PRELIMINARY HYDRAULICS REPORT
STRUCTURES M-21-I, M-21-J, & M-22-Y REPLACEMENT
As a part of the
REGION TWO BRIDGE BUNDLE PACKAGE
OTERO COUNTY, COLORADO

A Part of Sections 34 and 35, Township 25 South, Range 57 West of the 6th P.M.,
County of Otero, 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 Structures M-21-I, M-21-J, and M-22-Y as a part of the Colorado Department of Transportation (CDOT) Region 2 Bridge Bundle Project. These three structures were modeled together within one model. The project is located within Otero County at Mile Posts 56.454, 57.069, and 57.474, respectively, along US 350 between Trinidad and La Junta. Structures M-21-I, M-21-J and M-22-Y each cross over unnamed seasonal washes. Figure 1 below illustrates the project locations. The project is located in Sections 34 and 35, Township 25 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 M-21-I project site as a FEMA Zone A and the M-21-J and M-22-Y project sites as a FEMA Zone C, as determined by the Flood Insurance Rate Map (FIRM) 0801320225B effective date August 19, 1985, as shown in Appendix A. FEMA Zone A is a Special Flood Hazard Area (SFHA) inundated by the 100-year flood, however base flood elevations are not determined in a Zone A designation. FEMA Zone C denotes areas of minimal flooding. 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.

For stream crossings that are not within a Special Flood Hazard Area (SFHA) this project will meet CDOT and state requirements. For rural, two-lane highways, the design flow for bridges and culverts is the 25-year storm event. However, the CDOT DDM requires all non-jurisdictional flood areas to follow Colorado Water Conservation Board's guidelines, which state that any development or construction should not raise the 100-year flood event WSEs more than 0.5'. While this is not a statewide requirement, best practice is to follow these guidelines. Bridges M-21-J and M-22-Y fall into this category, but because the existing structure passes the 100-year flows, the proposed structures must be sized accordingly.

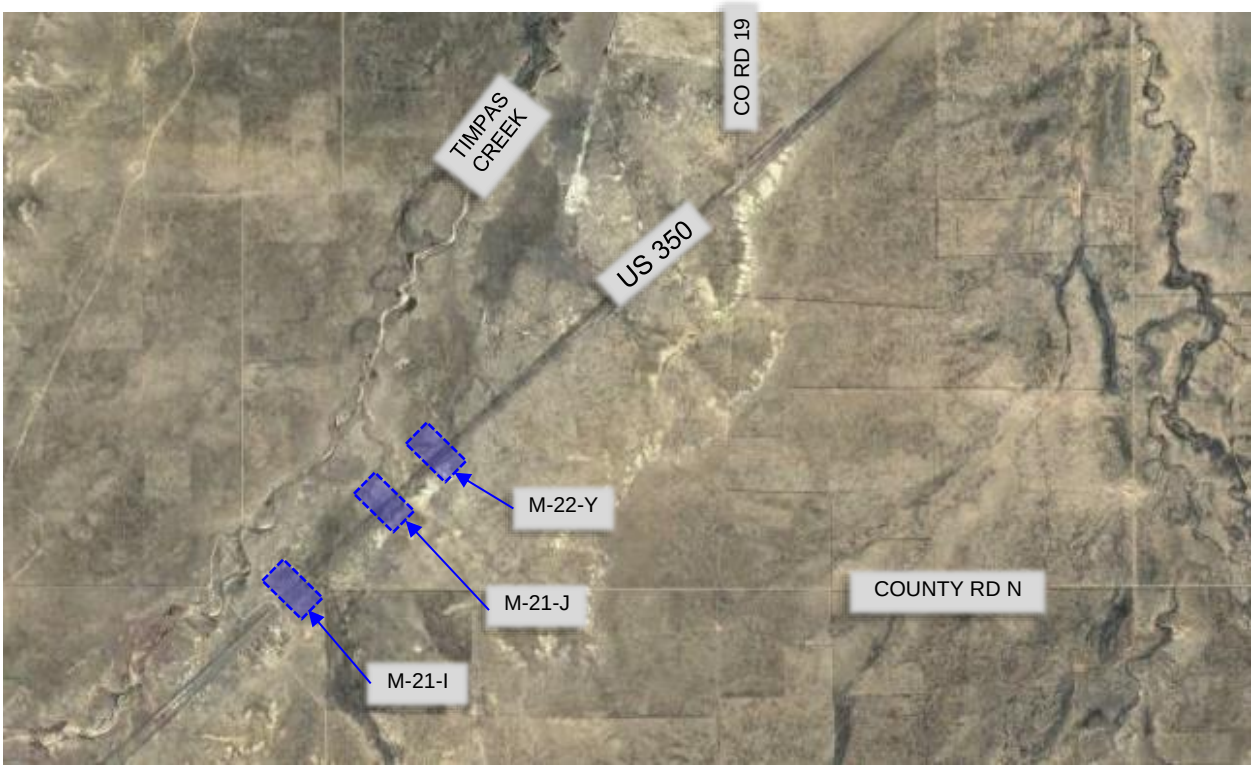


Figure 1: Vicinity Map

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 structures M-21-I, M-21-J and M-22-Y.

Table 1: Summary of Peak Discharge for Bridge M-21-I, M-21-J, and M-22-Y

River Location	Design Storm	25-year (cfs)	100-year (cfs)	500-year (cfs)
Upstream of M-21-I Bridge	100-year	1157	1,810	2,691
Upstream of M-21-J Bridge	25-year	595	947	1,423
Upstream of M-22-Y Bridge	25-year	56	107	Unknown

3. EXISTING CONDITIONS

3.1 Existing Structure

Structure M-21-I

Existing structure is a three-span treated timber stringer bridge built in 1935 to span a seasonal wash. The bridge is tangent. The existing bridges were based on a CDOT Standard P-117-B-H. The existing bridge consist of three 22'-6" spans and a width of 25'-0" curb to curb, 26'-0" out to out of deck between rails. The existing vertical clearance is approximately 7'-6". The existing bridge has 12 rows of stringers, 6"x20" wood stringers, spaced at 2'-2 ¾". The deck consists of wood planks, 3"x6".

Structure M-21-J

Existing structure is a two-span treated timber stringer bridge built in 1937 to span a seasonal wash. The bridge is tangent. The existing bridges were based on a CDOT Standard P-117-B-H. The existing bridge consist of two 23'-0" spans and a width of 25'-0" curb to curb, 26'-0" out to out of deck between rails. The existing vertical clearance is 6'-9". The existing bridge has 12 rows of stringers, 6"x20" wood stringers, spaced at 2'-3 1/4". The deck consists of wood planks, 3"x6".

Structure M-22-Y

Existing structure is a single span treated timber stringer bridge built in 1935 to span a seasonal wash. The bridge is tangent. The existing bridges were based on a CDOT Standard P-117-B-H 60. The existing bridge consist of one 23'-0" span and a width of 25'-0" curb to curb, 26'-0" out to out of deck between rails. The existing vertical clearance is 3'-0". The existing bridge has 12 rows of stringers, 6"x20" wood stringers, spaced at 2'-3 1/4". The deck consists of wood planks, 3"x6".

3.2 Watershed Overview

Structure M-21-I

The Seasonal Wash tributary to M-21-I is a dry channel that flows from the southeast to the northwest toward Timpas Creek. The watershed tributary to this Seasonal Wash is approximately 5.10 square miles in area. The watershed generally slopes to the north. The stream bed does not have a base flow.

The stream flows at a right angle 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 300 feet to the north, the channel crosses under the railroad prior to the confluence with Timpas Creek. The bridge for the railroad is an 8-span bridge with a total span of 110 feet.

Structure M-21-J

The Seasonal Wash tributary to M-21-J is a dry channel that flows from the southeast to the northwest toward Timpas Creek. The watershed tributary to this Seasonal Wash is approximately 2.48 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 angle to the current structure with an approximate angle of attack of 90 degrees. 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 160 feet to the north, the channel crosses under the railroad prior to the confluence with Timpas Creek. The bridge for the railroad is a 2-span bridge with a total span of 57 feet.

Structure M-22-Y

The Seasonal Wash tributary to M-22-Y is a dry channel that flows from the southeast to the northwest toward Timpas Creek. The watershed tributary to this Seasonal Wash is approximately 0.15 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 angle to the current structure with an approximate angle of attack of 90 degrees. 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 130 feet to the north, the channel crosses under the railroad prior to the confluence with Timpas Creek. The bridge for the railroad is a 2-span bridge with a total span of 22 feet.

3.3 Site Investigation

Structure M-21-I

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 no obvious scour damage to the base of the abutments or piers. Site photos are included in **Appendix C**.

Structure M-21-J

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 no obvious scour damage to the base of the abutments or piers. Site photos are included in **Appendix C**.

Structure M-22-Y

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 no obvious scour damage to the base of the abutments or piers. 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, three models were developed:

- Existing Conditions
- Proposed Conditions: Bridge Replacement
- Proposed Conditions: Box Culvert 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**.

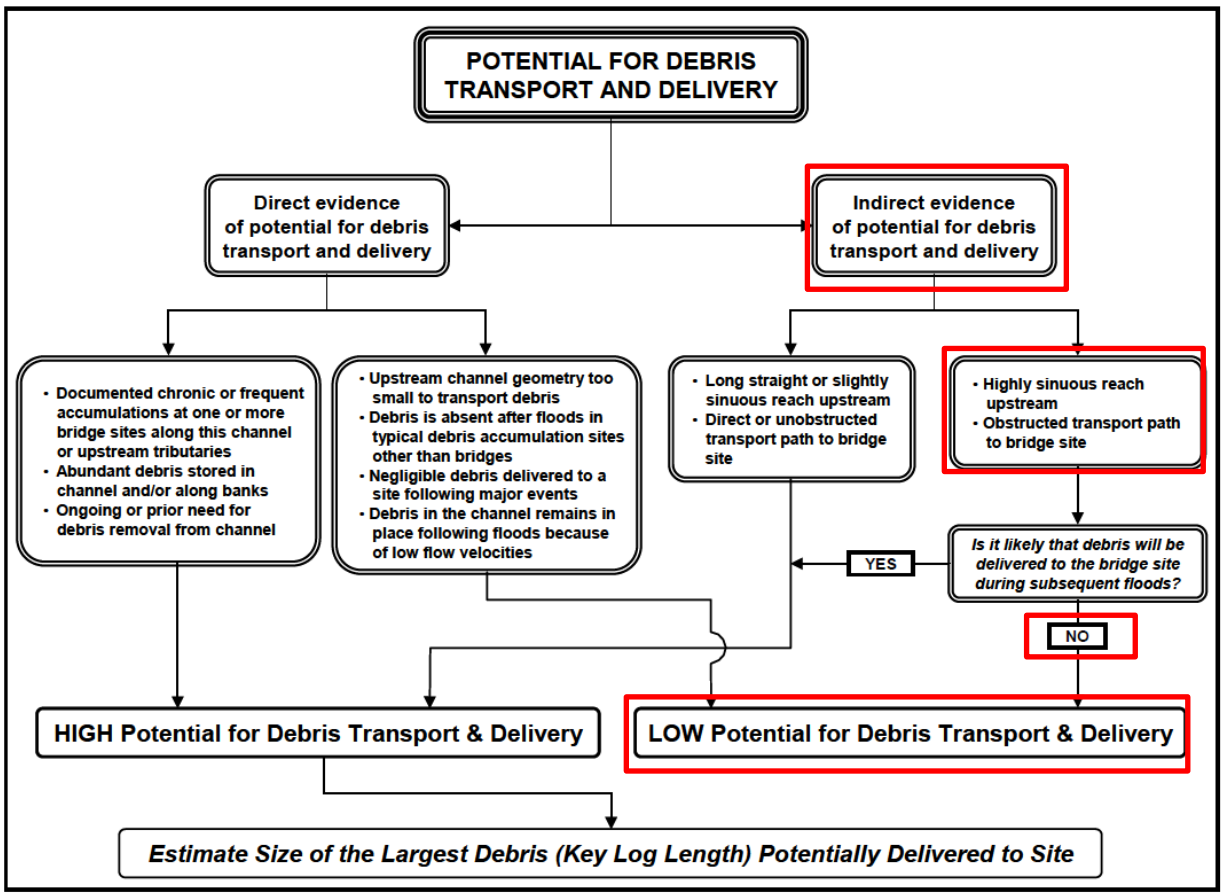


Figure 2: Flow Chart for Potential Debris Production (FHWA, HEC 20)

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.

These three channels were 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. However, the existing 100-year floodplain at M-21-I and M-22-Y hits the existing bridge girders, and due to funding and site constraints, it is not feasible to raise the bridge above the 100-year floodplain. The proposed preliminary design will not increase this condition. The 100-year water surface elevation at M-21-J provides 0.26-ft of freeboard which does not meet the 2-ft minimum but due to funding and site constraints, it is not feasible to raise the bridge above the 100-year floodplain.

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. Stanley Consultants performed a drone survey of the site in August 2020 which was used to add elevation detail at the railroad bridges downstream of each M-21-I, M-21-J, and M-22-Y. These three 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 overbanks. The total number of mesh elements in the existing model is 28,465 and 37,500 in the proposed model. The mesh extends approximately 1,100 feet upstream of and 6,200 feet downstream of the bridge M-21-I. The mesh extends approximately 1,200 feet upstream of and 3,100 feet downstream of the bridge M-21-J. The mesh extends approximately 1,300 feet upstream of and 2,400 feet downstream of the bridge M-22-Y.

4.3.3 Surface Roughness

Surface roughness, represented by the Manning's roughness coefficient, is presented in **Table 2** and Figure 4. 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
Overbanks	0.050
Dirt Road	0.020
Railroad/Gravel	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

Structure and Frequency Storm	Inflow (cfs)	Outflow Constant WSE (ft)
M-21-I 100-Year	1,810	4385.51
M-21-J 100-Year	947	4385.51
M-22-Y 100-Year	107	4390.52

4.3.5 Hydraulic Structures

Structure M-21-I

The modeled existing bridge geometry is based on the survey completed in August 2020. The survey data included shots detailing the bridge, including the existing pier locations. The high chord of the bridge is 4418.43 feet, while the low chord is 4416.23 feet. The bridge was modeled as overtopping which allows flow to overtop the bridge if the water surface elevation reaches an elevation greater than the high chord of the bridge.

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

The model included an existing railroad bridge downstream of the roadway crossing. The survey drone data included shots detailing the bridge, including the existing pier locations. The high chord of the bridge is 4421.77 feet, while the low chord is 4417.72 feet. The bridge was modeled as overtopping which allows flow to overtop the bridge if the water surface elevation reaches an elevation greater than the high chord of the bridge.

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

Structure M-21-J

The modeled existing bridge geometry is based on the survey completed in August 2020. The survey data included shots detailing the bridge, including the existing pier locations. The high chord of the bridge is 4409.70 feet, while the low chord is 4407.50 feet. The bridge was modeled as overtopping which allows flow to overtop the bridge if the water surface elevation reaches an elevation greater than the high chord of the bridge.

The model included an existing railroad bridge downstream of the roadway crossing. The survey drone data included shots detailing the bridge, including the existing pier locations. The high chord of the bridge is 4406.77 feet, while the low chord is 4404.50 feet. The bridge was modeled as overtopping which allows flow to overtop the bridge if the water surface elevation reaches an elevation greater than the high chord of the bridge.

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

Structure M-22-Y

The modeled existing bridge geometry is based on the survey completed in August 2020. The survey data included shots detailing the bridge, including the existing pier locations. The high chord of the bridge is 4409.70 feet, while the low chord is 4407.50 feet. The bridge was modeled as overtopping which allows flow to overtop the bridge if the water surface elevation reaches an elevation greater than the high chord of the bridge.

The model included an existing railroad bridge downstream of the roadway crossing. The survey drone data included shots detailing the bridge, including the existing pier locations. The high chord of the bridge is 4409.42 feet, while the low chord is 4406.66 feet. The bridge was modeled as overtopping which allows flow to overtop the bridge if the water surface elevation reaches an elevation greater than the high chord of the bridge.

The existing bridge pier 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

Existing Conditions

The hydraulic simulations are run with a 2.0 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.

Proposed Conditions

The hydraulic simulations for the Proposed Culverts model are run with a 0.5 second time step for 4 hours until a steady state solution is met. The hydraulic simulations for the Proposed Bridges model are run with a 2.0 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 for both proposed models.

4.4 Model Results

4.4.1 Existing Conditions

Structure M-21-I

The modeled existing bridge geometry is based on the survey completed in August 2020. The survey data included shots detailing the bridge, including the existing pier locations. The high chord of the roadway bridge is 4418.43 feet, while the low chord is 4416.23 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.

The range of depths experienced in the channel at the roadway bridge during the 100-year event is from 5.04 feet to 7.49 feet. The results demonstrate that the existing bridge does not overtop during the 100-year event. The results show that flows pond behind the embankment. Existing conditions 100-year depths of flow are shown in **Appendix D**.

Structure M-21-J

The modeled existing bridge geometry is based on the survey completed in August 2020. The survey data included shots detailing the bridge, including the existing pier locations. The high chord of the bridge is 4409.68 feet, while the low chord is 4407.50 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.

The range of depths experienced in the channel at the bridge during the 100-year event is from 6.24 feet to 6.47 feet. The results also demonstrate that the existing bridge does not overtop during the 100-year event. The results show that flows pond behind the embankment. Existing conditions 100-year depths of flow are shown in **Appendix D**.

Structure M-22-Y

The modeled existing bridge geometry is based on the survey completed in August 2020. The survey data included shots detailing the bridge, including the existing pier locations. The high chord of the bridge is 4409.70 feet, while the low chord is 4407.50 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.

The range of depths experienced in the channel at the bridge during the 100-year event is from 1.41 feet to 2.25 feet. The results demonstrate that the existing bridge does not overtop during the 100-year event. The results show that flows pond behind the embankment. 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.

4.4.2.1 Structure M-21-I

Proposed RCBC

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included widening the opening to accommodate multiple culverts and flattening the bottom of the channel at the crossing. The proposed model has 37,605 mesh elements. The culvert was modeled in 2D instead of using HY-8. Holes were added to the mesh to simulate the box culvert walls.

Due to the crossing's location within a floodplain, a similar sized opening 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 4 cell 20-foot wide by 7-foot tall structure. An opening of at least 7-feet was required to maintain a cattle crossing. This structure size was determined to allow zero rise in the WSEs of the channel.

Depths and velocity grids for the proposed RCBC show depths from 7.52 to 7.83 and velocities from 0.98 to 4.78 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 adding vertical abutments and slightly widening the opening. The proposed model has 37,275 mesh elements. The proposed model has a 72-foot span width, no piers, the low chord of the bridge is at 4116.0 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 RCBC show depths from 5.24 to 7.56 and velocities from 1.63 to 6.28 ft/s. See **Appendix F** for 100-year depths and velocities graphics for this option.

4.4.2.2 Structure M-21-J

Proposed RCBC

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included widening the opening to accommodate multiple culverts and flattening the bottom of the channel at the crossing. The proposed model has 37,605 mesh elements. The culvert was modeled in HY-8, integrated within SRH-2D. The use of HY-8 to model this culvert is acceptable due to the direction of flow being perpendicular to the roadway.

The existing condition does not overtop the road, so to maintain less than 0.5 feet of rise compared to the existing water surface elevation, a similar opening size was used for the box culverts. 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 20-foot wide by 7-foot tall structure. An opening of at least 7-feet was required to maintain a cattle

crossing. This structure size was determined to allow less than 0.5 feet of rise in the WSEs of the channel.

Depths and velocity grids for the proposed RCBC show depths from 6.46 to 6.97 and velocities from 1.78 to 3.44 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 adding vertical abutments and slightly widening the opening. The proposed model has 37,275 mesh elements. The proposed model has a 51-foot span width, no piers, the low chord of the bridge is at 4404.50 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 RCBC show depths from 6.11 to 6.61 and velocities from 1.41 to 3.10 ft/s. See **Appendix F** for 100-year depths and velocities graphics for this option.

4.4.2.3 Structure M-22-Y

Proposed RCBC

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included widening the opening to accommodate multiple culverts and flattening the bottom of the channel at the crossing. The proposed model has 37,605 mesh elements. The culvert was modeled in HY-8, integrated within SRH-2D. The use of HY-8 to model this culvert is acceptable due to the direction of flow being perpendicular to the roadway.

The existing condition does not overtop the road, so to maintain less than 0.5 feet of rise compared to the existing water surface elevation, a similar opening size was used for the box culverts. 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 2 cell 6-foot wide by 4-foot tall structure. This structure size was determined to allow less than 0.5 feet of rise in the WSEs of the channel.

Depths and velocity grids for the proposed RCBC show depths from 1.97 to 2.31 and velocities from 1.61 to 2.27 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 adding vertical abutments and slightly widening the opening. The proposed model has 37,275 mesh elements. The proposed model has a 28-foot span width, no piers, the low chord of the bridge is at 4407.8 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 RCBC show depths from 0.71 to 2.39 and velocities from 0.64 to 4.43 ft/s. See **Appendix F** for 100-year depths and velocities graphics for this option.

5. FEMA FLOODPLAIN (M-21-I) AND WSE ANALYSIS (M-21-J & M-22-Y)

5.1 Structure M-21-I

FEMA has designated the M-21-I 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.

As stated previously, the goal of this project is to provide CDOT with viable options for the replacement of structures within Zone A floodplains that cause zero rise. This will allow a no-rise certification to be completed by the design-build contractor. This certification will be required the Floodplain Development Permit is submitted to Otero County during the next phase of design, unless a LOMC is completed through FEMA.

Proposed RCBC

Based on modeling results, the proposed RCBC will not increase the WSE. Because the top elevation of the opening of the proposed RCBC is lower than the existing opening, there is a slight increase seen immediately upstream and downstream of the RCBC opening due to the increased headwater elevation.

In order to perform a comparison between the existing and proposed WSE, 12 cross sections were cut across the 2D hydraulic model results both upstream and downstream of the proposed bridge. 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 M-21-I

Cross Section	Location Relative to Proposed RCBC	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	4418.10	4418.10	0.00
2	Upstream	4417.78	4417.77	-0.01
3	Upstream	4417.51	4417.47	-0.04
4	Upstream	4417.00	4416.97	-0.03
5	Upstream	4417.03	4416.98	-0.05
6	Upstream	4416.37	4416.42	0.02
7	Downstream	4416.25	4416.32	0.05
8	Downstream	4415.37	4415.44	0.07
9	Downstream	4415.44	4415.46	0.02
10	Downstream	4414.59	4414.59	0.00
11	Downstream	4413.78	4413.78	0.00
12	Downstream	4412.88	4412.88	0.00

Proposed Bridge

Similarly, the model for the proposed bridge will not increase the WSE. The bridge opening for this option is very similar to the existing structure. Therefore, no change in WSE is expected.

For the proposed bridge, upstream of Bridge M-21-I (Cross Sections 1-6), the WSE decreases between 0.03 feet and 0.12 feet between existing and proposed. Downstream of Bridge M-21-I (Cross Sections 7-12), the WSE increases a maximum of 0.05 feet between existing and proposed. Cross Section 9 is located upstream of the railroad bridge and Cross Section 10 is downstream of the railroad.

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 5** also shows a WSE comparison at each section for the proposed bridge option.

Table 5: Comparison of Existing and Proposed Bridge WSE at M-21-I

Cross Section	Location Relative to Proposed Bridge	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	4418.10	4418.10	0.00
2	Upstream	4417.78	4417.78	0.00
3	Upstream	4417.51	4417.51	0.00
4	Upstream	4417.00	4416.95	-0.05
5	Upstream	4417.03	4417.03	0.00
6	Upstream	4416.37	4416.34	-0.03
7	Downstream	4416.25	4416.27	0.02
8	Downstream	4415.37	4415.42	0.05
9	Downstream	4415.42	4415.40	-0.02
10	Downstream	4414.59	4414.54	-0.05
11	Downstream	4413.78	4413.78	0.00
12	Downstream	4412.88	4412.88	0.00

5.2 Structure M-21-J

FEMA has designated the M-21-J project site as a Zone C, as determined by the FIRM 0801320225B effective date August 19, 1985, as shown Appendix A.

