CHAMP Phase III, Moffat County, Colorado
Hydrologic Analyses Report

CWCB CONTRACT # CT PDAA 2017-3860

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List of Abbreviations

CDOT	Colorado Department of Transportation
CHAMP	Colorado Hazard Mapping Program
CWCB	Colorado Water Conservation Board
DEM	Digital Elevation Model
EMA	Expected Moments Algorithm
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
HEC-HMS	Hydrologic Engineering Center – Hydrologic Modeling Software
HEC-SSP	Hydrologic Engineering Center – Statistical Software Package
LOMA	Letter of Map Amendment
LPIII	Log-Pearson Type III
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
USDA	United States Department of Agriculture
USGS	United States Geological Survey

Introduction

Amec Foster Wheeler is working with the Colorado Water Conservation Board (CWCB) to develop data in the Flood Risk Project for the Colorado Hazard Mapping (CHAMP) Phase III project for the Federal Emergency Management Agency (FEMA) that may or may not result in new or updated Flood Insurance Rate Maps (FIRM) and Flood Insurance Study (FIS) reports.

Scope

New hydrology was developed for several flooding sources within Moffat County: Big Gulch, Lay Creek and an Unnamed Stream. Hydrology for these areas was developed using Hydrologic Engineering Center – Hydrologic Modeling Software (HEC-HMS) procedures. Table 1 shows a summary of each of the Zone AE areas within Moffat County. The scoped reaches in Moffat County are displayed in Figure 1.

Table 1 – Detailed Study Summary of Methods

Flooding Source	Reach	Stream Miles	Hydrologic Methodology
Big Gulch	Confluence with Lay Creek to approximately 11,500 feet upstream of US-40 (just downstream of Unnamed crossing)	3.61	HEC-HMS
Lay Creek	Approximately 1,800 feet upstream of Highway 17 to approximately 19,500 feet upstream of US Highway 40	4.88	HEC-HMS
Unnamed Stream	Just upstream of US-40 to approximately 2,400 feet downstream of 7th Street	1.04	HEC-HMS

