Appendix D: Drainage Report

Final Drainage Report

Salina Junction – TO5

Project No. 4011.Sept12.C38

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April 2015

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I. INTRODUCTION

The Salina Junction Task Order #5 (TO5) is part of the emergency repair work being performed by Boulder County in response to flood events that occurred in September 2013. The Town of Salina is a former mining town approximately 7 miles west of Boulder, Colorado. The intersection of Four Mile Canyon Drive and Gold Run Road, which accesses the Town of Salina, is also known as Salina Junction.

This task order includes the confluence of two mountain streams, Fourmile Creek and Gold Run, located at Salina Junction with the outfall of Gold Run into Fourmile Creek occurring at the toe of the Fourmile Canyon Drive embankment. The September 2013 flood event blocked the existing Gold Run culvert with debris and consequent flood flow was conveyed over the Salina Junction roadway. As a temporary solution, Boulder County had bypassed the baseflow in Gold Run into a roadway ditch along the north side of Fourmile Canyon Drive that eventually drained to Fourmile Creek via an 18" CMP culvert. In the spring of 2014 the 42-inch CMP culvert entrance was unplugged to allow Gold Run flows to be routed under Salina Junction.

As a part of the post-flood roadway rehabilitation project, the County intends to provide a new structure that can pass a larger flood event and reduces the maintenance needs for this crossing. In order to determine the appropriate culvert opening, a comprehensive hydrologic and hydraulic analysis was performed.

The purpose of this report is to document the proposed hydraulic solution for Gold Run upstream and downstream of the Salina Junction intersection. This report describes the existing conditions hydrology, documents the field survey performed for this study, and analyzes the hydraulics and design of the proposed replacement bridge and roadway.

A. Location

Salina Junction Task Order #5 (TO5) is located within incorporated Boulder County in the Town of Salina, a former mining town approximately 7 miles west of Boulder, Colorado. The project includes Gold Run Road, Gold Run, and the intersection of Gold Run Road and Fourmile Canyon Drive. TO5 is in the NW1/4 of Section 17 of Township 1 North, Range 71 West of the 6th Principle Meridian, County of Boulder, State of Colorado.

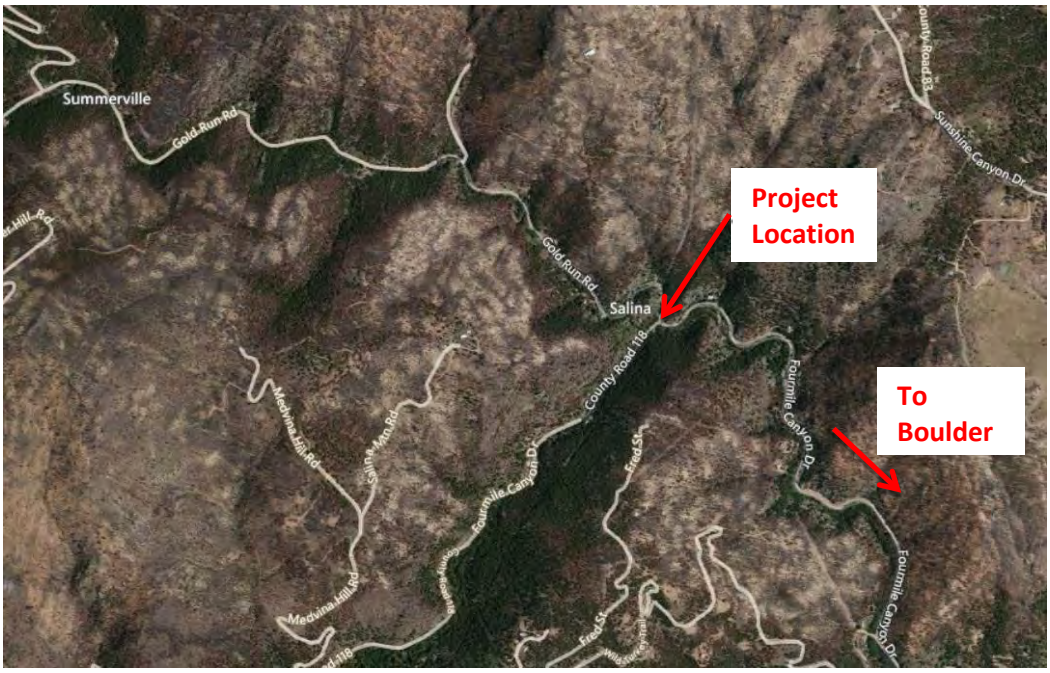

Figure I-1: Project Vicinity Map
(Map provided by Bing Maps)

Major drainageways and facilities include the confluence of two mountain streams, Fourmile Creek and Gold Run. The outfall of Gold Run into Fourmile Creek occurs south of the intersection of Gold Run Road and Fourmile Canyon Drive at the toe of the Fourmile Canyon Drive embankment.

