APPENDIX F.1

Flow Characterization

BACKGROUND

The St. Anthony mine site has two open pits and several waste rock piles that flank the Meyer Draw, the main tributary of the Arroyo del Valle (a large arroyo running through the center of the project site - see Figure 1). The St. Anthony Mine Closeout Plan proposes to excavate all piles located southwest of Meyer Draw and backfill excavated material into the two pits. The largest pile on the Site (Pile 4) will be regraded to stable slopes and left in place with an imported soil cover to support vegetative growth and protect from surface erosion.

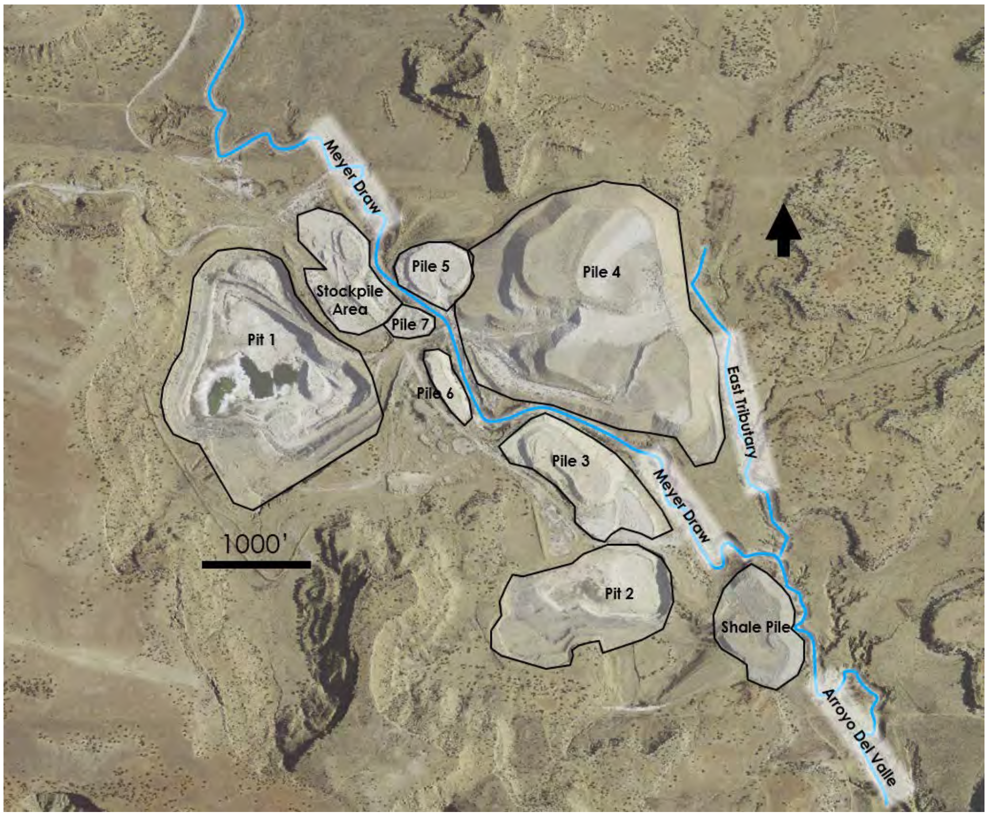

Figure 1: Project Site Existing Conditions (Photo Data: 05/31/2011)

Stantec proposes several surface water control facilities to convey runoff. These facilities are illustrated in the St. Anthony Mine Closeout Plan Design Drawings (design drawings) and are outlined below:

- Grade control structures along the Meyer Draw branch of the arroyo as it passes through the Site as well as bank armoring along the Meyer Draw and East Tributary branches of the arroyo where they run against regraded Pile 4 (see Sheets 10 and 11 of the design drawings).
- Pile 4 Bench Channels and Downdrain (see Sheets 9 of the design drawings).
- Pit 1 Diversion Channel and Pit 2 Diversion Channel (see Sheets 12 and 13 of the design drawings).

The design flows of these surface water conveyance facilities were the surface water runoff event with a 1 percent annual probability of occurrence (1 in 100-year storm). For reference, Stantec also analyzed the 2-year, 5-year and 10-year storm events under the existing conditions.

For hydrologic evaluations, Stantec developed hydrologic models to predict existing condition flows as well as proposed conditions.

Methods

Hydrology Model

The hydrology model used for this evaluation was the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center's – Hydrologic Modeling System (HEC-HMS) version 4.2.1, build 28. HEC-HMS simulates the precipitation-runoff processes of dendritic drainage basins and is applicable to a wide range of geographic conditions and drainage basin sizes.

Watershed Delineations and Model Element Construction

Attachment A shows watershed delineations and the model element construction within HEC-HMS for the hydrologic model of the existing and proposed site conditions. The site is entirely within the U.S. Geological Survey's (USGS) Hydrologic Unit Code (HUC) level 12 Arroyo del Valle Watershed (130202070802). Arroyo del Valle is the receiving waterbody within the watershed area. Drainage through the proposed remedial area has a watershed area of approximately 29.9 square miles, including existing pits.

