Technical Memorandum
Preliminary Hydraulic Analysis and Design of
STRUCTURE M-22-U REPLACEMENT
As a part of the
REGION TWO BRIDGE BUNDLE PACKAGE
OTERO COUNTY, COLORADO

A Part of Section 17, Township 24 South, Range 55 West of the 6th P.M.,
County of Las Animas, Colorado

February 5, 2021

Prepared for:

Colorado Department of Transportation
Region 2
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1. INTRODUCTION

1.1 Background and Purpose

The objective of Colorado Department of Transportation (CDOT) Region 2 Bridge Bundle Design Build project is to replace nineteen (19) rural structures spread across highway corridors in southern and western Colorado. The structures are located on US 350, US 24, CO 9, and CO 239. The role of Stanley Consultants is to assist CDOT in the design build procurement, geotechnical engineering, environmental clearances, survey, utility location and coordination, hydrology and hydraulics, preliminary structural design and roadway design.

This design build project is partially funded by the USDOT FHWA Competitive Highway Bridge Program grant (14 structures, project number 23558) and funds from the Colorado Bridge Enterprise (5 additional structures, project number 23559). These projects are combined to form one design-build project.

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

1.2 Site Description

The purpose of this report is to document the preliminary hydraulic analysis and design for the replacement of Structure M-22-U as a part of the CDOT Region 2 Bridge Bundle Design Build. The project is located within Otero County at Mile Post 69.817 along US 350, southwest of La Junta, Colorado. Structure M-22-U crosses over the Otero Ditch. Figure 1 below illustrates the project location. The project is located in Section 17, Township 24 South, Range 55 West of the 6th P.M., County of Otero, Colorado. **Figure 1** shows the project limits.

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

Figure 1: Vicinity Map

2. EXISTING CONDITIONS

2.1 Existing Structure

Existing structure is a single span concrete deck, steel I beam girder bridge built in 1935 to span the Otero Canal. The bridge is on a 45-degree skew. The existing bridge span length is 39.5 feet with a total structure length of 44.0 feet. The width of the existing bridge is 30.0 feet curb to curb, 33.5 feet out to out of deck. The existing vertical clearance is approximately 11.0 feet max.

2.2 Existing Ditch

Structure M-22-U spans over the Otero Ditch. This ditch carries irrigation flows to downstream customers. Irrigation water under the bridge goes from southwest to northeast. The existing ditch runs close to parallel to US 350 as it flows next to the bridge. It then turns and crosses under the bridge at about a 45-degree skew, then turns and flows to the northeast.

Initial discussions with the ditch company were performed to coordinate the design and determine decreed flows and document times of operation. Decreed flow in the ditch as provided by the ditch company is 123 cfs. This flowrate was used for all preliminary analysis. Decreed flows must be confirmed and documented in later phases of the design.

The ditch conveyance schedule is currently unknown. Construction schedule must be coordinated with the ditch company to avoid interruption of service for the canal.

2.3 Site Investigation

A site investigation by Stanley Consultants in August 2020 was performed to gain an understanding of the key hydraulic conditions of the ditch and to investigate the condition of the existing bridge. Site photos are included in **Appendix A**.

3. HYDRAULIC ANALYSIS

A hydraulic model was developed using the Hydrologic Engineering Center River Analysis System (HEC-RAS), version 5.0.7, a software developed by the U.S. Army Corps of Engineers (USACE). The model was run as a steady state flow model with the decreed flow of 123 cfs. For this analysis, three models were developed:

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

3.1 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. The elevation of the water surface 50 to 100 feet upstream of the face of the bridge shall be the elevation to which the freeboard is added to get the bottom or low-girder elevation of the bridge.

The channel was not identified as having a high potential for debris production. Therefore, if a bridge were to be selected as the preferred alternative for the proposed conveyance structure, 2 feet of freeboard would typically be required. The existing decreed flow WSE provides more than 2 feet of freeboard.

3.2 Modeling Parameters

3.2.1 Elevation Data

Existing conditions survey for the bridge and channel cross sections was performed by CDOT in June, 2020. This data source was used for the modeling elevation surface.

A local, custom projection was used for the data collection in the existing conditions survey. All elevations are referenced to NAVD 88 (feet).

3.2.2 Cross Sections

19 cross sections were added to the model spaced between 20 and 90 feet apart along the ditch channel. 10 were plotted upstream (southwest) of the bridge, and 8 were placed downstream (northeast).

3.2.3 Surface Roughness

A Manning's n-value was assigned to the channel, left, and right overbanks. These were defined based on aerial imagery, topography, a site visit in August, 2020, and engineering judgment. An n-value of 0.065 was used for the channel, and 0.035 was used for the left and

right overbanks. The decreed flow is completely contained within the main channel. Photos from the site visit used to confirm the n-values selected are shown in **Appendix A**.

3.2.4 Hydraulic Structures

The modeled existing bridge geometry is based on the survey completed in August 2020 and as-built information. The bridge slopes very gently down gradient from south to north. The high chord of the bridge is 4231.85 feet. With a superstructure depth of approximately 39 inches, the low chord is approximately 4228.60 feet.

3.3 Model Results

3.3.1 Existing Conditions

The existing condition model shows that flows within the channel are maintained at approximately 5.3 feet of depth. The existing WSE is 4223.32 at the cross section just upstream of the bridge, which is 5.28 feet of freeboard below the low chord of the bridge. Existing conditions WSEs are shown in **Appendix B**.

3.3.2 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 ditch hydraulics, and environmental impacts among others.

<u>Proposed RCBC</u>

This option was modeled using the same HEC-RAS model as was used for the existing conditions. Modifications to the model included implementing a proposed RCBC that has a 16-foot width and a 10-foot height. This culvert was modeled with a 79-foot length. The inlet of the culvert was modeled with flared wingwalls with a 0.4 entrance loss coefficient. The inverts of the box culvert were set at the thalweg of the channel which set the longitudinal slope of the culvert at 0.2%. The preliminary model shows the roadway embankment sloping at 3:1.

The proposed RCBC model shows the depth of flow in the channel to remain the same as existing upstream and downstream of the bridge, with slight changes to the WSEs at the RCBC. The WSE at the upstream cross section is 4223.33 feet. This is 0.01 feet higher than existing. This condition provides 4.75 feet of freeboard below the top of the box. See **Appendix C** for WSE comparison tables and HEC-RAS cross sections for the proposed RCBC alternative.

Please note that a smaller RCBC structure will provide adequate conveyance at this location. However, a 16'x10' RCBC was provided to allow for as large an opening as economically feasible per request of the ditch company. The size of the structure will need to be negotiated with the ditch company in later phases of the design.

<u>Proposed Bridge</u>

This option was modeled using the same HEC-RAS model as was used for the existing conditions. Modifications to the model included changing the superstructure depth to 30 inches. The deck of the proposed bridge is modeled at the same elevation as the existing structure. The abutment locations are revised to provide a 40-foot span.

The proposed bridge model shows the depth of flow in the channel to remain relatively the same as existing upstream and downstream of the bridge. The WSE at the upstream cross section is 4223.32 feet. This matches existing. This condition provides 6.03 feet of freeboard. See **Appendix D** for WSE comparison tables and HEC-RAS cross sections for the proposed bridge alternative.

Preferred Alternative

Because there is no major difference between the two alternatives, the preferred alternative for the replacement of the existing bridge is the RCBC.

4. 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, and outlet depth, velocity and Froude number was determined. To determine tailwater data, the downstream channel information was gathered from the survey data, and field inspection.

Allowable scour estimation was completed using HY-8. Soil parameters of the downstream channel were extracted from the geotechnical investigation. The estimated scour hole was then determined using HY-8. The estimated scour hole for this culvert was very small given the low velocity in the channel. Because of this result, no energy dissipation is required for the RCBC outlet. See **Appendix G** for geotechnical information and **Appendix F** for outlet protection analysis.

5. CONCLUSIONS

This report presents preliminary analysis and results from the hydraulic study for the Region 2 Bridge Bundle Design Build – Bridge M-22-U. This report documents preliminary analysis in determining costs for proposed structure replacement at this location.

A HEC-RAS 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 for the replacement of the existing bridge.

Based on the hydraulic analysis, the proposed replacement for this bridge is a 16-foot(width) by 10-foot(height) reinforced concrete box culvert (RCBC). The proposed freeboard is 4.75 feet and the proposed WSE upstream of the proposed bridge is 5966.97 feet. The proposed RCBC decreases the WSE at the entrance to the culvert.

6. 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. 15, Third Edition – Hydraulic Design of Energy Dissipators for Culverts and Channels". U.S. Department of Transportation Federal Highway Administration, July 2006.
4. "Hydraulic Engineering Circular No. 18 – Evaluating Scour At Bridges Fifth Edition". U.S. Department of Transportation Federal Highway Administration, April 2012.
5. "Hydraulic Engineering Circular No. 20 – Stream Stability at Highway Structures". U.S. Department of Transportation Federal Highway Administration, April 2012.
6. "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.
7. CDOT Region 2 2D Quick Check Hydrology Summary Report and Matrix, Colorado Department of Transportation, 2020.

APPENDIX A PHOTOS

PHOTO 1: DOWNSTREAM OF BRIDGE (LOOKING NORTHEAST)

STRUCTURE M-22-U

APPENDIX A

PHOTO 2: UPSTREAM OF BRIDGE (LOOKING SOUTHWEST)

