PRELIMINARY HYDRAULICS REPORT
STRUCTURE I-17-X REPLACEMENT
As a part of the
REGION TWO BRIDGE BUNDLE PACKAGE
EL PASO COUNTY, COLORADO

A Part of Section 36, Township 13 South, Range 68 West of the 6th P.M.,
County of El Paso, Colorado

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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 I-17-X as a part of the CDOT Region 2 Bridge Bundle Design Build. The project is located within El Paso County at Mile Post 295.45 along US 24 between Cascade and Manitou Springs. Structure I-17-X crosses Upper Fountain Creek. Figure 1 below illustrates the project location. The project is located in Section 36, Township 13 South, Range 68 West of the 6th P.M., County of El Paso, 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 AE, as determined by the Flood Insurance Rate Maps (FIRM) 08041C0489G effective date December 7, 2018, as shown in Appendix A. FEMA Zone AE is a special flood hazard area inundated by the 100-year flood, and base flood elevations are determined. 44 Code of Federal Regulations (CFR) 60.3 (c) state that for Zone AE floodplains, all cumulative impacts to the system from the time of the original study cannot result in a base flood elevation (BFE) increase of more than one foot. This report also reviews changes to the BFE from the proposed bridge design.

Figure 1: Vicinity Map

2. HYDROLOGY

Hydrology for the watershed tributary to this structure was not completed. The effective model provided by FEMA was obtained, and the flows from that model at the project location were utilized. Table 1 is a summary of the approximate flowrates for structure I-17-X.

Table 1: Summary of Peak Discharge for Bridge I-17-X

River Location	Design Storm	100-year (cfs)	200-year (cfs)	500-year (cfs)
Upstream of Bridge	100-year	3,143	unknown	5,521

3. EXISTING CONDITIONS

3.1 Existing Structure

The existing structure is a double cell, 10-ft by 8-ft concrete box culvert over Upper Fountain Creek. It was built in 1965. The box culvert's superstructure, substructure, and deck are all in need of repair. No utilities were found attached to the structure.

3.2 Watershed Overview

Upper Fountain Creek is a stream that flows from the northwest to the southeast toward the Arkansas River. The watershed tributary to Upper Fountain Creek is approximately 64.9 square miles in area. The watershed generally slopes to the south. The stream bed does have a base flow.

The stream flows at an angle of attack of 90 degrees to the current structure. The area surrounding the bridge is rural with eastbound and westbound lanes of US 24 on either side of the stream. Outside of the roadway, are undeveloped land with steep sloping mountainous terrain. A dirt parking lot exists to the east along the shoulder of westbound US 24 and a dirt driveway connects to the eastbound lanes of US 24 west of the structure.

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 revealed obvious concrete deterioration along the bottom of the box culverts. Site photos are included in **Appendix D**.

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, three models were developed:

- Existing Conditions
- Proposed Conditions: Bridge Replacement
- Proposed Conditions: Box Culvert Replacement
- Proposed Conditions: Arch Culvert Replacement

4.1 Debris potential

The potential for debris production and delivery is estimated to be high 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, shrubs, and trees present, as confirmed with the site visit in August 2020. Aerial imagery of the watershed near the bridge is shown in **Appendix C**.

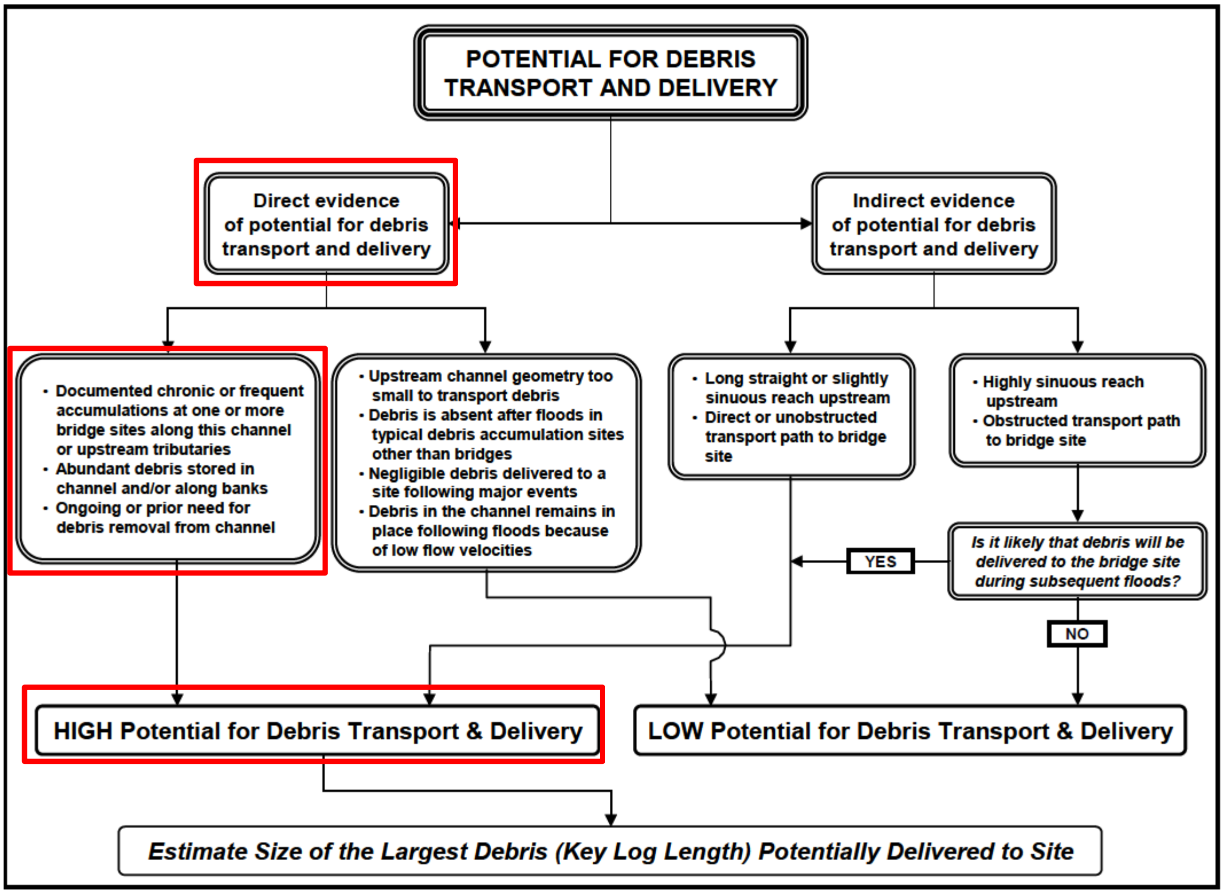


Figure 2: Flow Chart for Potential Debris Production (FHWA, HEC 20)

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

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 Central 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 17,118 and the mesh extends approximately 750 feet upstream of the bridge and 2,000 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
Light Vegetation	0.060
Open Space	0.055
Paved Road	0.016
Dirt Road	0.020

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	3,143	6,981.49

4.3.5 Hydraulic Structures

The modeled existing bridge geometry is based on the survey completed in August 2020. The survey data included shots detailing the structure. The inlet elevation of the culvert is 7021.59 and the outlet elevation of the culvert is 7020.10

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 0.5 second time step for 0.5 hours when 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 7.95 feet to 12.15 feet. The results also demonstrate that the existing structure overtops during the 100-year event. 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. 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 RCBC</u>

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included grading to widen the channel at the structure. The proposed model has 17,142 mesh elements. The use of HY-8 to model this culvert is acceptable due to the direction of flow being perpendicular to the roadway.

Because the existing condition overtops the road, a slightly larger opening size was used for the box culverts to keep the WSEs the same or lower than existing conditions. The preliminary model shows the roadway embankment sloping at 4:1 and the proposed culvert being 40 feet in length. The RCBC option for this structure required a 3 cell 12-foot wide by 8-foot tall structure. This structure size was determined to prevent overtopping the roadway.

Depths and velocity grids for the proposed RCBC show depths from 8.06 to 11.21 feet and velocities from 7.27 to 10.16 ft/s. See **Appendix E** for 100-year depths and velocities graphics for this option.

Proposed Arch Culvert

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included grading to widen the channel at the structure. The proposed model has 17,142 mesh elements. The use of HY-8 to model this culvert is acceptable due to the direction of flow being perpendicular to the roadway.

Because the existing condition overtops the road, a slightly larger opening size was used for the box culverts to keep the WSEs the same or lower than existing conditions. The preliminary model shows the roadway embankment sloping at 4:1 and the proposed culvert being 40 feet in length. The arch option for this structure required a 2-cell ALBC 59 which is an aluminum open bottom culvert with each structure being approximately 25' x 8.5'. This structure size was determined to prevent overtopping the roadway.

Depths and velocity grids for the proposed arch show depths from 9.17 to 11.85 feet and velocities from 5.26 to 6.91 ft/s. See **Appendix E** for 100-year depths and velocities graphics for this option.

Proposed Bridge

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included channel grading to widen the opening. The proposed model has 13,074 mesh elements. The proposed model has a 30-foot span width, no piers, the low chord of the bridge is at 7,031.50 elevation, and the high chord didn't change from the existing condition. Roadway embankments were graded at 4:1.

Depths and velocity grids for the proposed bridge show depths from 6.33 to 7.59 feet and velocities from 15.57 to 18.11 ft/s. See **Appendix F** for 100-year depths and velocities graphics for this option.