Watershed drainage basins were delineated using high-resolution survey data collected by Cooper Aerial (2011) where the data was available (near the mine site). Where no high-resolution survey data was available, Stantec used publicly available elevation data from the National Elevation Dataset (NED) collected by the USGS and published in 2013. This data was collected with 1/3 arc-second resolution.

Hyetograph Development

Frequency-Based Storms

Stantec developed the precipitation hyetographs for frequency-based storms using the center-peaking alternative block technique with the depth-duration frequency curves built from the National Oceanic and Atmospheric Association (NOAA) Precipitation Data Frequency Server (PDFS) (Bonnin et al, 2011).

The Precipitation Data Frequency Server (PDFS) provides storm depths for return periods ranging from 1-year to 1,000-years and for storm durations of 5 minutes to 60 days. Table 1 shows the PDFS annual maximum series, median confidence interval storm depths used in this analysis for a point located at the Eastern Edge of Pit 1 (Lat: 35.1633° and Long: -107.3030°).

Table 1: Precipitation Data Frequency Server (PDFS) Annual Maximum Series, Median Confidence Interval Storm Depths

Storm Duration (minutes)	100-Year Rainfall Depth (inches)	10-Year Rainfall Depth (inches)	5-Year Rainfall Depth (inches)	2-Year Rainfall Depth (inches)
5	0.620	0.393	0.325	0.224
10	0.942	0.598	0.494	0.341
15	1.17	0.741	0.612	0.423
30	1.57	0.998	0.825	0.570
60	1.95	1.24	1.02	0.705
120	2.25	1.41	1.16	0.814
180	2.32	1.46	1.21	0.858
360	2.48	1.60	1.35	0.973
720	2.64	1.75	1.48	1.08
1440	2.84	1.89	1.61	1.18

Stantec fit the depth values given in the PDFS to the analytical intensity-duration-frequency (IDF) relationship of the form shown below (Chow et al., 1988):

$$i = \frac{c}{T_d^e + f}$$

Where:

i = The design rainfall intensity (mm/hr)

T_d = The storm duration of the specific return period (15 minutes to 4320 minutes)

c, e, f = Fitting parameters

Table 2 gives the fitting parameters for the IDF curve, and Figure 2 shows the analytical IDF curves with the PDFS depth-duration points.

Table 2: IDF Curve Fitting Parameters

Fitting Parameter	100-Year Storm Value	10-Year Storm Value	5-Year Storm Value	2-Year Storm Value
c	88.8	57.3	47.0	32.2
e	0.982	0.896	0.895	0.890
f	7.77	7.95	7.86	7.82

