PRELIMINARY HYDRAULICS REPORT
STRUCTURE G-12-C REPLACEMENT
As a part of the
REGION TWO BRIDGE BUNDLE PACKAGE
PARK COUNTY, COLORADO

A Part of Section 1, Township 9 South, Range 78 West of the 6th P.M., County of Park, Colorado

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Prepared for:

Colorado Department of Transportation
Region 2
5615 Wills Boulevard
Pueblo, CO 81008
Phone (719) 546-5407

Prepared by:

Stanley Consultants INC.

8000 S Chester Street. Suite 500
Centennial, CO 80112
Phone (303) 799-6806
Contact: Joshua Root

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1. INTRODUCTION

1.1 Background and Purpose

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

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

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

1.2 Site Description

The purpose of this report is to document the preliminary hydraulic analysis and design for the replacement of Structure G-12-C as a part of the CDOT Region 2 Bridge Bundle Design Build. The project is located within Park County at Mile Post 71.45 along CO 9 just north of Alma. Structure G-12-C crosses over the Middle Fork South Platte River. Figure 1 below illustrates the project location. The project is located in Section 1, Township 9 South, Range 78 West of the 6^{th} P.M., County of Park, Colorado. **Figure 1** shows the project limits.

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

The Federal Emergency Management Agency (FEMA) has designated the project site as a FEMA Zone A, as determined by the Flood Insurance Rate Maps (FIRM) 08093C0325C effective date December 18, 2009, as shown in **Appendix A**. FEMA Zone A is a special flood hazard area inundated by the 100-year flood, however base flood elevations are not determined in a Zone A designation. 44 Code of Federal Regulations (CFR) 60.3 (b) state that for Zone A floodplains, all cumulative impacts to the system from the time of the original study cannot result in a water surface elevation (WSE) increase of more than one foot. This report also reviews changes to the WSE from the proposed bridge design.

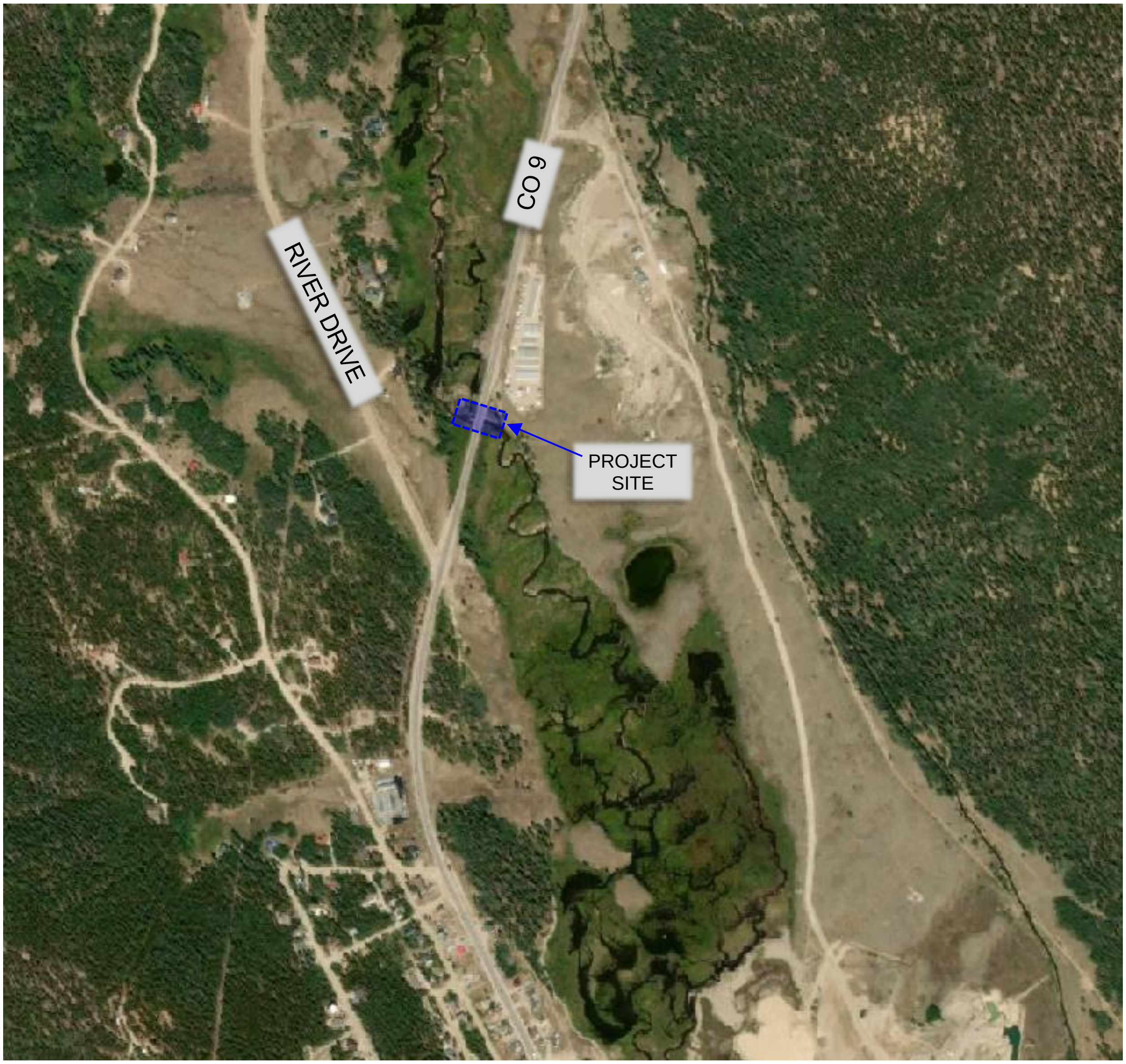


Figure 1: Vicinity Map

2. HYDROLOGY

Preliminary hydrology for the watershed tributary to this structure was provided by CDOT. A memorandum provided by CDOT has been provided that summarizes basin areas, runoff methodology and approximate flowrates derived from the preliminary analysis. Table 1 is a summary of the approximate flowrates provided by CDOT of structure G-12-C.

Table 1: Summary of Peak Discharge for Bridge G-12-C

River Location	Design Storm	100-year (cfs)	200-year (cfs)	500-year (cfs)
Upstream of Bridge	100-year	2,885	3,806	5,255

3. EXISTING CONDITIONS

3.1 Existing Structure

The existing structure is a double cell 10-ft by 10-ft Concrete Box Culvert over the Middle Fork South Platte River. It was built in 1938 and has concrete wingwalls. No utilities were found attached to the bridge.

3.2 Watershed Overview

The Middle Fork South Platte River flows from the north to the south toward Fairplay where it eventually joins with the South Fork and then outfalls into the South Platte near Hartsel. The watershed tributary to the Middle Fork South Platte River is approximately 22.26 square miles in area. The watershed generally slopes to the north. The stream bed does 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.

3.3 Site Investigation

A site investigation by Stanley Consultants in August 2020 was performed to gain an understanding of the key hydraulic and geomorphic features of the stream at the project site and of the overall watershed. This investigation found obvious scour damage to the walls of the box culverts and wingwalls with many sections of exposed rebar. Site photos are included in **Appendix B**.

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 high based on guidance from Federal Highway Administration (FHWA) Hydraulic Engineering Circular (HEC) No. 20. The flowchart for potential debris production is presented in Figure 2. The channel banks near the bridge are heavily vegetated with shrubs and trees as confirmed with the site visit in August 2020. Aerial imagery of the watershed near the bridge is shown in **Appendix B**.