Surrounding developments include private residents along Gold Run Road and Fourmile Canyon Drive.

B. Description of Property

TO5 encompasses approximately 0.8 acres and is characterized by primarily heavily forested areas with some areas of wildfire burn scars. Per the NRCS Soils Map, the entire project falls within the Juget-Rock outcrop complex, with a hydrologic soil group classification of D. Major drainageways include Fourmile Creek and Gold Run. Gold Run originates near the town of Gold Hill west of the town of Salina. From Gold Hill, Gold Run drains primarily east, following Gold Run Road, approximately 3.2 miles to the confluence with Fourmile Creek at Salina Junction. The approximate drainage area of Gold Run at Salina Junction is 2.5 square miles.

The existing Gold Run stream channel and culvert system were severely compromised during the September 2013 flood event. The design intent is to restore and improve the stream channel and route the storm flows up to the 10-year event under the Salina Junction intersection. Restoration includes geometric modification to Gold Run, a drainage gutter to collect nuisance flows, channel bank stability, replacing the existing culvert under Fourmile Canyon Drive with a concrete box culvert, and an energy dissipater before Gold Run outfalls into Fourmile Creek.

C. Existing Conditions

An approximately 100 foot wide corridor of survey and topographic data was collected as part of this project. The topographic data extents are from approximately 450 feet downstream of Salina Junction to approximately 450 feet upstream of the Salina Junction intersection.

The survey and topographic data were derived from two sources:

- LiDAR Mapping – The 2-ft contours, mapping, and planimetrics for the majority of the corridor were created by LiDAR survey and provided by FEMA Region VIII. The site was flown between October 2013 and January 2014 by Photo Science. The horizontal datum is NAD83 while the vertical datum is based on North American Vertical Datum of 1988 (NAVD 88).
- Field Survey – the 1-ft contours, mapping, and planimetrics for Salina Junction and existing culverts were created by ground survey and provided by David Evans and Associates, Inc. and Lund Partnership, Inc. The surveys were performed in early November 2013 and supplemented in July 2014 and January 2015. The horizontal datum is NAD83 while the vertical datum is based on North American Vertical Datum of 1988 (NAVD 88).

Site Visits

- On May 15, 2014 a site visit was performed to document the existing conditions hydraulic conditions. Figure II-1 includes photographs from the site visit.

Existing Culvert – Upstream Face

Existing Culvert – Downstream Face

Existing Channel – Looking Upstream

Existing Channel – Looking Downstream

Approximate Location of Proposed CBC U/S

Approximate Location of Proposed CBC D/S

Figure II-2: Project Photos

II. DRAINAGE BASINS AND SUB-BASINS

A. Major Basin Description

Fourmile Creek flows east along Fourmile Canyon Drive toward Boulder, CO. Major planning studies for Fourmile Creek include:

- FIRM Number 08013C0390J dated December 18, 2012
- Fourmile Creek Drainage Study, Gingery Associates, Inc., 1981
- Fourmile Canyon Post Fire Study, Wright Water Engineers, February 2010
- Boulder Creek Hydrologic Analysis, CH2MHill, August 2014

Drainage information for Gold Run watershed was taken from the Fourmile Canyon Post Fire Study. The Gold Run drainage area is 2.5 square miles. It is ultimately conveyed east along Gold Run Road and outfalls into Fourmile Creek.

B. Sub-Basin Description

Sub-Basin A1

Sub-Basin A1 is approximately 0.41 acres and located approximately 390 feet north of Salina Junction. This basin is 14% impervious and conveys tributary drainage via sheet flow and shallow gutter flow to a Type 13 inlet (IN-1) that outfalls to Gold Run via an 18-inch RCP. The ultimate outfall for drainage tributary to Sub-Basin A1 is Fourmile Creek. The gutter and storm sewer system is sized to convey nuisance (5-year or less) rainfall events. More intense storm events will overtop the gutter, resulting in sheet flow across Gold Run Road and down the embankment to Gold Run.

III. DRAINAGE DESIGN CRITERIA

A. Regulations

TO5 Drainage Report is prepared in accordance with the requirements of Boulder County Storm Drainage Criteria Manual (BCSDCM), Federal Highway Administration (FHWA), and the Urban Storm Drainage Criteria Manual (USDCM).

B. Development Criteria Reference and Constraints

Although the reach of Gold Run in the vicinity of Salina Junction has not been included in the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for Boulder County, the confluence of Gold Run and Fourmile Creek is useful for this study. The most recent hydrologic study for Gold Run was part of the Fourmile Canyon Post-Fire memorandum. These studies are summarized below.

