FLOOD HAZARD AREA DELINEATION
CLEAR CREEK

Prepared for:

Mile High Flood District

Jefferson County

Adams County

City and County of Denver

City of Golden

City of Wheat Ridge

City of Arvada

September 2022

Prepared by:

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September 2, 2022

Ms. Brooke Seymour, P.E., CFM
Planning and Floodplain Management Director
Urban Drainage and Flood Control District
2480 W. 26th Avenue, Suite 156B
Denver, Colorado 80211-5304

RE: Clear Creek FHAD Report – Agreement No. 15-11.07

Dear Ms. Seymour,

ICON Engineering, Inc., is pleased to submit this report, *"Flood Hazard Area Delineation – Clear Creek"* from the confluence with the South Platte River to approximately 2,040 feet upstream of U.S. Highway 6. This study identifies flood prone areas along Clear Creek impacting Jefferson County, Adams County, the City and County of Denver, as well as the Cities of Wheat Ridge, Golden, and Arvada.

The floodplain information presented in this study will be provided by the District to assist the impacted communities in floodplain management and regulation along this reach of Clear Creek.

This study provides documentation and drawings identifying the 1%-annual-chance (100-year) and 0.2%-annual-chance (500-year) floodplain limits, as well as the 10%- and 2%-annual-chance flood surface profiles, representative channel cross-sections, and major road crossings. Tabular information is included showing floodplain data and floodway information based on a 0.5-foot maximum increase in energy grade line.

For this project, the hydrology was revised by Wright Water Engineers, Inc. and reviewed by the Federal Emergency Management Agency (FEMA) in a Conditional Letter of Map Revision, or CLOMR (FEMA Case No. 16-08-0917R). The CLOMR was approved by FEMA on December 28, 2016.

We would like to acknowledge, and thank, you, the rest of the District Staff, as well as all of the project stakeholders for their assistance and contribution to this study.

Sincerely,

ICON Engineering, Inc.

Troy W. Carmann, P.E., CFM
Principal

Justen A. Hamann, P.E.
Project Manager

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SECTION 1 – INTRODUCTION

1.1 Authorization

The “Flood Hazard Area Delineation – Clear Creek” study was authorized by the Mile High Flood District (District) under joint sponsorship with Jefferson and Adams County, the City and County of Denver, City of Wheat Ridge, City of Golden, and the City of Arvada under Agreement No. 15-11.07. Notice to proceed for this Agreement was provided by the District on December 8, 2015.

1.2 Purpose and Scope

The intent of this report is to update two previous FHAD studies with new hydrologic information. The first study was completed in December 2005 by Ayres Associates and is titled “Flood Hazard Area Delineation – Clear Creek (Adams County).” The second study is dated April 2007 by ICON Engineering, Inc. and is titled “Flood Hazard Area Delineation – Clear Creek – Jefferson County & City and County of Denver.”

This study supersedes the previous studies and provides an up-to-date analysis of the existing floodplain along Clear Creek so that project stakeholders, and other users, can implement floodplain zoning ordinances, floodplain regulations, and other land-use controls, as needed, to reduce potential damages and adverse development in the floodplain. This report includes information on past flooding events and defines the nature and extent of probable future floods along an 18.2-mile reach of Clear Creek, from the confluence with the South Platte River to approximately 2,040 feet upstream of U.S. Highway 6 in the City of Golden.

The hydrology presented in this report was prepared by Wright Water Engineers, Inc. (WWE) and submitted for review to the Federal Emergency Management Agency (FEMA) as a Conditional Letter of Map Revision (CLOMR). The CLOMR was assigned a FEMA Case Number of 16-08-0917R and approved by FEMA on December 28, 2016. The WWE analysis was modified at the North Overflow to address the various split flow conditions.

The following is a summary of the scope of work for this study:

1. Coordination and Meetings with District and project stakeholders;
2. Field verification of bridge/culvert hydraulic parameters;
3. Calculation of water surface profiles for the 10-, 50-, 100, and 500-year flood events;
4. Delineation of the 100-year floodplain boundary on Flood Hazard Area Maps;
5. Determination of floodways based on encroachment resulting in a maximum increase in the energy grade line of 0.5 foot;
6. Preparation of a report which builds on the information presented in the previous studies and updates.

The floodplain delineation and flood profiles are based on existing floodplain and channel conditions. Flood elevations and the corresponding floodplains are often altered by road and bridge construction, floodplain development, flood control improvements, or natural processes. Prior to the utilization of this report for planning or design purposes, the user is advised to contact the District, or other local jurisdictions, to determine if the information presented in this report has been amended.

1.3 FHAD Process

This FHAD report was discussed at periodic meetings held between the engineer, project sponsors, and various project stakeholders at the District. Meetings with the District and local agencies were held as needed to document best available information and determine the most effective hydraulic modeling approach for given areas. Meetings with specific property owners, generally related to FEMA Letters of Map Revision, were held occasionally through the study period to incorporate and update specific mapping changes. Meetings with intergovernmental agencies and special districts were held to convey information on multi-jurisdictional projects such as the light rail line and other roadway projects. A public meeting was held virtually (due to the COVID-19 precautions in place at the time) in December 2020. Project correspondence is located in Appendix A.

1.4 Mapping & Field Surveys

The United States Geological Survey (USGS) provided the topographic mapping used for this study in the 2014 LiDAR mapping project. The mapping was prepared in accordance with FEMA and District specifications. LiDAR point cloud data was compiled for the project area as a raster grid digital elevation model by ICON Engineering, Inc. One-foot contours were developed by ICON Engineering, Inc. from the DEM across the project area on North American Vertical Datum of 1988 (NAVD88). The contours are depicted on work maps on the State Plane HARN (EPSG 2877) projection.

Project mapping was based on Federal Emergency Management Agency (FEMA) 2013 Post-flood LiDAR mapping completed by the U.S. Army Corps of Engineers with the following base terrain data attributes:

Name: 2013 South Platte River Flood Area 1
Collection Date: Fall 2013 – Spring 2014
Vertical Accuracy: 9.25 cm RMSE
Point Spacing: 0.7 m
Vertical Datum: NAVD88
Horizontal Datum: NAD83

The base terrain data was modified in several locations through the project area. In the course of the study, several locations were noticed along Clear Creek in which the LiDAR topography in the channel and overbanks did not accurately represent existing conditions. The areas consisted of cross sections near bridge crossings, new development in Golden, industrial land use stockpile areas, and other areas with verifiable terrain data were identified. After discussion with the District the decision was that topography from the effective studies could be used to supplement the FEMA LiDAR in these specific areas.