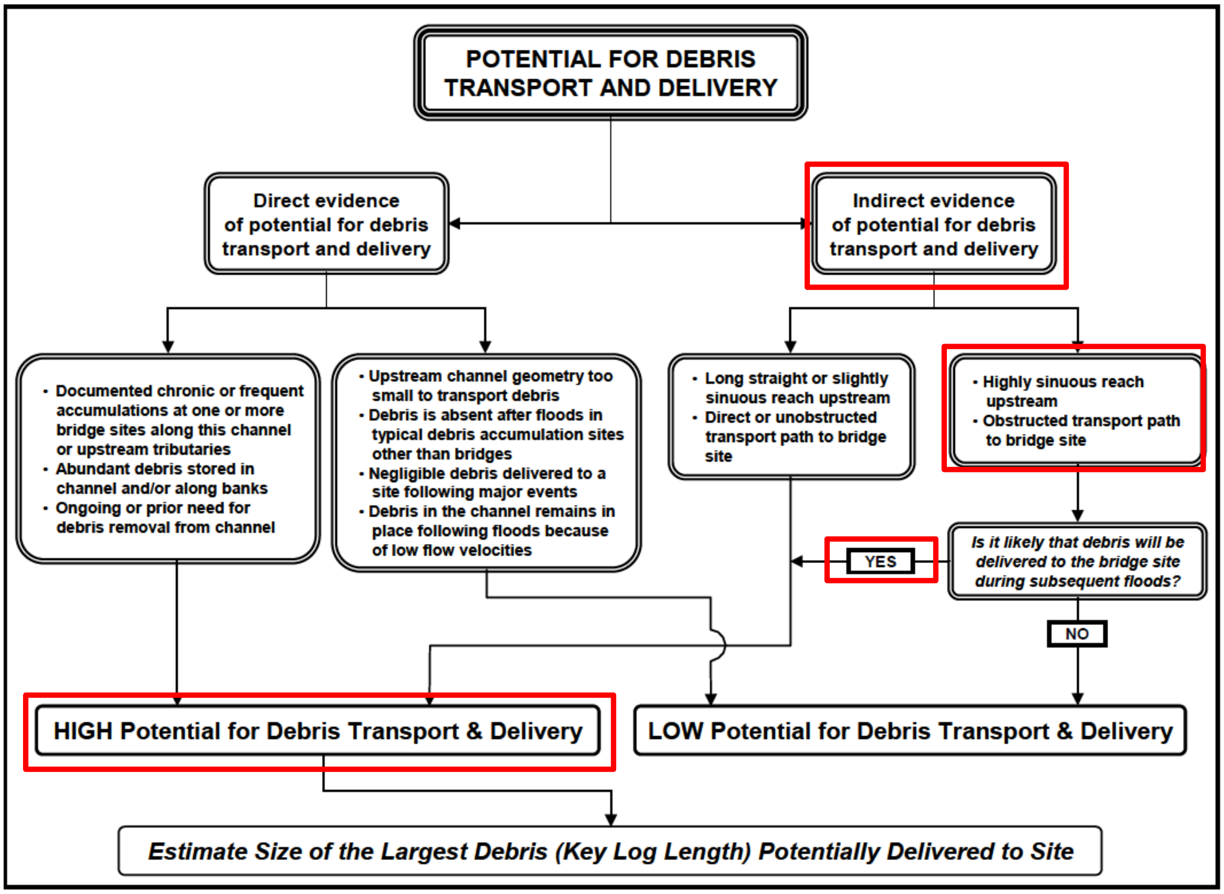


Figure 2: Flow Chart for Potential Debris Production (FHWA, HEC 20)

4.2 Freeboard

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

The channel was identified as having a high potential for debris production. Therefore, if a bridge is selected for the proposed conveyance structure, 4 feet of freeboard would typically be required. However, the existing 100-year floodplain overtops the roadway, and due to funding and site constraints, it is not feasible to raise the bridge above the 100-year floodplain. The proposed preliminary design improves the conditions.

4.3 Modeling Parameters

4.3.1 Elevation Data

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

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

4.3.2 Computational Mesh

The computational mesh is an unstructured mesh, which allows for the use of triangles and quadrilaterals, with variable element sizes. Roadways and the channel used quadrilaterals, with the face lined up perpendicular to flow. Triangles were typically used in the floodplain. The total number of mesh elements is 19,300 and the mesh extends approximately 980 feet upstream of the bridge and 1,300 feet downstream of the bridge.

4.3.3 Surface Roughness

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

Table 2: Manning's n-values

Land Use	n-value
Channel	0.035
Overbank	0.060
Paved Road	0.016
Open Space	0.055
Dirt Road	0.025

4.3.4 Boundary Conditions

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

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

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

Table 3: Model Boundary Condition Inputs

Frequency Storm	Inflow (cfs)	Outflow Constant WSE (ft)
100-Year	2,885	10,367.31

4.3.5 Hydraulic Structures

The modeled existing bridge geometry is based on the survey completed in August 2020. The survey data included shots detailing the box culvert. The crest elevation above the RCBC is 10,389.21 feet, while the top of the box opening is 10,386.55 feet. The culvert was modeled using HY-8 due to the flow being perpendicular to the roadway.

4.3.6 Simulation Control

The hydraulic simulations are run with a 0.50 second time step for 1 hour, when a steady state solution is met. The parabolic turbulence method is used with a coefficient of 0.7.

4.4 Model Results

4.4.1 Existing Conditions

The range of depths experienced in the channel at the culvert during the 100-year event is from 8.81 feet to 11.93 feet. Figure 5 presents the depth for the entire floodplain and the existing structure. The results also demonstrate that the existing culvert overtops during the 100-year event. The results show that flows pond behind the embankment as well. Existing conditions 100-year depths of flow are shown in **Appendix C**.

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. An arched culvert, reinforced concrete box culvert (RCBC), and bridge option were analyzed. Many factors were taken into consideration when determining the preferred alternative for this preliminary analysis. These factors included cost, constructability, effects on the stream hydraulics, environmental impacts, among others.

<u>Proposed Arched Culvert</u>

This option was modeled using the same SRH-2D model as was used for the existing conditions. Modifications to the model included widening the channel bottom at the crossing. The proposed model has 19,001 mesh elements. HY-8 was used to model the proposed culvert due to the flow being perpendicular to the roadway.

Because the existing condition overtops the road, a larger opening size was used for the box culverts to keep the WSEs the same or lower than existing conditions. The preliminary model shows the roadway embankment sloping at 4:1, and the proposed arched culvert being 47-feet 3-inches in length. The arched culvert option for this structure requires a double arched structure with each opening size approximately 24-foot wide by 10-feet 4-inches tall. This structure size was determined to prevent roadway overtopping. The arched option, with an open bottom, was reviewed for environmental concerns regarding fish passageways.

Depths and velocity grids for the proposed RCBC show depths from 6.94 to 10.59 ft and velocities from 6.85 to 8.78 ft/s. See **Appendix D** for 100-year depths and velocities graphics for this option.

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 channel bottom at the crossing. The proposed model has 19,001 mesh elements. HY-8 was used to model the proposed box culvert due to the flow being perpendicular to the roadway.

Because the existing condition overtops the road, a larger opening size was used for the box culvert to lower the WSEs and prevent roadway overtopping. 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, 20-foot wide by 10-foot tall box.

Depths and velocity grids for the proposed RCBC show depths from 6.94 to 10.59 ft and velocities from 6.85 to 8.78 ft/s. See **Appendix D** 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 widening the channel bottom and adding vertical abutments. The proposed model has 19,309 mesh elements. The proposed model has a 55-foot span width with no piers. The low chord of the bridge is at 10,386.88 elevation, and the high chord matched the top of roadway of the existing condition. Roadway embankments were graded at 4:1.

Depths and velocity grids for the proposed bridge show depths from 6.21 to 8.46 ft and velocities from 10.87 to 15.25 ft/s. See **Appendix E** for 100-year depths and velocities graphics for this option.

5. FEMA FLOODPLAIN ANALYSIS

FEMA has designated the project site as a Zone A, as determined by the FIRM #08093C0325C effective date December 18, 2009, as shown **Appendix A**.

FEMA Zone A is a special flood hazard area inundated by the 100-year flood; however base flood elevations are not determined in a Zone A designation. 44 CFR 60.3 (b) states that for Zone A floodplains, all cumulative impacts to the system from the time of the original study cannot result in a WSE increase of more than one foot. A Floodplain Development Permit will be submitted to Park County during the next phase of design. It is the goal of this preliminary analysis to provide CDOT with conveyance structure options that require no rise in WSEs, which will allow for a simpler floodplain permitting process for the design-build project.

Proposed RCBC

Based on modeling results, the proposed RCBC will decrease the WSE by more than 1 foot. Because the opening of the proposed culvert is about twice the size of the existing opening, the

WSE is expected to decrease and will no longer overtop the roadway. There is a lowering upstream and downstream of the RCBC opening. The proposed design followed CDOT's requirements to prevent roadway overtopping which led to the lowering. Due to the change in the water surface elevation, a LOMC will be required by FEMA.

In order to perform a comparison between the existing and proposed WSE, 9 cross sections were cut across the 2D hydraulic model results both upstream and downstream of the proposed opening. The average WSE was determined for both existing and the proposed RCBC option, as shown in **Appendix F**. The WSE comparison at these sections is shown in Table 4.

Table 4: Comparison of Existing and Proposed RCBC WSE

Cross Section	Location Relative to Proposed RCBC	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	10393.10	10393.03	-0.07
2	Upstream	10389.67	10389.10	-0.57
3	Upstream	10389.49	10388.25	-1.24
4	Upstream	10389.35	10387.82	-1.53
5	Upstream	10389.21	10387.63	-1.58
6	Downstream	10383.48	10382.82	-0.66
7	Downstream	10378.72	10378.72	0.00
8	Downstream	10375.16	10375.16	0.00
9	Downstream	10370.66	10370.66	0.00

Proposed Arched Culvert

Based on modeling results, the proposed arched culvert will decrease the WSE by more than 1 foot. Because the opening of the proposed culvert is about twice the size of the existing opening, the WSE is expected to decrease and will no longer overtop the roadway. There is a lowering upstream and downstream of the RCBC opening. The proposed design followed CDOT's requirements to prevent roadway overtopping which led to the lowering. Due to the change in the water surface elevation, a LOMC will be required by FEMA.

In order to perform a comparison between the existing and proposed WSE, 9 cross sections were cut across the 2D hydraulic model results both upstream and downstream of the proposed structure. The average WSE was determined for both existing and the proposed arched culvert option, as shown in **Appendix F**. The WSE comparison at these sections is shown in Table 5.

Table 5: Comparison of Existing and Proposed Arched Culvert WSE

Cross Section	Location Relative to Proposed Arched Culvert	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	10393.10	10393.02	-0.08
2	Upstream	10389.67	10389.10	-0.57
3	Upstream	10389.49	10388.25	-1.24

4	Upstream	10389.35	10387.82	-1.53
5	Upstream	10389.21	10387.63	-1.58
6	Downstream	10383.48	10382.83	-0.65
7	Downstream	10378.72	10378.61	-0.11
8	Downstream	10375.16	10375.16	0.00
9	Downstream	10370.66	10370.66	0.00

Proposed Bridge

Similarly, the model for the proposed bridge will decrease the WSE by more than 1 foot. The bridge opening for this option is also about twice as large as the existing structure. Therefore, a change in WSE is expected. The proposed design followed CDOT's requirements to prevent roadway overtopping which led to the lowering. Due to the change in the water surface elevation, a LOMC will be required by FEMA.

