PRELIMINARY HYDRAULICS REPORT
STRUCTURE M-21-B REPLACEMENT
As a part of the
REGION TWO BRIDGE BUNDLE PACKAGE
OTERO COUNTY, COLORADO

A Part of Section 19, Township 26 South, Range 57 West of the 6th P.M., County of Otero, Colorado

February 5, 2021

Prepared for:

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1. INTRODUCTION

1.1 Background and Purpose

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

The fourteen (14) of the structures in this design build project are jointly funded by the USDOT FHWA Competitive Highway Bridge Program grant and the Colorado Bridge Enterprise (Project No. 23558). The remaining five (5) structures are funded solely by the Colorado Bridge Enterprise (Project No. 23559). These projects are combined to form one design-build project. The two ARE structures are part of the five bridges funded by the Colorado Bridge Enterprise.

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

1.2 Site Description

The purpose of this report is to document the preliminary hydraulic analysis and design for the replacement of Structure M-21-B as a part of the CDOT Region 2 Bridge Bundle Design Build. The project is located within Otero County at Mile Post 51.682 along US 350 between Trinidad and La Junta. Structure M-21-B crosses over the Lone Tree Arroyo. **Figure 1** below illustrates the project location. The project is located in Section 19, Township 26 South, Range 57 West of the 6th P.M., County of Otero, Colorado. **Figure 1** shows the project limits.

The report will document preliminary hydrology, hydraulic, and scour analysis/outlet protection to support the proposed structure replacement design.

The Federal Emergency Management Agency (FEMA) has designated the project site as a FEMA Zone A, as determined by the Flood Insurance Rate Maps (FIRM) 0801320225B effective date August 19, 1985, as shown in **Appendix A**. FEMA Zone A is a special flood hazard area inundated by the 100-year flood, however base flood elevations are not determined in a Zone A designation. 44 Code of Federal Regulations (CFR) 60.3 (b) state that for Zone A floodplains, all cumulative impacts to the system from the time of the original study cannot result in a water surface elevation (WSE) increase of more than one foot. This report also reviews changes to the WSE from the proposed bridge design.

The goal for this preliminary analysis is to provide viable options for the design build contractor to achieve a no-rise condition for replacement structures within Zone A floodplains. The Otero County floodplain administrator has indicated that a no-rise certification will be necessary to obtain a floodplain development permit from the county. If a no-rise condition is not met, the contractor will be required to complete the Letter of Map Change (LOMC) process through FEMA.

Figure 1: Vicinity Map

2. HYDROLOGY

Preliminary hydrology for the watershed tributary to this structure was provided by CDOT. A memorandum provided by CDOT has been provided that summarizes basin areas, runoff methodology and approximate flowrates derived from the preliminary analysis. Table 1 is a summary of the approximate flowrates provided by CDOT of structure M-21-B.

Table 1: Summary of Peak Discharge for Bridge M-21-B

River Location	Design Storm	100-year (cfs)	200-year (cfs)	500-year (cfs)
Upstream of Bridge	100-year	3,146	3,892	5,001

3. EXISTING CONDITIONS

3.1 Existing Structure

The existing structure is a two-span concrete deck on steel I beam girders bridge built in 1937 to span Lone Tree Arroyo. The bridge is tangent. The existing bridge consist of two 40’-0” spans (bearing to bearing), with a total length of 84’-10” out to out of abutments. The width of the existing bridge is 30’-0” curb to curb, 33’-6” out to out of deck. The existing vertical clearance is approximately 9’-0”.

3.2 Watershed Overview

The Lone Tree Arroyo is a dry arroyo that flows from the southeast to the northwest toward Timpas Creek. The watershed tributary to Lone Tree Arroyo is approximately 18.32 square miles in area. The watershed generally slopes to the north. The stream bed does not have a base flow.

The stream flows at an approximate angle of attack of 90 degrees to the existing structure. The area surrounding the bridge is rural with undeveloped land to both upstream and downstream sides of the bridge.

Downstream of the roadway bridge, approximately 2050 feet to the north, the channel crosses under the railroad prior to the confluence with Timpas Creek. The bridge for the railroad is an single span bridge.

3.3 Site Investigation

A site investigation by Stanley Consultants in August 2020 was performed to gain an understanding of the key hydraulic and geomorphic features of the stream at the project site and of the overall watershed. This investigation found obvious cracking on the wing walls, abutments, underside of deck, and deck overhangs, spalling with reinforcement exposure on the deck overhangs, and efflorescence throughout the underside and overhangs of the deck. Site photos are included in **Appendix C**.

4. HYDRAULIC ANALYSIS

A two-dimensional (2D) hydraulic model was developed using the Sediment and River Hydraulics 2D model (SRH-2D) software developed by the USBR in 2008. A 2D model was chosen to represent this area due to the complexity of the stream and for the preliminary scour countermeasure design. The Surface Water Modeling System (SMS) was used to develop the inputs for the SRH-2D Version 13.0 model, as well as post-process the results. For this analysis, two models were developed:

- Existing Conditions

- Proposed Conditions: Bridge Replacement

4.1 Debris potential

The potential for debris production and delivery is estimated to be low (minimal) based on guidance from Federal Highway Administration (FHWA) Hydraulic Engineering Circular (HEC) No. 20. The flowchart for potential debris production is presented in **Figure 2**. The channel banks near the bridge are vegetated with tall grasses and shrubs, and no trees present, as confirmed with the site visit in August, 2020. Aerial imagery of the watershed near the bridge is shown in **Appendix C**.

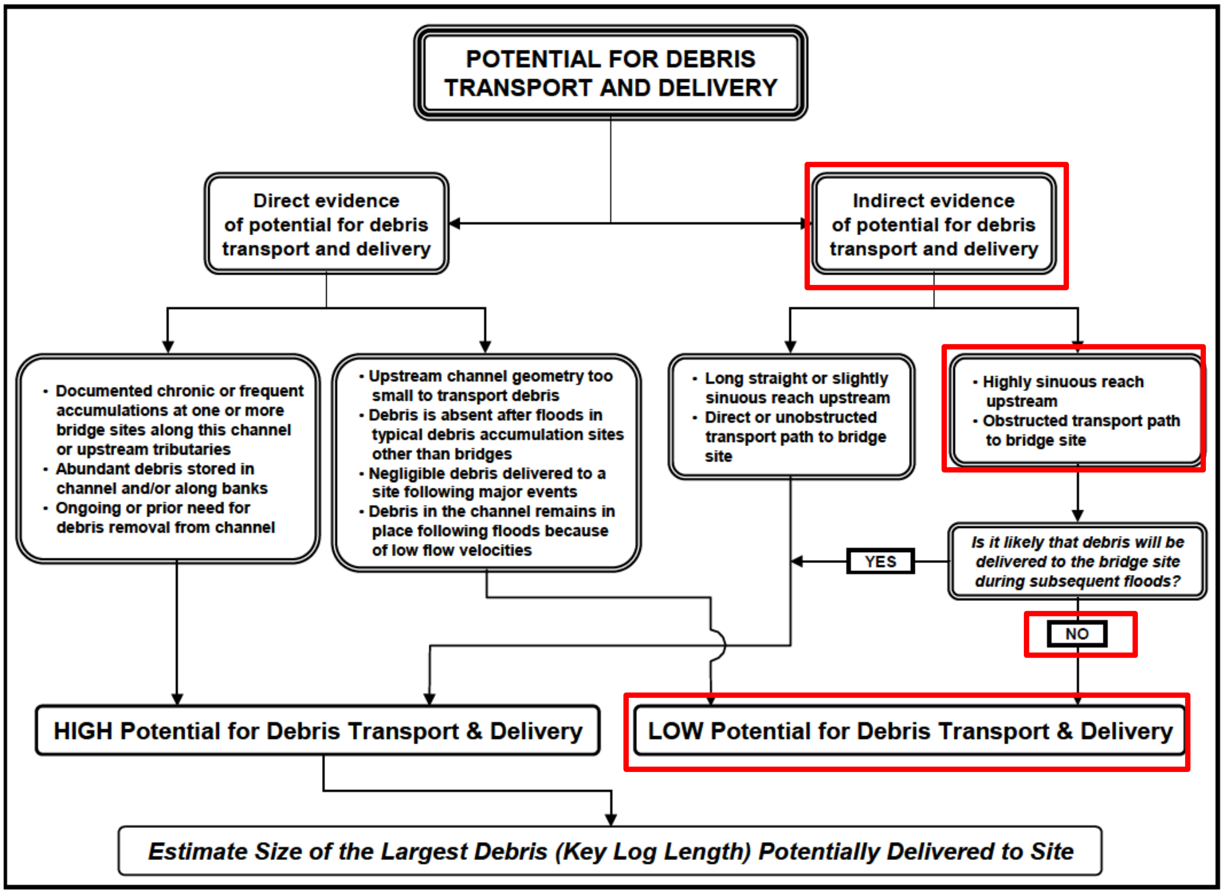


Figure 2: Flow Chart for Potential Debris Production (FHWA, HEC 20)