Fourmile Creek Drainage Study

In 1981, Gingery Associates, Inc. performed a detailed study of Fourmile Creek for Colorado Water Conservation Board (CWCB). The hydrologic analysis for the Gingery study was completed using the EPA's Storm Water Management Model (SWMM) rainfall-runoff computer model. Values for the 10-, 50-, 100-, and 500-year peak discharges were computed and adopted for use in the hydraulic analysis. The cross sections for the hydraulic analysis were cut off of aerial mapping (1:1200) and the structures were field surveyed. The water surface profiles for the selected recurrence intervals were computed utilizing the United States Army Corps of Engineers (USACE) HEC-2 computer program. The results of the study were incorporated into the Boulder County (and Incorporated Areas) FIRM and FIS.

Fourmile Canyon Post-Fire Study

In February 2011 Wright Water Engineers (WWE) prepared a memorandum for the Boulder County Transportation Department documenting their post-fire hydrologic findings for Fourmile Canyon. The purpose of the study was to investigate how the Fourmile Canyon watershed runoff was impacted by the severe wildfire in September 2010 of which approximately 6,200 acres in the foothills west of Boulder were burned. The WWE post-fire study developed a U.S. Army Corps of Engineers HEC-HMS rainfall-runoff computer model that differed from a standard hydrologic analysis by incorporating modified Curve Number values in order to describe the severity of the burn condition within the watershed. Debris flow estimates were also developed for the Fourmile Canyon watershed but these estimates have not been applied to any design considerations within our analysis for Salina Junction.

Boulder Creek Study

In August 2014 CH2MHill prepared a detailed report for the Colorado Department of Transportation (CDOT) documenting their rainfall-runoff hydrologic analysis for several watersheds that experienced extensive flooding in the September 2013 rainfall event. Within the Boulder Creek study the Fourmile Creek watershed was studied in detail with Gold Run as one of its subwatersheds (FMC-4A). The study is being used to prepare estimates of peak discharges within the Boulder Creek watershed to guide the design of permanent roadway and infrastructure improvements along the flood impacted streams.

FEMA Study

Fourmile Creek is mapped as a Zone AE (1-percent-annual-chance) floodplain on a Boulder County, CO (and Incorporated Areas) Flood Insurance Rate Map (FIRM) number 08013C0390J dated December 18, 2012. The Flood Insurance Study (FIS) accompanying the FIRM references a Colorado Water Conservation Board (CWCB) report as the historic study for Fourmile Creek.

C. Hydrological Criteria

Figure IV-1: East Plum Creek Watershed Map @ Faraway Place Bridge

The hydrologic analysis for Gold Run utilized portions of the WWE Fourmile Canyon Post-Fire hydrology in order to determine existing condition peak discharges for the 2-, 10-, 25-, and 100-year events. Because the WWE study was performed to determine post-fire peak discharges, certain parameters were modified in order to represent existing conditions. Note that the recent Boulder Creek study by CH2MHill was not utilized in developing hydrologic estimates for Salina Junction because the WWE Post-Fire hydrologic analysis was more detailed in its examination of the parameters used.

As noted in the 2011 memorandum, the WWE study utilized the U.S. Army Corp of Engineers HEC-HMS hydrologic computer model to develop the rainfall – runoff relationship for the Fourmile Canyon watershed. Within the HEC-HMS model the Gold Run Watershed was developed as seven subwatersheds each feeding into Gold Run for a total of 2.5 square mile drainage area. Rainfall distributions within the model were based on NOAA Atlas 2 (Volume III – Colorado) precipitation depths. NOAA Atlas 2 was superseded by NOAA Atlas 12 in 2013 with generally lower rainfall values within locations along Colorado's Front Range. As recommended by UDFCD these updated lower rainfall values are not warranted for the UDFCD region, the boundary of which is nearby in Boulder, due to the statistically insignificant changes in the updated atlas. Therefore, the precipitation depths used in the WWE have not been modified for this Gold Run study and are shown in Table IV-1.

Storm Event	Precipitation Depth (inches)
2-Year, 1-Hour	0.9
10-Year, 1-Hour	1.5
25-Year, 1-Hour	1.7
100-Year, 1-Hour	2.4

Table IV-1: Precipitation Depths

The Curve Number loss method was utilized in the WWE study using increased Curve Numbers to demonstrate the post-fire ground surface conditions. The Curve Numbers used within this study were modified to better represent the existing condition of the Gold Run watershed which is still recovering from the Fourmile Canyon fire in 2010. The comparison of the Curve Numbers used in both studies can be seen in Table IV-2, while the basin schematic can be seen in Figure IV-2.