For the proposed bridge, upstream of Bridge G-12-C (Cross Sections 1-5), the WSE decreases between 0.66 feet and 2.16 feet between existing and proposed. Downstream of Bridge G-12-C (Cross Sections 6-9), the WSE decreases a maximum of 1.25 feet between existing and proposed.

Appendix F shows the cross sections used for the proposed bridge option as well as the floodplain limit changes between existing and proposed for this scenario. Table 6 also shows a WSE comparison at each section for the proposed bridge option.

Table 6: Comparison of Existing and Proposed Bridge WSE

Cross Section	Location Relative to Proposed Bridge	Existing WSE (ft)	Proposed WSE (ft)	Proposed vs. Existing
1	Upstream	10393.10	10393.10	0.00
2	Upstream	10389.67	10389.01	-0.66
3	Upstream	10389.49	10387.95	-1.54
4	Upstream	10389.35	10387.35	-2.00
5	Upstream	10389.21	10387.05	-2.16
6	Downstream	10383.48	10382.83	-1.25
7	Downstream	10378.72	10378.72	0.00
8	Downstream	10375.16	10375.16	0.00
9	Downstream	10370.66	10370.66	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 G**.

6.2 Site Geology/Geotechnical Information and Impact to Scour Depths

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

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

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

6.3 Scour Results

Table 7 below summarizes the preliminary results for scour depths including contraction scour, abutment scour, and long-term scour at the bridge over the Middle Fork South Platte River.

Table 7: Scour Analysis Results

	Scour Type (ft)			
Storm Event	**Contraction**	**Abutment (Local)**	**Long-Term Degradation**	**Total***
100-Year	3.7	8.1	2.2	10.3
500-Year	5.0	10.4	3.9	14.3

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

6.4 Riprap Scour Countermeasures

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

This reach of the river has a high degree of meandering with braded tributaries and a notable flow contraction upstream of the bridge. Two of the river's tributaries form a confluence at the entrance of the bridge exacerbating turbulence and contraction scour. These conditions indicate a significant scour potential at this bridge crossing. Spill through abutments with riprap slope protection are recommended as scour countermeasures. The abutment will be designed with riprap slope protection around the abutments and along the roadway embankment. The riprap slope protection will be toed down to the 100-yr scour depth. The FHWA Hydraulic Toolbox Version 4.4 (FHWA, 2018) was used to size the riprap slope protection for the abutments. The riprap was sized for the 100-year hydraulic design event. The Hydraulic Toolbox applies methodology outlined in the FHWA Hydraulic Engineering Circular No. 23 Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance (HEC-23) for sizing riprap at abutments based on abutment type, set-back ratio, Froude number, specific gravity of rock riprap, and a characteristic velocity in the channel.

Results of the Hydraulic Toolbox analysis are provided in **Appendix H**. A riprap with D50 of 9-inches (in) (Class 3 per HEC-23) is recommended. The resulting recommended thickness is 18-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 abutment should extend 25' from the abutment corners along the roadway embankment and configured with the data shown in Table 8. Riprap placed below existing grade shall be constructed with a maximum 2:1 side slope. Riprap above grade will be placed at the roadway embankment slope and no steeper than 2:1.

Table 8: Countermeasure Summary

Countermeasure	D_{50}(in)	Recommended Thickness (in)	Side Slopes	Toe Down Depth (ft)	Bottom Ref. Elevation (ft)	Top Ref. Elevation (ft)
Riprap Apron	9	18	2:1	11	10365.3	10387.3

7. RCBC OUTLET ENERGY DISSIPATION

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

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

The energy dissipation alternative selected for this RCBC outlet is a riprap apron based on the Froude number of 0.65 which is less than 3. See results from HY-8 energy dissipation analysis in **Appendix G**.

8. CONCLUSIONS

This report presents preliminary analysis and results from the hydrologic and hydraulic study for the Region 2 Bridge Bundle Design Build – Bridge G-12-C. This report documents preliminary analysis in determining costs for proposed structure replacement at this location. It also includes preliminary FEMA floodplain analysis and scour analysis.

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

Based on the hydraulic analysis, the proposed replacement for this structure is a 2-cell arched corrugated aluminum culvert (ALBC 74) that has approximately a 24-ft span with a 10-ft rise.

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

Total design scour for the bridge abutments was determined to be 14.3 feet at the 500-year design event. This accounts for the contraction scour and long-term degradation impacts that could potentially affect the proposed bridge abutments. A riprap apron was designed in order to protect the proposed abutments.

9. REFERENCES

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

APPENDIX A FEMA FIRM 08093C0325C

NOTES TO USERS

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

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table shown on this map. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

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

Special Flood Hazard Areas were determined by **approximate study methods**. Therefore, no Flood Insurance Study Report was developed.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 13. The **horizontal datum** was NAD 83, GRS 1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

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

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

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

Base map information shown on this FIRM was derived from NAIP Orthophotography produced with a one meter ground resolution from photography dated 2005.

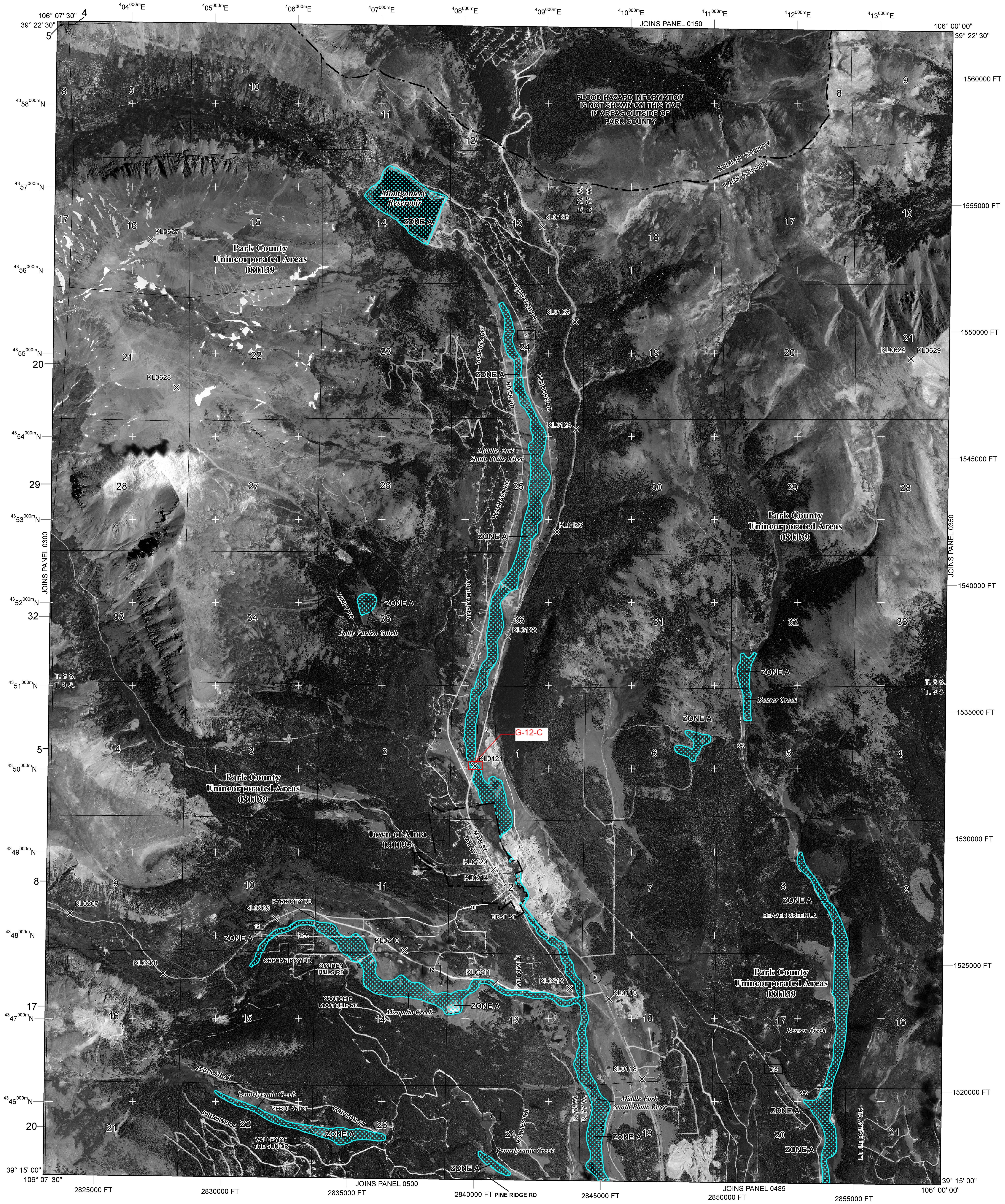
This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables for multiple streams in the Flood Insurance Study Report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

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

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

Contact the **FEMA Map Service Center** at 1-800-358-9616 for information on available products associated with this FIRM. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. The FEMA Map Service Center may also be reached by Fax at 1-800-358-9620 and its website at http://msc.fema.gov.

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



LEGEND

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

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

ZONE A No Base Flood Elevations determined.

ZONE AE Base Flood Elevations determined.

ZONE AH Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.

ZONE AO Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.

ZONE AR Special Flood Hazard Areas formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.

ZONE A99 Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.

ZONE V Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.

ZONE VE Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

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

OTHER FLOOD AREAS

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

OTHER AREAS

ZONE X Areas determined to be outside the 0.2% annual chance floodplain.