5. FEMA FLOODPLAIN ANALYSIS

The Federal Emergency Management Agency (FEMA) has designated the project site as a FEMA Zone AE, as determined by the Flood Insurance Rate Maps (FIRM) 08041C0489G effective date December 7, 2018, as shown in **Appendix A.**

FEMA Zone AE is a special flood hazard area inundated by the 100-year flood, base flood elevations are determined, and a Floodway is defined. 44 Code of Federal Regulations (CFR) 60.3 (c) state that for Zone AE floodplains, all cumulative impacts to the system from the time of the original study cannot result in a BFE increase of more than one foot. This report also reviews changes to the BFEs from the proposed RCBC and bridge design options. This preliminary report does not analyze the changes to the floodway. This analysis will be completed in later stages of design.

A comparison between the effective FEMA model BFEs, the existing conditions, and the proposed conditions was not completed as a part of this preliminary analysis. The final design hydraulic analysis will need to provide this information to prove a no-rise condition, or to complete the LOMC process to change the BFEs with this project.

Proposed RCBC

Based on modeling results, the proposed RCBC will not increase the WSE by more than 1 foot. Because the opening of the proposed RCBC is larger than the existing opening, a lower WSE is expected. The proposed design followed CDOT's requirements to prevent roadway overtopping which led to the lowering. Due to the change in the water surface elevation, a LOMC will be required by FEMA.

In order to perform a comparison between the existing and proposed WSE, 8 cross sections were cut across the 2D hydraulic model results both upstream and downstream of the proposed structure. The average WSE was determined for both existing and the proposed RCBC option, as shown in **Appendix G**. The WSE comparison at these sections is shown in Table 4.

Table 4: Comparison of Existing and Proposed RCBC WSE at I-17-X

Cross Section	Location Relative to Proposed RCBC	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	7044.75	7044.75	0.00
2	Upstream	7037.35	7037.32	-0.03
3	Upstream	7035.65	7035.12	-0.53
4	Upstream	7033.83	7032.35	-1.48
5	Downstream	7030.96	7029.04	-1.93
6	Downstream	7025.78	7025.76	-0.02
7	Downstream	7021.16	7021.07	-0.10
8	Downstream	7005.25	7005.25	0.00

Proposed Arch

Based on modeling results, the proposed RCBC will not increase the WSE by more than 1 foot. Because the opening of the proposed RCBC is larger than the existing opening, a lower WSE is expected. The proposed design followed CDOT's requirements to prevent roadway overtopping which led to the lowering. Due to the change in the water surface elevation, a LOMC will be required by FEMA.

In order to perform a comparison between the existing and proposed WSE, 8 cross sections were cut across the 2D hydraulic model results both upstream and downstream of the proposed structure. The average WSE was determined for both existing and the proposed arch option, as shown in **Appendix G**. The WSE comparison at these sections is shown in Table 5.

Table 5: Comparison of Existing and Proposed Arch WSE at I-17-X

Cross Section	Location Relative to Proposed Arch	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	7044.75	7044.75	0.00

2	Upstream	7037.35	7037.35	0.00
3	Upstream	7035.65	7035.02	-0.63
4	Upstream	7033.83	7032.90	-0.93
5	Downstream	7030.96	7029.85	-1.11
6	Downstream	7025.78	7025.83	0.05
7	Downstream	7021.16	7021.11	-0.05
8	Downstream	7005.25	7005.25	0.00

Proposed Bridge

Similarly, 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 expected. The proposed design followed CDOT's requirements to prevent roadway overtopping which led to the lowering. Due to the change in the water surface elevation, a LOMC will be required by FEMA.

For the proposed bridge, upstream of Bridge I-17-X (Cross Sections 1-4), the WSE decreases between 0.58 feet and 4.02 feet between existing and proposed. Downstream of Bridge I-17-X (Cross Sections 5-8), the WSE decreases a maximum of 3.40 feet between existing and proposed. **Appendix G** 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 6 also shows a WSE comparison at each section for the proposed bridge option.

Table 6: Comparison of Existing and Proposed Bridge WSE at I-17-X

Cross Section	Location Relative to Proposed Bridge	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	7044.75	7044.75	0.00
2	Upstream	7037.35	7037.43	0.08
3	Upstream	7035.65	7035.07	-0.58
4	Upstream	7033.83	7029.81	-4.02
5	Downstream	7030.96	7027.56	-3.40
6	Downstream	7025.78	7025.85	0.07
7	Downstream	7021.16	7021.10	-0.07
8	Downstream	7005.25	7005.25	0.00

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 Upper Fountain Creek 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. However, 200-year flows are not readily available. Therefore, scour was calculated for the 100- and 500-year events.

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 H**.

6.2 Site Geology/Geotechnical Information and Impact to Scour Depths

A geotechnical analysis was completed by 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 E**.

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 7 below summarizes the preliminary results for scour depths including contraction scour, abutment scour, and long-term scour at the bridge over Upper Fountain Creek.

Table 7: Scour Analysis Results

	Scour Type (ft)			
Storm Event	**Contraction**	**Abutment (Local)**	**Long-Term Degradation**	**Total***
100-Year	2.1	8.8	1.9	10.7
500-Year	2.3	11.9	3.3	15.3

*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 an aggressive river slope with the main channel confined between two roadway embankments. A confined tributary can lead to aggressive flow patterns and erosion, resulting in sediment being transported downstream. 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 abutments and wing walls shall be designed with a riprap revetment extending down to the 100-yr scour depth. The FHWA Hydraulic Toolbox Version 4.4 (FHWA, 2018) was used to size riprap at the bridge opening, around 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 maximum velocity in the channel.

Results of the Hydraulic Toolbox analysis are provided in **Appendix H**. A riprap with D50 of 30-inches (in) (Class VIII per HEC-23) is recommended. The resulting recommended thickness is 60-in based on HEC-23 for Class 3 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 the bridge opening should extend a minimum of 25' along the roadway embankment and configured with the data shown in Table 8. 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 8: Countermeasure Summary

Countermeasure	D_{50} (in)	Recommended Thickness (in)	Side Slopes	Toe Down Depth (ft)	Bottom Ref. Elevation (ft)	Top Ref. Elevation (ft)
Riprap	30	60	2:1	11	7010.0	7031.0
Wing Walls	N/A	N/A	N/A	11	7010.0	7031.0

7. RCBC OUTLET ENERGY DISSIPATION

The design procedure recommended in section 11.4 of the DDM was followed for outlet protection and energy dissipation at the outlet of the box culvert. All hydraulic data from the proposed culvert was gathered including height, width, length, slope, etc. The culvert control was determined to be outlet controlled, and outlet depth, velocity and Froude number was determined. To determine tailwater data, the downstream channel information was gathered from the survey data, field inspection, and the SRH-2D model.

Allowable scour estimation was completed using HY-8. Soil parameters of the downstream channel were extracted from the soils reports, and geotechnical investigation. The estimated scour hole was then determined using HY-8. Due to large scour hole estimates, energy dissipation was then considered.

The energy dissipation alternative selected for the RCBC and arched culvert outlets is a riprap apron based on the Froude number of 0.68 which is less than 3. See results from HY-8 energy dissipation analysis in **Appendix H**.

8. CONCLUSIONS

This report presents preliminary analysis and results from the hydrologic and hydraulic study for the Region 2 Bridge Bundle Design Build – Bridge I-17-X. 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 structure is a single span 30-ft bridge. The recommended freeboard is 4 feet and the proposed WSE 100 feet upstream of the proposed bridge is 7032.44 feet, giving a final recommended bridge low chord of 7036.44 feet. The proposed low chord is 7031.50 which does not meet the 4 feet of freeboard. However, this condition is not worse that the existing condition.

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 (c). A floodplain development permit is required to be approved through the El Paso County floodplain administrator during the final design phase of this Design Build project. Due to the change in the water surface elevation, a LOMC will be required by FEMA.

Total design scour for the bridge abutments was determined to be 15.3 feet at the 500-year design event. This accounts for the local scour and long-term degradation impacts that could potentially affect the proposed bridge abutments. A riprap apron was designed in order to protect the proposed abutments.

9. 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 08041C0489G

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 13. The **horizontal datum** was NAD83, GRS80 spheroid. Differences in datum, spheroid, projection or UTM zones zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the **North American Vertical Datum of 1988 (NAVD88)**. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov/ or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, MD 20910-3282

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at (301) 713-3242 or visit its website at http://www.ngs.noaa.gov/.

Base Map information shown on this FIRM was provided in digital format by El Paso County, Colorado Springs Utilities, City of Fountain, Bureau of Land Management, National Oceanic and Atmospheric Administration, United States Geological Survey, and Anderson Consulting Engineers, Inc. These data are current as of 2006.

This map reflects more detailed and up-to-date **stream channel configurations and floodplain delineations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the Flood Insurance Study Report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map. The profile baselines depicted on this map represent the hydraulic modeling baselines that match the flood profiles and Floodway Data Tables if applicable, in the FIS report. As a result, the profile baselines may deviate significantly from the new base map channel representation and may appear outside of the floodplain.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

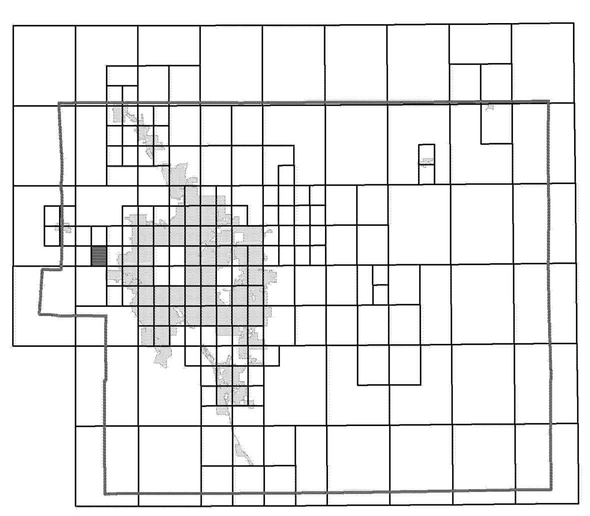
Contact **FEMA Map Service Center** (MSC) via the FEMA Map Information eXchange (FMIX) 1-877-336-2627 for information on available products associated with this FIRM. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. The MSC may also be reached by Fax at 1-800-358-9620 and its website at http://www.msc.fema.gov/.

