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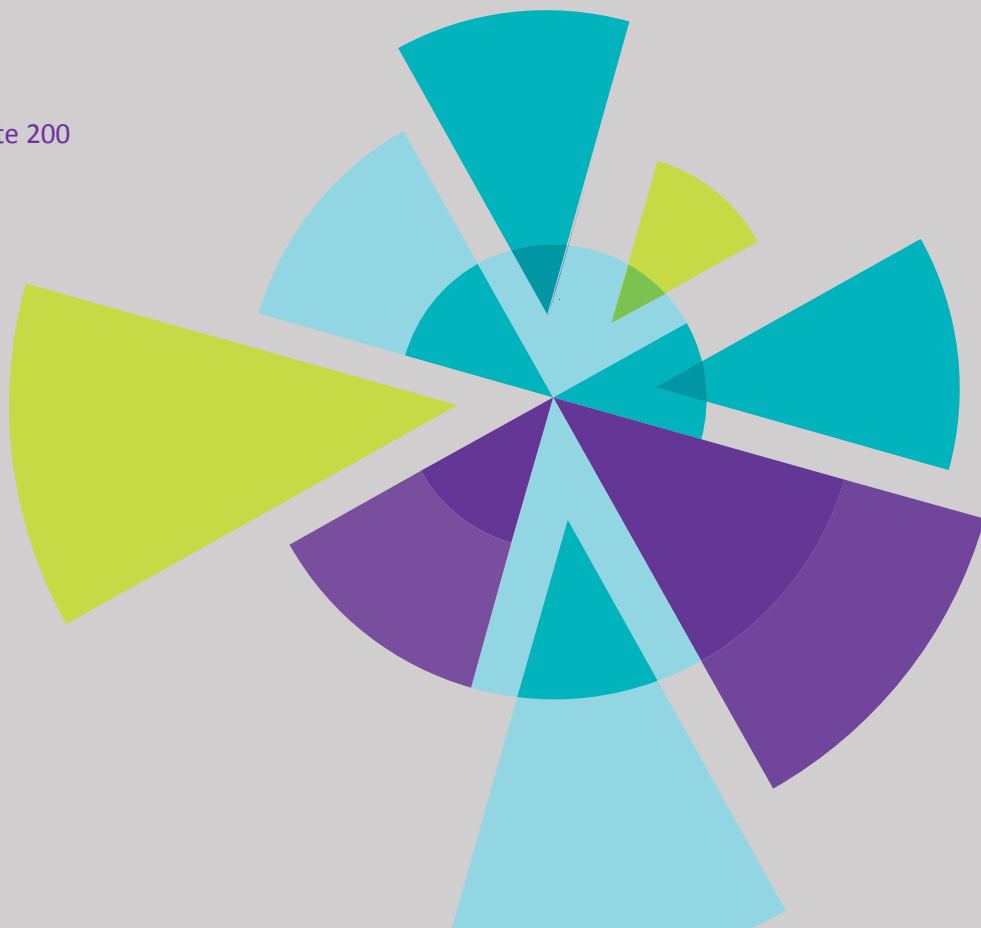
# CHAMP Phase III, Costilla County, Colorado Hydrologic Analyses Report

CWCB CONTRACT # CT PDAA 2017-3860

November 30, 2017

## Submitted by:

Amec Foster Wheeler  
Colorado Center Tower II  
2000 South Colorado Blvd., Suite 200  
Denver, CO 80222 USA



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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
GeoHMS	Geospatial Hydrologic Modeling Extension
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 detailed and approximate hydrology was developed for several streams within Costilla County. Detailed hydrology was required for the Zone AE (detailed study) sections of the Culebra and Rito Creeks near the city of San Luis. The detailed hydrology for these reaches was developed using the Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) model. A summary of the Zone AE reaches is shown in Table 1. Zone A (approximate study) reaches tributary to these flooding sources were also modeled using HEC-HMS. Bulletin 17C flood frequency analysis methods using Hydrologic Engineering Center – Statistical Software Package (HEC-SSP) were used for the Zone A areas on the Rio Grande as the drainage area is too large for regional regression equations to apply and the level of regulation by state reservoirs upstream. Regression equations were used to determine the hydrology for all remaining Zone A reaches in the county. The scoped Zone A and Zone AE reaches in Costilla County are displayed in Figure 1.