4.2 Freeboard

The CDOT Drainage Design Manual (2019) specifies freeboard requirements for all bridges. Freeboard is the minimum clearance between the design approach WSE and the low chord of the bridge. It is a factor of safety that acts as a buffer to account for unknown factors that could increase the height of the calculated WSE. Streams classified as high debris streams shall have a minimum of 4 feet of freeboard. Low-to-moderated streams CDOT highly encourages 2 feet be provided, where practical. The elevation of the water surface 50 to 100 feet upstream of the face of the bridge shall be the elevation to which the freeboard is added to get the bottom or low-girder elevation of the bridge.

The channel was not identified as having a high potential for debris production. Therefore, if a bridge is selected for the proposed conveyance structure, 2 feet of freeboard would typically be required. There is 2.06-ft of freeboard in the existing condition which increases to 3.91-ft in the proposed bridge condition.

4.3 Modeling Parameters

4.3.1 Elevation Data

Existing conditions survey for the bridge and channel cross sections was performed by CDOT in June, 2020. LiDAR was acquired by CDOT in June, 2020. These two data sources were combined for the modeling elevation surface.

A local, custom projection was used for the data collection in the existing conditions survey. The survey was converted into NAD 1983 Colorado State Plane South US Survey Feet for the hydraulic modeling. All elevations are referenced to NAVD 88 (feet).

4.3.2 Computational Mesh

The computational mesh is an unstructured mesh, which allows for the use of triangles and quadrilaterals, with variable element sizes. Roadways and the channel used quadrilaterals, with the face lined up perpendicular to flow. Triangles were typically used in the floodplain. The total number of mesh elements is 6,028 and the mesh extends approximately 1,030 feet upstream of the bridge and 830 feet downstream of the bridge.

4.3.3 Surface Roughness

Surface roughness, represented by the Manning's roughness coefficient, is presented in Table 2. A Manning's n-value was assigned to each land use based on aerial imagery, topography, a site visit in August, 2020, and engineering judgment. Photos from the site visit used to confirm the n-values selected are shown in **Appendix C**, and a map showing existing conditions materials coverages is shown in **Appendix D**.

Table 2: Manning's n-values

Land Use	n-value
Channel	0.035
Paved Road	0.016
Open Space	0.055

4.3.4 Boundary Conditions

The boundary conditions include a steady state inflow and a normal depth calculated outflow.

The peak flows developed in Table 1 were used to develop a steady-state inflow boundary condition. The inflow boundary condition extends the full length of the inundation boundary in the upstream portion of the project location. The model was set to a dry initial condition.

For the downstream boundary condition, the subcritical outflow option was selected. This outflow condition uses the inputs of anticipated flow, Manning's n-value, channel slope, and terrain data to determine the outflow constant water surface elevation. Table 3 presents the boundary condition values.

Table 3: Model Boundary Condition Inputs

Frequency Storm	Inflow (cfs)	Outflow Constant WSE (ft)
100-Year	3,146	4519.0

4.3.5 Hydraulic Structures

The modeled existing bridge geometry is based on the survey completed in June 2020. The survey data included shots detailing the bridge, including the existing pier locations. The high chord of the bridge is 4537.50 feet, while the low chord is 4533.70 feet.

The existing bridge piers were modeled as holes in the computational mesh, allowing flow to run around the piers which replicated true hydraulic conditions.

4.3.6 Simulation Control

The hydraulic simulations are run with a 1.0 second time step for 4 hours until a steady state solution is met. The parabolic turbulence method is used with a coefficient of 0.7.

4.4 Model Results

4.4.1 Existing Conditions

The range of depths experienced in the channel at the bridge during the 100-year event is from 0 feet to 10.5 feet. The results also demonstrate that flows are mostly confined within the channel. Existing conditions 100-year depths of flow are shown in **Appendix D**.

4.4.2 Alternatives Analysis

An alternatives/risk analysis was completed in the preliminary design process to determine the most feasible options for the hydraulic conveyance structure. Both a bridge and reinforced concrete box culvert (RCBC) option were analyzed; however, an RCBC option was determined to not be a feasible alternative because a no-rise condition was not able to be achieved. Many factors were taken into consideration when determining the preferred alternative for this preliminary analysis. These factors included cost, constructability, effects on the stream hydraulics, environmental impacts, among others.

<u>Proposed Bridge</u>

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included removing the existing bridge pier and modifying the pressure boundary condition to match the proposed bridge dimensions. The proposed model has 5,634 mesh elements. The proposed bridge has an 80-foot span width, no piers, the low chord of the bridge is at 4534.90 elevation, and the high chord is at 4537.70.

Depths and velocity grids for the proposed bridge show depths from 0 to 10.5 and velocities from 0 to 13.7. See **Appendix E** for 100-year depths and velocities graphics for this option.

5. FEMA FLOODPLAIN ANALYSIS

FEMA has designated the project site as a Zone A, as determined by the FIRM #0801320225B effective date August 19, 1985, as shown **Appendix A**.

FEMA Zone A is a special flood hazard area inundated by the 100-year flood, however base flood elevations are not determined in a Zone A designation. 44 CFR 60.3 (b) states that for Zone A floodplains, all cumulative impacts to the system from the time of the original study cannot result in a WSE increase of more than one foot. A Floodplain Development Permit will be submitted to Otero County during the next phase of design.

Proposed Bridge

The model for the proposed bridge will not increase the WSE by more than 1 foot. The bridge opening for this option is very similar to the existing structure. Therefore, no change in WSE is anticipated.

For the proposed bridge option, upstream of Bridge M-21-B (Cross Sections 1-5), the WSE decreases between 0.00 feet and 0.74 feet between existing and proposed. Downstream of Bridge M-21-B (Cross Sections 6-11), the WSE increases a maximum of 0.00 feet between existing and proposed. **Appendix F** shows the cross sections used for the proposed bridge option as well as the floodplain limit changes between existing and proposed for this scenario. Table 4 also shows a WSE comparison at each section for the proposed bridge option.

Table 4: Existing vs. Proposed WSE Table

Cross Section	Location Relative to Proposed Bridge	Existing WSE (ft)	Proposed WSE (ft)	PR vs EX*
1	Upstream	4535.79	4535.81	0.00
2	Upstream	4534.54	4534.56	0.00
3	Upstream	4533.02	4533.02	0.00
4	Upstream	4531.64	4530.99	-0.65
5	Upstream	4530.99	4530.24	-0.74
6	Downstream	4530.02	4529.97	-0.06
7	Downstream	4528.62	4528.58	-0.05
8	Downstream	4527.19	4527.23	0.00
9	Downstream	4526.16	4526.19	0.00
10	Downstream	4524.30	4524.33	0.00
11	Downstream	4523.25	4523.27	0.00

*Proposed-Existing

6. BRIDGE SCOUR ANALYSIS

6.1 Scour Overview

For the proposed bridge option as determined in the alternatives analysis, a scour analysis was performed for Lone Tree Arroyo at the bridge. The scour analysis is intended to inform the structural design of the crossing and countermeasure design. The FHWA recommends that bridges with complex flow characteristics use a 2D model to represent hydraulic conditions.

For the scour analysis, the FHWA Hydraulic Toolbox Version 4.4 software program was used. The Hydraulic Toolbox program uses equations presented in the FHWA Hydraulic Engineering Circular No. 18 Evaluation of Scour at Bridges (HEC-18) and the National Cooperative Highway Research Program (NCHRP) 24-20. SRH-2D was used as the hydraulic model platform and it has the capability to extract the data needed for these calculations directly from the model.