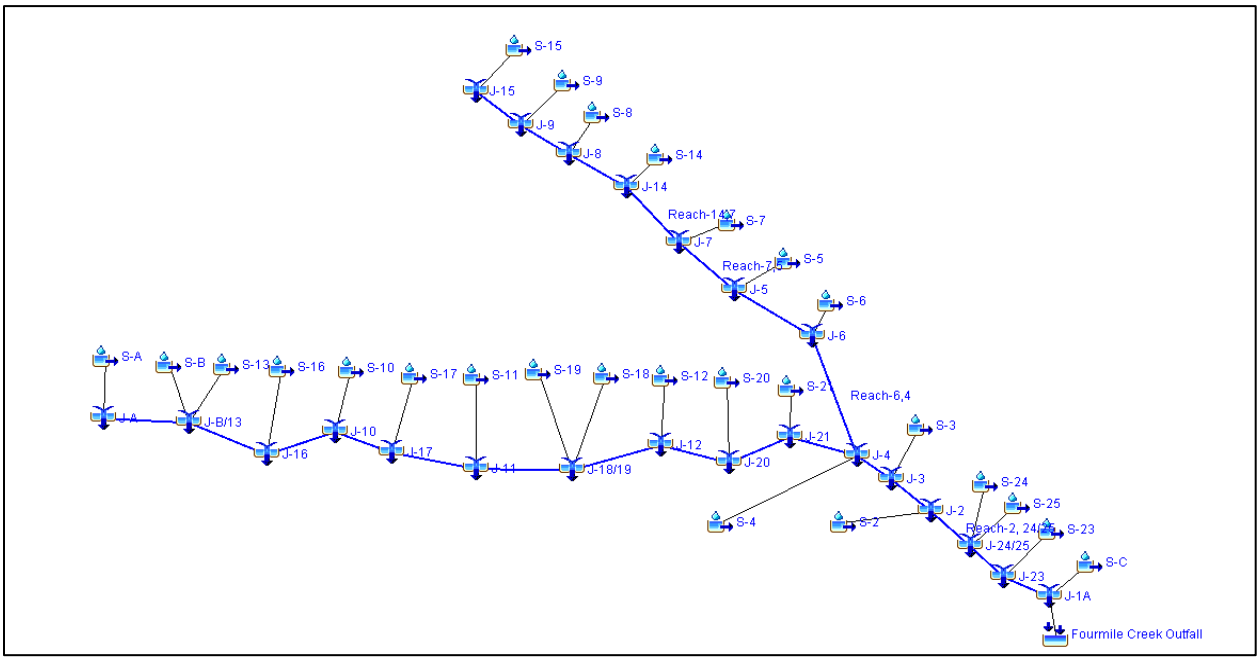

Figure IV-2: HEC-HMS hydrologic model schematic layout

Sub-basin ID	WWE Study Curve Number	Gold Run Curve Number
S-15	81	80
S-9	86	80
S-8	87	80
S-14	91	80
S-7	92	80
S-5	89	80
S-6	90	80

Table IV-2: Curve Number comparison

Other parameters used within the HEC-HMS hydrologic model such as Lag Time and Kinematic Wave values along with general routing relationships and parameters outside of Gold Run were unchanged from the WWE study.

The Salina Junction box culvert is located just upstream of the confluence of Gold Run and Fourmile Creek. This location within the HEC-HMS model is at Junction J-6 and the calculated peak discharges for the studied storm events are summarized in Table IV-3 and shown in Figure IV-3.