FEMA Zone C is not a special flood hazard area inundated by the 100-year flood. Because the existing structure passes the 100-year flood event flows without overtopping the road, the proposed structure must do the same. The CDOT DDM requires all non-jurisdictional flood areas to follow Colorado Water Conservation Board's guidelines, which state that any development or construction should not raise the 100-year flood event WSEs more than 0.5'. While this is not a statewide requirement, best practice is to follow these guidelines.

Proposed RCBC

Based on modeling results, the proposed RCBC will not increase the WSE by more than 0.5 feet. Because the opening height of the proposed RCBC is less than the existing or proposed bridge, there is a slight increase upstream and downstream, but these increases don't exceed 0.5 feet.

In order to perform a comparison between the existing and proposed WSE, 10 cross sections were cut across the 2D hydraulic model results both upstream and downstream of the proposed bridge. 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 6.**

Table 6: Comparison of Existing and Proposed RCBC WSE at M-21-J

Cross Section	Location Relative to Proposed RCBC	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	4406.39	4406.39	0.00
2	Upstream	4404.38	4404.58	0.20
3	Upstream	4404.31	4404.55	0.24
4	Upstream	4404.16	4404.47	0.31
5	Downstream	4404.06	4404.28	0.22
6	Downstream	4404.24	4404.42	0.18
7	Downstream	4403.65	4403.67	0.02
8	Downstream	4400.99	4401.01	0.02
9	Downstream	4398.36	4398.36	0.00
10	Downstream	4396.82	4396.82	0.00

Proposed Bridge

Similarly, the model for the proposed bridge will not increase the WSE by more than 0.5 feet. The bridge opening for this option is very similar to the existing structure. Therefore, no change in WSE is expected.

For the proposed bridge, upstream of Bridge M-21-J (Cross Sections 1-4), the WSE decreases between 0.00 feet and 0.04 feet between existing and proposed. Downstream of Bridge M-21-J (Cross Sections 5-10), the WSE increases a maximum of 0.08 feet between existing and proposed. Cross Section 7 is located upstream of the railroad bridge and Cross Section 8 is downstream of the railroad.

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 7** also shows a WSE comparison at each section for the proposed bridge option.

Table 7: Comparison of Existing and Proposed Bridge WSE at M-21-J

Cross Section	Location Relative to Proposed Bridge	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing

1	Upstream	4406.39	4406.42	0.03
2	Upstream	4404.38	4404.35	-0.03
3	Upstream	4404.31	4404.27	-0.04
4	Upstream	4404.16	4404.16	0.00
5	Downstream	4404.06	4404.09	0.03
6	Downstream	4404.24	4404.28	0.04
7	Downstream	4403.65	4403.57	-0.08
8	Downstream	4400.99	4400.80	-0.19
9	Downstream	4398.36	4398.36	0.00
10	Downstream	4396.82	4396.82	0.00

5.3 Structure M-22-Y

FEMA has designated the M-22-Y project site as a Zone C, as determined by the FIRM 0801320225B effective date August 19, 1985, as shown Appendix A.

FEMA Zone C is not a special flood hazard area inundated by the 100-year flood. Because the existing structure passes the 100-year flood event flows without overtopping the road, the proposed structure must do the same. The CDOT DDM requires all non-jurisdictional flood areas to follow Colorado Water Conservation Board's guidelines, which state that any development or construction should not raise the 100-year flood event WSEs more than 0.5'. While this is not a statewide requirement, best practice is to follow these guidelines.

Proposed RCBC

Based on modeling results, the proposed RCBC will not increase the WSE by more than 0.5 feet. Because the opening of the proposed RCBC is about the same as the existing opening, no change in WSE is expected.

In order to perform a comparison between the existing and proposed WSE, 9 cross sections were cut across the 2D hydraulic model results both upstream and downstream of the proposed bridge. 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 8**.

Table 8: Comparison of Existing and Proposed RCBC WSE at M-22-Y

Cross Section	Location Relative to Proposed RCBC	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	4413.11	4413.08	-0.03
2	Upstream	4410.22	4410.21	-0.01
3	Upstream	4406.91	4406.93	0.02
4	Downstream	4405.69	4405.70	0.01
5	Downstream	4405.56	4405.61	0.05

6	Downstream	4405.53	4405.59	0.06
7	Downstream	4403.48	4403.47	-0.01
8	Downstream	4402.49	4402.49	0.00
9	Downstream	4400.17	4400.17	0.00

Proposed Bridge

Similarly, the model for the proposed bridge will not increase the WSE by more than 0.5 feet. The bridge opening for this option is very similar to the existing structure. Therefore, no change in WSE is expected.

For the proposed bridge, upstream of Bridge M-22-Y (Cross Sections 1-3), the WSE decreases between 0.02 feet and 0.14 feet between existing and proposed. Downstream of Bridge M-22-Y (Cross Sections 4-9), the WSE increases a maximum of 0.02 feet between existing and proposed. Cross Section 6 is located upstream of the railroad bridge and Cross Section 7 is downstream of the railroad.

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 9** also shows a WSE comparison at each section for the proposed bridge option.

Table 9: Comparison of Existing and Proposed Bridge WSE at M-22-Y

Cross Section	Location Relative to Proposed Bridge	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	4413.11	4413.14	0.03
2	Upstream	4410.22	4410.21	-0.01
3	Upstream	4406.91	4406.86	-0.05
4	Downstream	4405.69	4405.71	0.02
5	Downstream	4405.56	4405.56	0.00
6	Downstream	4405.53	4405.53	0.00
7	Downstream	4403.48	4403.48	0.00
8	Downstream	4402.49	4402.49	0.00
9	Downstream	4400.17	4404.17	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 Hoe Ranch 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 C**. Because the bridge option for M-22-Y is not preferred, scour analysis was not provided for this structures.

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

Structure M-21-I

Table 10 below summarizes the preliminary results for scour depths including contraction scour, abutment scour, and long-term scour at the bridge over the seasonal wash.

Table 10: Scour Analysis Results for M-21-I

	Scour Type (ft)			
Storm Event	**Contraction**	**Abutment (Local)**	**Long-Term Degradation**	**Total***
100-Year	4.9	12.3	0.8	13.0

500-Year	7.0	16.0	1.4	17.4

* Contraction Scour is not included in the Total Scour when computing the NCHRP methodology.

Structure M-21-J

Table 11 below summarizes the preliminary results for scour depths including contraction scour, abutment scour, and long-term scour at the bridge over the seasonal wash.

Table 11: Scour Analysis Results for M-21-J

	Scour Type (ft)			
Storm Event	**Contraction**	**Abutment (Local)**	**Long-Term Degradation**	**Total***
100-Year	1.4	3.0	0.3	3.3
500-Year	3.4	5.9	0.4	6.3

* Contraction Scour is not included in the Total Scour when computing the NCHRP methodology.

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, a notable flow contraction upstream of the bridge and highly erosive soils. 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 average velocity in the channel.

Results of the Hydraulic Toolbox analysis are provided in **Appendix H**. A riprap with D50 of 12-inches (in) (Class 3 per HEC-23) is recommended. The resulting recommended thickness is 24-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 each wing wall should extend 25' from the end of the wing walls along the roadway embankment and configured with the data shown in **Tables 12 and 13**. 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.

Structure M-21-I

The riprap apron at each abutment should extend from elevation 4416.25 feet (100-year water surface elevation) down the maximum 2:1 side slope to the channel bottom. Less than 2-ft of freeboard is being proposed for this design due to height limitations between the 100-year water surface elevation and low chord of the bridge. As recommended by CDOT, to account for having freeboard less than 2-ft, 1-ft of flowfill will be placed between the abutment and riprap to protect the abutment from major flood events.

The top of the apron should be flush with the existing grade of the channel. Toeing-in the apron down to the long-term scour depth (elevation 4395.50 feet) is suggested to prevent channel scour undercutting. The upstream and downstream coverage should extend back from the abutment (e.g. perpendicular to the channel) 25 feet to protect the approach embankment.

Table 12: M-21-I Countermeasure Summary

Countermeasure	D_{50}(in)	Recommended Thickness (in)	Side Slopes	Toe Down Depth (ft)	Bottom Ref. Elevation (ft)	Top Ref. Elevation (ft)
Riprap Apron	12	24	2:1	13	4395.5	4418
Wing Walls	N/A	N/A	N/A	13	4395.5	4418

Structure M-21-J

The riprap apron at each abutment should extend from elevation 4404.06 feet (100-year water surface elevation) down the maximum 2:1 side slope to the channel bottom. The minimum recommended freeboard is 2-ft, which is provided at this bridge.

The top of the apron should be flush with the existing grade of the channel. Toeing-in the apron down to the long-term scour depth (elevation 4395.50 feet) is suggested to prevent channel scour undercutting. The upstream and downstream coverage should extend back from the abutment (e.g. perpendicular to the channel) 25 feet to protect the approach embankment.

Table 13: M-21-J Countermeasure Summary

Countermeasure	D_{50}(in)	Recommended Thickness (in)	Side Slopes	Toe Down Depth (ft)	Bottom Ref. Elevation (ft)	Top Ref. Elevation (ft)
Riprap Apron	9	18	2:1	4	4394.0	4404
Wing Walls	N/A	N/A	N/A	4	4395.5	4404

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. If large scour holes were estimated, energy dissipation was then considered.

The energy dissipation alternative selected for the M-21-I, M-21-J, and M-22-Y RCBC outlets is a concrete apron based on the Froude numbers of 0.28, 0.32, and 0.52, respectively, which are all 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 – Bridges M-21-I, M-21-J, and M-22-Y. 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 bridges and compare the WSEs and velocities to the proposed design. This model was utilized to optimize the proposed solution to replacement of the existing bridges.

Based on the hydraulic analysis, the proposed replacement for the M-21-I bridge is a single-span 72-foot span length bridge. The recommended freeboard is 2 feet and the proposed WSE 100 feet upstream of the proposed bridge is 4416.97 feet, giving a final recommended bridge low chord of 4418.97 feet. The proposed low chord is 4416.0 which does not meet the 2 feet of freeboard. However, this condition is not worse than the existing condition.

Based on the hydraulic analysis, the proposed replacement for the M-21-J bridge is a single-span 51-foot span length bridge. The recommended freeboard is 2 feet and the proposed WSE 100 feet upstream of the proposed bridge is 4404.27 feet, giving a final recommended bridge low chord of 4406.27 feet. The proposed low chord is 4404.50 which does not meet the 2 feet of freeboard. However, this condition is not worse than the existing condition.

Based on the hydraulic analysis, the proposed replacement for the M-22-Y bridge is a 2 cell 6-ft by 4-ft reinforced box culvert. There is no rise in the 100-year water surface elevation at this

structure. The headwater elevation at the culvert entrance is 2.38 ft and the Headwater to depth (HW/D) ration is 0.60 which meets CDOT requirements for HW/D of 1.5 for this culvert. Velocity through the culvert is 1.98 ft/s which is less than the maximum velocity for culverts according to the DDM.

Floodplain analysis demonstrates that the proposed bridge opening at M-21-I 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.

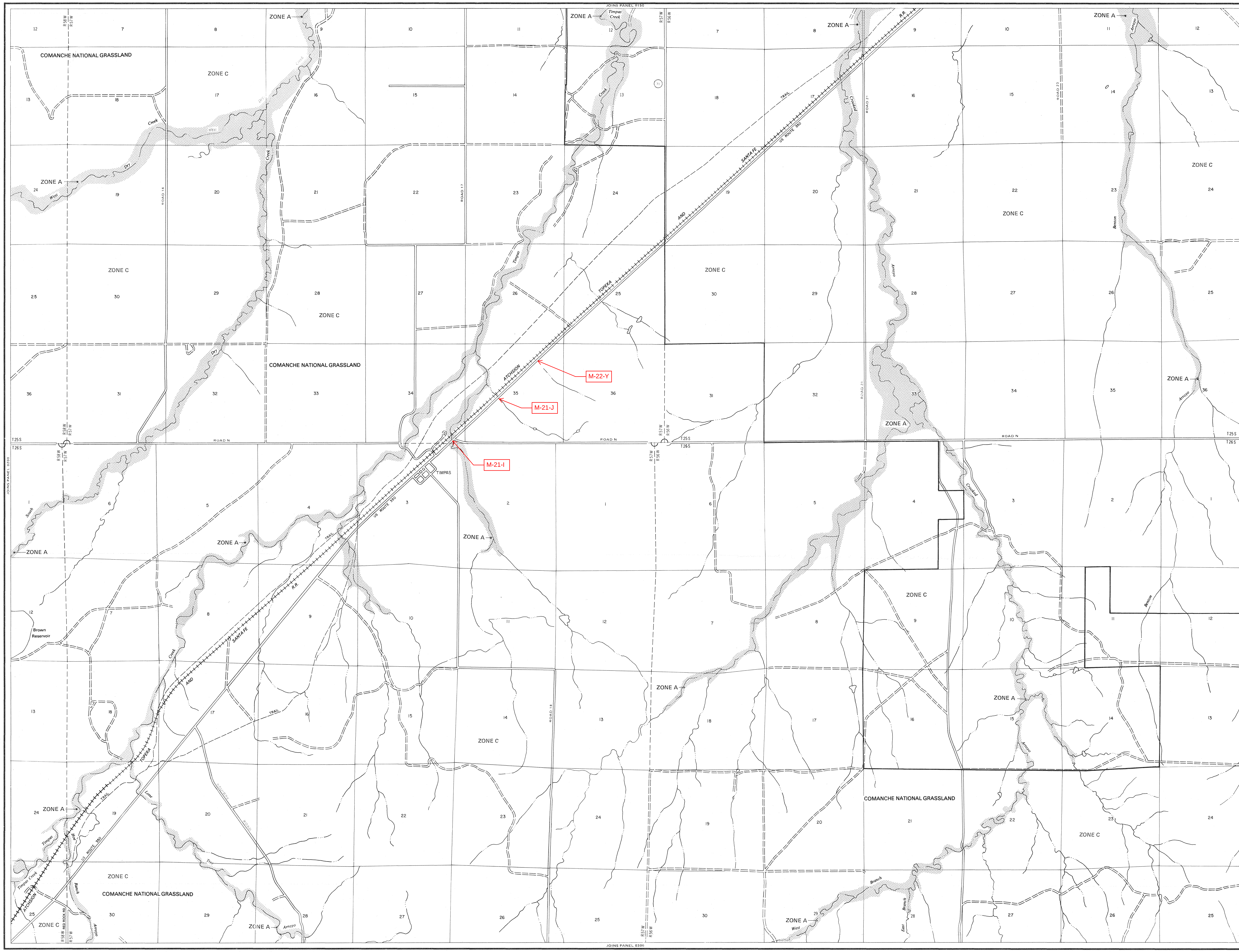
Total design scour for the M-21-I bridge abutments was determined to be 17.4 feet at the 500-year design event. This accounts for the local scour and long-term degradation impacts that could potentially affect the proposed bridge abutments. A riprap apron was designed in order to protect the proposed abutments.

Total design scour for the M-21-J bridge abutments was determined to be 6.3 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.

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 0801320225B



KEY TO MAP

SPECIAL FLOOD HAZARD AREA — ZONE A / ZONE B

Base Flood Elevation Line With Elevation In Feet**	513
Base Flood Elevation in Feet Where Uniform Within Zone**	(EL 987)
Elevation Reference Mark	RM7×
Zone D Boundary	— — —
River Mile	•M1.5

**Referenced to the National Geodetic Vertical Datum of 1929

EXPLANATION OF ZONE DESIGNATIONS

ZONE	EXPLANATION
A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
A0	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined.
AH	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
A99	Areas of 100-year flood to be protected by flood protection system under construction; base flood elevations and flood hazard factors not determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (Medium shading)
C	Areas of minimal flooding. (No shading)
D	Areas of undetermined, but possible, flood hazards.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
V1-V30	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors determined.

NOTES TO USER

Certain areas not in the special flood hazard areas (zones A and V) may be protected by flood control structures.

This map is for flood insurance purposes only; it does not necessarily show all areas subject to flooding in the community or all planimetric features outside special flood hazard areas.

For adjoining map panels, see separately printed Index To Map Panels.

INITIAL IDENTIFICATION:
NOVEMBER 22, 1974

FLOOD HAZARD BOUNDARY MAP REVISIONS:
NOVEMBER 8, 1977

FLOOD INSURANCE RATE MAP EFFECTIVE:
AUGUST 19, 1985

Refer to the FLOOD INSURANCE RATE MAP EFFECTIVE date shown on this map to determine when actuarial rates apply to structures in the zones where elevations or depths have been established.

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

APPROXIMATE SCALE IN FEET
2000 0 2000

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

OTERO COUNTY, COLORADO (UNINCORPORATED AREAS)

PANEL 225 OF 325
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
080132 0225 B

EFFECTIVE DATE:
AUGUST 19, 1985

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 Otero County, Colorado

November 11, 2020

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.

Custom Soil Resource Report
Soil Map

Map Scale: 1:2,080 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0 30 60 120 180

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

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	10.5	100.0%
Totals for Area of Interest		**10.5**	**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

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

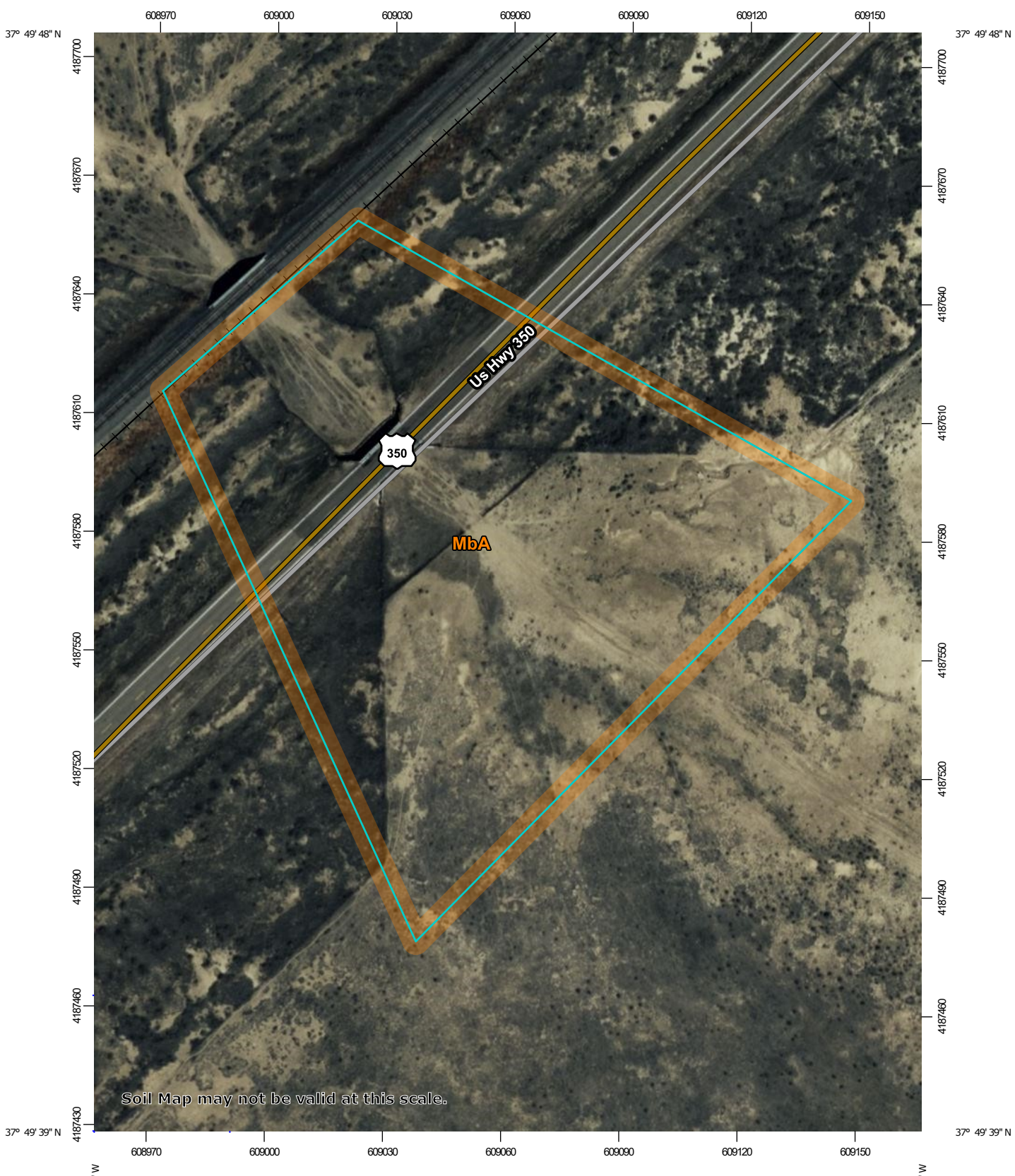
Custom Soil Resource Report for Otero County, Colorado

November 11, 2020

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.

Custom Soil Resource Report
Soil Map



Map Scale: 1:1,350 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0 20 40 80 120

Feet: 0 50 100 200 300

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 1:15,800.

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	3.9	100.0%
Totals for Area of Interest		**3.9**	**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.

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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

United States Department of Agriculture

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Custom Soil Resource Report for Otero County, Colorado

November 11, 2020

Soil Map

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Custom Soil Resource Report
Soil Map

Map Scale: 1:499 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0 5 10 20 30

Feet: 0 20 40 80 120

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

MAP LEGEND

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

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- Soil Map Unit Polygons
- Soil Map Unit Lines
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Special Point Features
- Blowout
- Borrow Pit
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- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
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- Very Stony Spot
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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	0.5	100.0%
Totals for Area of Interest		**0.5**	**100.0%**

Map Unit Descriptions

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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.