To represent more accurately a smooth thalweg profile along Clear Creek, a template of varying widths and depths was used to represent the channel section below the water surface. In general, the channel template characteristics was determined by comparing LiDAR elevation data with known surveyed elevations along the channel and at bridges, along with estimates of the low flow channel width from aerial photography. This modified the channel geometry in the hydraulic model without any modification to the project DEM.

Through the course of the study, there have been several supplemental surveys on the bridge crossings. As originally scoped, the bridges from both Jefferson County and Adams County FHADs were merged into a single model. This included field verification of the bridges, piers, and armoring conditions to ensure the combined model did not omit obvious changes to the Creek since the early 2000s. Also, in the course of ongoing floodplain management in the City of Arvada, a floodplain permit applicant completed independent survey on several bridges over Clear Creek and identified a vertical elevation discrepancy. Upon further review, it was decided that multiple bridges in the Arvada section of Clear Creek should be surveyed and checked against the elevations from the 2005 and 2007 FHADs.

Bridge deck information for crossings modeled in the 2005 and 2007 FHADs was directly carried forward to this study without modification. Several additional bridges were identified as being new or absent from the 2005 and 2007 FHADs. New bridges were surveyed under a separate contract with the District and included in the current HEC-RAS modeling.

Several on-ramp bridges near I-25 and I-270 were not included in the 2005 FHAD HEC-RAS model since they were significantly elevated above the floodplain elevations. Blocked obstructions have been used at bounding cross sections to represent the reduction in flow area caused by the piers. Previous FHAD bridge survey information was compiled from GEOSURV, Inc. in January 2006. Additional bridge and survey information was obtained by ICON Engineering, Inc. in April 2006, July 2006 and March 2007.

Additional visual survey on key bridges was collected by ICON in 2017 to verify as-built conditions and bridge geometry. The locations are generally within the City of Arvada and Wheat Ridge. More specific location information is provided in the technical appendices.

Additional field survey provided by the City of Arvada in 2016 for 11 specific bridges within the City Limits identified more specific bridge geometry information than originally collected in 2005 and 2006. Private sector survey and flood modeling efforts identified changes in the bridge geometries and led to an updated survey check on the 11 bridges. A 2021 survey in Golden measured the south bank near Ford/Washington. Survey information was incorporated into the latest hydraulic modeling.

1.5 Data Collection

This study started with the data collected from the two previous FHADs for Clear Creek, combining the upstream and downstream studies. Additional data was incorporated based on updated ground conditions and new study information. These data sources are summarized here:

- *Hydrology – Clear Creek, Jefferson and Adams Counties, Colorado*, US Army Corps of Engineers, Omaha District, 1978
- *Flood Hazard Area Delineation Clear Creek Adams County & Jefferson County*, Gingery Associates, Inc., 1979
- *Major Drainageway Planning Clear Creek Phase B*, Wright-McLaughlin Engineers, October 1981
- *Major Drainageway Planning Clear Creek Youngfield Through Golden Phase B Report*, Wright-McLaughlin Engineers, September 1982
- *Major Drainageway Planning Lower Clear Creek Phase B Update*, David J. Love & Associates, Inc., June 1988
- *Flood Hazard Area Delineation Clear Creek (Adams County)*, AYRES Associates, December 2005
- CLOMR, Case #16-08-0917R, Hydrology change for Clear Creek, Wright Water Engineers. February 2016
- CLOMR/LOMR, Case #13-08-0099R, for RTD Gold Line

1.6 Federal and Local Regulations

Flood hazards along Clear Creek have been designated and identified on the Flood Insurance Rate Map (FIRM) and Flood Insurance Study (FIS) for Jefferson County and Incorporated Areas, dated January 15, 2021, the FIS and FIRM for Adams County, dated September 28, 2018, and in the FIS and FIRM for the City and County of Denver, dated September 4, 2020. Community ordinances have adopted the FEMA FIRM and FIS reports to be utilized for the regulation of the floodplain. Please note that the information presented in this report updates the information on the FIS and on the FIRM. Until the information in this report is adopted into the FEMA's effective FIS and FIRM for each community through the Physical Map Revision (PRM) process, the current information shown on FIS and FIRM must still be utilized for regulation of the FEMA flood hazards and for flood insurance applications. However, each community is strongly encouraged to also use this report as a guide for regulating future development in the floodplain until it's adopted into the respective FEMA FIS and FIRMs.

1.7 Acknowledgements

This report was prepared with cooperation from local officials as well as public and private interests. In particular, we would like to acknowledge the assistance received from the District, Jefferson County, City and County of Denver, Adams County, Cities of Golden, Wheat Ridge, and Arvada. Finally, we would also like to express our appreciation for the work product provided by the engineers and consulting firms who had prepared the earlier studies on Clear Creek that have been relied upon for background information. A list of project participant stakeholders is provided in Table 1.

Table 1 - Project Participants and Stakeholders

Organization	Participant Name	Title
Mile High Flood District	Shea Thomas, P.E.	Manager, Master Planning Program
Mile High Flood District	Terri Fead, P.E.	Manager, Floodplain Management Program
Mile High Flood District	Brooke Seymour, P.E., CFM	Engineering Services Manager
Mile High Flood District	Dan Hill, PE	West Watershed, Watershed Manager
Mile High Flood District	Hung Teng Ho, P.E., CFM	Hydraulic Modeler
Jefferson County	Patrick O'Connell	Engineering Geologist
ICON Engineering, Inc.	Troy Carmann, P.E., CFM	Principal
ICON Engineering, Inc.	Craig Jacobson, P.E., CFM	Principal
ICON Engineering, Inc.	Justen Hamann, P.E.	Project Manager
ICON Engineering, Inc.	Ben Smith, P.E.	Project Engineer
ICON Engineering, Inc.	Brian LeDoux, P.E., CFM	Project Manager
ICON Engineering, Inc.	Jacob Marquez	Project Engineer
ICON Engineering, Inc.	John Klier	GIS Specialist
ICON Engineering, Inc.	Amanda Blair	Project Engineer
ICON Engineering, Inc.	Darren Harder	Engineering Technologist
City of Golden	Joe Puhr	City Engineer
City of Golden	Joseph Lammers, P.E., CFM	Civil Engineer
City of Wheat Ridge	Mark Westberg, P.E., CFM	Projects Supervisor
City of Arvada	Andrew Stewart, P.E., CFM	Senior Utilities Engineer/Floodplain Manager
City of and County of Denver	Jeremy Hamer, P.E., CFM	Engineering Supervisor/Floodplain Manager
Adams County	Greg Labrie. P.E., CFM	Senior Engineer

