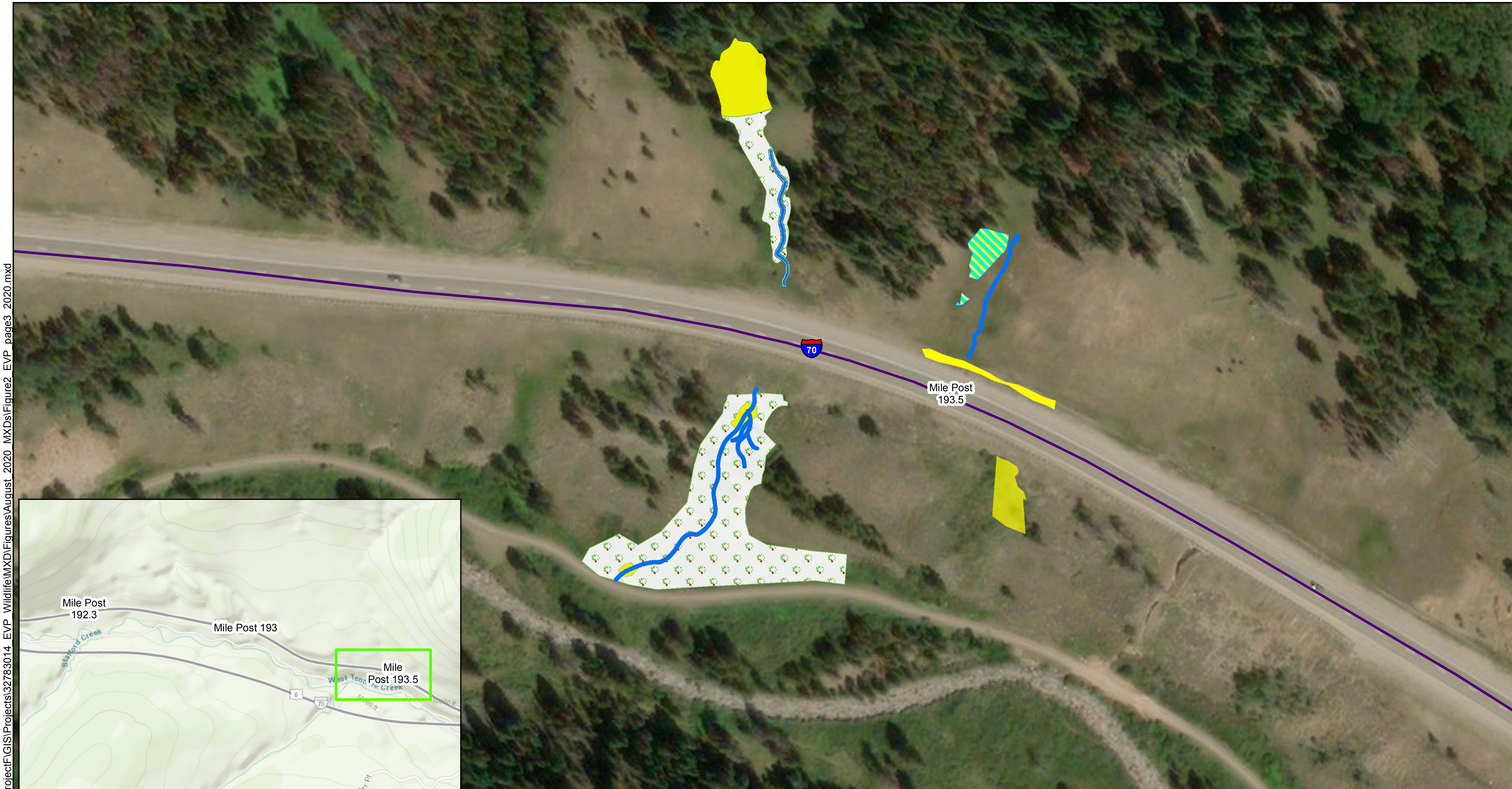
Vail Pass East Wildlife Passages Feasibility Study

wood.

By: GJK
Date: 08/28/2020
Project No.: 32783014

Figure 1

\\DEN-FS1\5007-Projects\LKW\ProjectF\GIS\Projects\32783014_EVP_Wildlife\MXD\Figures\August_2020_MXDs\Figure1_EVP_2020.mxd



Stream Channel
Potential Fen
Riparian
Potential Wetland
Interstate 70

SCALE: 1 inch = 104 feet

0 220 Feet

NATIONAL FOREST FOUNDATION

Wetlands and Waters
East Vail Pass
Summit County, CO

Vail Pass East Wildlife Passages Feasibility Study

wood.