If you have **questions about this map** or questions concerning the National Flood Insurance Program in general, please call **1-877-FEMA MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/business/nfip.

El Paso County Vertical Datum Offset Table

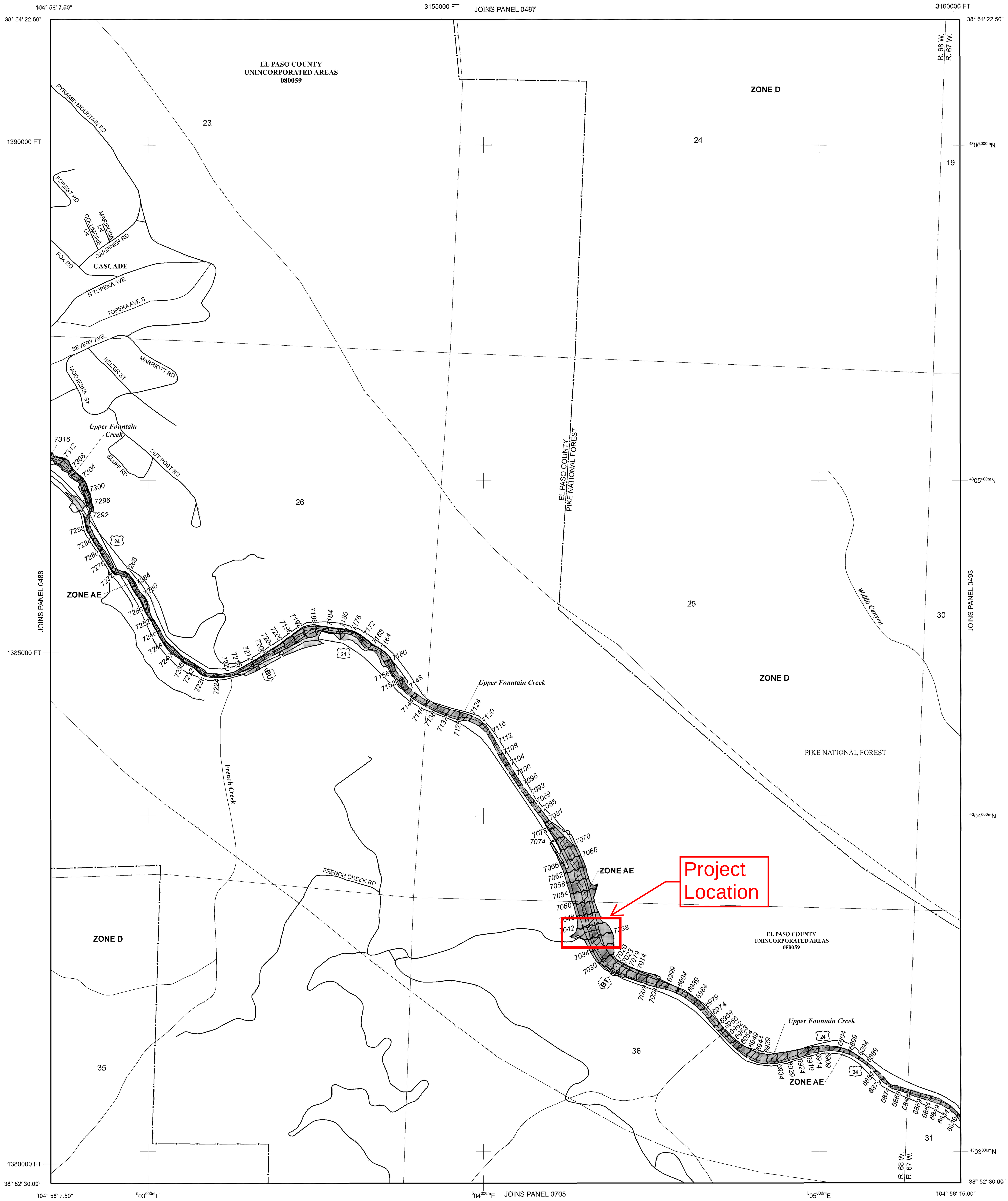
Flooding Source	Vertical Datum Offset (ft)
REFER TO SECTION 3.3 OF THE EL PASO COUNTY FLOOD INSURANCE STUDY FOR STREAM BY STREAM VERTICAL DATUM CONVERSION INFORMATION	

Panel Location Map



This Digital Flood Insurance Rate Map (DFIRM) was produced through a Cooperating Technical Partner (CTP) agreement between the State of Colorado Water Conservation Board (CWCB) and the Federal Emergency Management Agency (FEMA).

Additional Flood Hazard information and resources are available from local communities and the Colorado Water Conservation Board.



NOTE: MAP AREA SHOWN ON THIS PANEL IS LOCATED WITHIN TOWNSHIP 13 SOUTH, RANGE 67 WEST, AND TOWNSHIP 13 SOUTH, RANGE 68 WEST.

LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAS) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area Formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

	Floodplain boundary
	Floodway boundary
	Zone D Boundary
	CBRS and OPA boundary
	Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
513	Base Flood Elevation line and value; elevation in feet*
(EL 987)	Base Flood Elevation value where uniform within zone; elevation in feet*

* Referenced to the North American Vertical Datum of 1988 (NAVD 88)

A — A	Cross section line
23 - - - 23	Transect line
97° 07' 30.00" 32° 22' 30.00"	Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)
4275000mN	1000-meter Universal Transverse Mercator grid ticks, zone 13
6000000 FT	5000-foot grid ticks: Colorado State Plane coordinate system, central zone (FIPSZONE 0502), Lambert Conformal Conic Projection
DX5510 ×	Bench mark (see explanation in Notes to Users section of this FIRM panel)
• M1.5	River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
MARCH 17, 1997

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL
DECEMBER 7, 2018 - to update corporate limits, to change Base Flood Elevations and Special Flood Hazard Areas, to update map format, to add roads and road names, and to incorporate previously issued Letters of Map Revision.

For community map revision history prior to countywide mapping, refer to the Community Map History Table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 500'

250 0 500 1000 FEET

150 0 150 300 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0489G

FIRM
FLOOD INSURANCE RATE MAP
EL PASO COUNTY, COLORADO
AND INCORPORATED AREAS

PANEL 489 OF 1300

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
EL PASO COUNTY	080059	0489	G

Notice to User: The **Map Number** shown below should be used when placing map orders: the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
08041C0489G

MAP REVISED
DECEMBER 7, 2018

Federal Emergency Management Agency

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 Pike National Forest, Eastern Part, Colorado, Parts of Douglas, El Paso, Jefferson, and Teller Counties

December 14, 2020

Soil Map

Map Scale: 1:678 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 10, 20, 40, 60

Feet: 0, 30, 60, 120, 180

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

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 1:24,000.

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: Pike National Forest, Eastern Part, Colorado, Parts of Douglas, El Paso, Jefferson, and Teller Counties
Survey Area Data: Version 7, 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: Sep 11, 2018—Oct 20, 2018

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background

MAP LEGEND	MAP INFORMATION
	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
47	Sphinx, warm-Rock outcrop complex, 15 to 80 percent slopes	1.2	100.0%
Totals for Area of Interest		**1.2**	**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.

Pike National Forest, Eastern Part, Colorado, Parts of Douglas, El Paso, Jefferson, and Teller Counties

47—Sphinx, warm-Rock outcrop complex, 15 to 80 percent slopes

Map Unit Setting

National map unit symbol: jpjz
Elevation: 6,500 to 9,200 feet
Mean annual precipitation: 15 to 24 inches
Mean annual air temperature: 43 to 48 degrees F
Frost-free period: 70 to 125 days
Farmland classification: Not prime farmland

Map Unit Composition

Sphinx, warm, and similar soils: 60 percent
Rock outcrop: 25 percent
Minor components: 15 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Sphinx, Warm

Setting

Landform: Mountain slopes
Landform position (three-dimensional): Mountaintop, mountainflank
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Parent material: Weathered from granite

Typical profile

Oi - 0 to 1 inches: slightly decomposed plant material
A - 1 to 5 inches: gravelly coarse sandy loam
AC - 5 to 13 inches: very gravelly loamy coarse sand
Cr - 13 to 61 inches: weathered bedrock

Properties and qualities

Slope: 15 to 70 percent
Depth to restrictive feature: 10 to 20 inches to paralithic bedrock
Drainage class: Somewhat excessively drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water capacity: Very low (about 0.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 7e
Hydrologic Soil Group: D
Other vegetative classification: Ponderosa pine/kinnikinnick (PIPO/ARUV) (C1140)
Hydric soil rating: No

Description of Rock Outcrop

Setting

Landform: Mountain slopes
Landform position (three-dimensional): Mountaintop, mountainflank
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex

Typical profile

R - 0 to 61 inches: bedrock

Properties and qualities

Slope: 15 to 80 percent
Depth to restrictive feature: 0 inches to lithic bedrock
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately low (0.00 to 0.06 in/hr)
Available water capacity: Very low (about 0.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydrologic Soil Group: D
Hydric soil rating: No