**Table 1 – Detailed Study Summary of Methods**

<b>Flooding Source</b>	<b>Reach</b>	<b>Stream Miles</b>	<b>Hydrologic Methodology</b>
Culebra Creek	From just downstream of County Road P5 to just upstream of County Road N7, near the Town of San Luis	1.3	HEC-HMS
Rito Creek	From the confluence with Culebra Creek to just upstream of Casa Verde Real Drive, through the Town of San Luis	1.6	HEC-HMS

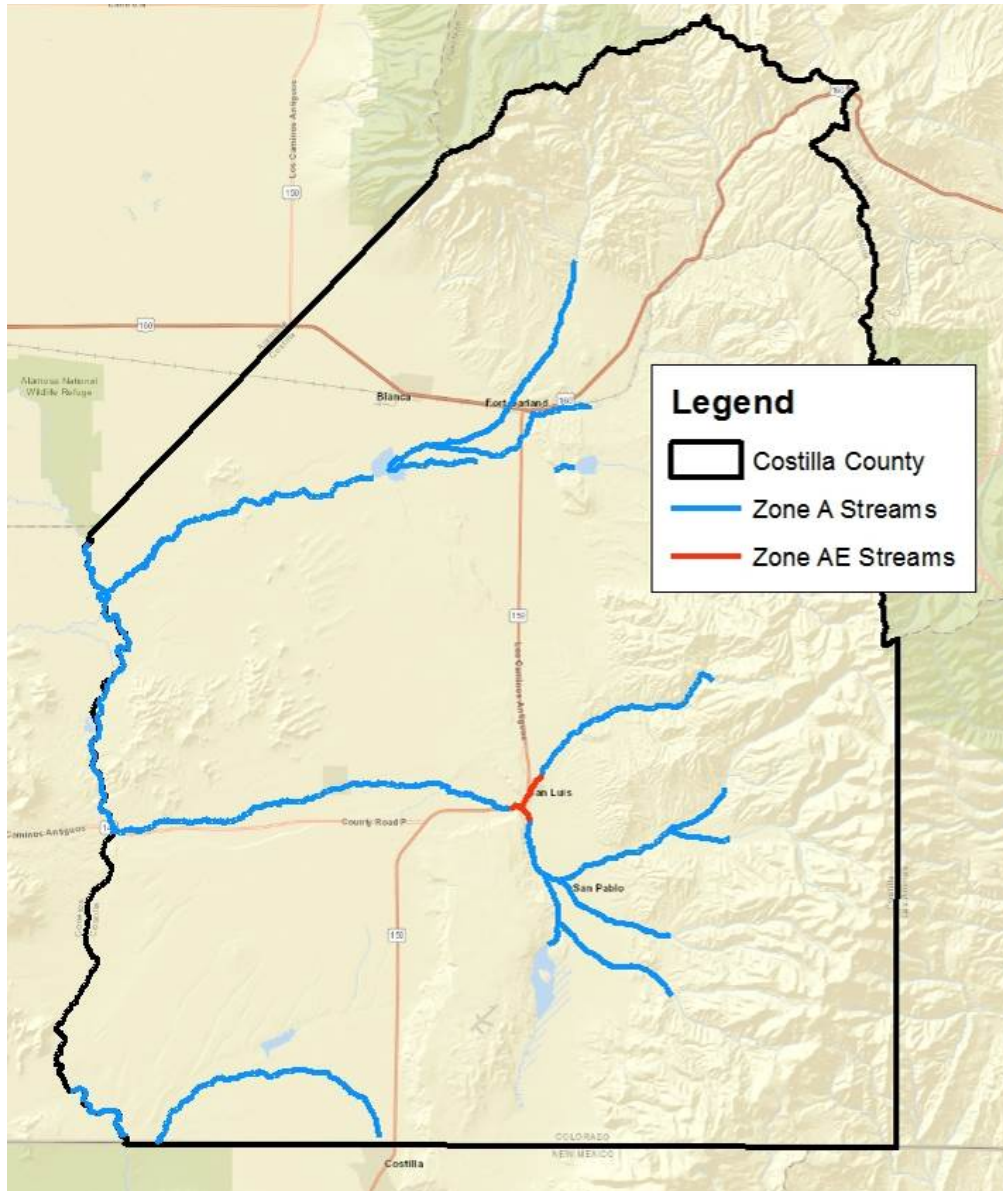


Figure 1 – Zone A and Zone AE reaches in Costilla County

## **Existing Hydrology**

### **Flood Insurance Study**

The current Costilla County, Colorado Unincorporated Areas FIRM defines Zone A – Approximate special flood hazard areas on both Rito And Culebra Creeks near the Town of San Luis. Within the Town, 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 Costilla County, it was concluded that no detailed study had been previously performed and no detailed hydrology exists.

### **Letters of Map Amendment**

As of October 2017, there are two Letters of Map Amendment (LOMAs) within Costilla County. The first is for removing a structure from the San Francisco Creek floodplain. The structure is located at 22474 County Road J.2 which has removed the structure from the floodplain. The second LOMA is for three structures on San Francisco Creek located at 22852 County Road H.2. Portions of the lots remain in the SFHA but the structures have been classified as Flood Zone C.

