Flood Hazard Area Delineation

Cherry Creek Minor Tributaries in Arapahoe County

October 2021

Project Sponsors:

MHFD MILE HIGH FLOOD DISTRICT

Southeast Metro Stormwater Authority

ARAPAHOE COUNTY COLORADO'S FIRST

AURORA

Prepared by:

Dewberry®

8100 East Maplewood Avenue, Suite 150
Greenwood Village, CO 80111

October 29, 2021

Mr. Jon Villines – Watershed Manager
Mile High Flood District
2480 West 26th Avenue, Suite 156-B
Denver, Colorado 80211

Subject: Cherry Creek Minor Tributaries
In Arapahoe County
Major Drainageway Plan Flood Hazard Area Delineation
MHFD Agreement No. 18-08.13

Dewberry Engineers is pleased to submit the Digital Flood Hazard Area Delineation Report for Cherry Creek Minor Tributaries in Arapahoe County to the Mile High Flood District, the Southeast Metro Stormwater Authority, and the City of Aurora.

This report provides a description of the watersheds, updated hydrologic modeling for eleven major basins upstream of Cherry Creek Reservoir, new detailed hydraulic modeling for five of the eleven major basins, and an assessment of damage that would occur under existing conditions in major flood events.

Included within the study area are more than twenty (20) miles of drainageways, which convey stormwater runoff from approximately 4,320 acres. Drivers for this project include providing additional data for unstudied areas, updating data from previously studied areas, quantifying potential impacts caused by limited regional detention, and providing guidance for development that is anticipated with the King's Point Development near 17 Mile Farm House.

Approximately 8.6 miles of detailed HEC-RAS hydraulic modeling was completed for five major basins: Little Raven Creek, Joplin Tributary, South Arapahoe Tributary, Chenango Tributary, and Kragelund Tributary.

The report format and submittal are intended to follow the requirements of the Mile High Flood District DFHAD Guidelines. This report provides the following information:

- A summary of the hydrologic and hydraulic analyses,
- HEC-RAS water surface profiles for the 10-, 25-, 50-, 100-, and 500-year storm events, and
- Delineation of the 100- and 500-year floodplains, and a 0.5-foot rise floodway.

This floodplain and floodway information provide Arapahoe County, City of Aurora, Southeast Metro Stormwater Authority, and Mile High Flood District updated or new analyses and mapping for better floodplain management, depending on each basin.

The project team at Dewberry acknowledges and thanks the Mile High Flood District, the Southeast Metro Stormwater Authority, the City of Aurora, and Arapahoe County for their assistance and cooperation in the preparation of this study. Thank you for the opportunity to complete this portion of the project.

Sincerely,

Danny Elsner, P.E., CFM
Water Resources Department Manager

Haley Heinemann, P.E., CFM
Engineer

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1.0 INTRODUCTION

1.1 Authorization

The Mile High Flood District (MHFD) contracted with Dewberry Engineers Inc. (previously Dewberry | J3) for engineering services to complete a Major Drainageway Plan (MDP) and Flood Hazard Area Delineation (FHAD) for the Cherry Creek Minor Tributaries in Arapahoe County. This report was authorized by the following project sponsors: MHFD, the Southeast Metro Stormwater Authority (SEMSWA), and the City of Aurora (COA). Arapahoe County (AC) is also involved in this project as a stakeholder. The specific tasks completed during this project were performed in accordance with the Agreement: Contract No. 18-08.13 executed on August 30, 2018.

1.2 Purpose and Scope

The purpose of this project is to create an MDP for 11 major basins and a FHAD for 5 of those major basins that are tributary to Cherry Creek. This project provides new and updated hydrology, flood hazard area mapping, alternatives analysis, and conceptual design for specific improvements that correct any deficiencies that are identified.

Several of the studied tributaries were previously unnamed and are subsequently named herein: Little Raven Creek (previously North Unnamed Tributary), Suhaka Creek (previously Tributary to Cottonwood Creek), and Kragelund Tributary (previously South Unnamed Tributary).

The tributaries included in this study are as follows: Little Raven Creek (LR), Suhaka Creek (S), Joplin Tributary (J), Grove Ranch Tributary (GR), Valley Club Acres Tributary (VCA), North Arapahoe Tributary (NA), South Arapahoe Tributary (SA), Chenango Tributary (C), Tagawa Tributary (T), Kragelund Tributary (K), 17 Mile Tributary (17).

Several of the tributaries in this study are comprised of little to no open channel or were excluded from the FHAD by the project sponsors. The tributaries included in the FHAD are as follows: Little Raven Creek (LR), Joplin Tributary (J), South Arapahoe Tributary (SA), Chenango Tributary (C), Kragelund Tributary (K).

The project stakeholders' primary goals are to confirm watershed hydrology, define the floodplain and flood risks, and evaluate alternatives to reduce or eliminate those risks, as necessary. This Major Drainageway Plan makes it possible to evaluate necessary improvements to reduce peak flows and stabilize tributary reaches by implementing detention (if possible), grade control, and water quality facilities.

A summary of the objectives of the study is as follows:

- Quantify project hydrology,
- Quantify magnitude of runoff and associated flood risks,
- Identify alternatives to address flood hazards and/or conveyance deficiencies, and
- Provide conceptual design for recommended improvements.

1.3 Planning Process

Portions of the project area have been studied in an Outfall Systems Plan that was completed in 1999 (WRC Engineering, Inc., 1999). Seven tributaries and 4 DFAs were previously studied in the 1999 Cherry Creek Corridor Reservoir to County Line Outfall Systems Plan by WRC (WRC Engineering, Inc., 1999). However, a detailed hydraulic analysis to define the distinct floodplains has not been completed. This data was approximately 20 years old at the time of this study and does not reflect all revisions to land use. Four notable areas of interest not captured by the 1999 study are the undeveloped areas within the watershed of Kragelund Tributary; drainage across the 17 Mile Farm property; the Grove Ranch area and active erosion at the Pioneer Hills Development. Additionally, 2 existing detention ponds, 1 on Joplin Tributary and 1 on North Arapahoe Tributary, are included in this analysis.

A kickoff meeting and several progress meetings were held to discuss the project goals, project status, hydrologic analysis, areas of concern, potential alternatives, and comments with MHFD and the project sponsors. The meetings were held on September 10, 2018, October 23, 2018, January 14, 2019, April 10, 2019, August 5, 2019, October 24, 2019 and February 2, 2021. Minutes from the meetings are included in Appendix A.

The baseline hydrology developed for this study represents an updated analysis using CUHP 2016 version 2.0.0 and EPA SWMM version 5.1. Further explanation of the hydrologic modeling process is included in **Section 3.0**.

MHFD and the project sponsors reviewed the draft baseline hydrology and returned comments on January 14, 2019. Comments were received on the flood hazard area delineation at each step of the review process. The comments were incorporated into the final report. Summaries of the review comments and responses are included in Appendix A.

A project website was created to provide updated information on the project and can be found at www.cherrycreektributaries.com.

*Following completion of the baseline hydrology in January 2018, additional storm sewer infrastructure data was obtained from CDOT As-Builts for the Arapahoe/Parker interchange project (Federal Aid Project No. STU 0831-107 dated May 9, 2012). These plans depict existing storm sewer lines that were not included in the municipal GIS shapefiles used to inform the original baseline hydrology modeling. In an effort to better characterize urban flooding on Arapahoe Road and within Valley Club Acres, the baseline hydrology SWMM model was revised to reflect the 2012 CDOT plans. The outputs documented in the text and appendices of this report have been updated to reflect these revisions. See **Section 3.7** for additional information.

1.4 Mapping and Surveys

One-foot contours from 2014 USGS LiDAR data were provided by MHFD for the Project Area, as well as a structure survey for detailed information at each crossing. Other information such as jurisdictional boundaries, stormwater infrastructure, and roadways were obtained from the COA, SEMSWA, and Arapahoe County. All data is spatially referenced using the *NAD 1983 Colorado State Plane, Central Zone* projected coordinate system and vertical elevations for the contours are referenced using the *NAVD 1988* vertical datum.

1.5 Data Collection

Background research and data collection were required to conduct the analysis and to develop this Major Drainageway Plan. This included development plans, drainage reports, topographic data, land use data and miscellaneous items. Stakeholders provided much of the topographic and land use data while Dewberry located the remainder. These sources are identified in **Table 1-1.**

Table 1-1 Collected Data

Source	Date	Description
MHFD	Sep 25, 2018	1-foot LIDAR contour shapefiles developed by the USGS in 2014.
SEMSWA	Sep 27, 2018	Impervious data for incorporated areas within the City of Centennial. Dewberry created project shape files to describe resultant Land Use.
City of Aurora	Oct 1, 2018	Digital PDF copies of development plans for the Kings Point Development.
MHFD	Nov 5, 2018	Detailed structure surveys by Wilson & Co were provided as AutoCAD electronic files.
National Land Cover Database	Nov 20, 2018	NLCD raster image with land use categories for entire area. Dewberry used this information to backcheck the Land Use layer.
City of Aurora & SEMSWA	Sep 27 & Nov 27, 2018	Detailed mapping of stormwater infrastructure was downloaded from the public domain as shapefiles.
Arapahoe County	Nov 27, 2018	Partial land use data, including the 2018 Comprehensive Plan provided as shapefiles. Dewberry created shapefiles where data was incomplete.
Arapahoe County & City of Aurora	Nov 27, 2018	Zoning data for some areas. Dewberry considered these shape files when developing a Land Use layer.
Arapahoe County	Nov 27, 2018	Natural water elements including streams and lakes.
SEMSWA & Arapahoe County	Dec 5, 2018	Development Plans for King's Point, Basin RB1-Pond 4 (RB1-4) Drainage Improvements, and Filings 7,8 & 9 of the Farm at Arapahoe County.
MHFD	Feb 6, 2019	Detailed structure survey for the North Arapahoe pond on North Arapahoe Tributary.
MHFD	July 8, 2019	Detailed structure survey for the Hinsdale Ave. crossing and the Chambers Rd. crossing on Joplin Tributary.

1.6 Acknowledgments

Project sponsors include:

- Mile High Flood District
- Southeast Metro Stormwater Authority
- Arapahoe County
- City of Aurora

Dewberry wishes to acknowledge the various individuals who assisted in the preparation of this Master Plan and who provided valuable contributions. The following individuals and the agencies they represented are:

Shea Thomas, PE	MHFD – Watershed Services Manager (Retired)
Jonathan Villines, PE, CFM	MHFD – Watershed Services Project Manager
Stacey Thompson, CFM	MHFD – Floodplain Manager
Hung-Teng Ho, PE, CFM	MHFD – Hydraulic Modeler
Melanie Poole, PE	MHFD – Project Engineer
Brik Zivkovich, CFM	MHFD – Staff Engineer
Stacey Thompson, CFM	SEMSWA – Group Manager, Floodplain and Master Planning (Retired)
Angela Howard, PE, CFM, LEED® AP	SEMSWA – Master Plan Coordinator
Cathleen Valencia, PE	Arapahoe County Public Works & Development – Engineer II
Roger Harvey	Arapahoe County – Open Space Planning Administrator
Craig Perl, PE, CFM	City of Aurora – Senior Engineer, Floodplain Administrator

The following project Dewberry team members contributed to the preparation of this study:

Ken Cecil, PE, CFM	Dewberry
Danny Elsner, PE, CFM	Dewberry
Haley Heinemann, PE, CFM	Dewberry
Dana Morris, EI, CFM	Dewberry
Katie Kerstiens, EI, CFM	Dewberry

2.0 STUDY AREA DESCRIPTION

2.1 Project Area

The project area consists of 11 tributaries upstream of Cherry Creek Reservoir within Arapahoe County (Project Reuse Watershed No. 4600). The watersheds are within the Cities of Aurora, Centennial, Greenwood Village, the Town of Foxfield, and unincorporated Arapahoe County. **Figure 2-1** shows the 11 watersheds and the FHAD reaches. **Table 2-1** and **Table 2-2** list the lengths, areas, and jurisdictions of each basin. Tributary lengths were either approximated from the MHFD stream layer or, if included in the FHAD analysis, determined during the hydraulic modeling phase.

Table 2-1 Watershed Areas and Tributary Lengths

Tributary	Tributary Length		Watershed Area	
	(ft)	(mi)	(ac)	(mi^2)
Little Raven Creek (LR)	**6,556/2,307**	**1.2/0.4**	**349**	**0.55**
Suhaka Creek (S)	6,100	1.2	360	0.56
Joplin Tributary (J)	**10,669/8,470**	**2.0/1.6**	**774**	**1.21**
Grove Ranch Tributary (GR)	4,450	0.8	81	0.13
Valley Club Acres Tributary (VCA)	5,350	1.0	207	0.32
North Arapahoe Tributary (NA)	9,874	1.9	372	0.58
South Arapahoe Tributary (SA)	**7,500/2,959**	**1.4/0.6**	**396**	**0.62**
Chenango Tributary (C)	**10,875/10,647**	**2.1/2.0**	**917**	**1.43**
Tagawa Tributary (T)	5,760	1.1	107	0.17
Kragelund Tributary (K)	**10,048/9,285**	**1.9/1.8**	**611**	**0.95**
17 Mile Tributary (17)	4,126	0.8	145	0.23
TOTAL			**4,319**	**6.75**

*__Bold__ = included in the FHAD study
Tributary Length = Total length/Length modeled in FHAD

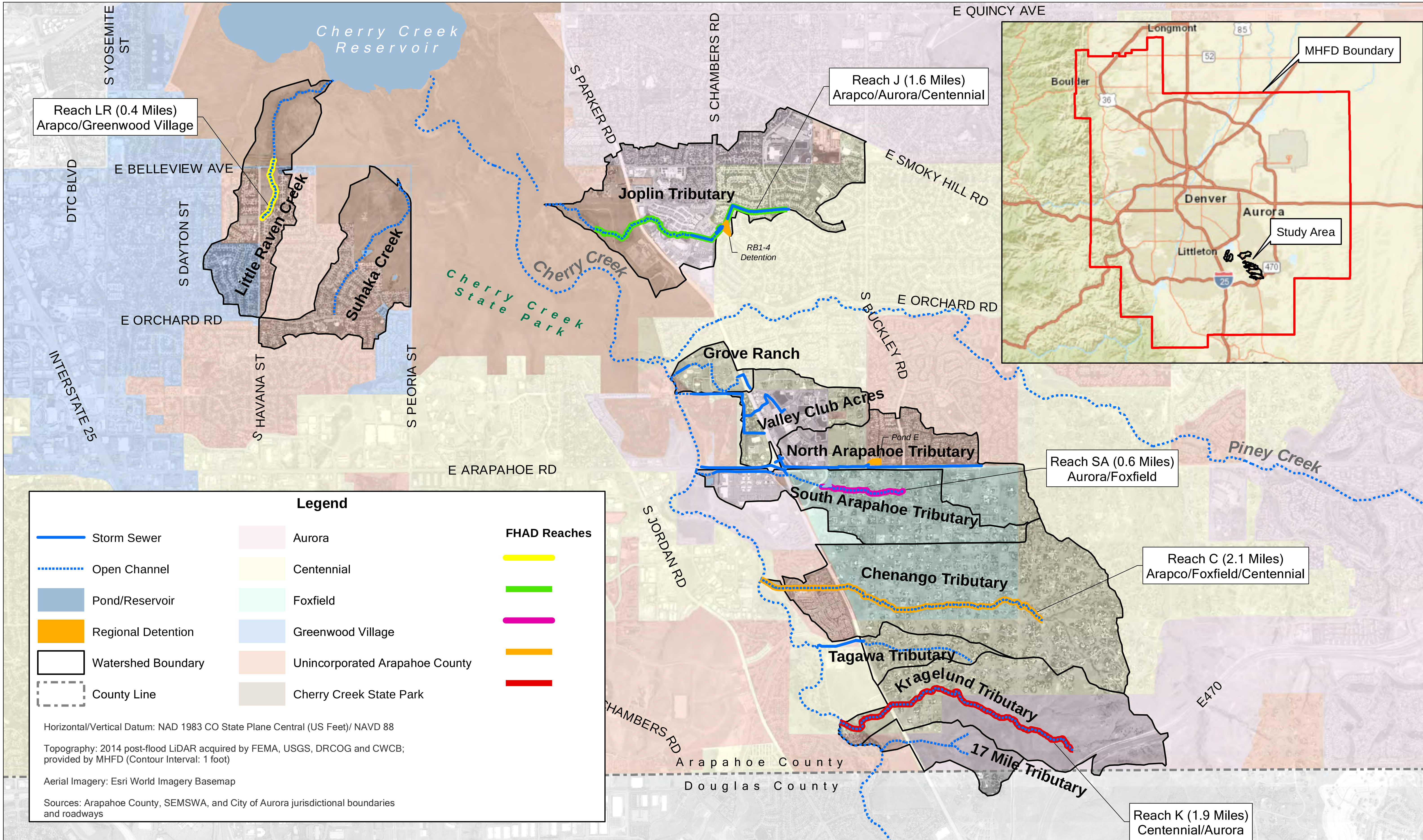
The overall project area is roughly bounded by Cherry Creek Reservoir to the north, S. Dayton St. to the west, S. Himalaya Way to the east, and the county line and E-470 to the south. Eight of the tributaries are bounded by Piney Creek to the north and the county line to the south, and outfall to Cherry Creek. Joplin lies north of Piney Creek, bounded by E. Smoky Hill Rd, and outfalls to Cherry Creek. Two tributaries do not outfall directly to Cherry Creek: Little Raven Creek and Suhaka Creek. Little Raven Creek outfalls directly to the reservoir and is bounded to the south by E. Orchard Rd. Suhaka Creek outfalls to Cottonwood Creek just upstream of the reservoir, and the basin is bounded to the west by S. Havana St. The total watershed area studied is 6.75 square miles or 4,319 acres.

Several of the tributaries in this study are comprised of little to no open channel or were excluded from the FHAD by the project sponsors. The tributaries included in the FHAD are as follows: Little Raven Creek (LR), Joplin Tributary (J), South Arapahoe Tributary (SA), Chenango Tributary (C), Kragelund Tributary (K). These tributaries are shown in bold in **Table 2-1** and **Table 2-2**.

Table 2-2 Watershed Outfalls and Jurisdictions

Tributary	Outfall	Jurisdiction
Little Raven Creek (LR)	**Cherry Creek Reservoir**	**SEMSWA, Unincorporated Arapahoe County, City of Greenwood Village, Cherry Creek State Park**
Suhaka Creek (S)	Cottonwood Creek	SEMSWA, Unincorporated Arapahoe County, City of Greenwood Village, Cherry Creek State Park
Joplin Tributary (J)	**Cherry Creek**	**SEMSWA, City of Aurora, Unincorporated Arapahoe County**
Grove Ranch Tributary (GR)	Cherry Creek	SEMSWA (City of Centennial, Unincorporated Arapahoe County)
Valley Club Acres Tributary (VCA)	Cherry Creek	SEMSWA (City of Centennial, Unincorporated Arapahoe County), City of Aurora
North Arapahoe Tributary (NA)	Cherry Creek	SEMSWA (City of Centennial, Unincorporated Arapahoe County), City of Aurora, Town of Foxfield
South Arapahoe Tributary (SA)	**Cherry Creek**	**SEMSWA, City of Aurora, Unincorporated Arapahoe County, Town of Foxfield**
Chenango Tributary (C)	**Cherry Creek**	**SEMSWA, City of Aurora, Unincorporated Arapahoe County, Town of Foxfield**
Tagawa Tributary (T)	Cherry Creek	SEMSWA (City of Centennial, Unincorporated Arapahoe County)
Kragelund Tributary (K)	**Cherry Creek**	**SEMSWA, City of Aurora (City of Centennial, Unincorporated Arapahoe County)**
17 Mile Tributary (17)	Cherry Creek	SEMSWA, City of Aurora (City of Centennial, Unincorporated Arapahoe County)

*__Bold__ = included in the FHAD study



Dewberry	Designed By: HH Drawn By: HH Checked By: KC/DE Date: 08/2021	MILE HIGH FLOOD DISTRICT, SOUTHEAST METRO STORMWATER AUTHORITY, CITY OF AURORA, AND ARAPAHOE COUNTY	CHERRY CREEK MINOR TRIBUTARIES IN ARAPAHOE COUNTY	PROJECT AREA MAP	FIGURE 2-1

2.2 Land Use

Due to the built-out nature of the studied basins, future land use hydrology is considered equal to existing for all basins except two: 17 Mile Tributary and Kragelund Tributary, where large swaths of undeveloped area still exist. As a result, existing conditions land use and hydrology in this study were developed for 17 and K only.

Most of the existing development in the Project Area consists of residential land use. Small pockets of office, commercial, and industrial developments are also present, primarily along the major local thoroughfares such as S. Parker Rd., E. Smoky Hill Rd., and E. Arapahoe Rd. Large portions of Little Raven Creek, Suhaka Creek and Joplin Tributary basins are located within the Cherry Creek State Park. The proposed King's Point Subdivision is anticipated to build out the remaining undeveloped area within the 17 Mile Tributary and Kragelund Tributary basins east of S. Parker Rd. sometime in the near future.

Land use for existing and future conditions was evaluated based on several pieces of data, referenced in **Table 1-1**. At the start of the project, Arapahoe County and SEMSWA provided future land use GIS data for areas of unincorporated Arapahoe County from the 2018 Comprehensive Plan and PDF maps of the Centennial NEXT Plan. Other data from the County's GIS portal were used to identify land use, including zoning, parks and open space, parcels, and lakes. Additional zoning data from the City of Aurora, the City of Centennial, and Douglas County was used to categorize land use in these areas. The spatial location of the 2 modeled regional detention ponds, Pond RB1-4 in Joplin Watershed and NA Pond (Pond E) in North Arapahoe Watershed, are from SEMSWA's detention pond data. And finally, the extents for S. Parker Rd. and E. Arapahoe Rd. were digitized by hand to include street imperviousness for these major roads. **Figure B-2** depicts the sources used to develop land use by location, as well as original Arapahoe County land use designations and original City of Aurora Zoning data.

To determine appropriate percent imperviousness values, the collected land use categories were converted to MHFD land use types and corresponding imperviousness values were assigned using *Table 6-3 Recommended Percentage Imperviousness Values* in the MHFD Criteria Manual Volume 1, which are included in **Table 2-3** for reference (Mile High Flood District, 2016). Composite imperviousness values calculated for each subwatershed are listed in **Table B-2** in Appendix B for the existing and future conditions hydrology and maps showing the existing and future land use are shown in **Figure B-1** as the *Existing Land Use Map* and the *Future Land Use Map* layers.

Planimetric data covering areas such as sidewalks, roofs, and roads was also made available for the City of Aurora and SEMSWA service area as a backcheck of assigned land use imperviousness values. Also, it may be noted that land use data from the National Land Coverage Database (NLCD) was used early in the study to verify the results using MHFD land use and values were similar.

Some specific areas were discussed by stakeholders to agree on some assumptions. First, S. Parker Rd. is planned to be expanded to 6 lanes in the future. This change is not considered as part of this study since S. Parker Rd., in addition to lakes, detention basins, and E. Arapahoe Rd., has been conservatively assigned as 100% impervious. Second, further development at 17 Mile Farm House was neglected since this area is only 1.8 acres large and the parcel has been assigned a conservative existing land use of single-family 2.5 acres or larger by the municipal data, even though most of the area is undeveloped.

Table 2-3 Land Use Categories and Imperviousness

Land Use	Imperviousness (%)
Apartments	75%
Business, Suburban	75%
Industrial, light	80%
Open Water	100%
Parks, cemeteries	10%
SF, 0.25 acres or less	45%
SF, 0.25-0.75 acres	30%
SF, 0.75-2.5 acres	20%
SF, 2.5 acres or larger	12%
Schools	55%
Streets	100%
Undeveloped Areas	2%

2.3 Reach Description

Descriptions of the tributaries are provided in the sections below. Major crossings are listed in **Table 2-4**.

Little Raven Creek (LR), previously referred to as North Unnamed Tributary, conveys runoff from an approximately 350-acre basin and is 7,700 feet in length. Little Raven Creek was named after the Principal Chief of the Southern Arapahoe Indians and was born on the central Great Plains around 1810 perhaps along the Platte River in present day Nebraska. The tributary is largely controlled by Cherry Creek State Park and is the only tributary in this study with an immediate outfall into Cherry Creek Reservoir. Regional detention and water quality are not present. Upstream of the reservoir, the tributary crosses under W. Lakeview Rd., which is located within the park and utilizes a partially buried, corrugated metal pipe (CMP) to convey the tributary flow. This pipe is a 36" CMP and partially silted in. Upstream to E. Belleview Ave., the tributary is dominated by dense vegetation, several mono-culture cattail areas, and a pedestrian trail crossing named "Pope Trail". The second road crossing is E. Belleview Ave. which utilizes 2 reinforced concrete pipes (RCPs), vertically offset by 5 feet, to convey the tributary flow. Upstream and south of E. Belleview Ave. is a wide storage basin with no outlet controls in place. This area is adjacent to The Hills development and is owned by Cherry Creek State Park. It inadvertently provides detention, however, does not appear to be maintained and thus is not included in evaluation. The tributary continues upstream of Cherry Creek State Park through Bear Park and across S. Havana St. via an elliptical 52" x 32" RCP.

Finally, the tributary continues upstream through a small concrete channel adjacent to the Hills West Swimming Pool and on to an open area that collects overland flow.

This tributary basin includes about 93 acres in the City of Greenwood Village and 256 acres in unincorporated Arapahoe County, 133 acres of which is served by SEMSWA. The area not served by SEMSWA is owned by Cherry Creek State Park. The area is fully built out and there are no vacant properties for future development within this basin. Site visits indicate that small reaches within the State Park may present the most significant challenge where active bank erosion is notable. There is at least 1 exposed utility present, and erosion is occurring in another location along the right bank.

Suhaka Creek (S) was added to the project scope of work during the Kickoff Meeting since it has not been previously studied. After the Comment Review meeting the name was changed from Tributary to Cottonwood Creek (TC) to Suhaka Creek, as described in the meeting minutes. Suhaka Tributary was named due to its proximity to the Suhaka Model Airfield named after an avid radio control airplane flyer. The tributary is a left bank tributary to Cottonwood Creek, which discharges to Cherry Creek Reservoir. The drainageway conveys runoff from approximately 360 acres of single-family development with open space at the downstream reaches. The major stormwater conveyance system is comprised of open channel flow that begins upstream near E. Orchard Rd. Further downstream, it crosses Cherry Creek Dr. with 2-48" RCPs. After this point, the tributary flows through a stock pond that is contained on the downstream end by a berm and an elevated broad-crested weir, and is subsequently conveyed as sheet flow to S. Peoria St. Runoff ponds behind a small inlet structure with an orifice plate and overflow grate and upon entering the structure, flows under S. Peoria St. via 2-12" RCP pipes. Flow then continues through a natural earthen channel to Cottonwood Creek.

Most of the watershed lies in unincorporated Arapahoe County with a small 9-acre area located in Greenwood Village near Lake Ct. Approximately 193 acres of this area is served by SEMSWA and the area not served by SEMSWA is owned by Cherry Creek State Park. Challenges include erosion upstream of the stock pond, poorly defined hydraulics from the stock pond to the outfall and lack of ponds that provide water quality or extended detention.

Joplin Tributary (J) is a large tributary to Cherry Creek and is approximately 9,700 feet in length. The downstream half of the tributary runs through Cherry Creek State Park where it crosses multiple park trails, and the other half upstream of S. Parker Rd. conveys runoff from dense, mixed-use developments comprised of commercial big box stores and single- and multi-family developments in the Cities of Aurora and Centennial. The drainageway conveys runoff from 775 acres with 600 acres upstream of Parker Rd. Runoff crosses S. Parker Rd. via 2-14' x 4' reinforced concrete box culverts. Construction is underway at Pioneer Hills Development from the crossing at S. Parker Rd. upstream to S. Chambers Rd. This reach is dominated by wetlands and retains a cross-section showing where the floodplain connects to the overbank areas. This section has challenges including severe right bank erosion encroaching on the adjacent multi-family development, a severe channel bend, and a complex outlet structure near S. Chambers Rd. Private water quality and detention ponds are located along the banks for Pioneer Hills and adjacent shopping centers. Upstream of S. Chambers Rd., runoff is conveyed along connected property lines between S. Granby Way and Home Depot.

Upstream of this, a City of Aurora 72" and a parallel City of Centennial 36" storm sewer is aligned for approximately 550 feet at the rear lot lines of adjoining single-family residences. The storm sewers are contained within a 40' easement with 20' on the City of Aurora side and 20' on the City of Centennial side. Upstream of the piped section at S. Joplin Way, the tributary daylights at Pond RB1-4 which is owned and maintained by SEMSWA. The pond is described in the as-built drawings for The Summit at Piney Creek development and appears to be in good condition, with a boulder-lined trickle channel and other appurtenances. A pre-sedimentation forebay and micro-pool are not present. The as-built drawings indicate a maintenance path was constructed; however, it was not visible during the site visit. Upstream from the pond, the tributary is contained in a 72" RCP.

The Joplin watershed combines a 360-acre area in the City of Aurora, a 218-acre area in the City of Centennial, and a 198-acre area in unincorporated Arapahoe County. SEMSWA serves the City of Centennial area and approximately 59 acres of unincorporated Arapahoe County. Subbasin J1 and parts of Subbasins J2, J3, and J4 near S. Parker Rd. are not served by SEMSWA and are located within Cherry Creek State Park. Challenges along Joplin Tributary include a lack of regional detention or water quality within the lower basin, some streambank erosion, stream maintenance, complex hydraulic conditions with possibly undersized elements, and potentially cumbersome easement issues should the parallel storm system need improvement.

Grove Ranch Tributary (GR) was added to the project scope of work during the Kickoff Meeting due to anticipated redevelopment and it is named in reference to the Grove Family properties within the watershed. It is the smallest watershed studied at 80 acres and less than a mile in basin length. The land use is defined by mixed-use and commercial development in the downstream basin and single-family residential development in the upstream basin. Runoff is conveyed across S. Parker Rd. by a 36" CMP and is conveyed from open channel to Cherry Creek via a 36" RCP.

The Grove Ranch watershed is served entirely by SEMSWA, with 77 acres located in the City of Centennial and 4 acres within unincorporated Arapahoe County. Challenges include poorly defined open channel hydraulics in the vicinity of the Fellowship Community Church, pooling wetlands upstream of pipe conveyance to Cherry Creek, and lack of ponds that provide water quality or extended detention.

Valley Club Acres Tributary (VCA) drains a tributary area of approximately 210 acres. The tributary is predominantly contained in storm sewer, with only 600 feet of open channel at the downstream confluence with Cherry Creek. The entire open channel reach is encumbered by the regulatory floodplain of Cherry Creek, as are approximately 1,500 feet of the upstream storm sewer. System capacity will need to be evaluated with this constraint in mind. This tributary is the outfall for part of the Arapahoe Crossing

Development and adjoining areas. Lower portions of the storm sewer in and around the Valley Country Club Golf Course transition from 8' x 3' RCBC to 66" RCP and then back to 8' x 3' RCBC.

The VCA area is composed of 110 acres in the City of Centennial, 91 acres in the City of Aurora, and 6 acres in unincorporated Arapahoe County. SEMSWA serves the areas in the City of Centennial and unincorporated Arapahoe County. Challenges include crowns not matching at pipe transitions mentioned in the previous paragraph and potentially undersized piping. If capacity is determined to be insufficient, alternatives will be complicated by multiple utilities including crossing and parallel sanitary lines, water lines, and golf course irrigation.

North Arapahoe Tributary (NA) was added to the project scope of work during the Kickoff Meeting to help address flows to Cherry Creek adjacent to E. Arapahoe Rd. Runoff from North Arapahoe watershed east of S. Buckley Rd. is conveyed in storm sewer and through a SEMSWA owned and maintained regional detention pond referred to herein as the North Arapahoe (NA) Pond. This pond is also referred to as Pond E by SEMSWA and is located in Tract A of Filing No. 9 for The Farm in Arapahoe County (P.R. Fletcher & Associates, Inc., 2000). Further downstream, runoff is conveyed under S. Parker Rd. in a 48" concrete pipe before discharging directly to Cherry Creek. The upper-most part of this watershed is located south of E. Arapahoe Rd. in the Town of Foxfield and drains to a downstream manhole that joins outflow from NA pond.

The North Arapahoe watershed combines a 372-acre area, 206 acres of which are served by SEMSWA, 114 acres by the Town of Foxfield, and 51 acres by the City of Aurora. This watershed includes 141 acres in unincorporated Arapahoe County. Challenges include NA Pond hydraulics due to discrepancies between LiDAR contours and as-built records, complex hydraulics at the S. Parker and E. Arapahoe Rd. interchange and upstream, and potentially undersized conveyance in downstream areas.

South Arapahoe Tributary (SA) was also added to the project scope of work during the Kickoff Meeting to help address flows to Cherry Creek along E. Arapahoe Rd. Runoff is discharged by a 12' x 6' RCBC that was designed to convey 645 cfs from the previously planned Southeast Regional Detention Basin. Research indicates that the Foxfield Outfall from the E. Arapahoe/S. Parker Interchange Water Quality Pond became MHFD maintenance eligible in January 2014. However, the downstream detention component of this pond is not publicly owned and maintained, or maintenance eligible, and so it is not included in project hydrology.

The SA watershed combines a 317-acre area in the Town of Foxfield, a 70-acre area in the City of Aurora, a 4.5-acre area in unincorporated Arapahoe County, and a 4-acre area in the City of Centennial. SEMSWA provides service to the City of Centennial area and 3 acres of unincorporated Arapahoe County. A small area along the east side of S. Parker Rd. in Subbasin SA2, an area of 1.5 acres, is located in unincorporated Arapahoe County but is not currently served by SEMSWA. Challenges include complex hydraulics at the S. Parker and E. Arapahoe interchange, WQ detention only and no regional detention, and potential bank instability in the downstream channel to the outfall.

Chenango Tributary (C) is the largest watershed and conveys runoff from 920 acres to Cherry Creek through the Cherry Creek Valley Ecological Park from the Chenango Development, which is a single-family large lot rural development that is fully built out. There are direct outfalls from the Landing at Cherry Creek development with no apparent water quality or detention. Red Hawk Ridge Elementary School provides some level of stormwater management. Regional detention and water quality do not exist along Chenango Tributary. Both developments discharge along a grouted sloping boulder drop structure and moderate infrastructure is located along portions of this tributary, predominantly in the downstream reaches. A sloped/tapered throat 10' x 5' RCBC crosses Cherokee Trail, and upstream a CDOT 3-barrel 12' x 6' RCBC with baffle chute drop structure crosses S. Parker Rd. The condition of these structures is good.

Upstream from S. Parker Rd., drainage infrastructure is more rural in design. At E. Hinsdale Way, a 54" CMP has incorporated a gated section at the outlet, presumably to function as fencing for the private property through which it passes. Seven additional public road crossings and 6 private drive crossings, some of which are bridges, are located upstream to the basin headwaters.

The Chenango watershed combines a 450-acre area in the City of Centennial, a 376-acre area in the Town of Foxfield, and a 90-acre area in unincorporated Arapahoe County. SEMSWA serves the areas in the City of Centennial and unincorporated Arapahoe County. Noted challenges that are present in this basin include no regional detention or water quality, a poorly defined or potentially undersized conveyance, a multi-split flow at the intersection of S. Richfield St. and E. Hinsdale Ave.; significant head cutting at S. Yampa St. with exposed twin 30" CMP and floating inverts due to erosion; widespread wetlands; at least 1 manmade impoundment with rusted and partially buried CMP; bank instability in the upper reaches; and numerous roadside ditches with timber grade control. The main tributary measures more than 2 miles in length with multiple left and right bank tributaries that measure another 1.5 miles in length.

Tagawa Tributary (T) was added to the project scope of work during the Kickoff Meeting as a direct flow area (DFA) to help address flows across S. Parker Rd. near Chenango and Kragelund Tributaries and was added as the 11th Tributary after removal of the remaining DFAs. Tagawa was named as a part of this study and has an area of approximately 107 acres. The tributary outfalls directly to Cherry Creek and is located to the south of Chenango Tributary and north of Kragelund Tributary. The crossing at S. Parker Rd. is located on the south side of E. Broncos Pkwy. The SEMSWA GIS data for stormwater mains indicates that the crossing is 2-42" pipes: 1 CMP and 1 RCP and both are noted to be in good condition. These pipes are also shown in the 1999 OSP (WRC Engineering, Inc., 1999). The area modeled is the portion east of S. Parker Rd. as this area will flow through the crossing at S. Parker Rd. and downstream 48" RCP piping to the Cherry Creek outfall.

The Tagawa watershed is entirely contained in the City of Centennial, which is served by SEMSWA. Challenges for Tagawa Tributary include poorly defined hydraulics upstream of S. Parker Rd., potentially undersized piping west of S. Parker Rd., and lack of ponds that provide water quality or extended detention.

Kragelund Tributary (K) conveys runoff from approximately 610 acres of mostly undeveloped land and provides the best opportunity for floodplain preservation. Before the Comment Review meeting Kragelund was referred to as South Unnamed Tributary, as described in the meeting minutes. Future development is anticipated from the headwaters near E-470 and King's Point, through privately owned property currently managed by the Vermillion Creek Metropolitan District, to the confluence with Cherry Creek within the PJCOS. There is currently no drainage easement across this property. Minimal infrastructure is present with the most prominent feature being a CDOT 22' x 8' RCBC crossing of S. Parker Rd. upstream of which, possibilities exist for regional detention and water quality. For approximately 2,800 feet upstream of S. Parker Rd., the floodplain is wide with no defined main channel. At this point, moderate channel definition begins, and it splits into a right stem (2,600 feet long) that drains southern portions of the existing Chenango development, and a left stem that proceeds towards the headwaters where it intersects a second right bank tributary (3,200 feet long). The majority of Kragelund Tributary is devoid of wetlands.

The Kragelund watershed combines a 343-acre area in the City of Aurora, a 259 acre-area in the City of Centennial, and 7-acre area in unincorporated Arapahoe County. SEMSWA serves the areas in the City of Centennial and unincorporated Arapahoe County. Challenges for Kragelund Tributary include upstream erosion near E-470, lack of ponds that provide water quality or extended detention, and undefined conveyance to Cherry Creek.

17 Mile Tributary (17) was added to the project scope of work during the Kickoff Meeting to help address flows across the 17 Mile House Farm Park. It is the most southern tributary of this study and is located just north of the Arapahoe County / Douglas County border. This poorly defined tributary drains approximately 145 acres, and is bisected by S. Parker Rd. through which, 2-48" RCP conveys runoff. This watershed is also largely undeveloped upstream of S. Parker Rd. but is expected to be fully built-out following development of King's Point.

17 Mile watershed combines a 97-acre area in the City of Aurora, a 17 acre-area in the City of Centennial, and 15-acre area in unincorporated Arapahoe County. SEMSWA serves the areas in the City of Centennial and unincorporated Arapahoe County. Challenges include poorly defined hydraulics from S. Parker Rd. to Cherry Creek and lack of ponds that provide water quality or extended detention.

Table 2-4 Major Crossing Structure Inventory

Tributary	Description	Road Crossing / Type
Little Raven Creek (LR)	54" RCP and 48" x 66" Box Culvert	E. Belleview Ave.
	Wooden pedestrian bridge	Cherry Creek State Park
	Culvert Crossings	Lakeview Rd., pedestrian trails and bike paths
Suhaka Creek (S)	2- 60" RCP	Cherry Creek Dr.
Joplin Tributary (J)	2- 14' x 4' Box Culverts	S. Parker Rd.
	Elevated Pipe Crossing	S. Parker Rd.
	RB1 Pond 4 / Powers Pond	S. Joplin Way and S. Chambers Rd.
	Drop Structures	S. Chambers Rd. near Bed Bath and Beyond
	Culvert Crossings	Dirt pedestrian trail
Grove Ranch Tributary (GR)	None	
Valley Club Acres (VCA) Tributary	Inlet Structure	S. Helena St.
North Arapahoe Tributary (NA)	None	
South Arapahoe Tributary (SA)	144" x 72" Box Culvert	Along E. Arapahoe Rd. from outfall to S. Parker Rd.
	WQ Pond and Outlet Structure	S. Lewiston St.
	Culvert Crossings	Across and/or along Richfield St., Pitkin St., Buckley Rd., S. Parker Rd., and private roads.
Chenango Tributary (C)	4' x 2' RC Box	Cherry Creek Trail
	Grouted boulder drop structures	Red Hawk Elementary School
	10' x 5' Box Culvert	Cherokee Trail
	3- 132" x 172" Box Culverts	S. Parker Rd.
	Culvert Crossings	Across and/or along Yampa St., Hinsdale Ave., Telluride Ct., Richfield St., and private drives
Kragelund Tributary (K)	22' x 8' Box Culvert	Crossing S. Parker Rd. at Kragelund Acres
17 Mile Tributary (17)	2- 48" RCP	S. Parker Rd.
	2- 48" RCP	Driveway at 17 Mile House

2.4 Flood History

This Master Plan lies within the FEMA Flood Insurance Rate Maps for Arapahoe County, Map Number 08005C, map panels 0476L, 0477L, 0181K, 0481L, and 0484L revised February 17, 2017, and Map Number 08005C, map panel 0483K revised December 17, 2010. None of the project tributaries are mapped on the effective FIRM panels. SEMSWA noted that a number of homeowners in the Valley Club Acres neighborhood (located along the North Arapahoe Tributary) reported that their crawl spaces had been flooded as a result of the heavy rainfall in the area on June 17th, 2019. The heavy rainfall guidance indicated up to 2.07 inches of rain were possible that day. There was no other statistical or anecdotal flood history available during the preparation of this Master Plan.

2.5 Environmental Assessment

See complimentary Major Drainageway Plan Report for Environmental Assessment.

3.0 HYDROLOGIC ANALYSIS

3.1 Overview

The hydrologic analysis presented herein was developed independent of the 1999 OSP and no existing model input files were recreated or available for use. Basins were delineated using 1-foot LiDAR data described in **Section 1.4**. Shapefiles for notable infrastructure such as road networks and storm conveyance systems were also used to logically subdivide major basins at points of interest. The analysis identifies drainage patterns and runoff characteristics for the following 9 storm events: the 1-, 2-, 5-, 10-, 25-, 50-, 100-, 500-year and water quality (WQ) storm events. Land use was analyzed for existing and future conditions and the resultant hydrology is the foundation for the subsequent evaluation of drainage facilities and the systemwide level of service.

The Colorado Urban Hydrograph Procedure program (CUHP) 2016 version 2.0.0 was used to develop runoff hydrographs which were then routed using the EPA Storm Water Management Model (EPA SWMM) version 5.1 to account for the effects of storm sewer, stream reaches, and detention on lag and time to peak. Input data for CUHP is subwatershed specific and includes rainfall depth, watershed area, distance to centroid, length of flow path, slope, composite imperviousness, and depression storage and soil infiltration rates. This data was obtained through GIS analysis and project research to accurately model individual sub-basin conditions. Values are in accordance with recommendations provided by the MHFD and CUHP manuals.

The baseline project hydrology for the study utilizes the future land use conditions model and the subsequent sections provide a summary of the information utilized to quantify the peak runoff values. The summary includes design rainfall, sub-watershed characteristics, hydrograph routing and the results of the analysis. Hydrologic calculations were approved by MHFD on February 4, 2019.

3.2 Design Rainfall

Design rainfall depths for the for the 1-, 2-, 5-, 10-, 25-, 50-, 100- and 500-year storm events were obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 (Volume 8, Version 2) Point Precipitation Frequency Estimates. Specifically, the 1-hour and 6-hour recurrence interval rainfall depths were utilized as direct inputs into the CUHP rain gage data. The WQ event is pre-defined, according to the CUHP manual, to be a 0.6 in. rainfall event for the 1-hour duration recurrence interval. None of the project basins exceed ten square miles and therefore no area adjustments to rainfall were required. This study is analyzing the WQ event and the 1-year storm event as part of a MHFD effort to assess WQ and bankfull conditions in the alternatives phase. **Table 3-1** summarizes the 1-hour and 6-hour rainfall depths, and the rainfall distributions developed by CUHP are in **Table B-1**.

Table 3-1 Point Rainfall

	Rainfall Depth (in)	
Recurrence Interval	1-Hour	6-Hour
1	0.721	1.19
2	0.868	1.39
5	1.13	1.77
10	1.37	2.13
25	1.73	2.67
50	2.03	3.13
100	2.36	3.63
500	3.21	4.96

3.3 Subwatershed Characteristics

Subwatershed Delineation

The 11 tributary basins are comprised of 44 subwatersheds. Each is shown on the subwatershed layer with the Baseline Hydrology Map in **Figure B-1**. The sub-basin sizes range from 21.8 to 140.0 acres, with the average value being 99.0 acres. The major basin boundary for each tributary was verified by evaluating LiDAR data, stormwater infrastructure, roadways, and field reconnaissance. Additional review of approved Drainage Reports, Construction Drawings, and As-Built Drawings within the Project Area further informed the development of the models. Where there is overlap, the basin delineation is reasonably comparable to the 1999 OSP. However, the sub-basin naming convention is fully independent and conforms to the tributary in which they are located, as follows:

Little Raven Creek: LR1 – LR3

Suhaka Creek: S1 – S3

Joplin Tributary: J1 – J8

Grove Ranch Tributary: GR1

Valley Club Acres Tributary: VCA1 – VCA2

North Arapahoe Tributary: NA1 – NA4

South Arapahoe Tributary: SA1 – SA4

Chenango Tributary: C1 – C9

Kragelund Tributary: K1 – K7

17 Mile Tributary: 17A – 17B

Reference the *Subwatershed Boundaries Map* layer of the Baseline Hydrology Map in **Figure B-1** for the locations and delineations of the CUHP sub-basins.

Numerous physical characteristics associated with each subwatershed are used to produce a storm runoff hydrograph for each subwatershed in CUHP. The hydrograph outputs from CUHP are saved in a tabular format to a text file that is then used as the Inflow file for SWMM. These hydrographs represent the overland flow for each subwatershed which are represented as nodes in SWMM. The CUHP input parameters that define the hydrograph for each subwatershed include the following and are further detailed in **Table B-2** located in Appendix B**.**

Drainage area (acres)

Length and Distance to Centroid (ft)

Watershed Slope (ft/ft)

Composite Imperviousness (%)

Horton's Soil Infiltration Rates

Depression Losses/Retention Storage Values

Watershed Imperviousness

Watershed imperviousness was determined using land use maps, zoning data, and aerial imagery. Most of the tributary watersheds are almost fully developed; therefore, the watershed imperviousness developed for 9 of the basins is considered future conditions (i.e. existing conditions = future conditions). The weighted average future percent imperviousness for all the studied basins is 33%. Existing watershed imperviousness was evaluated for the 17 Mile Tributary and the Kragelund Tributary only, since these basins are largely undeveloped at the time of this study. The weighted average existing percent imperviousness for each basin is 8% and 14%, respectively. King's Point, a planned development in the area, is anticipated to build out these basins east of S. Parker Rd. in the near future; the associated increase in imperviousness to 36% and 35% is reflected in the future conditions hydrology. For further description regarding how land use was used to determine subwatershed imperviousness, refer to **Section 2.2**.

3.3.1 NRCS Soil Information

Soil conditions for each subwatershed were used as CUHP inputs to determine the infiltration rates based on Horton's Equation. Data for soils was collected from the National Resources Conservation Service (NRCS) Web Soil Survey (USDA, 2018) and corresponding hydrology soil groups (HSG) were determined for each soil type. The 4 HSG types are A, B, C and D, with Type A having the highest infiltration rate and thus lowest runoff potential, and Type D have very low infiltration rates and high runoff potential. Soils in the overall Project Area are classified as: 11.8% Type A, 44.9% Type B, 20.6% Type C, and 22.7% Type D. HSG types and corresponding Horton values, including initial and final infiltration rates (in/hr) and decay coefficients (s^{-1}), were taken from *Table 6-7 Recommended Horton's equation parameters* in the MHFD Criteria Manual Volume 1. To determine composite Horton's parameters for each subcatchment for CUHP determination of infiltration rates, an area-weighted average was used. Refer to **Table B-2** in Appendix B for a summary of the resultant Horton's parameters and the Soils Map layer in **Figure B-1** for a map of the hydrologic soil groups. For Baseline Hydrographs, refer to **Figure B-4** in Appendix B.

3.4 Detention

Two regional detention facilities are included in the baseline hydrology EPA SWMM model: Pond RB1-4 on Joplin Tributary and North Arapahoe (NA) Pond on the North Arapahoe Tributary. North Arapahoe Pond serves the developments from Farm Filing No. 7, 8 & 9 where it is referred to as "Pond E". Both are publicly-owned and MHFD maintenance-eligible and are herein referred to as Pond RB1-4 and NA Pond. Detention rating curves for both were sourced from engineering reports, record drawings, and survey data that are on file with the project sponsors.

Pond RB1-4, which is owned and maintained by SEMSWA, is an on-line pond located on Joplin Tributary between E. Crestline Ave. and S. Joplin Way. The detention rating curves were developed from a stage-storage-discharge table located in the as-built drawings prepared for East Cherry Creek Valley (ECCV) Water and Sanitation District on April 28, 1994 (Muller Engineering Co., Inc., 1994). The as-built data is assumed to be correct and supersedes data presented in the approved drainage report "Cherry Creek Basin RB1 Drainage Improvements" dated November 1989 (Muller Engineering Co., Inc., 1989). The as-built stage-storage curve was back-checked using 2014 LiDAR 1-foot contours; the final stage-storage curve incorporates additional data points from the 2014 LiDAR and the same total storage volume as the 1994 as-builts. Refer to **Table B-3** in Appendix B for the Pond RB1-4 stage-storage-discharge curves.

NA Pond, also owned and maintained by SEMSWA, is not located on the main stem of the NA Tributary, however, sits on-line a tributary of North Arapahoe and serves Filings No. 7, 8 & 9 of the Farm at Arapahoe County. Detention rating curves were originally obtained from as-built drawings prepared on May 4, 2000 (Aztec Consultants & P.R. Fletcher & Associates, Inc., 2000) and the Phase III Drainage Erosion & Sedimentation Control Report dated 15, 1999 (P.R. Fletcher & Associates, Inc., 1999). However, it was noted that the 2014 LiDAR indicated that the total storage volume quoted in the as-builts was larger than physically feasible. Therefore, new stage-storage-discharge curves were calculated using survey data collected by the MHFD in February 2019. The new storage volume was calculated from the survey using the average-end area method and totaled 4.9 acre-feet as compared to the 2000/1999 volume of 11.1 acre-feet, at an elevation of 5772 feet (approximate top of berm). The UD-Detention spreadsheet (Version 3.07, Released February 2017) was used to estimate a new stage-discharge curve according to the surveyed outlet configuration. See **Table B-3** in Appendix B for the NA Pond stage-storage-discharge curves and calculations.

Neither of the 2 detention facilities was designed to detain the 500-year flow; therefore, additional points were added in the EPA SWMM model to both the stage-storage and stage-discharge curves, which minimally modifies the total storage volume but allows the 500-year maximum flows to pass without flooding model nodes.

3.5 Hydrograph Routing

Hydrograph routing for each subwatershed through the Cherry Creek Minor Tributary basins was modeled using EPA SWMM 5.1 and the Kinematic Wave routing method. The routing scheme described in this section applies to both existing and future conditions, as no changes to hydrologic routing is anticipated. Refer to the *Baseline Hydrology SWMM Routing Map* layer in **Figure B-1** and **Figure B-3** in Appendix B for a visual representation of the routing scheme. Summarized input and output files from EPA SWMM are included in **Table B-5** and **Table B-6**.

Each subwatershed is represented in EPA SWMM by a junction node with an invert elevation reflecting the lowest point in the subwatershed. Overland flow within each basin is routed via a conduit link labeled "SUB_OF" and contains no geometry or physical information additional to that reflected in the hydrograph output produced by CUHP. Design points are represented by junction nodes and contain the invert elevation found at that location, and these elevations dictate the slope of any attached link that represents open channel, stormwater sewer, or overflow conveyance elements. These links are labeled "SUB_OC", "SUB_SS", and "SUB_OVF", respectively.

Channel characteristics and the associated SWMM routing elements were estimated using topographic contours, aerial photography, GIS and plan data, and site visits. Stormwater infrastructure shapefiles from SEMSWA and the City of Aurora were the primary source of information for conduit shape, maximum depth, length, and material. For conduit lengths that included several pipe sizes, an average size was selected for the SWMM link. Lengths were estimated using ArcGIS in the *NAD 83 Colorado State Plane, Central Zone* projected coordinate system. Most stormwater sewer conveyance elements were reinforced concrete, which corresponds to a Manning's roughness coefficient of 0.013 and translates to a value of 0.016 for CUHP-connected models.

To obtain cross-section geometry for open channels, approximate sections were drawn using GeoHECRAS version 2.1.0.17569. Using this program and 2014 LiDAR elevation data, a total of 6 different 4-point channel geometries were established based on open channels studied in subwatersheds LR2, J3, SA2, C4, K4, and 17A. Each open channel conduit modeled corresponds to one of these geometries depending on similar geometry. Manning's roughness coefficients were estimated for each subwatershed using *Equation 6-8* from the MHFD Criteria Manual Volume 1. This equation suggests that Manning's roughness coefficient for open channels is directly proportional to the slope of the channel and inversely proportional to the hydraulic radius. FlowMaster V8i was used iteratively at various flow rates (cfs) to solve for the hydraulic radius and Manning's roughness coefficient for 5 slope cases: 1%, 1.5%, 2%, 2.5%, and 3%. Key tables were developed for each channel geometry and these tables were used for each conduit link to select a coefficient appropriate for the slope and channel shape. It should be noted that this determination was made using the original 8-point channel geometry determined for the 6 shapes; however, the geometries used for the SWMM conduits were reduced to 4 points to allow for hydrograph convergence. And finally, the open channel lengths and alignments were estimated using ArcGIS and 1-foot LiDAR-sourced contours.

To eliminate nodal flooding during larger storm events, 12 divider nodes were included at the following junctions: Lewiston_J, Laredo_J, Shalom_J, Fair_Place_VCA, Parker_T1, Waco_NA, Buckley_NA, Parker_NA, NA_M130, Parker_SA, NA_SA_S125, and NA_SA_S123. These nodes were assigned cutoff flow values just before surcharging and direct overflow to a secondary dummy link created to convey the entire flow downstream.

Finally, detention ponds were modeled using storage unit nodes with downstream outlet links. Each storage node and outlet link used a tabular stage-storage curve and stage-discharge curve as described in **Section 3.4**.

3.6 Previous Studies

Two sources of previous hydrologic analysis are available for the Cherry Creek Minor Tributaries to-date. The first is the 1999 Cherry Creek Corridor Reservoir to County Line Outfall Systems Plan (WRC Engineering, Inc., 1999). This is a regional study that provides a limited number of common design points for reference and comparison. The second source is individual site drainage reports. Drainage reports were referenced only where necessary for the modeling of regional detention ponds, as discussed in **Section 3.4**.

3.7 Results of Analysis

Peak flow rates for the existing and future land use conditions models were established at design points after incorporating the rainfall data, hydrologic characteristics, and drainage conveyance parameters within EPA SWMM. The basin-wide peak flow rate and volume results at each of the design points along the stream corridor for the WQ, 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year storm events are presented in Appendix B with key points shown in **Table 3-2**.

A summarized input and output file from the EPA SWMM version 5.1 model are included in Appendix B. These files provide the detailed information regarding subwatershed hydrologic input and the resulting hydrograph routing and peak flows. As noted earlier, only Kragelund Tributary and 17 Mile Tributary have existing conditions hydrology.

Following completion of the baseline hydrology in January 2018, additional storm sewer infrastructure data was obtained from CDOT As-Builts for the Arapahoe/Parker interchange project (Federal Aid Project No. STU 0831-107 dated May 9, 2012). These plans depict existing storm sewer lines that were not included in the municipal GIS shapefiles used to inform the original baseline hydrology modeling. In an effort to better characterize urban flooding on Arapahoe Road and within Valley Club Acres, the baseline hydrology

SWMM model was revised to reflect the 2012 CDOT plans. The outputs documented in the text and appendices of this report have been updated to reflect these revisions.

As a result of the 2012 CDOT plan modeling revisions, it was determined that the majority of North Arapahoe Tributary is redirected to South Arapahoe just upstream of S. Parker Road via a 48" RCP. The capacity of the 48" RCP is exceeded by the 100-year, resulting in approximately 200 cfs of overflow which would continue as street flow under the interchange on the north side of the road. Assuming this water can re-enter the storm system, all of this overflow fits within the capacity of an existing pipe that begins on the northwest corner of the Parker interchange and continues to Cherry Creek. North Arapahoe flow contained within the 48" RCP is routed to a 54" RCP that runs parallel to a second 54" RCP that serves South Arapahoe Tributary. The 54" RCPs combine on the west side of S. Parker Road into an 8' x 6' box that transitions quickly into a larger 12' x 6' box. The parallel 54" RCP sections overflow in the 100-year by approximately 150 cfs and the 12' x 6' box overflows by approximately 56 cfs.

Table 3-2 Peak Flows at Key Design Points

Basin	Location	Design Point	Existing (cfs)			Future (cfs)		
			Q_5	Q_{25}	Q_{100}	Q_5	Q_{25}	Q_{100}
Little Raven Creek (LR)	Outfall to Reservoir	LR_outfall	-	-	-	72	253	454
	E. Belleview Ave.	Belleview_LR	-	-	-	86	242	404
Suhaka Creek (S)	Cottonwood Creek Confluence	S_outfall	-	-	-	65	238	423
Joplin Tributary (J)	Outfall to Cherry Creek	J_outfall	-	-	-	173	348	613
	S. Parker Rd.	Parker_J	-	-	-	182	331	535
	RB1-4 Pond Outflow	out_RB1-4_pond	-	-	-	110	205	352
	RB1-4 Pond Inflow	RB1-4_pond	-	-	-	146	345	570
Grove Ranch Tributary (GR)	Outfall to Cherry Creek	GR_outfall	-	-	-	43	96	150
Valley Club Acres Tributary (VCA)	Outfall to Cherry Creek	VCA_outfall	-	-	-	83	211	349
North Arapahoe Tributary (NA)	Outfall to Cherry Creek	NA_outfall	-	-	-	0	0	191
	S. Buckley Rd.	Buckley_NA	-	-	-	45	150	325
South Arapahoe Tributary (SA)	Outfall to Cherry Creek	SA_outfall	-	-	-	148	455	717
	S. Parker Rd.	NA_SA_123	-	-	-	115	389	606
Chenango Tributary (C)	Outfall to Cherry Creek	C_outfall	-	-	-	112	478	942
	S. Parker Rd.	Parker_C	-	-	-	96	436	857
Tagawa Tributary (T)	Outfall to Cherry Creek	T_outfall	-	-	-	14	52	105
Kragelund Tributary (K)	Outfall to Cherry Creek	K_outfall	49	308	626	151	478	859
	S. Parker Rd.	Parker_K	50	307	615	149	472	839
	Tributary Confluence	Confluence_K	36	181	334	121	309	505
17 Mile Tributary (17)	Outfall to Cherry Creek	17_outfall	8	84	169	52	155	267
	S. Parker Rd.	Parker_17	6	70	141	47	135	229

Table 3-4 compares the results of the 1999 OSP with the results of this Master Plan, where applicable, for future conditions hydrology. The tributaries have only a handful of comparable points and not all of the tributaries were studied in the 1999 OSP (WRC Engineering, Inc., 1999). Several variables in this Master Plan differ from the 1999 OSP. Each of these variables affected the hydrology of the tributary basins to a different degree and therefore no overall trend exists of the change in peak flows. However, a unit discharge comparison, as shown in **Table 3-4**, indicates that both studies resulted in similar volumes of runoff per acre.

Notable items that differ between the 1999 OSP and this Master Plan are summarized below.

- Little Raven Creek, Suhaka Creek, and Joplin Tributary were not studied in the 1999 OSP.
- Compared to the 1999 OSP, the rainfall depths used in the current MDP are lower, except for the 1-year storm event. The 100-year 1-hour rainfall depth used in the 1999 OSP was 2.67 inches, as opposed to 2.36 inches used in this study.

Table 3-3 Rainfall Depths, 1999 OSP vs. MDP

Recurrence Interval	1-Hour Point Rainfall Depth (in)	
	1999 OSP	2019 MDP
1	0.4	0.721
2	0.97	0.868
5	1.38	1.13
10	1.65	1.37
50	2.32	2.03
100	2.67	2.36

- Residential land use east of S. Parker Rd. between E. Arapahoe Rd. and the southern boundary of the County was estimated as 5% and 8% vs. 20% in this Master Plan. This impacts most of the Chenango Tributary, Tagawa Tributary and South Arapahoe Tributary basins. Additionally, the 1999 OSP estimated the future King's Point development would increase existing imperviousness to 50% as opposed to the single-family land uses of 30% and 45% used in this study.
- With the benefit of a more refined data set, the variables used in this study's hydrologic analysis lead to a more detailed and comprehensive basin-wide examination. This study prepared a model with more detailed routing by identifying storm sewer drainage versus overland flow. Additionally, Manning's roughness coefficients were estimated using *Equation 6-8* from the MHFD Criteria Manual Volume 1, which resulted in overall higher values than those used in the 1999 OSP, but values that are more appropriate for hydrologic routing. Both of these factors result in differences in the timing of the storm hydrographs and, ultimately, the calculated peak flows.

Table 3-4 100-year Peak Flows, 1999 OSP vs. Current MDP

Basin	Design Point		Future Q_{100} (cfs)		Basin Area (acres)		Unit Discharge (cfs/acre)		Notes
	1999 OSP	2020 MDP	1999 OSP	2020 MDP	1999 OSP	2020 MDP	1999 OSP	2020 MDP	
Valley Club Acres Tributary (VCA)	164	Fair_Place_VCA	486	349	262.2	207	1.85	1.69	
North Arapahoe Tributary (NA)	n/a	Buckley_NA1	n/a	325	n/a	272	n/a	1.19	OSP combined North and South Arapahoe basins
South Arapahoe Tributary (SA)	126	Parker_SA	599	321	603.2	326	0.99	0.98	
Chenango Tributary (C)	112	Bridle_Trail_C	533	412	308.6	321	1.73	1.28	
Kragelund Tributary (K)	102	Confluence_K	453	505*	300.2	257	1.51	1.96*	*Existing is 334 cfs @ 1.30 cfs/acre
17 Mile Tributary (17)	108	Parker_17	171	229*	125.6	124	1.36	1.85*	*Existing is 141 cfs @ 1.14 cfs/acre

The following text notes the level of compatibility for comparison between design nodes found in the 1999 OSP versus design nodes used in this study. Unit discharges have been included in **Table 3-4** as an alternate form of comparison given the many variables that vary between this Master Plan and the 1999 OSP.

- The stakeholder interests along Grove Ranch Tributary are to address redevelopment within the lower reaches of the basin, identify the conveyance path, and identify the outfall to Cherry Creek. Therefore, the Grove Ranch Tributary is delineated as a single sub-basin downstream of S. Parker Rd. with its outfall located at Cherry Creek. The 1999 OSP does not provide adequate delineation downstream of S. Parker Rd. Its most useful design point is upstream of S. Parker Rd. at DP109, where the 100-year future conditions flow is reported as 77 cfs. Therefore, no comparison is made.

- Valley Club Acres is compared at design point 164, which is slightly upstream from the confluence with Cherry Creek. The next downstream design point is within the main stem of Cherry Creek and therefore, includes other upstream basins. Due to basin transfers, basin 57 - that was previously modeled as part of North Arapahoe (NA) Tributary - is modeled with Valley Club Acres Tributary in this study. A comparison is made, but it is not a direct correlation.
- The Chenango Tributary and Kragelund Tributary have common design points at the respective basin outfalls to Cherry Creek, as identified in **Table 3-4**.
- The 17 Mile Tributary is modeled with the 1999 OSP. However, a review of Figure A-6.2 in that report indicates that it was not routed to a design point. OSP basin 8 is upstream of S. Parker Rd. and therefore, it is assumed to be comparable to the design point listed in **Table 3-4**.

4.0 HYDRAULIC ANALYSIS

Several of the tributaries in this study are comprised of little to no open channel or were excluded from the FHAD by the project sponsors. The tributaries included in the FHAD are as follows: Little Raven Creek (LR), Joplin Tributary (J), South Arapahoe Tributary (SA), Chenango Tributary (C), Kragelund Tributary (K). These tributaries are shown in bold in **Table 2-1** and **Table 2-2**.

Flood Hazard Area Delineation (FHAD) hydrology is typically based on existing infrastructure and future land use conditions. For the Kragelund and 17 Mile Tributaries, the 100-year peak discharge for future land use conditions is greater than 30 percent (threshold established by FEMA) higher than the 100-year peak discharge for existing land use. Therefore, existing conditions hydrology was prepared for Kragelund and 17 Mile Tributaries and Kragelund Tributary's delineation is required to use existing land use conditions hydrology. 17 Mile Tributary is not included in the FHAD analysis. The other four FHAD tributaries were analyzed using the typical future land use conditions hydrology.

A one-dimensional (1D) hydraulic model was developed for each of the 5 tributaries included in the FHAD using the U.S. Army Corps of Engineer's HEC-RAS, Version 5.0.7. Cross-sectional profiles were populated electronically using a DEM (provided by MHFD) developed from the 2014 post-flood USGS topographic LiDAR. Major crossings were individually surveyed in the field by Wilson & Co. The models were run using a sub-critical regime in accordance with the floodplain mapping criteria. River centerlines were determined by tracing the low flow path for each tributary. All models are included in the Technical Appendix.

Flow data in the model came from the results of the EPA SWMM 5.1 hydrograph routing, as outlined in **Section 3.5.** A steady flow analysis was used to determine the flood profiles for the 10-, 25-, 50-, 100-, and 500-year storm events. All models reflect existing infrastructure and future flows, except Kragelund which reflects existing infrastructure with existing flows. Stakeholders agreed it should be existing flows because future flows won't be achieved due to detention requirements for future developments. Flow change locations were established at critical design points where there are significant changes in hydrology, as determined by the EPA SWMM model. The downstream boundary conditions for the Little Raven Creek and Joplin Tributary models were normal depth computations with a slope of 0.01. For the Chenango Tributary and Kragelund Tributary models, the downstream hydraulic controls were set to the 10-year flood elevation of Cherry Creek per MHFD guidelines. The South Arapahoe Tributary model was set to a known water surface elevation based on the headwater elevation of each flood profile at the Lewiston Way culvert crossing. Since the models were run in sub-critical, no upstream boundary conditions were specified in any of the models. Roughness values were chosen using USDCM Table 8-5 and Equation 9-1. Manning's n values were estimated for existing conditions using aerial imagery and Google street view and ranged from 0.05-0.16, shown in **Table 4-1**. Photographs of typical channel sections used to determine Manning's n values are included in Appendix C. In lieu of conveyance obstructions, areas with overland flow across residential and commercial areas use a higher Manning's n value to account for reduced flow around buildings. Ineffective flow areas were used to account for flow areas with little or no flow conveyance.

Table 4-1 Roughness Values

Category	Roughness Value
Native Grasses	0.05
Willow Stands	0.16
Herbaceous Wetlands	0.12
Housing/Commercial	0.1-0.2
Turf Grass	0.04
Fences	0.1

The Kragelund Tributary model contains a lateral weir structure from cross-section 1812 to 2101. There is shallow flooding occurring at this location, so the lateral weir structure was used to contain these cross-sections. A two-dimensional (2D) hydraulic model was used to model the shallow flooding beyond the lateral weir. Flows applied to the 2D model were estimated by the lateral weir structure for the 100-year and 500-year events.

A draft model was prepared for the North Arapahoe Tributary, which consists of shallow roadway flooding due to limited storm sewer capacity and no open channel. The initial results showed the floodplain to be contained within the right-of-way and therefore it was determined that a FHAD would not be appropriate. This draft model is included in the Technical Appendix as supplemental information only.

The floodway was defined for each tributary to establish the portion of the channel that must remain free from obstruction for effective conveyance of the 100-year flood. The floodway was defined using a 0.5-foot allowable rise in the Energy Grade Line (EGL) and the Hydraulic Grade Line (HGL). The floodway was delineated so that the encroachments were evenly distributed to the fullest extent possible.

Shallow flooding areas were identified at South Arapahoe Tributary crossing Arapahoe Road and Kragelund Tributary west of Parker Road. The South Arapahoe Tributary only included 500-year shallow flooding and Kragelund Tributary included 100- and 500-year shallow flooding. Two separate 2D HEC-RAS models were created of each tributary to model these areas and determine the shallow overland flow depth. Auto-delineation of the shallow flooding for both tributaries was exported from HEC-RAS and is shown on the flood maps.

Flood maps showing the 100-year, 500-year, and Floodway delineations are shown in Appendix E and identify areas, structures, and properties which have the potential of being inundated by the 100-year flood event. Flood profiles for the 10-, 25-, 50-, 100-, and 500-year events are shown in Appendix F. Locations of cross-sections and all hydraulic structures are shown on both the flood maps and profiles. The Floodplain and Floodway Data Table is shown in **Table D-1**. This table identifies the cross-sections;

channel thalweg elevations; 10-, 25-, 50-, 100-, and 500-year discharges and water surface elevations; 100-year floodplain top widths and EGL elevations; and the floodway water surface elevation, top width, cross-sectional area and velocity. The Agreement Table is shown in **Table D-2** and serves as quality control to ensure that data from the flood maps, flood profiles, and models agree. Each cross-section is listed in this table and compares the distance between cross-sections, the cumulative distance, floodplain and floodway top widths, and water surface elevations.

4.1 Evaluation of Existing Facilities

At each roadway crossing, a detailed survey of existing conveyance structures within the Project Area was provided by MHFD. Included with the survey were site photos, sketches of the entrance and outlet, detailed characteristics of the culvert's shape, size, length, inverts, overtopping elevations, and headwall/wingwall end treatments (if applicable). Photos of each crossing are included in Appendix C. **Table 4-2** summarizes the inventory of the existing facilities with the general capacity of each structure. Only structures determined large enough to be modeled are listed in **Table 4-2**. All modeled tributaries and structure capacities are based on future conditions hydrology except for Kragelund Tributary which uses existing conditions hydrology. There are 20 existing crossings between the 5 tributaries, 15 of them are included in the HEC-RAS models, all of which are culverts. Culvert capacity was evaluated using peak flows obtained from the study's hydrology.

4.2 Flood Hazards

The Project Area mostly consists of residential land use. There are small pockets of office, commercial, and industrial developments present, primarily along the major local thoroughfares. Large portions of Little Raven Creek, Suhaka Creek and Joplin Tributary basins are located within the Cherry Creek State Park.

If a 100-year flood occurred without any future improvements, a total of 17 structures would experience some level of flood inundation. Only three tributaries included in the FHAD have insurable structures in the 100-year floodplain: Little Raven Creek, Chenango Tributary, and Kragelund Tributary. Little Raven Creek has 3 residential structures and Chenango Tributary has 4 residential structures in the 100-year floodplain. Kragelund Tributary has 10 insurable structures in the 100-year floodplain; 9 of them are residential and 1 is commercial. The commercial structure is located within the 100-year shallow flooding. The Flood Maps in Appendix E show all insurable structures within the 100-year floodplain. The jurisdictions where the insurable structures are located are listed below:

- Little Raven Creek – 3 insurable structures located in unincorporated Arapahoe County
- Chenango Tributary – 4 insurable structures located in Town of Foxfield
- Kragelund Tributary – 10 insurable structures located in City of Centennial

Table 4-2 Existing Facilities

Jurisdiction	Location	Survey Number	Crossing Type	Size	General Capacity
Little Raven Creek (LR)					
Greenwood Village	E. Belleview Avenue	42	Culvert	54" RCP & 66" x 48" HERCP	100 yr
Arapco	Park Trail	43	Culvert	48" RCP	< 10 yr
Joplin Tributary (J)					
Arapco	S. Parker Road	33	Culvert	2-14.2' x 4.1' RCBC	500 yr
South Arapahoe Tributary (SA)					
Foxfield	S. Norfolk Court	25	Culvert	42" CMP	10 yr
Foxfield	S. Buckley Road	24	Culvert	2-66" CMP	100 yr
Foxfield	S. Pitkin Street	23	Culvert	60" CMP	50 yr
Chenango Tributary (C)					
Arapco	S. Cherokee Trail	20	Culvert	22.5' x 5.7' RCBC	500 yr
Arapco/ CDOT	S. Parker Road	19	Culvert	2-11' x 6' RCBC & 14' x 6' RCBC	500 yr
Foxfield	E. Hinsdale Way	18	Culvert	54" CMP	< 10yr
Foxfield	S. Richfield Street	11	Culvert	2-30" CMP	< 10 yr
Foxfield	S. Telluride Court	9	Culvert	3-30" CMP	< 10 yr
Foxfield	Private Drive	8	Culvert	30" CMP	< 10 yr
Foxfield	S. Yampa Street	4	Culvert	2-30" CMP	< 10 yr
Centennial	E. Hinsdale Avenue	46	Culvert	84" CMP	100 yr
Kragelund Tributary (K)					
Centennial	S. Parker Road	3	Culvert	22' x 7.4' RCBC	500 yr*

*Existing Conditions

4.3 Previous Analyses

This FHAD lies within the FEMA Flood Insurance Rate Maps for Arapahoe County, Map Number 08005C, map panels 0476L, 0477L, 0181K, 0481L, and 0484L revised February 17, 2017, and Map Number 08005C, map panel 0483K revised December 17, 2010. None of the project tributaries are mapped on the effective FIRM panels nor have been mapped by local studies. Therefore, comparisons between previous floodplain delineations cannot be made.

5.0 REFERENCES

Aztec Consultants & P.R. Fletcher & Associates, Inc. (2000). *The Farm at Arapahoe County Filing No. 7.* The Farm Development Company & Arapahoe 114, LLC.

Muller Engineering Co., Inc. (1989). *Cherry Creek Basin RB1 Drainage Improvements - Final Design Report.* ECCV Water and Sanitation District.

Muller Engineering Co., Inc. (1994). *Basin RB1-Pond 4 Drainage Improvements.* ECCV Water and Sanitation District.

P.R. Fletcher & Associates, Inc. (1999). *Phase III Drainage Report Erosion & Sedimentation Control Report for The Farm at Arapahoe County Filings 7 & 8.* The Farm Development Company & Arapahoe 114, LLC.

P.R. Fletcher & Associates, Inc. (2000). *The Farm at Arapahoe County Filing No. 9.*

Urban Drainage and Flood Control District. (2016). *Urban Storm Drainage Criteria Manual Volume 1.*

USDA. (2018). *Custom Soil Resource Report for Arapahoe and Douglas County Area, Colorado.* Retrieved from NRCS Web Soil Survey: https://websoilsurvey.sc.egov.usda.gov

WRC Engineering, Inc. (1999). *Cherry Creek Corridor Reservoir to County Line Outfall Systems.* Urban Drainage and Flood Control District.

APPENDIX A

PROJECT CORRESPONDENCE

MEETING MINUTES

J3 Engineering Consultants
8100 E. Maplewood Ave. #150
Greenwood Village, Colorado 80111
Phone: 303.368.5601
Fax: 303.368.5603

KICKOFF MEETING MINUTES

DATE/TIME: **SEPTEMBER 10, 2018 @ 10:30 A.M.**

LOCATION: **UDFCD OFFICE**

PROJECT: **CHERRY CREEK TRIBUTARIES MDP & FHAD**

ATTENDEES:

Shea Thomas - UDFCD
Richard Borchardt – UDFCD
Stacey Thompson – SEMSWA
Cathleen Valencia – Arapahoe County (Engineering)
Roger Harvey – Arapahoe County (Open Space)
Craig Perl – City of Aurora
Jonathan Villines – City of Aurora
Allie Beikmann – J3 Engineering
Ken Cecil – J3 Engineering

PURPOSE:

1. Project stakeholders and design team introductions
2. Review stakeholder known issues and project goals
3. Review project opportunities
4. Review project Scope & Schedule
5. Name the Unnamed Tributaries

DISCUSSION ITEMS:

1. Shea provided an overview of the revised Master Planning Process, which separates the project into four distinct phases beginning with Baseline Hydrology, then FHAD for the identification of flood risks, then alternatives analysis and concluding with conceptual design.
2. The three named tributaries were previously studied with the prior 1999 OSP. The unnamed tributaries have not been previously studied.

3. Additional tributaries that were not identified in the RFP were reviewed and added. These include:
    a. Tributary just west of northerly unnamed tributary
    b. Tributary just south of Arapahoe Road, with apparent Foxfield Drainage Basin.
    c. Note: Three tributaries just east of northerly tributary (Part of Cherry Creek Vistas) were noted as being part of Cottonwood Creek basin and therefore, not to be included with this study.
    d. If adding additional reaches, UDFCD may amend the contract on a dollar/foot of additional reach length.
4. SEMSWA is supportive of adding the 17-Mile House tributary, the Arapahoe/Parker interchange tributary, and would recommend including the easternmost of the northerly Unnamed Creek tributaries since it is open channel (the one that is UDFCD Maintenance Eligible).
5. UDFCD will review the DRAFT stream layer to verify the above additional tributaries, and any others that may have been missed. The following discussion includes what may result in additional tributaries to be included, or at least problem areas that require further investigation.
6. Stacey identified an area of concern for SEMSWA that is near E. Fair Place, just north of Valley Club Acres Tributary. It needs to be investigated if this area, informally referred to as the area tributary to Grove Ranch, should drain to Valley Club Acres Tributary. The land use case is called “Legends at Centennial” and is a congregate care facility. The Fellowship Community Church sold a portion of their parcel that is now in process with SEMSWA undergoing development review. The development plan is to discharge on-site detention pond flows into the Church retention pond. The viability of the Church retention pond is also in question. SEMSWA will provide additional data regarding this specific challenge.
7. Cathleen identified area south of the southerly unnamed tributary which drains to and across a portion of the 17 Mile House property and requested that it be included with this Master Plan. This area may have been studied in the 1999 OSP but may need to be added to this scope of work to address flooding problems at 17 Mile House. Roger noted that Arapahoe County Open Spaces has developed a 17-Mile House Farm Park Master Plan, but improvements have not been analyzed.
8. Shea requested local sponsor feedback whether or not resultant floodplains are to be mapped by FEMA or remain as CWCB regulated only. Jon indicated it depends on the study findings.

Stacey indicated that SEMSWA will be consistent with other regulated tributaries within their jurisdiction.

9. Cathleen asked if the study would identify funding and Shea stated that the study would only provide cost estimates broken down by jurisdiction.
10. Rich stated that he has received a call from the Townhomes (Pioneer Hills) adjacent to Joplin Tributary regarding erosion and asked that this study verify this statement. Ken confirmed that the channel is incised with sharp bends and active erosion.
11. Ken indicated that J3's cursory review during the proposal phase indicated that few detention or water quality facilities had been observed and that the Cherry Creek Basin Water Quality Authority may be interested in adding additional water quality to these tributaries. Shea will contact Cherry Creek Basin Water Quality Authority during the Alternatives Analysis phase to discuss water quality and their potential participation.
12. Jon would like to include an analysis of flow rates and velocities for roadway overtopping conditions. Shea said this would part of the Alternatives Analysis phase.
13. Shea requested local sponsor input regarding any known detention ponds. Rich mentioned the Belleview Pond, but only if the project will incorporate this tributary. Ken mentioned RB1-Pond 4 within Joplin Tributary. Rich and Shea confirmed that it is UDFCD maintained and that it should therefore be included with the baseline hydrology. The pond near the Arapahoe/Parker Roads Interchange was also identified as one that receives maintenance. Shea and Rich agreed to look for any information that UDFCD may have for this tributary or will otherwise contact CDOT for additional information.
14. A discussion regarding data collection and areas requiring further research followed and covered the following topics:
    a. Future Land Use Data – Aurora has made available all future land use data available for retrieval. J3 familiar with this data. Cathleen referenced the 2018 Comp Plan for the County and Stacey will verify what is available for the City of Centennial.
    b. Shea will provide 1-foot topography; will also initiate the structure survey once all of the additional reaches are identified that are to be included with this study.
    c. Aurora will provide site plan for Kings Point
        i. Shea indicated that Filings No. 1 and 2 show only a temporary pond – no permanent detention. This is not currently an acceptable solution.

    d. Cathleen noted a proposed detention pond near Parker Road that is planned with the King's Point Filing No. 1 Development. It outfalls under Parker Rd. and across the 17 Mile House property. (Note: location of this pond requires clarification – J3 to follow up with Cathleen). Roger noted that we would need to know where flows from the King's Point primary arterial would go.
    e. The southerly unnamed tributary does flow across Parker Road through an apparently adequately sized box culvert but is conveyed overland, and not within a defined channel. The alternatives analysis phase will need to identify a low-maintenance stream section for this reach.
    f. The Cherry Creek Basin Water Quality Authority watershed model was referenced. Rich will contact CCSP to get a better understanding of what that scope of work is so that if necessary, efforts can be coordinated.
15. Shea requested that we meet again in approximately five (5) weeks. Ken to begin scheduling.
16. Follow-up for the website is required.
17. Additional observations by J3 and/or discussion items are summarized below:

SOUTHERLY UNNAMED TRIBUTARY

- Mostly Undeveloped Land
    i. *Stacey made reference to the 17 Mile House Farm Park Master Plan and indicated that Arapahoe County Open Spaces is concerned with conveyance and increased flows from upstream King's Point development across the property. Open Spaces utilizes the property for parking during the Fall Festival.*
- Future Development
- Multiple Smaller Tributaries

CHENANGO TRIBUTARY

- Cherry Creek Valley Ecological Park;
    i. *Rich stated that we may need to consider improvements upstream of trail but in general, this reach appears in good shape.*
    ii. Roger indicated that Arapahoe County Open Spaces would support water quality facilities on the Eco Park property.
    iii. Stacey indicated that there is a large, undeveloped parcel on the west side of S Parker Rd in Centennial that is expected to develop. In addition to low-maintenance stream recommendations, this plan should recommend area to reserve for floodplain.
- Direct outfalls with no apparent water quality
- Lack of regional detention

- 1999 OSP crossings of South Parker Road – Routing impacts
- Rural drainage infrastructure upstream of Parker Road
- Multiple smaller tributaries

JOPLIN TRIBUTARY

- Densely developed basin
- Half of basin is aligned through Cherry Creek State Park;
    - i. *Rich requested that we show Cherry Creek State Park Property on all affected tributaries.*
    - ii. *A Cherry Creek Basin Water Quality Authority Watershed Plan is under development.*
- Active construction through Pioneer Hills Development
- Reach is dominated by wetlands
- Severe right bank erosion;
    - i. *Jon indicated a narrow area between the left bank water quality ponds and the right bank Pioneer Hills Development where the drainageway necks down; the floodplain is likely not contained through this pinch point.*
- Private detention and water quality ponds
- Complex outfall structure downstream of south chambers road
- Aurora and Centennial split easement (72" and 36" RCP)
- RB1-Pond 4
- Regional detention and water quality are not present

VALLEY CLUB ACRES TRIBUTARY

- Southeast Regional Detention Basin – verify;
    - i. *Stacey identified the pond at Northwest of Interchange. More research needed in this area as it is not clear which pond or outfall alternative was constructed.*
    - ii. *Stacey also indicated following the meeting that there is a sub-regional extended detention basin that serves the Centennial Center commercial development (NW corner of Parker/Arapahoe) that appears to tie into the Valley Club Acres outfall system.*
- 12' x 6' RCBC – verify as it impacts basin area
- Drainageway predominantly contained in storm sewer
- Only 600 feet of open channel; all of which are within Cherry Creek Floodplain
- Challenging design will be needed if existing storm is undersized

NORTHERLY UNNAMED TRIBUTARY

- Largely within Cherry Creek State Park
- Regional detention and water quality are not present
- Active bank erosion

Cherry Creek Tributaries MDP & FHAD
Kickoff Meeting Minutes

SCHEDULE

Kickoff Meeting	September 10, 2018
Progress Meeting (+5 Weeks)	TBD
Submit Draft Baseline Hydrology	November 16, 2018
Complete Review of Draft Baseline Hydrology	December 7, 2018
Comment Review Meeting	December 10, 2018
Complete Corrections to Draft Baseline Hydrology	December 28, 2018
Baseline Hydrology Approved	December 31, 2018

ACTION ITEMS

1. UDFCD (Shea) to review DRAFT stream layer to confirm additional tributaries for inclusion.
2. SEMSWA (Stacey) will provide additional drainage information for the area tributary to Grove Ranch Drainage.
3. UDFCD (Shea) to contact Cherry Creek Basin Water Quality Authority during the Alternatives Analysis phase to discuss water quality and potential participation.
4. UDFCD (Shea and Rich) to research additional information that may be available for the pond at the Parker/Arapahoe Road Interchange; this may require contacting CDOT.
5. J3 (Ken and Allie) will obtain as much public land use data that is currently available and request assistance from Stakeholders where necessary.
6. Arapahoe County (Cathleen) will provide J3 with additional information regarding the 2018 Comp Plan.
7. SEMSWA (Stacey) will verify availability of GIS layers for impervious land use areas what land use data from Centennial and provide what is available.
8. Aurora (J3 did not note a specific person) will provide site plan for King's Point
9. J3 (Ken and Allie) will follow up with Cathleen regarding Item 13.d
10. UDFCD (Rich) will contact Cherry Creek Basin Water Quality Authority to better identify the scope of work for their Watershed Master Plan.
11. J3 (Ken) will schedule a progress meeting
12. UDFCD (Rich) will relay website discussion to Shea for direction regarding web-based master plan.
13. J3 (Ken and Allie) will roll out project website in approximately two weeks.

Dewberry | J3
8100 E. Maplewood Ave. #150
Greenwood Village, Colorado 80111
Phone: 303.368.5601
Fax: 303.368.5603

PROGRESS MEETING MINUTES

DATE/TIME: **OCTOBER 23, 2018 @ 3:00 P.M.**
LOCATION: **UDFCD OFFICE**
PROJECT: **CHERRY CREEK TRIBUTARIES MDP & FHAD**

ATTENDEES:
Shea Thomas - UDFCD
Richard Borchardt – UDFCD
Stacey Thompson – SEMSWA
Angela Howard – SEMSWA (phone)
Roger Harvey – Arapahoe County
Craig Perl – City of Aurora (phone)
Jonathan Villines – City of Aurora (phone)
Allie Beikmann – J3 Engineering
Ken Cecil – J3 Engineering

PURPOSE

1. Review Action Item status.
2. Review project progress. See Discussion Item 1.
3. Review stakeholder input for sub-basin delineation. See Discussion Item 3.
4. Review schedule – First deliverable is Draft Baseline Hydrology. See Discussion Item 4.

DISCUSSION ITEMS

1. Ken provided an update regarding the status of action items identified at the project kickoff meeting, with most being complete. Incomplete items pertain to future phases and are not critical at this time. Dewberry | J3 will continue to track and request from assigned attendees at the appropriate time. The remaining items are:

    a. UDFCD (Shea) to contact Cherry Creek Basin Water Quality Authority during the Alternatives Analysis phase to discuss water quality and potential participation.

    b. UDFCD (Shea and Rich) to research additional information that may be available for the pond at the Parker/Arapahoe Road Interchange; this may require contacting CDOT.
    c. J3 (Ken and Allie) will follow up with Cathleen regarding Item 13.d (Detention Pond @ King's Point)
    d. UDFCD (Rich) will contact Cherry Creek Basin Water Quality Authority to better identify the scope of work for their Watershed Master Plan. Rich noted that he will contact Jim Swanson and Chuck Reid to discuss funding opportunities. It was further clarified that the project scope of work will not change based on potential overlap with the Cherry Creek Water Quality Authority. However, a comparison to benefit both studies is the goal.

2. An update of project progress was provided. The project team has been working with UDFCD behind the scenes to increase the project scope of work to include four additional tributaries as requested at the kickoff meeting. This includes critically evaluating the Grove Ranch basin, the Arapahoe Road basin, Cottonwood Basin, and 17 Mile Basin. It was agreed that each of these additional basins will be included with the project.

3. A discussion of the additional basins and their resultant floodplains followed. The results of the baseline hydrology and first look at hydraulics will help inform whether to map the floodplains with CWCB, FEMA, or neither on a tributary basis. A discussion of how to address each stream will be a portion of the comment review meeting agenda.

4. Analyzing the inclusion of the additional basins effectively ended on October 11. Consequently, the design team is approximately 3 weeks behind schedule and requests that the Draft Baseline Hydrology submittal and subsequent milestones be extended to December 7. A draft revised schedule was presented, but it was requested that the schedule be further modified so that the comment review meeting occur after the first of the year. UD approved the revised schedule during the meeting.

5. Shea provided stakeholder feedback regarding additional costs that will need to be funded for the inclusion of the additional tributaries with regard to future phases. This discussion

would be ongoing, but it was requested that that the project team proceed with the study and that funding will be resolved prior to the next phase.

6. Major basin delineation is undergoing internal QA/QC. A brief review of this process was discussed:

    a. Detailed subdivision boundaries are possible by reviewing development plans. It was decided that this level of detail is not warranted and that relying on the one-foot topography is sufficient.

    b. Several areas not within the major basins require further investigation. These areas will be included with the MDP as Direct Flow Areas but will not be included with alternative analysis or concept design.

    c. The Valley Club Golf Course major basin should be validated to ensure that portions of the course are outside of the major basin as shown on the draft meeting exhibit. Rich referenced the 2D model developed by Glenn Hamilton at Muller and that we could request this to help answer the question. However, since most of the golf course is within the floodplain of Cherry Creek, the basin presented in the draft meeting exhibit is appropriate.

    d. E470 Drainage Plans need to be reviewed to clarify whether or not all road drainage is captured within the Southern Unnamed Tributary.

    e. The outfall for the Cottonwood Basin at Peoria is not observable. It may be a silted in culvert. This should be picked up via structure survey.

7. Beginning sub-basin delineation and will rely on comments received at kickoff meeting to help identify logical design points. Additional input regarding known flooding locations or trouble areas was requested but no known areas were identified.

8. Future conditions hydrology is required for all basins. Because the southern two basins are undeveloped, the project team will also evaluate existing conditions hydrology.

9. Shea referenced the Interactive Hydrology Feature and will provide documentation as an example for Dewberry | J3 to follow for the MDP.

10. Open Discussion

Action Items

1. Doodle Poll for Comment Review Meeting (Ken).
2. Provide funding detail to stakeholders (Shea).
3. Stakeholders to resolve funding prior to next project phase (All).
4. Dewberry | J3 to continue with basin refinements (Ken, Allie & Danny).
5. Update and distribute schedule (Ken).

Project Schedule

Kickoff Meeting	September 10, 2018
Progress Meeting (+5 Weeks)	October 23, 2018
Submit Draft Baseline Hydrology	December 7, 2018
Complete Review of Draft Baseline Hydrology	December 28, 2018
Comment Review Meeting	December 31, 2018
Complete Corrections to Draft Baseline Hydrology	January 18, 2019
Baseline Hydrology Approved	January 21, 2019

Dewberry | J3
8100 E. Maplewood Ave. #150
Greenwood Village, Colorado 80111
Phone: 303.368.5601
Fax: 303.368.5603

COMMENT REVIEW MEETING MINUTES

DATE/TIME: **JANUARY 14, 2019 @ 1:00 P.M.**
LOCATION: **UDFCD OFFICE**
PROJECT: **CHERRY CREEK TRIBUTARIES MDP & FHAD**

ATTENDEES:
Shea Thomas - UDFCD
Dana Morris – UDFCD
Stacey Thompson – SEMSWA
Cathleen Valencia – Arapahoe County
Roger Harvey – Arapahoe County
Jonathan Villines – City of Aurora
Allie Beikmann – Dewberry | J3
Ken Cecil – Dewberry | J3
Danny Elsner – Dewberry | J3

PURPOSE

1. Review select comments and present comment response action plan.
   a. Reference on screen document for discussion.
2. Discuss next steps.

DISCUSSION ITEMS

1. Personnel Updates
   a. Kurt Bauer will be the new UDFCD project manager (PM) on this project and will be joining UDFCD in approximately one month.
   b. Jon Villines will be leaving the City of Aurora and joining UDFCD. Replacement for Jon is TBD. Jon also noted that he sent comments early that morning following return to work. Dewberry | J3 reviewed them and sent response back to Jon and Shea (UDFCD) on 1/18/2019.
   c. Dana Morris (UDFCD) will be conducting the FHAD review.

2. Project Title Name
   a. Current title needs clarification “Cherry Creek Tributaries Upstream of Cherry Creek Reservoir MDP”. UDFCD indicated the title needs to start with the main tributary name “Cherry Creek”.
   b. Proposed best option is “Cherry Creek Minor Tributaries in Arapahoe County MDP”. UDFCD will review and get back with us.
3. Tributary Names
   a. UDFCD indicated that unique names are important and ideally have reference to local landmarks, such as streets.
   b. North Unnamed Tributary (NU)
      i. Suggested Lake View Tributary and attendees accepted.
      ii. 2019-1-15 Update: Lakeview is already taken in Thornton. Dewberry | J3 proposed Little Raven Creek instead.
   c. Tributary to Cottonwood Creek (TC)
      i. Suggested Suhaka Tributary due to proximity to the model airfield. Suhaka is named after an avid radio-controlled airplane flyer who built and flew his own planes out of the field at Cherry Creek State Park, also named after him.
      ii. SEMSWA verified this name was acceptable on 1/18/2019. Suhaka is currently the last name of a member on the Centennial City Council.
   d. Valley Club Acres:
      i. Agree to use Valley Club Acres (VCA) instead of Valley Club (VC) throughout.
   e. North Arapahoe and Parker, South Arapahoe and Parker:
      i. Agreed to remove “and Parker” and modify to North Arapahoe Tributary and South Arapahoe Tributary (NA, SA).
   f. South Unnamed Tributary (SU):
      i. Suggested Kragland Tributary or Dransfeldt Tributary due to historical significance.
      ii. Roger indicated he would discuss with Karen at 17-Mile Farm House to find a good, historically significant name.

4. Clarified role of Arapahoe County in this project and agreed they are a stakeholder and SEMSWA is the sponsor that operates on their behalf. Wording will be clarified in the text and Arapahoe County logos will still be reflected in documents.
5. Dewberry | J3 asked if watershed numbers could be found online and what significance they have. UDFCD indicated they are part of a filing system that is generally not used anymore. Future MDP documents don't need to include it.
6. Main Tributary Comments
   a. TC: Exhibit makes it appear tributary outfalls to Cottonwood Creek prior to crossing Peoria. Please clarify.
      i. Outfall is downstream of Peoria. Dewberry | J3 will add a street name to clarify.
   b. J: Let's discuss your travel path for subcatchment J2, since the shape factor is a bit excessive.
      i. Attendees agreed to the approach of modifying the shape of the basin by removing the narrow "tail" downstream to get a better shape factor in CUHP.
   c. NAP1: Can we discuss the catchment delineation in this area? It seems odd that NAP1 would really narrow down this much without adjacent area contributing.
      i. NAP1 (NA1) will be cut off at Parker Rd. and the area downstream of Parker Rd. will be removed from hydrology. Upstream will be routed through piping infrastructure simulated in the model.
   d. NAP3: Should this be the downstream limit for NAP3? Arapahoe Rd would then be incorporated into NAP2.
      i. The current configuration is acceptable since this area doesn't go to the pond.
7. DFA Catchments
   a. Attendees agreed to remove all DFAs with the exception of C-DFA2 which will be modeled up to Parker Rd and renamed to Tagawa Tributary. The other DFA areas do not have definitive outfall points along the tributaries and large portions are already in the floodplain.
8. Ponds
   a. RB1-4
      i. Confirmed that SEMSWA owns and maintains this pond.

      ii. Dewberry | J3 indicated that the stage-storage curve in the report needs updating to match the current curve used in the model.
   b. NAP/Pond E (North Arapahoe Pond)
      i. Confirmed that SEMSWA owns and maintains this pond.
      ii. SEMSWA indicated that they want to clarify the Filings that are served by this pond. Documents from SEMSWA indicated it serves Filings 7, 8, and 9 for the Farm at Arapahoe County.
      iii. Agreed to call the pond "North Arapahoe Pond" or NA pond for model inputs. However, a section will be included in the text noting that this is also referred to as Pond E by local agencies.
      iv. Danny discussed how Dewberry | J3 developed the stage-storage-discharge curves and the discrepancies between as-built records and current LiDAR.
      v. Attendees agreed that a survey would be beneficial and Shea estimated it would take a couple weeks to get this done.
   c. SAP Pond
      i. Confirmed this pond is not publicly owned and maintained, and not maintenance eligible.
   d. NU Detention Pond
      i. Dewberry | J3 indicated that this pond has a pseudo-outlet works at E Belleview Ave. that consists of two pipes, one five feet above the other.
      ii. The parcel appears to be owned by the United States and is part of Cherry Creek State Park. It inadvertently provides detention and thus is not included in the model. It also doesn't appear to be maintained for detention.
      iii. Ken noted that the downstream-most pipe in CC State Park appears to be very undersized for current flow conditions. This will be included in the report since it may be of interest for the Park.
      iv. Shea noted that Rich Borchardt may be a good contact for future information re: the CC Basin Water Quality Authority model, as he will be working on the project.
   e. TC Detention Pond
      i. Agreed to refer to the identified pond as a "stock pond".

9. Imperviousness and Land Use
    a. J: SEMSWA had a comment regarding the Arapahoe County 2035 Transportation Plan for future widening of Parker Rd. from 4 to 6 lanes, and if any adjustments are necessary to the future conditions impervious values.
        i. Dewberry |J3 indicated that Parker Rd. and the ROW was drawn in as a 100% impervious area and is thus a conservative land use, since typically land use areas include the adjoining streets. Attendees agreed to use the resulting comp %I for both existing and future conditions and no changes need to be reflected for future conditions.
    b. VC-DFA: SEMSWA had a comment regarding future residential development in part of Valley Club Acres Golf Course. Since this DFA subbasin is going to be removed, this issue no longer needs addressing.
    c. GR: SEMSWA indicated an area is identified as "Urban Center" on Centennial's 2040 Comprehensive Plan (Centennial NEXT).
        i. Dewberry | J3 will determine the corresponding imperviousness value for Urban Center land use. The resulting comp %I will be used as the future conditions.
    d. C1: Much of this area is identified as "Regional Commercial" on the Arapahoe County 2018 Comprehensive Plan. It is currently built-out as residential.
        i. Attendees agree this future zoning type appears odd given the built-out nature of the area. Cathleen indicated she will check with long-range planners at Arapahoe County to confirm the accuracy of this projected land use.
    e. SU1: Part of this area is identified as "Urban Center" on Centennial's 2040 Comprehensive Plan (Centennial NEXT).
        i. Dewberry | J3 Will modify and the resulting comp %I will be used as the future conditions. There will be a separate existing conditions model for this subbasin since development is proposed in a large part of the tributary basin.
            1. Note: Dewberry | J3 found following this meeting that the Urban Center area extends to a small part of Subbasin 17A. The same method of existing vs. future for SU1 will be applied to 17A.
    f. 17A: SEMSWA comments that 17-Mile House Farm park has a master plan and %I values could be adjusted to account for future development.

        i. Dewberry | J3 indicated that the current %I value is conservative since a large area is considered single-family residential for the study even though it is a large open property. Since only 1.8 acres of the land is developable and the land use is conservative, attendees agreed to use the current comp %I of 13.7% but request language added to the text.
    g. What 100-yr rainfall value was used in the previous study? How does the %I compare between that study and this one? (OSP Study).
        i. Rainfall for the current MDP is lower than the 1999 OSP. Dewberry | J3 will show the difference for the 100-year rain event and compare to Table A-5 from the 1999 OSP at possible points of comparison.
    h. Often it's better to compare unit runoff (cfs/ac) rather than just runoff. Would that be a valid comparison in this case? (pg. 3-5, UD)
        i. New comparison table shown during the meeting will be added.
    i. Arapahoe County indicated that existing and future flows from the MDP do not match the Kings Point drainage report.
        i. Dewberry | J3 found that flows for subbasin 17B are close to the drainage report but much higher for the SU tributary because the MDP included a larger area and an overall higher comp %I. CUHP/SWMM models confirmed this, although there is still a difference of 120 cfs for the 100-yr.
        ii. The MDP does not include the proposed ponds. Shea noted that she will talk to Morgan at UDFCD to see if developers will run their models without the ponds and verify similar flows (higher flows).

10. Jurisdictional questions, appendix comments and grammatical error comments were not discussed as answers and edits are readily known.
11. Additional storm events
    a. UDFCD requested modeling of two additional storm events: the 1-year and water quality (WQ) events. This would entail a short paragraph discussing the events and inclusion of a separate table in the Appendix.
12. Project Budgeting
    a. UDFCD requested that Dewberry | J3 send a comparison table of tributary length to estimate additional project cost.
    b. UDFCD and SEMSWA to discuss funding.

13. FHAD
    a. The position on whether or not to conduct a FHAD for each tributary was discussed at the end of the meeting and the conclusions are below. SEMSWA noted that alternatives will be studied for tributaries even if a FHAD is not conducted for them. And UDFCD indicated that a FHAD is not required if overflow from storm infrastructure is contained in the street flow.
    b. North Unnamed Tributary – limits are from Belleview Avenue to NU3 basin.
    c. Tributary to Cottonwood – no FHAD.
    d. Joplin Tributary – limits are from Cherry Creek floodplain to at least J6 basin, may go farther along storm sewer if concentrated sheet flow puts properties into the floodplain.
    e. Grove Ranch Tributary – no FHAD.
    f. Valley Club Acres Tributary – no FHAD.
    g. North Arapahoe & Parker – limits could be along storm sewer if a floodplain is found in the overflow of the storm.
    h. South Arapahoe & Parker – limits could be along storm sewer in SAP1 basin, but will at least be from Parker to SAP4 basin.
    i. Chenango Tributary – limits are from Cherry Creek floodplain to C9 basin.
    j. South Unnamed Tributary – limits are from Cherry Creek floodplain to SU7 basin.
    k. 17 Mile – no FHAD.

