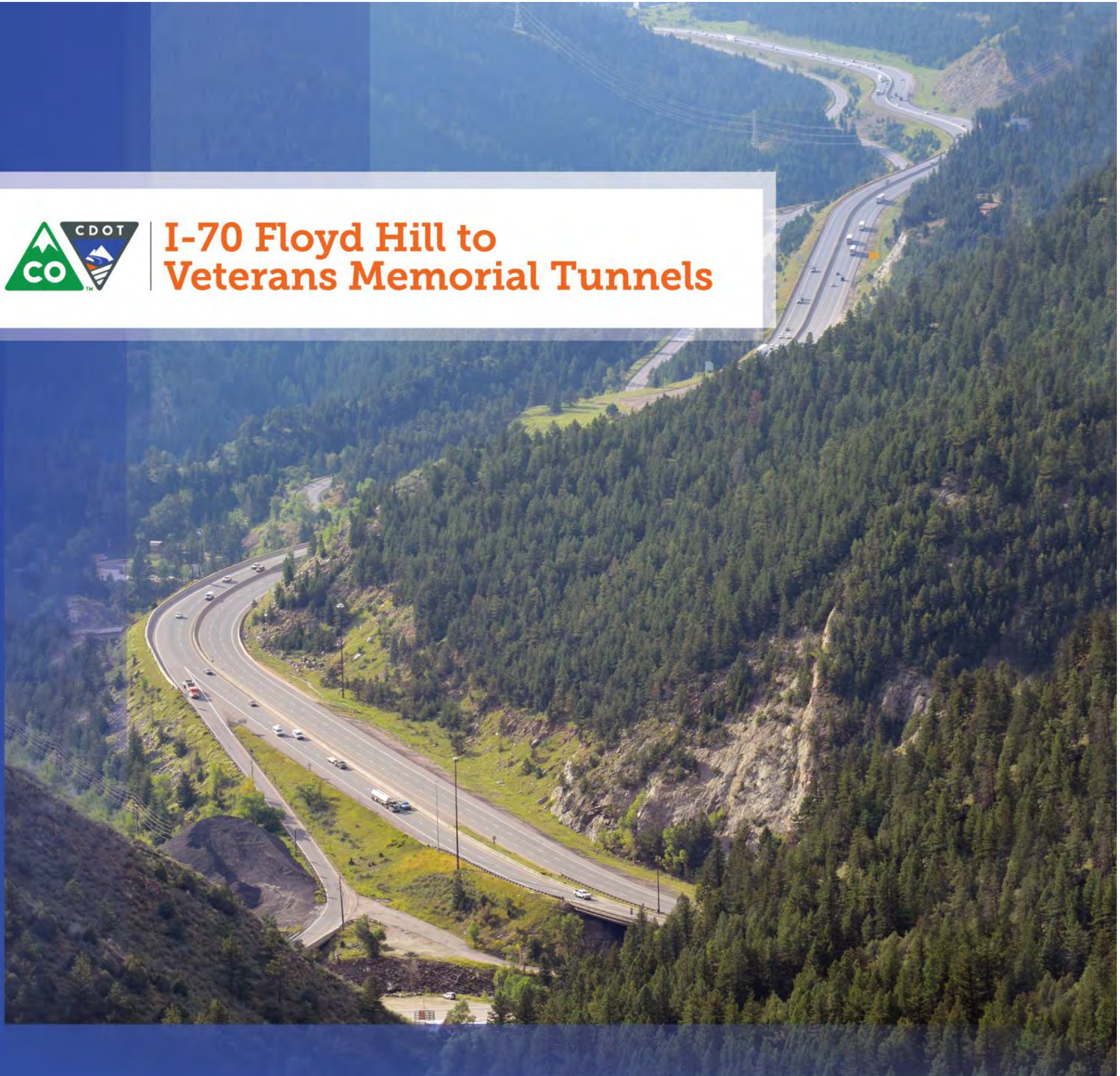


I-70 Floyd Hill to Veterans Memorial Tunnels

Draft Final

Clear Creek Conceptual Baseline Hydraulics Report

June 2020

Contents

Appendices

Exhibits

List of Acronyms

1D	One dimensional
2D	Two dimensional
AASHTO	American Association of State Highway and Transportation Officials
CDOT	Colorado Department of Transportation
CFR	Code of Federal Regulations
cfs	Cubic feet per second
CR	County Road
CWCB	Colorado Water Conservation Board
DDM	Drainage Design Manual
EA	Environmental Assessment
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
ft/s	feet per second
HUD-FIA	U.S. Department of Housing and Urban Development—Federal Insurance Administration
I-70	Interstate 70
LiDAR	Light Detection and Ranging
MHFD	Mile High Flood District
MP	Milepost
mph	Miles per hour
NEPA	National Environmental Protection Act
NFIP	National Flood Insurance Program
PEIS	Programmatic Environmental Impact Statement
Project	I-70 Floyd Hill to Veterans Memorial Tunnels Project
2019 Report	Draft Conceptual Clear Creek Baseline Hydraulics Report, submitted 2019
2020 Report	Conceptual Clear Creek Baseline Hydraulics Report, submitted 2020
ROD	Record of Decision
SMS	Aquaveo Surface Water Modeling System
UDFCD	Urban Drainage and Flood Control District
US 6	U.S. Highway 6
USACE	U.S. Army Corps of Engineers
USC	United States Code
USGS	U.S. Geological Survey
WSEL	Water surface elevation

1. Introduction

The Colorado Department of Transportation (CDOT) and the Federal Highway Administration (FHWA), in cooperation with local communities and other agencies, are conducting the Interstate 70 (I-70) Floyd Hill to Veterans Memorial Tunnels Environmental Assessment (EA) to advance a portion of the program of improvements for the I-70 Mountain Corridor identified in the 2011 Tier 1 *Final I-70 Mountain Corridor Programmatic Environmental Impact Statement* (PEIS) and approved in the 2011 *I-70 Mountain Corridor Record of Decision* (ROD). The EA is a Tier 2 National Environmental Policy Act (NEPA) process and is supported by resource-specific technical reports.

1.1. Background

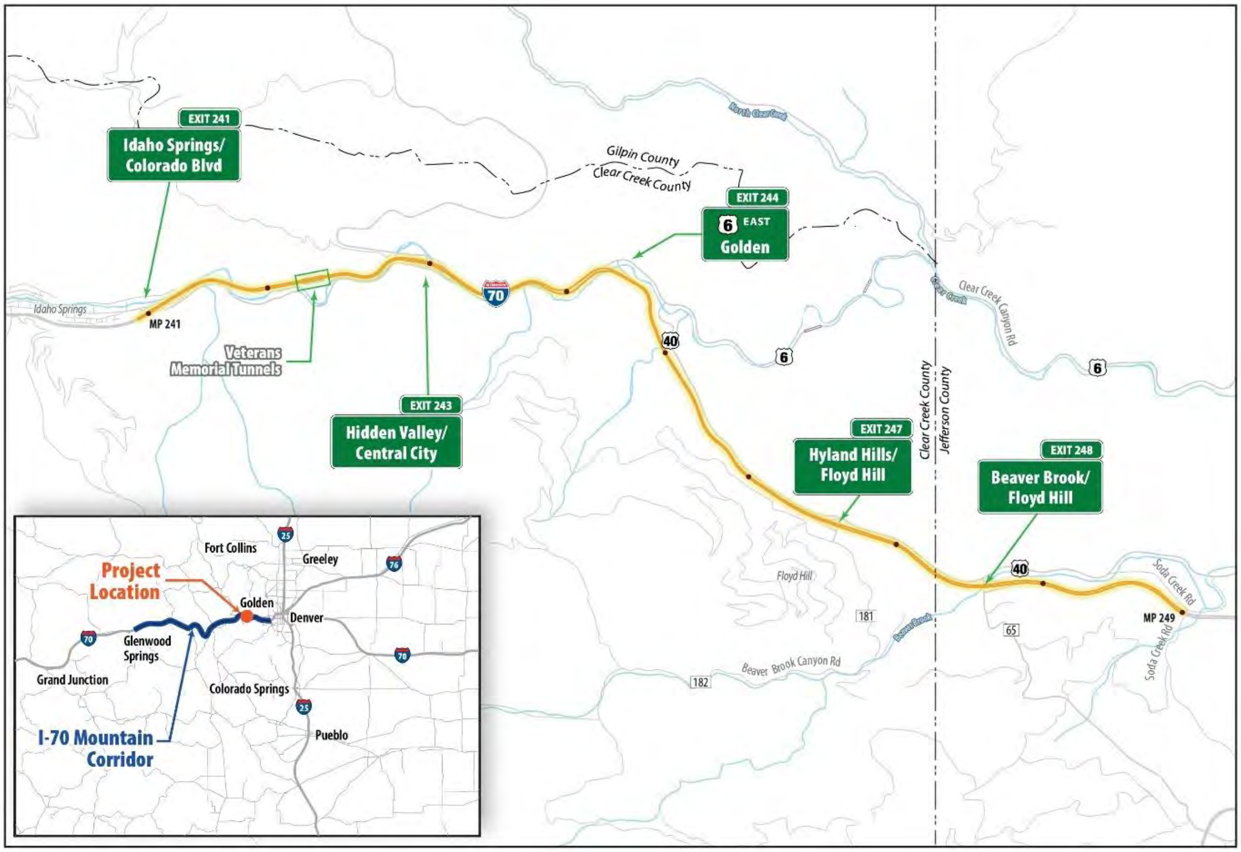
CDOT and FHWA propose improvements along approximately 8 miles of the I-70 Mountain Corridor from the top of Floyd Hill through the Veterans Memorial Tunnels to the eastern edge of Idaho Springs. The purpose of the Project is to improve travel time reliability, safety, and mobility, and address the deficient infrastructure through this area.

The major Project elements include:

- Adding a third westbound travel lane to the two-lane section of I-70 from the current three-lane to two-lane drop (approximately milepost (MP) 246) through the Veterans Memorial Tunnels
- Constructing a new frontage road between the U.S. Highway 6 (US 6) interchange and the Hidden Valley/Central City interchange
- Improving interchanges and intersections throughout the Project area
- Improving design speeds and stopping sight distance on horizontal curves
- Improving the multimodal trail (Clear Creek Greenway) between US 6 and the Veterans Memorial Tunnels
- Reducing animal-vehicle conflicts and improving wildlife connectivity with new and/or improved wildlife overpasses or underpasses

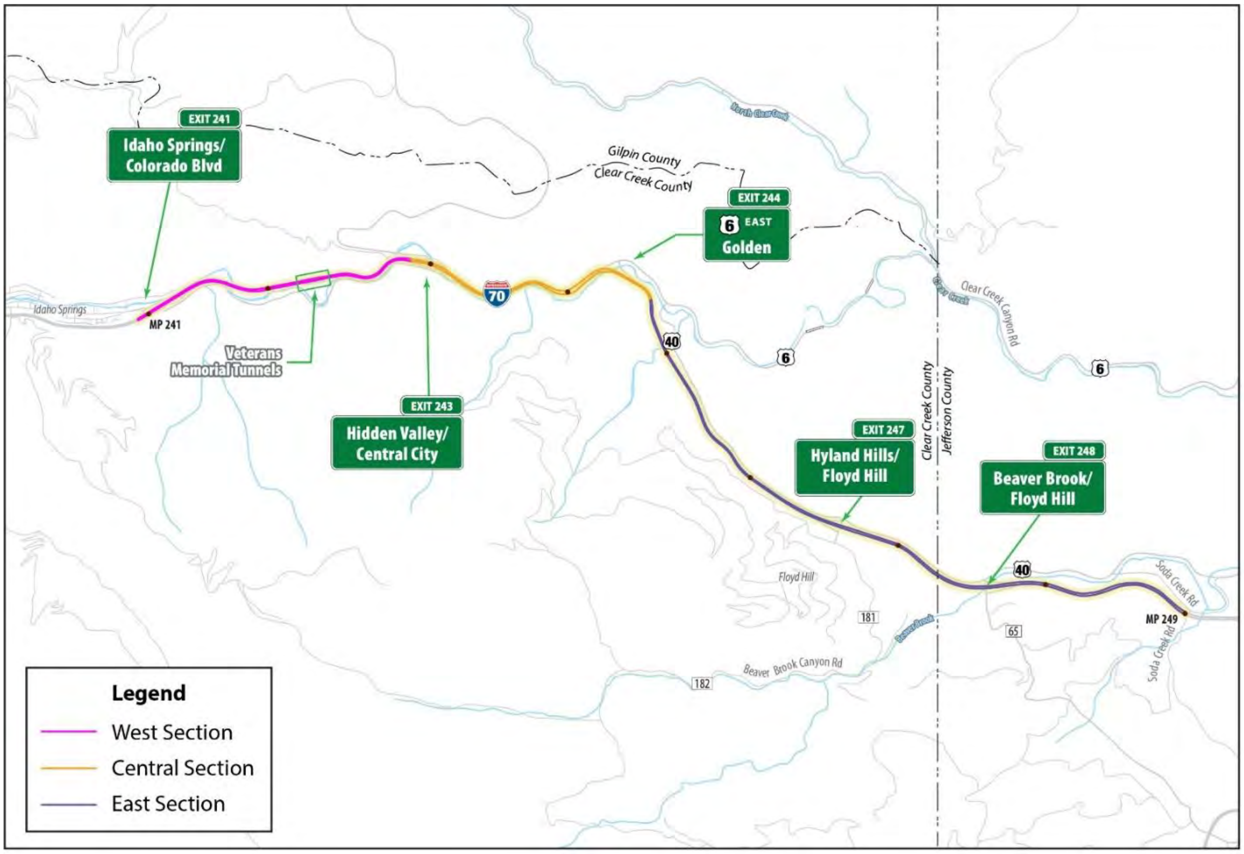
The Project is located on I-70 between MP 249 (east of the Beaver Brook/Floyd Hill interchange) and MP 241 (Idaho Springs/Colorado Boulevard), west of the Veterans Memorial Tunnels. It is located mostly in Clear Creek County, with the eastern end in Jefferson County (see Exhibit 1). The primary roadway construction activities would occur between County Road (CR) 65 (the Beaver Brook/Floyd Hill interchange) and the western portals of the Veterans Memorial Tunnels (MP 247.6 and MP 242.3, respectively), with the Project area extended east and west to account for signing, striping, and fencing.

Exhibit 1 Project Location



Three alternatives are being evaluated in the EA: (1) No Action Alternative, (2) Tunnel Alternative, and (3) Canyon Viaduct Alternative. The Project improvements are grouped into three geographic sections: (1) East Section (top of Floyd Hill to US 6 interchange), (2) Central Section (US 6 interchange to Hidden Valley/Central City interchange), and (3) West Section (Hidden Valley/Central City interchange through Veterans Memorial Tunnels) (see Exhibit 2).

Exhibit 2 East, Central, and West Project Sections



The No Action Alternative includes ongoing highway maintenance. In addition, due to its poor condition, the westbound I-70 bridge at the bottom of Floyd Hill is programmed to be replaced regardless of whether CDOT moves forward with one of the Action Alternatives. Under the No Action Alternative, the bridge would be replaced in its current location but would need to be designed to current standards, with a 55-mph design speed and improved sight distance with wider shoulders.

The Action Alternatives—the Tunnel Alternative and Canyon Viaduct Alternative—include the same improvements in the East Section and West Section to flatten curves, add a third westbound travel lane (new lane would be an Express Lane), provide wildlife and water quality features, and improve interchange/intersection operations.

Through the Central Section between the US 6 interchange and the Hidden Valley/Central City interchange, the action alternatives vary in how they provide for the third westbound I-70 travel lane and frontage road connections as follows:

- The Tunnel Alternative would realign westbound I-70 to the north (along the curve between MP 244.3 and MP 243.7) through a new 2,200-foot-long tunnel west of US 6. Eastbound I-70 would be realigned within the existing I-70 roadway template to flatten curves to improve design speed and sight distance. This alternative also would include two design options for the alignment of the new frontage road north or south of Clear Creek.
- The Canyon Viaduct Alternative would realign approximately one-half mile of both the westbound and eastbound I-70 lanes (along the curve between MP 244 and MP 243.5) on viaduct structures approximately 400 feet south of the existing I-70 alignment on the south side of Clear Creek Canyon. Through the realigned area, the frontage road would be constructed under

the viaduct on the existing I-70 roadway footprint north of Clear Creek. The Clear Creek Greenway would be reconstructed along its current alignment on the south side of Clear Creek, north of the viaduct. The viaduct would cross above Clear Creek and the Clear Creek Greenway twice.

Additional information regarding the alternatives evaluated in the EA can be found in *the I-70 Floyd Hill to Veterans Memorial Tunnels Alternatives Analysis Technical Report* (CDOT, 2020a).

1.2. Purpose of Study

The I-70 Floyd Hill to Veterans Memorial Tunnels Project (Project) runs adjacent to Clear Creek, the principal drainage of the Clear Creek Watershed, which comprises the majority of Clear Creek County, Colorado. This Clear Creek Conceptual Baseline Hydraulics Report (June 2020) documents the hydraulic design and floodplain permitting compliance. The Report presents the background and purpose of the Project, documents the hydrologic analysis performed, discusses considerations with respect to effective and corrected effective hydraulic models, and presents hydraulic design criteria and considerations. Additionally, the Report summarizes the hydraulic impacts of proposed project improvements and documents the results of the revised condition hydraulic evaluation and floodplain permitting process.

1.3. Previous Studies

Several previous studies were reviewed in the preparation of this Report, including:

- Flood Insurance Study—City of Idaho Springs, Colorado (1978). Prepared by Black and Veatch Consulting Engineers on behalf of the U.S. Department of Housing and Urban Development—Federal Insurance Administration (HUD-FIA). This study established the flow rates for Clear Creek near Idaho Springs using stream data through the mid 1970s.
- Engineering Division Technical Report, Hydrologic Analysis, Type 15 Flood Insurance Study, Clear Creek County, Colorado (1990). Prepared by the Omaha District of the U.S. Army Corps of Engineers (USACE). This Type 15 Flood Insurance Study (FIS) was eventually incorporated into a Preliminary FIS report by the Federal Emergency Management Agency (FEMA) dated February 8, 2017. It is anticipated that this Preliminary FIS eventually will become effective.
- Clear Creek Hydrology Report (2012). Prepared by ICON Engineering, this report represents the current effective hydrology for Clear Creek and is listed in the regulatory FIS as published by FEMA dated July 17, 2012.
- Flood Insurance Study—Clear Creek County and Incorporated Areas (2012). This FIS was effective for Clear Creek County until December 2019. Further discussion on this FIS is found in Section 3 of this Report.
- I-70 Twin Tunnels Widening Project, Final Drainage Report (2014). Prepared by Atkins North America, Inc. The Twin Tunnels Project widened the lanes of I-70 from Idaho Springs to the base of Floyd Hill to add capacity to the corridor and rebuilt the tunnels on the east side of Idaho Springs.
- Clear Creek Watershed Flood Study Mapping (2015). Prepared by ICON Engineering in 2013 and revised in 2015. This study was prepared to document the development of an enhanced detailed study floodplain for Clear Creek between the I-70 Twin Tunnels (now known as the Veterans Memorial Tunnels) to just downstream of Georgetown Lake for the 10-year, 25-year, 50-year, 100-year, and 500-year storm events.
- Flood Insurance Study—Clear Creek County and Incorporated Areas (2019). This is the most current effective FIS, and it became effective on December 20, 2019. The detailed study

boundary of this FIS runs one mile downstream from where the previously effective boundary ended. Further discussion on this FIS is found in Section 3 of this Report.

1.4. Topographic Mapping and Vertical Datum Considerations

The source of topographic data for the approximate Zone A portions of Clear Creek depicted on the currently effective Flood Insurance Rate Maps (FIRMs), dated March 19, 2007, and July 12, 2012, for panels 0819C0227D and 0819C0235E, respectively, is unknown. The Preliminary FIS has been published and became effective on December 20, 2019. The portions of Clear Creek re-evaluated for the preliminary study used elevation data from 2011-2012 Light Detection and Ranging (LiDAR) data provided by FEMA. For this study, topographic LiDAR data flown in 2013 were used for overbank cross sections. The vertical datum is North American Vertical Datum of 1988.

2. Design Criteria and Discussion

This section provides a summary of the applicable Project design criteria. The relevant criteria manuals listed below also are included in the electronic files in Appendix D.

2.1. Local Criteria

2.1.1. County of Clear Creek—*Roadway Design and Construction Manual*

The *Roadway Design and Construction Manual* for Clear Creek County states that, "… where new development is proposed along existing [Clear Creek] County roads, the developer's proposal shall include an analysis of the projected traffic volumes, along with information on existing road: right-of-way, widths, curves, intersections and surface drainage." The manual conforms to the CDOT requirements and specifications for bridge design.

The County has adopted the *Urban Storm Drainage Criteria Manual*, published by the Urban Drainage and Flood Control District (UDFCD, recently changed to Mile High Flood District [MHFD]), as one of its policy guides and design criteria manuals for road and bridge design. UDFCD states that criteria for bridge freeboard vary from 1 foot to 4 feet in Colorado depending on jurisdiction and risk of debris specific to the channel.

2.2. State Criteria and Guidelines

2.2.1. Colorado Drainage Law

Chapter 2 in Volume 1 of the most recent UDFCD *Criteria Manual* briefly discusses the principles of drainage and flood control law in the state of Colorado. In the chapter, 21 legal principles are listed that pertain to drainage law. Some of the applicable criteria for this Project include:

1. The owner of upstream property possesses a natural easement on land downstream for drainage of surface water flowing in its natural course. The upstream property owner may alter drainage conditions as long as the water is not sent down in a manner or quantity to do more harm to the downstream land than formerly.
2. On and after July 1, 2003, governmental entities have complete governmental immunity in regard to the drainage, flood control, and stormwater facilities that they own or maintain.
3. A natural watercourse may be used as a conduit or outlet for the drainage of lands, at least where the augmented flow will not tax the stream beyond its capacity and cause flooding of adjacent lands.
4. The boundaries of the floodplain should be accurately determined and based on a reasonable standard.
5. Adoption of a floodplain regulation to regulate flood-prone areas is a valid exercise of police power and is not a taking as long as the regulation does not go beyond protection of the public's health, safety, morals, and welfare.
6. The adoption by a municipality of floodplain ordinances to regulate flood-prone areas is a valid exercise of police power and is not a taking.
7. A professional engineer is required not only to serve the interests of his or her employer/client but is also required, as his or her primary obligation, to protect the safety, health, property, and welfare of the public.