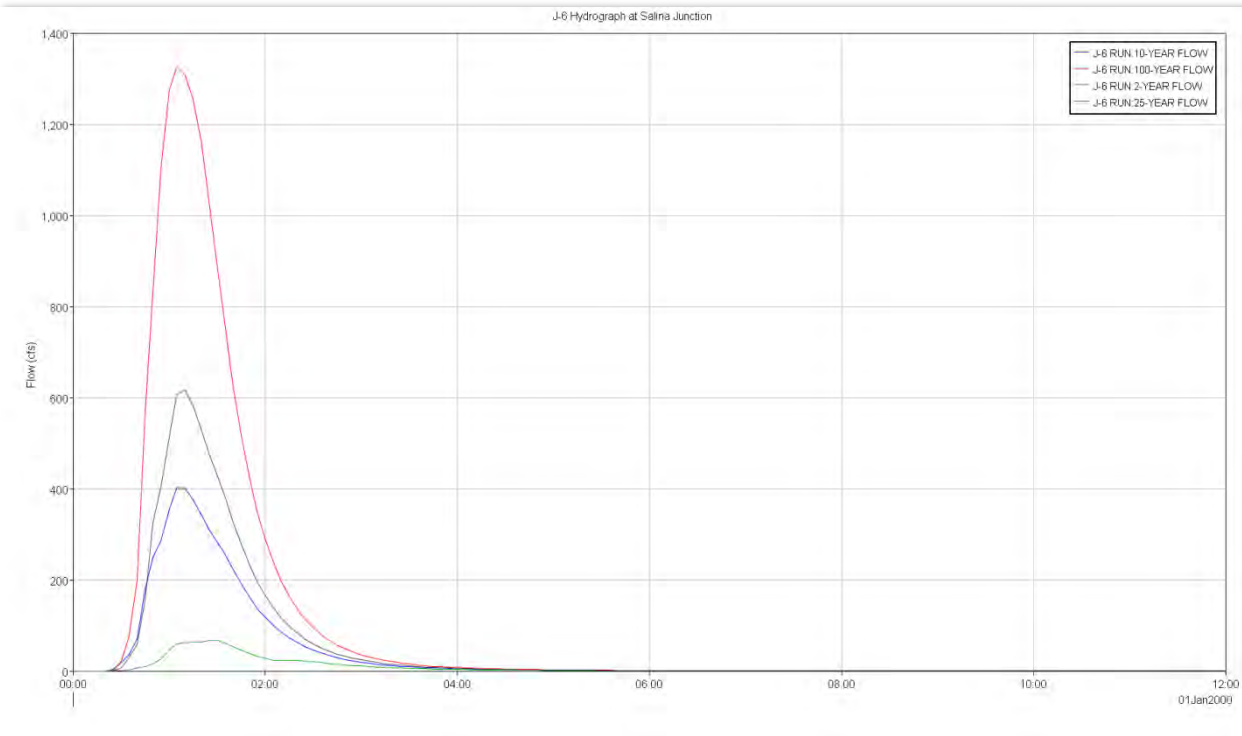

Figure IV-3: Calculated hydrograph for Gold Run at Salina Junction

Flooding Source and Location	Drainage Area (sq. mi.)	Peak Discharges (cfs)			
		2-year	10-year	25-year	100-year
Gold Run at Salina Junction	2.5	67	402	617	1,326

Table IV-3: Summary of Gold Run Discharges

The hydrologic calculations for the TO5 onsite drainage are performed using the Rational Method for drainage areas less than 90 acres. Rational Method parameters include drainage area (acres), a dimensionless runoff coefficient (C), and rainfall intensity (I) (inches/hour) for a selected storm frequency and duration to the time of concentration (Tc) (minutes). These parameters are entered into hydrology spreadsheets found in Appendix A1 to compute total runoff for each basin. The minor storm design rainfall is the 5 year event.

The runoff coefficient represents the fractional portion of precipitation that appears as runoff and is expressed as a constant between zero and one as a function of the drainage area land

use/impervious cover and drainage area slope. The C-values for Task Order 5 were assumed to be the same as Task Order 3 and are taken from Table 601 of the Boulder County Storm Drainage Criteria Manual (BCSDCM). A copy of this table is located in Appendix A2.

The rainfall intensity is found using a site specific IDF table obtained from the BCSDCM, Table 505. Salina Junction lies within Zone 2 of the Boulder County Rainfall Zones Figure 501. Copies of Table 505 and Figure 501 are located in Appendix A2. Storm precipitation is also listed in Table IV-4 below.

Frequency	5-min	10-min	15-min	30-min	60-min
2-year	3.24	2.51	2.12	1.47	0.93
5-year	4.52	3.51	2.96	2.05	1.30
10-year	5.43	4.21	3.56	2.46	1.56
50-year	7.55	5.86	4.95	3.43	2.17
100-year	8.49	6.59	5.56	3.86	2.44

Table IV-4: Rainfall Intensity

The BCSDCM Section 600 provides equations for the time of concentrations. The time of concentration has two components. The first is the initial time, T_i, which is the time runoff is sheet flowing. The second is the travel time, T_t, which is the time runoff is in a channel. For overland flow $T_i=(0.395(1.1-C_5)L^{0.5})/(S^{0.333})$. For this project L must be less than or equal to 500 feet. For channel flow $T_t=(L/v)/60$. Time of concentration $T_c = T_i + T_t$. A minimum of a 10 minute time of concentration is used for this project, as recommended in the BCSDCM for a non-urban watershed.

The time of concentration for Sub-Basin A1 is 10.00 minutes and the design flow for the 5 year event is 0.28 cfs. The basin drains into a Type 13 inlet. During the 5 year event, 0.22 cfs flows into the inlet and through an 18 inch RCP under Gold Run Rd. The storm sewer was sized using InRoads and conveys the 5 year event flow. Bypass flow (0.06 cfs) for the 5 year event continues along the side of the road and outfalls into Fourmile Creek. See Appendix A for onsite drainage calculations.

D. Hydraulic Criteria

Hydraulic modeling for Gold Run 450 ft. upstream of Salina Junction to its confluence with Fourmile Creek was developed with the USACE HEC-RAS, version 4.1 software. Topographic data used to define the stream geometry consisted of a Triangulated Irregular Network (TIN) derived from the 2-foot contours provided by FEMA and survey data from David Evans and Associates, Inc. and Lund Partnership, Inc.