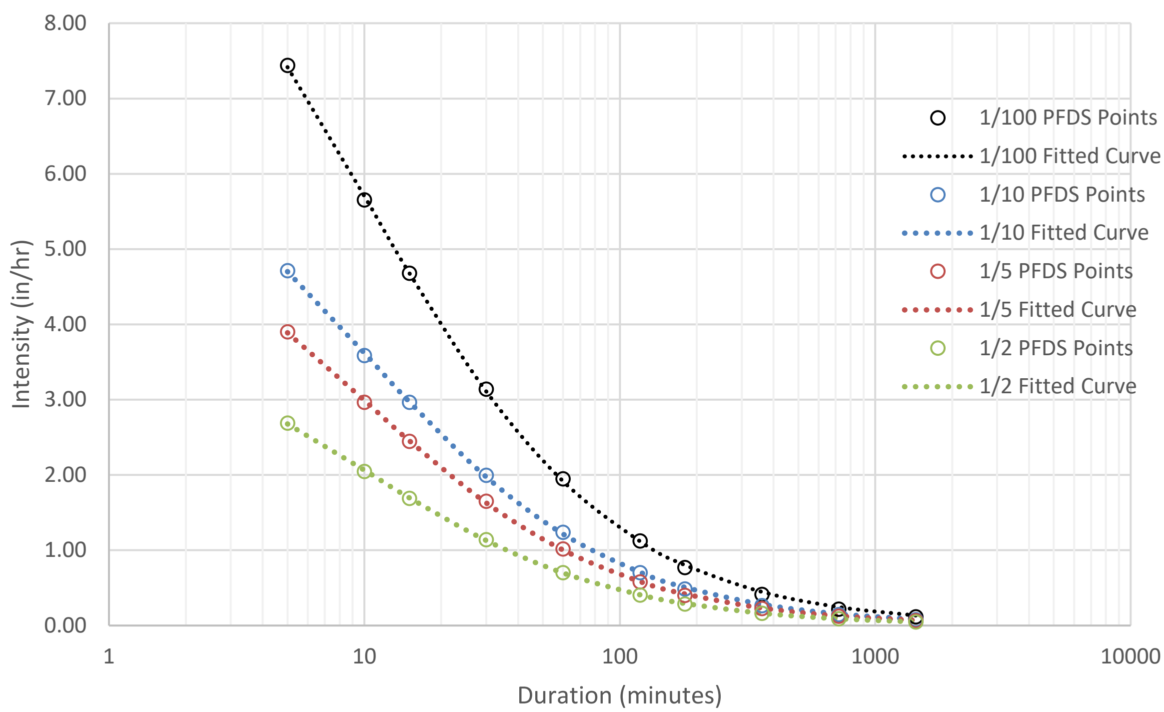

Figure 2: Intensity-Duration-Frequency Curves

Finally, Stantec constructed the cumulative alternating block hyetograph from the analytical IDF curves. Figure 3 shows cumulative hyetographs for the 1 in 100-year return frequency.

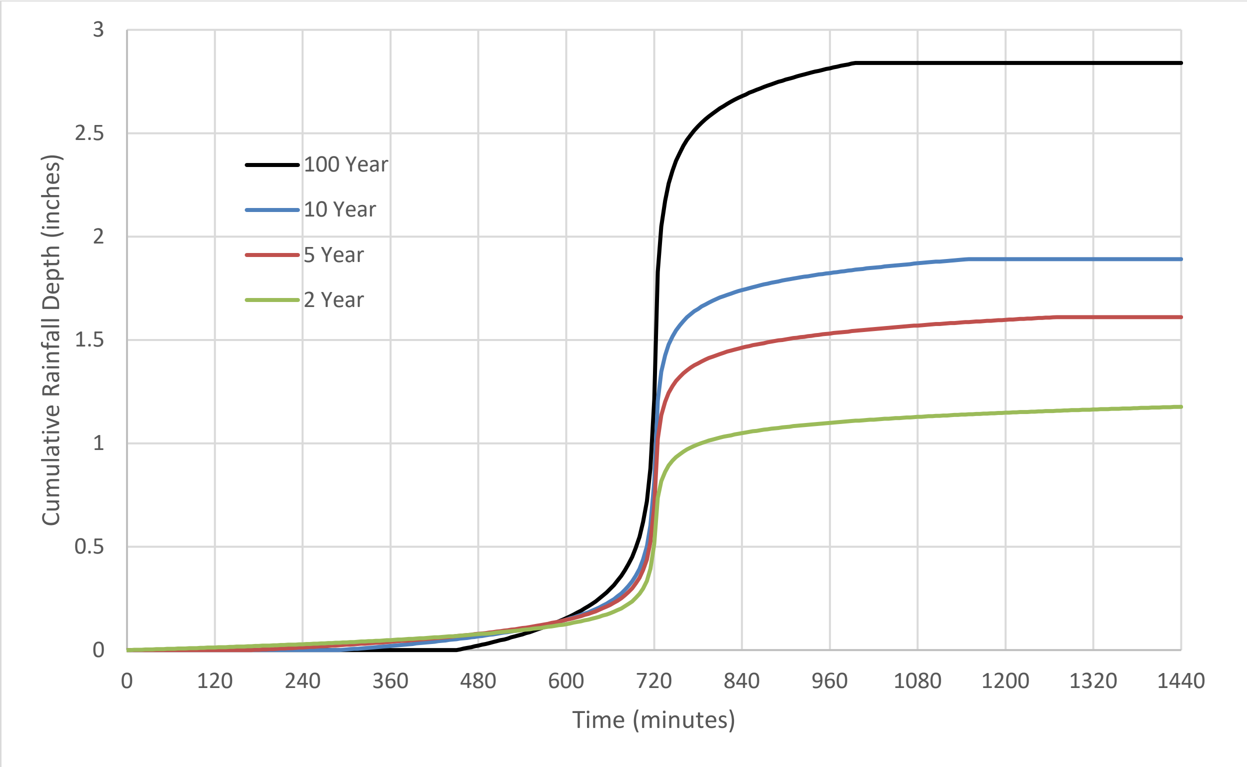

Figure 3: Cumulative Rainfall Hyetographs

Raw data represented in Figure 3 is provided in Attachment B.

Rainfall Losses

Depression Storage

Stantec specified a depression storage value of 0.1 inches for all areas excluding the Stockpile 4 regrade area. This value is mid-range of the values recommended for alluvial plains near Albuquerque, New Mexico (Sabol et al., 1982). Stantec assumed no depression storage for the proposed Pile 4 area because the reclaimed pile area is designed to shed water.

Infiltration Losses

Native Terrain Loss Parameters

The hydrologic models used the Green and Ampt (1911) method to simulate losses due to infiltration. The Green and Ampt parameters include the initial volumetric moisture content of the soil, the saturated volumetric moisture content of the soil, an initial suction head value, the saturated hydraulic conductivity of the soil, and the percent impervious area. Stantec applied these parameters as lumped-estimates at the subbasin level. Lumped estimates were calculated based on area-weighted averages of different soil conditions.