Based on Table 2.1 from HEC-18 and the conditions of the bridge, the 100-year event is used as the hydraulic design flood frequency, the 200-year event results are used as the scour design flood frequency, and the 500-year results are used as the scour design check flood frequency.

At the project site, the following scour components were calculated:

- Contraction Scour
- Abutment Scour
- Long-Term Degradation

All scour calculations can be found in **Appendix G**.

6.2 Site Geology/Geotechnical Information and Impact to Scour Depths

A geotechnical analysis was completed Yeh and Associates for the Project. Gradation of the stream bed was provided in this investigation and used for this preliminary scour analysis. Only one sample was taken from the channel, therefore this sample will be applied to abutment (local) scour, contraction scour and long-term degradation. Results from the geotechnical investigation is provided in **Appendix H**.

Borings at each abutment and one at each bridge approach, were also conducted as part of the field exploration. These were used to better understand subsurface conditions at the bridge crossing. Soils information from borings were not used in the scour analysis because boring samples at the abutments were assumed to not be as representative of channel bed conditions as the channel sample discussed above.

Because exact bedrock elevations are not known, no adjustment was made to the scour depths shown below.

6.3 Scour Results

Table 5 below summarizes the preliminary results for scour depths including contraction scour, abutment scour, pier scour, and long-term scour at the bridge over the Lone Tree Arroyo.

Table 5: Scour Analysis Results

	Scour Type (ft)			
Storm Event	**Contraction**	**Abutment (Local)**	**Long-Term Degradation**	**Total Abutment***
100-Year	**0.0**	**4.3**	**2.4**	**6.6**
500-Year	**0.8**	**6.7**	**2.7**	**9.4**

*Total is the sum of the abutment scour and long-term degradation

6.4 Riprap Scour Countermeasures

The proposed bridge foundations will be designed to withstand the effects of scour up to and including the 500-year Scour Design Check Flood Frequency. Scour countermeasures will be designed to protect the approach roadway and bridge embankments from the effects of scour for the 100-year Hydraulic Design Flood Frequency.

This reach of the river has a deep incised main channel with steep, near vertical banks and highly erosive soils. The deep nature of the main channel directly conveys most of the flood flow. There is a tributary downstream of the bridge forming a confluence of the main channel immediately downstream of the bridge. These conditions indicate a significant scour potential at this bridge crossing. Vertical wall abutments with wing walls and riprap are recommended as scour countermeasures. The abutment and wing walls shall be designed with a toe wall extending down to the 100-yr scour depth. The FHWA Hydraulic Toolbox Version 4.4 (FHWA, 2018) was used to size riprap at the ends of the proposed wing walls and along the roadway embankment. The riprap was sized for the 100-year hydraulic design event. The Hydraulic Toolbox applies methodology outlined in the FHWA Hydraulic Engineering Circular No. 23 Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance (HEC-23) for sizing riprap at abutments based on abutment type, set-back ratio, Froude number, specific gravity of rock riprap, and a characteristic velocity in the channel.

Results of the Hydraulic Toolbox analysis are provided in **Appendix G**, and preliminary design values summarized in Table 6. For the right (north) abutment, a riprap with D50 of 24-inches (in) (Class 6 per HEC-23) is recommended. The resulting recommended thickness is 48-in based on HEC-23 for Class 6 riprap. For the left (south) abutment, a riprap with D50 of 18-inches (in) (Class 5 per HEC-23) is recommended. The resulting recommended thickness is 36-in based on HEC-23 for Class 5 riprap. Refer to Table 506-2 of CDOT's Division 500 Structures Specifications for the required gradation.

Riprap shall also be placed over a Class 1, non-woven geotextile filter material. According to CDOT's Division 700 Materials Details, geotextile materials should be selected from the New York Department of Transportation's Approved Products List of Geosynthetic materials that meet the National Transportation Product Evaluation Program (NTPEP) and AASHTO M-288 testing requirements. Class 1 geotextiles is the only class approved for applications related to slope protection.

The riprap slope protection at each wing wall should extend 25' from the end of the wing walls along the roadway embankment and configured with the data shown in Table 5. Riprap placed below existing grade shall be constructed with a maximum 2:1 side slope. Riprap above grade will be placed at the roadway embankment slope and no steeper than 2:1.

Table 6: Countermeasure Summary

Countermeasure	D_{50}(in)	Recommended Thickness (in)	Side Slopes	Toe Down Depth (ft)	Bottom Ref. Elevation (ft)	Rop Ref. Elevation (ft)
Riprap Apron Left	**18**	**36**	**2:1**	**7**	**4517.9**	**4532.2**
Riprap Apron Right	**24**	**48**	**2:1**	**7**	**4517.9**	**4532.2**
Wing Walls	**N/A**	**N/A**	**N/A**	**7**	**4517.9**	**4532.2**

7. CONCLUSIONS

This report presents preliminary analysis and results from the hydrologic and hydraulic study for the Region 2 Bridge Bundle Design Build – Bridge M-21-B. This report documents preliminary analysis in determining costs for proposed structure replacement at this location. It also includes preliminary FEMA floodplain analysis and scour analysis.

A two-dimensional model was developed to analyze the flows through the existing bridge and compare the WSEs and velocities to the proposed design. This model was utilized to optimize the proposed solution to replacement of the existing bridge.

Based on the hydraulic analysis, the proposed replacement for this bridge is a single-span 80-foot span length bridge. The proposed freeboard is 2 feet and the proposed WSE 100 feet upstream of the proposed bridge is 4530.99 feet, giving a final recommended bridge low chord of 4532.99 feet. The proposed low chord is 4534.90 which with 3.91-ft of freeboard does meet the 2 feet minimum requirement.

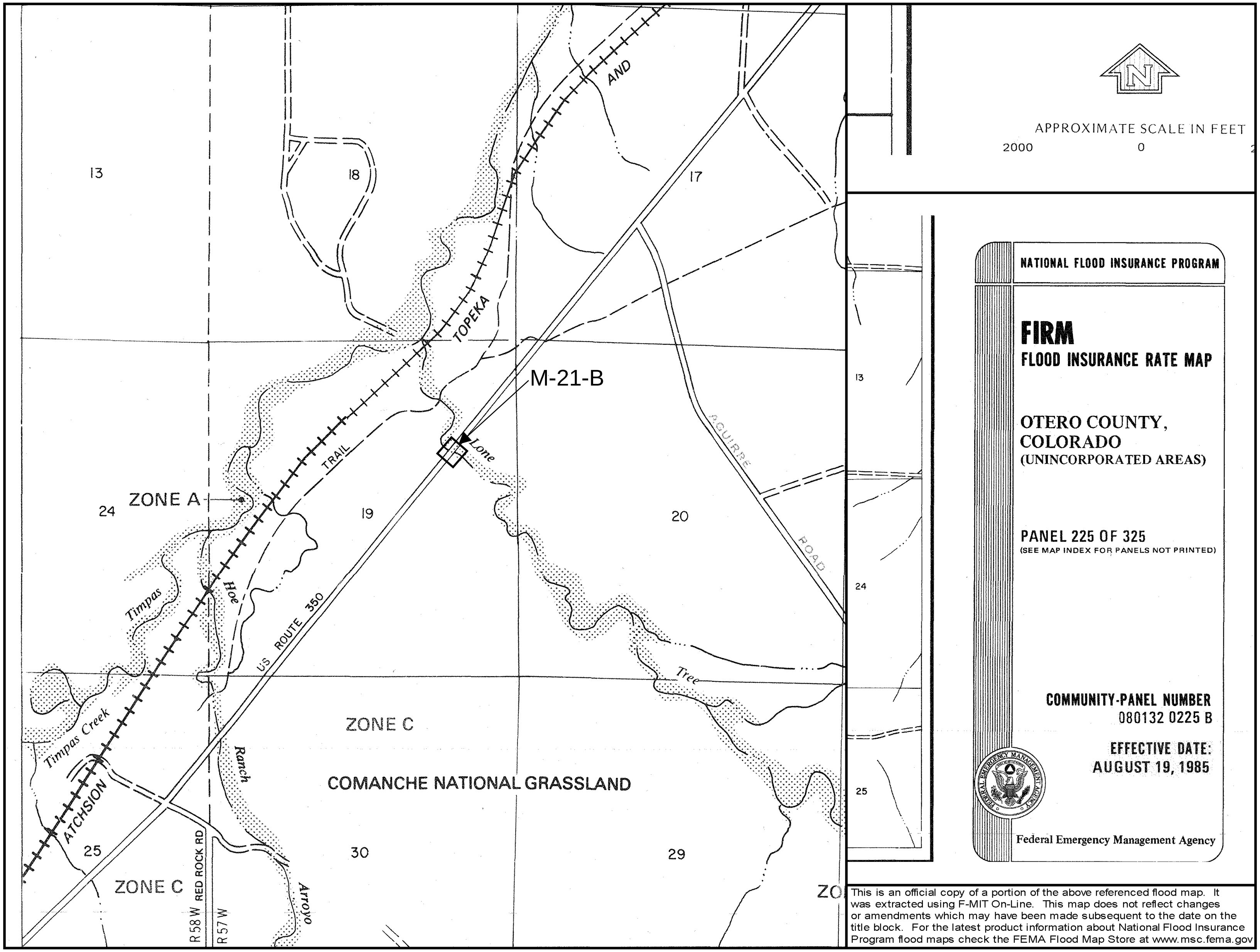
Floodplain analysis demonstrates that the proposed bridge opening will not cause a rise in flood levels during the 100-year design event. This meets guidelines in CFR Sections 60.3 (b). A floodplain development permit is required to be approved through the Otero County floodplain administrator during the final design phase of this Design Build project.