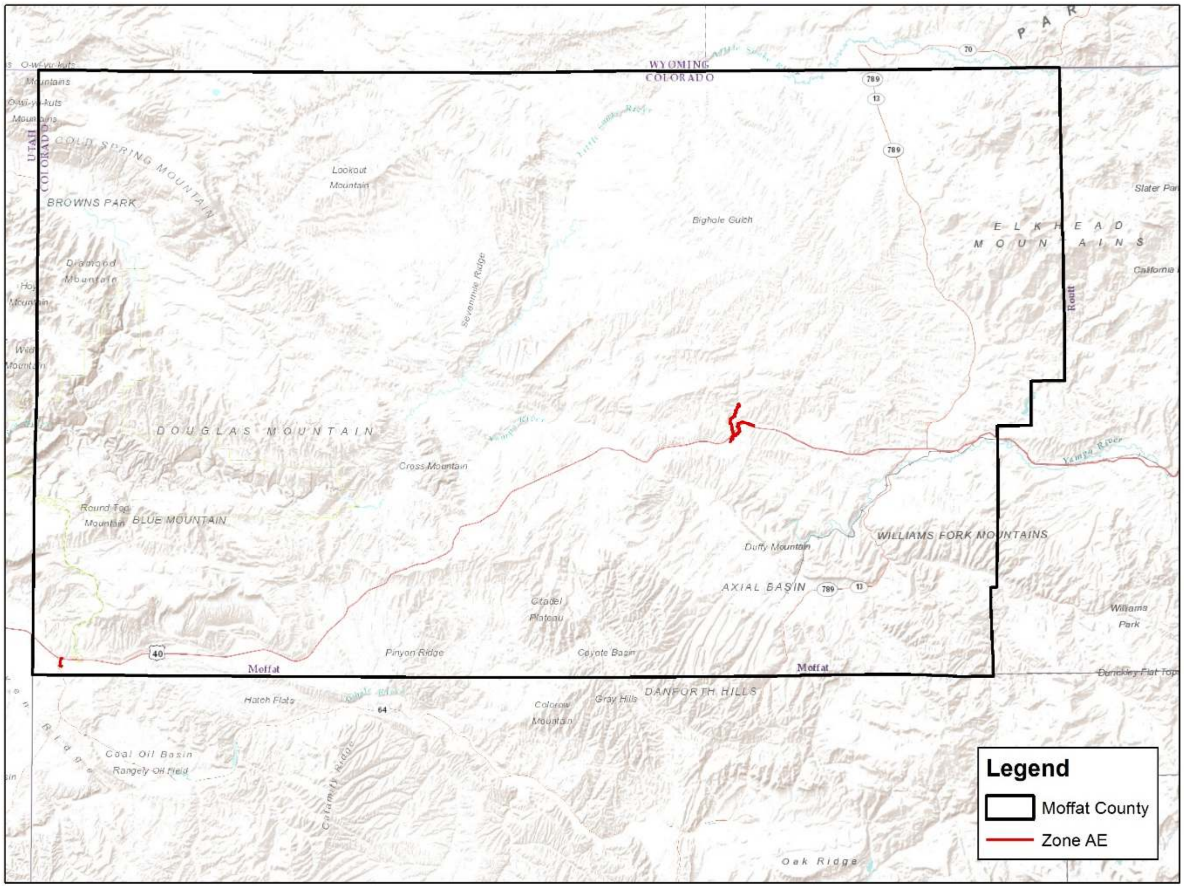

Figure 1 – Studied reaches in Moffat County

Existing Hydrology

Flood Insurance Study

The current Moffat County, Colorado has a FIS study for the City of Craig, published in 1984, and Unincorporated areas, published in 1982. Detailed studies were previously developed for Lay Creek and Big Gulch within Unincorporated Moffat County. Within the Town of Dinosaur, no special flood hazard areas have been defined but a FIRM map does exist. Based on this and the fact that no effective FIS exists for the Town, it was concluded that no detailed study had been previously performed and no detailed hydrology exists for the Unnamed Stream.

Letters of Map Change

As of November 2017, one Letter of Map Amendment (LOMA) were previously completed in Unincorporated Moffat County. No new hydrology was performed for the LOMA, and the areas contained within this Letter of Map Change fall outside the limits of this project.

Proposed Hydrology

Method Selection

HEC-HMS hydrology analysis was used to determine the hydrology for the Zone AE reaches. Results from the analysis were compared to regression results in the area to ensure the flow values produced were within a reasonable range of the results from the regression equations for the study region. However, the results of the regression seemed unreasonably high for the area, and were therefore disregarded.

Rainfall-Runoff Method

Two HEC-HMS model were developed for streams within Moffat county: one for Big Gulch and Lay Creek and a second for Unnamed Stream. By using HEC-GeoHMS Version 10.2 based on 10-meter LiDAR Digital Elevation Model (DEM), 92 sub-basins were delineated within the watershed encompassing Big Gulch and Lay Creek and 2 sub-basins were delineated within the watershed encompassing Unnamed Creek.

The sub-basin boundaries, land use data, and hydrologic soil group data were spatially intersected to generate a runoff curve number (CN) for each sub-basin in accordance with the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Runoff Curve Number methodology. This spatial intersection was performed using an Amec Foster Wheeler ArcGIS proprietary tool. Soil and land use data was downloaded from the NRCS website. Soils within the basin were determined to be a combination of hydrologic soil groups A, B, C, and D. Various land uses exist within the watershed, but primarily consist of shrubs and brush. The curve numbers used in the hydrologic model are presented in Table 3.

National Oceanic and Atmospheric Administration (NOAA) Atlas 14 was used to determine the rainfall depths for the 10-, 25-, 50-, 100- and 500-year return frequencies. The 100-year plus return frequency was determined by converting the upper 90% confidence interval of the NOAA Atlas 14 100-year flow depth to FEMA's standard 84% confidence limit. The SCS Type II Unit Hydrograph method was used to develop the model hydrographs.