Existing condition soil delineations were based on data available from the U.S. Department of Agriculture (USDA) National Resources Conservation Service (NRCS) gridded Soil Survey Geographic (gSSURGO) database for the state of New Mexico. The gSSURGO Database is derived from the official Soil Survey Geographic (SSURGO) Database. SSURGO generally has the most detailed level of soil geographic data developed by the National Cooperative Soil Survey (NCSS) in accordance with NCSS mapping standards

(NRCS, 2019). Stantec used the gSSURGO database to determine watershed-scale Green and Ampt Parameters.

Green and Ampt parameters were adjusted for post-remedy conditions, to reflect construction activities through the remedial action. The extents of the post-remedial work were made equivalent to the planned re-vegetation area, shown by Sheet 15 in the design drawings. This area is approximately equal to the limits of disturbance where soil impacts are most likely.

Post-Remedy Loss Parameters

For simplicity, Stantec assumed Green and Ampt parameters within the remedial action revegetation areas to have material properties equivalent to the borrow west material properties (shown in Table 3). The sampled material properties included fines content, clay content, in-situ volumetric water content, and estimated saturated volumetric water content. Soil water characteristic curves or saturated hydraulic conductivity data were not lab tested. To estimate the saturated hydraulic conductivity of the Borrow West material, Stantec used HYDRUS-1D which is coupled with Rosetta DLL (Dynamically Linked Library), which was independently developed by Marcel Schaap at the U.S. Salinity Laboratory. Rosetta implements pedotransfer functions which predict van Genuchten water retention parameters and the saturated hydraulic conductivity (Šimůnek et al., 2013). The saturated hydraulic conductivity was calculated using the percentage of sand, silt, and clay. Saturated conductivity values were also estimated using the Hazen equation for comparison. Compared to the Hazen estimates, the predicted values from Rosetta had lower conductivities and were selected for infiltration modeling. The final Green and Ampt parameters applied for the revegetated footprint are shown in Table 4. These values replaced the gSSURGO map unit values described in the previous section. Stantec calculated lumped watershed parameters for initial volumetric moisture content, saturated volumetric moisture content, and saturated hydraulic conductivity using the methods described in the previous sections. Suction head was also calculated using the previously described regression, based on the lumped saturated hydraulic conductivity values at the watershed level. Attachment C presents final Green and Ampt parameters for post-remedial modeling.

Table 3: Borrow West Material Properties

Soil	fines content (%)	clay content (%)	Silt content (%)	Sand content (%)	median d10 (mm)	Sat. hydraulic conductivity, Rosetta estimate (cm/sec)	Sat. hydraulic conductivity, Rosetta estimate (in/hr)	in-situ med. Vol. water content (%)	median estimated vol. saturated water content (%)
Borrow West	55	18	37	45	0.0011	1.29E-04	0.1829	8.9	28

Table 4: Green and Ampt Parameters for Post-Remedial Mine Areas

Initial Content (-)	Saturated Moisture Content (-)	Suction Head (in)	Ksat (in/hr)
0.090	0.280	6.622	0.1829

Suction Head

Stantec calculated suction head values using a regression between suction head and saturated hydraulic conductivity rates. Figure 4 shows the regression. Stantec obtained the data for this relationship from Rawls et al. (1993). The fitted distribution, using a conductivity in inches per hour and the resulting suction in inches, is:

$$\bar{S}_{S,WS} = 3.729 * \bar{K}_{S,WS}^{\ -0.338}$$

Where:

$\bar{K}_{S,WS}$ = The saturated hydraulic conductivity for each watershed (in/hr)
$\bar{S}_{WS}$ = The suction head for the watershed of interest (in)