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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

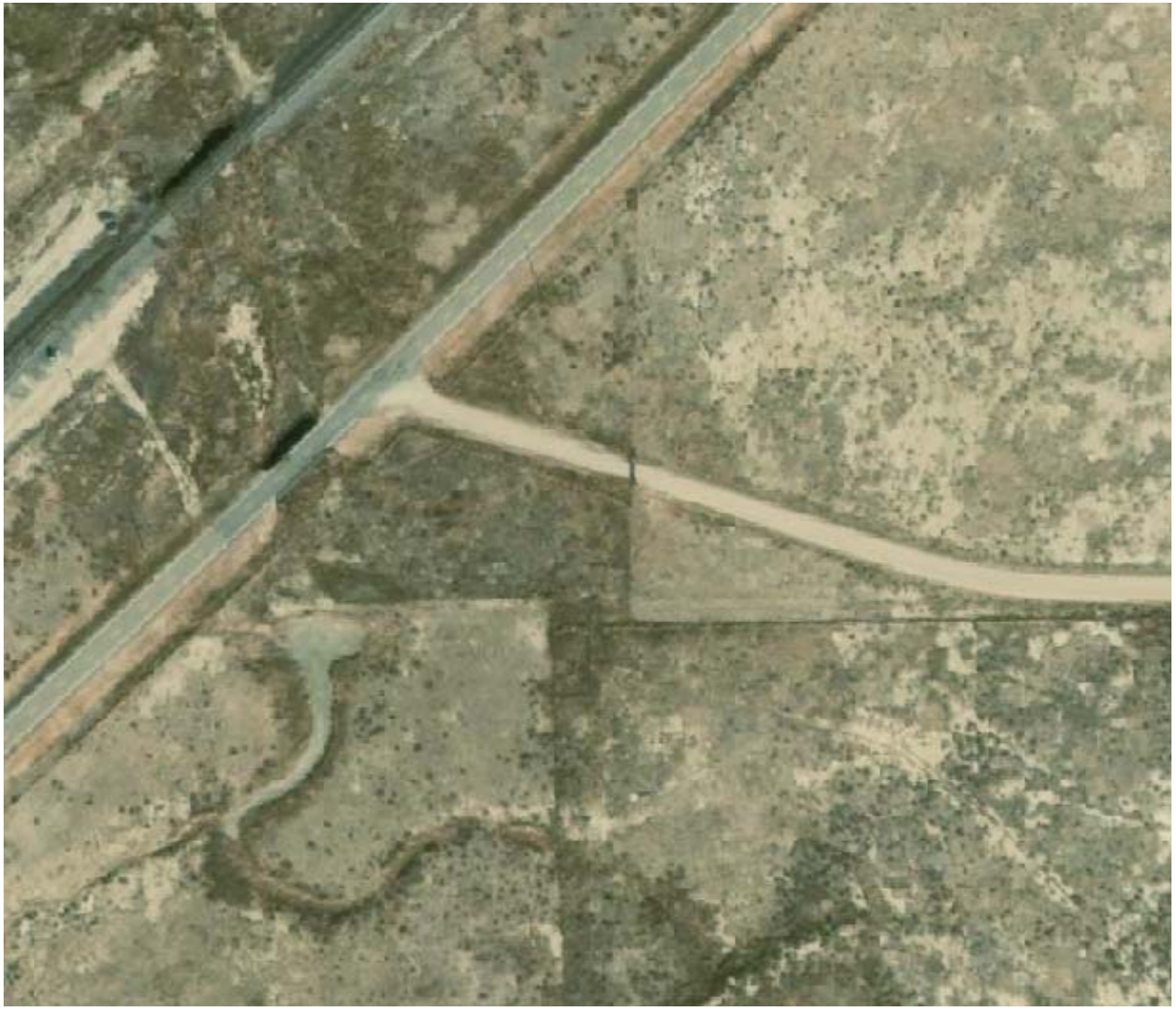
Haversid

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

APPENDIX C AERIAL IMAGERY AND PHOTOS



AERIAL IMAGERY AND PHOTOS
STRUCTURE M-21-I
FIGURE 1

AERIAL IMAGERY AND PHOTOS

STRUCTURE M-21-I

FIGURE 2

AERIAL IMAGERY AND PHOTOS

STRUCTURE M-21-I

FIGURE 3

AERIAL IMAGERY AND PHOTOS
STRUCTURE M-21-J
FIGURE 4

AERIAL IMAGERY AND PHOTOS

STRUCTURE M-21-J

FIGURE 5

AERIAL IMAGERY AND PHOTOS
STRUCTURE M-21-J
FIGURE 6

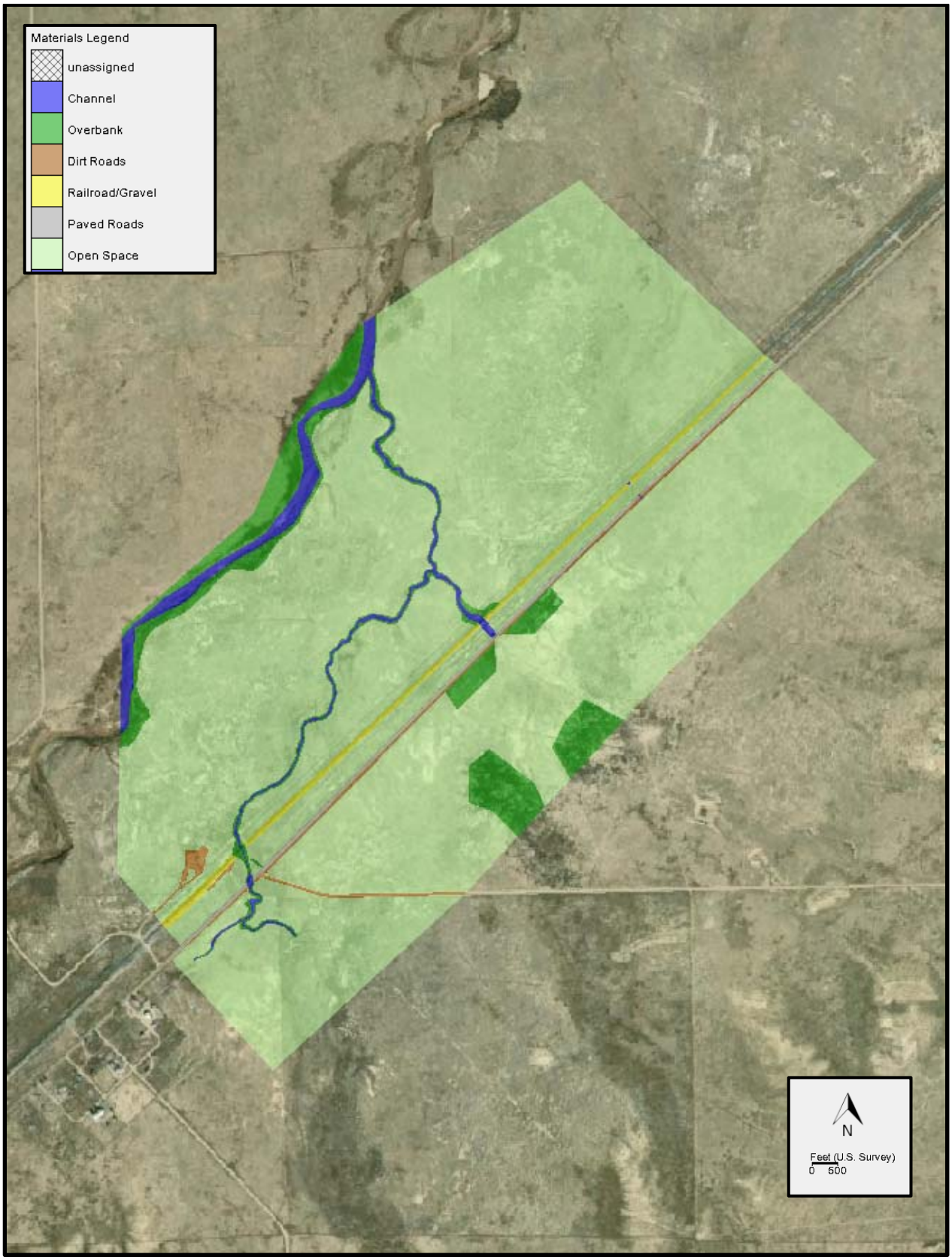
AERIAL IMAGERY AND PHOTOS
STRUCTURE M-21-J
FIGURE 7

AERIAL IMAGERY & PHOTOS
STRUCTURE M-22-Y
FIGURE 8

AERIAL IMAGERY & PHOTOS
STRUCTURE M-22-Y
FIGURE 9

AERIAL IMAGERY & PHOTOS
STRUCTURE M-22-Y
FIGURE 10

APPENDIX D EXISTING CONDITIONS MODEL GRAPHICS

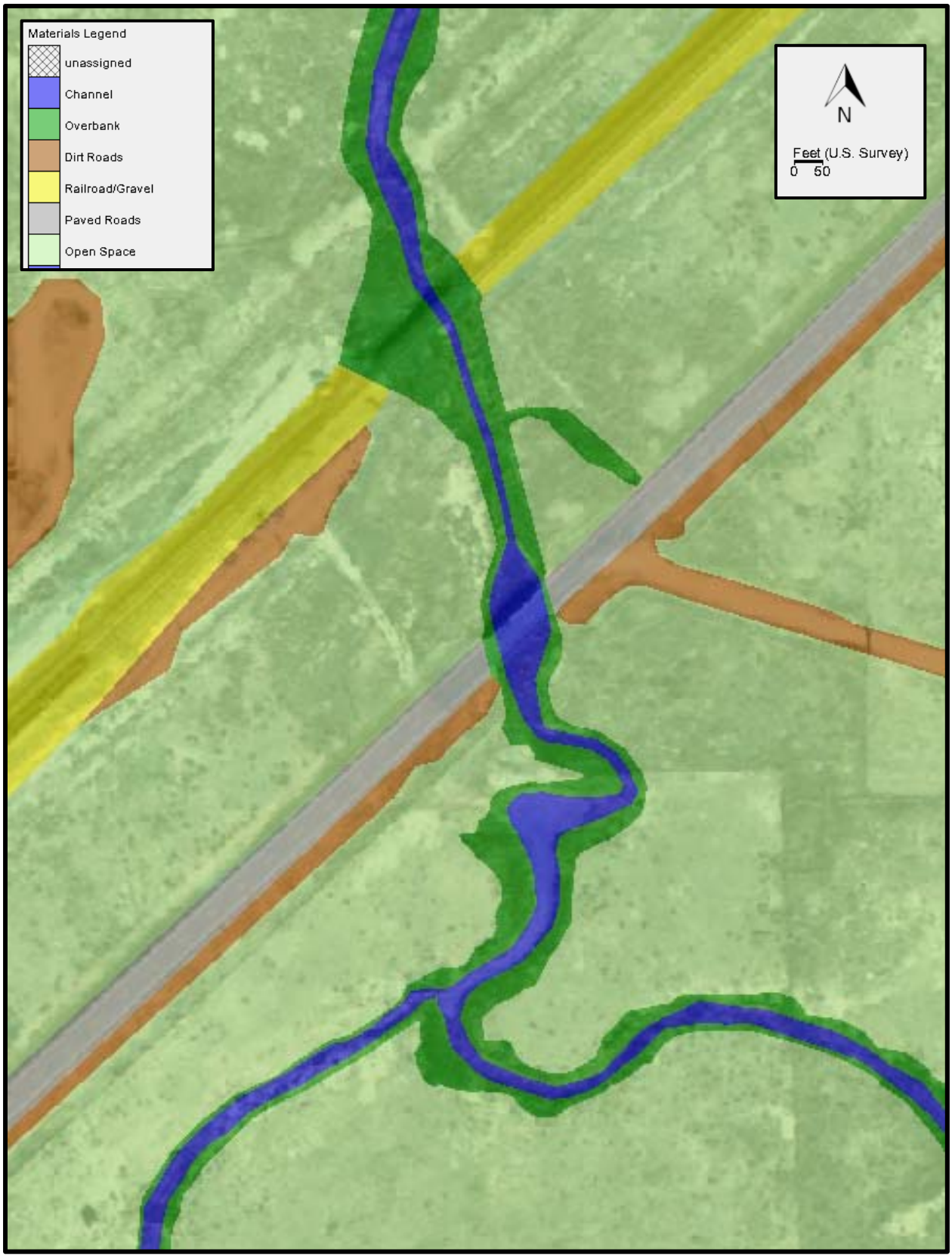


CDOT REGION 2 – BRIDGE BUNDLE

MATERIALS COVERAGE

STRUCTURES M-21-I, M-21-J & M-22-Y

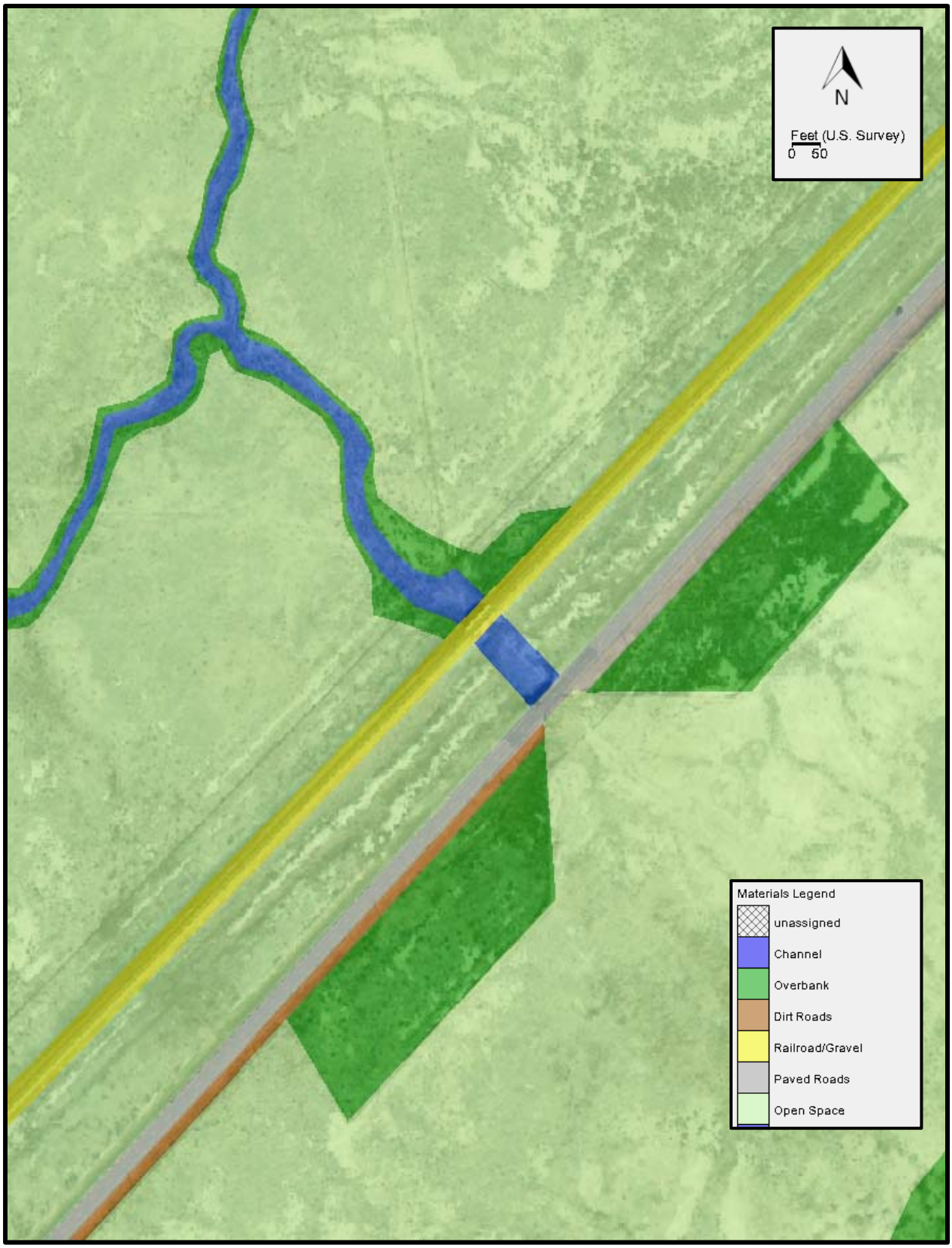
FIGURE 1



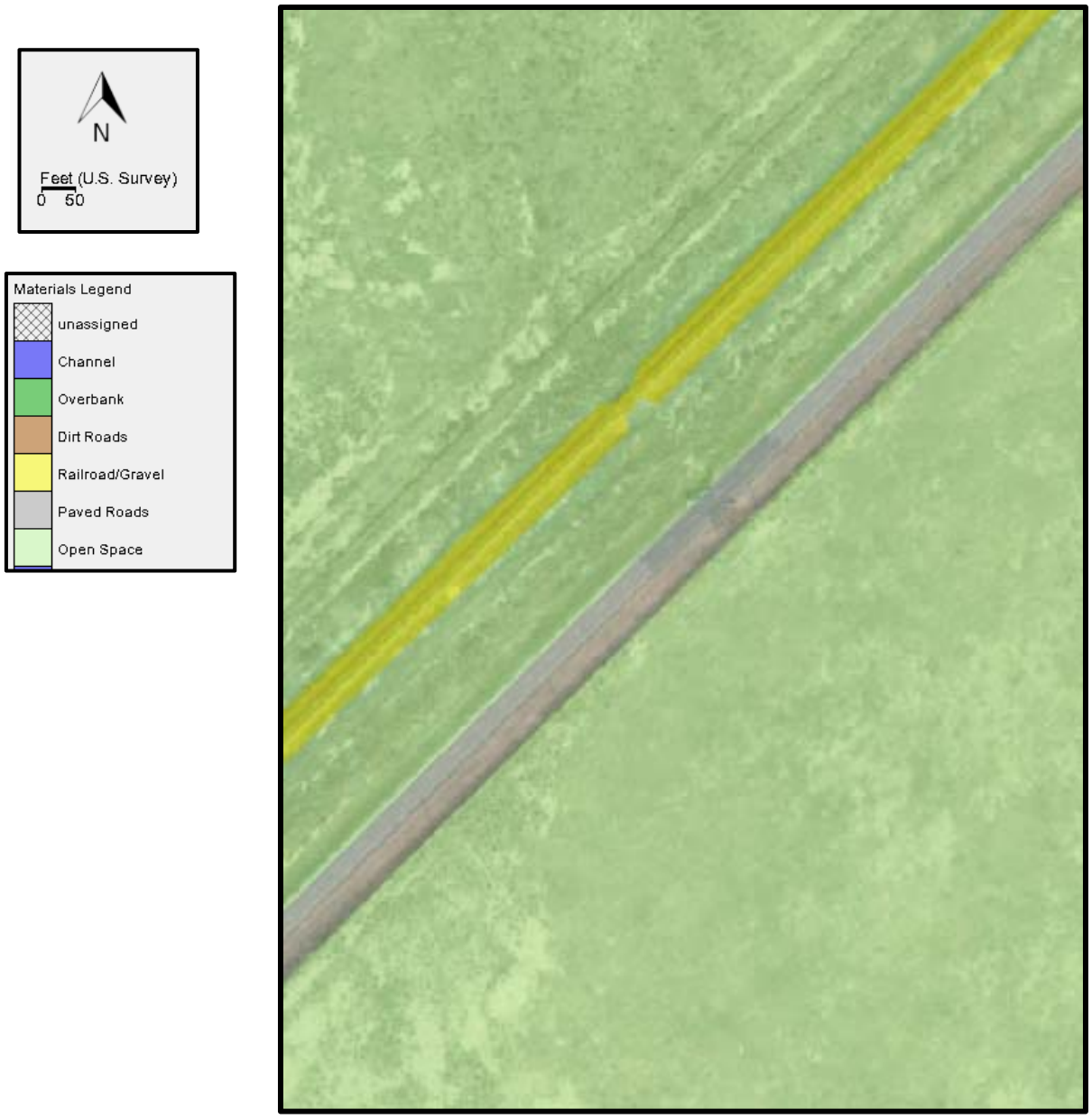
MATERIALS COVERAGE

STRUCTURE M-21-I

FIGURE 2



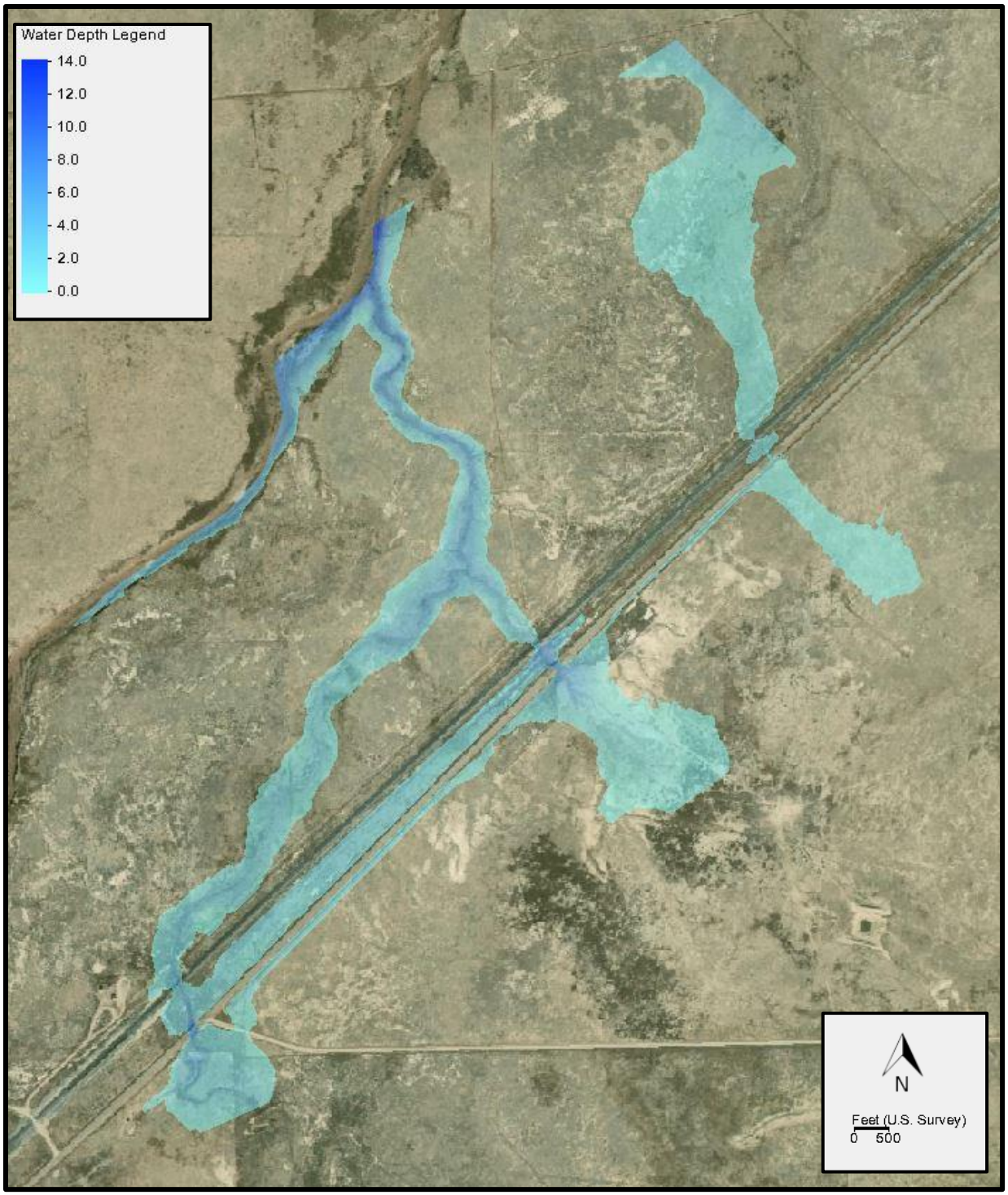
MATERIALS COVERAGE
STRUCTURE M-21-J
FIGURE 3