SECTION 2 – STUDY AREA DESCRIPTION

2.1 Project Area

The area included in this study extends from the confluence with the South Platte River in Adams County, at the downstream study limit and the City of Golden in Jefferson County, at the upstream study limit. The drainage basin is displayed in Figure 1. From Golden, Clear Creek flows through private property (Coors Brewing, Inc.) and through the Cities of Wheat Ridge and Arvada, the City and County of Denver, Jefferson County and Adams County. There are several interstate roadway crossings including Interstate-70 (I-70), Interstate-76 (I-76); arterial roadway crossings, including Kipling Street, and Wadsworth Boulevard, and Federal Boulevard; and several other collector and local roads located within the study reach. During the course of this study, many small-scale changes took place within the watershed but there were no large-scale changes affecting surface drainage at the watershed level.

Clear Creek is a left bank tributary to the South Platte River. The source of water for Clear Creek begins high in the Rocky Mountains, west of Denver and generally flows in an easterly direction from the Continental Divide towards the Denver Metropolitan Area. Prior to entering the Denver Metropolitan Area, Clear Creek exits Clear Creek Canyon and passes through the high plains around Golden. The drainage area at the Golden gage near the bluff line is approximately 400 square miles. From Golden, Clear Creek flows in a northeasterly direction, through the Denver Metropolitan Area to its confluence with the South Platte River, near the Derby neighborhood. At the Derby gage, located approximately 0.6 miles upstream from the mouth, Clear Creek has a drainage area of approximately 570 square miles. Elevations within the Clear Creek basin range from approximately 5,100 feet above mean sea level at the mouth to over 14,000 feet above mean sea level in the Rocky Mountains. The study area map for Clear Creek is shown in Figure 2.

The channel is well defined and consists of a gravelly bottom with mature vegetation along the channel banks. Shallow bedrock exists in several locations along Clear Creek between Sheridan Boulevard and the City of Golden. Development adjacent to the creek primarily consists of municipal, commercial, and residential areas.

NRCS soils information is available through the web portal. https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm The watershed shape is polygonal with long axis from west to east, short axis north to south. Long axis is approximately 8 times the length of the short axis of the watershed. Clear Creek has an average slope of 0.7%.

2.2 Land Use

The land use for the study reach has generally reached a fully developed condition. Due to this and the previous hydrology CLOMR by WWE, the existing and future land use conditions were not evaluated/compared as they would be in a typical FHAD study. Because of this, the typical table applying impervious values based on land use types is not valid here either.

From the South Platte River to the City of Golden, land use adjacent to Clear Creek is predominately residential with areas of municipal and commercial development scattered throughout the basin. There are many major arterial streets and highways that extend adjacent to and across the Clear Creek drainageway.

The study reach is comprised of a mix of developed and undeveloped land. Although much of the floodplain is devoted to open space and parks, residential and commercial areas exist along the creek. Additionally, large lakes and water storage ponds exist adjacent to Clear Creek and various water supply and agricultural ditches draw from Clear Creek. For over 150 years, the Coors Brewing Company has owned and maintained a significant portion of property adjacent to the channel between I-70, near Youngfield Street, and Golden. Many other, smaller parcels within the Clear Creek floodplain are legacy properties with a high likelihood for redevelopment.

Current land use maps are available from participating communities.

2.3 Reach Description

Clear Creek was divided into several smaller reaches, along the overall length of this study in order to provide descriptions and detail of the floodplain characteristics and flooding problem areas. Reach locations and limits are shown in Figure 3.

- ***Reach 1: Confluence with South Platte River to York Street -*** The flooding along the lower part of Clear Creek in Adams County from the South Platte River to York Street is primarily confined to lowlands and gravel pits. No residential areas are at risk in this reach. Commercial redevelopment and gravel mining operations are present in this reach. Past improvements to regional recreational trails, the Peaks to Plains trail along Clear Creek is a prime example, and open space bring public uses into the floodplain.

- ***Reach 2: York Street to Interstate 25 -*** Upstream of York Street, the commercial and industrial land use (auto auction parking lot) dominates the right overbank. The left overbank continues the open space and recreational trail uses. Past work on the interchange connecting I-270 to I-76 is elevated in several locations. The extension of I-270 added a two-bridge overpass crossing Clear Creek and except for the support piers, the bridge decks are well above the 100-year flood elevation in this area.

  From I-270 to Washington Street, the I-76 embankment on the south side of the creek contains the floodplain, and the north side abuts Colorado Highway 224 (E. 70th Ave). At Washington Street, the commercial and industrial land uses on the north side of the creek continue along 70th, but there is also a single residential parcel within the south bank of the channel. Outfalls and ponds are also included in the south overbank.

  Between Washington Street and I-25, there are two ramps with bridges that cross Clear Creek well above the 100-year floodplain. There are three small CDOT drop structures in the vicinity of I-25. These structures were incorporated into the hydraulic model using field-surveyed data for each structure.

- ***Reach 3: Interstate 25 to Federal Boulevard –*** the open space adjacent to the channel widens in this area, but overbank and floodplain areas remain multi-use. Recreation, open space, commercial, and residential land uses are in and adjacent to the creek corridor. Residential redevelopment in the last five years on the north overbank has followed the extension of light rail along Little Dry Creek. Mining and material handling operations associated with Martin Marietta and Brannan Sand and Gravel exist within this reach.

  Just upstream of the Regional Transportation District (RTD) B Line and the Burlington Northern and Santa Fe (BNSF) Railroad is the mouth of Little Dry Creek. Little Dry Creek is a notable tributary for recreational and multi-use connections. Little Dry Creek also has notable contributions to the base and peak flows in Clear Creek.