Minor Components

Sphinx, dark surface

Percent of map unit: 10 percent
Landform: Mountain slopes
Landform position (three-dimensional): Mountainflank
Down-slope shape: Linear, convex
Across-slope shape: Linear, convex
Other vegetative classification: Ponderosa pine/kinnikinnick (PIPO/ARUV) (C1140)
Hydric soil rating: No

Garber

Percent of map unit: 5 percent
Landform: Drainageways, mountain slopes
Landform position (three-dimensional): Mountainbase
Down-slope shape: Linear, convex, concave
Across-slope shape: Linear, convex, concave
Hydric soil rating: No

APPENDIX C AERIAL IMAGERY AND PHOTOS

AERIAL IMAGERY AND PHOTOS

STRUCTURE I-17-X

FIGURE 1

AERIAL IMAGERY AND PHOTOS
STRUCTURE I-17-X
FIGURE 2

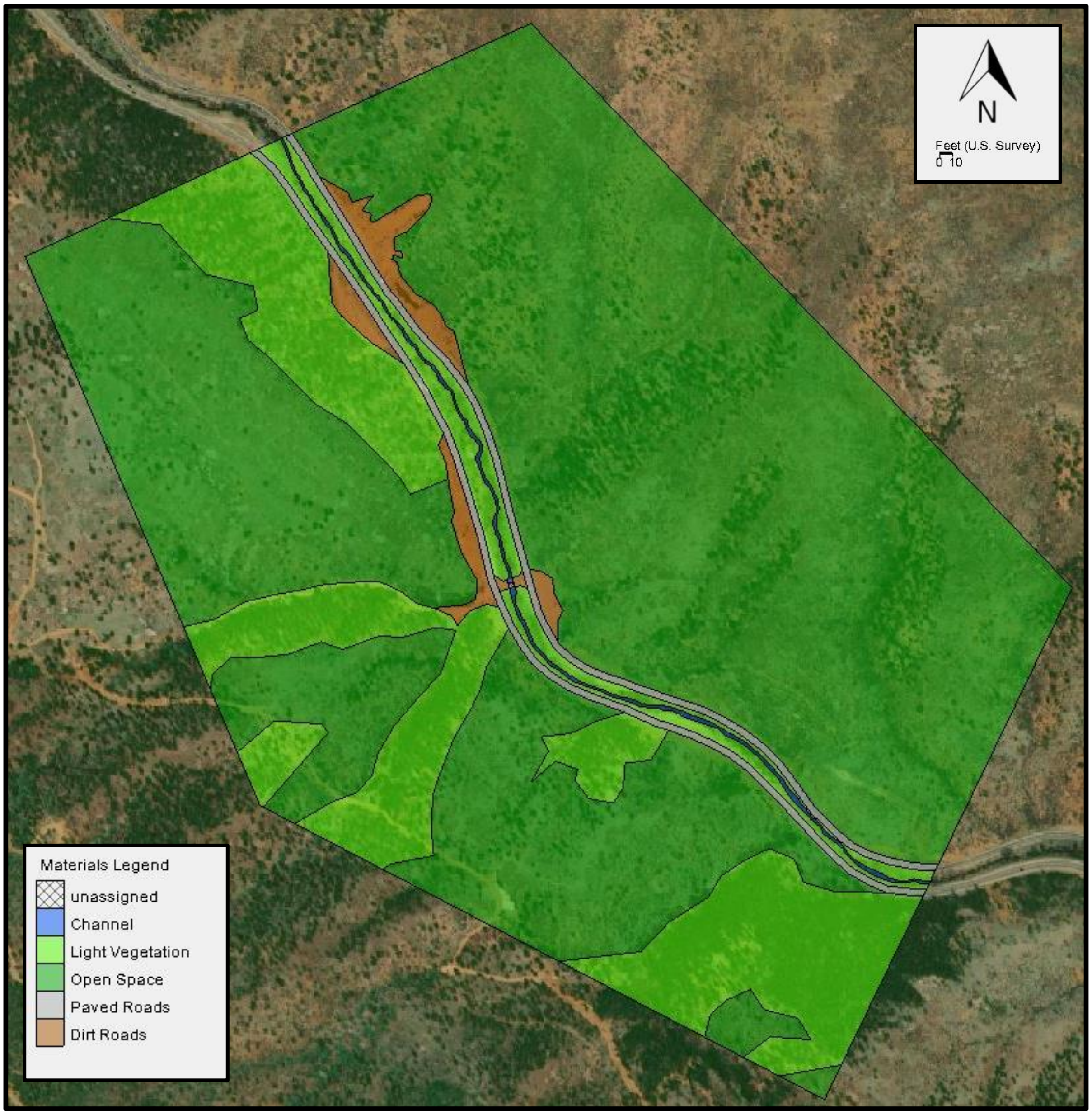
AERIAL IMAGERY AND PHOTOS

STRUCTURE I-17-X

FIGURE 3

AERIAL IMAGERY AND PHOTOS
STRUCTURE I-17-X
FIGURE 4

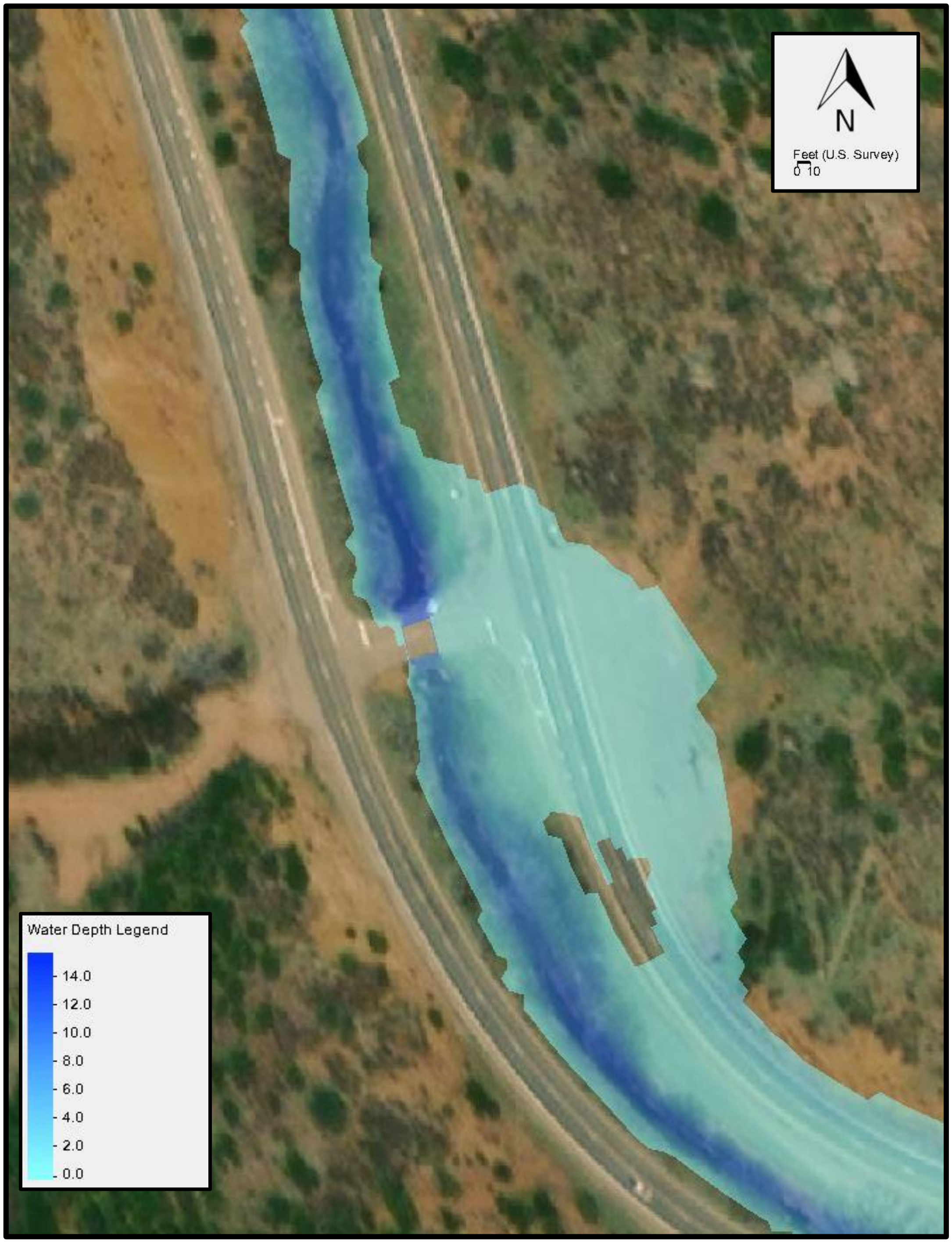
APPENDIX D EXISTING CONDITIONS MODEL GRAPHICS