Cherry Creek Tributaries MDP & FHAD
Comment Review Meeting Minutes

Action Items

1. All stakeholders to confirm that “Little Raven Creek” is an acceptable name for North Unnamed Tributary.
2. Stacey (SEMSWA) to verify Suhaka is an acceptable name for Tributary to Cottonwood.
3. Roger (AC) to discuss name options for South Unnamed with Karen at 17-Mile Farm House.
4. Shea (UDFCD) to schedule a survey for North Arapahoe pond to develop accurate stage-storage-discharge curves.
5. Cathleen (AC) to check with long-range planners at Arapahoe County to confirm the accuracy of “Regional Commerical” for the area of subbasin C1 (Chenango) under future conditions.
6. Dewberry | J3 to pick up comments in final baseline hydrology report as discussed in the meeting and provided in comments by the stakeholders.
7. Dewberry | J3 to send tributary length comparison table to UDFCD for review.
8. Dewberry | J3 will review Jon Villines comments and follow-up as necessary for inclusion.

Project Schedule

Kickoff Meeting	September 10, 2018
Progress Meeting (+5 Weeks)	October 23, 2018
Submit Draft Baseline Hydrology	December 14, 2018
Comment Review Meeting	January 14, 2019
Complete Corrections to Draft Baseline Hydrology	February 1, 2019
Baseline Hydrology Approved	February 4, 2019

8100 E. Maplewood Ave. #150
Greenwood Village, Colorado 80111
Phone: 303.368.5601
Fax: 303.368.5603

MEETING MINUTES

DATE/TIME: APRIL10, 2019 @ 11:00 A.M.
LOCATION: UDFCD OFFICE
PROJECT: CHERRY CREEK TRIBUTARIES FHAD – FHAD MODEL

ATTENDEES:

Terri Fead - UDFCD
Dana Morris – UDFCD
Shea Thomas - UDFCD
Jonathan Villines – UDFCD
Allie Beikmann – Dewberry | J3
Danny Elsner – Dewberry | J3
Haley Heinemann – Dewberry | J3

DISCUSSION ITEMS

1. **Introduction:** Danny and Shea gave an overview of the study area.
2. **General notes:**

- **No FHAD Basins**: Confirmed no FHAD will be completed for Suhaka, Grove Ranch, Valley Club Acres, Tagawa, and 17-Mile tributaries.
- **Reach Centerlines**: UDFCD noted that reach centerlines must extend to the centerline of Cherry Creek or edge of CC Reservoir, where applicable. Areas not mapped due to location in Cherry Creek State Park, conveyance in a 100-Year storm culvert, etc. will be noted appropriately.
- **100-Year, 500-Year guidance**: Haley requested clarification on the new FHAD review steps. Shea noted that the guidelines direct modelers toward a working 100-Year model prior to evaluating the 500-Year, but that storm events can be analyzed simultaneously if easier. Terri also noted that checking the 500-year event during model construction assists in drawing appropriately sized cross-sections and other model components.
- **Fences within floodplain**: UDFCD advised using higher Manning's n for areas with fences. UDFCD noted that typical ranges of areas with obstructions, such as buildings, are between 0.1 and 0.2, and higher values correspond to highly urbanized areas. UDFCD recommended using their guidelines to identify values.

3. **Little Raven**

- Limits: Confirmed mapping limits are from Belleview Ave. to Havana St. (LR3).
- Boundary Conditions: Determined that the downstream condition will be normal depth downstream of Belleview's culvert crossing and the culvert will be modeled in HEC-RAS.

4. **Joplin**

- Limits: Confirmed mapping limits are from 10-year Cherry Creek floodplain to the storm sewer at J7/J8 confluence.
- Boundary Conditions: Determined the downstream-most cross-section will occur just downsream of the 10-Year Cherry Creek floodplain and the associated boundary condition will be the 10-Year known water surface elevation at that location.
- Pond RB1-4
  - Downstream flow conditions: Confirmed that downstream of the pond, the modeled flow rate will reflect the overflow rate from the pond quantified in SWMM. A cross-section will be added on the downstream side of Chambers Rd., which is located at the confluence of the overflow and storm sewer flow, to adjust the flow to the total flow rate.
  - Upstream flow conditions: Stream alignment will be continuous along Joplin Tributary and through the pond. Boundary conditions will be prescribed on either side of the pond to account for the known water surface elevations from SWMM rating curves at the embankment and the full SWMM flow will be used through the pond.
- Street Capacity at J6 and J7
  - Confirmed that flowpaths don't need to be shown if spills don't occur during the 100-Year event. Reaches where the storm sewer contains the 100-year event do not need to be mapped or modeled for the FHAD.

5. **North Arapahoe**

- Limits: Confirmed mapping limits are from 10-Year Cherry Creek floodplain to the storm sewer at N3/N4 confluence.
- Boundary Conditions: The downstream-most cross-section will be just downstream of the 10-Year Cherry Creek floodplain and the boundary condition will be the 10-Year known water surface elevation at that location.
- Street Capacity at Arapahoe Rd.
  - Confirmed that flowpaths don't need to be shown if spills don't occur during the 100-Year event. Reaches where the storm sewer contains the 100-year event do not need to be mapped or modeled for the FHAD.

- 100-Year Spill
  - 2D Model: Dewberry | J3 to send the 2D model with the initial FHAD model submittal and a screen shot showing the flow split as soon as available.
  - UDFCD advised to model the split flow @ Lewiston in HEC-RAS and the connection to South Arapahoe will be discussed following the first submittal. Flows downstream of Lewiston will reflect the loss of flow to South Arapahoe at the split.

6. South Arapahoe

- Culvert capacity: Dewberry | J3 to verify 100-Year containment along Arapahoe Rd. from Parker Road to Cherry Creek, and the pipe connecting the CDOT pond to the existing WQ pond.
- Limits: Depending on containment of the 100-Year flows, the downstream- most point mapped will be the upstream end of the culvert crossing at Lewiston Way and the upstream-most point will be the open channel at the S3/S4 confluence.
- Boundary Conditions: The downstream boundary condition will be the head water elevation at the culvert crossing of Lewiston Way found w/ CulvertMaster or HY8.

7. Chenango

- Limits: Confirmed mapping limits are from the 10-year Cherry Creek floodplain to downstream point of Subbasin C9.
- Boundary Conditions: Determined the downstream-most cross-section will occur just downstream of the 10-Year Cherry Creek floodplain and the associated boundary condition will be the 10-Year known water surface elevation at that location.
- Non-UDFCD pond modeling: Confirmed that the pond will be modeled with no attenuation and the centerline will follow the path of the emergency overflow discharge.

8. Kragelund

- Limits: Confirmed mapping limits are from the 10-year Cherry Creek floodplain to downstream point of Subbasin K7.
- Boundary Conditions: Confirmed the downstream-most cross-section will occur just downstream of the 10-Year Cherry Creek floodplain and the associated boundary condition will be the 10-Year known water surface elevation at that location.
- Undefined Channel: Confirmed that longer cross-sections in the area upstream of Parker Rd. is acceptable to capture flow trending in two directions. The centerline will be drawn along the south based on the 2D model with obstructions added to the cross-sections to prevent cross-flow that would not occur in actuality.
- Future Flows:
  - Dewberry | J3 noted that future peak flows are greater than 30% larger than existing peak flows and require additional considerations per FHAD requirements.

  - UDFCD advised to use future flow rates for the FHAD to remain consistent with the rest of the project. UDFCD will discuss with SEMSWA whether existing flows also need to be modeled.
  - UDFCD also noted that particular stormwater conveyance measures, specifically regional detention, have potential to change and thus any affects these may have on actual observed flows at points of interest are not certain enough to consider at this time.

9. Other Items

- Requested items:
  - UDFCD will request a survey for the upper-most culvert at Hinsdale on Chenango. SEMSWA's infrastructure shapefiles indicate the crossing is equipped with an 84" CMP.
  - UDFCD will request a stock list of acronyms and abbreviations from the surveyor.
  - UDFCD will request the layer package (ie discuss with Morgan Lynch) and send/update as available.
- UDFCD to send GIS review tool.

ACTION ITEMS

1. Dewberry | J3 to include 2D HEC-RAS models with the first submittal for North Arapahoe and Kragelund to UDFCD for review of split flows.
2. Dewberry | J3 to update HEC-RAS models per discussion items and provide information re: selected Manning's values.
3. UDFCD to send GIS layer package and review tool.
4. UDFCD to inquire about survey acronym/abbreviation sheet from surveyor.
5. UDFCD to request a survey at Hinsdale upstream of the dam along Chenango, which SEMSWA infrastructure data indicates is an 84" CMP.
6. UDFCD to talk with Stacey at SEWSWA regarding increased Manning's n in Action Item 2 vs. blocked obstructions.

PROJECT SCHEDULE

Dewberry Model Review Submittal	April 22, 2019
UDFCD Review Wrap-up	May 3, 2019

Meeting Date: August 05, 2019

Time: 3:00 pm

Location: MHFD

Meeting Lead: Danny Elsner

Project: Cherry Creek Minor Tributaries in Arapahoe County FHAD

Purpose: Arapahoe Road Modeling and FHAD Submittal 1 Comments Review

Attendees: Jon Villines/MHFD, Shea Thomas/MHFD, Stacey Thompson/ SEMSWA, Allie Beikmann/Dewberry, Katie Kerstiens/Dewberry, Danny Elsner/Dewberry

Discussion Items

1. Arapahoe Road/ Valley Club Modeling
    a. Background information (hand out)
        i. Danny discussed the basin hydrology of Valley Club Acres (VCA) and the flooding that occurred on Helena Street in June. Danny introduced the handouts which show the magnitude of flows spilling along North Arapahoe to VCA, starting at Lewiston Way. An estimated 378 cfs spills to VCA.
        ii. Stacey mentioned that local residents called to inform SEMSWA that flooding occurred, however, the specifics, including what houses and the source of flooding, are unknown.
        iii. The group agreed there is a need to further assess the flood risk in this area and identify something that the state will approve for designating flood hazard areas. Best approach TBD.
    b. Options to move forward (hand out)
        i. Danny introduced five (5) alternatives to address mapping floods in this area at Arapahoe Road and Valley Club Acres. Discussion was summarized as follows:
            1. The first option was no FHAD for NA, conduct a storm sewer analysis and design infrastructure with sufficient 100-year capacity, and assume there are no longer basin transfers to VCA.
                a. Shea noted that with this option it falls to MHFD to notify owners of flood risk.
            2. The second option included option one plus a storm sewer alternatives analysis for VCA.
                a. Not ideal. Infrastructure in VCA is relatively sufficient and doesn't appear to cause the flooding and a larger pipe at Caley won't alleviate the flooding issues.
                b. Shea asked if the basin was greater than 130 acres and Danny clarified that it is however, both basins combined are less than 200 acres.

            3. The third option was a modified FHAD for NA and SA with 1D upstream modeling and 2D downstream modeling excluding VCA inflows.
                a. This option gained traction to evaluate the spills.
                b. Shea noted that they need to produce something that the state will approve for local governments to have legal authority to regulate these flood hazard areas. Currently, 2D models can't become approved FHADs because FEMA doesn't recognize 2D approaches yet. Ideally would be a 2D informed 1D model.
                c. Dewberry indicated they would look into this further.
            4. The fourth option included option three plus a storm sewer analysis for VCA and 2D model inflow.
                a. Not ideal (same reason as No. 2).
            5. The fifth option included option four plus hydrology routing (SWMM or unsteady).
                a. Not ideal (same reason as No. 2).
        ii. A modified option three was selected to move forward with. Shallow flooding will be looked at and if the flooding is 6 inches or more, then a flow path will be designated. Dewberry will look into a 2D informed 1D model to see if that's a possibility. Will first model from Lewiston to outfall with a 2D and send MHFD results and items for discussion before proceeding with any next steps.
        iii. MHFD also noted that in cases like the 20 cfs basin transfer on Lewiston, both basin models should include the flow unless it is known that the infrastructure will be modified to remove the transfer.
        iv. Shea and Stacey indicated they will look into what can be accepted by the state as, for instance, approximated flood risk assessments can't become regulatory.
        v. It was determined that SEMSWA will try to obtain additional information to help this assessment, including:
            1. As-built or survey information for pipe sizes on the north side of Arapahoe Rd., which are currently indicated by SEMSWA GIS data to be about 42" near the Cherry Creek outfall.
            2. Additional information regarding the specific homes that were flooded.
            3. Monitoring well data during the time of the storm (Dewberry | J3 will look into data for local wells).
2. FHAD Model Resubmittal: Comments that need more clarification/explanation were addressed.
    a. Submittal 1 comments
        i. Kragelund

1. Comment 3 – Future flows are to be used for FHAD and existing will be used for a separate model submittal.
    a. Jon will talk to Terri to confirm this approach and determine when this review of the existing conditions model will take place.
2. Comment 31F – Use split flow to confirm shallow flow depth is 6 inches or less, start with 2D model to get a sense of what is happening and send results to MHFD.
3. Comment 31G – Refer to Comment 31F. It was discussed to send a surveyor out to confirm berm/levee elevations.

ii. Chenango

1. Comment 25A – Jon is good with the LOB but needs clarification on the IEFA for the ROB. Haley to follow up with Jon for discussion.
2. Comment 26A – Danny explained that the crossing is extended since there is split flow that travels down the ditch, pools, and eventually overtops the road to make its way back to the main channel. Jon recommended modeling this split flow. Look at risk to adjacent homeowner. Alternatives could include filling in the ditch.
3. Comment 34B – Keep culvert as is, do not want to decrease capacity.
4. Comment 34C – Keep culvert as is, do not want to decrease capacity.

iii. North Arapahoe

1. Comment 1A – Jon said the flows are okay.
2. Comment 4A – Jon said the placement is okay but requested a follow up with Haley to discuss.

iv. Joplin

1. Comment 6 – Okay, Allie explained figure to Jon who is good with the modeling approach since it doesn't impact the floodplain.
2. Comment 7A – Jon approved the assumptions for flow through the new development at Joplin Way and Granby Way (overflow at manholes upstream of development). For purposes of documentation, we need to show the main channel following the 72" pipe with overflow along the Granby Way curb and gutter.

b. Floodway runs: Jon mentioned this is not necessary for submittal, but can be run for more information.

c. Resubmittal schedule: Schedule was reviewed and everyone agreed on the dates (see following page).

d. Next steps

Action Items

1. Dewberry will look into a 2D informed 1D model to analyze shallow flooding and will send results to MHFD.
2. Shea and Stacey to look into what can be accepted by the state.
3. Stacey will try to get further information on the homes that were flooded and will back check the pipe size on the north side of Arapahoe Road.
4. Dewberry will look into monitoring well data during the time of the storm.
    a. Update: Allie looked into this on 8/6/19 and did not see any continuously monitored well levels in the area.
5. Jon will talk to Terri regarding the following:
    a. Confirm the use of future flows for the FHAD and exiting flows for a separate model submittal.
    b. Confirm the shallow flow depth (6" or 12").
6. Dewberry will model the split flow and look at the risk to adjacent homeowner regarding Chenango Comment 26A.
7. Dewberry will show the main channel following the 72" pipe with overflow along the Granby Way curb and gutter in regards to Joplin Comment 7A.
8. Haley will follow up with Jon regarding:
    a. Chenango Comment 25A – IEFA for the ROB
    b. North Arapahoe Comment 4A – verify placement

Current Estimated Schedule

1. Model submittal for approval
    a. Dewberry – piecemeal, all by 8/19/19
    b. MHFD Review – 9/9/19
2. 100-year floodplain submittal
    a. Dewberry – 10/7/19 (+1 week for CASFM)
    b. MHFD Review – 10/28/19
3. Floodway and 500-year floodplain submittal
    a. Dewberry – 12/2/19
    b. MHFD Review – 1/6/20 (+2 weeks for Holidays)
4. Full Review Submittal
    a. Dewberry – 2/10/20
    b. MHFD Review – 3/2/20
5. Final Submittal
    a. Dewberry – 3/30/20

Date: February 2, 2021

Time: 2:00 PM

Location: Teams

Project: Cherry Creek Minor Tributaries in Arapahoe County FHAD

Purpose: Comment Review

Attendees: Jon Villines/MHFD, Hung-Teng Ho/MHFD, Melanie Poole/MHFD, Brik Zivkovich/MHFD, Laura Hinds/MHFD, Danny Elsner/Dewberry, Katie Kerstiens/Dewberry, Haley Heinemann/Dewberry

Agenda Items

Overview

- Asking only about comments that we need some clarification on.
- Some comments ask to validate approach on certain items. Not going to discuss these and assume that if we provide explanation/validation that they will be accepted.

Comment Review

1. Modeling Questions

1 - Chenango
XS 1991, the 500-year profile drawdown can be fixed by not modifying the low flow channel geometry to match the culvert opening. – *Is it optional to modify the low flow crossing to match survey?*

- Bounding XS are cut at location outside of crossing, so want XS to match natural channel outside of structure. HEC-RAS manual expands on this. Update this XS to match natural channel, which may include survey of the channel upstream of the structure.
  - This is new guidance following previous guidance to modify low flow channel to match culvert. (i.e. no obstruction by channel in front of culvert)
- For our current stage of review – Will only modify at this location because a drawdown is occurring. Other locations will be left in our current models that aren't causing profile changes, with the acknowledgment that there is a new procedure for future models.

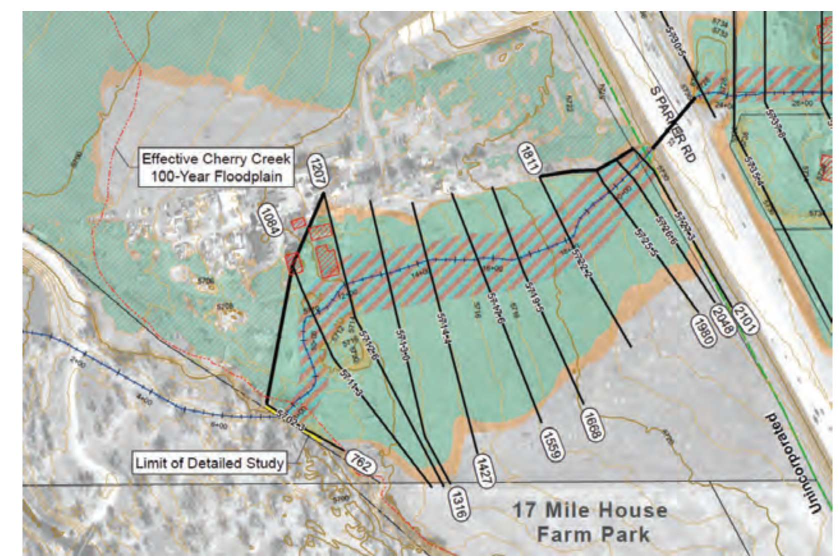
Dewberry

SECOND FLOODPLAIN REVIEW
MEETING MINUTES

XS 1084 - Kragelund

What is the need for the lateral structure? Please extend cross section cutline at right overbank to hit the high ground to contain all flood events. – *Confirm modeling approach here. Split flow to the east modeled in 2D.*

- Review test run model to see if removal of lateral structure is okay and that XS are contained throughout those XS. Should be good for existing and future conditions.
- Shallow flooding depth of <1ft is based on average depth, but because there are insurable structures near the circular drive it would be advantageous to exclude that area from the shallow flooding modeling and provide a Zone AE depth for those structures.
- Upstream lateral structure and 2D model is still okay approach.



XS 6845 – South Arapahoe

Please set IEFA downstream of crossings to non-permanent. – *Received previous direction to use permanent IEFA at all downstream xs. New protocol?*

- Models currently set upstream and downstream IEFA's to permanent from previous FHAD guidance.
- New approach is to set XS 3 IEFA's to permanent with standard heights based on road/structure being overtopped to provide more conservative result (usually). (Noted that this approach is still under discussion internally at MHFD and further guidance on this may be coming down the road.) If flow overtops a structure, then it is effective flow and is appropriate to use non-permanent IEFA at XS 1 and 2 and set elevations below the events that overtop.

- For our current stage of review – Will change IEFA of downstream crossings to non-permanent if there is a profile drawdown being caused. Otherwise we will leave as-is at this stage of the modeling. Also, will adjust downstream XS 1 and 2 IEFA to account for overtopping.

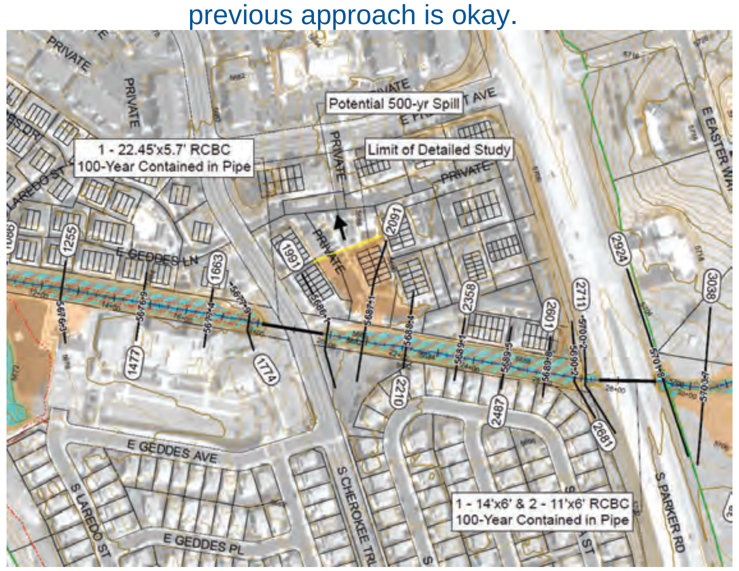
XS 6919 – South Arapahoe
Please set IEFA elevations to ensure consistent overtopping storm events between cross sections (Approach, US Face, DS Face, and Exit) at each crossing. – *Would like to discuss further to clarify what is being asked.*

- Reviewed this comment prior to meeting and it's okay in this instance because it is not causing a drawdown or other profile issue.
- For our current stage of review – Will double check that any drawdowns are corrected by adjusting downstream IEFA's to ensure consistent overtopping.

2. Floodplain Questions

12 - Chenango
XS 2091, please complete the 500-year floodplain boundary at right overbank area. - *Followed style of other recent FHADs. Possible to keep?*

- Believe flow should be shallow enough toward Fremont Avenue that we can estimate the 500-year will not travel further than the street. Make a logical transition here, follow contours and streets/curb. For future instances where we believe water will flow quite a distance away, the previous approach is okay.



Dewberry

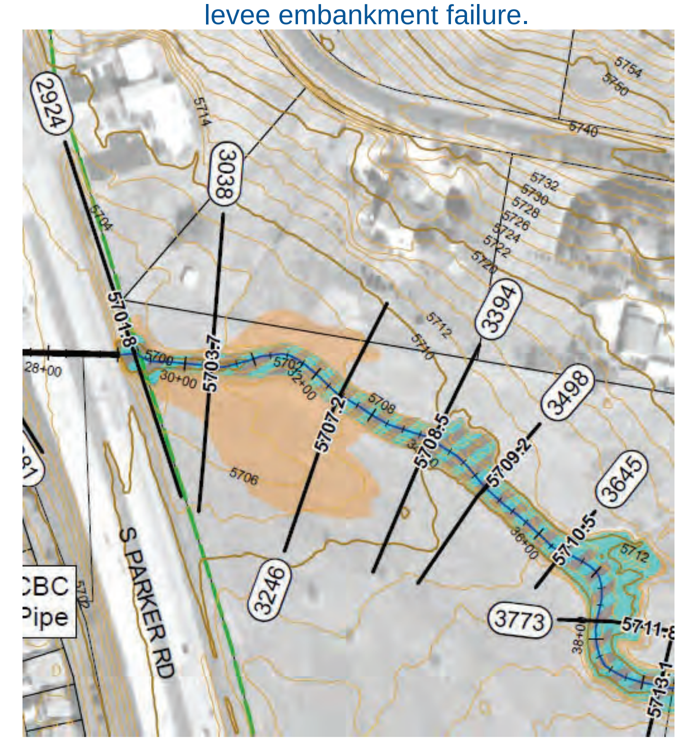
**SECOND FLOODPLAIN REVIEW
MEETING MINUTES**

13 - Chenango
XS 3246 & 3038, the left minor high ground is not regulatory levee embankment. Please include the low lying area with the floodplain. – *Can you clarify the levee/embankment consideration?*

- Noted that the industry doesn't have great guidance on when an embankment (what height/width) should be treated in this manner. Even if 100-year isn't hydraulically connected, suggest we include low lying area in floodplain to be conservative since embankment could fail. Include 2 top widths in table (xx/xx*): one that is just in channel and one that includes entire width.
    - o example of recent table.

5	Flooding Source:	Second Creek (Upper)										
7	Cross Section	River Station	Downstream Reach Distance, ft			Cumulative Distance, ft			FP Width, ft		0.5' FW Width, ft		
8			Model	Profile	Map	Model	Profile	Map	Model	Map	Model	Map	Mo
9			+/- 5% of Model			+/- 5% of Model			Largest value: 25 feet or 5% of Width on Map				
147	63618	636+18	382.83	---	382.83	45635.26	---	45635.3	811	350/811*	239	236.2567	517
148	63966	639+66	347.92	---	347.92	45983.18	---	45983.2	856	841.3247	326	323.8179	517

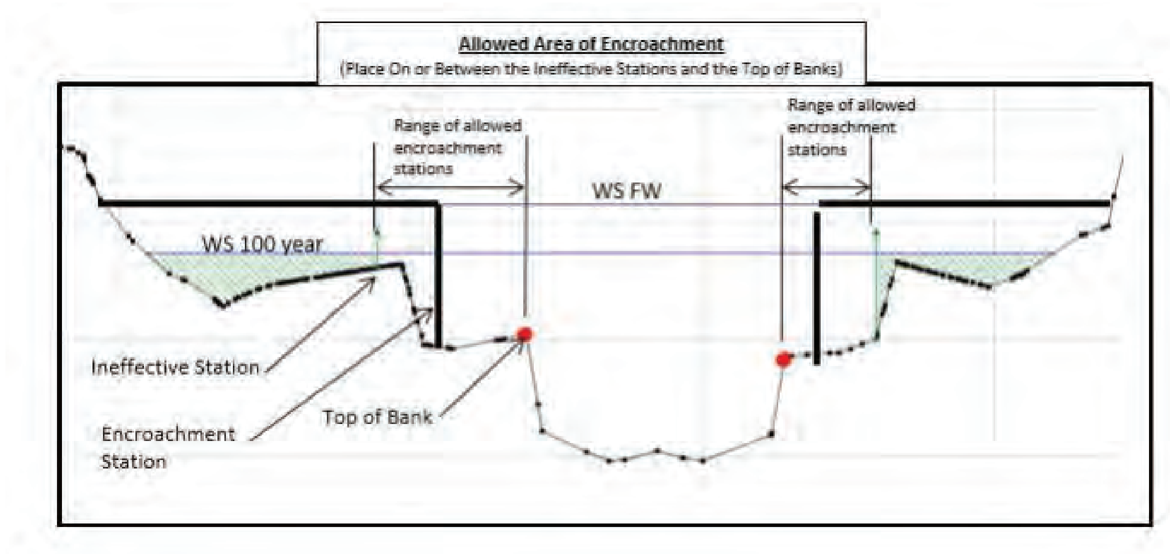
- Possible rule of thumb for now: if cross-section can't be trimmed because of 500-year hydraulic connection, may want to consider 100-year non-levee embankment failure.



3. Floodway Questions

16 - Chenango
Floodway Analysis, please avoid floodway top width include IEFA. – This comment shows up a few times. Is this a rule of thumb?

- Based on definition of a floodway – the water course that is preserved to convey effective flow; therefore, don't want to include area which has been denoted ineffective.
    - Helpful reference figure from NC:



Other Items

1. To send Jon scope change for Kragelund existing conditions modeling
2. Possible change order for other items – need to digest based on this meeting
3. Schedule?
    a. Change orders
    b. Resubmittal submit all together (Kragelund + all comments)
    c. Public Meeting will revisit this in a month

REVIEW COMMENTS AND RESPONSES

Date: April 29, 2019

To: Ms. Terri Fead, P.E.

From: Ken Cecil, P.E., CFM; Danny Elsner, P.E., CFM

Subject: Cherry Creek Minor Tributaries FHAD; Model Review Submittal 1

Message:

This technical memorandum documents the hydraulic analysis performed for the Cherry Creek Minor Tributaries in Arapahoe County FHAD, Model Review Submittal 1. Modeling notes that generally apply to all tributaries are listed first, followed by assumptions and items of note that are individual to each tributary. Supporting hydraulic calculations and references are attached to this memorandum. Prior to this submittal, a meeting was held at UDFCD on April 10, 2019 to clarify preliminary questions. Minutes from the meeting are also attached.

General Modeling Notes

HEC-RAS (version 5.0.6, subcritical, 1D) models are included for the following drainageways: Little Raven Creek, Joplin Tributary, North Arapahoe Tributary, South Arapahoe Tributary, Chenango Tributary, and Kragelund Tributary.

- All required peak profiles (10-, 25-, 50-, 100-, 500-yr) from the baseline hydrology are included. For all tributaries except Kragelund, existing conditions = future conditions. For reaches defined by storm sewer overflow and no open channel, only the return events and associated flows exceeding the SWMM-defined storm sewer capacity are modeled.
- All modeling was completed in Colorado State Plane Central with a NAD 83 horizontal datum and NAVD88 vertical datum.

Channel Alignments

- Tributary alignments were delineated following the channel thalweg per the smoothed Cherry Creek contours provided by UDFCD. Station 0+00 for each tributary is at the confluence of Cherry Creek (or Cherry Creek reservoir) regardless of the downstream limit of the study area.

Cross Sections

- Cross section geometry was populated using a 1'x1' raster created from the LAS dataset provided by UDFCD and created by USGS in 2014.
- Low flow channel inverts were modified to reflect UDFCD survey at existing structures. Where necessary, intermediate cross section inverts were interpolated between surveyed structures to remove adverse grade.
- Several instances of adverse grade exist along the modeled profiles. Instances of adverse grade were included where needed to capture areas of overland flow (no defined channel) and obstructions such as private driveways and berms.

Boundary Conditions

- Downstream boundary conditions vary for each tributary depending on the limits of the study and the availability of regulatory floodplain data for Cherry Creek. Effective Cherry Creek information was obtained from the 08005CV001D-5D FIS for Arapahoe County (revised September 28, 2018).
    - The North Arapahoe, Chenango, and Kragelund downstream boundary conditions use KWSELs set to the Cherry Creek 10-year water surface elevation interpolated from the FIS profiles. Refer to the attachment for calculations.
    - Little Raven: Normal depth of channel slope downstream of Belleview Avenue per limits of study.
    - Joplin: Normal depth of channel slope at downstream cross-section. (No regulatory floodplain is published for this area within Cherry Creek State Park.)
    - South Arapahoe: KWSEL's set to the calculated headwater at Lewiston Way. Headwater elevations for each profile were calculated in CulvertMaster. Calculations account for the series of culverts

running from the west side of Parker Road to the upstream side of Lewiston Way via a 54" CDOT pond outlet (Culvert 1) and the Lewiston Way culvert (Culvert 2). Calculations are attached.

- Additional boundary conditions were added for pond RB1-4 in Joplin Tributary and are discussed in that section.

Manning's N

- Roughness values were chosen using USDCM Table 8-5 and Equation 9-1. Photographs of typical sections are attached.
    - In lieu of conveyance obstructions, areas with overland flow occurring across residential and commercial areas use a higher Manning's roughness value between 0.1 and 0.2 to consider flow around buildings.
    - Several of the tributary floodplains are obstructed by perpendicular fencing, mainly associated with private yards. In some cases, along Chenango, the fencing crosses the channel. Anticipated blockages associated with the fencing is modeled with a high roughness value of 0.1.

Category	Roughness Value
Native Grasses	0.05
Willow stands, woody shrubs	0.16
Herbaceous wetlands	0.12
Asphalt (ex. parallel roadways)	0.02
Cobble Channel Bed	0.07
Gravel (ex. gravel parking lot)	0.025
Housing/Commercial	0.1-0.2
Grouted Boulder Drops/ Large riprap	0.1
Maintained Turf Grass	0.04
Fences (perpendicular to floodplain)	0.1

Structures

- Culverts and drops were modeled using the structure survey provided by UDFCD. Structure numbers from the UDFCD survey are included in the Bridge Culvert Data description box for each structure.

Ineffective Flow Areas

- IEFA's at crossings were set assuming approximate contraction rates of 1:1 and expansion rates of 2:1 – 4:1. IEFA's immediately upstream and downstream of roadway embankments were set to permanent.
- Conveyance areas within other channels, such as minor tributaries or roadway ditches, were discounted with IEFA's.

Little Raven Creek

- The Little Raven Creek model terminates at Belleview Avenue because the reach within Cherry Creek State Park will not be included in the FHAD.

Joplin Tributary

- Pond RB1-4: Cross section 7571 is set to the water surface elevations which were identified in the baseline hydrology SWMM model for the RB1-4 pond.
- Survey Data requested on 4/18/2019
  - Structure survey was requested for Chambers Road near station 6,363. SEMSWA infrastructure shapefile data identifies the culvert as a 54" RCP, which has been included in the model until the survey is received.
  - Topographic survey or as-builts were requested for the development located south of the Joplin Way and Chambers Rd. intersection. Until the survey is received, it is assumed that the 500-year overflow of the 72" pipe will be conveyed along S Granby Way and contained by approximate conveyance obstructions. **ACTION ITEM – Once survey is received, Dewberry | J3 will map the flow path and flood limits between S. Joplin Way and S. Chambers Road.**
- Flow Change Locations:
  - Overflow occurs upstream along Crestline Ave. and Helena in subbasins J6 and J7 between XS 8050 and 10270 for the 100-year and 500-year storm events. Flow rates for the overflow between Laredo and Lewiston (J7_SS_OVF) were taken from SWMM and not modified. The overflow rate for J6_SS_OVF was modified to include 80% of the overland flow rate for the subbasin since approximately 80% of subbasin J6 flows to the street before flowing downstream to Pond RB1-4. The totals of J6_SS_OVF and J6_OF are used for the total flow in street for mapping (194 cfs during the 100-year and 463 cfs during the 500-year). See table below for reference.

Node/Link	Description	CUHP/SWMM flow rate (cfs)		80% of overland flow (going to street) (cfs)		Total flow in street, Crestline Ave. and Helena St. (cfs)	
		100-YR	500-YR	100-YR	500-YR	100-YR	500-YR
J6_SS	Storm Sewer	347.74	348.55	-	-	-	-
J6_SS_OVF	Overflow	77.14	279.22	-	-	77.14	279.22
J6_OF	Subbasin overland flow	146.38	229.18	117.104	183.344	117.104	183.344
RB1-4_Pond	Total flow to pond	569.4	854.95	-	-	194.244	462.564

  - Overflow of the 72" pipe from Pond RB1-4 to Chambers Road crossing occurs for the 500-year storm event only and the flow rate for the model is 312 cfs, as determine in CUHP and SWMM.

North Arapahoe Tributary

- Several split flow locations have been identified along North Arapahoe. The model included with this submittal estimates the amount of flow leaving at each location with a lateral weir using the standard weir equation for a broad crested weir. Tailwater connections at all weirs are set to 'out of the system'. Weir coefficients were selected using the Hydrologic Engineering Center recommended values published in "Combined 1-D and 2-D modeling with HEC-RAS" (August 2013).
- A rough 2D model was completed to identify potential locations of split flow for the 1D model. The 2D model uses two plans: 1. Upstream of Parker Road and 2. Downstream of Parker Road. The model is included with this submittal. Because the terrain is very flat and the LiDAR does not capture curb and gutter elevations along North Arapahoe, the model was only used to identify potential problem areas and is not necessarily accurate in many locations. For example, the topo underneath the Parker Road bridge does not represent the existing median; therefore, a split flow to the south is introduced in the model which does not in reality occur.
- The following is a description of the split flows for the 100-year event. These locations are noted on the North Arapahoe hydraulic workmap. Note that the default maximum iterations was increased to 40 to allow for the split flows to optimize.
  1. Lewiston Way: Between Olathe Street and Lewiston Way approximately 19 cfs overtops the Arapahoe Road median. Curb and gutter contain this flow until Lewiston Way, where no gutter or cross pan exists, allowing water to escape to the south along Lewiston Way and potentially into the Walgreens parking lot.
     - Lateral weirs 5462 and 4660 were optimized together because both are considered one source of flow loss. Flow lost through these weirs was not subtracted from the main channel flows, assuming that this loss of flow may be resolved in the future.
  2. Downstream of Lewiston Way: Just downstream of Lewiston Way, the 100-year WSEL sits very close to the median elevation. Less than 1 cfs overtops the median and will be conveyed by curb and gutter to the next inlet on the south side of Arapahoe Road just west of the Parker Road southbound onramp.
     - This weir, 4444, was optimized alone. Flow lost through this weir was not subtracted from the main channel flows, assuming that this loss of flow may be resolved in the future.
  3. Parker Road to Cherry Creek: Downstream of Parker Road, the majority of North Arapahoe flows leave Arapahoe Road and spill to the north toward Sprint, Smashburger, and a handful of homes. This may warrant relocating the centerline of North Arapahoe tributary further to the north.
     - Lateral weirs 3462, 2764, 2339, 1485 were optimized together because of the large percentage of flow being lost to the northwest.
- **ACTION ITEM - Dewberry | J3 would like to coordinate with UDFCD regarding major modeling decisions such as split flow alignments and centerline modifications for North Arapahoe tributary. It appears that the major flow path should leave Arapahoe and head a bit north due to the split flow quantities. Note additional flows along Arapahoe from South Arapahoe may need to be included in this discussion.**

South Arapahoe Tributary

- During hydraulic analysis, it was determined that the CDOT pond located at the southeast corner of the Arapahoe and Parker intersection along South Arapahoe is overtopped during the 100-year and 500-year events. The overtopping elevation is estimated to be 5680' at the northwest corner of the pond. From preliminary CulvertMaster calculations, included in the boundary conditions attachment, it's estimated that about 45 cfs and 226 cfs could escape the pond in the 100-year and 500-year events, respectively.
- **ACTION ITEM - Dewberry | J3 would like to coordinate with UDFCD regarding modeling the flow loss at this pond and the possible combination discussed in North Arapahoe.**

Chenango Tributary

- **ACTION ITEM - Structure survey was requested on 4/18/2019 for East Hinsdale Avenue upstream of the dam near station 10,600. SEMSWA infrastructure shapefile data identifies the culvert as an 84" CMP, which has been included in the model until survey is received.**

- The existing dam located at station 98+41 is not recognized by UDFCD and was not included in the baseline hydrology. The channel alignment is routed around the dam by way of the emergency overflow located on the south side of the dam. Storage behind the dam was discounted with IEFAs.
- Roadway ditches are located on the north and south side of Hinsdale Avenue. Conveyance area associated with the ditches was made ineffective.
- The high Manning's n discussed with UDFCD was implemented within a majority of the area based on aerial view and the impact felt to the flow.

Kragelund Tributary

- In the April 10th pre-submittal meeting, the UDFCD project team was notified that the future conditions peak flows are more than 30% greater than the existing peak flows along Kragelund. UDFCD advised Dewberry | J3 to continue modeling future flows while it is determined whether existing flows also need to be modeled.
- The following is a description of split flows for the 100-year event. Split flows that were observed for smaller storm events are not noted here but were considered in the model using ineffective flow areas.
  1. Cross Section 6545 to 5879 in proposed King's Point Development: Drainage splits on either side of a ~500-foot long natural ridge, with the low-flow channel continuing along the east side of the ridge. This was modeled with longer cross-sections and ineffective flow areas rather than with lateral or weir structures due to the short length of the obstruction and wide floodplain downstream.
  2. Cross Section 4566 to 4162: Drainage splits on either side of a ~400-foot long natural ridge, with the low-flow channel continuing along the north side of the ridge. This was modeled with longer cross-sections and ineffective flow areas rather than with lateral or weir structures due to the short length of the obstruction and wide floodplain downstream.
- Neighborhood between E. Long Ave. and E Mineral Pl.:
  - Low Flow Channel Determination: From Cross Section 4162 to Parker Road, it appears that two possible flow channels exist: one to the north parallel to E Long Ave and one to the south that flows to a ditch along E Mineral Pl. Upstream invert elevations are similar and an abbreviated 2D flow analysis was conducted which found that flows split for very small events and slightly more drainage is conveyed in the Mineral Pl. channel. This channel was selected for the low-flow channel and IEFAs were used to preclude flow from the upper reaches of the flow area.
  - Flow South of E Mineral Pl.: Storm events overtop Mineral Pl. and pond the residence located south of the road. Since flow appears to remain there and pond up, IEFAs were added to remove this area from consideration in the model.
- Flow west of Parker Rd.: Flow spills from the main channel located downstream of the Parker Rd. crossing Northwest toward and across the open space. An abbreviated 2D model confirmed this flow preference and Dewberry | J3 will be requesting guidance from UDFCD to confirm the best approach for containing this part of the model.

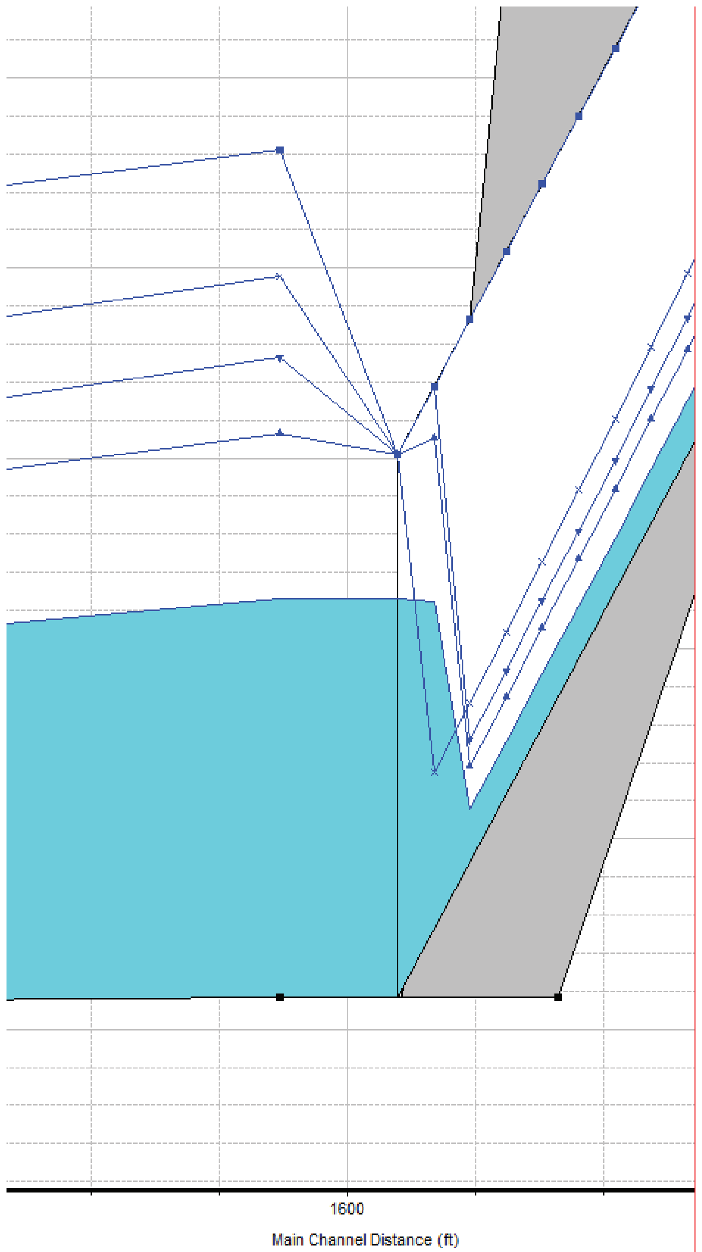
References:

1. **Reference A:** HEC-RAS Workmaps
2. **Reference B:** Manning's n Typical Sections
3. **Reference C:** Boundary Conditions
4. **Reference D:** April 10, 2019 Meeting Minutes
5. **Reference E:** North Arapahoe 2D Model (screen shots due to size)
6. **Reference E:** Kragelund 2D Models (screen shots due to size)
7. **Reference F:** Baseline Hydrology Report

REVIEW STEP 1 - MODEL REVIEW - Chenango

Plans, Flows, and Profiles

2. Verify there are no crossing profiles



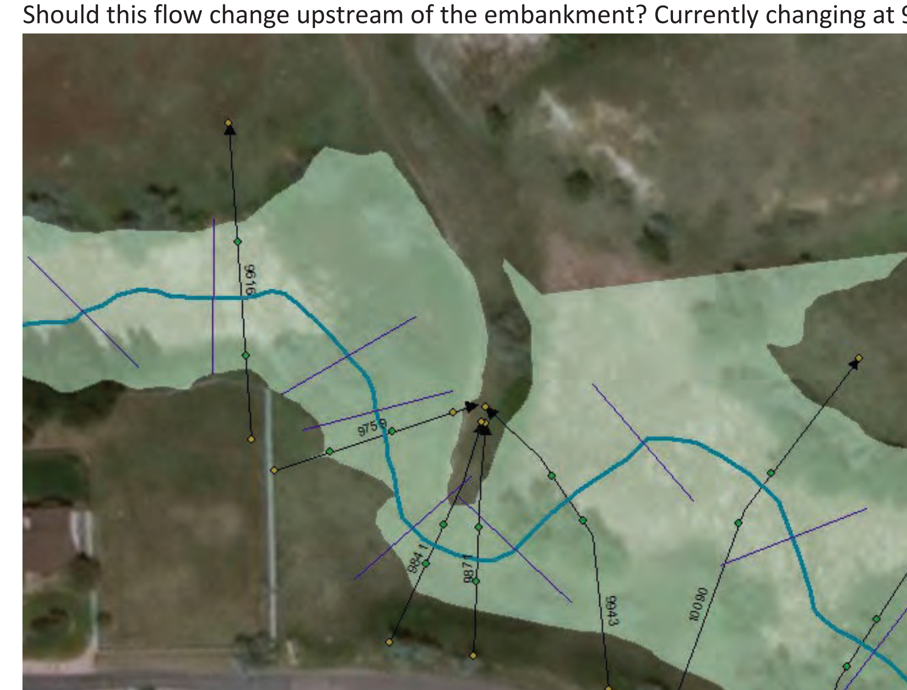
Response: Our understanding is that crossing profiles are acceptable when they occur within a structure. We believe there is a hydraulic jump at the downstream end of this structure that these crossing profiles depict. Propose leaving this as-is.

4. Verify RAS flow change locations match SWMM design points

    a. Flow changes are occurring at the structures, not at the upstream XS. Is this appropriate?

Response: SWMM flow change locations were offset upstream to the next SWMM design point. When the design point was located at a road crossing, the flow change was applied at the structure's downstream XS so that the "correct" flow was applied through the structure. Confirmed this is okay at meeting.

    b. Should this flow change upstream of the embankment? Currently changing at 9616.



Response: Flow change moved to XS 9943.

Reach Lengths/Cross Section Widths

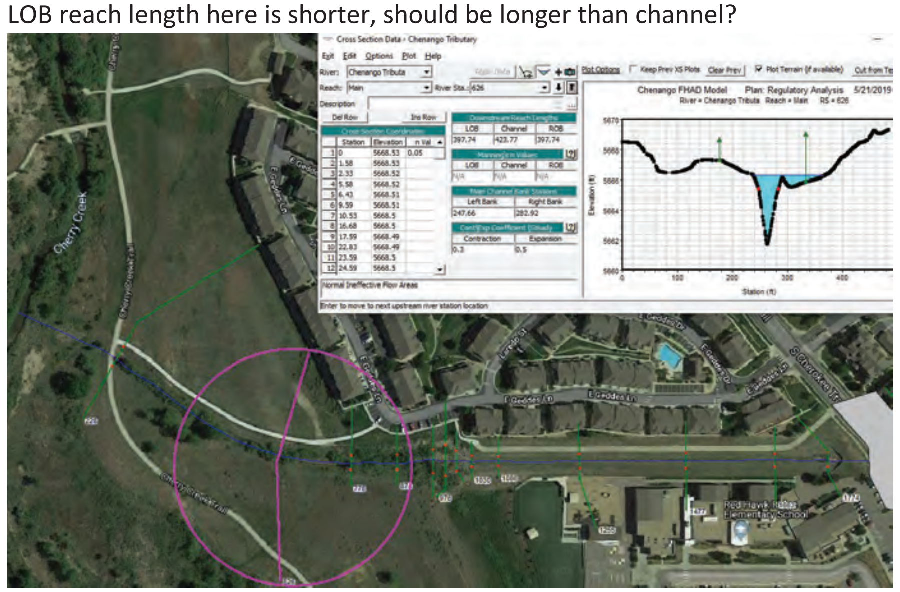
8. Verify RAS and GIS reach lengths are in agreement (XS Location Test Tool)

   a. Downstream-most reach length is off by about 30 feet, 423 in model, looks like it should be closer to 398?

Response: Reach length has been corrected.

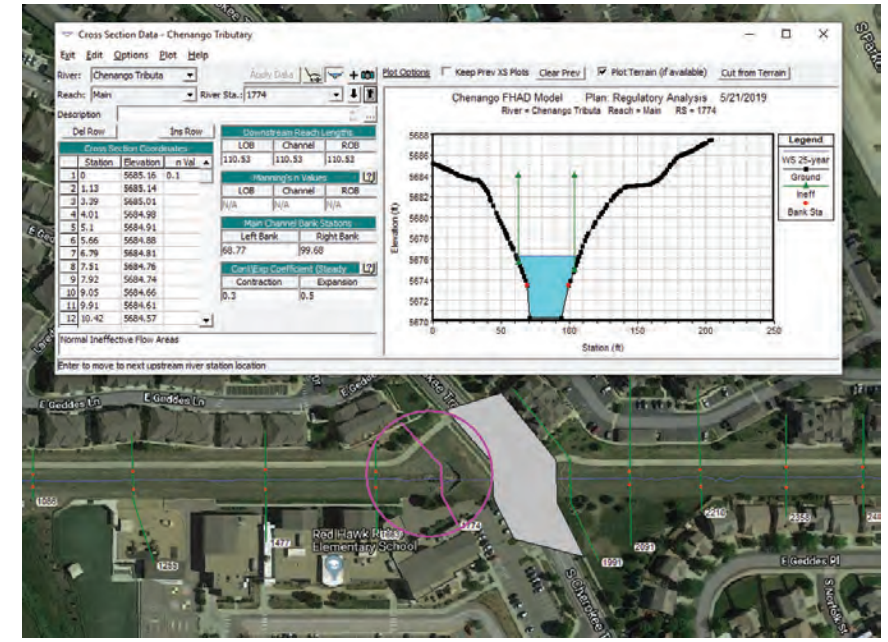
10. Verify overbank lengths are reasonable and different from channel lengths (when appropriate)

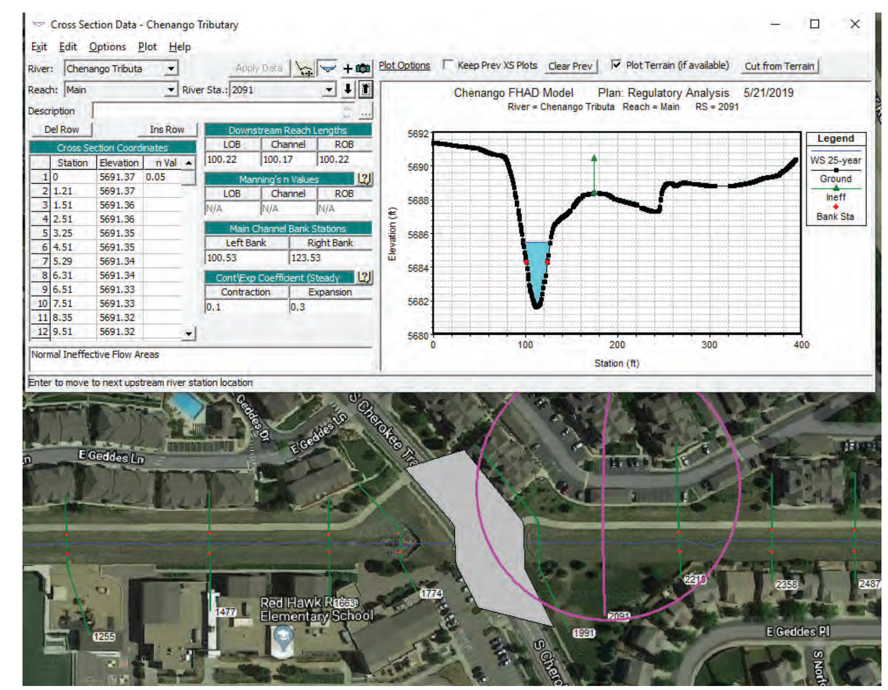
   a. LOB reach length here is shorter, should be longer than channel?



Response: Agreed. Reach length has been corrected.

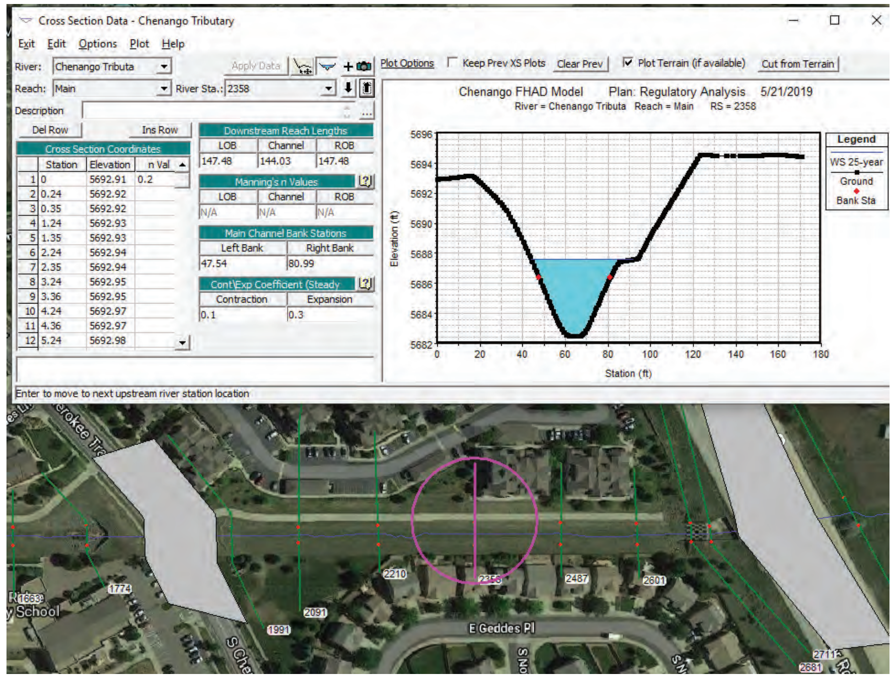
   b. These overbank reach lengths should be different?





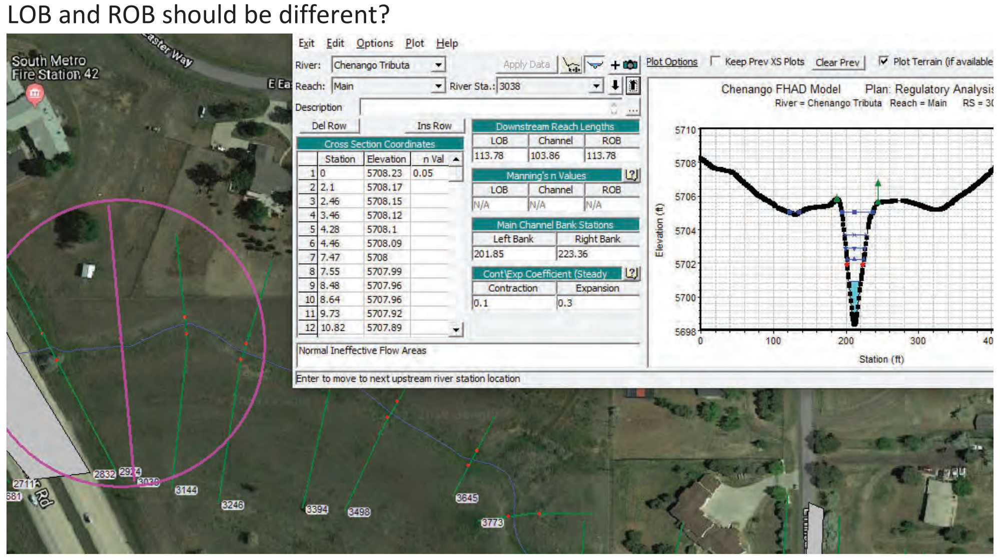
Response: Agreed. Reach lengths have been corrected. Note that some values are very similar due to the straight, engineered nature of the channel.

d. Channel should be longer than the overbanks?



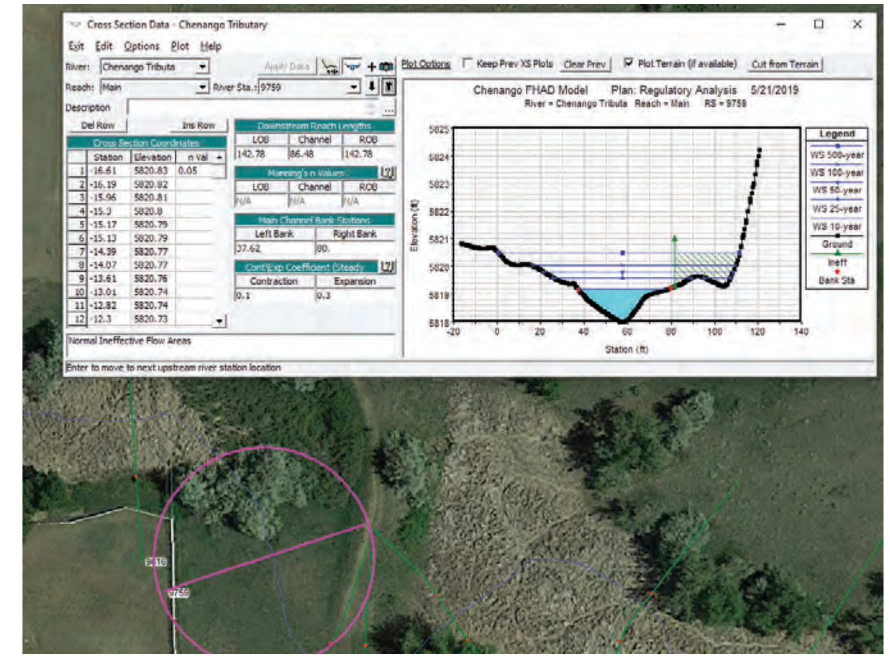
Response: The channel CL is delineated to follow the contours for low flow, while the overbanks are following a less-sinuous overbank flow path. While the channel reach length is slightly longer than the overbanks, all three will be averaged out in the calculations.

e. LOB and ROB should be different?



Response: Agreed. Reach lengths have been corrected.

f. LOB should be shorter than Channel and ROB should be longer?



Response: Agreed. Reach lengths have been corrected.

g. Not all XSs were commented on: Please go through all XSs and verify that LOB and ROB reach lengths are varied accurately.

Response: XS's were reviewed and reach lengths have been corrected as necessary.

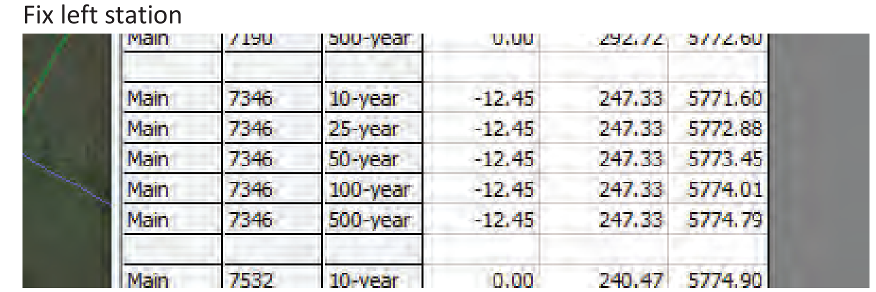
11. Verify cross section IDs correspond with cross section stationing (ideally)

    a. They vary by the value of the downstream-most reach length (same as Kragelund).

    Response: XS ID's have been corrected as necessary.

12. Verify GIS cross section width corresponds to cross section width in RAS model (considering skew)

    a. Fix left station



Main	7190	500-year	0.00	292.72	5772.60
Main	7346	10-year	-12.45	247.33	5771.60
Main	7346	25-year	-12.45	247.33	5772.88
Main	7346	50-year	-12.45	247.33	5773.45
Main	7346	100-year	-12.45	247.33	5774.01
Main	7346	500-year	-12.45	247.33	5774.79
Main	7532	10-year	0.00	240.47	5774.90

b.

Main	9759	10-year	-16.61	120.72	5819.17
Main	9759	25-year	-16.61	120.72	5819.60
Main	9759	50-year	-16.61	120.72	5819.81
Main	9759	100-year	-16.61	120.72	5820.03
Main	9759	500-year	-16.61	120.72	5820.50

c.

Main	10446	10-year	-29.67	351.04	5823.22
Main	10446	25-year	-29.67	351.04	5823.83
Main	10446	50-year	-29.67	351.04	5824.15
Main	10446	100-year	-29.67	351.04	5824.53
Main	10446	500-year	-29.67	351.04	5825.26

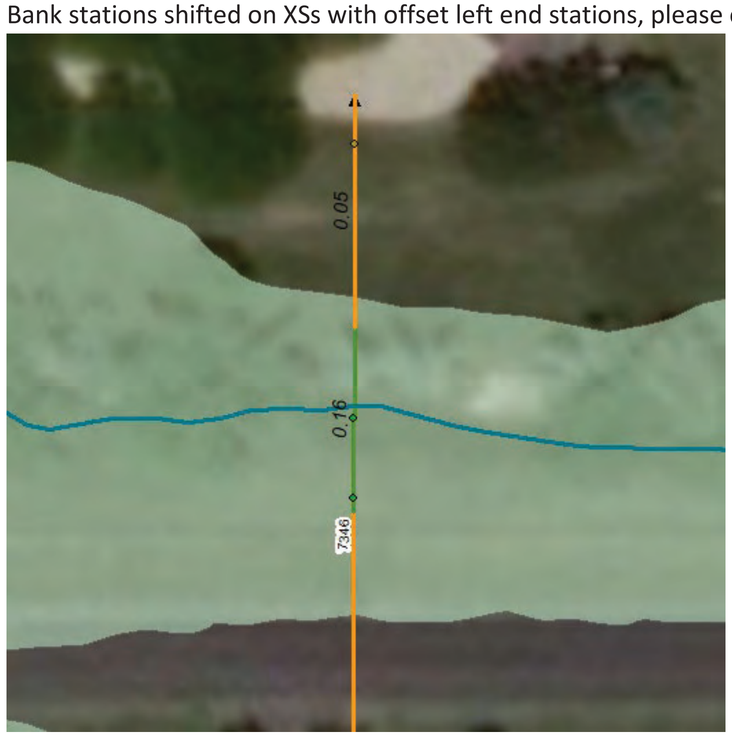
Response: XS stationing has been modified to start at 0.

Cross Sections

22. Verify bank stations are reasonable at each cross section (Plot RAS Cross Section Extents Tool):

    b. Channel alignment is between bank stations

        i. Bank stations shifted on XSs with offset left end stations, please check.



Response: Bank stations corrected per modification of XS stationing to start at 0.

23. Verify backwater areas and depressions are represented by IEFA and permanence as appropriate (All Geo Reviews Tool)

    a. Are these IEFAs because of expansion from the culvert, or because of ponding in this low area?

Response: IEFA's represent expansion from culvert in this area.

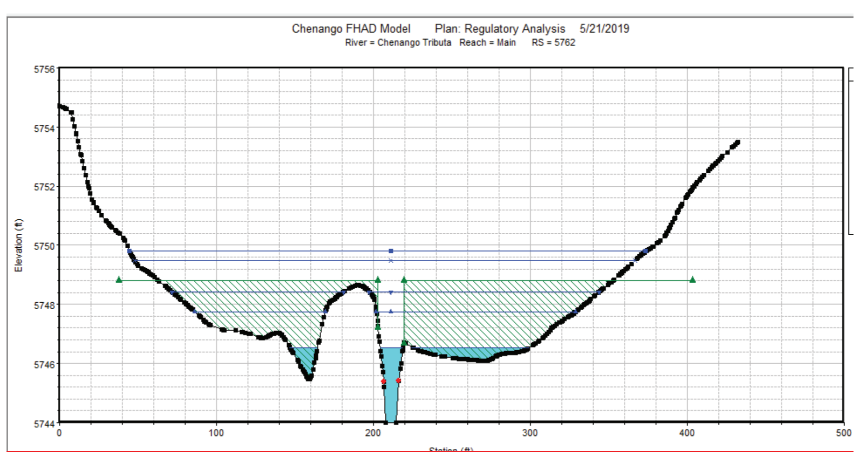
24. Verify building conveyance shadows are handled with obstructions/IEFA/high Manning's n (All Geo Reviews Tool)

    a. Shouldn't this section of the embankment be IEFA?

Response: Agreed. Circled sections have been made IEFA.

25. Verify canals/ditches are obstructed or IEFA (All Geo Reviews Tool)

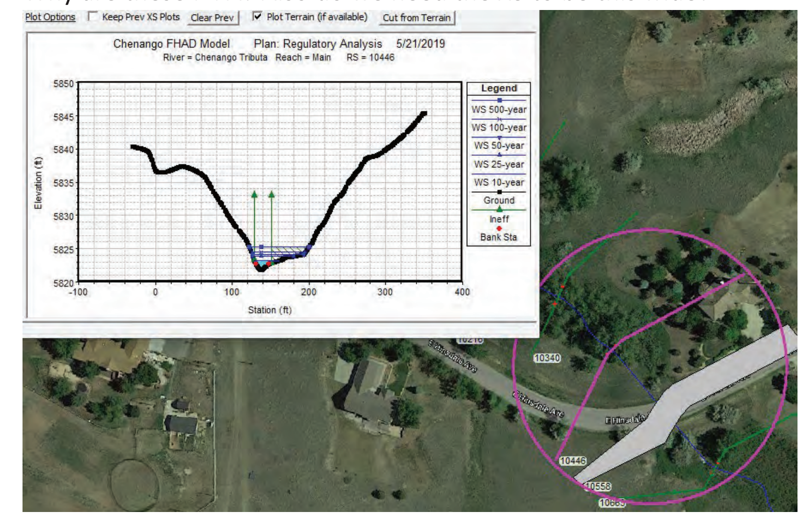
    a. Are the roadside ditches assumed to be full with local flow, and that's why they're not counted for conveyance? But that flow would have been added at the upstream flow change point, so isn't it accurate to convey it here? Because flow on the south side might not ever make it back over the road into the main channel? Ditch small enough not to make a significant impact on floodplain?



Response: I believe on previous FHAD's we have excluded the conveyance area from other tributaries or local ditches from the floodplain models. Flow on the south side was considered ineffective with the assumption that the culverts at Crossing 17 are not part of the main system, but for the ditch. This area was discussed at the comment meeting and confirmed that the ditch on the south side will be disregarded.

26. Verify IEFAs are reasonable and consistent for adjacent cross sections.

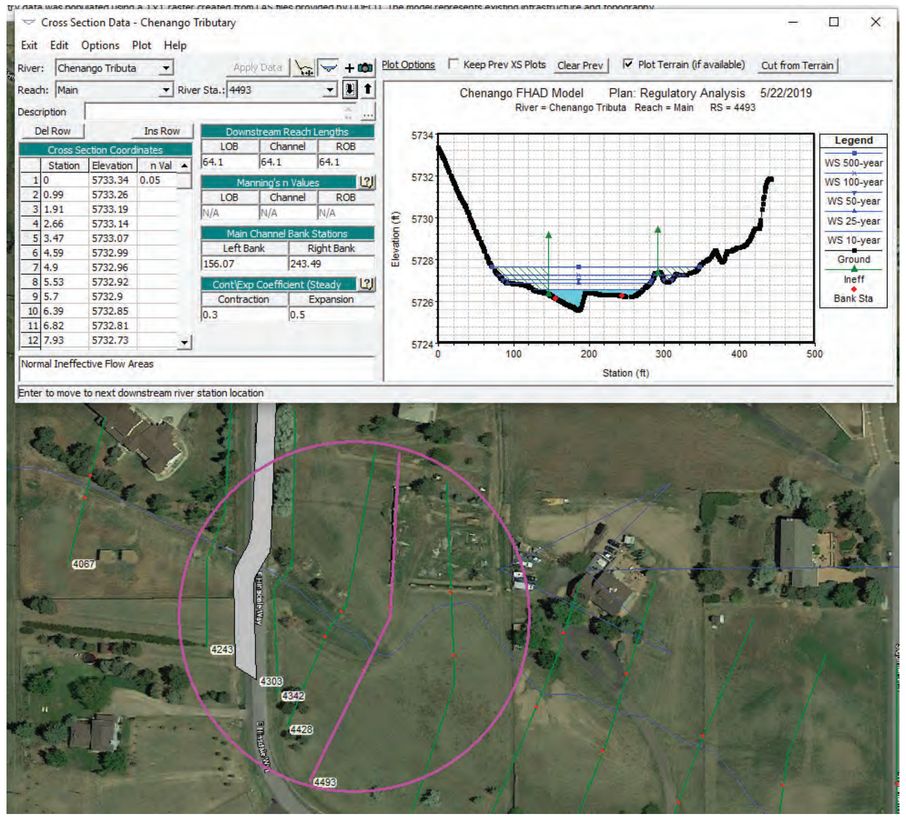
    a. Why are these IEFA? Also do we need the XS to be this wide?



Response: IEFA's are represent expansion from the culvert. XS' have been trimmed some. However, there is potential for split flow down the southern side of Hinsdale Avenue, and back over the road. Confirmed with 2D modeling that the 500-year only splits. Jon has reached out to SEMSWA to confirm if it is okay to include the limits of the 2D area in the Zone X unregulated. No split flows are to be added as of now.

27. Contraction/expansion coefficients are appropriate

a. Do increased coefficients need to begin this far upstream of the culvert?

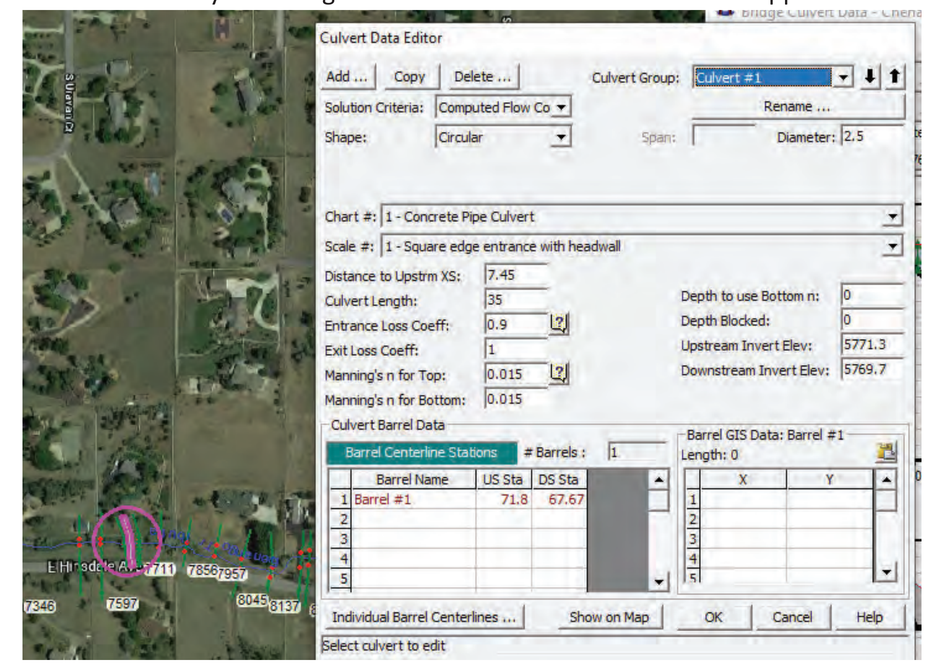


Response: Expansion/ contraction coefficients were generally applied along the full distance that contraction took place upstream of structures. The coefficients have been limited to the two XS's upstream instead of three.

Hydraulic Structures

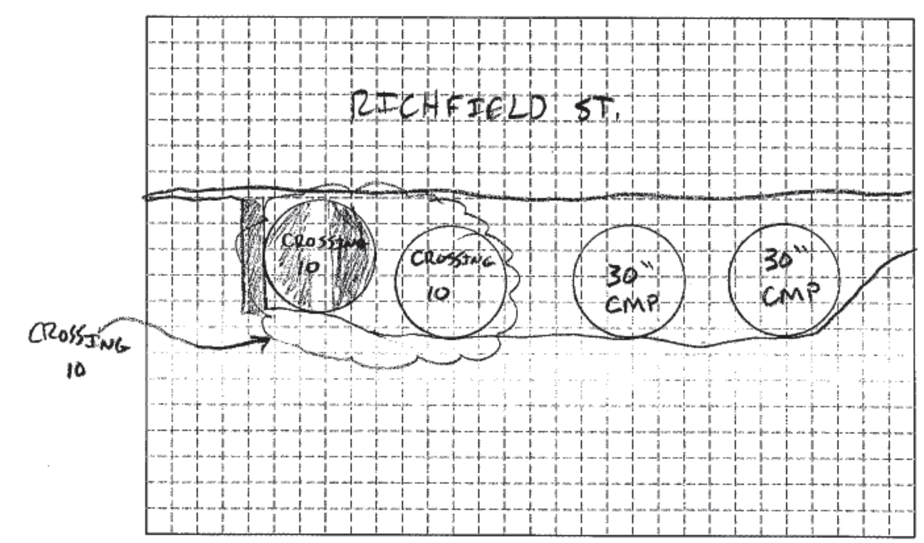
34. Geometry - top of road/low chord/invert elevations/culvert sizes (survey .csv data into ArcMap)

a. This survey shows this culvert as half full of sediment, but it doesn't appear to be modeled this way? Crossing 8. Also Chart and Scale selected not applicable to CMP?



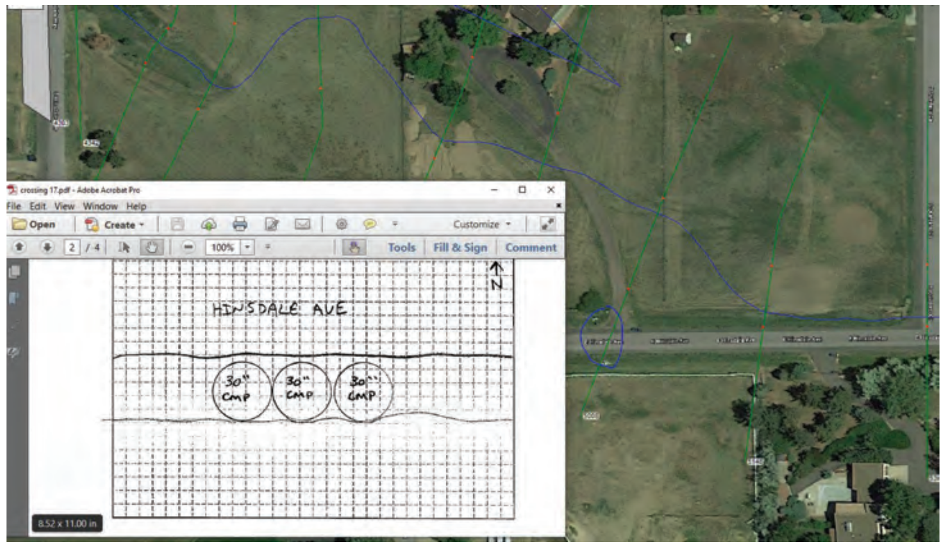
Response: As a general rule, FEMA calls for hydraulic structures to be assumed free of blockage and debris loading is not modeled in hydraulic analysis for NFIP studies. The same approach was assumed for the FHAD. Chart and scale modified to reflect CMP.

b. RS 5786 doesn't model the other two culverts that cross Hinsdale – should we model this as a separate flow path and a split?



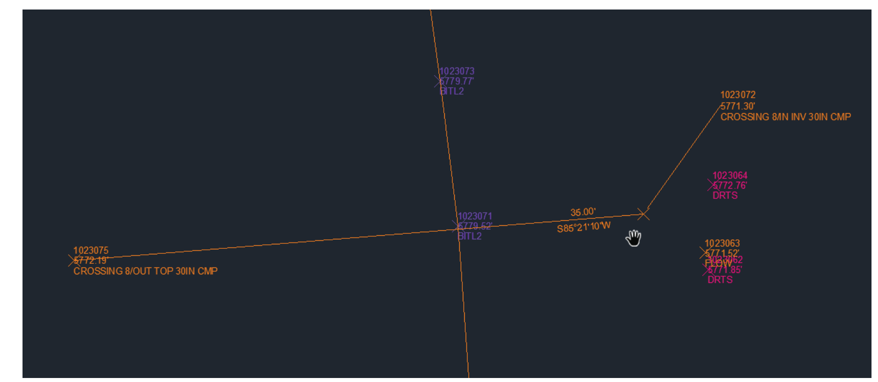
Response: Discussed during meeting. These culverts serve the ditch to the south and are being disregarded.

c. Do we know if this crossing is intended to bring the south ditch back into the main channel? Do we need to model this? Crossing 17



Response: Discussed during meeting. These culverts serve the ditch to the south and are being disregarded.

d. Roadway crest elevations don't match?

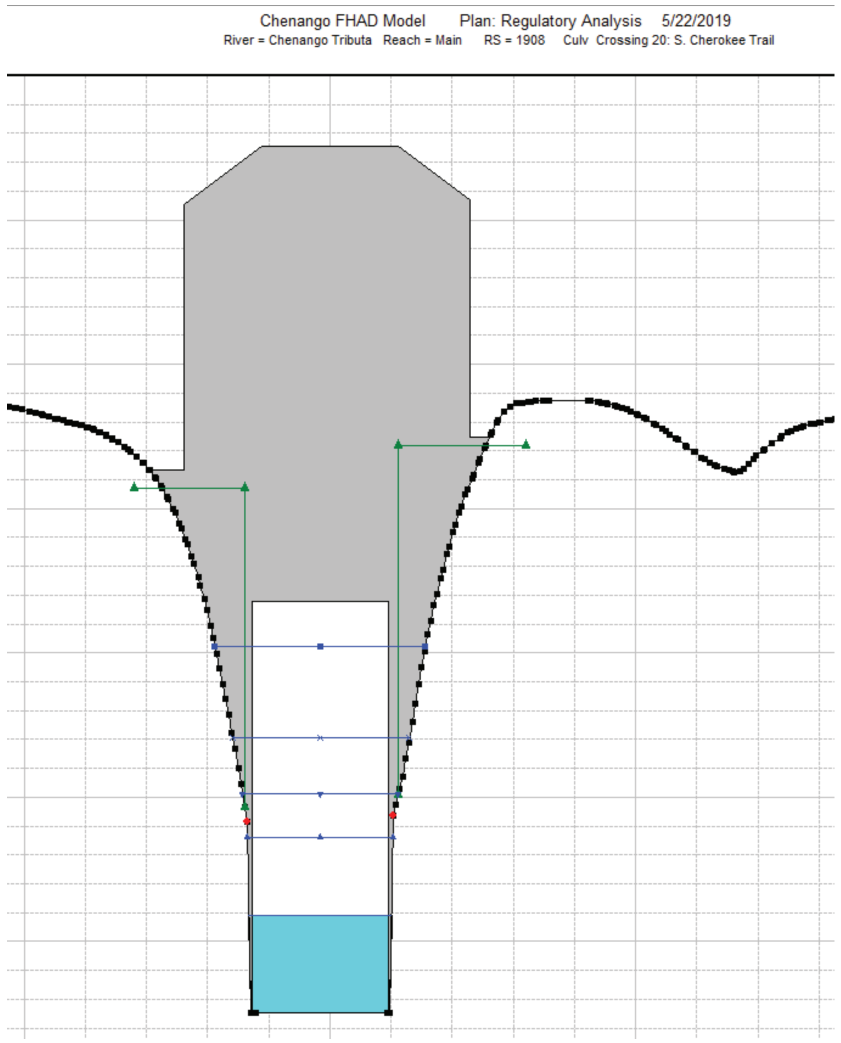


Response: Road deck elevations have been modified by hand to correspond with the structure survey.

37. Ineffective flow area assumptions, appropriate permanence

a. IEFAs upstream of bridge and culvert crossings should be permanent and set to the top of road elevation.

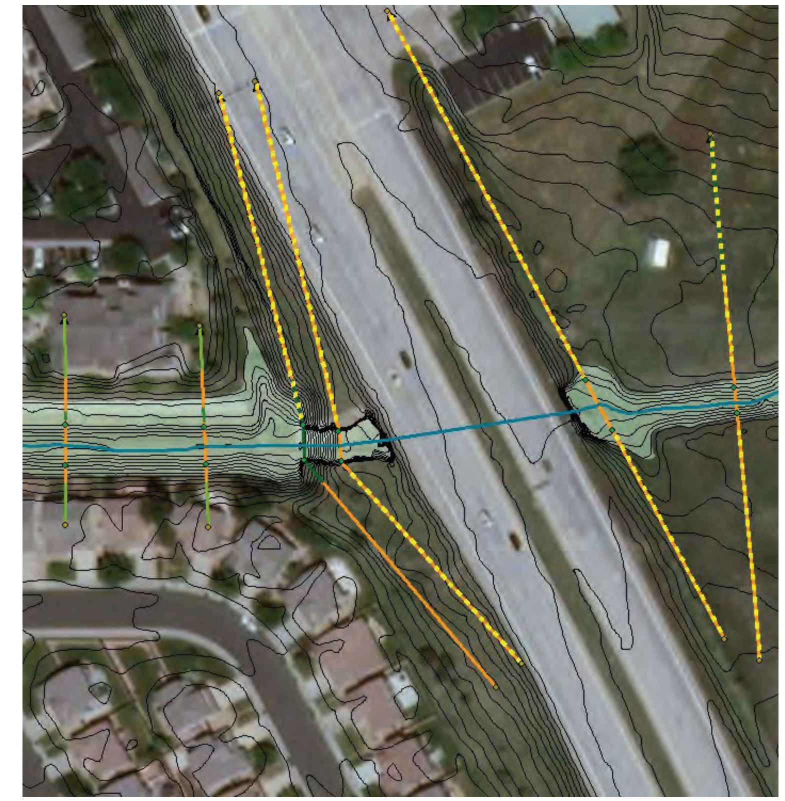
i. What exactly is happening here?



Response: The bridge deck has been modified by hand to reflect obstruction of flow that would be caused by the large chain-link fence located along the headwall of the culvert. The road crest is actually lower than the headwall elevation at this location, so embankment blockage is only represented by the headwall and chain-link fencing.

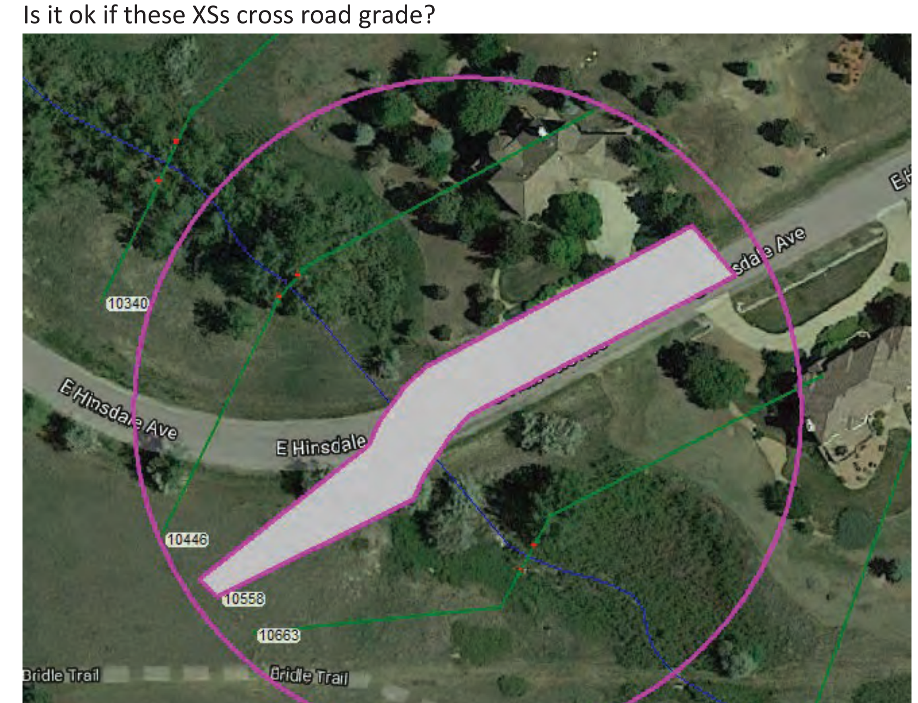
39. Verify cross sections up/downstream of structures do not cross road grade

a. XSs crossing road grade



Response: XS's have been trimmed.

b. Is it ok if these XSs cross road grade?



Response: XS's have been trimmed and no longer cross the roadway.

40. Verify all significant hydraulic structures are modeled

    a. See earlier comments about modeling of Hinsdale culverts.

    Response: Discussed during meeting. The referenced culverts serve the ditch to the south and are being disregarded.

REVIEW STEP 1 - MODEL REVIEW - Joplin

Plans, Flows, and Profiles

3. Verify HEC-RAS peak flow discharges against hydrology (compare to Hydrology Peak Flow Table and/or Discharge Profiles)

    a. According to our stream delineation, the major drainageway (and thus the floodplain) should start at S Laredo St.

    Response: Per our phone conversation, the alignment is okay. We have delineated *past* Laredo St. upstream to Lewiston, which is the outflow location of subbasin J8. The baseline hydrology and FHAD both show our understanding of the delineation is up to Lewiston.

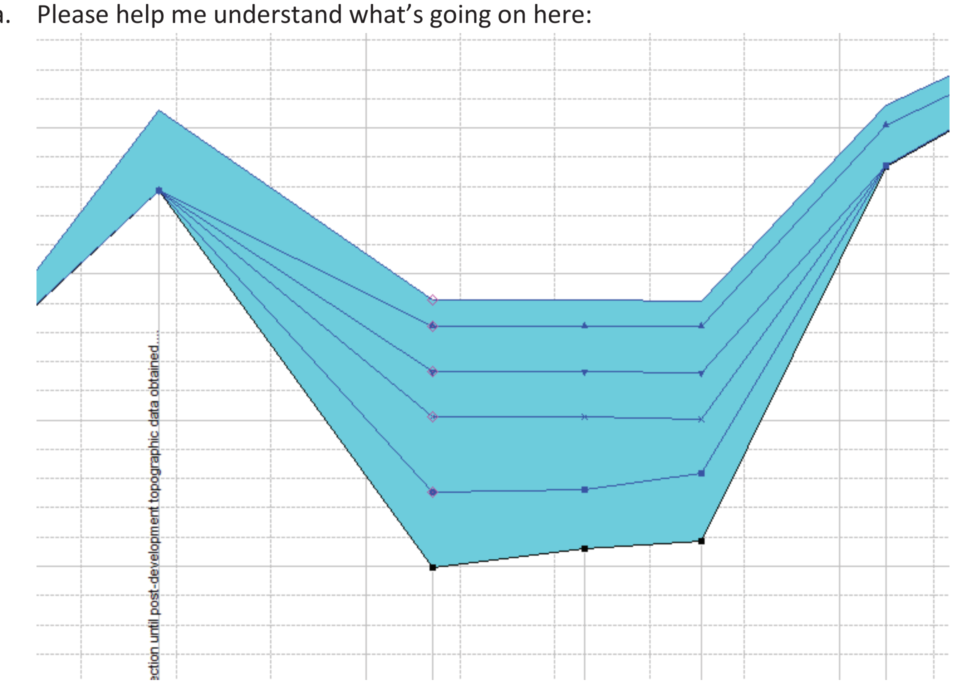
4. Verify RAS flow change locations match SWMM design points

    a. It would greatly simplify the review to be able to view the SWMM schematic in GIS. Please provide a shapefile with the SWMM schematic for all tributaries.

    Response: Per our phone conversation, Dewberry | J3 will try to export SWMM GIS files for this in a timely manner.

6. Verify any set WSELs against rating curve information (as for a detention basin, or complex inlet condition)

    a. Please help me understand what's going on here:



Response: Pond RB1-4: Cross section 7571 is set to the water surface elevations which were identified in the baseline hydrology SWMM model for the RB1-4 pond. Overflow of the 72” pipe from Pond RB1-4 to Chambers Road crossing occurs for the 500-year storm event only and the flow rate for the model is 312 cfs, as determine in CUHP and SWMM.

Also, discussed this in the August meeting and clarified the modeling approach with Jon.

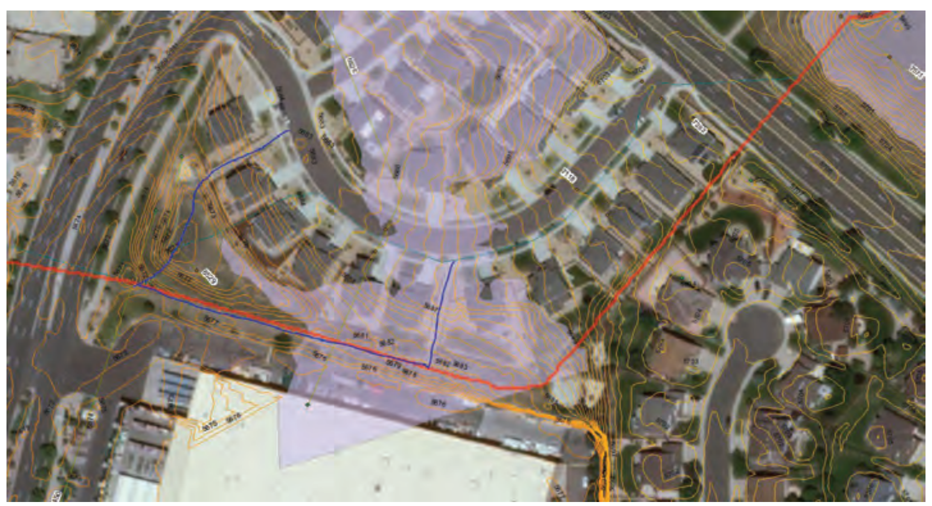
Reach Lengths/Cross Section Widths

7. Verify channel alignment is reasonable and follows low flow channel as indicated by contours

   a. I understand the delineation will be updated with the new survey in the area around S Granby Way. Is 2D modeling going to be needed here?

   Response: No, 2D modeling isn’t necessary. We can assume, based on new survey, that overflow occurs at upstream manholes of this development. Both manholes that would potentially overflow would flow to Granby Way to the new flowpath.

   Also, discussed this comment with Jon in the August meeting. Jon approved the assumptions for flow through the new development at Joplin Way and Granby Way (overflow at manholes upstream of the development). He noted that for purposes of documentation, we need to show the main channel following the 72” pipe with overflow along the Granby Way curb and gutter.



   b. Hard to compare to the GIS because our background aerial is so low res, but according to the latest Google Earth image this looks like the low flow path going into Parker Rd.

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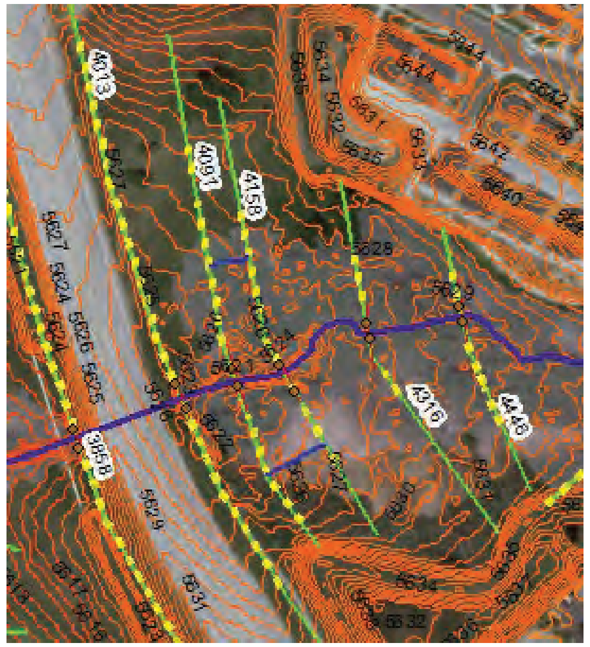
   Response: The low flow channel near Parker Rd. is well defined in the elevation file but agree that it doesn’t matchup with the aerial. As we understand it, the elevation data drives the delineation and we feel that the alignment is a good representation.

10. Verify overbank lengths are reasonable and different from channel lengths (when appropriate)

   a. The skew of these XSs in the overbank seems as though it doesn’t always accurately represent the actual flow direction of water and requires big differences in overbank and channel reach lengths. Please explain the reasoning for these alignments.

   Response: Agree, the downstream cross-sections were generally lengthened and reworked to follow contours and capture the flowpaths downstream of Parker Rd. This was done with attention to detail and removed most of the “dog-eared”-type XSs that you see here.

a. ROB downstream length is longer than the LOB and the channel on XS 4158 – is this accurate?

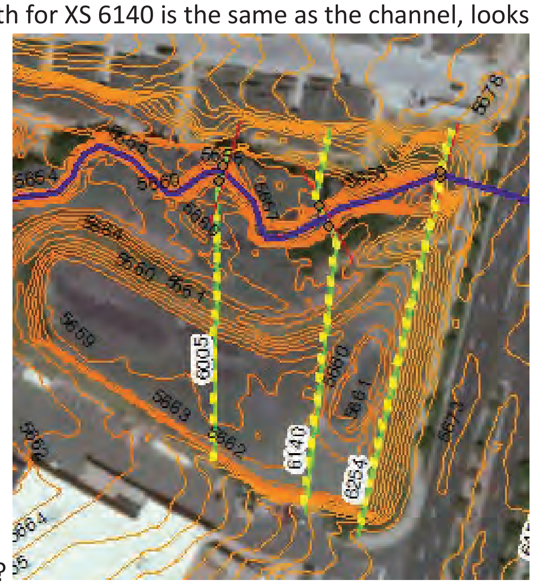


Response: No, this was not accurate. We modified the flowline delineations and have better estimates now (for instance, LOB is now 10 feet longer than the ROB here).

b. Please revisit and confirm all XS overbank downstream reach lengths.

Response: Re-calculated reach and overbank lengths for all cross-sections.

c. DS LOB reach length for XS 6140 is the same as the channel, looks as though it should be quite a bit shorter?

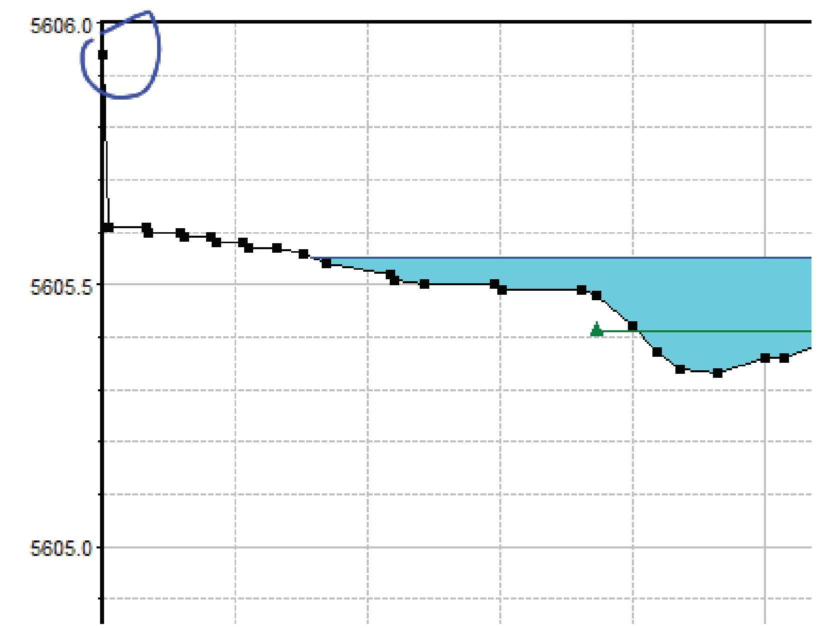


Response: The LOB reach length is now about 10 feet shorter than the channel length.

Cross Sections

15. Verify cross section geometry is within criteria (not uncontained)

    a. Is this high point on LOB of XS 2999 real? Don't see it in topo (and this XS is very close to being uncontained).



Response: Agree, extended the LOB several feet, re-extracted geometry and re-stationed, and fixed manning's.

16. Verify cross section alignment represents level water surface

    a. See item 10. a.

Response: Also see response for 10a.

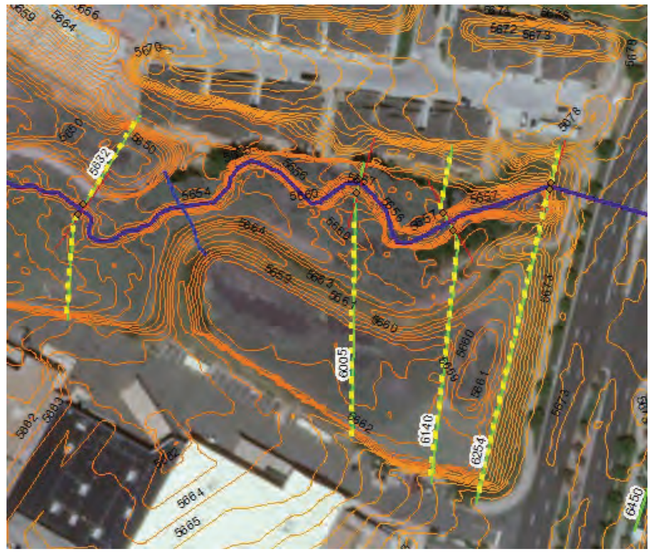
17. Verify cross sections are perpendicular to flow direction or have appropriate skew

    a. Bankfull sections look perpendicular to flow, but not always necessarily the overbanks, per previous comments. Please review overbank XS alignment.

Response: Also see response for 10a. Many cross-sections were modified to better represent the flow paths.

19. Verify adequate cross section densities, especially near buildings/homes

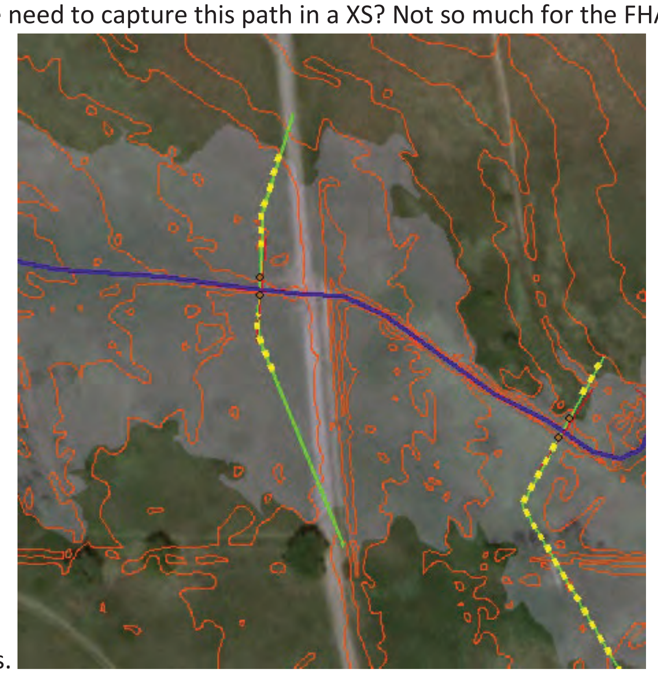
    a. Do we need another XS at the confined area between these ponds?



Response: Agree, added a cross-section 5793 for additional detail.

20. Verify road grades, dams, and other areas of high ground are represented by cross sections (check for missed controls and constrictions)

    a. Do we need to capture this path in a XS? Not so much for the FHAD but for smaller events.

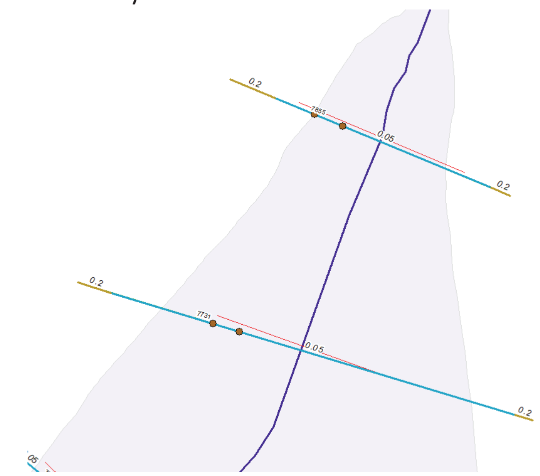


Response: Agree. Removed the cross-section just downstream and added one to follow the footpath. Also added one upstream to capture the pool.

22. Verify bank stations are reasonable at each cross section (Plot RAS Cross Section Extents Tool):

    b. Channel alignment is between bank stations

       i. I believe your left station doesn't start at 0 on these two XSs.



Response: Fixed stationing at these cross-sections.