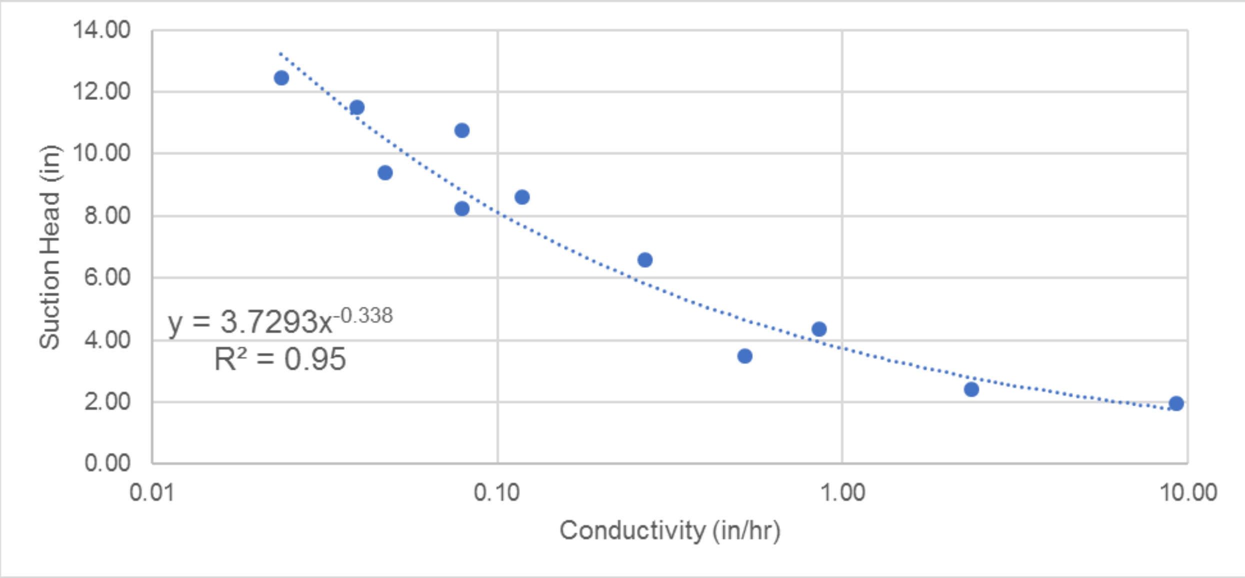

Figure 4: Regression of calculated Suction Head Values as a Function of Hydraulic Conductivity

Hydrograph Transform

The hydrologic model uses the synthetic Clark Unit Hydrograph (UH) to transform rainfall excess to a runoff hydrograph at a catchment outlet. The Clark UH requires estimating two parameters: the time of concentration, Tc, and the storage coefficient, R, which represent the time translation and attenuation of a flood wave within a watershed.

Time of Concentration

Tc values were estimated using two different methods: (1) the empirically based Sabol (1993) Tc equation, and (2) the velocity-based method (McCuen et al., 2002). The following sections describe these approaches and Attachment C provides computation worksheets of the values computed for Tc and R values. Stantec used two Tc methods to address the differing catchment types, because no one method is appropriate for all catchment types. The Sabol (1993) time of concentration method is more appropriate for native catchments. The velocity-based time of concentration method (McCuen et al., 2002) is more appropriate for catchments with drainage dominated by engineered channels or where engineered practices have modified runoff slopes.

As presented below, the Sabol Tc method produces a Tc value constant for all storms; the velocity-based method produces a Tc that varies with the peak storm intensity. Also note that Tc is an input to calculate R. Therefore, for the velocity-based method, Tc and R both vary with the design storm intensity. In this evaluation, the Tc and R values associated with the 100-year event were assumed for all modeled storms.

Also note, nominal values equal to 0.5 hours were assumed for Tc and R for the Pit 1 drainage (hydrologic model element Ex-SB5) in the existing and proposed conditions models. This is justified as this drainage is a sink and does not route into other drainages.

Sabol Tc Method

The Sabol (1993) time of concentration, developed specifically for the desert southwest, is calculated as:

$$T_c = 2.4 * A^{0.1} * L^{0.25} * \ {L_{ca}}^{0.25} * S^{-0.2}$$

Where:

T_c	=	Time of concentration (hours)
A	=	Area (square miles)
L	=	Hydraulically most distant length (miles)
L_{ca}	=	Length along the longest flow path from centroid (miles)
S	=	Slope along the longest flow path (ft/mile)

Velocity-Based Method

The velocity-based method computes the Tc as the sum of (1) the sheet flow travel time, (2) shallow concentrated flow travel time, and (3) open channel flow travel time (McCuen et al., 2002):

$$T_c = \ T_{sf} + T_{sc} + T_{oc}$$

Where:

T_c	=	Time of concentration (hours)
T_{sf}	=	Sheet flow travel time (hours)
T_{sc}	=	Shallow concentrated flow travel time (hours)
T_{oc}	=	Open channel flow travel time (hours)

The following subsections describe methods used to estimate sheet flow, shallow concentrated flow, and open channel flow parameters.

<u>Sheet Flow Travel Time, T_{sf}</u>

The sheet flow travel time, T_{sf}, was calculated using the expression below (McCuen et al., 2002):

$$T_{sf} = \frac{0.93}{i^{0.4}} \left(\frac{nL}{\sqrt{S_{sf}}} \right)^{0.6} \ / \ 60$$

Where:

T_{sf}	=	Sheet flow travel time (hours)
i	=	Rainfall intensity for storm of Tc duration (inches/hour)
n	=	Manning's roughness coefficient
S_{sf}	=	Surface slope along the flow path length (feet/feet)
L_{sf}	=	Flow path length (feet) with a maximum distance of 100 feet or nL/S^0.5
60	=	Conversion from minutes to hours

Stantec estimated values for L_{sf} and S from available site topography. Manning's n values were estimated from roughness coefficients presented by McCuen et al. (2002, Table 2.1) who recommends roughness values of 0.13 which is similar to values prescribed for natural range land in the reference.