MATERIALS COVERAGE

STRUCTURE I-17-X

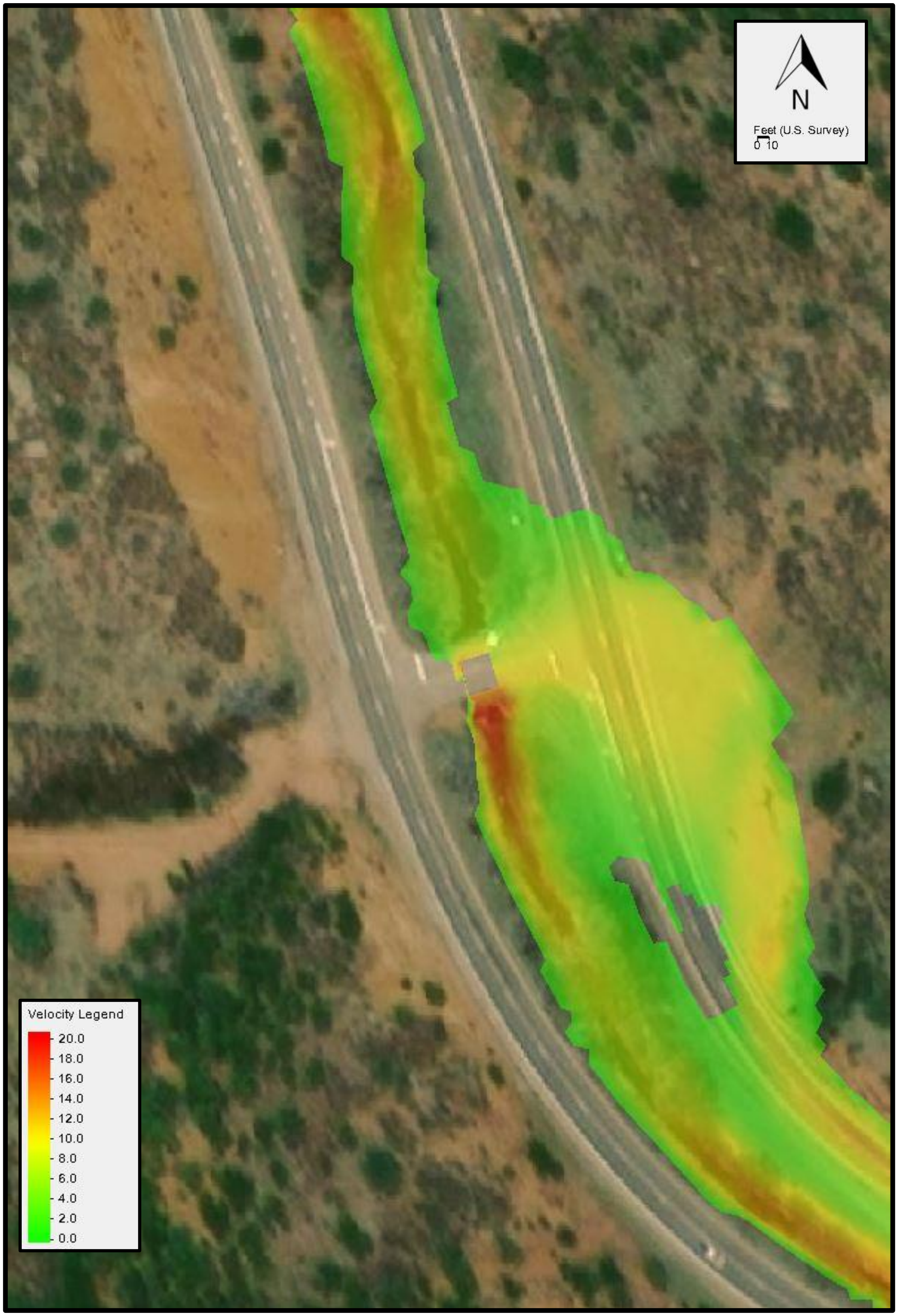
FIGURE 1



EXISTING CONDITIONS – WATER DEPTH

STRUCTURE I-17-X

FIGURE 2



EXISTING CONDITIONS – VELOCITY

STRUCTURE I-17-X

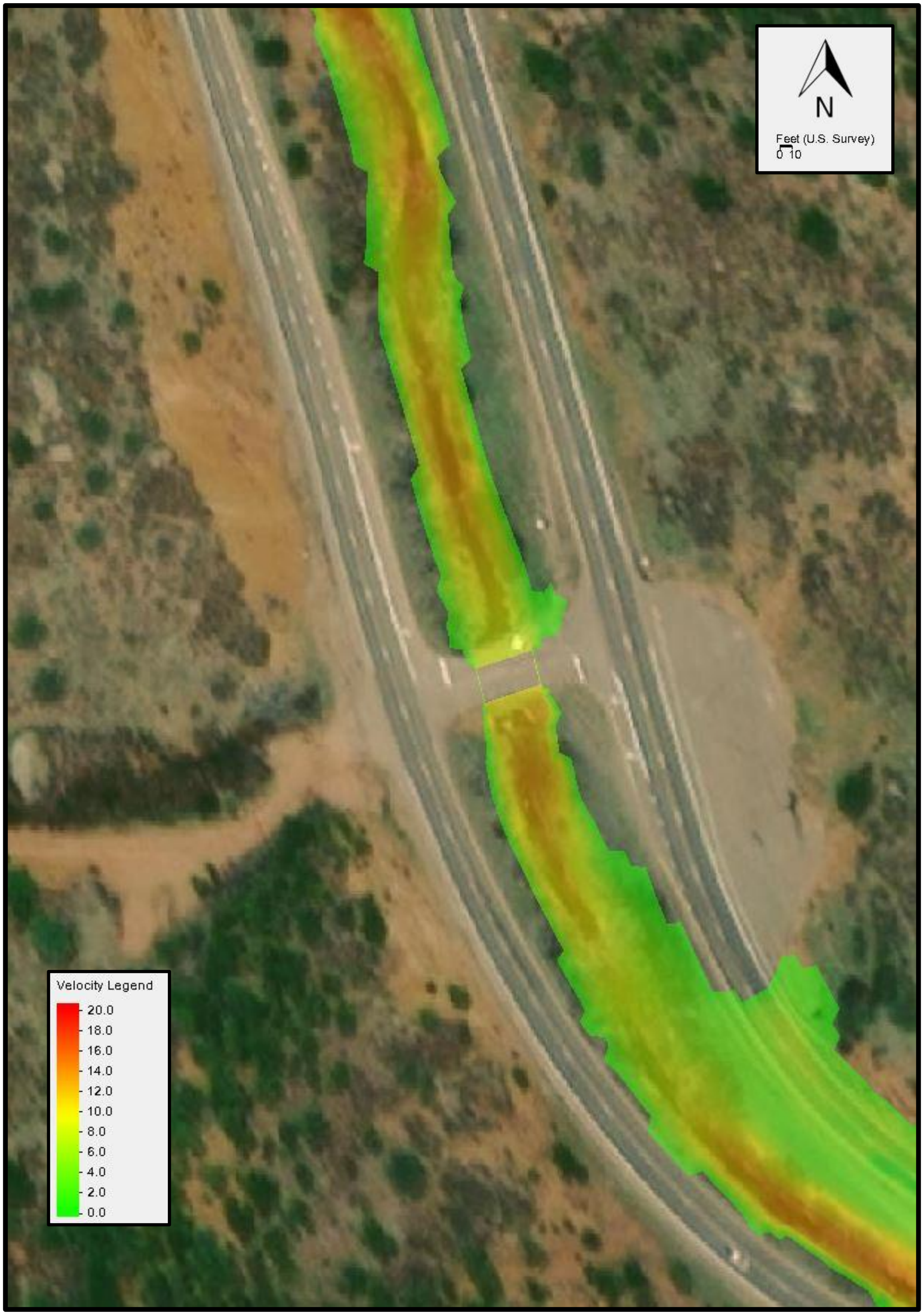
FIGURE 3

APPENDIX E PROPOSED RCBC ALTERNATIVE MODEL GRAPHICS

PROPOSED CONDITIONS – WATER DEPTH

RCBC AT STRCUTURE I-17-X

FIGURE 1



PROPOSED CONDITIONS – VELOCITY

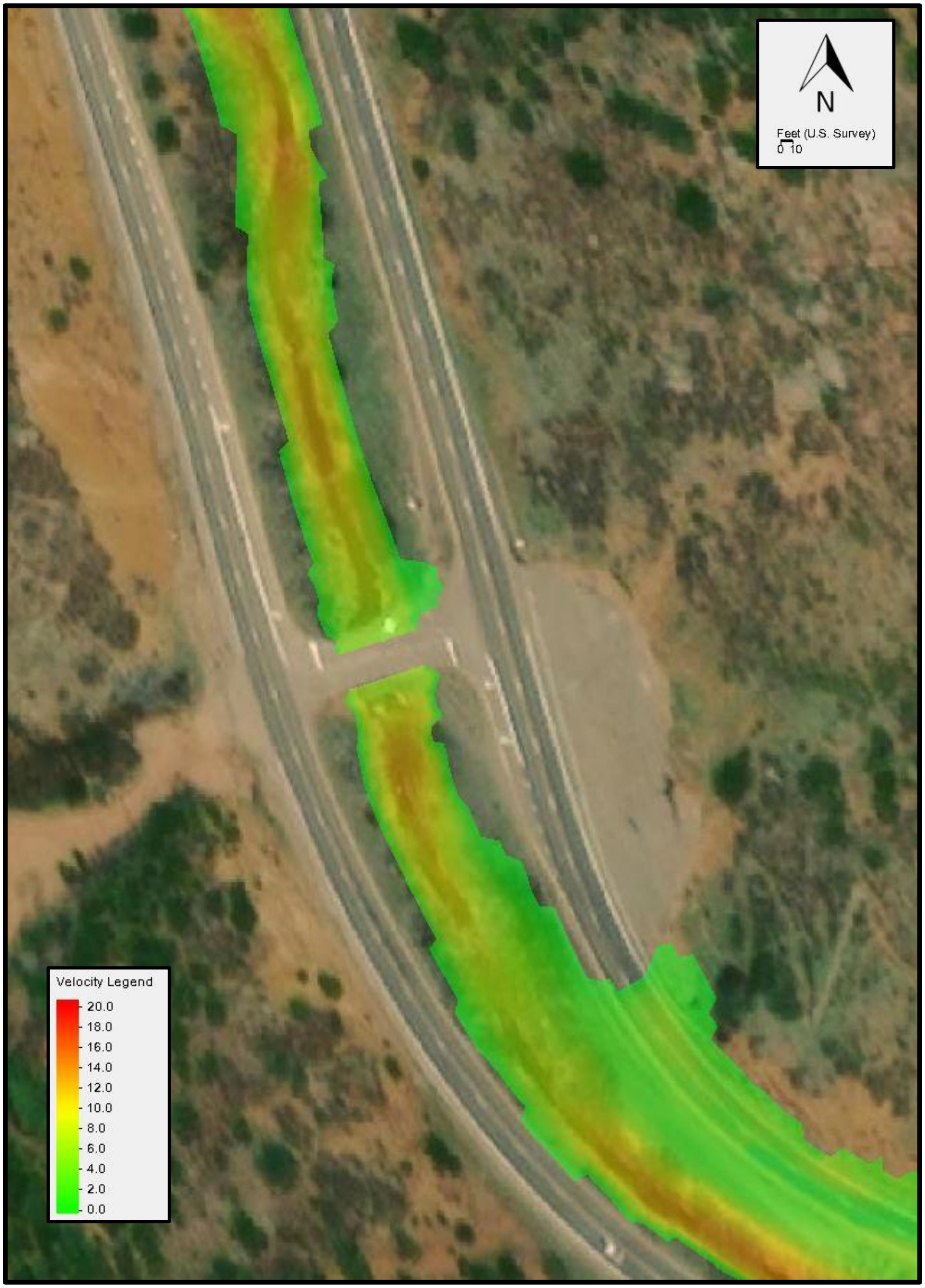
RCBC AT STRUCTURE I-17-X

FIGURE 2

PROPOSED CONDITIONS – WATER DEPTH

ARCH CULVERT AT STRCUTURE I-17-X

FIGURE 3



PROPOSED CONDITIONS – VELOCITY
ARCH CULVERT AT STRUCTURE I-17-X