2.2.2. Colorado Water Conservation Board

The Colorado Water Conservation Board (CWCB) is the state agency that is responsible for protecting Colorado's streams, which includes flood mitigation. The CWCB sets standards for regulatory floodplains in the state, including assisting communities to develop sound floodplain management practices. Rules for the 1-percent-annual-chance floodplain, commonly referred to as the 100-year floodplain, are of state-wide concern to the CWCB. CWCB also has rules that require any stream alteration activity (defined in Rule 4 as any manmade activity within a stream or floodplain that alters the natural channel, geometry, or flow characteristics of the stream) proposed by a project proponent to be evaluated for its impact on the regulatory floodplain and to be in compliance with all applicable federal, state, and local floodplain rules, regulations, and ordinances.

2.2.3. CDOT

Multiple criteria are set forth in the CDOT *Drainage Design Manual* (DDM). Some of the specific criteria pertaining to natural stream channels include:

- Embankment encroachment in any stream channel or floodplain should be avoided.
- If encroachment into a floodplain cannot be avoided, the hydraulic effects of floodplain encroachment shall be evaluated over a full range of frequency-based peak discharges for the 2-year design flood and 100-year recurrence intervals on any major highway facility.
- If relocation of a stream channel is unavoidable, the cross-sectional shape, meander, pattern, roughness, sediment transport, and slope shall conform to the existing conditions insofar as practicable. Some means of energy dissipation or grade control may be necessary when existing conditions cannot be duplicated.
- Streambank stabilization (see Chapter 17—Bank Protection) shall be provided, when appropriate, as a result of any stream disturbance such as encroachment and shall include both upstream and downstream banks as well as the local site.
- Bends should have radii equal to the natural bends in the vicinity. The minimum radius for subcritical flow should be three times the water surface width.
- Channel side slopes shall not exceed the angle of repose of the soil and/or lining and shall be 2:1 or flatter in the case of rock-riprap lining. Vegetated channel side slopes shall be 4:1 or flatter.
- Channel freeboard shall follow the same requirements set forth in Chapter 10 for bridges. A minimum of 1 foot of freeboard should be provided for all open channels designed.

Some of the specific criteria to be used in the hydraulic analysis and design of bridges include:

- The final design selection should consider the maximum backwater allowed by the National Flood Insurance Program (NFIP), unless exceeding the limit can be justified by special hydraulic conditions.
- The final design should not significantly alter the existing flow distribution in the floodplain.
- The "crest-vertical curve profile" is the preferred highway bridge crossing profile when allowing for embankment overtopping at a lower discharge and for adequate deck drainage.
- Sag vertical curves can cause deck drainage to pond and ice up on the bridges and should be avoided.
- Horizontal curve transitions cause water to flow across lanes and should not be located on a bridge because of icing and hydroplaning problems.
- Clearance or freeboard should be provided between the low girder and the design water surface to allow for the passage of ice and debris.
- The design capacity of any bridge will be the flow that will pass through the bridge with adequate freeboard and without roadway overtopping.

- Estimate all degradation and aggradation plus contraction scour and local scour for the design year and for the 500-year event. Indicate the total scour envelope with a continuous line drawn such that the structural designer may adequately design substructure components. Scour depths are to be estimated with consideration of the local geology.
- Velocities through the structure(s) will not damage either the highway facility or increase damages to adjacent property.
- Pier spacing and orientation and abutment location shall be designed to minimize flow disruption and potential scour. Bridge piers should not be placed in the main channel area.
- Foundation design and/or scour countermeasures shall be made to avoid failure by scour. Typically, substructure components are designed to avoid failure by scour.
- Although appropriate in some debris-prone streams, connecting a discrete pier column to a debris-deflecting wall can significantly increase scour depths if the channel alignment ever shifts. A debris-deflecting wall also can greatly increase the stiffness of a pier, which reduces the number of available design options. More preferably, a long span bridge design reduces the number of piers and, therefore, reduces the benefits derived from debris-deflecting walls. It is now often more efficient for a designer to simply design a pier (and, if necessary, the superstructure) for increased stream loads due to debris.
- When two or more bridges are constructed in parallel over a channel, care should be taken to align the piers and to provide streamlined grading and protection for abutments. This abutment grading is to minimize expansion or contraction of flow between the two bridges.
- Commercial mining of sands and gravel in streams is common because the material is clean and well-graded and the stream replenishes the supply. Borrow pits, either upstream or downstream of a highway-stream crossing, can cause or aggravate scour at the bridge. This fact should be considered when calculating bridge scour, and it should be estimated by sediment transport modeling.
- Minimize disruption of ecosystems. Consider preserving valuable characteristics that are unique to the floodplain and stream.
- Economic analysis of the design shall include complete life cycle costs and benefits. Factors that should be considered are construction, maintenance, operation, and any potential liabilities.
- Adequate right of way shall be provided upstream and downstream of a structure for maintenance operations.

According to the DDM, the freeboard is the minimum clearance between the design approach water surface elevation and the low girder of the bridge. For a high-debris stream, freeboard should be 4 feet or more. The water surface 50 feet to 100 feet upstream of the face of the bridge should be the elevation to which the freeboard is added to get the bottom or low girder elevation of the bridge.

2.3. Federal and National Criteria and Guidelines

2.3.1. FEMA

FEMA administers the NFIP and provides communities flood hazard information upon which floodplain management regulations are based. Each community that joins the NFIP is required to adopt a floodplain management ordinance that meets or exceeds the minimum NFIP requirements. The overriding purpose of the floodplain management regulations is to ensure that participating communities account for flood hazards, to the extent that they are known, in all official actions relating to land management and use. The specific requirements for the regulatory floodplain type by which Clear Creek is designated are located in 44 Code of Federal Regulations (CFR) Section 60.3(b), where FEMA has provided a map with approximate A Zones.

Most of the floodplain regulations in Section 60.3(b) pertain to development and subdivisions, which are not applicable for this Project. The applicable standards are:

> 60.3(a)(1): Require permits (from the community floodplain administrator) for all proposed construction or other development in the community.
>
> 60.3(a)(2): Review proposed development to assure that all necessary permits have been received from those governmental agencies from which approval is required by federal or state law, including Section 404 of the Federal Water Pollution Control Act Amendments of 1972, 33 United States Code (USC) 1334.
>
> 60.3(b)(6): Notify, in riverine situations, adjacent communities and the State Coordinating Office prior to any alteration or relocation of a watercourse and submit copies of such notifications to the Federal Insurance Administrator.
>
> 60.3(b)(7): Assure that the flood-carrying capacity within the altered or relocated portion of any watercourse is maintained.
>
> 60.3(d)(3): Prohibit encroachments—including fill, new construction, substantial improvements and other development—within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge.

2.3.2. FHWA and AASHTO

Design criteria and guidelines from FHWA and the American Association of State Highway and Transportation Officials (AASHTO) are incorporated into the CDOT DDM. Refer to Section 2.2.3 for CDOT DDM criteria.

2.4. Selected Bridge Design Criteria and Parameters

Since Clear Creek is a high-debris stream, CDOT's DDM requirement of 4 feet minimum freeboard between the anticipated water surface in the 100-year storm and the bottom of the bridge deck will be used for bridge design in this Project. Water surface elevation at cross sections 50-feet to 100-feet upstream of the bridge is used to determine the freeboard at the bridge. Pier spacing and orientation and abutment location will be designed to minimize flow disruption and potential scour. Bridge piers should not be placed in the main channel area. CDOT's criteria also will be used for scour analysis at the bridge.

Clear Creek accommodates recreational activities, such as rafting. As a result, the minimum freeboard for the 100-year storm event has been increased to 5 feet to accommodate recreational activities.

3. Hydrology

3.1. Effective Regulatory

The current effective hydrology for Clear Creek is listed in the regulatory FIS, as published by FEMA, for Clear Creek County, Colorado and Incorporated Areas was revised on December 20, 2019. The extent of the detailed regulatory boundary in the previous effective FIS (2012) ended at the corporate limits of the City of Idaho Springs, which is upstream of the Project extent. The effective preliminary FIS (2019) extended the detailed portion to a location approximately one mile downstream of the previous limit of detailed study. Downstream of this new detailed study limit, the approximate Zone A from the 2012 and earlier FIRMs is depicted on the 2019 FIRMs. There is no effective hydrology available for the approximate Zone A reach within the Project limits.

3.2. Previous Flooding History

The largest recorded flood event within the Clear Creek watershed occurred in August 1888. A historic peak of 8,700 cubic feet per second (cfs) was recorded at the Forks Creek stream gauge just upstream of Golden, Colorado, which was active from 1888 to 1912. The largest recorded flood through Idaho Springs occurred due to the failure of Georgetown Lake Dam in June 1965. More recently, heavy rainfall and flooding occurred on September 15, 2013, affecting Clear Creek and approximately 200 miles of streams all along the Front Range.

3.3. Best-Available Hydrology

Peak flows for Clear Creek, as contained in the Clear Creek County Preliminary FIS, date back to the 1990 USACE study, which used stream flow data up to 1986. The best-available hydrology consists of raw streamflow data collected at nearby U.S. Geological Survey (USGS) stream gauges. As shown in Exhibit 3, active streamflow gauges near the Project area contain more current hydrologic/streamflow data than were used in the Preliminary FIS. These data were used to carry out an updated regression analysis to produce more accurate design flow rates for Clear Creek within the study area.

Exhibit 3 Selected Clear Creek USGS Stream Gauges

USGS ID	Location	Years of Record[1]	No. of Peaks	Reported Area (sq. mi.)	Historic Records
06716500	Near Lawson, CO	1946 to 1986, 1995 to 2017+	64	147	
06718300	Above Johnson Gulch	1995 to 2005	11	267	
06719000	At Forks Creek, CO	1888 to 1912	15	339	8,700 cfs—Aug. 1, 1888
06719500	Near Golden, CO	1911 to 1974	64	399	
06719505	At Golden, CO	1975 to 2017+	43	394	

1 Provisional peak flows for water year 2018 are available for active gauges (near Lawson and at Golden)

ICON Engineering performed hydrologic analysis along Clear Creek from just downstream of Georgetown Lake to the I-70 Twin Tunnels in the 2012 *Clear Creek Hydrology Report*. The study used a regional regression equation to determine the discharges along Clear Creek. This report is included in the electronic files in Appendix D.

3.4. Discharge Probability

A flood-frequency analysis was performed to determine the magnitude and frequency of flood discharges based on records of annual maximum instantaneous peak discharges collected for Clear Creek in the area of the Project. Bulletin 17C (England, 2018) was published as a follow-up and logical progression from the previously published methodology known as Bulletin 17B. A more-detailed description of the Clear Creek flood frequency analysis is contained in the October 2, 2018, Technical Memorandum titled *I-70 Floyd Hill to Veterans Memorial Tunnels Project—Hydrologic Approach for Clear Creek*, in Appendix A.

The peak flows used in the flood-frequency analysis are reasonable based on the long records at multiple stream gauges and the inclusion of paleoflood information. The at-site peaks then were estimated using an equation to obtain area-weighted values between two stream gauges on the same stream. As shown in Exhibit 4, the recommended 100-year design flow for the Project Area is 4,375 cfs, which is higher than previous studies (3,624 cfs from the 2012 ICON study). This difference is due to using an updated methodology as prescribed by Bulletin 17C and including the paleoflood information near Golden. The higher flows are conservative but reasonable when looking at the whole flood history of the area. Also note that, for the higher flood events (50-year, 100-year, 500-year, etc.), the 2012 ICON study results are very close to the lower bound of the 68-percent confidence interval of the Bulletin 17C peak flows. This shows that these updated results are close to the limits of being statistically significant.

Exhibit 4 Bulletin 17C Results for Bridge and Scour Analysis and Regulatory Flows for Floodplain Analysis

Location	Area (sq. mi.)	10-yr (cfs)	25-yr (cfs)	50-yr (cfs)	100-yr (cfs)	500-yr (cfs)
Just upstream of Twin Tunnels (recommended flows) (Bulletin 17C flows)	263.0	2,251	2,987	3,635	4,375	6,542
Lower and upper 68% confidence intervals		2,034 2,510	2,638 3,402	3,118 4,228	3,622 5,230	4,948 8,497
Same location (from ICON 2012 study) (Regulatory Flows)	263.0	2,312	2,769	3,174	3,624	4,889

For regulatory purposes, the effective hydrology flows from the ICON study and Preliminary FIS report will be used. The 100-year flow from the 2012 ICON study from here on will be referred to as the regulatory flow. For bridge design, scour analysis, and scour countermeasures, the Project will use peak flows developed using Bulletin 17C.

4. Effective Condition

4.1. Published Effective Condition

As stated previously, the current effective hydraulic condition for Clear Creek is listed in the regulatory FIS as published by FEMA for Clear Creek County, Colorado, and Incorporated Areas, revised on December 20, 2019. The extent of this effective regulatory study runs one mile downstream from where the previously effective boundary ended. There is no effective hydraulic study available within the Project limits.

4.2. Duplicate Effective Condition

Due to the absence of an effective regulatory condition, a duplicate effective analysis does not apply.

5. Existing Conditions

In 2019, Atkins submitted the *Draft Conceptual Clear Creek Baseline Hydraulics Report* (2019 Report), that provided conceptual hydraulics analysis using USACE HEC-RAS one-dimensional (1D) modeling for an understanding of floodplain impacts between the existing and proposed conditions. During the preparation of the 2019 design, CDOT and Atkins agreed to the following:

- Floodplain Permitting: Use HEC-RAS 1D modeling and FEMA effective flows to report differences in the floodplain.
- Stream and Bridge Hydraulics: Use SRH-2D two-dimensional (2D) modeling and Bulletin 17C for design flows to assess impacts of proposed improvements.

This Report will summarize methods and results from 2D modeling shown in the 20% design presented in June 2020.

An existing conditions hydraulic model for Clear Creek within the Project Area was developed using Aquaveo Surface Water Modeling System (SMS) 13.0.9. The 2D model consists of a 3.3-mile reach of Clear Creek that extends from just upstream of the Doghead Rail Bridge on the upstream end to just downstream of the US 6 Bridge at Johnson Gulch on the downstream end.

5.1. Terrain

The existing terrain was determined from LiDAR data and supplemented with ground survey. Ground survey was used within the Creek banklines to approximate the channel bathymetry, as the available LiDAR data are limited by the surface of the water.

LiDAR data were obtained from USGS. The data accurately map the topography surrounding Clear Creek but are limited within the stream channel due to the surface of the water. As such, the LiDAR data were used for areas outside the channel boundary. The data were projected to a project-specific coordinate system, TwinTunnels_CO_SPFT_Cen_NAD83. In SMS, the LiDAR data were filtered using a 2-degree filter to remove points that did not add any details to the surface and then were filtered to remove any duplicate points.

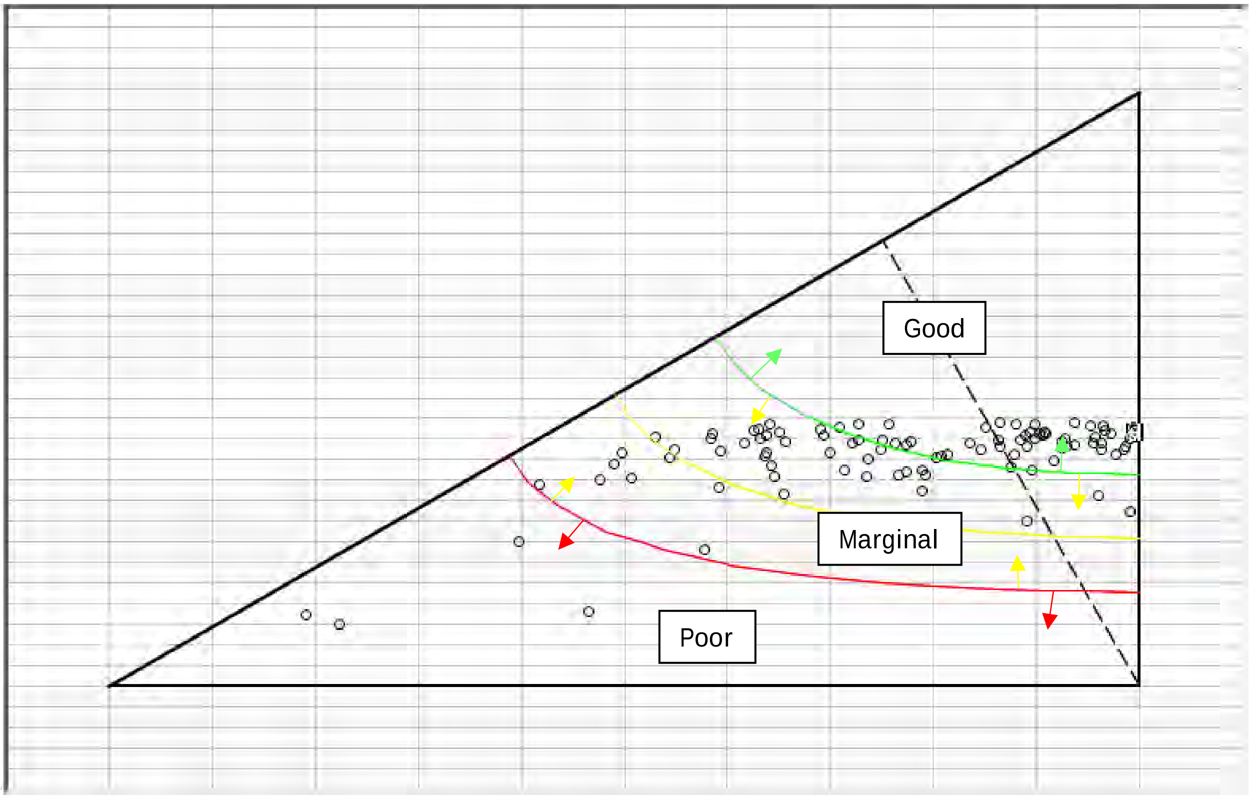
Ground survey for the Project was completed by CDOT and received by Atkins in 2018 and bridge survey was completed by Ascent Group, Inc. and received by Atkins in 2018. The ground survey covers the area of I-70 from the west end of the Veterans Memorial Tunnels to the top of Floyd Hill. The survey coverage of Clear Creek ends one mile east of the current US 6 and I-70 off- and on-ramps.

In SMS, the ground survey was merged with the LiDAR data and the scatter points from LiDAR were removed within the survey data boundary.

5.2. Mesh

The existing mesh was generated using the patch method within the channel and the pave method outside the channel. Breaklines were added throughout the channel to achieve rectangular elements. The average element size within the channel is 25-30 sq. ft., while the elements outside the channel range from 15 to 50 sq. ft. The mesh angle quality statistics are shown in Exhibit 5. Most elements fall in the “Good” range, with some in the “Marginal” range and a few in the “Poor” range. All elements in the “Poor” range are on the mesh boundary, well away from the channel, and most in the “Marginal” range fall outside the channel.

Exhibit 5 Existing Mesh Angle Representation Region Plot



5.3. Materials Coverage

Materials and corresponding Manning's n values used in the model are shown in Exhibit 6. These numbers were confirmed by the accepted Manning's n-value from the 2019 Report HEC-RAS model.

Exhibit 6 Existing Manning's Roughness Values

Material	Manning's Roughness
Channel	0.045
Overbanks	0.055
Dense Trees	0.09

5.4. Boundary Conditions

The existing conditions simulation is required to assess Project impacts. This results in three separate boundary conditions coverage maps. The upstream boundary conditions used the Bulletin 17C 10-year, 100-year, and 500-year peak flow rates mentioned in Section 3, Exhibit 4. The downstream boundary conditions used a constant water surface elevation (WSEL) defined by the 2019 Report from Clear Creek HEC-RAS. These numbers are shown in Exhibit 7.

Exhibit 7 Existing Conditions Model Boundary Conditions

Storm Event (year)	Upstream Boundary Condition: Bulletin 17C Peak Flow (cfs)	Downstream Boundary Condition: HEC-RAS Constant WSEL (ft)
10	2,251	7,157.62
100	4,375	7,160.43
500	6,542	7162.68

5.5. Obstructions Coverage/Hydraulic Structures

In the Project Area, Clear Creek crosses 12 existing bridges, which were incorporated in the existing model.

Exhibit 8 shows the dimensions of each existing bridge and its piers that were used to create obstructions. Bridge decks were not included in the model due to SRH-2D limitations on modeling obstructions, except as noted in the exhibit. This approach should not impact results for a 100 year storm event, evidenced by freeboard in Exhibit 21. This assumption would need to be revaluated for larger storm events.

Pier data for each bridge is also shown in Exhibit 8, however it only shows data for a generic pier and is not representative of the actual number of piers. Each pier set was given a "Z Value" (bottom elevation) well below the actual channel bottom and corresponding height to ensure the pier would extend to the low chord elevation of the bridge deck, above the WSEL.