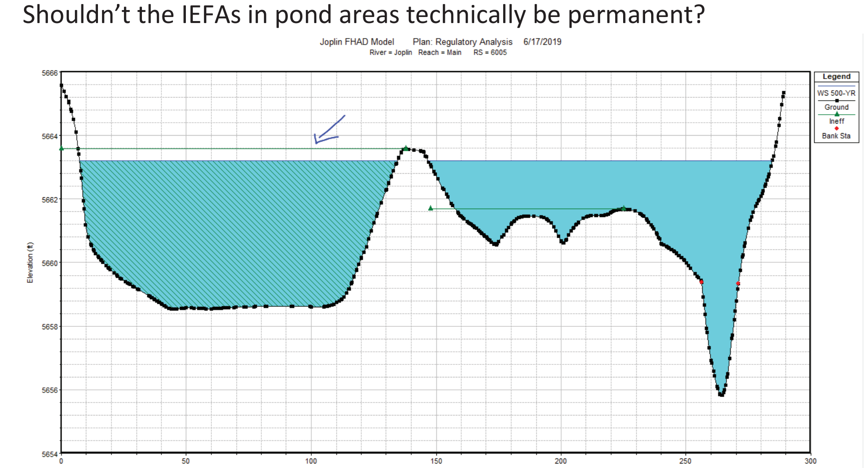
23. Verify backwater areas and depressions are represented by IEFA and permanence as appropriate (All Geo Reviews Tool)

    a. See 26. a.

Response: Also see response for 26a.

26. Verify IEFAs are reasonable and consistent for adjacent cross sections.

    a. Shouldn't the IEFAs in pond areas technically be permanent?



Response: Agree, made LOB pond permanent IEFAs for 5793, 6005, and 6140 and ROB pond permanent IEFA for 5632.

27. Contraction/expansion coefficients are appropriate

    a. Did you mean to have 0.3 contraction coefficient on XS 6140?

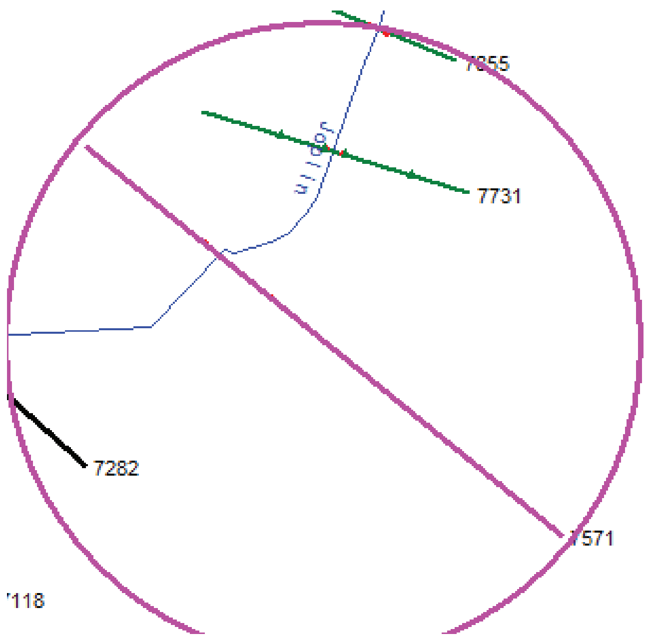
    Response: Yes, contraction/expansion is 0.3/0.5 for 6140 since it is two downstream from the crossing.

    b. 0.5 expansion on XS 6529?

    Response: Yes, contraction/expansion is 0.3/0.5 for 6529 since it is two downstream from the crossing.

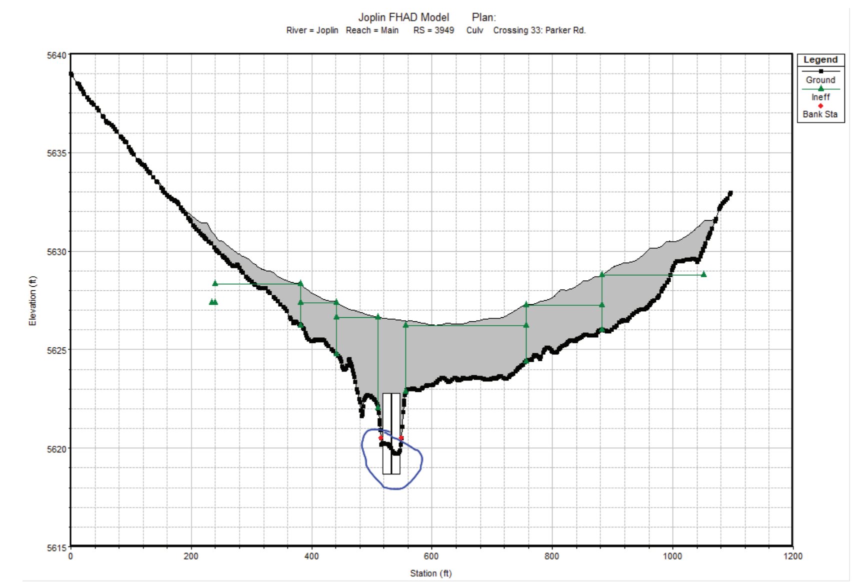
    c. Do we need higher expansion coefficient here?

    Response: Agree, modified expansion coefficient for pond XSs 7571, 7731, and 7855.

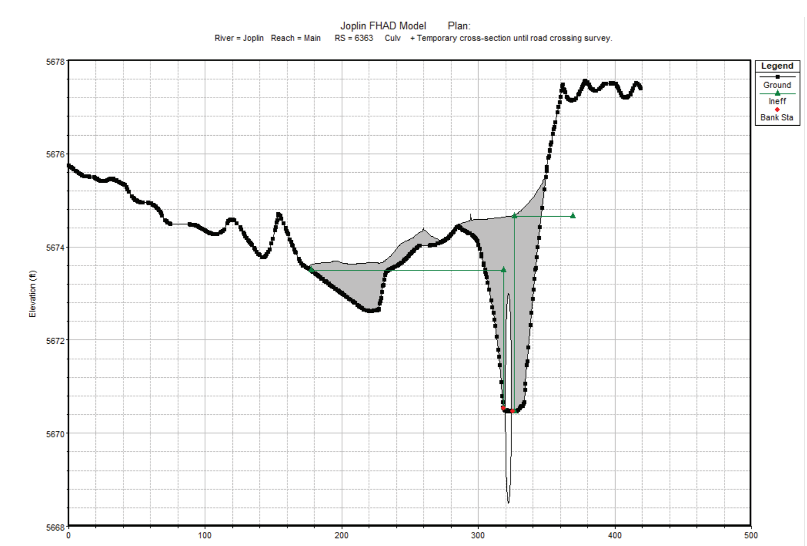


29. Check that channel invert elevations decrease when moving downstream. (Not always incorrect, but needs to be verified/justified.)

    a. Where LiDAR shows channel invert elevations higher than the surveyed inverts of the nearby crossing structures, we recommend connecting surveyed invert elevations through the channel reach.



Response: Modified culvert inverts/ground elevations to match survey.



Response: Modified culvert inverts/ground elevations to match survey.

Flow Splits

31. Verify other flow split/distribution methods are sound

    a. We need to be sure that we are apportioning the overland flow in this area appropriately.

    Response: Agree, refer to response to item 7a.

Hydraulic Structures

34. Geometry - top of road/low chord/invert elevations/culvert sizes (survey .csv data into ArcMap)

    a. Roadway elevation from survey doesn't match IEFA/XS for Parker Road culvert?

    Response: Agree, added a 24" railing to the upstream and downstream roadway elevations based on the structure survey dimensions for Parker Road and Chambers.

35. Verify adjacent cross section inverts have been modified appropriately and match culverts inlets/outlets

    a. See 29. a.

    Response: Also see response to 29.a.

(another item from Little Raven section): XS 7118 on Joplin – change IEFA to not overlap stations with blocked obstructions.

Response: IEFAs in this area no longer intersect any conveyance obstructions.

REVIEW STEP 1 - MODEL REVIEW – Kragelund

Plans, Flows, and Profiles

3. Verify HEC-RAS peak flow discharges against hydrology (compare to Hydrology Peak Flow Table and/or Discharge Profiles)
    a. FHAD HEC-RAS flows for Kragelund represent future conditions hydrology, correct? Existing conditions hydrology will be submitted with the FIRM.

    Response: A new plan for existing conditions flows has been added to the model.

5. Verify discharges are identical between all plans
    a. Some WSEs converge at RS 9644 and 5879 (and these RSs do not correspond to XSs) – what is happening here? At these cross sections we have critical flow, please correct.

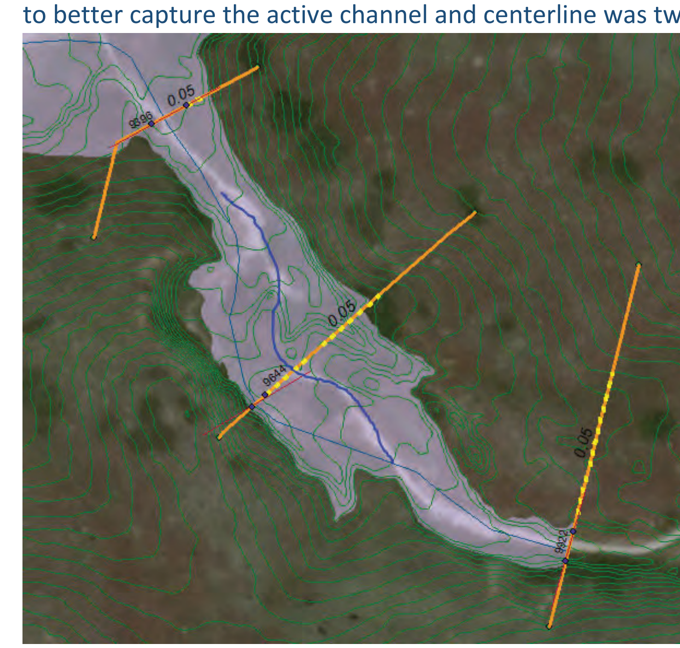
    Response: Modified XSs 9644 and 5879 so that profiles don't converge and become critical during minor storm events.

Reach Lengths/Cross Section Widths

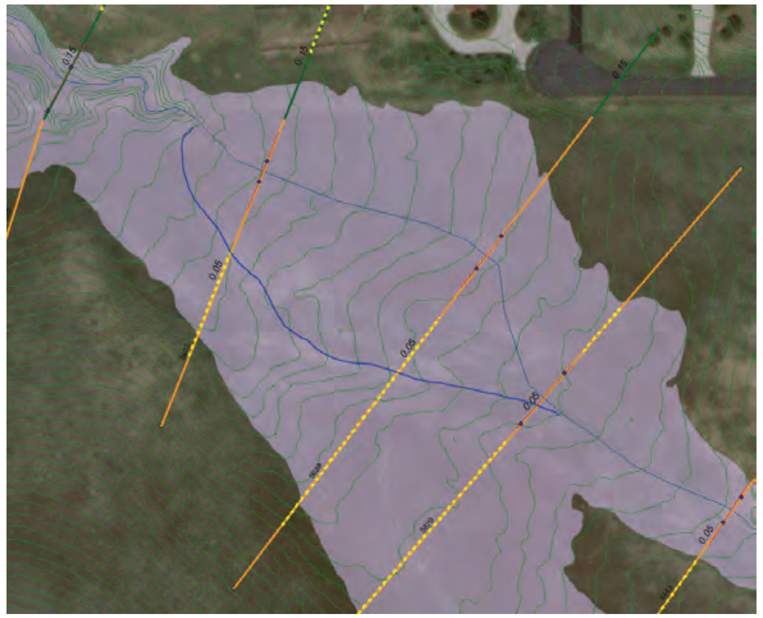
7. Verify channel alignment is reasonable and follows low flow channel as indicated by contours
    a. Aerial seems to indicate a clear low flow channel (sand bed?), not followed in all locations. What is the basis for choice of low flow in areas like this?

    Response: We used the contours and .las files to delineate the channel and the cross-sections as the model would be difficult to run if we used the aerial for reference. The contours just don't line up with the aerial at the upstream section that was pointed out.

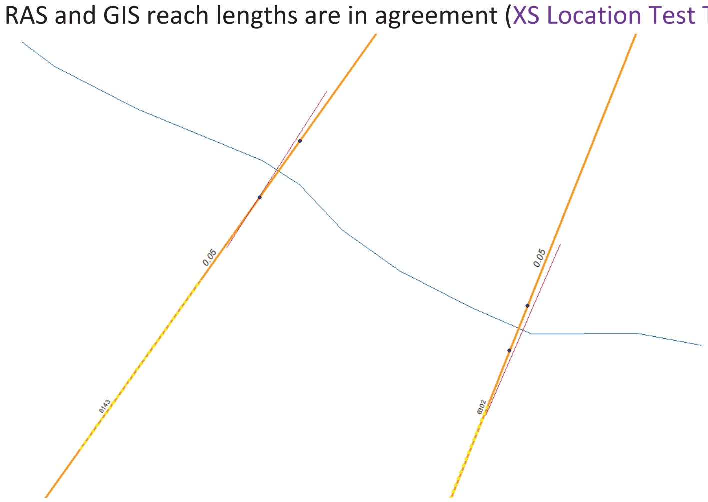
    a. 9644: Disagree with the proposed alignment. The alignment suggested follows a ridgeline. The existing centerline looks good but the cross-section was moved/modified to better capture the active channel and centerline was tweaked a bit for precision.



b. 5879: Agree with the proposed alignment. Moved the centerline to following the low-flow channel to the southwest of the original alignment and adjusted cross-sections accordingly.



8. Verify RAS and GIS reach lengths are in agreement (XS Location Test Tool)



a. Are these off a little bit, or is this just a rendering issue?

Response: Agree. Fixed flow lengths at the end of editing to ensure channel and flowpath lengths are appropriate.

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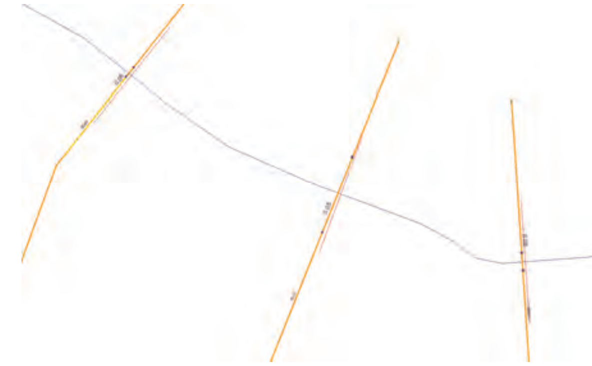
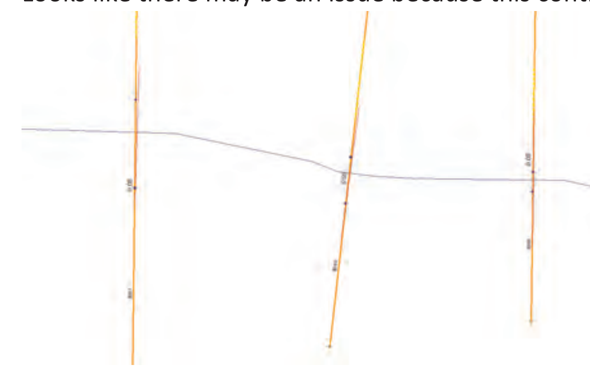
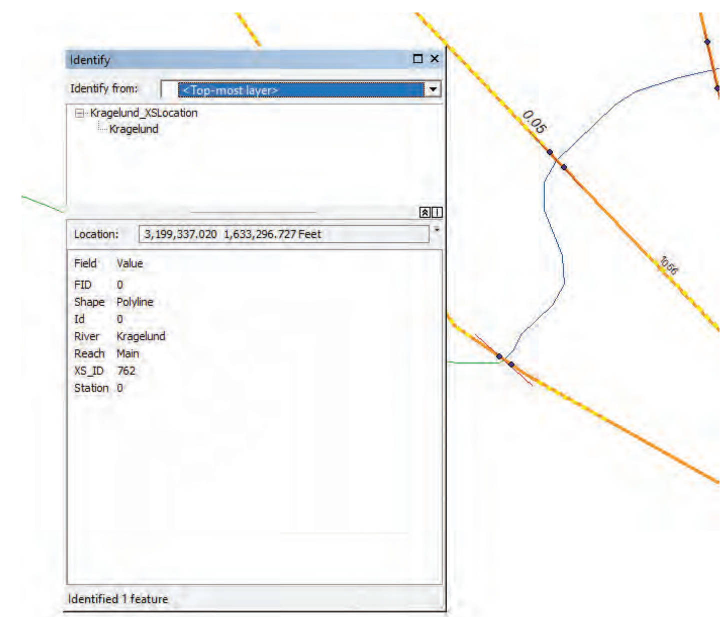


c. Looks like there may be an issue because this continues upstream.



d. They gradually go back to matching…



e. Do these not match because of the downstream confluence reach? Do they need to add downstream reach length of 762 to the first cross section?

Response: Fixed the flow lengths of the first cross-section.

Cross Sections

15. Verify cross section geometry is within criteria (not uncontained)
    a. XS 2639 is contained only by IEFA on the LOB – is this realistic?

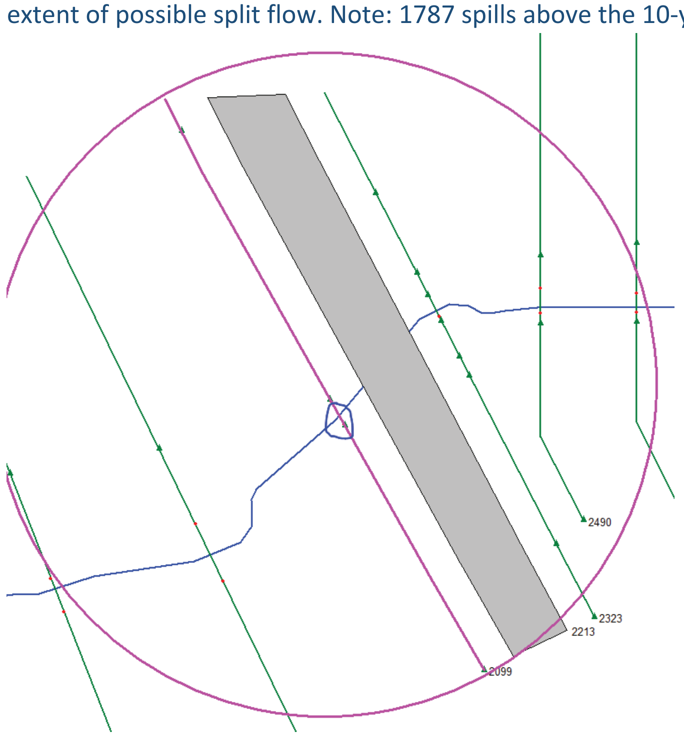
Response: XS's in this area have been extended on the LOB for containment of the 500-year other than at locations of LSs.

16. Verify cross section alignment represents level water surface
    a. It would be helpful to be able to overlay the 2D model results on the GIS to analyze cross-section placement.

Response: Agree. 2D model coincides with most flow following the low flow channel and a small portion spilling to the north for larger storm events. This was used to modify the cross-sections downstream of Parker Rd. this go around.

17. Verify cross sections are perpendicular to flow direction or have appropriate skew

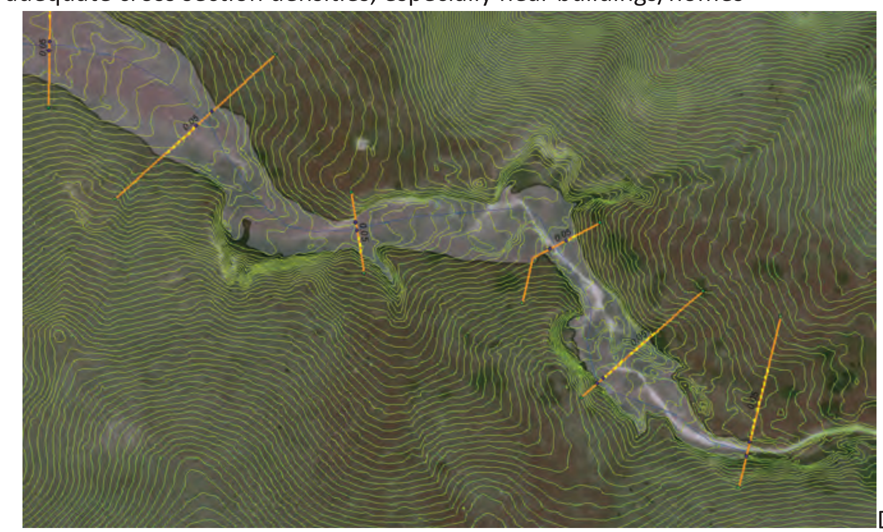
    a. Do we need skew at this XS?
    Response: Not anymore. Modified XS alignment for 2099 to be perp. to centerline. Also, added a few additional cross-sections downstream of 2099 to capture the extent extent of possible split flow. Note: 1787 spills above the 10-year, and 1855 (500-year).



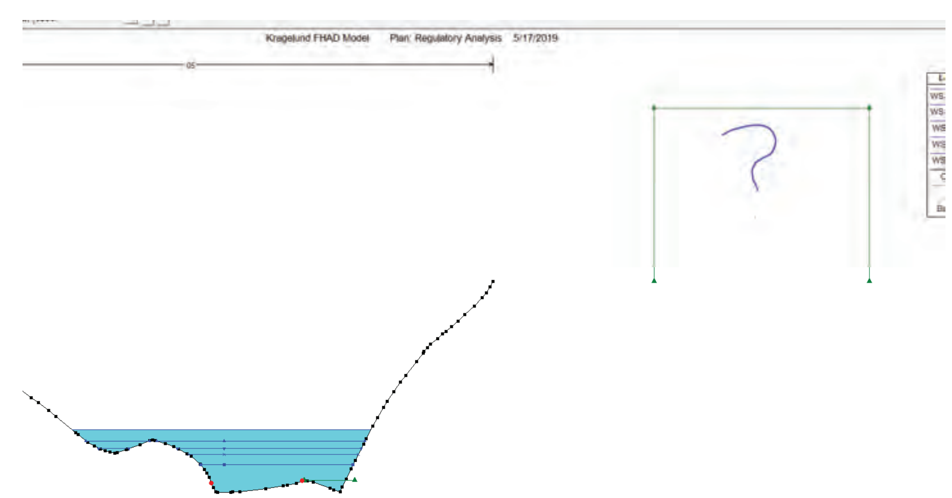
18. Verify cross sections match contours
    a. XS overbanks not always perpendicular to contours – issue? Usually outside of floodplain. Can some of the XSs be trimmed closer to the 500-year to eliminate the issues of their not being perpendicular to contours?

    Response: Agree, cross-sections were modified in several areas to follow contours.

19. Verify adequate cross section densities, especially near buildings/homes

    a. Do we need an additional XS downstream of XS 9396 to capture change in topography?

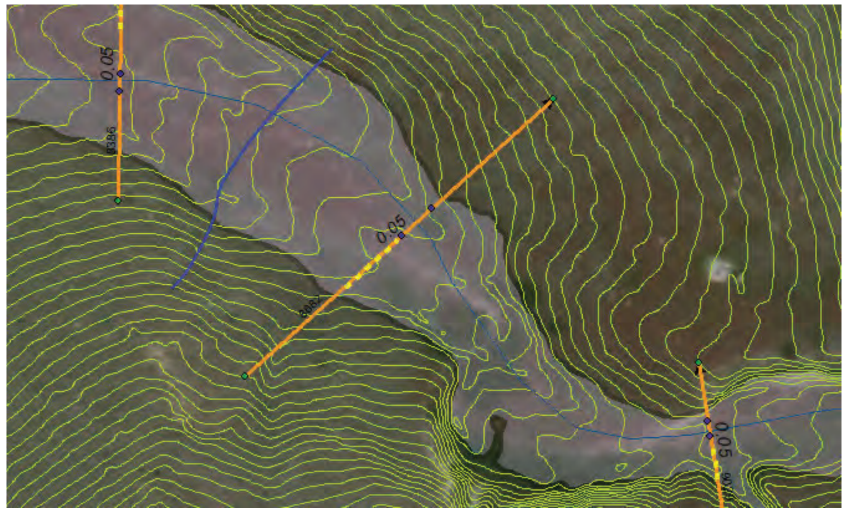
    Response: Agree, added a downstream XS.

    b. 

    Response: Removed irrelevant IEFAs.

c. Additional XS needed here to represent expansion in flow? Move XS upstream to capture beginning of expansion and increase coefficient?

Response: Agree, added a downstream XS.



21. Verify Manning's n values are reasonable and represent area between cross sections (All Geo Reviews Tool)

a. 

0.15 seems high for the ditch and grass overland sections of this reach.

Response: Agree, updated to 0.12 to reflect the range (0.1-0.2) for housing/commercial but also be higher than simply perpendicular fences (0.1).

c. 

This area looks like higher than 0.05 roughness?

Response: Agree, added a section for the commercial area west of Parker (0.12) and a section for the wetlands/forest (0.12).

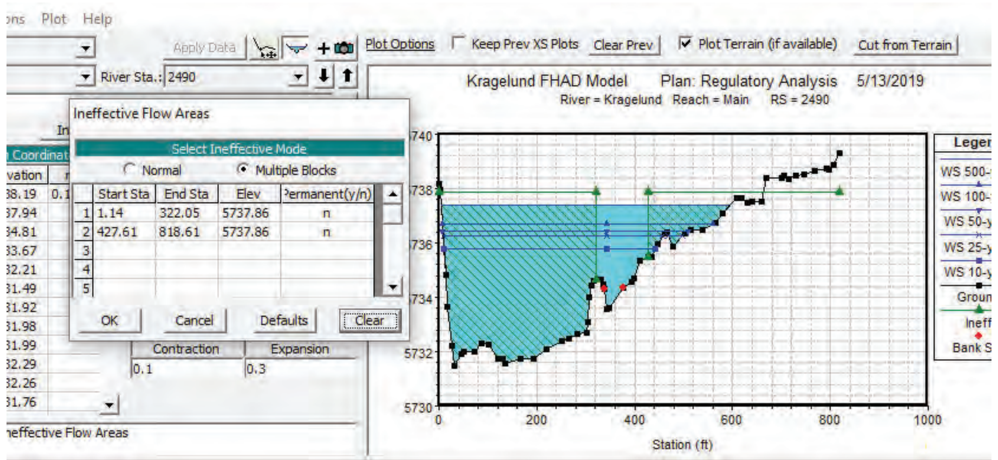
d. For most XSs we are using the same n-value for the main channel and the overbanks. Are we sure this is accurate?

Response: Reviewed and yes there are several areas with the same n (ie in upstream grassy areas) but Manning's n appears appropriate for each XS now for LOBs, ROBs, and channel.

23. Verify backwater areas and depressions are represented by IEFA and permanence as appropriate (All Geo Reviews Tool)

a. Is this being modeled so that no flow is overtopping the road, even as IEFA/storage? What is the basis for setting this elevation in the IEFA?

Response: Agree, see bullet point 15.



24. Verify building conveyance shadows are handled with obstructions/IEFA/high Manning's n (All Geo Reviews Tool)
    a. See item 21 re: structures downstream of Parker Rd.

    Response: Refer to response for item 21.

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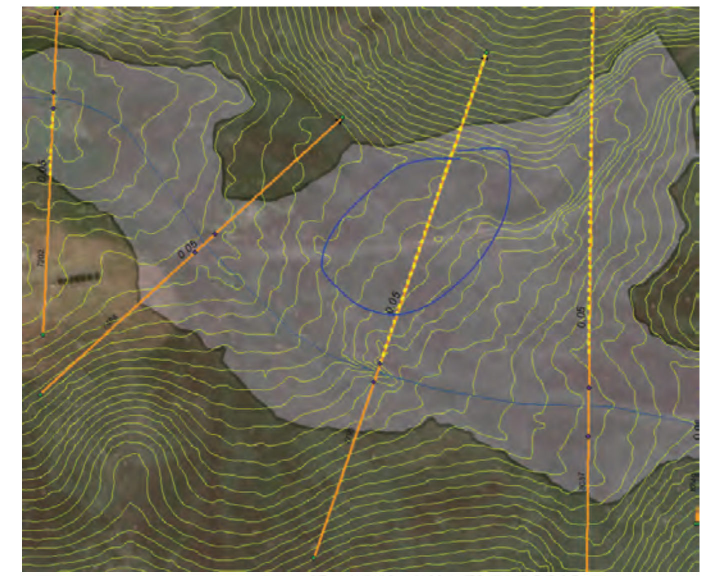
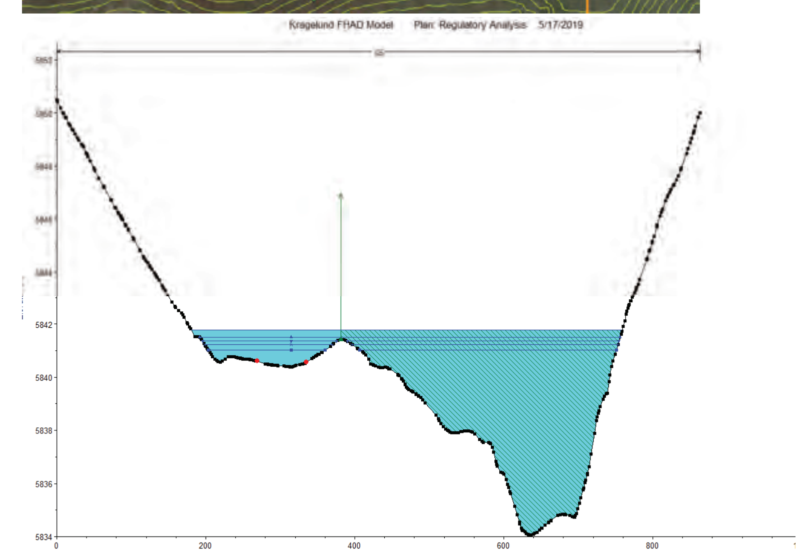
26. Verify IEFAs are reasonable and consistent for adjacent cross sections.
    a. Is it realistic to say that all of this area is ineffective?

    Response: Yes. XS 7924 (7795 prev), and upstream and downstream cross-sections, remove the area of a joining tributary (at the Confluence design point). The area becomes including when the ridgeline separating the tributary becomes insignificant.



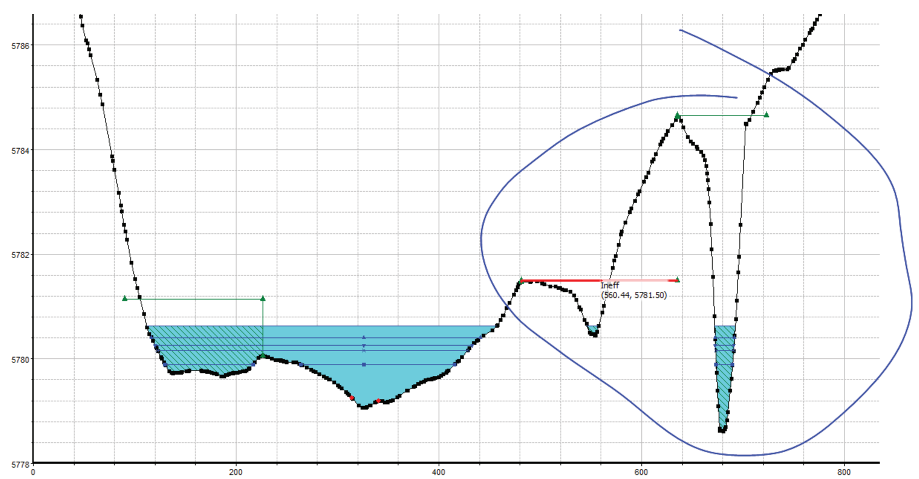


Should this just be a normal IEFA from the high point on the ROB?

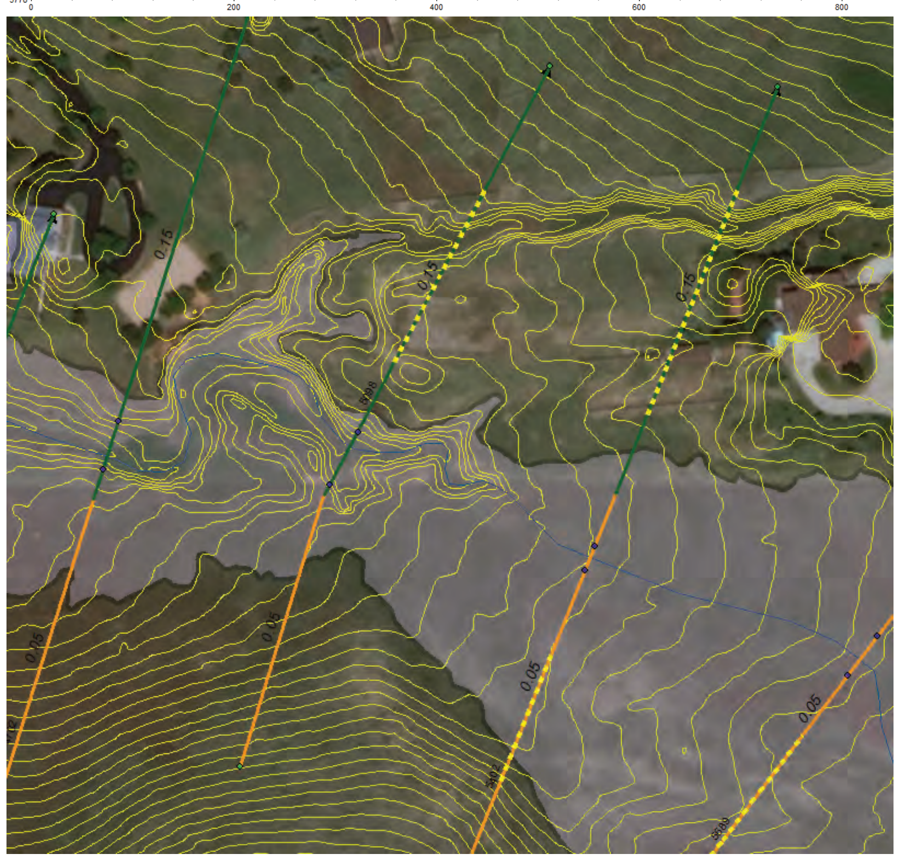
Response: Our opinion is that is shouldn't be for the reason stated previously.

e. Shouldn't we trim these cross sections to exclude the side channel?

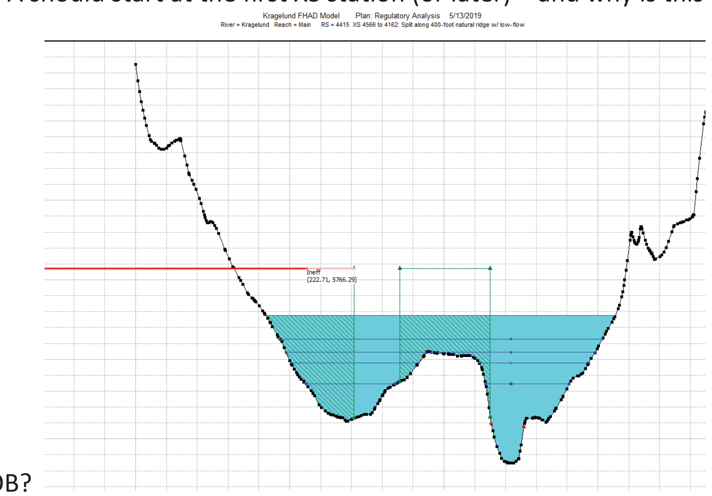
Response: Agree, trimmed XSs.



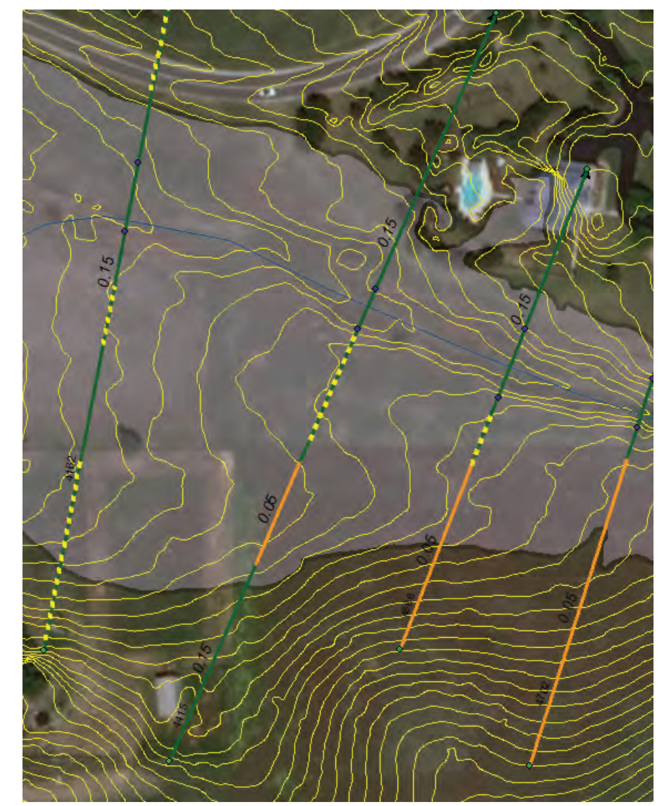
f.



a. IEFA should start at the first XS station (or later) – and why is this not normal IEFA on the

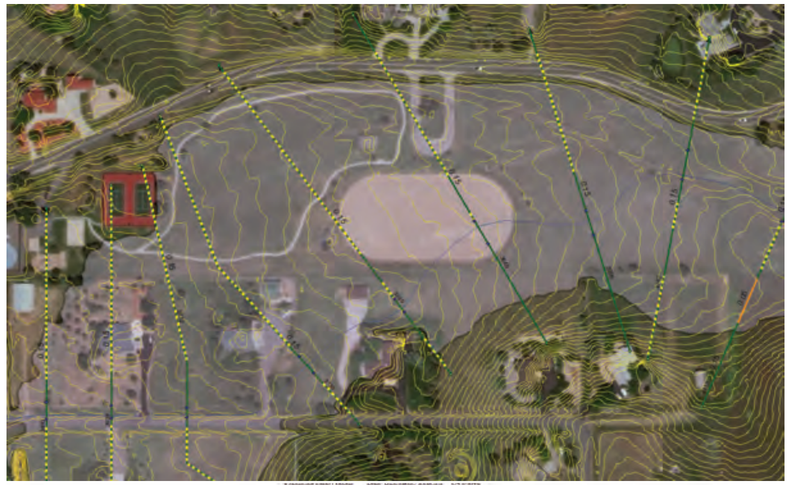


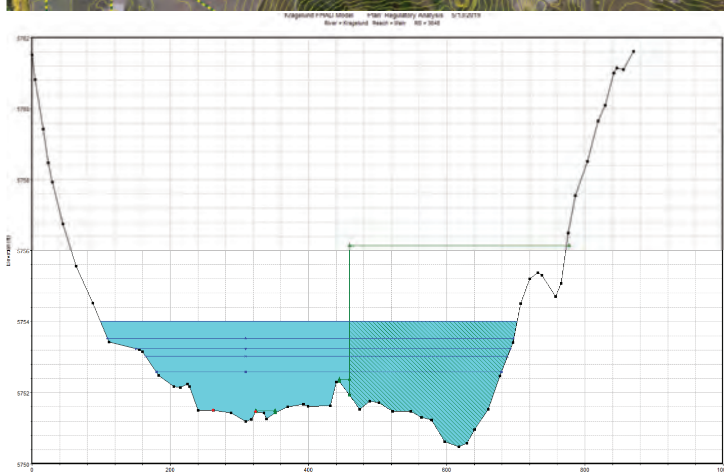
LOB?



Response: 4658/4505/4245/3954: IEFA on left raised to remove small spill during 500-year event that will spill and pool. 4415 is now XS 4505 and the XS alignment was adjusted to be perpendicular to flow and contours which fixed much of the "two flow-paths" issue.

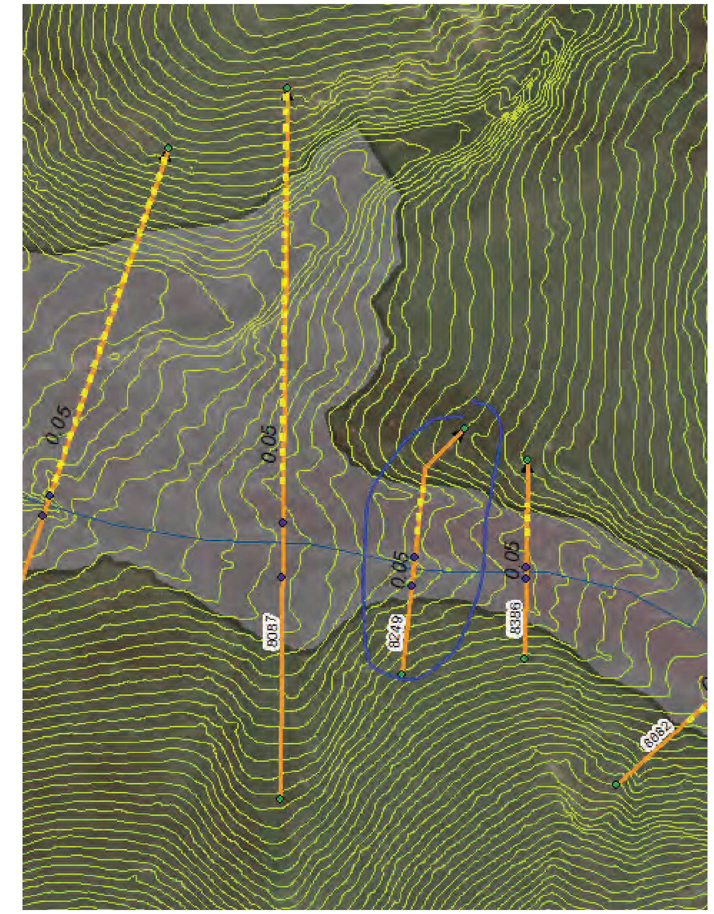
b. Why is flow blocked from this side of the split entirely?





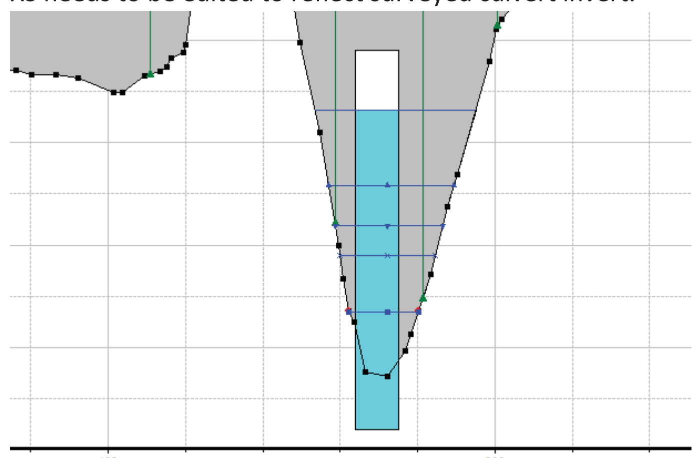
Response: 3955 to 2419: IEFA on right raised to eliminate other possible flow channel and reflet ineffective flow spilling out into park. The other channel has a longer flowpath and when cross-sections are cut for our delineated channel, a straight-line runs through the opposing channel at a point when it's lower (for approx. two XSs). It should remain IEFA because downstream near Parker Rd., the flow pools and slinks back to the ditch, which is the main low-flow channel we are following.

27. Contraction/expansion coefficients are appropriate
    a. 8249 is being modeled with a 0.5 expansion coefficient, but 8087's RB is entirely IEFA



Response: Changed expansion and contraction coefficients back to 0.1/0.3 since cross sections were modified slightly to capture the expansion.

29. Check that channel invert elevations decrease when moving downstream. (Not always incorrect, but needs to be verified/justified.)
    a. Where LiDAR shows channel invert elevations higher than the surveyed inverts of the nearby crossing structures, we recommend connecting surveyed invert elevations through the channel reach.
        i. XS needs to be edited to reflect surveyed culvert invert.

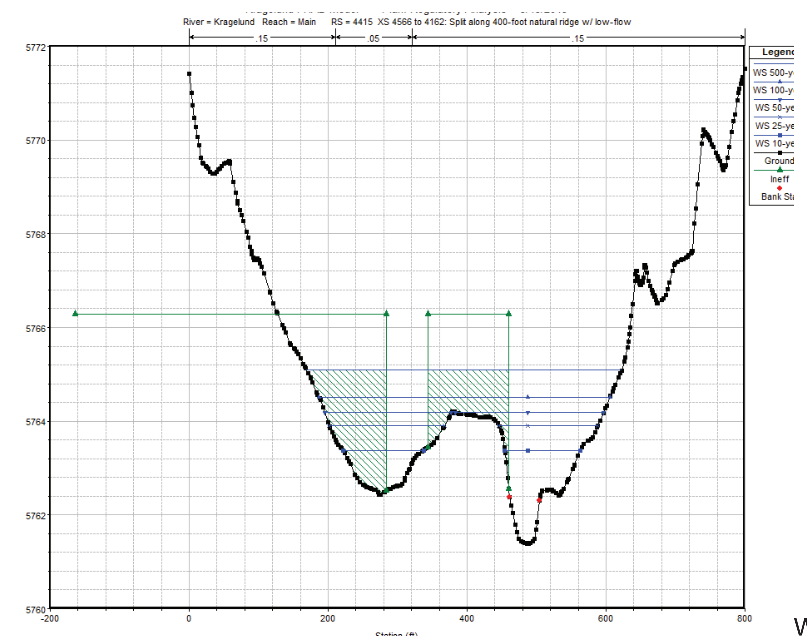


Response: Modified ground inverts for Parker Rd. crossing 2213.

Flow Splits

31. Verify other flow split/distribution methods are sound
    a. How do 2D results and preliminary 1D floodplain correlate? Seems as though 2D would provide more accurate delineation in the undeveloped part of Kragelund.

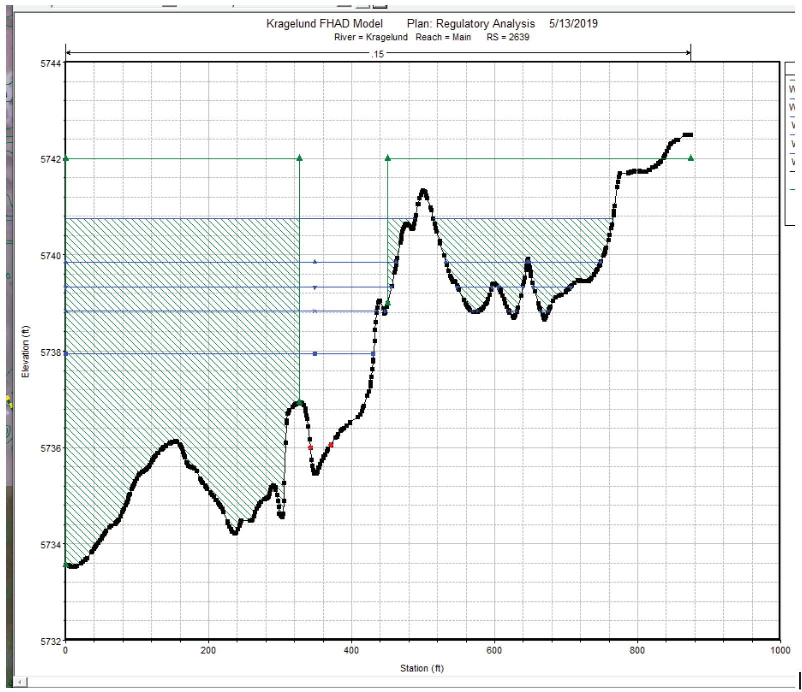
Response: We used a 2D model to backcheck our flowpaths for downstream of Parker Rd. and upstream. It does provide a more accurate delineation. We are confident that we have a good channel alignment for undeveloped area of Kragelund, as well, in the upstream areas. Minor modifications were made this go-around to be sure.

b.  Why is this modelled with permanent IEFAs on the ridge? What about the left bank?

Response: Refer to response for 26.D. This is no longer the case due to realignment of the cross-section to match contours and flowpaths.

c.  Why is flow precluded from entering the northern branch with IEFAs? Don't we want to represent the flow in this area? Or is the intent to be conservative by showing all flow routed through the developed section?

Response: Refer to response 26.E.



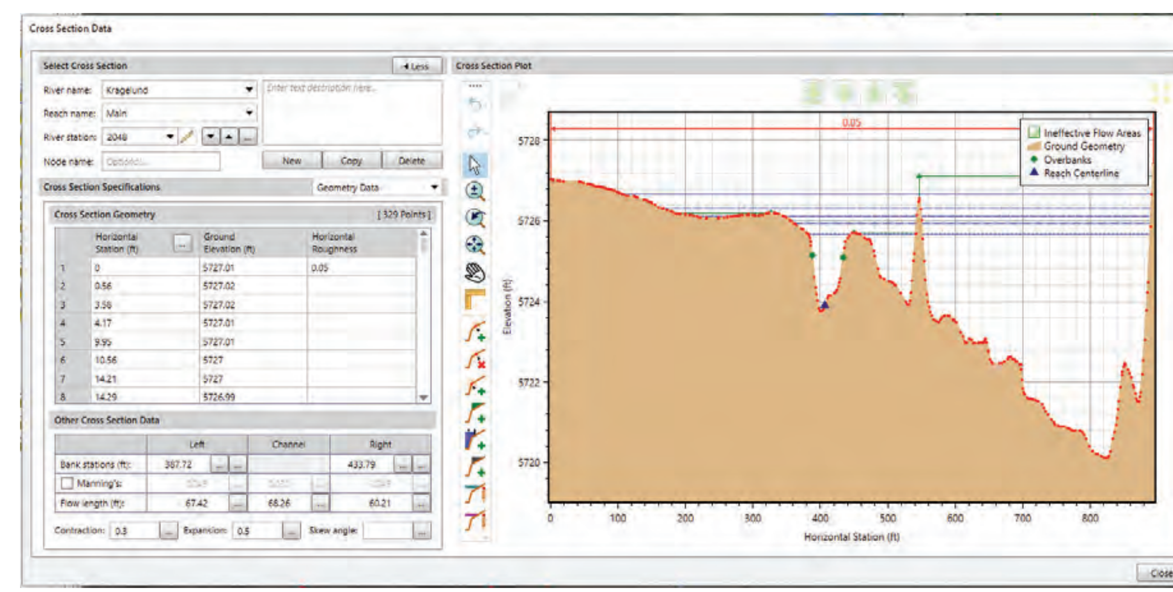
g. Is it realistic to force all the flow to remain north of the road and flow into the culvert? The topo (as well as the lack of any defined channel downstream of Parker Rd.) suggest this is not what happens.

Response: Refer to response 15.A. and 26.E. The model now reflects ponded flow on the south side of Mineral Place and while peak flow is likely reduced by weir flow over the road, the full peak Q is kept past Parker Road for future conditions which might result in all of the flow making it through the culvert.

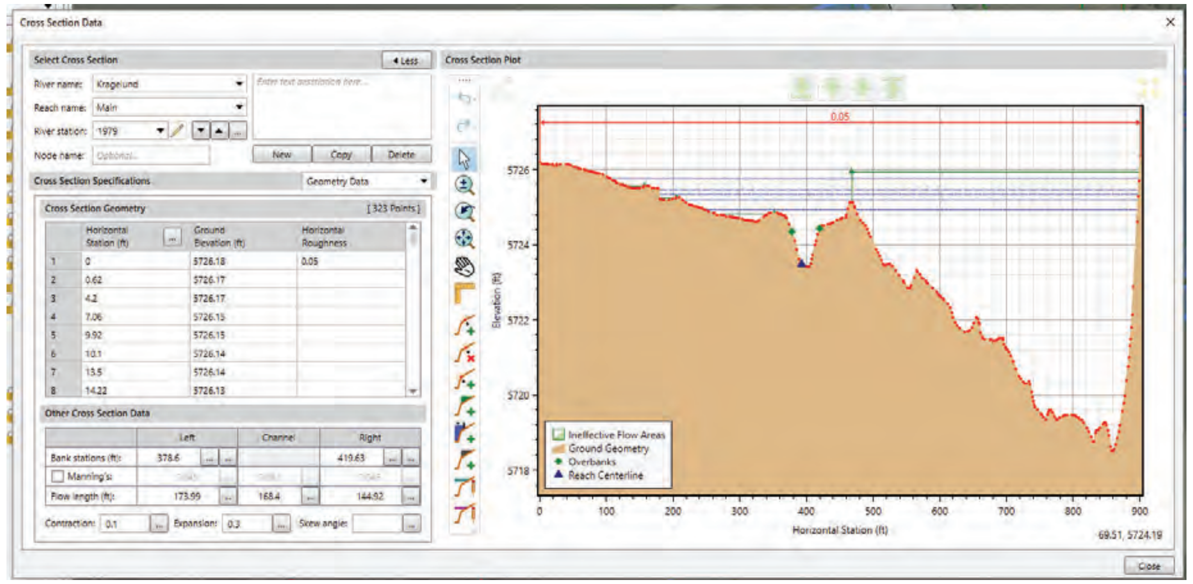
h. Downstream of Parker Rd., can we use the 2D model to determine the ratio of flow split and model this as two separate reaches in RAS?

Response: Flow spills north for some storm events. As discussed with MHFD, the area to the north will be mapped as shallow flooding, and a lateral structure will be added to the model to quantify the flow leaving the site. This spill location widens out and travels overland for a couple hundred feet before reaching the floodplain.

(added)

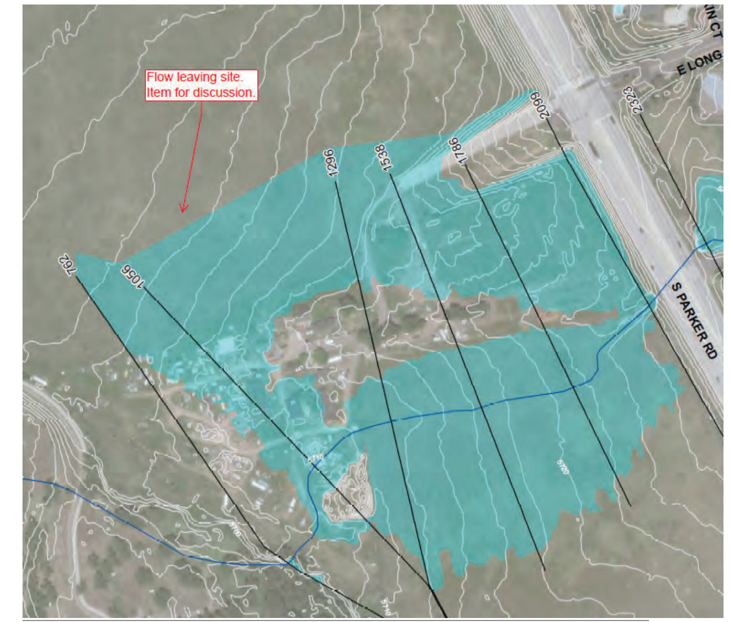


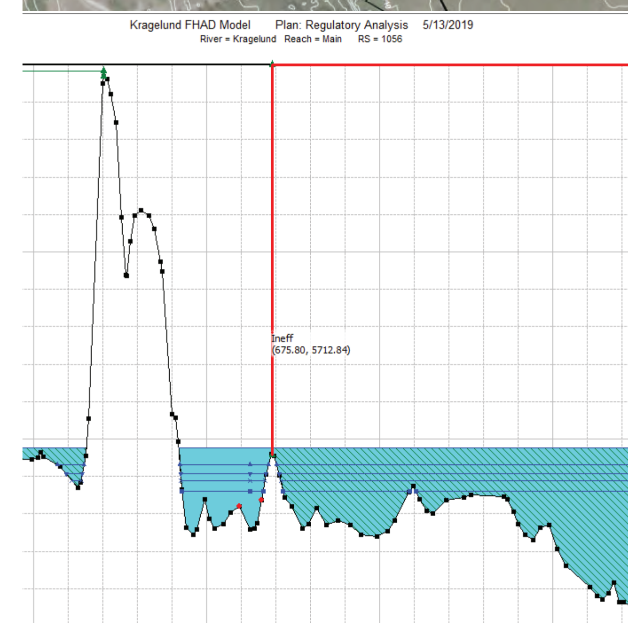
(added)



(added)

i. The flow is not currently modeled as leaving the site, right?
Response: Flow is now modeled as leaving with a LS, see previous response item.

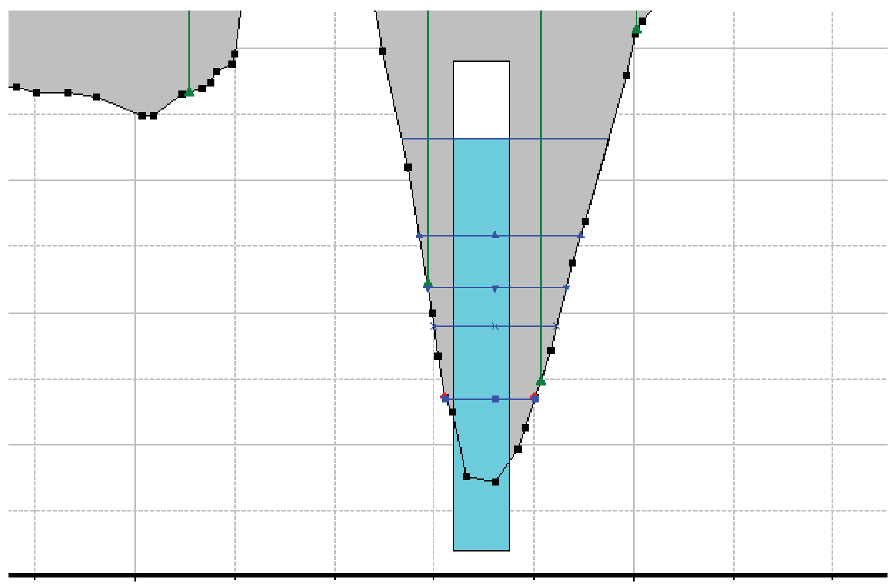
j. 

k. 

Hydraulic Structures

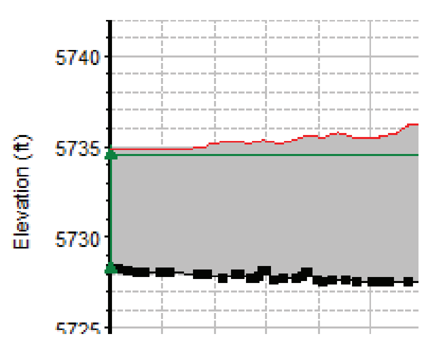
35. Verify adjacent cross section inverts have been modified appropriately and match culverts inlets/outlets

Response: Refer to item 29.a.

a. 

37. Ineffective flow area assumptions, appropriate permanence
    b. IEFAs downstream of bridge and culvert crossings should be set to an elevation between low chord and top of road corresponding to the elevation when significant weir flow occurs.
        i. This is close, but not exactly at the same elevation as the low point in the road?

Response: Modified to match elevations.



REVIEW STEP 1 - MODEL REVIEW – Little Raven

Plans, Flows, and Profiles

1. There are two cross sections on Little Raven downstream of Belleview. Should these cross sections carry the LR_outfall flow? (There will not be a floodplain delineated d/s of Belleview)

   Response: Yes, agree with this approach. Modified the flow rates for these two cross-sections by adding the LR_outfall flow to XS 4437.

Cross Sections

5. Should there be an additional cross section d/s of 6304 to model the expansion d/s of the crossing?

   Response: Yes, agree with this approach. Added a cross-section 6175 which improved the apparent floodplain.

6. Please ensure that cross sections are perpendicular to flow direction. Specifically, please review the orientation of the LOB at cross sections 6096 and 5561.

   Response: Modified 5561 and 6096 to follow contours and re-assign the LOB length.

7. Verify Manning's n values are reasonable and represent area between cross sections (All Geo Reviews Tool)

    a. What is the reasoning for Manning's N = 0.18 in the upper portion of Little Raven? This value seems high. Can we trim the Xs's here so that they do not intersect the houses?

   Response: Agree. Modified to 0.12 in "Hills at Cherry Creek Park" which is more similar to a herbaceous wetland, and modified residential area to 0.15, the average value for housing and commercial. Also this ROB bank has several trees and thus 0.15 seems appropriate. Also, trimmed cross-sections 6096, 5967, 5903 for houses and 4248 since extends far past 500-year.

9. Verify IEFAs are reasonable and consistent for adjacent cross sections.

    a. Please add IEFA in the LOB of XS 6096, 6304, 5903

    Response: Revised the LOB for 6096 per previous comment, and added an IEFA for small portion of new geometry. Added IEFAs for 6304 and 5903 as well.

    b. Should there be IEFA in the ROB of cross section 4248?

    Response: Yes, added IEFA for ROB of 4248.

    c. Please review IEFA along all of Little Raven. Why are there multiple cross sections with IEFA above the 500-yr event?

    Response: IEFAs above the 500-year are described below.

    a. Roadway crossing at Belleview Ave has IEFA's that follow the road elevations, however the 500-year does spill over the road.

b. Sta. 5213 5275 5354 5435 5561: This area is a secondary channel that is only approximately 200 feet and thus is omitted. The majority remains in the larger channel and both converge to form a broad channel downstream.
c. Sta. 5729 5903: This area ponds up and doesn't contribute to continuous flow down the channel and is thus omitted.

10. Please review contraction/expansion coefficients at all cross sections. Values of 0.3-0.5 are typically used at crossings.

    Response: Agreed. Modified to 0.3/0.5 for road crossings and one natural expansion/ contraction near 6096, and 0.1/0.3 all others.

11. Check elevation at XS 4192 (does not decrease in downstream direction)

    Response: This area is broad, flat, and very vegetated. The ground is undulating and the alignment shown is our best understanding given the data and looking into different options. The elevation difference is less than a tenth of a foot so it's minor, and it appears the area is often wet which confirms this.

Hydraulic Structures

12. Culvert #2 at Belleview should be 4.5 feet in diameter.

    Response: Agree, adjusted from 4' to 4.5'.

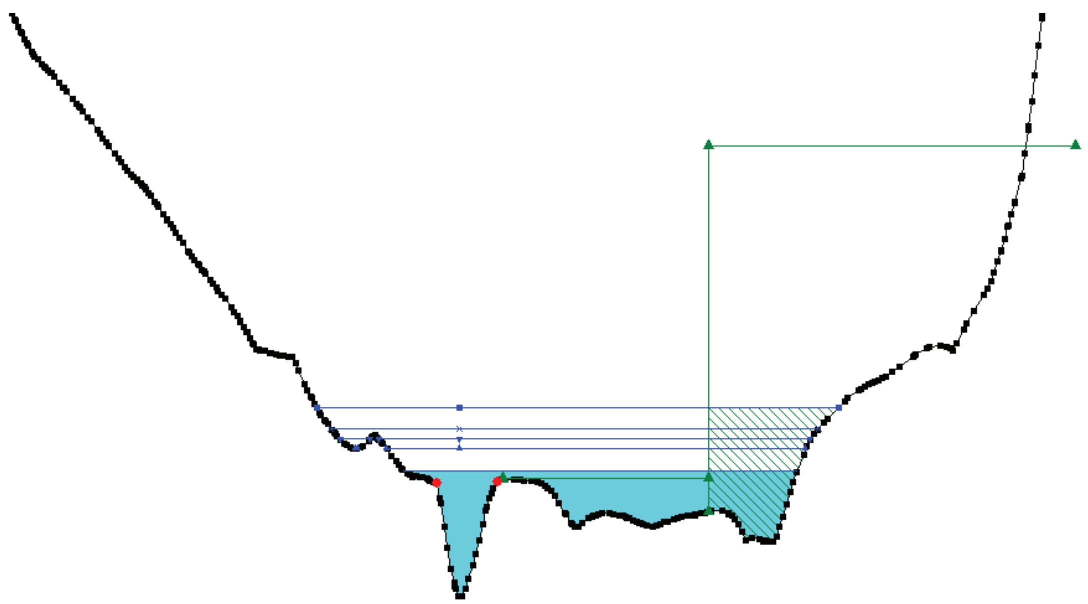
13. Should the railing at Belleview be modeled as blocked?

    Response: Yes, agree, added a 22" railing to the upstream and downstream roadway elevations based on the structure survey dimensions.

Modify bank stations as follows:
Response: Modified XS 5103 so that resemble actual bank edges.

Revise all IEFA as follows:

Response: This modification was not actually identified in these review comments. On phone with Jon, he confirmed there wasn't a specific change here. The overall intent was to point out the areas with IEFAs above the 500-year which are clarified in an earlier comment response bullet.



REVIEW STEP 1 - MODEL REVIEW – North Arapahoe

Note: Following the North Arapahoe comments on Model Review Submittal 1, as-builts at the North Arapahoe and Parker Road interchange were obtained from CDOT. These as-builts show an additional pipe that takes the majority of flow from the northeast corner of Parker and Arapahoe to the southeast corner where it eventually combines into the large South Arapahoe box culvert. The Baseline Hydrology was revised to incorporate this newly identified infrastructure. These modifications resulted in a change to the source of flooding at the Arapahoe Crossings shopping center from North Arapahoe to South Arapahoe. These results were discussed in a meeting with Jon on October 23, 2019 and it was determined that (upon approval of the District and the local stakeholders) the existing North Arapahoe 1D model would be truncated at Parker Road. It is anticipated that this model will be considered informational only, and a finalized FHAD for North Arapahoe will not be necessary. Some of the comments below may no longer apply.

Plans, Flows, and Profiles

1. Verify all required profiles are included per agreement (10-, 25-, 50-, 100-, 500-yr)
    a. The model does not include the 10- and 25-year profiles.

    Response: Flows for these profiles were not included because there is no overflow until the last node. Because HEC-RAS requires a flow through the length of the model, crossing profiles are caused when using 0.1 cfs in the upper limits of the model. Jon confirmed the exclusion of other profiles is appropriate in the comment review meeting on August 05, 2019.

3. Verify HEC-RAS peak flow discharges against hydrology (compare to Hydrology Peak Flow Table and/or Discharge Profiles)
    a. HEC-RAS discharges do not appear to match SWMM model, please confirm discharges

Basin	Design Point	Future Conditions Peak Flow (cfs)								
		Q_{WQ}	Q_1	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
North Arapahoe Tributary	NA_outfall	32	42	56	82	116	229	326	476	800
North Arapahoe Tributary	Parker_NA	33	42	57	82	116	229	326	476	800
North Arapahoe Tributary	Buckley_NA1	15	21	29	45	65	150	217	325	542
North Arapahoe Tributary	Waco_NA	3	4	6	10	15	33	44	59	92
North Arapahoe Tributary	NA_pond	23	29	39	56	77	138	176	226	336
North Arapahoe Tributary	NA1	24	30	41	56	77	131	166	209	308
North Arapahoe Tributary	NA2	23	29	39	56	77	138	176	226	336
North Arapahoe Tributary	NA3	9	12	16	23	30	60	79	103	158
North Arapahoe Tributary	NA4	3	4	6	10	15	33	44	59	92

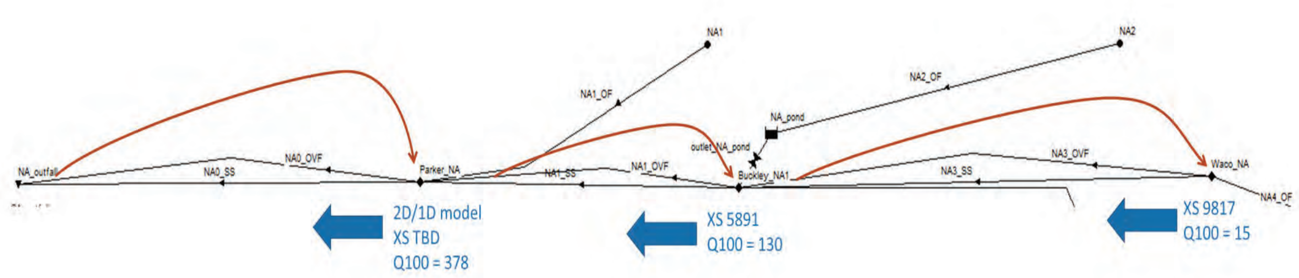
	River	Reach	RS	50-year	100-year	500-year
1	North Arapahoe T	Main	9817	1	15	48
2	North Arapahoe T	Main	5891	22	130	346
3	North Arapahoe T	Main	2765	228	378	702

2765=Parker SA, 5891=Buckley NA1, 9817=Waco_NA

Response: The discharges included in the model reflect the storm sewer surcharge Qs associated with the overflow conduits (i.e. water not contained by the storm sewers). The values from the design points shown in the screenshot account for the total flow included in the storm sewers. This was discussed with Jon on a phone call on August 13, 2019.

4. Verify RAS flow change locations match SWMM design points
    a. Flow change locations and SWMM design points don't appear to match (and flow appears to be routed at the downstream node of the reach rather than the upstream node), please confirm design points.

    Response: Flow change locations are based on the NAO_OVF, NA1_OVF, and NA3_OVF. Because these are representative of lengths of storm sewer, instead of design points, the flows are applied at the starting point of the length of sewer. For example, NA0_OVF is applied at Parker_NA. This approach is analogous to standard flow change locations for nodes and is conservative. This approach assumes that local flow will enter and leave the storm main before the major slug of flow from upstream reaches that location. This was discussed with Jon on a phone call on August 13, 2019.

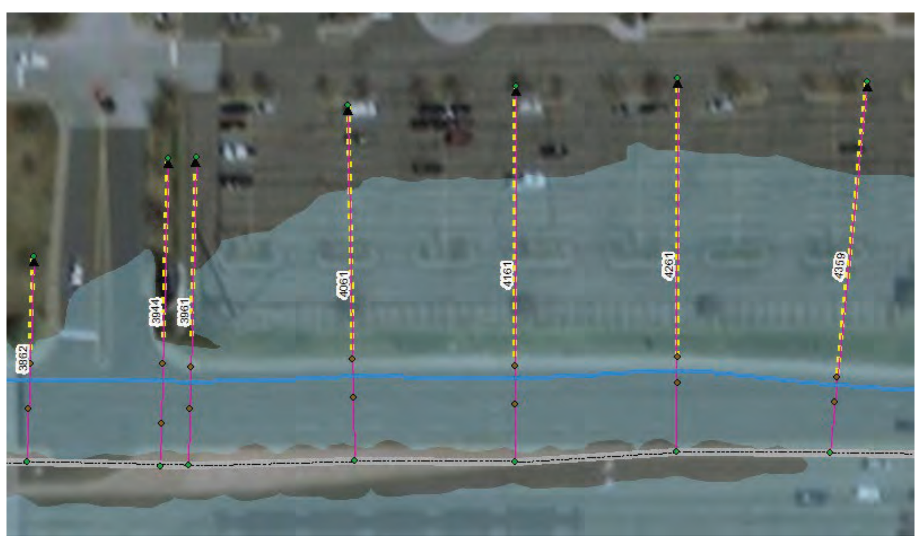


Cross Sections

19. Verify adequate cross section densities, especially near buildings/homes
    a. We're going to have to delineate the floodplain in the spill west of Parker Rd. somehow.

    Response: See Note at the beginning of this document.

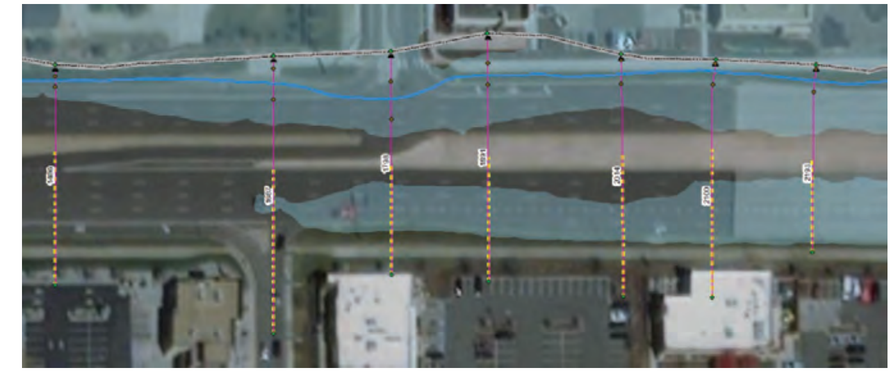
23. Verify backwater areas and depressions are represented by IEFA and permanence as appropriate (All Geo Reviews Tool)
    a. Would this area really be ineffective? Seems as though spill flow is contained and sloped in the direction of main channel flow according to the XSs.



Response: Agreed. Reduced IEFA to XS 3961, which is set just behind the berm captured by XS 3944.

    b. Same question as above, is this area really ineffective? I guess it doesn't matter if the 500-year flow never gets over there, we could just trim the XSs?

November 22, 2019
FHAD Submittal No. 2
Comment Responses
North Arapahoe Tributary



Response: It is believed that flow does make it over to the south side of Arapahoe via the upstream split. It does not appear to recombine with the "main channel" on the north side of Arapahoe, and therefore was modeled as ineffective flow.

Flow Splits

30. Lateral Structures:
    d. HW/TW stationing
        i. Please add descriptions to lateral structures.

        Response: Descriptions will be added to lateral structures as necessary if used in the modeling approach chosen for this area.

    f. Verify that optimized lateral structure models and hard-wired flow changes are included with submittal (optimized model to support hardwired flows)
        i. We need to figure out how to account for all of the flow that's leaving the system (and the flow that is remaining in the system but shown to be leaving in the 2D models).

        Response: See Note at the beginning of this document.

REVIEW STEP 1 - MODEL REVIEW – South Arapahoe

Do we need to include these areas with DA > 130 AC? Was this discussed previously?

Response: Modeling extents were discussed previously and identified as the above. Please discuss internally and advise if the extents need to be revised.

Plans, Flows, and Profiles

3. Verify HEC-RAS peak flow discharges against hydrology (compare to Hydrology Peak Flow Table and/or Discharge Profiles)

    a. What is happening with the additional flow routed to the SA outfall in the SWMM model? Is the 500-year contained in a pipe between Lewiston Way and the CDOT pond?

    Response: Yes, the 500-year is contained in a box culvert between Lewiston Way and the CDOT pond. However, in the 100-year and 500-year events the CDOT pond loses approximately 50 to 250 cfs onto Arapahoe Road. This split will be part of the modeling approach selected for the Arapahoe Crossings shallow flooding area.

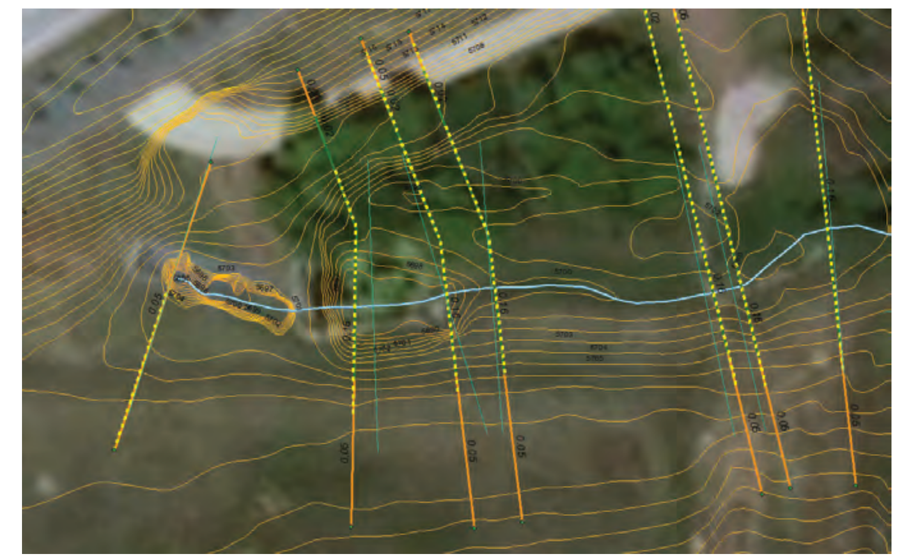
4. Verify RAS flow change locations match SWMM design points
    a. OK except for the flow and routing missing between the SA and NA models.

    Response: Agreed. A plan of action has been made regarding the modeling in the western Arapahoe area after incorporating the CDOT As-Built data into the Baseline Hydrology. The South Arapahoe 1D model will be supplemented with 2D modeling for the 500-year shallow flooding in and around Arapahoe Crossings. See Meeting Minutes from October 24, 2019 for further detail.

Reach Lengths/Cross Section Widths

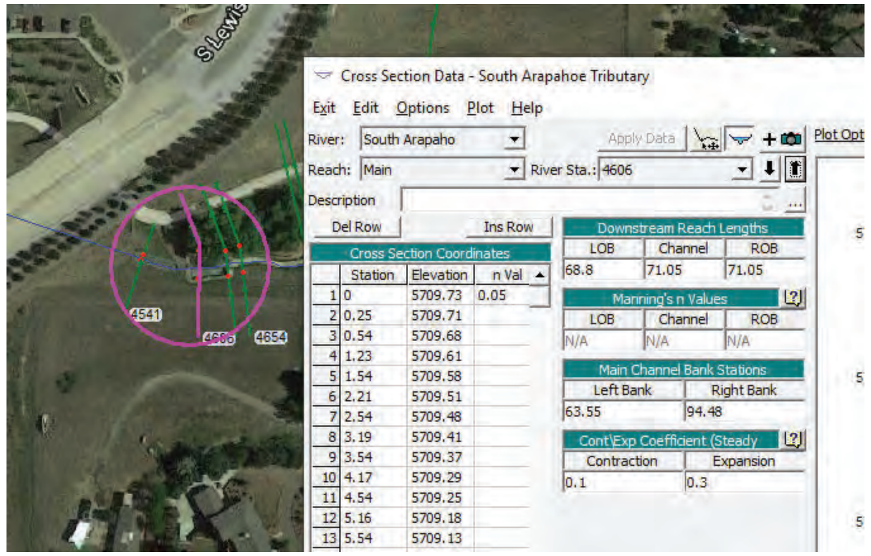
8. Verify RAS and GIS reach lengths are in agreement (XS Location Test Tool)

    a. There appear to be discrepancies between downstream reach lengths and the XS locations in GIS. For example the first XS has 71 feet in HEC-RAS but only about 65 feet in GIS. Please check all downstream reach lengths.



Response: Agreed. Reach lengths have been adjusted as necessary.

10. Verify overbank lengths are reasonable and different from channel lengths (when appropriate)
    a. LOB should be longer than ROB for this XS.



Response: Agreed. Reach length has been corrected.

    b. There appear to be discrepancies in overbank reach lengths throughout the tributary. In many cases ROB and channel lengths are the same when they should be different, and it seems likely that this is the cause of the errors in channel stationing identified by the XSLocation test (commented in 8. a.). Please review all downstream reach lengths for channel and overbanks.

Response: Agreed. Reach lengths have been reviewed and corrected as necessary throughout the model.

Cross Sections

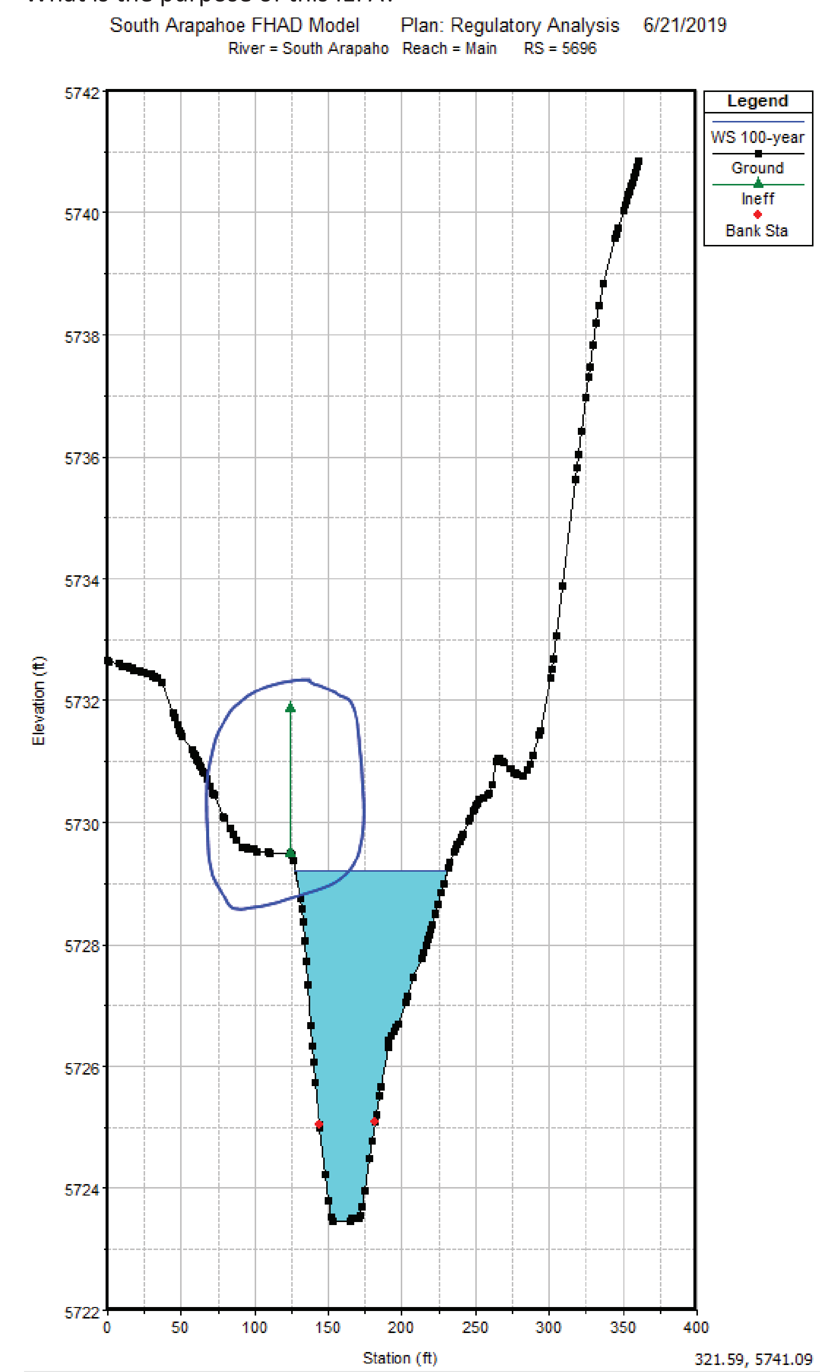
21. Verify Manning's n values are reasonable and represent area between cross sections (All Geo Reviews Tool)
    a. Do we need to use 0.1 for the perpendicular fending at crossings and elsewhere?

Response: Agreed. Additional locations for perpendicular fencing, including here, have been increased to 0.1.

22. Verify bank stations are reasonable at each cross section (Plot RAS Cross Section Extents Tool):
    b. Channel alignment is between bank stations
        i. 5932 has a station off.

Response: XS stationing has been modified to start at 0.

23. Verify backwater areas and depressions are represented by IEFA and permanence as appropriate (All Geo Reviews Tool)
    a. What is the purpose of this IEFA?



Response: Flow associated with the 500-year event is ineffective at this XS.

27. Contraction/expansion coefficients are appropriate
    a. Is XS 6039 meant to have the higher expansion and contraction coefficients?

    Response: Expansion/contraction coefficient reduced to default value.

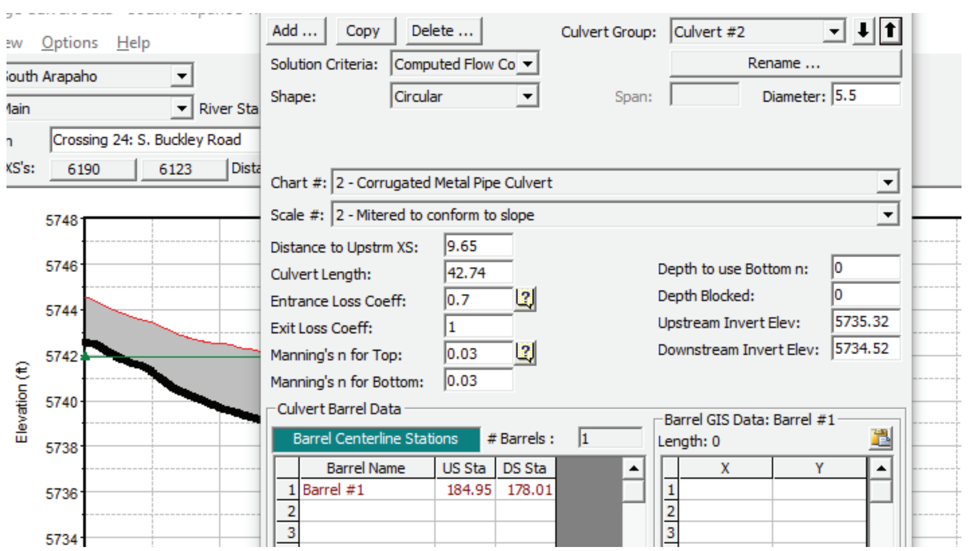
Flow Splits

31. Verify other flow split/distribution methods are sound
    a. Does SA flow entirely into NA, or does some portion of SA have its own outfall to Cherry Creek? Need to discuss what happens downstream of Lewiston Way.

    Response: The majority of SA flow is routed to its own outfall at Cherry Creek as in the SWMM model. The only basin transfer from SA to NA is overtopping at the CDOT pond. Agreed, a modeling approach for the western Arapahoe Road area will be discussed and identified.

Hydraulic Structures

34. Geometry - top of road/low chord/invert elevations/culvert sizes (survey .csv data into ArcMap)
    a. What is the source of the different invert elevation for the second culvert at crossing 24?



Response: The source of both invert elevations is from the UDFCD provided survey.

37. Ineffective flow area assumptions, appropriate permanence
    a. IEFAs upstream of bridge and culvert crossings should be permanent and set to the top of road elevation.

    b. IEFAs downstream of bridge and culvert crossings should be set to an elevation between low chord and top of road corresponding to the elevation when significant weir flow occurs.
       i. Please confirm that this is the case on your downstream culvert cross sections and that IEFAs are placed at appropriate elevations.

       Response: IEFAs at crossings have been confirmed.

Dewberry

MEMORANDUM

Date: November 22, 2019

Subject: Revised Hydraulic Modeling Approach for North and South Arapahoe Tributaries – Submittal 2 (Model Review)

Message:

This memorandum documents the revised hydraulic analysis for the North and South Arapahoe Tributaries FHADs for Submittal 2 (Model Review).

Revisions to Baseline Hydrology

Storm sewer infrastructure data from CDOT As-Builts for the Arapahoe/Parker Interchange project (Federal Aid Project No. STU 0831-107 dated May 9, 2012) were provided by SEMSWA on August 30, 2019. These plans show existing storm sewer lines that were not identified in the municipal GIS shapefile data which was used to inform the original Baseline Hydrology model. In an effort to better characterize flooding on Arapahoe Road and within Valley Club Acres, the Baseline Hydrology SWMM model was revised to reflect the plans. See Figure 1.

As a result of these modifications, it has been identified that the majority of North Arapahoe is redirected to South Arapahoe just upstream of Parker Road via an existing 48" RCP. The capacity of the 48" RCP is exceeded by the 100-year, resulting in approximately 200 cfs of overflow which would continue as street flow under the interchange on the north side of the road. Assuming this water can enter the system, all of this overflow fits within the capacity of an existing pipe that begins on the northwest corner of the Parker interchange and continues to Cherry Creek. North Arapahoe flow contained within the 48" RCP is routed to a 54" RCP that runs parallel to a South Arapahoe 54" RCP under Parker Road before being combined with South Arapahoe flow in an 8'x6' box and then a larger 12'x6' box. The parallel 54" RCP segments overflow in the 100-year by ~150 cfs and the large 12'x6' box overflows by ~56 cfs.

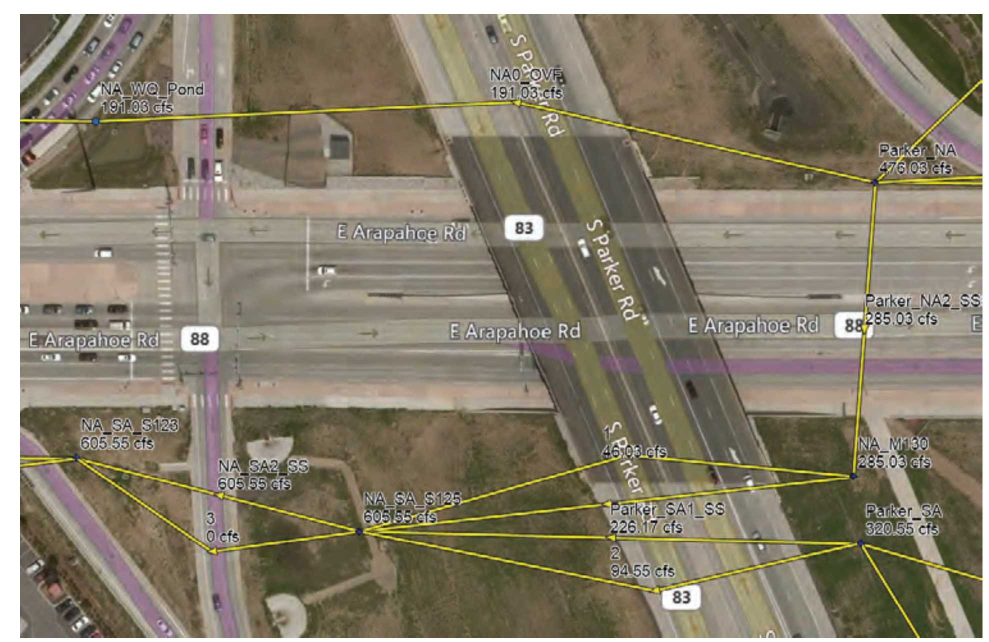


Figure 1 SWMM Revisions

Revisions to Hydraulic Modeling

General Assumptions

- Assuming flows enter the storm system, the 100-year peak flows from both North and South Arapahoe tributaries are either contained within the storm sewer or within the roadway.
  - The SA 100-year of 56 cfs can be contained within the south lanes of Arapahoe. See Attachment B gutter calculations.
- Localized flooding occurs in and around the 4 CDOT ponds at the Arapahoe/Parker interchange but this is considered outside of the scope of the FHAD because the storm sewer not associated with the ponds is adequately sized and no insurable structures are located immediately around the ponds.

North Arapahoe Tributary

- Comments from Review Step 1 were addressed.
- Peak flows were updated to reflect the revised hydrology.
- The new hydrology was discussed in a meeting with Jon Villines (MHFD) on October 23, 2019 and it was determined that (upon approval of the District and the local stakeholders) the existing North Arapahoe 1D model would be truncated before Parker Road because it is no longer considered a source of flooding outside of the roadway. It is anticipated that this model will be needed for informational use only and that a finalized FHAD for North Arapahoe will not be necessary.
- A lateral weir is located in the model along the Arapahoe Road median roughly between S. Olathe Street and a few hundred feet upstream of Parker Road. This lateral weir quantifies the flow that can cross the median to the southern lanes of Arapahoe Road: ~15 cfs in the 100yr, and ~88 cfs in the 500yr. Similar to the flow being modeled by the model's mainstem on the north side lanes, this flow will for the most part also continue as roadway/ gutter flow on Arapahoe Road. A small amount of flow may escape to the south along S. Lewiston Way because there is no visible cross pan at this location. This flow was not modeled because it does not exceed the capacity of the roadways.

South Arapahoe Tributary

- Comments from Review Step 1 were addressed.
- The extents of the 1D model were not changed.
- The downstream boundary condition for the 1D model was updated per changes to the hydrology.
  - Different methodologies for defining the tailwater of the South Arapahoe S. Lewiston Way culvert were discussed. It was decided that the Baseline Hydrology (BH) overflow values for the CDOT pond are the most conservative because the pipe flows don't account for the increased capacity that would result from headwater in the pond. So, the BH overflow values were summed and used to back-calculate the water surface elevation (WSEL) for events that exceeded the pipe capacity underneath Parker Road. These elevations were used as tailwater conditions for a CulvertMaster calc to determine the headwater (HW) elevation at Crossing 28: Lewiston Way (the end of the 1D South Arapahoe model). For events lower than overtopping, it was determined that the culvert length and slope

controlled the flow conditions, rather than tailwater (TW) elevation, thus a specific TW calculation was not needed for the 10-year and 25-year flows and a full pond elevation was assumed.

- A 2D model was created to estimate 500-year shallow flooding resulting from inadequate pipe capacity between the Arapahoe/Parker interchange and the Cherry Creek outfall. The model was run quasi-steady state to simulate the typical 1D modeling approach. Running the model quasi-steady state fills in ponds and approximates the typical 1D steady flow run. NLCD 2011 was used to assign manning's n values.

Attachments:

1. **Attachment A:** Revised Baseline Hydrology SWMM model (See SWMM folder included with submittal).
2. **Attachment B:** SA Gutter/Street Capacity FlowMaster Report

Attachment B

GUTTER/STREET CAPACITY CALC FOR SOUTH ARAPAHOE ROAD DOWNSTREAM OF ARAPAHOE/PARKER INTERCHANGE

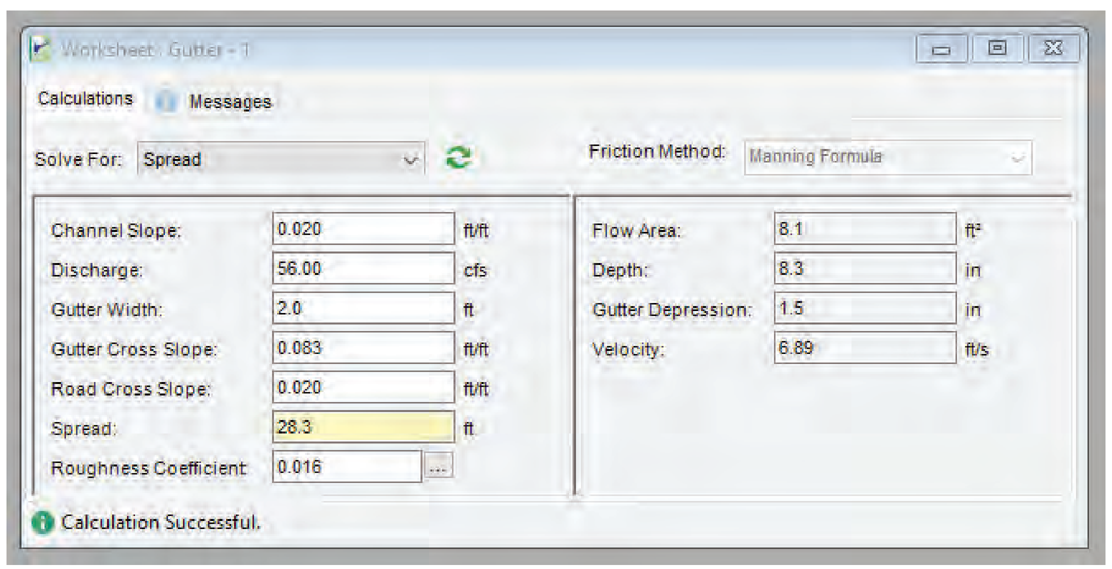
Worksheet for Gutter - 1

Project Description	
Solve For	Spread

Input Data	
Channel Slope	0.020
Discharge	56.00
Gutter Width	2.0
Gutter Cross Slope	0.083
Road Cross Slope	0.020
Roughness Coefficient	0.016

Results	
Spread	28.3
Flow Area	8.1
Depth	8.3
Gutter Depression	1.5
Velocity	6.89

Messages	
Notes	11/11/2019 South Arapahoe gutter capacity check downstream of Arapahoe/Parker interchange for 100-year Q = 56 cfs.



FHAD Review Comment Memo

Title: Cherry Creek Tribs – Little Raven
Consultant: Dewberry
Date Received: 11/15/2019
Date Returned: 06/25/2020
Review Phase: 2 - 100-Year Floodplain Delineation
UDFCD Reviewer: David Crooks

Products Received:
☒ All required submittal files for this phase were received.
☐ The following required submittal files for this phase were not received:
- N/A

☐ The following supplemental submittal files for this phase were received:
- N/A

Reviewed Model Files and Dates:
CCT_Little_Raven.prj (*11/25/2019*) (*List events*)
CCT_Little_Raven.p01
CCT_Little_Raven.p01.hdf
CCT_Little_Raven.p02
CCT_Little_Raven.p02.hdf
CCT_Little_Raven.g01
CCT_Little_Raven.g01.hdf
CCT_Little_Raven.f01
CCT_Little_Raven.f02

Products Not Reviewed:
N/A

Comments Geodatabase:
N/A

General Comments:
Review Step 2 – 100-Year Floodplain Delineation
Agreement Table:

No Comments

Floodplain Work Maps (GIS):

XS-4538 – Flow contained within culvert for 100-yr. Note added to map.

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Title: Cherry Creek Tribs – Joplin
Consultant: Dewberry
Date Received: 12/02/2019
Date Returned: 6/25/2020
Review Phase: 2 - 100-Year Floodplain Delineation
UDFCD Reviewer: Brik Zivkovich

Products Received:
☒ All required submittal files for this phase were received.
☐ The following required submittal files for this phase were not received:
- N/A

☐ The following supplemental submittal files for this phase were received:
- N/A

Reviewed Model Files and Dates:
List all model files review for this submittal.
CCT_Joplin.prj (*12/02/2019*) (*List events*)
CCT_Joplin.p01
CCT_Joplin.p01.hdf
CCT_Joplin.p02
CCT_Joplin.p02.hdf
CCT_Joplin.g01
CCT_Joplin.g01.hdf
CCT_Joplin.f01
CCT_Joplin.f02

Products Not Reviewed:
N/A

Comments Geodatabase:
N/A

General Comments:
Review Step 2 – 100-Year Floodplain Delineation
Agreement Table:

No comments

Floodplain Work Map Notes (GIS):

Flow contained in culvert between XS-7746 and XS-7420 for 100-yr. Confirming overtopping during 500-year?

- Reviewed channel alignment and determined that there is likely no hydraulic connectivity between the RB1-4 pond outlet and the local storm sewer under S. Granby Way (where overland flow was being presented in the previous model). Therefore, the CL alignment has been revised to follow the outlet pipe alignment across Joplin, in between the subdivisions, along the north side of Home Depot and finally under Chambers Road and back into the open channel. Per the BH, the 100-year is contained in this pipe. This change also eliminates the need for modeling a culvert under Chambers Road, as that culvert is associated with the Pioneer Hills onsite detention pond, and not the main channel of Joplin, which is contained within the same pipe from the Joplin pond. The cross section ID's upstream of Joplin Way were updated to reflect the new cumulative stationing.

Other model revisions:

- The pond design report was reviewed, and it was confirmed that the 500-year will likely overtop RB1-4 at the overflow weir at the southeast corner (not on Joplin Way at the outlet box). This indicates that any concentrated flow associated with the 500-year will escape to the south-east and never reconnect with the tributary. No concentrated flows are anticipated through the Pioneer Hills filing No. 8 subdivision. Therefore, its suggested that no overland flow is mapped for the 500-year here and a note is added re: a potential 500-year of approx. 200 cfs to the southeast.
- It was discovered that the first XS ID was incorrect in the previous submittal. All other reach lengths were okay, but all ID's had to be updated so they matched stream stationing.

XS-6349: Should this be the location of the flow change? Check flow profile at downstream side of roadway crossing. Disconnected floodplain from model between XS-6349 and XS-5885 (left of main flood hazard lane). Discussed with MHFD on 8/11: Flow change location moved to suggested location just downstream of the road crossing. The ponds have been included as IEFA and as part of the FP per guidance on adjacent on-site ponds.

Check area between XS-5724 and XS- 5246 (right of main flood hazard lane) modeled as IEFA? See hydraulic oxbows for modeling methods (Kinney Creek at Parker Rd example). Discussed with MHFD on 8/11: The ponds have been included as IEFA and as part of the FP per guidance on adjacent on-site ponds.

XS-4857 – Cutline based on low flow channel. Directionality could be realigned (south to north) to banks following topography. Discussed with MHFD on 8/11: Cutline realignment would be

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minor and have minimal effect on the WSE. Additionally, there are no insurable structures in the vicinity that would be impacted. Therefore, cutline left as-is.

XS-3950 – Above ground utilities on downstream side of roadway. Note added to map.

XS-4105 – Check extents of FP width. Channelized to shallow concentrated. See upstream cross sections. The floodplain delineation has been modified to show a more gradual transition to wide shallow flooding.

XS-2785 and XS-2802 – Why is there a double XS here? The double XS is here to account for the obstruction of flow caused by the park trail.

Protecting People, Property and Our Environment.

Title: Cherry Creek Tribs – Chenango
Consultant: Dewberry
Date Received: 12/9/2019
Date Returned: 6/25/2020
Review Phase: 2 - 100-Year Floodplain Delineation
UDFCD Reviewer: Laura Hinds

Products Received:
☒ All required submittal files for this phase were received.
☐ The following required submittal files for this phase were not received:
- N/A

☐ The following supplemental submittal files for this phase were received:
- N/A

Reviewed Model Files and Dates:
CCT_Chenango.prj (*12/09/2019*) (*List events*)
CCT_Chenango.p01
CCT_Chenango.p01.hdf
CCT_Chenango.p02
CCT_Chenango.p02.hdf
CCT_Chenango.g01
CCT_Chenango.g01.hdf
CCT_Chenango.f01
CCT_Chenango.f02

Products Not Reviewed:
N/A

Comments Geodatabase:
N/A

General Comments:
Review Step 2 – 100-Year Floodplain Delineation
Agreement Table:

XS-4992 – Please provide additional explanation to justify this inclusion.

XS-3246 – Please provide brief explanation (i.e. "Water unable to reach LOB IEFA from upstream or downstream XSs. Comment expanded upon - water unable to reach LOB IEFA from upstream or downstream cross-sections.

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XS-1255 – Please provide brief explanation of why this area is excluded at this XS. Comment expanded upon - water unable to reach LOB IEFA from upstream or downstream cross-sections.

XS-1030 – Add note describing the discrepancy between model top width and work map at Cherry Creek tie-in Discussed with MHFD on 8/11: MHFD will discuss internally how we would like to depict the tributary floodplains and cross-sections in relation to the Cherry Creek floodplain. For now, the entire model (based on the CC 10-year WSE as the downstream boundary condition/starting location) has been displayed and the Cherry Creek floodplain limits have been added for reference.

Floodplain Work Maps (GIS):

XS-228 – Show Cherry Creek effective floodplain Effective Cherry Creek floodplain has been added to all maps.

XS-228 through XS-1030 – Adjust floodplain to account for the backwater effect from Cherry Creek Discussed with MHFD on 8/11: MHFD will discuss internally how we would like to depict the tributary floodplains and cross-sections in relation to the Cherry Creek floodplain. For now, the entire model (based on the CC 10-year WSE) has been displayed and the Cherry Creek floodplain limits have been added for reference.