- ***Reach 4: Federal Boulevard to Sheridan Boulevard --*** Upstream of Federal, this reach includes park and open space property on the north bank. Upstream of I-76 the channel is more constrained. The south overflow is an overflow area on the south side of Clear Creek, immediately west of Sheridan Boulevard. The south overflow spills back to the main Clear Creek channel just downstream of the I-76 crossing. Approaching Sheridan, the north overflow spills north of I-76 and has significant modeling to address complex hydraulic conditions. The north overflow is the result of Clear Creek splitting into two separate flow paths. Clear Creek splits approximately 370 feet upstream of Sheridan Boulevard. The North overflow rejoins the main channel just before the Union Pacific (UP) Railroad and the RTD Gold (G) Line just upstream of Federal Boulevard.

- ***Reach 5: Upstream of Sheridan Boulevard to Wadsworth Boulevard –*** This reach is located within the City and County of Denver and the Cities of Wheat Ridge and Arvada. The reach contains approximately 2.0 miles of drainageway. Included in this reach are crossings with I-76, 52nd Avenue, Marshall Street, I-70, and Wadsworth Boulevard. The channel is well defined with abundant vegetation and an average channel slope around 0.5%. Isolated areas of channel degradation and scour exist. Bedrock has also been observed within the channel bed in several areas. The channel corridor includes parks, trails, open space areas, and areas of residential and commercial development. Additionally, Ralston Creek confluences into Clear Creek just upstream of Sheridan Boulevard.

- ***Reach 6: Wadsworth Boulevard to Kipling Street*** - This reach is located within the City of Wheat Ridge and covers approximately 1.9 miles of drainageway. Included within this reach are crossings with 44th Avenue, Kipling Street, and several pedestrian bridges. The development areas along this reach are predominately residential with areas for parks, trails, and open space. The residential areas encroach significantly into the 100-year Clear Creek floodplain. The channel is abundant with vegetation, and bedrock has been observed within the channel bed at several locations. Lena Gulch confluences with Clear Creek just downstream of Kipling Street. The channel invert for Lena Gulch is lower than Clear Creek and therefore Lena Gulch does not drain well at its downstream end.

- ***Reach 7: Kipling Street to Interstate-70 -*** This reach is located within the City of Wheat Ridge and covers approximately 1.9 miles of drainageway. Included within this reach are crossings with Youngfield Street, I-70, and several pedestrian bridges. Development areas along this reach are predominately residential and commercial with areas for parks, trails, and open space. The channel through this reach is abundant with vegetation and has an average channel slope of around 0.6%. Prospect Lake, Tabor Lake, and West Lake are located along the channel, downstream of Youngfield Street. Clear Creek's 100-year floodplain extends into these three lakes. The Wheat Ridge Greenbelt is also located in this reach.

  Reach 8: Interstate-70 to McIntyre Street - This reach is located within unincorporated areas of Jefferson County and covers approximately 1.7 miles of drainageway. Much of the property is owned and maintained by Coors Brewing Company. Areas adjacent to I-70 are currently being redevelopment by Coors. Additional development in the City of Wheat Ridge upstream of I-70 has expanded the land use on the south overbank. Generally, Clear Creek is well vegetated and stable, with an average channel slope of 0.9%. Much of the channel has been channelized in the past between the Coors Railroad tracks and an embankment separating Clear Creek from Coors's large water storage ponds, located to the south of Clear Creek. A large drop structure exists downstream of the pedestrian bridge and several smaller drops exists downstream of the Coors Railroad crossing.

- ***Reach 9: McIntyre Street to the Confluence with Tucker Gulch -*** This reach is located within unincorporated areas of Jefferson County and the City of Golden and covers approximately 2.6 miles of drainageway. Much of the property is owned and maintained by Coors Brewing Company. Included within this reach are crossings of a railroad bridge, three vehicle access bridges, and three pedestrian bridges. Several irrigation ditch diversions are located along this reach. Clear Creek is vegetated through this reach, however, much of the drainageway has been channelized over time and the channel no longer reflects its natural state.

- ***Reach 10: Confluence with Tucker Gulch to Upstream Study Limits -*** This reach is located within unincorporated areas of Jefferson County and the City of Golden. The reach covers approximately 1.4 miles of drainageway, with an average channel slope of around 0.9%. Much of the land use adjacent to the channel is residential, commercial, and municipal. Many improvements have been constructed along Clear Creek to create a river walk setting. Additionally, a kayak course has been built within the creek and is a very popular recreational activity. Within Golden, Clear Creek crosses several pedestrian bridges, as well as roadway bridges at Ford Street, Washington Street, and Highway 6.

Table 2 – Major Crossing Structure Inventory

Reach	Structure
2	I-270 Overpass
2	Two Ramps with Bridges
4	I-76 Overpass
5	I-76 Overpass
5	52nd Avenue Bridge
5	Marshall Street Bridge
5	I-70 Overpass
5	Wadsworth Blvd Bridge
6	44th Avenue Bridge
6	Kipling Street Bridge
6	Multiple Pedestrian Bridges
7	Youngfield Street Bridge
7	I-70 Overpass
7	Multiple Pedestrian Bridges
9	Railroad Bridge
9	Three Vehicle Access Bridges
9	Three Pedestrian Bridges
10	Multiple Pedestrian Bridges
10	Ford Street Bridge
10	Washington Street Bridge
10	Highway 6 Bridge