Exhibit 8 Existing Bridge Dimensions

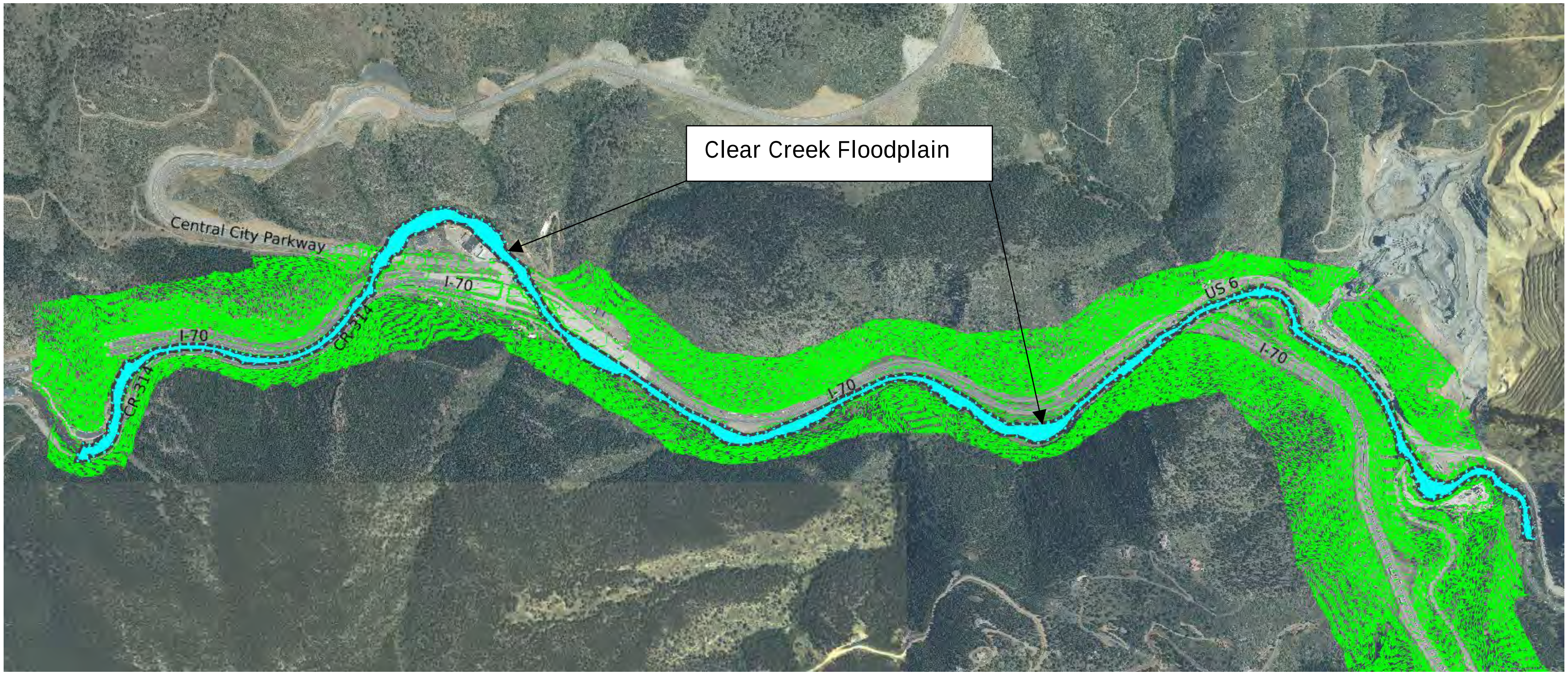
Project Station	CDOT Structure ID	Bridge Low Chord Elev (feet)	Bridge Width (feet)	Deck Depth (feet)	Pier Width (feet)	Pier Height (feet)	Z Value (feet)
2000+00	-	7,364.42	57.2	4.07	3.06	10.93	7,350.58
2024+10	F-15-BR	7,329.02	98.1	12.35	6.80	8.63	7,320.39
2025+45	F-15-BH	7,337.24	61.2	8.3	2.53	25.45	7,311.79
2026+85	-	7,340.77	55.2	14.71	5.75	22.04	7,318.73
2027+62	-	7,325.15	6.9	8.28	5.05	18.50	7,306.65
2038+54	F-15-D	7,306.37	39.8	5.77	2.94	13.85	7,292.52
2039+33[1]	F-15-CQ	7,300.77	45.21	10.46	-	-	-
2040+50	F-15-BX	7,304.85	310.83	5.99	7.73	16.59	7,288.26
2104+81	F-15-CM	7,236.18	158.4	10.48	4.50	21.09	7,215.09
2104+90	F-15-BL	7,263.55	53.2	10.59	3.88	51.24	7,212.31
2108+04	F-15-BM	7,225.58	35.8	6.71	2.88	19.63	7,205.95
2127+91	F-15-CN	7,211.21	34.9	10.3	3.50	33.22	7,177.99

[1]This bridge was modeled in conjunction with a pressure boundary condition to simulate possible overtopping. This is the only bridge within the model where WSEL reaches the bridge deck, thereby causing pressurized flow.

5.6. Floodplain Results

The existing floodplain is confined mostly within the channel limits. The existing floodplain extent is shown in Exhibit 9, with summary of WSELs in Section 6.6. More detailed workmaps can be found in Appendix B. The floodplain is based on Bulletin 17C flows, as mentioned in Section 3.4.

Exhibit 9 Existing Conditions Floodplain



6. Proposed Conditions

A proposed conditions hydraulic model for Clear Creek within the Project Area was developed using SRH-2D within Aquaveo SMS version 13.0.9. Similar to the existing conditions model discussed in Section 5, the 2D proposed conditions model consists of a single 3.3-mile reach of Clear Creek that extends from just upstream of the Doghead Rail Bridge on the upstream end to just downstream of the US 6 Bridge at Johnson Gulch on the downstream end.

Since two alternatives are considered, two proposed models were developed:

- Tunnel Alternative would realign westbound I-70 to the north (along the curve between MP 244.3 and MP 243.7) through a new 2,200-foot-long tunnel west of US 6. Eastbound I-70 would be realigned within the existing I-70 roadway template to flatten curves to improve design speed and sight distance.
- Canyon Viaduct Alternative would realign approximately one-half mile of both the westbound and eastbound I-70 lanes (along the curve between MP 244 and MP 243.5) on viaduct structures approximately 400 feet south of the existing I-70 alignment on the south side of Clear Creek Canyon. Through the realigned area, the frontage road would be constructed under the viaduct on the existing I-70 roadway footprint north of Clear Creek. The Clear Creek Greenway would be reconstructed along its current alignment on the south side of Clear Creek, north of the viaduct. The viaduct would cross above Clear Creek and the Clear Creek Greenway twice.

Additional information regarding the alternatives evaluated in the Environmental Assessment (EA) can be found in *the I-70 Floyd Hill to Veterans Memorial Tunnels Alternatives Analysis Technical Report*.

6.1. Terrain

The proposed terrain was determined using the same LiDAR and ground survey as the existing model, with the addition of the proposed design. The proposed designs were added as XML files from a combination of the roadway linework, the Clear Creek realignment, and the pond designs.

In SMS, the ground survey was merged with the proposed Clear Creek realignment scatter set to create a Clear Creek scatter set, while the proposed roadway/pond scatter set was merged with the LiDAR data to create a scatter set of all points outside the Creek. The two sets then were merged, prioritizing the Clear Creek scatter set, to create a combined set used for analysis.

6.2. Mesh

The proposed meshes were both created similarly to the existing, generated using the patch method within the channel and the pave method outside the channel. Breaklines were added throughout the channel to achieve rectangular elements. The average element size within the channel is 25-30 sq. ft., while the elements outside the channel range from 15 to 50 sq. ft. The mesh angle quality statistics for the Canyon and Tunnel meshes are shown in Exhibit 10 and 11, respectively. Most elements fall in the "Good" range, with some in the "Marginal" range and a few in the "Poor" range. All elements in the "Poor" range and most elements in the "Marginal" range fall outside the channel.

Exhibit 10 Proposed Tunnel Angle Representation Region Plot

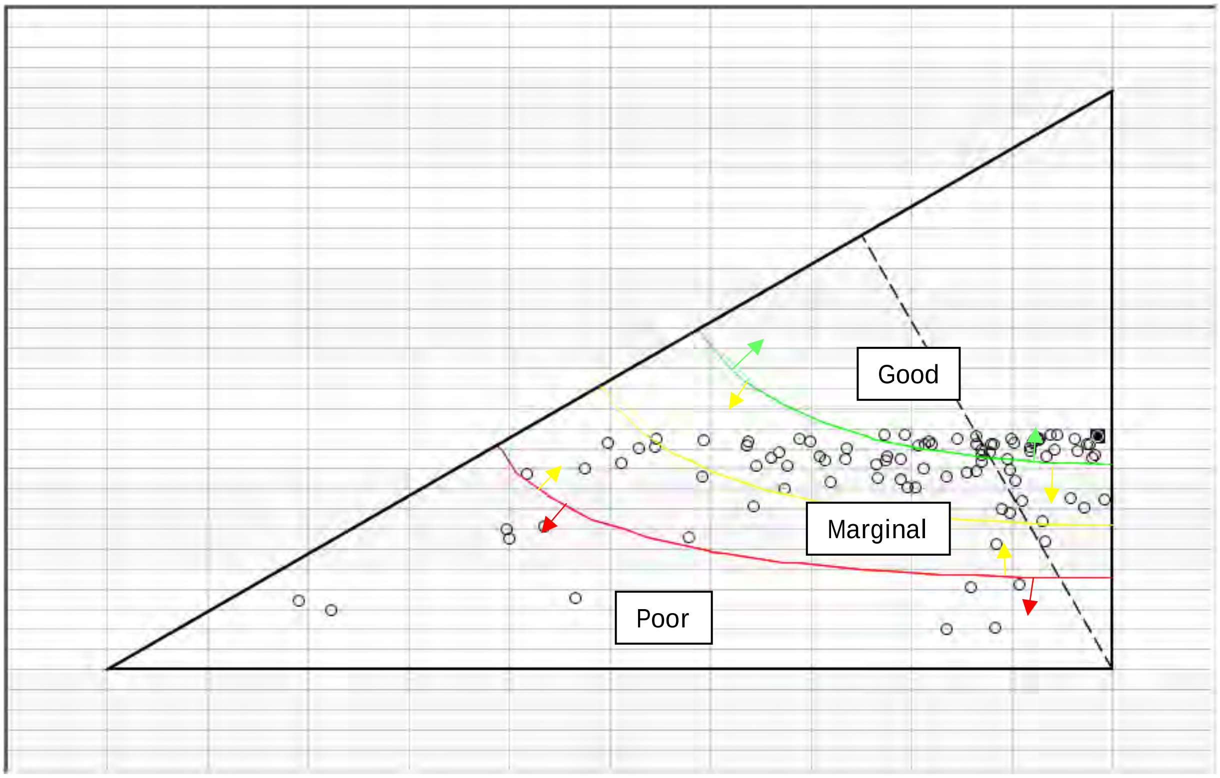
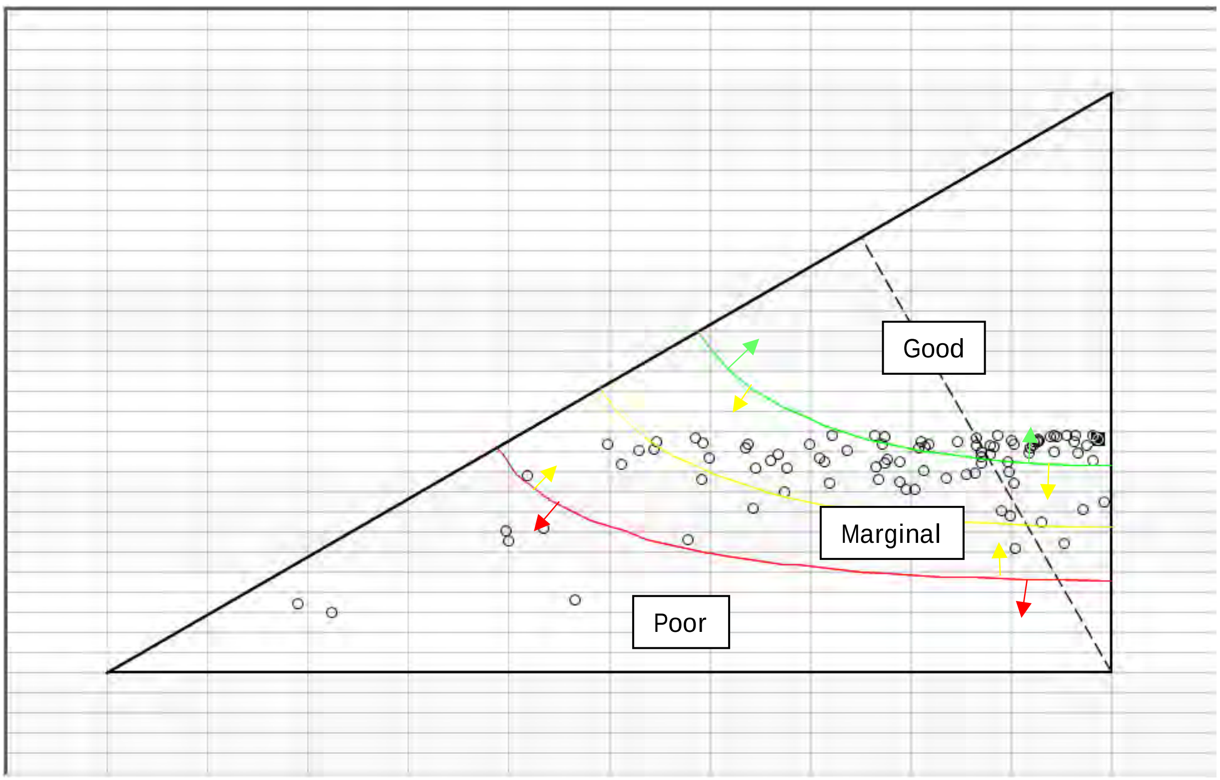


Exhibit 11 Proposed Canyon Angle Representation Region Plot



6.3. Materials Coverage

Materials and corresponding Manning's n values used in the model are shown in Exhibit 12. These numbers were confirmed by the accepted Manning's n-value from the 2019 Report HEC-RAS model.

Exhibit 12 **Proposed Manning's Roughness Values**

Material	Manning's Roughness
Channel	0.045
Overbanks	0.055
Dense Trees	0.09

6.4. Boundary Conditions

Like the existing conditions, three simulations are required to assess Project impacts. This results in three separate boundary conditions coverage maps. The upstream boundary conditions used the Bulletin 17C 10-year, 100-year, and 500-year peak flow rates mentioned in Section 3, Exhibit 4. The downstream boundary conditions used a constant WSEL defined by the 2019 Report for Clear Creek HEC-RAS. These numbers are shown in Exhibit 13.

Exhibit 13 Proposed Conditions Model Boundary Conditions

Storm Event (year)	Upstream Boundary Condition: Bulletin 17C Peak Flow (cfs)	Downstream Boundary Condition: HEC-RAS Constant WSEL (feet)
10	2,251	7,157.62
100	4,375	7,160.43
500	6,542	7162.68

6.5. Obstructions Coverage

With the design of two alternatives, two obstruction coverage maps are required.

6.5.1. Tunnel Alternative Obstructions Coverage

In the Tunnel Alternative design, there are five proposed bridges (four completely new and one expansion of an existing bridge) and three existing bridges that will be removed. There are three additional bridges in the Tunnel Alternative Design, but they do not affect channel hydraulics and are not modelled. Proposed Tunnel Alternative bridges are shown in Exhibit 14, their data are found below in Exhibit 15, and a more-detailed summary of bridge hydraulics is presented in the Section 7.

Due to modeling constraints, bridge decks were only modeled if the WSEL was expected to reach the bridge low chord. The bridge at Project Station 2039+33 was the only bridge low enough to require the bridge deck to be modelled. The bridge deck was modelled using a pressure flow condition. For all other bridges only piers were modelled, which was done using obstructions.

Exhibit 15 shows generic pier data for each bridge, however it is not representative of the actual number of piers. Each pier set was given a "Z Value" (bottom elevation) well below the actual channel bottom and corresponding height to ensure the pier would extend to the low chord elevation of the bridge deck, above the WSEL.

Exhibit 14 Proposed Tunnel Alternative Bridges

Exhibit 15 Proposed Tunnel Alternative Bridge Data

Project Station	Bridge Status*	CDOT Structure ID**	Bridge Location	Lowest Low Chord (feet)	Bridge Width (feet)	Deck Depth (feet)	Pier Width (feet)	Pier Height (feet)	Z Value (feet)
2000+00	Ex	-	Doghead Rail Bridge	7,364.42	57.2	4.07	3.06	10.93	7,350.58
2022+40	Prop	-	Bridge E	7,331.07	60.44	8.00	5.00	25.00	7,306.07
2024+10	RR	-	Bridge D	7,329.02	81.47	8.00	8.00	20.00	7,309.02
2026+85	Ex	-	Central City Pkwy	7,340.77	55.2	14.71	6.80	11.14	7,319.36
2027+62	Ex	-	Ped Bridge @ Water Plant	7,325.15	6.9	8.28	5.05	18.50	7,306.65
2038+54	Ex	F-15-D	"Unnamed Rd" @ Hidden Valley Interchange	7,306.37	39.8	5.77	2.94	13.85	7,292.52
2039+33	Ex	F-15-CQ	WB I-70 OFF @ Hidden Valley Interchange	7,300.77	45.21	10.46	—	—	—
2040+50	Ex	F-15-BX	EB & WB I-70 @ Hidden Valley Interchange	7,304.85	310.83	5.99	7.73	16.59	7,288.26
2043+18	Prop	-	Bridge F	7,299.98	47.38	7.00	5.00	30.00	7,269.98
2103+70	RR	-	Bridge C	7,268.61	67.00	8.00	6.00	50.00	7,218.61
2105+70	RR	-	Bridge B	7,263.95	59.00	7.00	5.00	60.00	7,203.95

Project Station	Bridge Status*	CDOT Structure ID**	Bridge Location	Lowest Low Chord (feet)	Bridge Width (feet)	Deck Depth (feet)	Pier Width (feet)	Pier Height (feet)	Z Value (feet)
2108+04	Ex	F-15-BM	WB I-70 OFF @ Quarry	7,225.58	35.8	6.71	3.00	16.00	7209.58
2127+91	Ex	F-15-CN	US 6 @ Johnson Gulch	7,211.21	34.9	10.3	3.50	33.22	7,177.99

*Ex: bridges to remain the same as in existing conditions; Prop: new bridge added; RR: remove and replace existing bridge with upgraded design
**Proposed bridges will not receive structure IDs until a design alternative has been selected

6.5.2. Canyon Viaduct Alternative Obstructions Coverage

There are eight proposed bridges within the Canyon Viaduct Alternative model limits (seven completely new bridges and one expansion of an existing bridge). The same three existing bridges will be removed. There are three additional bridges in the Canyon Alternative Design, but they do not affect channel hydraulics and are not modelled. Proposed Canyon Viaduct Alternative bridges are shown in Exhibit 16 and their data is found in Exhibit 17. Bridges A/B and C cross Clear Creek twice and are included twice in Exhibit 17 for each crossing.

As with the Tunnel Alternative Bridges, due to modeling constraints, bridge decks were only modeled if the WSEL was expected to reach the bridge low chord. The bridge at Project Station 2039+33 was the only bridge low enough to require the bridge deck to be modelled. The bridge deck was modelled using a pressure flow condition. For all other bridges only piers were modelled, which was done using obstructions. Exhibit 17 shows generic pier data for each bridge, however it is not representative of the actual number of piers. Each pier set was given a “Z Value” (bottom elevation) well below the actual channel bottom and corresponding height to ensure the pier would extend to the low chord elevation of the bridge deck, above the WSEL.

Exhibit 16 Proposed Canyon Viaduct Alternative Bridges

Exhibit 17 Proposed Canyon Viaduct Alternative Bridge Data

Project Station	Bridge Status*	CDOT Structure ID**	Bridge Location	Lowest Low Chord	Bridge Width	Deck Depth	Pier Width	Pier Height	Z Value
2000+00	Ex	-	Doghead Rail Bridge	7,364.42	57.2	4.07	3.06	10.93	7,350.58
2022+40	Prop	-	Bridge E	7,331.07	60.44	8.00	5.00	25.00	7,306.07
2024+10	RR	-	Bridge D	7,329.02	81.47	8.00	8.00	20.00	7,309.02
2026+85	Ex	-	Central City Pkwy	7,340.77	55.2	14.71	6.80	11.14	7,319.36
2027+62	Ex	-	Ped Bridge @ Water Plant	7,325.15	6.9	8.28	5.05	18.50	7,306.65
2038+54	Ex	F-15-D	"Unnamed Rd" @ Hidden Valley Interchange	7,306.37	39.8	5.77	2.94	13.85	7,292.52
2039+33	Ex	F-15-CQ	WB I-70 OFF @ Hidden Valley Interchange	7,300.77	45.21	10.46	-	-	-
2040+50	Ex	F-15-BX	EB & WB I-70 @ Hidden Valley Interchange	7,304.85	310.83	5.99	7.73	16.59	7,288.26
2043+18	Prop	-	Bridge F	7,299.98	47.38	7.00	5.00	30.00	7,269.98
6067+00	Prop	-	Bridge M	7,300.62	67.00	10.00	9.00	30	7,271.00
6067+00	Prop	-	Bridge N	7,301.99	63.00	10.00	9.00	37	7,265.00

Project Station	Bridge Status*	CDOT Structure ID**	Bridge Location	Lowest Low Chord	Bridge Width	Deck Depth	Pier Width	Pier Height	Z Value
6083+00	Prop	-	Bridge A/B (U/S)	7,291.17	67.00	10.00	9.00	34	7,257.0
6083+00	Prop	-	Bridge C (U/S)	7,290.85	63.00	10.00	9.00	46	7,245.0
6104+00	RR	-	Bridge A/B (D/S)	7,294.82	67.00	10.00	9.00	69	7,225.5
6104+00	RR	-	Bridge C (D/S)	7,280.80	63.00	10.00	9.00	65	7,216.0
6108+50	RR	-	Bridge P	7,221.15	46.75	8.00	-	-	-
2127+91	Ex	F-15-CN	US 6 @ Johnson Gulch	7,211.21	34.9	10.3	3.50	33.22	7,177.99

*Ex: bridges to remain the same as in existing conditions; Prop: new bridge added; RR: remove and replace existing bridge with upgraded design
**Proposed bridges will not receive structure IDs until a design alternative has been selected

6.6. Floodplain Results and Comparisons

Exhibit 18 shows the water surface elevation comparison between existing and proposed conditions at several project locations. The proposed floodplains for the Tunnel Alternative and the Canyon Viaduct Alternative are shown in Exhibit 19 and Exhibit 20, respectively. More detailed workmaps can be found in Appendix C.