ZONE D Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

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

1% Annual Chance Floodplain Boundary

0.2% Annual Chance Floodplain Boundary

Floodway boundary

Zone D boundary

CBRS and OPA boundary

Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.

513 — Base Flood Elevation line and value; elevation in feet*

(EL 987) — Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A — A Cross section line

23 - - - 23 Transect line

Culvert

Bridge

45° 02' 08", 93° 02' 12" — Geographic coordinates referenced to the North American Datum of 1983 (NAD 83) Western Hemisphere

3100000 FT — 5000-foot ticks: Colorado State Plane Central Zone (FIPS Zone 0502), Lambert Conformal Conic projection

4989000m N — 1000-meter Universal Transverse Mercator grid values, zone 13

DX5510 × — Bench mark (see explanation in Notes to Users section of this FIRM panel)

• M1.5 — River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
December 18, 2009

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

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

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

MAP SCALE 1" = 2000'

1000 0 2000 4000 FEET
600 0 600 1200 METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0325C

FIRM

FLOOD INSURANCE RATE MAP

PARK COUNTY, COLORADO (AND INCORPORATED AREAS)

PANEL 325 OF 1350

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
ALMA, TOWN OF	080095	0325	C
PARK COUNTY	080139	0325	C

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

MAP NUMBER 08093C0325C

EFFECTIVE DATE DECEMBER 18, 2009

Federal Emergency Management Agency

APPENDIX B AERIAL IMAGERY AND PHOTOS

CDOT REGION 2 – BRIDGE BUNDLE

AERIAL IMAGERY AND PHOTOS

STRUCTURE G-12-C

FIGURE 1

AERIAL IMAGERY AND PHOTOS

STRUCTURE G-12-C

FIGURE 2

AERIAL IMAGERY AND PHOTOS

STRUCTURE G-12-C

FIGURE 3

AERIAL IMAGERY AND PHOTOS

STRUCTURE G-12-C

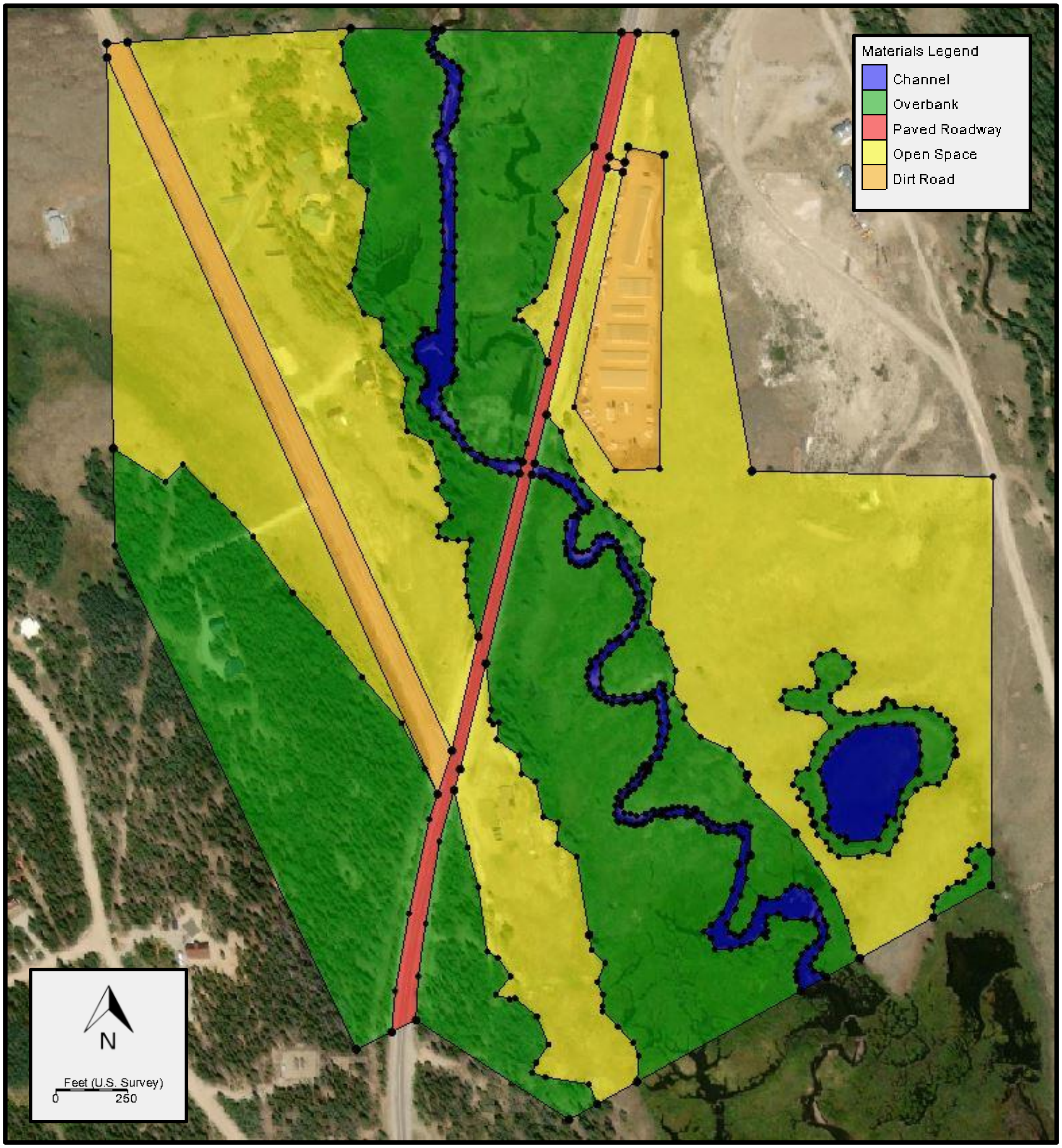
FIGURE 4

AERIAL IMAGERY AND PHOTOS

STRUCTURE G-12-C

FIGURE 5

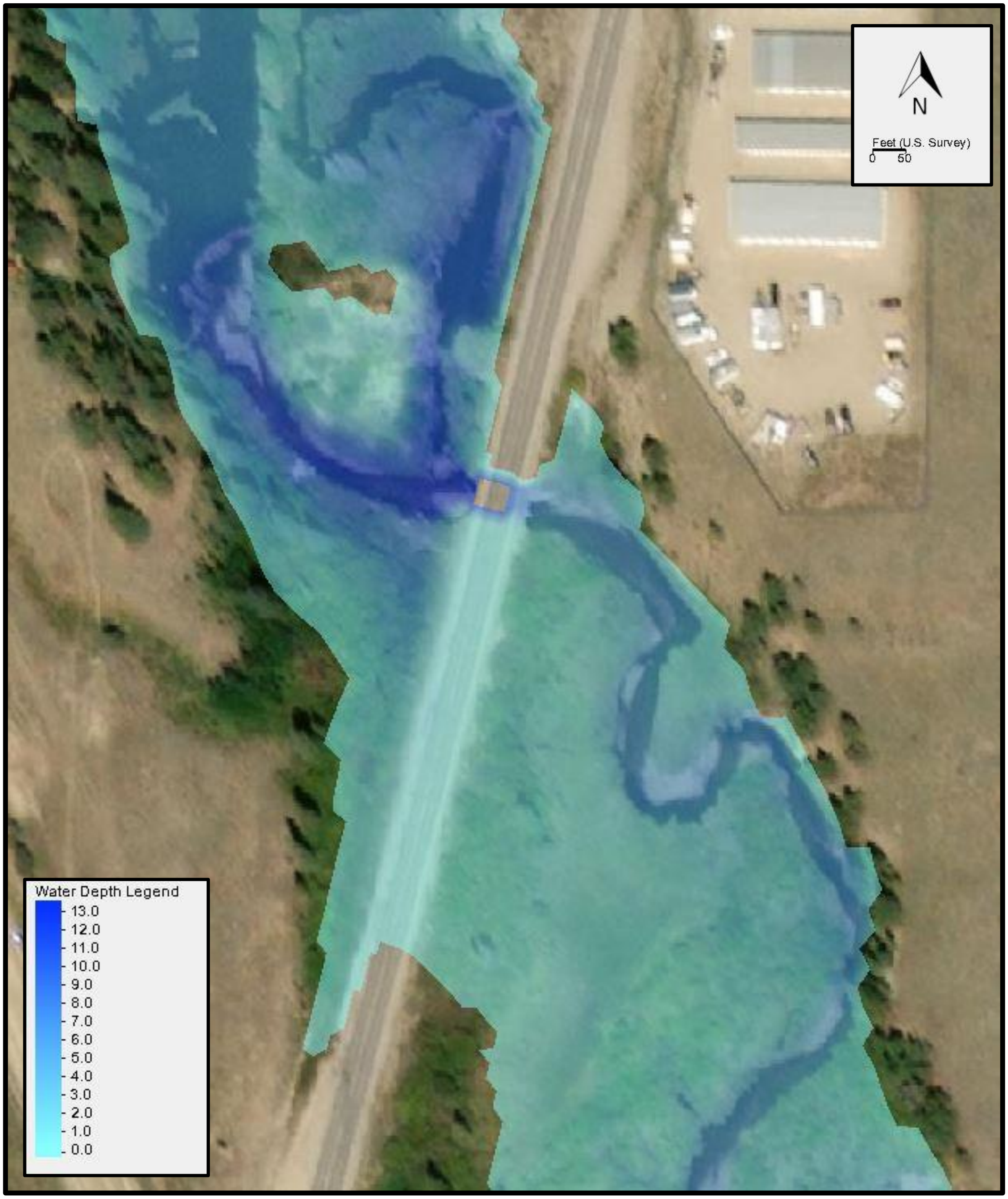
APPENDIX C EXISTING CONDITIONS MODEL GRAPHICS



MATERIALS COVERAGE

STRUCTURE G-12-C