Onsite storm sewer was modeled for the 5 year event and sized using the BCSDCM and InRoads (see Appendix A).

IV. DRAINAGE FACILITY DESIGN

A. Hydraulic Modeling

Existing Conditions Modeling Details

Water surface profiles were computed for the 10-, 25-, and 100-year events. HEC-RAS cross sections were located at important hydraulic control points and hydraulic structures. Spacing between cross sections did not exceed 50 ft. and averaged 30 ft.

The selection of coefficients (Manning's, Expansion/Contraction) for the HEC-RAS model was based on engineering judgment, site visits, previous studies, and experience. Known water surface elevation for Fourmile Creek, taken from the effective FEMA FIS flood profiles, was used as the downstream boundary condition for the Gold Run hydraulic model. Fourmile Creek has a significantly larger drainage basin area (15.9 sq. mi.) than that of Gold Run (2.5 sq. mi.) so as a conservative estimate of the potential flood elevation of Fourmile Creek, the water surface elevation of the 10-year flood event (6592.5 NAVD-88) was used as the known water surface elevation at the confluence.

The existing conditions analysis showed that the 42-inch CMP culvert at Salina Junction is significantly undersized to safely convey the discharges on Gold Run. A large amount of flow for all events from the 10-yr through the 100-yr are conveyed over the existing roadway. Figure V-1 shows the results of the HEC-RAS modeling for all events for Gold Run at Salina Junction.

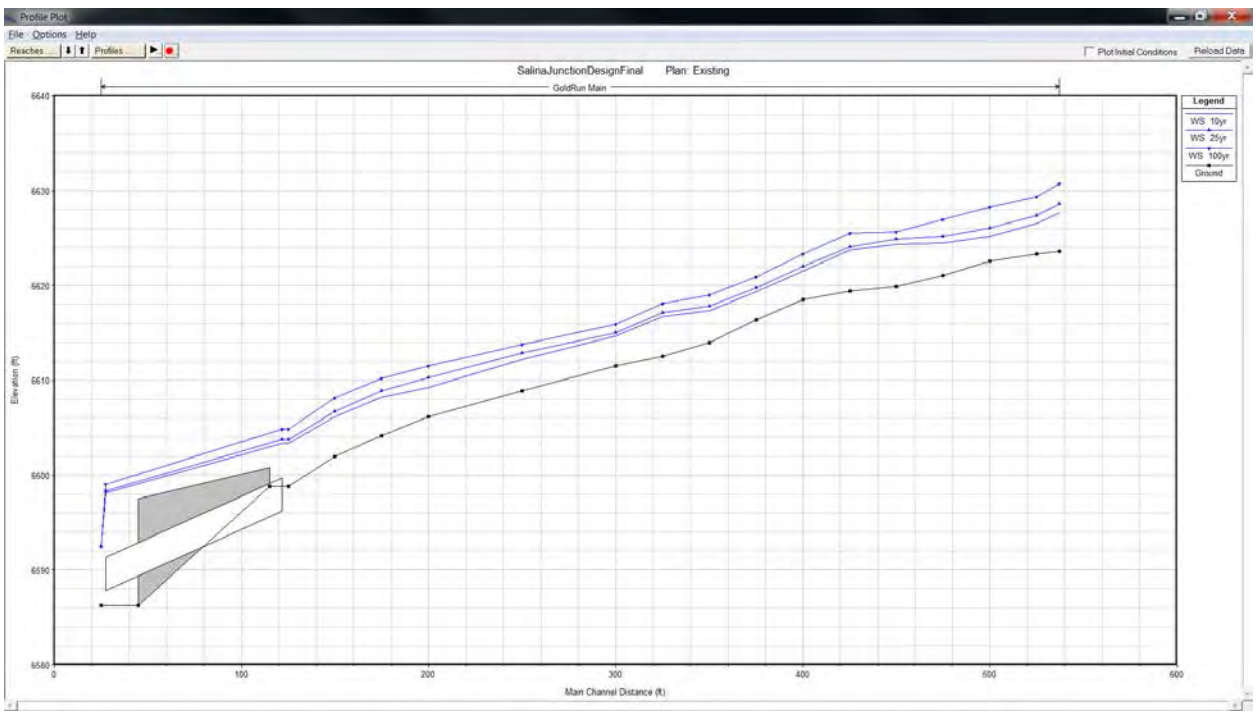

Figure V-1: Existing Conditions HEC-RAS results at Salina Junction

Proposed Conditions Model

After reviewing the existing conditions model the defined project goals were established. The project goals included designing a structure that would balance hydraulic capacity, long term maintenance, environmental and project impacts, and cost. During the initial phase of the project a series of proposed alternatives were created. Modifications were made to the Gold Run geometry in the HEC-RAS model for the various alternatives, and minor modifications were made to the cross sections immediately upstream and downstream of Salina Junction for some alternatives where it was necessary to accommodate the proposed structures.