Total design scour for the bridge abutments was determined to be 9.4 feet at the 500-year design event. This accounts for the contraction scour and long-term degradation impacts that could potentially affect the proposed bridge abutments. Vertical wall abutments with wing walls and riprap are recommended as scour countermeasures.

8. REFERENCES

1. “Colorado Department of Transportation Drainage Design Manual”, Colorado Department of Transportation, 2019.
2. Mile High Flood District, Urban Storm Drainage Criteria Manual (USDCM), Volumes I, II, and III, August 2018.
3. “Hydraulic Engineering Circular No. 18 – Evaluating Scour At Bridges Fifth Edition”. U.S. Department of Transportation Federal Highway Administration, April 2012.
4. “Hydraulic Engineering Circular No. 20 – Stream Stability at Highway Structures”. U.S. Department of Transportation Federal Highway Administration, April 2012.
5. “Hydraulic Engineering Circular No. 23 – Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance – Third Edition,” U.S. Department of Transportation, Federal Highway Administration, September 2009.
6. CDOT Region 2 2D Quick Check Hydrology Summary Report and Matrix, Colorado Department of Transportation, 2020.

APPENDIX A FEMA FIRM



FEMA FIRM

STRUCTURE M-21-B

FIGURE 1

APPENDIX B NRCS SOIL SURVEY

United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Otero County, Colorado

November 16, 2020

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

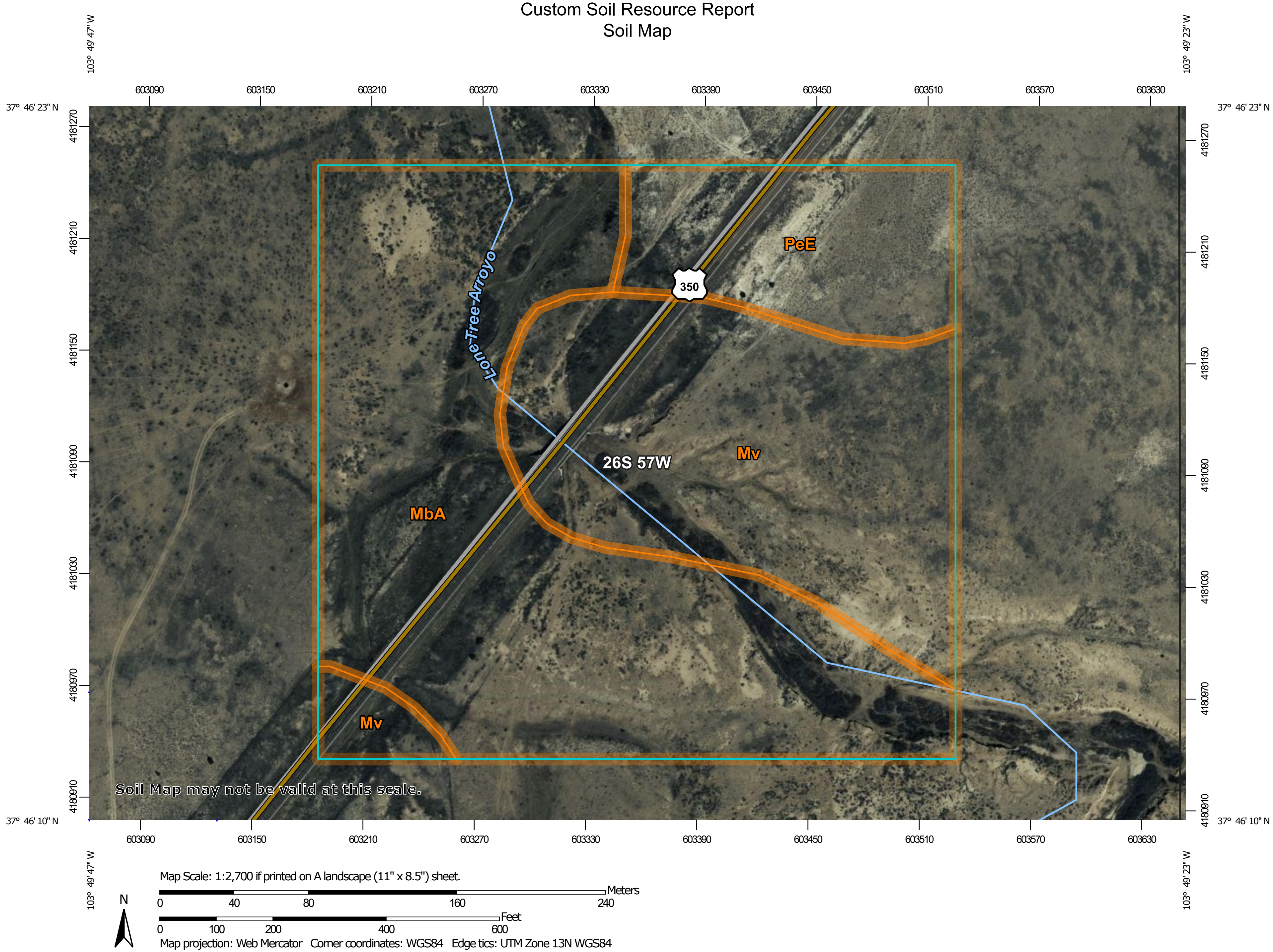
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map



Map Scale: 1:2,700 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 40, 80, 160, 240

Feet: 0, 100, 200, 400, 600

Map projection: Web Mercator   Corner coordinates: WGS84   Edge tics: UTM Zone 13N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Political Features
- PLSS Township and Range
- PLSS Section

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:15,800.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Otero County, Colorado
Survey Area Data: Version 18, Jun 5, 2020

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 31, 2020—Apr 7, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
MbA	Manzanola silty clay loam, dry, saline, 0 to 2 percent slopes	14.3	52.6%
Mv	Minnequa-Manvel silt loams, 1 to 6 percent slopes, dry	9.2	33.9%
PeE	Penrose channery loam, 1 to 15 percent slopes	3.7	13.5%
Totals for Area of Interest		**27.2**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Otero County, Colorado

MbA—Manzanola silty clay loam, dry, saline, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 2rgrd
Elevation: 4,000 to 5,500 feet
Mean annual precipitation: 10 to 12 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 130 to 170 days
Farmland classification: Not prime farmland

Map Unit Composition

Manzanola, dry, saline, and similar soils: 90 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Manzanola, Dry, Saline

Setting

Landform: Terraces, drainageways, fan remnants, interfluves
Landform position (two-dimensional): Footslope, summit
Landform position (three-dimensional): Side slope, tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from shale