By: GJK

Project No.: 32783014

Date: 08/28/2020

Figure 2: Page 3

\\DEN-FS1\5007-Projects\LKW\ProjectF\GIS\Projects\32783014 EVP Wildlife\MXD\Figures\August 2020 MXDs\Figure2 EVP page3 2020.mxd

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

\\DEN-FS1\5007-Projects\LKW\ProjectF\GIS\Projects\32783014 EVP Wildlife\MXD\Figures\August 2020 MXDs\Figure2 EVP page2 2020.mxd

Interstate 70

Stream Channel

Potential Wetland

N

SCALE:1 inch = 104 feet

0 220 Feet

NATIONAL FOREST FOUNDATION

Wetlands and Waters
East Vail Pass
Summit County, CO

Vail Pass East Wildlife Passages Feasibility Study

wood.

By: GJK | Project No.: 32783014

Date: 08/28/2020 | **Figure 2: Page 2**

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Stream Channel
Interstate 70
Riparian
Potential Wetland

N

SCALE: 1 inch = 82 feet

0 170 Feet

NATIONAL FOREST FOUNDATION

Wetlands and Waters
East Vail Pass
Summit County, CO

Vail Pass East Wildlife Passages Feasibility Study

wood.

By: GJK

Project No.: 32783014

Date: 08/28/2020

Figure 2: Page 1

\\DEN-FS15007-Projects\LKW\ProjectF\GIS\Projects\32783014_EVP_Wildlife\MXD\Figures\August_2020_MXDs\Figure2_EVP_page1_2020.mxd

Appendix F

Cost Estimates

East Vail Pass Wildlife Crossing
Area 1: Buried Bridge

wood.

CREATED BY: KDB 8/29/2020
CHECKED BY: JJW 8/28/2020

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	COST
203-00000	Unclassified Excavation	CY	14,685	$ 18.00	$ 264,330
207-00205	Topsoil	CY	305	$ 20.00	$ 6,100
304-06007	Aggregate Base Course (Class 6)	CY	388	$ 45.00	$ 17,460
403-34731	Hot Mix Asphalt (Grading SX) (75) (PG 58-34)	TON	329	$ 90.00	$ 29,610
420-00000	Geomembrane	SY	622	$ 20.24	$ 12,591
502-11489	Steel Piling (HP 14x89)	LF	648	$ 148.96	$ 96,526
504-06400	Soil Nail Wall	SF	357	$ 22.11	$ 7,891
506-00212	Riprap (12 Inch)	CY	414	$ 100.00	$ 41,400
514-03411	Retaining Wall (1) (Alternative Systems)	SF	4,360	$ 90.00	$ 392,400
601-03040	Concrete Class D (Bridge)	CY	189	$ 850.00	$ 160,650
602-00000	Reinforcing Steel	LB	17,500	$ 1.25	$ 21,875
602-00020	Reinforcing Steel (Epoxy Coated)	LB	22,222	$ 1.35	$ 30,000
606-00301	Guardrail Type 3 (6-3 Post Spacing)	LF	1,000	$ 40.00	$ 40,000
618-00172	Prestressed Concrete I (BT72)	LF	418	$ 231.86	$ 96,915
621-00450	Detour Pavement	SY	3,760	$ 60.00	$ 225,600
630-80370	Concrete Barrier (Temporary)	LF	2,200	$ 45.00	$ 99,000
606-11030	Bridge Rail Type 10M	LF	170	$ 209.40	$ 35,597
	Landscaping	ACRE	0.67	$ 4,000.00	$ 2,680

a)		SUBTOTAL		$ 1,580,626
b)	Contingency	30%	of a)	$ 474,188
c)	Mobilization	10%	of a) + b)	$ 205,481
d)	Erosion Control	3%	of a) + b)	$ 61,644
e)	Traffic Control	10%	of a) + b)	$ 205,481
		TOTAL		$ 2,527,420

East Vail Pass Wildlife Crossing
Area 2: Buried Arch

wood.