XS-4992 through XS-5148 – Fill in floodplain. Floodplain filled in.

XS-9759 – Is water surface transitioning at roughly equal rates on both banks in this area? Hard to tell due to imbalance in overbank lengths, but looks like ROB might hold the 5820 contour for a little too long? Adjusted 100-year floodplain on ROB between XS-9759 and XS-9616 to transition at a rate more equal to the rate on the LOB.

Protecting People, Property and Our Environment.

Title: **Cherry Creek Tribs – Kragelund**
Consultant: Dewberry
Date Received: 2/20/2020
Date Returned: 6/25/2020
Review Phase: 2 - 100-Year Floodplain Delineation
UDFCD Reviewer: Jon Villines

Products Received:
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☐ The following required submittal files for this phase were not received:
- N/A

☐ The following supplemental submittal files for this phase were received:
- N/A

Reviewed Model Files and Dates:
CCT_Kragelund.prj (*12/02/2019*) (*100-yr*)
CCT_Kragelund.p01
CCT_Kragelund.p01.hdf
CCT_Kragelund.p02
CCT_Kragelund.p02.hdf
CCT_Kragelund.g01
CCT_Kragelund.g01.hdf
CCT_Kragelund.f01
CCT_Kragelund.f02

Products Not Reviewed:
N/A

Comments Geodatabase:
N/A
General Comments:
Hydraulic Structures: XYZ
Review Step 2 – 100-Year Floodplain Delineation
Agreement Table:

XS-6360 – Why was this area excluded here but nowhere else? The floodplain delineation has been modified to better represent this area.

XS-5685 – Why would the floodplain be expanded beyond the WSE shown in the model for a confined channel section like this? XS doesn't seem to support the expansion. The floodplain delineation has been modified to better represent this area.

XS-4505 – This appears to maybe be the wrong comment? Map width is less than model width at this XS Floodplain delineation excludes unrealistic flow area that is not hydraulically connected.

XS-1980 – How is the new WSE derived? Provide some additional explanation here. Floodplain top width includes overland flow from upstream.

XS-762, 1084 and 1207 - These comments need to be expanded to specify how and why the delineation is expanded. Is it due to the 2D model in these areas? How are we determining WSE at these XSs? We have adopted Hung Teng's recommended comments.

Floodplain Work Maps (GIS):

XS-9754 – Right and left cross-section elevations not symmetrical to stream centerline. The floodplain delineation has been modified so the right and left cross-section elevations are symmetrical.

XS-5685 – Did we include additional area here because we don't have detailed survey on the LOB? Does the XS need to be updated? The floodplain delineation has been modified to better represent this area.

Between XS-3153 and XS-2823 – Please represent the likely spill location over E Mineral Pl as accurately as possible. Discussed with MHFD on 8/11: The likely spill location has been interpolated between cross-sections.

XS-2651 – Is high ground accurately reflected in the delineation here? There are dry parts of the XS in the model. Please confirm that WS is accurately represented according to topo at all locations in each XS. Discussed with MHFD on 8/11: MHFD will reach out to the FPA to see if they would like to certify this home higher than the floodplain elevation. For now, the house is shown inside the floodplain.

XS-2419 – The model XS indicates a significant area in the middle of this water surface that is above the 100-year WSE, doesn't appear to be reflected in the floodplain. Was a decision made to exclude this berm? Discussed with MHFD on 8/11: It is our understanding that the common practice is to show small islands of high ground as inundated within the floodplain rather than as an island of dry ground. The delineation has been left as-is.

XS-2336 - XS does not appear to represent a level WS. Right and left cross-section elevations not symmetrical to stream centerline. Trimmed XS in model and modified floodplain delineation.

XS-1207 and 1084 – These XSs will need to be extended to include the entire floodplain width. XSs have been extended.

Confluence – How will the 2D floodplain tie-in with the Cherry Creek effective floodplain? Discussed with MHFD on 8/11: MHFD will discuss internally how we would like to depict the tributary floodplains and cross-sections in relation to the Cherry Creek floodplain. For now, the entire model (based on the CC 10-year WSE) has been displayed and the Cherry Creek floodplain limits have been added for reference.

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Title: Cherry Creek Tribs – South Arapahoe
Consultant: Dewberry
Date Received: 12/19/2019
Date Returned: 6/25/2020
Review Phase: 2 - 100-Year Floodplain Delineation
UDFCD Reviewer: Hung-Teng Ho

Products Received:
☒ All required submittal files for this phase were received.
☐ The following required submittal files for this phase were not received:
- List files if needed

☐ The following supplemental submittal files for this phase were received:
- List files if needed

Reviewed Model Files and Dates:
CCT_S_Arapahoe.prj (*12/19/2019*) (*List events*)
CCT_S_Arapahoe.p01
CCT_S_Arapahoe.p01.hdf
CCT_S_Arapahoe.p02
CCT_S_Arapahoe.p02.hdf
CCT_S_Arapahoe.g01
CCT_S_Arapahoe.g01.hdf
CCT_S_Arapahoe.f01
CCT_S_Arapahoe.f02

Products Not Reviewed:
N/A

Comments Geodatabase:
N/A

General Comments:

Review Step 2 – 100-Year Floodplain Delineation
Agreement Table:

XS-6880 – Floodplain top width includes overland flow from upstream. (Please refer to the recommended comments in the DFHAD Guideline.) Comment updated in agreement table.

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XS-5490 – Floodplain top width includes overland flow from upstream. (Please refer to the recommended comments in the DFHAD Guideline.) Comment updated in agreement table.

XS-5033 – Floodplain delineation excludes unrealistic flow area that is not hydraulically connected. Or, use blocked obstruction in HEC-RAS hydraulic model to remove this area Comment updated in agreement table.

Floodplain Work Maps (GIS):

XS-7500 – Trim floodplain at XS. Limit of study area. Trimmed floodplain at XS-7500.

Between XS-6919 and XS-6845 – Floodplain delineation across roadway follows contours and provides reasonable transition. Extended 100-year floodplain over the roadway.

XS-6190 – Fills in floodplain between the upstream cross-section and roadway embankment. Adjusted 100-year floodplain between XS-6190 and roadway to match the WSEL of XS-6190.

Between XS-6190 and XS-6123 – 100-yr Floodplain contained in culverts. Note added to map.

Between XS-5552 and XS-5460 – Floodplain delineation across roadway follows contours and provides reasonable transition. Extended 100-year floodplain over the roadway.

XS-4541 – Limit of detailed study? Downstream tie-in? Added limits of detailed study to map.

We are available to discuss or review any of these comments. Please feel free to contact me with any questions or concerns.

Sincerely,

Mile High Flood District

***Jon Villines*, PE, CFM**

Chenango Tributary

1. Multiple-profile Run
    - XS 1991, the 500-year profile drawdown can be fixed by not modifying the low flow channel geometry to match the culvert opening. Reverted XS 1991 geometry back to unmodified terrain.
    - XS 8866, the drawdowns can be fixed by adjusting the elevations of IEFAs to allowable the overtopping flow continues downstream without obstruction. Adjusted to try to follow this methodology. 500-year drawdown improved.
2. Sta. 10563 Hinsdale Avenue (Crossing 46), the following parameters are not the normal parameters used for modeling a culvert. Please include the supporting information in the description tab or revise the parameters as necessary.
    - The culvert Solution Criteria used "Outlet Control" instead of "Computed Flow Control". Changed to "Computed Flow Control"
    - The entrance loss coefficient used 0.2 for pipe projecting from fill. Changed to 0.9 for pipe projecting from fill.
    - The Manning's n-value used 0.016 for CMP. Changed to 0.03 for CMP (max value to be consistent across all models).
3. Sta. 8905 Yampa St (Crossing 4), please verify the following parameters. Please include the supporting information in the description tab or revise the parameters as necessary.
    - Please verify the entrance configuration why they are very different. Entrance configuration changed to CMP culvert and pipe projecting from fill.
    - Culvert #1 used Chart # 55 with entrance loss coefficient 0.9 that is not normal. Changed Culvert #1 to match Culvert #2 settings.
    - Please verify the Manning's n-values per pipe material. Kept manning's n of 0.03 for CMP (max value to be consistent across all models).
    - Modified IEFA to reduce profile drawdown at d/s side of culvert
4. XS 8673 and 8514, please provide information/reason for the permanent IEFA in the description tab. If this is a permanent pool, should the permanent IEFA be applied consistently across the pond? IEFA removed from XS 8673 for pond. Description added to XS 8514: Permanent IEFA reflects flow blocked by private road.
5. XS 8276 & 8496, please provide information/reason for the permanent IEFA in the description tab. Description added to XS 8276: Permanent IEFA reflects flow blocked by private road. Description added to XS 8496: Permanent IEFA is used to delimit main flow path between bank stations (based on contours) instead of secondary flow path.
6. XS 8137, please continue the floodplain delineation at south side of E Hinsdale Ave to tie back floodplain at downstream side of XS 7346.
   Continued the floodplain delineation at south side of E Hinsdale Ave between XS 8137-7346. Extended cross-sections to include.
7. Sta. 7686 Private Drive (Crossing 8), the following parameters are not the normal parameters used for modeling a culvert. Please include the supporting information in the description tab or revise the parameters as necessary.
    - The Manning's n-value used 0.015 for CMP. Changed to 0.03 for CMP (max value to be consistent across all models).
8. Sta. 7156 Telluride Court (Crossing 9), the following parameters are not the normal parameters used for modeling a culvert. Please include the supporting information in the description tab or revise the parameters as necessary.
    - The Manning's n-value used 0.03 for CMP. Kept manning's n of 0.03 for CMP (max value to be consistent across all models).
9. Sta. 5798 S Richfield St (Crossing 11), the following parameters are not the normal parameters used for modeling a culvert. Please include the supporting information in the description tab or revise the parameters as necessary.
    - CMP projecting form fill used entrance loss coefficient 0.2. Changed to 0.9 for pipe projecting from fill.
    - The Manning's n-value used 0.03 for CMP. Kept manning's n of 0.03 for CMP (max value to be consistent across all models).
10. XS 5148, the description is not clear. There is no adverse grade at either downstream side or upstream side. Meant for XS 5300. Moved note to that XS.
11. Sta. 4299 E Hinsdale Way (Crossing 18), the following parameters are not the normal parameters used for modeling a culvert. Please include the supporting information in the description tab or revise the parameters as necessary.
    - CMP mitered to conform to slope used entrance loss coefficient 0.2. Changed to 0.7 for pipe mitered to conform to slope.
    - The Manning's n-value used 0.03 for CMP. Kept manning's n of 0.03 for CMP (max value to be consistent across all models).
    - An IEFA approximate 2 feet above the roadway crown was used at the right overbank area at the upstream side of culvert, but there is not similar obstruction at the downstream side. Reduced IEFA in the area to avoid being overly conservative. These IEFA are also representing a bit of conveyance shadow from the upstream high ground (at a 4:1) and are helping reduce the stark change in flow area, which was causing some issues with the 500-year profile.
12. XS 2091, please complete the 500-year floodplain boundary at right overbank area. Completed 500-year floodplain boundary at right overbank area.
13. XS 3246 & 3038, the left minor high ground is not regulatory levee embankment. Please include the low lying area with the floodplain.
    Added the low lying area within the floodplain.
14. XS 697, 778, 950, 976, 998, 1030, 2681, 5300, 5350, 5587, 5607, 8137, 8467, 8496 & 8514, the Cont\Exp coefficients were increased to 0.3/0.5. Please provide information/reason for the increased coefficient values in the description tab. Information has been added to description tabs as necessary. Coefficients were reduced to standard at XS where 0.3/0.5 appeared too conservative/no effect on WSEL.
15. XS 4342, 4428, 4992, 5148, 5300, 5350, 5372, 5497, 5587, 5607, 5687, 6013, 6546, 6713, 6877, 9759, 9871, 9943, 10090 & 10216, the IEFAs were not surely necessary or too much without clear obstruction. Please provide information/reason for the IEFAs in the description tab.
    Note: IEFAs can pre-determine the limits of floodway encroachment that means in favor of the allowable fill in the floodway fringe. Care should be used to avoid arbitrary IEFAs. Thank you for

the guidance. IEFAs were reviewed at each cross section. Reductions were made to avoid pre-determination of floodway limits or reasoning was added to description tab.

16. Floodway Analysis

    There were enough changes in the baseline model that the floodway model was updated throughout entire reach.

    - Please avoid floodway top width include IEFA.
      Avoided floodway top widths including IEFA where possible. There are several cross-sections where this is not possible: 432, 5838, 7190, 7667, 7711, and 8949. These cross-sections have encroachments in as far as possible while maintaining delta WS and EG below 0.5 ft.
    - XS 8820, left floodway encroachment station is outside the 100-year floodplain.
      Adjusted the encroachments so they are within the floodplain.
    - XS 8866, left and right floodway encroachment stations are outside the 100-year floodplain.
      Adjusted the encroachments so they are within the floodplain.
    - XS 1255, please increase left floodway encroachment to avoid impact at developed parcel if it is feasible.
      Increased left floodway encroachment.
    - XS 2601 to 2681 & XS 3394 to 3498, please smooth the right floodway boundary by trimming the backwater area.
      Smoothed out the right floodway boundary between 2601 to 2681 and 3394 to 3498.
    - XS 8253 to XS 886, please use equal conveyance reduction as much as possible, or please provide explanation why the floodway encroachments are appropriate.
      Reviewed floodway encroachments and used equal conveyance as much as possible after following guidelines based on IEFAs and high grounds. In areas where the floodplain crosses E. Hinsdale Ave., the floodway has more encroachment on the left bank to keep the floodway off of the road where possible.
    - XS 9841 upstream, is there any flood storage at this location? No flood storage was included in the baseline hydrology at this location.

Joplin Tributary

1. Please include clarification in the plan description field to explain the reason of using 0.33 for the Maximum Difference Tolerance instead of using the default value of 0.3.
   It was an error for it to be set at 0.33, reset value to 0.3.
2. The cross section stations in the GIS shapefile are different from the cross section stations in the HEC-RAS hydraulic model.
   Fixed the cross section stations in the shapefile to match the HEC-RAS model.
3. XS 2959,
   a. Please provide explanation for the adverse thalweg slope in the description tab.
      Added a note in the description tab for this XS.
   b. The 500-year floodplain top width includes overland flow from upstream that is good. Please request using the same approach for the 100-year floodplain top width at left overbank.
      Adjusted 100-year floodplain at left overbank to account for overland flow from upstream.
4. XS 5640, the “oxbow-like features” is a W.Q. detention which is hydraulically connected to the main channel at upstream side of the detention. The detention is impacted by backwater and can be designated as Zone AH. The cutline of cross section 5640 ends at the berm of the detention is OK. It is also OK if the cutline was extended pass the detention and the detention area was blocked with IEFA. The benefit of the expanded cross section is the floodplain top width can be measured along the cross section 5640.
   No action needed.
5. XS 7970 to XS 8449, detention facility.
   a. Please provide the source of known water surface elevations in the description tab.
      Added a note in the description tab that the known water surface elevations are from the baseline hydrology modeling.
   b. Please expand the upstream limit of floodway analysis to include this detention, if the detention volume was counted in the baseline hydrology. Please assume floodplain = floodway within the detention.
      Added encroachments for these XS in model and extended floodway delineation to include this detention.
   c. The downstream pipe does not have the 500-year capacity. The overflow in the 500-year event flows in the different path to Piney Creek. Please quantify the 500-year overland flow and label the limit of detailed study. The 500-year overland flow path is obvious and easy to identify. It would be beneficial to include a description for the potential 500-year overland flow path.
      Added additional information like requested.
6. In general, the floodplain and floodway delineation should:
   a. Please confirm that the floodplain boundary should only cross the same contours once.
      Ensured the floodplain boundary only crosses the same contour once and fixed any locations that did.

b. The left and right floodplain boundary should cross the same contours at the locations where are approximately symmetric to the river centerline.
Reviewed and revised to improve approximate symmetry.
c. Floodway boundary should be coincident to or inside the 100-year floodplain.
Ensured the floodway boundary was not outside the 100-year floodplain.

7. In general, floodway top width should not include IEFA and high ground.
    a. XS 3923, floodway top width includes IEFA and high ground.
    Adjusted the encroachments so they do not include high ground or IEFA
    b. XS 4357, floodway right encroachment is on high ground.
    Adjusted right encroachment so it is not on the high ground and is within the floodplain.
    c. XS 5898, floodway top width includes IEFA.
    Adjusted right encroachment to not include IEFA. Kept the left encroachment as is since the WSEL is above the elevation of the IEFA and adjusting this encroachment increases the difference in WSEL above 0.5ft.
    d. XS 6406, right encroachment is outside of floodplain.
    Adjusted right encroachment inward to be within floodplain.

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FHAD Review Comment Memo

Title: Cherry Creek Tribs - Kragelund
Consultant: Dewberry
Date Received: 8/25/2020
Date Returned: 01/08/2021
Review Phase: 3 - 500-yr Floodplain
MHFD Reviewer: Melanie Poole

Products Received:
☒ All required submittal files for this phase were received:
- Shapefiles
- Agreement Table
- Floodplain Delineation Map (Existing)
- Floodplain Delineation Map (Future)

Reviewed Model Files and Dates:
Kragelund FHAD Model.prj (08/25/2020)
Regulatory Analysis Future Conditions.p01
Regulatory Analysis Existing Conditions.p02
Floodway.p03
Kragelund Tributary.g01
2019 Baseline Hydrology Future.f01
2019 Baseline Hydrology Existing.f02
Floodway.f03

Comments Geodatabase:
Please review the attached comment geodatabase “CCT_Kragelund_2020-12-11_Step3_FHADReview”. The Date, Status, Type, Comment, and Commenter fields will be completed by the MHFD reviewer. Respond to each comment using the dropdown list in the Response field and provide any additional information in the ComResponse field. Please provide the responder’s name in the Responder field.

- “Accepted” indicates the comment was addressed.
- “Rejected” indicates the comment was not addressed; please provide an explanation.
- “General” indicates the comment was addressed for the entire model, not just at that point. Please provide a response in the response letter.
- “Discuss” indicates that more discussion is required; please provide an explanation.

General Comments:

1) As discussed in our meeting on 12/01/2020, please provide the existing conditions model including 100-yr and 500-yr floodplain maps with smoothed floodplain and annotated cross-sections, existing conditions 100-yr floodway, and existing conditions agreement table with future submittals. Additionally continue to include the 100-yr future conditions within the model, but no need to include future conditions mapping or floodway. 500-yr future conditions were also kept in the model.
2) Please see red-lined agreement table for comments. While these comments are based on the future conditions, these comments should be considered when preparing the existing conditions agreement table. Noted and referred back to.
3) Many comments made in the geodatabase are in reference to the future conditions mapping/ model. These comments are labeled as "FUTURE" and are marked with a status of closed. This portion of the review was completed prior to the decision to no longer continue with the future conditions floodway or mapping, but are included as reference as they should be considered when developing the existing conditions modeling and mapping. Noted and referred back to.

HEC-RAS 2D Comments:

1) Please continue modeling the existing and future conditions 100-yr and 500-yr for the shallow flooding areas. Only the existing 100-year and 500-year limits will be mapped.
   100yr and 500yr shallow flooding are mapped and labeled as such. Holes and polygons <150 sf were removed to simplify.
2) Please verify the simulation time of the model is long enough to capture the entire flooding extents.
   Confirmed simulation time is long enough for each run to reach quasi-steady state.
3) Please verify no water surface elevations mapped in this area exceed 1-ft in the existing 100-year event.
   Within the area of interest, there are a few isolated locations with max depth just above 1-ft (max ~ 1.3 ft), shown below, for the existing 100-year. It is assumed these are negligible and should not affect the classification of shallow flooding average 1-ft in the mapped area.

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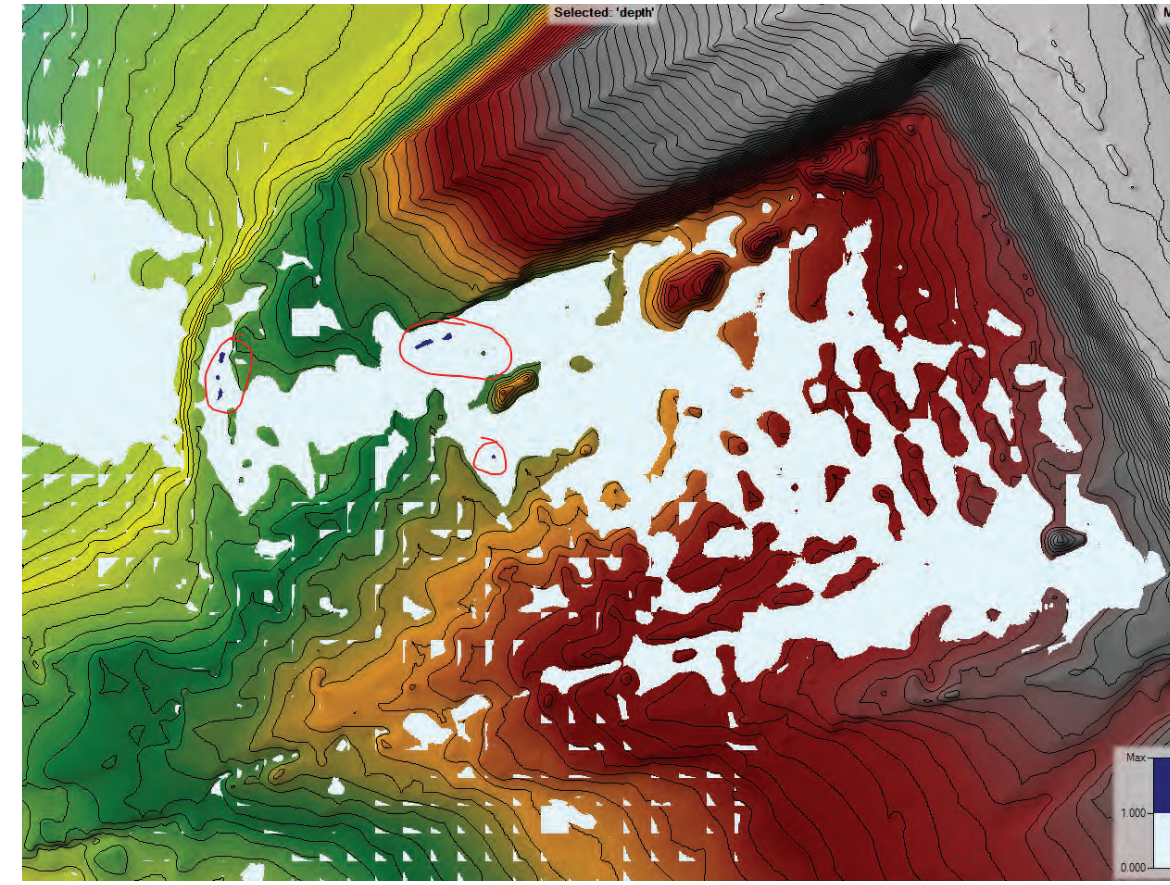

We are available to discuss or review any of these comments. Please feel free to contact me with any questions or concerns.

Sincerely,

Melanie Poole

Melanie Poole, PE
Mile High Flood District

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Little Raven

1. Please include clarification in the plan description field to explain the reason of using 0.33 for the Maximum Difference Tolerance instead of using the default value of 0.3. Tolerance was inadvertently changed and has been reverted back to the default value of 0.3.
2. Please provide justification for using higher expansion coefficient at XS 6181 in the description tab or revise the expansion coefficient as necessary. Higher expansion coefficient was inadvertent. Value was reverted back to default. (Negligible impacts to WSEL).
3. Culvert 6324;
   - Please provide supporting document for the revised culvert length, e.g. photos, on site structure measurement certified by P.E. etc. Confirmed original survey length appears appropriate. Reverted to the original 19.84' length.
   - Please confirm the culvert entrance configuration per survey information. (The aerial image shows different entrance configuration from the modeled entrance. The aerial maybe not correct. Just want to confirm.) Modified culvert scale # per survey information.
4. Floodway analysis:
   a. XS 4249, please increase floodway encroachment to create a potential maximum rise at the most downstream cross section. It might need a minor adjustment to the bank stations. Adjusted bank stations and encroachments as necessary to create max possible rise at XS.
   b. XS 4442, 4538, floodway top widths include IEFAs. Please increase the floodway encroachments or explain why the floodway analysis is appropriate. Floodway encroachments increased to exclude IEFAs.
   c. XS 5972 to XS 6556, please reconfigure (increase) the floodway encroachment and reasonably meet the maximum allowable increases in H.G.L. and E.G.L. It is preferred to not including the private properties inside the floodway. Reconfigured in this area to move away from private properties and gain max increases.

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FHAD Review Comment Memo

Title: Cherry Creek Tribs – South Arapahoe
Consultant: Dewberry
Date Received: 8/25/2020
Date Returned: 01/08/2020
Review Phase: 3 - 500-yr Floodplain
MHFD Reviewer: Melanie Poole

Products Received:
☒ All required submittal files for this phase were received:
- Shapefiles
- Agreement Table
- Floodplain Delineation Map

Reviewed Model Files and Dates:
CCT_SouthArapahoe.prj (08/25/2020)
Floodway.p01
Regulatory Analysis.p04
South Arapahoe Tributary.g01
2019 Baseline Hydrology.f02
Floodway.f01

Comments Geodatabase:
Please review the attached comment geodatabase "CCT_South Arapahoe_20201106_Step3 _FHADReview". The Date, Status, Type, Comment, and Commenter fields will be completed by the MHFD reviewer. Respond to each comment using the dropdown list in the Response field and provide any additional information in the ComResponse field. Please provide the responder's name in the Responder field.
- "Accepted" indicates the comment was addressed.
- "Rejected" indicates the comment was not addressed; please provide an explanation.
- "General" indicates the comment was addressed for the entire model, not just at that point. Please provide a response in the response letter.
- "Discuss" indicates that more discussion is required; please provide an explanation.

General Comments:
1) Please provide responses to comments with each submittal. Responses included in geodatabase.

2) Please see red-lined agreement table for comments. Comments addressed.
3) Please see red-lined floodplain map for comments. Comments addressed.

HEC-RAS 2D Comments:

1) Please continue modeling and mapping the future conditions 500-yr for the shallow flooding areas. Completed.
2) Please verify the simulation time of the model is long enough to capture the entire flooding extents. Confirmed.

We are available to discuss or review any of these comments. Please feel free to contact me with any questions or concerns.

Sincerely,

Melanie Poole

Melanie Poole, PE
Mile High Flood District

FHAD Review Comment Memo

Title: Cherry Creek Tribs - Chenango
Consultant: Dewberry
Date Received: 04/16/2021
Date Returned: 07/01/2021
Review Phase: 3 - 500-yr Floodplain
MHFD Reviewer: Laura Hinds

Products Received:
☒ All required submittal files for this phase were received:
- Shapefiles
- Agreement Table
- Floodplain Delineation Map
- 1D HEC-RAS Model
- Responses to previous comments

HEC-RAS 1D Comments:

1) XS 8905 – the IEFA's were removed completely on the downstream side. Please replace the IEFA and adjust the elevation on the left bank to allow flow to overtop the roadway.
   Added in the IEFA's to the downstream side of XS 8905 and followed guidance from the District on profile consistency.

2) XS 8949 – Please confirm the ground is reflecting the survey
   Edited the ground of XS 8949 to reflect the survey.

We are available to discuss or review any of these comments. Please feel free to contact me with any questions or concerns.

Thank you,

Laura Hinds
Mile High Flood District

MHFD
MILE HIGH FLOOD DISTRICT
2480 W. 26th Ave Suite 156-B | Denver, CO 80211
TEL 303 455 6277 | FAX 303 455 7880
www.mhfd.org

FHAD Review Comment Memo

Title: Cherry Creek Tribs - Kragelund
Consultant: Dewberry
Date Received: 04/16/2021
Date Returned: 07/01/2021
Review Phase: 3 - 500-yr Floodplain
MHFD Reviewer: Melanie Poole

Products Received:
☒ All required submittal files for this phase were received:
- Shapefiles
- Agreement Table
- Floodplain Delineation Map
- 1D HEC-RAS Model
- 2D HEC-RAS Model
- Responses to previous comments

General Comments:

1) Please see red-lined agreement table for comments.
   Addressed all comments on agreement table.
2) Please see red-lined workmap for comments.
   Addressed all comments on workmap.

HEC-RAS 1D Comments:

3) Please include essential information, e.g. horizontal and vertical datum, company info, final date of the model, etc. in the description field in the hydraulic model.
   Added information in the description field of the model.
4) Please remove ineffective flow areas from cross-sections 3416 and 7947 or please explain the need for their use.
   Cross-section 7947 crosses a secondary channel that has an invert lower than the main tributary. IEFA is being used to make the lowest elevation at the tributary as well as represent the flood shadow in the area of expansion. The IEFA was removed from cross-section 3416.

HEC-RAS 2D Comments:

5) Please label the future plan files as such.
   Renamed future plans.

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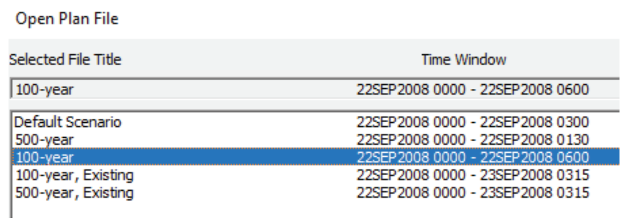

6) Please remove any unused terrain or plan files from the model.
   Removed unused terrain and plan files from model.

We are available to discuss or review any of these comments. Please feel free to contact me with any questions or concerns.

Sincerely,

Melanie Poole, PE
Mile High Flood District

MHFD MILE HIGH FLOOD DISTRICT
2480 W. 26th Ave Suite 156-B | Denver, CO 80211
TEL 303 455 6277 | FAX 303 455 7880
www.mhfd.org

FHAD Review Comment Memo

Title: Cherry Creek Tribs – South Arapahoe
Consultant: Dewberry
Date Received: 04/16/2021
Date Returned: 07/01/2021
Review Phase: 3 - 500-yr Floodplain
MHFD Reviewer: Melanie Poole

Products Received:
☒ All required submittal files for this phase were received:
- Shapefiles
- Agreement Table
- Floodplain Delineation Map
- 1D HEC-RAS Model
- 2D HEC-RAS Model
- Responses to previous comments

General Comments:
1) Please see red-lined agreement table for comments.
   Addressed all comments on agreement table.
2) Please see red-lined workmap for comments.
   Addressed all comments on workmap.

HEC-RAS 1D Comments:
1) Please include essential information, e.g. horizontal and vertical datum, company info, final date of the model, etc. in the description field in the hydraulic model.
   Added information in the description field of the model.
2) Please include right ineffective flow area for XS 5568 or explain the reasoning for not including.
   Added in the right IEFA for XS 5568.

HEC-RAS 2D Comments:
3) Please remove any unused terrain or plan files from the model.
   Removed unused terrain and plan files from model.

We are available to discuss or review any of these comments. Please feel free to contact me with any questions or concerns.

Sincerely,

Melanie Poole

Melanie Poole, PE
Mile High Flood District

FHAD Review Comment Memo

Title: Cherry Creek Tribs - Little Raven
Consultant: Dewberry
Date Received: 04/16/2021
Date Returned: 07/01/2021
Review Phase: 3 - 500-yr Floodplain
MHFD Reviewer: David Crooks

Products Received:
☒ All required submittal files for this phase were received:
- Shapefiles
- Agreement Table
- Floodplain Delineation Map
- 1D HEC-RAS Model
- 2D HEC-RAS Model
- Responses to previous comments

General Comments:
All MHFD comments sufficiently addressed.

Title: Cherry Creek Tribs - Joplin
Consultant: Dewberry
Date Received: 04/16/2021
Date Returned: 07/01/2021
Review Phase: 3 - 500-yr Floodplain
MHFD Reviewer: David Crooks

Products Received:
☒ All required submittal files for this phase were received:
- Shapefiles
- Agreement Table
- Floodplain Delineation Map
- 1D HEC-RAS Model
- 2D HEC-RAS Model
- Responses to previous comments

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General Comments:
All MHFD comments sufficiently addressed.

We are available to discuss or review any of these comments. Please feel free to contact me with any questions or concerns.

Sincerely,

David Crooks
Mile High Flood District

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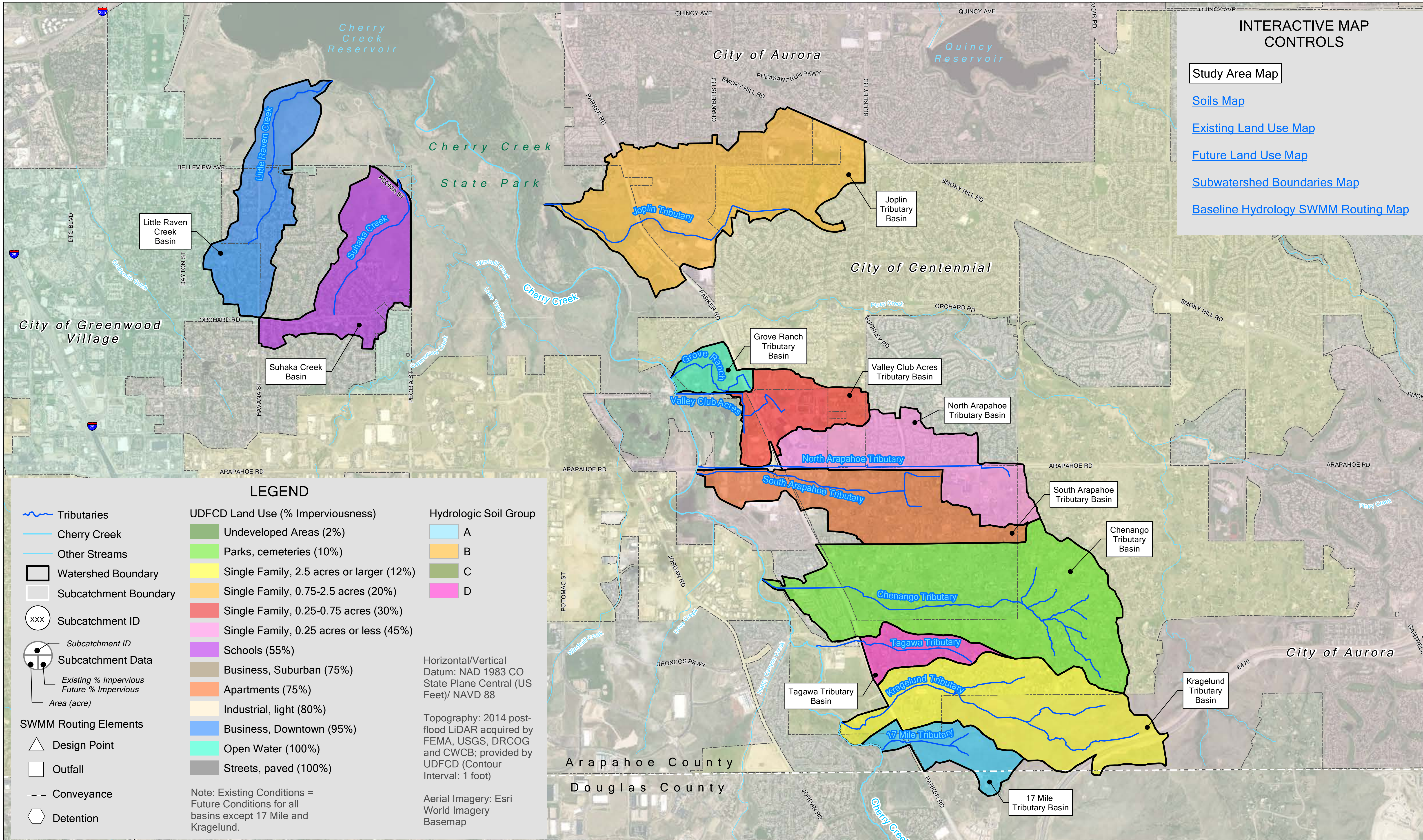
APPENDIX B

HYDROLOGIC ANALYSIS SUPPORT DOCUMENTS



Dewberry | J3

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O 303-368-5601
www.dewberry.com

Designed By: AB
Drawn By: HH
Checked By: KC/DE
Date: 02/2019

N
0 1,500 3,000
Scale in Feet
1 inch = 3,000 feet

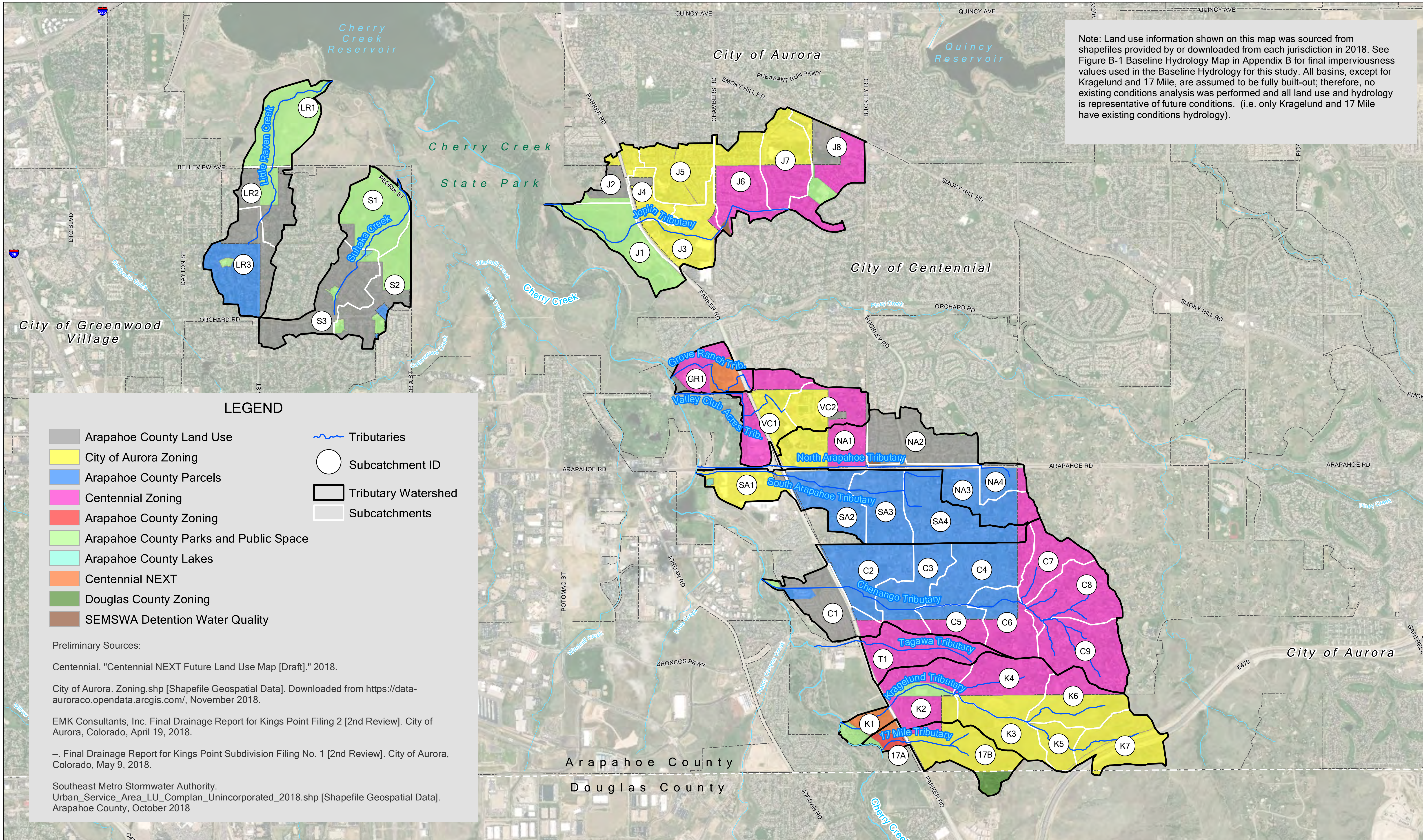
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT, SOUTHEAST METRO STORMWATER AUTHORITY, CITY OF AURORA, AND ARAPAHOE COUNTY

CHERRY CREEK MINOR TRIBUTARIES IN ARAPAHOE COUNTY

BASELINE HYDROLOGY MAP

FIGURE B-1

Sheet 1 of 1



Note: Land use information shown on this map was sourced from shapefiles provided by or downloaded from each jurisdiction in 2018. See Figure B-1 Baseline Hydrology Map in Appendix B for final imperviousness values used in the Baseline Hydrology for this study. All basins, except for Kragelund and 17 Mile, are assumed to be fully built-out; therefore, no existing conditions analysis was performed and all land use and hydrology is representative of future conditions. (i.e. only Kragelund and 17 Mile have existing conditions hydrology).

Preliminary Sources:

Centennial. "Centennial NEXT Future Land Use Map [Draft]." 2018.

City of Aurora. Zoning.shp [Shapefile Geospatial Data]. Downloaded from https://data-auroraco.opendata.arcgis.com/, November 2018.

EMK Consultants, Inc. Final Drainage Report for Kings Point Filing 2 [2nd Review]. City of Aurora, Colorado, April 19, 2018.

–. Final Drainage Report for Kings Point Subdivision Filing No. 1 [2nd Review]. City of Aurora, Colorado, May 9, 2018.

Southeast Metro Stormwater Authority. Urban_Service_Area_LU_Complan_Unincorporated_2018.shp [Shapefile Geospatial Data]. Arapahoe County, October 2018

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Checked By: KC/DE
Date: 02/2019

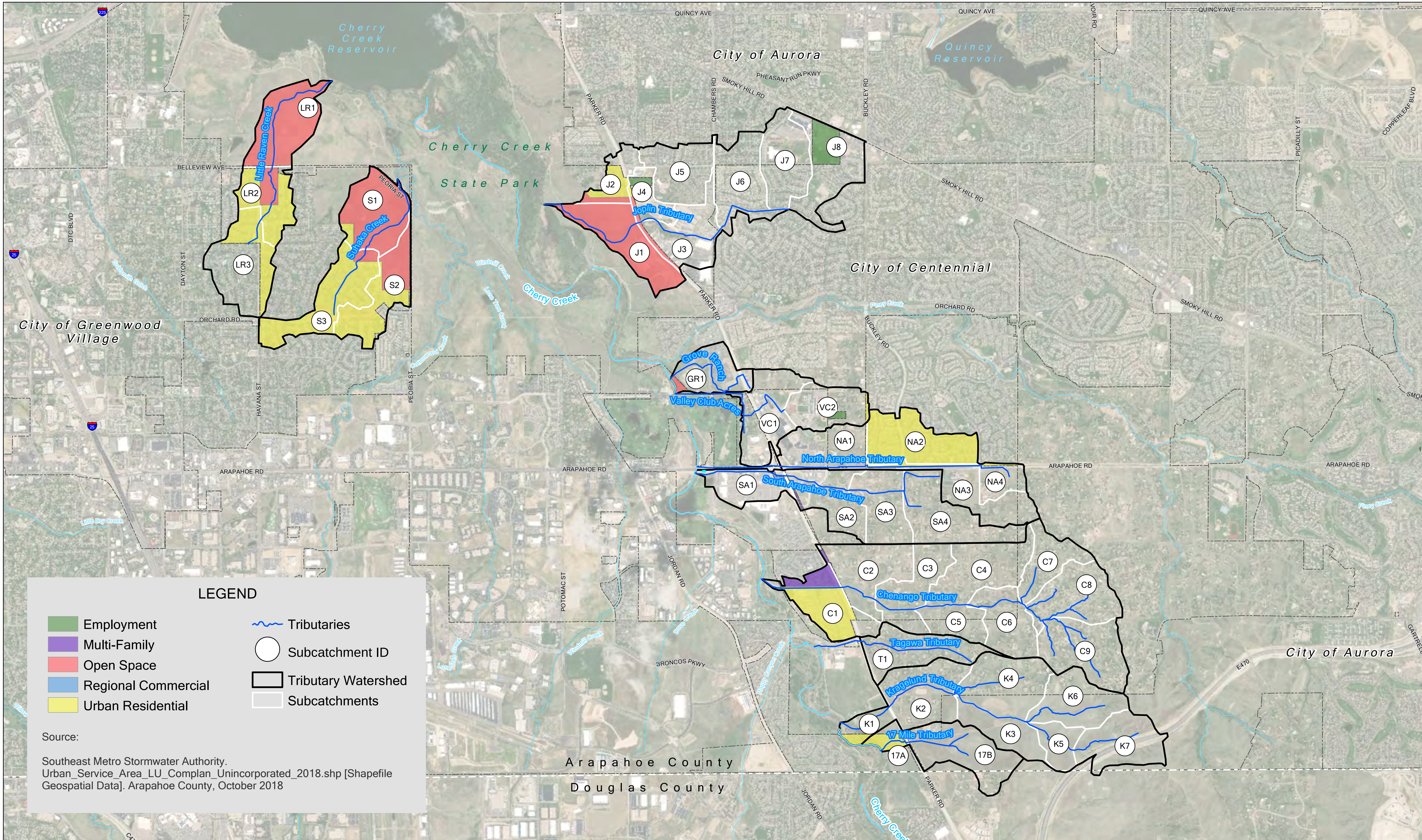
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT, SOUTHEAST METRO STORMWATER AUTHORITY, CITY OF AURORA, AND ARAPAHOE COUNTY

CHERRY CREEK MINOR TRIBUTARIES IN ARAPAHOE COUNTY

LAND USE SOURCES

FIGURE B-2

Sheet 1 of 3



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Designed By: AB
Drawn By: HH
Checked By: KC/DE
Date: 02/2019

N

0 1,500 3,000
Scale in Feet
1 inch = 3,000 feet

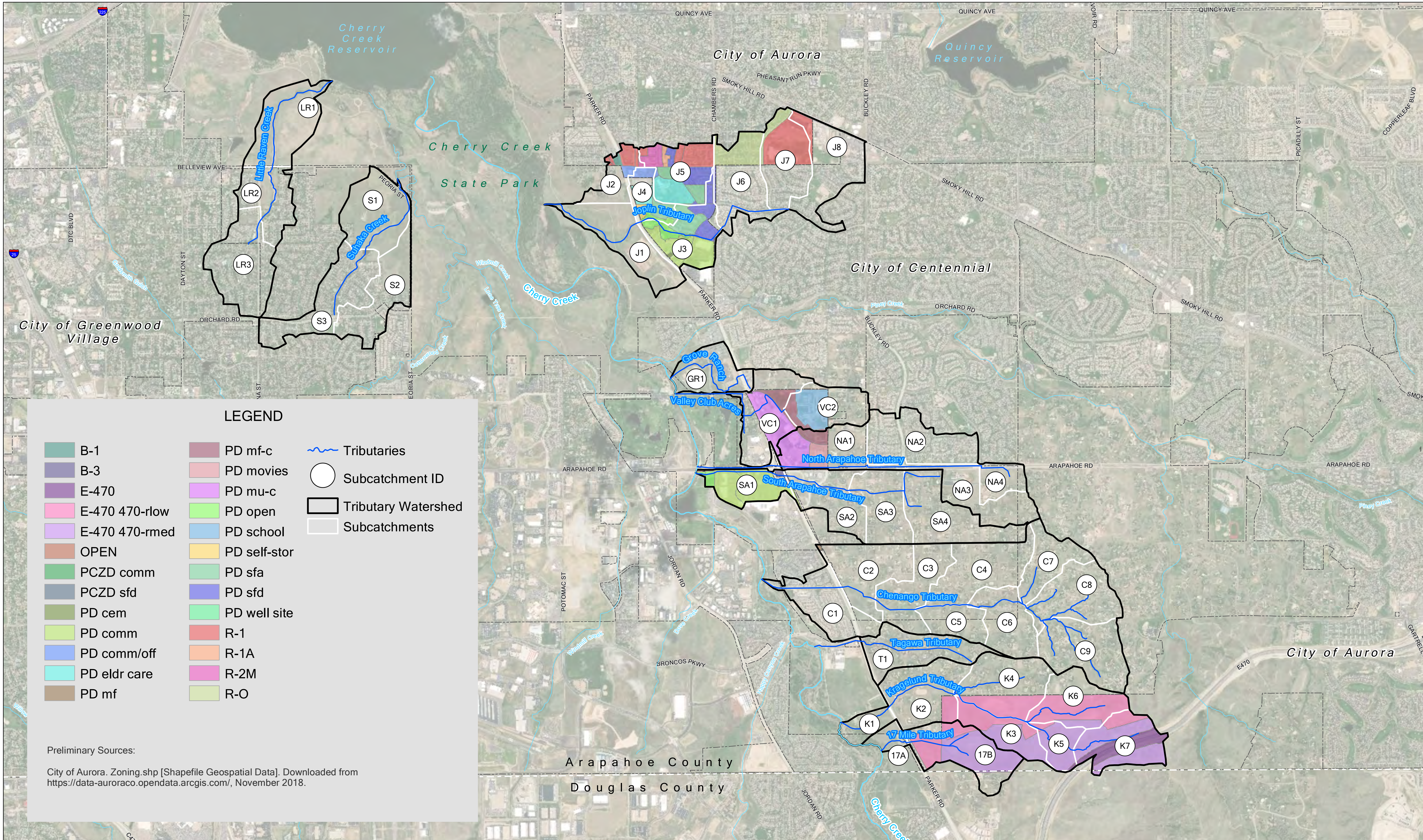
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT, SOUTHEAST METRO STORMWATER AUTHORITY, CITY OF AURORA, AND ARAPAHOE COUNTY

CHERRY CREEK MINOR TRIBUTARIES IN ARAPAHOE COUNTY

ARAPAHOE COUNTY LAND USE DATA

FIGURE B-2

Sheet 2 of 3



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Checked By: KC/DE
Date: 02/2019

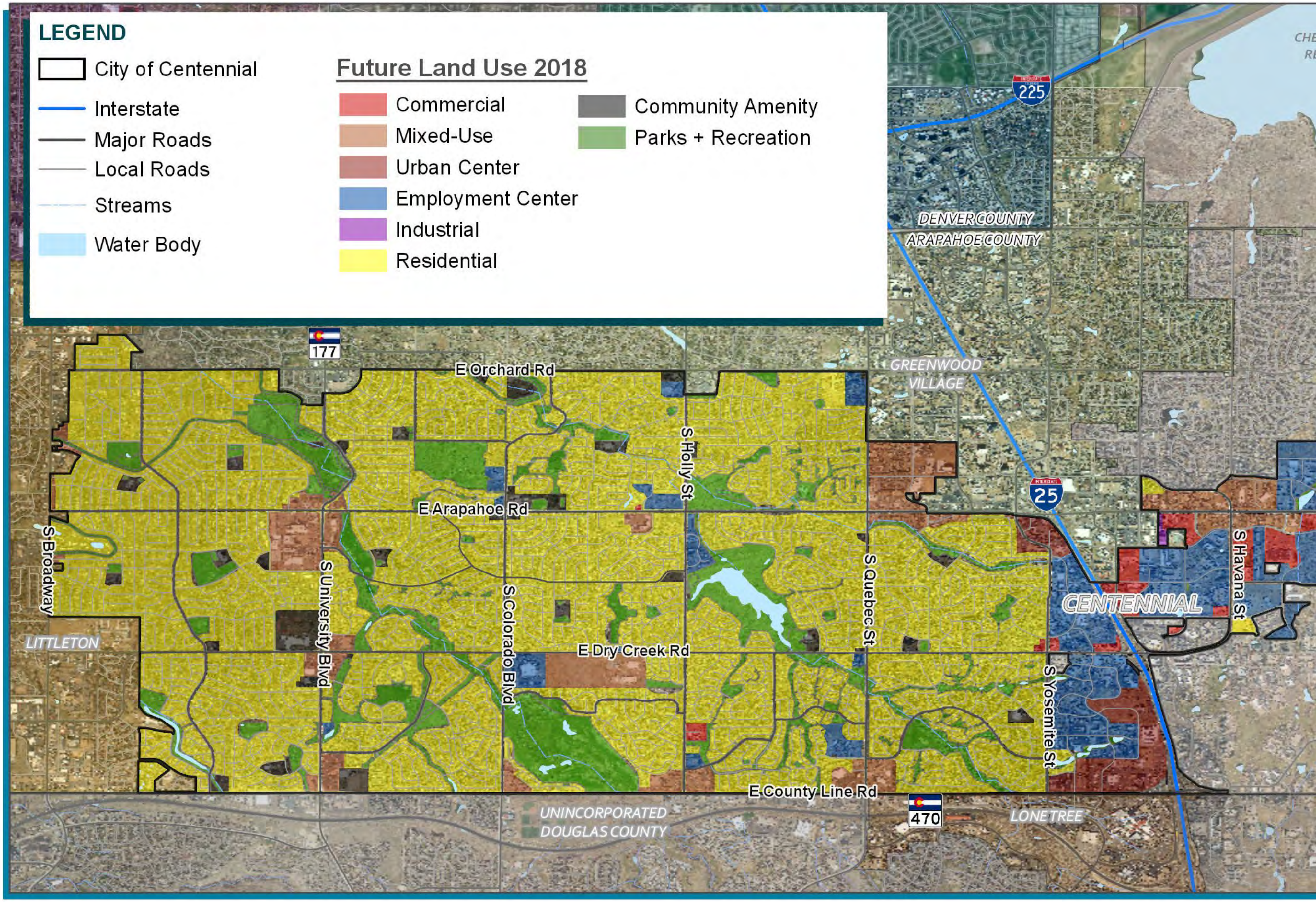
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT, SOUTHEAST METRO STORMWATER AUTHORITY, CITY OF AURORA, AND ARAPAHOE COUNTY

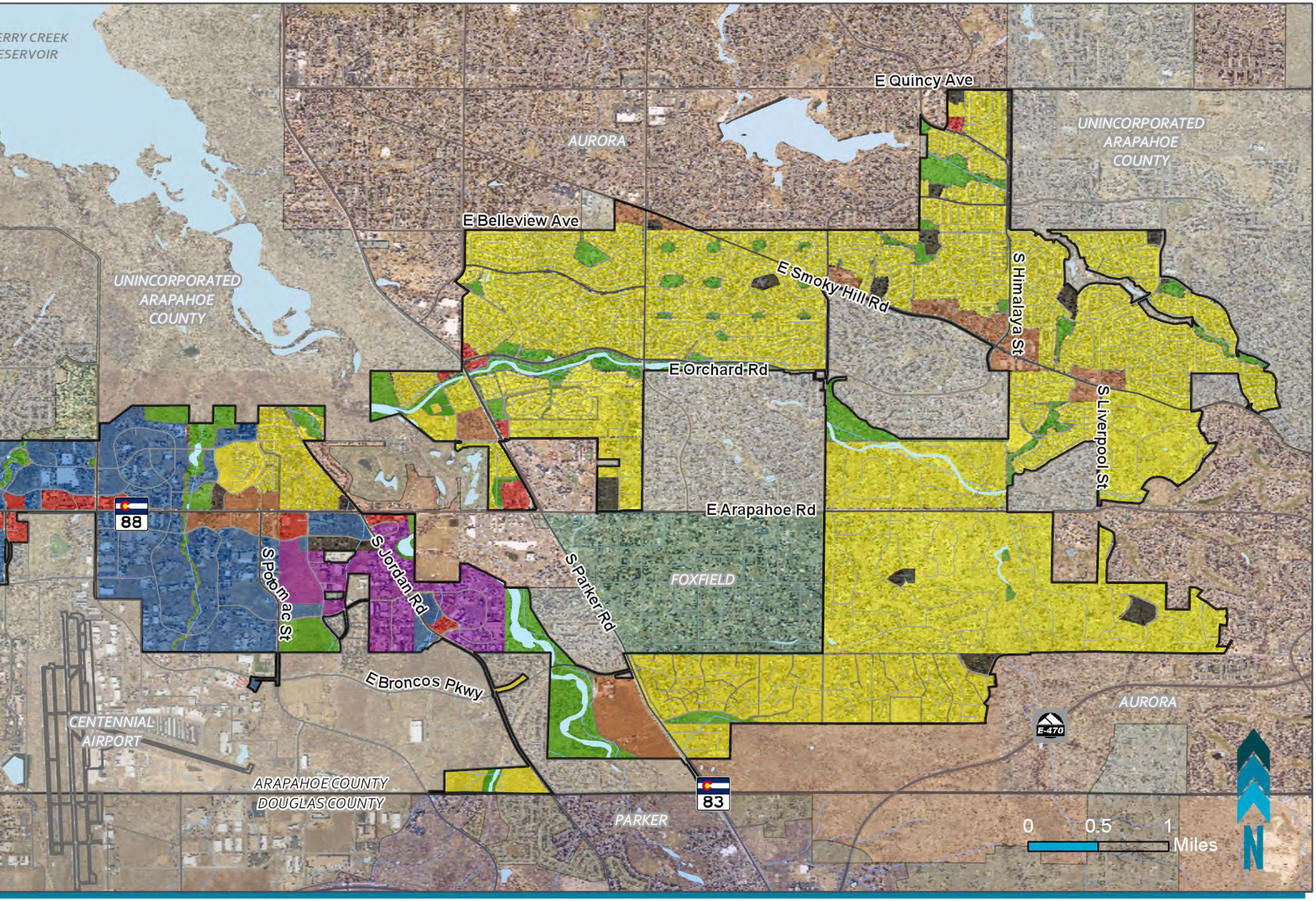
CHERRY CREEK MINOR TRIBUTARIES IN ARAPAHOE COUNTY

CITY OF AURORA ZONING DATA

FIGURE B-2

FUTURE LAND USE MAP




ERRY CREEK
ESERVOIR
AURORA
E Quincy Ave
UNINCORPORATED
ARAPAHOE
COUNTY
E Belleview Ave
E Smoky Hill Rd
S Himalaya St
UNINCORPORATED
ARAPAHOE
COUNTY
E Orchard Rd
S Liverpool St
88
E Arapahoe Rd
S Jordan Rd
S Potomac St
S Parker Rd
FOXFIELD
E Broncos Pkwy
CENTENNIAL
AIRPORT
AURORA
E-470
ARAPAHOE COUNTY
DOUGLAS COUNTY
83
PARKER
0
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Miles
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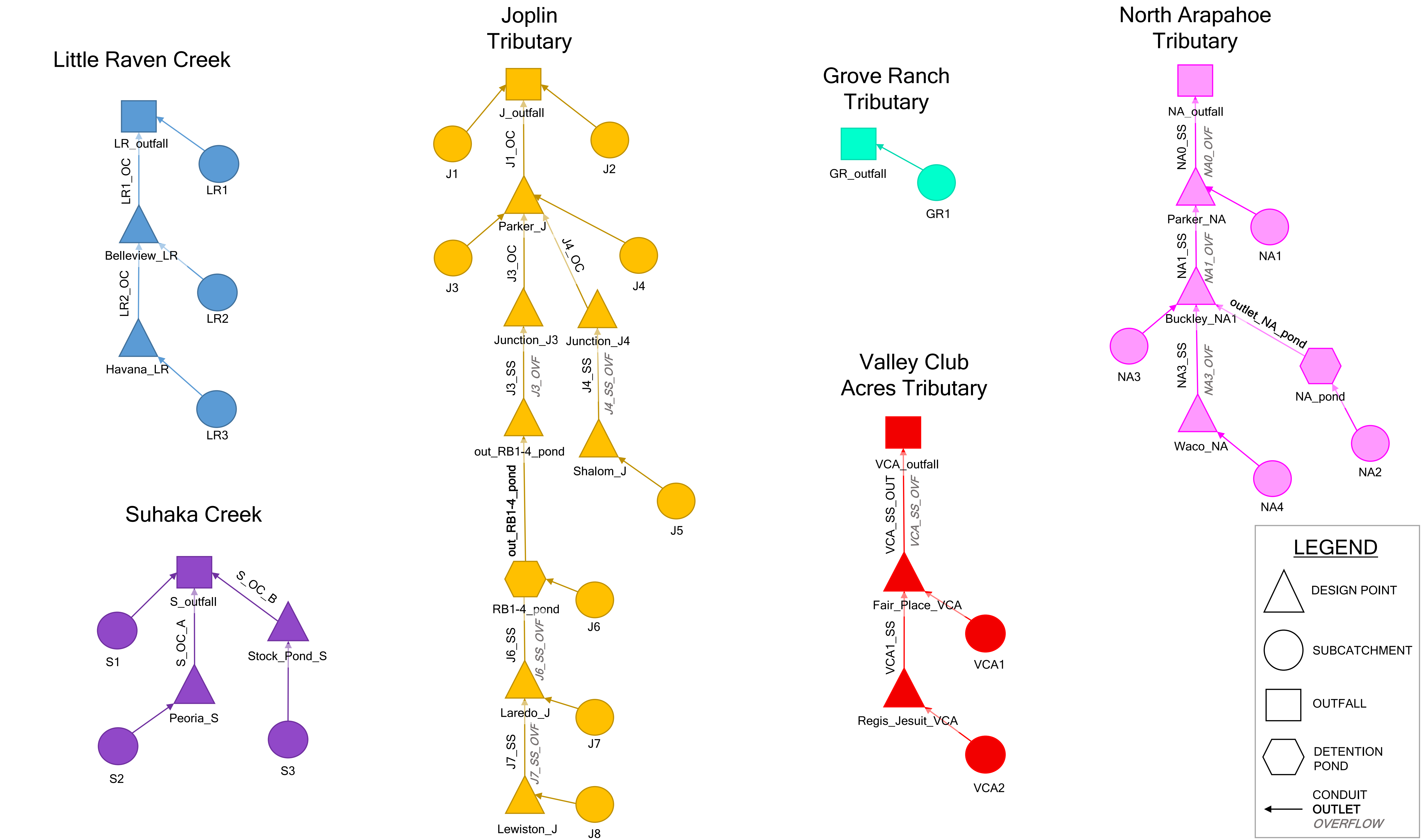

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Designed By: AB
Drawn By: HH
Checked By: KC/DE
Date: 02/2019

NOT TO SCALE

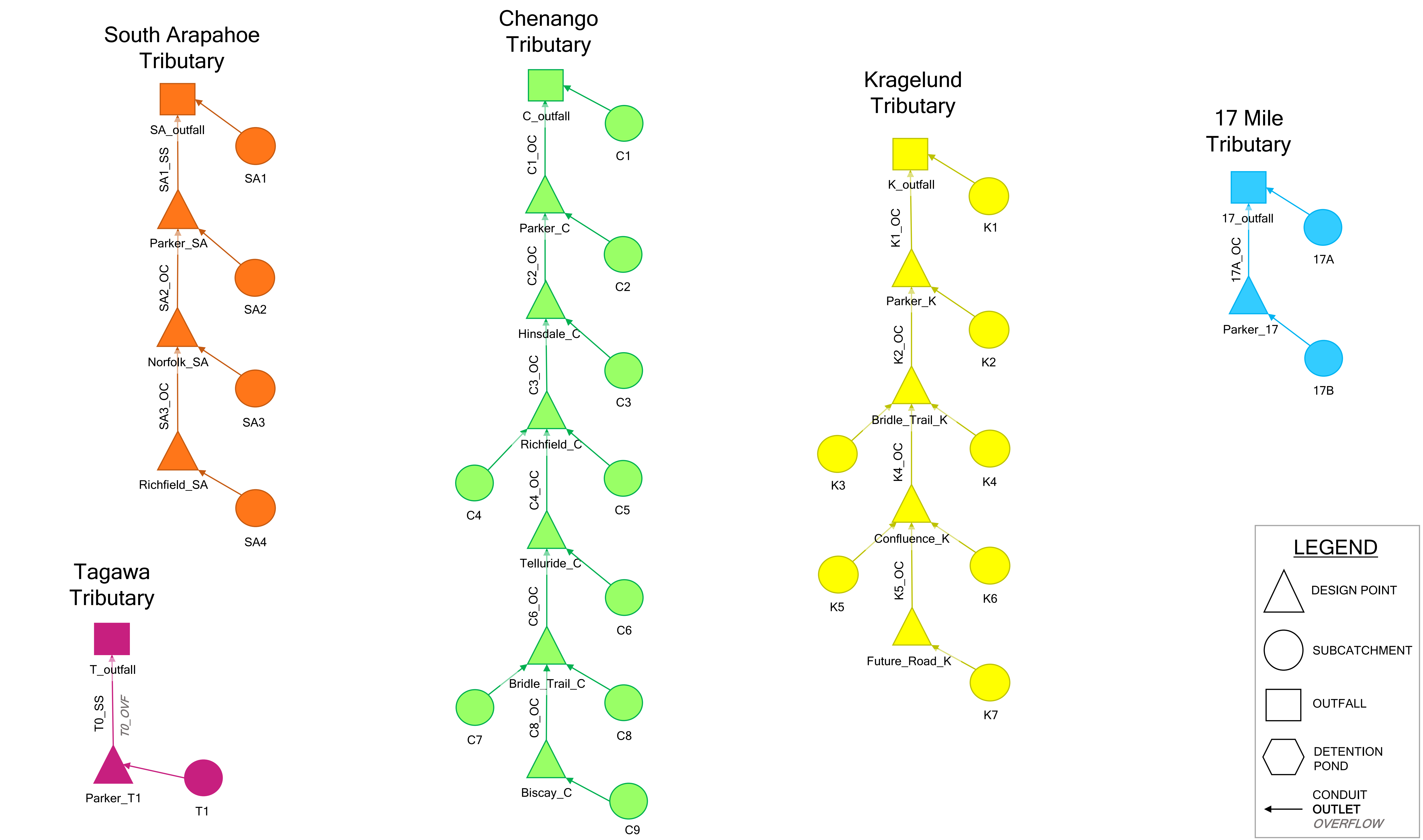
URBAN DRAINAGE AND FLOOD CONTROL DISTRICT, SOUTHEAST METRO STORMWATER AUTHORITY, CITY OF AURORA, AND ARAPAHOE COUNTY

CHERRY CREEK TRIBUTARIES UPSTREAM OF CHERRY CREEK RESERVOIR MDP & FHAD

SWMM ROUTING SCHEMATIC

FIGURE B-3

Sheet 1 of 2



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Greenwood Village, CO 80111
O 303-368-5601
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Designed By: AB
Drawn By: HH
Checked By: KC/DE
Date: 02/2019

NOT TO SCALE

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT, SOUTHEAST METRO STORMWATER AUTHORITY, CITY OF AURORA, AND ARAPAHOE COUNTY

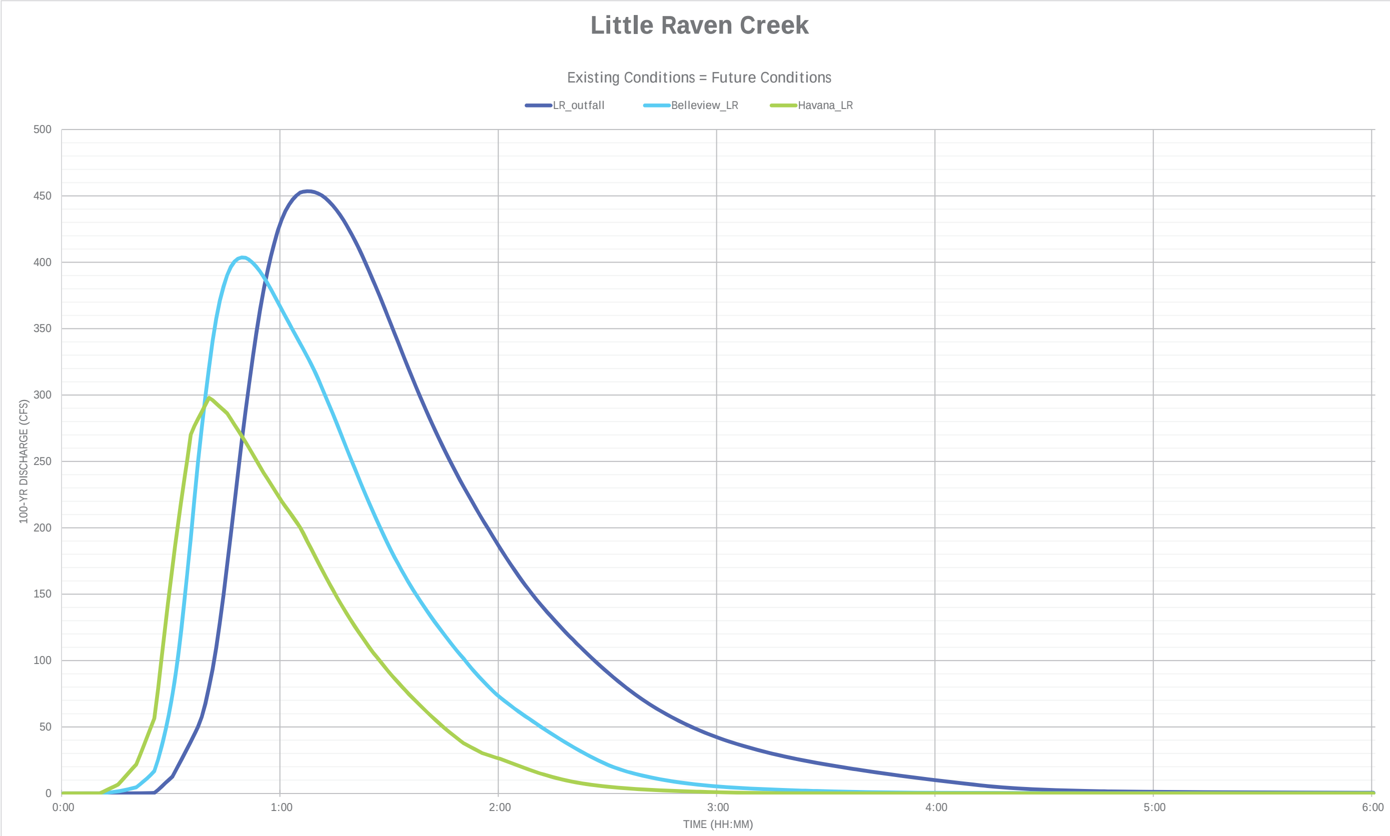
CHERRY CREEK TRIBUTARIES UPSTREAM OF CHERRY CREEK RESERVOIR MDP & FHAD

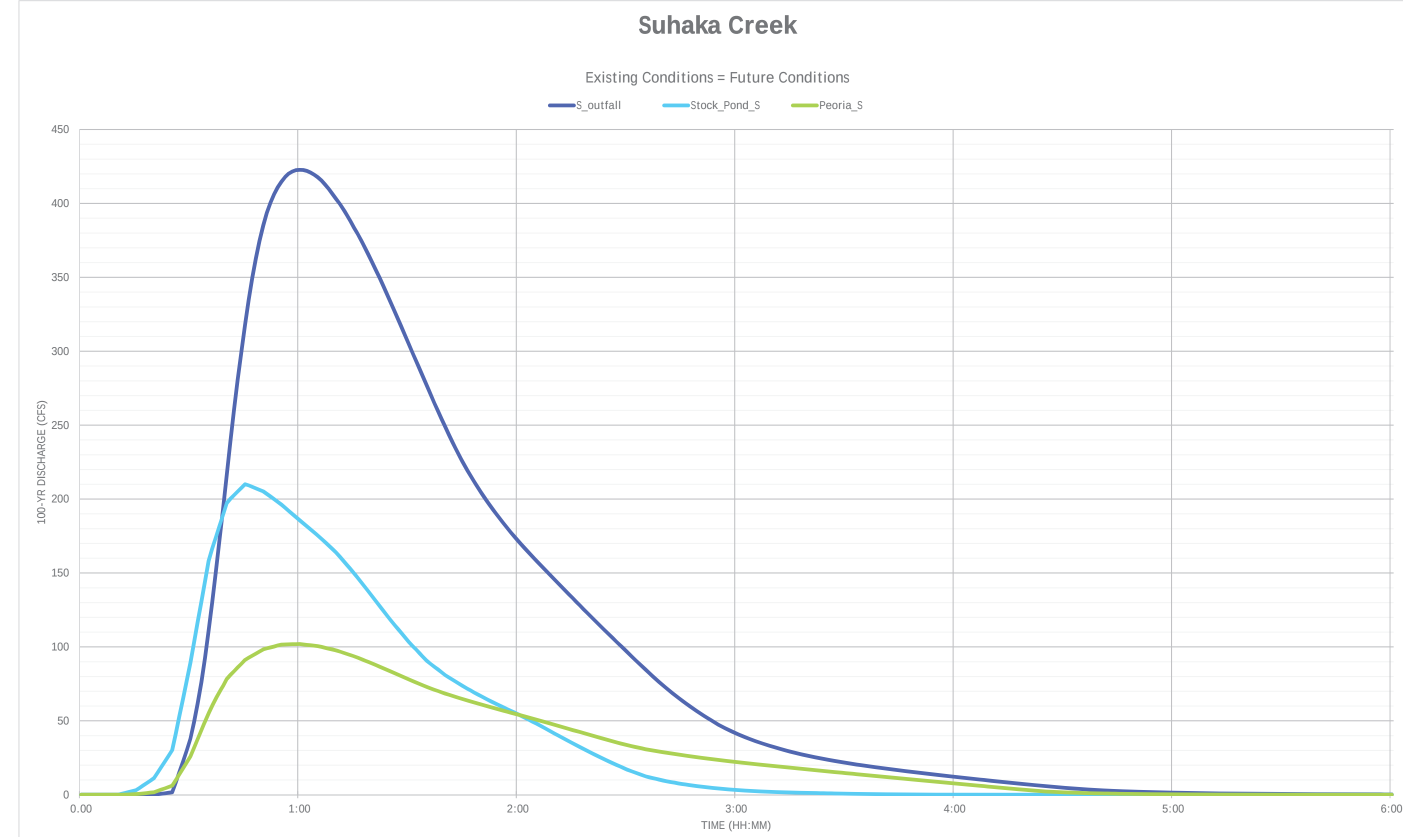
SWMM ROUTING SCHEMATIC

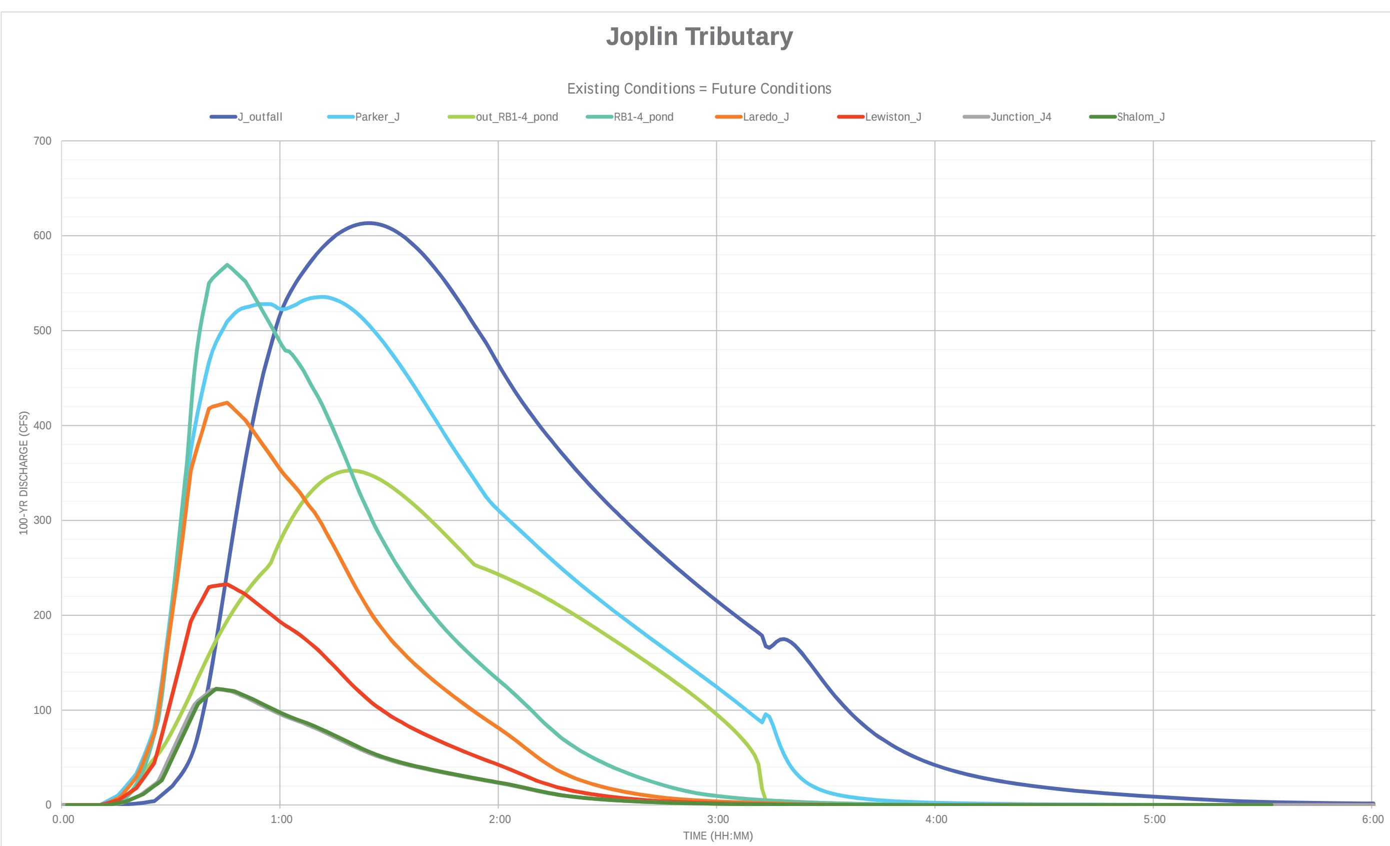
FIGURE B-3

Sheet 2 of 2

Figure B-4. Baseline Hydrographs







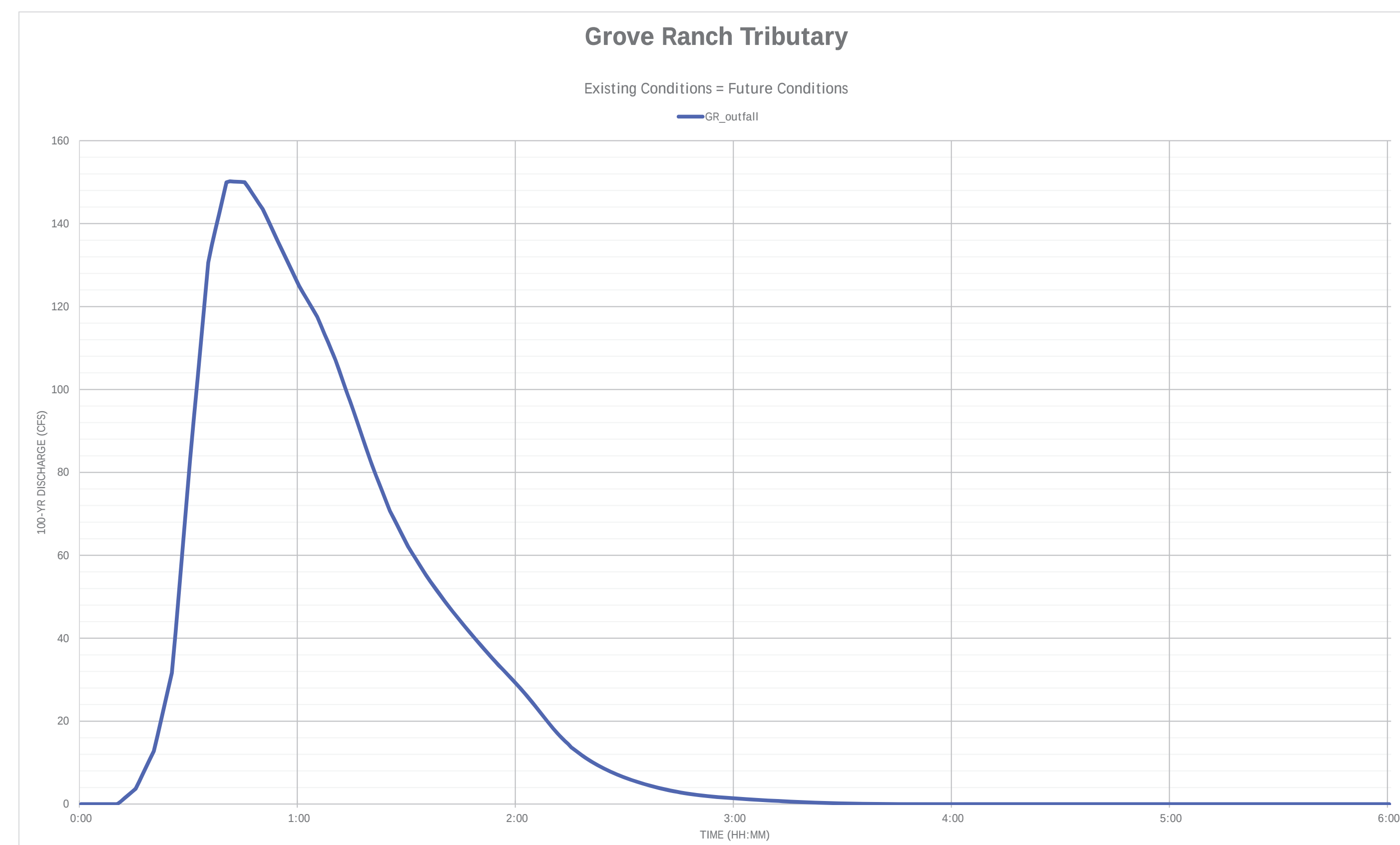
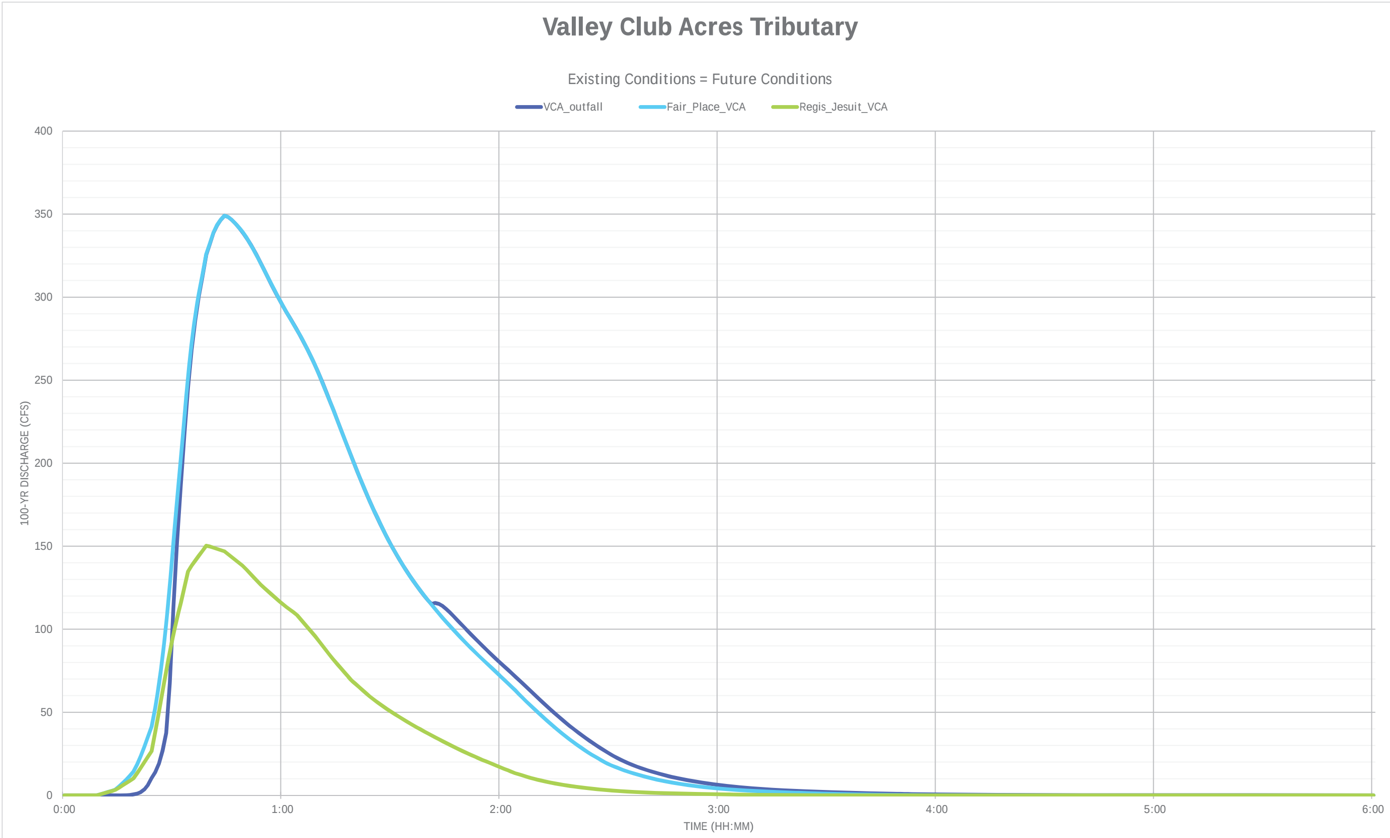
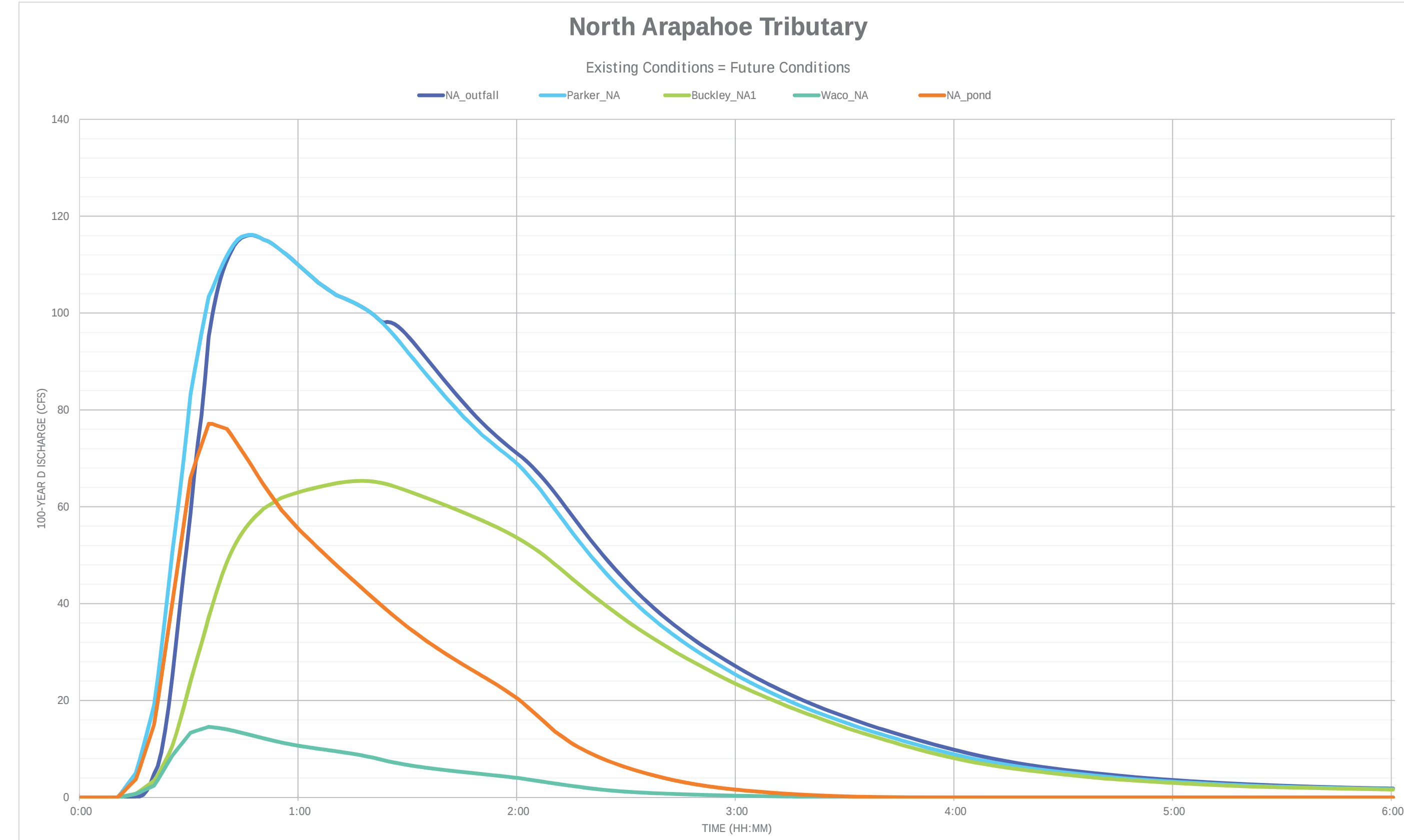
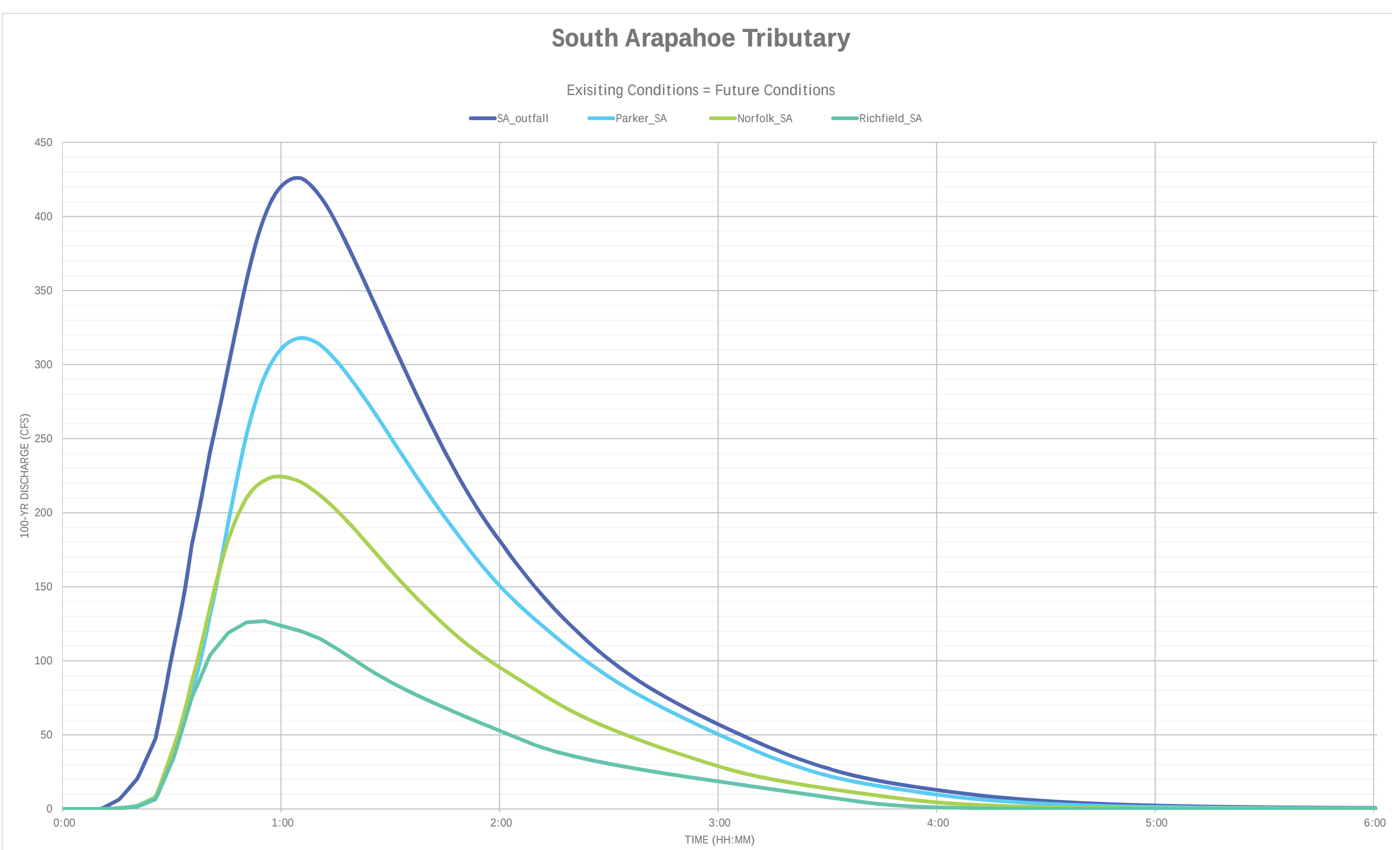


Figure B-4. Baseline Hydrographs







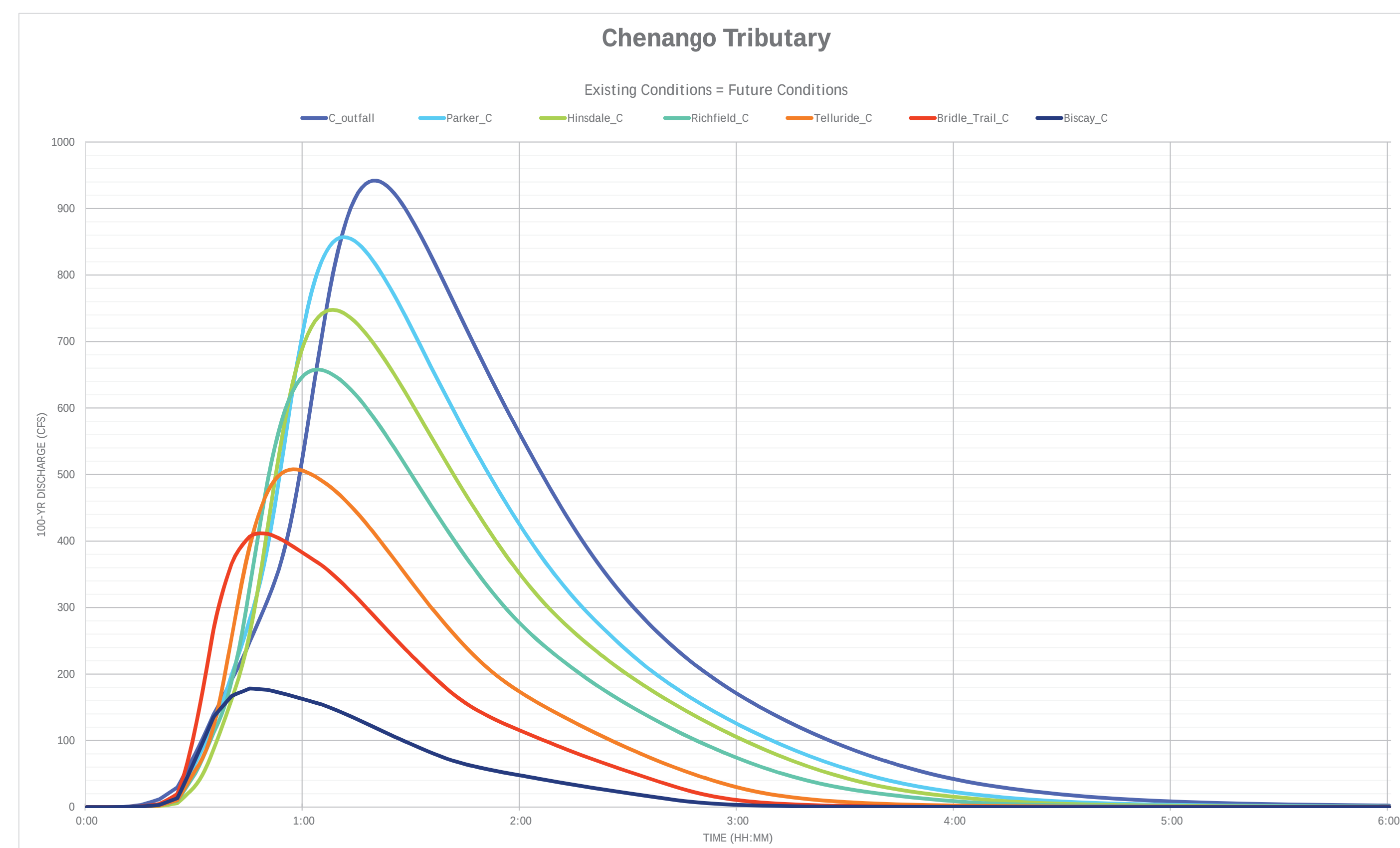
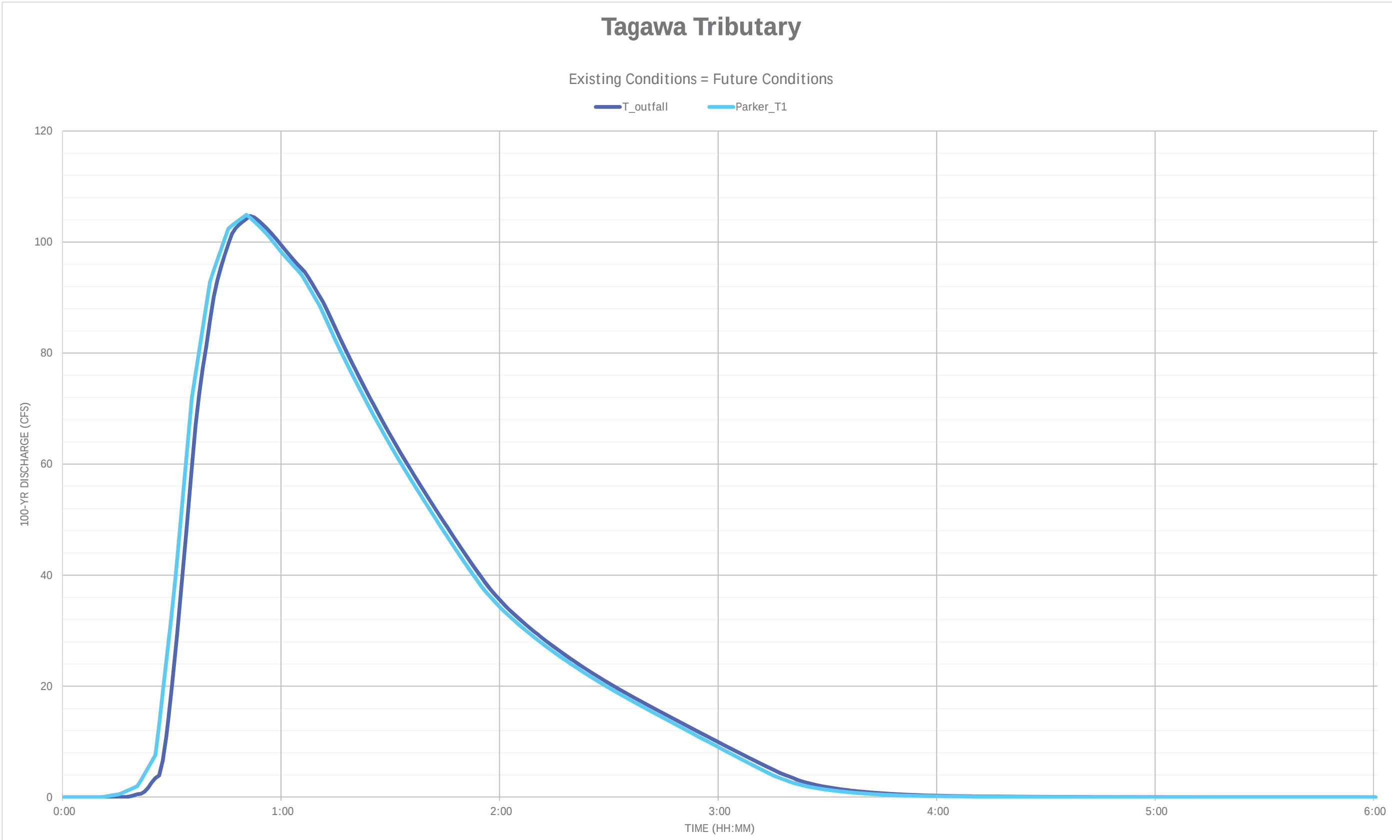
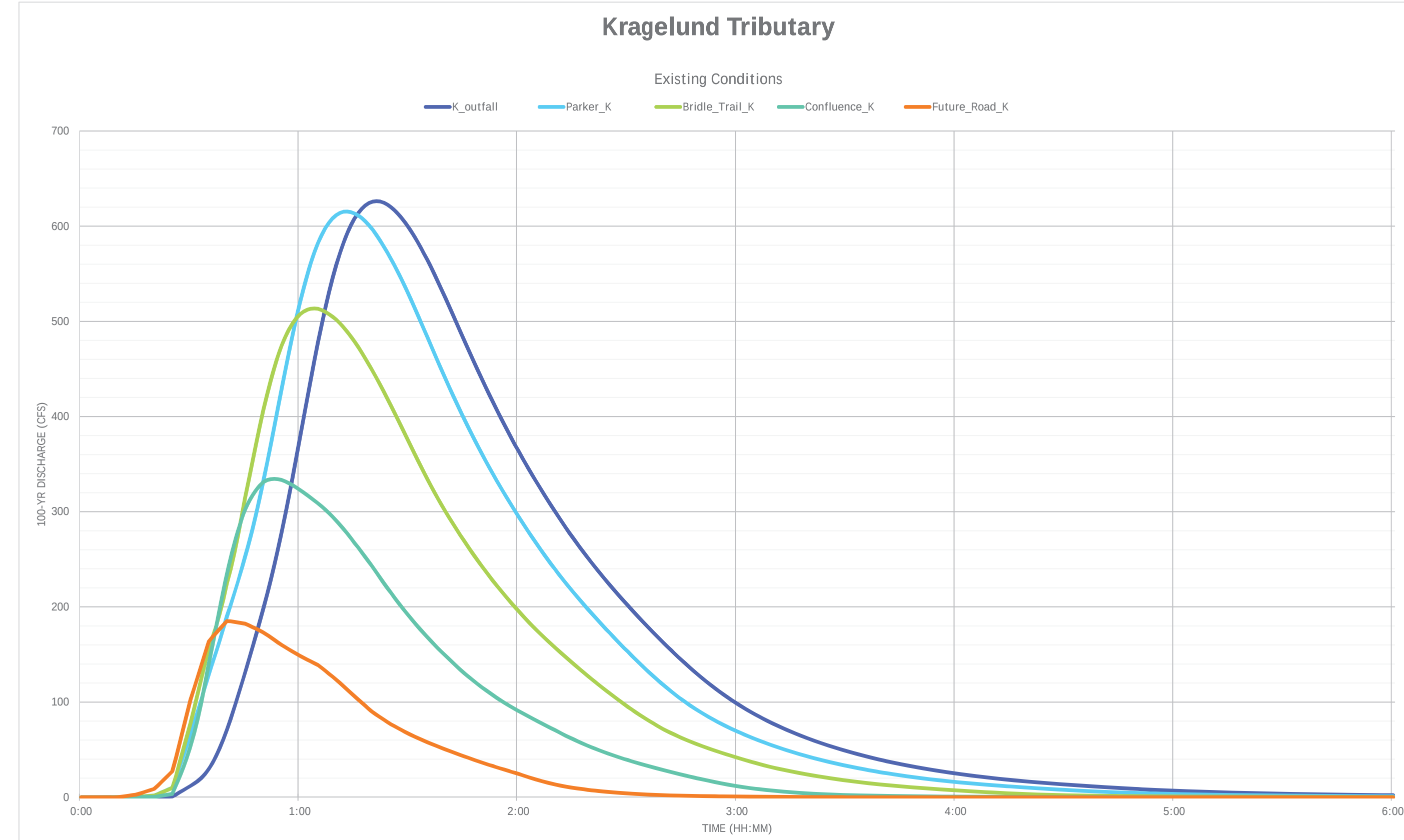
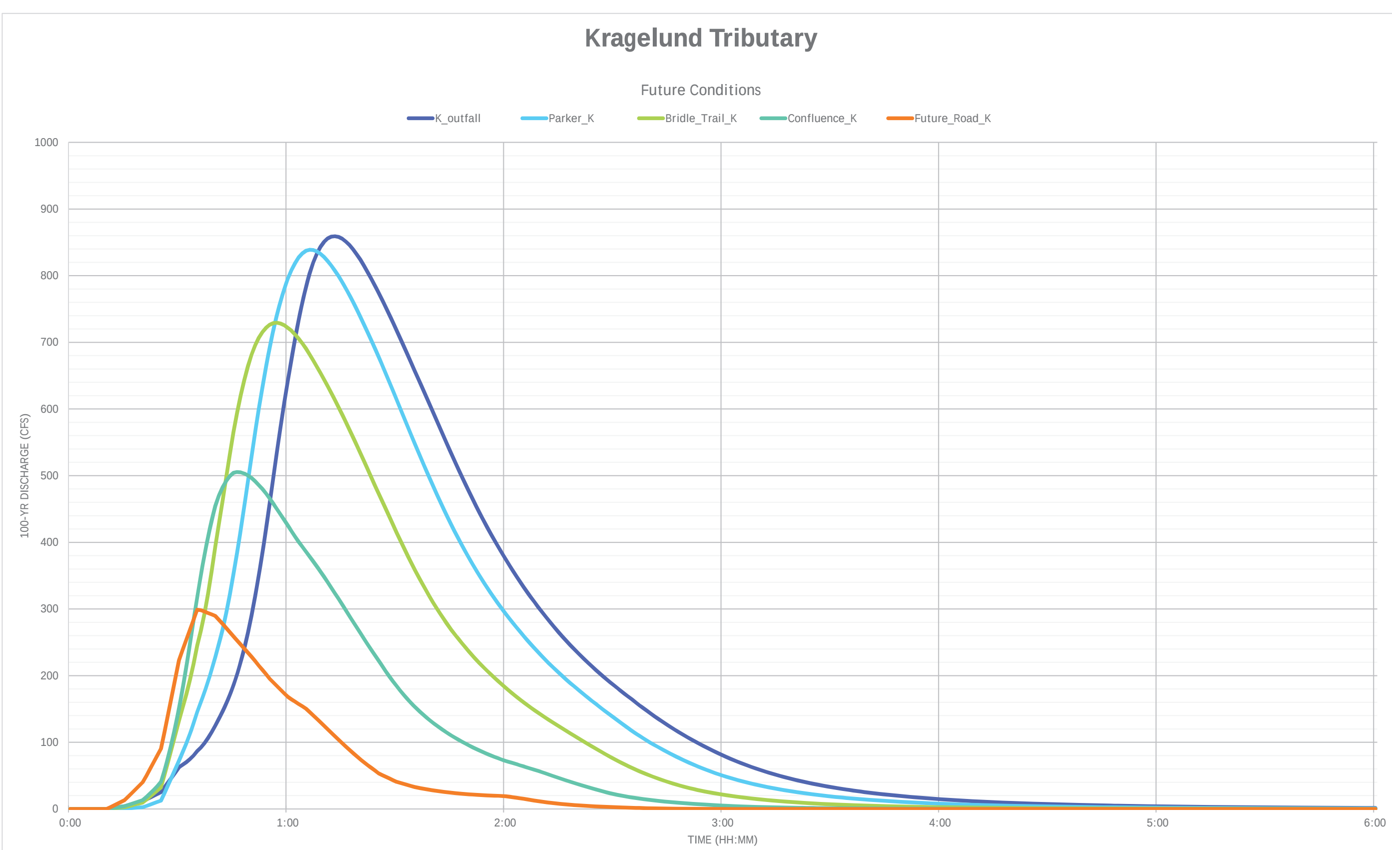