Typical profile

A - 0 to 4 inches: silty clay loam
Bt1 - 4 to 11 inches: clay loam
Bt2 - 11 to 20 inches: clay loam
Bky - 20 to 33 inches: silty clay loam
By - 33 to 79 inches: clay loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 14 percent
Gypsum, maximum content: 3 percent
Maximum salinity: Moderately saline (8.0 to 15.0 mmhos/cm)
Sodium adsorption ratio, maximum: 12.0
Available water capacity: Moderate (about 8.0 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 6c
Hydrologic Soil Group: C
Ecological site: R069XY037CO - Saline Overflow LRU's A & B
Hydric soil rating: No

Minor Components

Haversid

Percent of map unit: 5 percent
Landform: Drainageways, terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R069XY037CO - Saline Overflow LRU's A & B
Hydric soil rating: No

Aguilar

Percent of map unit: 5 percent
Landform: Fan remnants
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear
Ecological site: R069XY033CO - Salt Flat LRU's A & B
Other vegetative classification: Salt Flat #33 (069AY033CO_2), Sodic, Sodic/Saline (G069XW027CO)
Hydric soil rating: No

Mv—Minnequa-Manvel silt loams, 1 to 6 percent slopes, dry

Map Unit Setting

National map unit symbol: 2rgqm
Elevation: 4,000 to 6,000 feet
Mean annual precipitation: 10 to 12 inches
Mean annual air temperature: 50 to 54 degrees F
Frost-free period: 130 to 170 days
Farmland classification: Not prime farmland

Map Unit Composition

Minnequa, dry, and similar soils: 55 percent
Manvel, dry, and similar soils: 30 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Minnequa, Dry

Setting

Landform: Pediments, ridges
Landform position (two-dimensional): Summit, shoulder
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear, convex
Parent material: Slope alluvium and/or residuum weathered from limestone and shale

Typical profile

A - 0 to 6 inches: silt loam
Bw - 6 to 17 inches: silt loam
Bk - 17 to 35 inches: silty clay loam
Cr - 35 to 60 inches: bedrock

Properties and qualities

Slope: 1 to 6 percent
Depth to restrictive feature: 20 to 39 inches to paralithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 45 percent
Gypsum, maximum content: 5 percent
Maximum salinity: Nonsaline to slightly saline (0.1 to 4.0 mmhos/cm)
Sodium adsorption ratio, maximum: 8.0
Available water capacity: Low (about 5.9 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: C
Ecological site: R069XY006CO - Loamy Plains, LRU's A & B 10-14 Inches, P.Z.
Forage suitability group: Loamy (G069XW017CO)
Other vegetative classification: Loamy (G069XW017CO)
Hydric soil rating: No

Description of Manvel, Dry

Setting

Landform: Fans, interfluves
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Side slope, interfluve
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Parent material: Alluvium derived from limestone and shale

Typical profile

A - 0 to 7 inches: silt loam
Bk1 - 7 to 25 inches: silt loam
Bk2 - 25 to 49 inches: silt loam
Bk3 - 49 to 79 inches: silt loam

Properties and qualities

Slope: 1 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent

Gypsum, maximum content: 3 percent
Maximum salinity: Nonsaline to moderately saline (1.0 to 8.0 mmhos/cm)
Sodium adsorption ratio, maximum: 5.0
Available water capacity: Moderate (about 8.6 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability classification (nonirrigated): 6e
Hydrologic Soil Group: B
Ecological site: R069XY006CO - Loamy Plains, LRU's A & B 10-14 Inches, P.Z.
Forage suitability group: Loamy, Limy (G069XW022CO)
Other vegetative classification: Loamy Plains #6 (069XY006CO_2), Loamy, Limy (G069XW022CO)
Hydric soil rating: No

Minor Components

Manvel, deep, dry

Percent of map unit: 10 percent
Landform: Fans, interfluves
Landform position (two-dimensional): Toeslope, footslope
Landform position (three-dimensional): Side slope, interfluve
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Ecological site: R069XY006CO - Loamy Plains, LRU's A & B 10-14 Inches, P.Z.
Other vegetative classification: Loamy Plains #6 (069XY006CO_2), Loamy, Limy (G069XW022CO)
Hydric soil rating: No

Penrose

Percent of map unit: 5 percent
Landform: Hogbacks, hills, scarps
Landform position (two-dimensional): Summit, shoulder, backslope
Landform position (three-dimensional): Side slope, crest
Down-slope shape: Convex, linear
Across-slope shape: Convex, linear
Ecological site: R069XY058CO - Limestone Breaks LRU's A & B
Other vegetative classification: Limestone Breaks #58 (069XY058CO_2), Not Suited (G069XW000CO)
Hydric soil rating: No

PeE—Penrose channery loam, 1 to 15 percent slopes

Map Unit Setting

National map unit symbol: 2rgr9
Elevation: 3,800 to 6,000 feet
Mean annual precipitation: 10 to 14 inches
Mean annual air temperature: 48 to 54 degrees F
Frost-free period: 125 to 170 days

Farmland classification: Not prime farmland

Map Unit Composition

Penrose and similar soils: 80 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Penrose

Setting

Landform: Hogbacks, hills, scarps
Landform position (two-dimensional): Backslope, shoulder
Landform position (three-dimensional): Side slope, crest
Down-slope shape: Convex, linear
Across-slope shape: Convex, linear
Parent material: Slope alluvium over residuum weathered from limestone

Typical profile

A - 0 to 4 inches: channery loam
C - 4 to 15 inches: channery loam
R - 15 to 79 inches: bedrock

Properties and qualities

Slope: 1 to 15 percent
Depth to restrictive feature: 10 to 20 inches to lithic bedrock
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 70 percent
Maximum salinity: Nonsaline (0.1 to 1.0 mmhos/cm)
Sodium adsorption ratio, maximum: 1.0
Available water capacity: Very low (about 2.0 inches)

Interpretive groups

Land capability classification (irrigated): 6s
Land capability classification (nonirrigated): 6s
Hydrologic Soil Group: D
Ecological site: R069XY058CO - Limestone Breaks LRU's A & B
Forage suitability group: Not Suited (G069XW000CO)
Other vegetative classification: Not Suited (G069XW000CO)
Hydric soil rating: No

Minor Components

Rock outcrop

Percent of map unit: 10 percent
Hydric soil rating: No

Minnequa

Percent of map unit: 5 percent
Landform: Interfluves, ridges
Landform position (two-dimensional): Summit, shoulder
Landform position (three-dimensional): Crest
Down-slope shape: Linear

Across-slope shape: Linear, convex
Ecological site: R069XY006CO - Loamy Plains, LRU's A & B 10-14 Inches, P.Z.
Other vegetative classification: Loamy (G069XW017CO)
Hydric soil rating: No

Manvel

Percent of map unit: 5 percent
Landform: Fans, interfluves
Landform position (two-dimensional): Footslope
Landform position (three-dimensional): Base slope, interfluve
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Ecological site: R069XY006CO - Loamy Plains, LRU's A & B 10-14 Inches, P.Z.
Other vegetative classification: Loamy, Limy (G069XW022CO)
Hydric soil rating: No

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APPENDIX C AERIAL IMAGERY AND PHOTOS