## **Proposed Hydrology**

### **Method Selection**

Several hydrologic methodologies were used in determining the hydrology for Costilla County. Bulletin 17C stream gage analysis was used to determine the hydrology for the two Zone A reaches on the Rio Grande. A HEC-HMS model (Version 4.2.1) was constructed to determine the hydrology for the two AE reaches on Rito and Culebra Creeks, and all Zone A streams tributary to these flooding sources. Regression analyses were used for the hydrology for all remaining Zone A reaches.

### **Bulletin 17C Summary**

Bulletin 17C updated the peak flow frequency analysis (FFA) by combining future work outlined in Bulletin 17B, new statistical methods, and flood processes from post-Bulletin 17B investigations (England, et al., 2015). The changes between Bulletin 17C (Recommended Draft – April 2017), and Bulletin 17B (published September 1981) are fairly pronounced:

- A new statistical approach called the Expected Moments Algorithm which allows the user to add “interval estimates” or data ranges, rather than individual explicit data points.
- An improvement to the Grubbs-Beck Test allowing for multiple outliers to be censored.
- An improvement to the method used to compute confidence intervals.

Bulletin 17C computes distribution parameters by combining non-standard, censored, or historical data, which performs as a more integrated method compared to Bulletin 17B (Cohn, Lane, & Baier, 1997). EMA is applied to calculate parameters of the Log Pearson Type III distribution in Bulletin 17C (US Army Corps of Engineers, 2016). The results from Bulletin 17C analysis also include improved confidence intervals of frequency curve, which accounts for the uncertainties influenced by censored value and historical data.

## USGS Qualification Codes

USGS qualification codes were available for all data downloaded from the USGS website. Table 2 shows the codes encountered in the gage data for the Rio Grande River along with an approach of how they were incorporated into the FFA.

**Table 2 - USGS Qualification Codes and Approach**

Code #	Description	Approach
1	Discharge is a Maximum Daily Average	If not one of five highest recorded flows in analysis, treated as systematic record. If in highest five flows, values are investigated further and possibly adjusted based on other peak vs. average daily discharge comparison points.
2	Discharge is an Estimate	Data given +/- 25% error bounds in analysis.
5	Discharge affected to unknown degree by Regulation or Diversion	Data has been censored to only use records from 1953 and on due to the construction of agricultural diversions and storage facilities around this time. Flows are treated as expected in any future given year with the influence of the reservoir accounted for.
6	Discharge affected by Regulation or Diversion	Data has been censored to only use records from 1953 and on due to the construction of agricultural diversions and storage facilities around this time. Flows are treated as expected in any future given year with the influence of the reservoir accounted for.

## Bulletin 17C Analysis using Log-Pearson Type III and EMA

Three U.S. Geological Survey (USGS) gaging stations along the Rio Grande were initially evaluated by flood frequency analysis HEC-SSP Version 2.1.1 using the Log-Pearson Type III (LPIII) and Expected Moments Algorithm (EMA) outlined in Bulletin 17C. The three gages include the Rio Grande at the Colorado-New Mexico State Line (08252000), the Rio Grande near Lobatos, Colorado (08251500), and the Rio Grande Above the Mouth of Trinchera Creek Near Lasauses, CO (08240000). For the final analysis, the gage near Lasauses and Lobatos were used.

The Rio Grande does not have a large amount of regulation in the upper parts of the basin upstream of the Zone A study area. Within Costilla County, there are two privately-owned reservoirs located on Trinchera Creek which is tributary and upstream of the Rio Grande Zone A study area.

For the gage near Lasauses, CO, there are a large number of PILFs which have been censored by setting the Low Outlier Threshold to 700 cfs. This produces a curve which better fits the data and produces results more in line with downstream gages.

The annual peak flow data was extracted directly from the USGS website using the internal tool within HEC-SSP. Skew is a measure of the asymmetry of the probability distribution of a real-valued random variable about its mean. Station Skew option is based solely on computing a skew from the data points contained in the dataset. As there have been no other Regional Skew studies in the area that are in compliance with Bulletin 17C, the station skew of the gage was used. Final flows from the FFA analysis are shown in Table 3.