MATERIALS COVERAGE

STRUCTURE M-22-Y

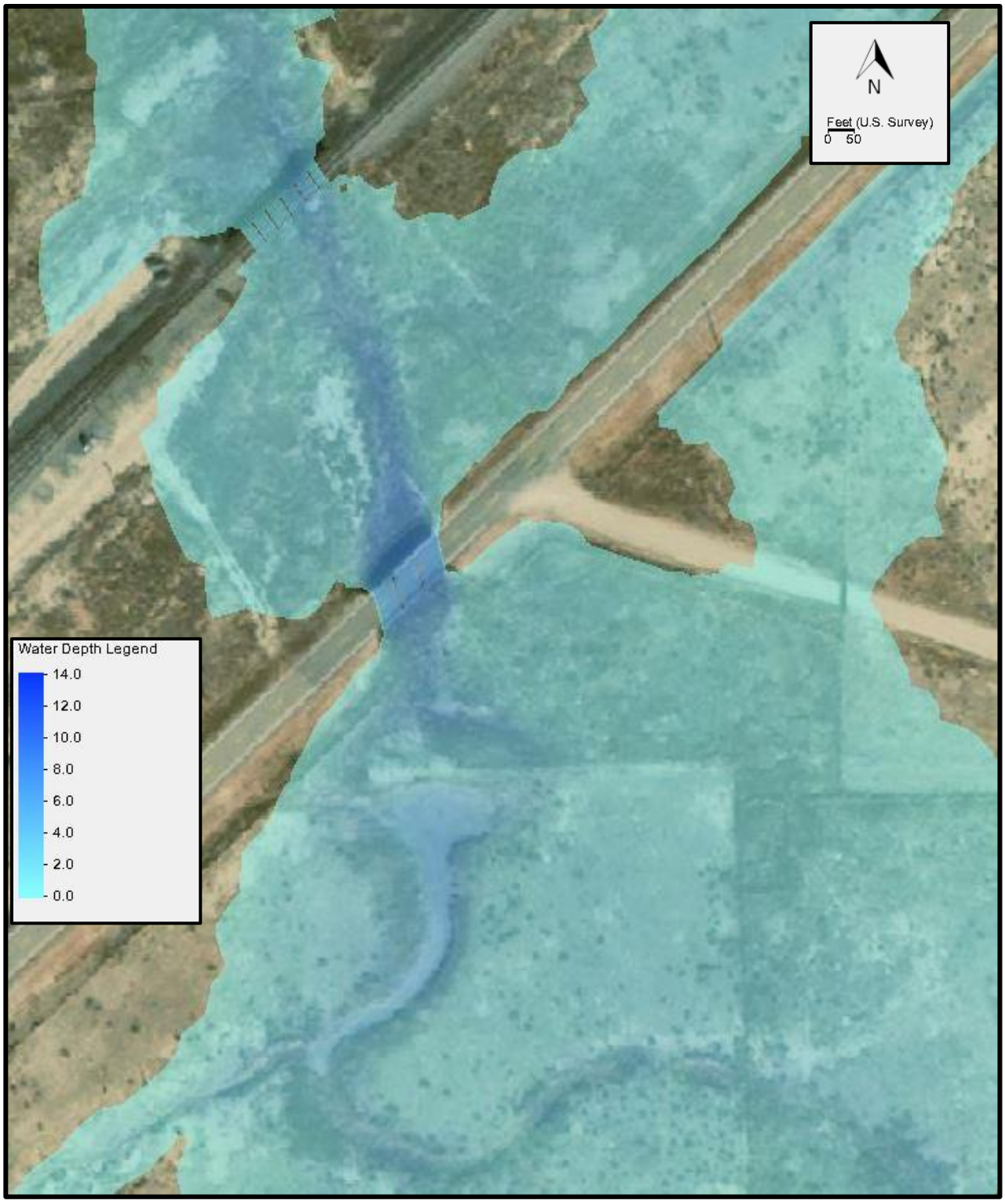
FIGURE 4



EXISTING CONDITIONS – WATER DEPTH

STRUCTURES M-21-I, M-21-J & M-22-Y

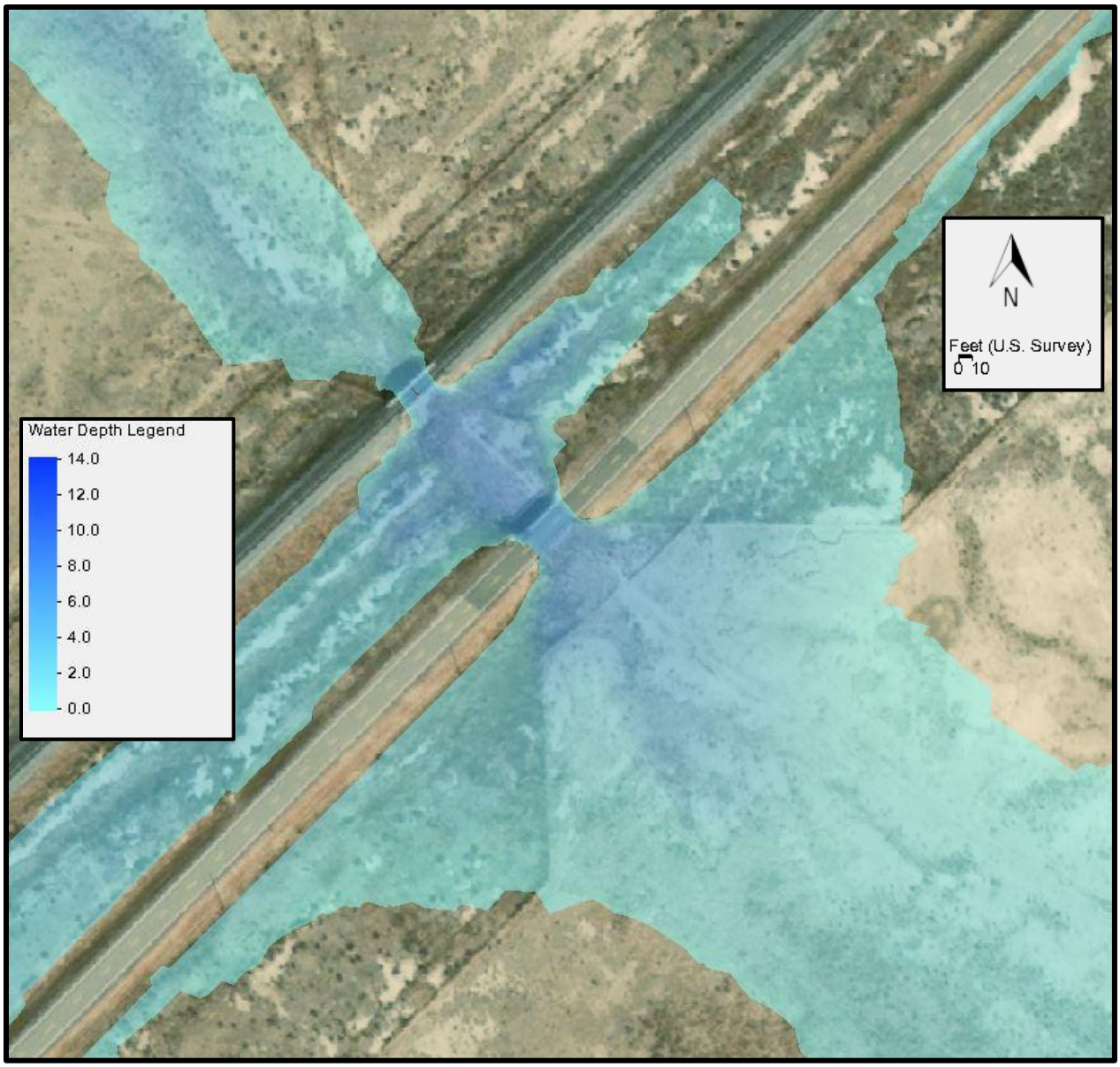
FIGURE 5



EXISTING CONDITIONS – WATER DEPTH

STRUCTURE M-21-I

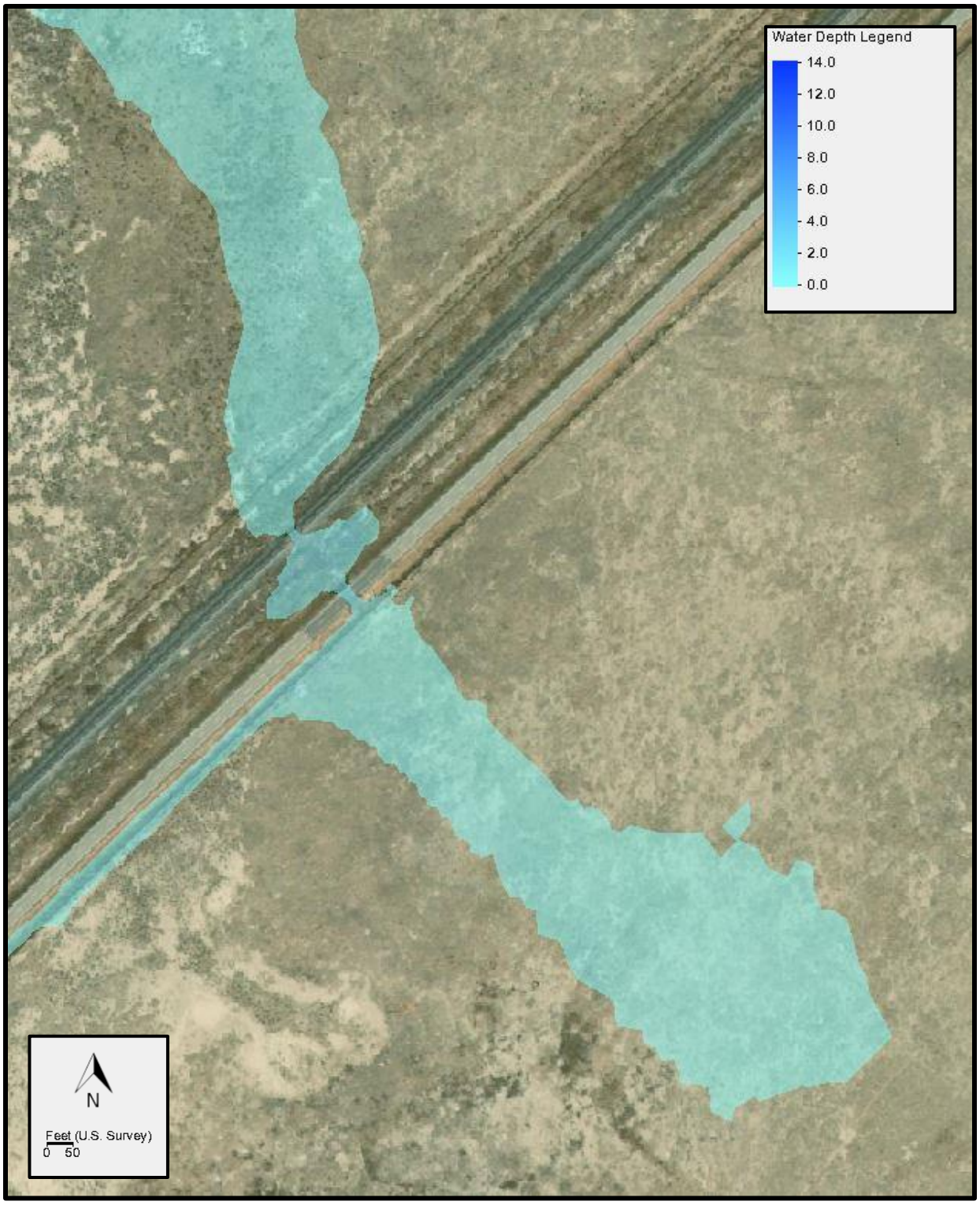
FIGURE 6



EXISTING CONDITIONS – WATER DEPTH

STRUCTURE M-21-J

FIGURE 7



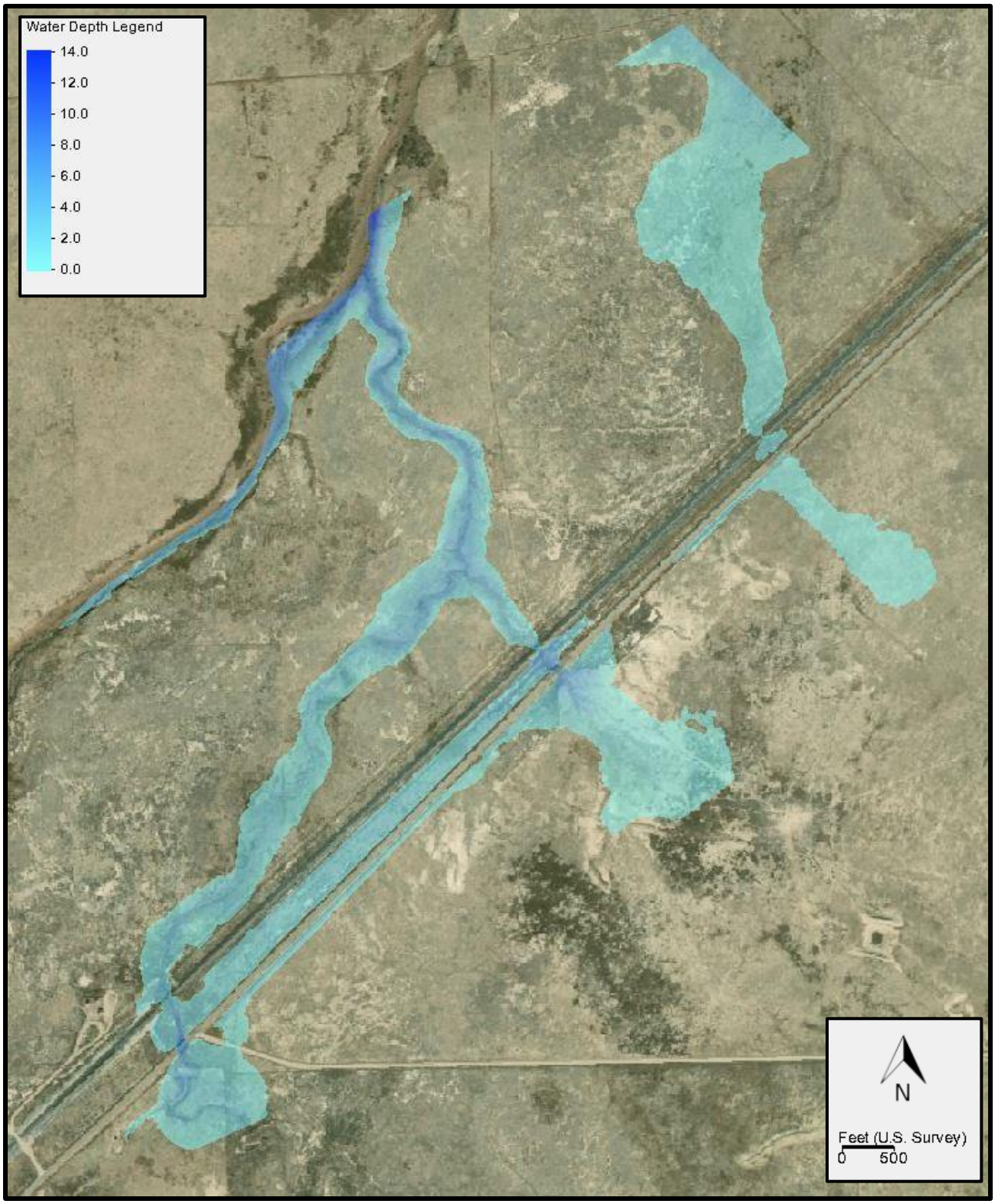
S

EXISTING CONDITIONS – WATER DEPTH

STRUCTURE M-22-Y

FIGURE 8

APPENDIX E PROPOSED RCBC ALTERNATIVE MODEL GRAPHICS

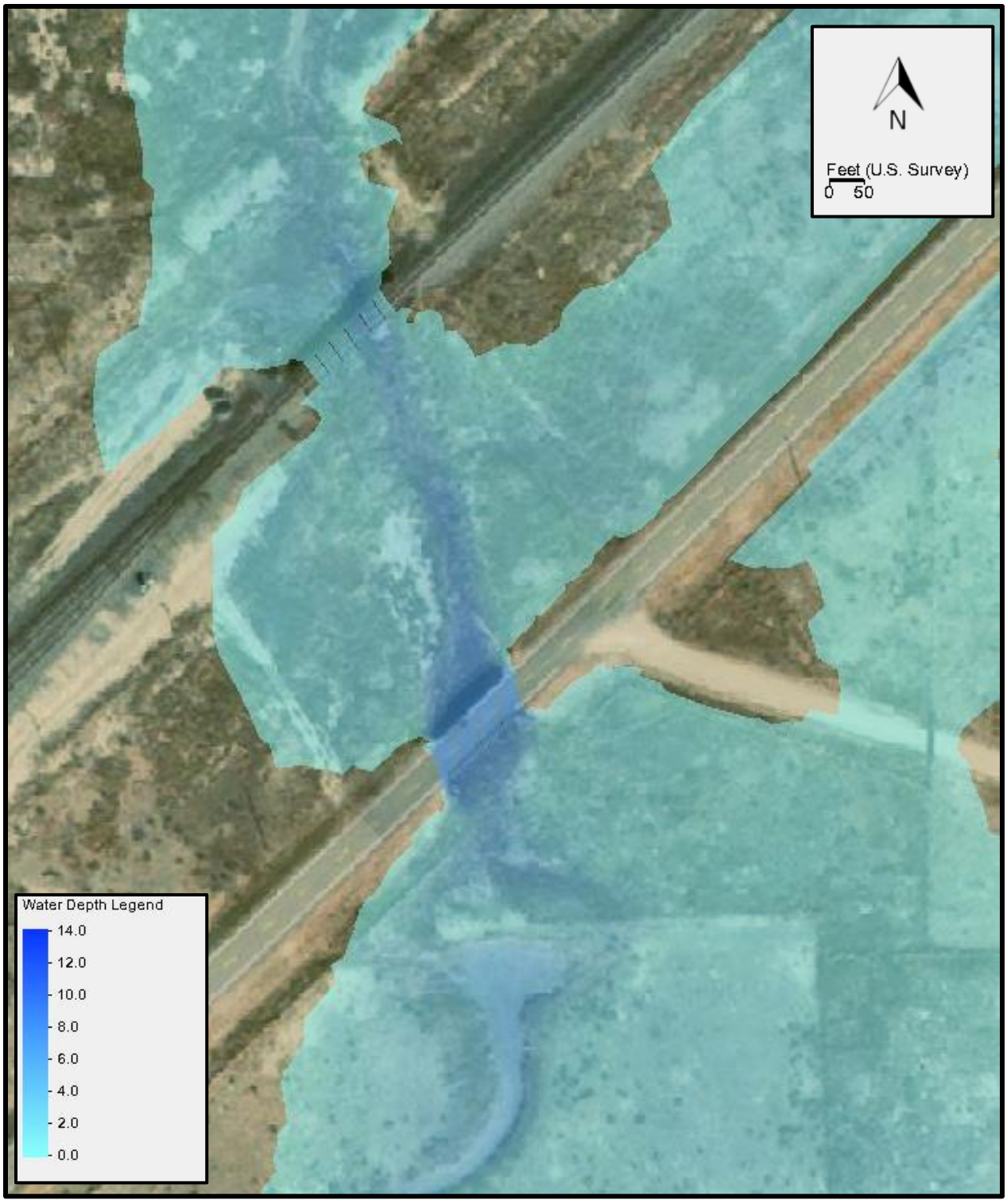


CDOT REGION 2 – BRIDGE BUNDLE

PROPOSED CONDITIONS – WATER DEPTH

STRUCTURES RCBC AT M-21-I, M-21-J & M-22-Y

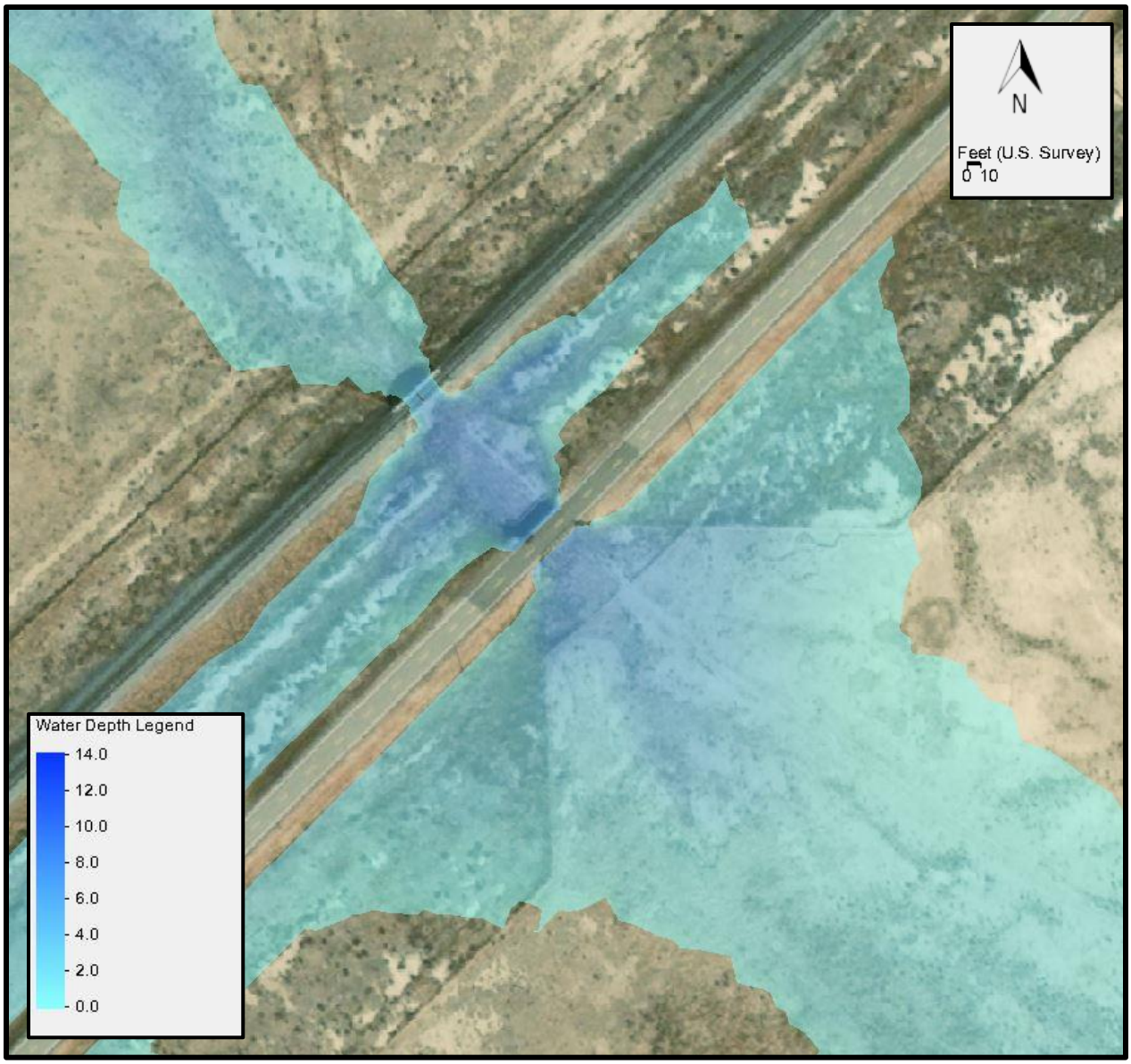
FIGURE 1



PROPOSED CONDITIONS – WATER DEPTH

RCBC AT STRUCTURE M-21-I

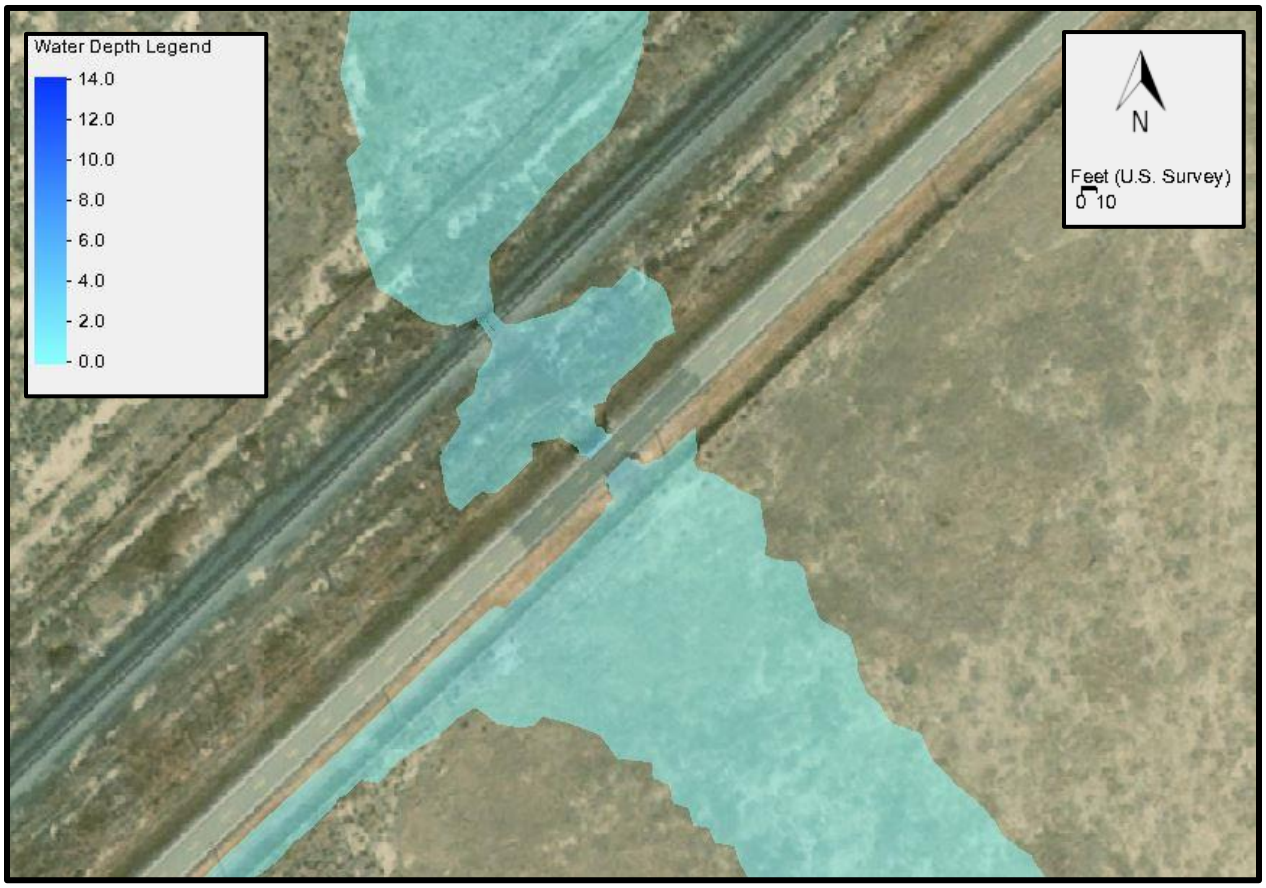
FIGURE 2



PROPOSED CONDITIONS – WATER DEPTH

RCBC AT STRUCTURE M-21-J

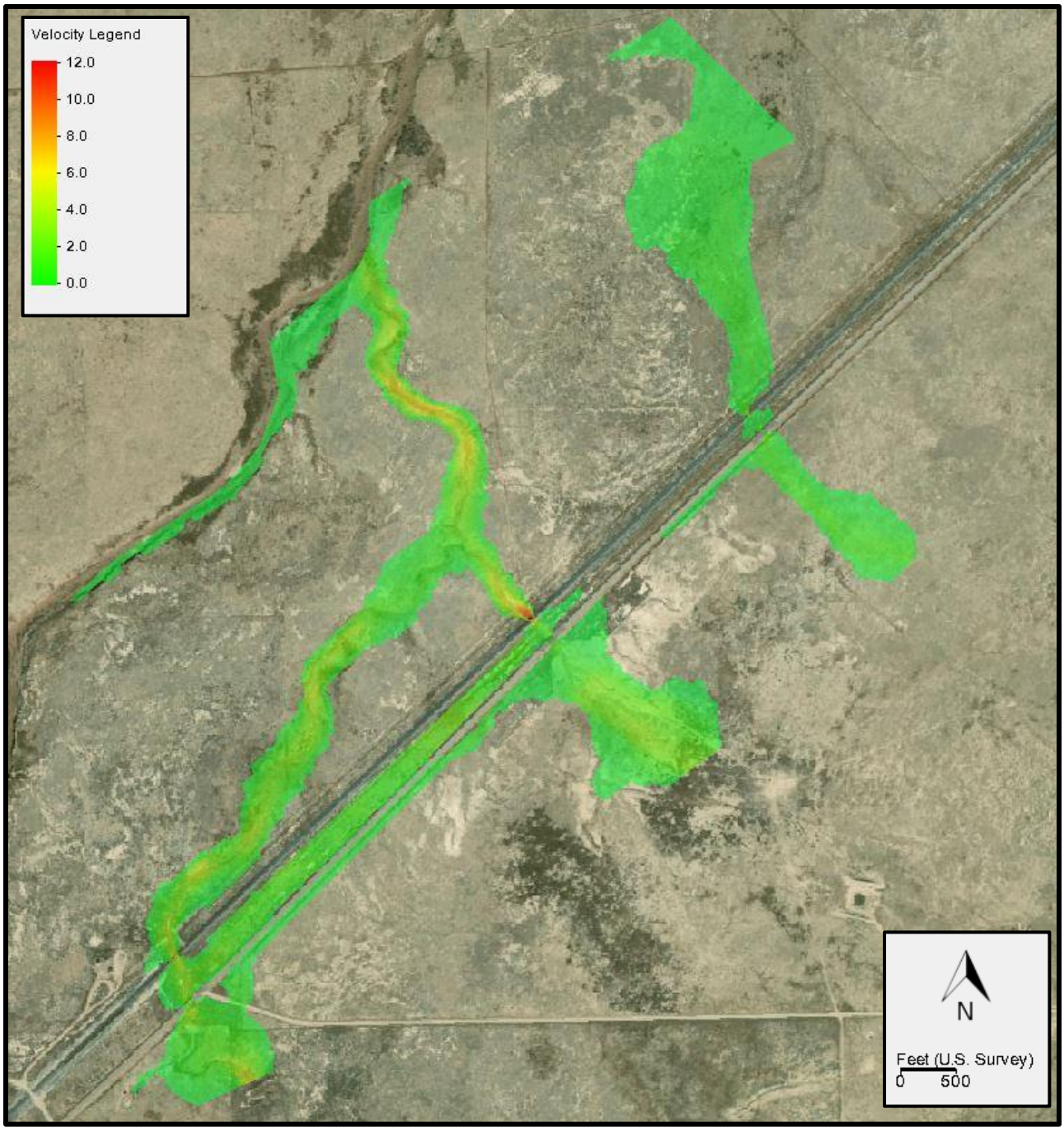
FIGURE 3