STRUCTURE M-22-U

APPENDIX A

PHOTO 3: BRIDGE LOOKING SOUTHWEST

STRUCTURE M-22-U

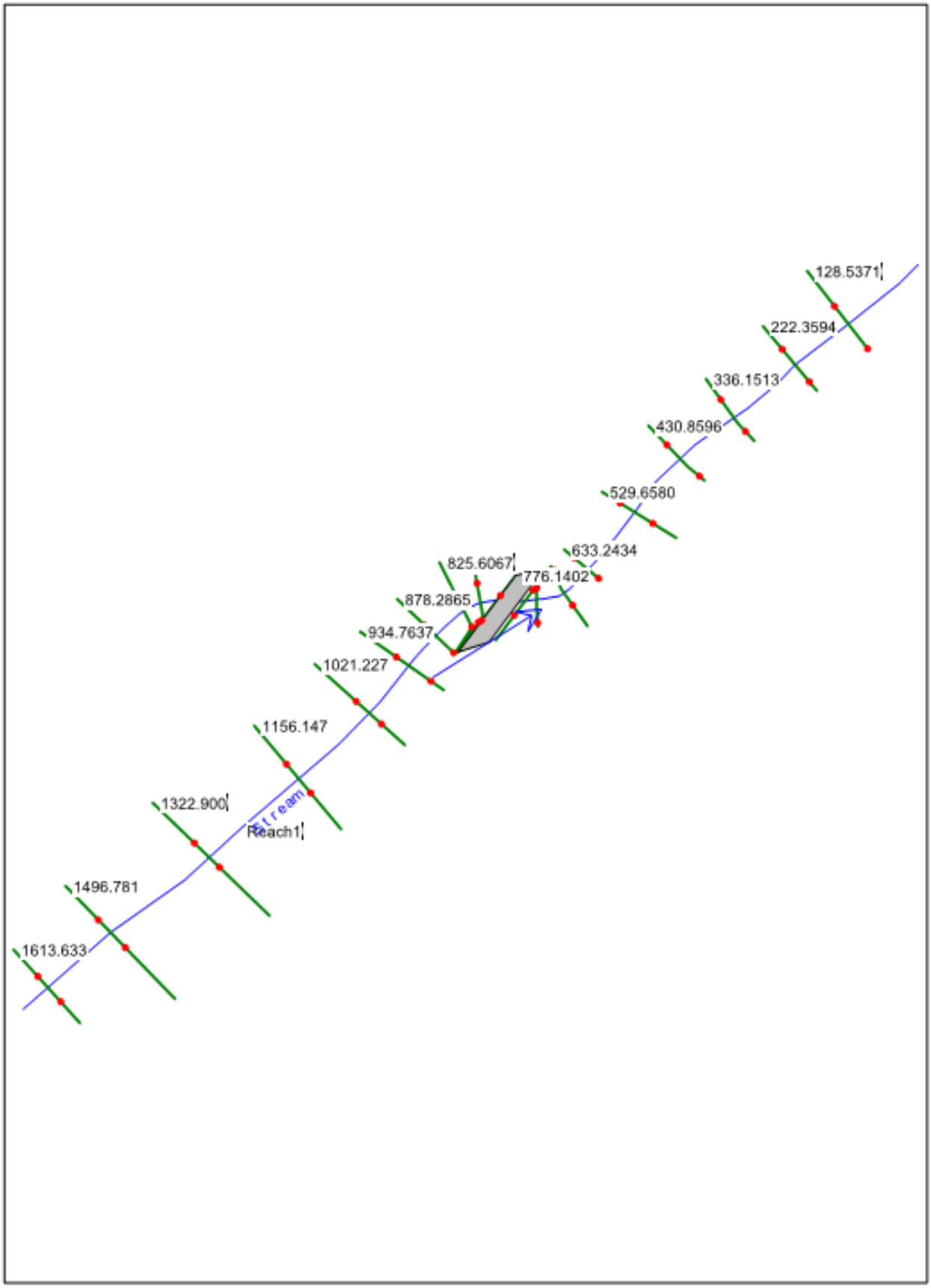
APPENDIX A

PHOTO 4: DITCH UNDER THE BRIDGE (LOOKING SOUTHWEST)

STRUCTURE M-22-U

APPENDIX A

APPENDIX B EXISTING CONDITIONS ANALYSIS GRAPHICS



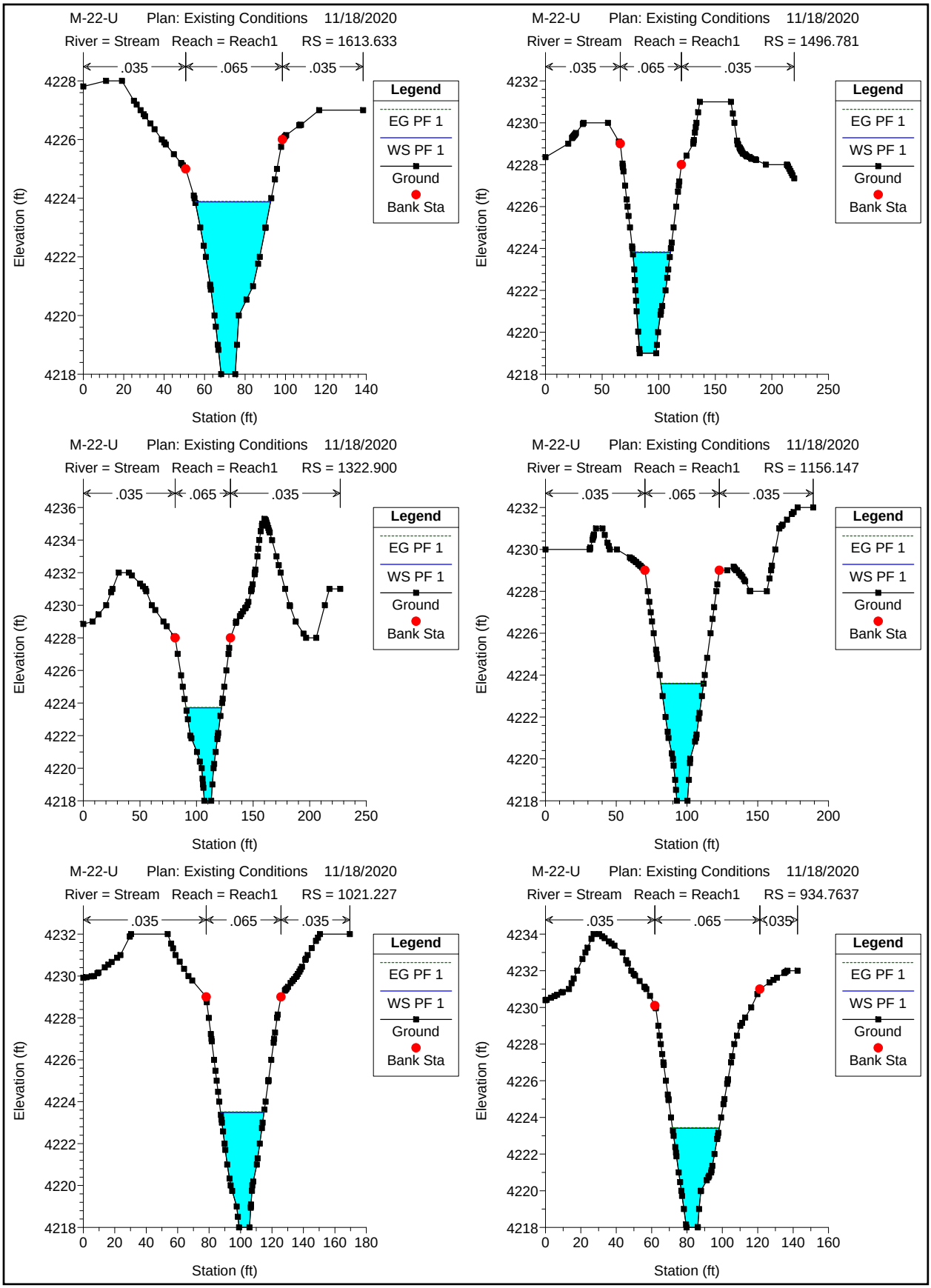
EXISTING CONDITIONS HEC-RAS LAYOUT

STRUCTURE M-22-U

APPENDIX B

HEC-RAS Plan: Existing River: Stream Reach: Reach1 Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach1	1613.633	PF 1	123.00	4218.00	4223.88		4223.89	0.000475	1.03	119.24	37.28	0.10
Reach1	1496.781	PF 1	123.00	4219.00	4223.82		4223.84	0.000481	1.08	113.86	33.34	0.10
Reach1	1322.900	PF 1	123.00	4218.00	4223.71		4223.73	0.000747	1.26	97.87	31.29	0.13
Reach1	1156.147	PF 1	123.00	4218.00	4223.59		4223.61	0.000670	1.23	99.77	30.23	0.12
Reach1	1021.227	PF 1	123.00	4218.00	4223.49		4223.52	0.000746	1.31	93.57	27.64	0.13
Reach1	934.7637	PF 1	123.00	4218.00	4223.41		4223.45	0.000950	1.43	85.90	26.38	0.14
Reach1	878.2865	PF 1	123.00	4218.00	4223.36		4223.39	0.000950	1.49	82.43	23.51	0.14
Reach1	825.6067	PF 1	123.00	4218.00	4223.34		4223.36	0.000367	0.99	124.31	33.84	0.09
Reach1	799.6081	PF 1	123.00	4218.00	4223.33		4223.35	0.000369	0.99	124.43	34.13	0.09
Reach1	776.1402	PF 1	123.00	4218.00	4223.33	4219.44	4223.34	0.000290	0.89	138.90	35.15	0.08
Reach1	737		Bridge									
Reach1	736.9400	PF 1	123.00	4218.00	4223.30		4223.32	0.000478	1.05	117.00	35.39	0.10
Reach1	720.1744	PF 1	123.00	4218.00	4223.29		4223.31	0.000685	1.25	98.05	28.72	0.12
Reach1	680.3944	PF 1	123.00	4218.00	4223.24		4223.27	0.001184	1.55	79.15	25.70	0.16
Reach1	633.2434	PF 1	123.00	4218.00	4223.19		4223.22	0.001004	1.52	80.99	23.56	0.14
Reach1	529.6580	PF 1	123.00	4218.00	4223.09		4223.12	0.000969	1.38	89.38	30.85	0.14
Reach1	430.8596	PF 1	123.00	4218.00	4223.01		4223.03	0.000718	1.21	101.42	33.80	0.12
Reach1	336.1513	PF 1	123.00	4218.00	4222.93		4222.96	0.000955	1.36	90.23	31.08	0.14
Reach1	222.3594	PF 1	123.00	4217.00	4222.84		4222.86	0.000716	1.22	100.43	32.45	0.12
Reach1	128.5371	PF 1	123.00	4217.00	4222.76	4219.17	4222.79	0.000800	1.29	95.70	31.23	0.13