The sheet flow calculation uses iterative computations to solve for storm intensity and the sheet flow travel time. Stantec related storm intensities to travel time using the analytical IDF relationships developed for 100-year storm event.

Shallow Concentrated Flow Travel Time, T_{sc}

The shallow concentrated flow travel time, T_{sc}, was calculated as (McCuen et al., 2002):

$$T_{sc} = \frac{L_{sc}}{V_{sc} * 3600}$$

Where:

T_{sc}	=	Time of concentration (hours)
L_{sc}	=	Shallow concentrated flow path length (feet)
V_{sc}	=	Shallow concentrated flow velocity (feet per second)
3600	=	Conversion from seconds to hours

$$V_{sc} = 33 * k * \sqrt{S_{sc}}$$

Where:

V_{sc}	=	Shallow concentrated flow velocity (feet per second)
k	=	Velocity-slope relationship constant
S_{sc}	=	Surface slope along the flow path length (feet/feet)

Stantec estimated values for L_{sc} and S from the available site topography and then computed the shallow concentrated flow coefficient, k, using McCuen (2002, Table 2.2). The values selected for hydrologic analysis is 0.457 which is approximated to represent Grassed Waterways.

Open Channel (Concentrated Flow) Travel Time, T_{oc}

The open channel flow travel time, T_{oc}, was calculated as:

$$T_{oc} = \frac{L_{oc}}{V_{oc} * 3600}$$

Where:

T_{oc}	=	Open channel travel time (hours)
V_{oc}	=	Open channel flow velocity (feet per second)
3600	=	Conversion from seconds to hours (seconds/hour)

Open channel flow velocity is calculated using Manning's equation as given below:

$$V_{oc} = \frac{1.486}{n} * Rh^{2/3} * S_{oc}{}^{0.5}$$

Where:

V_{oc}	=	Open channel flow velocity (feet per second)
n	=	Manning's roughness coefficient
Rh	=	Hydraulic radius of the cross sectional flow area (feet)
S_{oc}	=	Surface slope along the flow path length (feet/feet)

Values for L_{sc} and S were estimated from the available site topography. Manning's roughness coefficient values, n, were determined from (Chow et al., 1988). The values selected for hydrologic analysis is 0.04.

Manning's equation was solved iteratively to find a flow depth (and hydraulic radius) that satisfied the overall T_c. The representative flow used to compute the depth in the equations was 2/3 of the simulated peak flow at catchment outlet (NMDOT, 1995).

Clark Unit Hydrograph Storage Coefficient (R Parameter)

The Clark UH R parameter was computed using the Sabol (1993) equation:

$$R = 0.37 * {T_c}^{1.11} * L^{0.80} * \ A^{-0.57}$$

Where:

R	=	Clark UH storage coefficient (hours)
T_c	=	Time of concentration as calculated in Section 5.1 or 5.2 (hours)
L	=	Length of the longest hydraulic flow path (miles)
A	=	Area (square miles)

Channel Routing

The hydrologic models use the Muskingum-Cunge method to simulate routing through natural and engineered channels between catchment outlet points. The Muskingum-Cunge method couples the Manning formula and the convective-diffusion equation to compute the hydrograph travel time and hydrograph peak attenuation through a channel reach. No additional losses were applied to the channel reaches; therefore, Stantec observed only minor attenuation of the peak flows, indicating that channel reach specifications have a limited impact on the modeled peak flows.

For simplicity, channel dimensions were approximated as triangular shaped channel with 2:1 side slopes. These channel dimensions are simplified versions of the actual channel geometry (which have limited impact on the estimated peak flow values). A roughness of 0.04 was assigned to all channels.

Results

The simulated peak flows, and total runoff volumes for all model elements outlined in the watershed maps shown in Attachment A are provided in Attachment D.

Check with Regional Data

For an independent check of the computed runoff values, Stantec evaluated runoff estimates of the large (approximately 26.6mi^2) upstream basin (Ex_SB-1) using the USGS regression equations (Waltemeyer, 2008). The St. Anthony site is in USGS Flood Region 6. The manual provides regionally regressed estimates of peak discharge in a watershed computed as a function of the drainage basin area. The regression equation predicts a peak 100-year discharge for Ex_SB-1 to be 4460 cfs which is within 10 percent of the value predicted by the hydrologic model (4067 cfs).