The proposed floodplains are very similar to the existing floodplain, indicating that the proposed improvements to Clear Creek have little impact on the existing water surface elevation. All floodplains are based on Bulletin 17C flow. The proposed WSEL for both the Tunnel and Canyon Viaduct Alternatives are higher than the existing WSEL at the existing I-70 offramp bridge at the Hidden Valley Interchange. However, the floodplain limits still are outside any existing development. At most locations downstream of the Hidden Valley Interchange, the proposed WSELs are lower than in the existing conditions.

Exhibit 18 Proposed and Existing Condition 100-Yr WSELs at Bridge Locations

Project Station	Location	Existing Condition WSEL (ft)	Proposed Tunnel WSEL (ft)	Proposed Canyon WSEL (ft)
2000+00 (west of roadway boundary)	Doghead Rail Bridge	7361.2	7361.2	7361.2
2022+40	Bridge E	7327.7	7327.3	7327.4
2024+10	Bridge D/Existing I-70 EB	7326.0	7325.5	7326.2
2025+40	Existing I-70 WB	7321.1	7320.3	7322.1
2026+85	Central City Pkwy	7316.1	7316.1	7316.0
2027+62	Ped Bridge @ Water Plant	7314.3	7314.2	7314.2
2038+54	"Unnamed Rd" @ Hidden Valley Interchange	7303.0	7303.4	7303.5
2039+33	WB I-70 OFF @ Hidden Valley Interchange	7301.2	7304.3	7304.9
2040+50	EB & WB I-70 @ Hidden Valley Interchange	7301.1	7301.0	7301.4
2043+18	Bridge F	7295.7	7295.7	7295.8
6067+00	Bridge N	7271.4	7271.2	7271.1
6067+00	Bridge M	7267.6	7267.8	7267.8
6083+00	Bridge A/B (U/S)	7244.0	7244.0	7244.0
6083+00	Bridge C (U/S)	7242.2	7242.1	7242.1
6104+00	Bridge C (D/S)	7225.9	7224.4	7224.4
6104+00	Bridge A/B (D/S)	7221.7	7221.4	7221.401
2103+54	EB I-70 @ Quarry	7225.9	7224.5	7224.4
2103+70	Bridge C	7222.8	7222.1	7222.2
2105+17	WB I-70 @ Quarry	7220.9	7220.1	7220.5
2105+70	Bridge B	7219.9	7219.5	7219.9
2108+04	WB I-70 OFF @ Quarry	7214.1	7214.3	7213.7
6108+50	Bridge P	7214.3	7214.4	7213.8
2127+91	US 6 @ Johnson Gulch	7184.8	7185.7	7185.6

Exhibit 19 Proposed Tunnel Alternative Floodplain

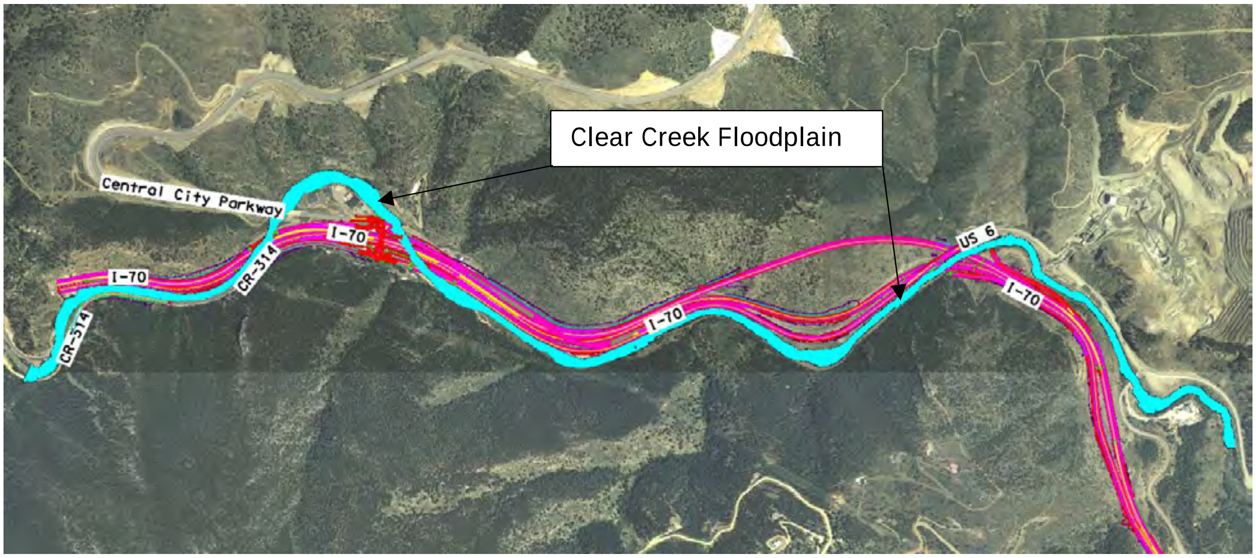
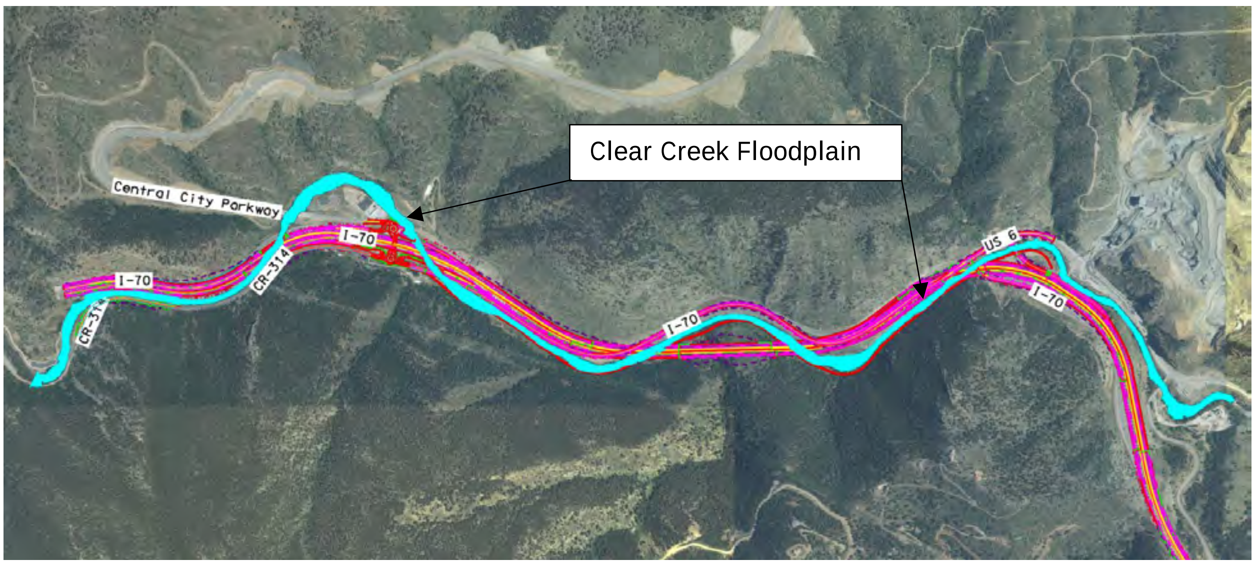


Exhibit 20 Proposed Canyon Viaduct Alternative Floodplain



7. Bridge Hydraulics

7.1. Tunnel Alternative Bridges

As mentioned previously, eight of the bridges in the proposed conditions model remain the same as in the existing conditions. Three existing bridges are removed and replaced. They consist of:

- Project Station 2024+10, Bridge E, on I-70 Westbound—In the existing conditions, this bridge has two piers. Although the proposed bridge has four piers, the area of the proposed bridge opening has increased by approximately 1,300 square feet. The bridge is proposed to be widened by approximately 60 feet.
- Project Station 2103+70, Bridge C, on I-70 Eastbound—The area of the proposed bridge opening has increased by approximately 7,500 square feet. The number of piers remains the same. One of the piers is moved away from the main channel flow area. The bridge is proposed to be widened by almost 50 feet.
- Project Station 2105+70, Bridge B, on I-70 Westbound—The number of piers remains the same and the area of the proposed bridge opening has increased by approximately 6 square feet. The bridge is proposed to be widened by almost 25 feet.

Two new bridges will be added in the proposed condition. The first new bridge is located at Project Station 2022+40, Bridge D. The area of the bridge opening is 3,243 square feet with four 8-foot-wide piers. This bridge is approximately 190 feet wide. The second new bridge is at Project Station 2043+18, Bridge F, and it will connect East Idaho Springs to I-70 eastbound. The area of the proposed bridge opening is approximately 2,595 square feet with two 8-foot-wide piers. The width of this bridge is approximately 150 feet.

Bridge calculations will use peak discharges generated from Bulletin 17C.

The proposed conditions SMS model is included in the electronic files in Appendix D.

7.1.1. Freeboard

For high-debris, recreational streams such as Clear Creek, a minimum of 5 feet of freeboard is required at bridge locations for the 100-year event. Exhibit 21 summarizes the 100-year freeboard at Tunnel Alternative bridges for the existing and proposed conditions models.

Exhibit 21 Freeboard Summary at Tunnel Alternative Bridges for 100-Year Event using Bulletin 17C Flows

Project Station	Bridge Status*	Bridge Location	Design Flow (cfs)	Available Freeboard (Feet)	
				Existing	Proposed
2000+00	Ex	Doghead Rail Bridge	4,375	3.22	3.22
2022+40	Prop	Bridge E	4,375	3.37	3.77
2024+10	RR	Bridge D	4,375	3.02	3.52
2026+85	Ex	Central City Pkwy	4,375	24.67	24.67
2027+62	Ex	Ped Bridge @ Water Plant	4,375	10.85	10.95

Project Station	Bridge Status*	Bridge Location	Design Flow (cfs)	Available Freeboard (Feet)	
				Existing	Proposed
2038+54	Ex	"Unnamed Rd" @ Hidden Valley Interchange	4,375	3.37	2.97
2039+33	Ex	WB I-70 OFF @ Hidden Valley Interchange	4,375	-0.43	-3.53
2040+50	Ex	EB & WB I-70 @ Hidden Valley Interchange	4,375	3.75	3.85
2043+18	Prop	Bridge F	4,375	4.28	4.28
2103+70	RR	Bridge C	4,375	45.81	46.51
2105+70	RR	Bridge B	4,375	44.05	44.45
2108+04	Ex	WB I-70 OFF @ Quarry	4,375	11.48	11.28
2127+91	Ex	US 6 @ Johnson Gulch	4,375	26.41	25.51

*Ex: bridges to remain the same as in existing conditions; Prop: new bridge added; RR: remove and replace existing bridge with upgraded design

Six of the 13 bridges in the Tunnel alternative meet freeboard requirements. Of the seven that don't, three have more freeboard in the proposed model than in the existing and two remain the same. Of the two bridges where freeboard decreases, at Project Station 2038+54 the change is -0.4 ft and at Project Station 2039+33 the change is -3.1 ft. No overtopping occurs in the proposed conditions that does not occur in existing conditions.

7.1.2. Piers

The proposed conditions SMS model incorporates the pier size and shape for both existing and proposed bridges. A variety of pier types were used on the various bridges on this stretch of Clear Creek. According to the preliminary design layout, piers are placed outside of the main channel area to minimize flow disruption and potential scour. The proposed piers for the replacement bridges and for the new bridges are similar in size. Where additional piers are proposed, the reduction in flow area is more than compensated for by a larger overall bridge opening, as discussed previously. Additionally, since many of the bridges have substantial freeboard, the impact to freeboard caused by additional piers is negligible. Expected scour potential and mitigation will be investigated and determined in a future phase of the Project to verify the required depths of proposed footings.

7.2. Canyon Viaduct Alternative Bridges

As mentioned previously, seven of the bridges in the Canyon Viaduct Alternative model remain the same as in the existing conditions. Four existing bridges are removed and replaced. They include:

- Project Station 2024+10, Bridge E, on I-70 Westbound—In the existing conditions, this bridge has two piers. Although the proposed bridge has four piers, the area of the proposed bridge opening has increased by approximately 1,300 square feet. The bridge is proposed to be widened by approximately 60 feet.

- Project Station 6104+00, Bridge C (downstream), on I-70 Eastbound—The area of the proposed bridge opening extends past the channel banks on either side, significantly wider than the existing bridge, and the bridge deck low chord elevation rose by 44 feet. The number of piers in the channel remains the same. The proposed bridge width is reduced by almost 20 feet.
- Project Station 6104+00, Bridge A/B (downstream), on I-70 Westbound—The area of the proposed bridge opening extends past the channel banks on either side, significantly wider than the existing bridge, and the bridge deck elevation rose by 31 feet. The number of piers in the channel remains the same. The bridge is proposed to be widened by 14 feet.
- Project Station 6108+50, Bridge P—All piers are removed in the proposed conditions. The proposed bridge deck low chord elevation decreases by 4 feet but the bridge deck is still 15 feet above the channel floor and all piers are removed. The bridge width increases by 15 feet.

Six new bridges will be added in the proposed conditions:

- Project Station 2022+40, Bridge D—The area of the bridge opening is 3,243 square feet with four 8-foot-wide piers. This bridge is approximately 190 feet wide.
- Project Station 2043+18, Bridge F—Bridge F will connect East Idaho Springs to I-70 eastbound. The area of the proposed bridge opening is approximately 2,595 square feet with two 8-foot-wide piers. The width of this bridge is approximately 150 feet.
- Project Station 6067+00, Bridge N—The bridge opening extends well past the channel banks. It has three 9-foot-diameter piers within the channel area and is 63 feet wide.
- Project Station 6067+00, Bridge M—The bridge opening extends well past the channel banks. It has two 9-foot-diameter piers within the channel area and is 67 feet wide. Bridge M is parallel to and just downstream of Bridge N.
- Project Station 6083+00, Bridge A/B (upstream)—The bridge opening extends well past the channel banks. It has two 9-foot-diameter piers within the channel area and is 67 feet wide.
- Project Station 6083+00, Bridge C (upstream)—The bridge opening extends well past the channel banks. It has two 9-foot-diameter piers within the channel area and is 63 feet wide. Bridge M is parallel to and just downstream of Bridge N.

Bridge calculations will use peak discharges generated from Bulletin 17C. The proposed conditions SMS model is included in the electronic files in Appendix D.

7.2.1. Freeboard

As mentioned above, a minimum of 5 feet of freeboard is required at bridge locations for the 100-year event. Exhibit 22 summarizes the 100-year freeboard at Canyon Alternative bridges for the existing and proposed conditions models.

Exhibit 22 Freeboard Summary at Canyon Viaduct Alternative Bridges for 100-Year Event using Bulletin 17C Flows

Project Station	Bridge Status*	Bridge Location	Design Flow (cfs)	Available Freeboard (Feet)	
				Existing	Proposed
2000+00	Ex	Doghead Rail Bridge	4,375	3.22	3.22
2022+40	Prop	Bridge E	4,375	3.37	3.67
2024+10	RR	Bridge D	4,375	3.02	2.82
2026+85	Ex	Central City Pkwy	4,375	24.67	24.77

Project Station	Bridge Status*	Bridge Location	Design Flow (cfs)	Available Freeboard (Feet)	
				Existing	Proposed
2027+62	EX	Ped Bridge @ Water Plant	4,375	10.85	10.95
2038+54	Ex	"Unnamed Rd" @ Hidden Valley Interchange	4,375	3.37	2.87
2039+33	Ex	WB I-70 OFF @ Hidden Valley Interchange	4,375	-0.43	-4.13
2040+50	Ex	EB & WB I-70 @ Hidden Valley Interchange	4,375	3.75	3.45
2043+18	Prop	Bridge F	4,375	4.28	4.18
6067+00	Prop	Bridge N	4,375	30.59	30.89
6067+00	Prop	Bridge M	4,375	33.02	32.82
6083+00	Prop	Bridge A/B (U/S)	4,375	47.17	47.17
6083+00	Prop	Bridge C (U/S)	4,375	48.65	48.75
6104+00	RR	Bridge A/B (D/S)	4,375	54.90	56.40
6104+00	RR	Bridge C (D/S)	4,375	73.12	73.42
6108+50	RR	Bridge P	4,375	6.85	7.35
2127+91	Ex	US 6 @ Johnson Gulch	4,375	26.41	25.61

*Ex: bridges to remain the same as in existing conditions; Prop: new bridge added; RR: remove and replace existing bridge with upgraded design

Ten of the 17 bridges in the Tunnel alternative meet freeboard requirements. Of the seven that don’t, one has more freeboard in the proposed model than in the existing and one remains the same. Of the five bridges where freeboard decreases, at Project Station 2024+10 the change is -0.2’, at Project Station 2038+54 the change is -0.5’, at Project Station 2039+33 the change is -3.7 ft, at Project Station 2040+50 the change is -0.3’, and at Project Station 2043+18 the change is -0.1’. No overtopping occurs in the proposed conditions that does not occur in existing conditions.

7.2.2. Piers

The proposed conditions SMS model incorporates the pier size and shape for both existing and proposed bridges. A variety of pier types were used on the various bridges on this stretch of Clear Creek. According to the preliminary design layout, piers are placed outside of the main channel area to minimize flow disruption and potential scour. The proposed piers for the replacement bridges and for the new bridges are similar in size. Where additional piers are proposed, the reduction in flow area is more than compensated for by a larger overall bridge opening, as discussed previously. Additionally, since many of the bridges have substantial freeboard, the impact to freeboard caused by additional piers is negligible. Expected scour potential and mitigation will be investigated and determined in a future phase of the Project to verify the required depths of proposed footings.

8. Scour Evaluations

As part of the conceptual analysis, no scour evaluations were completed. The primary focus of the conceptual analysis was to determine the water surface elevations of the proposed bridges. Assumptions for hydraulic analysis were based on subcritical flow regime to determine the worst-case scenario for freeboard. Since a subcritical model would underestimate river velocities, which is a key factor in a scour analysis, a model that computes a mixed flow regime will be produced to carry out the scour analysis. The scour evaluation will analyze the anticipated local pier scour, the local abutment scour, and the long-term scour. Based on the results, the piers for the proposed bridges will be designed using the most conservative depth.

Scour calculations will use peak discharges generated from Bulletin 17C.

9. Compliance with Requirements

9.1. Local—*Roadway Design and Construction Manual*, County of Clear Creek

Traffic volume analysis—along with width, curve, right of way, and intersection analysis—were performed for the 2016 *I-70 Mountain Corridor Design Speed Study*, in compliance with Clear Creek County regulations.

9.2. State—CWCB Rules and Regulations

CWCB Rule 12, Effects of Flood Mitigation Measures and Stream Alterations Activities on Regulatory Floodplains, Paragraph E, requires any stream alteration activity (defined in Rule 4 as any manmade activity within a stream or floodplain that alters the natural channel, geometry, or flow characteristics of the stream) proposed by a project proponent to be evaluated for its impact on the regulatory floodplain and to be in compliance with all applicable federal, state, and local floodplain rules, regulations, and ordinances. This submittal meets this rule.

9.3. Federal—NFIP Regulations

This Project will conform to the requirements of 44 CFR Section 60.3(a) and (b). Not all the requirements in Section 60.3(a) and (b) are applicable for this Project. All the necessary permits will be requested from the community floodplain administrator as well as state and federal government agencies. Adjacent community officials will be notified of any alterations. Flood-carrying capacity within the altered or relocated portion of any watercourse will be maintained.

10. References

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Appendix A. Bulletin 17C Hydrology

Technical Memorandum

To:	Tammy Eggers, P.E.
From:	K.C. Robinson, P.E., CFM
Subject:	I-70 Floyd Hill to Veterans Memorial Tunnels Project—Hydrologic Approach for Clear Creek
Date:	October 2, 2018

Hydrologic Background

The current effective hydrology for Clear Creek is listed in the regulatory Flood Insurance Study (FIS) as published by the Federal Emergency Management Agency (FEMA), dated July 17, 2012. The effective flows were published for the City of Idaho Springs, but not farther downstream. Even though the most recent FIS report was published in 2012, the flow rates for Clear Creek near Idaho Springs were from a study completed in 1978 by Black & Veatch, Consulting Engineers, using stream data up through the mid 1970s. In 1990, a Type 15 Flood Insurance Study for Clear Creek was published by the Omaha District of the U.S. Army Corps of Engineers (USACE). This study by the USACE eventually was incorporated into a Preliminary FIS report by FEMA dated February 8, 2017. It is believed that this Preliminary FIS eventually will become effective.

Since the peak flows for Clear Creek date back to the 1990 Corps study, and used stream flow data up to 1986, there are concerns that advances in hydrologic methods in the intervening years would be important to incorporate to accurately capture the flood risk and peak flow rates used for the design of current and future projects.

Methodology

Clear Creek has multiple stream gauges maintained by the U.S. Geological Survey (USGS) that have measured historic flow rates. Table 1 lists some of the stream gauges near the Floyd Hill project area. Stream gauge measurements are some of the most important data for determining hydrologic peak flow rates since they capture the hydrologic response of a watershed. If enough flow events are measured, advanced statistical analysis can be used to estimate the 1-percent annual chance peak flow, often called the “100-year” flow.

Figure 1 shows the overall watershed of Clear Creek upstream of the gauge in Golden, Colorado. Also shown are some of the active and inactive USGS stream gauges that were inspected for use in a flood frequency analysis.