M-22-U Plan: Existing Conditions 11/18/2020
River = Stream Reach = Reach1 RS = 1613.633
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Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Existing Conditions 11/18/2020
River = Stream Reach = Reach1 RS = 1496.781
.035 .065 .035
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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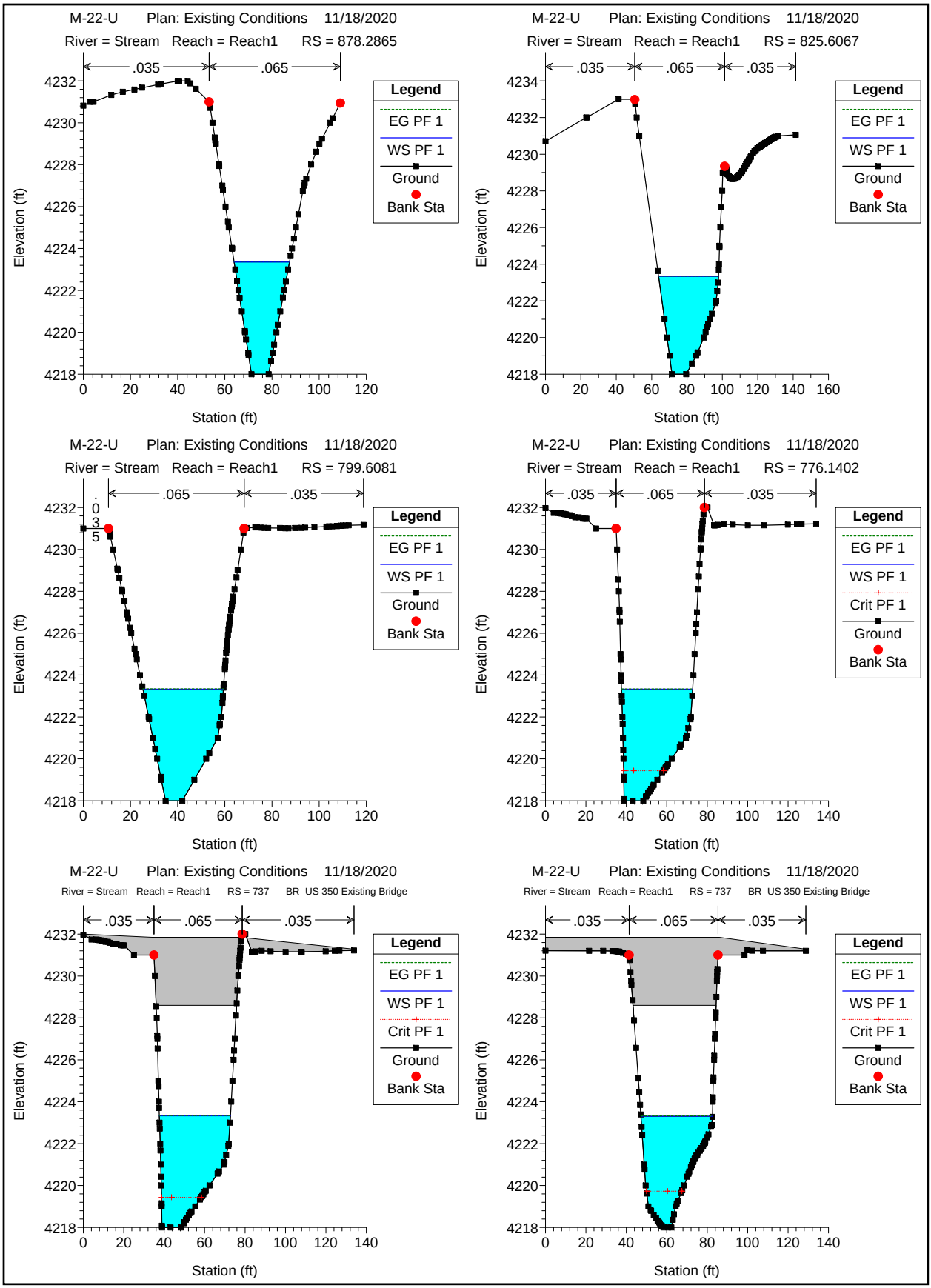
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)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Station (ft)
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Bank Sta
Elevation (ft)
Station (ft)
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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.065
.035
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WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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.065
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Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Existing Conditions 11/18/2020
River = Stream Reach = Reach1 RS = 737 BR US 350 Existing Bridge
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Crit PF 1
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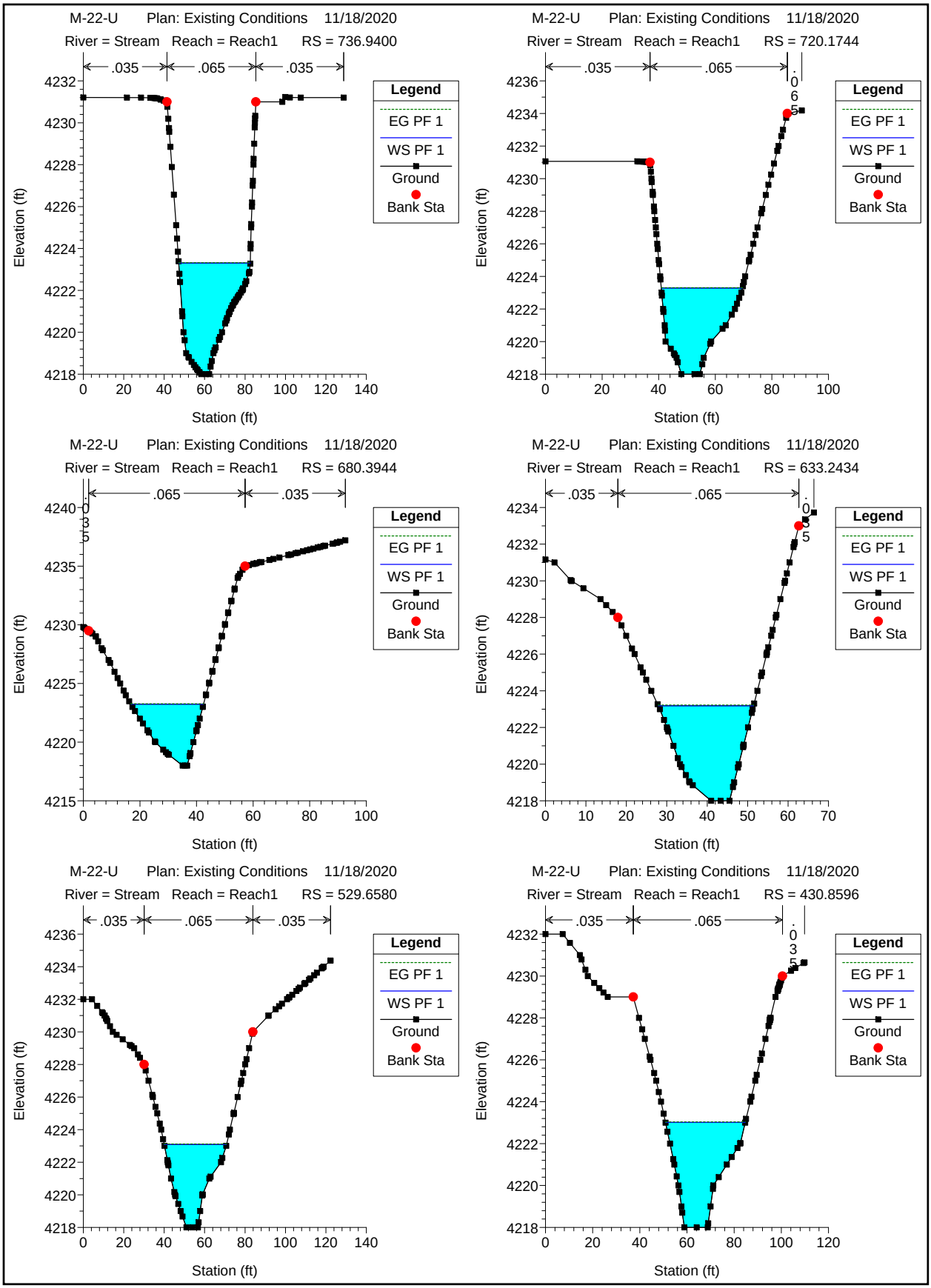
Bank Sta
Elevation (ft)
Station (ft)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Bank Sta
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Station (ft)
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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Bank Sta
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Station (ft)
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Station (ft)
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Station (ft)
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Bank Sta
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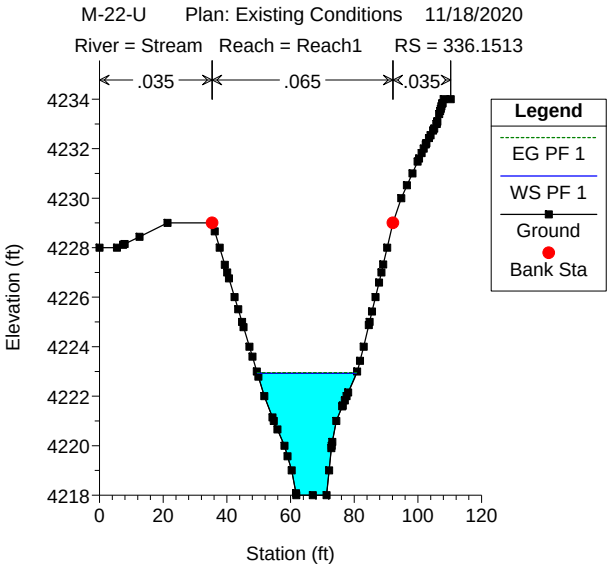
Station (ft)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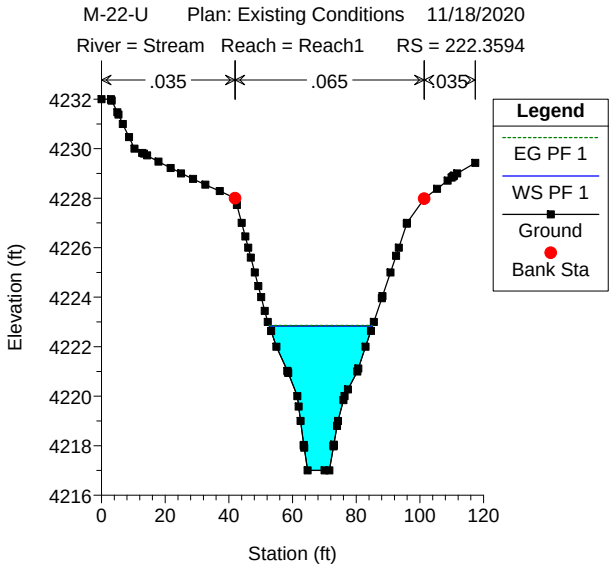
Bank Sta
Elevation (ft)
Station (ft)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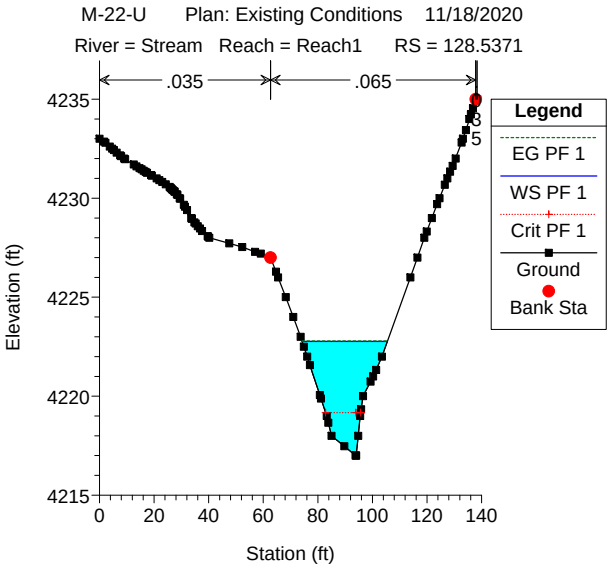
Ground
Bank Sta
Elevation (ft)
Station (ft)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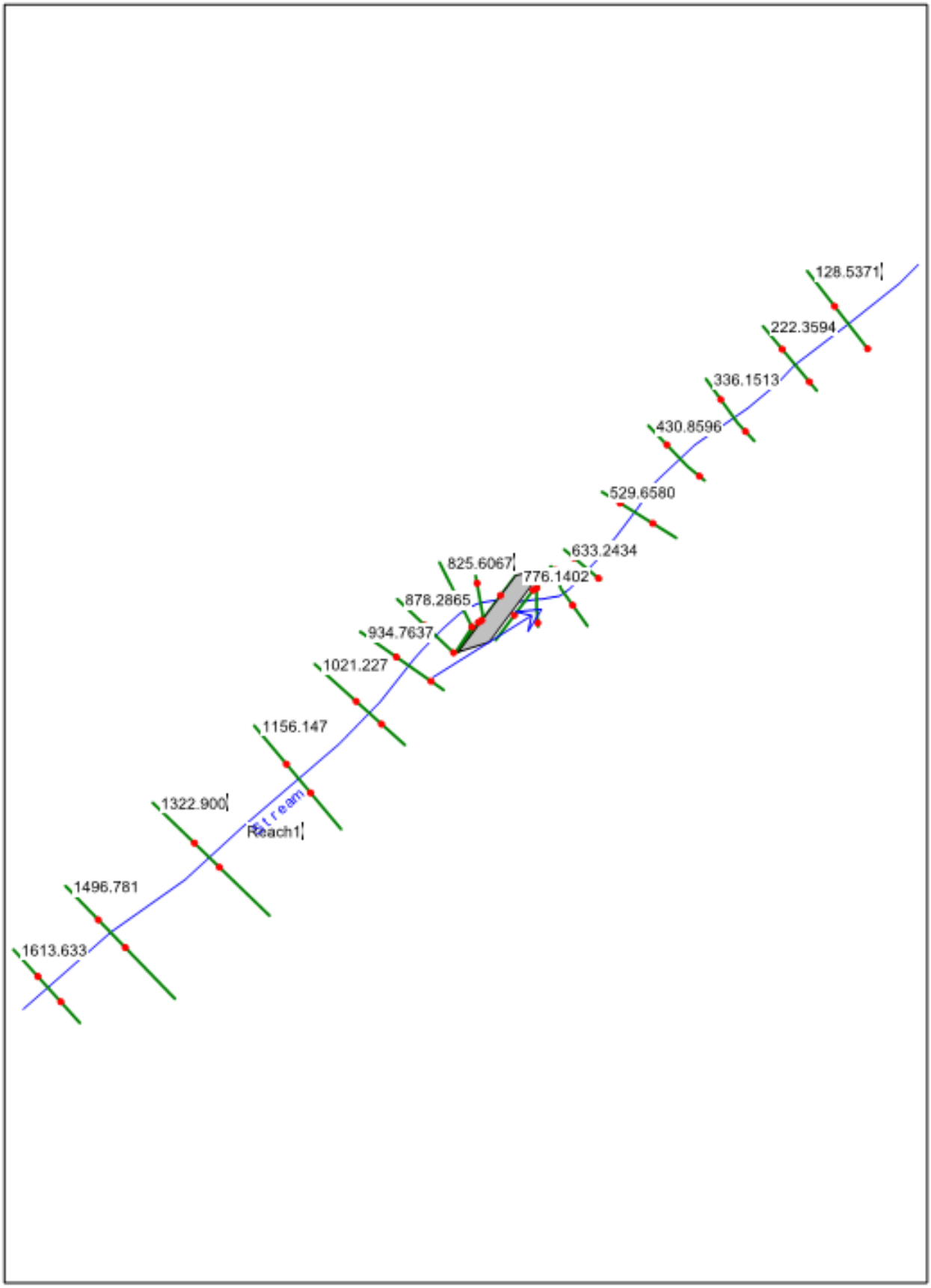
Crit PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)