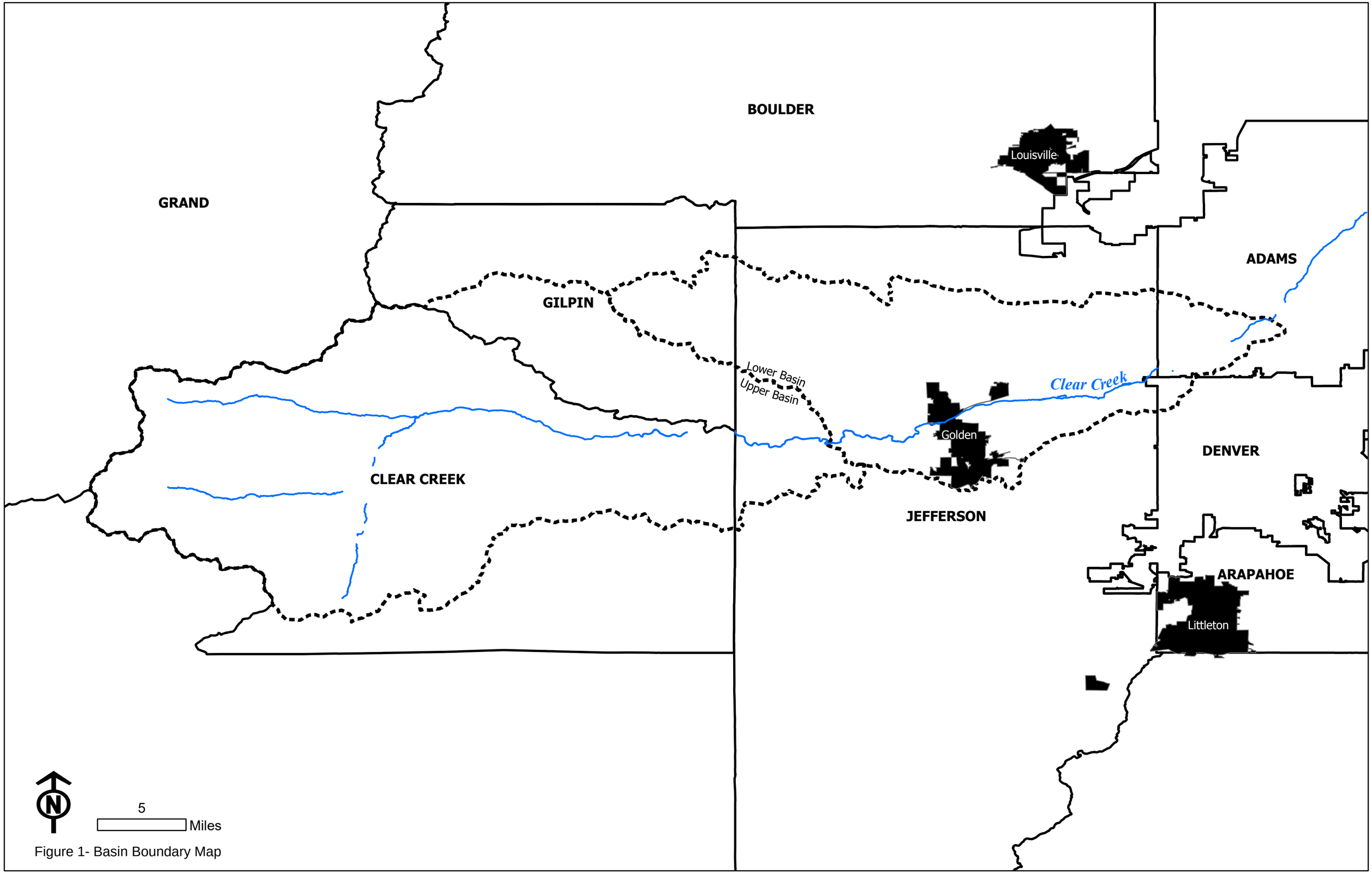

Figure 1- Basin Boundary Map

Project Area

6,000 Feet

N

Figure 2 - Vicinity Map

1 - Confluence with South Platte River to I25

2 - I25 to N. Pecos St

3 - N. Pecos St to Federal Blvd

4 - Federal Blvd to Sheridan Blvd

5 - Sheridan Blvd to Wadsworth Blvd

6 - Wadsworth Blvd to Kipling St

7 - Kipling St to I70

8 - I70 to McIntyre St

9 - McIntyre St to the Confluence with Tucker Gulch

10 - Confluence with Tucker Gulch to Upstream Study Limits

5,000 Feet

Figure 3 - Reach Map

2.4 Flood History

Historically, flooding in the Clear Creek basin has been relatively infrequent. Since 1864, twelve floods have been reported on Clear Creek and its tributaries. No lives have been reported lost due to flood related causes in the Clear Creek basin. The following descriptions of the floods of August 1888, June 1956, and July 1965 are typical of the information currently available (Gingery 1979), with additional information regarding the recent September 2013 Flood.

August 1888: This flood resulted from cloudbursts on the eastern slope of the Front Range of the Rocky Mountains. A discharge of 8,700 cubic feet per second (cfs) was reported at the mouth of Clear Creek canyon. This is the largest measured discharge in the history of this gaging station, which is located 1.5 miles upstream from Golden.

June 1956: Unusually heavy snowmelt runoff resulted in the failure of the Georgetown Dam located about 1 mile downstream from Georgetown. The peak discharge passing the gage above Golden was 5,250 cfs. By the time the crest reached the gaging station near the mouth of Clear Creek, it was reduced to 2,880 cfs.

July 23-26, 1965: On July 23 and 24, during severe storms over the headwaters of Clear Creek and Tucker Gulch, 4.5 inches of rain was reported to have fallen in Tucker Gulch in an hour, which caused flash flooding in Golden, however, flooding extended only a short distance downstream. In Golden, flood waters from Tucker Gulch spread over about 17 blocks and caused an estimated $112,000 damage to 69 residences, three commercial enterprises, three railroad bridges, four street bridges, and utility lines. At Georgetown, debris blocked the channel and diverted the waters down a street, thereby causing extensive washing of the surface and the flooding of several basements.

September 2013: One of the largest floods on record affecting the front range of Colorado, this event was focused generally north of Clear Creek. The Clear Creek basin experienced limited damages from storm discharges compared to communities in Boulder, Lyons, Longmont, and Estes Park. However, with a small meteorological shift south in the storm path, the Clear Creek basin and associated floodplain properties would have seen significant damages.

2.5 Wetland and Riparian Zones

An assessment of wetland and riparian areas was completed by ERO Resources, Inc. in July 2006 along the Clear Creek channel reach. Wetland and riparian areas were evaluated based on existing aerial photography and limited field assessments. This was completed for a previous FHAD and thus was not necessary to update for this version.

Vegetation in the study area has been modified by past development and by current recreation use. Because of the modifications and the overall reduction in the extent of plant communities, the remaining vegetation becomes especially important. The remaining riparian community along Clear Creek is the primary reason the corridor is so heavily used by wildlife and recreation users.