**Table 3 – Bulletin 17C Stream Gage Analysis**

Gage/Location		Drainage Area <sup>2</sup> (mi <sup>2</sup> )	Projection Ratio	Peak Discharge (cfs)					
Number	Name			10%	4%	2%	1%	1% Plus	0.2%
08251500	Rio Grande near Lobatos, Colorado	7,480	1.00	4,340	5,760	6,810	7,830	9,610	10,100
-	Rio Grande below Conejos River Diversion	7,010	1.23	3,460	4,850	5,980	7,160	9,950	10,100
-	Rio Grande above Confluence with Conejos River <sup>1</sup>	6,210	1.09	3,110	4,360	5,370	6,440	8,950	9,070
08240000	Rio Grande Above the Mouth of Trinchera Creek Near Lasausas, CO	5,710	1.00	2,890	4,050	4,990	5,980	8,310	8,420

[1] Per WRIR 99-4190 - Coefficient for Rio Grande Region for projecting gaging stations on the same stream is 0.88 and is only applicable when drainage areas are between 0.5 and 1.5 times the drainage area of the projected gage.

## Gage Projection

The methodology outlined in the Water Resources Investigations Report 99-4190 “Analysis of the Magnitude and Frequency of Floods in Colorado” was consulted to project gage results to locations on the same stream. Costilla County is entirely located within the Rio Grande Region so an exponent ( $x$ ) of 0.88 as used in Equation (3) from the Water Resources Investigations Report.

$$Q_{T(u)} = Q_{T(g)}(A_u/A_g)^x$$

Equation (3): Peak Discharge Projection

Where  $Q_{T(u)}$  is the peak discharge, in cubic feet per second, at the ungaged site for T-year recurrence interval;  $Q_{T(g)}$  is the weighted peak discharge, in cubic feet per second, at the gaged site for T-year recurrence interval;  $A_u$  is the drainage area, in square miles, at the ungaged site;  $A_g$  is the drainage area, in square miles, at the gaged site; and  $x$  is the average exponent for drainage area. The peak discharge projection was used to project flows from the Lasauses, Colorado Gage to a location downstream to just below the confluence with the Conejos River. The upstream gage was used over the downstream gage near Lobatos, Colorado as it produced the more conservative flows despite being above the confluence.

## Regression Equation Methodology

The regression equation method was used for all Zone A streams not analyzed using HEC-HMS or Bulletin 17C analysis. The regression equations are taken from the Scientific Investigations Report (SIR) 2009-5136 titled “*Regional Regression Equations for Estimation of Natural Streamflow Statistics in Colorado*”. The regional regression equations developed in this report are derived from statistical relationships between stream flow records and applicable station, basin and climatic characteristics. Regional regression equations along with predicted uncertainty are generally a reliable and cost-effective means for estimating streamflow statistics at ungaged sites.

The USGS online modeling program, StreamStats, was used to delineate the watershed, generate supporting shapefiles and produce the USGS regression equation peak flow outputs for each stream. StreamStats allows the user to obtain streamflow statistics for both gaged and ungaged sites by selecting a specific stream location on a map interface. If user selects the location of a USGS streamgage, the user will receive previously published information for the streamgage from a database. If the location of interest lacks a streamgage, StreamStats delineates the basin upstream from the selected location, computes basin and climatic characteristics, and provides estimates of the streamflow statistics using the latest regional regression equations for that area, providing a weighted average if the basin falls within multiple hydraulic regions.

Flow change locations along each stream were delineated at regular intervals from the outlet up the streams. A flow change location was determined by finding the location on the stream where an approximate 8% reduction in the 100-year peak flow occurs compared to the outlet. From the first point after the outlet on, the user delineated up the stream until an approximate 10% reduction in the 100-year peak flow from the previously determined point was found and determined to be the next flow change location.

The scoped streams within Costilla County are entirely within the Rio Grande Region. The regression equations for the Rio Grande Region are shown in Figure 2 below.

**Peak Streamflow Equations for Rio Grande Hydrologic Region**

Generalized least-squares (GLS) regression, 44 stations

Approximate range of predictor variables

*A*: 2–517 square miles and *P*: 19–45 inches

$Q_2 = 10^{-3.00} A^{1.00} P^{2.46}$	√	SEP = 67,	pseudoR <sup>2</sup> = 80,	SME = 64,
$Q_5 = 10^{-2.04} A^{0.95} P^{2.02}$	√	SEP = 57,	pseudoR <sup>2</sup> = 83,	SME = 55,
$Q_{10} = 10^{-1.55} A^{0.93} P^{1.80}$	√	SEP = 54,	pseudoR <sup>2</sup> = 84,	SME = 51,
$Q_{25} = 10^{-1.01} A^{0.91} P^{1.55}$	√	SEP = 52,	pseudoR <sup>2</sup> = 84,	SME = 49,
$Q_{50} = 10^{-0.66} A^{0.89} P^{1.39}$	√	SEP = 51,	pseudoR <sup>2</sup> = 85,	SME = 48,
$Q_{100} = 10^{-0.19} A^{0.87} P^{1.17}$	√	SEP = 51,	pseudoR <sup>2</sup> = 85,	SME = 48,
$Q_{200} = 10^{-0.03} A^{0.86} P^{1.11}$	√	SEP = 52,	pseudoR <sup>2</sup> = 84,	SME = 49, and
$Q_{300} = 10^{0.52} A^{0.84} P^{0.85}$	√	SEP = 54,	pseudoR <sup>2</sup> = 84,	SME = 49.