Based on feedback from Boulder County and its constituents, a large box culvert with no bends and away from the hillside was advanced as the preferred alternative for final refinement and analysis. The proposed conditions hydraulic results represent the final design of the selected alternative.

Figure V-2 summarizes the results of the hydraulic analysis of the final design for Gold Run at Salina Junction. The existing and proposed conditions model results for all profiles and all cross sections are included in Appendix B1. The proposed conditions design results in an 8'x8' CBC that passes the 10-year event due to the increased conveyance through the larger culvert opening and increased channel size through the project area. Appendix B2 includes the HY-8 analysis report for the existing and proposed culvert under Fourmile Canyon Drive.

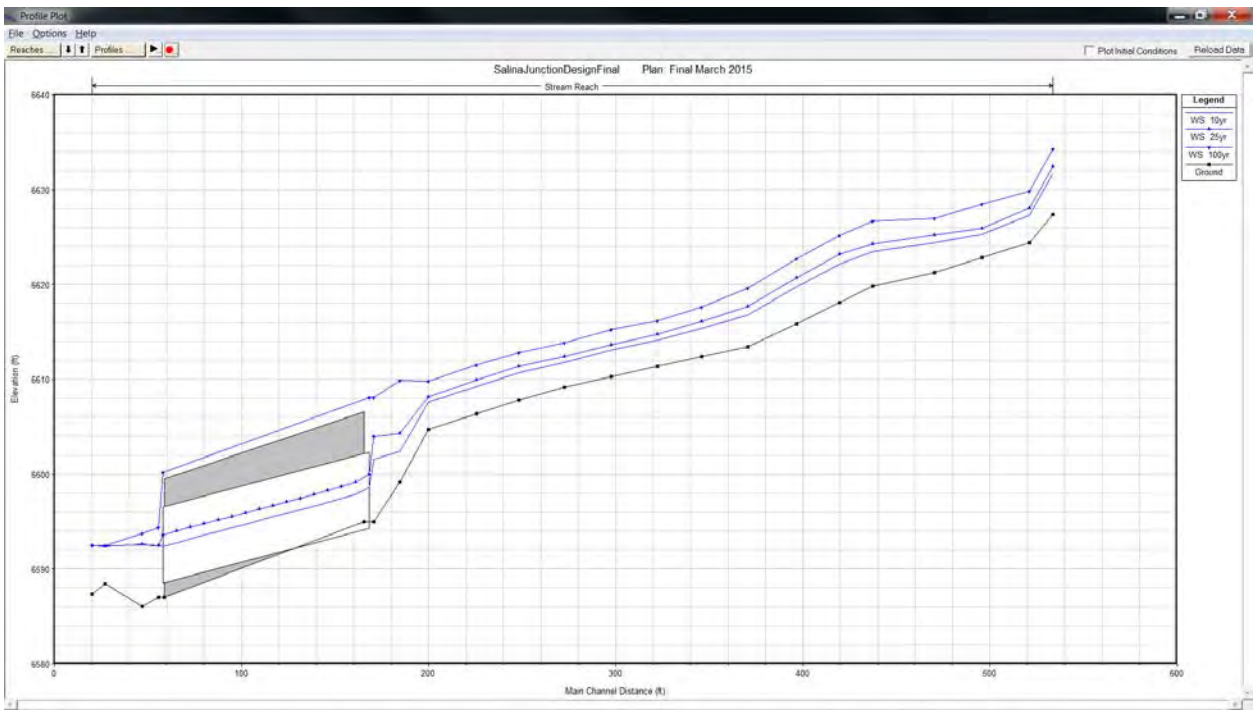

Figure V-2: Proposed Conditions HEC-RAS results at Salina Junction

B. Erosion Control Design

Stream Stability

Stream stability along Gold Run at Salina Junction is a concern due to the high velocities found on steep gradient mountain streams. Several techniques have been utilized to counteract the erosive forces expected during flood events. Stabilization includes geometric modifications to the centerline and cross section of Gold Run north of Fourmile Canyon Drive.