Riparian vegetation in the corridor is dominated by mature stands of plains cottonwood, with Siberian elm and Russian olive (non-native species) also present in great numbers. Sandbar willow, a fast-growing shrub, is a major understory component of the riparian community in many places. Because of past development and stream channelization, in most reaches, the riparian community along Clear Creek is limited to narrow bands of trees along the banks. In places, particularly parks and open space areas, the riparian community extends across much of the floodplain. Although riparian vegetation is not protected by local, state, or federal regulations, government entities typically discourage removal of riparian vegetation and often require replacing removed trees at some replacement ratio.

As with the riparian community, wetlands along Clear Creek are often limited to narrow strips along the stream banks. An exception is an area south of Clear Creek just east of I-70 in the Wheat Ridge Greenbelt. This area was mined in the past for gravel, so there are open water bodies, and supplemental sources of groundwater support extensive wetlands along the base of a bluff that overlooks the area. Wetlands are also present around the margins of many of the ponds and lakes in the study area. Some wetlands are protected by Section 404 of the Clean Water Act. Activities such as constructing drop structures, stabilizing banks, or changing channel geometry that would impact wetlands adjacent to waters (streams, lakes, ponds, etc.) under jurisdiction of the COE would require authorization.

2.6 Wildlife and Threatened or Endangered Species

Because of its highly developed setting, Clear Creek is a regionally important natural resource. Golden, Wheat Ridge, and Jefferson County have several parks and open space areas along the drainageway and within the study area. These provide areas of forage and shelter for a variety of wildlife such as waterfowl, songbirds, deer, coyote, and red fox. Aside from birds using the Clear Creek corridor as a stopping point during migration, most of the wildlife species found in the corridor are tolerant of development and the presence of humans. Despite their tolerance for human proximity, they still rely on areas such as the Clear Creek corridor for refuge. In addition to terrestrial wildlife, fish are also present in the study area. Clear Creek, lakes, and ponds support a variety of native and non-native species, including rainbow trout, carp, largemouth bass, bluegill, and minnows. The Colorado Division of Wildlife stocks some of the lakes in the study area with largemouth bass and bluegill. The poor water quality in Clear Creek limits the fish population.

Some species of plants and animals are protected or managed by state and federal entities. The Colorado Division of Wildlife manages and enforces regulation related to wildlife, including fish. Federally threatened and endangered species are protected under the Endangered Species Act of 1973 (ESA). Significant adverse effects to a federally listed species or its habitat require consultation with the U.S. Fish and Wildlife Service under Section 7 or 10 of the ESA. Migratory birds, their active nests, and eggs are protected by the Migratory Bird Treaty Act. It is illegal to kill, harm, or harass a migratory bird or to damage an active nest or eggs.

Three species listed as threatened under the ESA are known to occur in, or in the vicinity of, the study area – Preble's meadow jumping mouse, Ute ladies'-tresses orchid, and bald eagle. Preble's

and the orchid are associated with wetlands and streams along the foothills. Bald eagle use lakes and riparian areas for feeding, roosting, and nesting. Much of the study area is located in the Preble's meadow jumping mouse block clearance zone, within which Preble's is assumed to be absent. Clear Creek west of I-70 is not in the clearance zone. Ute ladies'-tresses orchid is present on Clear Creek at the west end of the study area, just west of State Hwy. 93 and in Prospect Park just east of I-70 in the Wheat Ridge Greenbelt. While no bald eagle roosts or nests have been identified in the study area at the time of this study, the number of bald eagles in the Denver Metropolitan area has been increasing and it would not be unusual for eagles to roost or nest in the Clear Creek riparian corridor.

SECTION 3 – HYDROLOGIC ANALYSIS

3.1 Overview

The hydrology summary prepared for this study was taken directly from the CLOMR (FEMA Case No. 16-08-0917R) prepared by Wright Water Engineers.

Before the completion of the CLOMR in 2016 previous hydrology came from District FHAD and Master Planning reports.

3.2 Previous Studies

Hydrology along Clear Creek was originally calculated by the (COE) in a report provided to the District in 1979. The COE hydrology is the source of hydrology in subsequent District FHAD and Master Planning studies. Additionally, the COE hydrology has been accepted and used by the Federal Emergency Management Agency (FEMA) in Flood Insurance Studies for incorporated and unincorporated areas in both Jefferson and Adams Counties. A listing of District and FEMA studies incorporating the previous COE hydrology is listed below. The hydrology recommended for this study is from previous CLOMR reports.

3.3 Hydrology

As previously mentioned, the hydrology for this study was taken from CLOMR Case #16-08-0917R. Full hydrologic analysis and FEMA review information is provided in the technical appendix.

Table 3 - Clear Creek Peak Discharge Summary

Peak Discharge Flows (cfs)				
Clear Creek Location	10-yr	50-yr	100-yr	500-yr
US Highway 6	3300	6900	8600	18300
Ford Street	3300	7000	8800	18600
McIntyre Street	3500	7500	9500	19800
I-70	3500	7500	9500	19800
44th Avenue	3700	8000	10200	21100
U/S Ralston / I-76	3700	8000	10200	21100
Sheridan Blvd	4500	9600	12600	19200
Federal Blvd	4500	9600	12800	25500
Broadway	4900	10400	14100	27700
Washington St	4900	10400	14100	27700
S. Platte Confluence	4900	10400	14100	27700

SECTION 4 – HYDRAULIC ANALYSIS

4.1 General

A Flood Hazard Area Delineation (FHAD) has been completed for Clear Creek. FHAD maps have been generated and are contained in the Appendix of this study. The purpose of the FHAD mapping is to identify areas, structures, and property which have the potential of being inundated in flood events. In addition to the FHAD mapping, floodways have been defined along Clear Creek to establish the portion of the channel that must remain free of obstruction to allow for conveyance of the 100-year flood without increases over 0.5-foot in water surface elevation.

4.2 Hydraulic Evaluation of Existing Facilities

The 100-year and 500-year floodplain delineation are shown on FHAD maps in Appendix E. Additionally, profiles for the 10-year and 50-year events, typical channel cross-sections, and cross-sections at hydraulic structures are also presented on the FHAD profiles sheets in Appendix F. The pertinent floodplain and floodway data are displayed in Table 3. This table identifies the channel cross-section locations; thalweg elevations; 10-, 50-, 100-, and 500-year discharges and water surface elevations, 100-year velocities; channel topwidths, and cross-sectional area; and left, right and total floodway widths the 0.5-foot floodway.