Figure B-4. Baseline Hydrographs







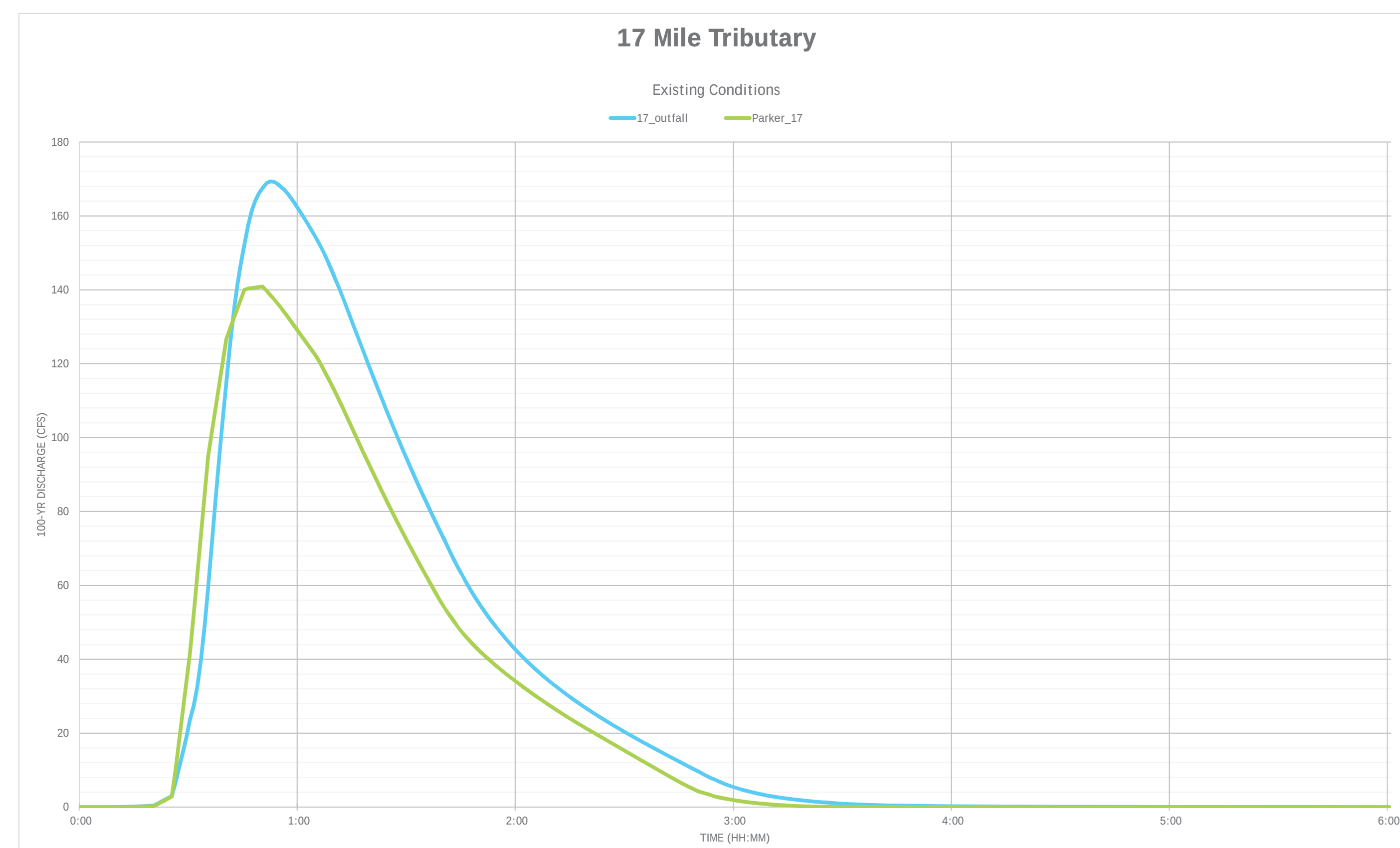


Figure B-4. Baseline Hydrographs

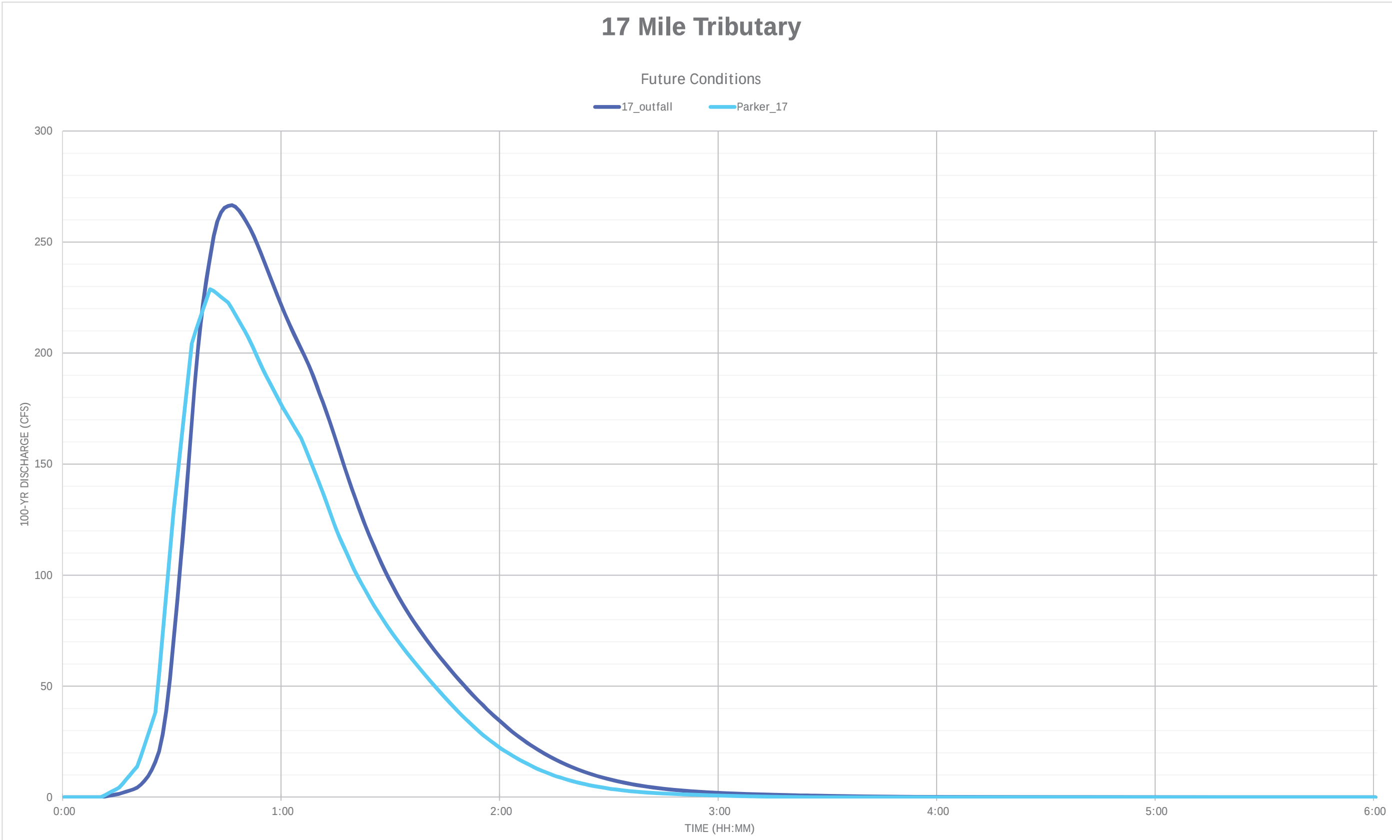
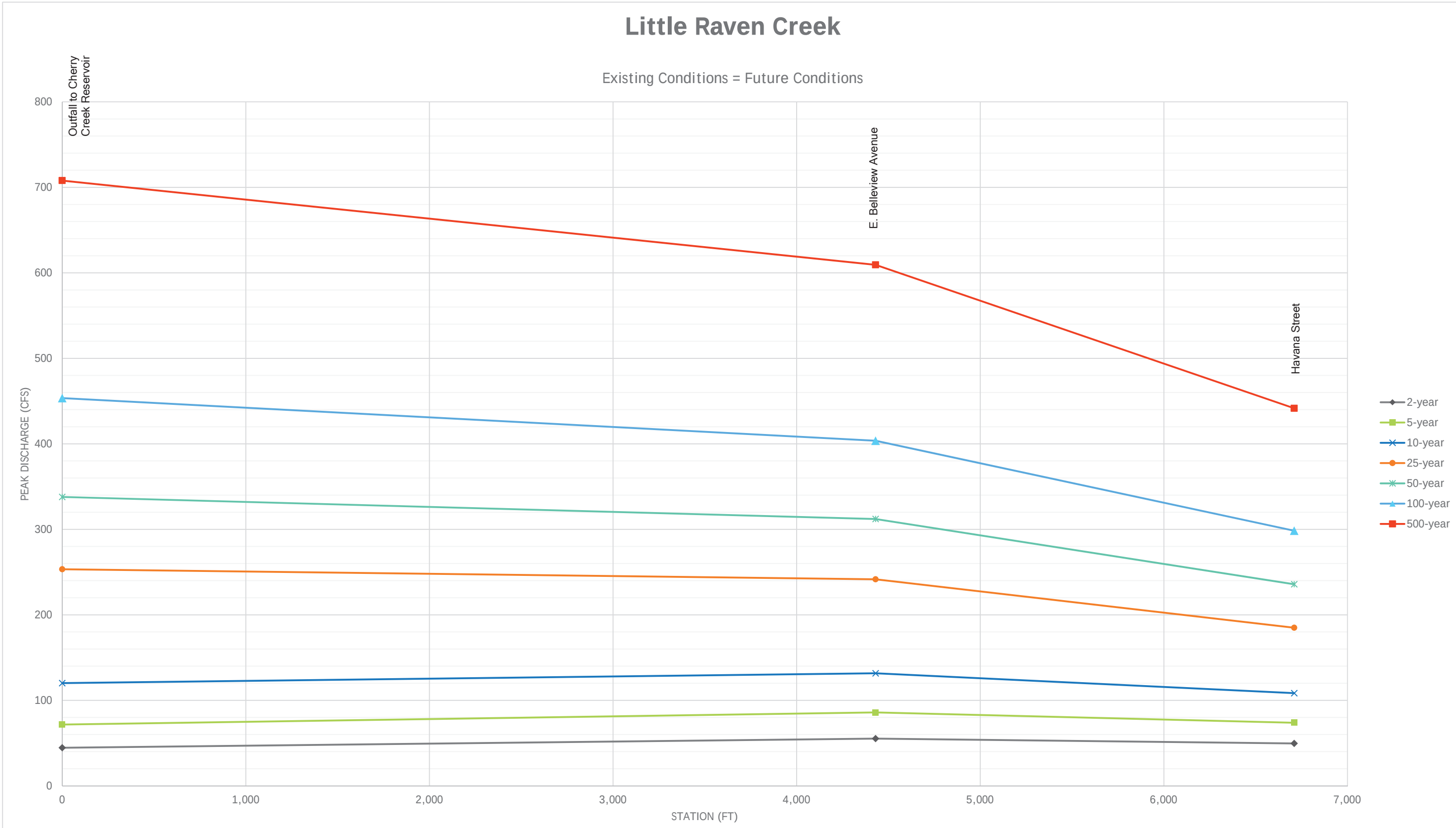
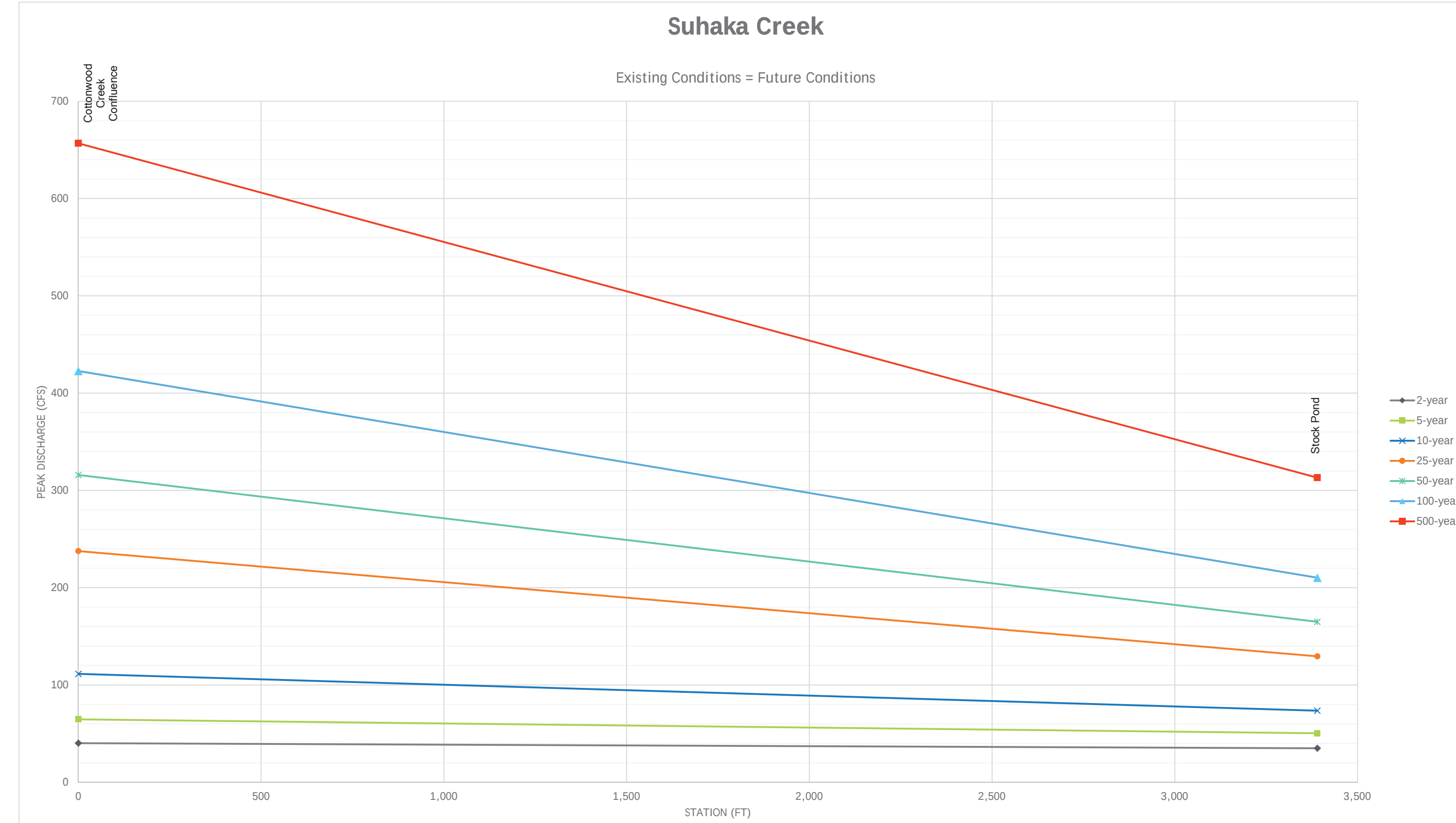
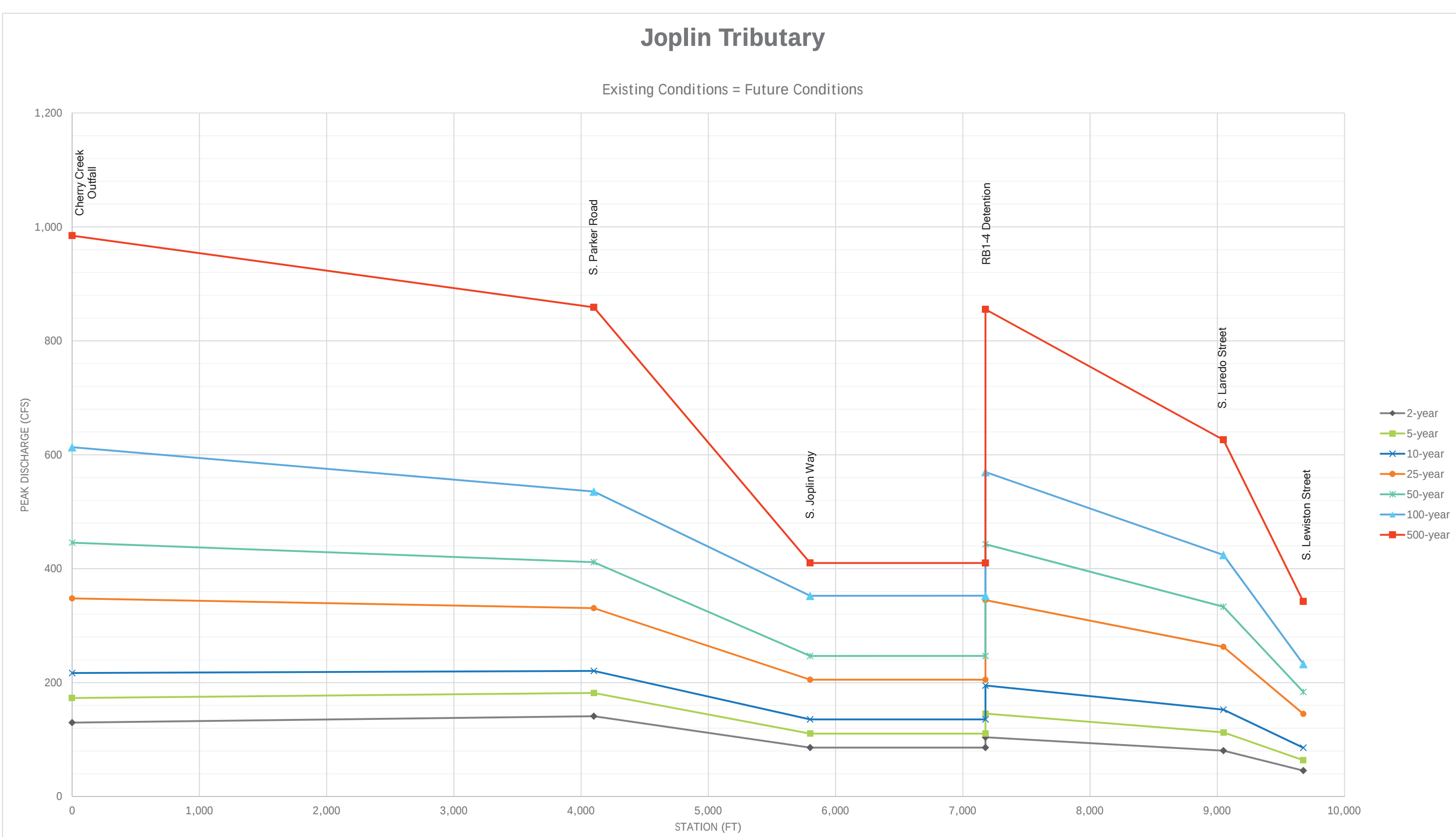


Figure B-5. Baseline Peak Flow Profiles







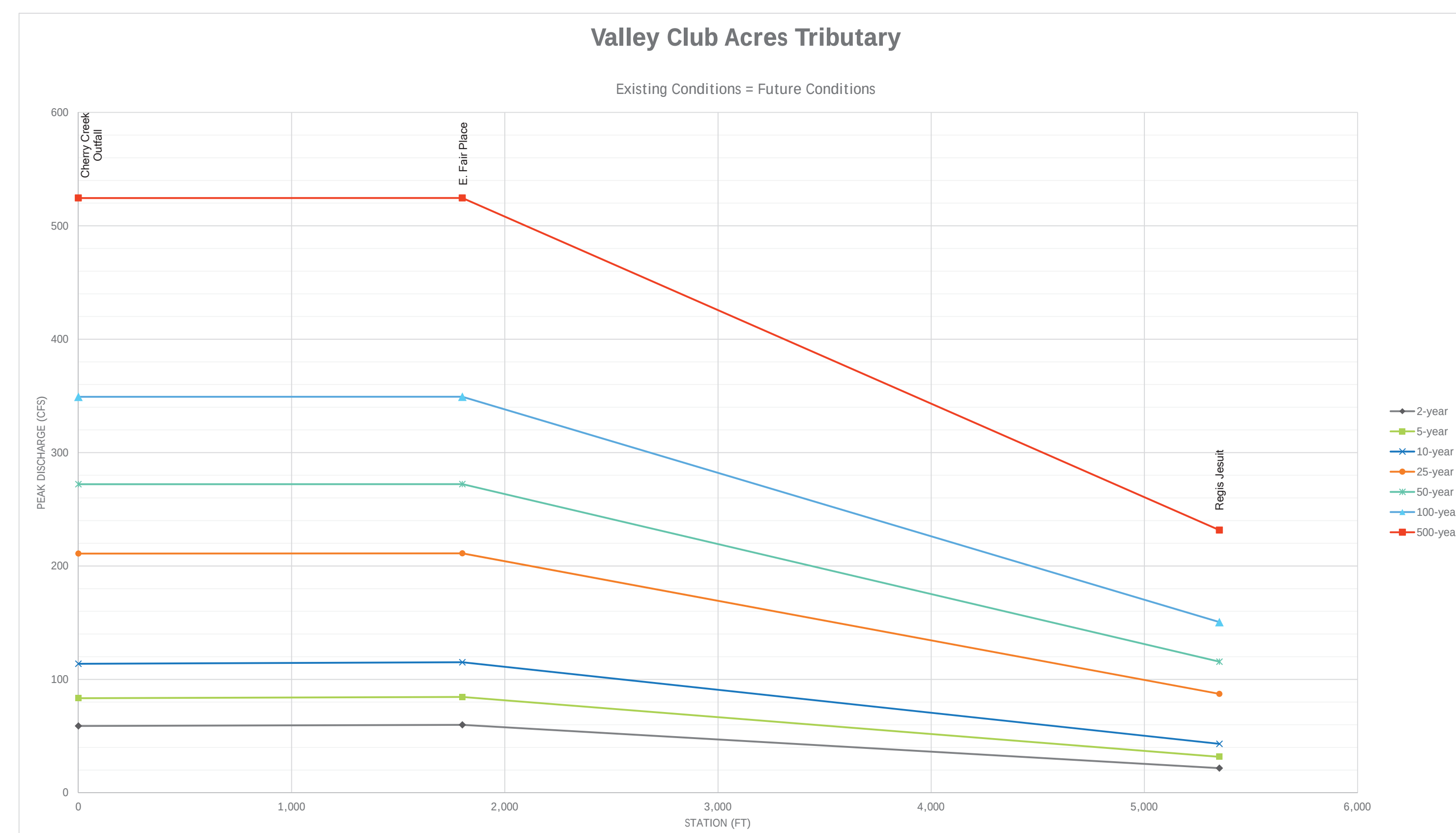
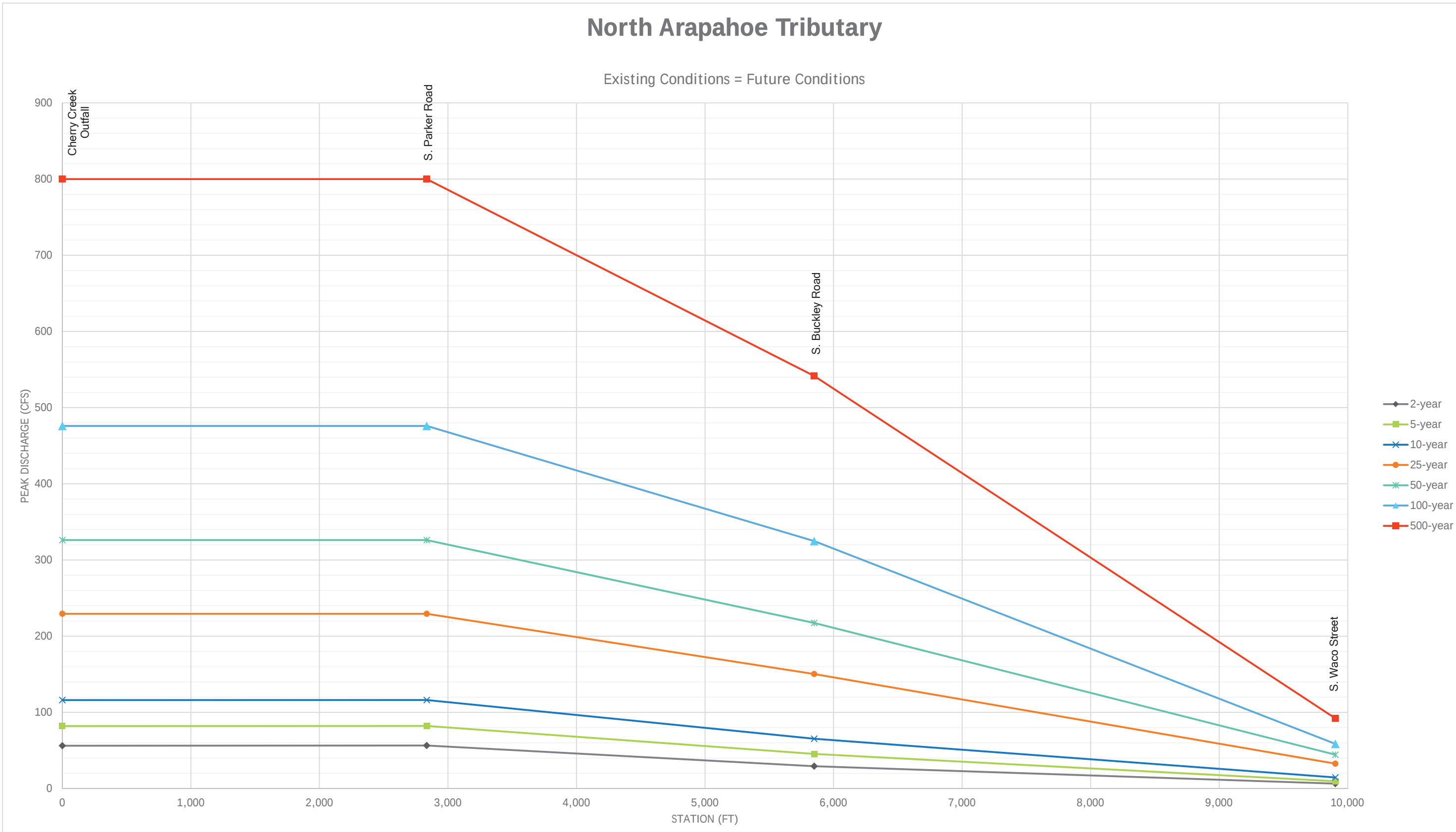
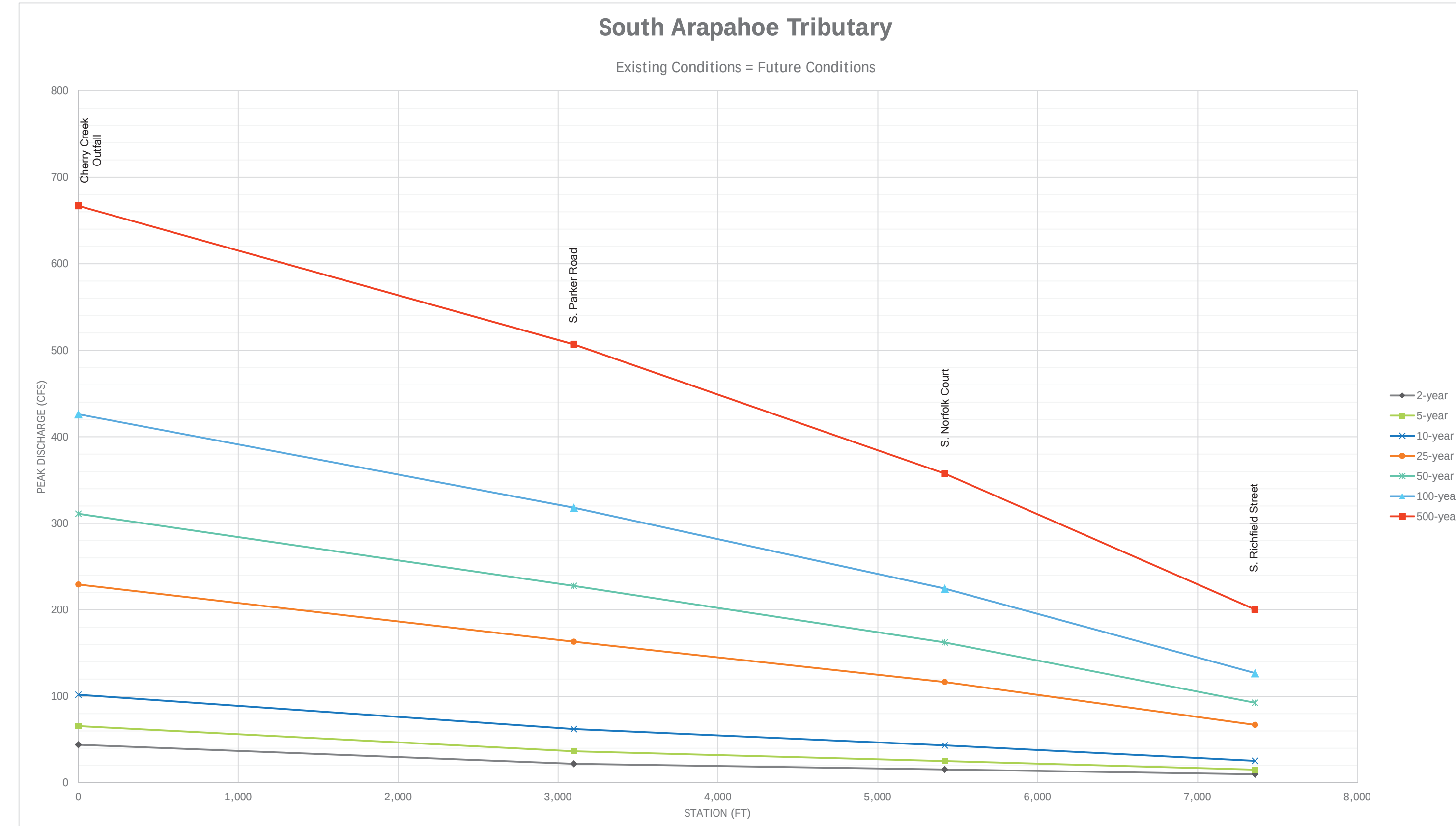
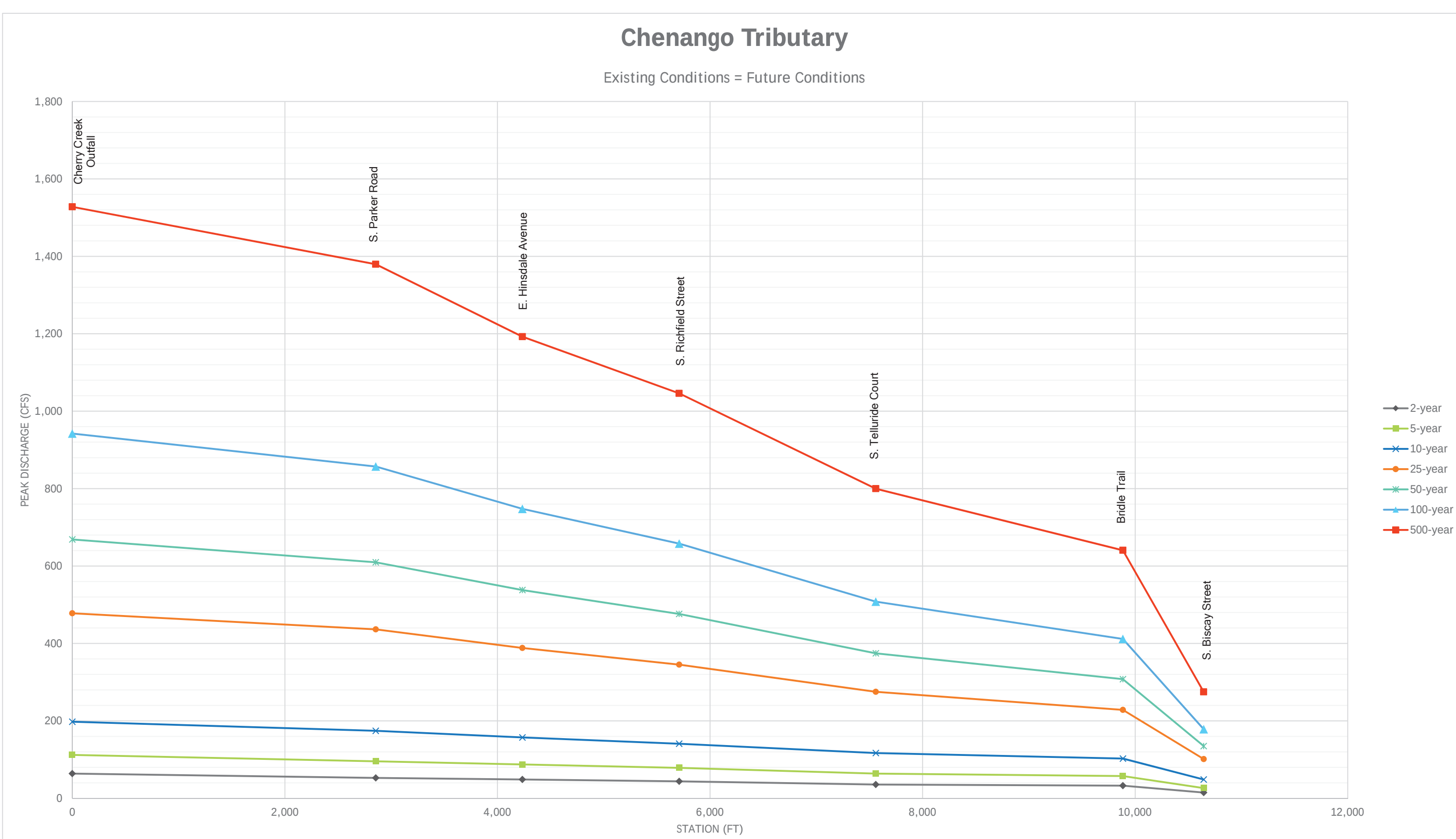


Figure B-5. Baseline Peak Flow Profiles







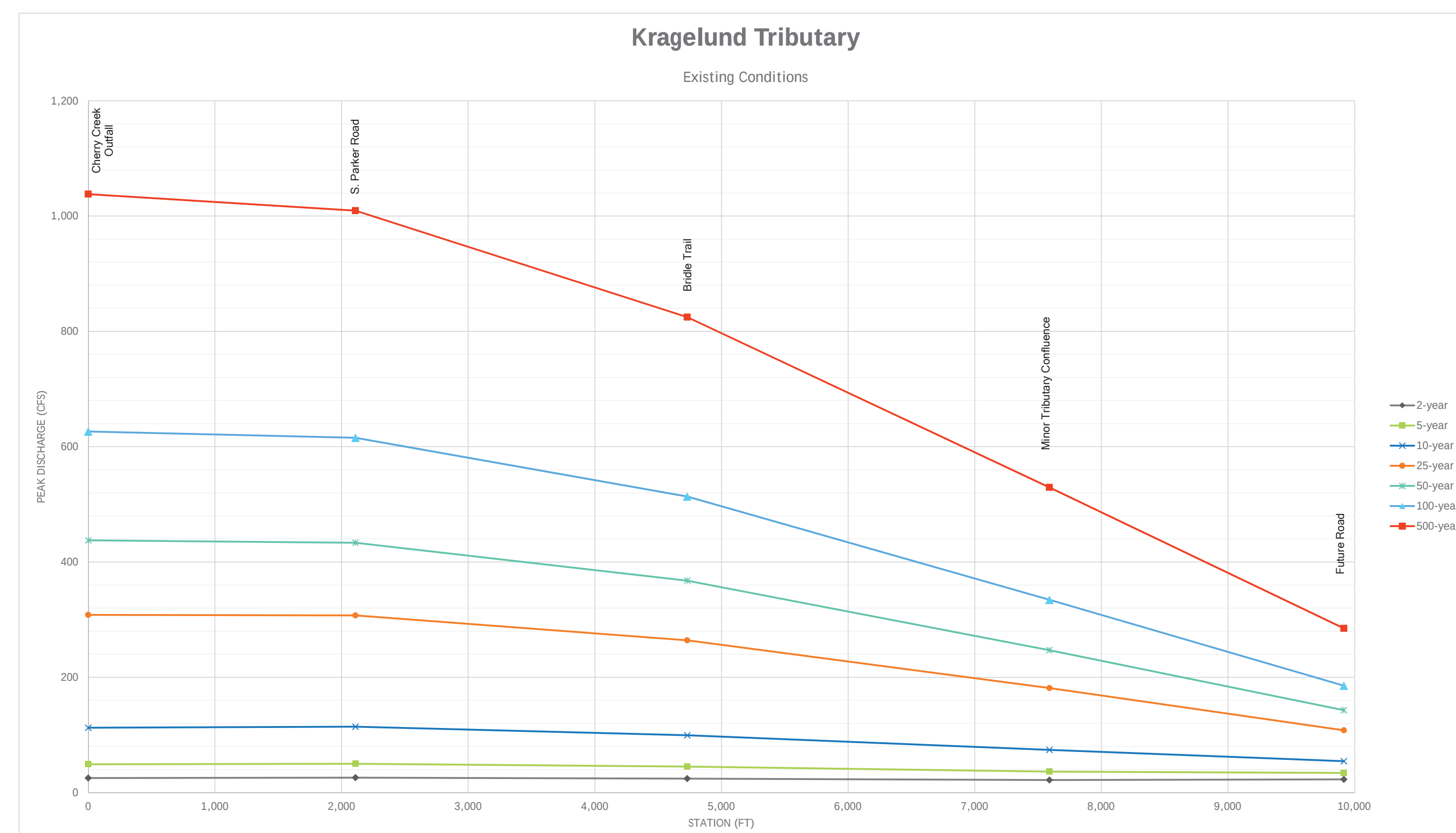


Figure B-5. Baseline Peak Flow Profiles

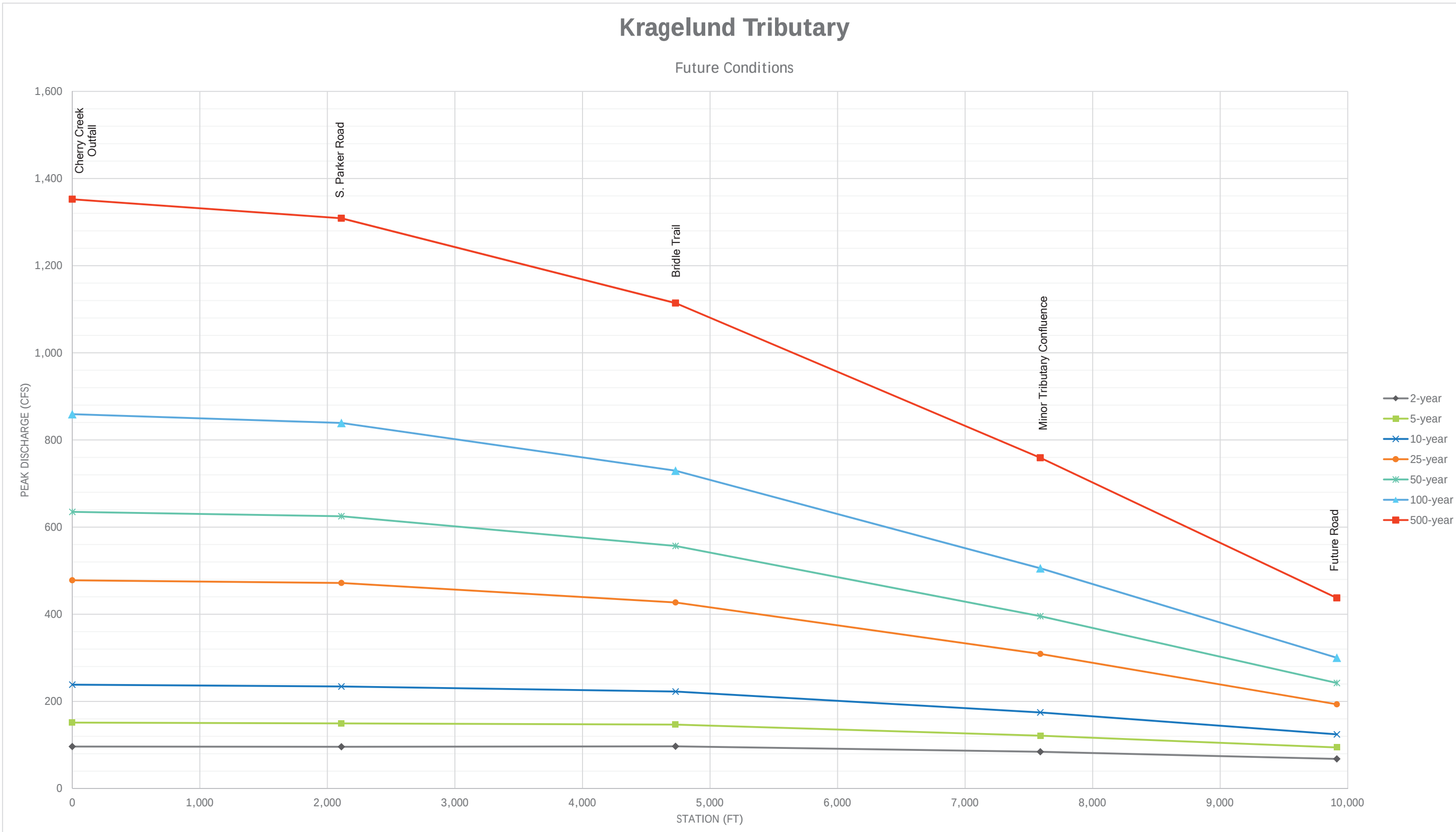


Table B-1. Rainfall Distributions

Comment	Cherry Creek Trib Water Qual	
1 Hr Depth	0.6	
Return Period	WQ	
Time	**Depth**	**CurveValue**
0:05	0.012	0.020
0:10	0.024	0.040
0:15	0.050	0.084
0:20	0.096	0.160
0:25	0.150	0.250
0:30	0.084	0.140
0:35	0.038	0.063
0:40	0.030	0.050
0:45	0.018	0.030
0:50	0.018	0.030
0:55	0.018	0.030
1:00	0.018	0.030
1:05	0.018	0.030
1:10	0.012	0.020
1:15	0.012	0.020
1:20	0.012	0.020
1:25	0.012	0.020
1:30	0.012	0.020
1:35	0.012	0.020
1:40	0.012	0.020
1:45	0.012	0.020
1:50	0.012	0.020
1:55	0.006	0.010
2:00	0.006	0.010
2:05	0.000	0.000

Comment	Cherry Creek Trib 1YR	
1 Hr Depth	0.721	
Return Period	1 Year*	
Time	**Depth**	**CurveValue**
0:05	0.014	0.020
0:10	0.029	0.040
0:15	0.061	0.084
0:20	0.115	0.160
0:25	0.180	0.250
0:30	0.101	0.140
0:35	0.045	0.063
0:40	0.036	0.050
0:45	0.022	0.030
0:50	0.022	0.030
0:55	0.022	0.030
1:00	0.022	0.030
1:05	0.022	0.030
1:10	0.014	0.020
1:15	0.014	0.020
1:20	0.014	0.020
1:25	0.014	0.020
1:30	0.014	0.020
1:35	0.014	0.020
1:40	0.014	0.020
1:45	0.014	0.020
1:50	0.014	0.020
1:55	0.007	0.010
2:00	0.007	0.010
2:05	0.000	0.000

Comment	Cherry Creek Trib 2YR	
1 Hr Depth	0.868	
Return Period	2 Years	
Time	**Depth**	**CurveValue**
0:05	0.017	0.020
0:10	0.035	0.040
0:15	0.073	0.084
0:20	0.139	0.160
0:25	0.217	0.250
0:30	0.122	0.140
0:35	0.055	0.063
0:40	0.043	0.050
0:45	0.026	0.030
0:50	0.026	0.030
0:55	0.026	0.030
1:00	0.026	0.030
1:05	0.026	0.030
1:10	0.017	0.020
1:15	0.017	0.020
1:20	0.017	0.020
1:25	0.017	0.020
1:30	0.017	0.020
1:35	0.017	0.020
1:40	0.017	0.020
1:45	0.017	0.020
1:50	0.017	0.020
1:55	0.009	0.010
2:00	0.009	0.010
2:05	0.000	0.000

Comment	Cherry Creek Trib 5YR	
1 Hr Depth	1.13	
Return Period	5 Years	
Time	**Depth**	**CurveValue**
0:05	0.023	0.020
0:10	0.042	0.037
0:15	0.098	0.087
0:20	0.173	0.153
0:25	0.283	0.250
0:30	0.147	0.130
0:35	0.066	0.058
0:40	0.050	0.044
0:45	0.041	0.036
0:50	0.041	0.036
0:55	0.034	0.030
1:00	0.034	0.030
1:05	0.034	0.030
1:10	0.034	0.030
1:15	0.028	0.025
1:20	0.025	0.022
1:25	0.025	0.022
1:30	0.025	0.022
1:35	0.025	0.022
1:40	0.017	0.015
1:45	0.017	0.015
1:50	0.017	0.015
1:55	0.017	0.015
2:00	0.015	0.013
2:05	0.000	0.000

Comment	Cherry Creek Trib 10YR	
1 Hr Depth	1.37	
Return Period	10 Years	
Time	**Depth**	**CurveValue**
0:05	0.027	0.020
0:10	0.051	0.037
0:15	0.112	0.082
0:20	0.206	0.150
0:25	0.343	0.250
0:30	0.164	0.120
0:35	0.077	0.056
0:40	0.059	0.043
0:45	0.052	0.038
0:50	0.044	0.032
0:55	0.044	0.032
1:00	0.044	0.032
1:05	0.044	0.032
1:10	0.044	0.032
1:15	0.044	0.032
1:20	0.034	0.025
1:25	0.026	0.019
1:30	0.026	0.019
1:35	0.026	0.019
1:40	0.026	0.019
1:45	0.026	0.019
1:50	0.026	0.019
1:55	0.023	0.017
2:00	0.018	0.013
2:05	0.000	0.000

*The temporal distribution for the 1-hour, 1-year design storm was assumed to be the same as that used by the 2-year design storm distribution as prepared by CUHP and defined in UDSCM Volume 1 Table 5-2.

1-Hour Depths taken from NOAA Atlas 14 Point Precipitation Frequency Estimates

Comment	Cherry Creek Trib 25YR	
1 Hr Depth	1.73	
Return Period	25 Years	
Time	Depth	CurveValue
0:05	0.022	0.013
0:10	0.061	0.035
0:15	0.087	0.050
0:20	0.138	0.080
0:25	0.260	0.150
0:30	0.433	0.250
0:35	0.208	0.120
0:40	0.138	0.080
0:45	0.087	0.050
0:50	0.087	0.050
0:55	0.055	0.032
1:00	0.055	0.032
1:05	0.055	0.032
1:10	0.042	0.024
1:15	0.042	0.024
1:20	0.031	0.018
1:25	0.031	0.018
1:30	0.024	0.014
1:35	0.024	0.014
1:40	0.024	0.014
1:45	0.024	0.014
1:50	0.024	0.014
1:55	0.024	0.014
2:00	0.024	0.014
2:05	0.000	0.000

Comment	Cherry Creek Trib 50YR	
1 Hr Depth	2.03	
Return Period	50 Years	
Time	Depth	CurveValue
0:05	0.026	0.013
0:10	0.071	0.035
0:15	0.102	0.050
0:20	0.162	0.080
0:25	0.305	0.150
0:30	0.508	0.250
0:35	0.244	0.120
0:40	0.162	0.080
0:45	0.102	0.050
0:50	0.102	0.050
0:55	0.065	0.032
1:00	0.065	0.032
1:05	0.065	0.032
1:10	0.049	0.024
1:15	0.049	0.024
1:20	0.037	0.018
1:25	0.037	0.018
1:30	0.028	0.014
1:35	0.028	0.014
1:40	0.028	0.014
1:45	0.028	0.014
1:50	0.028	0.014
1:55	0.028	0.014
2:00	0.028	0.014
2:05	0.000	0.000

Comment	Cherry Creek Trib 100YR	
1 Hr Depth	2.36	
Return Period	100 Years	
Time	Depth	CurveValue
0:05	0.024	0.010
0:10	0.071	0.030
0:15	0.109	0.046
0:20	0.189	0.080
0:25	0.330	0.140
0:30	0.590	0.250
0:35	0.330	0.140
0:40	0.189	0.080
0:45	0.146	0.062
0:50	0.118	0.050
0:55	0.094	0.040
1:00	0.094	0.040
1:05	0.094	0.040
1:10	0.047	0.020
1:15	0.047	0.020
1:20	0.028	0.012
1:25	0.028	0.012
1:30	0.028	0.012
1:35	0.028	0.012
1:40	0.028	0.012
1:45	0.028	0.012
1:50	0.028	0.012
1:55	0.028	0.012
2:00	0.028	0.012
2:05	0.000	0.000

Comment	Cherry Creek Trib 500YR	
1 Hr Depth	3.21	
Return Period	500 Years	
Time	Depth	CurveValue
0:05	0.032	0.010
0:10	0.096	0.030
0:15	0.148	0.046
0:20	0.257	0.080
0:25	0.449	0.140
0:30	0.803	0.250
0:35	0.449	0.140
0:40	0.257	0.080
0:45	0.199	0.062
0:50	0.161	0.050
0:55	0.128	0.040
1:00	0.128	0.040
1:05	0.128	0.040
1:10	0.064	0.020
1:15	0.064	0.020
1:20	0.039	0.012
1:25	0.039	0.012
1:30	0.039	0.012
1:35	0.039	0.012
1:40	0.039	0.012
1:45	0.039	0.012
1:50	0.039	0.012
1:55	0.039	0.012
2:00	0.039	0.012
2:05	0.000	0.000

1-Hour Depths taken from NOAA Atlas 14 Point Precipitation Frequency Estimates

CUHP SUBCATCHMENTS

									Maximum Depression Storage (Watershed inches)		Horton's Infiltration Parameters			DCIA
Subcatchment Name	EPA SWMM Target Node	Area (mi^2)	Area (acres)	Length to Centroid (mi)	Length (mi)	Slope (ft/ft)	% Imprv (Existing)	% Imprv (Future)	Pervious	Impervious	Initial Rate (in/hr)	Decay Coefficient (1/seconds)	Final Rate (in/hr)	Level 0, 1, or 2
17A	17A	0.03	21.8	0.10	0.22	0.034	13.68	36.05	0.40	0.10	3.645	0.0017	0.561	0
17B	17B	0.19	123.7	0.38	0.74	0.046	6.62	36.21	0.40	0.10	4.489	0.0018	0.599	0
NA1	NA1	0.16	99.8	0.38	0.81	0.030	--	50.61	0.40	0.10	4.385	0.0018	0.592	0
NA2	NA2	0.20	127.8	0.44	0.82	0.017	--	44.93	0.40	0.10	4.500	0.0018	0.600	0
NA3	NA3	0.16	102.9	0.86	1.39	0.021	--	40.69	0.40	0.10	4.582	0.0016	0.665	0
NA4	NA4	0.06	41.3	0.18	0.48	0.029	--	28.24	0.40	0.10	4.545	0.0017	0.636	0
SA1	SA1	0.11	70.1	0.40	0.74	0.022	--	69.54	0.40	0.10	3.344	0.0018	0.523	0
SA2	SA2	0.15	98.5	0.40	0.94	0.027	--	24.33	0.40	0.10	4.500	0.0018	0.600	0
SA3	SA3	0.15	94.8	0.33	0.73	0.024	--	20.01	0.40	0.10	4.500	0.0018	0.600	0
SA4	SA4	0.21	132.2	0.40	1.22	0.024	--	20.01	0.40	0.10	4.532	0.0017	0.625	0
C1	C1	0.17	106.2	0.55	0.97	0.021	--	49.45	0.40	0.10	3.737	0.0017	0.589	0
C2	C2	0.18	117.0	0.30	0.71	0.031	--	18.67	0.40	0.10	4.500	0.0018	0.600	0
C3	C3	0.16	101.5	0.42	0.93	0.024	--	20.00	0.40	0.10	4.209	0.0018	0.581	0
C4	C4	0.20	125.6	0.59	1.13	0.031	--	20.00	0.40	0.10	4.614	0.0015	0.700	0
C5	C5	0.09	54.7	0.36	0.64	0.036	--	20.00	0.40	0.10	3.130	0.0018	0.509	0
C6	C6	0.14	91.7	0.32	0.66	0.039	--	20.00	0.40	0.10	3.346	0.0017	0.560	0
C7	C7	0.11	72.1	0.38	0.64	0.052	--	20.00	0.40	0.10	3.780	0.0014	0.695	0
C8	C8	0.18	116.1	0.46	0.70	0.051	--	20.00	0.40	0.10	3.000	0.0018	0.500	0
C9	C9	0.21	132.2	0.42	0.83	0.048	--	20.00	0.40	0.10	3.002	0.0018	0.500	0
GR1	GR1	0.13	80.7	0.38	0.84	0.017	--	53.51	0.40	0.10	3.472	0.0018	0.544	0
J1	J1	0.19	119.8	0.64	1.13	0.015	--	2.66	0.40	0.10	3.885	0.0015	0.674	0
J2	J2	0.08	50.9	0.44	0.77	0.033	--	28.20	0.40	0.10	4.825	0.0010	0.880	0
J3	J3	0.17	106.0	0.36	0.89	0.028	--	54.12	0.40	0.10	4.804	0.0011	0.844	0
J4	J4	0.07	45.2	0.20	0.47	0.030	--	42.83	0.40	0.10	5.000	0.0007	1.000	0
J5	J5	0.16	100.6	0.37	0.81	0.028	--	40.67	0.40	0.10	4.994	0.0007	0.995	0
J6	J6	0.18	117.2	0.51	1.07	0.017	--	42.07	0.40	0.10	4.743	0.0013	0.794	0
J7	J7	0.17	108.5	0.48	0.77	0.017	--	48.05	0.40	0.10	4.503	0.0018	0.602	0
J8	J8	0.20	125.9	0.49	0.87	0.018	--	51.70	0.40	0.10	4.500	0.0018	0.600	0
LR3	LR3	0.22	140.0	0.35	0.77	0.028	--	42.47	0.40	0.10	3.000	0.0018	0.500	0
LR2	LR2	0.13	84.7	0.27	0.64	0.025	--	28.12	0.40	0.10	3.000	0.0018	0.500	0
LR1	LR1	0.19	123.9	0.50	0.99	0.019	--	2.08	0.40	0.10	3.238	0.0017	0.541	0
K1	K1	0.05	33.6	0.19	0.40	0.022	5.91	59.45	0.40	0.10	3.833	0.0013	0.707	0
K2	K2	0.19	124.3	0.27	0.75	0.027	15.79	18.49	0.40	0.10	3.659	0.0018	0.544	0
K3	K3	0.11	69.2	0.44	0.93	0.035	2.00	38.48	0.40	0.10	3.692	0.0018	0.546	0
K4	K4	0.20	126.4	0.38	0.69	0.042	14.57	22.98	0.40	0.10	3.029	0.0018	0.502	0

Table B-2. CUHP Subcatchment Input Data

									Maximum Depression Storage (Watershed inches)		Horton's Infiltration Parameters			DCIA
Subcatchment Name	EPA SWMM Target Node	Area (mi^2)	Area (acres)	Length to Centroid (mi)	Length (mi)	Slope (ft/ft)	% Imprv (Existing)	% Imprv (Future)	Pervious	Impervious	Initial Rate (in/hr)	Decay Coefficient (1/seconds)	Final Rate (in/hr)	Level 0, 1, or 2
K5	K5	0.07	45.3	0.30	0.53	0.041	4.22	44.80	0.40	0.10	3.545	0.0018	0.536	0
K6	K6	0.16	104.2	0.39	0.79	0.052	7.43	28.42	0.40	0.10	3.322	0.0018	0.521	0
K7	K7	0.17	107.9	0.36	0.72	0.052	31.70	59.55	0.40	0.10	4.005	0.0018	0.567	0
S1	S1	0.19	120.5	0.31	0.70	0.022	--	4.19	0.40	0.10	3.183	0.0018	0.512	0
S2	S2	0.17	108.6	0.63	1.11	0.021	--	26.75	0.40	0.10	3.129	0.0018	0.514	0
S3	S3	0.20	130.7	0.49	1.16	0.024	--	43.13	0.40	0.10	3.114	0.0017	0.529	0
VCA1	VCA1	0.19	120.2	0.42	1.03	0.010	--	51.33	0.40	0.10	4.275	0.0018	0.585	0
VCA2	VCA2	0.14	86.7	0.35	0.61	0.036	--	37.29	0.40	0.10	4.581	0.0016	0.665	0
T1	T1	0.17	74.2	0.38	1.02	0.033	--	21.88	0.40	0.10	4.202	0.0013	0.732	0

Table B-3. Detention Basin Rating Curves

North Arapahoe Detention Pond [1] (i.e. Pond E)
Design Point: NA_pond

Stage-Storage			
Elevation	Depth (ft)	Area (SF)	Storage (AF)
5764.6	0.0	2,015	0.00
5765	0.4	4,029	0.03
5766	1.4	7,745	0.16
5767	2.4	13,713	0.41
5768	3.4	19,405	0.79
5769	4.4	28,097	1.33
5770	5.4	47,234	2.20
5771	6.4	60,011	3.43
5772	7.4	65,787	4.87
5773	8.4	65,787	6.38
5774	9.4	65,787	7.89

Stage-Discharge	
Depth (ft)	Total Discharge (cfs)
0.0	0.0
0.25	0.1
0.5	0.2
0.75	0.2
1.0	0.3
1.25	0.4
1.5	0.5
1.75	0.5
2.0	0.6
2.25	0.7
2.5	0.8
2.75	0.9
3.0	0.9
3.25	1.0
3.5	1.1
3.75	1.4
4.0	2.2
4.25	3.4
4.5	5.1
4.75	7.0
5.0	9.4
5.25	12.1
5.5	15.1
5.75	18.4
6.0	22.1
6.25	26.1
6.5	30.4
6.75	34.2
7.0	36.6
7.25	45.9
7.5	61.5
7.75	81.1
8.0	100.5
8.25	122.4
8.5	173.3
8.75	239.3
9.0	317.3
9.25	405.5
9.4	464.3

1. A detention rating curve was originally developed from as-built drawings prepared on May 4, 2000 by Aztec and P.R. Fletcher & Associates. However, 2014 LiDAR of the pond data varies significantly from the as-built data and new stage-storage-discharge curves were defined using survey data collected by UDFCD in February 2019. See Section 3.4 DETENTION for more detail.

2. Cells highlighted in red are above the surveyed pond top of berm but were included in the Baseline Hydrology SWMM model for continuity of the larger flow events.

RB1-4 Detention Pond [1]
Design Point: RB1-4_pond

Stage-Storage			
Elevation	Depth (ft)	Area (SF)	Storage (AF)
5687.5	0	0	0.00
5688	0.5	328	0.00
5689	1.5	2,222	0.03
5690	2.5	22,311	0.31
5691	3.5	41,170	1.04
5692	4.5	60,321	2.21
5693	5.5	75,858	3.77
5694	6.5	86,332	5.63
5695	7.5	95,521	7.72
5696	8.5	104,107	10.01
5697	9.5	112,990	12.50
5698	10.5	121,937	15.20
5699	11.5	131,448	18.11

Stage-Discharge	
Depth (ft)	Total Discharge (cfs)
0	0
9.4	253
11.5	410
11.6	800

1. The detention rating curve was developed from as-built drawings prepared for East Cherry Creek Valley (ECCV) Water and Sanitation District on April 28, 1994 (Muller Engineering Co.). The as-built data is assumed to be correct and supersedes data presented in the November 1989 Muller Engineering drainage report.

RB1-4 REGIONAL DETENTION

BASIN INFORMATION

A S - BUILT

~~CONTRACT~~ DRAWINGS FOR THE CONSTRUCTION OF

BASIN RB1-POND 4
DRAINAGE IMPROVEMENTS

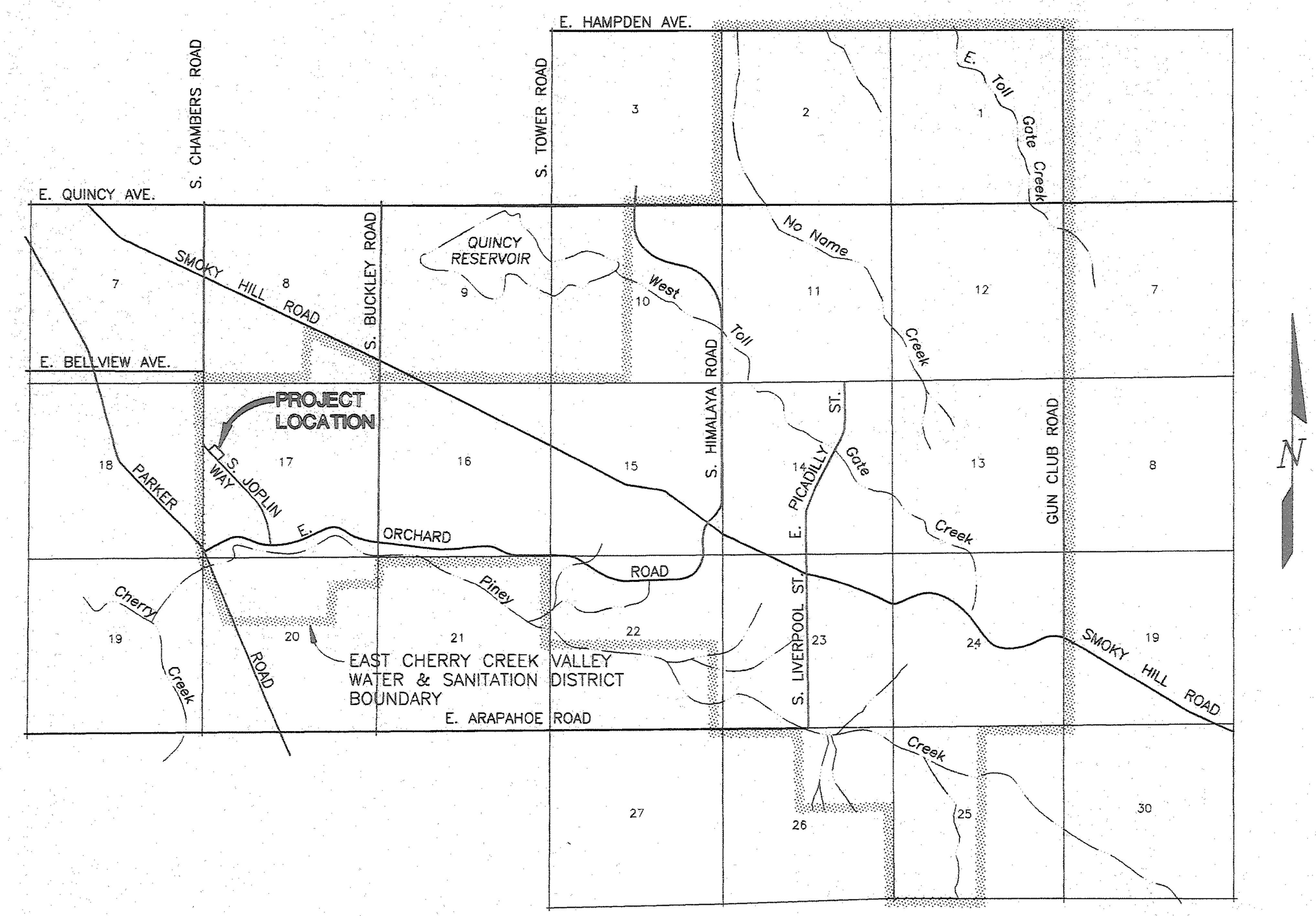
APRIL, 1994

GENERAL NOTES:

1. THE DIRECTOR, DEPARTMENT OF HIGHWAYS/ENGINEERING (COUNTY ENGINEER) STAMP AND SIGNATURE AFFIXED TO THIS DOCUMENT INDICATES THE DEPARTMENT OF HIGHWAYS/ENGINEERING HAS REVIEWED THE DOCUMENT AND FOUND IT IN GENERAL CONFORMANCE WITH THE ARAPAHOE COUNTY SUBDIVISION REGULATIONS, OR APPROVED VARIANCES TO THOSE REGULATIONS. THE DIRECTOR, DONE THROUGH APPROVAL OF THIS DOCUMENT, ASSUMES NO RESPONSIBILITY, OTHER THAN STATED ABOVE, FOR THE COMPLETENESS AND/OR ACCURACY OF THESE DOCUMENTS. THE COUNTY DOES NOT ACCEPT THE LIABILITY FOR FACILITIES DESIGNED BY OTHERS.
2. ALL MATERIALS AND WORKMANSHIP FOR WORK INDICATED "TO BE MAINTAINED BY ARAPAHOE COUNTY" SHALL BE SUBJECT TO INSPECTION BY THE ARAPAHOE COUNTY DEPARTMENT OF HIGHWAYS/ENGINEERING. THE COUNTY RESERVES THE RIGHT TO ACCEPT OR REJECT ANY SUCH MATERIALS AND WORKMANSHIP THAT DOES NOT CONFORM TO ITS STANDARDS AND SPECIFICATIONS. CONCRETE SHALL NOT BE PLACED UNTIL A POUR SLIP HAS BEEN ISSUED. POUR SLIPS WILL NOT BE ISSUED UNLESS THE CONTRACTOR HAS, AT THE JOB SITE, A COPY OF THE APPROVED PLANS BEARING THE SIGNATURE OF THE DIRECTOR, DOHE. IF AN ARAPAHOE COUNTY ENGINEERING INSPECTOR IS NOT AVAILABLE AFTER PROPER NOTICE OF CONSTRUCTION ACTIVITY HAS BEEN PROVIDED, THE PERMITTEE MAY COMMENCE WORK WITHOUT A POUR SLIP. HOWEVER, ARAPAHOE COUNTY RESERVES THE RIGHT NOT TO ACCEPT THE STRUCTURE IF SUBSEQUENT TESTING REVEALS AN IMPROPER INSTALLATION.
3. THE CONTRACTOR SHALL NOTIFY THE ARAPAHOE COUNTY DEPARTMENT OF HIGHWAYS/ENGINEERING INSPECTION SECTION, TELEPHONE NUMBER 795-4640 A MINIMUM OF 48 HOURS AND A MAXIMUM OF 96 HOURS PRIOR TO STARTING CONSTRUCTION.
4. THE CONTRACTOR SHALL HAVE ONE (1) SIGNED COPY OF THE PLANS (APPROVED BY THE DEPARTMENT OF HIGHWAYS/ENGINEERING) AT THE JOB SITE AT ALL TIMES.
5. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE ACCEPTANCE AND CONTROL OF ALL FLOWS, IN AND ENTERING ALL DRAINAGE FACILITIES AFFECTED BY THIS PROJECT. THE CONTRACTOR SHALL BE RESPONSIBLE FOR TAKING REASONABLE STEPS THROUGH DIKING, DIVERSION PONDING, CONTROL OF EQUIPMENT OPERATIONS AND CONSTRUCTION OF SILT CAPTURING BASINS AS DETAILED ON THE PLANS TO PREVENT POLLUTION OF CHERRY CREEK.
6. LOCATIONS OF UTILITIES REPRESENT THE BEST-KNOWN LOCATIONS AT THE TIME OF PREPARATION OF DRAWINGS. THE CONTRACTOR SHALL FIELD-LOCATE ALL UTILITIES IN ADVANCE OF EXCAVATION. RELOCATION OF UTILITIES MAY OR MAY NOT BE NEEDED AFTER THEY ARE EXPOSED. ACTUAL RELOCATION OF LINES WILL NOT BE THE RESPONSIBILITY OF THE CONTRACTOR; BUT THE CONTRACTOR SHALL COOPERATE WITH UTILITY COMPANIES TO COORDINATE THE RELOCATION EFFORT. LINES NOT RELOCATED SHALL BE PROTECTED BY THE CONTRACTOR IN PLACE. NO ADDITIONAL PAYMENT WILL BE ALLOWED FOR THE MINOR ADJUSTMENT OF STRUCTURES IN ORDER TO CLEAR A CONFLICTING UTILITY. CONTACT UTILITY COMPANIES 48 HOURS IN ADVANCE WHEN WORKING ADJACENT TO THE UTILITY.

U.S. WEST (TELEPHONE)	534-6700
PUBLIC SERVICE (GAS)	534-6700
INTERMOUNTAIN REA (ELECTRIC)	688-3100
WYCO PIPELINE CO. (GAS)	690-8721
EAST CHERRY CREEK VALLEY WATER AND SANITATION DISTRICT(WATER AND SEWER)	693-3800

7. ALL EXPOSED CONCRETE SHALL HAVE A CLASS 2 OR CLASS 5 FINISH. ALL EXPOSED CONCRETE CORNERS SHALL HAVE A 3/4" X 3/4" CHAMFER. CONCRETE IN ALL STRUCTURES EXCEPT FOR THE LOW FLOW CHANNEL AND MANHOLE BASES SHALL BE CLASS D. CONCRETE IN THE LOW FLOW CHANNEL AND MANHOLE BASES MAY BE CLASS A OR B.
8. ALL REINFORCING STEEL SHALL BE GRADE 60.
9. ALL CONCRETE PIPE SHALL BE ASTM C76, CLASS III, UNLESS OTHERWISE SHOWN. ALL JOINTS ARE SEALANT JOINTS.
10. SOIL COMPACTION REQUIREMENTS BENEATH CONCRETE STRUCTURES ARE 100% OF THE MAXIMUM DRY DENSITY MEASURED IN ACCORDANCE WITH ASTM D698. SOILS WITHIN REMAINDER OF THE PROJECT SHALL BE COMPACTED TO 95% OF THE MAXIMUM DRY DENSITY, MEASURED AS REFERENCED.
11. CONCRETE SIDEWALK AND CURB AND GUTTER SHALL BE REMOVED AT A JOINT IF THE JOINT IS LESS THAN FOUR FEET FROM A LENGTH TO BE REMOVED.
12. THE CONSTRUCTION WORK AREA IS LIMITED TO THE PUBLIC RIGHT-OF-WAY AND EASEMENTS SHOWN ON THE DRAWINGS. ALL AREAS DISTURBED SHALL BE REVEGETATED WITH NATIVE GRASSES, UNLESS OTHERWISE SHOWN ON THE DRAWINGS. SEE SPECIFICATIONS REGARDING SOIL PREPARATION AND SEEDING DETAILS.
13. CONTRACTOR TO OBTAIN APPROPRIATE COUNTY PERMITS TO ADDRESS TRAFFIC CONTROL, RIGHT OF WAY USE, ETC.



LOCATION MAP

SHEET INDEX

PREPARED BY:

MULLER ENGINEERING CO., INC.
CONSULTING ENGINEERS
IRONGATE 4, SUITE 100
777 S. WADSWORTH BLVD.
LAKEWOOD, COLORADO 80226
(303) 988-4939

"I HEARBY AFFIRM THAT THESE FINAL CONSTRUCTION PLANS FOR THE CHERRY CREEK IMPROVEMENTS AT BASIN RB1 WERE PREPARED UNDER MY DIRECT SUPERVISION IN ACCORDANCE WITH THE REQUIREMENTS OF THE ROADWAY DESIGN AND CONSTRUCTION STANDARDS AND THE STORM DRAINAGE DESIGN AND TECHNICAL CRITERIA OF ARAPAHOE COUNTY AS AMENDED AND AGREED TO BY THE INTERGOVERNMENTAL AGREEMENT BETWEEN ECCV W&S DISTRICT AND ARAPAHOE COUNTY."

[signature] 4/28/94

MICHAEL S. DUNGAN, P.E. PROJECT MANAGER — DATE
MULLER ENGINEERING COMPANY, INC.
DISTRICT MANAGER

PREPARED FOR:

EAST CHERRY CREEK VALLEY WATER AND SANITATION DISTRICT

REVIEWED FOR EAST CHERRY CREEK VALLEY AND SANITATION DISTRICT

DATE

" To the best of my knowledge, belief, and opinion, the drainage facilities were constructed in accordance with the design intent of the approved drainage report and construction drawings."

[signature] 2/28/95

Michael S. Dungan P.E. , Project Manager — Date
Muller Engineering Company Inc.

RECORD DRAWING 1/10/95
date

This record drawing has been prepared, in part, based upon information furnished by others. While this information is believed to be reliable, Muller Engineering Company, Inc. cannot assure its accuracy, and thus is not responsible for the accuracy of this record drawing or for any errors or omissions which may have been incorporated into it as a result. Those relying on this record drawing are advised to obtain independent verification of its accuracy before applying it for any purpose.

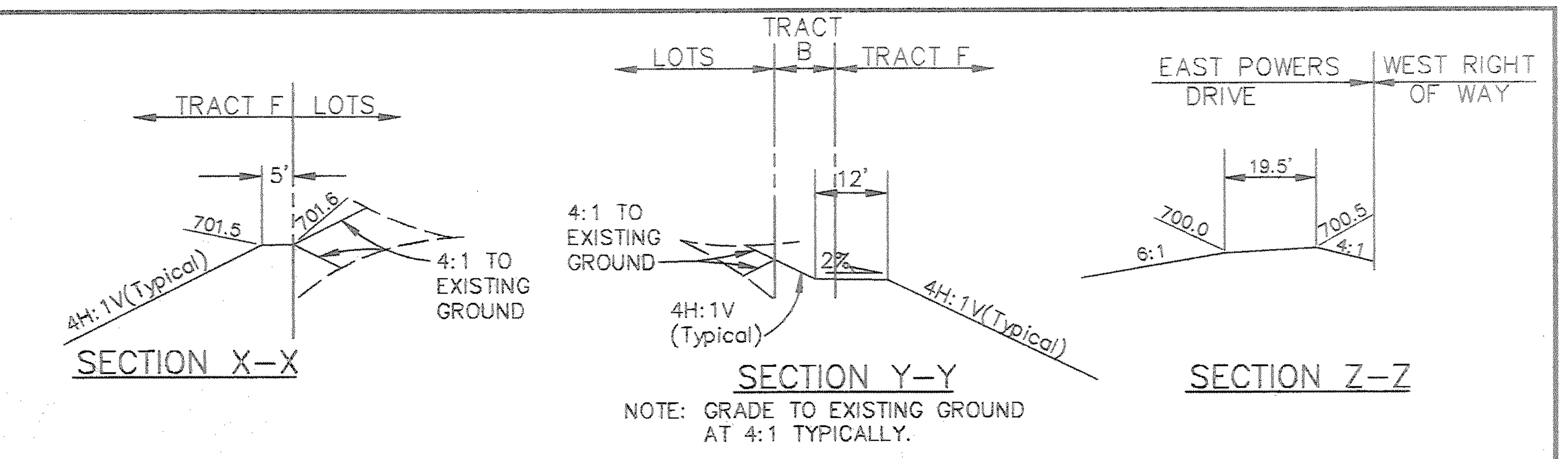
RB1-POND 4
DRAINAGE IMPROVEMENTS
MEC PROJECT NO. 9402
SHEET 1 OF 8

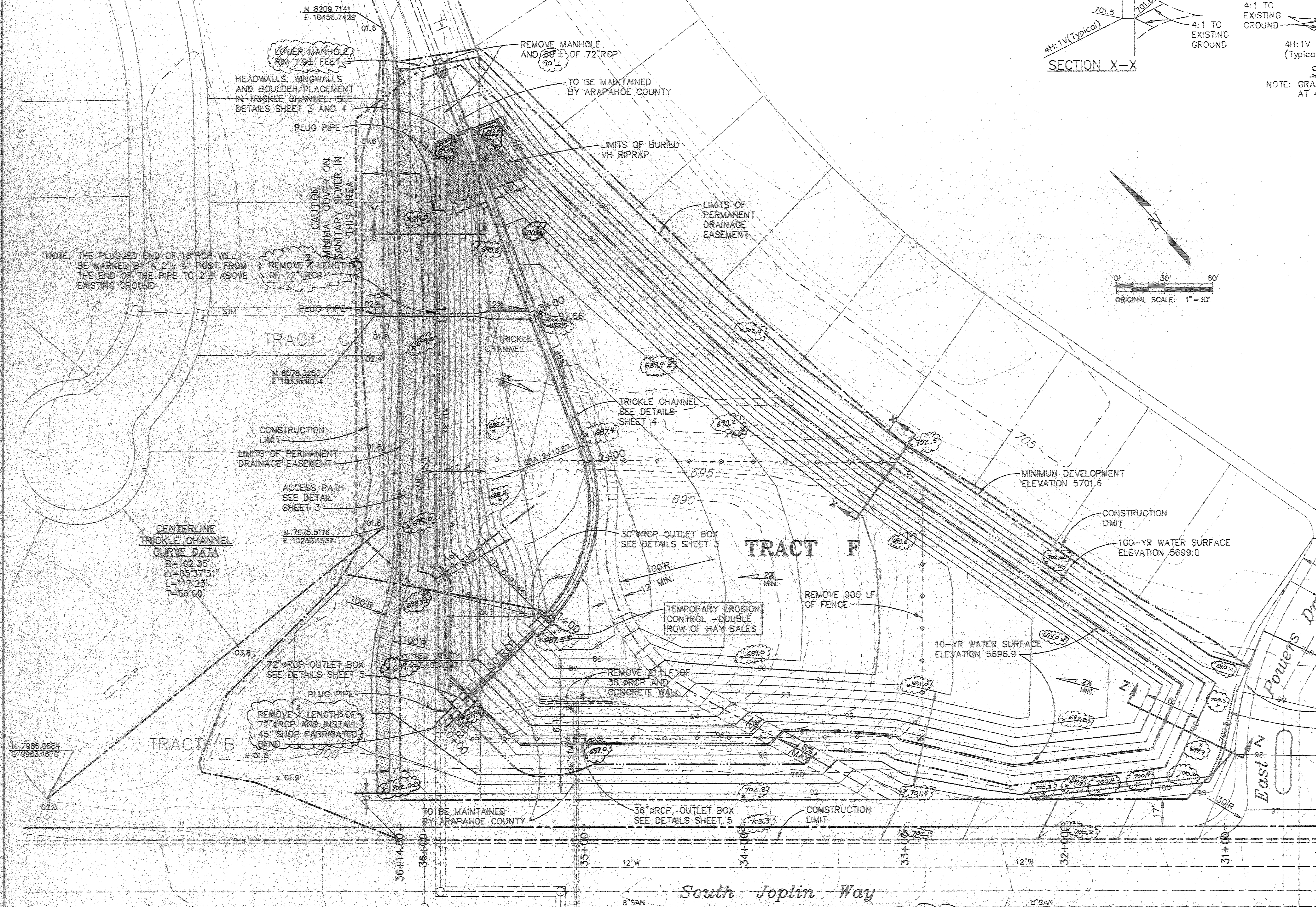
MULLER

DEPARTMENT OF HIGHWAY/ENGINEERING APPROVAL BLOCK

RB1-CVR 07/27/94

PINEY CREEK NO. 10





NOTES:

1.) ALL DISTURBED AREAS WILL BE RESEEDED. SEE SPECS FOR SEED MIX.
2.) SEE SHEET 4 FOR PROFILE OF POND TRICKLE CHANNEL AND STORM SEWER.
3.) SEE SHEET 8 FOR AREAS IN WHICH TO PLACE EXCESS MATERIAL. COMPACT EXCESS MATERIAL TO 95%.
4.) SITE DEVELOPMENT REFLECTS INFORMATION PROVIDED BY J.R. ENGINEERING LTD. PINEY CREEK FILING NO.10 PRELIMINARY PLAT 3/17/94.
5.) PROPOSED CONTOURS REPRESENT FINISHED GRADE ELEVATIONS.
6.) SEE SHEET 7 FOR PROPOSED SANITARY SEWER AND WATERLINE LAYOUT

EVENT	10 YEAR	100 YEAR
WATER SURFACE ELEVATION	5696.9	5699.0
RELEASE RATE	253 cfs	410 cfs
VOLUME	~~12.8~~ ACRES 12.5 ACRES	~~18.4~~ ACRES 18.1 ACRES

MAINTENANCE REQUIREMENTS

1.) POND TO BE MAINTAINED BY EAST CHERRY CREEK VALLEY WATER AND SANITATION DISTRICT WITH URBAN DRAINAGE AND FLOOD CONTROL DISTRICT MAINTENANCE ELIGIBILITY.

2.) AFTER COMPLETION AND ACCEPTANCE THE STORM SEWER WILL BE MAINTAINED BY ARAPAHOE COUNTY.

3.) FUTURE LANDSCAPING TO BE MAINTAINED BY HOMEOWNER'S ASSOCIATION.

BENCHMARK

TOP OF CAP IN RANGE BOX @ INTERSECTION OF CENTERLINE OF EAST PRENTICE DRIVE AND CENTERLINE OF SOUTH HELENA STREET (PINEY CREEK FILING NO. 11) ELEVATION =5711.94

RECORD DRAWING 1/10/95

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△ AS-BUILT INFORMATION SHOWN IN BUBBLES.

COORDINATE LIST	NORTH	EAST
NW CORNER SECTION 17	10000.13063	10001.55611
W 1/4 CORNER SECTION 17	7350.62187	9977.84067
INTERSECTION OF S. JOPLIN WAY & EAST POWERS DRIVE	7435.92977	10527.83137
EAST POWERS DRIVE P.I.	7530.1017	10609.6938
EAST POWERS DRIVE AND P.I.	7570.57784	10726.26913

REVISIONS

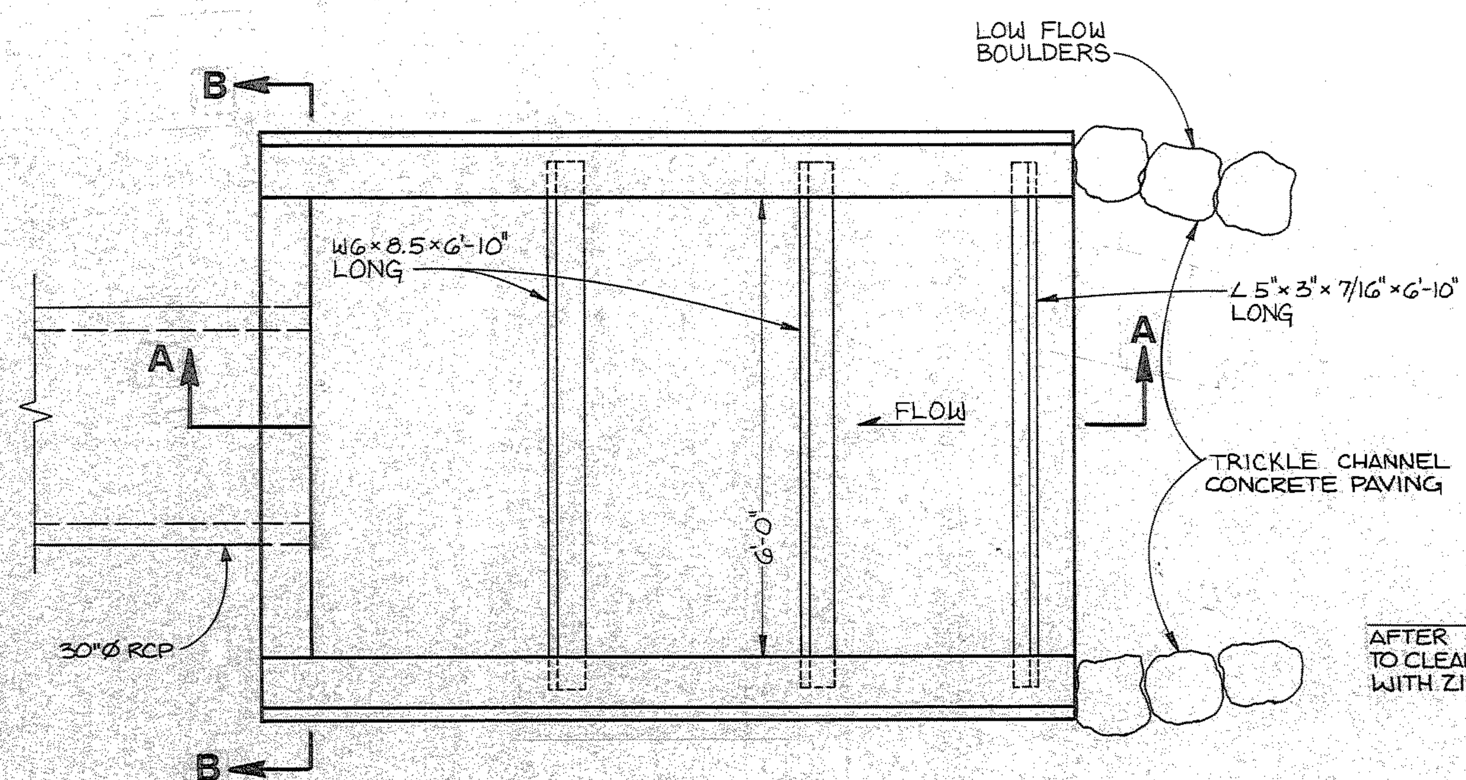
NO.	DATE	BY	CHK'D	DESCRIPTION
△	1/10/95	BGB		AS-BUILT DRAWINGS PREPARED

MULLER ENGINEERING CO., INC.
CONSULTING ENGINEERS
IRONGATE 4, SUITE 100
777 S. WADSWORTH BLVD.
LAKEWOOD, COLORADO 80226
(303) 988-4939

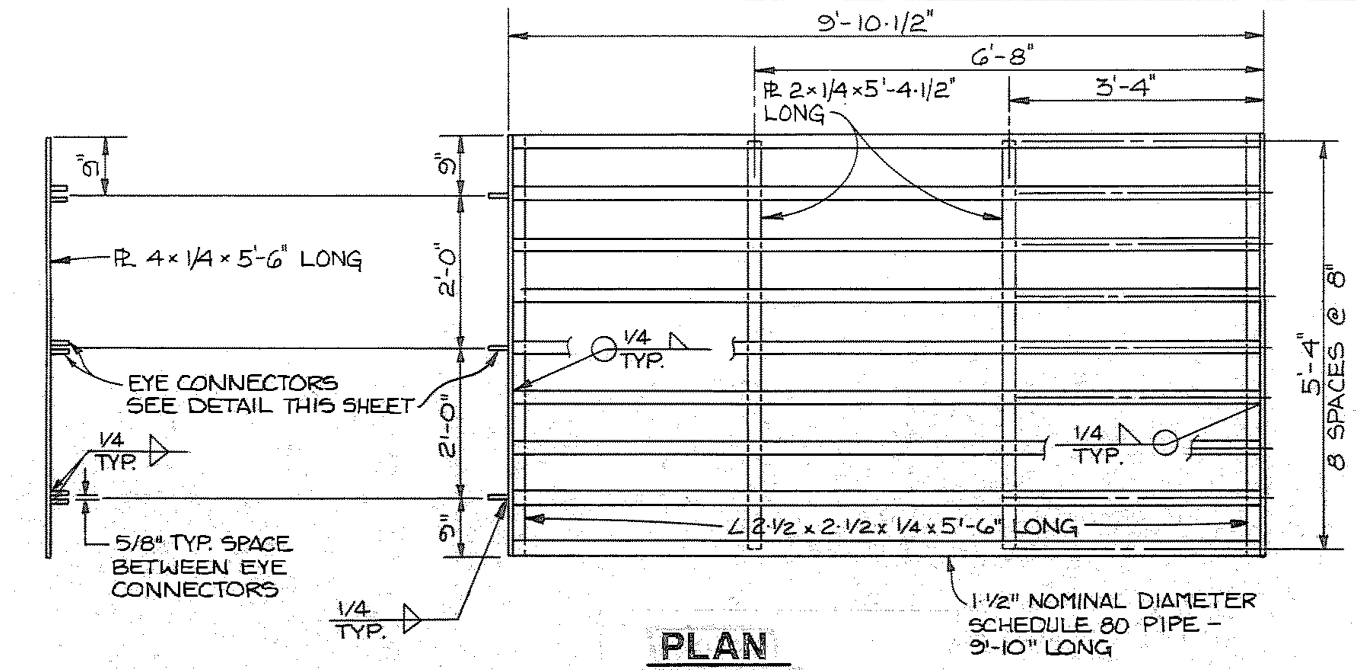
BASIN RB1 POND 4 DRAINAGE IMPROVEMENTS
CONSTRUCTION DRAWINGS
GENERAL PLAN

East Cherry Creek Valley Water & Sanitation District
4343 S. Buckley Road, Suite 300
Aurora, Colorado 80015
(303) 693-3800

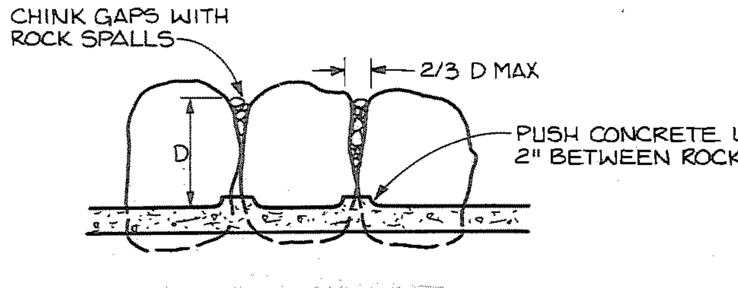
DESIGNED	RLK	DATE	08/01/94
DRAWN	JHK	FILE	RB1-PD4
CHECKED	MSD	PROJ. NO.	9402.01
SCALE	1"=30'	SHEET	2 OF 8



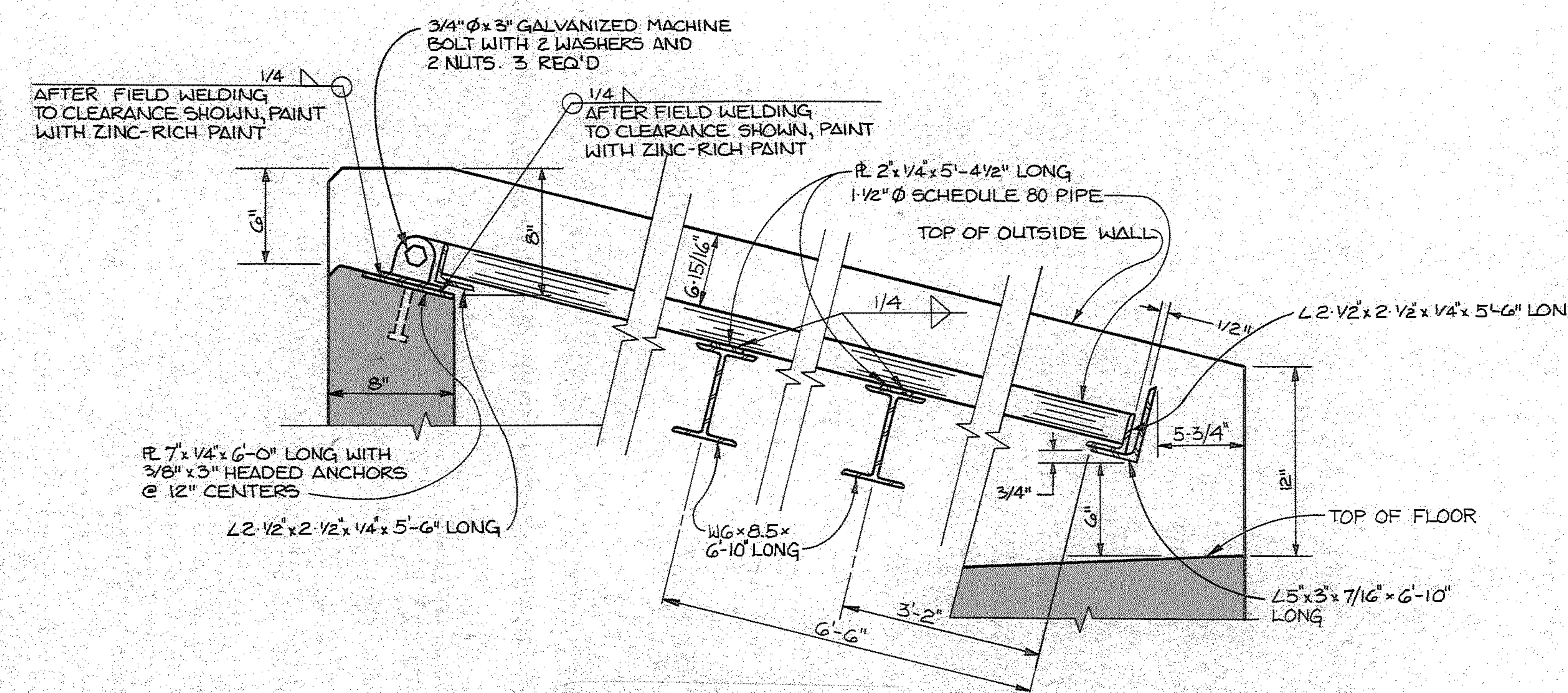
PLAN
1/2"=1'-0"
TRASHRACK NOT SHOWN



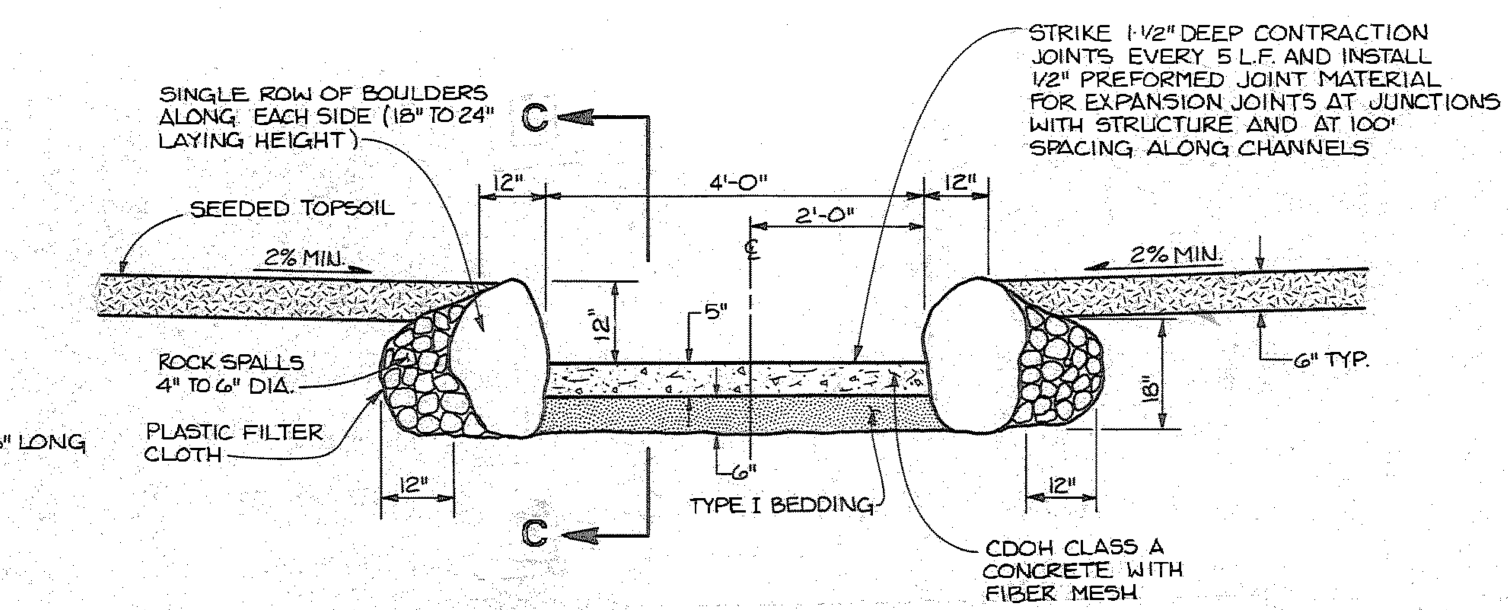
PLAN
1/2"=1'-0"



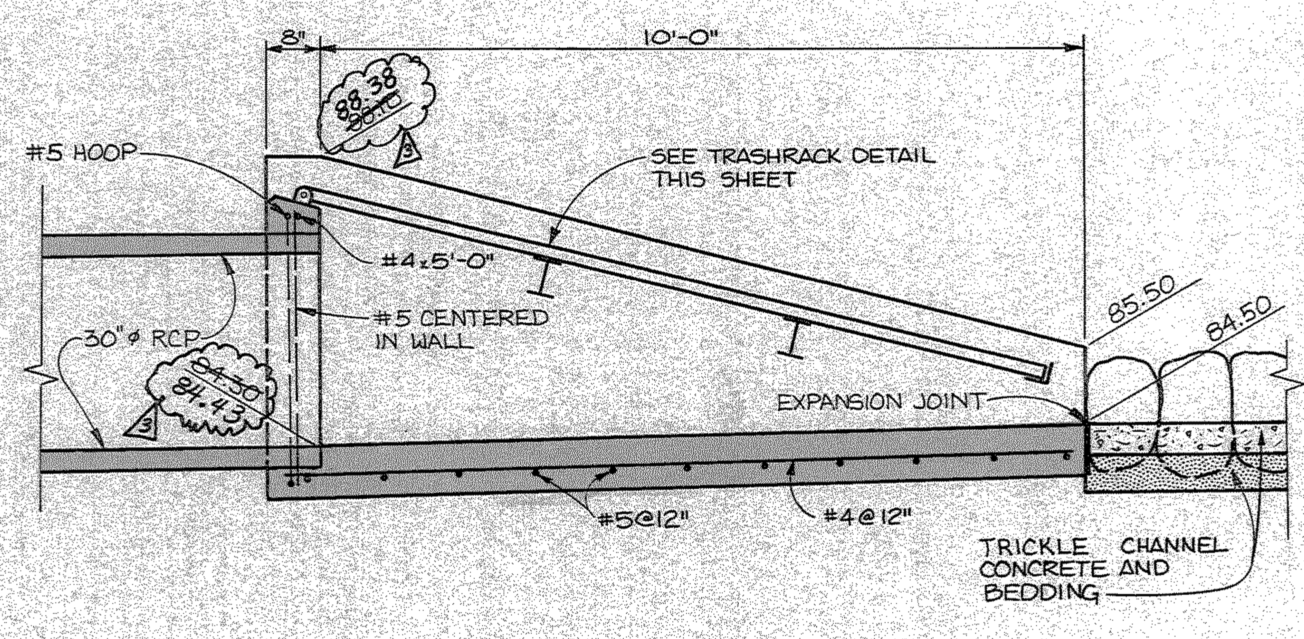
SECTION C-C
NO SCALE



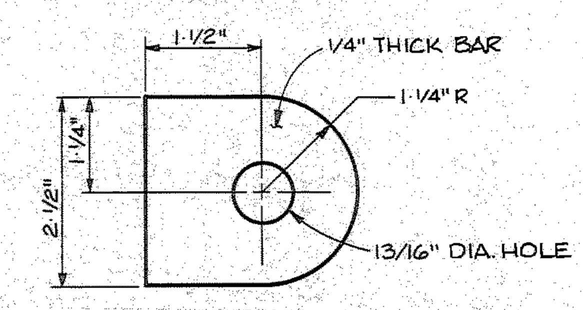
TRASHRACK DETAIL
1-1/2"=1'-0"



TRICKLE CHANNEL TYPICAL SECTION
NO SCALE



SECTION A-A
1/2"=1'-0"



EYE CONNECTOR DETAIL
1/2"=1'-0"

NOTES

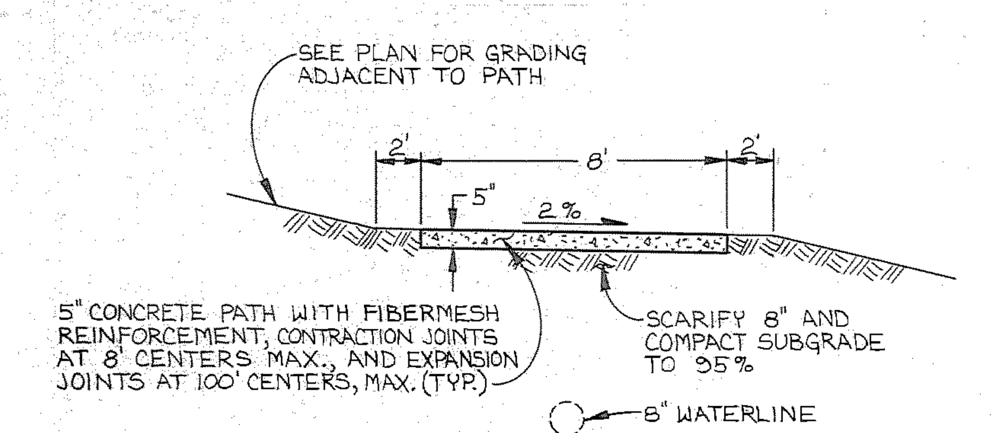
1.) TRASHRACK AND SUPPORTS, PLATES, AND HARDWARE SHALL BE HOT-DIP GALVANIZED AFTER FABRICATION.