Bank Stability

The Gold Run channel banks between Gold Run and Gold Run Road will be protected by 24-inch soil riprap. The channel side slope riprap calculations were performed in accordance with Federal Highway Administration's Hydraulic Engineering Circular No. 23 (HEC-23, FHWA 2009) as employed by the Federal Highway Administration's Hydraulic Toolbox. Appendix C contains the riprap sizing calculations for side slope countermeasures. Note, that due to limitations with

respect to allowable roadway width along with the steep slopes necessary to convey the flood event through the design 8'x8' CIP CBC into Fourmile Creek the channel bottom may further aggredate and degredate during even routine flood events. It is expected that in areas where the channel bottom consists of bedrock, or large outcropping rock, the channel bottom would be stripped of soil but otherwise show little sign of bedform change because horizontal movement would be significantly less likely. In the bedrock channel bottom condition within the proposed design reach, lateral bedform change is limited by the riprap slope stability efforts in place. Note, without significant geotechnical investigations including subsurface analysis the stability of Gold Run (especially at locations with abrupt transitions and where the channel width is narrow as well as where the water surface freeboard to the road surface is minimal) cannot be safely guaranteed from not experiencing aggradation, degradation, lateral movement and possible failure. Yearly investigation of Gold Run channel and culvert conditions by a geomorphologic expert is recommended.

Parameter	**Input**
Channel Lining Type:	Riprap
Side Slope	2.5:1
Channel Width	8
Longitudinal Slope	0.08
Manning's n	0.065
Flow	402 cfs
Lining Input Parameters	
D50:	2 ft.
Riprap Specific Weight:	165 lb/ft^3
Water Specific Weight:	62.4 lb/ft^3
Riprap Shape	Angular
Safety Factor:	1
Calculated Safety Factor:	1.5
Channel Bottom Shear Results	
Reynold's Number:	441426
Shield's Parameter:	0.15
shear stress on channel bottom:	14 lb/ft^2
Permissible shear stress for channel bottom:	18.2 lb/ft^2
Stable D50:	2.3 ft.
Channel Side Shear Results	
K1:	0.835
K2:	1
Kb:	0
shear stress on side of channel:	14 lb/ft^2
Permissible shear stress for side of channel:	18.2 lb/ft^2
Stable Side D50:	1.9

Table V-1: Riprap sizing calculation

Culvert Impact Basin

The downstream side of the Salina Junction culvert is protected with a riprap impact basin. The countermeasure calculations were performed in accordance with Federal Highway Administration's Hydraulic Engineering Circular No. 14 (HEC-14, FHWA 2006) as employed by the Federal Highway Administration's HY-8 Version 7.3. Appendix D contains the riprap sizing calculations for the impact basin energy dissipater.

C. Onsite Drainage Design

A CDOT Type 2 gutter will be installed parallel to Gold Run Road. The gutter is designed to convey seepage from the canyon rock and nuisance flows from the road. The storm sewer is designed to convey the 5 year storm event as directed by Boulder County. The runoff is conveyed to a Type 13 inlet and under Gold Run Road by an 18-inch RCP. The 24-inch riprap along the bank of Gold Run provides outlet protection for the proposed culvert.

V. CONCLUSIONS

A. Compliance with Standards

Gold Run and onsite drainage design comply with Boulder County Storm Drainage Criteria Manual.

B. Hydrologic Analysis

The hydrologic analysis developed for Gold Run was developed off the WWE Post-Fire hydrology study. When compared to the recent CH2MHill Boulder Creek study, in which Gold Run is modeled as a single subbasin (FMC-4A), the results of this study are significantly higher. When comparing the two studies in detail it can be seen that several parameters of the two studies differ with respect to the current basin condition (curve number), precipitation event, and routing. The parameter estimates used within the CH2MHill study are generalized due to Gold Run being a small subbasin studied as part of the larger Boulder Creek watershed. The HEC-HMS hydrologic model used in this study provides a more detailed analysis for Gold Run using appropriate methodology and parameters.

C. Drainage Concept

The onsite storm sewer will convey the 5 year storm event without causing damage. Gold Run will convey the 10 year storm safely through Salina Junction. Energy dissipater is incorporated into the design to prevent localized scour at the confluence of Gold Run and Fourmile Creek.

VI. REFERENCES

1. Boulder County Storm Drainage Criteria Manual. July 1984.

2. Boulder Creek Hydrologic Analysis, Prepared for Colorado Department of Transportation, CH2MHill, August 2014.

3. Federal Emergency Management Agency. Flood Insurance Rate Map (FIRM), Boulder County, Colorado and Incorporated Areas, Map Number 0801C0390J, Effective December 18, 2012.

4. Federal Highway Administration's Hydraulic Engineering Circular No. 14 (HEC-14), 2006.

5. Federal Highway Administration's Hydraulic Engineering Circular No. 23 (HEC-23), 2009.

6. Floodplain Information Report, Upper Boulder Creek and Fourmile Creek. Prepared for Boulder County and Colorado Water Conservation Board, Gingery Associates, Inc., December 1981.

7. Fourmile Canyon Post-Fire Memorandum, Prepared for Boulder County Transportation Department, Wright Water Engineering. February 21, 2011.

8. Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/accessed [July 31, 2014].