APPENDIX C PROPOSED RCBC ALTERNATIVE ANALYSIS GRAPHICS



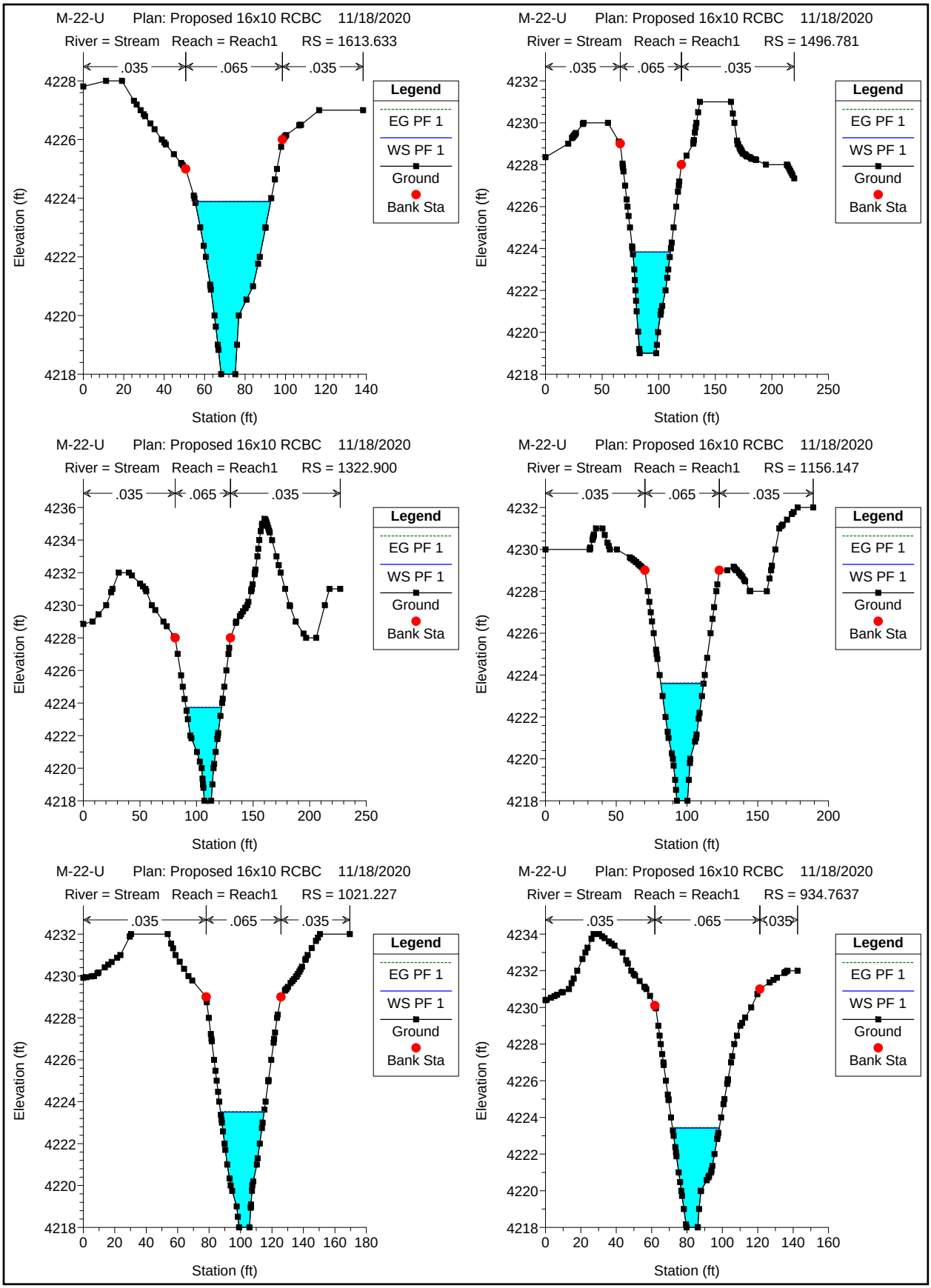
PROPOSED RCBC HEC-RAS LAYOUT

STRUCTURE M-22-U

APPENDIX C

HEC-RAS Plan: 16x10 River: Stream Reach: Reach1 Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach1	1613.633	PF 1	123.00	4218.00	4223.88		4223.90	0.000471	1.03	119.61	37.34	0.10
Reach1	1496.781	PF 1	123.00	4219.00	4223.83		4223.85	0.000477	1.08	114.20	33.38	0.10
Reach1	1322.900	PF 1	123.00	4218.00	4223.72		4223.74	0.000740	1.25	98.22	31.34	0.12
Reach1	1156.147	PF 1	123.00	4218.00	4223.60		4223.63	0.000663	1.23	100.14	30.28	0.12
Reach1	1021.227	PF 1	123.00	4218.00	4223.50		4223.53	0.000738	1.31	93.93	27.68	0.13
Reach1	934.7637	PF 1	123.00	4218.00	4223.43		4223.46	0.000939	1.43	86.25	26.43	0.14
Reach1	878.2865	PF 1	123.00	4218.00	4223.37		4223.40	0.000940	1.49	82.75	23.55	0.14
Reach1	825.6067	PF 1	123.00	4218.00	4223.35		4223.37	0.000363	0.99	124.77	33.87	0.09
Reach1	799.6081	PF 1	123.00	4218.00	4223.35		4223.36	0.000365	0.98	124.91	34.16	0.09
Reach1	776.1402	PF 1	123.00	4218.00	4223.34	4219.44	4223.35	0.000287	0.88	139.40	35.17	0.08
Reach1	737		Culvert									
Reach1	736.9400	PF 1	123.00	4218.00	4223.30		4223.32	0.000478	1.05	117.00	35.39	0.10
Reach1	720.1744	PF 1	123.00	4218.00	4223.29		4223.31	0.000685	1.25	98.05	28.72	0.12
Reach1	680.3944	PF 1	123.00	4218.00	4223.24		4223.27	0.001184	1.55	79.15	25.70	0.16
Reach1	633.2434	PF 1	123.00	4218.00	4223.19		4223.22	0.001004	1.52	80.99	23.56	0.14
Reach1	529.6580	PF 1	123.00	4218.00	4223.09		4223.12	0.000969	1.38	89.38	30.85	0.14
Reach1	430.8596	PF 1	123.00	4218.00	4223.01		4223.03	0.000718	1.21	101.42	33.80	0.12
Reach1	336.1513	PF 1	123.00	4218.00	4222.93		4222.96	0.000955	1.36	90.23	31.08	0.14
Reach1	222.3594	PF 1	123.00	4217.00	4222.84		4222.86	0.000716	1.22	100.43	32.45	0.12
Reach1	128.5371	PF 1	123.00	4217.00	4222.76	4219.17	4222.79	0.000800	1.29	95.70	31.23	0.13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River = Stream Reach = Reach1 RS = 1613.633
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Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 1496.781
.035 .065 .035
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 1322.900
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Legend
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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River = Stream Reach = Reach1 RS = 1156.147