FIGURE 4

APPENDIX F PROPOSED BRIDGE ALTERNATIVE MODEL GRAPHICS

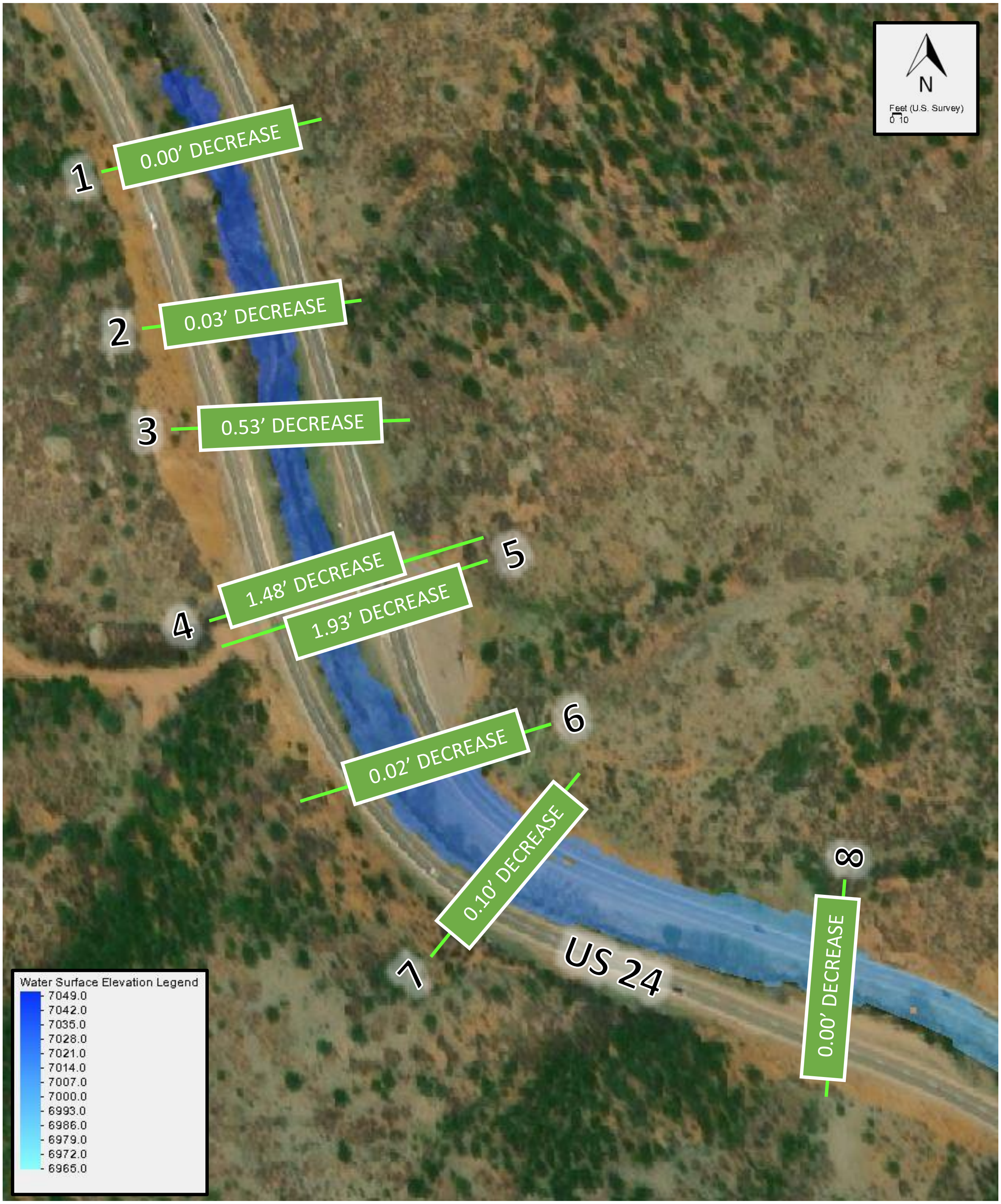
PROPOSED CONDITIONS – WATER DEPTH

BRIDGE AT STRUCTURE I-17-X

FIGURE 1

PROPOSED CONDITIONS – VELOCITY
BRIDGE AT STRUCTURE I-17-X
FIGURE 2

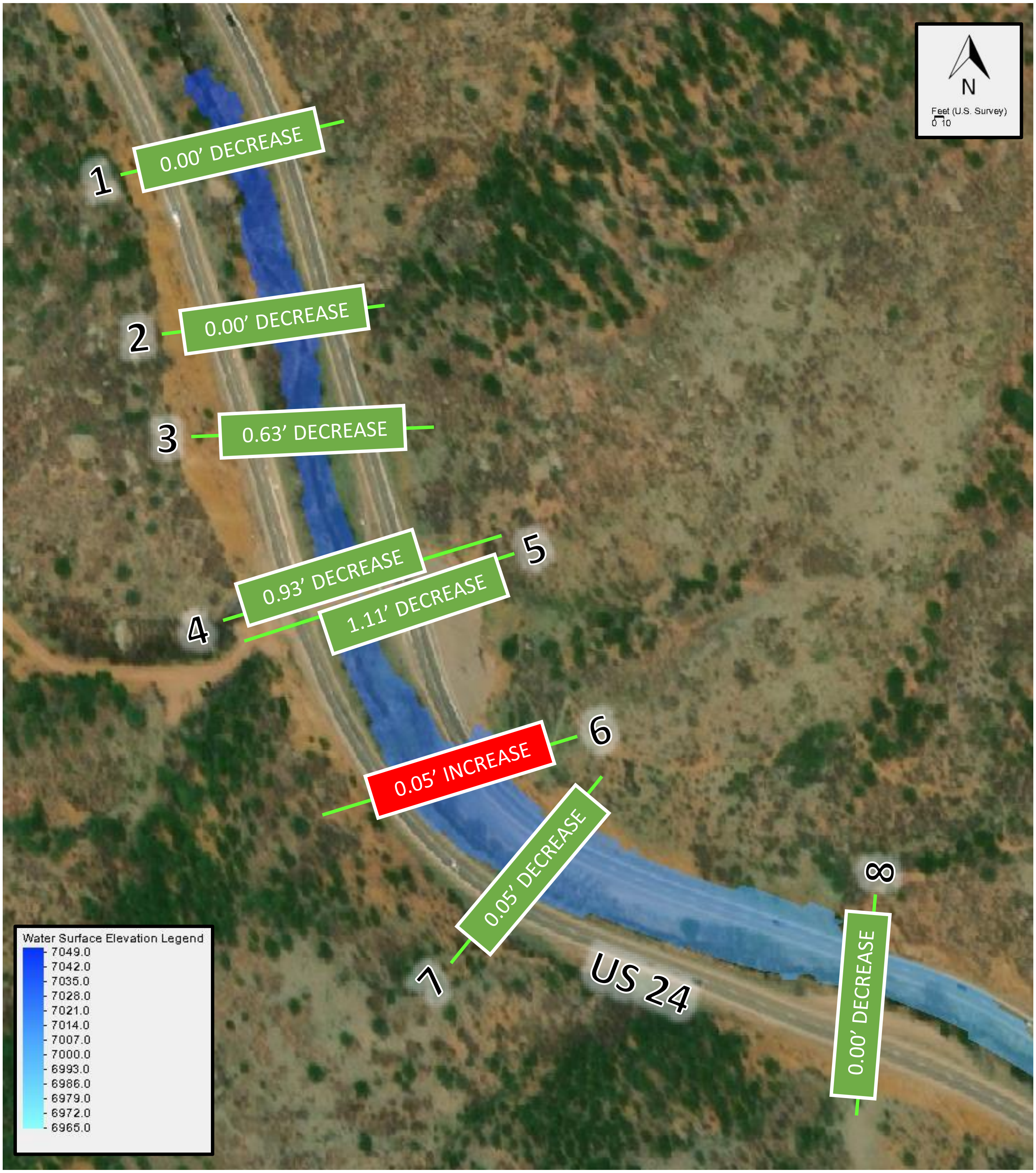
APPENDIX G WATER SURFACE ELEVATION COMPARISON GRAPHICS



WATER SURFACE ELEVATION COMPARISON – RCBC OPTION

STRUCTURE I-17-X

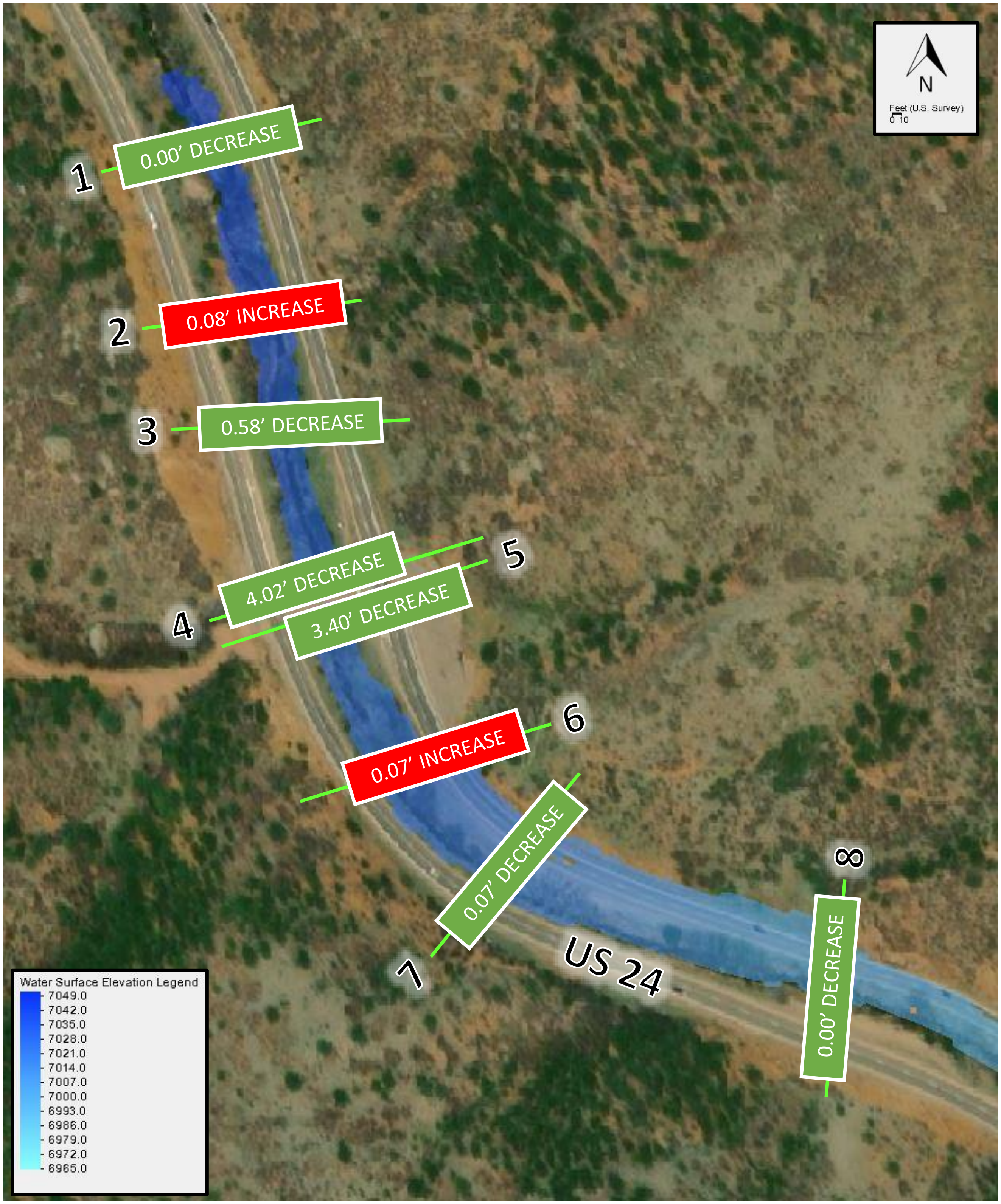
FIGURE 1



WATER SURFACE ELEVATION COMPARISON – ARCH OPTION

STRUCTURE I-17-X

FIGURE 2



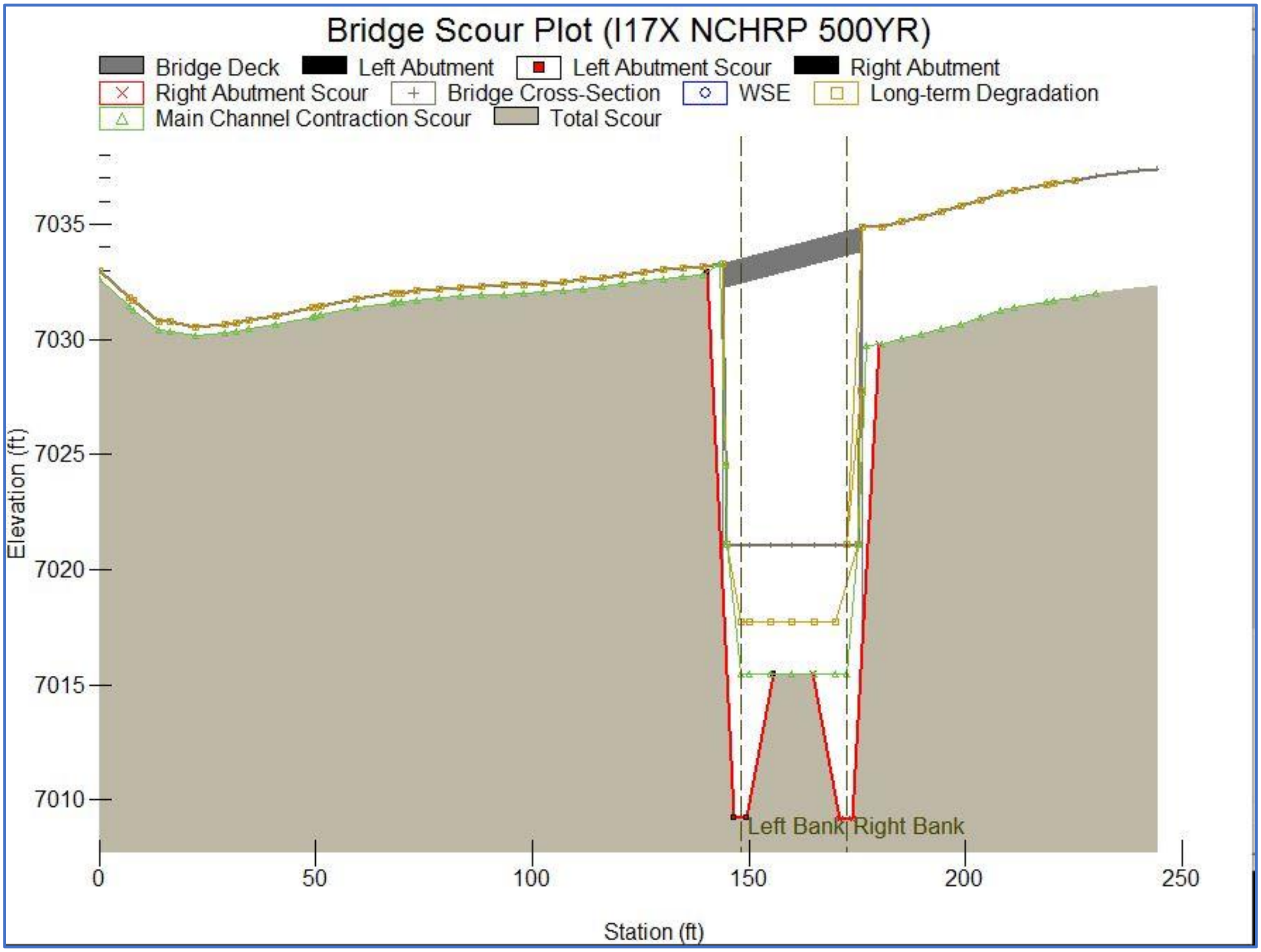
CDOT REGION 2 – BRIDGE BUNDLE

WATER SURFACE ELEVATION COMPARISON – BRIDGE OPTION

STRUCTURE I-17-X

FIGURE 3

APPENDIX H ENERGY DISSIPATION ANALYSIS



SCOUR PLOT
STRUCTURE I-17-X
FIGURE 1

Hydraulic Analysis Report

Project Data

Project Title: I-17-X 100YR

Designer: Stanley Consultants

Project Date: Thursday, December 17, 2020

Project Units: U.S. Customary Units

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 at the abutment is used.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 5 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: 6.7 ft

Flow Depth at Toe of Abutment: 5.7 ft

Calculations will use either total or overbank discharges.