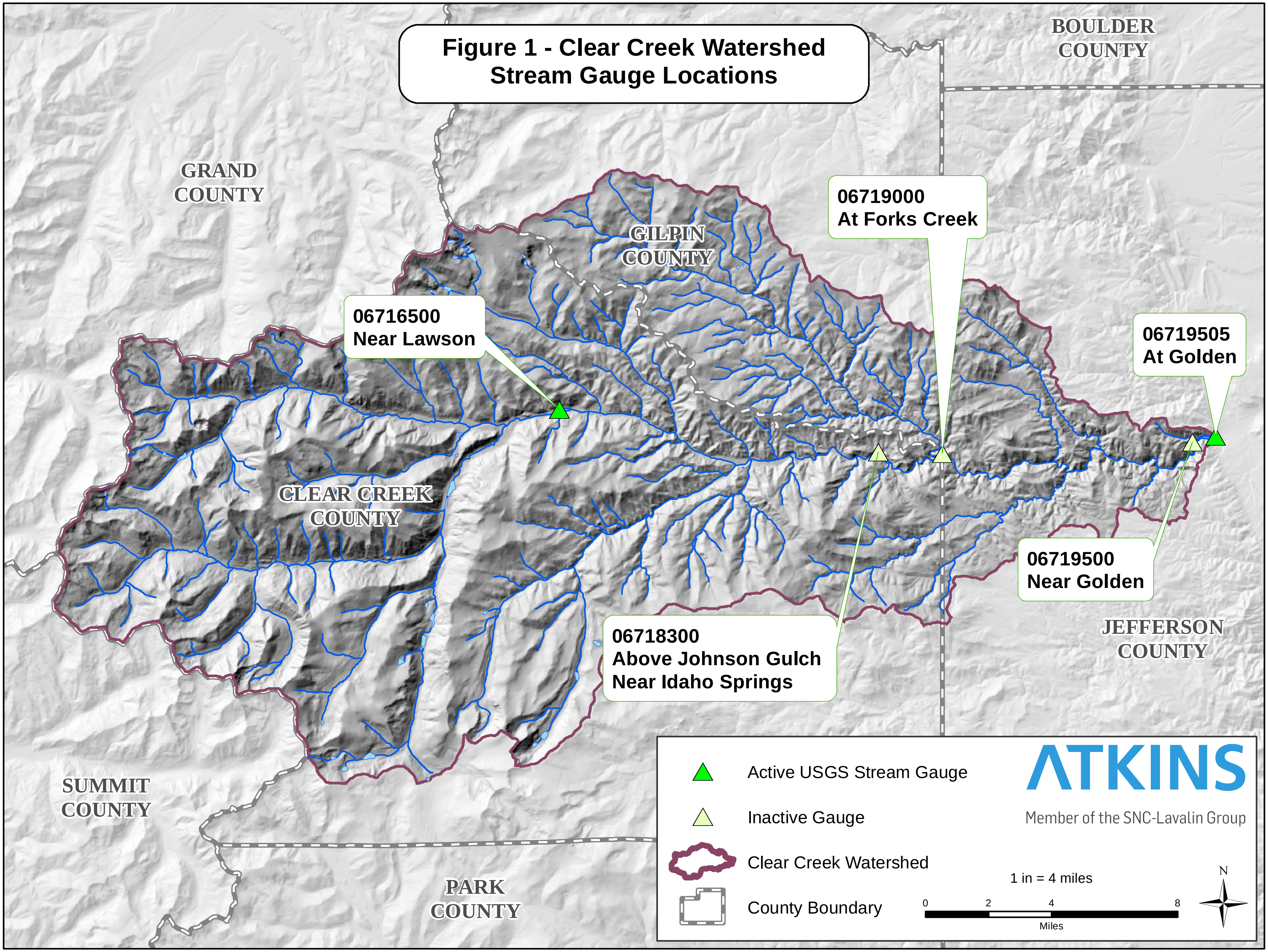

Figure 1 - Clear Creek Watershed Stream Gauge Locations

Table 1. Selected Clear Creek USGS Stream Gauges

USGS ID	Location	Years of Record[1]	No. of Peaks	Reported Area (sq. mi.)	Historic Records
06716500	Near Lawson, CO	1946-1986, 1995-2017+	64	147	
06718300	Above Johnson Gulch	1995-2005	11	267	
06719000	At Forks Creek, CO	1888-1912	15	339	8,700 cfs—Aug. 1, 1888
06719500	Near Golden, CO	1911-1974	64	399	
06719505	At Golden, CO	1975-2017+	43	394	

[1]Provisional peak flows for water year 2018 are available for active gauges (near Lawson and at Golden).

The Floyd Hill project area is between the Lawson gauge and other downstream gauges (Golden, Forks Creek, etc). One gauge, 06718300, above Johnson Gulch and near Idaho Springs, is at an ideal location to the project area. Only 11 years were recorded (1995-2005), which is very small for accurate flood frequency analysis. The peaks do seem well correlated with those from the Lawson gauge, so use of the older gauge with more readings is appropriate in this case, with adjustments discussed later.

The most current methodology for determining peak flow rates was published this year (2018), titled *Guidelines for Determining Flood Flow Frequency*, also known as Bulletin 17C. This is a follow-up and logical progression from the previously published methodology known as Bulletin 17B (1982).

The following benefits can be gleaned from adhering to the guidelines in Bulletin 17C.

Extended years of record—The previous studies (Black & Veatch, 1978; USACE, 1990) used stream data with shorter records. This study used data up to water year 2017. While provisional 2018 rates also are available, they were not used because they may change still upon final approval for publication by the USGS.

Record combination—The gauge at Golden was moved to a different location between water years 1974 and 1975. The USGS-reported contributing drainage area between 06719500 (399 sq. miles) and 06719505 (394 sq. miles) is less than 2 percent different from each other. The measured drainage areas are even closer (less than 1 percent). As such, combining the gauge records allows for a much longer, continuous record of 107 years of historical data.

Paleoflood data—Paleoflood data are those that are not observed directly, but through other means and usually have occurred many years before the start of human record. As reported in the most recent state regression report for Colorado (SIR 2016-5099), investigation into paleoflood data throughout the state can yield improvements to flood frequency analyses and Bulletin 17C is expressly able to use this information. V.R. Baker reported a paleoflood in the location of the Golden gauge of approximately 50,100 cfs (37,600 to 62,600 range of uncertainty) occurring approximately 6,000 years before present. As with the results in SIR 2016-5099, this information was added to the combined Golden gauge record. This paleoflood would register as an approximate “10,000-year” flood.

PILFs and Multiple Grubbs-Beck—Bulletin 17B recognized the possibility that low flows could adversely distort the flood frequency curve and had a test to remove a low "outlier" from the calculations. Bulletin 17C recognizes that low flows may not even be from the same hydrologic mechanism that generates the more important, higher flood flows. As such, routines are used to remove potentially influential low flows (PILFs) from the analysis to achieve a much better fit in the upper portions of the flood frequency curve. The Multiple Grubbs-Beck test identified 17 PILFs for the Lawson gauge (below 818 cfs) and no PILFs for the combined Golden gauge.

Skew—The statistical parameter that is highly influential for the extremely rare flooding event is the skew coefficient. Generally, results from short stream records can be improved by weighting the skew of the stream station with a skew value that is calculated regionally. Current guidance is to check to see if it would be appropriate to weight the skew computed at the stream gauge with a skew computed regionally. The previous 1990 USACE study checked its results by using the methods in Bulletin 17B and weighting the station skew with one that was calculated for the South Platte River Basin (0.18) as part of an older study. Bulletin 17B (Plate I) estimated the regional skew coefficient to be -0.166 in this area. If the regional and station skew differ by more than 0.5, examination of the data is encouraged, especially if the flood-producing characteristics of the watershed differ from those used to develop regional skew values. In this case, the combined Golden gauge had a station skew coefficient (including paleoflood data) of 0.946. The skew for this station is higher due to inclusion of the paleoflood data. Station skew was, therefore, used for Golden. The Lawson gauge had a station skew estimate of -0.19, once PILFs were removed. Station skew was used due to the record length, and to be consistent with the choice on both gauges.

Bayesian Generalized Least Squares (B-GLS)—Recent advancement in statistical computations have found that the older method of computing a regional skew value can exhibit cross-correlations and not estimate the uncertainty with the computed regional skew value. The figure in Plate I of Bulletin 17B was computed with older stream gauges (only up to the mid 1970s) and used older statistical methods. Specifically stated in Bulletin 17C, "the regional skew estimates published in [Bulletin 17B] are not recommended for use in flood frequency studies." While current updated skew estimates are available for many states, Colorado does not yet have updated regional skew estimates computed with B-GLS—thus, another reason to use station skew.

Additional Information

Note also that Clear Creek experienced reported failures of Georgetown Dam in 1952 and 1956. The largest flows at both the Lawson and Golden gauges are a result of these dam failures. These peak flows were removed from the analysis. Bulletin 17C allows for "censored" data and flood thresholds to be entered as part of extended information. A threshold, in this case, is the largest flood that would need to have occurred to register a "reading" at the gauge. In addition, the years 1987 to 1994 do not have recorded peaks due to the Lawson gauge not operating. For these years, the threshold limits were inferred from the largest flows recorded at the Golden gauge during this period. Thus, the largest flow seen at Golden was set as the low threshold at Lawson for these missing years. Table 2 lists the different upper and lower threshold values that were used.

Table 2. Threshold Values for Bulletin 17C Analysis

USGS ID	Location	Years	Lower Threshold (cfs)	Upper Threshold (cfs)	Comment
06716500	Near Lawson, CO	1946-1986, 1995-2017	0	∞	Default values for systematic gauge record
06716500	Near Lawson, CO	1952	2,230	∞	Censored year due to dam failure
06716500	Near Lawson, CO	1956	6,130	∞	Censored year due to dam failure
06716500	Near Lawson, CO	1987-1994	2,300	∞	No gauge readings; low threshold from Golden gauge peak in 1995
06719500 06719505	Golden, CO (combined)	1911-2017	0	∞	Default values for systematic gauge record
06719500	Golden, CO	1952	3,140	∞	Censored year due to dam failure
06719500	Golden, CO	1956	5,250	∞	Censored year due to dam failure
06719500	Golden, CO	6000 Before Present	37,600	∞	Paleoflood from Baker, V.R., 1974, *Paleohydraulic Interpretation of Quaternary Alluvium near Golden, CO*

The results of the flood frequency analysis at both the Lawson gauge (06716500) and the combined Golden gauge (06719500 & 06719505) are shown in Table 3. The 1-percent annual chance peak flow computed at Lawson is 2,008 cfs. The largest recorded flow not a result of a dam failure at this gauge is 2,240 cfs on June 17, 1965. This is the same date that extensive flooding was experienced throughout the Front Range. Exceeding 2,008 cfs once since 1946 seems to be a valid check on the reasonableness of the estimated peak flow. The calculated 1-percent annual chance peak flow at Golden is 7,498 cfs. The highest recorded peak flow at either of the Golden gauges since 1911 was 5,890 cfs on September 9, 1933. While not exceeded in 107 years of record, the inactive stream gauge at Forks Creek (0671900), which was active from 1888-1902 upstream of Golden, recorded a historic peak of 8,700 cfs in August 1888. Again, this seems to add reasonableness to the calculated peak flows using Bulletin 17C.

Table 3. Bulletin 17C Results

USGS ID	Location	Years	Area (sq. mi.)	10-yr (cfs)	25-yr (cfs)	50-yr (cfs)	100-yr (cfs)	500-yr (cfs)
06716500	Near Lawson, CO	1946-1986, 1995-2017	146.6	1,491	1,709	1,862	2,008	2,330
Lower and upper 68% confidence intervals				1,392 1,617	1,577 1,903	1,700 2,134	1,811 2,383	2,031 3,042
06719500 06719505	Golden, CO (combined with paleo)	1911-2017	394	2,992	4,396	5,773	7,498	13,360
Lower and upper 68% confidence intervals				2,644 3,403	3,766 5,084	4,742 6,783	5,849 9,006	9,159 17,290

The project area is just downstream of the Veterans Memorial Tunnels (formerly the Twin Tunnels). According to the USGS StreamStats website, the contributing drainage area from the Clear Creek watershed for the project area is approximately 263 square miles at this location. To transfer the results from a flood frequency analysis at a stream gauge to an ungauged location between two gauges, the following equation was used.

Equation 1

$$logQ_u = logQ_{g1} + \frac{[(logQ_{g2} - logQ_{g1}) * (logA_u - logA_{g1})]}{logA_{g2} - logA_{g1}}$$

Where Q_u = Flow at ungauged location

$Q_{g1,2}$ = Flow at gauge #1 or gauge #2

A_u = Total drainage area at ungauged location

$A_{g1,2}$ = Total drainage area at gauge #1 or gauge #2

Using this equation, area-adjusted peak flow rates can be calculated at intermediate locations between the Lawson and Golden gauges. Table 4 shows the peak flow results using Equation 1 that are recommended for the project area, including the lower and upper 68 percent confidence intervals. Also shown are the peak flows at the same location that were reported in the 2012 Icon Engineering, Inc., study, using extrapolation from other locations upstream that had calculated flows.

Table 4. Area-adjusted Results for Project Area

Location	Area (sq. mi.)	10-yr (cfs)	25-yr (cfs)	50-yr (cfs)	100-yr (cfs)	500-yr (cfs)
Just upstream of the Twin Tunnels (recommended flows)	263.0	2,251	2,987	3,635	4,375	6,542
Lower and upper 68% confidence intervals		2,034 2,510	2,638 3,402	3,118 4,228	3,622 5,230	4,948 8,497
Same location (from Icon 2012 Study)	263.0	2,312	2,769	3,174	3,624	4,889

Conclusion

The methodology described in Bulletin 17C was used to estimate updated peak flow rates for Clear Creek in the area of the Floyd Hill project. The peak flows are reasonable based on the long records at multiple stream gauges and the inclusion of paleoflood information. The at-site peaks then were estimated using an equation to obtain area-weighted values between two stream gauges on the same stream. The recommended 1-percent annual chance flow for the project area is 4,375 cfs, which is higher than previous studies (3,624 cfs from the 2012 Icon study). This is due to using an updated methodology as prescribed by Bulletin 17C and including the paleoflood information near Golden. The higher flows are conservative, but reasonable when looking at the whole flood history of the area. It should also be noted that for the higher flood events (50-yr, 100-yr, 500-yr, etc), the 2012 Icon study results are very close to the lower bound of the 68 percent confidence interval of the Bulletin 17C peak flows. This shows that these updated results are close to the limits of being statistically significant.

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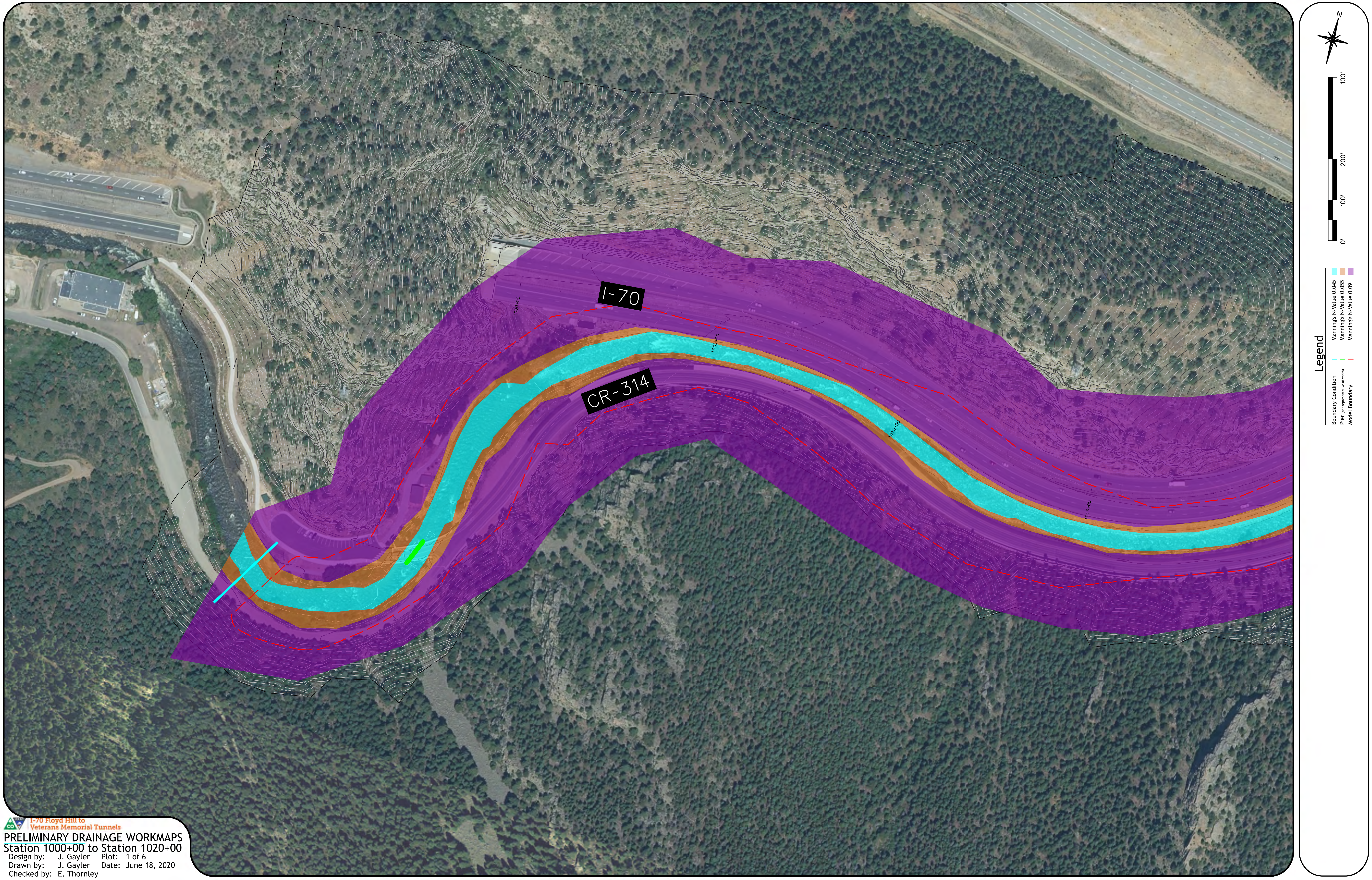
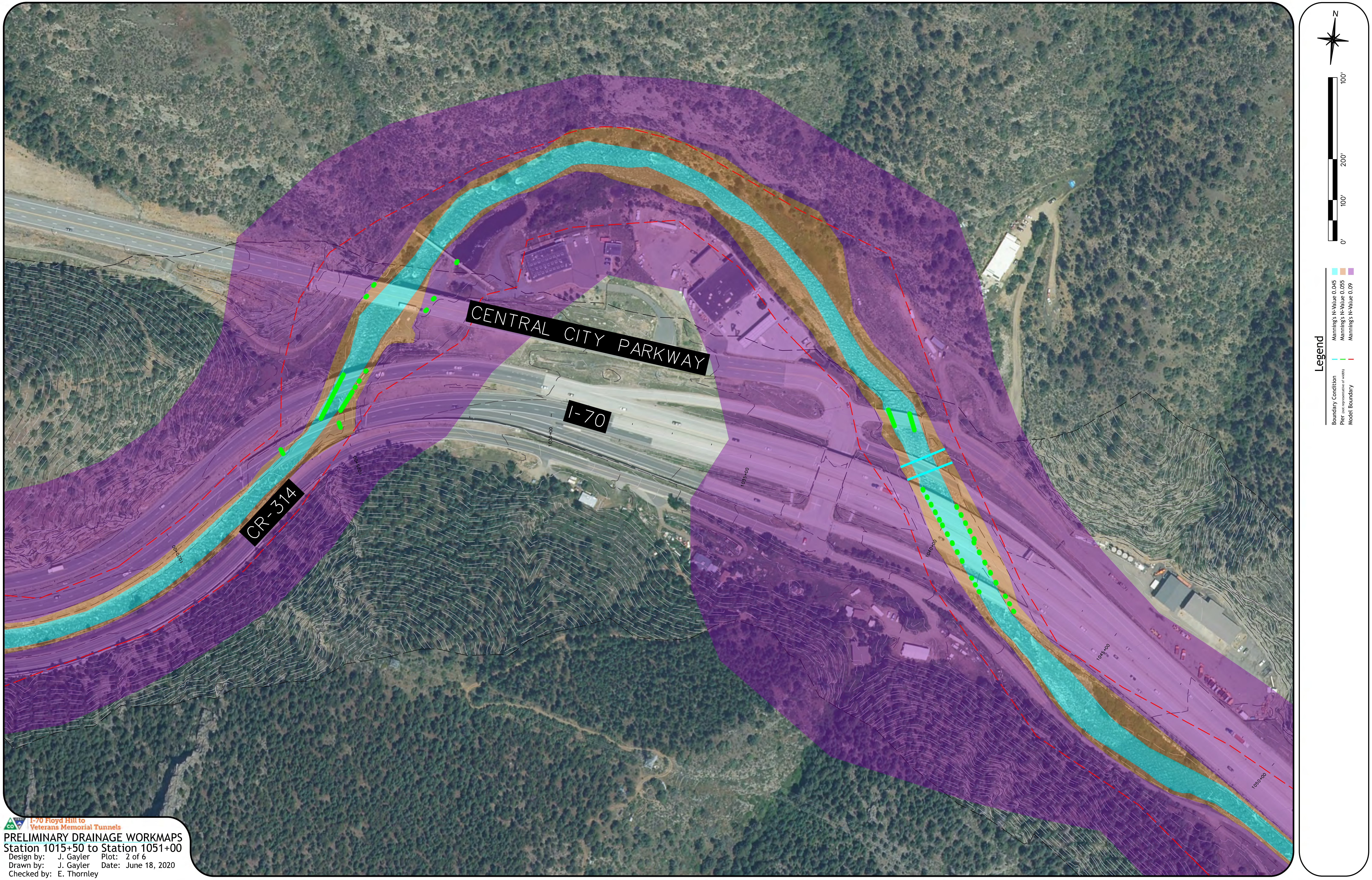
Appendix B. Existing Condition Workmaps