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Ground
Bank Sta
Elevation (ft)
Station (ft)
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River = Stream Reach = Reach1 RS = 1021.227
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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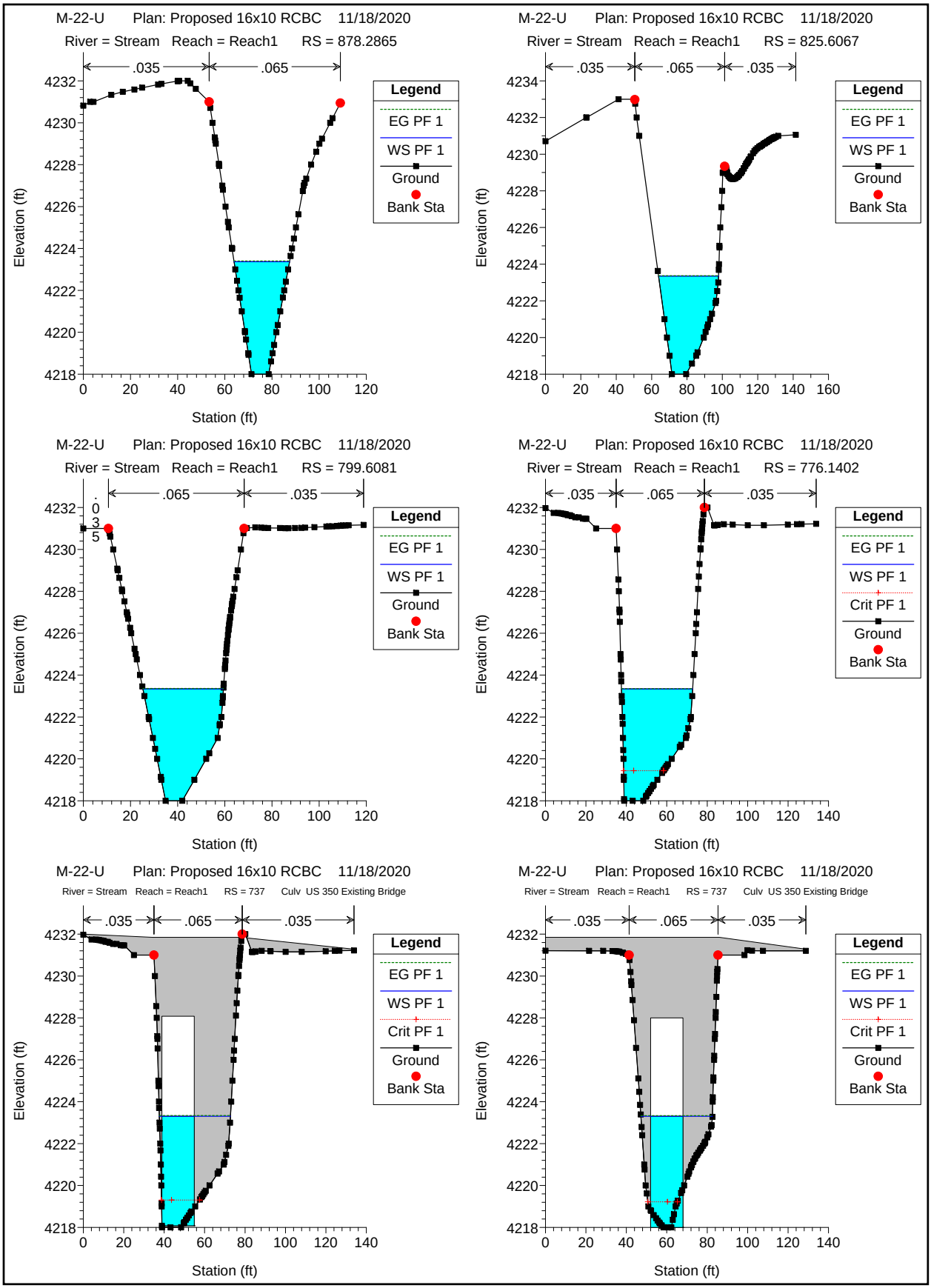
Bank Sta
Elevation (ft)
Station (ft)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River = Stream Reach = Reach1 RS = 878.2865
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 825.6067
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.035
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 799.6081
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Legend
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 776.1402
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.065
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Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 737 Culv US 350 Existing Bridge
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.065
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Legend
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WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 737 Culv US 350 Existing Bridge
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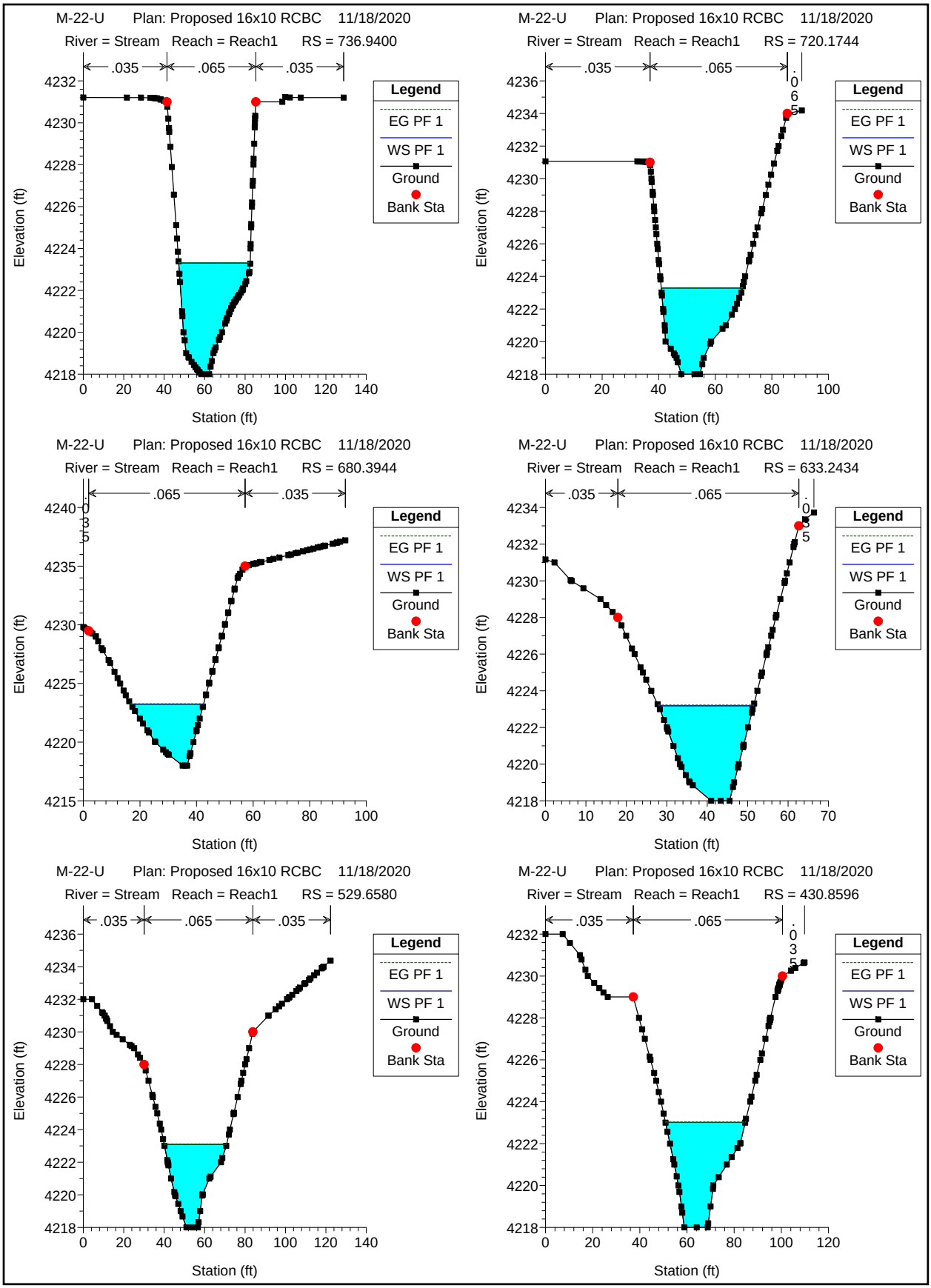
.065
.035
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)


M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 736.9400
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Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 720.1744
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Legend
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 680.3944
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Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 633.2434
.035 .065 .035
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 529.6580
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Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 430.8596
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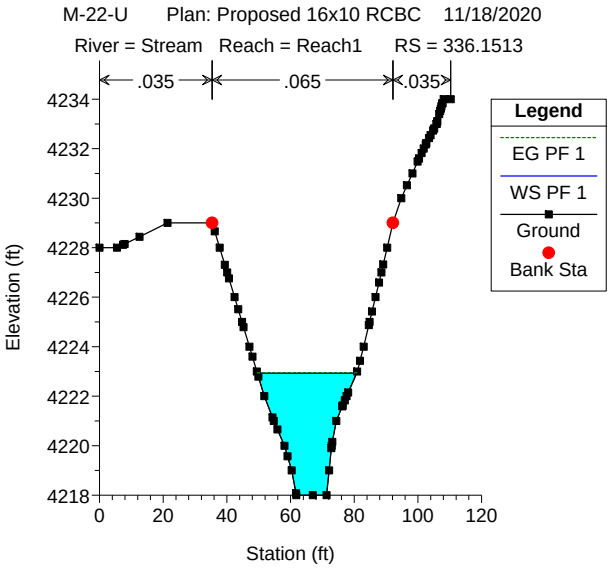
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)


M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 336.1513
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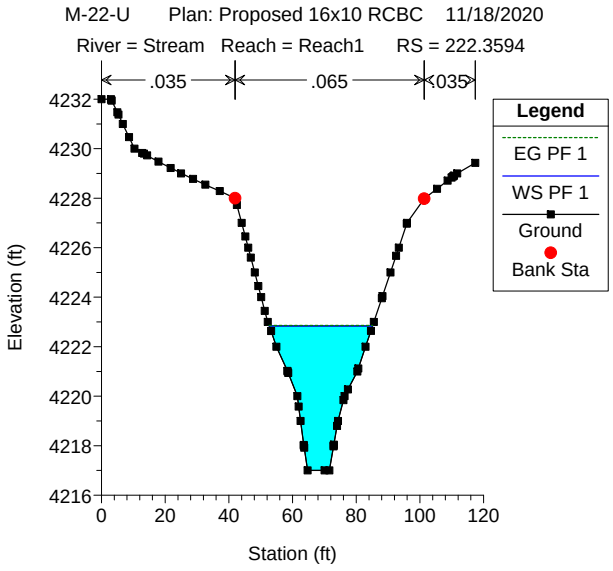
.065
.035
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)