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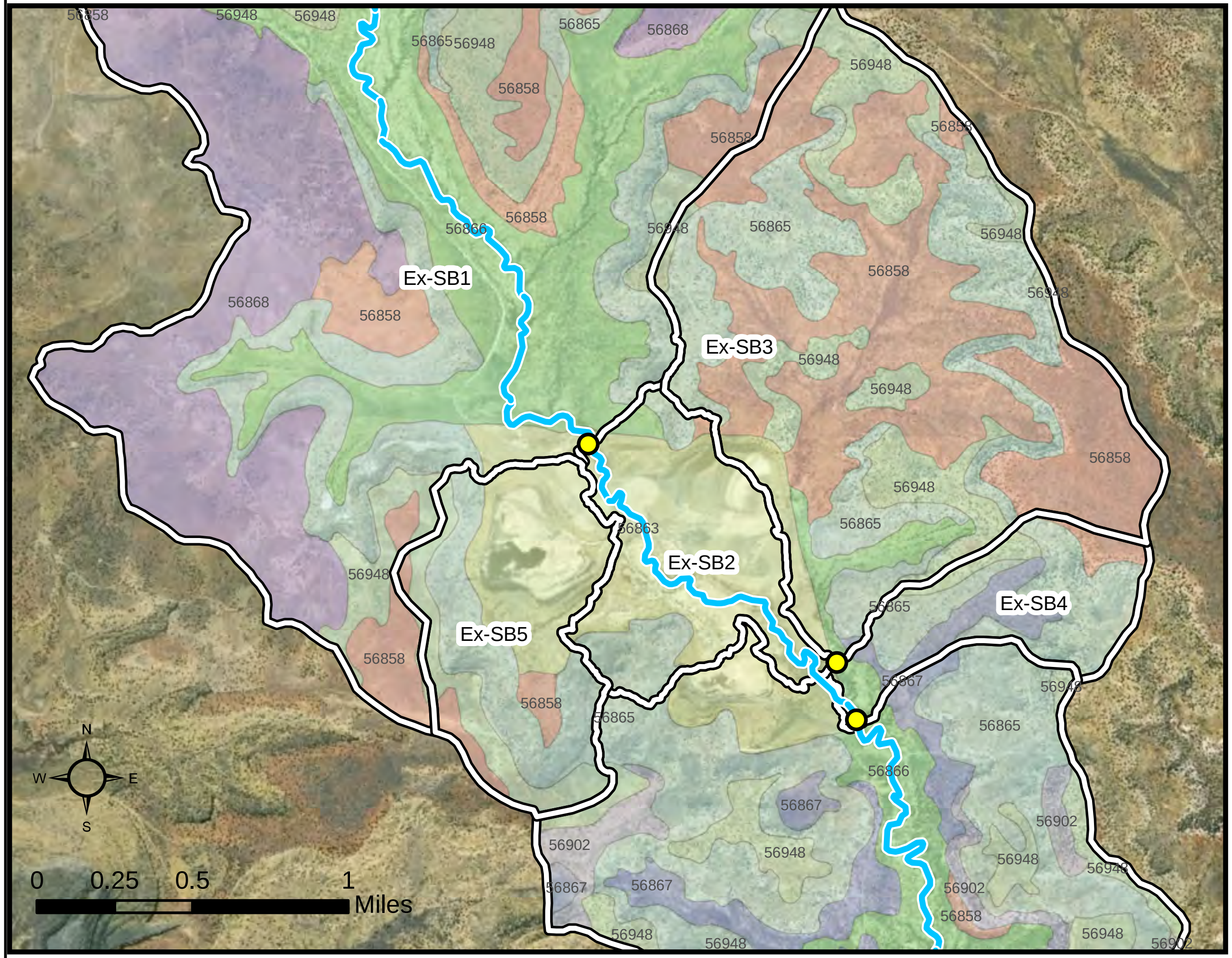
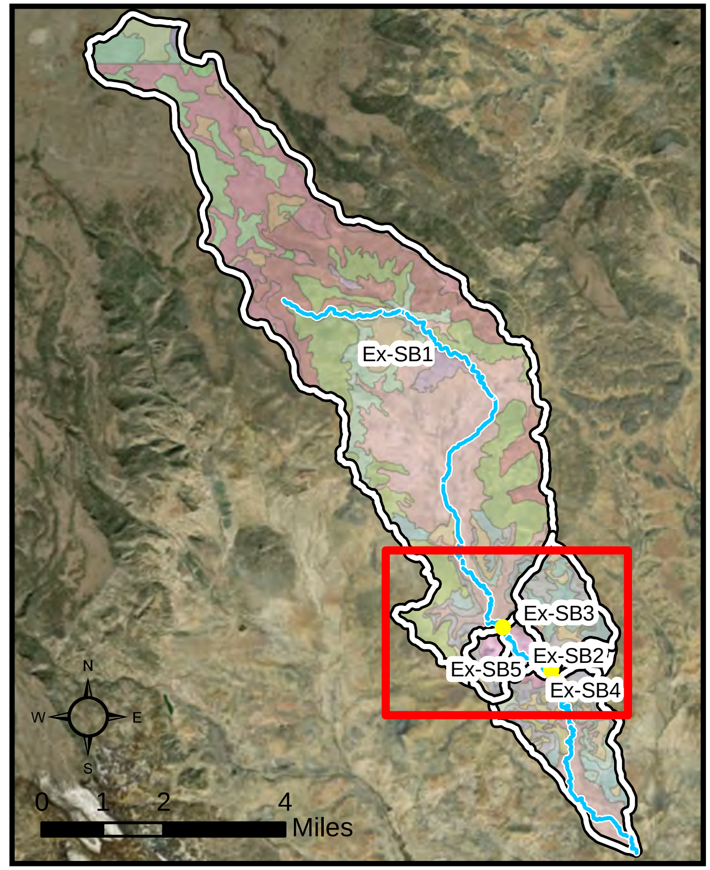
ATTACHMENT A