I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS
Station 1000+00 to Station 1020+00

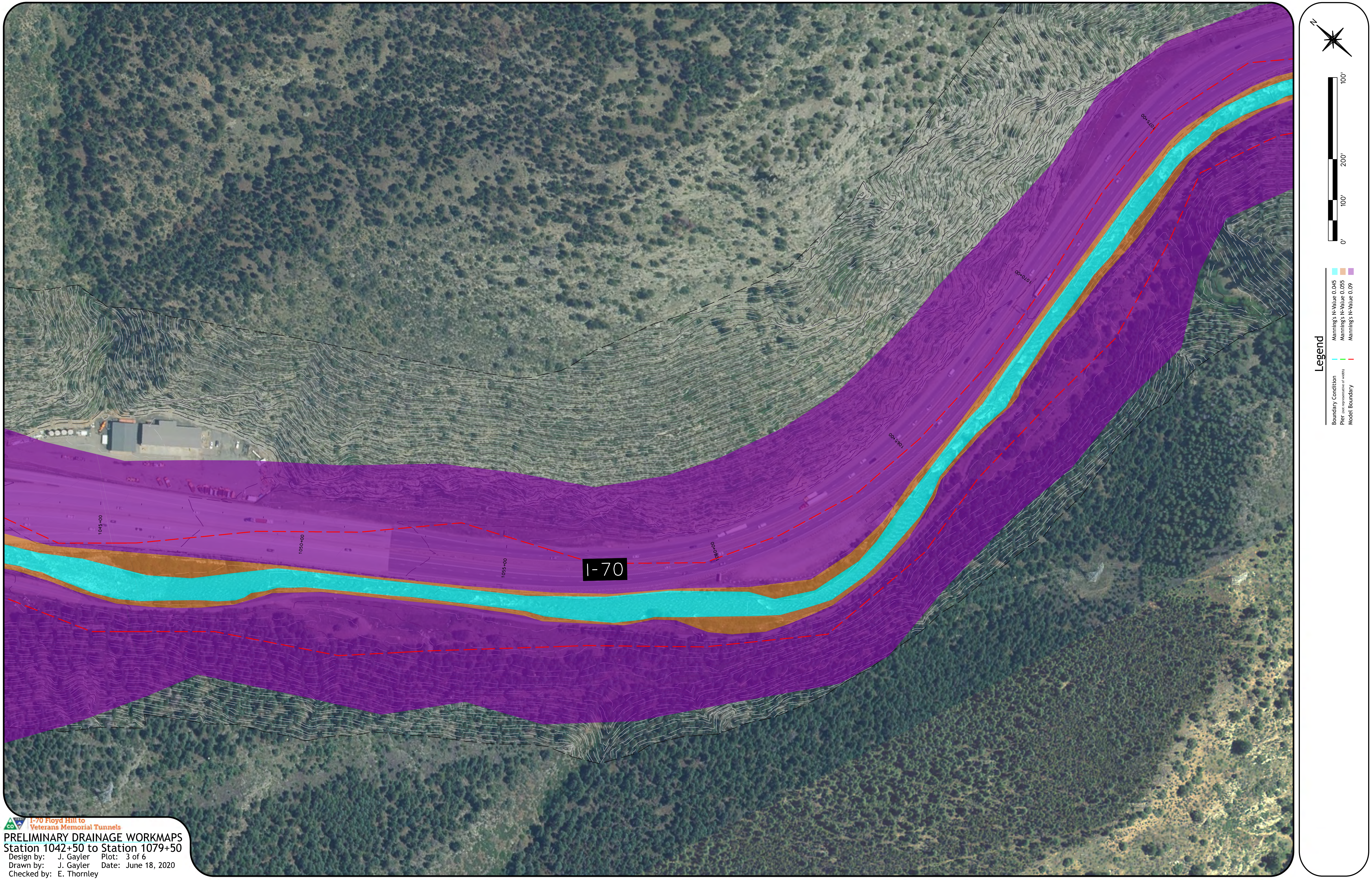
Design by: J. Gayler Plot: 1 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley



I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS
Station 1015+50 to Station 1051+00

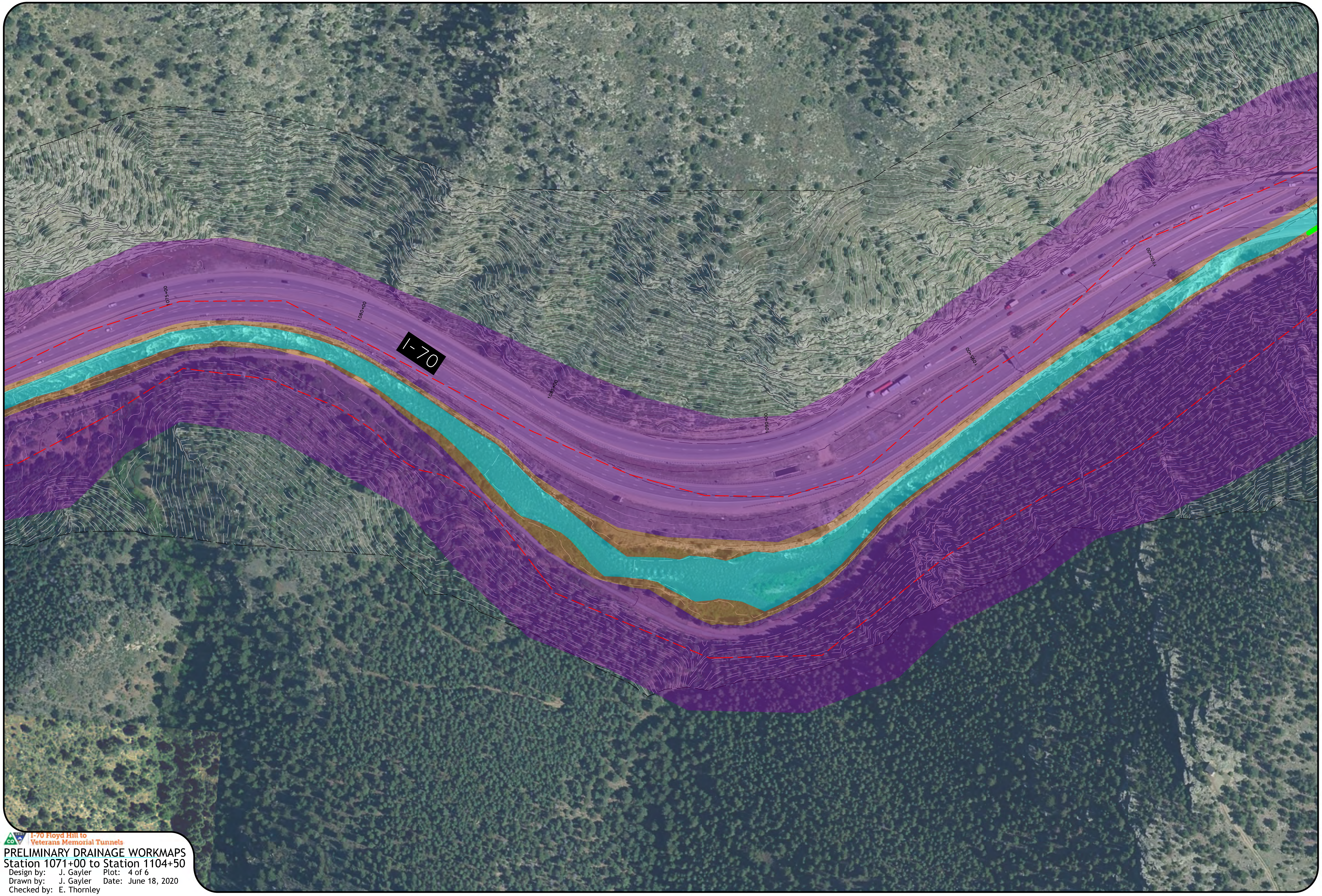
Design by: J. Gayler Plot: 2 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley



I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS
Station 1042+50 to Station 1079+50

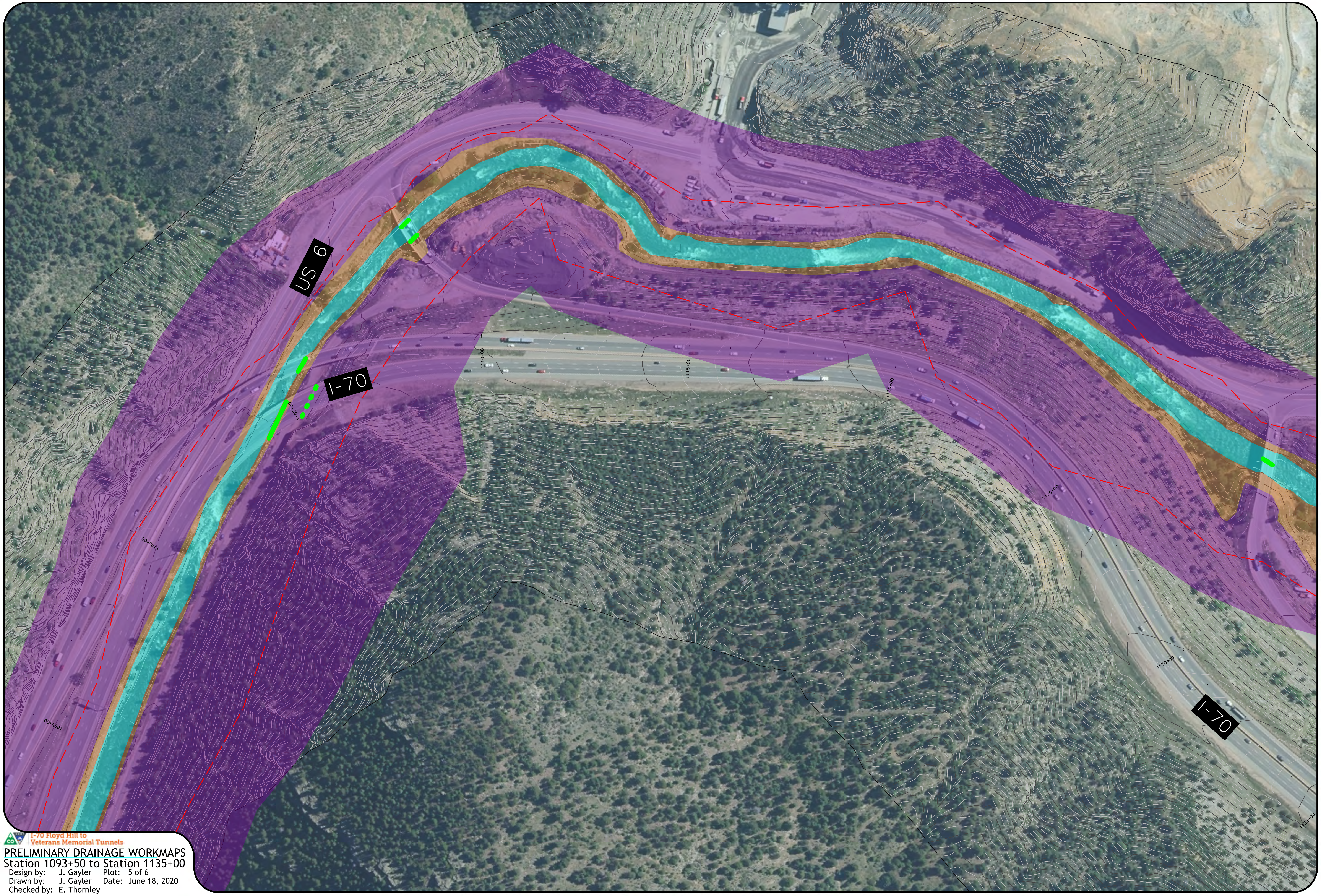
Design by: J. Gayler Plot: 3 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley

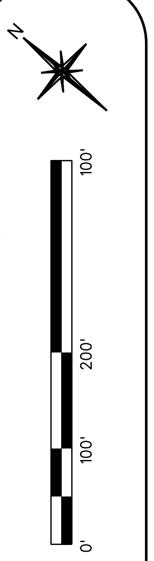


I-70 Floyd Hill to
Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS
Station 1071+00 to Station 1104+50

Design by: J. Gayler Plot: 4 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley





Legend

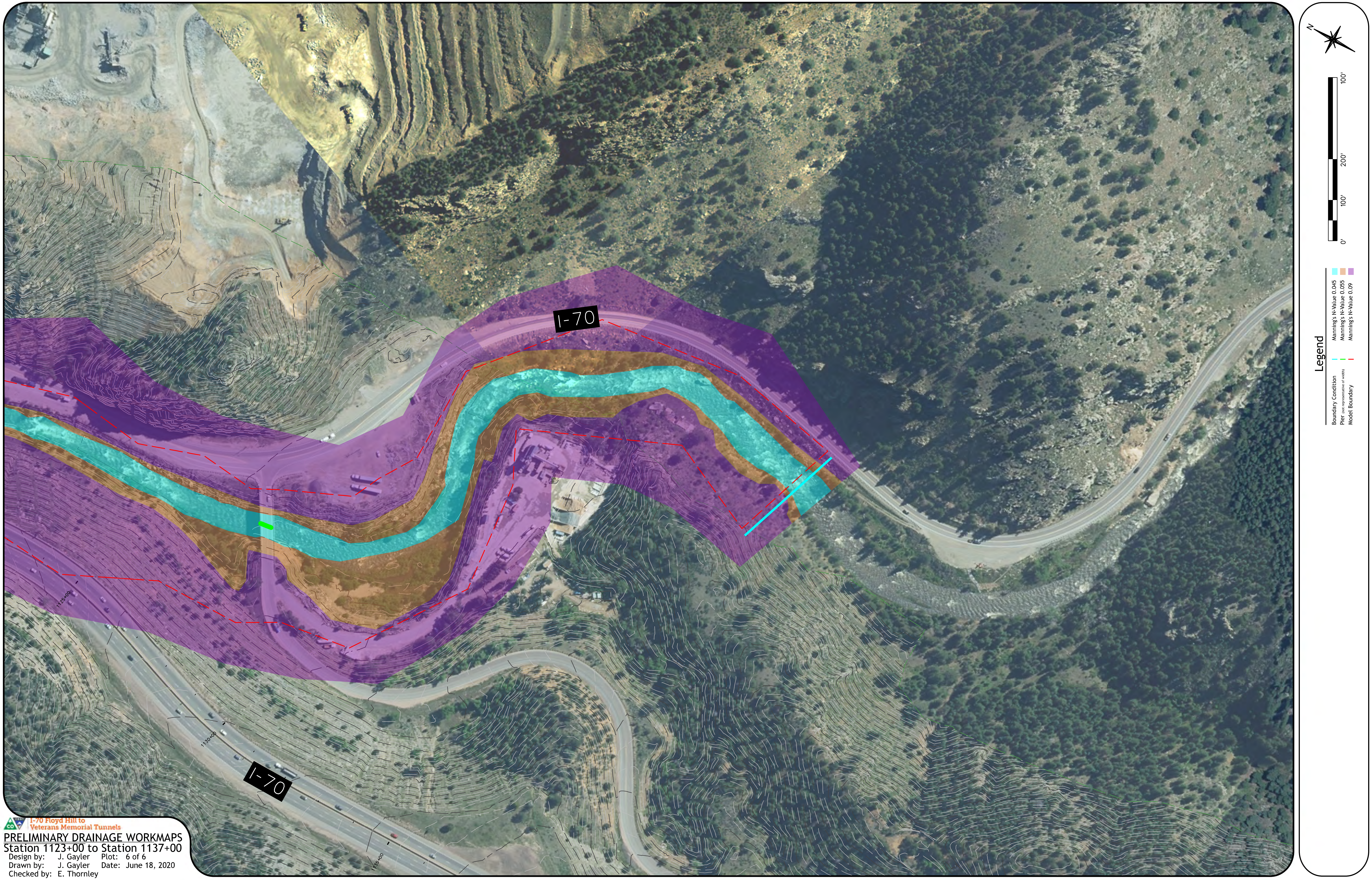
- Boundary Condition (cyan line)
- Pier (not representative of width) (green line)
- Model Boundary (red line)
- Manning's N-Value 0.045
- Manning's N-Value 0.055
- Manning's N-Value 0.09

I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS

Station 1093+50 to Station 1135+00

Design by: J. Gayler Plot: 5 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley



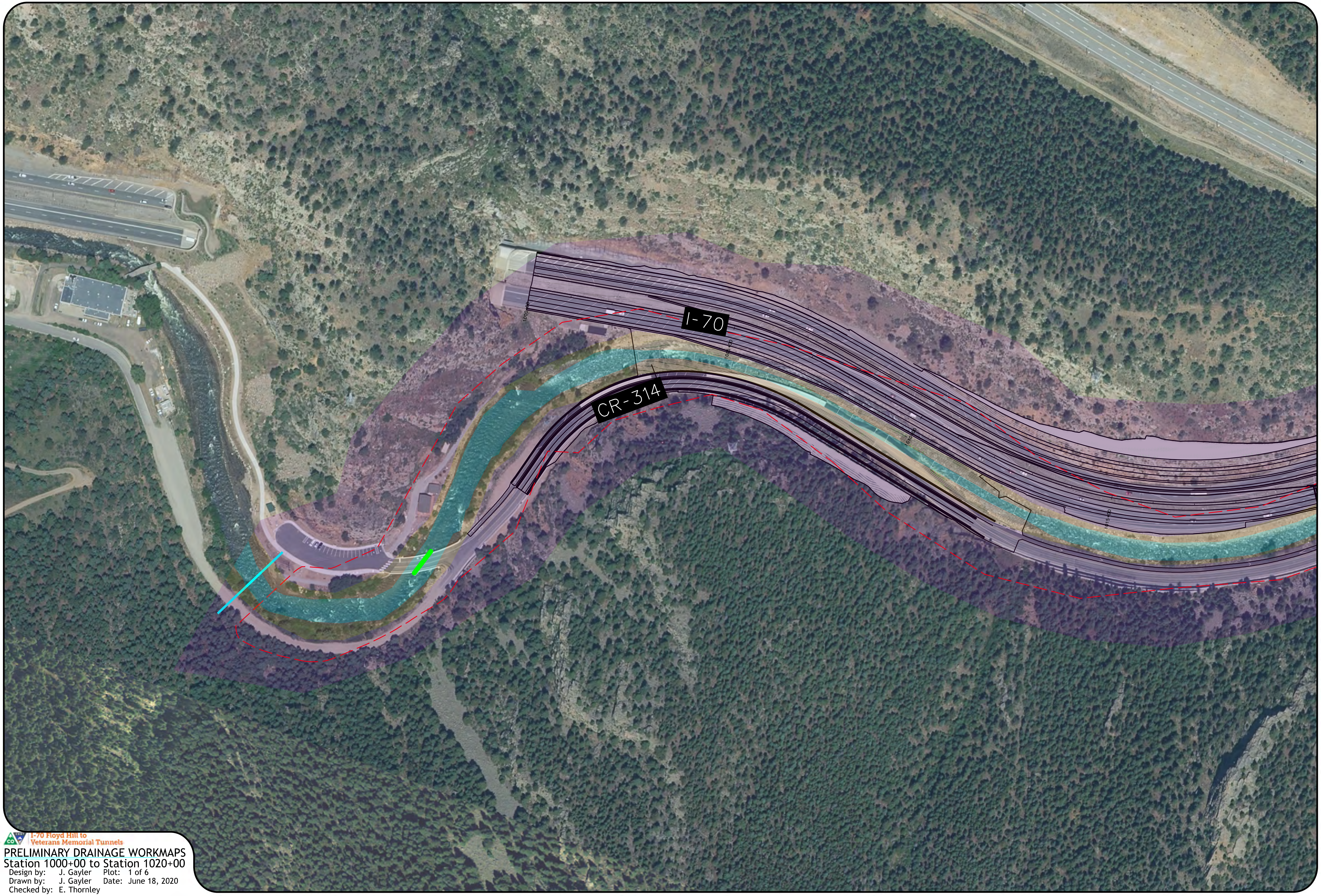
I-70 Floyd Hill to Veterans Memorial Tunnels

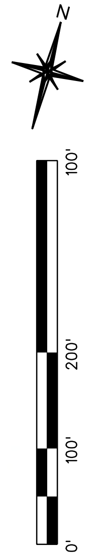
PRELIMINARY DRAINAGE WORKMAPS
Station 1123+00 to Station 1137+00

Design by: J. Gayler Plot: 6 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley

Appendix C. Proposed Condition Workmaps

C.1 Proposed Tunnel Alternative Workmaps





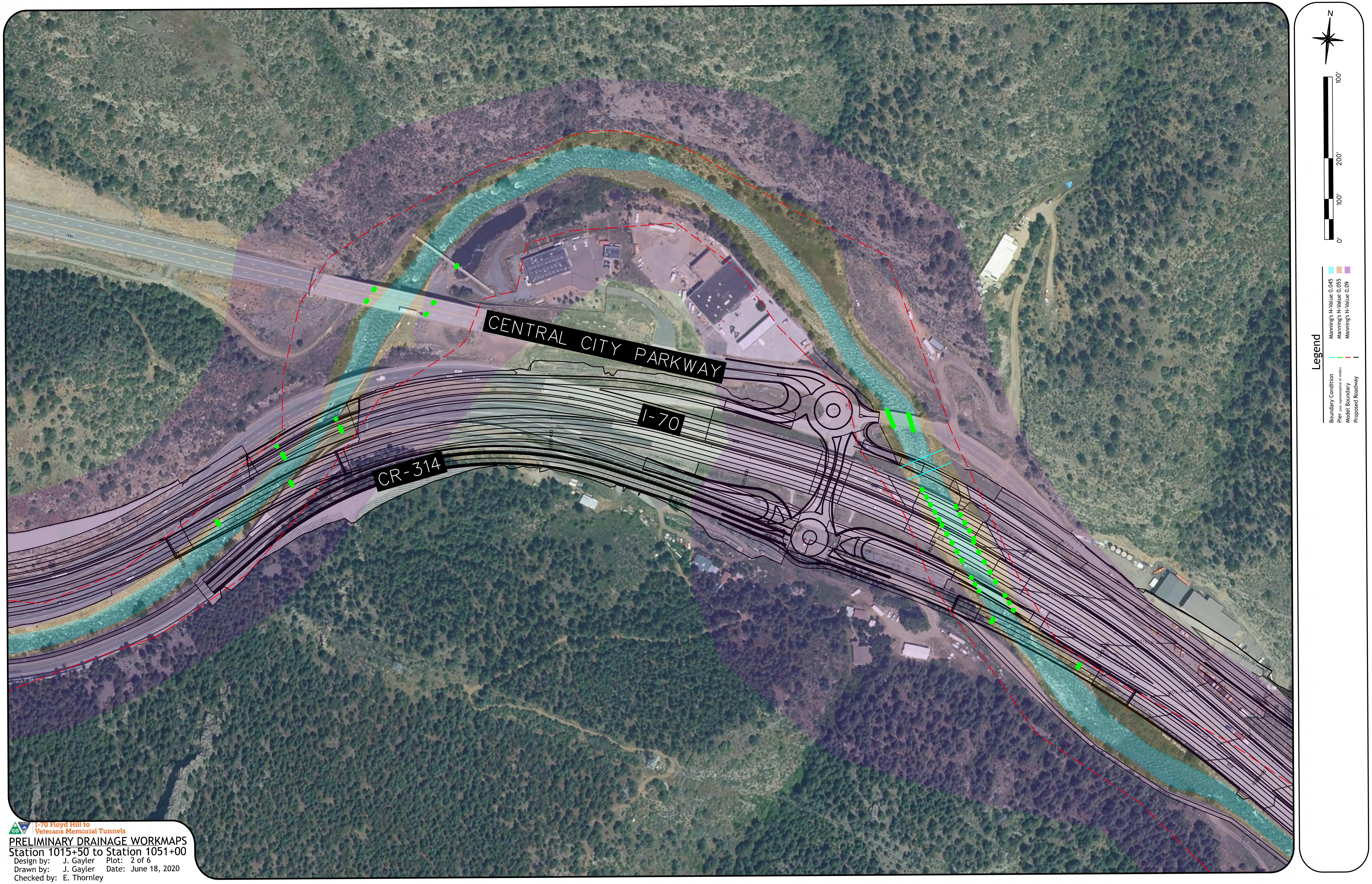
Legend

Boundary Condition	Manning's N-Value 0.045
Pier (not representative of width)	Manning's N-Value 0.055
Model Boundary	Manning's N-Value 0.09
Proposed Roadway	

I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS
Station 1000+00 to Station 1020+00

Design by: J. Gayler Plot: 1 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley

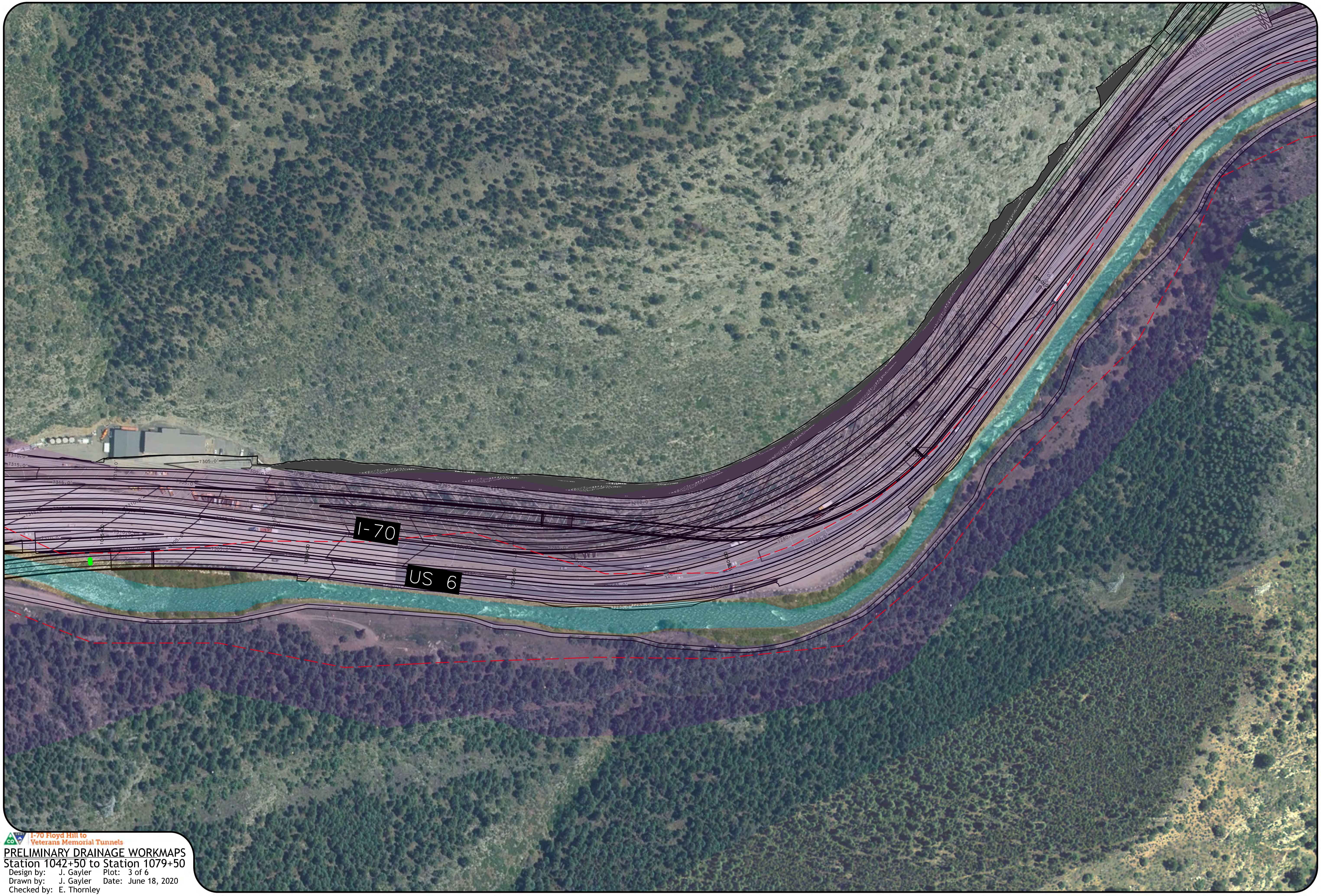


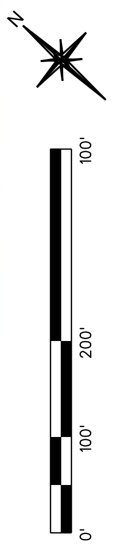
I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS

Station 1015+50 to Station 1051+00

Design by: J. Gayler Plot: 2 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley





Legend

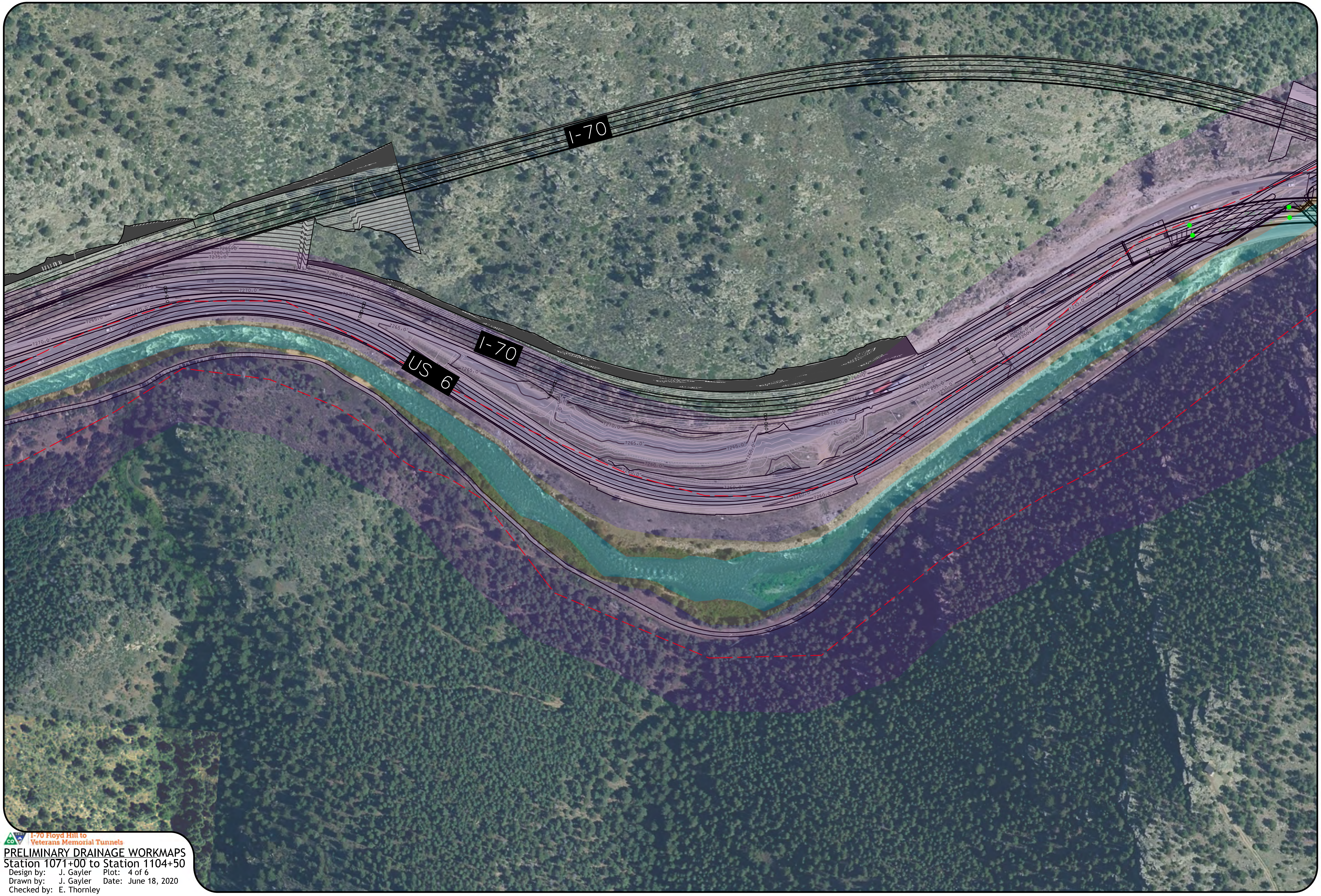
- Boundary Condition
- Pier (not representative of width)
- Model Boundary
- Proposed Roadway
- Manning's N-Value 0.045
- Manning's N-Value 0.055
- Manning's N-Value 0.09

I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS

Station 1042+50 to Station 1079+50

Design by: J. Gayler Plot: 3 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley



N

0' 100' 200' 100'

Legend

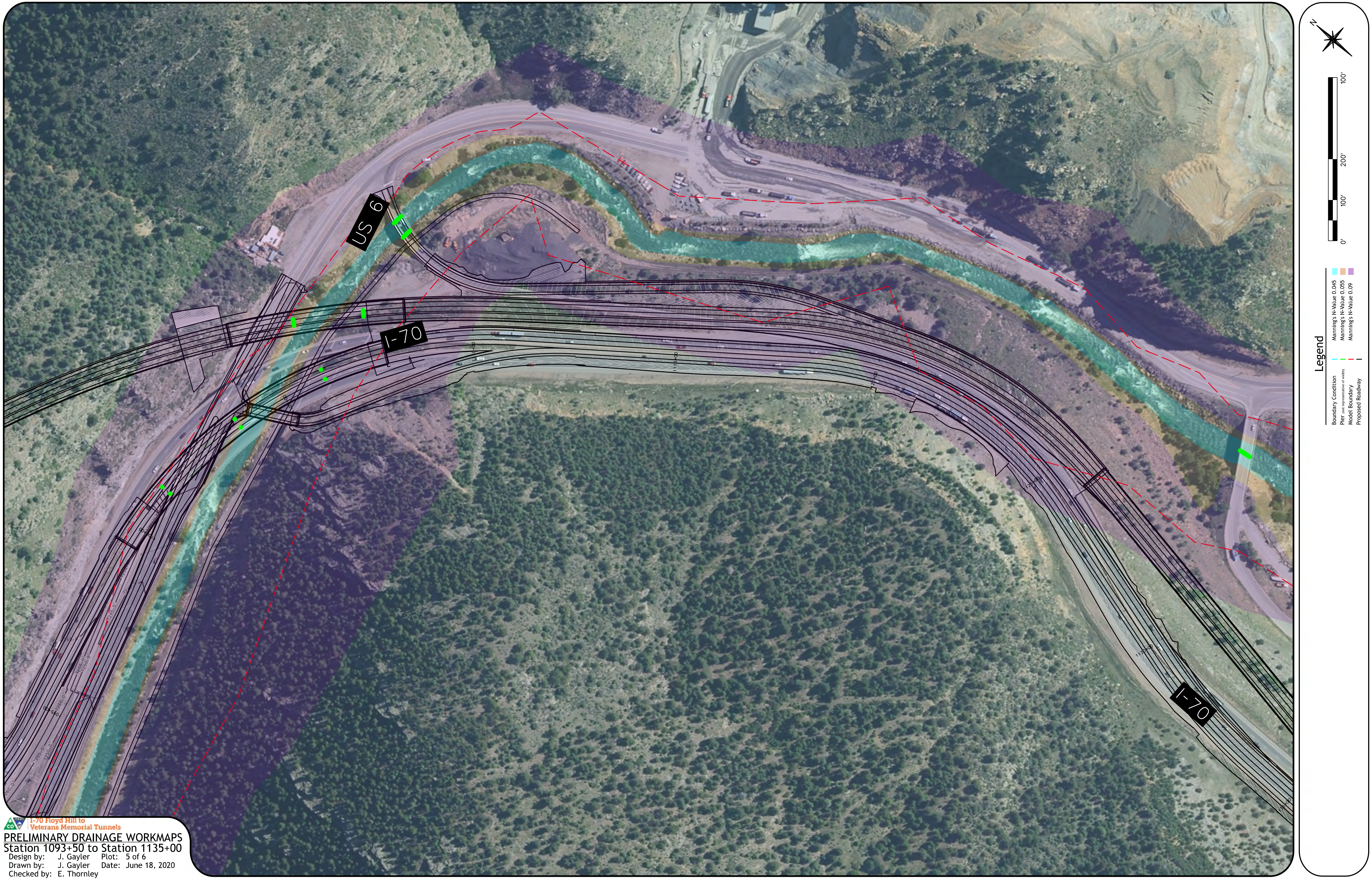
- Boundary Condition
- Pier (not representative of width)
- Model Boundary
- Proposed Roadway
- Manning's N-Value 0.045
- Manning's N-Value 0.055
- Manning's N-Value 0.09

I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS

Station 1071+00 to Station 1104+50

Design by: J. Gayler   Plot: 4 of 6
Drawn by: J. Gayler   Date: June 18, 2020
Checked by: E. Thornley



I-70 Floyd Hill to Veterans Memorial Tunnels

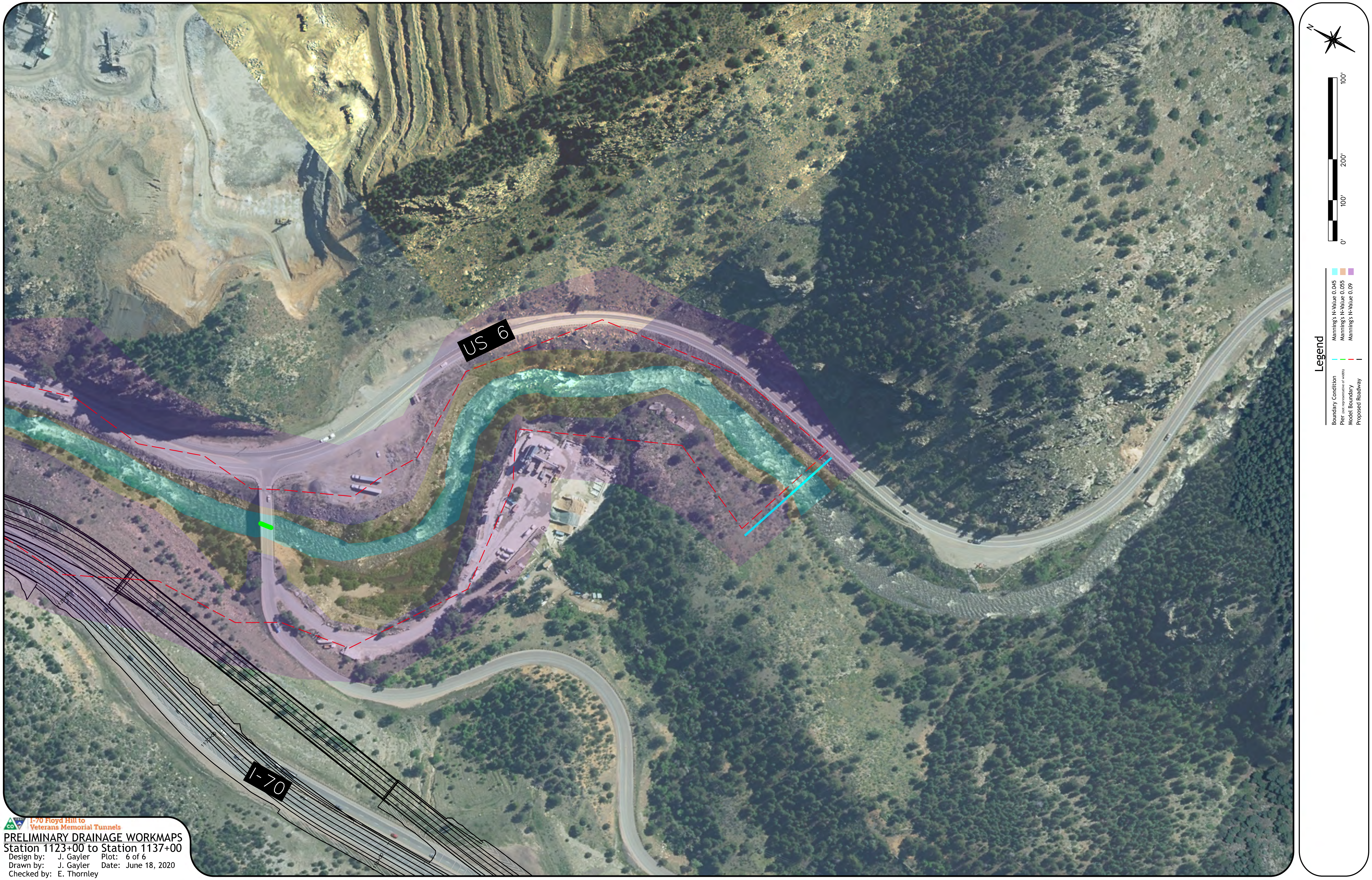
PRELIMINARY DRAINAGE WORKMAPS

Station 1093+50 to Station 1135+00

Design by: J. Gayler Plot: 5 of 6

Drawn by: J. Gayler Date: June 18, 2020

Checked by: E. Thornley

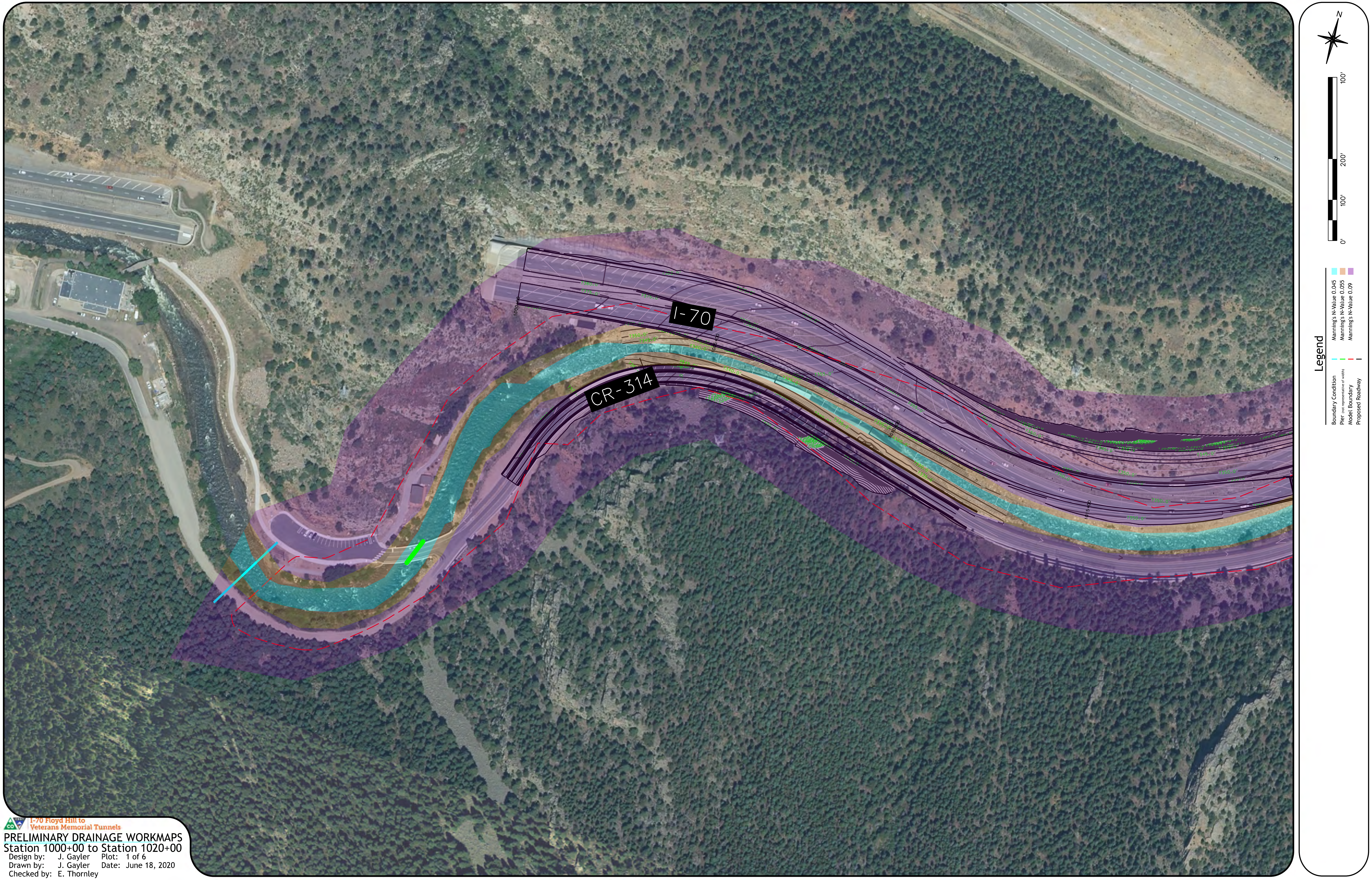


I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS
Station 1123+00 to Station 1137+00