M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 222.3594
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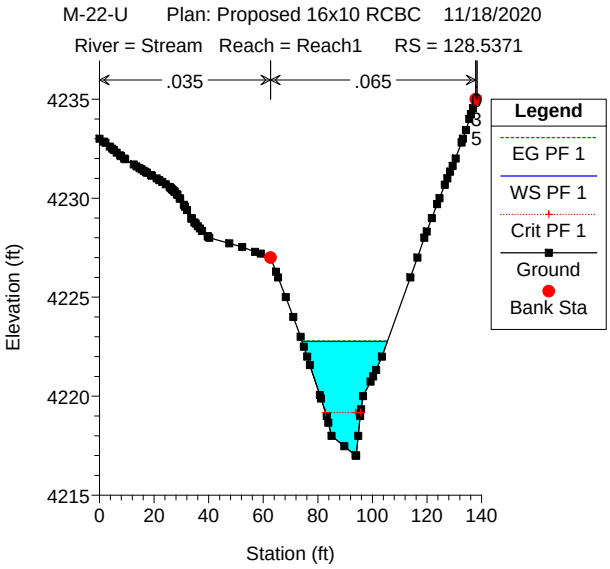
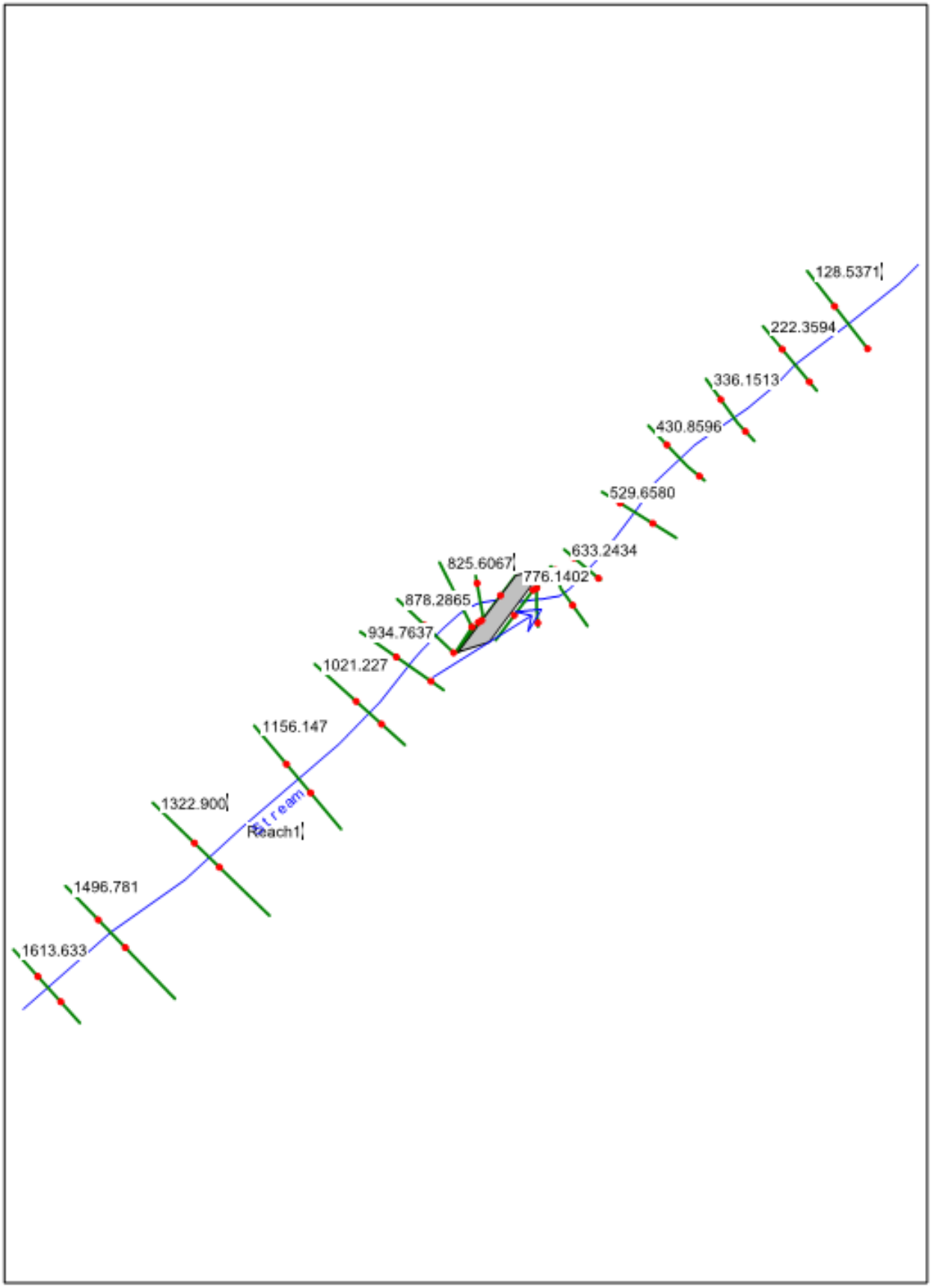
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)


M-22-U Plan: Proposed 16x10 RCBC 11/18/2020
River = Stream Reach = Reach1 RS = 128.5371
.035
.065
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)

APPENDIX D PROPOSED BRIDGE ALTERNATIVE ANALYSIS GRAPHICS


128.5371
222.3594
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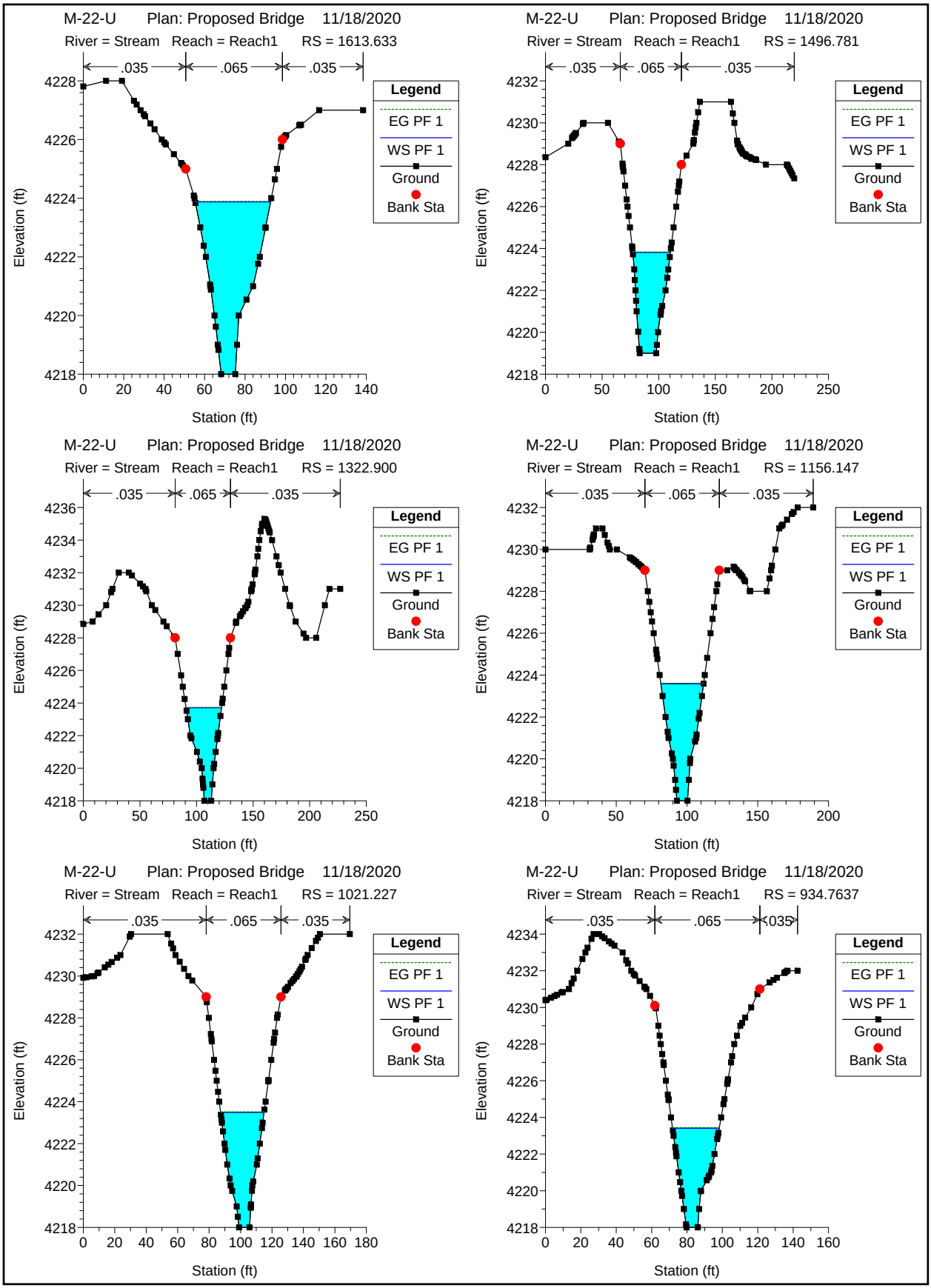
430.8596
529.6580
633.2434
776.1402
825.6067
878.2865
934.7637
1021.227
1156.147
1322.900
Reach1
1496.781
1613.633

HEC-RAS Plan: PropBridge River: Stream Reach: Reach1 Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach1	1613.633	PF 1	123.00	4218.00	4223.87		4223.89	0.000475	1.03	119.22	37.28	0.10
Reach1	1496.781	PF 1	123.00	4219.00	4223.82		4223.83	0.000481	1.08	113.84	33.33	0.10
Reach1	1322.900	PF 1	123.00	4218.00	4223.71		4223.73	0.000748	1.26	97.85	31.29	0.13
Reach1	1156.147	PF 1	123.00	4218.00	4223.59		4223.61	0.000670	1.23	99.75	30.23	0.12
Reach1	1021.227	PF 1	123.00	4218.00	4223.49		4223.52	0.000747	1.31	93.55	27.63	0.13
Reach1	934.7637	PF 1	123.00	4218.00	4223.41		4223.44	0.000950	1.43	85.89	26.38	0.14
Reach1	878.2865	PF 1	123.00	4218.00	4223.36		4223.39	0.000950	1.49	82.42	23.51	0.14
Reach1	825.6067	PF 1	123.00	4218.00	4223.34		4223.36	0.000367	0.99	124.29	33.84	0.09
Reach1	799.6081	PF 1	123.00	4218.00	4223.33		4223.35	0.000369	0.99	124.41	34.13	0.09
Reach1	776.1402	PF 1	123.00	4218.00	4223.33	4219.45	4223.34	0.000283	0.89	138.76	35.15	0.08
Reach1	737		Bridge									
Reach1	736.9400	PF 1	123.00	4218.00	4223.30	4219.73	4223.32	0.000466	1.05	116.76	35.39	0.10
Reach1	720.1744	PF 1	123.00	4218.00	4223.29		4223.31	0.000685	1.25	98.05	28.72	0.12
Reach1	680.3944	PF 1	123.00	4218.00	4223.24		4223.27	0.001184	1.55	79.15	25.70	0.16
Reach1	633.2434	PF 1	123.00	4218.00	4223.19		4223.22	0.001004	1.52	80.99	23.56	0.14
Reach1	529.6580	PF 1	123.00	4218.00	4223.09		4223.12	0.000969	1.38	89.38	30.85	0.14
Reach1	430.8596	PF 1	123.00	4218.00	4223.01		4223.03	0.000718	1.21	101.42	33.80	0.12
Reach1	336.1513	PF 1	123.00	4218.00	4222.93		4222.96	0.000955	1.36	90.23	31.08	0.14
Reach1	222.3594	PF 1	123.00	4217.00	4222.84		4222.86	0.000716	1.22	100.43	32.45	0.12
Reach1	128.5371	PF 1	123.00	4217.00	4222.76	4219.17	4222.79	0.000800	1.29	95.70	31.23	0.13