Total Discharge: 3143 cfs

Overbank Discharge: 444.56 cfs

Total Bridge Area: 196 ft^2

Setback Area: 30.7 ft^2

Maximum Channel Velocity: 16.04 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 0.746269

Characteristic Velocity: 16.0357 ft/s

Froude Number at the Abutment Toe: 1.18413

Abutment Coefficient: 0.69

Computed D50: 29.9897 in

Design D50 = 30 in
Thickness = 60 in
Design D50 > Computed D50
30 in > 29.9897 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS VIII

Riprap Class Order: 8

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

d100: 60 in

d85: 42.5 in

d50: 31.5 in

d15: 22 in

Layout Recommendations

Minimum Riprap Thickness: 60 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 11.4 ft

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

See HEC 23, Figure 14.7

No channel used in calculations

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 at the abutment is used.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 5 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: 6.7 ft

Flow Depth at Toe of Abutment: 4.6 ft

Calculations will use either total or overbank discharges.

Total Discharge: 3143 cfs

Overbank Discharge: 426.9 cfs

Total Bridge Area: 209.5 ft^2

Setback Area: 25.9 ft^2

Maximum Channel Velocity: 15 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 0.746269

Characteristic Velocity: 15.0024 ft/s

Froude Number at the Abutment Toe: 1.23319

Abutment Coefficient: 0.69

Computed D50: 24.4789 in

Design D50 = 30 in

Thickness = 60 in

Design D50 > Computed D50

30 in > 24.4789 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS VII

Riprap Class Order: 7

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

d100: 49.5 in

d85: 35 in

d50: 25.5 in

d15: 17.5 in

Layout Recommendations

Minimum Riprap Thickness: 60 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 9.2 ft

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

See HEC 23, Figure 14.7

No channel used in calculations

HY-8 Energy Dissipation Report

Scour Hole Geometry

Parameter	Value	Units
Select Culvert and Flow		
Crossing	Proposed	
Culvert	Proposed RCBC	
Flow	3143.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	36.0	ft
Culvert Height	8.0	ft
Outlet Depth	8.00	ft
Outlet Velocity	10.91	ft/s
Froude Number	0.68	
Tailwater Depth	8.30	ft
Tailwater Velocity	12.37	ft/s
Tailwater Slope (SO)	0.0250	
Scour Data		
Time to Peak		
Note:	if Time to Peak is unknown, enter 30 min	
Time to Peak	30.00	min
Cohesion	Noncohesive	
D16 Value	0.42	mm
D84 Value	12.00	mm
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Soil Sigma	5.35	
Scour Hole Dimensions		
Length	-1.#IO	ft
Width	-1.#IO	ft
Depth	-1.#IO	ft
Volume	-1.#IO	ft^3
DS at .4(LS)	-1.#IO	ft
Tailwater Depth (TW)	8.304	ft
Velocity with TW and WS	-1.#IO	ft/s

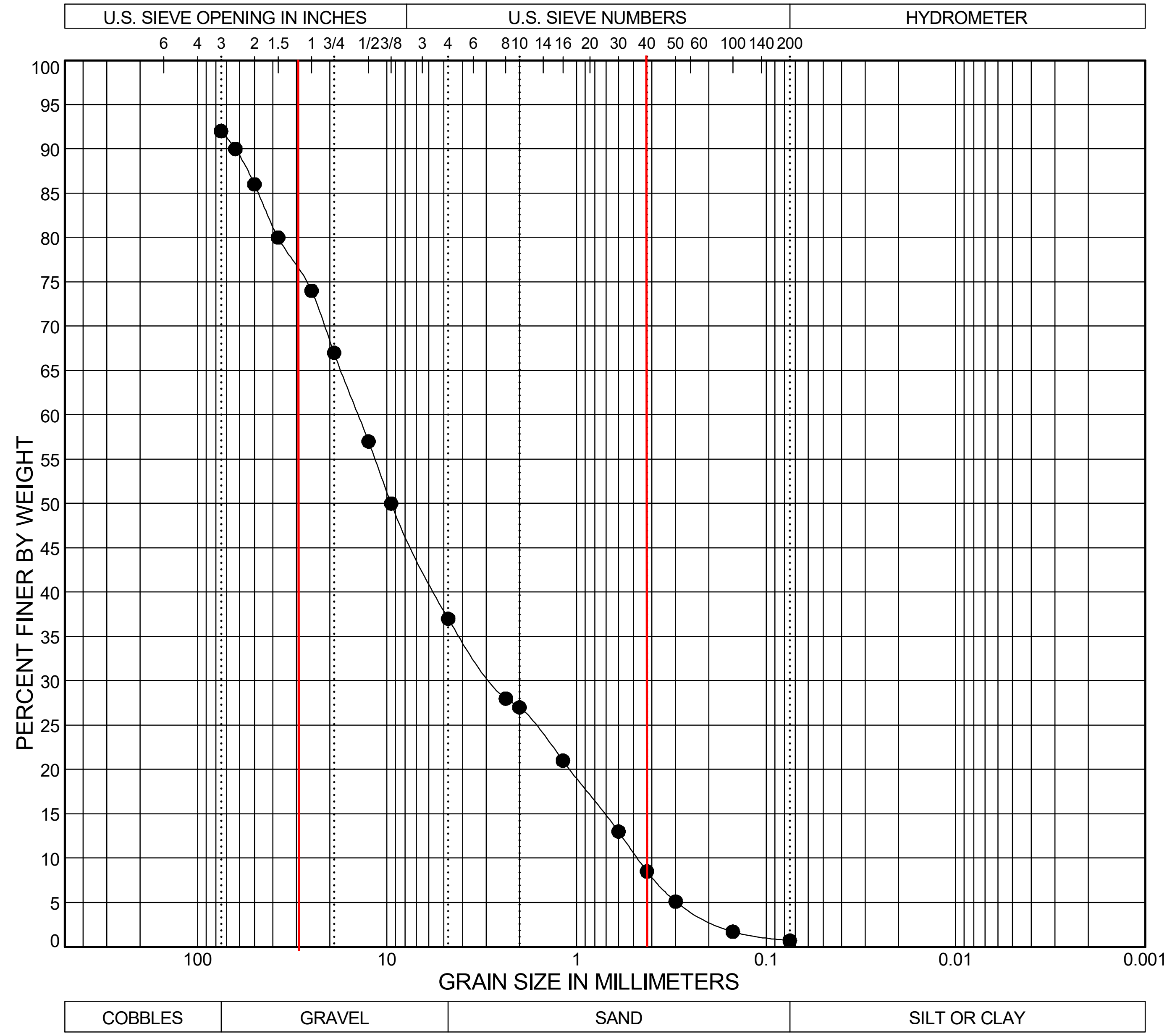
HY-8 Energy Dissipation Report

External Energy Dissipator

Parameter	Value	Units
Select Culvert and Flow		
Crossing	Proposed	
Culvert	Proposed RCBC	
Flow	3143.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	36.0	ft
Culvert Height	8.0	ft
Outlet Depth	8.00	ft
Outlet Velocity	10.91	ft/s
Froude Number	0.68	
Tailwater Depth	8.30	ft
Tailwater Velocity	12.37	ft/s
Tailwater Slope (SO)	0.0250	
External Dissipator Data		
External Dissipator Category	Streambed Level Structures	
External Dissipator Type	Riprap Basin	
Restrictions		
Froude Number	<3	
Input Data		
Condition to be used to Compute Basin Outlet Velocity	Best Fit Curve	
D50 of the Riprap Mixture		
Note:	Minimum HS/D50 = 2 is Obtained if D50 = 0.383 ft	
D50 of the Riprap Mixture	0.383	ft
DMax of the Riprap Mixture	1.500	ft
Results		
Brink Depth	8.043	ft
Brink Velocity	10.855	ft/s
Depth (YE)	8.043	ft
Riprap Thickness	2.250	ft
Riprap Foreslope	3.0000	ft
Check HS/D50		
Note:	OK if HS/D50 > 2.0	
HS/D50	2.001	
HS/D50 Check	HS/D50 is OK	
Check D50/YE		
Note:	OK if 0.1 < D50/YE < 0.7	
Check D50/YE	0.048	
D50/YE Check	D50/YE is NOT OK	
Basin Length (LB)	144.000	ft
Basin Width	132.000	ft
Apron Length	36.000	ft
Pool Length	108.000	ft
Pool Depth (HS)	0.767	ft
TW/YE	1.032	
Tailwater Depth (TW)	8.304	ft
Average Velocity with TW	2.547	ft/s
Critical Depth (Yc)	2.568	ft
Average Velocity with Yc	8.925	ft/s
Downstream Riprap for High TW		
Distance: 1 LB		
Velocity	8.114	ft/s
Size	0.429	ft
Distance: 2 LB		
Velocity	4.398	ft/s
Size	0.126	ft
Distance: 3 LB		
Velocity	2.923	ft/s
Size	0.056	ft
Distance: 4 LB		
Velocity	2.188	ft/s
Size	0.031	ft

9-inch riprap stilling basin proposed at the CBC outfall. Dimensions listed here follow the Riprap Basin design as outlined in HEC-14 - "Hydraulic Design of Energy Dissipators for Culverts and Channels"

APPENDIX I GEOTECHNICAL INFORMATION



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

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

SIEVE ANALYSIS

FIGURE S- 6

Project No. 220-063 Date: 11-24-2020
Report By: D. Gruenwald Yeh Lab: Colorado Springs
Checked By: J. McCall

CDOT Region 2 Bridge Bundle
Scour Test Results
Structure I-17-X

03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/24/20