PROPOSED CONDITIONS – WATER DEPTH

RCBC AT STRUCTURE M-22-Y

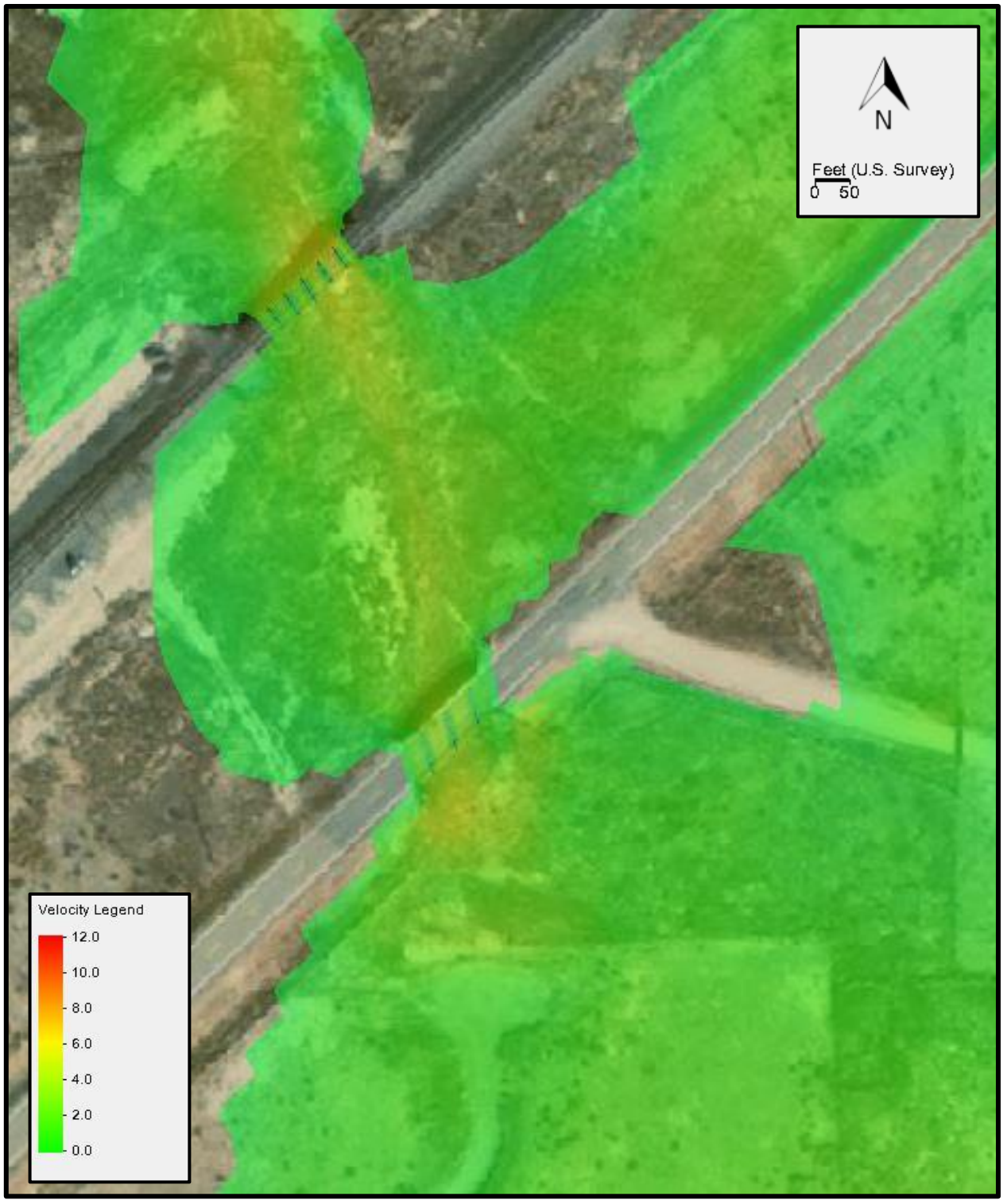
FIGURE 4



PROPOSED CONDITIONS – VELOCITY

RCBC AT STRUCTURES M-21-I, M-21-J & M-22-Y

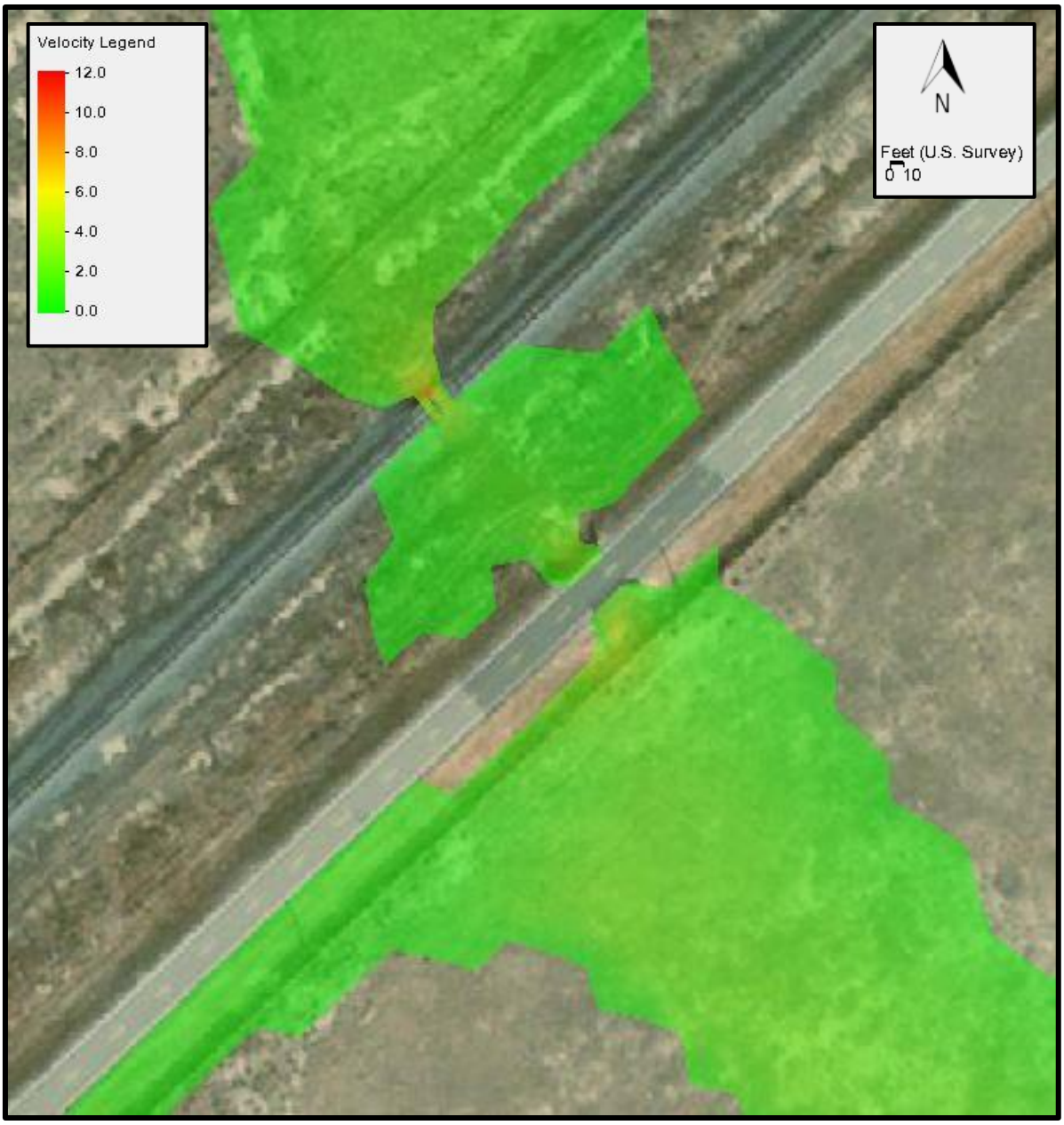
FIGURE 5



PROPOSED CONDITIONS – VELOCITY

RCBC AT STRUCTURE M-21-I

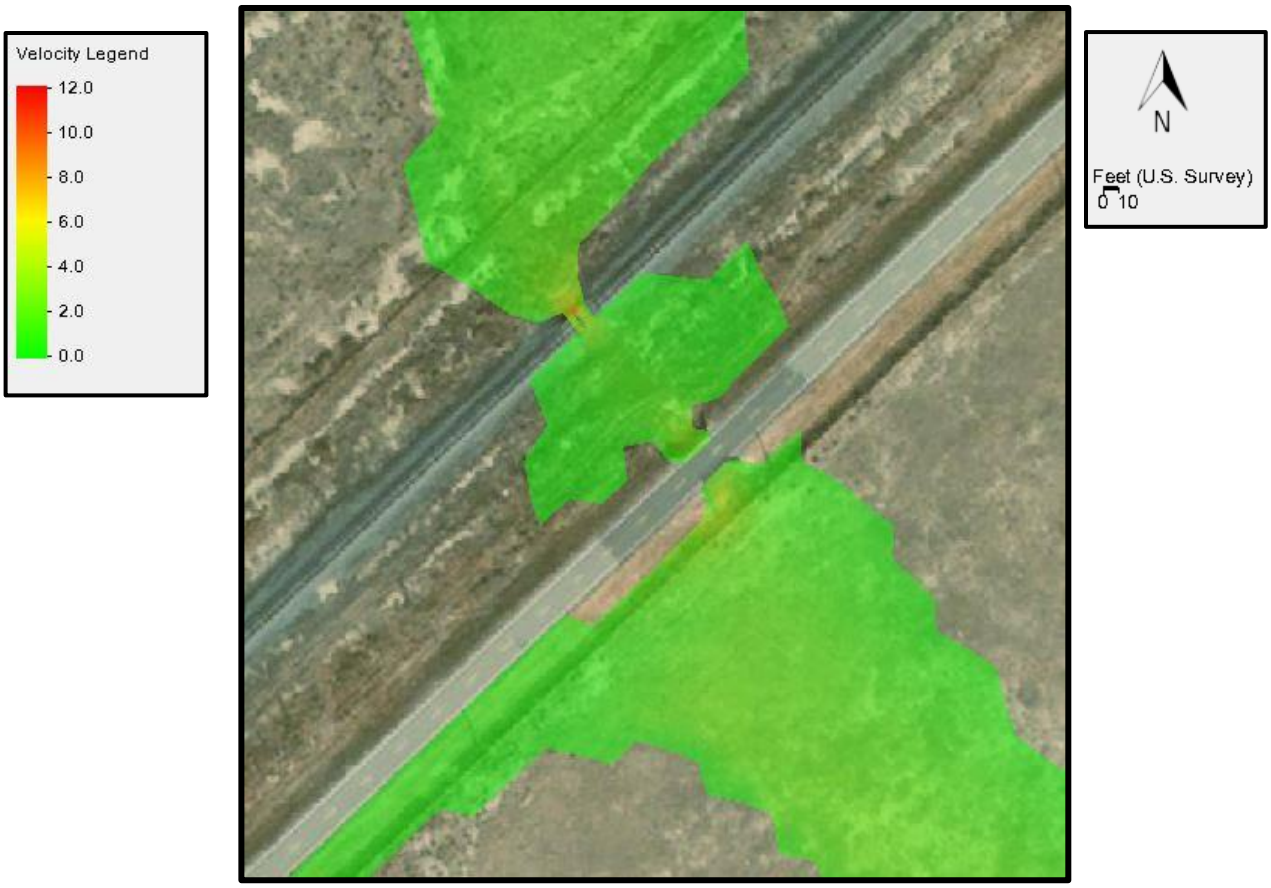
FIGURE 6



PROPOSED CONDITIONS – VELOCITY

RCBC AT STRUCTURE M-21-J

FIGURE 7

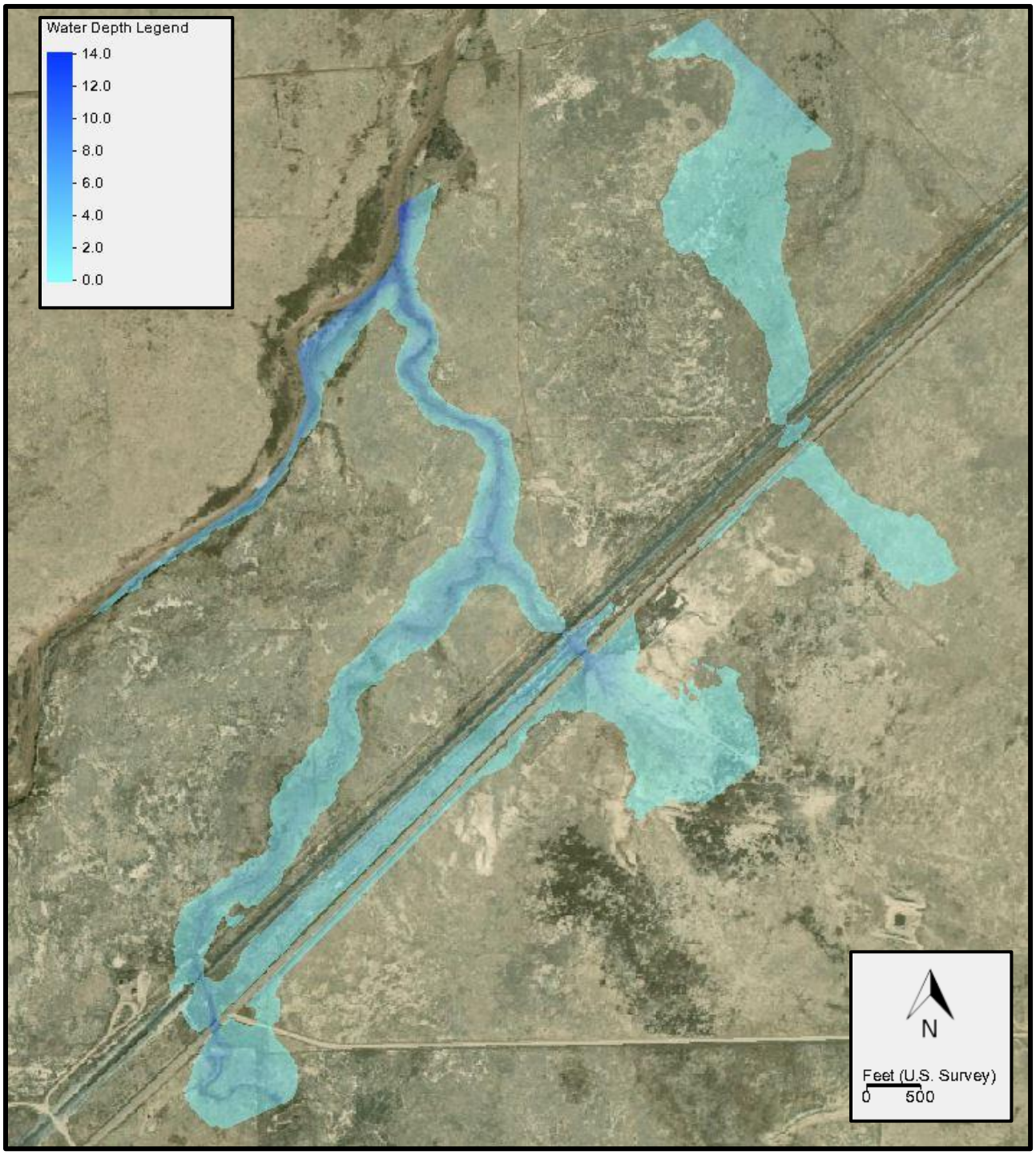


PROPOSED CONDITIONS – VELOCITY

RCBC AT STRUCTURE M-22-Y

FIGURE 8

APPENDIX F PROPOSED BRIDGE ALTERNATIVE MODEL GRAPHICS

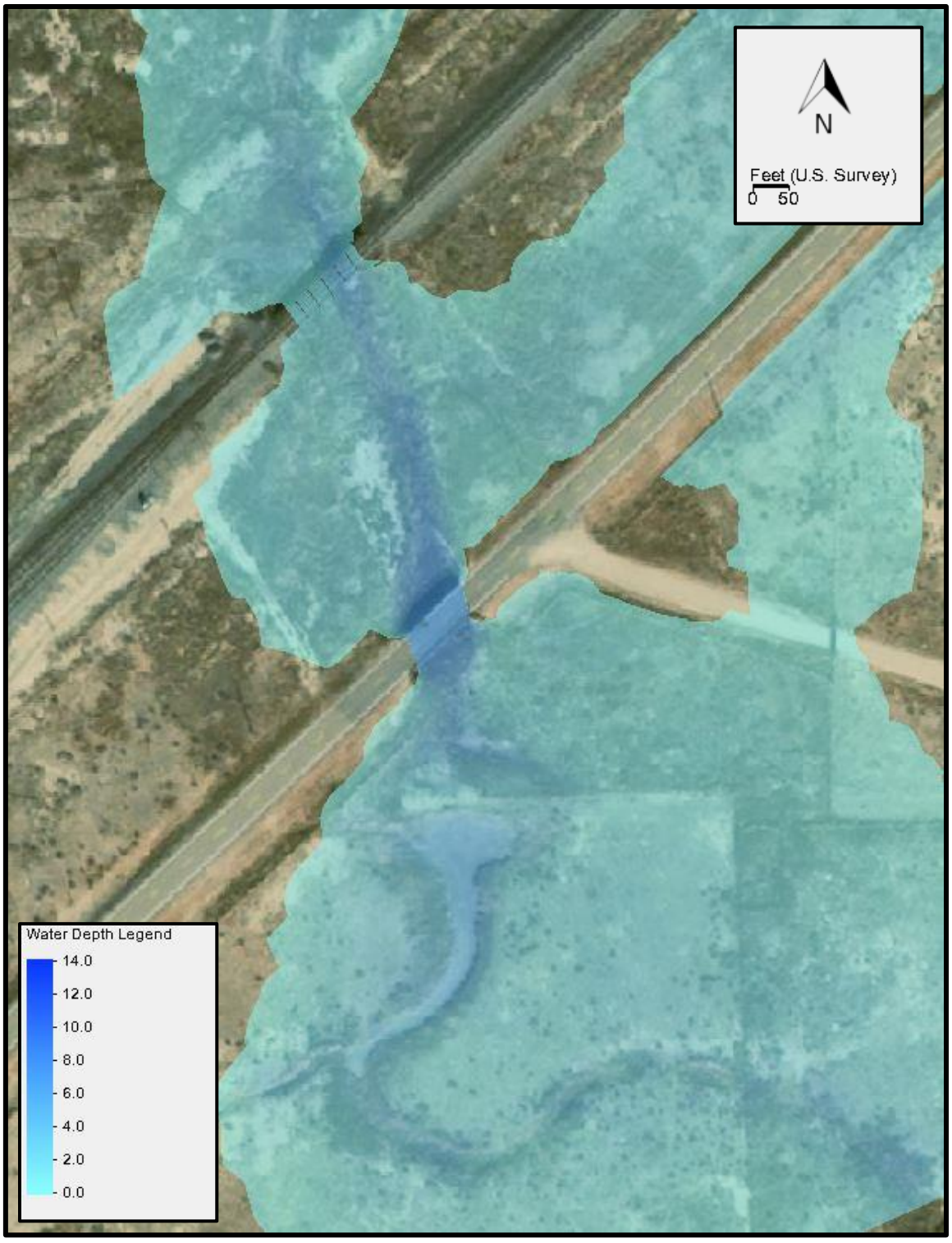


CDOT REGION 2 – BRIDGE BUNDLE

PROPOSED CONDITIONS – WATER DEPTH

BRIDGES AT STRUCTURES M-21-I, M-21-J & M-22-Y

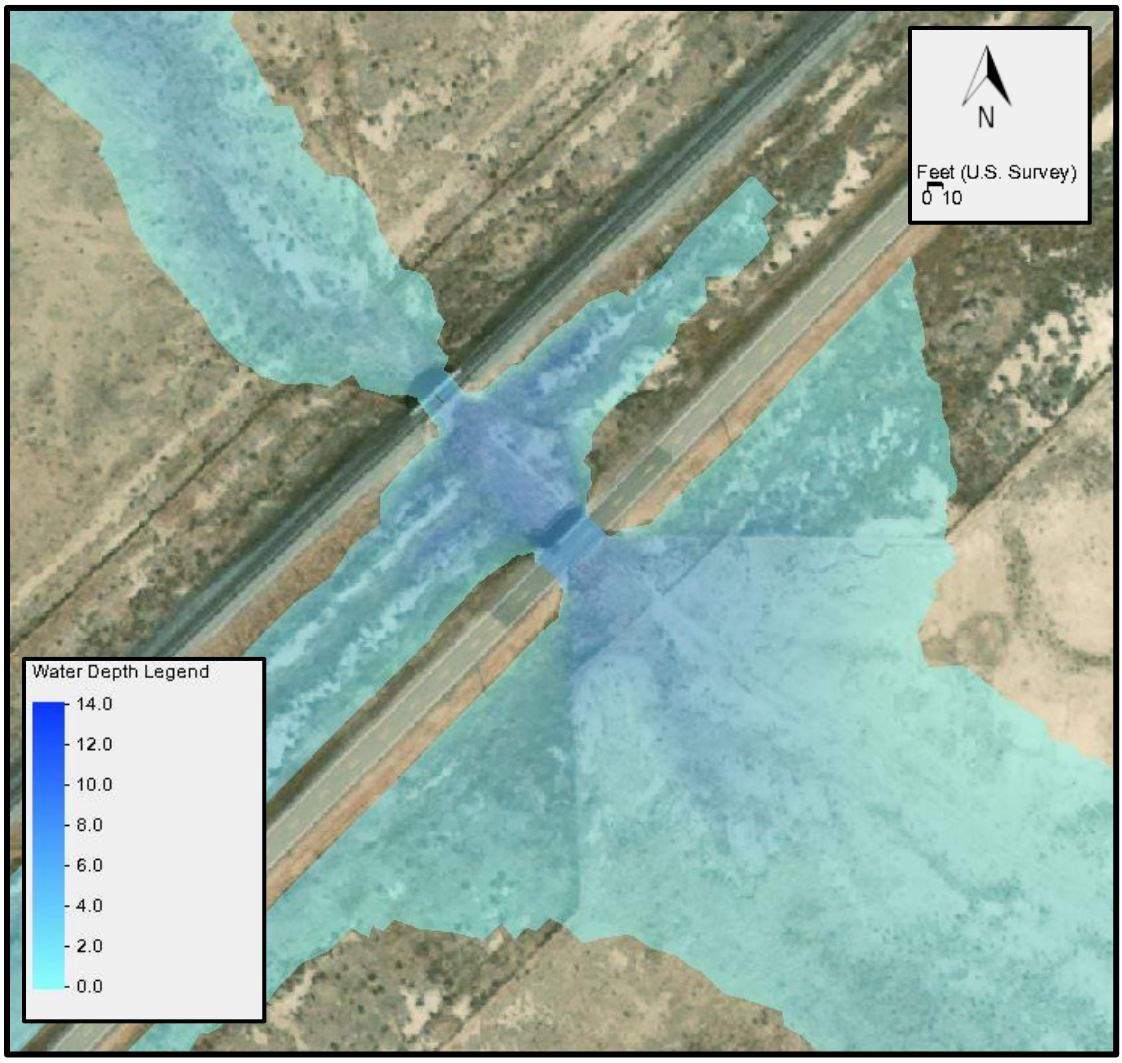
FIGURE 1



PROPOSED CONDITIONS – WATER DEPTH

BRIDGE AT STRUCTURE M-21-I

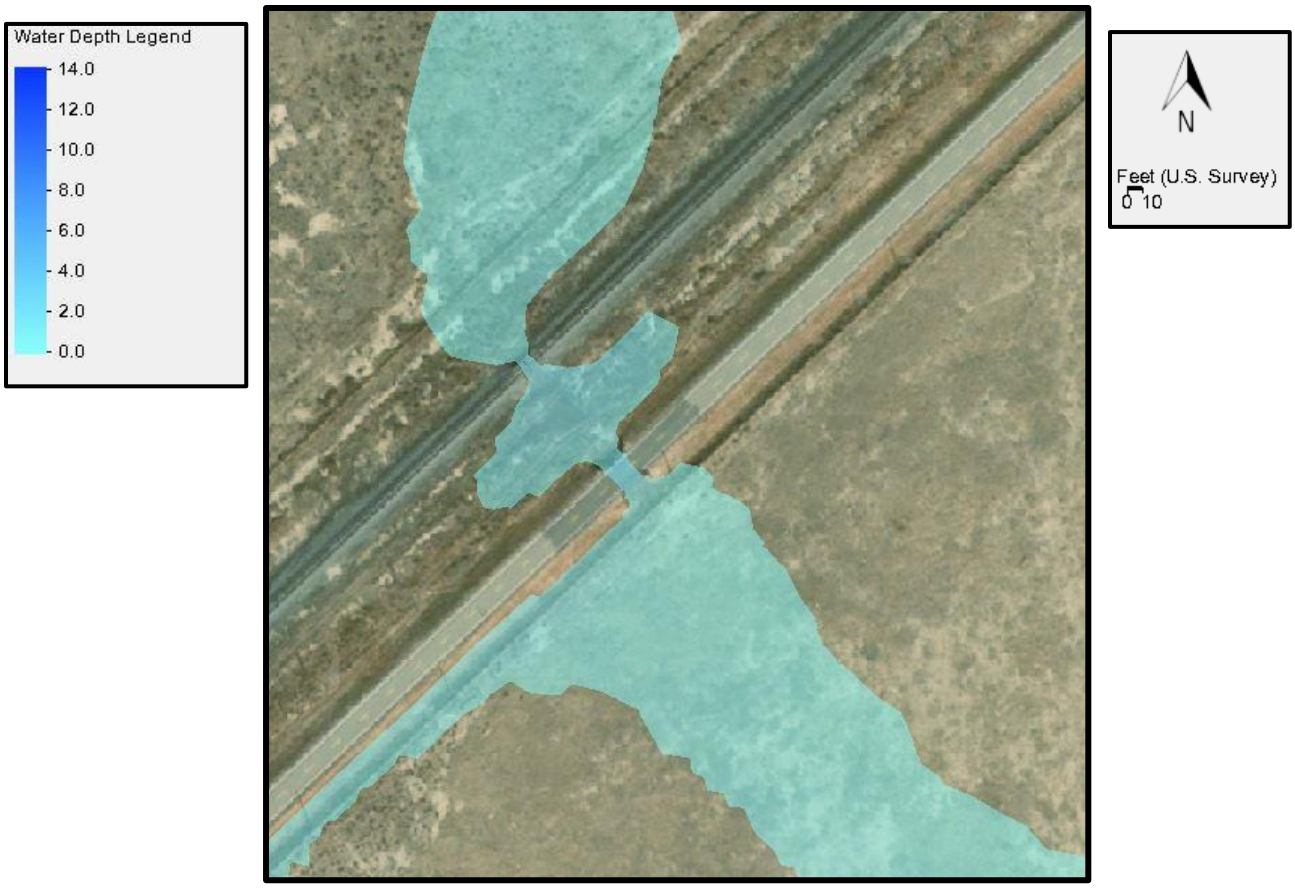
FIGURE 2



PROPOSED CONDITIONS – WATER DEPTH

BRIDGE AT STRUCTURE M-21-J

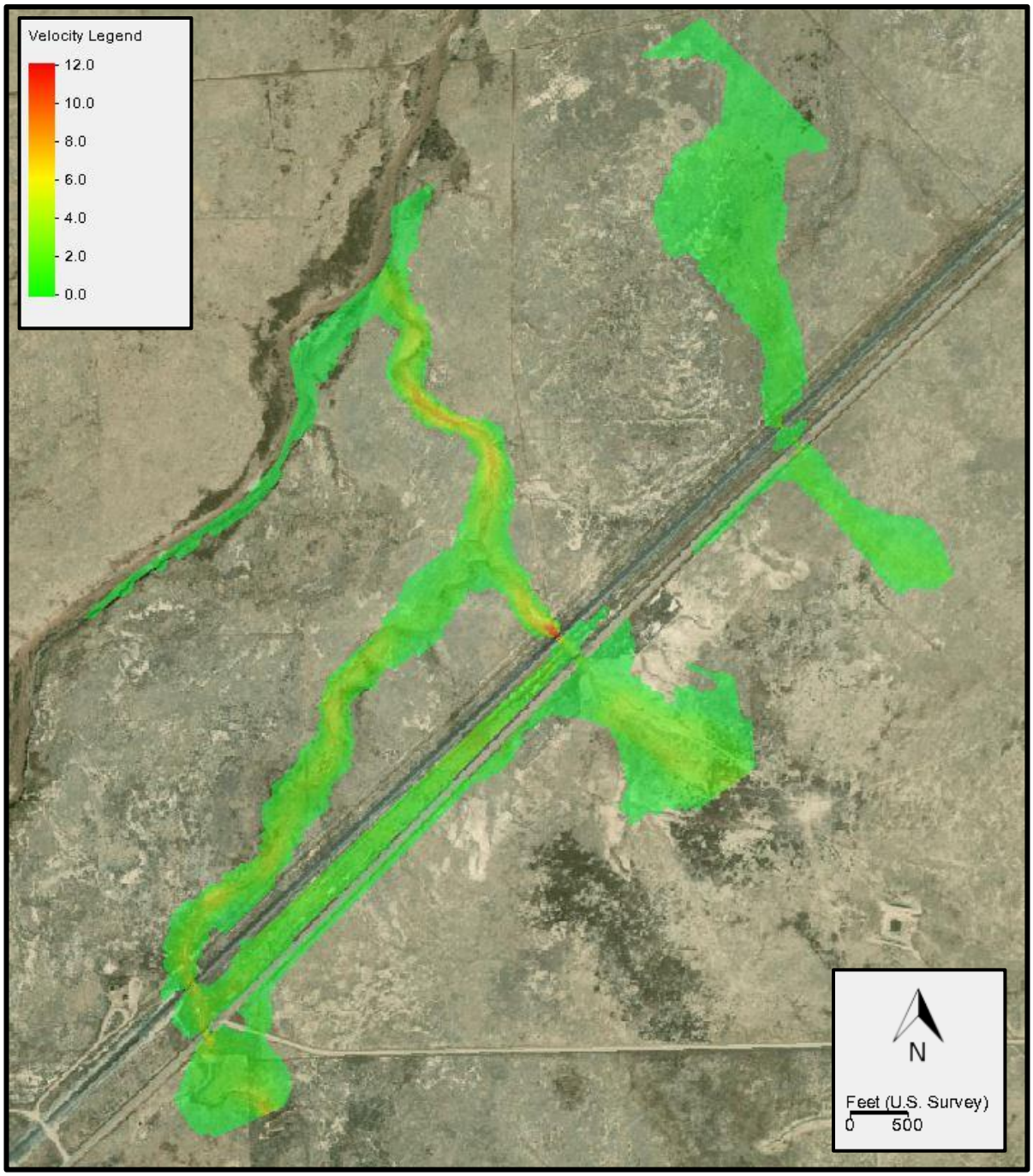