FIGURE 1



EXISTING CONDITIONS – WATER DEPTH

STRUCTURE G-12-C

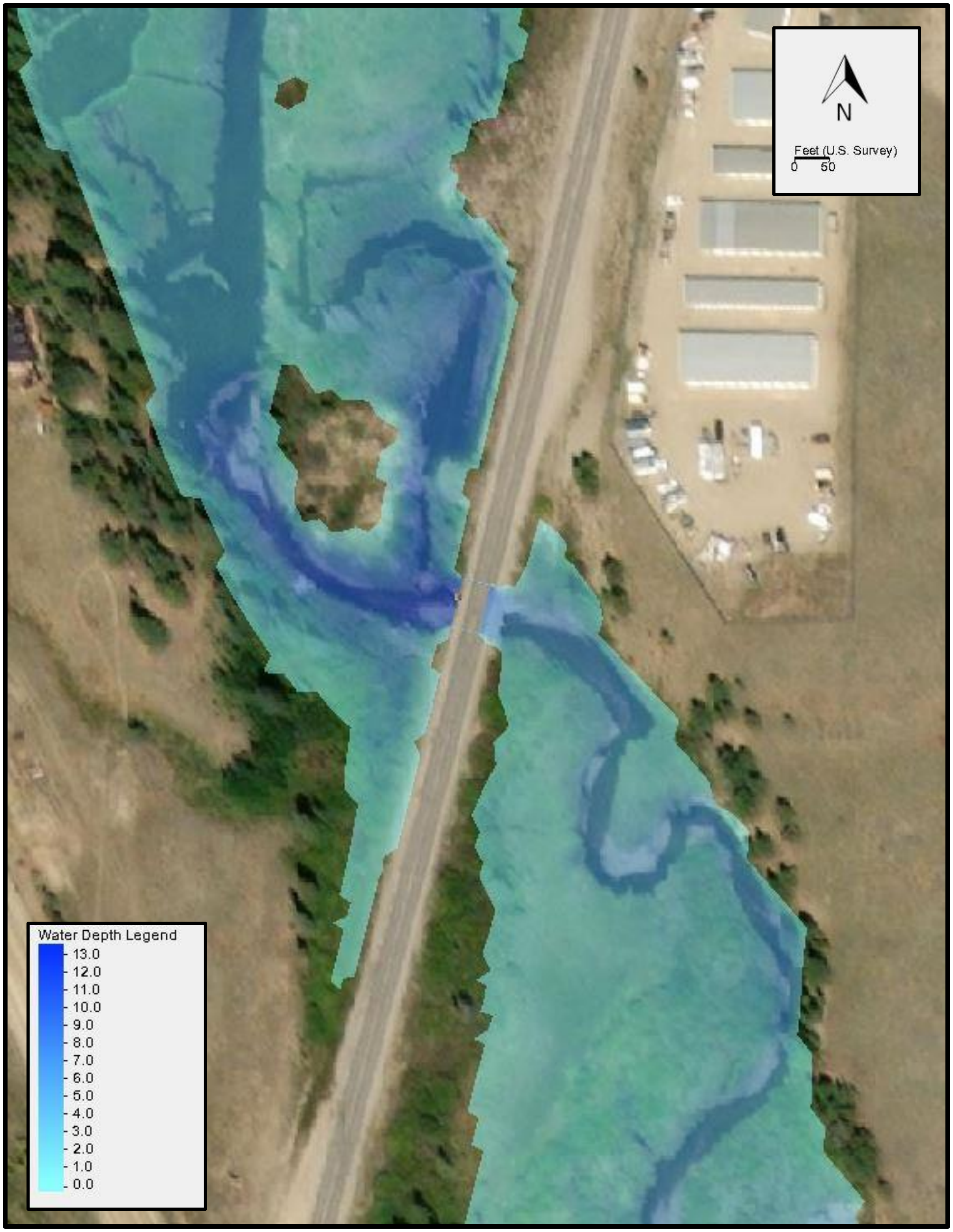
FIGURE 2

EXISTING CONDITIONS – VELOCITY

STRUCTURE G-12-C

FIGURE 3

APPENDIX D PROPOSED CULVERT ALTERNATIVE MODEL GRAPHICS



PROPOSED CONDITIONS – WATER DEPTH

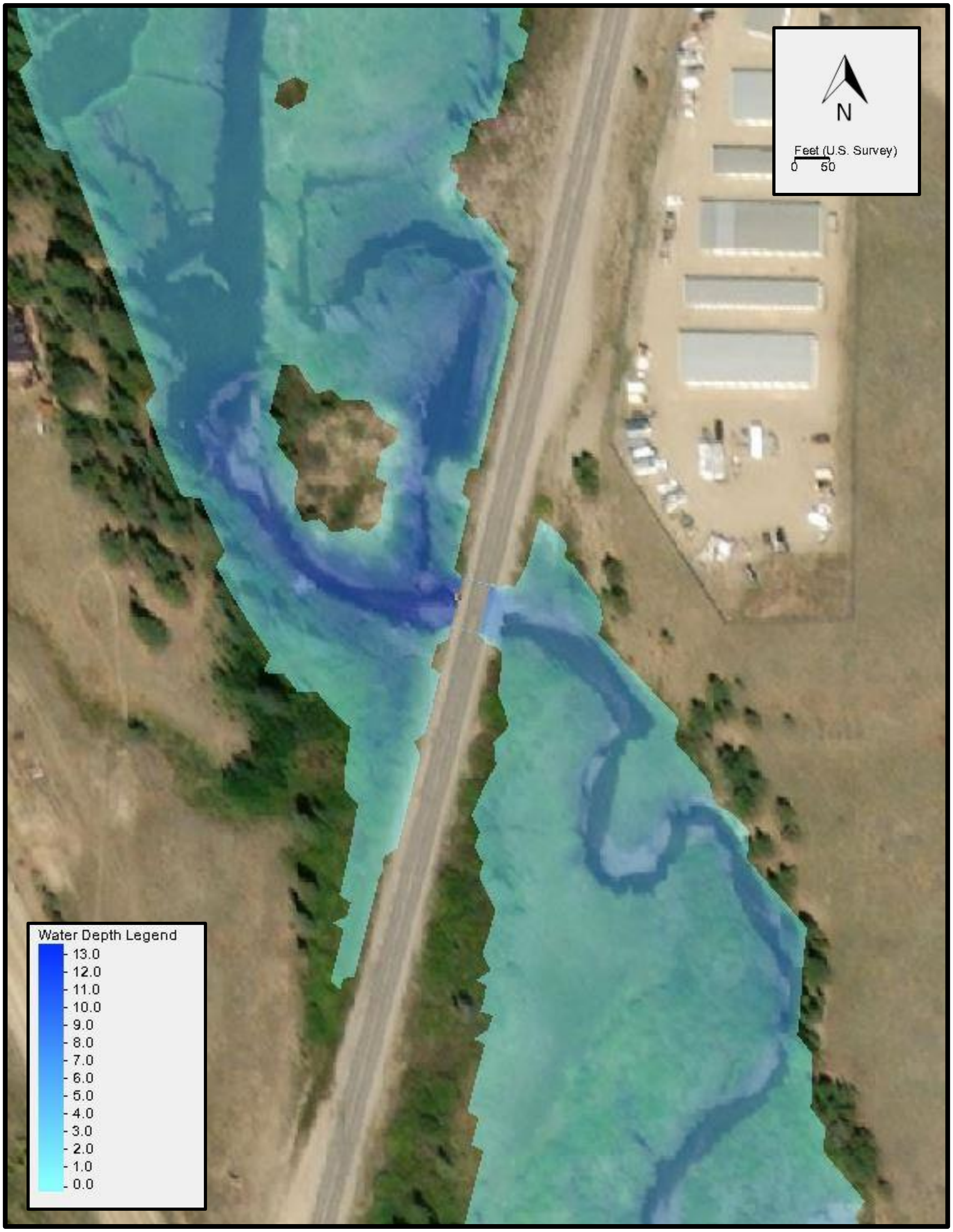
RCBC AT STRCUTURE G-12-C

FIGURE 1

PROPOSED CONDITIONS – VELOCITY

RCBC AT STRUCTURE G-12-C

FIGURE 2



PROPOSED CONDITIONS – WATER DEPTH

ARCHED CULVERT AT STRCUTURE G-12-C

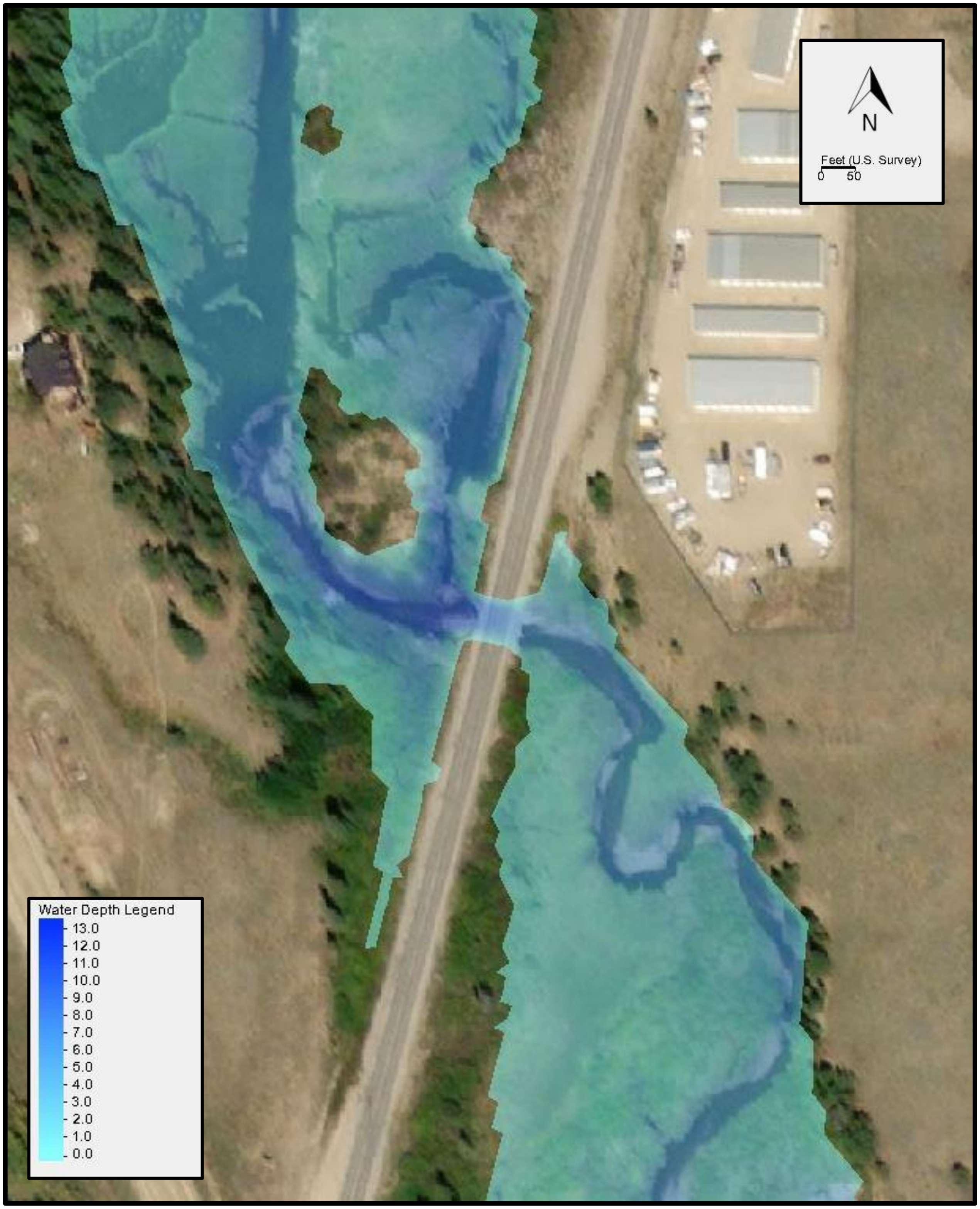
FIGURE 3

PROPOSED CONDITIONS – VELOCITY

ARCHED CULVERT AT STRUCTURE G-12-C

FIGURE 4

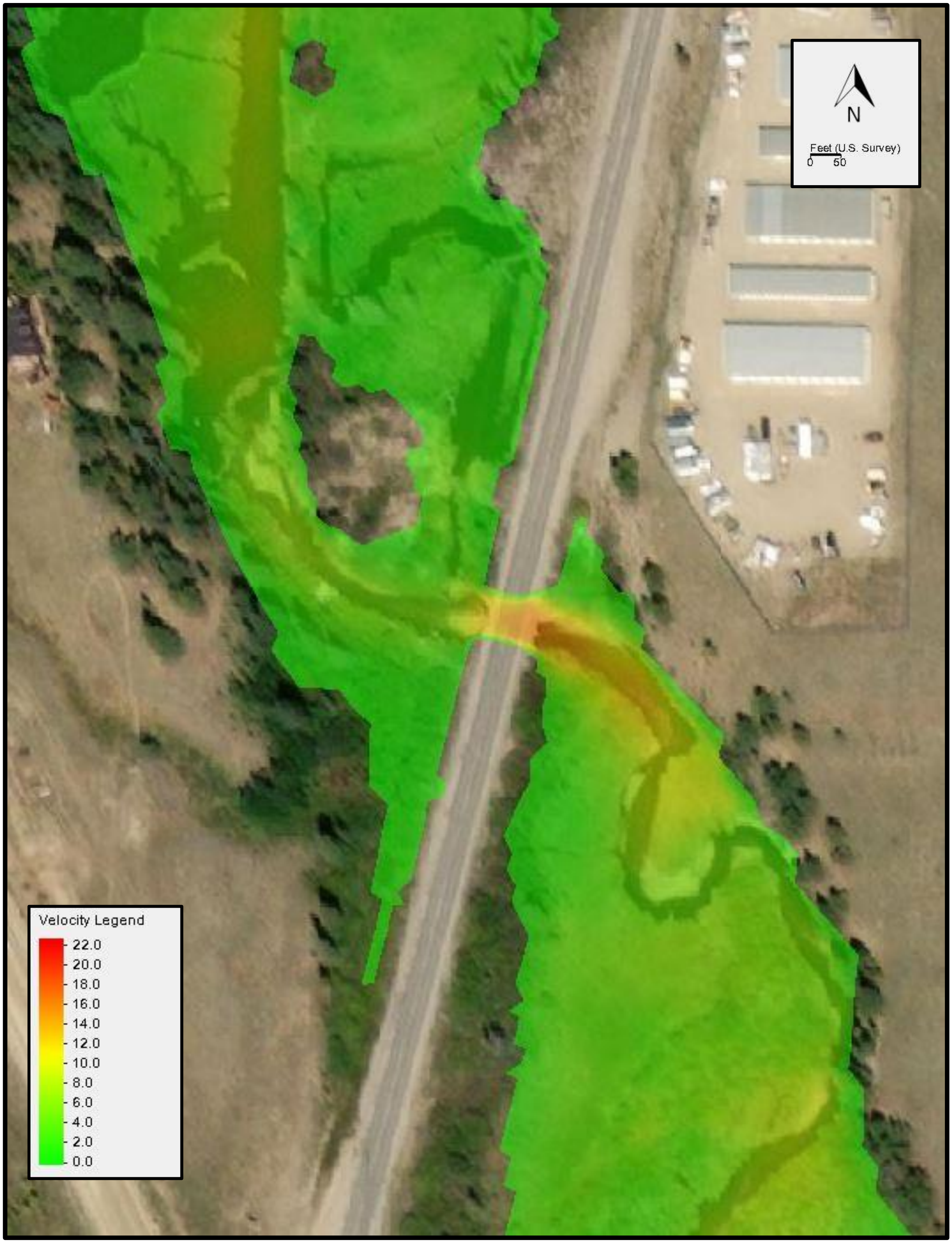
APPENDIX E PROPOSED BRIDGE ALTERNATIVE MODEL GRAPHICS



PROPOSED CONDITIONS – WATER DEPTH

BRIDGE AT STRUCTURE G-12-C

FIGURE 1

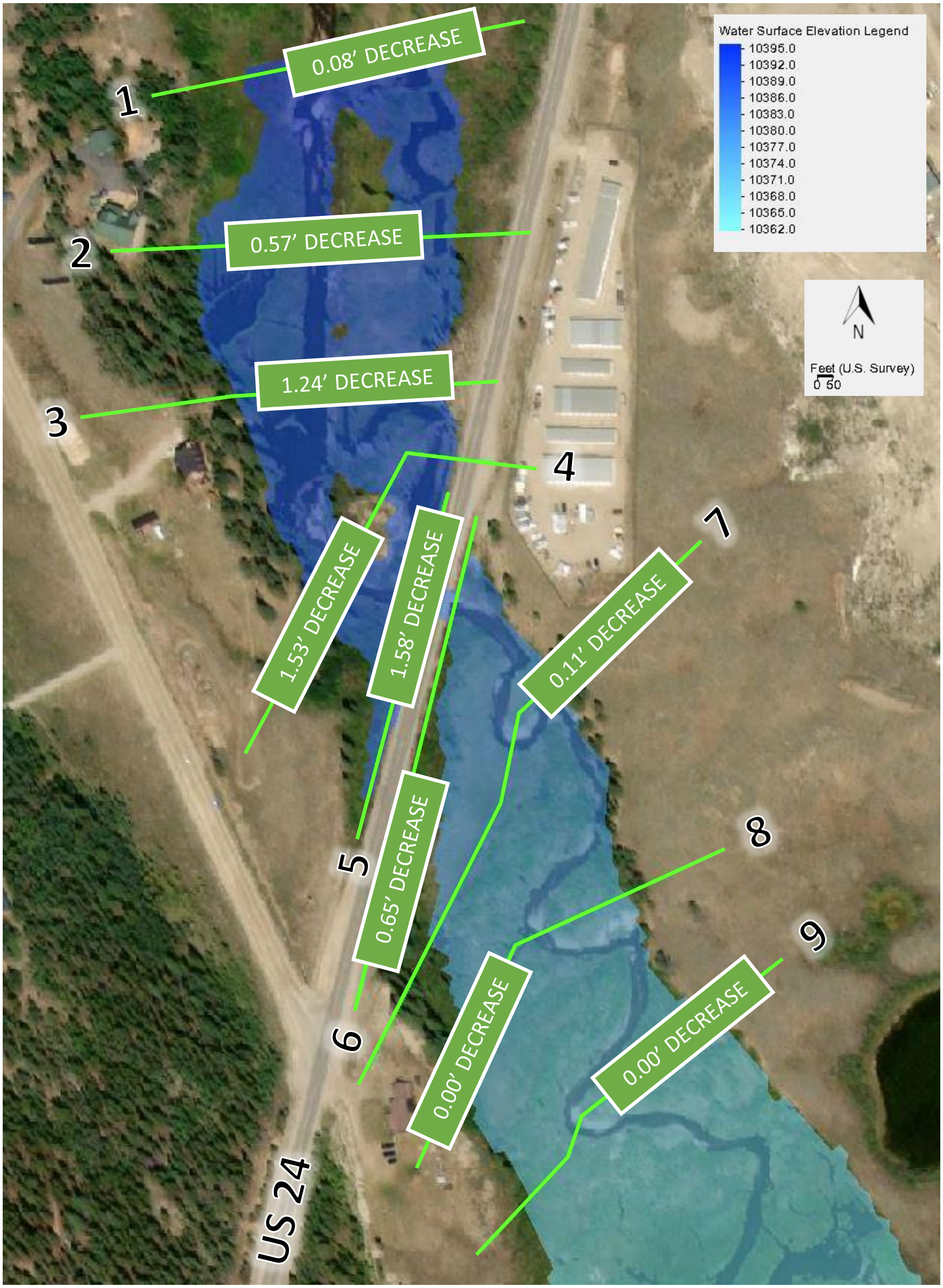


PROPOSED CONDITIONS – VELOCITY

BRIDGE AT STRUCTURE G-12-C

FIGURE 2

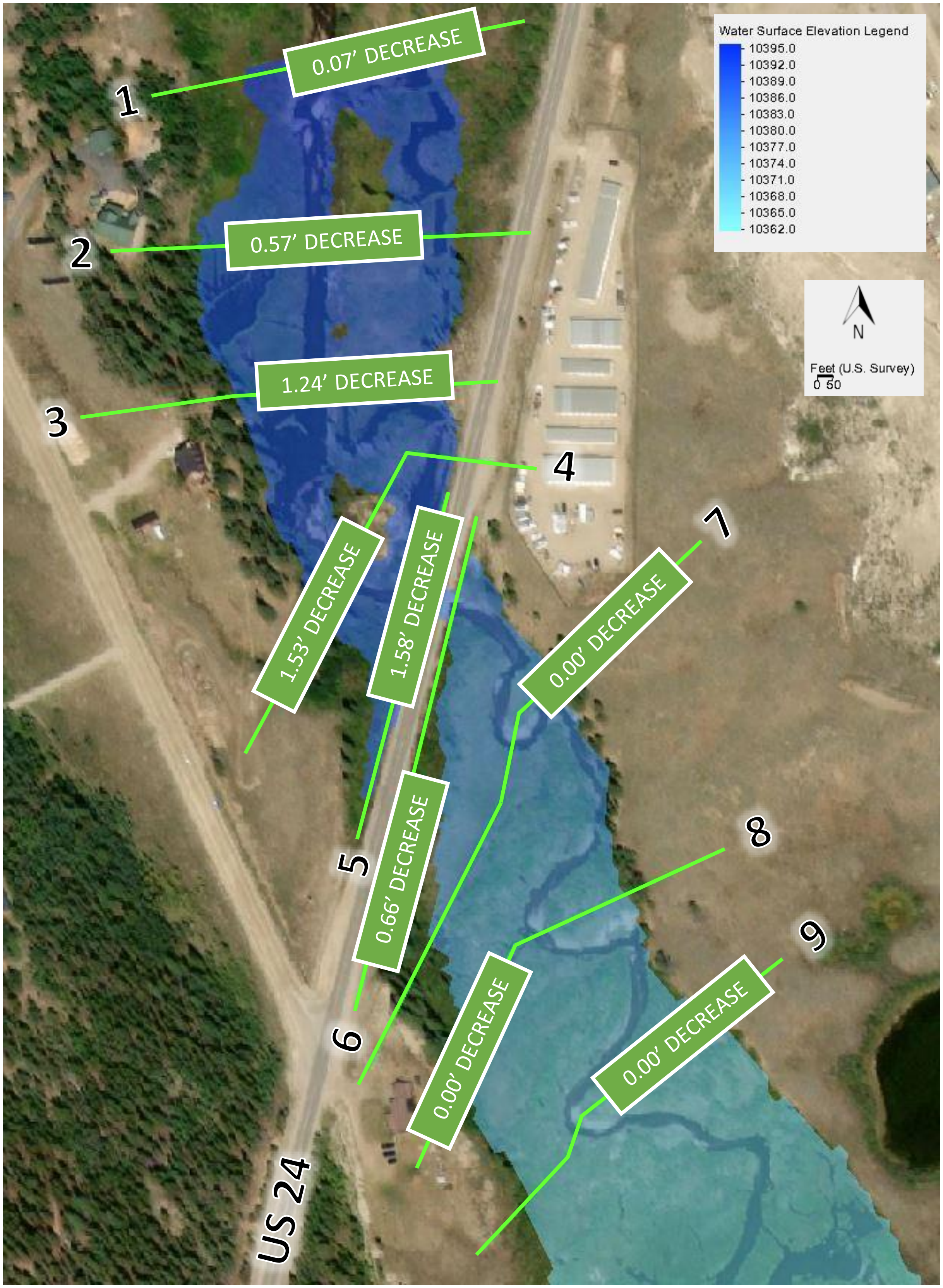
APPENDIX F WATER SURFACE ELEVATION GRAPHICS



WATER SURFACE ELEVATION COMPARISON – RCBC OPTION

STRUCTURE G-12-C

FIGURE 1