EXISTING CHANNEL CONDITIONS AND BRIDGE DAMAGE TO DECK OVERHANGS

STRUCTURE M-21-B

FIGURE 1

EXISTING BRIDGE ABUTMENT WITH CRACKING

STRUCTURE M-21-B

FIGURE 2

EXISTING BRIDGE DECK UNDERSIDE

STRUCTURE M-21-B

FIGURE 3

AERIAL IMAGERY OF LONE TREE ARROYO WATERSHED NEAR BRIDGE

STRUCTURE M-21-B

FIGURE 4

APPENDIX D EXISTING CONDITIONS MODEL GRAPHICS

EXISTING CONDITIONS MATERIALS COVERAGES

STRUCTURE M-21-B

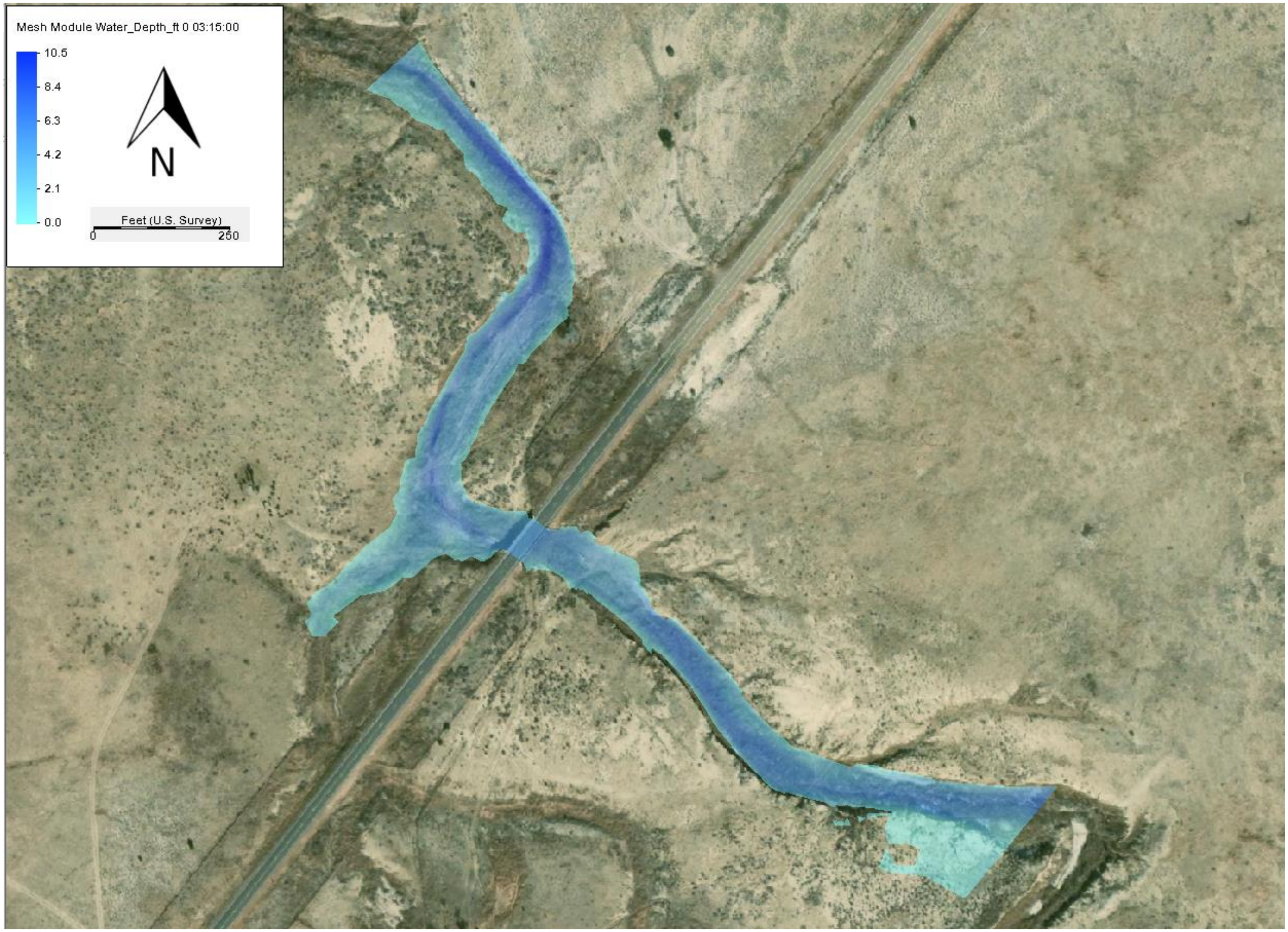
FIGURE 1

EXISTING CONDITIONS 100-YEAR DEPTH RESULTS

STRUCTURE M-21-B

FIGURE 2

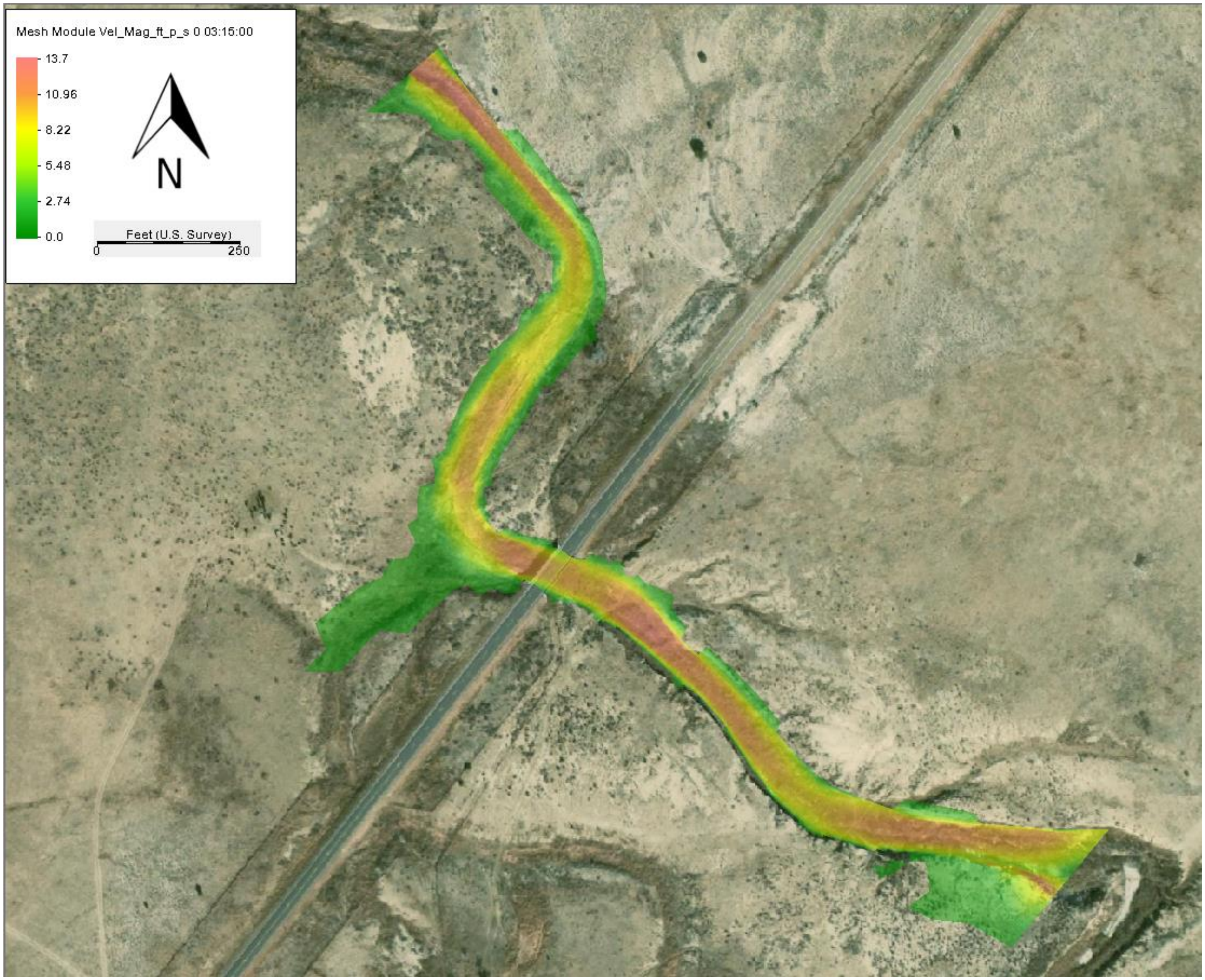
APPENDIX E PROPOSED BRIDGE ALTERNATIVE MODEL GRAPHICS



PROPOSED CONDITIONS 100-YEAR DEPTH RESULTS

STRUCTURE M-21-B

FIGURE 1

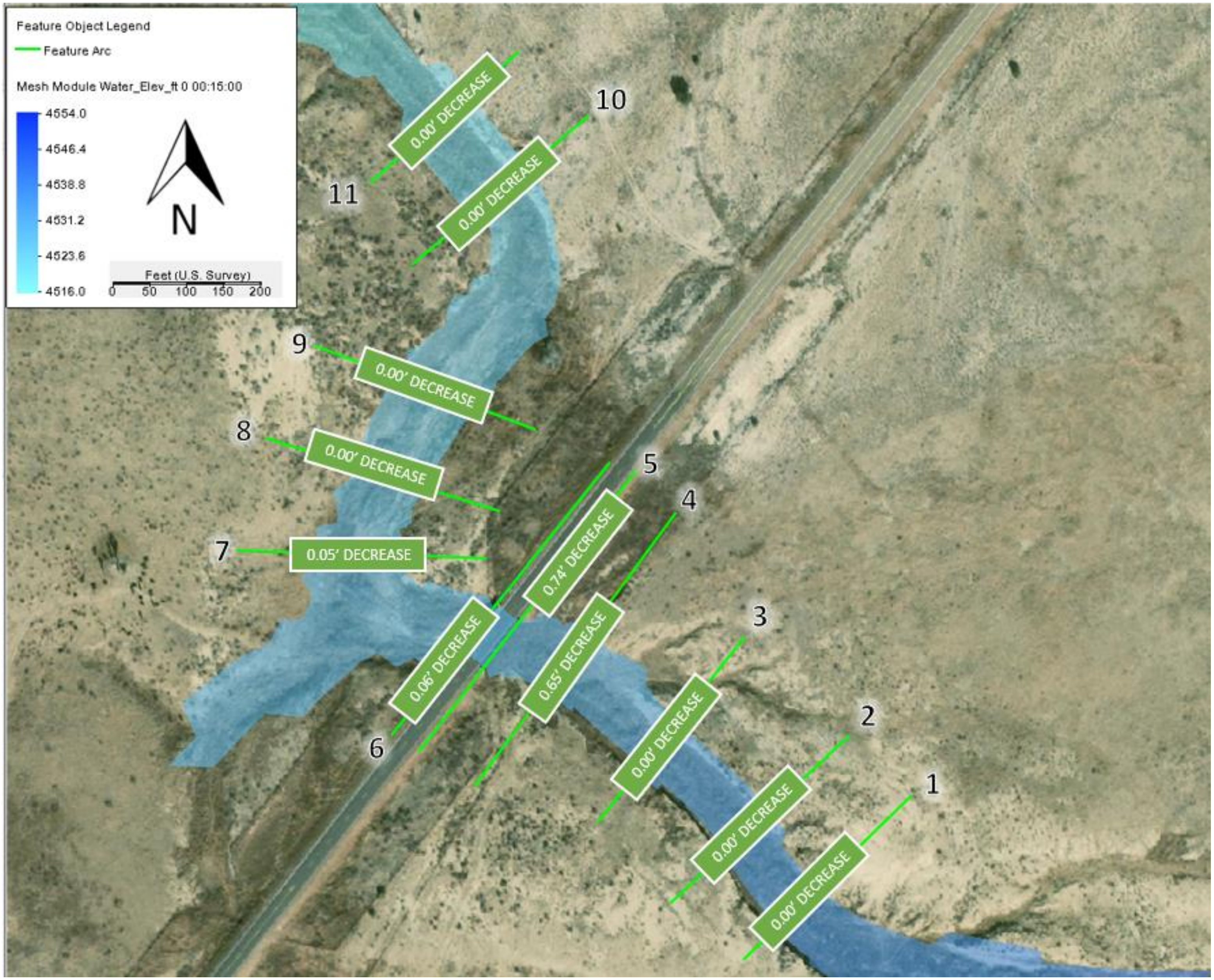


PROPOSED CONDITIONS 100-YEAR VELOCITY RESULTS

STRUCTURE M-21-B

FIGURE 2

APPENDIX F WATER SURFACE ELEVATION COMPARISON GRAPHICS

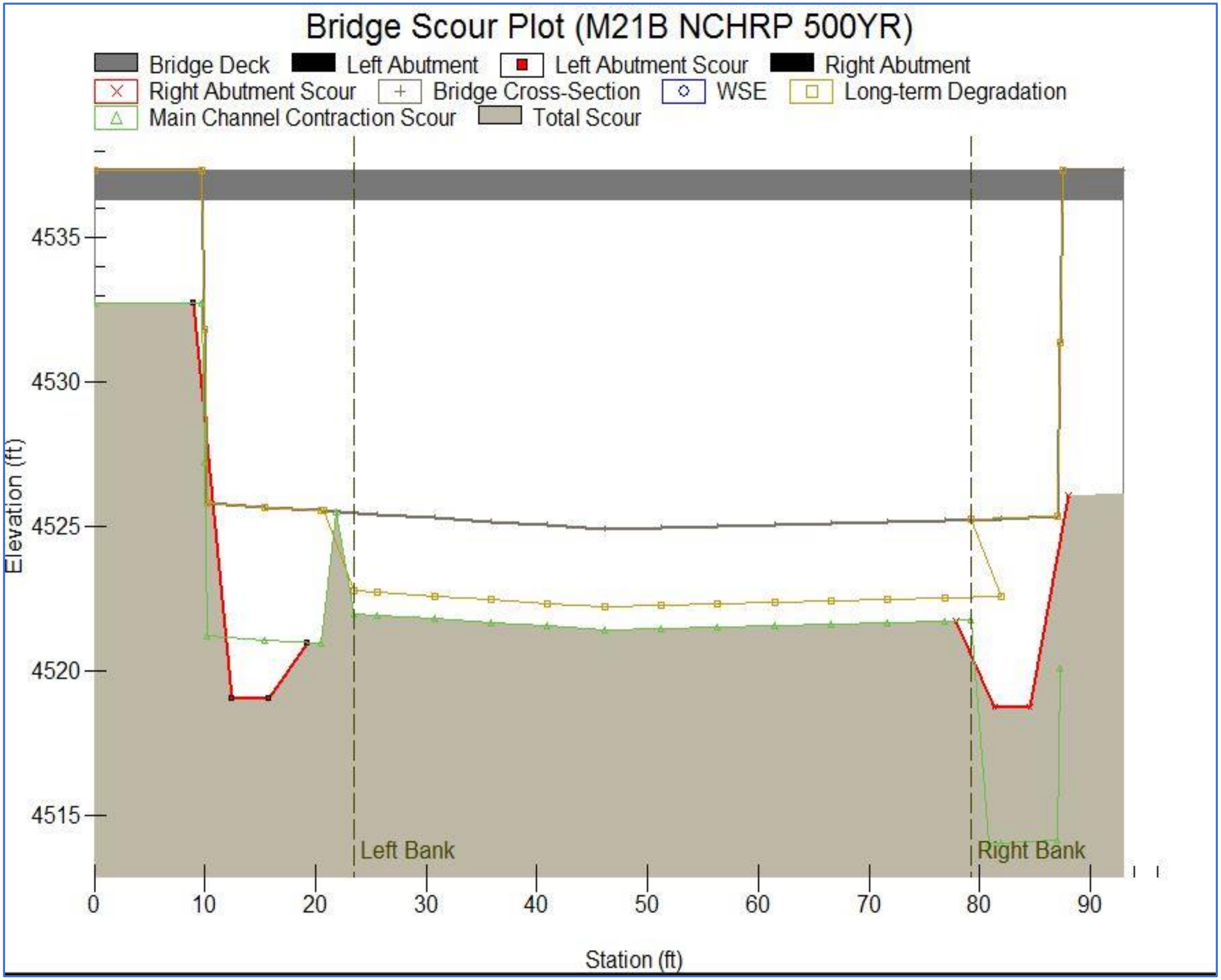


CROSS SECTION USED TO COMPARE PROPOSED AND EXISTING RESULTS

STRUCTURE M-21-B

FIGURE 1

APPENDIX G BRIDGE SCOUR ANALYSIS



PROPOSED BRIDGE SCOUR PLOT
STRUCTURE M-21-B
FIGURE 1

Hydraulic Analysis Report

Project Data

Project Title: M-21-B 100YR

Designer: Stanley Consultants

Project Date: Tuesday, December 1, 2020

Project Units: U.S. Customary Units

Riprap Analysis: Right Abutment

Notes: The Total Bridge Area was adjusted until the characteristic velocity matched the maximum channel velocity. This allows for a more conservative calculation at the abutment. Based on engineering judgement, the D50 is rounded to the next highest class. When results are considered liberal, the maximum channel velocity is used in lieu of the average to achieve more practical results. When results are considered conservative, the average channel velocity is used in lieu of the maximum to achieve more practical results. For this calculation, the average velocity is used.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 10 ft

The set-back length is the distance from the near edge of the main channel to the toe of abutment

Main Channel Average Flow Depth: 5.658 ft

Flow Depth at Toe of Abutment: 5.56 ft

Calculations will use either total or overbank discharges.