Table 2 – NOAA Atlas 14 Rainfall Depths

Model	Rainfall Depths (in)					
	10%	4%	2%	1%	1% Plus	0.20%
Big Gulch/ Lay Creek	1.77	2.15	2.47	2.80	3.33	3.69
Unnamed Stream	1.60	1.91	2.15	2.40	2.77	3.03

The time of concentration for each sub-basin was calculated following the methodology outlined in Chapter 15 of the National Engineering Handbook and from TR-55 Urban Hydrology for Small Watersheds. The longest flow path, basin topography and the 2-year NOAA Atlas 14 rainfall depth for each sub-basin were inputs into an Amec Foster Wheeler ArcGIS proprietary tool that uses the methodologies outlined in the documents listed above to calculate the time of concentration for each sub-basin. The longest flow path input is a shapefile that segments out sheet, shallow, and channel flow sections and provides roughness characteristics. The tool first uses the basin topography to calculate the slope of each segment from the longest flow path shapefile. The 2-year rainfall depth and roughness characteristics are then used with the calculated slopes to determine the velocity of water for each segment. The tool then calculates the time of concentration using the segment lengths and calculated velocity. Finally, the tool dissolves the segments so that there is one time of concentration for each sub-basin. The resulting time of concentrations for each sub-basin are presented in Table 3.

Table 3 – Sub-basin Parameters

Model	Sub-basin ID	Area (mi2)	CN	Time of Concentration (hrs)	Storage Coefficient (hrs)
Big Gulch/ Lay Creek	W7010	1.67	70	0.88	0.88
Big Gulch/ Lay Creek	W7020	4.16	75	1.60	1.60
Big Gulch/ Lay Creek	W7030	1.04	66	1.59	2.38
Big Gulch/ Lay Creek	W7040	3.74	68	2.33	3.50
Big Gulch/ Lay Creek	W7050	1.74	76	0.97	1.45
Big Gulch/ Lay Creek	W7060	2.64	69	1.23	1.84
Big Gulch/ Lay Creek	W7070	4.04	72	1.53	2.30
Big Gulch/ Lay Creek	W7080	3.09	63	1.41	2.11
Big Gulch/ Lay Creek	W7110	2.77	65	2.01	3.01
Big Gulch/ Lay Creek	W7130	1.40	68	1.31	1.96
Big Gulch/ Lay Creek	W7150	0.66	63	1.26	1.89

Model	Sub-basin ID	Area (mi2)	CN	Time of Concentration (hrs)	Storage Coefficient (hrs)
Big Gulch/ Lay Creek	W7160	1.54	68	1.67	2.51
Big Gulch/ Lay Creek	W7170	1.24	70	0.87	1.30
Big Gulch/ Lay Creek	W7180	2.75	70	1.80	2.69
Big Gulch/ Lay Creek	W7190	1.16	66	1.00	1.50
Big Gulch/ Lay Creek	W7200	2.33	65	2.01	3.02
Big Gulch/ Lay Creek	W7210	4.77	69	3.00	4.50
Big Gulch/ Lay Creek	W7230	1.01	70	0.64	0.95
Big Gulch/ Lay Creek	W7240	2.99	64	1.56	2.35
Big Gulch/ Lay Creek	W7250	2.49	58	1.70	2.56
Big Gulch/ Lay Creek	W7260	1.70	62	1.38	2.06
Big Gulch/ Lay Creek	W7270	3.52	70	1.69	2.54
Big Gulch/ Lay Creek	W7280	3.31	66	2.01	3.01
Big Gulch/ Lay Creek	W7290	3.41	69	1.66	2.49
Big Gulch/ Lay Creek	W7300	1.29	62	1.03	1.54
Big Gulch/ Lay Creek	W7330	1.42	64	0.92	1.38
Big Gulch/ Lay Creek	W7340	1.06	71	0.99	1.49
Big Gulch/ Lay Creek	W7350	4.24	67	2.66	3.99
Big Gulch/ Lay Creek	W7370	1.61	63	1.45	2.17
Big Gulch/ Lay Creek	W7390	2.31	65	1.38	2.08
Big Gulch/ Lay Creek	W7400	1.43	68	1.25	1.88
Big Gulch/ Lay Creek	W7410	2.54	68	1.53	2.29
Big Gulch/ Lay Creek	W7430	0.26	61	0.97	1.46
Big Gulch/ Lay Creek	W7440	5.16	66	2.43	3.64