WATER SURFACE ELEVATION COMPARISON – ARCHED OPTION

STRUCTURE G-12-C

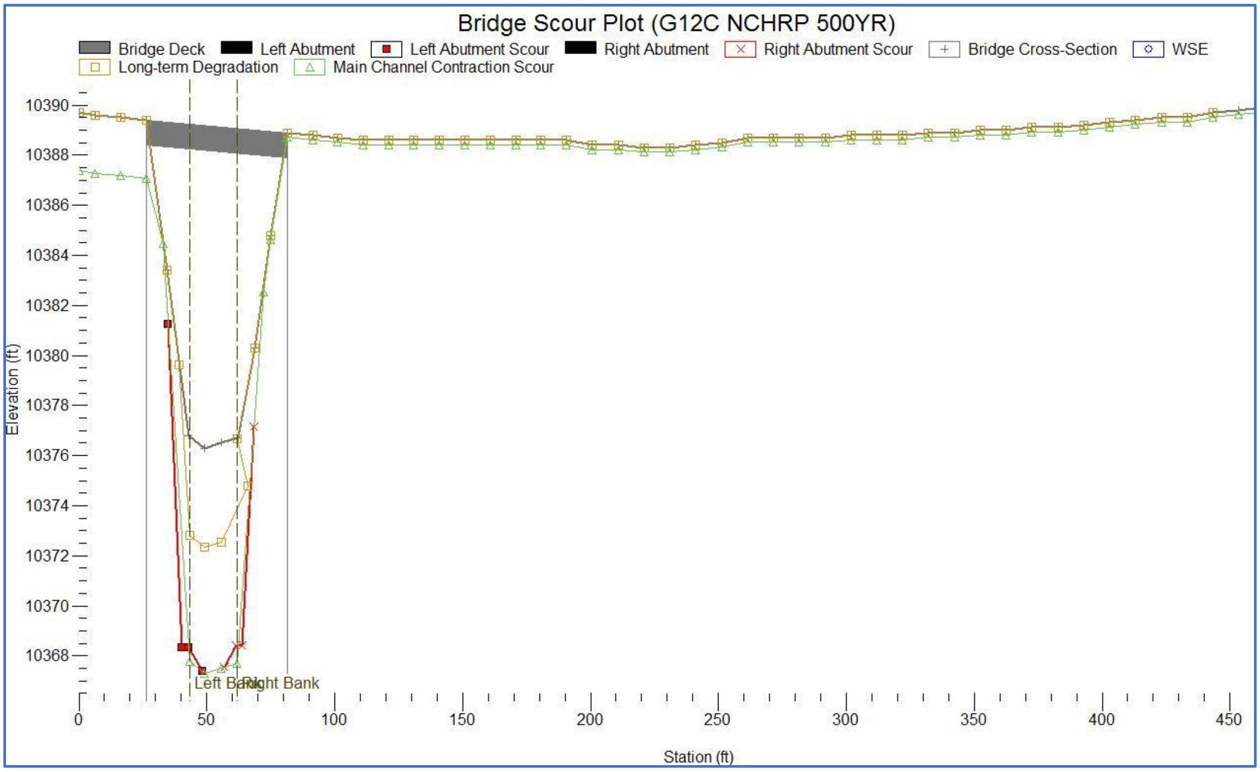
FIGURE 2

WATER SURFACE ELEVATION COMPARISON – BRIDGE OPTION

STRUCTURE G-12-C

FIGURE 3

APPENDIX G BRIDGE SCOUR ANALYSIS


Bridge Scour Plot (G12C NCHRP 500YR)
Bridge Deck
Left Abutment
Left Abutment Scour
Right Abutment
Right Abutment Scour
Bridge Cross-Section
WSE
Long-term Degradation
Main Channel Contraction Scour
Elevation (ft)
10390
10388
10386
10384
10382
10380
10378
10376
10374
10372
10370
10368
Left Bank
Right Bank
0
50
100
150
200
250
300
350
400
450
Station (ft)

Hydraulic Analysis Report

Project Data

Project Title: G-12-C 100YR

Designer: Stanley Consultants

Project Date: Monday, December 7, 2020

Project Units: U.S. Customary Units

Riprap Analysis: Left Abutment

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

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 15.34 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: 7.45 ft

Flow Depth at Toe of Abutment: 1.58 ft

Calculations will use either total or overbank discharges.