2.) MISCELLANEOUS STEEL SHALL MEET THE REQUIREMENTS OF ASTM A36.

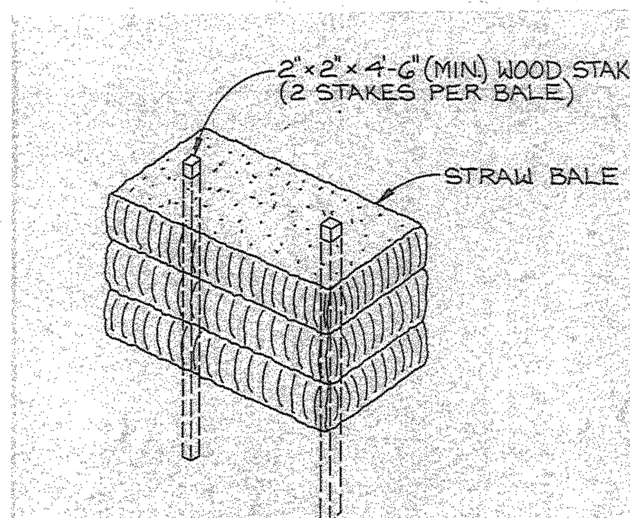
3.) HEADED ANCHORS SHALL BE NELSON WITH FLUXED ENDS OR APPROVED EQUAL.

4.) PIPE SHALL BE ASTM A501 OR A53.

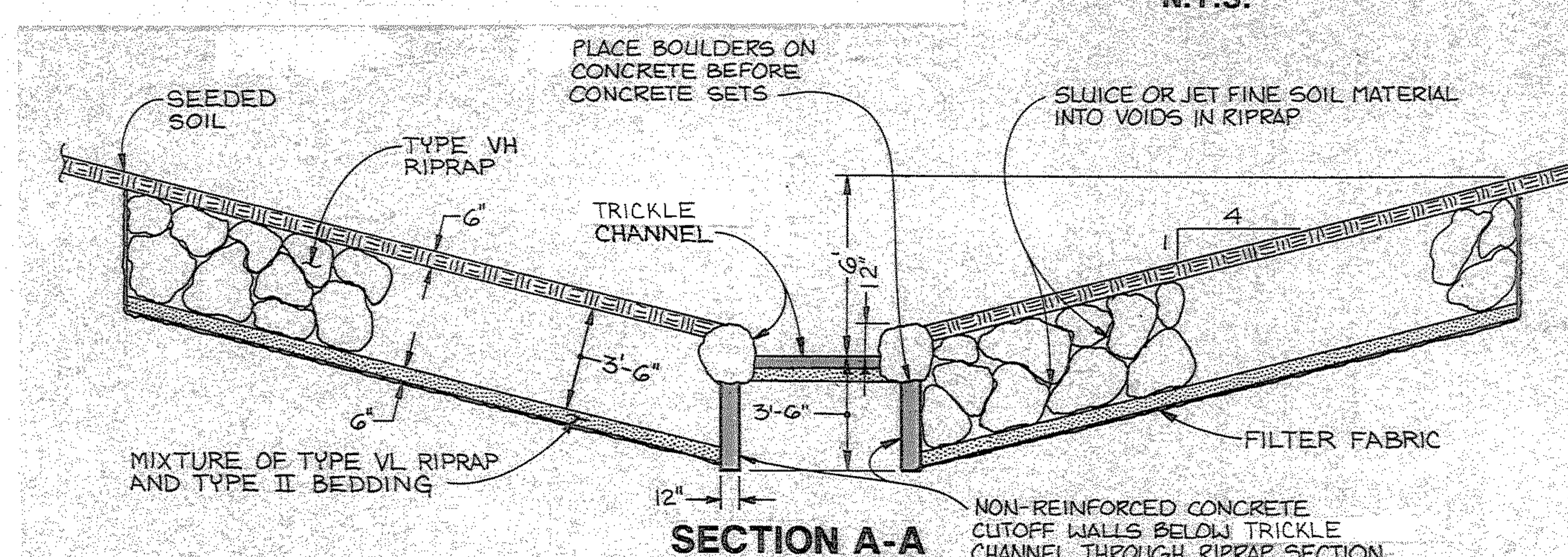
CALL UTILITY NOTIFICATION CENTER OF COLORADO
1-800-922-1987
OR 534-6700 IN METRO DENVER
CALL 2-BUSINESS DAYS IN ADVANCE BEFORE YOU DIG, GRADE, OR EXCAVATE FOR THE MARKING OF UNDERGROUND MEMBER UTILITIES.



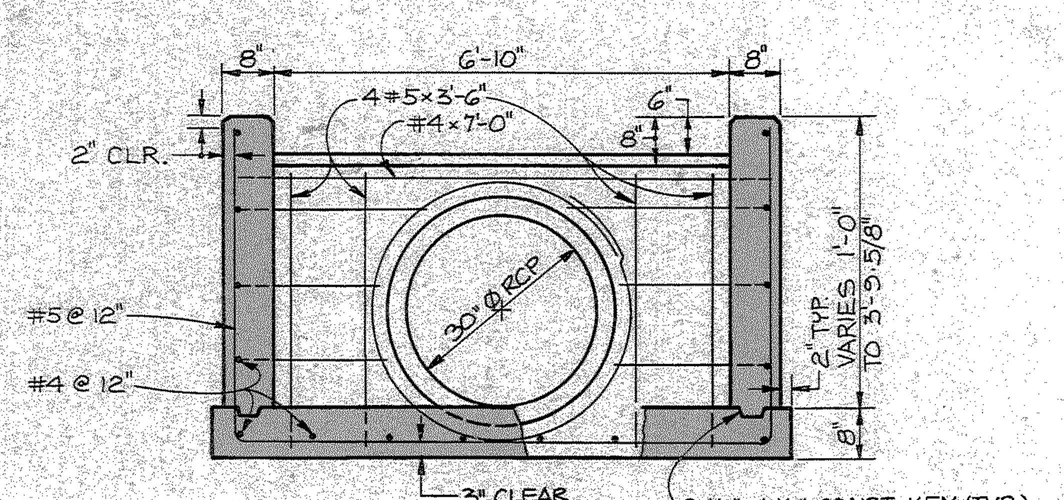
ACCESS PATH DETAIL



STRAW BALE DETAIL
N.T.S.



SECTION A-A
1"=5'



SECTION B-B
1/2"=1'-0"
TRASHRACK NOT SHOWN
SEE DETAIL FOR INSTALLATION

3 CONSTRUCTION (AS-BUILT) WAS IN SUBSTANTIAL COMPLIANCE WITH DETAILS, LINES, AND GRADES SHOWN ON THIS SHEET

RECORD DRAWING 1/10/95

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REVISIONS

NO.	DATE	BY	CHK'D.	DESCRIPTION
1	11/01/89	CLJ	MSD	ADDED ARAPAHOE COUNTY AND UDFCD REVIEW COMMENTS
2	4/28/94	JHK	MSD	UPDATED DRAWINGS
3	1/10/95	BAB		PREPARE AS-BUILT DRAWINGS

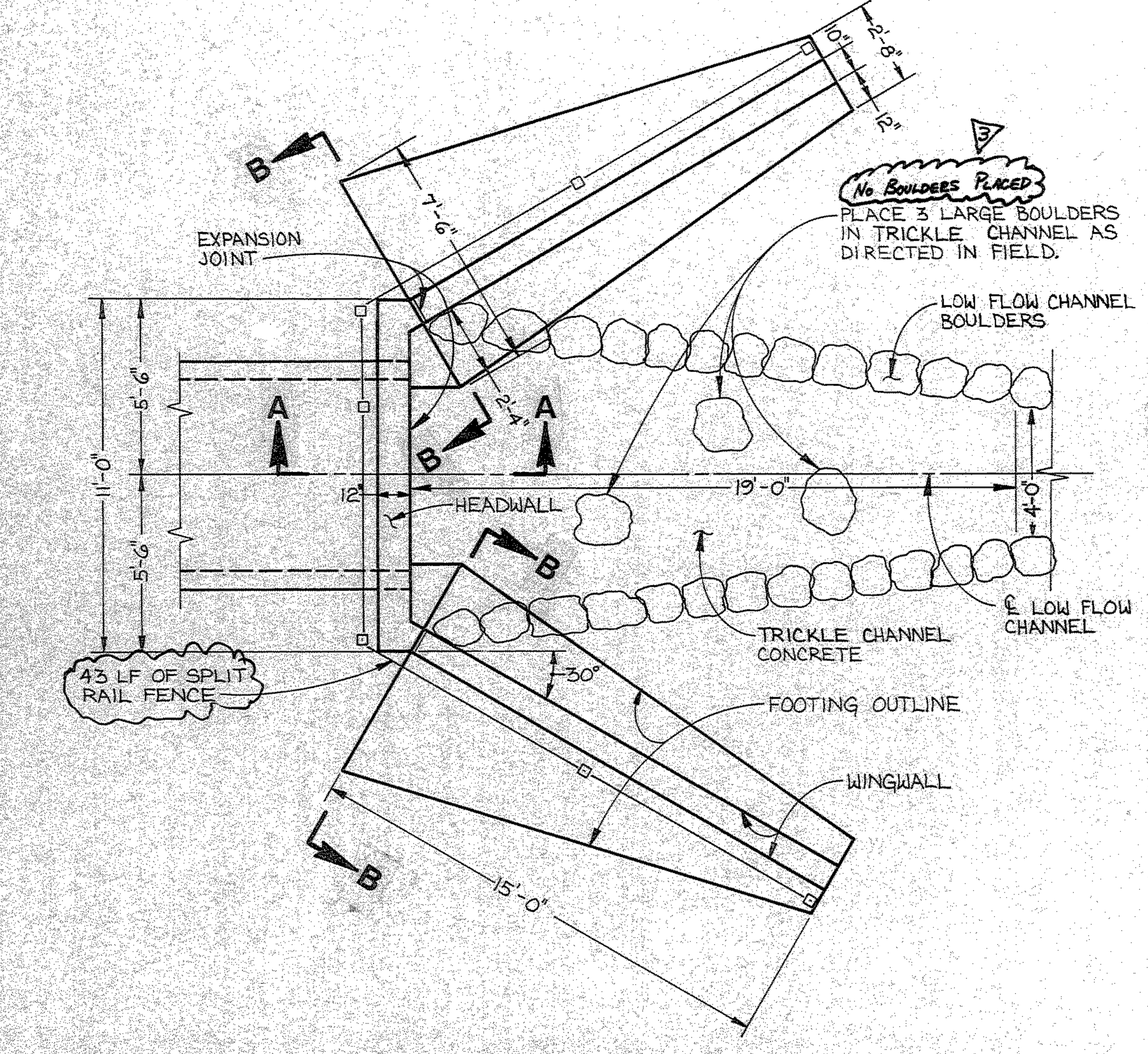
MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS

EAST CHERRY CREEK VALLEY WATER AND SANITATION DISTRICT
4343 S. BUCKLEY ROAD SUITE 300
AURORA, COLORADO 80015
(303) 693-3800

BASIN RB 1 POND 4 DRAINAGE IMPROVEMENTS CONSTRUCTION DRAWINGS

MISCELLANEOUS DETAILS

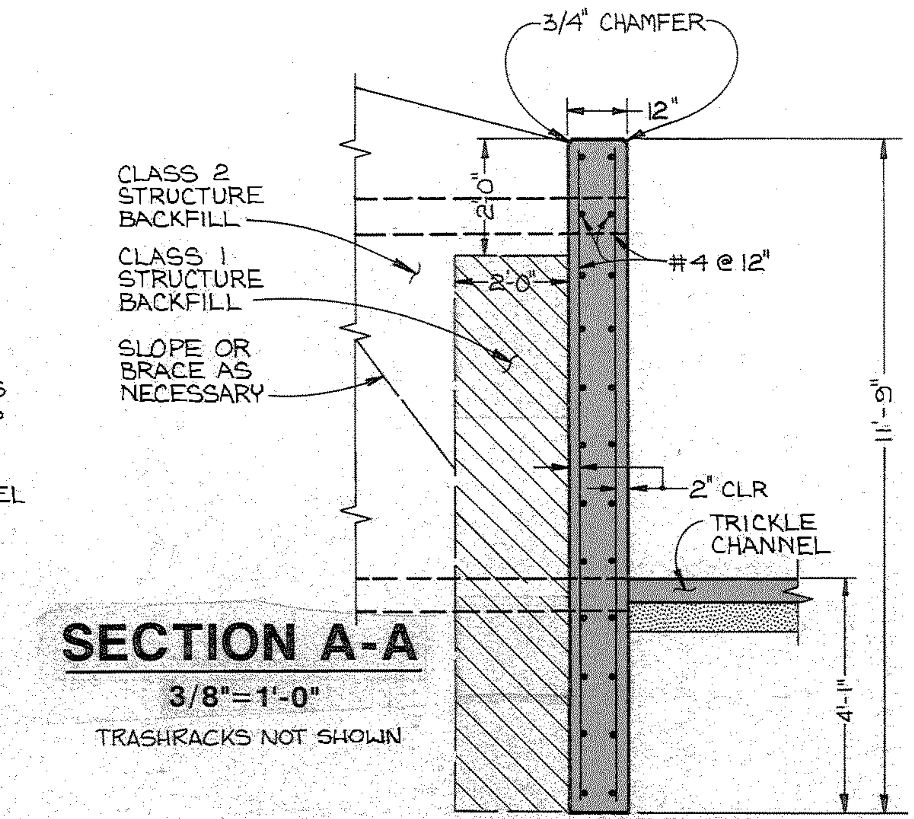
DESIGNED	MSD	DATE	JULY, 1994
DRAWN	JHK	DWG. NO.	
CHECKED	MSD	PROJ. NO.	9402.01
SCALE	AS SHOWN	SHEET	3 OF 8



STORM SEWER OUTLET PLAN

1/4"=1'-0"

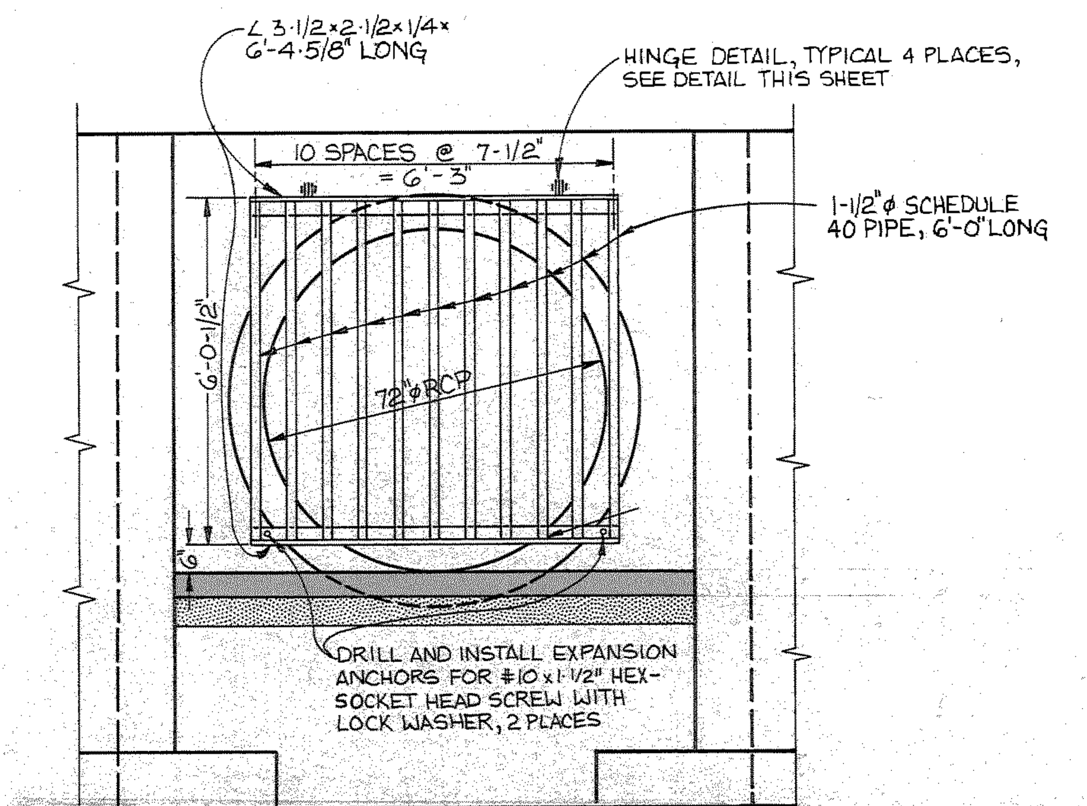
TRASHRACK NOT SHOWN- SEE INSTALLATION DETAIL THIS SHEET



SECTION A-A

3/8"=1'-0"

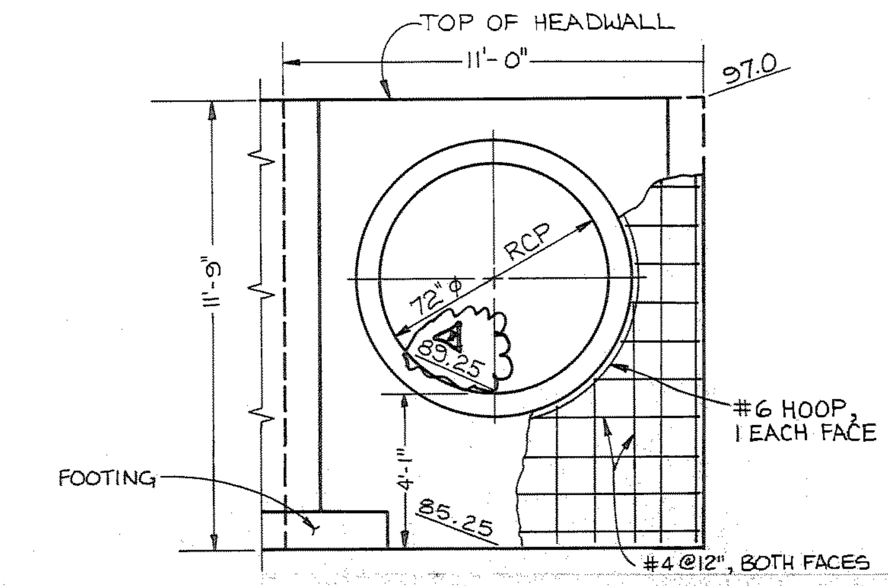
TRASHRACKS NOT SHOWN



TRASHRACK AND INSTALLATION DETAIL

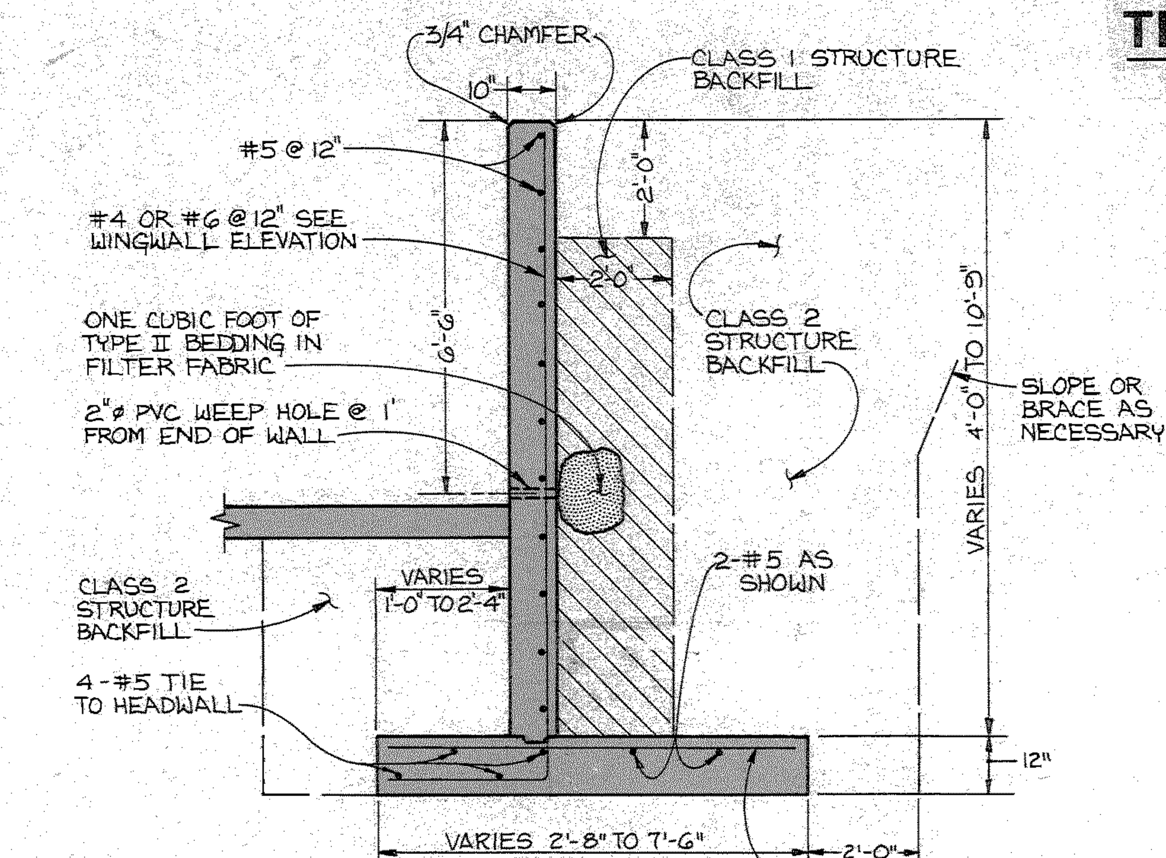
3/8"=1'-0"

SEE SHEET 5 FOR NOTES CONCERNING GRATES AND METAL WORK.



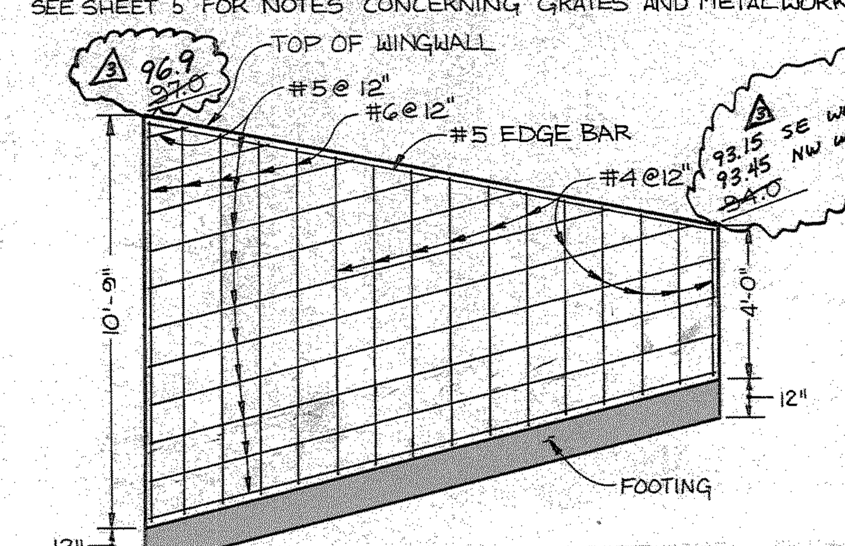
HEADWALL ELEVATION

1/4"=1'-0"



SECTION B-B

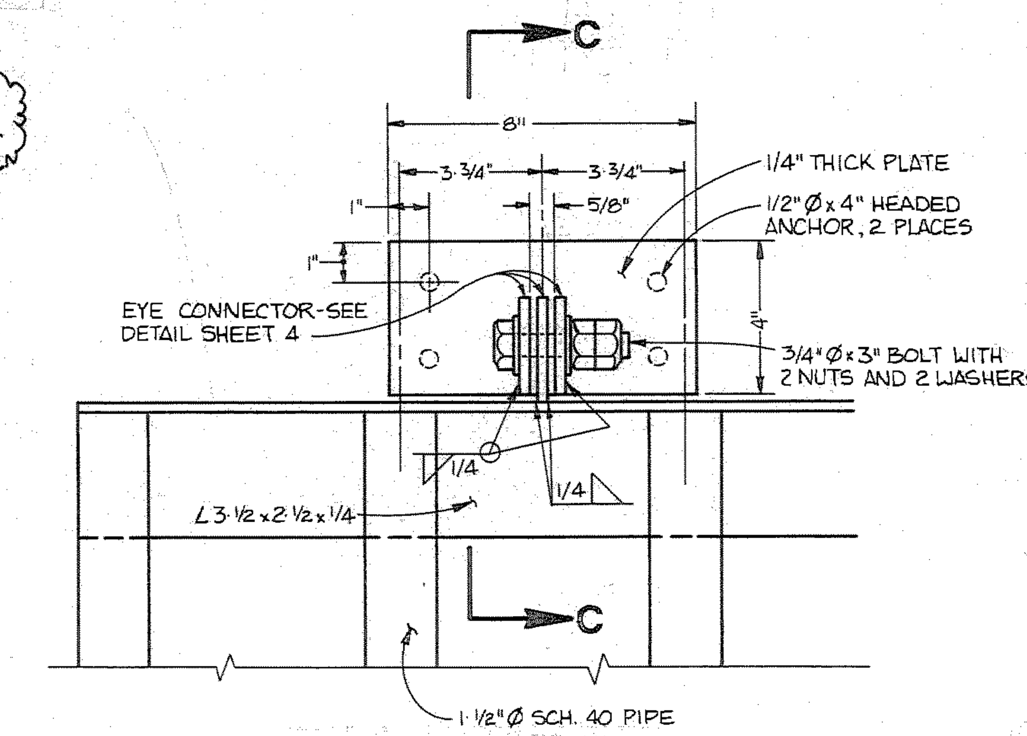
3/8"=1'-0"



EAST WINGWALL ELEVATION

1/4"=1'-0"

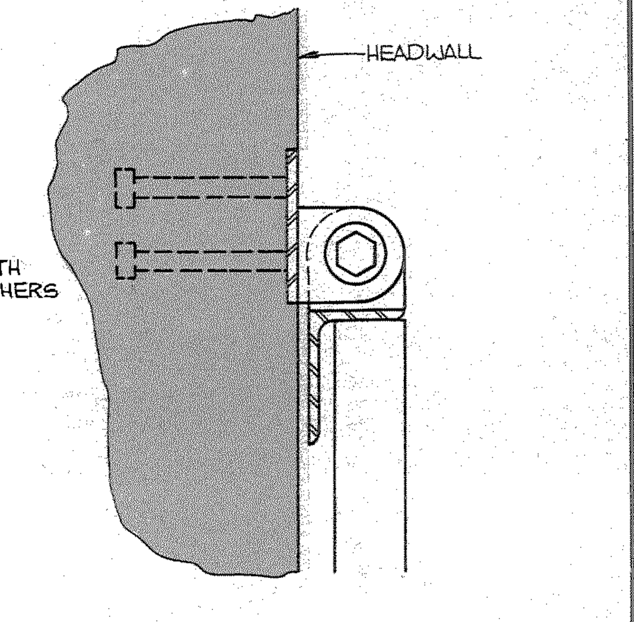
WEST WINGWALL SIMILAR



HINGE DETAIL

3"=1'-0"

2 REQUIRED

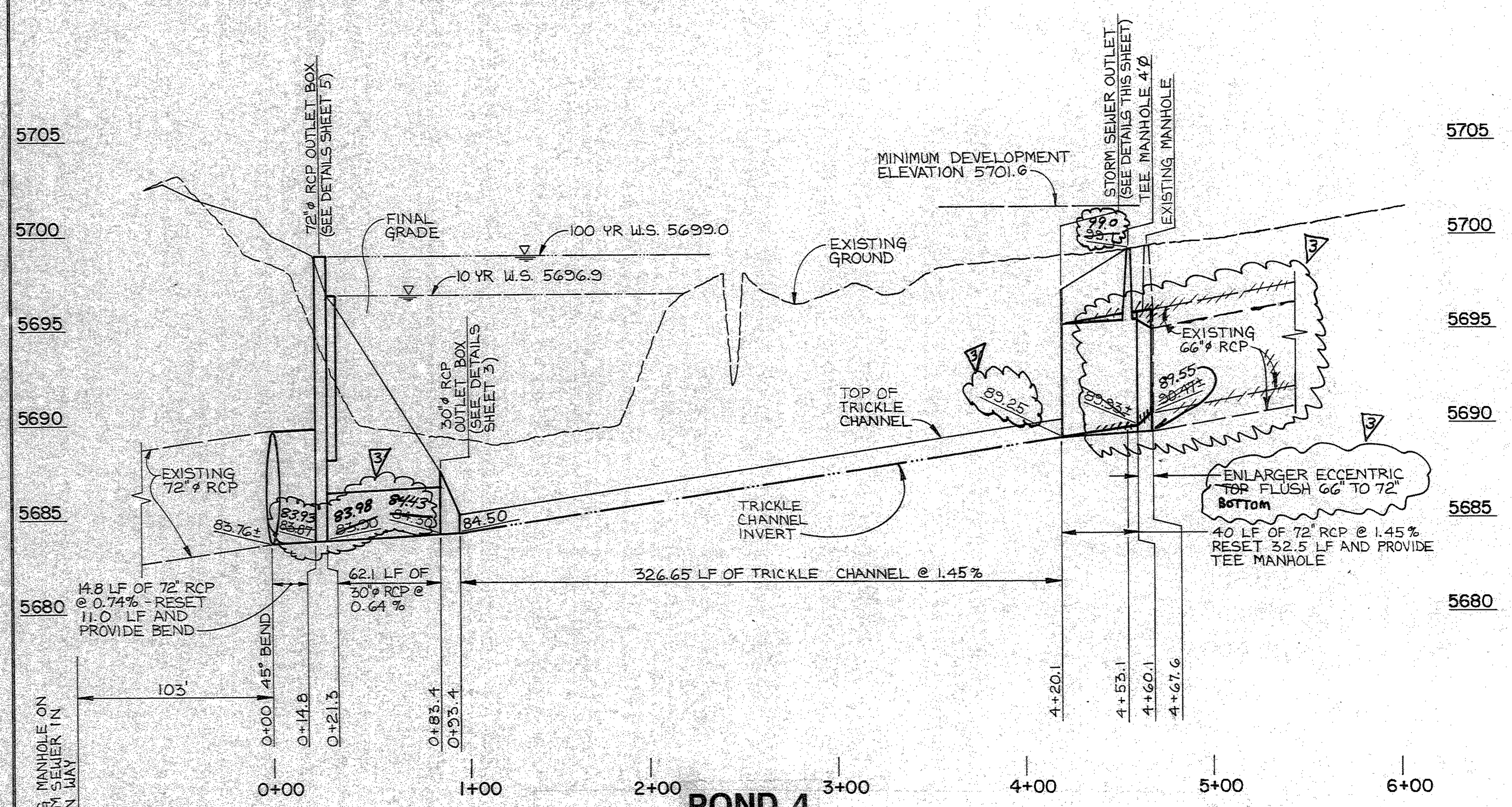


SECTION C-C

3"=1'-0"

MAINTENANCE REQUIREMENTS

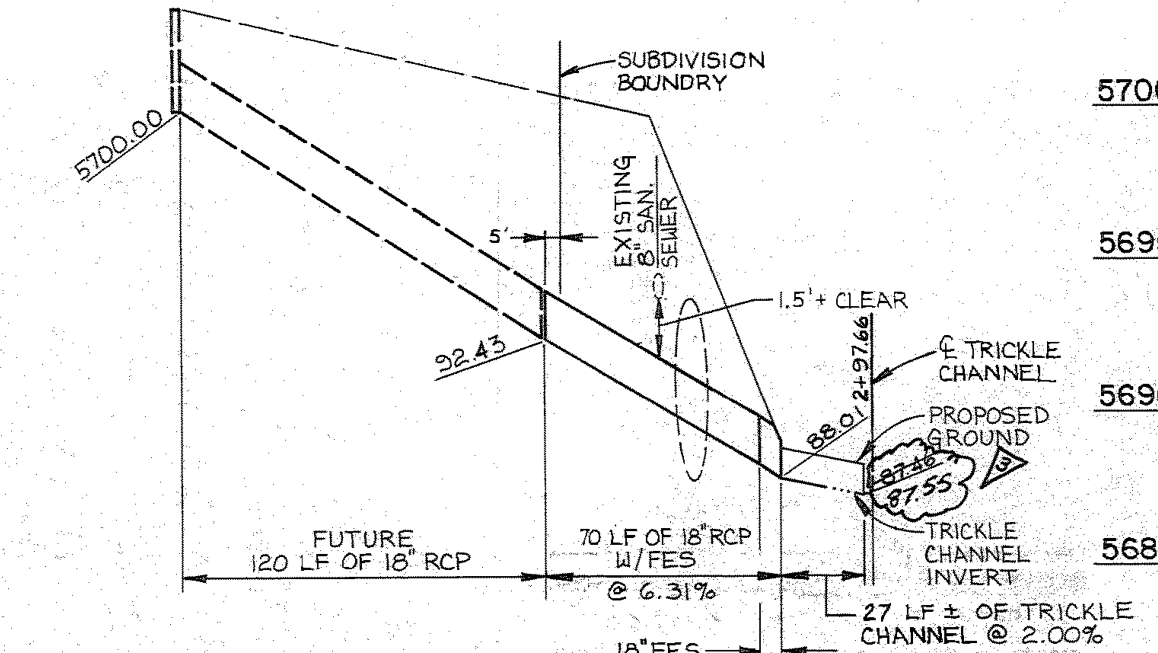
1. STORM SEWERS AND STORM SEWER OUTLETS WITH HEADWALLS AND ENTRY RACKS TO BE MAINTAINED BY ARAPAHOE COUNTY.
2. POND, LOW FLOW CHANNEL, AND POND OUTLET STRUCTURES TO BE MAINTAINED BY EAST CHERRY CREEK VALLEY WATER AND SANITATION DISTRICT WITH ELIGIBILITY FOR UDFCD MAINTENANCE ASSISTANCE.
3. FUTURE LANDSCAPING TO BE MAINTAINED BY HOMEOWNER'S ASSOCIATION.



POND 4
TRICKLE CHANNEL AND STORM SEWER PROFILE

1"=50' Hor. 1"=5' Vert.

SEE SHEET 2 FOR PLAN OF POND



STORM SEWER AND TRICKLE CHANNEL PROFILE

1"=50' Hor. 1"=5' Vert.

CONSTRUCTION (AS-BUILT) WAS IN SUBSTANTIAL COMPLIANCE W/ THE LINES, GRADES, AND DETAILS AS SHOWN ON THIS SHEET

RECORD DRAWING 1/10/95

REVISIONS				
NO.	DATE	BY	CHK'D.	DESCRIPTION
1	11/01/93	CLT	MSD	ADDED ARAPAHOE COUNTY AND UDFCD REVIEW COMMENTS
2	4/28/94	JHK	MSD	UPDATED DRAWINGS
3	1/10/95	BJB		PREPARE AS-BUILT DRAWINGS

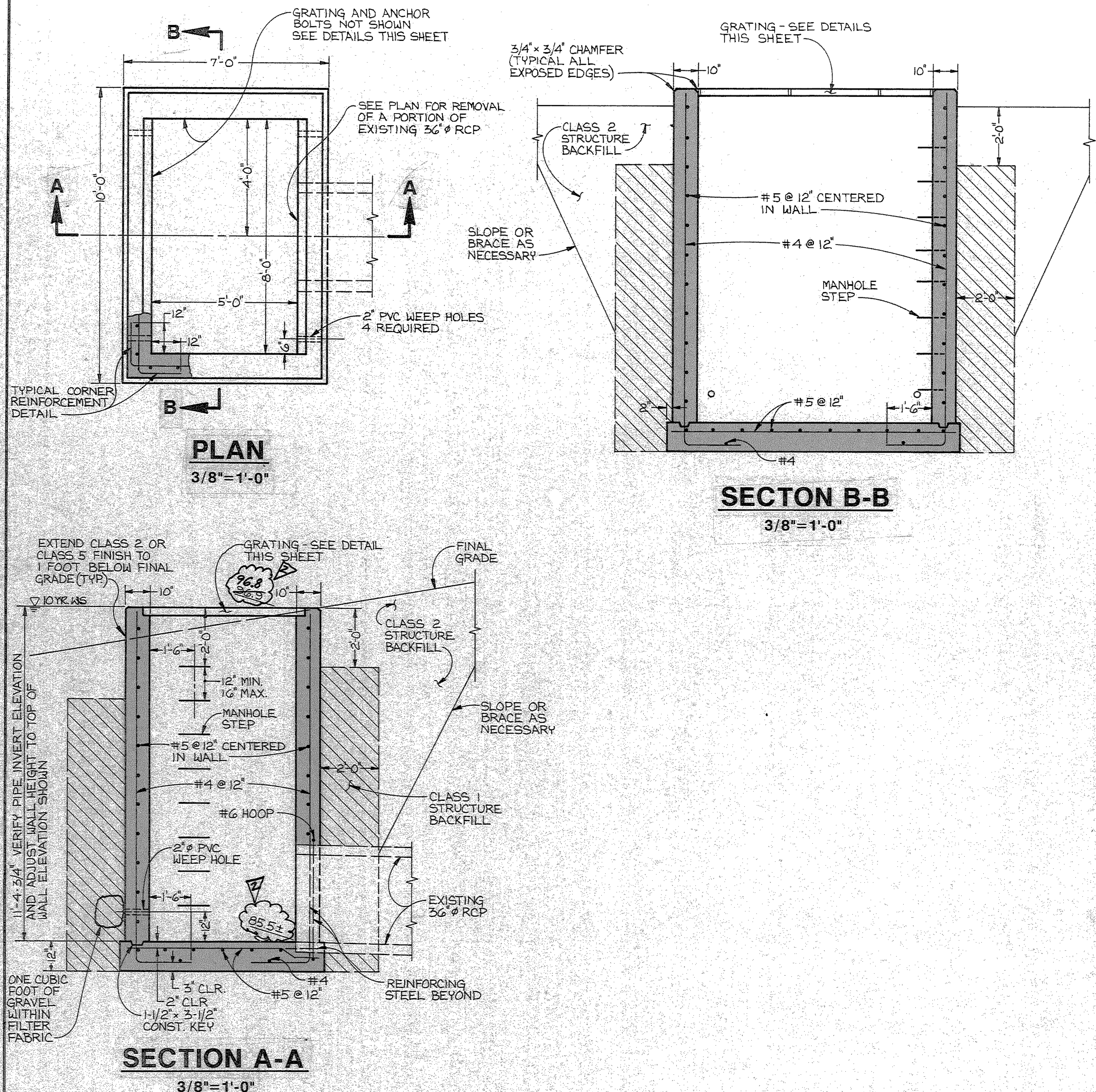
BASIN RB 1 POND 4 DRAINAGE IMPROVEMENTS
CONSTRUCTION DRAWINGS

POND 4 PROFILE AND HEADWALL DETAILS

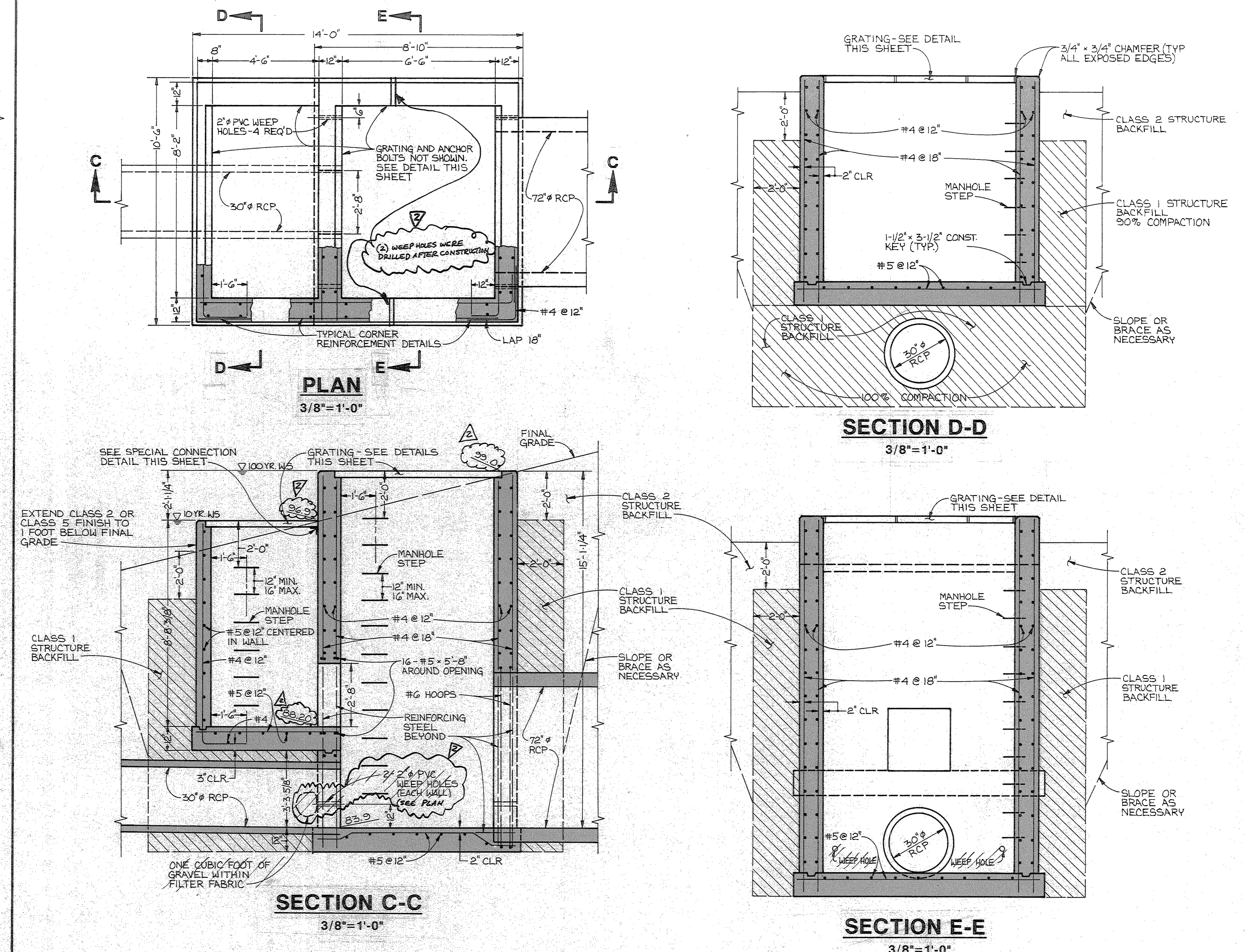
MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS

EAST CHERRY CREEK VALLEY WATER AND SANITATION DISTRICT
4343 S. BUCKLEY ROAD, SUITE 300
AURORA, COLORADO 80015
(303) 693-3800

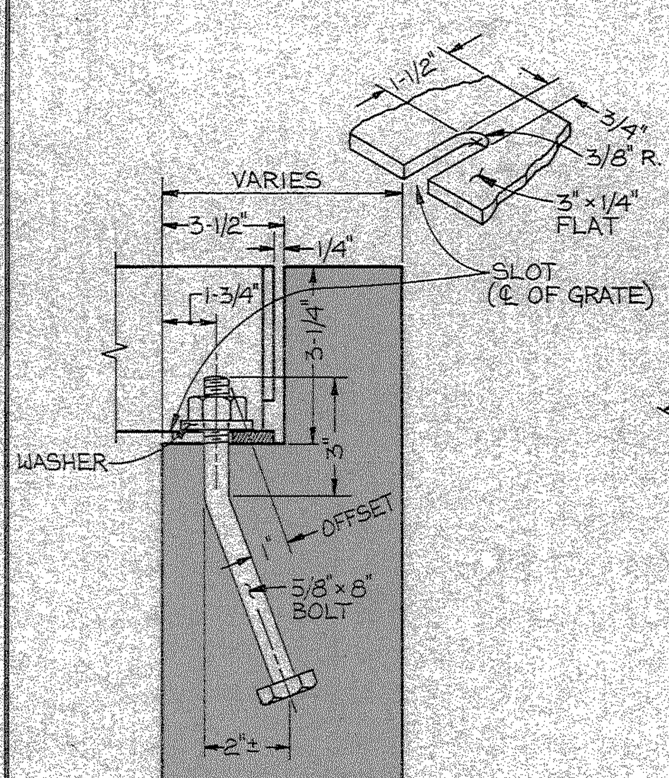
DESIGNED	MSD	DATE	APRIL, 1994
DRAWN	JHK	DWG. NO.	
CHECKED	MSD	PROJ. NO.	9402.01
SCALE	AS SHOWN	SHEET	4 OF 8



36"Ø RCP OUTLET BOX



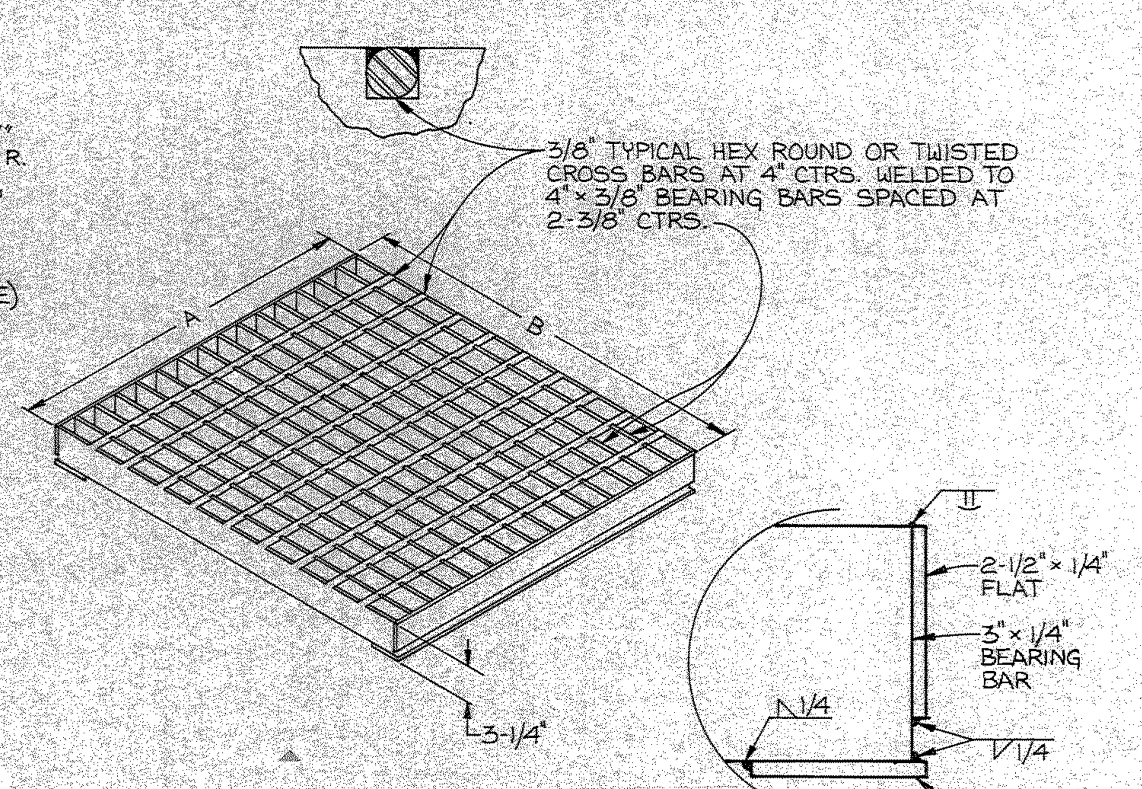
72"Ø RCP OUTLET BOX



GRATE INSTALLATION DETAIL

NO SCALE

2 BOLTS REQUIRED PER GRATE PANEL ONE BOLT AT EACH END APPROXIMATELY CENTERED. LOCATE BOLT LOCATIONS TO MATCH GRATING SLOTS.



CLOSE MESH GRATING DETAIL

NO SCALE

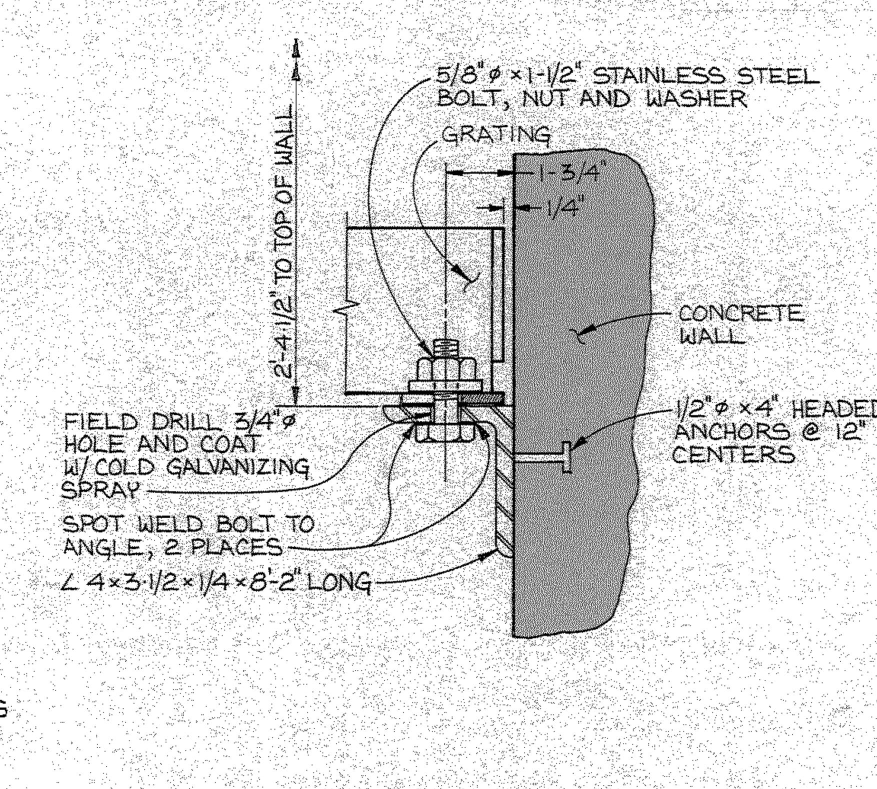
SEE TABLE FOR DIMENSIONS AND NUMBER OF GRATES REQUIRED

TABLE OF GRATE DIMENSIONS

Finished Grate Dimensions A	Finished Grate Dimensions B	Number of Grates Required
2'-11-7/8"	5'-6-1/2"	2
1'-9-5/8"	5'-6-1/2"	1
2'-11-7/8"	4'-9"	2
2'-0"	4'-9"	1
2'-11-7/8"	7'-0-1/2"	2
2'-0"	7'-0-1/2"	1

NOTES:

1. FIELD VERIFY DIMENSIONS BEFORE ORDERING GRATING.
2. GRATING AND ALL SUPPORTS, PLATES AND HARDWARE SHALL BE HOT-DIP GALVANIZED AFTER FABRICATION.
3. MISCELLANEOUS STEEL SHALL MEET THE REQUIREMENTS OF ASTM A36.
4. PIPE SHALL MEET THE REQUIREMENTS OF ASTM A53, GRADE B OR A501.



SPECIAL CONNECTION DETAIL

NO SCALE

GRATING DETAILS

△2 CONSTRUCTION (AS-BUILT) IN SUBSTANTIAL COMPLIANCE WITH THE LINES, GRADES AND DETAILS AS SHOWN ON THIS SHEET

RECORD DRAWING 1/10/95 date

This record drawing has been prepared, in part, based upon information furnished by others. While this information is believed to be reliable, Muller Engineering Company, Inc. cannot assure its accuracy, and thus is not responsible for the accuracy of this record drawing or for any errors or omissions which may have been incorporated into it as a result. Those relying on this record drawing are advised to obtain independent verification of its accuracy before applying it for any purpose.

REVISIONS

NO.	DATE	BY	CHK'D.	DESCRIPTION
△1	11/01/94	CLJ	MSD	ADDED ARAPAHOE COUNTY AND UDFCD REVIEW COMMENTS
△2	1/10/95	BAB		PREPARE AS-BUILT DRAWINGS

MULLER ENGINEERING COMPANY, INC.
CONSULTING ENGINEERS

EAST CHERRY CREEK VALLEY WATER AND SANITATION DISTRICT
4343 S. BUCKLEY ROAD SUITE 300
AURORA, COLORADO 80015
(303) 693-3800

BASIN RB 1 POND 4 DRAINAGE IMPROVEMENTS CONSTRUCTION DRAWINGS

POND 4 OUTLET BOX DETAILS

DESIGNED	MSD	DATE	APRIL, 1994
DRAWN	JHK	DWG. NO.	
CHECKED	MSD	PROJ. NO.	9402.01
SCALE	AS SHOWN	SHEET	5 OF 8

SCALE: 1"=30' HORIZ.
1"=5' VERT.

REVISIONS				
NO.	DATE	BY	CHK'D	DESCRIPTION
△	1/10/95	BAB		AS-CONSTRUCTED DWGS PREPARED

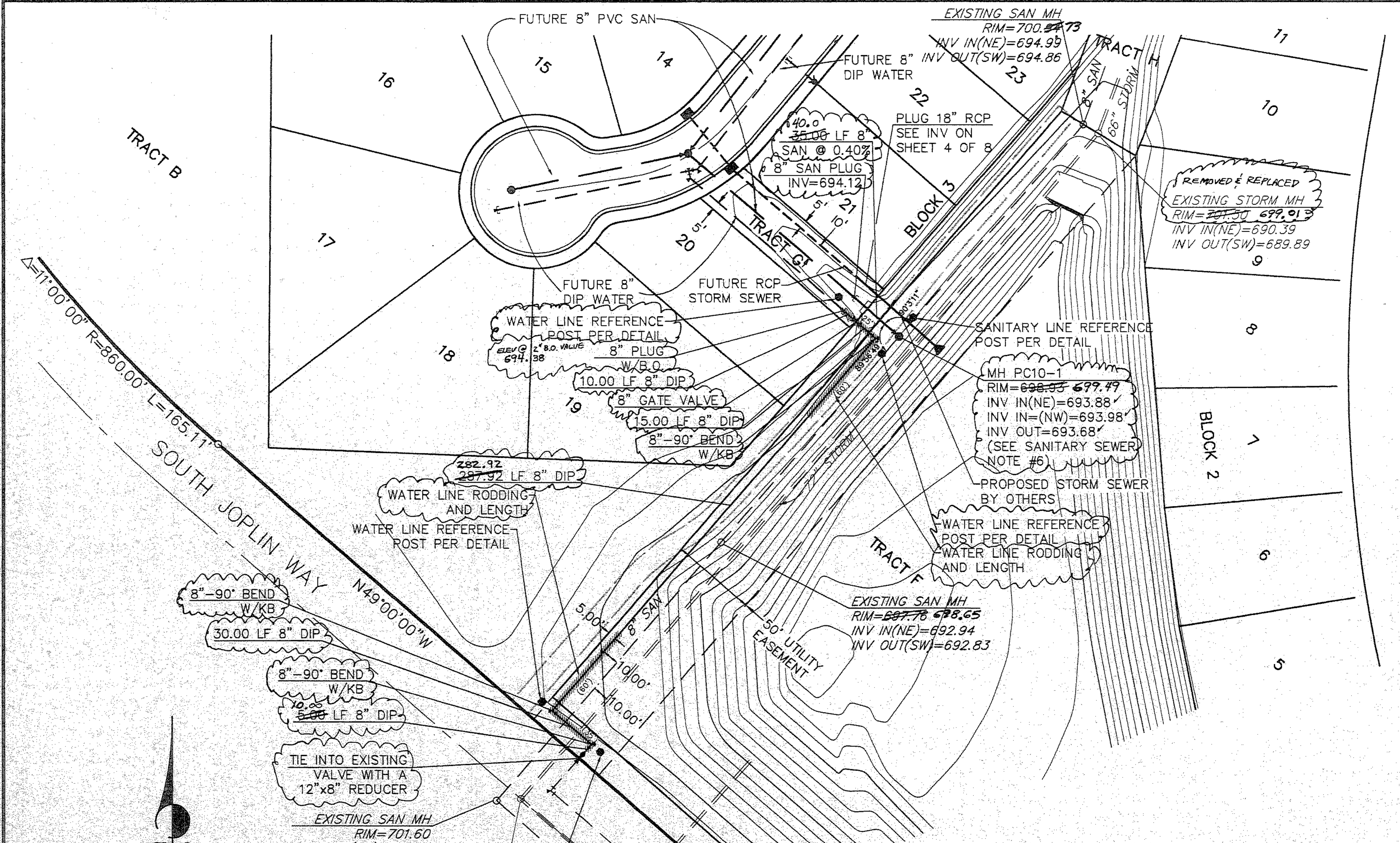
BASIN RB1 POND 4 DRAINAGE
IMPROVEMENTS
CONSTRUCTION DRAWINGS

POND 4 CROSS SECTIONS

MULLER ENGINEERING CO., INC.
CONSULTING ENGINEERS
IRONGATE 4, SUITE 100
777 S. WADSWORTH BLVD.
LAKEWOOD, COLORADO 80226
(303) 988-4939

East Cherry Creek Valley
Water & Sanitation District
4343 S. Buckley Road, Suite 300
Aurora, Colorado 80015
(303) 693-3800

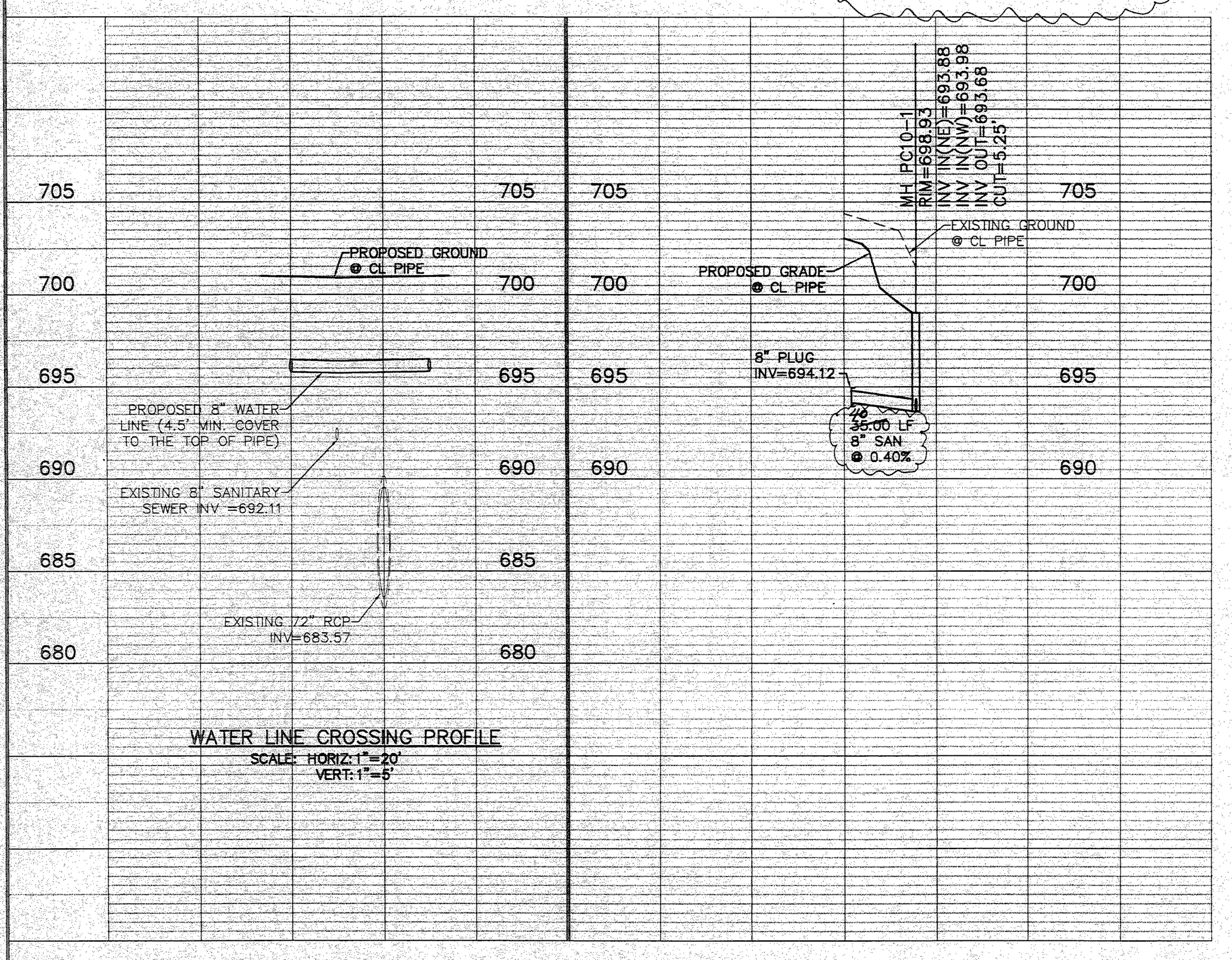
DESIGNED	RLK	DATE	5/4/94
DRAWN	JHK	FILE	RB1-SEC
CHECKED	MSD	PROJ. NO.	9402.01
SCALE	AS SHOWN	SHEET	6 OF 8



SEE SHEET 8 OF 8 FOR SANITARY SEWER DETAILS.

INSPECTION OF INSTALLATION BY MEURER AND ASSOCIATES MARK SKELSKEY

AS-BUILT INFORMATION GATHERED BY MUELLER ENGINEERING'S BRUCE BEHRER



WATER LINE CROSSING PROFILE
SCALE: HORIZ:1"=20'
VERT:1"=5'

SANITARY SEWER

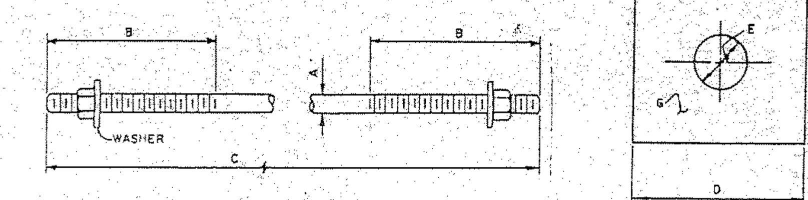
1. ALL SANITARY SEWER MAINS AND SYSTEM PLANS AND CONSTRUCTION, SHALL CONFORM WITH THE EAST CHERRY CREEK VALLEY WATER AND SANITATION DISTRICT STANDARDS AND SPECIFICATIONS, AND BE SUBJECT TO CONSTRUCTION AND OBSERVATIONS BY DISTRICT PERSONNEL OR REPRESENTATIVES. COPIES OF THE DISTRICT STANDARDS AND SPECIFICATIONS MAY BE OBTAINED FROM MEURER AND ASSOCIATES, INC., OR THE DISTRICT MANAGER. THE OWNER, HIS ENGINEER OR CONTRACTOR, SHALL SCHEDULE A PRECONSTRUCTION MEETING WITH THE DISTRICT MANAGER AND DISTRICT ENGINEER AT LEAST 48 HOURS PRIOR TO THE START OF CONSTRUCTION. PLANS WITH THE DISTRICT REVIEW STAMP WILL BE DISTRIBUTED AT THE PRECONSTRUCTION MEETING. NO CONSTRUCTION WILL BE PERMITTED UNTIL FORMAL COMPLETION OF EASEMENTS AND RECORDING, AND PRIOR TO THE PRECONSTRUCTION MEETING.
2. THE PIPE USED FOR SANITARY SEWER MAINS SHALL BE IN ACCORDANCE WITH ASTM D-3034 SDR 35 PVC PIPE IN PAVED RIGHTS-OF-WAY AND EASEMENTS, AND A.W.W.A. C-900, CLASS 150 IN UNPAVED EASEMENTS.
3. PROBATIONARY ACCEPTANCE OF THE NEW SANITARY SEWER MAINS IS CONTINGENT UPON RECEIVING COPIES OF:
   A. SANITARY SEWER TRENCH COMPACTION TEST RESULTS, AND,
   B. RECORD DRAWINGS
4. THE SANITARY SEWER SYSTEM WILL BE TESTED IN ACCORDANCE WITH THE DISTRICT STANDARDS AND SPECIFICATIONS. THE DISTRICT WILL;
   A. LAMP 100% OF THE NEW SYSTEM,
   B. LOW PRESSURE AIR TEST 100% OF THE NEW SYSTEM, AND,
   C. DEFLECTION TEST, AT A MINIMUM OF 33% OF THE SYSTEM FIFTEEN (15) FEET OR LESS IN DEPTH, AND 100% OF THE SYSTEM GREATER THAN FIFTEEN (15) FEET IN DEPTH.
5. MANHOLE RIMS SHALL BE SET AT AN ELEVATION RELATIVE TO THE PAVEMENT, IN ACCORDANCE WITH CITY/COUNTY STANDARDS. WHETHER THE MANHOLE IS IN A PAVED OR UNPAVED GRADE, A MINIMUM OF ONE (1) AND A MAXIMUM OF FOUR (4) ROWS OF BRICK SHALL BE USED TO ADJUST RIM ELEVATIONS TO FINAL GRADE. THE MAXIMUM ACCEPTABLE VERTICAL ADJUSTMENT UTILIZING BRICK IS TWELVE (12) INCHES.
6. CONNECTIONS TO EXISTING DISTRICT LINES WILL ONLY BE PERMITTED UPON ACCEPTANCE OF THE NEW SANITARY SEWER SYSTEM. EXISTING PIPE AT THE POINT OF CONNECTION SHALL NOT BE "BROKEN OUT" UNTIL THE NEW SYSTEM IS ACCEPTED.
7. THE DISTRICT, ITS REPRESENTATIVE, AND/OR THE DISTRICT ENGINEER, IS NOT A GUARANTOR OF THE CONSTRUCTING CONTRACTORS' OBLIGATIONS AND PERFORMANCE OF CONTRACT.
8. OBSERVATIONS OF WORK IN PROGRESS AND ON-SITE VISITS ARE NOT TO BE CONSTRUED AS A GUARANTEE BY THE DISTRICT OR DISTRICT ENGINEER OF THE CONTRACTORS' CONTRACTUAL COMMITMENT.
9. THE DISTRICT AND/OR DISTRICT ENGINEER, IS NOT RESPONSIBLE FOR SAFETY IN, ON, OR ABOUT THE PROJECT SITE, NOR FOR COMPLIANCE BY THE APPROPRIATE PARTY OF ANY REGULATIONS RELATING THERETO.
10. THE DISTRICT AND/OR DISTRICT ENGINEER, EXERCISES NO CONTROL OF THE SAFETY OF ADEQUACY OF ANY EQUIPMENT, BUILDING COMPONENTS, SCAFFOLDING, FORMS, OR ANY OTHER WORK AIDS USED IN OR ABOUT THE PROJECT, OR IN THE SUPERINTENDING OF THE SAME.
11. THE CONTRACTOR SHALL VERIFY EXISTING MANHOLE INVERTS TO BE CONNECTED TO PRIOR TO CONSTRUCTION STAKING.
12. THE CONTRACTOR SHALL TAKE CARE TO PROPERLY SHAPE ALL MANHOLE INVERTS AND BENCHES IN ACCORDANCE WITH DISTRICT STANDARDS AND SPECIFICATIONS, TO PROMOTE SMOOTH FLOW THROUGH THE MANHOLE. INVERTS OF LINES INTERSECTING AT 90° AND AT HIGHLY DIVERGENT OR FLAT SLOPES ARE ESPECIALLY CRITICAL. MANHOLE INVERTS SHALL BE CONSTRUCTED WITH A SMOOTH TROWEL FINISH, AND BENCHES FINISHED WITH A LIGHT BROOM, NON-SKID FINISH.
13. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE PROTECTION OF ALL UTILITY LINES WHETHER SHOWN ON THE PLANS OR NOT.
14. MAINTAIN MINIMUM OF 10 FEET SEPARATION BETWEEN WATER AND SANITARY SEWER MAINS.
15. DISTANCES FOR SEWER ARE FROM CENTER OF MANHOLE TO CENTER OF MANHOLE.
16. THE SANITARY SEWER SERVICES SHALL BE STUBBED OUT. THE STUB SHALL EXTEND INTO THE LOT TEN (10) FEET. THE CONTRACTOR SHALL FURNISH THE DISTRICT WITH AN AS-BUILT LOCATION OF THE WYE.
17. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE PROCUREMENT OF ALL PERMITS NECESSARY FOR THE CONSTRUCTION OF THE SANITARY SEWER LINE WORK.
18. ESTIMATED COST OF SANITARY SEWER MAIN CONSTRUCTION IS $ 1,800.
19. ESTIMATED QUANTITIES (SANITARY SEWER) ARE AS FOLLOWS:
   35 LF – 8" PVC AWWA C900 CLASS 150
   1 EA – 4' DIAMETER MANHOLES

GENERAL NOTES – WATER

1. ALL WATER LINES AND SYSTEM PLANS AND CONSTRUCTION, SHALL CONFORM WITH THE EAST CHERRY CREEK VALLEY WATER AND SANITATION DISTRICT STANDARDS AND SPECIFICATIONS, AND BE SUBJECT TO CONSTRUCTION OBSERVATION BY DISTRICT PERSONNEL OR REPRESENTATIVES. COPIES OF THE DISTRICT STANDARDS AND SPECIFICATIONS MAY BE OBTAINED FROM MEURER AND ASSOCIATES, INC., OR THE DISTRICT MANAGER. THE OWNER, HIS ENGINEER OR CONTRACTOR, SHALL SCHEDULE A PRECONSTRUCTION MEETING WITH THE DISTRICT MANAGER AND DISTRICT ENGINEER AT LEAST 48 HOURS PRIOR TO THE START OF CONSTRUCTION. PLANS WITH THE DISTRICT REVIEW STAMP WILL BE DISTRIBUTED AT THE PRECONSTRUCTION MEETING. NO CONSTRUCTION WILL BE PERMITTED UNTIL FORMAL COMPLETION OF EASEMENTS AND RECORDING, AND PRIOR TO THE PRECONSTRUCTION MEETING.
2. THE PIPE SPECIFIED BY THE OWNER OR HIS ENGINEER FOR THE WATER LINES IN THE PROJECT IS CLASS 50, DUCTILE IRON PIPE. ALL WATER LINES SHALL HAVE A MINIMUM OF FOUR AND ONE-HALF (4-1/2) FEET OF COVER AND BE LOCATED A MINIMUM OF TEN (10) FEET FROM THE SANITARY SEWER, AND FIVE (5) FEET FROM THE EDGE OF CONCRETE CURB AND GUTTER PAN.
3. PROBATIONARY ACCEPTANCE OF THE NEW WATER LINES IS CONTINGENT UPON RECEIVING COPIES OF:
   A. WATER LINE TRENCH COMPACTION TEST RESULTS,
   B. RECORD DRAWINGS, AND
   C. HEALTH DEPARTMENT TESTS. (CHLORINE AND/OR CLEAR WATER AS REQUIRED.)
4. THEORETICAL STATIC WATER PRESSURES ARE ESTIMATED TO RANGE FROM 69 PSI AT USGS ELEVATION 5920 TO 56 PSI AT USGS ELEVATION 5950 BASED UPON A HYDRAULIC GRADIENT OF USGS ELEVATION OF 6079. THE DISTRICT HAS PROVIDED ONLY THE HYDRAULIC GRADIENT ELEVATION.
5. ALL WATER LINE VALVES SHALL BE SET AT THE INTERSECTION OF THE EXTENDED PROPERTY LINE AND WATER LINE EXCEPT WHERE THAT POINT FALLS IN THE FLOW LINE OF A CONCRETE CROSS PAN. IN THAT CASE, THE VALVE SHALL BE LOCATED SO THAT SURFACE DRAINAGE DOES NOT INFILTRATE THE VALVE BOX. OTHER VALVE LOCATIONS MAY BE REQUIRED AS SHOWN ON THE PLANS. VALVE BOXES SHALL BE SET AT AN ELEVATION IN ACCORDANCE WITH ARAPAHOE COUNTY PAVING REQUIREMENTS.
6. POLYETHYLENE WRAPPING SHALL BE INSTALLED AROUND ALL DUCTILE IRON PIPE, FITTINGS, VALVES, FIRE HYDRANT BARRELS, AND RODS AND CLAMPS. MINIMUM THICKNESS OF POLYETHYLENE WRAPPING SHALL BE 8 MILS.
7. ALL WATER LINES SHALL BE CHLORINATED IN ACCORDANCE WITH A.W.W.A. C-601, "DISINFECTING WATER MAINS". THE PREFERRED METHOD IS TO USE SUFFICIENT CHLORINE TABLETS TO PRODUCE A 50 MG/L SOLUTION. THE TABLETS SHALL BE ADHERED TO THE TOP OF THE PIPE WITH A FOOD GRADE ADHESIVE. THE CHLORINATION OF THE WATER LINE SHALL BE PERFORMED PRIOR TO THE HYDROSTATIC TESTING.
8. ALL WATER LINES SHALL BE HYDROSTATIC TESTED IN ACCORDANCE WITH A.W.W.A C-600 SECTION 4, "HYDROSTATIC TESTING". ALL WATER LINES SHALL BE TESTED TO A MINIMUM OF 150 PSI. THE TEST SHALL BE SCHEDULED BY THE DISTRICT AND COORDINATED WITH ANY OTHER REVIEWING OR APPROVING AGENCY. THE ALLOWABLE LEAKAGE RATES ARE AS FOLLOWS:

PIPE SIZE INSIDE DIAMETER	ALLOWABLE LEAKAGE PER 1000 FEET GALLONS PER HOUR
6"	0.55 GAL/HOUR
8"	0.74 GAL/HOUR
12"	1.10 GAL/HOUR

9. ALL BENDS, TEES, FIRE HYDRANTS, BLOW-OFFS, AND PLUGS AT DEAD END MAINS SHALL BE PROTECTED FROM THRUST BY USING CONCRETE THRUST BLOCKS PER THE DISTRICT'S STANDARD DRAWING.
10. WHEN IT IS NECESSARY TO LOWER OR RAISE WATER LINES AT STORM DRAINS AND OTHER UTILITY CROSSINGS, A MINIMUM CLEARANCE OF 1.50 FEET SHALL BE MAINTAINED BETWEEN OUTSIDES OF PIPES.
11. THE CONTRACTOR SHALL HAVE IN HIS POSSESSION AT ALL TIMES ONE (1) SIGNED COPY OF THE PLANS WHICH HAVE BEEN APPROVED BY THE DISTRICT.
12. ALL BENDS SHALL BE RODDED. ALL WORK SHALL BE INSPECTED AND APPROVED BY PERSONNEL OF THE DISTRICT AT LEAST 48 HOURS PRIOR TO THE START OF CONSTRUCTION. A SET OF AS-BUILT PLANS SHALL BE PROVIDED TO THE DISTRICT ENGINEER PRIOR TO FINAL ACCEPTANCE OF THIS PROJECT.
13. PRIOR TO INSTALLATION OF WATER MAINS, ROAD CONSTRUCTION MUST HAVE PROGRESSED TO AT LEAST THE "SUB-GRADE" STAGE. SUB-GRADE IS DEFINED AS AN ELEVATION OF NO MORE THAN SEVEN INCHES BELOW THE FINISHED STREET GRADE. ALL VALVE BOXES AND FIRE HYDRANTS WILL BE ADJUSTED TO THE FINAL FINISHED GRADE BY THE CONTRACTOR.
14. THE ESTIMATED COST OF WATER MAIN CONSTRUCTION IS $ 7,700.
15. THE ESTIMATED QUANTITIES ARE AS FOLLOWS:
   335 LF – 8" DIP
   2 EA – 45° – 8" BENDS
   1 EA – 90° – 8" BENDS
   1 EA – 8" PLUG
   1 EA – 12" X 8" REDUCER
   1 EA – TIE TO EXISTING VALVE
   1 EA – 8" GATE VALVE
   1 EA – 2" BLOW-OFF



TIE ROD DETAIL

WASHER DETAIL

TIE RODS			
A	B	C	
ROD DIAMETER	THREAD LENGTH	ROD LENGTH	GRADE
3/4", 1"	6"	1' TO 11' & 20'	MS
3/4"-1 1/2"	All Thread	1' TO 11' & 20'	HS

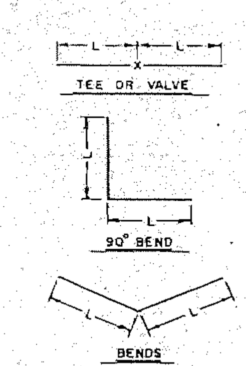
WASHERS		
D	E	G
WIDTH	HOLE DIAMETER	THICKNESS
5"	1/8" Larger than Rod Ø	1/2"
6"	1/8" Larger than Rod Ø	5/8"

NOTE:
1. SEE TIED JOINTS ROD DIMENSIONS SHEET.
2. SEE CLAMP DETAILS AND DIMENSIONS (SHEET 21.) FOR PROPER PLACEMENT OF WASHERS.
3. MS = MILD STEEL
   HS = HIGH STRENGTH

TIE ROD AND WASHER DETAILS

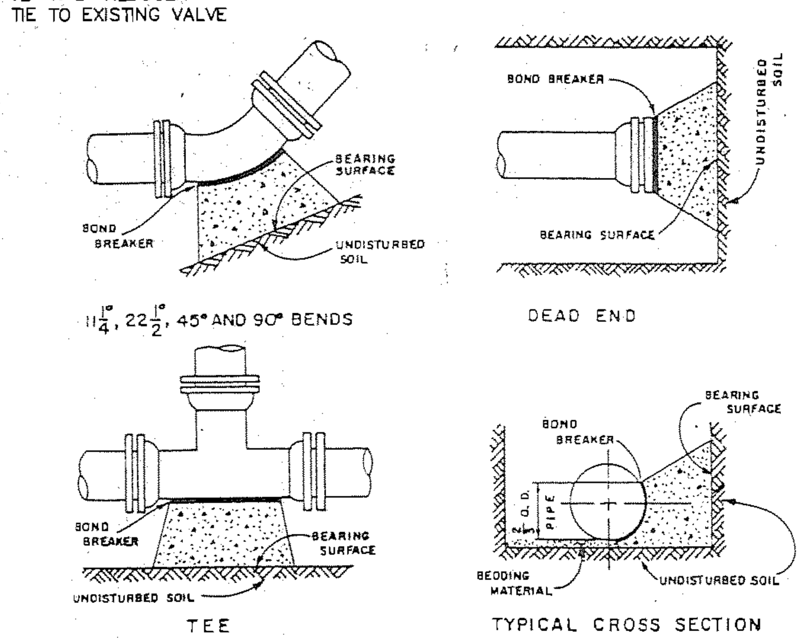
ROD DIAMETER, GRADE & LENGTH OF TIED PIPE

PIPE SIZE	4"			6"			8"			12"			16"			20"			24"		
FITTING	D	L	G	D	L	G	D	L	G	D	L	G	D	L	G	D	L	G	D	L	G
90° BEND, TEE, PLUG OR VALVE	3/4"	30'		[illegible]	45'	M.S.	3/4"	60'	M.S.	3/4"	86'	H.S.	1"	108'	H.S.	1 1/4"	132'	H.S.	–	155.0'	–
45° BEND	3/4"	9'	M.S.	3/4"	13'	M.S.	3/4"	18'	M.S.	3/4"	25'	M.S.	1"	32'	M.S.	3/4"	39'	H.S.	–	45.0'	–
22 1/2° BEND	3/4"	1.0'	M.S.	3/4"	4'	M.S.	3/4"	5'	M.S.	3/4"	7'	M.S.	3/4"	8'	M.S.	3/4"	10'	M.S.	–	12.0'	–
11 1/4° BEND	—	—	—	—	—	—	3/4"	1.0'	M.S.	3/4"	2'	M.S.	3/4"	2'	M.S.	3/4"	3'	M.S.	–	3.0'	–



NOTES:
1- LENGTH OF TIED PIPE MEASURED EACH WAY FROM VALVES AND BENDS.
2- CLAMPS AND RODS NOT ALLOWED FOR 24" AND LARGER PIPES.
3- D= DIAMETER, L = LENTH, G = GRADE
   M.S. = MILD STEEL, H.S. = HIGH STRENGTH.
4- MINIMUM 4.5' GROUND COVER REQUIRED.
5- BASED ON 150 PSI INTERNAL PRESSURE, FOR L AND PRESSURES LISTED ON SHEET 16 OF 68 FOR D AND G.
6- M.S. MEANS MILD STEEL ROD A.S.T.M STANDARD DESIGNATION A-36.
7- H.S. MEANS HIGH STRENGTH ROD A.S.T.M. STANDARD DESIGNATION A-193 GRADE B-7.
8- NUTS SHALL BE A.S.T.M. STANDARD DESIGNATION A-307 GRADE A OR B HEXAGON HEAVY SERIES.
9- SEE TIE ROD DETAIL DRAWING. ALSO, TIE ROD COUPLING DETAILS, CLAMP DETAILS AND SET CLAMP DETAILS.
10- LENGTH REFERS TO THE AMOUNT OF PIPE WHICH MUST BE TIED TOGETHER AND IS NOT NECESSARILY THE LENGTH OF THE RODS.

LENGTH OF TIED PIPE

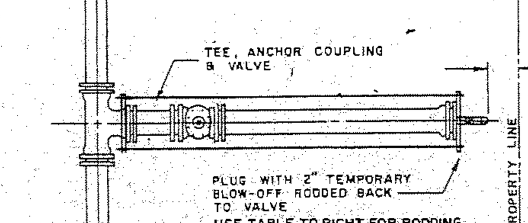


NOTES:
1- BEARING SURFACES SHOWN IN CHART ARE MINIMUM.
2- BASED ON 150 PSI INTERNAL PIPE PRESSURE PLUS WATER HAMMER.
   4", 6", 8" AND 12" WATER HAMMER = 110 P.S.I.
   16", 20" AND 24" WATER HAMMER = 70 P.S.I.
3- SEE SECTION 6.43 AND SECTION 8.20 OF THE ENGINEERING STANDARDS.
4- BASED ON 3,000 psf SOIL BEARING CAPACITY.
5- NA = NOT APPLICABLE.

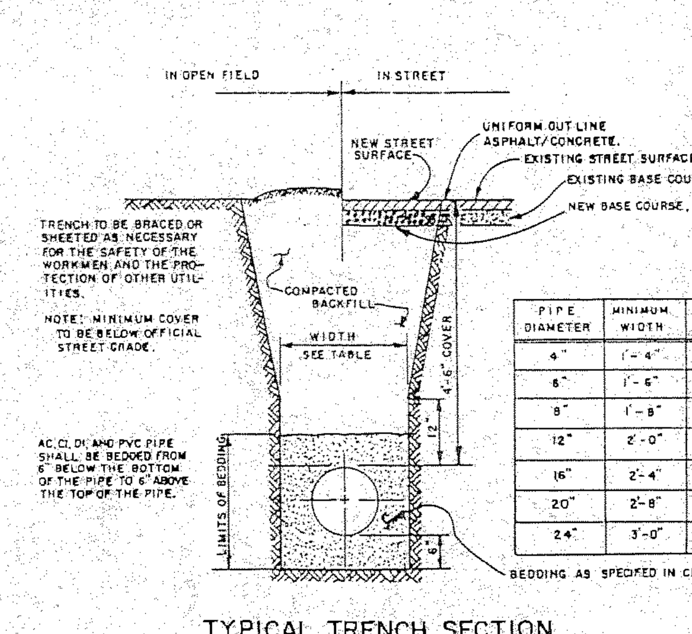
MINIMUM BEARING SURFACE AREA
(IN SQUARE FEET)

SIZE OF PIPE	BENDS 11 1/4°	22 1/2°	45°	90°	TEE OR DEAD END
4"	1.00	1.00	1.00	NA	1.50
6"	1.00	1.25	2.25	NA	3.00
8"	1.00	2.00	4.00	NA	5.25
12"	2.25	4.50	8.75	NA	11.25
16"	3.75	7.50	14.50	27.00	19.00
20"	5.00	10.00	19.50	35.50	25.00
24"	7.00	14.00	27.75	51.00	36.00

CONCRETE KICKBLOCKS BEARING SURFACES AND INSTALLATION



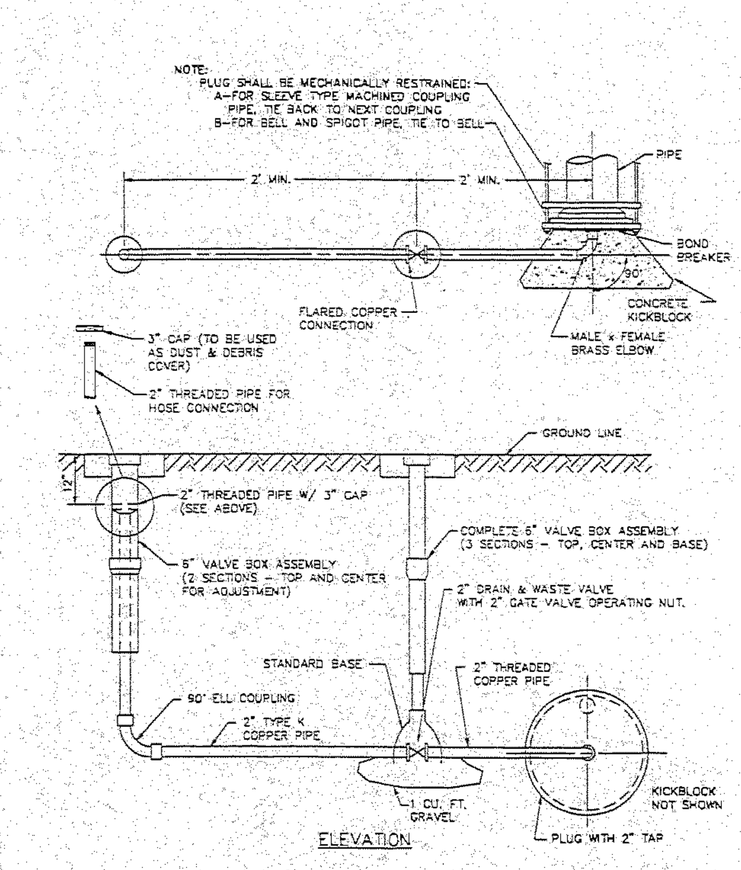
STUB-OUT CONFIGURATIONS FOR FUTURE EXTENSIONS



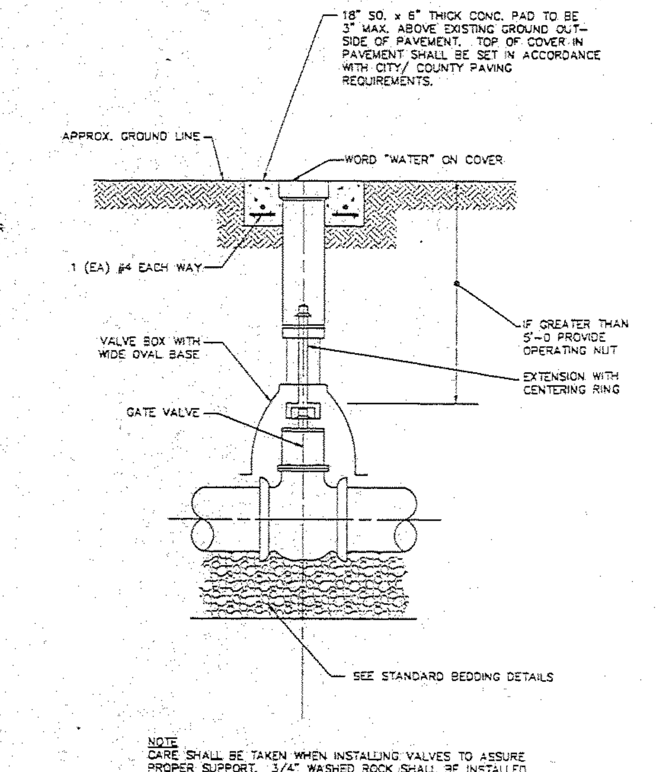
PIPE DIAMETER	MINIMUM WIDTH	MAXIMUM WIDTH
4"	1'-4"	20"
6"	1'-6"	22"
8"	1'-8"	24"
12"	2'-0"	28"
16"	2'-4"	32"
20"	2'-8"	36"
24"	3'-0"	40"

TYPICAL TRENCH SECTION

TYPICAL TRENCH SECTION PIPE PROTECTION

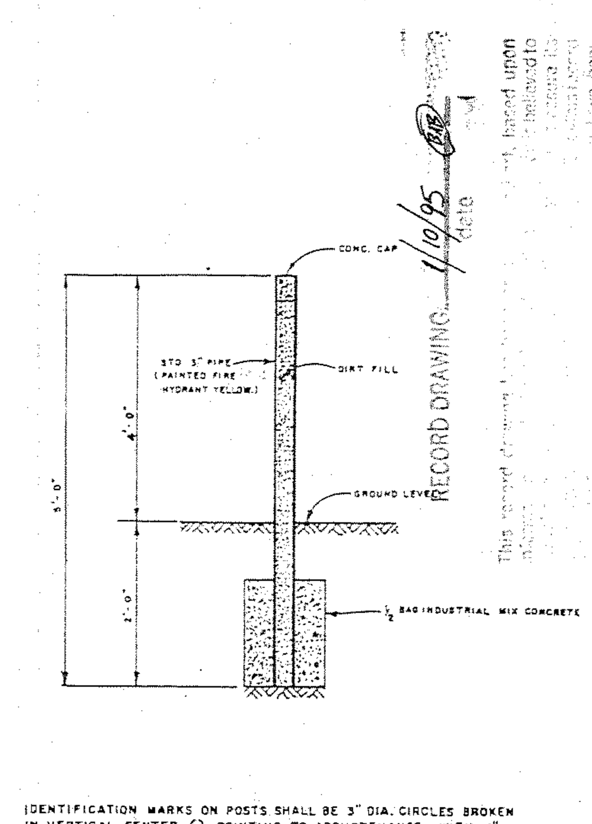


BLOW-OFF DETAIL



VALVES SHALL NOT BE PLACED IN CONCRETE CROSS PANS.

GATE VALVE DETAIL



IDENTIFICATION MARKS ON POSTS SHALL BE 3" DIA. CIRCLES BROKEN IN VERTICAL CENTER ( ) POINTING TO APPURTENANCE, WITH 1" STENCILS INSIDE INDICATING TYPE OF APPURTENANCE (W.V., 12" VALVE, ETC.) AND THE DISTANCE IN FEET AND INCHES FROM POST.

REFERENCE POST TYPICAL DETAIL

UNTIL SUCH TIME AS THESE DRAWINGS ARE APPROVED BY THE APPROPRIATE REVIEWING AGENCIES, JR ENGINEERING, LTD. APPROVES THEIR USE ONLY FOR THE PURPOSES DESIGNATED BY WRITTEN AUTHORIZATION.

CALL UTILITY NOTIFICATION CENTER OF COLORADO
1-800-922-1987 OR 534-6700 IN METRO DENVER
CALL 2-BUSINESS DAYS IN ADVANCE BEFORE YOU DIG, GRADE, OR EXCAVATE FOR THE MARKING OF UNDERGROUND MEMBER UTILITIES.

JR Engineering, Ltd.
6110 Greenwood Plaza Blvd.
Englewood, Colorado 80111
Tel (303) 740-9393
FAX (303) 721-9019

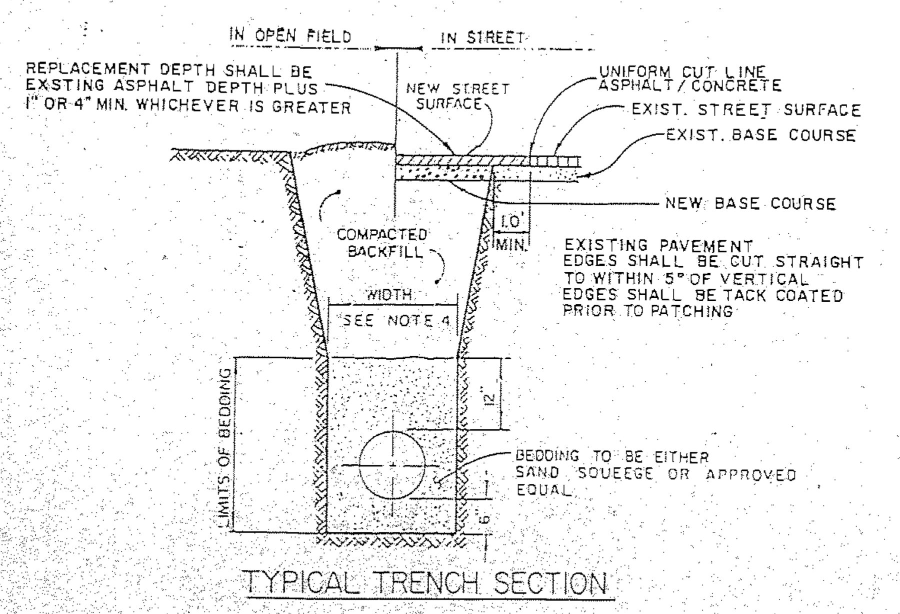
No.	REVISION	BY	DATE
1	PER DISTRICT COMMENTS	RFL	6/21/94
2	AS-BUILT INFORMATION BY MUELLER ENGINEERING	BAB	

SCALE	1"=50'
DATE	05/09/94
DES. BY	RFL
CHK. BY	
DWN. BY	RFL

PINEY CREEK FILING NO. 10
WATER AND SANITARY SEWER PLAN AND PROFILE AND DETAILS
PREPARED FOR RICHMOND HOMES

SHEET 7 OF 8
JOB NO. 1533.47
REV. 0

PLOT SCALE 1=50, DATE 06/22/94, TIME 17:56, FILE X:\153347\ACAD\PC10UTP7.DWG

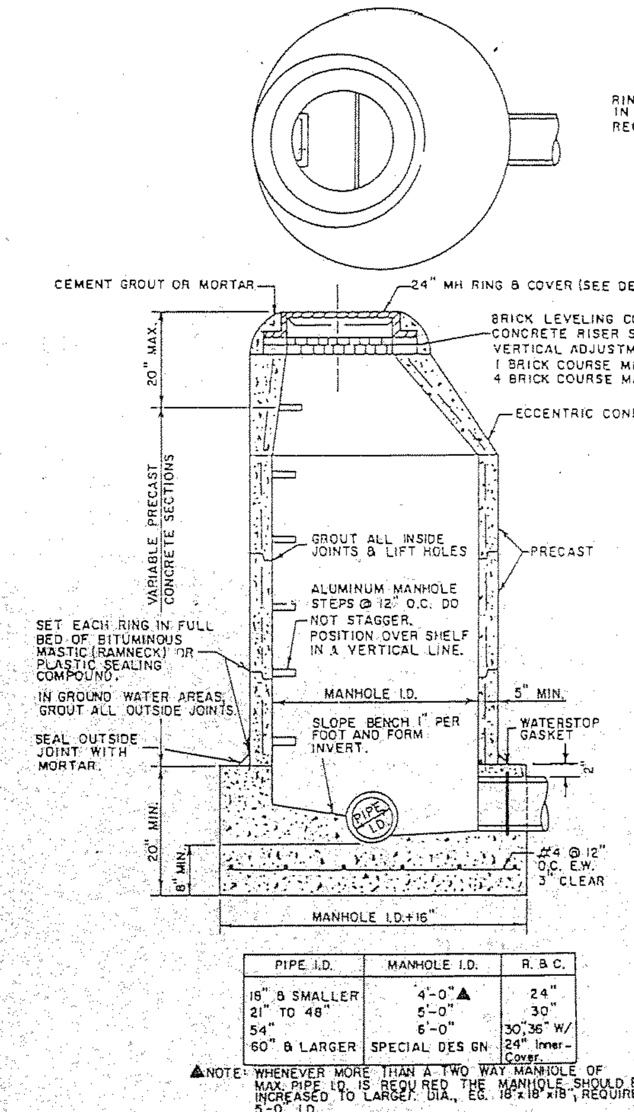


TYPICAL TRENCH SECTION

NOTES:

1. THE TRENCH SHALL BE IN ACCORDANCE WITH APPLICABLE LOCAL, STATE, AND FEDERAL SPECIFICATIONS AND SAFETY REGULATIONS.
2. A CONSTRUCTION TRAFFIC CONTROL PLAN SHALL BE SUBMITTED TO AND APPROVED BY ARAPAHOE COUNTY PRIOR TO ISSUANCE OF CONSTRUCTION PERMITS IN THE COUNTY RIGHT-OF-WAY.
3. PIPE SHALL BE BEDDED FROM 6" BELOW THE BOTTOM OF THE PIPE TO 12" ABOVE THE TOP OF PIPE.
4. TRENCH WIDTH SHALL NOT BE MORE THAN 16" NOR LESS THAN 12" WIDER THAN THE LARGEST OUTSIDE DIAMETER OF THE PIPE.
5. SHOULD THE TRENCH BE EXCAVATED WIDER THAN ALLOWED, A CONCRETE CRADLE SHALL BE PLACED WITH 2500 P.S.I. CONCRETE FROM TRENCH BOTTOM TO PIPE SPRINGLINE.(SEE SPECIAL BEDDING DETAIL.)
6. BACKFILL COMPACTION REQUIREMENTS: MINIMUM DENSITY WILL BE DETERMINED IN ACCORDANCE WITH A.A.S.H.T.O. DESIGNATION T99 OR T180 AS DEFINED BY THE STANDARD SPECIFICATION SECTION 203.11 OF THE STATE OF COLORADO STANDARD SPECIFICATION FOR ROAD AND BRIDGE CONSTRUCTION. COMPACTION SHALL BE MIN. 95% S.P.D. IN STREET R.O.W; OUTSIDE OF STREET R.O.W. SHALL BE 90% S.P.D.
7. FULL DEPTH ASPHALT CAN BE USED AS AN ALTERNATIVE TO BASE COURSE. A RATIO OF 3 INCHES BASE COUSE TO 1 INCH OF ASPHALT SHALL BE USED IN THE SUBSTITUTION. A TEMPORARY COLD-MIX ASPHALT PATCH, 4" IN DEPTH, WILL BE REQUIRED FOR ALL STREET CUTS IF A PERMANENT HOT-MIX ASPALT PATCH CANNOT BE APPLIED AFTER CONSTRUCTION IS COMPLETED.
8. THIS TRENCH PATCHING DETAILS REQUIREMENTS IN ADDITION TO THOSE SPECIFIED IN THE LATEST EDITION OF THE COLORADO DEPARTMENT OF HIGHWAY'S STANDARD SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION.