FIGURE 3



PROPOSED CONDITIONS – WATER DEPTH

BRIDGE AT STRUCTURE M-22-Y

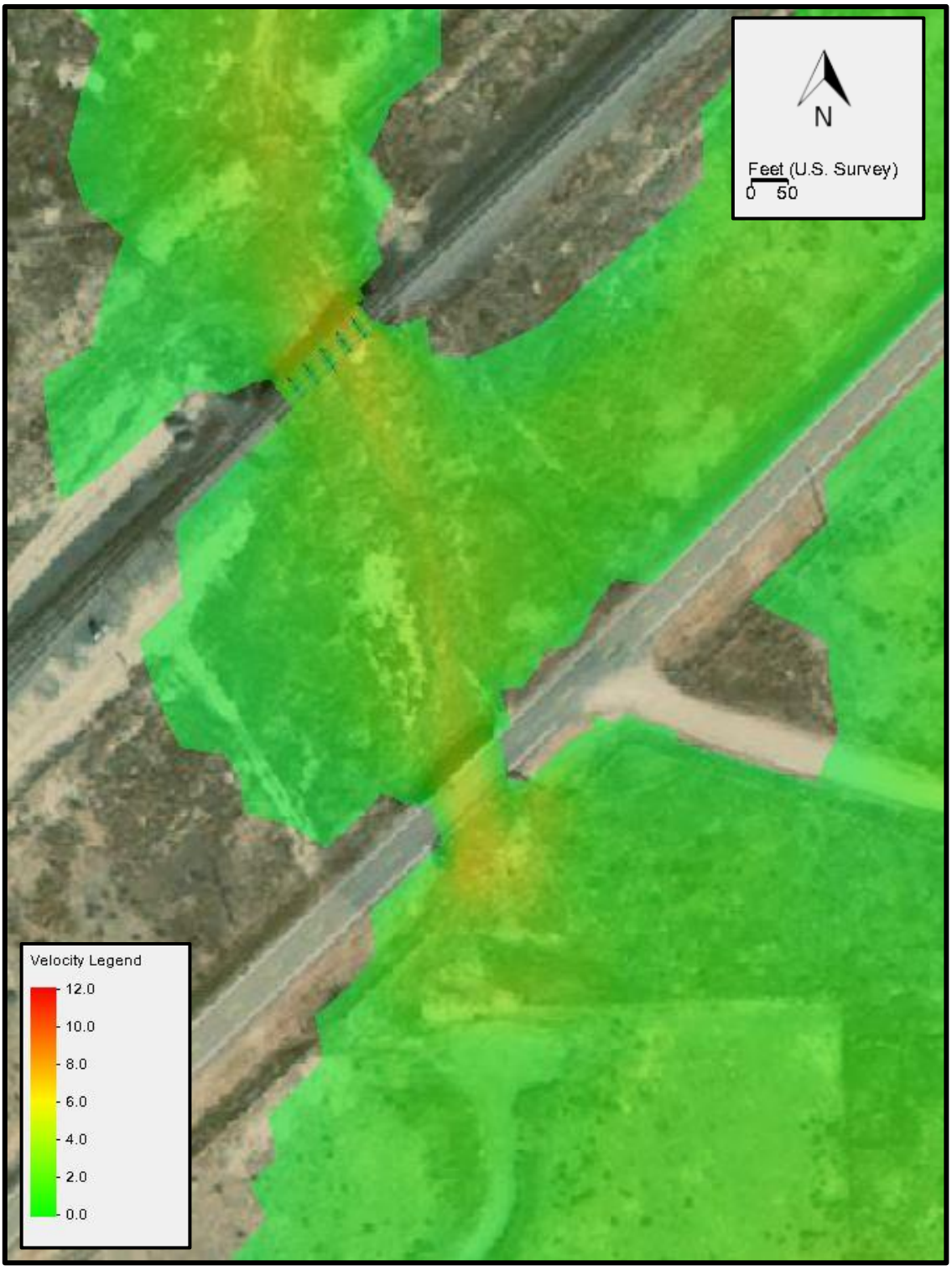
FIGURE 4



PROPOSED CONDITIONS – VELOCITY

BRDIGE AT STRUCTURES M-21-I, M-21-J & M-22-Y

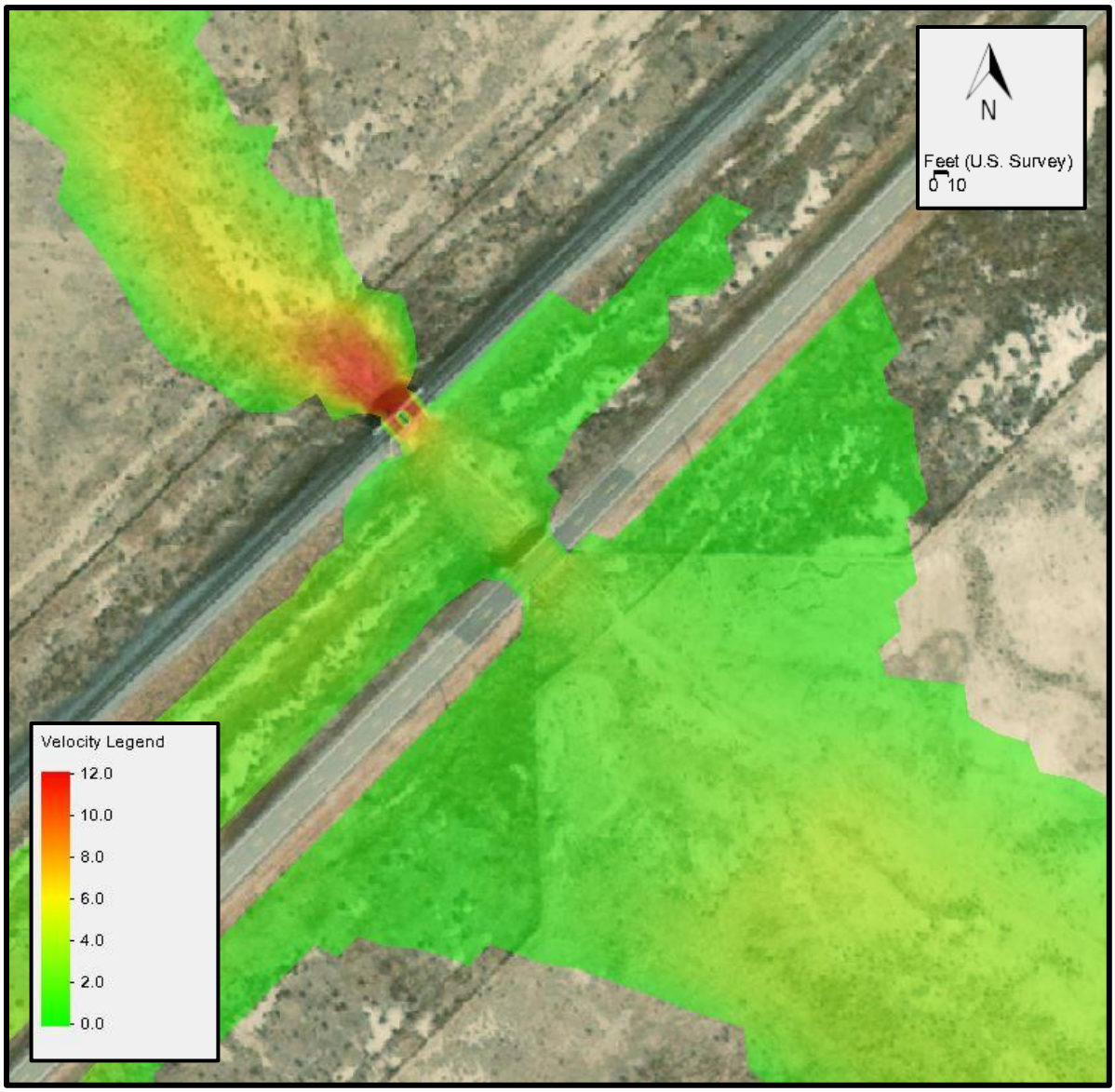
FIGURE 5



PROPOSED CONDITIONS – VELOCITY

BRIDGE AT STRUCTURE M-21-I

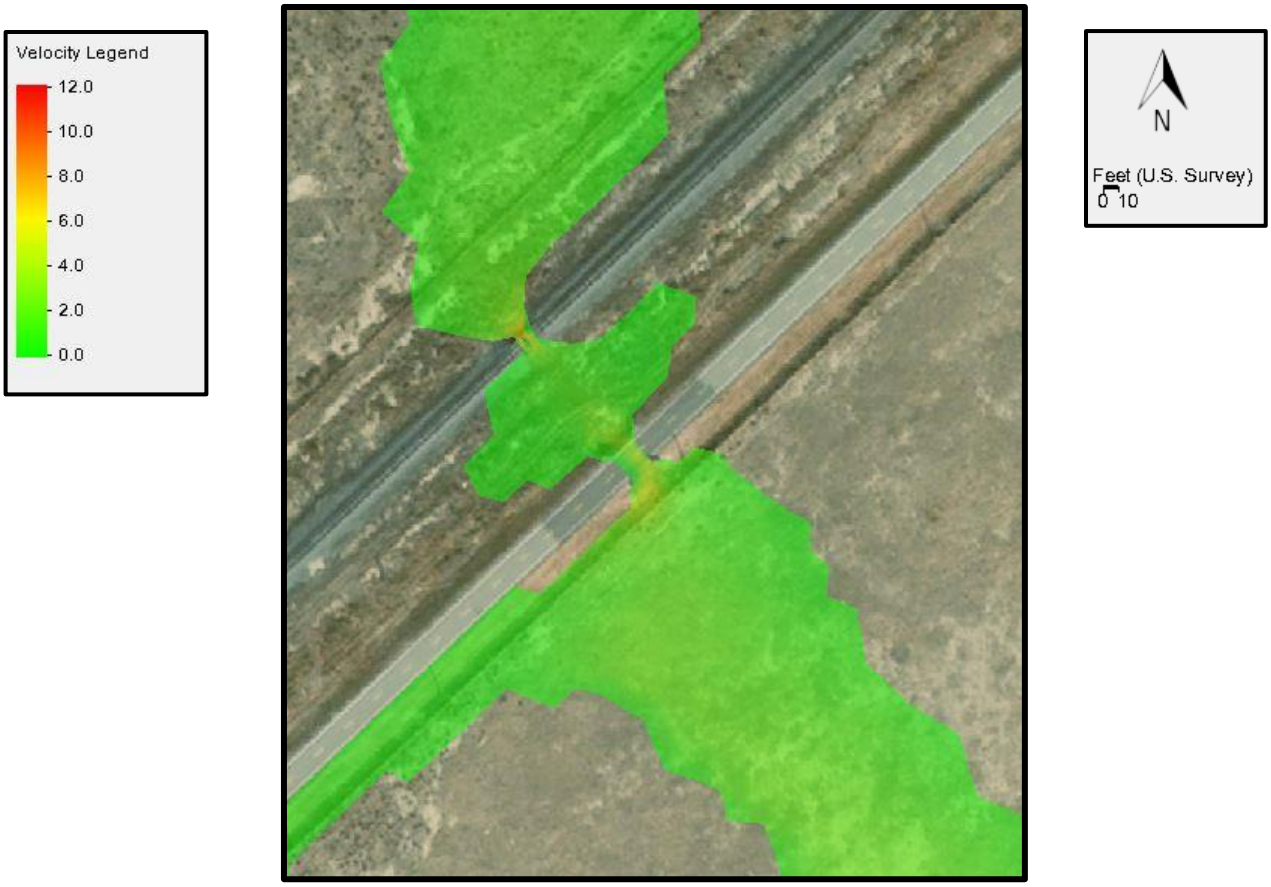
FIGURE 6



PROPOSED CONDITIONS – VELOCITY

BRIDGE AT STRUCTURE M-21-J

FIGURE 7

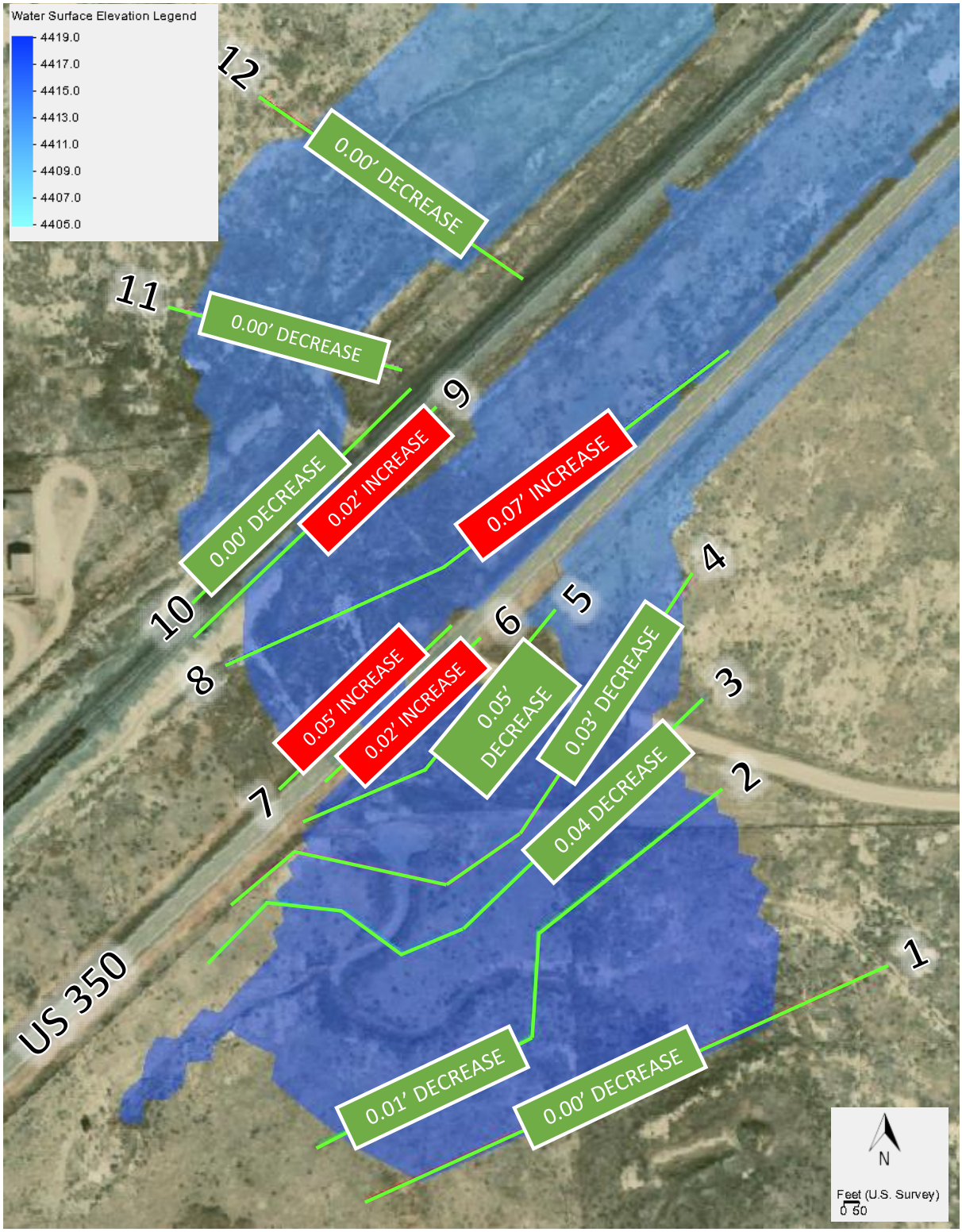


PROPOSED CONDITIONS – VELOCITY

BRIDGE AT STRUCTURE M-22-Y

FIGURE 8

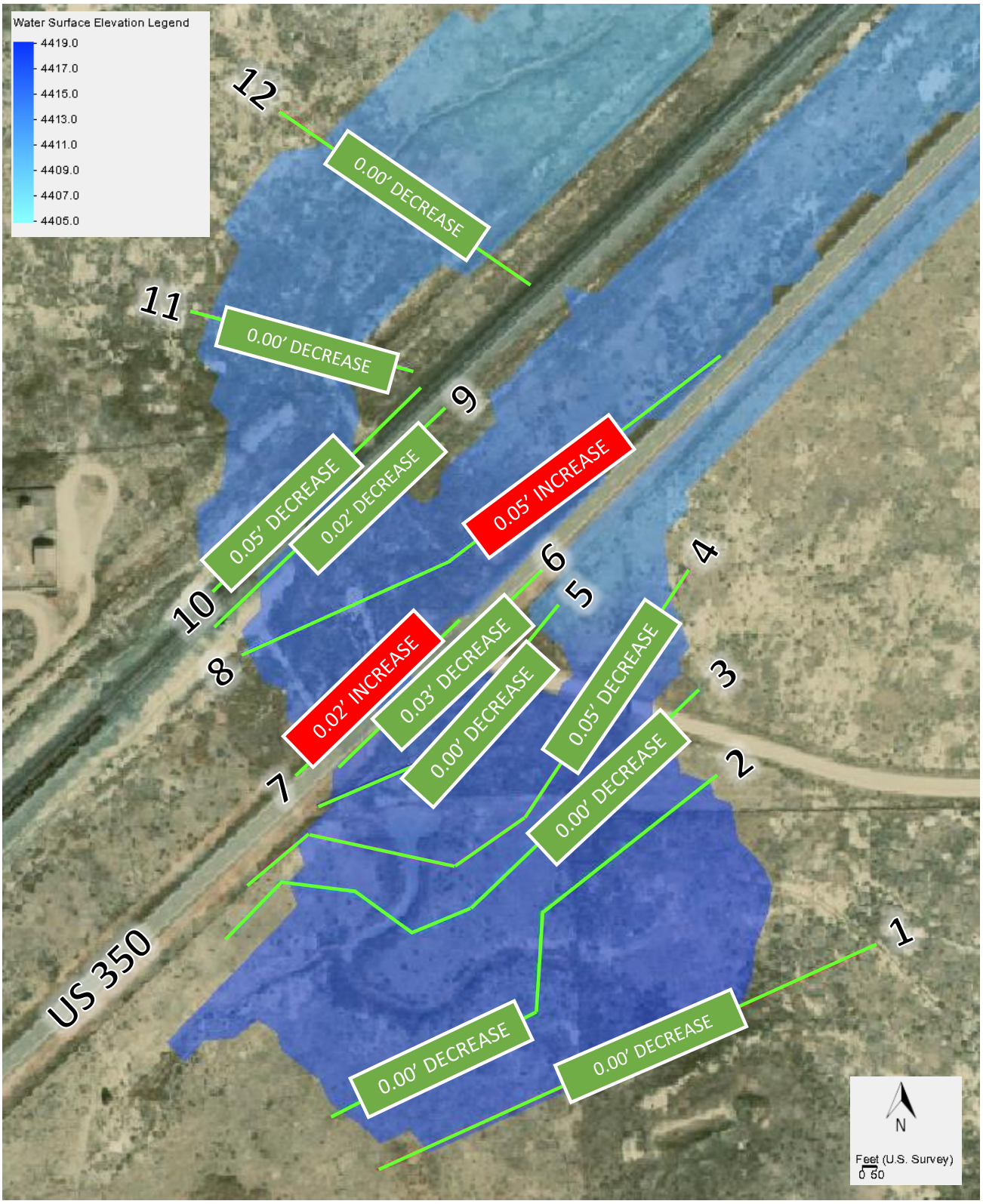
APPENDIX G WATER SURFACE ELEVATION GRAPHICS



WATER SURFACE ELEVATION COMPARISON – RCBC OPTION

STRUCTURES M-21-I

FIGURE 1

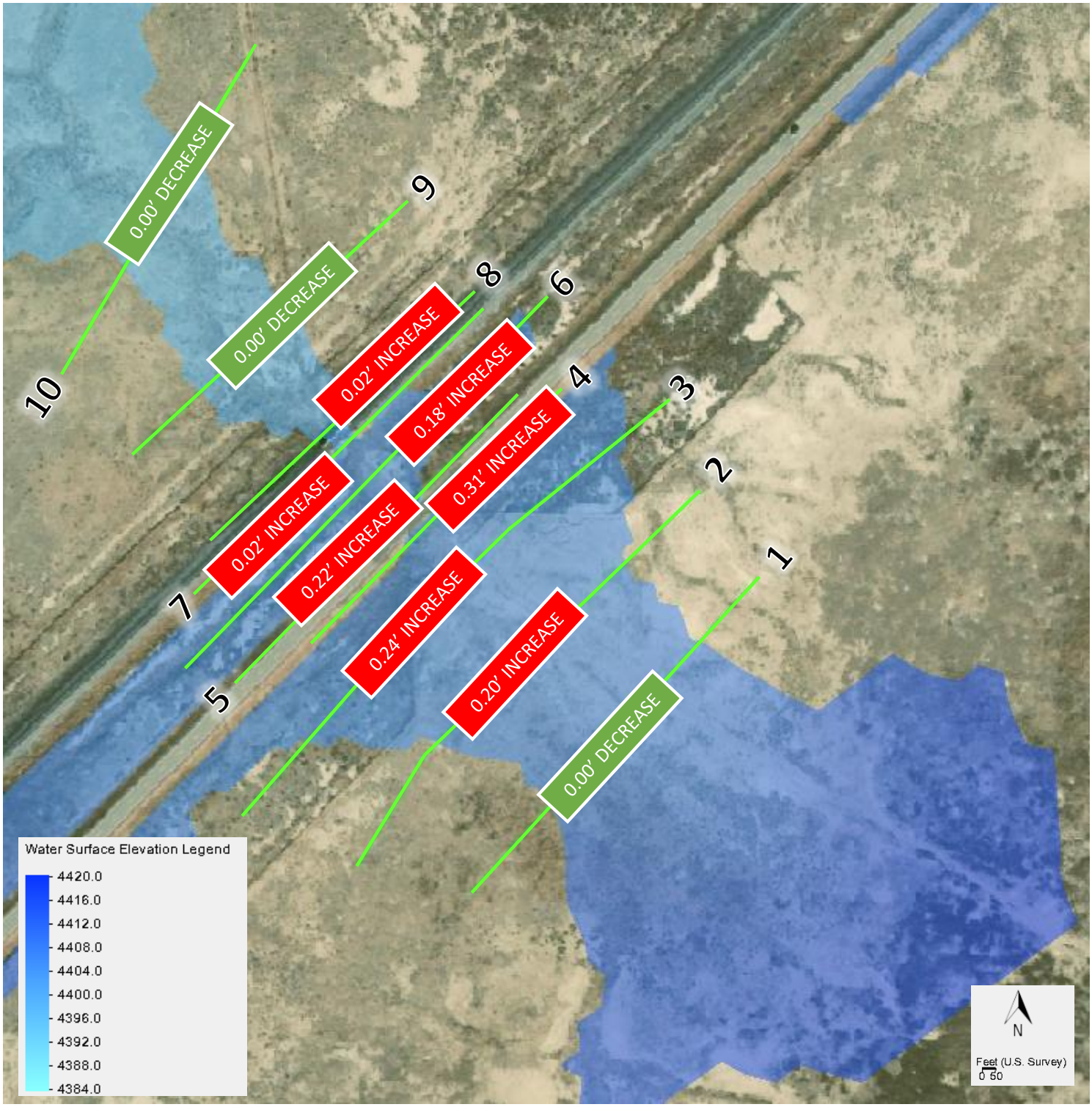


CDOT REGION 2 – BRIDGE BUNDLE

WATER SURFACE ELEVATION COMPARISON – BRIDGE OPTION

STRUCTURE M-21-I

FIGURE 2

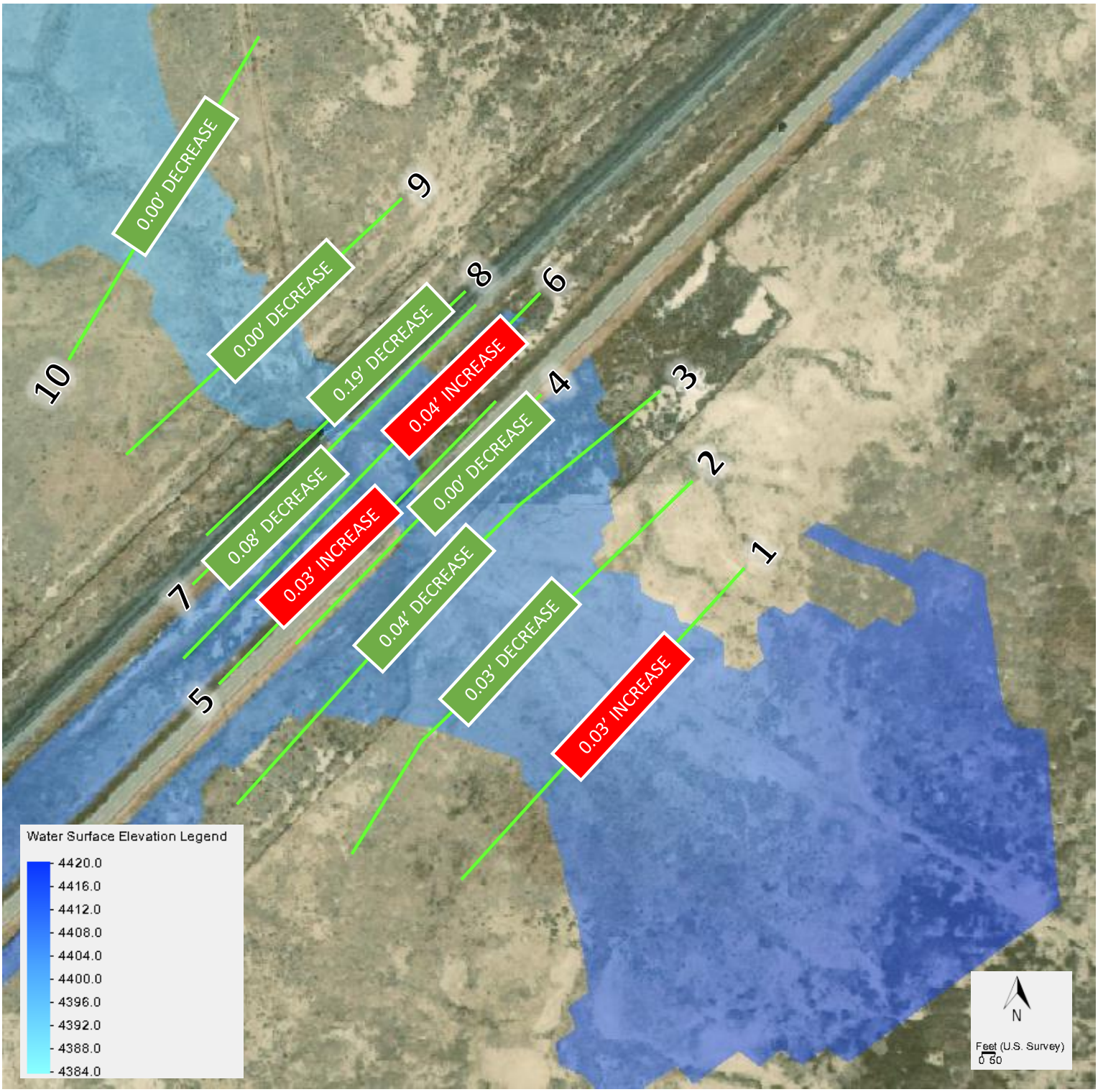


CDOT REGION 2 – BRIDGE BUNDLE

WATER SURFACE ELEVATION COMPARISON – RCBC OPTION