Total Discharge: 3146 cfs

Overbank Discharge: 414 cfs

Total Bridge Area: 338.5 ft^2

Setback Area: 118 ft^2

Maximum Channel Velocity: 9.29 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 1.76741

Characteristic Velocity: 9.29394 ft/s

Froude Number at the Abutment Toe: 0.69488

Abutment Coefficient: 1.02

Computed D50: 19.9156 in

Design D50 = 24 in

Thickness = 48 in

Design D50 > Computed D50

24 in > 19.9156 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS VI

Riprap Class Order: 6

The following values are an **'average'** of the size fraction range for the selected riprap class.

d100: 42 in

d85: 30 in

d50: 21.5 in

d15: 15 in

Layout Recommendations

Minimum Riprap Thickness: 48 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 11.12 ft

Minimum Extent of "Wrap Around" beyond the Abutment Radius, along the Approach Embankment: 25 ft

See HEC 23, Figure 14.7

Riprap Analysis: Left Abutment

Notes: The Total Bridge Area was adjusted until the characteristic velocity matched the maximum channel velocity. This allows for a more conservative calculation at the abutment. Based on engineering judgement, the D50 is rounded to the next highest class. When results are considered liberal, the maximum channel velocity is used in lieu of the average to achieve more practical results. When results are considered conservative, the average channel velocity is used in lieu of the maximum to achieve more practical results. For this calculation, the average velocity is used.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 10 ft

The set-back length is the distance from the near edge of the main channel to the toe of abutment

Main Channel Average Flow Depth: 5.658 ft

Flow Depth at Toe of Abutment: 3.54 ft

Calculations will use either total or overbank discharges.

Total Discharge: 3146 cfs

Overbank Discharge: 828 cfs

Total Bridge Area: 338.5 ft^2

Setback Area: 200 ft^2

Maximum Channel Velocity: 9.29 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 1.76741

Characteristic Velocity: 9.29394 ft/s

Froude Number at the Abutment Toe: 0.870855

Abutment Coefficient: 0.69

Computed D50: 17.0897 in

Design D50 = 18 in

Thickness = 36 in

Design D50 > Computed D50

18 in > 17.0897 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS V

Riprap Class Order: 5

The following values are an **'average'** of the size fraction range for the selected riprap class.

d100: 36 in

d85: 25.5 in

d50: 18.5 in

d15: 13 in

Layout Recommendations

Minimum Riprap Thickness: 36 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 7.08 ft

Minimum Extent of "Wrap Around" beyond the Abutment Radius, along the Approach Embankment: 25 ft

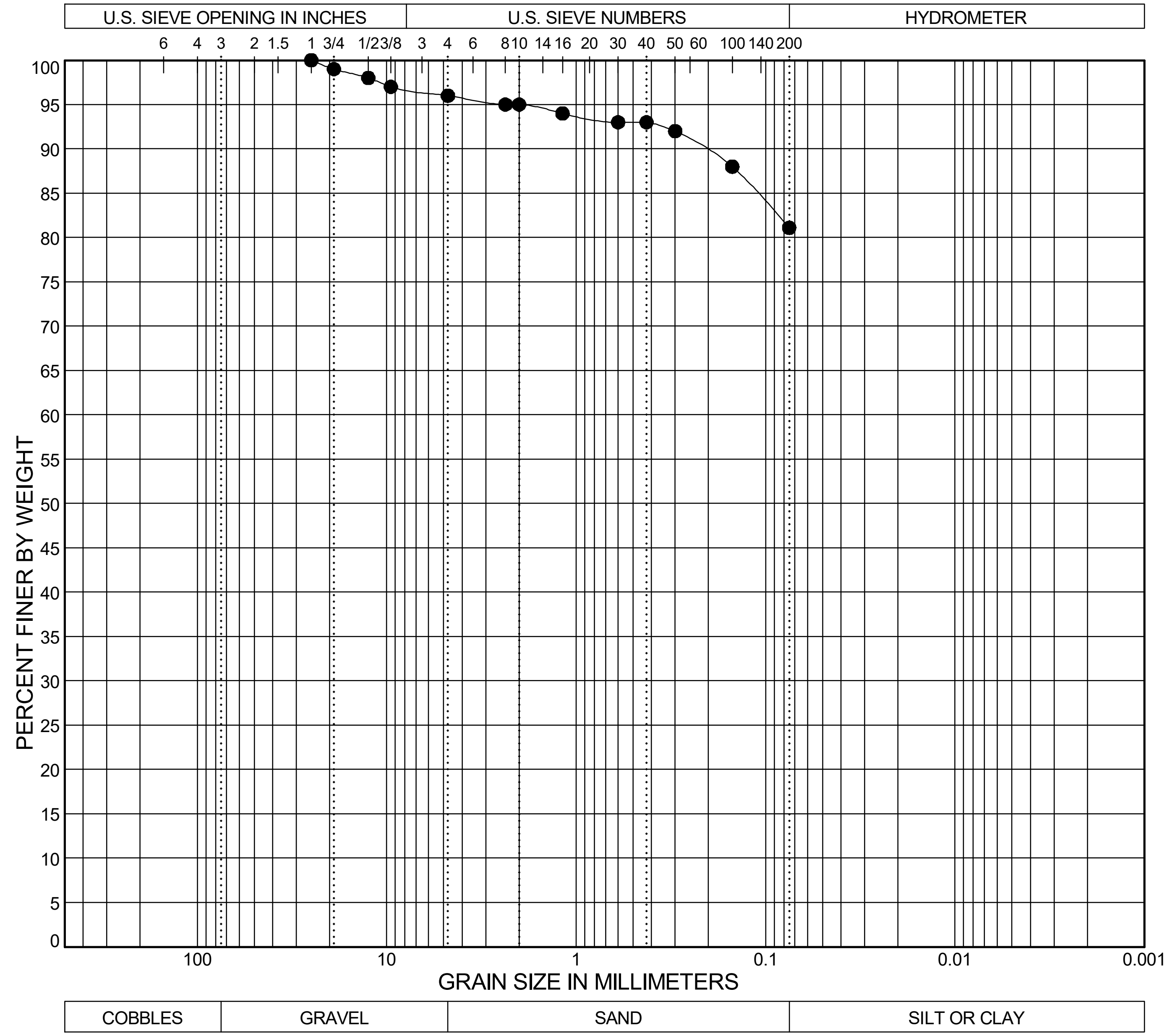
See HEC 23, Figure 14.7

APPENDIX H GEOTECHNICAL INFORMATION

Summary of Laboratory Test Results

Project No: 220-063 Project Name: CDOT Region 2 Bridge Bundle - Scour Test Results Date: 11-06-2020

Sample Location			Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			pH	Water Soluble Sulfate (%)	Water Soluble Chloride (%)	Resistivity (ohm-cm)	Swell (+) / Collapse (-) (% at Load in psf)	Unconf. Comp. Strength (psi)	R-Value	Classification	
Boring No.	Depth (ft)	Sample Type			Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI								AASHTO	USCS
M-21-B Scour	0	BULK	6.1		4.0	14.9	81.1												
M-21-C Scour	0	BULK	3.5		72.0	20.1	7.9												
M-21-I Scour	0	BULK	4.5		0.0	5.3	94.7												
M-21-J Scour	0	BULK	7.3		1.0	3.5	95.5												
M-22-U Scour	0	BULK	5.9		31.0	24.3	44.7												
M-22-Y Scour	0	BULK	11.9		1.0	11.9	87.1												
N-21-C Scour	0	BULK	1.8		61.0	21.0	18.0												
N-21-F Scour	0	BULK	11.8		2.0	16.4	81.6												
O-19-D Scour	0	BULK	2.7		6.0	56.7	37.3												
P-19-G Scour	0	BULK	1.1		21.0	53.4	25.6												



	BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
										%Silt	%Clay
●	**M-21-B Scour**	**0.0**						**4.0**	**14.9**	**81.1**	

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SIEVE ANALYSIS

FIGURE S- 1

Project No. 220-063 Date: 11-06-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Scour Test Results