Water surface elevations were determined using the U.S. Army Corps of Engineer's step backwater program HEC-RAS, version 5.0.7. Cross-section data was developed from the digital elevation model (DEM) and filtered to reduce the number of points in each cross-section. Estimates of channel and overbank roughness were made from aerial photographs and field observations. Manning's 'n' values ranged from 0.03 to 0.045 in the channel and from 0.03 to 0.12 in the overbank areas. Blocked obstructions and ineffective flow were utilized to account for large structures and flow conveyance paths.

Through the course of this study, several specific reaches of Clear Creek required in depth analysis and careful consideration of modeling variables. Technical backup on many of these areas is included in Appendix C. A brief summary of select reaches is provided here:

- *Tabor Lake Split.* The hydraulic modeling along the main channel of Clear Creek has a natural and obvious split at Tabor Lake, on the north bank downstream of Youngfield Street. Lateral structures were used in the one-dimensional hydraulic model to estimate the flow split into the lake and continuing along the main channel. Hydraulic conditions between the active channel and static water surface controlled by lake embankments are estimated by the lateral structures. Floodway encroachment analysis was not performed for this flow split.
- *2D modeling.* Additional information on the 2D modeling is included herein and with technical memos included in Appendix C for the North Overflow, South Overflow and 44th Avenue. Through the course of the study, the limitations on one-dimensional analyses of these areas were clear – flow paths would align with engineering judgement for one direction but become disconnected from expectations for other related flow paths. Two-dimensional modeling allowed for multiple flow paths to be more accurately represented then entered into the one-dimensional model based on known water surface elevations, peak discharges, and other set variables. See Appendix C and following split flow narrative. Below is a summary of the areas requiring in-depth analysis.
- *North Overflow.* The North Overflow is located east of Sheridan Boulevard and north of I-76. The North Overflow rejoins the main channel downstream of Lowell Boulevard. The 2D analysis provides the best information on the assumptions and results for the North Overflow floodplain delineation. This is a modification of the WWE CLOMR specific to the split flow conditions. In general, the overtopping split at Sheridan Boulevard starts the overflow path, but detailed analysis had to consider the complexity of right overbank flow upstream of I-76 as well. Moving downstream, identifying a centerline for the flowpath is highly subjective based on existing topography and benefited greatly from the 2D modeling results. Future work should consider a channel alignment adjacent to the interstate as the most direct flow path following the Recommended Plan from the 2005 MDP by Ayres Associates, then work overbank capacity and floodway delineation northward from that channel alignment.
- *South Overflow.* The South Overflow is located southeast of I-76, west of Sheridan Boulevard and north of west 52nd Avenue. As the North Overflow work developed, the complexity of flow south of the interstate and influence of an embankment led the project stakeholders to consider 2D analysis of the South Overflow to inform south overbank flooding and spills. Flow between Sheridan and 52nd Avenue was a focus of a specific analysis to evaluate the embankment and overland flows.
- *44th Avenue.* Overbank flooding near 44th Avenue benefited from the 2D analysis in defining flood depth and flow direction. The number of residential structures compounded the flood risk and the cross sections were not sufficient to represent risk across the residential areas. A 2D model provided additional information to inform the 1D model and better represent the flood risks specific to residential land use.
- *Pecos Street*. The right overbank spill on Pecos Street was identified in the original 1D modeling as a potential split flow. Based on the complexity of roadway embankments and overpasses in this location, additional 2D analysis provided a more reasonable hydraulic result and floodplain than the initial 1D HEC-RAS analysis.
- *Bridge Survey.* Through the course of the study, there have been several supplemental surveys on the bridge crossings. As originally scoped, the bridges from both Jefferson County and Adams County FHADs were merged into a single model. This included field verification of the bridges, piers, and armoring conditions to ensure the combined model did not omit obvious changes to the Creek since the early 2000s. Also, in the course of ongoing floodplain management in the City of Arvada, a floodplain permit applicant completed independent survey on several bridges over Clear Creek and identified a vertical elevation discrepancy. Upon further review, it was decided that multiple bridges in the Arvada section of Clear Creek should be surveyed and checked against the elevations from the 2005 and 2007 FHADs.
- *The RTD Gold Line.* The RTD G Line is located north of I-76, east of Lowell Boulevard, and west of Federal Boulevard. The light rail project was designed and constructed in the course of this study. A number of updated studies and as-built conditions affected the floodplain delineation along Clear Creek in the vicinity of the Little Dry Creek confluence. This study

incorporated CLOMR information as it was available and ultimately integrated as-built LOMR information. There was not a LOMR for either CLOMR 13-08-099R (for the Gold Line near Federal) or 13-08-0217R (for the B Line at the mouth of Little Dry Creek). This study incorporates the final data for these two CLOMR cases.

- *RTD B Line/Mouth of Little Dry Creek.* The hydraulic conditions at Little Dry Creek are based on the CLOMR, participating agencies agreed to incorporate as-built changes through the FHAD and subsequent PMR.
- *Stockpile analysis.* In two locations on the lower reaches of Clear Creek there are active construction operations that include stockpiles in and near the floodplain. Ongoing floodplain management of these land-uses manage the responsibilities and restrictions of those stockpiles. For the purpose of this study, certain assumptions on existing conditions and existing topography had to be documented. The Brannan and Martin Marietta operations were studied, surveyed, and modeled to provide a baseline condition for future regulatory mapping and alignment with the ongoing floodplain management strategies.
- *City of Golden upstream of Ford Street.* The LiDAR topography and initial modeling for areas upstream of Ford Street in Golden did not reflect previously permitted wall and building elevations. With additional survey information and reference to floodplain permit information, the delineation on the south overbank upstream of Ford Street was refined to more accurately reflect flood risk on the multi-family residentials structures adjacent to the Clear Creek trail.

Detailed technical information is available is available in the full technical memorandums in Appendix C.