STRUCTURE M-21-J

FIGURE 3

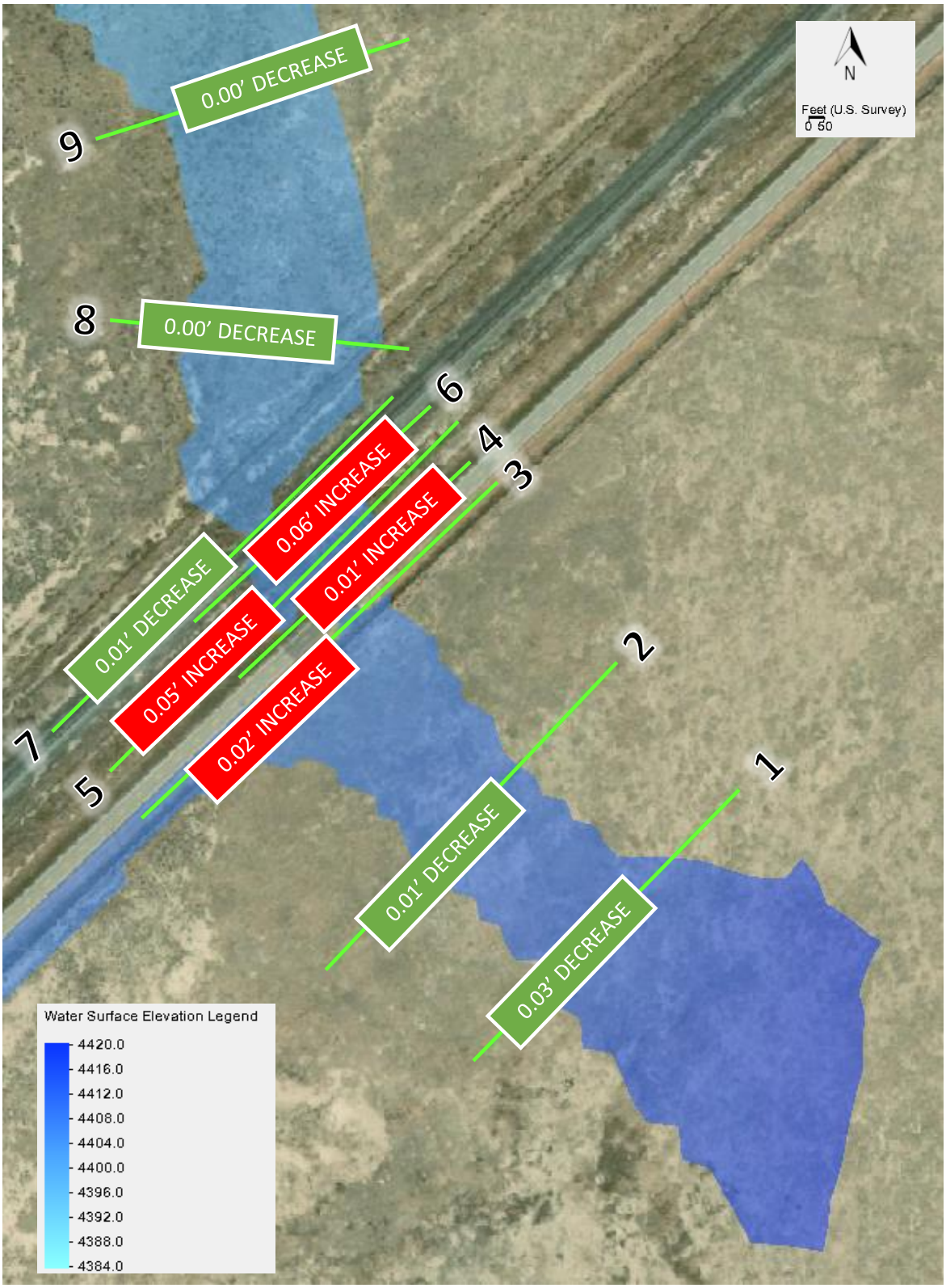


CDOT REGION 2 – BRIDGE BUNDLE

WATER SURFACE ELEVATION COMPARISON – BRDIGE OPTION

STRUCTURE M-21-J

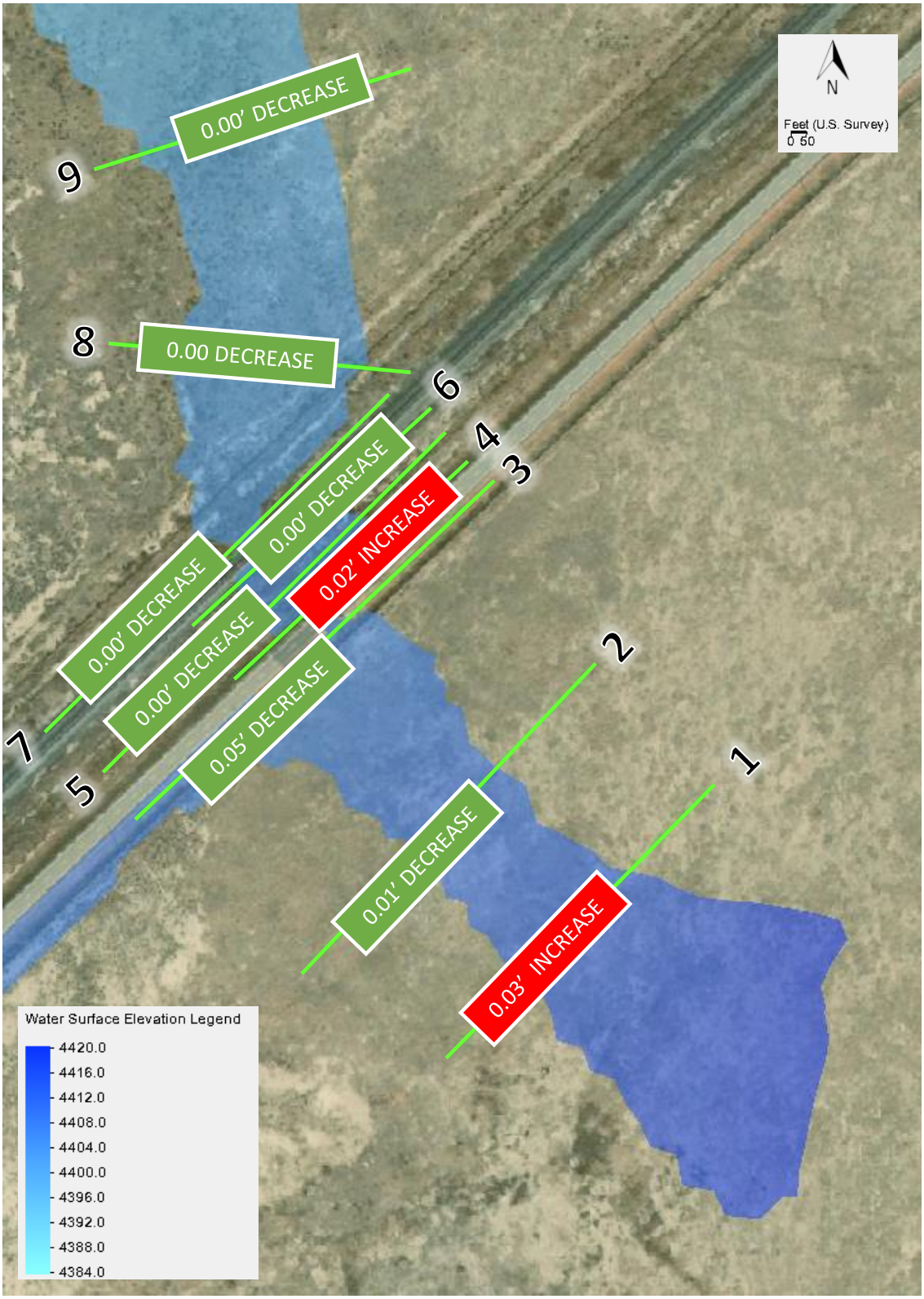
FIGURE 4



WATER SURFACE ELEVATION COMPARISON – RCBC OPTION

STRUCTURE M-22-Y

FIGURE 5

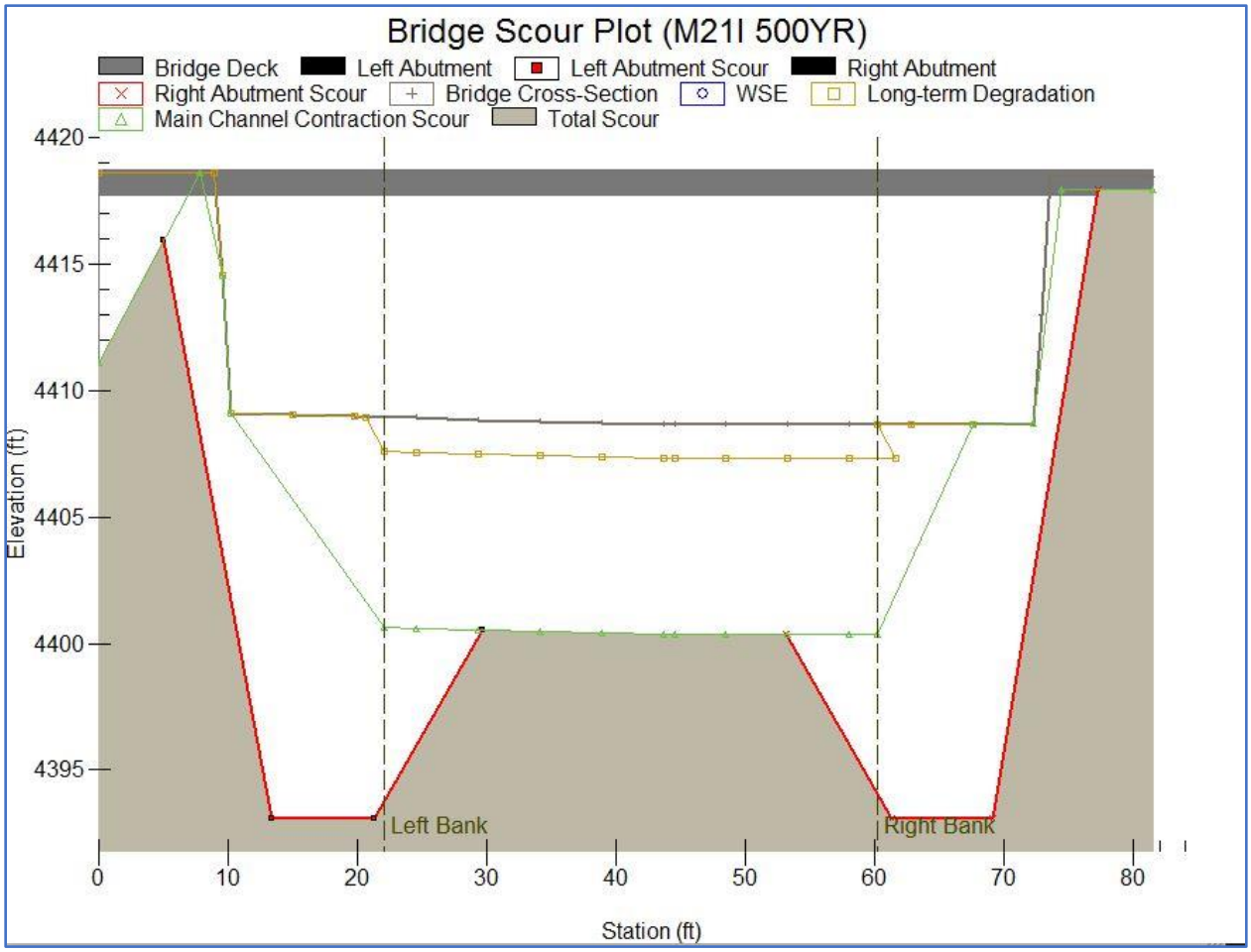


WATER SURFACE ELEVATION COMPARISON – BRIDGE OPTION

STRUCTURE M-22-Y

FIGURE 6

APPENDIX H BRIDGE SCOUR ANALYSIS



SCOUR RESULTS
STRUCTURE M-21-I
FIGURE 1

Hydraulic Analysis Report

Project Data

Project Title: M-21-I 100YR
Designer: Stanley Consultants
Project Date: Thursday, November 19, 2020
Project Units: U.S. Customary Units

Riprap Analysis: Left Abutment

Note: 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.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 8 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: 4.5 ft

Flow Depth at Toe of Abutment: 4.3 ft

Calculations will use either total or overbank discharges.