Design by: J. Gayler Plot: 6 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley

C.2 Proposed Canyon Viaduct Alternative Workmaps

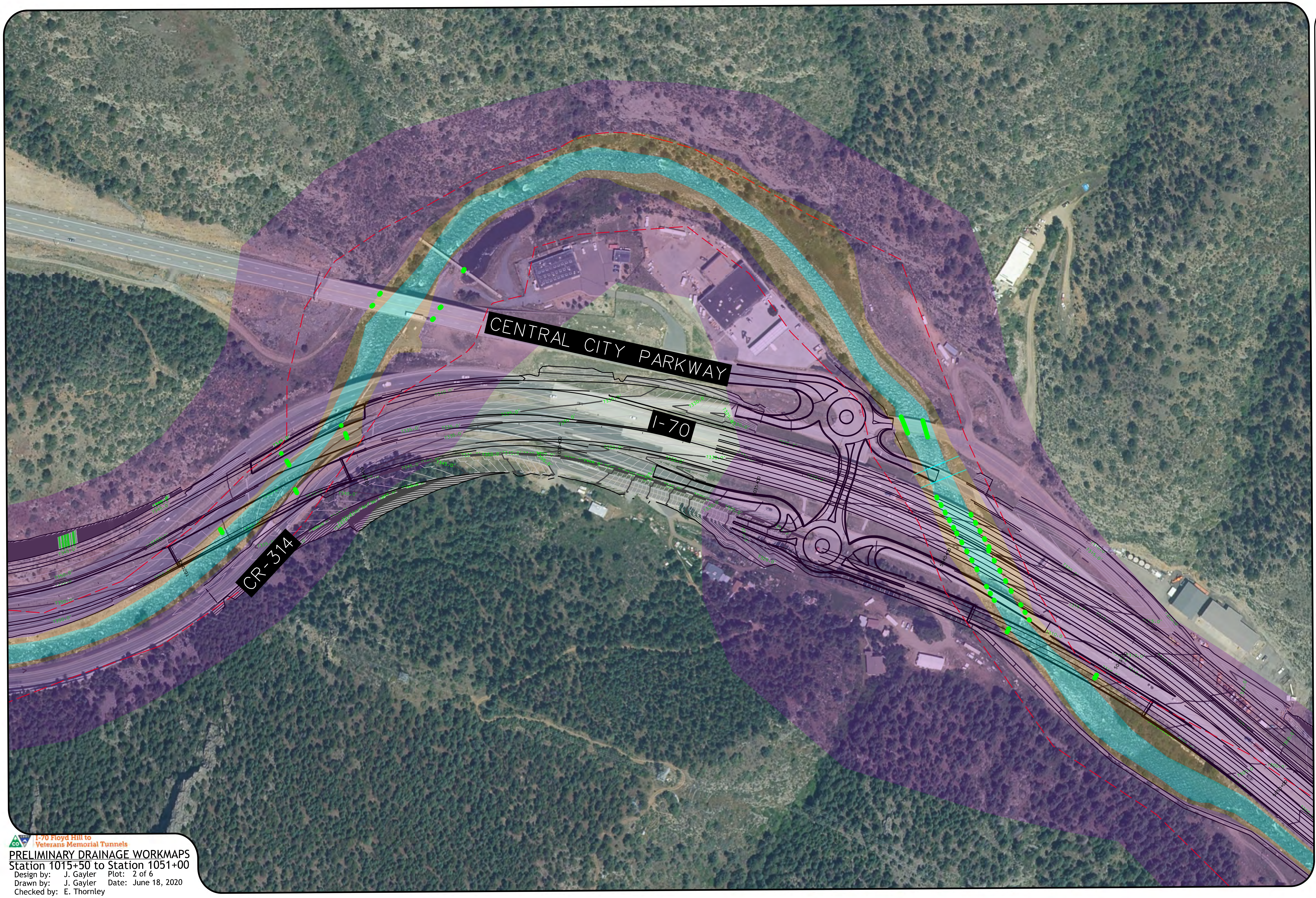


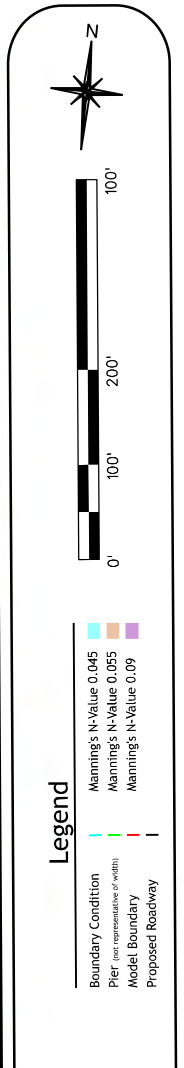
I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS

Station 1000+00 to Station 1020+00

Design by: J. Gayler Plot: 1 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley



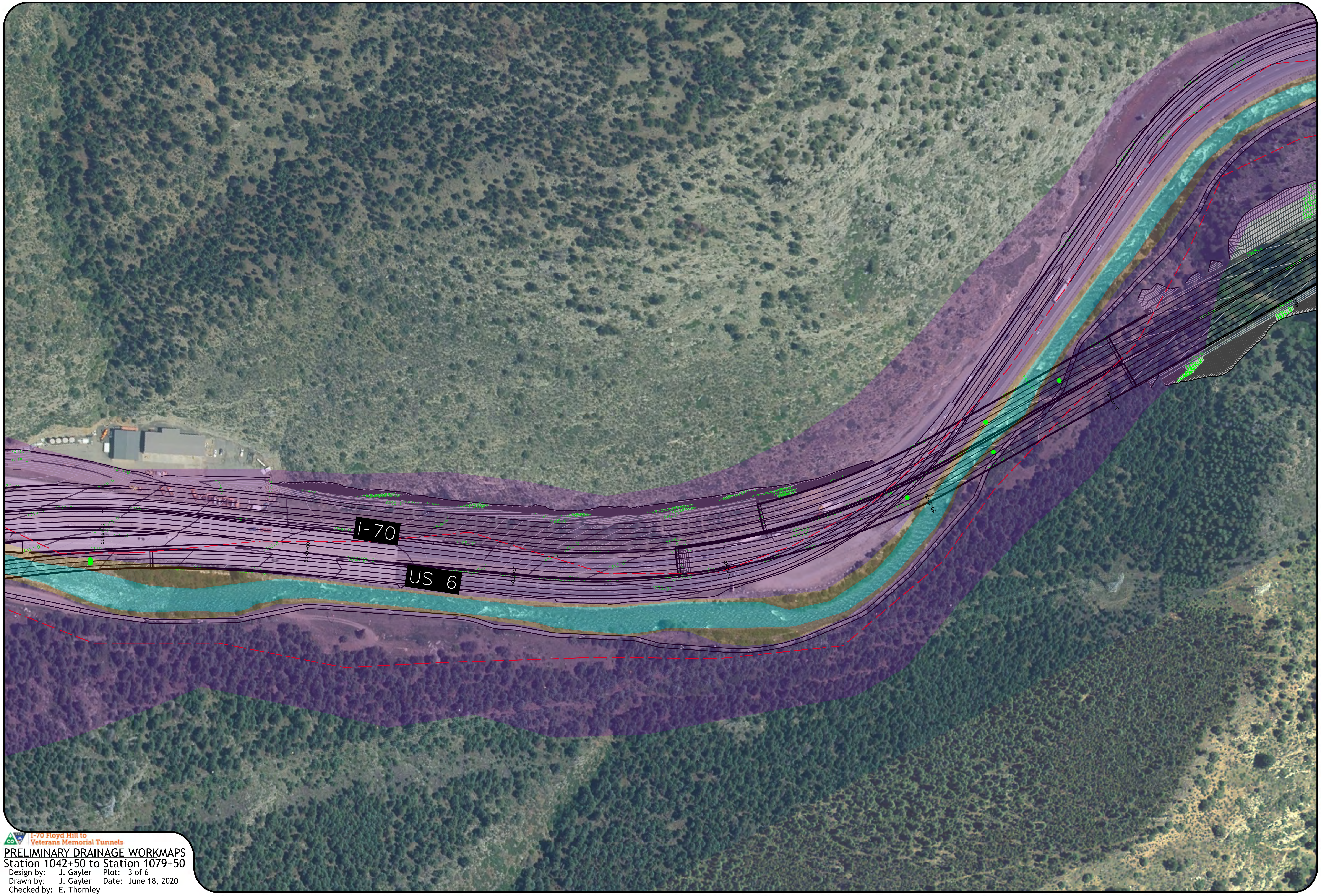


I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS

Station 1015+50 to Station 1051+00

Design by: J. Gayler Plot: 2 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley



0' 100' 200' 100'

Legend

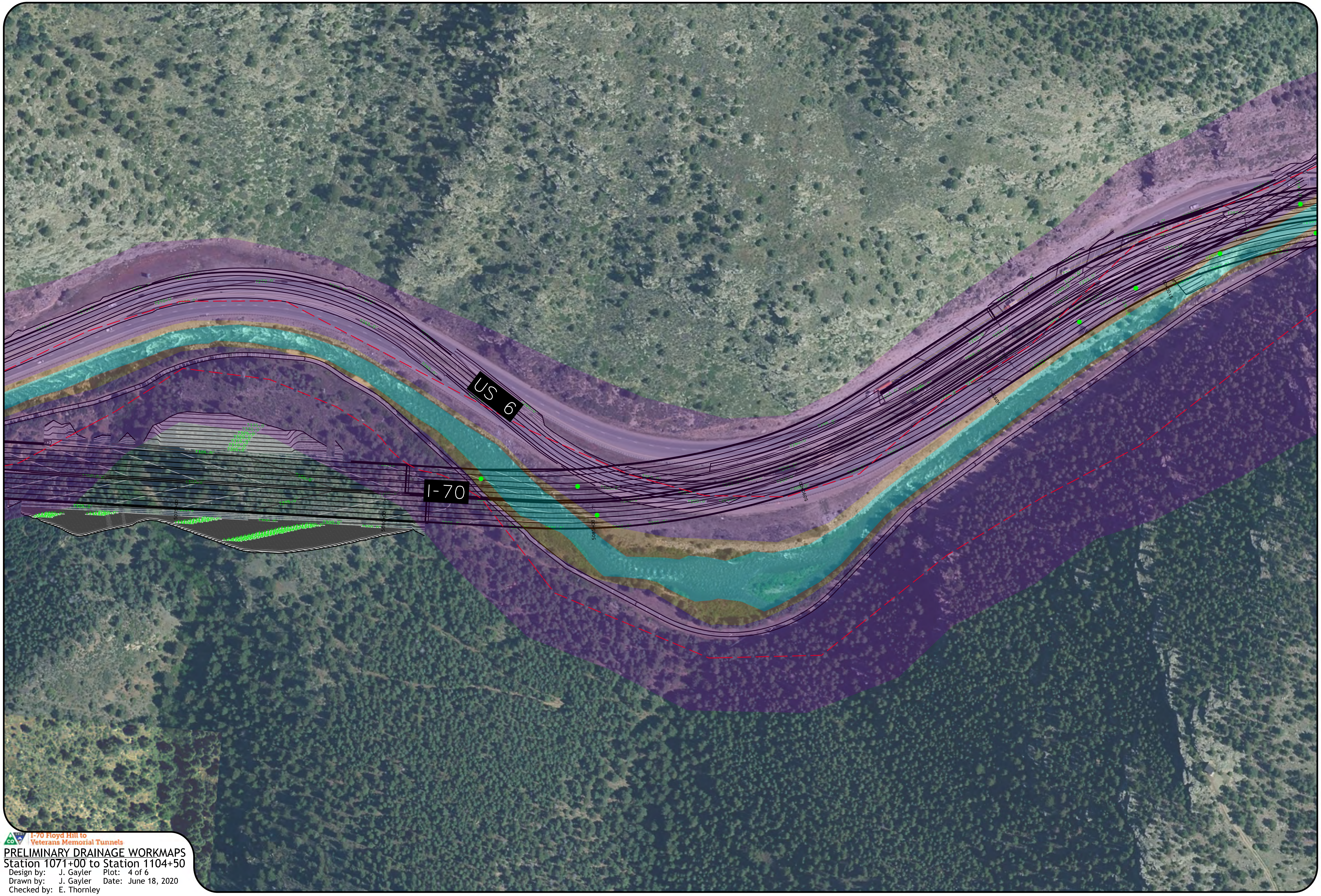
Boundary Condition	Manning's N-Value 0.045
Pier (not representative of width)	Manning's N-Value 0.055
Model Boundary	Manning's N-Value 0.09
Proposed Roadway	

I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS

Station 1042+50 to Station 1079+50

Design by: J. Gayler Plot: 3 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley

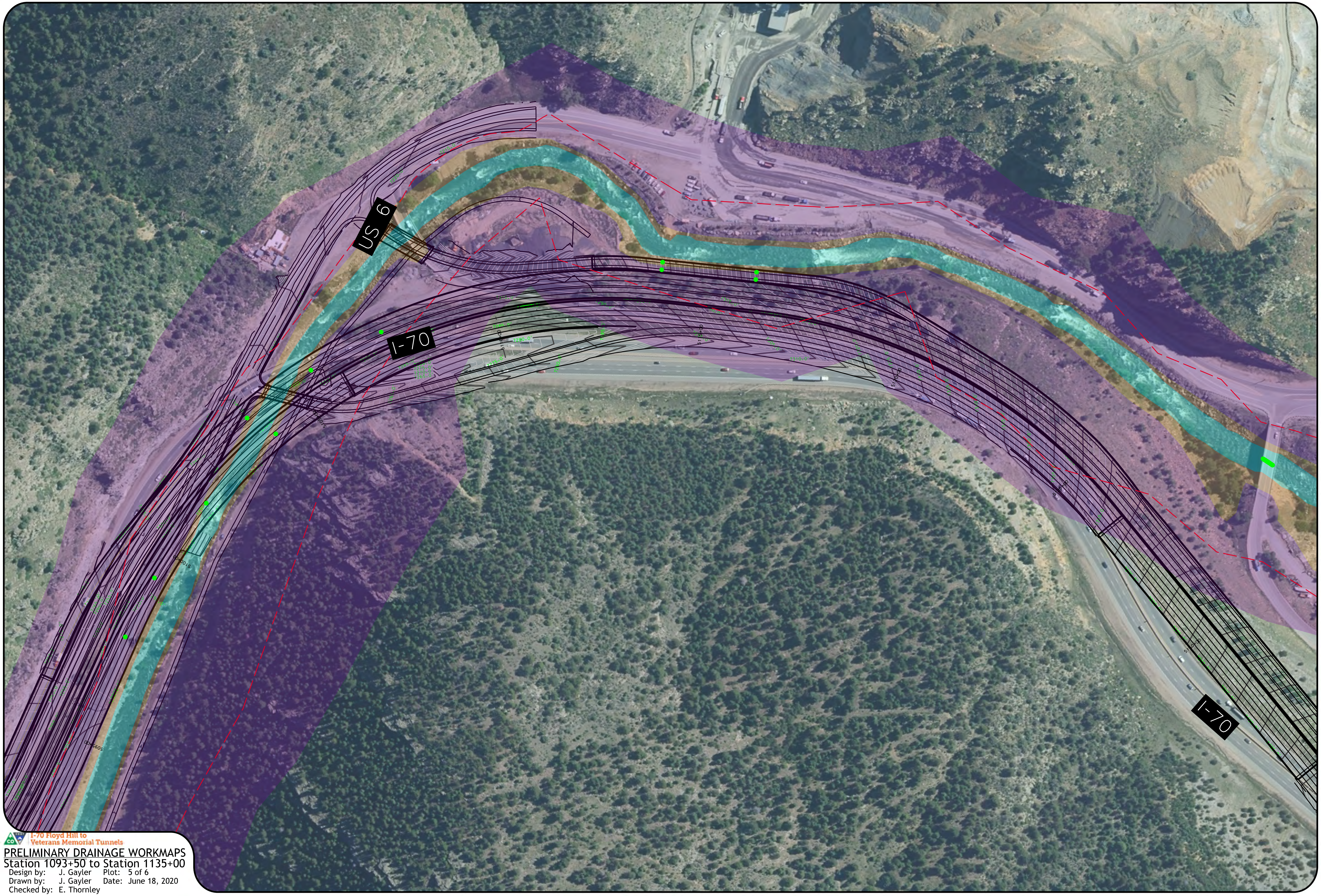


I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS

Station 1071+00 to Station 1104+50

Design by: J. Gayler Plot: 4 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley



Legend

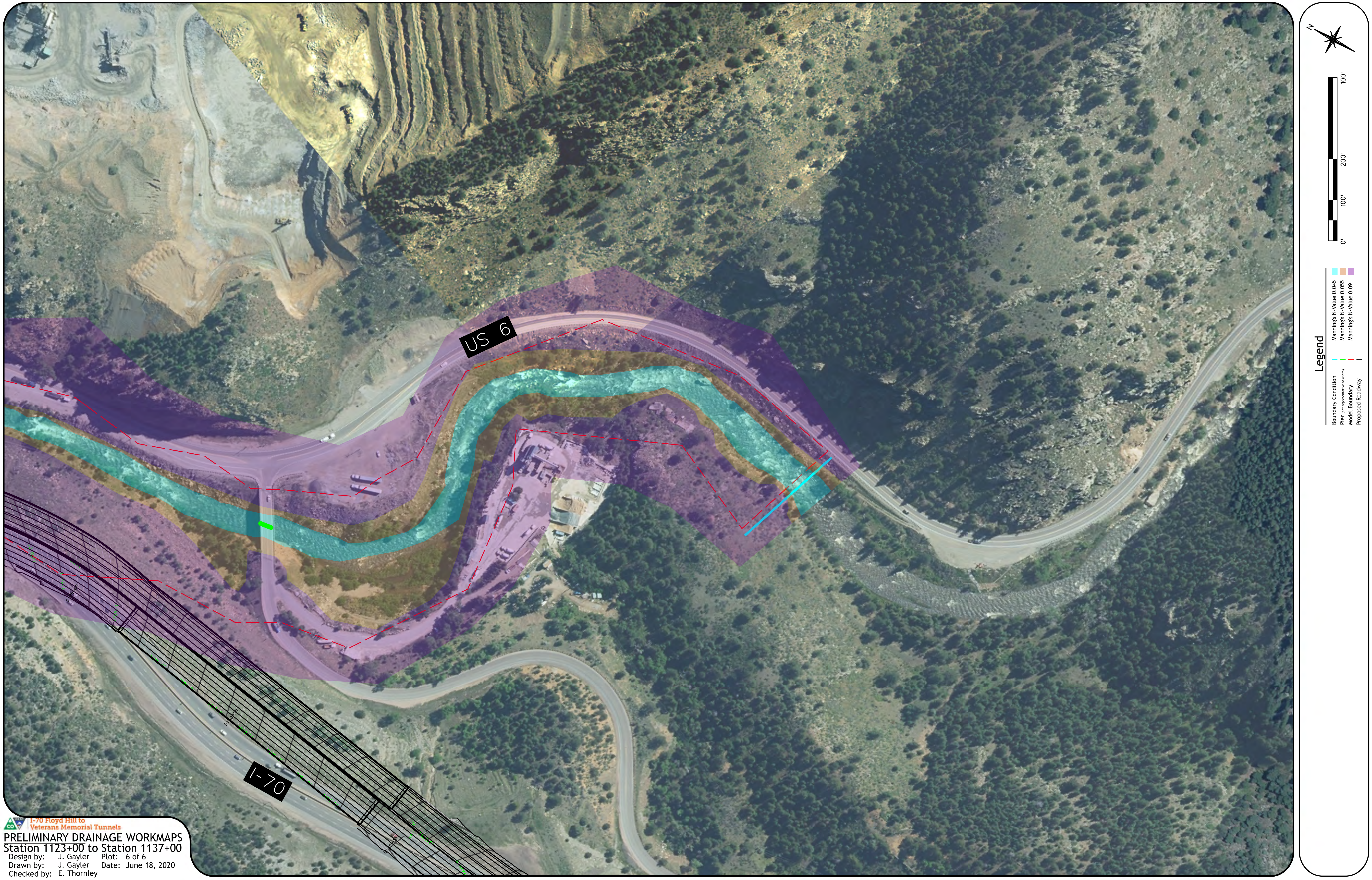
- Boundary Condition
- Pier (not representative of width)
- Model Boundary
- Proposed Roadway
- Manning's N-Value 0.045
- Manning's N-Value 0.055
- Manning's N-Value 0.09

I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS

Station 1093+50 to Station 1135+00

Design by: J. Gayler Plot: 5 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley



I-70 Floyd Hill to Veterans Memorial Tunnels

PRELIMINARY DRAINAGE WORKMAPS

Station 1123+00 to Station 1137+00

Design by: J. Gayler Plot: 6 of 6
Drawn by: J. Gayler Date: June 18, 2020
Checked by: E. Thornley

Appendix D. Electronic Files (Report and Hydraulic Models)