**Figure 2 – Peak Streamflow Equations for the Rio Grande Hydrologic Region**

[SEP, standard error prediction; SME standard model error]

Most of the Zone A areas within Costilla County are forked tributaries from other Zone A areas until the downstream tributary reaches the confluence with the Rio Grande. Watersheds for these tributaries are delineated by specifying drainage points at tributaries just upstream of their confluences with the downstream tributary in StreamStats. In many cases to be conservative, the highest flows obtained from within the basin were applied to the entire reach. Regression was used on Trinchera Creek even with the presences of two reservoirs as these structures are privately owned and maintained. Table 4 shows a summary of the regression equation results as well as the error bounds for the expected values. The drainage areas listed reflect the location of the point, however the peak discharges listed reflect the highest flows on the reach being applied.

**Table 4– Regression Analysis Parameters and Results**

Location	Drainage Area (mi <sup>2</sup> )	Peak Discharges (cfs)					
		10%	4%	2%	1%	1% Plus	0.2%
Costilla Creek-North of CO-NM border	349	1390 (639-2141) 54% Error	2030 (974-3086) 52% Error	2490 (1220-3760) 51% Error	3380 (1656-5100) 51% Error	5100	5540 (1843-5837) 54% Error
Costilla Creek-¼ upstream of stream outlet	325	1390 (639-2141) 54% Error	2030 (974-3086) 52% Error	2490 (1220-3760) 51% Error	3380 (1656-5100) 51% Error	5100	5540 (1843-5837) 54% Error

Location	Drainage Area (mi <sup>2</sup> )	Peak Discharges (cfs)					
		10%	4%	2%	1%	1% Plus	0.2%
Costilla Creek-East of CR 13.2 and N of CN-NM border	237	1360 (626-2090) 54% Error	1910 (917-2900) 52% Error	2310 (1130-3490) 51% Error	3050 (1500-4610) 51% Error	4610	4820 (2220-7420) 54% Error
Sangre de Cristo Creek-Inside Smith Reservoir	321	1240 (570-1910) 54% Error	1830 (878-2780) 52% Error	2260 (1110-3410) 51% Error	3090 (1510-4670) 51% Error	4670	5140 (2360-7920) 54% Error
Sangre de Cristo Creek-At the confluence with Ute Creek	308	1240 (570-1910) 54% Error	1830 (878-2780) 52% Error	2260 (1110-3410) 51% Error	3090 (1510-4670) 51% Error	4670	5140 (2360-7920) 54% Error
Sangre de Cristo Creek-Midway upstream study reach	258	1050 (483-1620) 54% Error	1550 (744-2360) 52% Error	1920 (941-2900) 51% Error	2640 (1290-3990) 51% Error	3990	4420 (2030-6810) 54% Error
Sangre de Cristo Creek-At study reach inlet	185	742 (341-1140) 54% Error	1110 (533-1690) 52% Error	1390 (681-2100) 51% Error	1930 (946-2910) 51% Error	2910	3280 (1510-5050) 54% Error
Trinchera Creek Reach 1- At Costilla and Conejos County border	497	1410 (649-2170) 54% Error	2140 (1030-3250) 52% Error	2710 (1330-4090) 51% Error	3810 (1870-5750) 51% Error	5850	6610 (3040-10200) 54% Error
Trinchera Creek Reach 1- At outlet of Smith Reservoir	397	1410 (649-2170) 54% Error	2140 (1030-3250) 52% Error	2710 (1330-4090) 51% Error	3810 (1870-5750) 51% Error	5850	6610 (3040-10200) 54% Error
Trinchera Creek Reach 2A – at inlet to Smith Reservoir	74	365 (197-562) 54% Error	543 (282-825) 52% Error	686 (350-1040) 51% Error	953 (486-1440) 51% Error	1440	1630 (880-2510) 54% Error
Trinchera Creek Reach 2B-Outlet of Mountain House Reservoir	72	355 (163-547) 54% Error	528 (253-803) 52% Error	668 (327-1010) 51% Error	927 (454-1400) 51% Error	1400	1580 (727-2430) 54% Error
Ute Creek	44.9	230 (106-354) 54% Error	336 (161-511) 52% Error	422 (4207-637) 51% Error	578 (283-873) 51% Error	873	967 (445-1489) 54% Error
Ute Creek	34.9	230 (106-354) 54% Error	336 (161-511) 52% Error	422 (4207-637) 51% Error	578 (283-873) 51% Error	873	967 (445-1489) 54% Error