Total Discharge: 1810 cfs

Overbank Discharge: 394 cfs

Total Bridge Area: 270 ft^2

Setback Area: 78.5 ft^2

Maximum Channel Velocity: 6.7 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 1.77778

Characteristic Velocity: 6.7037 ft/s

Froude Number at the Abutment Toe: 0.569939

Abutment Coefficient: 1.02

Computed D50: 10.3615 in

Design D50 = 12 in

Thickness = 24 in

Design D50 > Computed D50

12 in > 10.3615 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS III

Riprap Class Order: 3

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

d100: 24 in

d85: 17 in

d50: 12.5 in

d15: 9 in

Layout Recommendations

Minimum Riprap Thickness: 24 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 8.6 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

Note: 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.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 11 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: 4.5 ft

Flow Depth at Toe of Abutment: 3.3 ft

Calculations will use either total or overbank discharges.

Total Discharge: 1810 cfs

Overbank Discharge: 394 cfs

Total Bridge Area: 270 ft^2

Setback Area: 78.5 ft^2

Maximum Channel Velocity: 6.7 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 2.44444

Characteristic Velocity: 6.7037 ft/s

Froude Number at the Abutment Toe: 0.650587

Abutment Coefficient: 1.02

Computed D50: 10.3615 in

Design D50 = 12 in

Thickness = 24 in

Design D50 > Computed D50

12 in > 10.3615 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS III

Riprap Class Order: 3

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

d100: 24 in

d85: 17 in

d50: 12.5 in

d15: 9 in

Layout Recommendations

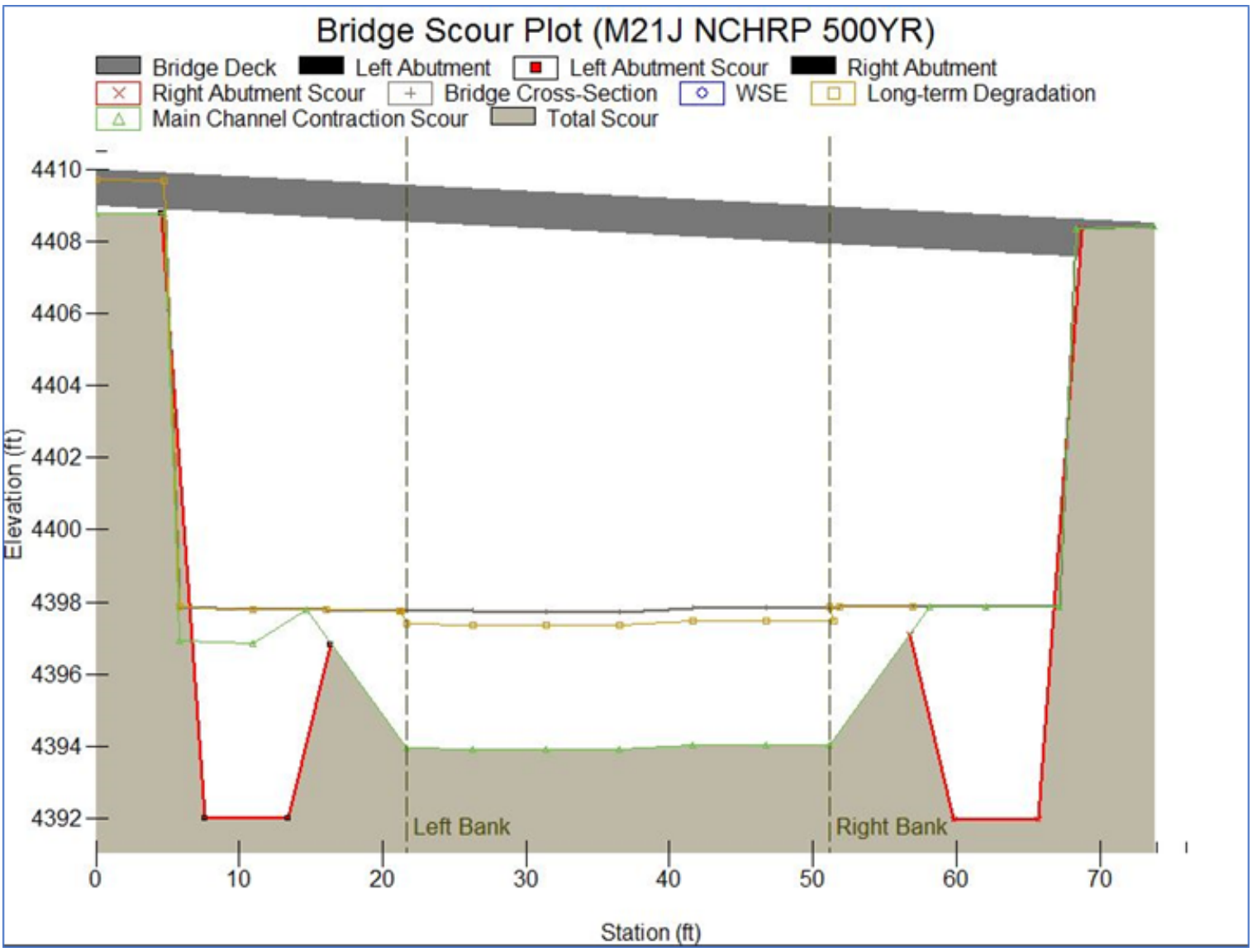
Minimum Riprap Thickness: 288 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 6.6 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



SCOUR RESULTS
STRUCTURE M-21-J
FIGURE 2

Hydraulic Analysis Report

Project Data

Project Title: M-21-J 100YR
Designer: Stanley Consultants
Project Date: Wednesday, November 25, 2020
Project Units: U.S. Customary Units

Riprap Analysis: Left Abutment

Note: 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.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 15 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: 6.62 ft

Flow Depth at Toe of Abutment: 6.2 ft

Calculations will use either total or overbank discharges.

Total Discharge: 947 cfs

Overbank Discharge: 236.75 cfs

Total Bridge Area: 305 ft^2

Setback Area: 178.23 ft^2

Maximum Channel Velocity: 3.11 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 2.26586

Characteristic Velocity: 3.10492 ft/s

Froude Number at the Abutment Toe: 0.219837

Abutment Coefficient: 1.02

Computed D50: 2.22276 in

Design D50 = 9 in

Thickness = 18 in

Design D50 > Computed D50

9 in > 2.22276 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS II

Riprap Class Order: 2

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

d100: 18 in

d85: 13 in

d50: 9.5 in

d15: 7 in

Layout Recommendations

Minimum Riprap Thickness: 18 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 12.4 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

Note: 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.

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 15.3 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: 6.62 ft

Flow Depth at Toe of Abutment: 6.15 ft

Calculations will use either total or overbank discharges.

Total Discharge: 947 cfs

Overbank Discharge: 236.75 cfs

Total Bridge Area: 305 ft^2

Setback Area: 181.8 ft^2

Maximum Channel Velocity: 3.11 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 2.31118

Characteristic Velocity: 3.10492 ft/s

Froude Number at the Abutment Toe: 0.220729

Abutment Coefficient: 1.02

Computed D50: 2.22276 in

Design D50 = 9 in

Thickness = 18 in

Design D50 > Computed D50

9 in > 2.22276 in

Riprap Class

Riprap shape should be angular

Riprap Class Name: CLASS II

Riprap Class Order: 2

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

d100: 18 in

d85: 13 in

d50: 9.5 in

d15: 7 in

Layout Recommendations

Minimum Riprap Thickness: 18 in

Minimum Horizontal Extent of the Toe Apron from the Abutment Toe: 12.3 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	M-21-I	
Culvert	M21I RCBC	
Flow	1810.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	80.0	ft
Culvert Height	7.0	ft
Outlet Depth	5.82	ft
Outlet Velocity	3.89	ft/s
Froude Number	0.28	
Tailwater Depth	5.82	ft
Tailwater Velocity	7.19	ft/s
Tailwater Slope (SO)	0.0025	
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	0.15	mm
D84 Value	5.00	mm
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Soil Sigma	5.77	
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)	5.819	ft
Velocity with TW and WS	-1.#IO	ft/s

HY-8 Energy Dissipation Report

Scour Hole Geometry

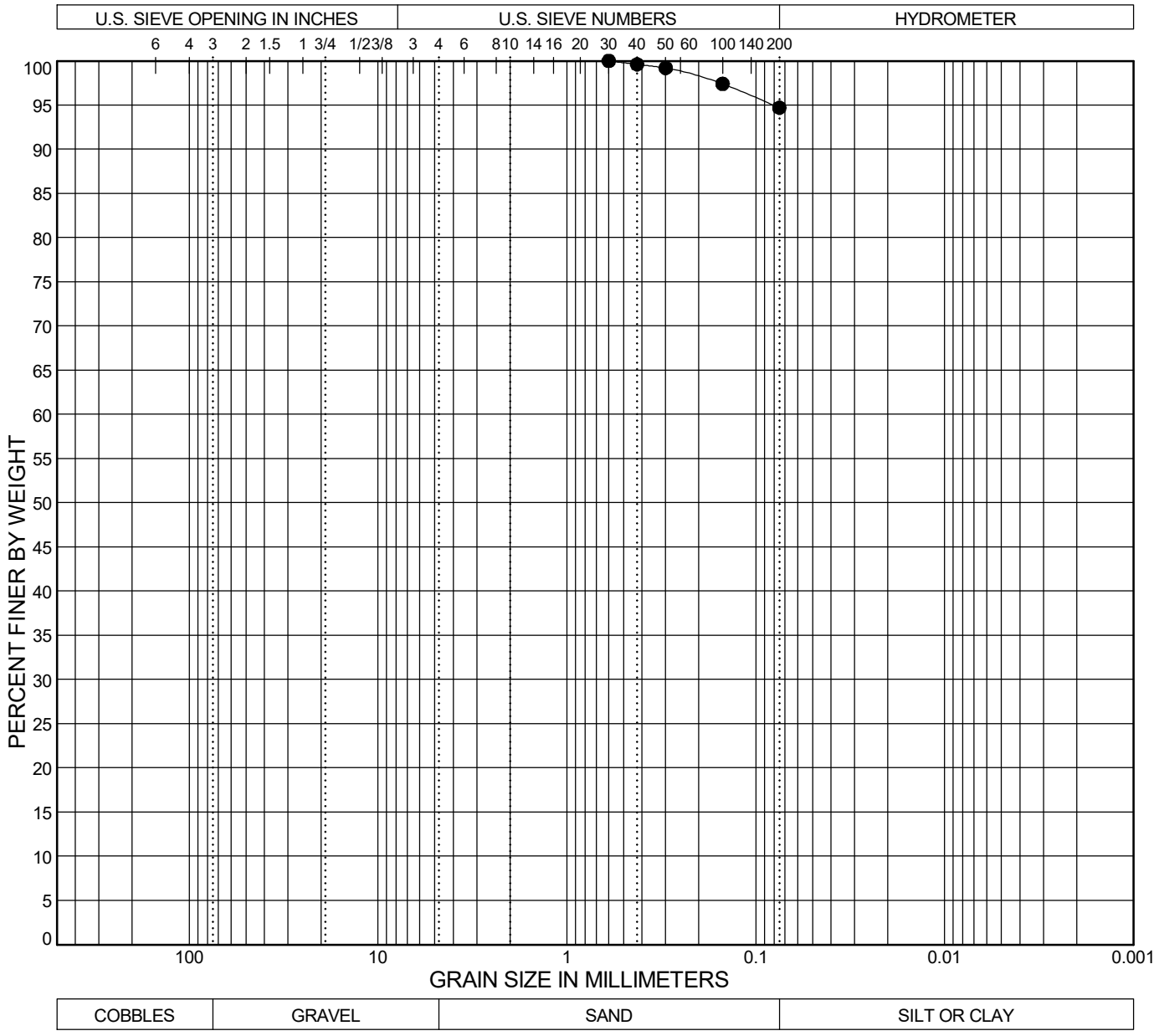
Parameter	Value	Units
Select Culvert and Flow		
Crossing	M-21-J	
Culvert	M21J RCBC	
Flow	947.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	60.0	ft
Culvert Height	7.0	ft
Outlet Depth	4.24	ft
Outlet Velocity	3.72	ft/s
Froude Number	0.32	
Tailwater Depth	4.24	ft
Tailwater Velocity	6.04	ft/s
Tailwater Slope (SO)	0.0013	
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	0.15	mm
D84 Value	4.75	mm
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Soil Sigma	5.63	
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)	4.242	ft
Velocity with TW and WS	-1.#IO	ft/s

HY-8 Energy Dissipation Report

Scour Hole Geometry

Parameter	Value	Units
Select Culvert and Flow		
Crossing	M-22-Y	
Culvert	M22Y RCBC	
Flow	107.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	12.0	ft
Culvert Height	4.0	ft
Outlet Depth	2.09	ft
Outlet Velocity	4.26	ft/s
Froude Number	0.52	
Tailwater Depth	2.09	ft
Tailwater Velocity	3.56	ft/s
Tailwater Slope (SO)	0.0050	
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	0.15	mm
D84 Value	4.75	mm
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Soil Sigma	5.63	
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)	2.091	ft
Velocity with TW and WS	-1.#IO	ft/s

APPENDIX I GEOTECHNICAL INFORMATION



BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
									%Silt	%Clay
● **M-21-I Scour**	**0.0**						**0.0**	**5.3**	**94.7**	

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

SIEVE ANALYSIS

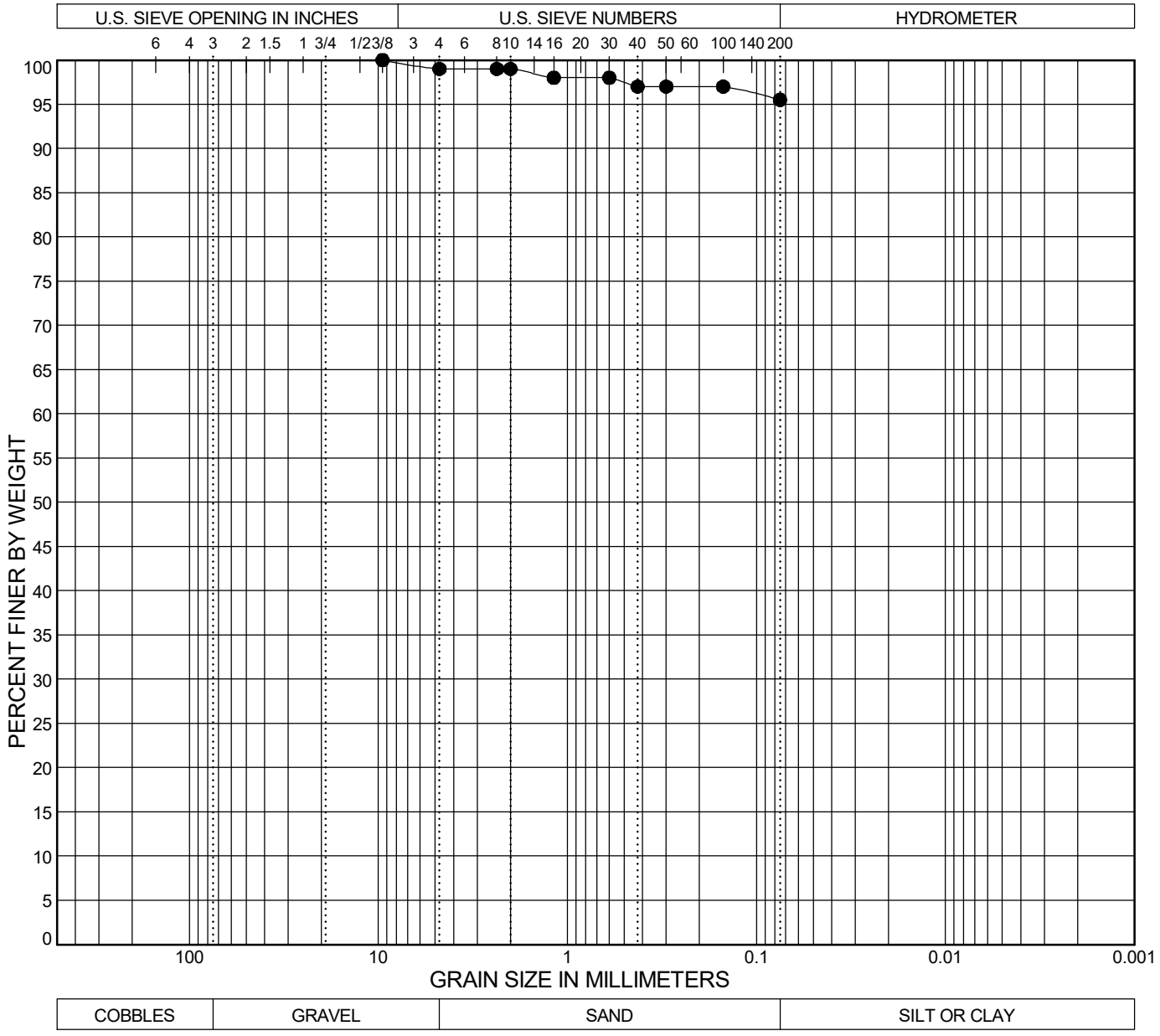
FIGURE

S- 3

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

03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/6/20



BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
									%Silt	%Clay
● **M-21-J Scour**	**0.0**						**1.0**	**3.5**	**95.5**	

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SIEVE ANALYSIS

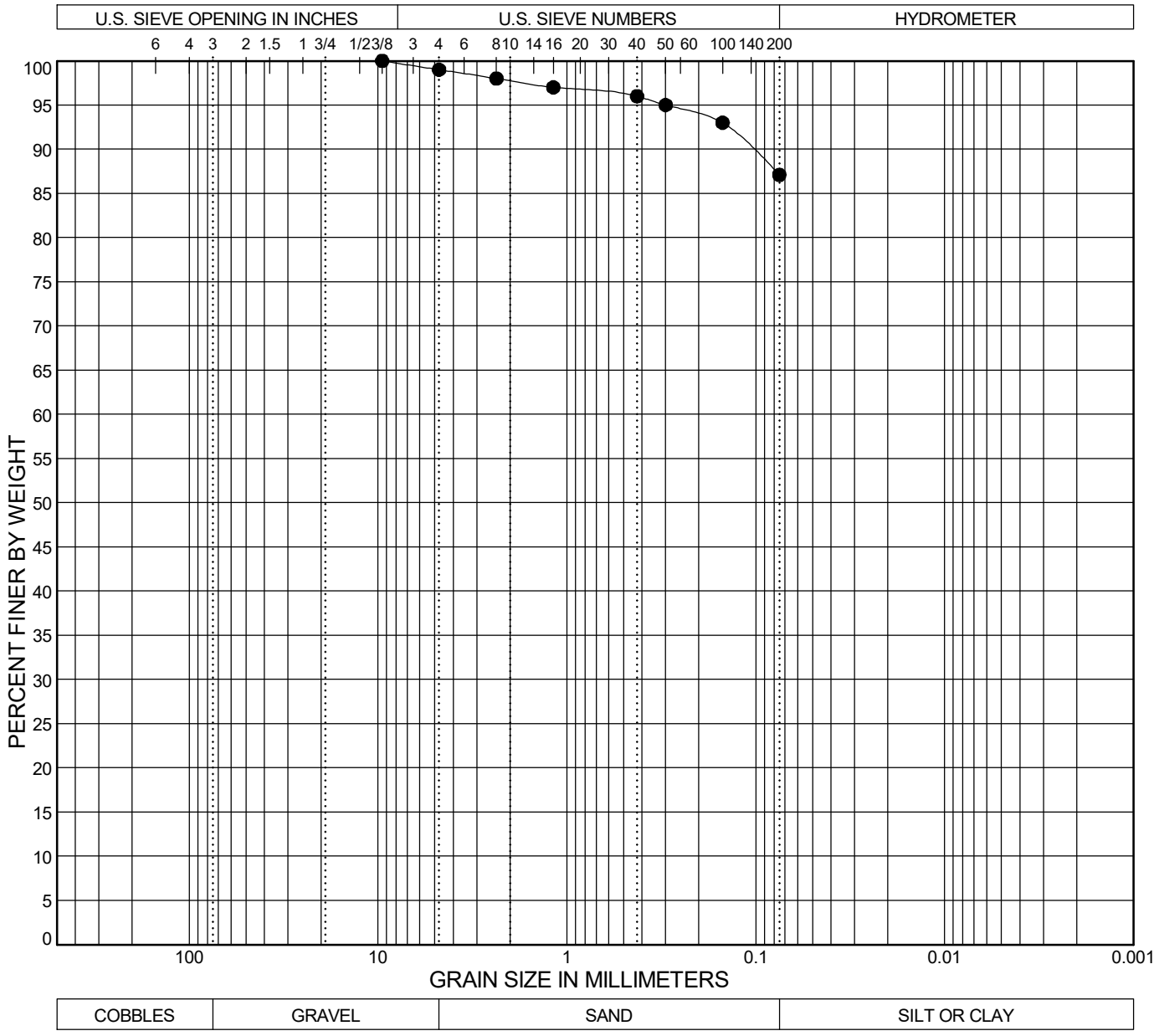
FIGURE

S- 4

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

03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/6/20



BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
									%Silt	%Clay
● **M-22-Y Scour**	**0.0**						**1.0**	**11.9**	**87.1**	

Yeh and Associates, Inc.
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SIEVE ANALYSIS

FIGURE

S- 6

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

03 GRAIN SIZE YEH 220-063 R2 BRIDGE BUNDLE.GPJ 2019 YEH COLORADO TEMPLATE.GDT 2019 YEH COLORADO LIBRARY.GLB 11/6/20