Model	Sub-basin ID	Area (mi2)	CN	Time of Concentration (hrs)	Storage Coefficient (hrs)
Big Gulch/ Lay Creek	W7460	4.75	65	1.67	2.51
Big Gulch/ Lay Creek	W7480	1.16	67	0.75	0.75
Big Gulch/ Lay Creek	W7490	1.66	62	1.47	2.2
Big Gulch/ Lay Creek	W7500	1.18	63	1.15	1.72
Big Gulch/ Lay Creek	W7510	2.04	68	1.25	1.87
Big Gulch/ Lay Creek	W7520	3.48	72	2.21	3.31
Big Gulch/ Lay Creek	W7530	2.74	70	1.64	2.46
Big Gulch/ Lay Creek	W7560	2.77	65	2.05	3.08
Big Gulch/ Lay Creek	W7580	1.63	64	1.55	2.32
Big Gulch/ Lay Creek	W7590	1.47	76	1.26	1.89
Big Gulch/ Lay Creek	W7600	0.53	75	0.79	1.19
Big Gulch/ Lay Creek	W7610	2.74	62	1.38	2.07
Big Gulch/ Lay Creek	W7620	0.87	70	1.03	1.55
Big Gulch/ Lay Creek	W7630	1.14	65	0.75	1.13
Big Gulch/ Lay Creek	W7640	1.20	74	1.19	1.79
Big Gulch/ Lay Creek	W7650	1.97	63	1.32	1.98
Big Gulch/ Lay Creek	W7670	2.95	64	1.45	2.18
Big Gulch/ Lay Creek	W7700	1.10	72	0.73	0.73
Big Gulch/ Lay Creek	W7710	1.64	66	1.82	2.73
Big Gulch/ Lay Creek	W7720	0.17	63	0.45	0.68
Big Gulch/ Lay Creek	W7730	1.01	65	0.95	0.95
Big Gulch/ Lay Creek	W7740	1.67	67	1.27	1.27
Big Gulch/ Lay Creek	W7750	1.16	65	1.99	2.99

Model	Sub-basin ID	Area (mi2)	CN	Time of Concentration (hrs)	Storage Coefficient (hrs)
Big Gulch/ Lay Creek	W7760	1.84	69	0.92	1.37
Big Gulch/ Lay Creek	W7780	2.36	67	1.41	2.11
Big Gulch/ Lay Creek	W7790	2.64	66	1.14	1.71
Big Gulch/ Lay Creek	W7800	1.45	62	1.54	2.31
Big Gulch/ Lay Creek	W7820	2.41	63	1.15	1.73
Big Gulch/ Lay Creek	W7830	2.96	60	1.94	2.92
Big Gulch/ Lay Creek	W7840	2.12	70	2.37	3.55
Big Gulch/ Lay Creek	W7850	1.03	63	0.66	0.99
Big Gulch/ Lay Creek	W7860	1.54	63	1.41	2.11
Big Gulch/ Lay Creek	W7870	2.78	62	2.54	3.81
Big Gulch/ Lay Creek	W7880	2.12	60	1.31	1.31
Big Gulch/ Lay Creek	W7890	4.09	61	2.36	3.54
Big Gulch/ Lay Creek	W7900	2.56	60	1.95	2.92
Big Gulch/ Lay Creek	W7910	3.47	66	1.96	2.93
Big Gulch/ Lay Creek	W7920	1.21	62	1.54	2.31
Big Gulch/ Lay Creek	W7930	2.15	57	1.84	2.75
Big Gulch/ Lay Creek	W7940	2.63	61	1.53	2.3
Big Gulch/ Lay Creek	W7950	1.24	54	0.85	0.85
Big Gulch/ Lay Creek	W7960	1.76	59	2.06	3.1
Big Gulch/ Lay Creek	W7970	1.14	65	0.92	0.92
Big Gulch/ Lay Creek	W7980	0.22	63	1.05	1.57
Big Gulch/ Lay Creek	W7990	1.58	61	1.52	2.29
Big Gulch/ Lay Creek	W8010	1.75	57	1.09	1.64

Model	Sub-basin ID	Area (mi2)	CN	Time of Concentration (hrs)	Storage Coefficient (hrs)
Big Gulch/ Lay Creek	W8020	1.75	56	2.48	3.72
Big Gulch/ Lay Creek	W8030	1.37	64	1.50	2.25
Big Gulch/ Lay Creek	W8050	4.14	61	2.57	3.86
Big Gulch/ Lay Creek	W8060	1.24	66	1.11	1.66
Big Gulch/ Lay Creek	W8070	2.28	61	1.56	2.34
Big Gulch/ Lay Creek	W8110	0.66	60	1.15	1.73
Big Gulch/ Lay Creek	W8130	0.96	66	2.03	3.05
Big Gulch/ Lay Creek	W8150	2.09	60	1.30	1.95
Big Gulch/ Lay Creek	W8160	3.14	63	2.60	3.90
Big Gulch/ Lay Creek	W8170	1.04	66	1.43	2.14
Big Gulch/ Lay Creek	W8240	5.24	66	2.65	3.97
Big Gulch/ Lay Creek	W8250	5.03	70	2.85	4.28
Unnamed Stream	W520	1.04	77	2.30	3.45
Unnamed Stream	W530	0.57	68	1.67	1.36