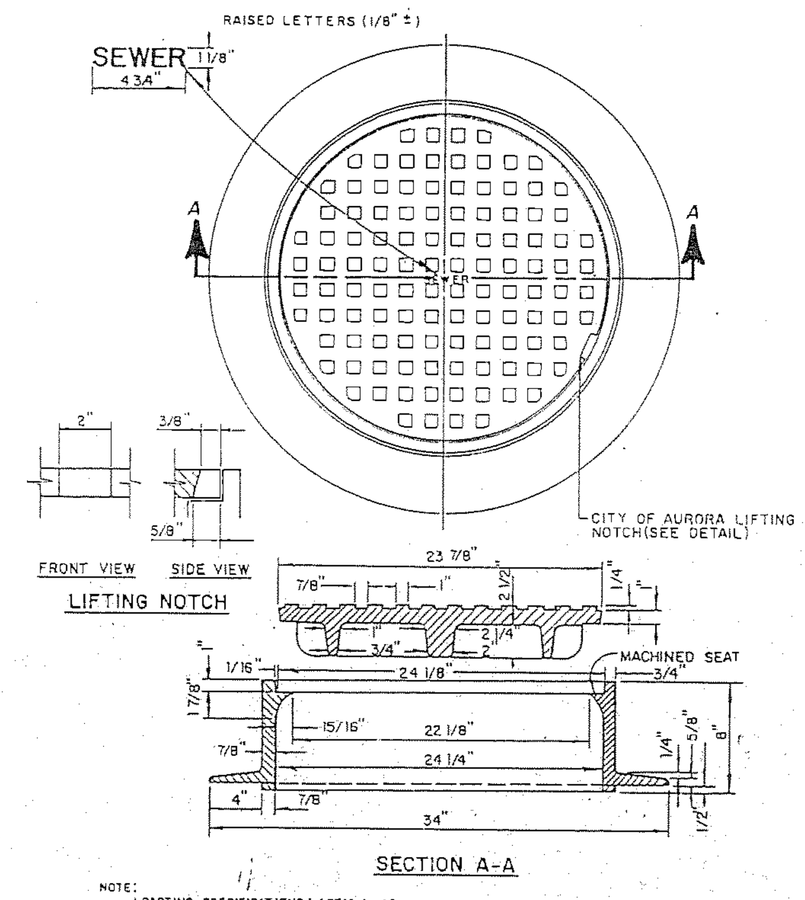
STANDARD BEDDING



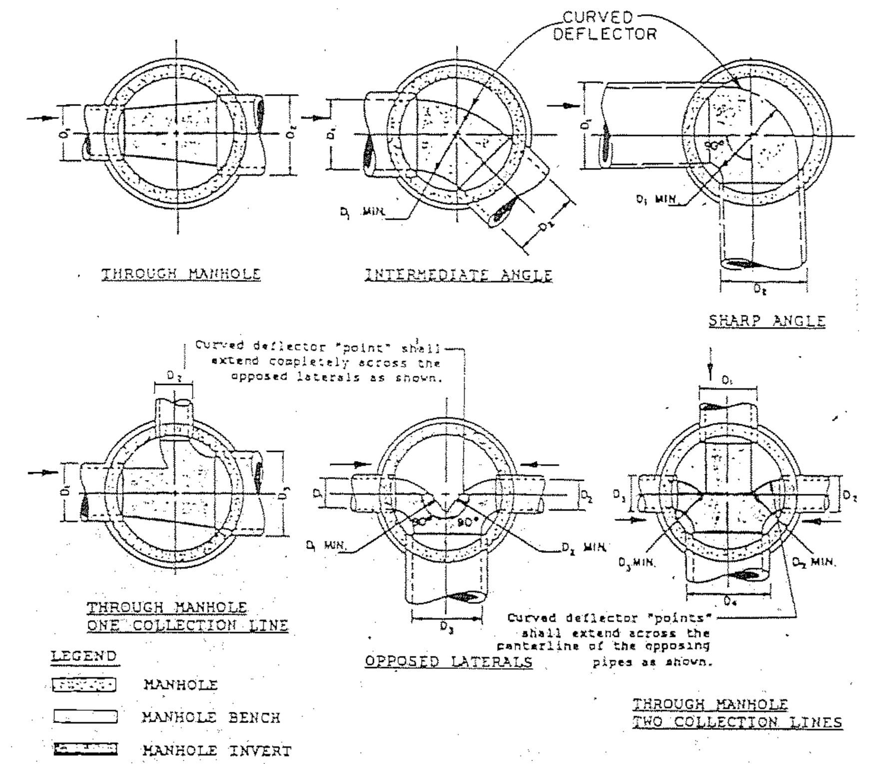
NOTES:

1. MANHOLE BARREL MINIMUM DIAMETER SHALL CONFORM TO TABLE BELOW.
2. SHAPING FOR SMOOTH MANHOLE INVERTS MUST BE DONE BY FORMING OR SHAPING BASE CONCRETE.
3. MANHOLE STEPS SHALL BE ALCOA NO. 12653B OR APPROVED EQUAL.(SEE ALUMINUM STEP DETAIL FOR FUTHER INFORMATION).
4. PRECAST CONCRETE SECTIONS SHALL CONFORM TO ASTM C-478.
5. BLOCK-OUTS WHEN APPROVED SHALL EXTEND A MAX. OF 6" PAST MANHOLE O.D. AND BE SATISFACTORILY PLUGGED AND SEALED.
6. CONCRETE MANHOLES MAY BE POURED IN PLACE ONLY WITH PRIOR APPROVAL.
7. ALL MORTAR GROUT SHALL BE MIXED WITH TYPE II CEMENT.
8. BENCH MUST HAVE A BRUSHED, NON-SKID SURFACE.
9. OUTFALL OR DROP MANHOLES SHALL BE LINED WITH SIKAGARD NO. 62 OR APPROVED EQUAL, COATED WITH 20 MIL. MIN. APPLIED IN 4-7 MIL. LAYERS, PER MANUFACTURERS SPECIFICATIONS.

PRECAST MANHOLE



24" MANHOLE RING AND COVER



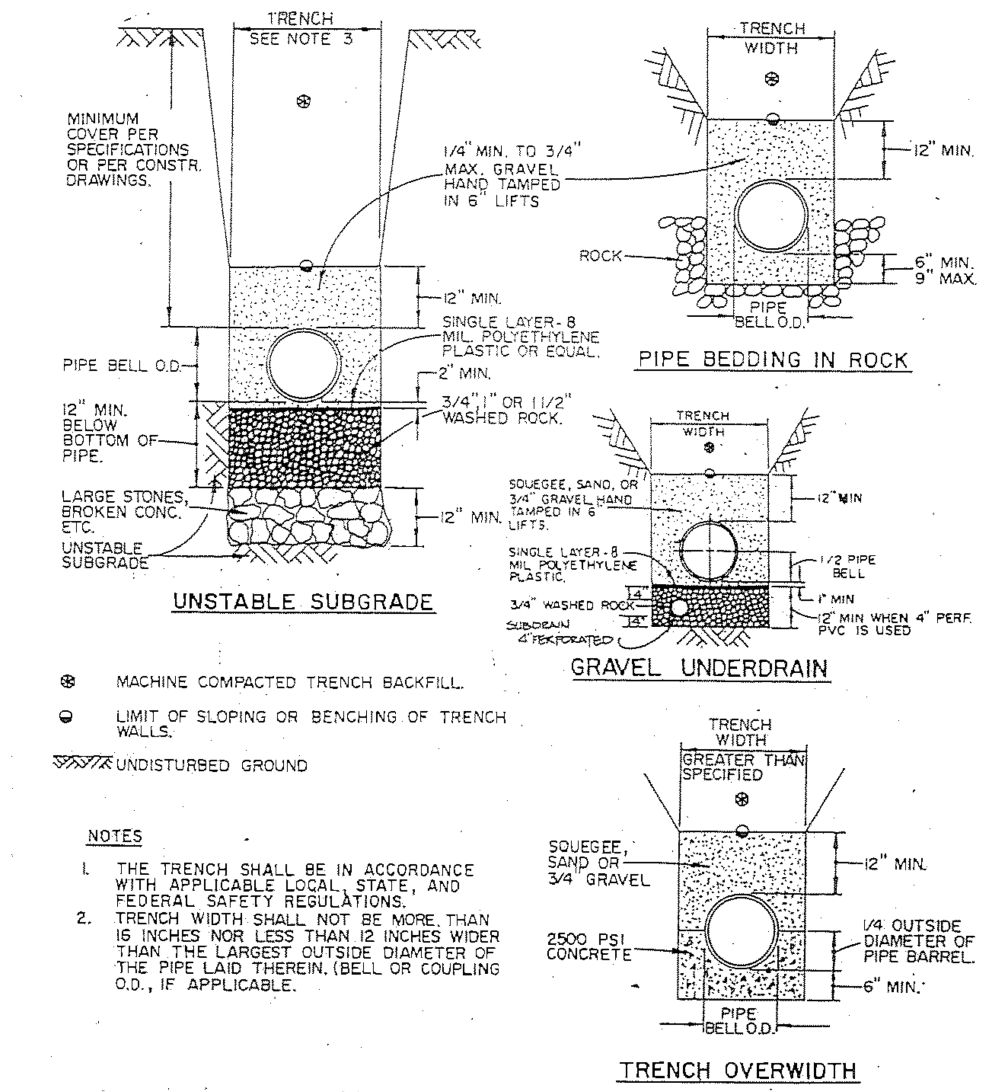
LEGEND

- MANHOLE
- MANHOLE BENCH
- MANHOLE INVERT

NOTES

1. Pipe invert elevations and drop through manholes shall be in conformance with the reviewed and signed Construction Plans. The intention is to promote smooth, non-turbulent flow through the manholes by keeping the larger lines lower in the manhole and bringing the smaller lines in slightly higher.
2. Maximum inside drop through any manhole shall be 12 inches.
3. Minimum drop through any manhole shall be 0.2 Ft.
4. All invert deflectors shall be curved in shape to provide smooth flow transitions as shown on this detail.
5. Minimum angle between the centerline of any incoming pipe and the centerline of the outgoing pipe shall be 90 degrees.

MANHOLE BASE AND DEFLECTOR

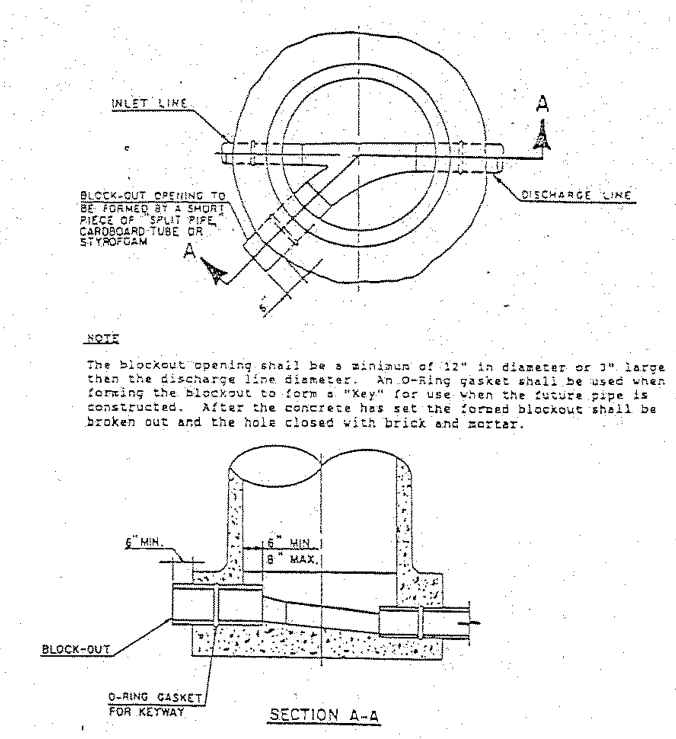


- MACHINE COMPACTED TRENCH BACKFILL.
- LIMIT OF SLOPING OR BENCHING OF TRENCH WALLS.
- UNDISTURBED GROUND

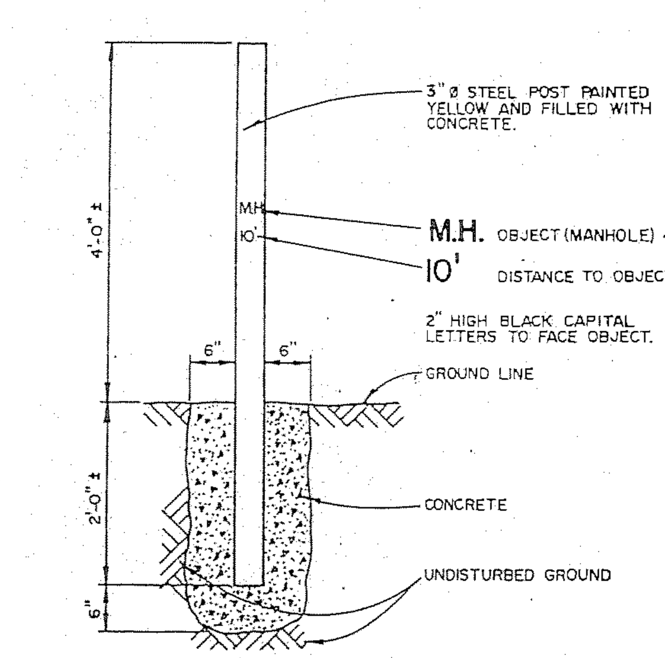
NOTES

1. THE TRENCH SHALL BE IN ACCORDANCE WITH APPLICABLE LOCAL, STATE, AND FEDERAL SAFETY REGULATIONS.
2. TRENCH WIDTH SHALL NOT BE MORE THAN 16 INCHES NOR LESS THAN 12 INCHES WIDER THAN THE LARGEST OUTSIDE DIAMETER OF THE PIPE LAID THEREIN. (BELL OR COUPLING O.D., IF APPLICABLE.

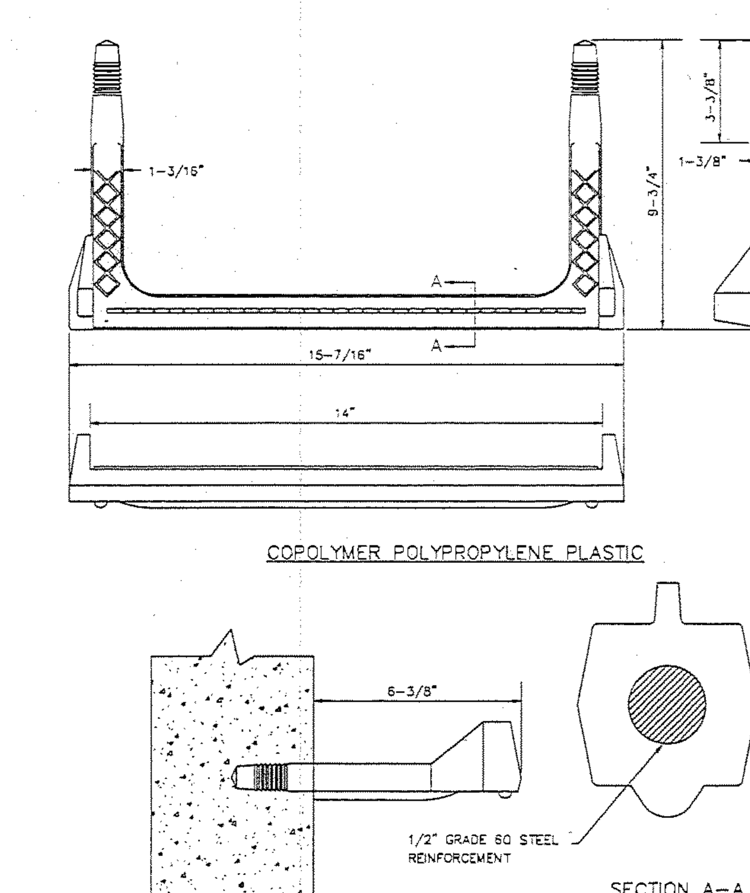
SPECIAL BEDDING DETAILS



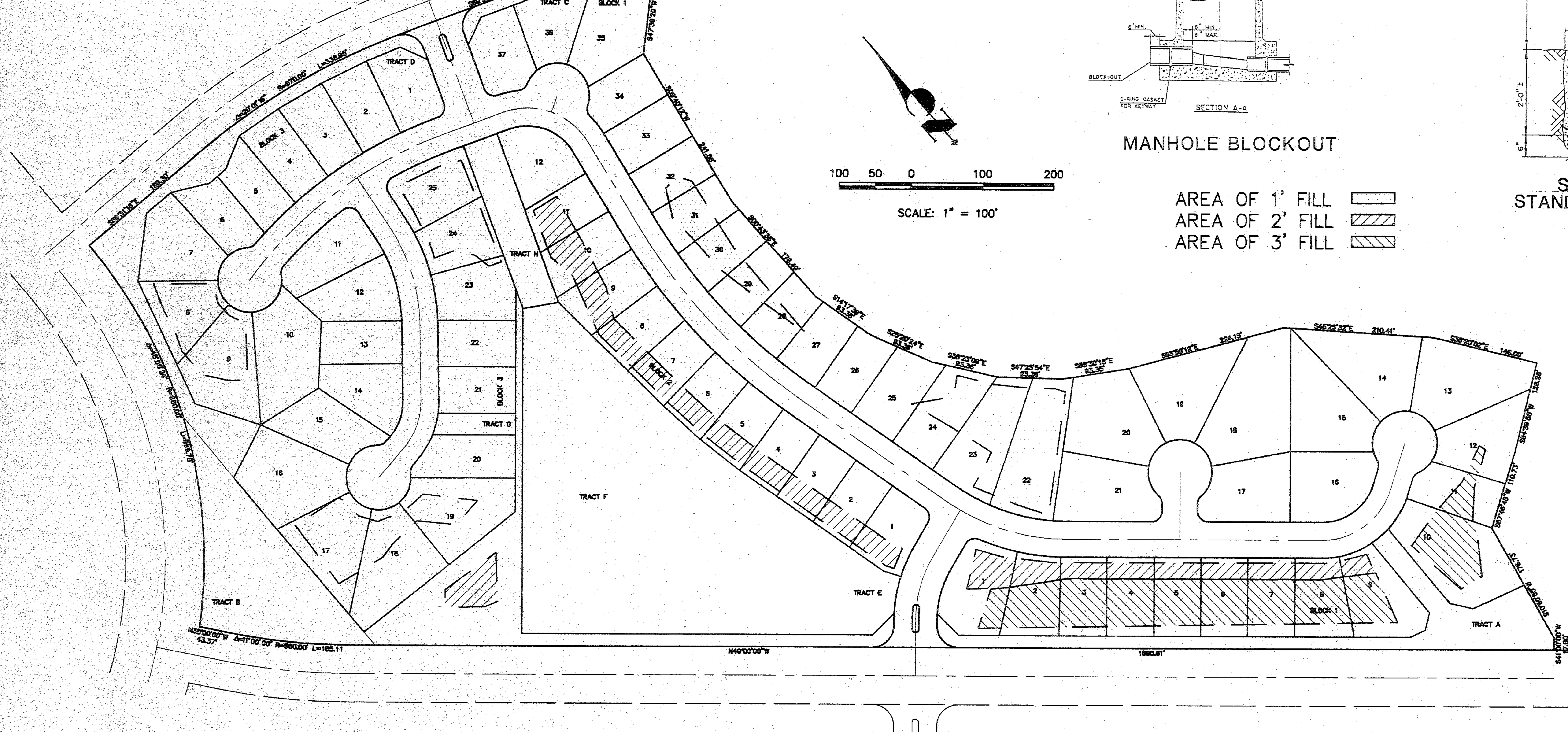
MANHOLE BLOCKOUT



SANITARY SEWER STANDARD MARKER POST



PLASTIC STEP



SCALE: 1" = 100'

AREA OF 1' FILL
AREA OF 2' FILL
AREA OF 3' FILL

TOTAL FILL AREA = 10,520 CY
15% = 1,580 CY
TOTAL = 12,100 CY

INSPECTION OF WATER AND SEWER CONSTRUCTION PROVIDED BY MEURER AND ASSOCIATES MARK SKELSKY

AS-CONSTRUCTED INFORMATION IS SHOWN WITHIN BUBBLES

RECORD DRAWING 1/10/95

FOR INFORMATION ONLY

UNTIL SUCH TIME AS THESE DRAWINGS ARE APPROVED BY THE APPROPRIATE REVIEWING AGENCIES, JR ENGINEERING, LTD. APPROVES THEIR USE ONLY FOR THE PURPOSES DESIGNATED BY WRITTEN AUTHORIZATION.

CALL UTILITY NOTIFICATION CENTER OF COLORADO
1-800-922-1987
OR 534-6700 IN METRO DENVER
CALL 2-BUSINESS DAYS IN ADVANCE BEFORE YOU DIG, GRADE, OR EXCAVATE FOR THE MARKING OF UNDERGROUND MEMBER UTILITIES.

JR Engineering, Ltd.
6110 Greenwood Plaza Blvd.
Englewood, Colorado 80111
Tel. (303) 740-9393
FAX (303) 721-9019

No.	REVISION	BY	DATE
1	PREPARE AS-BUILT DRAWINGS	BAB	1/10/95

SCALE	1"=50'
DATE	05/09/94
DES. BY	RFL
CHK. BY	
DWN. BY	RFL

PINEY CREEK FILING NO. 10

AREA FOR PLACEMENT OF FILL MATERIALS

PREPARED FOR RICHMOND HOMES

SHEET 8 OF 8

JOB NO.	REV.
1533.47	0

PLOT SCALE 1=100, DATE 05/12/94, TIME 08:05, FILE X:\153347\ACAD\PC10GR.DWG

MEC 9402

NORTH ARAPAHOE REGIONAL

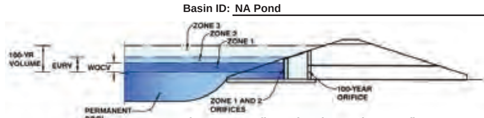
DETENTION BASIN INFORMATION

DETENTION BASIN STAGE-STORAGE TABLE BUILDER

UD-Detention, Version 3.07 (February 2017)

Project: Cherry Creek Minor Tributaries in Arapahoe County MDP

Basin ID: NA Pond



Example Zone Configuration (Retention Pond)

Required Volume Calculation

Selected BMP Type =	**EDB**			
Watershed Area =	127.80	acres		
Watershed Length =	4,335	ft		
Watershed Slope =	0.017	ft/ft		
Watershed Imperviousness =	46.50%	percent		
Percentage Hydrologic Soil Group A =	0.0%	percent		
Percentage Hydrologic Soil Group B =	100.0%	percent		
Percentage Hydrologic Soil Groups C/D =	0.0%	percent		
Desired WQCV Drain Time =	40.0	hours		
Location for 1-hr Rainfall Depths =	User Input			
Water Quality Capture Volume (WQCV) =	2.097	acre-feet	Optional User Override 1-hr Precipitation	
Excess Urban Runoff Volume (EURV) =	6.316	acre-feet		
2-yr Runoff Volume (P1 = 0.87 in.) =	3.688	acre-feet	0.87	inches
5-yr Runoff Volume (P1 = 1.13 in.) =	5.233	acre-feet	1.13	inches
10-yr Runoff Volume (P1 = 1.37 in.) =	7.470	acre-feet	1.37	inches
25-yr Runoff Volume (P1 = 1.73 in.) =	11.783	acre-feet	1.73	inches
50-yr Runoff Volume (P1 = 2.03 in.) =	14.816	acre-feet	2.03	inches
100-yr Runoff Volume (P1 = 2.36 in.) =	18.817	acre-feet	2.36	inches
500-yr Runoff Volume (P1 = 3.21 in.) =	28.199	acre-feet	3.21	inches
Approximate 2-yr Detention Volume =	3.450	acre-feet		
Approximate 5-yr Detention Volume =	4.914	acre-feet		
Approximate 10-yr Detention Volume =	6.844	acre-feet		
Approximate 25-yr Detention Volume =	8.329	acre-feet		
Approximate 50-yr Detention Volume =	9.093	acre-feet		
Approximate 100-yr Detention Volume =	10.627	acre-feet		

Stage-Storage Calculation

Zone 1 Volume (WQCV) =	2.097	acre-feet
Zone 2 Volume (100-year - Zone 1) =	8.530	acre-feet
Select Zone 3 Storage Volume (Optional) =		acre-feet
Total Detention Basin Volume =	10.627	acre-feet
Initial Surcharge Volume (ISV) =	user	ft^3
Initial Surcharge Depth (ISD) =	user	ft
Total Available Detention Depth (H_{total}) =	user	ft
Depth of Trickle Channel (H_{TC}) =	user	ft
Slope of Trickle Channel (S_{TC}) =	user	ft/ft
Slopes of Main Basin Sides (S_{main}) =	user	H:V
Basin Length-to-Width Ratio ($R_{L/W}$) =	user	
Initial Surcharge Area (A_{ISV}) =	user	ft^2
Surcharge Volume Length (L_{ISV}) =	user	ft
Surcharge Volume Width (W_{ISV}) =	user	ft
Depth of Basin Floor (H_{FLOOR}) =	user	ft
Length of Basin Floor (L_{FLOOR}) =	user	ft
Width of Basin Floor (W_{FLOOR}) =	user	ft
Area of Basin Floor (A_{FLOOR}) =	user	ft^2
Volume of Basin Floor (V_{FLOOR}) =	user	ft^3
Depth of Main Basin (H_{MAIN}) =	user	ft
Length of Main Basin (L_{MAIN}) =	user	ft
Width of Main Basin (W_{MAIN}) =	user	ft
Area of Main Basin (A_{MAIN}) =	user	ft^2
Volume of Main Basin (V_{MAIN}) =	user	ft^3
Calculated Total Basin Volume (V_{total}) =	**user**	acre-feet

Depth Increment = 1 ft

Stage - Storage Description	Stage (ft)	Optional Override Stage (ft)	Length (ft)	Width (ft)	Area (ft^2)	Optional Override Area (ft^2)	Area (acre)	Volume (ft^3)	Volume (ac-ft)
Top of Micropool	--	0.00	--	--	--	2,015	0.046		
	--	0.40	--	--	--	4,029	0.092	1,169	0.027
	--	1.40	--	--	--	7,745	0.178	7,018	0.161
	--	2.40	--	--	--	13,713	0.315	17,824	0.409
	--	3.40	--	--	--	19,405	0.445	34,383	0.789
	--	4.40	--	--	--	28,097	0.645	58,135	1.335
	--	5.40	--	--	--	47,234	1.084	95,800	2.199
	--	6.40	--	--	--	60,011	1.378	149,423	3.430
	--	7.40	--	--	--	65,787	1.510	212,322	4.874
	--	8.40	--	--	--	65,787	1.510	278,109	6.385
	--	9.40	--	--	--	65,787	1.510	343,896	7.895
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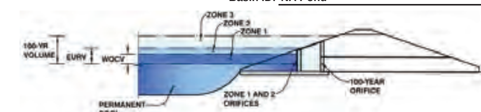
Detention Basin Outlet Structure Design

UD-Detention, Version 3.07 (February 2017)

Project: Cherry Creek Minor Tributaries in Arapahoe County MDP

Basin ID: NA Pond



Example Zone Configuration (Retention Pond)

	Stage (ft)	Zone Volume (ac-ft)	Outlet Type
Zone 1 (WQCV)	5.31	2.097	Orifice Plate
Zone 2 (100-year)		8.530	Rectangular Orifice
Zone 3			Weir&Pipe (Circular)
		10.627	Total

User Input: Orifice at Underdrain Outlet (typically used to drain WQCV in a Filtration BMP)

Underdrain Orifice Invert Depth =	N/A	ft (distance below the filtration media surface)
Underdrain Orifice Diameter =	N/A	inches

Calculated Parameters for Underdrain

Underdrain Orifice Area =	N/A	ft^2
Underdrain Orifice Centroid =	N/A	feet

User Input: Orifice Plate with one or more orifices or Elliptical Slot Weir (typically used to drain WQCV and/or EURV in a sedimentation BMP)

Invert of Lowest Orifice =	0.00	ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Orifice Plate =	3.56	ft (relative to basin bottom at Stage = 0 ft)
Orifice Plate: Orifice Vertical Spacing =	N/A	inches
Orifice Plate: Orifice Area per Row =	N/A	inches

Calculated Parameters for Plate

WQ Orifice Area per Row =	N/A	ft^2
Elliptical Half-Width =	N/A	feet
Elliptical Slot Centroid =	N/A	feet
Elliptical Slot Area =	N/A	ft^2

User Input: Stage and Total Area of Each Orifice Row (numbered from lowest to highest)

	Row 1 (required)	Row 2 (optional)	Row 3 (optional)	Row 4 (optional)	Row 5 (optional)	Row 6 (optional)	Row 7 (optional)	Row 8 (optional)
Stage of Orifice Centroid (ft)	0.06	0.40	0.73	1.06	1.40	1.73	2.06	2.40
Orifice Area (sq. inches)	7.07	1.77	1.77	1.77	1.77	1.77	1.77	1.77

	Row 9 (optional)	Row 10 (optional)	Row 11 (optional)	Row 12 (optional)	Row 13 (optional)	Row 14 (optional)	Row 15 (optional)	Row 16 (optional)
Stage of Orifice Centroid (ft)	2.73	3.06	3.40					
Orifice Area (sq. inches)	1.77	1.77	1.77					

User Input: Vertical Orifice (Circular or Rectangular)

	Zone 2 Rectangular	Not Selected	
Invert of Vertical Orifice =	3.56	N/A	ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Vertical Orifice =	7.01	N/A	ft (relative to basin bottom at Stage = 0 ft)
Vertical Orifice Height =	37.20	N/A	inches
Vertical Orifice Width =	20.25		inches

Calculated Parameters for Vertical Orifice

	Zone 2 Rectangular	Not Selected	
Vertical Orifice Area =	5.23	N/A	ft^2
Vertical Orifice Centroid =	1.55	N/A	feet

User Input: Overflow Weir (Dropbox) and Grate (Flat or Sloped)

	Zone 3 Weir	Not Selected	
Overflow Weir Front Edge Height, Ho =	7.01	N/A	ft (relative to basin bottom at Stage = 0 ft)
Overflow Weir Front Edge Length =	10.83	N/A	feet
Overflow Weir Slope =	0.00	N/A	H:V (enter zero for flat grate)
Horiz. Length of Weir Sides =	3.04	N/A	feet
Overflow Grate Open Area % =	70%	N/A	%, grate open area/total area
Debris Clogging % =	50%	N/A	%

Calculated Parameters for Overflow Weir

	Zone 3 Weir	Not Selected	
Height of Grate Upper Edge, H_t =	7.01	N/A	feet
Over Flow Weir Slope Length =	3.04	N/A	feet
Grate Open Area / 100-yr Orifice Area =	2.40	N/A	should be ≥ 4
Overflow Grate Open Area w/o Debris =	23.05	N/A	ft^2
Overflow Grate Open Area w/ Debris =	11.53	N/A	ft^2

User Input: Outlet Pipe w/ Flow Restriction Plate (Circular Orifice, Restrictor Plate, or Rectangular Orifice)

	Zone 3 Circular	Not Selected	
Depth to Invert of Outlet Pipe =	2.21	N/A	ft (distance below basin bottom at Stage = 0 ft)
Circular Orifice Diameter =	42.00	N/A	inches

Calculated Parameters for Outlet Pipe w/ Flow Restriction Plate

	Zone 3 Circular	Not Selected	
Outlet Orifice Area =	9.62	N/A	ft^2
Outlet Orifice Centroid =	1.75	N/A	feet
Half-Central Angle of Restrictor Plate on Pipe =	N/A	N/A	radians

User Input: Emergency Spillway (Rectangular or Trapezoidal)

Spillway Invert Stage=	8.16	ft (relative to basin bottom at Stage = 0 ft)
Spillway Crest Length =	73.00	feet
Spillway End Slopes =	4.00	H:V
Freeboard above Max Water Surface =	2.00	feet

Calculated Parameters for Spillway

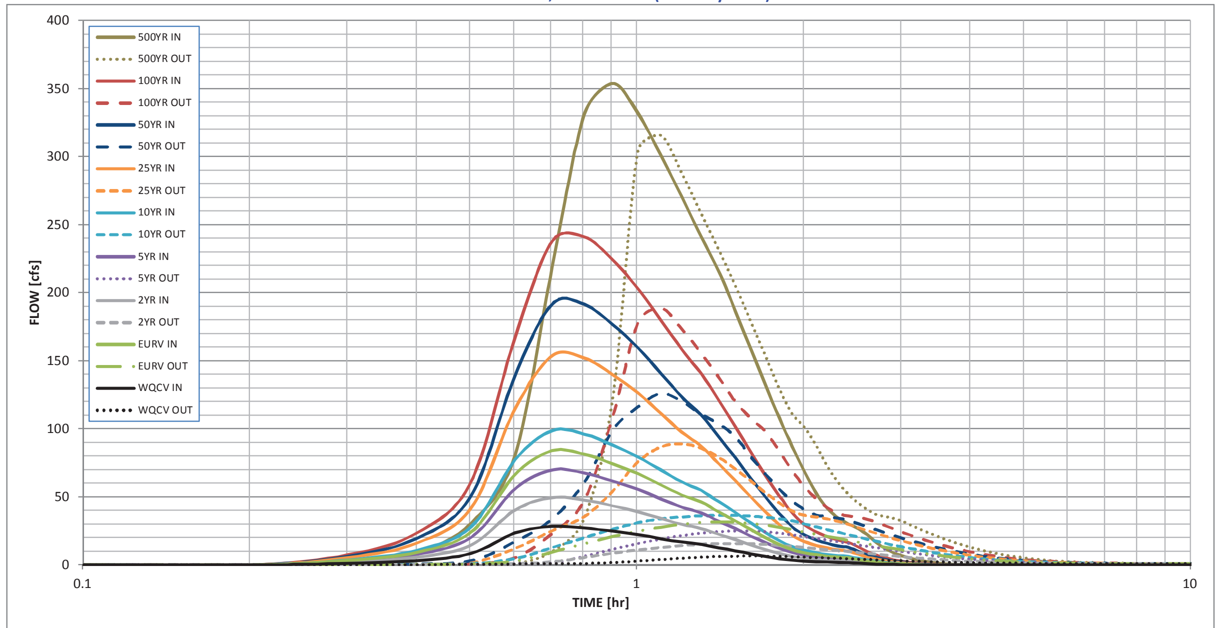
Spillway Design Flow Depth=	1.03	feet
Stage at Top of Freeboard =	11.19	feet
Basin Area at Top of Freeboard =	1.51	acres

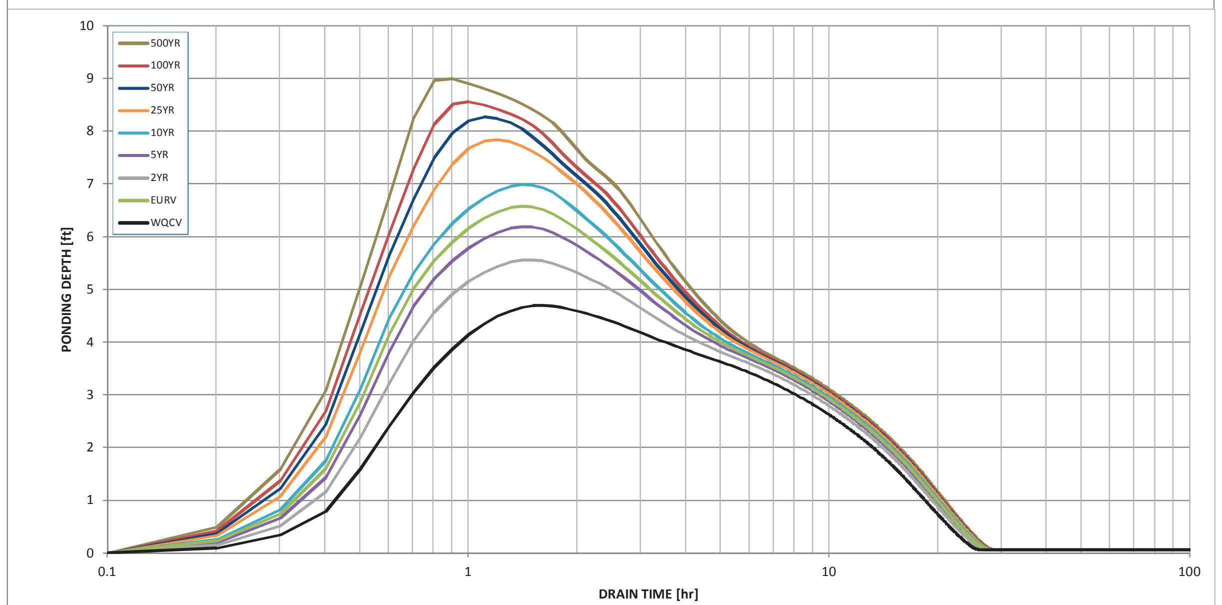
Routed Hydrograph Results

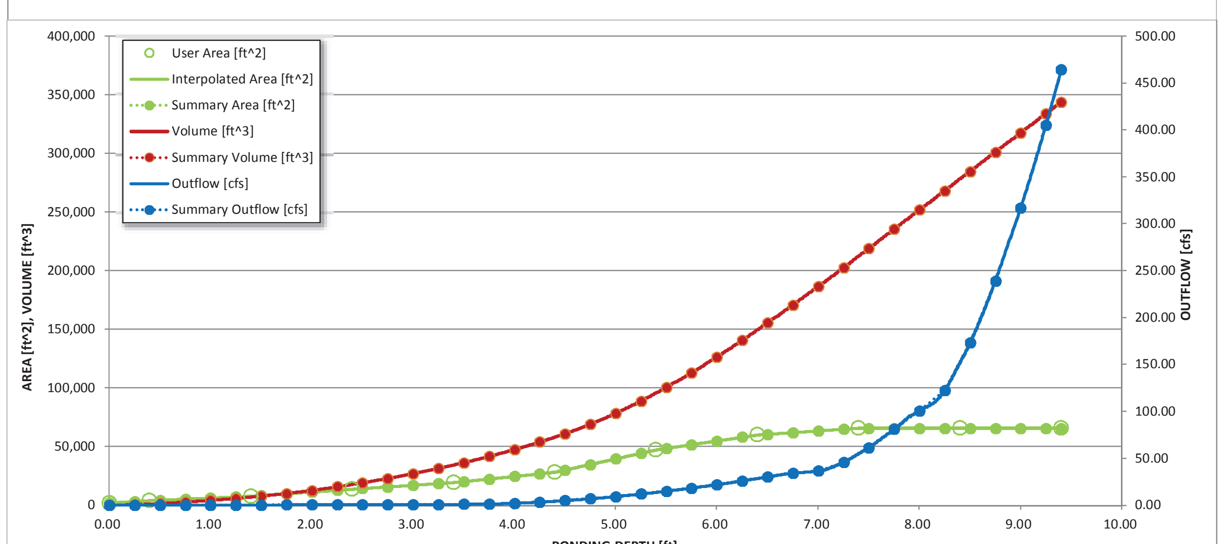
Design Storm Return Period =	WQCV	EURV	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	500 Year
One-Hour Rainfall Depth (in) =	0.53	1.07	0.87	1.13	1.37	1.73	2.03	2.36	3.21
Calculated Runoff Volume (acre-ft) =	2.097	6.316	3.688	5.233	7.470	11.783	14.816	18.817	28.199
OPTIONAL Override Runoff Volume (acre-ft) =									
Inflow Hydrograph Volume (acre-ft) =	2.096	6.311	3.687	5.230	7.459	11.774	14.812	18.807	28.191
Predevelopment Unit Peak Flow, q (cfs/acre) =	0.00	0.00	0.01	0.01	0.12	0.46	0.66	0.94	1.52
Predevelopment Peak Q (cfs) =	0.0	0.0	0.9	1.6	15.4	58.8	85.0	119.7	194.0
Peak Inflow Q (cfs) =	28.5	84.0	49.6	69.9	98.8	153.8	191.8	241.3	353.9
Peak Outflow Q (cfs) =	6.6	31.7	15.9	25.1	36.5	89.0	126.1	188.9	315.9
Ratio Peak Outflow to Predevelopment Q =	N/A	N/A	N/A	15.8	2.4	1.5	1.5	1.6	1.6
Structure Controlling Flow =	Vertical Orifice 1	Vertical Orifice 1	Vertical Orifice 1	Vertical Orifice 1	Vertical Orifice 1	Overflow Grate 1	Spillway	Spillway	Spillway
Max Velocity through Grate 1 (fps) =	N/A	N/A	N/A	N/A	N/A	2.0	3.1	3.6	3.9
Max Velocity through Grate 2 (fps) =	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Time to Drain 97% of Inflow Volume (hours) =	20	17	19	18	17	14	13	11	8
Time to Drain 99% of Inflow Volume (hours) =	**23**	22	23	22	21	20	19	18	16
Maximum Ponding Depth (ft) =	4.70	6.57	5.56	6.19	6.99	7.84	8.27	8.56	9.00
Area at Maximum Ponding Depth (acres) =	0.77	1.40	1.13	1.31	1.46	1.51	1.51	1.51	1.51
Maximum Volume Stored (acre-ft) =	1.540	3.666	2.377	3.134	4.266	5.539	6.188	6.626	7.276

Detention Basin Outlet Structure Design

UD-Detention, Version 3.07 (February 2017)







Detention Basin Outlet Structure Design

UD-Detention, Version 3.07 (February 2017)

Summary Stage-Area-Volume-Discharge Relationships

The user can create a summary S-A-V-D by entering the desired stage increments and the remainder of the table will populate automatically.

The user should graphically compare the summary S-A-V-D table to the full S-A-V-D table in the chart to confirm it captures all key transition points.

Stage - Storage Description	Stage [ft]	Area [ft^2]	Area [acres]	Volume [ft^3]	Volume [ac-ft]	Total Outflow [cfs]
	0.00	2,015	0.046	0	0.000	0.00
	0.25	3,223	0.074	629	0.014	0.10
	0.50	4,363	0.100	1,586	0.036	0.17
	0.75	5,292	0.121	2,793	0.064	0.24
	1.00	6,221	0.143	4,232	0.097	0.30
	1.25	7,150	0.164	5,904	0.136	0.38
	1.50	8,282	0.190	7,817	0.179	0.45
	1.75	9,774	0.224	10,074	0.231	0.52
	2.00	11,266	0.259	12,703	0.292	0.60
	2.25	12,818	0.294	15,834	0.364	0.69
	2.50	14,282	0.328	19,224	0.441	0.78
	2.75	15,705	0.361	22,972	0.527	0.86
	3.00	17,128	0.393	27,077	0.622	0.95
	3.25	18,551	0.426	31,537	0.724	1.04
	3.50	20,275	0.465	36,367	0.835	1.14
	3.75	22,448	0.515	41,708	0.957	1.43
	4.00	24,621	0.565	47,591	1.093	2.22
	4.25	26,794	0.615	54,018	1.240	3.44
	4.50	30,011	0.689	61,040	1.401	5.05
	4.75	34,795	0.799	69,141	1.587	7.04
	5.00	39,580	0.909	78,438	1.801	9.38
	5.25	44,364	1.018	88,931	2.042	12.07
	5.50	48,512	1.114	100,588	2.309	15.09
	5.75	51,706	1.187	113,115	2.597	18.44
	6.00	54,900	1.260	126,441	2.903	22.10
	6.25	58,095	1.334	140,565	3.227	26.07
	6.50	60,589	1.391	155,453	3.569	30.35
	6.75	62,033	1.424	170,781	3.921	34.17
	7.00	63,477	1.457	186,470	4.281	36.58
	7.25	64,921	1.490	202,519	4.649	45.88
	7.50	65,787	1.510	218,901	5.025	61.50
	7.75	65,787	1.510	235,348	5.403	81.09
	8.00	65,787	1.510	251,795	5.780	100.54
	8.25	65,787	1.510	268,241	6.158	122.40
	8.50	65,787	1.510	284,688	6.536	173.34
	8.75	65,787	1.510	301,135	6.913	239.31
	9.00	65,787	1.510	317,582	7.291	317.29
	9.25	65,787	1.510	334,028	7.668	405.48
	9.40	65,787	1.510	343,896	7.895	464.30

For best results, include the stages of all grade slope changes (e.g. ISV and Floor) from the S-A-V table on Sheet 'Basin'.

Also include the inverts of all outlets (e.g. vertical orifice, overflow grate, and spillway, where applicable).


1.5" HOLE
SPACED 2.5" APART
INV 1ST HOLE FROM TOP = 6.25"
INV LAST HOLE FROM TOP =
58.25"

BASELINE PEAK FLOWS

Basin	Design Point	Drainage Area (acres)	Existing Percent Imperviousness	Future Percent Imperviousness	Existing Conditions Peak Flow (cfs)									Future Conditions Peak Flow (cfs)								
					Q_{WQ}	Q_1	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}	Q_{WQ}	Q_1	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
Little Raven Creek	LR_outfall	349	-	25	-	-	-	-	-	-	-	-	-	23	32	45	72	120	253	338	454	708
Little Raven Creek	Belleview_LR	225	-	37	-	-	-	-	-	-	-	-	-	28	40	55	86	132	242	312	404	609
Little Raven Creek	Havana_LR	140	-	42	-	-	-	-	-	-	-	-	-	27	37	50	74	108	185	236	298	442
Little Raven Creek	LR1	124	-	2	-	-	-	-	-	-	-	-	-	0.1	0.4	1	2	15	50	72	102	166
Little Raven Creek	LR2	85	-	28	-	-	-	-	-	-	-	-	-	7	10	14	23	39	75	98	129	196
Little Raven Creek	LR3	140	-	42	-	-	-	-	-	-	-	-	-	27	37	50	74	108	185	236	298	442
Suhaka Creek	S_outfall	360	-	25	-	-	-	-	-	-	-	-	-	21	29	40	65	111	238	316	423	657
Suhaka Creek	Peoria_S	109	-	27	-	-	-	-	-	-	-	-	-	5	7	10	17	28	58	77	102	157
Suhaka Creek	Stock_Pond_S	131	-	43	-	-	-	-	-	-	-	-	-	19	26	35	50	74	129	165	210	313
Suhaka Creek	S1	121	-	4	-	-	-	-	-	-	-	-	-	0.5	1	2	7	27	74	103	142	226
Suhaka Creek	S2	109	-	27	-	-	-	-	-	-	-	-	-	5	7	10	17	28	58	77	102	157
Suhaka Creek	S3	131	-	43	-	-	-	-	-	-	-	-	-	19	26	35	50	74	129	165	210	313
Joplin Tributary	J_outfall	774	-	39	-	-	-	-	-	-	-	-	-	84	104	130	173	217	348	446	613	985
Joplin Tributary	Parker_J	603	-	47	-	-	-	-	-	-	-	-	-	96	116	141	182	221	331	411	535	859
Joplin Tributary	Junction_J3	352	-	47	-	-	-	-	-	-	-	-	-	59	70	86	110	135	205	247	352	410
Joplin Tributary	out_RB1-4_pond	352	-	47	-	-	-	-	-	-	-	-	-	59	70	86	110	135	205	247	353	410
Joplin Tributary	RB1-4_pond	352	-	47	-	-	-	-	-	-	-	-	-	63	79	104	146	195	345	443	570	855
Joplin Tributary	Laredo_J	234	-	50	-	-	-	-	-	-	-	-	-	48	60	81	113	153	263	333	424	626
Joplin Tributary	Lewiston_J	126	-	52	-	-	-	-	-	-	-	-	-	27	34	46	64	86	145	184	233	342
Joplin Tributary	Junction_J4	101	-	41	-	-	-	-	-	-	-	-	-	16	20	24	32	40	63	87	122	208
Joplin Tributary	Shalom_J	101	-	41	-	-	-	-	-	-	-	-	-	16	20	25	32	41	63	87	123	208
Joplin Tributary	J1	120	-	3	-	-	-	-	-	-	-	-	-	0.0	0.2	1	1	3	29	46	70	120
Joplin Tributary	J2	51	-	28	-	-	-	-	-	-	-	-	-	2	3	4	6	8	17	26	37	65
Joplin Tributary	J3	106	-	55	-	-	-	-	-	-	-	-	-	30	37	46	62	78	127	164	210	319
Joplin Tributary	J4	45	-	43	-	-	-	-	-	-	-	-	-	9	11	14	18	23	35	47	66	111
Joplin Tributary	J5	101	-	41	-	-	-	-	-	-	-	-	-	16	20	25	32	41	63	87	123	208
Joplin Tributary	J6	117	-	42	-	-	-	-	-	-	-	-	-	15	19	24	34	44	82	110	146	229
Joplin Tributary	J7	109	-	48	-	-	-	-	-	-	-	-	-	21	26	35	49	67	118	150	191	284
Joplin Tributary	J8	126	-	52	-	-	-	-	-	-	-	-	-	27	34	46	64	86	145	184	233	342
Grove Ranch Tributary	GR_outfall	81	-	54	-	-	-	-	-	-	-	-	-	18	23	31	43	59	96	121	150	221
Grove Ranch Tributary	GR1	81	-	54	-	-	-	-	-	-	-	-	-	18	23	31	43	59	96	121	150	221
Valley Club Acres Tributary	VCA_outfall	207	-	45	-	-	-	-	-	-	-	-	-	34	43	59	83	114	211	272	349	524
Valley Club Acres Tributary	Fair_Place_VCA	207	-	45	-	-	-	-	-	-	-	-	-	35	44	60	85	115	211	272	349	525
Valley Club Acres Tributary	Regis_Jesuit_VCA	87	-	37	-	-	-	-	-	-	-	-	-	12	15	22	32	43	87	116	151	232
Valley Club Acres Tributary	VCA1	120	-	51	-	-	-	-	-	-	-	-	-	23	29	39	54	73	126	159	201	297
Valley Club Acres Tributary	VCA2	87	-	37	-	-	-	-	-	-	-	-	-	12	15	22	32	43	87	116	151	232
North Arapahoe Tributary	NA_outfall	372	-	44	-	-	-	-	-	-	-	-	-	32	42	56	82	116	229	326	476	800
North Arapahoe Tributary	Parker_NA	372	-	44	-	-	-	-	-	-	-	-	-	33	42	57	82	116	229	326	476	800
North Arapahoe Tributary	Buckley_NA1	272	-	41	-	-	-	-	-	-	-	-	-	15	21	29	45	65	150	217	325	542
North Arapahoe Tributary	Waco_NA	41	-	28	-	-	-	-	-	-	-	-	-	3	4	6	10	15	33	44	59	92
North Arapahoe Tributary	NA_pond	128	-	46	-	-	-	-	-	-	-	-	-	23	29	39	56	77	138	176	226	336
North Arapahoe Tributary	NA1	100	-	51	-	-	-	-	-	-	-	-	-	24	30	41	56	77	131	166	209	308
North Arapahoe Tributary	NA2	128	-	46	-	-	-	-	-	-	-	-	-	23	29	39	56	77	138	176	226	336
North Arapahoe Tributary	NA3	103	-	41	-	-	-	-	-	-	-	-	-	9	12	16	23	30	60	79	103	158
North Arapahoe Tributary	NA4	41	-	28	-	-	-	-	-	-	-	-	-	3	4	6	10	15	33	44	59	92
South Arapahoe Tributary	SA_outfall	396	-	30	-	-	-	-	-	-	-	-	-	26	33	44	66	102	229	311	426	667
South Arapahoe Tributary	Parker_SA	326	-	21	-	-	-	-	-	-	-	-	-	8	14	22	36	62	163	228	318	507
South Arapahoe Tributary	Norfolk_SA	227	-	20	-	-	-	-	-	-	-	-	-	6	10	15	25	43	117	162	225	357
South Arapahoe Tributary	Richfield_SA	132	-	20	-	-	-	-	-	-	-	-	-	4	7	10	15	25	67	93	127	200
South Arapahoe Tributary	SA1	70	-	70	-	-	-	-	-	-	-	-	-	26	32	42	56	73	110	134	164	233
South Arapahoe Tributary	SA2	98	-	24	-	-	-	-	-	-	-	-	-	4	7	10	15	25	58	79	105	164
South Arapahoe Tributary	SA3	95	-	20	-	-	-	-	-	-	-	-	-	3	6	9	13	24	59	80	109	170
South Arapahoe Tributary	SA4	132	-	20	-	-	-	-	-	-	-	-	-	4	7	10	15	25	67	93	127	200
Chenango Tributary	C_outfall	917	-	23	-	-	-	-	-	-	-	-	-	26	43	64	112	198	478	669	942	1,528
Chenango Tributary	Parker_C	811	-	20	-	-	-	-	-	-	-	-	-	21	34	53	96	174	436	610	857	1,379
Chenango Tributary	Hinsdale_C	694	-	20	-	-	-	-	-	-	-	-	-	19	32	49	87	157	388	538	748	1,192
Chenango Tributary	Richfield_C	593	-	20	-	-	-	-	-	-	-	-	-	17	29	44	79	141	345	476	658	1,046
Chenango Tributary	Telluride_C	412	-	20	-	-	-	-	-	-	-	-	-	14	24	36	64	117	275	375	508	800
Chenango Tributary	Bridle_Trail_C	321	-	20	-	-	-	-	-	-	-	-	-	13	22	33	58	103	228	308	412	641
Chenango Tributary	Biscay_C	132	-	20	-	-	-	-	-	-	-	-	-	6	10	15	26	49	101	135	178	275
Chenango Tributary	C1	106	-	49	-	-	-	-	-	-	-	-	-	19	25	33	46	63	109	139	176	261
Chenango Tributary	C2	117	-	19	-	-	-	-	-	-	-	-	-	4	8	12	18	33	83	114	155	243
Chenango Tributary	C3	102	-	20	-	-	-	-	-	-	-	-	-	3	5	8	12	23	55	75	102	160
Chenango Tributary	C4	126	-	20	-	-	-	-	-	-	-	-	-	3	5	8	12	17	52	74	105	170
Chenango Tributary	C5	55	-	20	-	-	-	-	-	-	-	-	-	2	3	5	9	16	34	46	61	94

BASELINE PEAK FLOWS																							
Basin	Design Point	Drainage Area (acres)	Existing Percent Imperviousness	Future Percent Imperviousness	Existing Conditions Peak Flow (cfs)									Future Conditions Peak Flow (cfs)									
					Q_{WQ}	Q_1	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}	Q_{WQ}	Q_1	Q_2	Q_5	Q_{10}	Q_{25}	Q_{50}	Q_{100}	Q_{500}
Chenango Tributary	C6	92	-	20	-	-	-	-	-	-	-	-	-	4	7	10	15	29	68	91	122	191
Chenango Tributary	C7	72	-	20	-	-	-	-	-	-	-	-	-	2	4	6	10	14	40	57	79	128
Chenango Tributary	C8	116	-	20	-	-	-	-	-	-	-	-	-	6	9	13	23	43	90	120	158	243
Chenango Tributary	C9	132	-	20	-	-	-	-	-	-	-	-	-	6	10	15	26	49	101	135	178	275
Tagawa Tributary	T_outfall	107	-	22	-	-	-	-	-	-	-	-	-	3	5	9	14	18	52	74	105	180
Tagawa Tributary	Parker_T1	107	-	22	-	-	-	-	-	-	-	-	-	3	6	9	14	19	52	75	105	171
Tagawa Tributary	T1	107	-	22	-	-	-	-	-	-	-	-	-	3	6	9	14	19	52	75	105	171
Kragelund Tributary	K_outfall	611	14	42	9	16	25	49	113	308	438	626	1,038	50	69	96	151	238	478	635	859	1,352
Kragelund Tributary	Parker_K	577	14	40	9	16	26	50	114	307	433	615	1,009	50	69	96	149	234	472	625	839	1,309
Kragelund Tributary	Bridle_Trail_K	453	14	43	9	16	24	45	99	264	368	514	825	52	70	97	147	223	427	557	729	1,114
Kragelund Tributary	Confluence_K	257	17	49	9	15	22	36	74	181	247	334	529	47	62	84	121	175	309	396	505	759
Kragelund Tributary	Future_Road_K	108	32	60	10	16	23	34	54	108	143	185	285	42	53	68	94	124	193	242	300	437
Kragelund Tributary	K1	34	6	59	0.1	0.2	1	1	2	13	21	30	52	12	15	18	25	32	50	64	80	118
Kragelund Tributary	K2	124	16	18	4	7	11	17	38	91	123	166	260	5	9	13	20	41	95	128	171	266
Kragelund Tributary	K3	69	2	38	0.1	0.2	0.4	1	8	27	39	55	90	8	11	14.7	21	32	59	76	98	148
Kragelund Tributary	K4	126	15	23	4	7	10	21	43	95	129	172	267	8	13	18	30	53	108	143	188	288
Kragelund Tributary	K5	45	4	45	0.1	0.4	1	2	8	24	34	47	75	9	12	16	22	32	56	71	90	133
Kragelund Tributary	K6	104	7	28	1	2	4	8	24	64	89	121	193	8	12	17	27	46	91	120	157	241
Kragelund Tributary	K7	108	32	60	10	16	23	34	54	108	143	185	285	42	53	68	94	124	193	242	300	437
17 Mile Tributary	17_outfall	145	8	36	1	2	4	8	24	84	121	169	275	18	25	36	52	78	155	204	267	408
17 Mile Tributary	Parker_17	124	7	36	0.4	2	3	6	20	70	101	141	228	17	23	32	47	70	135	177	229	349
17 Mile Tributary	17A	22	14	36	1	1	2	3	7	19	26	35	55	4	5	7	11	16	30	39	51	77
17 Mile Tributary	17B	124	7	36	0.4	2	3	6	20	70	101	141	228	17	23	32	47	70	135	177	229	349

(-) Existing Conditions = Future Conditions

BASELINE RUNOFF VOLUMES

Basin	Design Point	Drainage Area (acres)	Existing Percent Imperviousness	Future Percent Imperviousness	Existing Conditions Runoff Volume (acre-feet)									Future Conditions Runoff Volume (acre-feet)								
					V_{WQ}	V_1	V_2	V_5	V_{10}	V_{25}	V_{50}	V_{100}	V_{500}	V_{WQ}	V_1	V_2	V_5	V_{10}	V_{25}	V_{50}	V_{100}	V_{500}
Little Raven Creek	LR_outfall	349	-	25	-	-	-	-	-	-	-	-	-	3.4	4.5	5.9	8.9	14.5	26.7	35.3	47.0	72.7
Little Raven Creek	Belleview_LR	225	-	37	-	-	-	-	-	-	-	-	-	3.1	4.1	5.3	8.2	12.0	19.7	25.3	32.5	49.4
Little Raven Creek	Havana_LR	140	-	42	-	-	-	-	-	-	-	-	-	2.3	2.9	3.8	5.7	8.2	12.9	16.5	20.9	31.3
Little Raven Creek	LR1	124	-	2	-	-	-	-	-	-	-	-	-	0.0	0.1	0.1	0.2	1.7	6.1	8.9	13.0	21.9
Little Raven Creek	LR2	85	-	28	-	-	-	-	-	-	-	-	-	0.7	1.0	1.4	2.3	3.7	6.6	8.7	11.4	17.7
Little Raven Creek	LR3	140	-	42	-	-	-	-	-	-	-	-	-	2.3	2.9	3.8	5.7	8.2	12.9	16.5	20.9	31.3
Suhaka Creek	S_outfall	360	-	25	-	-	-	-	-	-	-	-	-	3.2	4.3	5.7	8.8	14.4	26.9	35.6	47.6	74.0
Suhaka Creek	Peoria_S	109	-	27	-	-	-	-	-	-	-	-	-	0.8	1.2	1.7	2.7	4.4	8.2	10.9	14.4	22.4
Suhaka Creek	Stock_Pond_S	131	-	43	-	-	-	-	-	-	-	-	-	2.2	2.8	3.6	5.2	7.4	11.9	15.2	19.3	29.1
Suhaka Creek	S1	121	-	4	-	-	-	-	-	-	-	-	-	0.0	0.1	0.2	0.7	2.2	6.5	9.3	13.3	22.0
Suhaka Creek	S2	109	-	27	-	-	-	-	-	-	-	-	-	0.8	1.2	1.7	2.7	4.4	8.2	10.9	14.4	22.4
Suhaka Creek	S3	131	-	43	-	-	-	-	-	-	-	-	-	2.2	2.8	3.6	5.2	7.4	11.9	15.2	19.3	29.1
Joplin Tributary	J_outfall	774	-	39	-	-	-	-	-	-	-	-	-	12.5	15.3	19.2	26.5	34.7	55.9	72.7	96.7	141.5
Joplin Tributary	Parker_J	603	-	47	-	-	-	-	-	-	-	-	-	11.4	14.0	17.6	24.3	31.6	47.9	61.1	78.9	112.0
Joplin Tributary	Junction_J3	352	-	47	-	-	-	-	-	-	-	-	-	6.5	8.1	10.3	14.5	19.2	30.3	38.7	49.7	65.7
Joplin Tributary	out_RB1-4_pond	352	-	47	-	-	-	-	-	-	-	-	-	6.5	8.1	10.3	14.5	19.2	30.3	38.7	49.7	65.7
Joplin Tributary	RB1-4_pond	352	-	47	-	-	-	-	-	-	-	-	-	6.5	8.1	10.3	14.5	19.2	30.3	38.7	49.7	75.5
Joplin Tributary	Laredo_J	234	-	50	-	-	-	-	-	-	-	-	-	4.7	5.8	7.5	10.5	14.1	22.0	27.8	35.3	52.5
Joplin Tributary	Lewiston_J	126	-	52	-	-	-	-	-	-	-	-	-	2.6	3.3	4.2	5.9	7.8	12.1	15.2	19.2	28.5
Joplin Tributary	Junction_J4	101	-	41	-	-	-	-	-	-	-	-	-	1.5	1.9	2.3	3.1	4.0	5.5	7.2	9.8	16.3
Joplin Tributary	Shalom_J	101	-	41	-	-	-	-	-	-	-	-	-	1.5	1.9	2.4	3.1	4.0	5.6	7.2	9.8	16.3
Joplin Tributary	J1	120	-	3	-	-	-	-	-	-	-	-	-	0.0	0.0	0.1	0.2	0.5	4.2	6.8	10.8	18.8
Joplin Tributary	J2	51	-	28	-	-	-	-	-	-	-	-	-	0.4	0.5	0.6	0.9	1.3	2.3	3.3	4.7	8.2
Joplin Tributary	J3	106	-	55	-	-	-	-	-	-	-	-	-	2.4	3.0	3.7	5.0	6.3	9.1	11.6	14.8	22.4
Joplin Tributary	J4	45	-	43	-	-	-	-	-	-	-	-	-	0.7	0.9	1.1	1.5	1.9	2.6	3.4	4.5	7.4
Joplin Tributary	J5	101	-	41	-	-	-	-	-	-	-	-	-	1.5	1.9	2.4	3.1	4.0	5.6	7.2	9.8	16.3
Joplin Tributary	J6	117	-	42	-	-	-	-	-	-	-	-	-	1.9	2.3	2.8	4.0	5.2	8.4	11.0	14.6	22.9
Joplin Tributary	J7	109	-	48	-	-	-	-	-	-	-	-	-	2.1	2.6	3.3	4.7	6.3	9.9	12.6	16.1	24.1
Joplin Tributary	J8	126	-	52	-	-	-	-	-	-	-	-	-	2.6	3.3	4.2	5.9	7.8	12.1	15.2	19.2	28.5
Grove Ranch Tributary	GR_outfall	81	-	54	-	-	-	-	-	-	-	-	-	1.8	2.2	2.8	4.0	5.4	8.1	10.2	12.7	18.8
Grove Ranch Tributary	GR1	81	-	54	-	-	-	-	-	-	-	-	-	1.8	2.2	2.8	4.0	5.4	8.1	10.2	12.7	18.8
Valley Club Acres Tributary	VCA_outfall	207	-	45	-	-	-	-	-	-	-	-	-	3.7	4.5	5.9	8.3	11.2	18.0	23.0	29.6	44.8
Valley Club Acres Tributary	Fair_Place_VCA	207	-	45	-	-	-	-	-	-	-	-	-	3.6	4.5	5.9	8.3	11.1	18.0	23.0	29.6	44.8
Valley Club Acres Tributary	Regis_Jesuit_VCA	87	-	37	-	-	-	-	-	-	-	-	-	1.1	1.4	1.9	2.7	3.7	6.5	8.5	11.3	17.5
Valley Club Acres Tributary	VCA1	120	-	51	-	-	-	-	-	-	-	-	-	2.5	3.1	4.0	5.6	7.5	11.5	14.5	18.3	27.3
Valley Club Acres Tributary	VCA2	87	-	37	-	-	-	-	-	-	-	-	-	1.1	1.4	1.9	2.7	3.7	6.5	8.5	11.3	17.5
North Arapahoe Tributary	NA_outfall	372	-	44	-	-	-	-	-	-	-	-	-	6.2	7.7	10.0	14.2	19.3	31.6	40.8	52.5	79.5
North Arapahoe Tributary	Parker_NA	372	-	44	-	-	-	-	-	-	-	-	-	6.2	7.7	10.0	14.2	19.3	31.6	40.8	52.5	79.5
North Arapahoe Tributary	Buckley_NA1	272	-	41	-	-	-	-	-	-	-	-	-	4.1	5.2	6.8	9.7	13.2	22.2	28.8	37.4	57.1
North Arapahoe Tributary	Waco_NA	41	-	28	-	-	-	-	-	-	-	-	-	0.3	0.4	0.6	0.9	1.4	2.7	3.7	5.0	7.9
North Arapahoe Tributary	NA_pond	128	-	46	-	-	-	-	-	-	-	-	-	2.3	2.8	3.7	5.2	7.1	11.4	14.5	18.6	28.0
North Arapahoe Tributary	NA1	100	-	51	-	-	-	-	-	-	-	-	-	2.0	2.5	3.3	4.5	6.1	9.5	12.0	15.1	22.5
North Arapahoe Tributary	NA2	128	-	46	-	-	-	-	-	-	-	-	-	2.3	2.8	3.7	5.2	7.1	11.4	14.5	18.6	28.0
North Arapahoe Tributary	NA3	103	-	41	-	-	-	-	-	-	-	-	-	1.6	2.0	2.5	3.6	4.8	8.1	10.6	13.9	21.3
North Arapahoe Tributary	NA4	41	-	28	-	-	-	-	-	-	-	-	-	0.3	0.4	0.6	0.9	1.4	2.7	3.7	5.0	7.9
South Arapahoe Tributary	SA_outfall	396	-	30	-	-	-	-	-	-	-	-	-	3.7	5.1	6.8	10.2	15.1	28.4	38.1	50.6	79.2
South Arapahoe Tributary	Parker_SA	326	-	21	-	-	-	-	-	-	-	-	-	1.6	2.5	3.5	5.6	9.1	20.0	27.8	38.4	61.7
South Arapahoe Tributary	Norfolk_SA	227	-	20	-	-	-	-	-	-	-	-	-	1.0	1.5	2.2	3.6	5.9	13.5	18.9	26.3	42.4
South Arapahoe Tributary	Richfield_SA	132	-	20	-	-	-	-	-	-	-	-	-	0.5	0.9	1.2	2.0	3.3	7.7	10.8	15.1	24.4
South Arapahoe Tributary	SA1	70	-	70	-	-	-	-	-	-	-	-	-	2.1	2.6	3.3	4.6	6.0	8.3	10.1	12.3	17.6
South Arapahoe Tributary	SA2	98	-	24	-	-	-	-	-	-	-	-	-	0.6	0.9	1.2	1.9	3.1	6.4	8.8	11.9	19.0
South Arapahoe Tributary	SA3	95	-	20	-	-	-	-	-	-	-	-	-	0.4	0.6	0.9	1.5	2.5	5.7	8.0	11.0	17.8
South Arapahoe Tributary	SA4	132	-	20	-	-	-	-	-	-	-	-	-	0.5	0.9	1.2	2.0	3.3	7.7	10.8	15.1	24.4
Chenango Tributary	C_outfall	917	-	23	-	-	-	-	-	-	-	-	-	5.8	8.4	11.7	18.8	30.3	61.4	83.5	113.2	179.5
Chenango Tributary	Parker_C	811	-	20	-	-	-	-	-	-	-	-	-	3.7	5.7	8.2	13.9	23.7	51.3	70.3	97.0	155.3
Chenango Tributary	Hinsdale_C	694	-	20	-	-	-	-	-	-	-	-	-	3.2	5.0	7.2	12.2	20.7	44.2	60.8	83.5	133.2
Chenango Tributary	Richfield_C	593	-	20	-	-	-	-	-	-	-	-	-	2.8	4.2	6.1	10.5	17.8	37.7	51.9	71.2	113.9
Chenango Tributary	Telluride_C	412	-	20	-	-	-	-	-	-	-	-	-	2.0	3.1	4.4	7.6	13.3	27.4	37.4	50.9	80.7
Chenango Tributary	Bridle_Trail_C	321	-	20	-	-	-	-	-	-	-	-	-	1.5	2.3	3.3	6.0	10.3	21.1	28.9	39.3	62.6
Chenango Tributary	Biscay_C	132	-	20	-	-	-	-	-	-	-	-	-	0.7	1.0	1.4	2.6	4.7	9.3	12.5	16.8	26.5
Chenango Tributary	C1	106	-	49	-	-	-	-	-	-	-	-	-	2.1	2.6	3.4	4.7	6.4	10.0	12.6	16.0	23.8
Chenango Tributary	C2	117	-	19	-	-	-	-	-	-	-	-	-	0.4	0.7	1.0	1.7	3.0	6.9	9.7	13.5	21.8
Chenango Tributary	C3	102	-	20	-	-	-	-	-	-	-	-	-	0.4	0.7	1.0	1.6	2.9	6.3	8.7	12.0	19.3
Chenango Tributary	C4	126	-	20	-	-	-	-	-	-	-	-	-	0.5	0.7	1.1	1.8	2.5	6.4	9.2	13.3	22.0
Chenango Tributary	C5	55	-	20	-	-	-	-	-	-	-	-	-	0.3	0.4	0.6	1.0	1.9	3.8	5.1	6.9	10.9

BASELINE RUNOFF VOLUMES

Basin	Design Point	Drainage Area (acres)	Existing Percent Imperviousness	Future Percent Imperviousness	Existing Conditions Runoff Volume (acre-feet)									Future Conditions Runoff Volume (acre-feet)								
					V_{WQ}	V_1	V_2	V_5	V_{10}	V_{25}	V_{50}	V_{100}	V_{500}	V_{WQ}	V_1	V_2	V_5	V_{10}	V_{25}	V_{50}	V_{100}	V_{500}
Chenango Tributary	C6	92	-	20	-	-	-	-	-	-	-	-	-	0.4	0.6	0.9	1.5	2.7	5.9	8.1	11.0	17.7
Chenango Tributary	C7	72	-	20	-	-	-	-	-	-	-	-	-	0.3	0.4	0.6	1.0	1.5	3.7	5.3	7.7	12.7
Chenango Tributary	C8	116	-	20	-	-	-	-	-	-	-	-	-	0.6	0.9	1.3	2.3	4.1	8.1	11.0	14.8	23.3
Chenango Tributary	C9	132	-	20	-	-	-	-	-	-	-	-	-	0.7	1.0	1.4	2.6	4.7	9.3	12.5	16.8	26.5
Tagawa Tributary	T_outfall	107	-	22	-	-	-	-	-	-	-	-	-	0.5	0.7	1.0	1.6	2.3	5.3	7.6	11.1	18.5
Tagawa Tributary	Parker_T1	107	-	22	-	-	-	-	-	-	-	-	-	0.5	0.7	1.0	1.6	2.3	5.3	7.7	11.1	18.5
Tagawa Tributary	T1	107	-	22	-	-	-	-	-	-	-	-	-	0.5	0.7	1.0	1.6	2.3	5.3	7.7	11.1	18.5
Kragelund Tributary	K_outfall	611	14	42	2.2	3.3	4.8	8.2	16.4	38.1	52.8	73.0	117.2	8.1	10.6	13.8	20.4	30.2	51.6	66.9	86.5	132.0
Kragelund Tributary	Parker_K	577	14	40	2.1	3.3	4.7	8.0	16.1	36.5	50.6	69.7	111.7	7.2	9.5	12.4	18.5	27.8	47.9	62.3	81.0	123.7
Kragelund Tributary	Bridle_Trail_K	453	14	43	1.7	2.5	3.6	6.2	12.5	28.5	39.3	54.3	87.2	6.5	8.5	11.0	16.3	23.8	39.3	50.6	65.4	98.8
Kragelund Tributary	Confluence_K	257	17	49	1.2	1.8	2.5	4.0	7.5	16.6	22.7	31.0	49.7	4.6	5.8	7.5	10.7	15.0	23.8	30.2	38.4	57.4
Kragelund Tributary	Future_Road_K	108	32	60	1.0	1.5	2.0	2.9	4.5	8.2	10.8	14.2	22.1	2.7	3.3	4.3	5.9	7.8	11.4	14.1	17.5	25.6
Kragelund Tributary	K1	34	6	59	0.0	0.0	0.1	0.1	0.2	1.2	1.9	3.0	5.2	0.8	1.0	1.3	1.8	2.2	3.3	4.1	5.2	7.6
Kragelund Tributary	K2	124	16	18	0.4	0.6	0.9	1.6	3.3	7.7	10.6	14.6	23.6	0.5	0.8	1.2	1.9	3.7	8.0	11.0	15.0	24.0
Kragelund Tributary	K3	69	2	38	0.0	0.0	0.1	0.1	0.9	3.4	4.9	7.2	12.1	1.0	1.3	1.6	2.4	3.5	5.9	7.6	9.8	14.9
Kragelund Tributary	K4	126	15	23	0.4	0.6	0.9	1.9	3.8	8.2	11.2	15.4	24.6	0.8	1.1	1.6	2.8	4.8	9.2	12.3	16.4	25.7
Kragelund Tributary	K5	45	4	45	0.0	0.0	0.1	0.2	0.7	2.3	3.4	4.8	8.1	0.8	1.0	1.3	1.9	2.6	4.2	5.3	6.7	10.1
Kragelund Tributary	K6	104	7	28	0.1	0.2	0.3	0.8	2.1	5.8	8.3	11.7	19.2	0.9	1.2	1.7	2.7	4.3	7.9	10.5	13.9	21.5
Kragelund Tributary	K7	108	32	60	1.0	1.5	2.0	2.9	4.5	8.2	10.8	14.2	22.1	2.7	3.3	4.3	5.9	7.8	11.4	14.1	17.5	25.6
17 Mile Tributary	17_outfall	145	8	36	0.1	0.2	0.4	0.8	2.1	7.2	10.4	15.2	25.4	1.8	2.4	3.1	4.6	6.5	11.4	14.9	19.5	30.1
17 Mile Tributary	Parker_17	124	7	36	0.1	0.2	0.3	0.6	1.6	5.8	8.6	12.7	21.3	1.5	2.0	2.6	3.8	5.5	9.7	12.6	16.6	25.6
17 Mile Tributary	17A	22	14	36	0.0	0.1	0.1	0.2	0.5	1.2	1.7	2.4	4.0	0.3	0.3	0.5	0.7	1.0	1.7	2.2	2.9	4.5
17 Mile Tributary	17B	124	7	36	0.1	0.2	0.3	0.6	1.6	5.8	8.6	12.7	21.3	1.5	2.0	2.6	3.8	5.5	9.7	12.6	16.6	25.6

(-) Existing Conditions = Future Conditions

Table B-5. 100-year SWMM Input & Output, Existing Conditions

Note: Existing Conditions = Future Conditions for all basins except 17 Mile and Kragelund.

```
[Baseline Hydrology SWMM Input]
;;Cherry Creek Tribs U/S of Cherry Creek Reservoir

[OPTIONS]
;;Option             Value
FLOW_UNITS           CFS
INFILTRATION         HORTON
FLOW_ROUTING         KINWAVE
LINK_OFFSETS         DEPTH
MIN_SLOPE            0
ALLOW_PONDING        NO
SKIP_STEADY_STATE    NO

START_DATE           12/01/2018
START_TIME           00:00:00
REPORT_START_DATE    12/01/2018
REPORT_START_TIME    00:00:00
END_DATE             12/02/2018
END_TIME             00:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:01:00
WET_STEP             00:05:00
DRY_STEP             00:05:00
ROUTING_STEP         0:00:05

INERTIAL_DAMPING     PARTIAL
NORMAL_FLOW_LIMITED  BOTH
FORCE_MAIN_EQUATION  H-W
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         12.557
MAX_TRIALS           8
HEAD_TOLERANCE       0.005
SYS_FLOW_TOL         5
LAT_FLOW_TOL         5
MINIMUM_STEP         0.5
THREADS              1

[FILES]
;;Interfacing Files
USE INFLOWS "J:\506004\WR_DRN\CUHP\OUT\CC_Ex_100yr_0mi^2_BH.txt"

[EVAPORATION]
;;Data Source    Parameters
;;-------------- ----------------
CONSTANT         0.0
DRY_ONLY         NO

[JUNCTIONS]
;;Name           Elevation  MaxDepth   InitDepth  SurDepth   Aponded
;;-------------- ---------- ---------- ---------- ---------- ---------
-
Belleview_LR     5609       0          0          0          0
Havana_LR        5645       0          0          0          0
Peoria_S         5580       0          0          0          0
Stock_Pond_S     5621       0          0          0          0
Parker_J         5619       0          0          0          0
Junction_J3      5663       0          0          0          0
Junction_J4      5629.87    1.13       0          0          0
Regis_Jesuit_VCA 5689       0          0          0          0
Parker_SA        5656       0          0          0          0
Norfolk_SA       5720       0          0          0          0
Richfield_SA     5760       0          0          0          0
Parker_C         5698       0          0          0          0
Hinsdale_C       5718       0          0          0          0
Richfield_C      5745       0          0          0          0
Telluride_C      5774       0          0          0          0
Bridle_Trail_C   5814       0          0          0          0
Biscay_C         5828       0          0          0          0
Parker_K         5724       0          0          0          0
Bridle_Trail_K   5765       0          0          0          0
Confluence_K     5831       0          0          0          0
Future_Road_K    5890       0          0          0          0
Parker_17        5729       0          0          0          0
LR3              5645       0          0          0          0
LR2              5609       0          0          0          0
LR1              5552       0          0          0          0
S3               5621       0          0          0          0
S2               5580       0          0          0          0
S1               5565       0          0          0          0
J8               5738       0          0          0          0
J7               5729       0          0          0          0
J6               5688       0          0          0          0
J5               5645       0          0          0          0
J2               5579       0          0          0          0
J4               5619       0          0          0          0
J3               5619       0          0          0          0
J1               5579       0          0          0          0
VCA1             5631       0          0          0          0
VCA2             5689       0          0          0          0
NA1              5631       0          0          0          0
NA2              5765       0          0          0          0
NA4              5833       0          0          0          0
NA3              5769       0          0          0          0
SA4              5760       0          0          0          0
SA3              5720       0          0          0          0
SA2              5656       0          0          0          0
SA1              5633       0          0          0          0
C2               5698       0          0          0          0
17B              5729       0          0          0          0
17A              5695       0          0          0          0
K1               5690       0          0          0          0
```

Note: Existing Conditions = Future Conditions
for all basins except 17 Mile and Kragelund.

```
K2               5724      0         0         0         0
K3               5765      0         0         0         0
K4               5765      0         0         0         0
K6               5831      0         0         0         0
K7               5890      0         0         0         0
K5               5831      0         0         0         0
C9               5828      0         0         0         0
C8               5817      0         0         0         0
C7               5814      0         0         0         0
C4               5745      0         0         0         0
C3               5718      0         0         0         0
C6               5774      0         0         0         0
C5               5745      0         0         0         0
C1               5658      0         0         0         0
T1               5710      0         0         0         0
GR1              5620      0         0         0         0

[OUTFALLS]
;;Name           Elevation  Type       Stage Data       Gated    Route
To
;;-------------- ---------- ---------- ---------------- -------- -----
-----------
LR_outfall       5552       FREE                        NO
S_outfall        5565       FREE                        NO
J_outfall        5579       FREE                        NO
VCA_outfall      5622       FREE                        NO
NA_outfall       5631       FREE                        NO
SA_outfall       5633       FREE                        NO
T_outfall        5673       FREE                        NO
C_outfall        5658       FREE                        NO
K_outfall        5690       FREE                        NO
17_outfall       5695       FREE                        NO
GR_outfall       5620       FREE                        NO

[DIVIDERS]
;;Name           Elevation  Diverted Link    Type       Parameters
;;-------------- ---------- ---------------- ---------- ----------
Lewiston_J       5731.16    J7_SS_OVF        CUTOFF     170.5      7.7
0          0          0
Laredo_J         5717.75    J6_SS_OVF        CUTOFF     347        10
0          0          0
Shalom_J         5638.73    J4_SS_OVF        CUTOFF     122
15.27      0          0          0
Fair_Place_VCA   5626.3     VCA_SS_OVF       CUTOFF     115        4.7
0          0          0
Parker_T1        5705.6     T0_OVF           OVERFLOW   4          0
0          0
Waco_NA          5825.75    NA3_OVF          CUTOFF     43.7       6.6
0          0          0
Buckley_NA1      5756.02    NA1_OVF          CUTOFF     195.2
16.5       0          0          0
```

```
out_RB1-4_pond   5687.5     J3_OVF           CUTOFF     458.8      13
0          0          0
Parker_NA        5671.69    NA0_OVF          CUTOFF     97.9
16.5       0          0          0

[STORAGE]
;;Name           Elev.    MaxDepth   InitDepth  Shape      Curve
Name/Params            N/A       Fevap     Psi        Ksat      IMD
;;-------------- -------- ---------- ----------- ---------- ----------
---------------- -------- --------          -------- --------
RB1-4_pond       5687.5   11.5       0          TABULAR    RB1-
4_storage              0         0
NA_pond          5764.58  9.4        0          TABULAR    NA_storage
0         0

[CONDUITS]
;;Name           From Node        To Node          Length
Roughness  InOffset   OutOffset  InitFlow   MaxFlow
;;-------------- ---------------- ---------------- ---------- --------
-- ---------- ---------- ---------- ----------
LR1_OC           Belleview_LR     LR_outfall       4430       0.07
0          0          0          0
LR2_OC           Havana_LR        Belleview_LR     2280       0.076
0          0          0          0
S_OC_A           Peoria_S         S_outfall        1230       0.067
0          0          0          0
S_OC_B           Stock_Pond_S     S_outfall        3390       0.078
0          0          0          0
J1_OC            Parker_J         J_outfall        4100       0.063
0          0          0          0
J3_OC            Junction_J3      Parker_J         1700       0.097
0          0          0          0
J4_OC            Junction_J4      Parker_J         485        0.09
0          0          0          0
J3_SS            out_RB1-4_pond   Junction_J3      1378       0.016
0          0          0          0
J4_SS            Shalom_J         Junction_J4      807        0.016
0          0          0          0
J6_SS            Laredo_J         RB1-4_pond       1870       0.016
0          0          0          0
J7_SS            Lewiston_J       Laredo_J         628        0.016
0          0          0          0
VCA_SS_OUT       Fair_Place_VCA   VCA_outfall      1801       0.016
0          0          0          0
VCA1_SS          Regis_Jesuit_VCA Fair_Place_VCA   3551       0.016
0          0          0          0
NA1_SS           Buckley_NA1      Parker_NA        3014       0.016
0          0          0          0
NA3_SS           Waco_NA          Buckley_NA1      4055       0.016
0          0          0          0
SA1_SS           Parker_SA        SA_outfall       3099       0.016
0          0          0          0
```

Note: Existing Conditions = Future Conditions for all basins except 17 Mile and Kragelund.

SA2_OC	Norfolk_SA	Parker_SA	2320	0.088	0	0	0	0
SA3_OC	Richfield_SA	Norfolk_SA	1940	0.079	0	0	0	0
T0_SS	Parker_T1	T_outfall	1604	0.016	0	0	0	0
C1_OC	Parker_C	C_outfall	2855	0.07	0	0	0	0
C2_OC	Hinsdale_C	Parker_C	1380	0.07	0	0	0	0
C3_OC	Richfield_C	Hinsdale_C	1475	0.077	0	0	0	0
C4_OC	Telluride_C	Richfield_C	1850	0.074	0	0	0	0
C6_OC	Bridle_Trail_C	Telluride_C	2325	0.076	0	0	0	0
C8_OC	Biscay_C	Bridle_Trail_C	760	0.077	0	0	0	0
K1_OC	Parker_K	K_outfall	2110	0.077	0	0	0	0
K2_OC	Bridle_Trail_K	Parker_K	2620	0.077	0	0	0	0
K4_OC	Confluence_K	Bridle_Trail_K	2860	0.088	0	0	0	0
K5_OC	Future_Road_K	Confluence_K	2325	0.091	0	0	0	0
17A_OC	Parker_17	17_outfall	1120	0.099	0	0	0	0
LR3_OF	LR3	Havana_LR	400	0.01	0	0	0	0
LR2_OF	LR2	Belleview_LR	400	0.01	0	0	0	0
LR1_OF	LR1	LR_outfall	400	0.01	0	0	0	0
S3_OF	S3	Stock_Pond_S	400	0.01	0	0	0	0
S2_OF	S2	Peoria_S	400	0.01	0	0	0	0
S_OF	S1	S_outfall	400	0.01	0	0	0	0
J8_OF	J8	Lewiston_J	400	0.01	0	0	0	0
J7_OF	J7	Laredo_J	400	0.01	0	0	0	0
J6_OF	J6	RB1-4_pond	400	0.01	0	0	0	0
J5_OF	J5	Shalom_J	400	0.01	0	0	0	0
J4_OF	J4	Parker_J	400	0.01	0	0	0	0
J3_OF	J3	Parker_J	400	0.01	0	0	0	0
J1_OF	J1	J_outfall	400	0.01	0	0	0	0
J2_OF	J2	J_outfall	400	0.01	0	0	0	0
VCA1_OF	VCA1	Fair_Place_VCA	400	0.01	0	0	0	0
VCA2_OF	VCA2	Regis_Jesuit_VCA	400	0.01	0	0	0	0
NA1_OF	NA1	Parker_NA	400	0.01	0	0	0	0
NA2_OF	NA2	NA_pond	400	0.01	0	0	0	0
NA4_OF	NA4	Waco_NA	400	0.01	0	0	0	0
NA3_OF	NA3	Buckley_NA1	400	0.01	0	0	0	0
SA4_OF	SA4	Richfield_SA	400	0.01	0	0	0	0
SA3_OF	SA3	Norfolk_SA	400	0.01	0	0	0	0
SA2_OF	SA2	Parker_SA	400	0.01	0	0	0	0
SA1_OF	SA1	SA_outfall	400	0.01	0	0	0	0
C2_OF	C2	Parker_C	400	0.01	0	0	0	0
C3_OF	C3	Hinsdale_C	400	0.01	0	0	0	0
C4_OF	C4	Richfield_C	400	0.01	0	0	0	0
C5_OF	C5	Richfield_C	400	0.01	0	0	0	0
C6_OF	C6	Telluride_C	400	0.01	0	0	0	0
C7_OF	C7	Bridle_Trail_C	400	0.01	0	0	0	0
C8_OF	C8	Bridle_Trail_C	400	0.01	0	0	0	0
C9_OF	C9	Biscay_C	400	0.01	0	0	0	0
C1_OF	C1	C_outfall	400	0.01	0	0	0	0
T1_OF	T1	Parker_T1	400	0.01	0	0	0	0
K1_OF	K1	K_outfall	400	0.01	0	0	0	0
K2_OF	K2	Parker_K	400	0.01	0	0	0	0
17B_OF	17B	Parker_17	400	0.01	0	0	0	0
K3_OF	K3	Bridle_Trail_K	400	0.01	0	0	0	0

Note: Existing Conditions = Future Conditions for all basins except 17 Mile and Kragelund.

```
K5_OF            K5               Confluence_K     400        0.01
0          0          0          0
K6_OF            K6               Confluence_K     400        0.01
0          0          0          0
K7_OF            K7               Future_Road_K    400        0.01
0          0          0          0
K4_OF            K4               Bridle_Trail_K   400        0.01
0          0          0          0
17A_OF           17A              17_outfall       400        0.01
0          0          0          0
J7_SS_OVF        Lewiston_J       Laredo_J         400        0.01
0          0          0          0
J6_SS_OVF        Laredo_J         RB1-4_pond       400        0.01
0          0          0          0
J4_SS_OVF        Shalom_J         Junction_J4      400        0.01
0          0          0          0
VCA_SS_OVF       Fair_Place_VCA   VCA_outfall      400        0.01
0          0          0          0
T0_OVF           Parker_T1        T_outfall        400        0.01
0          0          0          0
NA3_OVF          Waco_NA          Buckley_NA1      400        0.01
0          0          0          0
NA1_OVF          Buckley_NA1      Parker_NA        400        0.01
0          0          0          0
J3_OVF           out_RB1-4_pond   Junction_J3      400        0.01
0          0          0          0
GR1_OF           GR1              GR_outfall       400        0.01
0          0          0          0
NA0_SS           Parker_NA        NA_outfall       2835       0.016
0          0          0          0
NA0_OVF          Parker_NA        NA_outfall       400        0.01
0          0          0          0

[OUTLETS]
;;Name           From Node        To Node          Offset     Type
QTable/Qcoeff    Qexpon     Gated
;;-------------- ---------------- ---------------- ---------- --------
------- ---------------- ---------- --------
outlet_RB1-4_pond RB1-4_pond       out_RB1-4_pond   0
TABULAR/DEPTH   RB1-4_rating              NO
outlet_NA_pond   NA_pond          Buckley_NA1      0
TABULAR/DEPTH   NA_rating                 NO

[XSECTIONS]
;;Link           Shape        Geom1            Geom2      Geom3
Geom4      Barrels    Culvert
;;-------------- ------------ ---------------- ---------- ---------- -
--------- ---------- ----------
LR1_OC           IRREGULAR    LR2_OC           0          0          0
1
LR2_OC           IRREGULAR    LR2_OC           0          0          0
1
```

```
S_OC_A           IRREGULAR    LR2_OC           0          0          0
1
S_OC_B           IRREGULAR    LR2_OC           0          0          0
1
J1_OC            IRREGULAR    J3_OC            0          0          0
1
J3_OC            IRREGULAR    J3_OC            0          0          0
1
J4_OC            IRREGULAR    J3_OC            0          0          0
1
J3_SS            CIRCULAR     6                0          0          0
1
J4_SS            CIRCULAR     4                0          0          0
1
J6_SS            CIRCULAR     5.5              0          0          0
1
J7_SS            CIRCULAR     4                0          0          0
1
VCA_SS_OUT       RECT_CLOSED  3                8          0          0
1
VCA1_SS          CIRCULAR     5.5              0          0          0
1
NA1_SS           CIRCULAR     4                0          0          0
1
NA3_SS           CIRCULAR     2.5              0          0          0
1
SA1_SS           RECT_OPEN    6                12         0          0
1
SA2_OC           IRREGULAR    SA2_OC           0          0          0
1
SA3_OC           IRREGULAR    SA2_OC           0          0          0
1
T0_SS            CIRCULAR     4                0          0          0
1
C1_OC            IRREGULAR    C4_OC            0          0          0
1
C2_OC            IRREGULAR    C4_OC            0          0          0
1
C3_OC            IRREGULAR    C4_OC            0          0          0
1
C4_OC            IRREGULAR    C4_OC            0          0          0
1
C6_OC            IRREGULAR    C4_OC            0          0          0
1
C8_OC            IRREGULAR    C4_OC            0          0          0
1
K1_OC            IRREGULAR    K4_OC            0          0          0
1
K2_OC            IRREGULAR    K4_OC            0          0          0
1
K4_OC            IRREGULAR    K4_OC            0          0          0
1
```

Note: Existing Conditions = Future Conditions for all basins except 17 Mile and Kragelund.

K5_OC	IRREGULAR	K4_OC	0	0	0	1
17A_OC	IRREGULAR	17A	0	0	0	1
LR3_OF	DUMMY	0	0	0	0	1
LR2_OF	DUMMY	0	0	0	0	1
LR1_OF	DUMMY	0	0	0	0	1
S3_OF	DUMMY	0	0	0	0	1
S2_OF	DUMMY	0	0	0	0	1
S_OF	DUMMY	0	0	0	0	1
J8_OF	DUMMY	0	0	0	0	1
J7_OF	DUMMY	0	0	0	0	1
J6_OF	DUMMY	0	0	0	0	1
J5_OF	DUMMY	0	0	0	0	1
J4_OF	DUMMY	0	0	0	0	1
J3_OF	DUMMY	0	0	0	0	1
J1_OF	DUMMY	0	0	0	0	1
J2_OF	DUMMY	0	0	0	0	1
VCA1_OF	DUMMY	0	0	0	0	1
VCA2_OF	DUMMY	0	0	0	0	1
NA1_OF	DUMMY	0	0	0	0	1
NA2_OF	DUMMY	0	0	0	0	1
NA4_OF	DUMMY	0	0	0	0	1
NA3_OF	DUMMY	0	0	0	0	1
SA4_OF	DUMMY	0	0	0	0	1
SA3_OF	DUMMY	0	0	0	0	1
SA2_OF	DUMMY	0	0	0	0	1
SA1_OF	DUMMY	0	0	0	0	1
C2_OF	DUMMY	0	0	0	0	1
C3_OF	DUMMY	0	0	0	0	1
C4_OF	DUMMY	0	0	0	0	1
C5_OF	DUMMY	0	0	0	0	1
C6_OF	DUMMY	0	0	0	0	1
C7_OF	DUMMY	0	0	0	0	1
C8_OF	DUMMY	0	0	0	0	1
C9_OF	DUMMY	0	0	0	0	1
C1_OF	DUMMY	0	0	0	0	1
T1_OF	DUMMY	0	0	0	0	1
K1_OF	DUMMY	0	0	0	0	1
K2_OF	DUMMY	0	0	0	0	1
17B_OF	DUMMY	0	0	0	0	1
K3_OF	DUMMY	0	0	0	0	1
K5_OF	DUMMY	0	0	0	0	1
K6_OF	DUMMY	0	0	0	0	1
K7_OF	DUMMY	0	0	0	0	1
K4_OF	DUMMY	0	0	0	0	1
17A_OF	DUMMY	0	0	0	0	1
J7_SS_OVF	DUMMY	0	0	0	0	1
J6_SS_OVF	DUMMY	0	0	0	0	1
J4_SS_OVF	DUMMY	0	0	0	0	1
VCA_SS_OVF	DUMMY	0	0	0	0	1
T0_OVF	DUMMY	0	0	0	0	1
NA3_OVF	DUMMY	0	0	0	0	1
NA1_OVF	DUMMY	0	0	0	0	1

```
J3_OVF          DUMMY       0                0          0          0
1
GR1_OF          DUMMY       0                0          0          0
1
NA0_SS          CIRCULAR    3.5              0          0          0
1
NA0_OVF         DUMMY       0                0          0          0
1

[TRANSECTS]
;;Transect Data in HEC-2 format
;
NC 0.073    0.073    0.073
X1 LR2_OC            4        20       65       0.0      0.0      0.0
0.0      0.0
GR 5615     0        5609     37.5     5609     47.5     5615     85
;
NC 0.083    0.083    0.083
X1 J3_OC             4        20       100      0.0      0.0      0.0
0.0      0.0
GR 5614     0        5609     50       5609     70       5614     120
;
NC 0.084    0.084    0.084
X1 SA2_OC            4        28       52       0.0      0.0      0.0
0.0      0.0
GR 5711     0        5705.5   35       5705.5   45       5711     80
;
NC 0.074    0.074    0.074
X1 C4_OC             4        50       90       0.0      0.0      0.0
0.0      0.0
GR 5761     0        5755.5   65       5755.5   75       5761     140
;
NC 0.083    0.083    0.083
X1 K4_OC             4        25       101      0.0      0.0      0.0
0.0      0.0
GR 5780     0        5776     53       5776     73       5779     126
;
NC 0.099    0.099    0.099
X1 17A               4        22       60       0.0      0.0      0.0
0.0      0.0
GR 5712.5   0        5709.5   33       5709.5   49       5712.5   82

[CURVES]
;;Name           Type       X-Value    Y-Value
;;-------------- ---------- ---------- ----------
RB1-4_rating     Rating     0          0
RB1-4_rating                9.4        253
RB1-4_rating                11.5       410
RB1-4_rating                11.6       800
;
NA_rating        Rating     0          0
NA_rating                   0.25       0.099577919
NA_rating                   0.5        0.172682303
NA_rating                   0.75       0.235463946
NA_rating                   1          0.303475519
NA_rating                   1.25       0.378053554
NA_rating                   1.5        0.452743879
NA_rating                   1.75       0.523860156
NA_rating                   2          0.602156867
NA_rating                   2.25       0.690636693
NA_rating                   2.5        0.776927912
NA_rating                   2.75       0.860797569
NA_rating                   3          0.947930776
NA_rating                   3.25       1.044520098
NA_rating                   3.5        1.141315466
NA_rating                   3.75       1.427128841
NA_rating                   4          2.217337784
NA_rating                   4.25       3.437682479
NA_rating                   4.5        5.05247785
NA_rating                   4.75       7.039439785
NA_rating                   5          9.382521139
NA_rating                   5.25       12.06927874
NA_rating                   5.5        15.08960806
NA_rating                   5.75       18.43503888
NA_rating                   6          22.09830396
NA_rating                   6.25       26.07305627
NA_rating                   6.5        30.35367403
NA_rating                   6.75       34.16548676
NA_rating                   7          36.58187651
NA_rating                   7.25       45.87887399
NA_rating                   7.5        61.50071109
NA_rating                   7.75       81.09168456
NA_rating                   8          100.5413678
NA_rating                   8.25       122.3952724
NA_rating                   8.5        173.3363635
NA_rating                   8.75       239.3125024
NA_rating                   9          317.2942551
NA_rating                   9.25       405.4828343
NA_rating                   9.4        464.2985611
;
RB1-4_storage    Storage    0.0        0
RB1-4_storage               0.5        328
RB1-4_storage               1.5        2222
RB1-4_storage               2.5        22311
RB1-4_storage               3.5        41170
RB1-4_storage               4.5        60321
RB1-4_storage               5.5        75858
RB1-4_storage               6.5        86332
RB1-4_storage               7.5        95521
RB1-4_storage               8.5        104107
RB1-4_storage               9.5        112990
RB1-4_storage               10.5       121937
RB1-4_storage               11.5       131448
;
```

```
NA_storage       Storage    0          2015
NA_storage                  0.4        4028.5
NA_storage                  1.4        7744.803
NA_storage                  2.4        13712.894
NA_storage                  3.4        19405.348
NA_storage                  4.4        28097.354
NA_storage                  5.4        47234.436
NA_storage                  6.4        60011.204
NA_storage                  7.4        65786.986
NA_storage                  8.4        65786.986
NA_storage                  9.4        65786.986

[REPORT]
;;Reporting Options
INPUT      NO
CONTROLS   NO
SUBCATCHMENTS ALL
NODES ALL
LINKS ALL

[TAGS]

[MAP]
DIMENSIONS -2727.273 0.000 12727.273 10000.000
Units      None

[COORDINATES]
;;Node           X-Coord            Y-Coord
;;-------------- ------------------ ------------------
Belleview_LR     -123.123           8276.677
Havana_LR        -252.770           7640.991
Peoria_S         1527.855           7754.128
Stock_Pond_S     1010.237           7302.238
Parker_J         4212.105           7615.032
Junction_J3      4882.479           7462.368
Junction_J4      4371.553           7768.648
Regis_Jesuit_VCA 5966.849           5401.173
Parker_SA        5972.160           4615.175
Norfolk_SA       6718.568           4442.553
Richfield_SA     7370.156           4437.690
Parker_C         6631.041           3292.549
Hinsdale_C       7034.637           3151.534
Richfield_C      7501.446           3029.969
Telluride_C      8114.133           3085.889
Bridle_Trail_C   8790.034           3090.751
Biscay_C         9016.145           2898.679
Parker_K         7199.965           1862.945
Bridle_Trail_K   7968.256           2028.274
Confluence_K     8814.347           1702.480
Future_Road_K    9385.702           1366.961
Parker_17        7423.645           1459.350
LR3              -491.676           7030.960
LR2              39.980             7737.180
LR1              90.166             8615.430
S3               624.102            6776.536
S2               1313.661           6895.122
S1               838.769            7732.998
J8               6593.833           8275.416
J7               5980.369           8205.306
J6               5406.342           8262.270
J5               4661.421           8336.762
J2               4034.812           8319.235
J4               4337.162           8060.703
J3               4931.228           7223.949
J1               4424.799           7188.708
VCA1             5848.912           5554.265
VCA2             6650.797           5506.064
NA1              6855.406           5031.735
NA2              8013.564           5032.820
NA4              8740.957           4603.396
NA3              8459.378           4196.992
SA4              8109.965           3968.022
SA3              7325.608           4024.987
SA2              6799.782           4125.770
SA1              5752.511           4480.703
C2               7268.643           3573.653
17B              8233.267           1213.789
17A              7202.397           1595.503
K1               7022.480           1675.735
K2               7664.343           1794.869
K3               8692.782           1437.468
K4               8644.156           2322.461
K6               9283.588           2008.823
K7               10335.963          1338.891
K5               9222.805           1247.827
C9               9796.991           2473.799
C8               9735.645           3152.991
C7               9152.854           3753.310
C4               8561.300           3674.436
C3               7728.741           3547.361
C6               8736.575           2627.165
C5               8061.765           2898.842
C1               6791.018           2885.696
T1               7991.654           2578.964
GR1              5274.885           5913.579
LR_outfall       600.387            9309.666
S_outfall        1366.321           8133.280
J_outfall        3129.927           7841.141
VCA_outfall      4662.222           5584.703
NA_outfall       4920.786           4725.636
SA_outfall       4899.957           4644.351
T_outfall        6384.231           2499.017
C_outfall        5685.266           3389.801
K_outfall        6623.748           1685.461
```

```
17_outfall       7097.851          1366.961
GR_outfall       4636.318          5812.849
Lewiston_J       6015.436          7829.562
Laredo_J         5773.126          7792.686
Shalom_J         4467.849          7866.084
Fair_Place_VCA   5272.176          5592.329
Parker_T1        6901.788          2534.646
Waco_NA          8270.083          4743.724
Buckley_NA1      6942.831          4717.330
out_RB1-4_pond   5207.572          7550.921
Parker_NA        6049.035          4729.177
RB1-4_pond       5244.212          7583.078
NA_pond          7032.246          4835.941

[VERTICES]
;;Link          X-Coord            Y-Coord
;;-------------- ------------------ ------------------
LR1_OC           -39.481           9016.916
LR2_OC           -89.666           7891.920
S_OC_B           1181.705          7507.163
S_OC_B           1478.637          7703.723
J3_SS            5076.347          7414.844
J6_SS            5319.937          7778.454
C1_OC            5857.889          3290.118
K1_OC            6808.526          1619.816
LR1_OF           198.901           9004.369
J8_OF            6300.610          7900.577
J2_OF            3785.394          7860.260
NA1_OF           6340.787          4761.594
NA3_OF           8082.527          4313.694
NA3_OF           7861.278          4717.290
C3_OF            7445.526          3270.667
C4_OF            7754.301          3081.026
C6_OF            8345.107          3068.869
C8_OF            9042.889          3005.656
C1_OF            5957.572          3273.098
C1_OF            5809.263          3309.568
K3_OF            8118.996          1824.045
K5_OF            8999.126          1607.659
J7_SS_OVF        5902.881          7873.780
J6_SS_OVF        5309.509          7786.517
J4_SS_OVF        4380.048          7844.493
VCA_SS_OVF       5048.151          5604.438
T0_OVF           6637.415          2457.233
NA3_OVF          7598.916          4792.742
NA1_OVF          6568.539          4761.101
J3_OVF           5069.958          7505.387
NA0_OVF          5517.588          4782.996


  EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.012)
```

```
  --------------------------------------------------------------

  WARNING 04: minimum elevation drop used for Conduit LR3_OF
  WARNING 04: minimum elevation drop used for Conduit LR2_OF
  WARNING 04: minimum elevation drop used for Conduit LR1_OF
  WARNING 04: minimum elevation drop used for Conduit S3_OF
  WARNING 04: minimum elevation drop used for Conduit S2_OF
  WARNING 04: minimum elevation drop used for Conduit S_OF
  WARNING 04: minimum elevation drop used for Conduit J4_OF
  WARNING 04: minimum elevation drop used for Conduit J3_OF
  WARNING 04: minimum elevation drop used for Conduit J1_OF
  WARNING 04: minimum elevation drop used for Conduit J2_OF
  WARNING 04: minimum elevation drop used for Conduit VCA2_OF
  WARNING 04: minimum elevation drop used for Conduit SA4_OF
  WARNING 04: minimum elevation drop used for Conduit SA3_OF
  WARNING 04: minimum elevation drop used for Conduit SA2_OF
  WARNING 04: minimum elevation drop used for Conduit SA1_OF
  WARNING 04: minimum elevation drop used for Conduit C2_OF
  WARNING 04: minimum elevation drop used for Conduit C3_OF
  WARNING 04: minimum elevation drop used for Conduit C4_OF
  WARNING 04: minimum elevation drop used for Conduit C5_OF
  WARNING 04: minimum elevation drop used for Conduit C6_OF
  WARNING 04: minimum elevation drop used for Conduit C7_OF
  WARNING 04: minimum elevation drop used for Conduit C9_OF
  WARNING 04: minimum elevation drop used for Conduit C1_OF
  WARNING 04: minimum elevation drop used for Conduit K1_OF
  WARNING 04: minimum elevation drop used for Conduit K2_OF
  WARNING 04: minimum elevation drop used for Conduit 17B_OF
  WARNING 04: minimum elevation drop used for Conduit K3_OF
  WARNING 04: minimum elevation drop used for Conduit K5_OF
  WARNING 04: minimum elevation drop used for Conduit K6_OF
  WARNING 04: minimum elevation drop used for Conduit K7_OF
  WARNING 04: minimum elevation drop used for Conduit K4_OF
  WARNING 04: minimum elevation drop used for Conduit 17A_OF
  WARNING 04: minimum elevation drop used for Conduit GR1_OF
  WARNING 02: maximum depth increased for Node Junction_J4
  WARNING 02: maximum depth increased for Node Fair_Place_VCA

  *********************************************************
  NOTE: The summary statistics displayed in this report are
  based on results found at every computational time step,
  not just on results from each reporting time step.
  *********************************************************

  ****************
  Analysis Options
  ****************
  Flow Units ............... CFS
  Process Models:
    Rainfall/Runoff ........ NO
    RDII ................... NO
    Snowmelt ............... NO
```

```
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Flow Routing Method ...... KINWAVE
Starting Date ............ 12/01/2018 00:00:00
Ending Date .............. 12/02/2018 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:01:00
Routing Time Step ........ 5.00 sec


**************************        Volume         Volume
Flow Routing Continuity        acre-feet      10^6 gal
**************************     ---------      ---------
Dry Weather Inflow .......         0.000          0.000
Wet Weather Inflow .......         0.000          0.000
Groundwater Inflow .......         0.000          0.000
RDII Inflow ..............         0.000          0.000
External Inflow ..........       541.315        176.396
External Outflow .........       549.077        178.925
Flooding Loss ............         0.000          0.000
Evaporation Loss .........         0.000          0.000
Exfiltration Loss ........         0.000          0.000
Initial Stored Volume ....         0.000          0.000
Final Stored Volume ......         0.076          0.025
Continuity Error (%) .....        -1.448


********************************
Highest Flow Instability Indexes
********************************
Link J3_SS (5)
Link J3_OC (5)
Link outlet_RB1-4_pond (4)
Link J1_OC (3)


*************************
Routing Time Step Summary
*************************
Minimum Time Step           :     5.00 sec
Average Time Step           :     5.00 sec
Maximum Time Step           :     5.00 sec
Percent in Steady State     :     0.00
Average Iterations per Step :     1.00
Percent Not Converging      :     0.00


******************
Node Depth Summary
******************
```

```
  ---------------------------------------------------------------------
-------------
                                Average  Maximum  Maximum  Time of
Max    Reported
                                  Depth    Depth      HGL
Occurrence   Max Depth
  Node                 Type        Feet     Feet     Feet  days
hr:min        Feet
  ---------------------------------------------------------------------
-------------
  Belleview_LR         JUNCTION    0.22     3.46  5612.46     0
00:49        3.46
  Havana_LR            JUNCTION    0.16     2.89  5647.89     0
00:40        2.88
  Peoria_S             JUNCTION    0.19     1.86  5581.86     0
01:00        1.86
  Stock_Pond_S         JUNCTION    0.17     2.43  5623.43     0
00:45        2.43
  Parker_J             JUNCTION    0.34     3.42  5622.42     0
01:11        3.42
  Junction_J3          JUNCTION    0.35     3.94  5666.94     0
01:20        3.94
  Junction_J4          JUNCTION    0.18     3.27  5633.14     0
00:42        3.27
  Regis_Jesuit_VCA     JUNCTION    0.14     2.47  5691.47     0
00:40        2.47
  Parker_SA            JUNCTION    0.23     2.35  5658.35     0
01:07        2.35
  Norfolk_SA           JUNCTION    0.22     2.37  5722.37     0
00:58        2.37
  Richfield_SA         JUNCTION    0.17     1.94  5761.94     0
00:55        1.94
  Parker_C             JUNCTION    0.40     3.90  5701.90     0
01:11        3.90
  Hinsdale_C           JUNCTION    0.36     3.66  5721.66     0
01:07        3.66
  Richfield_C          JUNCTION    0.31     3.30  5748.30     0
01:03        3.30
  Telluride_C          JUNCTION    0.25     3.06  5777.06     0
00:57        3.06
  Bridle_Trail_C       JUNCTION    0.20     2.75  5816.75     0
00:48        2.75
  Biscay_C             JUNCTION    0.13     1.89  5829.89     0
00:45        1.89
  Parker_K             JUNCTION    0.28     2.91  5726.91     0
01:12        2.91
  Bridle_Trail_K       JUNCTION    0.24     2.71  5767.71     0
01:03        2.71
  Confluence_K         JUNCTION    0.15     2.04  5833.04     0
00:52        2.04
```

Note: Existing Conditions = Future Conditions for all basins except 17 Mile and Kragelund.