CREATED BY:	KDB	8/29/2020
CHECKED BY:	JJW	8/28/2020

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	COST
203-00000	Unclassified Excavation	CY	12,180	$ 18.00	$ 219,240
207-00205	Topsoil	CY	1,035	$ 20.00	$ 20,700
304-06007	Aggregate Base Course (Class 6)	CY	493	$ 45.00	$ 22,185
403-34731	Hot Mix Asphalt (Grading SX) (75) (PG 58-34)	TON	329	$ 90.00	$ 29,610
420-00000	Geomembrane	SY	1,092	$ 20.24	$ 22,105
503-00048	Drilled Caisson (48 Inch)	LF	400	$ 439.12	$ 175,649
504-06400	Soil Nail Wall	SF	214	$ 22.11	$ 4,730
506-00224	Riprap (24 Inch)	CY	1,092	$ 120.00	$ 131,040
514-03411	Retaining Wall (1) (Alternative Systems)	SF	3,210	$ 90.00	$ 288,900
601-03030	Concrete Class D (Box Culvert)	CY	83	$ 800.00	$ 66,400
602-00000	Reinforcing Steel	LB	14,583	$ 1.25	$ 18,229
603-85095	Precast Concrete Arch Bridge System	L S	1	$ 750,000.00	$ 750,000
606-00301	Guardrail Type 3 (6-3 Post Spacing)	LF	1,000	$ 40.00	$ 40,000
621-00450	Detour Pavement	SY	4,100	$ 60.00	$ 246,000
630-80370	Concrete Barrier (Temporary)	LF	2,300	$ 45.00	$ 103,500
606-11030	Bridge Rail Type 10M	LF	88	$ 209.40	$ 18,427
	Landscaping	ACRE	2.78	$ 4,000.00	$ 11,120
a)				SUBTOTAL	$ 2,167,835
b)	Contingency		30%	of a)	$ 650,350
c)	Mobilization		10%	of a) + b)	$ 281,819
d)	Erosion Control		3%	of a) + b)	$ 84,546
e)	Traffic Control		10%	of a) + b)	$ 281,819
				TOTAL	$ 3,466,368

East Vail Pass Wildlife Crossing

Area 3: Hourglass-Shaped Overpass

wood.

CREATED BY:	KDB	8/29/2020
CHECKED BY:	JJW	8/28/2020

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	COST
206-00000	Structure Excavation	CY	1,904	$ 28.00	$ 53,312
206-00100	Structure Backfill (Class 1)	CY	28,533	$ 50.00	$ 1,426,650
203-00060	Embankment Material (Complete In Place)	CY	14,266	$ 18.00	$ 256,788
207-00205	Topsoil	CY	876	$ 20.00	$ 17,520
304-06007	Aggregate Base Course (Class 6)	CY	25	$ 45.00	$ 1,125
420-00000	Geomembrane	SY	114	$ 20.24	$ 2,308
502-11489	Steel Piling (HP 14x89)	LF	780	$ 148.96	$ 116,189
506-00218	Riprap (18 Inch)	CY	113	$ 110.00	$ 12,430
514-03411	Retaining Wall (1) (Alternative Systems)	SF	20,377	$ 90.00	$ 1,833,930
601-03040	Concrete Class D (Bridge)	CY	438	$ 850.00	$ 372,300
602-00000	Reinforcing Steel	LB	38,759	$ 1.25	$ 48,449
602-00020	Reinforcing Steel (Epoxy Coated)	LB	54,322	$ 1.35	$ 73,335
604-25000	Vane Grate Inlet Special	EACH	3	$ 10,000.00	$ 30,000
604-39000	Manhole Special	EACH	5	$ 18,503.95	$ 92,520
606-00301	Guardrail Type 3 (6-3 Post Spacing)	LF	1,000	$ 40.00	$ 40,000
618-10084	Precast Concrete U Girder (U84)(Pre-Tensioned)	LF	288	$ 500.00	$ 144,000
618-10384	Precast Concrete U Girder (U84)(Curved)	LF	192	$ 550.00	$ 105,600
624-20024	24 Inch Drainage Pipe (Class 0)	LF	240	$ 100.00	$ 24,000
624-20036	36 Inch Drainage Pipe (Class 0)	LF	145	$ 130.00	$ 18,850
	Landscaping	L S	1.00	$ 50,000.00	$ 50,000

a)			SUBTOTAL	$ 4,719,305
b)	Contingency	30%	of a)	$ 1,415,791
c)	Mobilization	10%	of a) + b)	$ 613,510
d)	Erosion Control	3%	of a) + b)	$ 184,053
e)	Traffic Control	10%	of a) + b)	$ 613,510
			TOTAL	$ 7,546,168