## Rainfall-Runoff Method

A single HEC-HMS model was developed for the two detailed study streams within Costilla County, Culebra Creek and Rito Creek, as well as several Zone A streams, including El Paso Creek, San Francisco Creek, Vallejos Creek and Ventero Creek. 151 sub-basins were delineated using HEC-GeoHMS Version 10.2 based on a merged combination of 2-meter LiDAR Digital Elevation Model (DEM) and a 10-meter LiDAR DEM. The 2-meter LiDAR DEM covered most of the basin except for the Eastern extents, which the 10-meter LiDAR DEM was used to supplement.

The sub-basin boundaries, land use data, and hydrologic soil group data were spatially intersected to generate an accurate 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, including impervious roadway, commercial and residential, a mine site, woods and brush. Land use types and conditions were calibrated within the constraints of TR-55 to adjust the CN values so that the calculated runoff from the HEC-HMS model fell within StreamStats regression standard error results. The curve numbers used in the hydrologic model are presented in Table 6.

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. Two gaging stations from NOAA Atlas 14 were used in the analysis: Culebra and San Luis 1 S. The rainfall depths from the Culebra station were applied to the sub-basins designated to be within the mountain region and the San Luis 1 S station rainfall depths were applied to the sub-basins in the foothills region. The rainfall depths for each return period for each station are shown in Table 5. Table 6 shows the region each sub-basin is within. The SCS Type II Unit Hydrograph method was used to develop the model hydrographs for each region. Since HEC-HMS does not allow for multiple rainfall depths be entered for the same return period and applied to different basins, the SCS Type II Unit Hydrographs were developed outside of the model and manually inputted as rainfall gage data.

**Table 5 – NOAA Atlas 14 Rainfall Depths**

Region	Rainfall Depths (in)					
	10%	4%	2%	1%	1% Plus	0.20%
Foothills	1.72	2.1	2.41	2.74	3.58	3.59
Mountain	2.53	3.07	3.53	4.02	4.78	5.31

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 finally 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 6.

**Table 6 – Sub-basin Parameters**

Sub-basin ID	Area (mi <sup>2</sup> )	CN	Time of Concentration (hrs)	Storage Coefficient (hrs)	Rainfall Region
W1580	1.37	56	1.66	1.36	Mountain
W1600	1.17	43	0.43	0.29	Mountain
W1610	0.90	61	0.81	1.21	Mountain
W1640	1.28	63	1.75	1.17	Foothills
W1660	2.09	63	1.41	2.11	Foothills
W1670	1.99	51	0.73	1.10	Foothills
W1680	1.23	66	1.22	1.22	Foothills
W1700	0.09	53	0.44	0.36	Foothills
W1730	2.06	49	1.00	1.00	Foothills
W1770	3.13	43	0.36	0.30	Mountain
W1780	1.94	53	1.05	0.70	Mountain
W1790	1.22	58	1.22	0.81	Foothills
W1810	1.49	51	2.56	1.71	Foothills
W1820	0.27	63	0.86	0.70	Foothills
W1830	1.92	48	3.21	2.62	Foothills
W1840	2.21	50	1.04	1.56	Foothills
W1850	0.82	53	0.67	0.67	Foothills
W1870	1.38	50	0.45	0.45	Mountain
W1880	0.03	43	0.30	0.45	Foothills
W1890	1.96	52	0.97	0.79	Foothills
W1910	1.73	58	0.39	0.59	Mountain
W1930	1.52	57	1.20	0.80	Foothills
W1970	1.22	45	1.17	1.75	Foothills
W2010	1.54	37	0.69	0.46	Foothills
W2070	1.39	55	1.65	1.65	Foothills
W2100	1.43	47	1.59	2.38	Foothills
W2110	1.43	53	2.15	1.76	Foothills
W2150	0.26	46	1.07	0.71	Foothills