The Muskingum-Cunge routing method was used to route the flow from the sub-basins through the watershed. The method is based on the combination of the conservation of mass and the diffusion representation of the conservation of momentum. The routing parameters are recalculated for every time step based on the channel properties and flow depth. Representative channel cross sections taken from the merged LiDAR DEM were utilized in this method.

The resulting peak discharges and drainage area at each flow change location are summarized in

Table **4**.

Table 4– Rainfall Runoff Analysis Parameters and Results

Location	Drainage Area (mi^2)	Peak Discharges (cfs)					
		10%	4%	2%	1%	1% Plus	0.2%
Big Gulch Creek, At the confluence with Lay Creek	103.1	433	900	1,580	2,400	4,040	5,240
Lay Creek, 5,200ft downstream of confluence of Lay Creek and Big Gulch	197.5	945	2,010	3,180	4,410	7,250	9,430
Lay Creek, 20,500ft upstream of confluence of Lay Creek and Big Gulch Creek	89.3	684	1,500	2,450	3,620	5,930	7,750
Unnamed Stream, 2,200 downstream of Dinosaur city limits	1.61	19	38.5	54.7	75.6	111	139

<u>HMS-Model Calibration</u>

The HEC-HMS discharges at each location listed in

Table **4** were compared with regression equation results to verify the HEC-HMS results. The 100-year return frequency HEC-HMS discharges for each basin were below the error bounds of the results that were produced by regression flows. All the model parameters were checked, and it was determined that in order to match regression flows, curve numbers and time of concentration parameters in particular, would need to be adjusted to limits that could not be justified for this area. Investigation into the regression equations showed that the flows are highly dependent on the area above 7,500 feet. Given that there is no area above 7,500 feet, Streamstats uses a value of 1% above 7,500 feet in order to make the equation work. However, at these low percentages, the equation is highly sensitive. By increasing the percent above 7,500 feet parameter to 2%, the flow at the outlet drops by over 40% total in comparison to when the parameter is set to1% above 7,500 feet. Therefore, it was determined that the regression results for this region cannot be used for calibration where there is no area above 7,500 feet. Table 5 shows the comparison of these parameters.

Table 5 – HMS Parameter Comparison with Streamstats

	HMS Parameters			Streamstats Parameters		
Flooding Source	Drainage Area	CN	Tc	Drainage Area	CN	Tc
Big Gulch	100	64	12.4	104	69	12.7
Lay Creek	197	66	12.8	198	70	12.9
Unnamed Stream	1.61	74	2.3	1.6	68	2.4

The drainage areas and time of concentration for each basin appear to fall within a reasonable range of each other. The curve numbers for Big Gulch Creek and Lay Creek appear a few CN units less than those produced by Streamstats. The predominant land use for the two basins is a shrub and scrub mix. Using the "Good" classification for the Desert Shrub found in the TR-55 manual, this produces curve numbers of 49, 68, 79 and 84 for A, B, C and D soils, respectively. Given that these curve numbers used for this land use type were able to be calibrated to regression flows in other areas of Western Colorado as part of the CHAMP Phase III project, it is determined that maintaining these curve numbers is reasonable.

The curve numbers for Unnamed Stream appear a few values higher than those produced by Streamstats. In this case, Streamstats shows that the area is 90% Hydrologic Soil Type B and 0% Type C. However, the data used from the Web Soil Survey provided by USDA NRCS indicates that approximately 18% of the basin is Type C and 17% of the basin is Type D. The soil survey soil classifications were verified, and justify the higher CN values used in Unnamed Stream. Therefore, it was determined the parameters for Unnamed Stream used in HEC-HMS were reasonable.

MIP Submittal File Structure

All hydrologic data development TSDN files have been submitted digitally along with this TSDN. The contents have been structure according to the May 2017 Data Capture Standards (DCS) Technical Reference.

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