Total Discharge: 2885 cfs

Overbank Discharge: 871.5 cfs

Total Bridge Area: 322 ft^2

Setback Area: 162.604 ft^2

Maximum Channel Velocity: 8.97 ft/s

Specific Gravity of Riprap: 2.65

Result Parameters

Set-back ratio: 2.05906

Characteristic Velocity: 8.95963 ft/s

Froude Number at the Abutment Toe: 1.25663

Abutment Coefficient: 0.69

Computed D50: 8.45244 in

Design D50 = 9 in

Thickness = 18 in

Design D50 > Computed D50

9 in > 8.45244 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: 3.16 ft

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

See HEC 23, Figure 14.7

Riprap Analysis: Right Abutment

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

Input Parameters

Riprap Type: Abutment/Guide Bank

The structure is a guidebank

Set-back Length: 15.34 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: 7.45 ft

Flow Depth at Toe of Abutment: 1.58 ft

Calculations will use either total or overbank discharges.

Total Discharge: 2885 cfs

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Total Bridge Area: 322 ft^2

Setback Area: 162.604 ft^2

Maximum Channel Velocity: 8.97 ft/s

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Result Parameters

Set-back ratio: 2.05906

Characteristic Velocity: 8.95963 ft/s

Froude Number at the Abutment Toe: 1.25663

Abutment Coefficient: 0.69

Computed D50: 8.45244 in

Design D50 = 9 in

Thickness = 18 in

Design D50 > Computed D50

9 in > 8.45244 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: 3.16 ft

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

See HEC 23, Figure 14.7

No channel used in calculations

HY-8 Energy Dissipation Report

Scour Hole Geometry

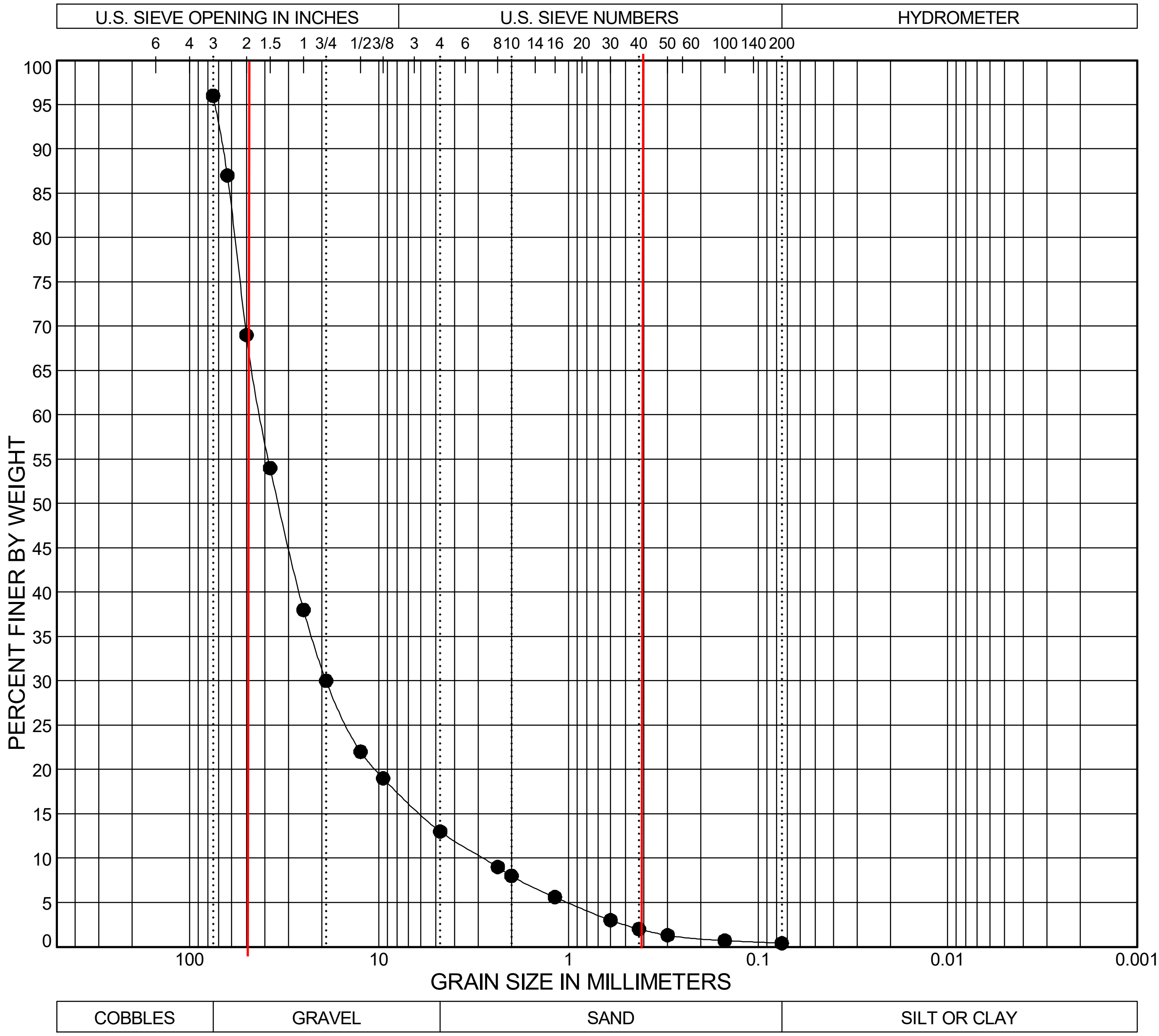
Parameter	Value	Units
Select Culvert and Flow		
Crossing	Proposed Box	
Culvert	Box	
Flow	2885.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	40.0	ft
Culvert Height	10.0	ft
Outlet Depth	7.25	ft
Outlet Velocity	9.95	ft/s
Froude Number	0.65	
Tailwater Depth	7.25	ft
Tailwater Velocity	8.12	ft/s
Tailwater Slope (SO)	0.0000	
Scour Data		
Time to Peak		
Note:	if Time to Peak is unknown, enter 30 min	
Time to Peak	30.00	min
Cohesion	Noncohesive	
D16 Value	0.42	mm
D84 Value	50.00	mm
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Soil Sigma	10.91	
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)	7.248	ft
Velocity with TW and WS	-1.#IO	ft/s

HY-8 Energy Dissipation Report

External Energy Dissipator

Parameter	Value	Units
Select Culvert and Flow		
Crossing	Proposed Box	
Culvert	Box	
Flow	2885.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	40.0	ft
Culvert Height	10.0	ft
Outlet Depth	7.25	ft
Outlet Velocity	9.95	ft/s
Froude Number	0.65	
Tailwater Depth	7.25	ft
Tailwater Velocity	8.12	ft/s
Tailwater Slope (SO)	0.0000	
External Dissipator Data		
External Dissipator Category	Streambed Level Structures	
External Dissipator Type	Riprap Basin	
Restrictions		
Froude Number	<3	
Input Data		
Condition to be used to Compute Basin Outlet Velocity	Best Fit Curve	
D50 of the Riprap Mixture		
Note:	Minimum HS/D50 = 2 is Obtained if D50 = 0.324 ft	
D50 of the Riprap Mixture	0.324	ft
DMax of the Riprap Mixture	1.500	ft
Results		
Brink Depth	7.248	ft
Brink Velocity	9.951	ft/s
Depth (YE)	7.248	ft
Riprap Thickness	2.250	ft
Riprap Foreslope	3.0000	ft
Check HS/D50		
Note:	OK if HS/D50 > 2.0	
HS/D50	2.121	
HS/D50 Check	HS/D50 is OK	
Check D50/YE		
Note:	OK if 0.1 < D50/YE < 0.7	
Check D50/YE	0.045	
D50/YE Check	D50/YE is NOT OK	
Basin Length (LB)	160.000	ft
Basin Width	146.667	ft
Apron Length	40.000	ft
Pool Length	120.000	ft
Pool Depth (HS)	0.687	ft
TW/YE	1.000	
Tailwater Depth (TW)	7.248	ft
Average Velocity with TW	2.470	ft/s
Critical Depth (Yc)	2.267	ft
Average Velocity with Yc	8.417	ft/s
Downstream Riprap for High TW		
Distance: 1 LB		
Velocity	6.917	ft/s
Size	0.312	ft
Distance: 2 LB		
Velocity	3.618	ft/s
Size	0.085	Ft
Distance: 3 LB		
Velocity	2.405	ft/s
Size	0.038	ft
Distance: 4 LB		
Velocity	1.800	ft/s
Size	0.021	ft

APPENDIX H GEOTECHNICAL INFORMATION



	BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines %Silt	%Fines %Clay
●	**G-12-C Scour**	**0.0**	**A-1-a (0)**	**GP**	**NV**	**NP**	**NP**	**83.0**	**12.6**	**0.4**	

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

SIEVE ANALYSIS

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

CDOT Region 2 Bridge Bundle
Scour Test Results
Structure G-12-C

FIGURE

S- 1