4.3 Split Flow Areas

Several areas of split flows were identified along the project reach. These areas are described in more detail in the Flooded Areas (Section 4.6) and have been discussed in multiple stakeholder meetings over the course of the study. Split flows were typically evaluated by defining a lateral spill weir and balancing water surface elevations and discharge of the flow leaving the main channel with the flow continuing downstream. This was completed using the lateral structure optimization routine in HEC-RAS. Once the flow balance was established, the overall discharges were changed in the HEC-RAS model to match the optimization and the models were re-run without activating the optimization routine. The split flow reaches were exported into an independent hydraulic model.

Two-dimensional flood modeling was used to inform the one-dimensional model in several locations in the study area, with particular benefit for split flow locations. The 2D models provided higher resolution on multiple flow directions across the natural and developed topography of Clear Creek. Please see discussion in the previous section on the location requiring more in-depth analysis with 2D modeling.

4.4 Two-Dimensional Hydraulic Analysis

In an effort to assist the Clear Creek FHAD hydraulic 1D modeling effort, a series of 2D models were developed at key locations along Clear Creek. These locations include:

- Left overbank spill across 44th Avenue from Kipling to XS 48477
- Right overbank spill across Sheridan Boulevard from 52nd Avenue to XS 32573 (the “South Overflow”)
- Right overbank spill across I-76 and Federal Boulevard from XS 28381 to XS23255 (the “Federal Split”)
- Right overbank spill between XS 22613 to XS 22088 (Pecos Area)
- Left overbank spill in the ‘North Overflow’ area

The purpose of these models is to provide spill discharge information, approximate floodplain limits, and to provide flow path alignments for the key areas noted above as needed.

The 2D modeling was completed using HEC-RAS (v. 5.0.7). General modeling parameters include the following:

- 30 ft by 30 ft mesh spacing
- Break lines at key locations (channels, top of bank etc.)
- Bridge structures where deck is close to or below 100-year 1D water surface elevations (bridge structures are approximated by culverts in 2D HEC-RAS)
- Buildings were integrated into the elevation surface for the model and set as breaklines

Additional information is provided in the technical appendix in the full technical memorandums in Appendix C.

4.5 Floodway Encroachment Analysis

The 0.5-foot floodway was established predominately using encroachment method 4 in HEC-RAS. Method 4 encroachment provides an equal loss of conveyance in the cross-section overbanks to achieve a target change in water surface elevation and resulting energy grade line. In areas where the method 4 encroachment was resulting in floodway surcharges outside of the allowable change in energy grade, or negative floodway surcharges occurred, either no encroachment, or a method 1, encroachment option was utilized. For a method 1 encroachment, the exact location of the floodway stationing was defined manually. Typically, when the method 1 encroachment was used, the floodway width was set equivalent to the 100-year floodplain top width (i.e., no encroachment). The floodway left and right widths are measured from the channel stationing line which correlates approximately to the centerline of the channel. Pertinent floodway data is displayed in Appendix C.

4.6 Flooded Areas

The work maps and online flood map viewer are very useful tools for evaluating flooded areas within the study reach. Pan, zoom, and various base map functions allow for user driven review

of basic inundation limits up through a risk assessment for specific locations. There are a few areas with noteworthy flooding limits summarized here.

- Upstream of York Street, north overbank flooding with the 500-year storm inundates commercial properties with the south overbank only slightly elevated above the same flood risk.
- Upstream of I-25, complex flow paths and transportation related obstructions to the flow path cause backwater and diverted flows to inundate several properties.
- Between Broadway and Pecos, a significant constriction in the flow path results in backwater flooding towards Pecos and diverted flow paths around properties towards Broadway during the 500-year storm. Influences from industrial/gravel operations and irrigation canals further complicates the flood risk mapping in this area.
- Flood risk upstream and downstream of Federal Boulevard is highly congested by transportation infrastructure, existing commercial and private structures, and natural topography. Split flow analyses and detailed modeling in this area provides a best estimate of clear water flood risk.
- At Sheridan Boulevard, the North Overflow is one of the most distinct and difficult features of the Clear Creek floodplain analysis. Additional 2D analysis, detailed survey, land use assumptions, and multi-variable dynamic conditions make for a very complicated representation of flood risk. The interstate bisects a natural topography for the Clear Creek floodplain. With sufficient planning, the north overflow can restore a functional North Overbank flow path that reduces flood risk on north and south overbanks of Clear Creek.
- Downstream of 44th Avenue, overbank flooding affects multiple residential structures in the north overbank. Natural topography in this area and existing development leads towards individual structure mitigation or structural flood control alternatives that further restrict the natural floodplain conditions.
- Flood risk from approximately Kipling to McIntyre is not complicated by interstate transportation infrastructure. Flooding follows generally natural topography and active floodplain management on land use, natural area maintenance, and other interactive strategies can be effective.
- The Coors Brewery property is the most channelized section of Clear Creek to protect not only private industrial infrastructure, but also the wastewater treatment plant shared with Jefferson County and the City of Golden.
- Upstream of Tucker Gulch, the City of Golden's Clear Creek corridor has multiple residential and commercial mixed-use properties adjacent to the creek with intentional recreational opportunities within the creek. Flood risk is generally contained, but should be monitored during large-scale events.

4.7 Comparison with the Effective Flood Insurance Study

A comparison was made between the information presented in the FHAD and the effective Flood Insurance Study (FIS). In general, the 100-year Base Flood Elevations (BFEs) along Clear Creek remain similar, or increase, as compared to the effective water surface elevations presented in the FIS reports and on the FEMA Flood Insurance Rate Maps (FIRMs).

Areas where split flows have been identified generally result in increased flood hazard area delineation. Other areas were identified where the channel has been shifted due to development, such as within the City and County of Denver, adjacent to I-76.

The differences in the model results between this study and the previous studies and reports primarily result from, basin development and changes, updated detailed mapping, and cross-section selection and placement.

4.8 500-Year Flood Hazard Analysis

The 500-year flood hazard area and flood elevations were identified as part of this study. 500-year water surface elevations are presented in Appendix D. A supplemental flood hazard delineation was developed for eventual use in the FEMA Flood Insurance Study. It should be noted that at some locations, the 500-year discharges are not completely contained within the hydraulic cross-section's limits modeled in this study and the flood hazard delineation extended beyond the project mapping limits. As a result, the ends of these sections are vertically extended.

SECTION 5 – REFERENCES

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