Sub-basin ID	Area (mi2)	CN	Time of Concentration (hrs)	Storage Coefficient (hrs)	Rainfall Region
W2160	0.24	53	0.81	0.81	Foothills
W2170	1.88	50	2.17	3.25	Foothills
W2190	0.00	70	0.14	0.21	Foothills
W2200	1.31	59	1.07	1.07	Foothills
W2210	1.23	55	0.75	0.75	Foothills
W2220	0.02	33	0.37	0.25	Foothills
W2230	0.03	79	0.28	0.42	Foothills
W2240	0.02	81	0.35	0.35	Foothills
W2260	2.21	46	0.74	0.61	Mountain
W2270	2.20	61	1.14	0.76	Foothills
W2300	2.71	64	0.51	0.34	Mountain
W2310	1.21	66	1.44	0.96	Foothills
W2320	0.51	72	1.71	2.57	Foothills
W2360	0.04	74	0.70	0.57	Foothills
W2460	1.88	38	0.43	0.43	Mountain
W2490	1.02	65	1.52	1.25	Foothills
W2500	1.09	62	2.10	3.14	Foothills
W2530	2.00	59	1.21	1.81	Foothills
W2540	2.11	49	1.75	1.75	Foothills
W2550	3.40	53	1.35	2.03	Foothills
W2560	9.43	69	4.41	3.60	Foothills
W2570	0.05	73	0.44	0.66	Foothills
W2610	1.49	70	1.96	2.94	Foothills
W2860	5.92	39	1.04	1.04	Mountain
W2890	2.08	51	1.78	1.46	Mountain
W2920	1.97	70	2.04	3.05	Foothills
W2930	1.03	60	2.27	3.41	Foothills
W3060	4.77	59	3.66	5.49	Foothills
W3070	1.53	48	2.76	4.14	Foothills
W3100	9.85	47	2.02	3.03	Foothills
W3170	0.69	58	1.92	2.89	Foothills
W3270	0.76	72	1.39	2.09	Foothills
W3300	0.49	74	1.08	1.62	Foothills
W3320	1.08	57	2.27	1.51	Foothills
W3330	0.09	79	0.57	0.47	Foothills
W3350	2.03	58	1.00	1.50	Foothills
W3360	0.13	64	0.79	1.19	Foothills
W3370	0.94	63	1.28	0.85	Foothills

Sub-basin ID	Area (mi2)	CN	Time of Concentration (hrs)	Storage Coefficient (hrs)	Rainfall Region
W3380	0.08	73	0.64	0.64	Foothills
W3740	3.48	45	1.14	0.94	Mountain
W3840	2.96	57	1.77	1.45	Foothills
W3980	1.63	65	1.84	2.76	Foothills
W4240	11.15	49	2.04	2.04	Foothills
W4350	4.83	60	3.34	3.34	Foothills
W5130	4.33	49	0.81	0.66	Mountain
W5270	1.65	56	1.41	1.41	Foothills
W5330	1.52	59	2.34	1.91	Foothills
W5380	0.87	47	1.03	0.68	Foothills
W5430	1.52	54	0.61	0.50	Foothills
W5470	0.86	65	1.12	0.91	Foothills
W5480	0.78	61	0.92	0.92	Foothills
W5690	5.47	45	1.16	0.95	Mountain
W5990	3.17	53	0.91	0.91	Foothills
W6090	2.14	55	0.95	0.95	Foothills
W6230	1.10	36	0.83	0.55	Mountain
W6240	4.06	58	0.61	0.50	Mountain
W6380	5.04	57	0.72	0.59	Mountain
W6540	4.47	66	1.80	2.70	Foothills
W6650	6.56	40	0.94	0.77	Mountain
W6750	2.43	55	0.47	0.31	Mountain
W6790	2.26	42	0.40	0.32	Mountain
W6850	2.35	62	3.27	4.91	Foothills
W6890	1.40	61	2.40	1.96	Foothills
W6900	0.92	68	2.04	3.06	Foothills
W6990	1.56	62	0.85	0.85	Foothills
W7000	2.98	48	1.23	0.82	Foothills
W7050	1.47	42	0.33	0.27	Mountain
W7090	1.10	41	0.95	0.78	Foothills
W7100	1.90	42	0.65	0.97	Mountain
W7200	4.21	41	0.90	0.73	Mountain
W7350	5.17	62	3.30	4.96	Foothills
W7400	1.80	53	1.55	2.33	Foothills
W7410	1.93	54	1.01	1.52	Foothills
W7470	0.73	41	0.68	1.02	Foothills
W7500	1.47	46	1.12	1.68	Foothills
W7510	1.48	45	0.71	0.71	Foothills