M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 1613.633
.035 .065 .035
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 1496.781
.035 .065 .035
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 1322.900
.035 .065 .035
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 1156.147
.035 .065 .035
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 1021.227
.035 .065 .035
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 934.7637
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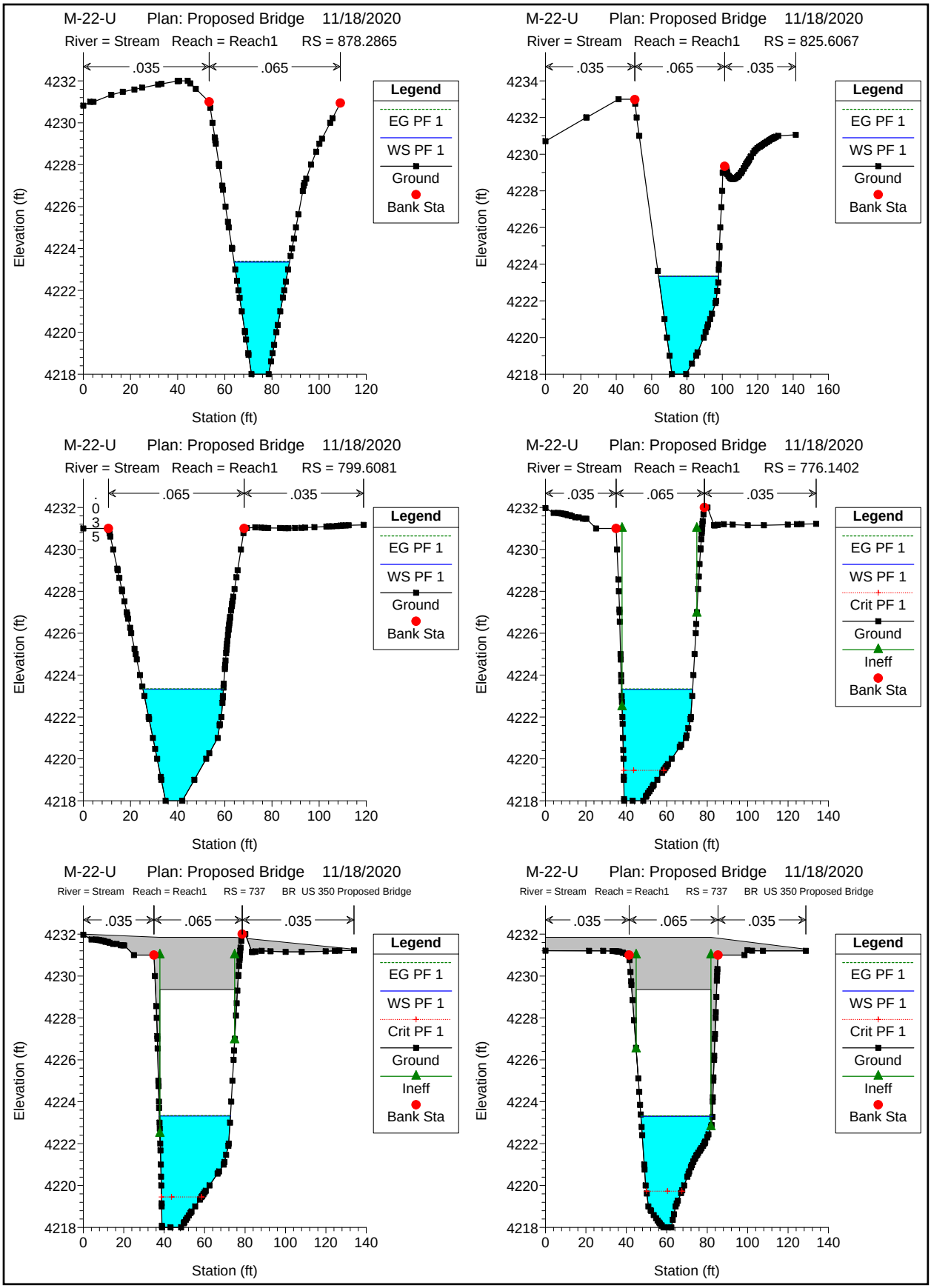
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)


M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 878.2865
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.065
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 825.6067
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.065
.035
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 799.6081
.035
.065
.035
Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 776.1402
.035
.065
.035
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 737 BR US 350 Proposed Bridge
.035
.065
.035
Legend
EG PF 1
WS PF 1
Crit PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 737 BR US 350 Proposed Bridge
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Legend
EG PF 1
WS PF 1
Crit PF 1
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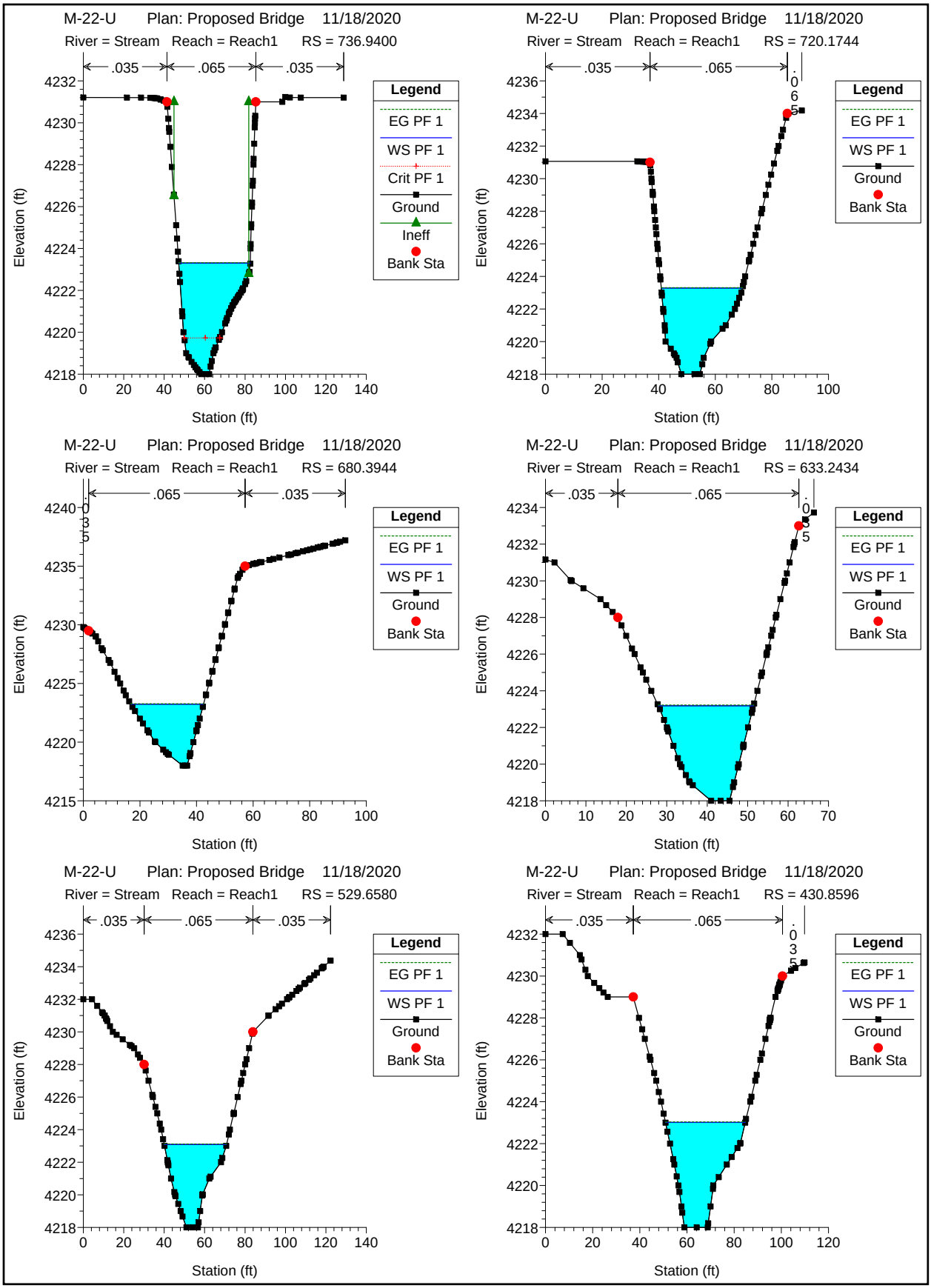
Ineff
Bank Sta
Elevation (ft)
Station (ft)


M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 736.9400
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Crit PF 1
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 720.1744
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Legend
EG PF 1
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 680.3944
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 633.2434
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Legend
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 529.6580
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Legend
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WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
M-22-U Plan: Proposed Bridge 11/18/2020
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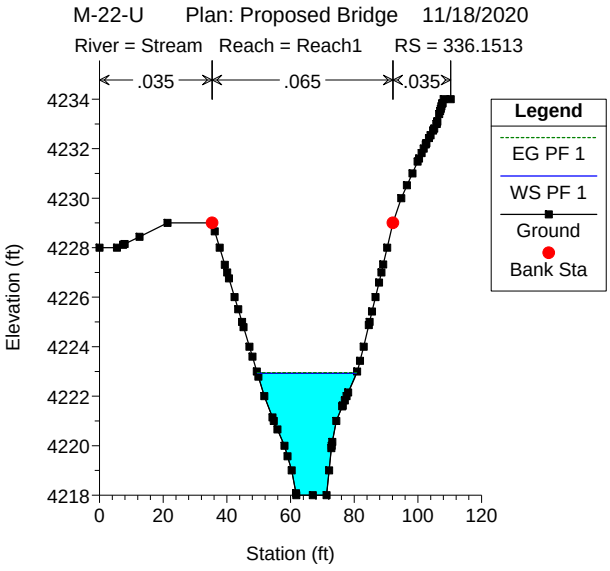
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)


M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 336.1513
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Legend
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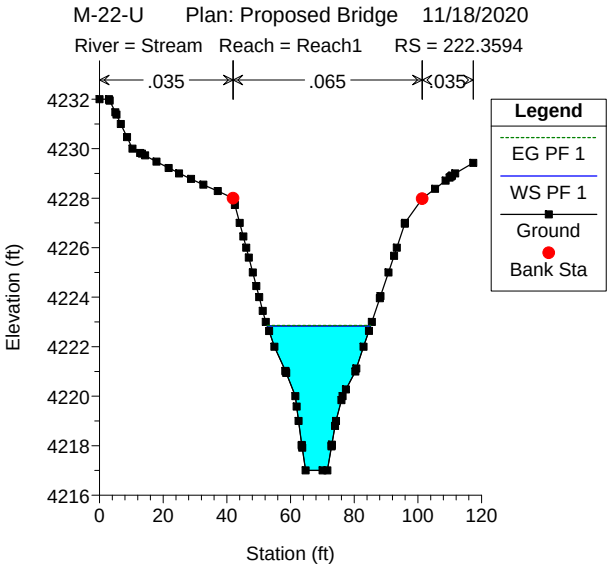
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)