Future_Road_K	JUNCTION	0.09	1.52	5891.52	0	00:40	1.52
Parker_17	JUNCTION	0.10	1.58	5730.58	0	00:50	1.58
LR3	JUNCTION	0.00	0.00	5645.00	0	00:00	0.00
LR2	JUNCTION	0.00	0.00	5609.00	0	00:00	0.00
LR1	JUNCTION	0.00	0.00	5552.00	0	00:00	0.00
S3	JUNCTION	0.00	0.00	5621.00	0	00:00	0.00
S2	JUNCTION	0.00	0.00	5580.00	0	00:00	0.00
S1	JUNCTION	0.00	0.00	5565.00	0	00:00	0.00
J8	JUNCTION	0.00	0.00	5738.00	0	00:00	0.00
J7	JUNCTION	0.00	0.00	5729.00	0	00:00	0.00
J6	JUNCTION	0.00	0.00	5688.00	0	00:00	0.00
J5	JUNCTION	0.00	0.00	5645.00	0	00:00	0.00
J2	JUNCTION	0.00	0.00	5579.00	0	00:00	0.00
J4	JUNCTION	0.00	0.00	5619.00	0	00:00	0.00
J3	JUNCTION	0.00	0.00	5619.00	0	00:00	0.00
J1	JUNCTION	0.00	0.00	5579.00	0	00:00	0.00
VCA1	JUNCTION	0.00	0.00	5631.00	0	00:00	0.00
VCA2	JUNCTION	0.00	0.00	5689.00	0	00:00	0.00
NA1	JUNCTION	0.00	0.00	5631.00	0	00:00	0.00
NA2	JUNCTION	0.00	0.00	5765.00	0	00:00	0.00
NA4	JUNCTION	0.00	0.00	5833.00	0	00:00	0.00
NA3	JUNCTION	0.00	0.00	5769.00	0	00:00	0.00
SA4	JUNCTION	0.00	0.00	5760.00	0	00:00	0.00
SA3	JUNCTION	0.00	0.00	5720.00	0	00:00	0.00
SA2	JUNCTION	0.00	0.00	5656.00	0	00:00	0.00
SA1	JUNCTION	0.00	0.00	5633.00	0	00:00	0.00
C2	JUNCTION	0.00	0.00	5698.00	0	00:00	0.00
17B	JUNCTION	0.00	0.00	5729.00	0	00:00	0.00
17A	JUNCTION	0.00	0.00	5695.00	0	00:00	0.00
K1	JUNCTION	0.00	0.00	5690.00	0	00:00	0.00
K2	JUNCTION	0.00	0.00	5724.00	0	00:00	0.00
K3	JUNCTION	0.00	0.00	5765.00	0	00:00	0.00
K4	JUNCTION	0.00	0.00	5765.00	0	00:00	0.00
K6	JUNCTION	0.00	0.00	5831.00	0	00:00	0.00
K7	JUNCTION	0.00	0.00	5890.00	0	00:00	0.00
K5	JUNCTION	0.00	0.00	5831.00	0	00:00	0.00
C9	JUNCTION	0.00	0.00	5828.00	0	00:00	0.00
C8	JUNCTION	0.00	0.00	5817.00	0	00:00	0.00
C7	JUNCTION	0.00	0.00	5814.00	0	00:00	0.00
C4	JUNCTION	0.00	0.00	5745.00	0	00:00	0.00
C3	JUNCTION	0.00	0.00	5718.00	0	00:00	0.00
C6	JUNCTION	0.00	0.00	5774.00	0	00:00	0.00
C5	JUNCTION	0.00	0.00	5745.00	0	00:00	0.00
C1	JUNCTION	0.00	0.00	5658.00	0	00:00	0.00
T1	JUNCTION	0.00	0.00	5710.00	0	00:00	0.00
GR1	JUNCTION	0.00	0.00	5620.00	0	00:00	0.00
LR_outfall	OUTFALL	0.26	3.27	5555.27	0	01:08	3.27
S_outfall	OUTFALL	0.22	2.33	5567.33	0	01:01	2.33
J_outfall	OUTFALL	0.39	3.40	5582.40	0	01:27	3.40
VCA_outfall	OUTFALL	0.20	2.43	5624.43	0	01:43	2.43
NA_outfall	OUTFALL	0.55	2.90	5633.90	0	02:20	2.89
SA_outfall	OUTFALL	0.19	2.34	5635.34	0	01:08	2.34

Note: Existing Conditions = Future Conditions for all basins except 17 Mile and Kragelund.

T_outfall	OUTFALL	0.17	2.30	5675.30	0	00:51	2.30
C_outfall	OUTFALL	0.41	3.85	5661.85	0	01:21	3.85
K_outfall	OUTFALL	0.29	2.89	5692.89	0	01:21	2.89
17_outfall	OUTFALL	0.11	1.57	5696.57	0	00:53	1.57
GR_outfall	OUTFALL	0.00	0.00	5620.00	0	00:00	0.00
Lewiston_J	DIVIDER	0.21	3.28	5734.44	0	00:33	3.28
Laredo_J	DIVIDER	0.28	4.51	5722.26	0	00:34	4.51
Shalom_J	DIVIDER	0.18	3.27	5642.00	0	00:39	3.27
Fair_Place_VCA	DIVIDER	0.20	2.45	5628.75	0	00:45	2.45
Parker_T1	DIVIDER	0.17	2.31	5707.91	0	00:50	2.31
Waco_NA	DIVIDER	0.13	2.05	5827.80	0	00:32	2.05
Buckley_NA1	DIVIDER	0.47	3.28	5759.30	0	00:45	3.28
out_RB1-4_pond	DIVIDER	0.35	3.94	5691.44	0	01:19	3.94
Parker_NA	DIVIDER	0.56	3.29	5674.98	0	01:37	3.29
RB1-4_pond	STORAGE	0.88	10.73	5698.23	0	01:19	10.73
NA_pond	STORAGE	2.95	8.51	5773.09	0	01:04	8.51

****
Node Inflow Summary
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Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days	hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal	Flow Balance Error Percent
Belleview_LR	JUNCTION	0.00	403.67	0	00:49	0	10.6	0.000
Havana_LR	JUNCTION	0.00	298.37	0	00:40	0	6.82	0.000
Peoria_S	JUNCTION	0.00	101.97	0	01:00	0	4.69	0.000
Stock_Pond_S	JUNCTION	0.00	210.26	0	00:45	0	6.29	0.000
Parker_J	JUNCTION	0.00	535.49	0	01:11	0	25.7	0.000
Junction_J3	JUNCTION	0.00	352.47	0	01:20	0	16.2	0.000
Junction_J4	JUNCTION	0.00	121.87	0	00:42	0	3.18	0.000
Regis_Jesuit_VCA	JUNCTION	0.00	150.53	0	00:40	0	3.68	0.000
Parker_SA	JUNCTION	0.00	317.99	0	01:05	0	12.5	0.000
Norfolk_SA	JUNCTION	0.00	224.51	0	00:58	0	8.56	0.000
Richfield_SA	JUNCTION	0.00	126.80	0	00:55	0	4.91	0.000
Parker_C	JUNCTION	0.00	857.09	0	01:11	0	31.6	0.000
Hinsdale_C	JUNCTION	0.00	747.71	0	01:07	0	27.2	0.000
Richfield_C	JUNCTION	0.00	657.82	0	01:03	0	23.2	0.000
Telluride_C	JUNCTION	0.00	507.99	0	00:57	0	16.6	0.000
Bridle_Trail_C	JUNCTION	0.00	411.64	0	00:48	0	12.8	0.000
Biscay_C	JUNCTION	0.00	178.39	0	00:45	0	5.49	0.000
Parker_K	JUNCTION	0.00	615.45	0	01:12	0	22.7	0.000
Bridle_Trail_K	JUNCTION	0.00	513.51	0	01:03	0	17.7	0.000
Confluence_K	JUNCTION	0.00	334.43	0	00:52	0	10.1	0.000
Future_Road_K	JUNCTION	0.00	185.44	0	00:40	0	4.63	0.000
Parker_17	JUNCTION	0.00	140.87	0	00:50	0	4.13	0.000
LR3	JUNCTION	298.37	298.37	0	00:40	6.82	6.82	0.000
LR2	JUNCTION	129.14	129.14	0	00:45	3.73	3.73	0.000
LR1	JUNCTION	101.66	101.66	0	01:00	4.23	4.23	0.000
S3	JUNCTION	210.26	210.26	0	00:45	6.29	6.29	0.000
S2	JUNCTION	101.97	101.97	0	01:00	4.69	4.69	0.000

Note: Existing Conditions = Future Conditions for all basins except 17 Mile and Kragelund.

S1	JUNCTION	141.81	141.81	0	00:50	4.34	4.34	0.000
J8	JUNCTION	232.67	232.67	0	00:45	6.25	6.25	0.000
J7	JUNCTION	191.47	191.47	0	00:45	5.23	5.23	0.000
J6	JUNCTION	146.38	146.38	0	00:50	4.77	4.77	0.000
J5	JUNCTION	122.80	122.80	0	00:40	3.18	3.18	0.000
J2	JUNCTION	37.41	37.41	0	00:50	1.53	1.53	0.000
J4	JUNCTION	66.39	66.39	0	00:40	1.47	1.47	0.000
J3	JUNCTION	209.86	209.86	0	00:40	4.82	4.82	0.000
J1	JUNCTION	70.04	70.04	0	01:05	3.51	3.51	0.000
VCA1	JUNCTION	201.48	201.48	0	00:45	5.97	5.97	0.000
VCA2	JUNCTION	150.53	150.53	0	00:40	3.68	3.68	0.000
NA1	JUNCTION	208.71	208.71	0	00:40	4.92	4.92	0.000
NA2	JUNCTION	225.69	225.69	0	00:45	6.06	6.06	0.000
NA4	JUNCTION	58.66	58.66	0	00:40	1.64	1.64	0.000
NA3	JUNCTION	103.46	103.46	0	00:55	4.52	4.52	0.000
SA4	JUNCTION	126.80	126.80	0	00:55	4.91	4.91	0.000
SA3	JUNCTION	108.73	108.73	0	00:50	3.6	3.6	0.000
SA2	JUNCTION	105.35	105.35	0	00:50	3.89	3.89	0.000
SA1	JUNCTION	163.67	163.67	0	00:40	4.01	4.01	0.000
C2	JUNCTION	154.81	154.81	0	00:45	4.39	4.39	0.000
17B	JUNCTION	140.87	140.87	0	00:50	4.13	4.13	0.000
17A	JUNCTION	34.55	34.55	0	00:40	0.798	0.798	0.000
K1	JUNCTION	30.48	30.48	0	00:45	0.973	0.973	0.000
K2	JUNCTION	165.59	165.59	0	00:45	4.77	4.77	0.000
K3	JUNCTION	55.17	55.17	0	01:00	2.35	2.35	0.000
K4	JUNCTION	172.15	172.15	0	00:45	5.01	5.01	0.000
K6	JUNCTION	121.37	121.37	0	00:50	3.81	3.81	0.000
K7	JUNCTION	185.44	185.44	0	00:40	4.63	4.63	0.000
K5	JUNCTION	46.64	46.64	0	00:50	1.58	1.58	0.000
C9	JUNCTION	178.39	178.39	0	00:45	5.49	5.49	0.000
C8	JUNCTION	158.13	158.13	0	00:45	4.82	4.82	0.000
C7	JUNCTION	79.31	79.31	0	00:45	2.5	2.5	0.000
C4	JUNCTION	104.80	104.80	0	00:55	4.33	4.33	0.000
C3	JUNCTION	101.60	101.60	0	00:50	3.92	3.92	0.000
C6	JUNCTION	122.15	122.15	0	00:45	3.6	3.6	0.000
C5	JUNCTION	60.80	60.80	0	00:50	2.25	2.25	0.000
C1	JUNCTION	176.28	176.28	0	00:45	5.2	5.2	0.000
T1	JUNCTION	104.95	104.95	0	00:50	3.62	3.62	0.000
GR1	JUNCTION	150.25	150.25	0	00:40	4.14	4.14	0.000
LR_outfall	OUTFALL	0.00	453.53	0	01:07	0	15.3	0.000
S_outfall	OUTFALL	0.00	422.74	0	01:00	0	15.5	0.000
J_outfall	OUTFALL	0.00	613.26	0	01:24	0	31.5	0.000
VCA_outfall	OUTFALL	0.00	349.18	0	00:45	0	9.65	0.000
NA_outfall	OUTFALL	0.00	476.03	0	00:59	0	17.1	0.000
SA_outfall	OUTFALL	0.00	426.06	0	01:04	0	16.5	0.000
T_outfall	OUTFALL	0.00	104.71	0	00:51	0	3.61	0.000
C_outfall	OUTFALL	0.00	942.12	0	01:19	0	36.9	0.000
K_outfall	OUTFALL	0.00	626.36	0	01:21	0	23.8	0.000
17_outfall	OUTFALL	0.00	169.37	0	00:52	0	4.96	0.000
GR_outfall	OUTFALL	0.00	150.25	0	00:40	0	4.14	0.000
Lewiston_J	DIVIDER	0.00	232.67	0	00:45	0	6.25	0.000
Laredo_J	DIVIDER	0.00	424.14	0	00:45	0	11.5	0.000

Note: Existing Conditions = Future Conditions for all basins except 17 Mile and Kragelund.

```
  Shalom_J               DIVIDER       0.00   122.80     0  00:40
0        3.18      0.000
  Fair_Place_VCA         DIVIDER       0.00   349.24     0  00:45
0        9.64      0.000
  Parker_T1              DIVIDER       0.00   104.95     0  00:50
0        3.62      0.000
  Waco_NA                DIVIDER       0.00    58.66     0  00:40
0        1.64      0.000
  Buckley_NA1            DIVIDER       0.00   324.75     0  01:03
0        12.2      0.000
  out_RB1-4_pond         DIVIDER       0.00   352.51     0  01:19
0        16.2      0.000
  Parker_NA              DIVIDER       0.00   476.03     0  00:59
0        17.1      0.000
  RB1-4_pond             STORAGE       0.00   569.69     0  00:45
0        16.2      0.011
  NA_pond                STORAGE       0.00   225.69     0  00:45
0        6.06      0.028


  *********************
  Node Flooding Summary
  *********************

  No nodes were flooded.


  **********************
  Storage Volume Summary
  **********************

  ----------------------------------------------------------------------
------------------------------
                       Average     Avg  Evap Exfil       Maximum
Max     Time of Max    Maximum
                        Volume    Pcnt  Pcnt  Pcnt        Volume
Pcnt      Occurrence    Outflow
  Storage Unit        1000 ft3    Full  Loss  Loss      1000 ft3
Full     days hr:min       CFS
  ----------------------------------------------------------------------
------------------------------
  RB1-4_pond            43.139       5     0     0       690.474
88       0  01:18     352.51
  NA_pond               43.569      13     0     0       285.349
83       0  01:04     175.99


  ***********************
  Outfall Loading Summary
  ***********************

  -----------------------------------------------------------
```

```
                        Flow       Avg       Max       Total
                        Freq      Flow      Flow      Volume
  Outfall Node          Pcnt       CFS       CFS    10^6 gal
  -----------------------------------------------------------
  LR_outfall           99.13     23.83    453.53      15.265
  S_outfall            79.69     30.02    422.74      15.460
  J_outfall            99.30     49.02    613.26      31.456
  VCA_outfall          44.97     33.19    349.18       9.646
  NA_outfall           99.08     26.74    476.03      17.120
  SA_outfall           99.30     25.75    426.06      16.526
  T_outfall            22.65     24.69    104.71       3.615
  C_outfall            99.30     57.56    942.12      36.938
  K_outfall            99.28     37.07    626.36      23.785
  17_outfall           44.81     17.12    169.37       4.958
  GR_outfall           14.91     43.00    150.25       4.143
  -----------------------------------------------------------
  System               72.95    367.98   4310.13     178.912


  ********************
  Link Flow Summary
  ********************

  ----------------------------------------------------------------------
---------
                               Maximum  Time of Max   Maximum
Max/    Max/
                                |Flow|   Occurrence    |Veloc|
Full    Full
  Link                 Type        CFS  days hr:min    ft/sec
Flow   Depth
  ----------------------------------------------------------------------
---------
  LR1_OC               CHANNEL  355.23     0  01:08      3.92
0.24    0.54
  LR2_OC               CHANNEL  278.12     0  00:50      3.75
0.17    0.46
  S_OC_A               CHANNEL  101.42     0  01:05      2.55
0.07    0.31
  S_OC_B               CHANNEL  191.94     0  01:01      3.51
0.12    0.39
  J1_OC                CHANNEL  526.08     0  01:27      3.35
0.42    0.68
  J3_OC                CHANNEL  351.13     0  01:25      4.41
0.17    0.45
  J4_OC                CHANNEL  121.27     0  00:44      2.64
0.06    0.27
  J3_SS                CONDUIT  352.47     0  01:20     17.90
0.77    0.66
  J4_SS                CONDUIT  121.87     0  00:42     11.16
1.00    0.82
```

Note: Existing Conditions = Future Conditions
for all basins except 17 Mile and Kragelund.

```
  J6_SS                   CONDUIT    347.74     0  01:01      16.83
1.00    0.82
  J7_SS                   CONDUIT    170.68     0  01:08      15.55
1.00    0.82
  VCA_SS_OUT              CONDUIT    115.86     0  01:43       6.08
1.00    0.80
  VCA1_SS                 CONDUIT    147.93     0  00:45      14.61
0.41    0.44
  NA1_SS                  CONDUIT    196.00     0  01:37      18.03
1.00    0.82
  NA3_SS                  CONDUIT     44.22     0  01:10      10.70
1.01    0.82
  SA1_SS                  CONDUIT    317.45     0  01:08      11.36
0.26    0.39
  SA2_OC                  CHANNEL    221.56     0  01:07       3.84
0.14    0.43
  SA3_OC                  CHANNEL    123.79     0  01:02       2.96
0.09    0.35
  T0_SS                   CONDUIT    104.71     0  00:51      14.02
0.63    0.58
  C1_OC                   CHANNEL    834.46     0  01:21       4.01
0.42    0.70
  C2_OC                   CHANNEL    743.91     0  01:12       3.87
0.36    0.66
  C3_OC                   CHANNEL    654.25     0  01:08       4.09
0.29    0.60
  C4_OC                   CHANNEL    500.33     0  01:04       3.63
0.24    0.55
  C6_OC                   CHANNEL    397.45     0  00:58       3.56
0.18    0.49
  C8_OC                   CHANNEL    177.03     0  00:50       2.93
0.08    0.34
  K1_OC                   CHANNEL    606.59     0  01:21       3.32
0.45    0.72
  K2_OC                   CHANNEL    498.06     0  01:16       3.17
0.38    0.66
  K4_OC                   CHANNEL    315.77     0  01:08       3.28
0.20    0.50
  K5_OC                   CHANNEL    170.71     0  00:55       2.87
0.10    0.36
  17A_OC                  CHANNEL    139.29     0  00:53       2.69
0.25    0.52
  LR3_OF                  DUMMY      298.37     0  00:40
  LR2_OF                  DUMMY      129.14     0  00:45
  LR1_OF                  DUMMY      101.66     0  01:00
  S3_OF                   DUMMY      210.26     0  00:45
  S2_OF                   DUMMY      101.97     0  01:00
  S_OF                    DUMMY      141.81     0  00:50
  J8_OF                   DUMMY      232.67     0  00:45
  J7_OF                   DUMMY      191.47     0  00:45
  J6_OF                   DUMMY      146.38     0  00:50
  J5_OF                   DUMMY      122.80     0  00:40
  J4_OF                   DUMMY       66.39     0  00:40
  J3_OF                   DUMMY      209.86     0  00:40
  J1_OF                   DUMMY       70.04     0  01:05
  J2_OF                   DUMMY       37.41     0  00:50
  VCA1_OF                 DUMMY      201.48     0  00:45
  VCA2_OF                 DUMMY      150.53     0  00:40
  NA1_OF                  DUMMY      208.71     0  00:40
  NA2_OF                  DUMMY      225.69     0  00:45
  NA4_OF                  DUMMY       58.66     0  00:40
  NA3_OF                  DUMMY      103.46     0  00:55
  SA4_OF                  DUMMY      126.80     0  00:55
  SA3_OF                  DUMMY      108.73     0  00:50
  SA2_OF                  DUMMY      105.35     0  00:50
  SA1_OF                  DUMMY      163.67     0  00:40
  C2_OF                   DUMMY      154.81     0  00:45
  C3_OF                   DUMMY      101.60     0  00:50
  C4_OF                   DUMMY      104.80     0  00:55
  C5_OF                   DUMMY       60.80     0  00:50
  C6_OF                   DUMMY      122.15     0  00:45
  C7_OF                   DUMMY       79.31     0  00:45
  C8_OF                   DUMMY      158.13     0  00:45
  C9_OF                   DUMMY      178.39     0  00:45
  C1_OF                   DUMMY      176.28     0  00:45
  T1_OF                   DUMMY      104.95     0  00:50
  K1_OF                   DUMMY       30.48     0  00:45
  K2_OF                   DUMMY      165.59     0  00:45
  17B_OF                  DUMMY      140.87     0  00:50
  K3_OF                   DUMMY       55.17     0  01:00
  K5_OF                   DUMMY       46.64     0  00:50
  K6_OF                   DUMMY      121.37     0  00:50
  K7_OF                   DUMMY      185.44     0  00:40
  K4_OF                   DUMMY      172.15     0  00:45
  17A_OF                  DUMMY       34.55     0  00:40
  J7_SS_OVF               DUMMY       62.17     0  00:45
  J6_SS_OVF               DUMMY       77.14     0  00:45
  J4_SS_OVF               DUMMY        0.80     0  00:40
  VCA_SS_OVF              DUMMY      234.24     0  00:45
  T0_OVF                  DUMMY        0.00     0  00:00
  NA3_OVF                 DUMMY       14.96     0  00:40
  NA1_OVF                 DUMMY      129.55     0  01:03
  J3_OVF                  DUMMY        0.00     0  00:00
  GR1_OF                  DUMMY      150.25     0  00:40
  NA0_SS                  CONDUIT     98.74     0  02:20      12.02
1.01    0.82
  NA0_OVF                 DUMMY      378.13     0  00:59
  outlet_RB1-4_pond       DUMMY      352.51     0  01:19
  outlet_NA_pond          DUMMY      175.99     0  01:04


  *************************
  Conduit Surcharge Summary
  *************************
```

Note: Existing Conditions = Future Conditions for all basins except 17 Mile and Kragelund.

Conduit	Hours Full Both Ends	Hours Full Upstream	Hours Full Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
J6_SS	0.01	0.01	0.01	0.02	0.01
J7_SS	0.01	0.01	0.01	0.01	0.01
VCA_SS_OUT	0.01	0.01	0.01	0.03	0.01
NA1_SS	0.01	0.01	0.01	0.03	0.01
NA3_SS	0.01	0.01	0.01	0.07	0.01
NA0_SS	0.01	0.01	0.01	0.04	0.01

```
  Analysis begun on:  Mon Feb 11 11:07:13 2019
  Analysis ended on:  Mon Feb 11 11:07:14 2019
  Total elapsed time: 00:00:01
```

```
[Baseline Hydrology SWMM Input]
;;Cherry Creek Tribs U/S of Cherry Creek Reservoir

[OPTIONS]
;;Option             Value
FLOW_UNITS           CFS
INFILTRATION         HORTON
FLOW_ROUTING         KINWAVE
LINK_OFFSETS         DEPTH
MIN_SLOPE            0
ALLOW_PONDING        NO
SKIP_STEADY_STATE    NO

START_DATE           12/01/2018
START_TIME           00:00:00
REPORT_START_DATE    12/01/2018
REPORT_START_TIME    00:00:00
END_DATE             12/02/2018
END_TIME             00:00:00
SWEEP_START          01/01
SWEEP_END            12/31
DRY_DAYS             0
REPORT_STEP          00:01:00
WET_STEP             00:05:00
DRY_STEP             00:05:00
ROUTING_STEP         0:00:05

INERTIAL_DAMPING     PARTIAL
NORMAL_FLOW_LIMITED  BOTH
FORCE_MAIN_EQUATION  H-W
VARIABLE_STEP        0.75
LENGTHENING_STEP     0
MIN_SURFAREA         12.557
MAX_TRIALS           8
HEAD_TOLERANCE       0.005
SYS_FLOW_TOL         5
LAT_FLOW_TOL         5
MINIMUM_STEP         0.5
THREADS              1

[FILES]
;;Interfacing Files
USE INFLOWS "J:\506004\WR_DRN\CUHP\OUT\CC_Fut_100yr_0mi^2_BH.txt"

[EVAPORATION]
;;Data Source    Parameters
;;-------------- ----------------
CONSTANT         0.0
DRY_ONLY         NO

[JUNCTIONS]
;;Name           Elevation  MaxDepth   InitDepth  SurDepth   Aponded
;;-------------- ---------- ---------- ---------- ---------- ----------
Belleview_LR     5609       0          0          0          0
Havana_LR        5645       0          0          0          0
Peoria_S         5580       0          0          0          0
Stock_Pond_S     5621       0          0          0          0
Parker_J         5619       0          0          0          0
Junction_J3      5663       0          0          0          0
Junction_J4      5629.87    1.13       0          0          0
Regis_Jesuit_VCA 5689       0          0          0          0
Parker_SA        5656       0          0          0          0
Norfolk_SA       5720       0          0          0          0
Richfield_SA     5760       0          0          0          0
Parker_C         5698       0          0          0          0
Hinsdale_C       5718       0          0          0          0
Richfield_C      5745       0          0          0          0
Telluride_C      5774       0          0          0          0
Bridle_Trail_C   5814       0          0          0          0
Biscay_C         5828       0          0          0          0
Parker_K         5724       0          0          0          0
Bridle_Trail_K   5765       0          0          0          0
Confluence_K     5831       0          0          0          0
Future_Road_K    5890       0          0          0          0
Parker_17        5729       0          0          0          0
LR3              5645       0          0          0          0
LR2              5609       0          0          0          0
LR1              5552       0          0          0          0
S3               5621       0          0          0          0
S2               5580       0          0          0          0
S1               5565       0          0          0          0
J8               5738       0          0          0          0
J7               5729       0          0          0          0
J6               5688       0          0          0          0
J5               5645       0          0          0          0
J2               5579       0          0          0          0
J4               5619       0          0          0          0
J3               5619       0          0          0          0
J1               5579       0          0          0          0
VCA1             5631       0          0          0          0
VCA2             5689       0          0          0          0
NA1              5631       0          0          0          0
NA2              5765       0          0          0          0
NA4              5833       0          0          0          0
NA3              5769       0          0          0          0
SA4              5760       0          0          0          0
SA3              5720       0          0          0          0
SA2              5656       0          0          0          0
SA1              5633       0          0          0          0
C2               5698       0          0          0          0
17B              5729       0          0          0          0
17A              5695       0          0          0          0
K1               5690       0          0          0          0
```

```
K2               5724      0          0          0          0
K3               5765      0          0          0          0
K4               5765      0          0          0          0
K6               5831      0          0          0          0
K7               5890      0          0          0          0
K5               5831      0          0          0          0
C9               5828      0          0          0          0
C8               5817      0          0          0          0
C7               5814      0          0          0          0
C4               5745      0          0          0          0
C3               5718      0          0          0          0
C6               5774      0          0          0          0
C5               5745      0          0          0          0
C1               5658      0          0          0          0
T1               5710      0          0          0          0
GR1              5620      0          0          0          0

[OUTFALLS]
;;Name           Elevation  Type       Stage Data       Gated    Route
To
;;-------------- ---------- ---------- ---------------- -------- -----
-----------
LR_outfall       5552       FREE                        NO
S_outfall        5565       FREE                        NO
J_outfall        5579       FREE                        NO
VCA_outfall      5622       FREE                        NO
NA_outfall       5631       FREE                        NO
SA_outfall       5633       FREE                        NO
T_outfall        5673       FREE                        NO
C_outfall        5658       FREE                        NO
K_outfall        5690       FREE                        NO
17_outfall       5695       FREE                        NO
GR_outfall       5620       FREE                        NO

[DIVIDERS]
;;Name           Elevation  Diverted Link    Type       Parameters
;;-------------- ---------- ---------------- ---------- ----------
Lewiston_J       5731.16    J7_SS_OVF        CUTOFF     170.5      7.7
0          0          0
Laredo_J         5717.75    J6_SS_OVF        CUTOFF     347        10
0          0          0
Shalom_J         5638.73    J4_SS_OVF        CUTOFF     122
15.27      0          0          0
Fair_Place_VCA   5626.3     VCA_SS_OVF       CUTOFF     115        4.7
0          0          0
Parker_T1        5705.6     T0_OVF           OVERFLOW   4          0
0          0
Waco_NA          5825.75    NA3_OVF          CUTOFF     43.7       6.6
0          0          0
Buckley_NA1      5756.02    NA1_OVF          CUTOFF     195.2
16.5       0          0          0
```

```
out_RB1-4_pond   5687.5     J3_OVF           CUTOFF     458.8      13
0          0          0
Parker_NA        5671.69    NA0_OVF          CUTOFF     97.9
16.5       0          0          0

[STORAGE]
;;Name           Elev.    MaxDepth   InitDepth  Shape      Curve
Name/Params            N/A      Fevap    Psi       Ksat     IMD
;;-------------- -------- ---------- ----------- ---------- ----------
---------------- -------- --------          -------- --------
RB1-4_pond       5687.5   11.5       0          TABULAR    RB1-
4_storage                 0        0
NA_pond          5764.58  9.4        0          TABULAR    NA_storage
0        0

[CONDUITS]
;;Name           From Node        To Node          Length
Roughness  InOffset   OutOffset  InitFlow   MaxFlow
;;-------------- ---------------- ---------------- ---------- --------
-- ---------- ---------- ---------- ----------
LR1_OC           Belleview_LR     LR_outfall       4430       0.07
0          0          0          0
LR2_OC           Havana_LR        Belleview_LR     2280       0.076
0          0          0          0
S_OC_A           Peoria_S         S_outfall        1230       0.067
0          0          0          0
S_OC_B           Stock_Pond_S     S_outfall        3390       0.078
0          0          0          0
J1_OC            Parker_J         J_outfall        4100       0.063
0          0          0          0
J3_OC            Junction_J3      Parker_J         1700       0.097
0          0          0          0
J4_OC            Junction_J4      Parker_J         485        0.09
0          0          0          0
J3_SS            out_RB1-4_pond   Junction_J3      1378       0.016
0          0          0          0
J4_SS            Shalom_J         Junction_J4      807        0.016
0          0          0          0
J6_SS            Laredo_J         RB1-4_pond       1870       0.016
0          0          0          0
J7_SS            Lewiston_J       Laredo_J         628        0.016
0          0          0          0
VCA_SS_OUT       Fair_Place_VCA   VCA_outfall      1801       0.016
0          0          0          0
VCA1_SS          Regis_Jesuit_VCA Fair_Place_VCA   3551       0.016
0          0          0          0
NA1_SS           Buckley_NA1      Parker_NA        3014       0.016
0          0          0          0
NA3_SS           Waco_NA          Buckley_NA1      4055       0.016
0          0          0          0
SA1_SS           Parker_SA        SA_outfall       3099       0.016
0          0          0          0
```

SA2_OC	Norfolk_SA	Parker_SA	2320	0.088	0	0	0	0
SA3_OC	Richfield_SA	Norfolk_SA	1940	0.079	0	0	0	0
T0_SS	Parker_T1	T_outfall	1604	0.016	0	0	0	0
C1_OC	Parker_C	C_outfall	2855	0.07	0	0	0	0
C2_OC	Hinsdale_C	Parker_C	1380	0.07	0	0	0	0
C3_OC	Richfield_C	Hinsdale_C	1475	0.077	0	0	0	0
C4_OC	Telluride_C	Richfield_C	1850	0.074	0	0	0	0
C6_OC	Bridle_Trail_C	Telluride_C	2325	0.076	0	0	0	0
C8_OC	Biscay_C	Bridle_Trail_C	760	0.077	0	0	0	0
K1_OC	Parker_K	K_outfall	2110	0.077	0	0	0	0
K2_OC	Bridle_Trail_K	Parker_K	2620	0.077	0	0	0	0
K4_OC	Confluence_K	Bridle_Trail_K	2860	0.088	0	0	0	0
K5_OC	Future_Road_K	Confluence_K	2325	0.091	0	0	0	0
17A_OC	Parker_17	17_outfall	1120	0.099	0	0	0	0
LR3_OF	LR3	Havana_LR	400	0.01	0	0	0	0
LR2_OF	LR2	Belleview_LR	400	0.01	0	0	0	0
LR1_OF	LR1	LR_outfall	400	0.01	0	0	0	0
S3_OF	S3	Stock_Pond_S	400	0.01	0	0	0	0
S2_OF	S2	Peoria_S	400	0.01	0	0	0	0
S_OF	S1	S_outfall	400	0.01	0	0	0	0
J8_OF	J8	Lewiston_J	400	0.01	0	0	0	0
J7_OF	J7	Laredo_J	400	0.01	0	0	0	0
J6_OF	J6	RB1-4_pond	400	0.01	0	0	0	0
J5_OF	J5	Shalom_J	400	0.01	0	0	0	0
J4_OF	J4	Parker_J	400	0.01	0	0	0	0
J3_OF	J3	Parker_J	400	0.01	0	0	0	0
J1_OF	J1	J_outfall	400	0.01	0	0	0	0
J2_OF	J2	J_outfall	400	0.01	0	0	0	0
VCA1_OF	VCA1	Fair_Place_VCA	400	0.01	0	0	0	0
VCA2_OF	VCA2	Regis_Jesuit_VCA	400	0.01	0	0	0	0
NA1_OF	NA1	Parker_NA	400	0.01	0	0	0	0
NA2_OF	NA2	NA_pond	400	0.01	0	0	0	0
NA4_OF	NA4	Waco_NA	400	0.01	0	0	0	0
NA3_OF	NA3	Buckley_NA1	400	0.01	0	0	0	0
SA4_OF	SA4	Richfield_SA	400	0.01	0	0	0	0
SA3_OF	SA3	Norfolk_SA	400	0.01	0	0	0	0
SA2_OF	SA2	Parker_SA	400	0.01	0	0	0	0
SA1_OF	SA1	SA_outfall	400	0.01	0	0	0	0
C2_OF	C2	Parker_C	400	0.01	0	0	0	0
C3_OF	C3	Hinsdale_C	400	0.01	0	0	0	0
C4_OF	C4	Richfield_C	400	0.01	0	0	0	0
C5_OF	C5	Richfield_C	400	0.01	0	0	0	0
C6_OF	C6	Telluride_C	400	0.01	0	0	0	0
C7_OF	C7	Bridle_Trail_C	400	0.01	0	0	0	0
C8_OF	C8	Bridle_Trail_C	400	0.01	0	0	0	0
C9_OF	C9	Biscay_C	400	0.01	0	0	0	0
C1_OF	C1	C_outfall	400	0.01	0	0	0	0
T1_OF	T1	Parker_T1	400	0.01	0	0	0	0
K1_OF	K1	K_outfall	400	0.01	0	0	0	0
K2_OF	K2	Parker_K	400	0.01	0	0	0	0
17B_OF	17B	Parker_17	400	0.01	0	0	0	0
K3_OF	K3	Bridle_Trail_K	400	0.01	0	0	0	0

```
K5_OF            K5               Confluence_K     400        0.01
0          0          0          0
K6_OF            K6               Confluence_K     400        0.01
0          0          0          0
K7_OF            K7               Future_Road_K    400        0.01
0          0          0          0
K4_OF            K4               Bridle_Trail_K   400        0.01
0          0          0          0
17A_OF           17A              17_outfall       400        0.01
0          0          0          0
J7_SS_OVF        Lewiston_J       Laredo_J         400        0.01
0          0          0          0
J6_SS_OVF        Laredo_J         RB1-4_pond       400        0.01
0          0          0          0
J4_SS_OVF        Shalom_J         Junction_J4      400        0.01
0          0          0          0
VCA_SS_OVF       Fair_Place_VCA   VCA_outfall      400        0.01
0          0          0          0
T0_OVF           Parker_T1        T_outfall        400        0.01
0          0          0          0
NA3_OVF          Waco_NA          Buckley_NA1      400        0.01
0          0          0          0
NA1_OVF          Buckley_NA1      Parker_NA        400        0.01
0          0          0          0
J3_OVF           out_RB1-4_pond   Junction_J3      400        0.01
0          0          0          0
GR1_OF           GR1              GR_outfall       400        0.01
0          0          0          0
NA0_SS           Parker_NA        NA_outfall       2835       0.016
0          0          0          0
NA0_OVF          Parker_NA        NA_outfall       400        0.01
0          0          0          0

[OUTLETS]
;;Name           From Node        To Node          Offset     Type
QTable/Qcoeff    Qexpon     Gated
;;-------------- ---------------- ---------------- ---------- --------
------- ---------------- ---------- --------
outlet_RB1-4_pond RB1-4_pond       out_RB1-4_pond   0
TABULAR/DEPTH   RB1-4_rating               NO
outlet_NA_pond   NA_pond          Buckley_NA1      0
TABULAR/DEPTH   NA_rating                  NO

[XSECTIONS]
;;Link           Shape        Geom1            Geom2      Geom3
Geom4      Barrels    Culvert
;;-------------- ------------ ---------------- ---------- ---------- -
--------- ---------- ----------
LR1_OC           IRREGULAR    LR2_OC           0          0          0
1
LR2_OC           IRREGULAR    LR2_OC           0          0          0
1
S_OC_A           IRREGULAR    LR2_OC           0          0          0
1
S_OC_B           IRREGULAR    LR2_OC           0          0          0
1
J1_OC            IRREGULAR    J3_OC            0          0          0
1
J3_OC            IRREGULAR    J3_OC            0          0          0
1
J4_OC            IRREGULAR    J3_OC            0          0          0
1
J3_SS            CIRCULAR     6                0          0          0
1
J4_SS            CIRCULAR     4                0          0          0
1
J6_SS            CIRCULAR     5.5              0          0          0
1
J7_SS            CIRCULAR     4                0          0          0
1
VCA_SS_OUT       RECT_CLOSED  3                8          0          0
1
VCA1_SS          CIRCULAR     5.5              0          0          0
1
NA1_SS           CIRCULAR     4                0          0          0
1
NA3_SS           CIRCULAR     2.5              0          0          0
1
SA1_SS           RECT_OPEN    6                12         0          0
1
SA2_OC           IRREGULAR    SA2_OC           0          0          0
1
SA3_OC           IRREGULAR    SA2_OC           0          0          0
1
T0_SS            CIRCULAR     4                0          0          0
1
C1_OC            IRREGULAR    C4_OC            0          0          0
1
C2_OC            IRREGULAR    C4_OC            0          0          0
1
C3_OC            IRREGULAR    C4_OC            0          0          0
1
C4_OC            IRREGULAR    C4_OC            0          0          0
1
C6_OC            IRREGULAR    C4_OC            0          0          0
1
C8_OC            IRREGULAR    C4_OC            0          0          0
1
K1_OC            IRREGULAR    K4_OC            0          0          0
1
K2_OC            IRREGULAR    K4_OC            0          0          0
1
K4_OC            IRREGULAR    K4_OC            0          0          0
1
```

K5_OC	IRREGULAR	K4_OC	0	0	0	1
17A_OC	IRREGULAR	17A	0	0	0	1
LR3_OF	DUMMY	0	0	0	0	1
LR2_OF	DUMMY	0	0	0	0	1
LR1_OF	DUMMY	0	0	0	0	1
S3_OF	DUMMY	0	0	0	0	1
S2_OF	DUMMY	0	0	0	0	1
S_OF	DUMMY	0	0	0	0	1
J8_OF	DUMMY	0	0	0	0	1
J7_OF	DUMMY	0	0	0	0	1
J6_OF	DUMMY	0	0	0	0	1
J5_OF	DUMMY	0	0	0	0	1
J4_OF	DUMMY	0	0	0	0	1
J3_OF	DUMMY	0	0	0	0	1
J1_OF	DUMMY	0	0	0	0	1
J2_OF	DUMMY	0	0	0	0	1
VCA1_OF	DUMMY	0	0	0	0	1
VCA2_OF	DUMMY	0	0	0	0	1
NA1_OF	DUMMY	0	0	0	0	1
NA2_OF	DUMMY	0	0	0	0	1
NA4_OF	DUMMY	0	0	0	0	1
NA3_OF	DUMMY	0	0	0	0	1
SA4_OF	DUMMY	0	0	0	0	1
SA3_OF	DUMMY	0	0	0	0	1
SA2_OF	DUMMY	0	0	0	0	1
SA1_OF	DUMMY	0	0	0	0	1
C2_OF	DUMMY	0	0	0	0	1
C3_OF	DUMMY	0	0	0	0	1
C4_OF	DUMMY	0	0	0	0	1
C5_OF	DUMMY	0	0	0	0	1
C6_OF	DUMMY	0	0	0	0	1
C7_OF	DUMMY	0	0	0	0	1
C8_OF	DUMMY	0	0	0	0	1
C9_OF	DUMMY	0	0	0	0	1
C1_OF	DUMMY	0	0	0	0	1
T1_OF	DUMMY	0	0	0	0	1
K1_OF	DUMMY	0	0	0	0	1
K2_OF	DUMMY	0	0	0	0	1
17B_OF	DUMMY	0	0	0	0	1
K3_OF	DUMMY	0	0	0	0	1
K5_OF	DUMMY	0	0	0	0	1
K6_OF	DUMMY	0	0	0	0	1
K7_OF	DUMMY	0	0	0	0	1
K4_OF	DUMMY	0	0	0	0	1
17A_OF	DUMMY	0	0	0	0	1
J7_SS_OVF	DUMMY	0	0	0	0	1
J6_SS_OVF	DUMMY	0	0	0	0	1
J4_SS_OVF	DUMMY	0	0	0	0	1
VCA_SS_OVF	DUMMY	0	0	0	0	1
T0_OVF	DUMMY	0	0	0	0	1
NA3_OVF	DUMMY	0	0	0	0	1
NA1_OVF	DUMMY	0	0	0	0	1

```
J3_OVF          DUMMY       0           0       0       0
1
GR1_OF          DUMMY       0           0       0       0
1
NA0_SS          CIRCULAR    3.5         0       0       0
1
NA0_OVF         DUMMY       0           0       0       0
1

[TRANSECTS]
;;Transect Data in HEC-2 format
;
NC 0.073    0.073    0.073
X1 LR2_OC            4        20       65       0.0      0.0      0.0
0.0      0.0
GR 5615     0        5609     37.5     5609     47.5     5615     85
;
NC 0.083    0.083    0.083
X1 J3_OC             4        20       100      0.0      0.0      0.0
0.0      0.0
GR 5614     0        5609     50       5609     70       5614     120
;
NC 0.084    0.084    0.084
X1 SA2_OC            4        28       52       0.0      0.0      0.0
0.0      0.0
GR 5711     0        5705.5   35       5705.5   45       5711     80
;
NC 0.074    0.074    0.074
X1 C4_OC             4        50       90       0.0      0.0      0.0
0.0      0.0
GR 5761     0        5755.5   65       5755.5   75       5761     140
;
NC 0.083    0.083    0.083
X1 K4_OC             4        25       101      0.0      0.0      0.0
0.0      0.0
GR 5780     0        5776     53       5776     73       5779     126
;
NC 0.099    0.099    0.099
X1 17A               4        22       60       0.0      0.0      0.0
0.0      0.0
GR 5712.5   0        5709.5   33       5709.5   49       5712.5   82

[CURVES]
;;Name           Type       X-Value    Y-Value
;;-------------- ---------- ---------- ----------
RB1-4_rating     Rating     0          0
RB1-4_rating                9.4        253
RB1-4_rating                11.5       410
RB1-4_rating                11.6       800
;
NA_rating        Rating     0          0
NA_rating                   0.25       0.099577919
NA_rating                   0.5        0.172682303
NA_rating                   0.75       0.235463946
NA_rating                   1          0.303475519
NA_rating                   1.25       0.378053554
NA_rating                   1.5        0.452743879
NA_rating                   1.75       0.523860156
NA_rating                   2          0.602156867
NA_rating                   2.25       0.690636693
NA_rating                   2.5        0.776927912
NA_rating                   2.75       0.860797569
NA_rating                   3          0.947930776
NA_rating                   3.25       1.044520098
NA_rating                   3.5        1.141315466
NA_rating                   3.75       1.427128841
NA_rating                   4          2.217337784
NA_rating                   4.25       3.437682479
NA_rating                   4.5        5.05247785
NA_rating                   4.75       7.039439785
NA_rating                   5          9.382521139
NA_rating                   5.25       12.06927874
NA_rating                   5.5        15.08960806
NA_rating                   5.75       18.43503888
NA_rating                   6          22.09830396
NA_rating                   6.25       26.07305627
NA_rating                   6.5        30.35367403
NA_rating                   6.75       34.16548676
NA_rating                   7          36.58187651
NA_rating                   7.25       45.87887399
NA_rating                   7.5        61.50071109
NA_rating                   7.75       81.09168456
NA_rating                   8          100.5413678
NA_rating                   8.25       122.3952724
NA_rating                   8.5        173.3363635
NA_rating                   8.75       239.3125024
NA_rating                   9          317.2942551
NA_rating                   9.25       405.4828343
NA_rating                   9.4        464.2985611
;
RB1-4_storage    Storage    0.0        0
RB1-4_storage               0.5        328
RB1-4_storage               1.5        2222
RB1-4_storage               2.5        22311
RB1-4_storage               3.5        41170
RB1-4_storage               4.5        60321
RB1-4_storage               5.5        75858
RB1-4_storage               6.5        86332
RB1-4_storage               7.5        95521
RB1-4_storage               8.5        104107
RB1-4_storage               9.5        112990
RB1-4_storage               10.5       121937
RB1-4_storage               11.5       131448
;
```

```
NA_storage       Storage    0          2015
NA_storage                  0.4        4028.5
NA_storage                  1.4        7744.803
NA_storage                  2.4        13712.894
NA_storage                  3.4        19405.348
NA_storage                  4.4        28097.354
NA_storage                  5.4        47234.436
NA_storage                  6.4        60011.204
NA_storage                  7.4        65786.986
NA_storage                  8.4        65786.986
NA_storage                  9.4        65786.986

[REPORT]
;;Reporting Options
INPUT      NO
CONTROLS   NO
SUBCATCHMENTS ALL
NODES ALL
LINKS ALL

[TAGS]

[MAP]
DIMENSIONS -2727.273 0.000 12727.273 10000.000
Units      None

[COORDINATES]
;;Node           X-Coord            Y-Coord
;;-------------- ------------------ ------------------
Belleview_LR     -123.123           8276.677
Havana_LR        -252.770           7640.991
Peoria_S         1527.855           7754.128
Stock_Pond_S     1010.237           7302.238
Parker_J         4212.105           7615.032
Junction_J3      4882.479           7462.368
Junction_J4      4371.553           7768.648
Regis_Jesuit_VCA 5966.849           5401.173
Parker_SA        5972.160           4615.175
Norfolk_SA       6718.568           4442.553
Richfield_SA     7370.156           4437.690
Parker_C         6631.041           3292.549
Hinsdale_C       7034.637           3151.534
Richfield_C      7501.446           3029.969
Telluride_C      8114.133           3085.889
Bridle_Trail_C   8790.034           3090.751
Biscay_C         9016.145           2898.679
Parker_K         7199.965           1862.945
Bridle_Trail_K   7968.256           2028.274
Confluence_K     8814.347           1702.480
Future_Road_K    9385.702           1366.961
Parker_17        7423.645           1459.350
LR3              -491.676           7030.960
LR2              39.980             7737.180
LR1              90.166             8615.430
S3               624.102            6776.536
S2               1313.661           6895.122
S1               838.769            7732.998
J8               6593.833           8275.416
J7               5980.369           8205.306
J6               5406.342           8262.270
J5               4661.421           8336.762
J2               4034.812           8319.235
J4               4337.162           8060.703
J3               4931.228           7223.949
J1               4424.799           7188.708
VCA1             5848.912           5554.265
VCA2             6650.797           5506.064
NA1              6855.406           5031.735
NA2              8013.564           5032.820
NA4              8740.957           4603.396
NA3              8459.378           4196.992
SA4              8109.965           3968.022
SA3              7325.608           4024.987
SA2              6799.782           4125.770
SA1              5752.511           4480.703
C2               7268.643           3573.653
17B              8233.267           1213.789
17A              7202.397           1595.503
K1               7022.480           1675.735
K2               7664.343           1794.869
K3               8692.782           1437.468
K4               8644.156           2322.461
K6               9283.588           2008.823
K7               10335.963          1338.891
K5               9222.805           1247.827
C9               9796.991           2473.799
C8               9735.645           3152.991
C7               9152.854           3753.310
C4               8561.300           3674.436
C3               7728.741           3547.361
C6               8736.575           2627.165
C5               8061.765           2898.842
C1               6791.018           2885.696
T1               7991.654           2578.964
GR1              5274.885           5913.579
LR_outfall       600.387            9309.666
S_outfall        1366.321           8133.280
J_outfall        3129.927           7841.141
VCA_outfall      4662.222           5584.703
NA_outfall       4920.786           4725.636
SA_outfall       4899.957           4644.351
T_outfall        6384.231           2499.017
C_outfall        5685.266           3389.801
K_outfall        6623.748           1685.461
```

```
17_outfall       7097.851          1366.961
GR_outfall       4636.318          5812.849
Lewiston_J       6015.436          7829.562
Laredo_J         5773.126          7792.686
Shalom_J         4467.849          7866.084
Fair_Place_VCA   5272.176          5592.329
Parker_T1        6901.788          2534.646
Waco_NA          8270.083          4743.724
Buckley_NA1      6942.831          4717.330
out_RB1-4_pond   5207.572          7550.921
Parker_NA        6049.035          4729.177
RB1-4_pond       5244.212          7583.078
NA_pond          7032.246          4835.941

[VERTICES]
;;Link           X-Coord            Y-Coord
;;-------------- ------------------ ------------------
LR1_OC           -39.481            9016.916
LR2_OC           -89.666            7891.920
S_OC_B           1181.705           7507.163
S_OC_B           1478.637           7703.723
J3_SS            5076.347           7414.844
J6_SS            5319.937           7778.454
C1_OC            5857.889           3290.118
K1_OC            6808.526           1619.816
LR1_OF           198.901            9004.369
J8_OF            6300.610           7900.577
J2_OF            3785.394           7860.260
NA1_OF           6340.787           4761.594
NA3_OF           8082.527           4313.694
NA3_OF           7861.278           4717.290
C3_OF            7445.526           3270.667
C4_OF            7754.301           3081.026
C6_OF            8345.107           3068.869
C8_OF            9042.889           3005.656
C1_OF            5957.572           3273.098
C1_OF            5809.263           3309.568
K3_OF            8118.996           1824.045
K5_OF            8999.126           1607.659
J7_SS_OVF        5902.881           7873.780
J6_SS_OVF        5309.509           7786.517
J4_SS_OVF        4380.048           7844.493
VCA_SS_OVF       5048.151           5604.438
T0_OVF           6637.415           2457.233
NA3_OVF          7598.916           4792.742
NA1_OVF          6568.539           4761.101
J3_OVF           5069.958           7505.387
NA0_OVF          5517.588           4782.996


  EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.012)
  --------------------------------------------------------------

  WARNING 04: minimum elevation drop used for Conduit LR3_OF
  WARNING 04: minimum elevation drop used for Conduit LR2_OF
  WARNING 04: minimum elevation drop used for Conduit LR1_OF
  WARNING 04: minimum elevation drop used for Conduit S3_OF
  WARNING 04: minimum elevation drop used for Conduit S2_OF
  WARNING 04: minimum elevation drop used for Conduit S_OF
  WARNING 04: minimum elevation drop used for Conduit J4_OF
  WARNING 04: minimum elevation drop used for Conduit J3_OF
  WARNING 04: minimum elevation drop used for Conduit J1_OF
  WARNING 04: minimum elevation drop used for Conduit J2_OF
  WARNING 04: minimum elevation drop used for Conduit VCA2_OF
  WARNING 04: minimum elevation drop used for Conduit SA4_OF
  WARNING 04: minimum elevation drop used for Conduit SA3_OF
  WARNING 04: minimum elevation drop used for Conduit SA2_OF
  WARNING 04: minimum elevation drop used for Conduit SA1_OF
  WARNING 04: minimum elevation drop used for Conduit C2_OF
  WARNING 04: minimum elevation drop used for Conduit C3_OF
  WARNING 04: minimum elevation drop used for Conduit C4_OF
  WARNING 04: minimum elevation drop used for Conduit C5_OF
  WARNING 04: minimum elevation drop used for Conduit C6_OF
  WARNING 04: minimum elevation drop used for Conduit C7_OF
  WARNING 04: minimum elevation drop used for Conduit C9_OF
  WARNING 04: minimum elevation drop used for Conduit C1_OF
  WARNING 04: minimum elevation drop used for Conduit K1_OF
  WARNING 04: minimum elevation drop used for Conduit K2_OF
  WARNING 04: minimum elevation drop used for Conduit 17B_OF
  WARNING 04: minimum elevation drop used for Conduit K3_OF
  WARNING 04: minimum elevation drop used for Conduit K5_OF
  WARNING 04: minimum elevation drop used for Conduit K6_OF
  WARNING 04: minimum elevation drop used for Conduit K7_OF
  WARNING 04: minimum elevation drop used for Conduit K4_OF
  WARNING 04: minimum elevation drop used for Conduit 17A_OF
  WARNING 04: minimum elevation drop used for Conduit GR1_OF
  WARNING 02: maximum depth increased for Node Junction_J4
  WARNING 02: maximum depth increased for Node Fair_Place_VCA

  *********************************************************
  NOTE: The summary statistics displayed in this report are
  based on results found at every computational time step,
  not just on results from each reporting time step.
  *********************************************************

  ****************
  Analysis Options
  ****************
  Flow Units ............... CFS
  Process Models:
    Rainfall/Runoff ........ NO
    RDII ................... NO
    Snowmelt ............... NO
```

Groundwater .... NO
Flow Routing .... YES
Ponding Allowed .... NO
Water Quality .... NO
Flow Routing Method ...... KINWAVE
Starting Date 12/01/2018 00:00:00
Ending Date 12/02/2018 00:00:00
Antecedent Dry Days 0.0
Report Time Step 00:01:00
Routing Time Step .... 5.00 sec

****
Flow Routing Continuity
****

	Volume acre-feet	Volume 10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	0.000	0.000
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	559.246	182.239
External Outflow	566.949	184.749
Flooding Loss	0.000	0.000
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.076	0.025
Continuity Error (%)	-1.391	

****
Highest Flow Instability Indexes
****

Link J3_SS (5)
Link J3_OC (5)
Link outlet_RB1-4_pond (4)
Link J1_OC (3)

****
Routing Time Step Summary
****

Minimum Time Step : 5.00 sec
Average Time Step : 5.00 sec
Maximum Time Step : 5.00 sec
Percent in Steady State : 0.00
Average Iterations per Step : 1.00
Percent Not Converging : 0.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days	hr:min	Reported Max Depth Feet
Belleview_LR	JUNCTION	0.22	3.46	5612.46	0	00:49	3.46
Havana_LR	JUNCTION	0.16	2.89	5647.89	0	00:40	2.88
Peoria_S	JUNCTION	0.19	1.86	5581.86	0	01:00	1.86
Stock_Pond_S	JUNCTION	0.17	2.43	5623.43	0	00:45	2.43
Parker_J	JUNCTION	0.34	3.42	5622.42	0	01:11	3.42
Junction_J3	JUNCTION	0.35	3.94	5666.94	0	01:20	3.94
Junction_J4	JUNCTION	0.18	3.27	5633.14	0	00:42	3.27
Regis_Jesuit_VCA	JUNCTION	0.14	2.47	5691.47	0	00:40	2.47
Parker_SA	JUNCTION	0.23	2.35	5658.35	0	01:07	2.35
Norfolk_SA	JUNCTION	0.22	2.37	5722.37	0	00:58	2.37
Richfield_SA	JUNCTION	0.17	1.94	5761.94	0	00:55	1.94
Parker_C	JUNCTION	0.40	3.90	5701.90	0	01:11	3.90
Hinsdale_C	JUNCTION	0.36	3.66	5721.66	0	01:07	3.66
Richfield_C	JUNCTION	0.31	3.30	5748.30	0	01:03	3.30
Telluride_C	JUNCTION	0.25	3.06	5777.06	0	00:57	3.06
Bridle_Trail_C	JUNCTION	0.20	2.75	5816.75	0	00:48	2.75
Biscay_C	JUNCTION	0.13	1.89	5829.89	0	00:45	1.89
Parker_K	JUNCTION	0.28	3.30	5727.30	0	01:06	3.30
Bridle_Trail_K	JUNCTION	0.24	3.14	5768.14	0	00:56	3.14
Confluence_K	JUNCTION	0.15	2.46	5833.46	0	00:46	2.46

Future_Road_K	JUNCTION	0.09	1.90	5891.90	0	00:35	1.90
Parker_17	JUNCTION	0.11	1.99	5730.99	0	00:40	1.99
LR3	JUNCTION	0.00	0.00	5645.00	0	00:00	0.00
LR2	JUNCTION	0.00	0.00	5609.00	0	00:00	0.00
LR1	JUNCTION	0.00	0.00	5552.00	0	00:00	0.00
S3	JUNCTION	0.00	0.00	5621.00	0	00:00	0.00
S2	JUNCTION	0.00	0.00	5580.00	0	00:00	0.00
S1	JUNCTION	0.00	0.00	5565.00	0	00:00	0.00
J8	JUNCTION	0.00	0.00	5738.00	0	00:00	0.00
J7	JUNCTION	0.00	0.00	5729.00	0	00:00	0.00
J6	JUNCTION	0.00	0.00	5688.00	0	00:00	0.00
J5	JUNCTION	0.00	0.00	5645.00	0	00:00	0.00
J2	JUNCTION	0.00	0.00	5579.00	0	00:00	0.00
J4	JUNCTION	0.00	0.00	5619.00	0	00:00	0.00
J3	JUNCTION	0.00	0.00	5619.00	0	00:00	0.00
J1	JUNCTION	0.00	0.00	5579.00	0	00:00	0.00
VCA1	JUNCTION	0.00	0.00	5631.00	0	00:00	0.00
VCA2	JUNCTION	0.00	0.00	5689.00	0	00:00	0.00
NA1	JUNCTION	0.00	0.00	5631.00	0	00:00	0.00
NA2	JUNCTION	0.00	0.00	5765.00	0	00:00	0.00
NA4	JUNCTION	0.00	0.00	5833.00	0	00:00	0.00
NA3	JUNCTION	0.00	0.00	5769.00	0	00:00	0.00
SA4	JUNCTION	0.00	0.00	5760.00	0	00:00	0.00
SA3	JUNCTION	0.00	0.00	5720.00	0	00:00	0.00
SA2	JUNCTION	0.00	0.00	5656.00	0	00:00	0.00
SA1	JUNCTION	0.00	0.00	5633.00	0	00:00	0.00
C2	JUNCTION	0.00	0.00	5698.00	0	00:00	0.00
17B	JUNCTION	0.00	0.00	5729.00	0	00:00	0.00
17A	JUNCTION	0.00	0.00	5695.00	0	00:00	0.00
K1	JUNCTION	0.00	0.00	5690.00	0	00:00	0.00
K2	JUNCTION	0.00	0.00	5724.00	0	00:00	0.00
K3	JUNCTION	0.00	0.00	5765.00	0	00:00	0.00
K4	JUNCTION	0.00	0.00	5765.00	0	00:00	0.00
K6	JUNCTION	0.00	0.00	5831.00	0	00:00	0.00
K7	JUNCTION	0.00	0.00	5890.00	0	00:00	0.00
K5	JUNCTION	0.00	0.00	5831.00	0	00:00	0.00
C9	JUNCTION	0.00	0.00	5828.00	0	00:00	0.00
C8	JUNCTION	0.00	0.00	5817.00	0	00:00	0.00
C7	JUNCTION	0.00	0.00	5814.00	0	00:00	0.00
C4	JUNCTION	0.00	0.00	5745.00	0	00:00	0.00
C3	JUNCTION	0.00	0.00	5718.00	0	00:00	0.00
C6	JUNCTION	0.00	0.00	5774.00	0	00:00	0.00
C5	JUNCTION	0.00	0.00	5745.00	0	00:00	0.00
C1	JUNCTION	0.00	0.00	5658.00	0	00:00	0.00
T1	JUNCTION	0.00	0.00	5710.00	0	00:00	0.00
GR1	JUNCTION	0.00	0.00	5620.00	0	00:00	0.00
LR_outfall	OUTFALL	0.26	3.27	5555.27	0	01:08	3.27
S_outfall	OUTFALL	0.22	2.33	5567.33	0	01:01	2.33
J_outfall	OUTFALL	0.39	3.40	5582.40	0	01:27	3.40
VCA_outfall	OUTFALL	0.20	2.43	5624.43	0	01:43	2.43
NA_outfall	OUTFALL	0.55	2.90	5633.90	0	02:20	2.89
SA_outfall	OUTFALL	0.19	2.34	5635.34	0	01:08	2.34

```
  T_outfall           OUTFALL      0.17     2.30  5675.30     0
00:51        2.30
  C_outfall           OUTFALL      0.41     3.85  5661.85     0
01:21        3.85
  K_outfall           OUTFALL      0.29     3.28  5693.28     0
01:13        3.28
  17_outfall          OUTFALL      0.11     1.97  5696.97     0
00:46        1.97
  GR_outfall          OUTFALL      0.00     0.00  5620.00     0
00:00        0.00
  Lewiston_J          DIVIDER      0.21     3.28  5734.44     0
00:33        3.28
  Laredo_J            DIVIDER      0.28     4.51  5722.26     0
00:34        4.51
  Shalom_J            DIVIDER      0.18     3.27  5642.00     0
00:39        3.27
  Fair_Place_VCA      DIVIDER      0.20     2.45  5628.75     0
00:45        2.45
  Parker_T1           DIVIDER      0.17     2.31  5707.91     0
00:50        2.31
  Waco_NA             DIVIDER      0.13     2.05  5827.80     0
00:32        2.05
  Buckley_NA1         DIVIDER      0.47     3.28  5759.30     0
00:45        3.28
  out_RB1-4_pond      DIVIDER      0.35     3.94  5691.44     0
01:19        3.94
  Parker_NA           DIVIDER      0.56     3.29  5674.98     0
01:37        3.29
  RB1-4_pond          STORAGE      0.88    10.73  5698.23     0
01:19       10.73
  NA_pond             STORAGE      2.95     8.51  5773.09     0
01:04        8.51


  ******************
  Node Inflow Summary
  ******************

  -------------------------------------------------------------------
-----------------------------
                                              Maximum  Maximum
Lateral       Total        Flow
                                              Lateral    Total  Time of Max
Inflow      Inflow     Balance
                                               Inflow   Inflow   Occurrence
Volume      Volume       Error
  Node                Type            CFS      CFS  days hr:min
10^6 gal    10^6 gal     Percent
  -------------------------------------------------------------------
-----------------------------
  Belleview_LR        JUNCTION      0.00   403.67     0  00:49
0        10.6       0.000
  Havana_LR           JUNCTION      0.00   298.37     0  00:40
0        6.82       0.000
  Peoria_S            JUNCTION      0.00   101.97     0  01:00
0        4.69       0.000
  Stock_Pond_S        JUNCTION      0.00   210.26     0  00:45
0        6.29       0.000
  Parker_J            JUNCTION      0.00   535.49     0  01:11
0        25.7       0.000
  Junction_J3         JUNCTION      0.00   352.47     0  01:20
0        16.2       0.000
  Junction_J4         JUNCTION      0.00   121.87     0  00:42
0        3.18       0.000
  Regis_Jesuit_VCA    JUNCTION      0.00   150.53     0  00:40
0        3.68       0.000
  Parker_SA           JUNCTION      0.00   317.99     0  01:05
0        12.5       0.000
  Norfolk_SA          JUNCTION      0.00   224.51     0  00:58
0        8.56       0.000
  Richfield_SA        JUNCTION      0.00   126.80     0  00:55
0        4.91       0.000
  Parker_C            JUNCTION      0.00   857.09     0  01:11
0        31.6       0.000
  Hinsdale_C          JUNCTION      0.00   747.71     0  01:07
0        27.2       0.000
  Richfield_C         JUNCTION      0.00   657.82     0  01:03
0        23.2       0.000
  Telluride_C         JUNCTION      0.00   507.99     0  00:57
0        16.6       0.000
  Bridle_Trail_C      JUNCTION      0.00   411.64     0  00:48
0        12.8       0.000
  Biscay_C            JUNCTION      0.00   178.39     0  00:45
0        5.49       0.000
  Parker_K            JUNCTION      0.00   838.96     0  01:06
0        26.4       0.000
  Bridle_Trail_K      JUNCTION      0.00   729.46     0  00:56
0        21.3       0.000
  Confluence_K        JUNCTION      0.00   505.48     0  00:46
0        12.5       0.000
  Future_Road_K       JUNCTION      0.00   300.21     0  00:35
0        5.71       0.000
  Parker_17           JUNCTION      0.00   229.15     0  00:40
0        5.41       0.000
  LR3                 JUNCTION    298.37   298.37     0  00:40
6.82        6.82        0.000
  LR2                 JUNCTION    129.14   129.14     0  00:45
3.73        3.73        0.000
  LR1                 JUNCTION    101.66   101.66     0  01:00
4.23        4.23        0.000
  S3                  JUNCTION    210.26   210.26     0  00:45
6.29        6.29        0.000
  S2                  JUNCTION    101.97   101.97     0  01:00
4.69        4.69        0.000
```

S1	JUNCTION	141.81	141.81	0	00:50	4.34	4.34	0.000
J8	JUNCTION	232.67	232.67	0	00:45	6.25	6.25	0.000
J7	JUNCTION	191.47	191.47	0	00:45	5.23	5.23	0.000
J6	JUNCTION	146.38	146.38	0	00:50	4.77	4.77	0.000
J5	JUNCTION	122.80	122.80	0	00:40	3.18	3.18	0.000
J2	JUNCTION	37.41	37.41	0	00:50	1.53	1.53	0.000
J4	JUNCTION	66.39	66.39	0	00:40	1.47	1.47	0.000
J3	JUNCTION	209.86	209.86	0	00:40	4.82	4.82	0.000
J1	JUNCTION	70.04	70.04	0	01:05	3.51	3.51	0.000
VCA1	JUNCTION	201.48	201.48	0	00:45	5.97	5.97	0.000
VCA2	JUNCTION	150.53	150.53	0	00:40	3.68	3.68	0.000
NA1	JUNCTION	208.71	208.71	0	00:40	4.92	4.92	0.000
NA2	JUNCTION	225.69	225.69	0	00:45	6.06	6.06	0.000
NA4	JUNCTION	58.66	58.66	0	00:40	1.64	1.64	0.000
NA3	JUNCTION	103.46	103.46	0	00:55	4.52	4.52	0.000
SA4	JUNCTION	126.80	126.80	0	00:55	4.91	4.91	0.000
SA3	JUNCTION	108.73	108.73	0	00:50	3.6	3.6	0.000
SA2	JUNCTION	105.35	105.35	0	00:50	3.89	3.89	0.000
SA1	JUNCTION	163.67	163.67	0	00:40	4.01	4.01	0.000
C2	JUNCTION	154.81	154.81	0	00:45	4.39	4.39	0.000
17B	JUNCTION	229.15	229.15	0	00:40	5.41	5.41	0.000
17A	JUNCTION	50.58	50.58	0	00:35	0.95	0.95	0.000
K1	JUNCTION	79.95	79.95	0	00:35	1.69	1.69	0.000
K2	JUNCTION	170.56	170.56	0	00:45	4.88	4.88	0.000
K3	JUNCTION	98.30	98.30	0	00:45	3.19	3.19	0.000
K4	JUNCTION	188.35	188.35	0	00:45	5.36	5.36	0.000
K6	JUNCTION	157.48	157.48	0	00:45	4.52	4.52	0.000
K7	JUNCTION	300.21	300.21	0	00:35	5.71	5.71	0.000
K5	JUNCTION	89.58	89.58	0	00:40	2.19	2.19	0.000
C9	JUNCTION	178.39	178.39	0	00:45	5.49	5.49	0.000
C8	JUNCTION	158.13	158.13	0	00:45	4.82	4.82	0.000
C7	JUNCTION	79.31	79.31	0	00:45	2.5	2.5	0.000
C4	JUNCTION	104.80	104.80	0	00:55	4.33	4.33	0.000
C3	JUNCTION	101.60	101.60	0	00:50	3.92	3.92	0.000
C6	JUNCTION	122.15	122.15	0	00:45	3.6	3.6	0.000
C5	JUNCTION	60.80	60.80	0	00:50	2.25	2.25	0.000
C1	JUNCTION	176.28	176.28	0	00:45	5.2	5.2	0.000
T1	JUNCTION	104.95	104.95	0	00:50	3.62	3.62	0.000
GR1	JUNCTION	150.25	150.25	0	00:40	4.14	4.14	0.000
LR_outfall	OUTFALL	0.00	453.53	0	01:07	0	15.3	0.000
S_outfall	OUTFALL	0.00	422.74	0	01:00	0	15.5	0.000
J_outfall	OUTFALL	0.00	613.26	0	01:24	0	31.5	0.000
VCA_outfall	OUTFALL	0.00	349.18	0	00:45	0	9.65	0.000
NA_outfall	OUTFALL	0.00	476.03	0	00:59	0	17.1	0.000
SA_outfall	OUTFALL	0.00	426.06	0	01:04	0	16.5	0.000
T_outfall	OUTFALL	0.00	104.71	0	00:51	0	3.61	0.000
C_outfall	OUTFALL	0.00	942.12	0	01:19	0	36.9	0.000
K_outfall	OUTFALL	0.00	859.16	0	01:12	0	28.2	0.000
17_outfall	OUTFALL	0.00	266.65	0	00:45	0	6.37	0.000
GR_outfall	OUTFALL	0.00	150.25	0	00:40	0	4.14	0.000
Lewiston_J	DIVIDER	0.00	232.67	0	00:45	0	6.25	0.000
Laredo_J	DIVIDER	0.00	424.14	0	00:45	0	11.5	0.000

```
  Shalom_J             DIVIDER       0.00   122.80     0  00:40
0        3.18       0.000
  Fair_Place_VCA       DIVIDER       0.00   349.24     0  00:45
0        9.64       0.000
  Parker_T1            DIVIDER       0.00   104.95     0  00:50
0        3.62       0.000
  Waco_NA              DIVIDER       0.00    58.66     0  00:40
0        1.64       0.000
  Buckley_NA1          DIVIDER       0.00   324.75     0  01:03
0        12.2       0.000
  out_RB1-4_pond       DIVIDER       0.00   352.51     0  01:19
0        16.2       0.000
  Parker_NA            DIVIDER       0.00   476.03     0  00:59
0        17.1       0.000
  RB1-4_pond           STORAGE       0.00   569.69     0  00:45
0        16.2       0.011
  NA_pond              STORAGE       0.00   225.69     0  00:45
0        6.06       0.028


  *********************
  Node Flooding Summary
  *********************

  No nodes were flooded.


  **********************
  Storage Volume Summary
  **********************

  ----------------------------------------------------------------------
------------------------------
                       Average     Avg  Evap Exfil       Maximum
Max    Time of Max    Maximum
                        Volume    Pcnt  Pcnt  Pcnt        Volume
Pcnt     Occurrence    Outflow
  Storage Unit        1000 ft3    Full  Loss  Loss      1000 ft3
Full    days hr:min        CFS
  ----------------------------------------------------------------------
------------------------------
  RB1-4_pond            43.139       5     0     0       690.474
88       0  01:18     352.51
  NA_pond               43.569      13     0     0       285.349
83       0  01:04     175.99


  ***********************
  Outfall Loading Summary
  ***********************

  -----------------------------------------------------------
```

```
                      Flow       Avg       Max       Total
                      Freq      Flow      Flow      Volume
  Outfall Node        Pcnt       CFS       CFS    10^6 gal
  -----------------------------------------------------------
  LR_outfall         99.13     23.83    453.53      15.265
  S_outfall          79.69     30.02    422.74      15.460
  J_outfall          99.30     49.02    613.26      31.456
  VCA_outfall        44.97     33.19    349.18       9.646
  NA_outfall         99.08     26.74    476.03      17.120
  SA_outfall         99.30     25.75    426.06      16.526
  T_outfall          22.65     24.69    104.71       3.615
  C_outfall          99.30     57.56    942.12      36.938
  K_outfall          99.30     43.94    859.16      28.195
  17_outfall         43.70     22.56    266.65       6.371
  GR_outfall         14.91     43.00    150.25       4.143
  -----------------------------------------------------------
  System             72.85    380.29   4627.49     184.735


  ********************
  Link Flow Summary
  ********************

  --------------------------------------------------------------------
---------
                               Maximum  Time of Max   Maximum
Max/    Max/
                                |Flow|   Occurrence   |Veloc|
Full    Full
  Link                 Type        CFS  days hr:min    ft/sec
Flow   Depth
  --------------------------------------------------------------------
---------
  LR1_OC               CHANNEL    355.23     0  01:08      3.92
0.24    0.54
  LR2_OC               CHANNEL    278.12     0  00:50      3.75
0.17    0.46
  S_OC_A               CHANNEL    101.42     0  01:05      2.55
0.07    0.31
  S_OC_B               CHANNEL    191.94     0  01:01      3.51
0.12    0.39
  J1_OC                CHANNEL    526.08     0  01:27      3.35
0.42    0.68
  J3_OC                CHANNEL    351.13     0  01:25      4.41
0.17    0.45
  J4_OC                CHANNEL    121.27     0  00:44      2.64
0.06    0.27
  J3_SS                CONDUIT    352.47     0  01:20     17.90
0.77    0.66
  J4_SS                CONDUIT    121.87     0  00:42     11.16
1.00    0.82
```

J6_SS	CONDUIT	347.74	0	01:01	16.83	1.00	0.82
J7_SS	CONDUIT	170.68	0	01:08	15.55	1.00	0.82
VCA_SS_OUT	CONDUIT	115.86	0	01:43	6.08	1.00	0.80
VCA1_SS	CONDUIT	147.93	0	00:45	14.61	0.41	0.44
NA1_SS	CONDUIT	196.00	0	01:37	18.03	1.00	0.82
NA3_SS	CONDUIT	44.22	0	01:10	10.70	1.01	0.82
SA1_SS	CONDUIT	317.45	0	01:08	11.36	0.26	0.39
SA2_OC	CHANNEL	221.56	0	01:07	3.84	0.14	0.43
SA3_OC	CHANNEL	123.79	0	01:02	2.96	0.09	0.35
T0_SS	CONDUIT	104.71	0	00:51	14.02	0.63	0.58
C1_OC	CHANNEL	834.46	0	01:21	4.01	0.42	0.70
C2_OC	CHANNEL	743.91	0	01:12	3.87	0.36	0.66
C3_OC	CHANNEL	654.25	0	01:08	4.09	0.29	0.60
C4_OC	CHANNEL	500.33	0	01:04	3.63	0.24	0.55
C6_OC	CHANNEL	397.45	0	00:58	3.56	0.18	0.49
C8_OC	CHANNEL	177.03	0	00:50	2.93	0.08	0.34
K1_OC	CHANNEL	824.85	0	01:13	3.63	0.62	0.82
K2_OC	CHANNEL	701.19	0	01:07	3.45	0.53	0.77
K4_OC	CHANNEL	469.75	0	00:58	3.63	0.29	0.59
K5_OC	CHANNEL	265.26	0	00:47	3.30	0.16	0.45
17A_OC	CHANNEL	223.42	0	00:46	3.06	0.40	0.65
LR3_OF	DUMMY	298.37	0	00:40			
LR2_OF	DUMMY	129.14	0	00:45			
LR1_OF	DUMMY	101.66	0	01:00			
S3_OF	DUMMY	210.26	0	00:45			
S2_OF	DUMMY	101.97	0	01:00			
S_OF	DUMMY	141.81	0	00:50			
J8_OF	DUMMY	232.67	0	00:45			
J7_OF	DUMMY	191.47	0	00:45			
J6_OF	DUMMY	146.38	0	00:50			
J5_OF	DUMMY	122.80	0	00:40			
J4_OF	DUMMY	66.39	0	00:40			
J3_OF	DUMMY	209.86	0	00:40			
J1_OF	DUMMY	70.04	0	01:05			
J2_OF	DUMMY	37.41	0	00:50			
VCA1_OF	DUMMY	201.48	0	00:45			
VCA2_OF	DUMMY	150.53	0	00:40			
NA1_OF	DUMMY	208.71	0	00:40			
NA2_OF	DUMMY	225.69	0	00:45			
NA4_OF	DUMMY	58.66	0	00:40			
NA3_OF	DUMMY	103.46	0	00:55			
SA4_OF	DUMMY	126.80	0	00:55			
SA3_OF	DUMMY	108.73	0	00:50			
SA2_OF	DUMMY	105.35	0	00:50			
SA1_OF	DUMMY	163.67	0	00:40			
C2_OF	DUMMY	154.81	0	00:45			
C3_OF	DUMMY	101.60	0	00:50			
C4_OF	DUMMY	104.80	0	00:55			
C5_OF	DUMMY	60.80	0	00:50			
C6_OF	DUMMY	122.15	0	00:45			
C7_OF	DUMMY	79.31	0	00:45			
C8_OF	DUMMY	158.13	0	00:45			
C9_OF	DUMMY	178.39	0	00:45			
C1_OF	DUMMY	176.28	0	00:45			
T1_OF	DUMMY	104.95	0	00:50			
K1_OF	DUMMY	79.95	0	00:35			
K2_OF	DUMMY	170.56	0	00:45			
17B_OF	DUMMY	229.15	0	00:40			
K3_OF	DUMMY	98.30	0	00:45			
K5_OF	DUMMY	89.58	0	00:40			
K6_OF	DUMMY	157.48	0	00:45			
K7_OF	DUMMY	300.21	0	00:35			
K4_OF	DUMMY	188.35	0	00:45			
17A_OF	DUMMY	50.58	0	00:35			
J7_SS_OVF	DUMMY	62.17	0	00:45			
J6_SS_OVF	DUMMY	77.14	0	00:45			
J4_SS_OVF	DUMMY	0.80	0	00:40			
VCA_SS_OVF	DUMMY	234.24	0	00:45			
T0_OVF	DUMMY	0.00	0	00:00			
NA3_OVF	DUMMY	14.96	0	00:40			
NA1_OVF	DUMMY	129.55	0	01:03			
J3_OVF	DUMMY	0.00	0	00:00			
GR1_OF	DUMMY	150.25	0	00:40			
NA0_SS	CONDUIT	98.74	0	02:20	12.02	1.01	0.82
NA0_OVF	DUMMY	378.13	0	00:59			
outlet_RB1-4_pond	DUMMY	352.51	0	01:19			
outlet_NA_pond	DUMMY	175.99	0	01:04			

****
Conduit Surcharge Summary
****

Conduit	Hours Full: Both Ends	Hours Full: Upstream	Hours Full: Dnstream	Hours Above Full Normal Flow	Hours Capacity Limited
J6_SS	0.01	0.01	0.01	0.02	0.01
J7_SS	0.01	0.01	0.01	0.01	0.01
VCA_SS_OUT	0.01	0.01	0.01	0.03	0.01
NA1_SS	0.01	0.01	0.01	0.03	0.01
NA3_SS	0.01	0.01	0.01	0.07	0.01
NA0_SS	0.01	0.01	0.01	0.04	0.01

Analysis begun on: Mon Feb 11 10:59:27 2019
Analysis ended on: Mon Feb 11 10:59:28 2019
Total elapsed time: 00:00:01

APPENDIX C

HYDRAULIC ANALYSIS SUPPORT DOCUMENTS

MODELING MEMOS

Date: April 29, 2019

To: Ms. Terri Fead, P.E.

From: Ken Cecil, P.E., CFM; Danny Elsner, P.E., CFM

Subject: Cherry Creek Minor Tributaries FHAD; Model Review Submittal 1

Message:

This technical memorandum documents the hydraulic analysis performed for the Cherry Creek Minor Tributaries in Arapahoe County FHAD, Model Review Submittal 1. Modeling notes that generally apply to all tributaries are listed first, followed by assumptions and items of note that are individual to each tributary. Supporting hydraulic calculations and references are attached to this memorandum. Prior to this submittal, a meeting was held at UDFCD on April 10, 2019 to clarify preliminary questions. Minutes from the meeting are also attached.

General Modeling Notes

HEC-RAS (version 5.0.6, subcritical, 1D) models are included for the following drainageways: Little Raven Creek, Joplin Tributary, North Arapahoe Tributary, South Arapahoe Tributary, Chenango Tributary, and Kragelund Tributary.

- All required peak profiles (10-, 25-, 50-, 100-, 500-yr) from the baseline hydrology are included. For all tributaries except Kragelund, existing conditions = future conditions. For reaches defined by storm sewer overflow and no open channel, only the return events and associated flows exceeding the SWMM-defined storm sewer capacity are modeled.
- All modeling was completed in Colorado State Plane Central with a NAD 83 horizontal datum and NAVD88 vertical datum.

Channel Alignments

- Tributary alignments were delineated following the channel thalweg per the smoothed Cherry Creek contours provided by UDFCD. Station 0+00 for each tributary is at the confluence of Cherry Creek (or Cherry Creek reservoir) regardless of the downstream limit of the study area.

Cross Sections

- Cross section geometry was populated using a 1'x1' raster created from the LAS dataset provided by UDFCD and created by USGS in 2014.
- Low flow channel inverts were modified to reflect UDFCD survey at existing structures. Where necessary, intermediate cross section inverts were interpolated between surveyed structures to remove adverse grade.
- Several instances of adverse grade exist along the modeled profiles. Instances of adverse grade were included where needed to capture areas of overland flow (no defined channel) and obstructions such as private driveways and berms.

Boundary Conditions

- Downstream boundary conditions vary for each tributary depending on the limits of the study and the availability of regulatory floodplain data for Cherry Creek. Effective Cherry Creek information was obtained from the 08005CV001D-5D FIS for Arapahoe County (revised September 28, 2018).
    - The North Arapahoe, Chenango, and Kragelund downstream boundary conditions use KWSELs set to the Cherry Creek 10-year water surface elevation interpolated from the FIS profiles. Refer to the attachment for calculations.
    - Little Raven: Normal depth of channel slope downstream of Belleview Avenue per limits of study.
    - Joplin: Normal depth of channel slope at downstream cross-section. (No regulatory floodplain is published for this area within Cherry Creek State Park.)
    - South Arapahoe: KWSEL's set to the calculated headwater at Lewiston Way. Headwater elevations for each profile were calculated in CulvertMaster. Calculations account for the series of culverts

running from the west side of Parker Road to the upstream side of Lewiston Way via a 54" CDOT pond outlet (Culvert 1) and the Lewiston Way culvert (Culvert 2). Calculations are attached.

- Additional boundary conditions were added for pond RB1-4 in Joplin Tributary and are discussed in that section.

Manning's N

- Roughness values were chosen using USDCM Table 8-5 and Equation 9-1. Photographs of typical sections are attached.
    - In lieu of conveyance obstructions, areas with overland flow occurring across residential and commercial areas use a higher Manning's roughness value between 0.1 and 0.2 to consider flow around buildings.
    - Several of the tributary floodplains are obstructed by perpendicular fencing, mainly associated with private yards. In some cases, along Chenango, the fencing crosses the channel. Anticipated blockages associated with the fencing is modeled with a high roughness value of 0.1.

Category	Roughness Value
Native Grasses	0.05
Willow stands, woody shrubs	0.16
Herbaceous wetlands	0.12
Asphalt (ex. parallel roadways)	0.02
Cobble Channel Bed	0.07
Gravel (ex. gravel parking lot)	0.025
Housing/Commercial	0.1-0.2
Grouted Boulder Drops/ Large riprap	0.1
Maintained Turf Grass	0.04
Fences (perpendicular to floodplain)	0.1

Structures

- Culverts and drops were modeled using the structure survey provided by UDFCD. Structure numbers from the UDFCD survey are included in the Bridge Culvert Data description box for each structure.

Ineffective Flow Areas

- IEFA's at crossings were set assuming approximate contraction rates of 1:1 and expansion rates of 2:1 – 4:1. IEFA's immediately upstream and downstream of roadway embankments were set to permanent.
- Conveyance areas within other channels, such as minor tributaries or roadway ditches, were discounted with IEFA's.

Little Raven Creek

- The Little Raven Creek model terminates at Belleview Avenue because the reach within Cherry Creek State Park will not be included in the FHAD.

Joplin Tributary

- Pond RB1-4: Cross section 7571 is set to the water surface elevations which were identified in the baseline hydrology SWMM model for the RB1-4 pond.
- Survey Data requested on 4/18/2019
  - Structure survey was requested for Chambers Road near station 6,363. SEMSWA infrastructure shapefile data identifies the culvert as a 54" RCP, which has been included in the model until the survey is received.
  - Topographic survey or as-builts were requested for the development located south of the Joplin Way and Chambers Rd. intersection. Until the survey is received, it is assumed that the 500-year overflow of the 72" pipe will be conveyed along S Granby Way and contained by approximate conveyance obstructions. **ACTION ITEM – Once survey is received, Dewberry | J3 will map the flow path and flood limits between S. Joplin Way and S. Chambers Road.**
- Flow Change Locations:
  - Overflow occurs upstream along Crestline Ave. and Helena in subbasins J6 and J7 between XS 8050 and 10270 for the 100-year and 500-year storm events. Flow rates for the overflow between Laredo and Lewiston (J7_SS_OVF) were taken from SWMM and not modified. The overflow rate for J6_SS_OVF was modified to include 80% of the overland flow rate for the subbasin since approximately 80% of subbasin J6 flows to the street before flowing downstream to Pond RB1-4. The totals of J6_SS_OVF and J6_OF are used for the total flow in street for mapping (194 cfs during the 100-year and 463 cfs during the 500-year). See table below for reference.

Node/Link	Description	CUHP/SWMM flow rate (cfs)		80% of overland flow (going to street) (cfs)		Total flow in street, Crestline Ave. and Helena St. (cfs)	
		100-YR	500-YR	100-YR	500-YR	100-YR	500-YR
J6_SS	Storm Sewer	347.74	348.55	-	-	-	-
J6_SS_OVF	Overflow	77.14	279.22	-	-	77.14	279.22
J6_OF	Subbasin overland flow	146.38	229.18	117.104	183.344	117.104	183.344
RB1-4_Pond	Total flow to pond	569.4	854.95	-	-	194.244	462.564

  - Overflow of the 72" pipe from Pond RB1-4 to Chambers Road crossing occurs for the 500-year storm event only and the flow rate for the model is 312 cfs, as determine in CUHP and SWMM.

North Arapahoe Tributary

- Several split flow locations have been identified along North Arapahoe. The model included with this submittal estimates the amount of flow leaving at each location with a lateral weir using the standard weir equation for a broad crested weir. Tailwater connections at all weirs are set to 'out of the system'. Weir coefficients were selected using the Hydrologic Engineering Center recommended values published in "Combined 1-D and 2-D modeling with HEC-RAS" (August 2013).
- A rough 2D model was completed to identify potential locations of split flow for the 1D model. The 2D model uses two plans: 1. Upstream of Parker Road and 2. Downstream of Parker Road. The model is included with this submittal. Because the terrain is very flat and the LiDAR does not capture curb and gutter elevations along North Arapahoe, the model was only used to identify potential problem areas and is not necessarily accurate in many locations. For example, the topo underneath the Parker Road bridge does not represent the existing median; therefore, a split flow to the south is introduced in the model which does not in reality occur.
- The following is a description of the split flows for the 100-year event. These locations are noted on the North Arapahoe hydraulic workmap. Note that the default maximum iterations was increased to 40 to allow for the split flows to optimize.
  1. Lewiston Way: Between Olathe Street and Lewiston Way approximately 19 cfs overtops the Arapahoe Road median. Curb and gutter contain this flow until Lewiston Way, where no gutter or cross pan exists, allowing water to escape to the south along Lewiston Way and potentially into the Walgreens parking lot.
     - Lateral weirs 5462 and 4660 were optimized together because both are considered one source of flow loss. Flow lost through these weirs was not subtracted from the main channel flows, assuming that this loss of flow may be resolved in the future.
  2. Downstream of Lewiston Way: Just downstream of Lewiston Way, the 100-year WSEL sits very close to the median elevation. Less than 1 cfs overtops the median and will be conveyed by curb and gutter to the next inlet on the south side of Arapahoe Road just west of the Parker Road southbound onramp.
     - This weir, 4444, was optimized alone. Flow lost through this weir was not subtracted from the main channel flows, assuming that this loss of flow may be resolved in the future.
  3. Parker Road to Cherry Creek: Downstream of Parker Road, the majority of North Arapahoe flows leave Arapahoe Road and spill to the north toward Sprint, Smashburger, and a handful of homes. This may warrant relocating the centerline of North Arapahoe tributary further to the north.
     - Lateral weirs 3462, 2764, 2339, 1485 were optimized together because of the large percentage of flow being lost to the northwest.
- **ACTION ITEM - Dewberry | J3 would like to coordinate with UDFCD regarding major modeling decisions such as split flow alignments and centerline modifications for North Arapahoe tributary. It appears that the major flow path should leave Arapahoe and head a bit north due to the split flow quantities. Note additional flows along Arapahoe from South Arapahoe may need to be included in this discussion.**

South Arapahoe Tributary

- During hydraulic analysis, it was determined that the CDOT pond located at the southeast corner of the Arapahoe and Parker intersection along South Arapahoe is overtopped during the 100-year and 500-year events. The overtopping elevation is estimated to be 5680' at the northwest corner of the pond. From preliminary CulvertMaster calculations, included in the boundary conditions attachment, it's estimated that about 45 cfs and 226 cfs could escape the pond in the 100-year and 500-year events, respectively.
- **ACTION ITEM - Dewberry | J3 would like to coordinate with UDFCD regarding modeling the flow loss at this pond and the possible combination discussed in North Arapahoe.**

Chenango Tributary

- **ACTION ITEM - Structure survey was requested on 4/18/2019 for East Hinsdale Avenue upstream of the dam near station 10,600. SEMSWA infrastructure shapefile data identifies the culvert as an 84" CMP, which has been included in the model until survey is received.**

- The existing dam located at station 98+41 is not recognized by UDFCD and was not included in the baseline hydrology. The channel alignment is routed around the dam by way of the emergency overflow located on the south side of the dam. Storage behind the dam was discounted with IEFAs.
- Roadway ditches are located on the north and south side of Hinsdale Avenue. Conveyance area associated with the ditches was made ineffective.
- The high Manning's n discussed with UDFCD was implemented within a majority of the area based on aerial view and the impact felt to the flow.

Kragelund Tributary

- In the April 10th pre-submittal meeting, the UDFCD project team was notified that the future conditions peak flows are more than 30% greater than the existing peak flows along Kragelund. UDFCD advised Dewberry | J3 to continue modeling future flows while it is determined whether existing flows also need to be modeled.
- The following is a description of split flows for the 100-year event. Split flows that were observed for smaller storm events are not noted here but were considered in the model using ineffective flow areas.
    1. Cross Section 6545 to 5879 in proposed King's Point Development: Drainage splits on either side of a ~500-foot long natural ridge, with the low-flow channel continuing along the east side of the ridge. This was modeled with longer cross-sections and ineffective flow areas rather than with lateral or weir structures due to the short length of the obstruction and wide floodplain downstream.
    2. Cross Section 4566 to 4162: Drainage splits on either side of a ~400-foot long natural ridge, with the low-flow channel continuing along the north side of the ridge. This was modeled with longer cross-sections and ineffective flow areas rather than with lateral or weir structures due to the short length of the obstruction and wide floodplain downstream.
- Neighborhood between E. Long Ave. and E Mineral Pl.:
    - Low Flow Channel Determination: From Cross Section 4162 to Parker Road, it appears that two possible flow channels exist: one to the north parallel to E Long Ave and one to the south that flows to a ditch along E Mineral Pl. Upstream invert elevations are similar and an abbreviated 2D flow analysis was conducted which found that flows split for very small events and slightly more drainage is conveyed in the Mineral Pl. channel. This channel was selected for the low-flow channel and IEFAs were used to preclude flow from the upper reaches of the flow area.
    - Flow South of E Mineral Pl.: Storm events overtop Mineral Pl. and pond the residence located south of the road. Since flow appears to remain there and pond up, IEFAs were added to remove this area from consideration in the model.
- Flow west of Parker Rd.: Flow spills from the main channel located downstream of the Parker Rd. crossing Northwest toward and across the open space. An abbreviated 2D model confirmed this flow preference and Dewberry | J3 will be requesting guidance from UDFCD to confirm the best approach for containing this part of the model.

References:

1. **Reference A:** HEC-RAS Workmaps
2. **Reference B:** Manning's n Typical Sections
3. **Reference C:** Boundary Conditions
4. **Reference D:** April 10, 2019 Meeting Minutes
5. **Reference E:** North Arapahoe 2D Model (screen shots due to size)
6. **Reference E:** Kragelund 2D Models (screen shots due to size)
7. **Reference F:** Baseline Hydrology Report

EXISTING HYDRAULIC STRUCTURES


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