Sub-basin ID	Area (mi2)	CN	Time of Concentration (hrs)	Storage Coefficient (hrs)	Rainfall Region
W7560	1.84	51	2.05	3.07	Foothills
W7600	0.45	64	2.31	3.47	Foothills
W7610	1.37	57	1.05	1.05	Foothills
W7660	2.76	46	0.91	1.36	Foothills
W7700	2.36	61	2.06	3.09	Foothills
W7720	1.59	54	1.17	1.75	Foothills
W7860	2.19	43	0.41	0.61	Mountain
W7960	0.95	51	1.13	1.13	Foothills
W8010	0.86	54	1.15	1.72	Foothills
W8050	1.26	60	1.17	0.78	Foothills
W8060	0.34	56	1.19	1.79	Foothills
W8230	4.24	58	2.83	2.83	Foothills
W8370	3.16	44	1.72	2.57	Foothills
W8400	1.44	43	1.79	1.46	Mountain
W8410	1.69	34	1.91	1.91	Mountain
W8450	1.62	48	0.72	0.72	Mountain
W8460	1.42	51	0.40	0.33	Mountain
W8680	2.96	35	1.22	1.22	Mountain
W8720	1.35	65	1.41	1.15	Foothills
W8730	1.60	50	0.97	0.80	Mountain
W8790	0.77	38	0.39	0.26	Mountain
W8820	0.76	65	0.77	0.52	Foothills
W8830	1.39	55	0.46	0.69	Mountain
W8880	0.87	50	0.86	1.29	Foothills
W8920	0.98	59	0.99	0.66	Foothills
W8930	1.04	54	0.76	0.62	Foothills
W9130	2.79	54	1.67	2.50	Foothills
W9280	2.73	58	1.94	1.30	Foothills
W9460	1.26	45	1.58	1.06	Foothills
W9470	1.24	51	0.84	0.84	Foothills
W9510	1.36	44	0.90	0.74	Foothills
W9520	1.13	50	1.20	0.98	Foothills
W9570	2.50	51	1.39	1.39	Mountain
W9620	1.52	49	1.30	1.30	Foothills
W9670	3.55	43	0.62	0.62	Mountain
W9800	0.88	54	1.04	1.56	Foothills
W9860	2.32	69	1.88	1.88	Foothills
W24470	2.85	63	1.28	1.05	Foothills

Sub-basin ID	Area (mi <sup>2</sup> )	CN	Time of Concentration (hrs)	Storage Coefficient (hrs)	Rainfall Region
W24530	2.62	45	3.07	2.05	Mountain
W2501	0.56	71	0.81	0.81	Foothills
W25530	2.89	61	1.73	1.42	Foothills
W25540	1.49	53	1.17	1.17	Foothills
W26710	0.08	75	1.47	2.20	Foothills
W26720	0.41	76	1.64	1.09	Foothills
W27980	0.93	53	1.34	2.01	Foothills
W28180	5.93	52	1.86	1.86	Foothills
W28190	2.08	49	1.84	1.84	Foothills

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 7.

**Table 7– Rainfall Runoff Analysis Parameters and Results**

Location	Drainage Area (mi <sup>2</sup> )	Peak Discharges (cfs)					
		10%	4%	2%	1%	1% Plus	0.2%
Culebra Creek Reach 1-at confluence with Rio Grande	379	1650	2900	4240	6610	13100	15700
Culebra Creek Reach 2-just downstream of CR-P 5	294	420	1220	2410	4320	10300	13100
Culebra Creek Reach 2- just upstream of confluence of Rito Creek	263	361	1050	2000	3680	9230	11400
Culebra Creek Reach 3-South of 1 <sup>st</sup> street in San Luis	250	354	1030	1950	3590	8920	11100

Location	Drainage Area (mi <sup>2</sup> )	Peak Discharges (cfs)					
		10%	4%	2%	1%	1% Plus	0.2%
Culebra Creek Reach 3- Northwest of the intersection of CR-19 and CR-L 5	118	217	711	1450	2500	6090	8360
Culebra Creek Reach 3- Downstream of the confluence of Culebra Creek and Vallejos Creek	87	207	645	1350	2450	5530	7350
Culebra Creek Reach 3- Intersection of CR-L7 and CR-25.5	33	225	665	1290	2270	4490	6010
El Paso- at confluence with Rito Creek	67	220	663	1300	2330	5030	6860
Rito Reach 1- at confluence with Culebra Creek	29	75	209	388	589	1400	1720
Rito Reach 2- immediately upstream of Casa Verde Real Drive	25	69	196	362	549	1290	1600
Rito Reach 2- Intersection of Rito Seco Rd. and Forbes Rd.	17	62	176	323	478	1040	1340
Rito Reach 2- Intersection of Rito Seco Rd. and Wood Rd.	12	51	130	230	323	648	930
San Francisco Creek- Confluence of San Francisco and Ventero Creek	29	25	92	212	422	1130	1350
San Francisco Creek- East of CR-21	25	11	50	131	288	829	1040

Location	Drainage Area (mi <sup>2</sup> )	Peak Discharges (cfs)					
		10%	4%	2%	1%	1% Plus	0.2%
San Francisco Creek- Confluence with Alamosito Creek	19	9	39	105	232	627	848
Vallejos Creek- Confluence with Culebra Creek	30	56	196	406	728	1650	2230
Ventero Creek- outlet of Sanchez Reservoir	95	107	262	466	782	1980	2240

### **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.

## **References**

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