M-22-U Plan: Proposed Bridge 11/18/2020
River = Stream Reach = Reach1 RS = 222.3594
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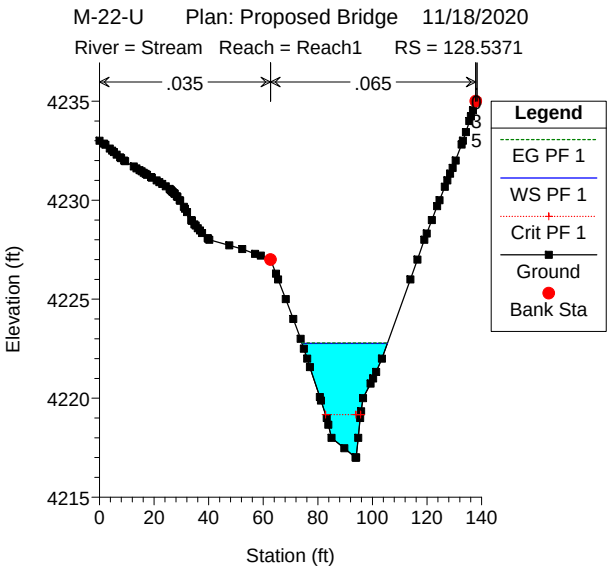
Ground
Bank Sta
Elevation (ft)
Station (ft)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WS PF 1
Crit PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)

APPENDIX E WATER SURFACE ELEVATION COMPARISON

CDOT BRIDGE BUNDLE DESIGN BUILD - M-22-U OVER OTERO DITCH

Table 1: Otero Ditch Water Surface Elevation Comparison

Design JRR Date 11/13/2020

Check JM Date 11/16/2020

Project Name/Identifyer:

CDOT Bridge Bundle - M-22-U

Design Discharge (cfs)	HEC-RAS Section	Existing Conditions WSE (HEC-RAS) NAVD 88	Proposed RCBC WSE NAVD 88	Proposed RCBC - Existing	Proposed Bridge WSE NAVD 88	Proposed Bridge- Existing Condition
123	1613.63	4223.88	4223.88	0.00	4223.87	-0.01
	1496.78	4223.82	4223.83	0.01	4223.82	0.00
	1322.90	4223.71	4223.72	0.01	4223.71	0.00
	1156.15	4223.59	4223.60	0.01	4223.59	0.00
	1021.23	4223.49	4223.50	0.01	4223.49	0.00
	934.76	4223.41	4223.43	0.02	4223.41	0.00
	878.29	4223.36	4223.37	0.01	4223.36	0.00
	825.61	4223.34	4223.35	0.01	4223.34	0.00
	799.61	4223.33	4223.35	0.02	4223.33	0.00
	776.14	4223.33	4223.34	0.01	4223.33	0.00
Bridge/Culvert	737.00			-		-
	736.94	4223.30	4223.30	0.00	4223.30	0.00
	720.17	4223.29	4223.29	0.00	4223.29	0.00
	680.39	4223.24	4223.24	0.00	4223.24	0.00
	633.24	4223.19	4223.19	0.00	4223.19	0.00
	529.66	4223.09	4223.09	0.00	4223.09	0.00
	430.86	4223.01	4223.01	0.00	4223.01	0.00
	336.15	4222.93	4222.93	0.00	4222.93	0.00
	222.36	4222.84	4222.84	0.00	4222.84	0.00
	128.54	4222.76	4222.76	0.00	4222.76	0.00

APPENDIX F OUTLET PROTECTION ANALYSIS

HY-8 Energy Dissipation Report

Scour Hole Geometry

Parameter	Value	Units
Select Culvert and Flow		
Crossing	M-22-U	
Culvert	Culvert 1	
Flow	123.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	16.0	ft
Culvert Height	10.0	ft
Outlet Depth	2.63	ft
Outlet Velocity	2.92	ft/s
Froude Number	0.32	
Tailwater Depth	2.63	ft
Tailwater Velocity	2.82	ft/s
Tailwater Slope (SO)	0.0020	
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	0.30	mm
D84 Value	16.00	mm
Tailwater Flow Depth after Culvert Outlet	Normal Depth	
Results		
Assumptions		
Soil Sigma	7.30	
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)	2.634	ft
Velocity with TW and WS	-1.#IO	ft/s

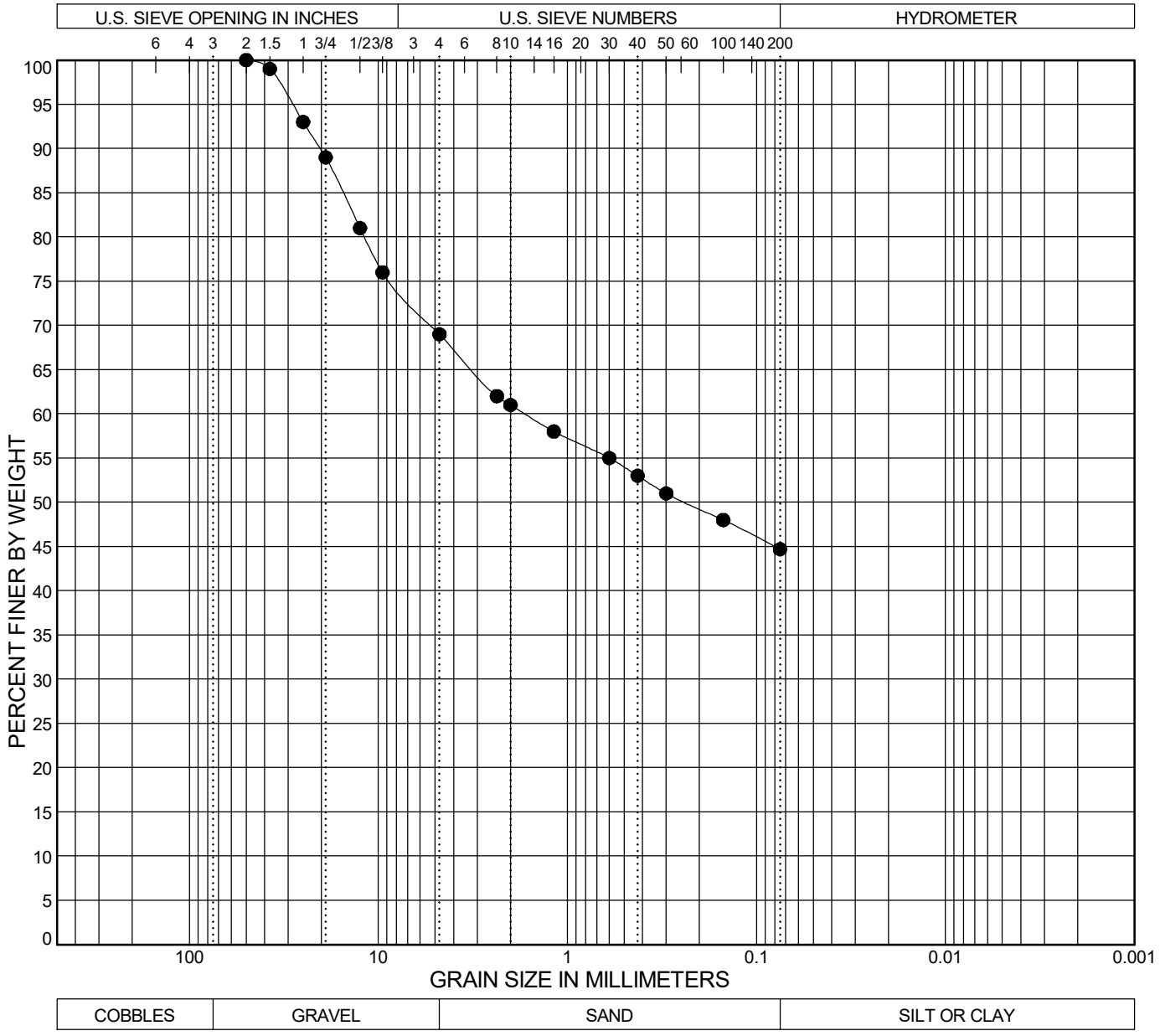
HY-8 Energy Dissipation Report

External Energy Dissipator

Parameter	Value	Units
Select Culvert and Flow		
Crossing	M-22-U	
Culvert	Culvert 1	
Flow	123.00	cfs
Culvert Data		
Culvert Width (including multiple barrels)	16.0	ft
Culvert Height	10.0	ft
Outlet Depth	2.63	ft
Outlet Velocity	2.92	ft/s
Froude Number	0.32	
Tailwater Depth	2.63	ft
Tailwater Velocity	2.82	ft/s
Tailwater Slope (SO)	0.0020	
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	Envelope Curve	
D50 of the Riprap Mixture		
Note:	Minimum HS/D50 = 2 is Obtained if D50 = 0.050 ft	
D50 of the Riprap Mixture	0.050	ft
DMax of the Riprap Mixture	0.100	ft
Results		
Brink Depth	2.678	ft
Brink Velocity	2.870	ft/s
Depth (YE)	2.678	ft
Riprap Thickness	0.150	ft
Riprap Foreslope	0.2000	ft
Check HS/D50		
Note:	OK if HS/D50 > 2.0	
HS/D50	2.165	
HS/D50 Check	HS/D50 is OK	
Check D50/YE		
Note:	OK if 0.1 < D50/YE < 0.7	
Check D50/YE	0.019	
D50/YE Check	D50/YE is NOT OK	
Basin Length (LB)	64.000	ft
Basin Width	58.667	ft
Apron Length	16.000	ft
Pool Length	48.000	ft
Pool Depth (HS)	0.108	ft
TW/YE	0.983	
Tailwater Depth (TW)	2.634	ft
Average Velocity with TW	0.730	ft/s

Critical Depth (Yc)	0.512	ft
Average Velocity with Yc	4.022	ft/s
Downstream Riprap for High TW		
Distance: 1 LB		
Velocity	1.954	ft/s
Size	0.025	ft
Distance: 2 LB		
Velocity	1.011	ft/s
Size	0.007	ft
Distance: 3 LB		
Velocity	0.672	ft/s
Size	0.003	ft
Distance: 4 LB		
Velocity	0.503	ft/s
Size	0.002	ft

APPENDIX G GEOTECHNICAL INFORMATION



BOREHOLE	DEPTH (ft)	AASHTO Classification	USCS Classification	LL	PL	PI	%Gravel	%Sand	%Fines	
									%Silt	%Clay
● **M-22-U Scour**	**0.0**						**31.0**	**24.3**	**44.7**	

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

SIEVE ANALYSIS

FIGURE

S- 5

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