Watershed Delineation Maps, HEC-HMS Element Construction, Watershed Area Tables





Legend

- Basin Outlets
- Arroyo del Valle
- Existing Sub-basins

HUC12 Soils Mapunit

56858	56865	56870	56902	57298
56863	56866	56871	56903	57299
	56867	56872	56909	57300
	56868	56873	56948	

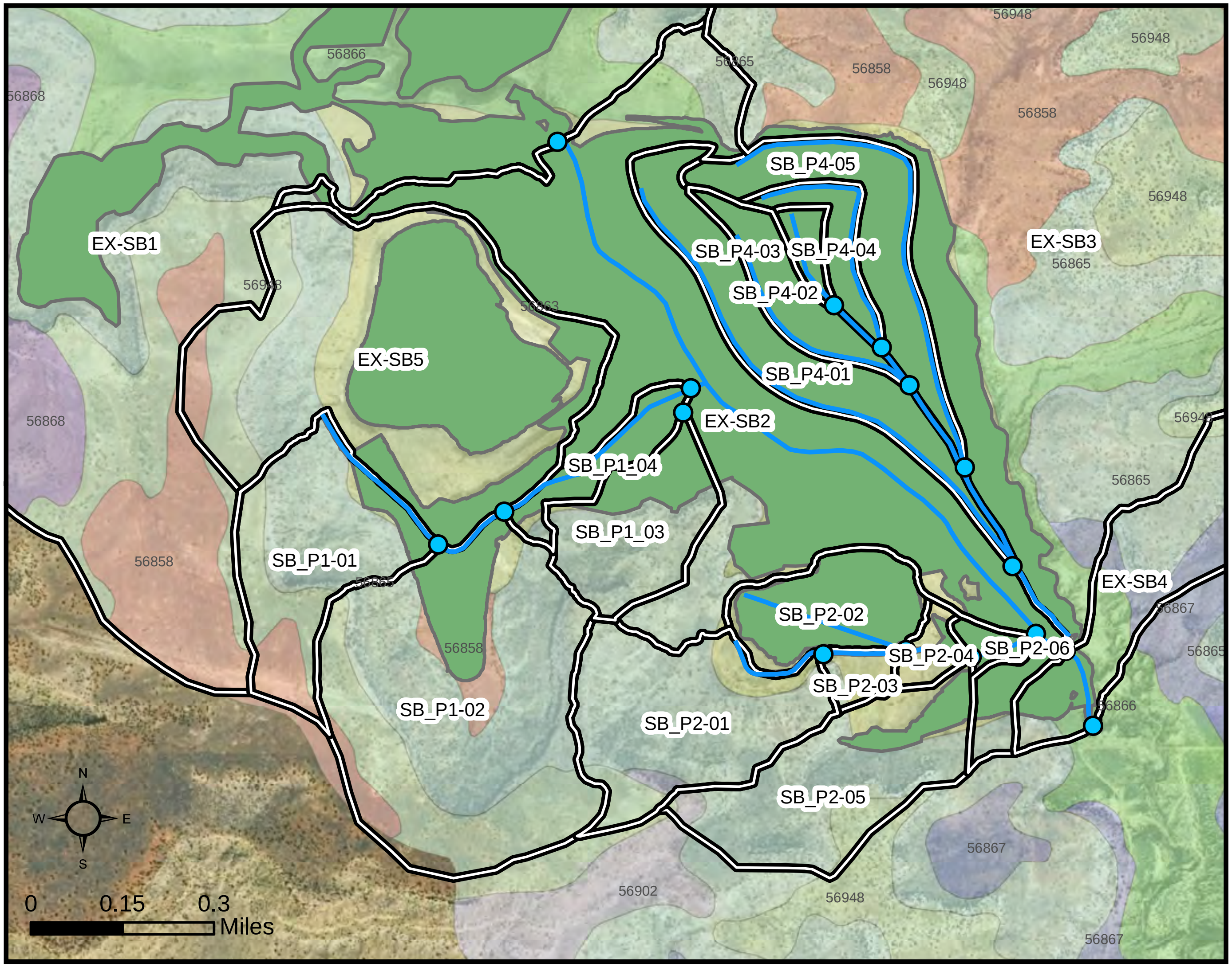
Stantec

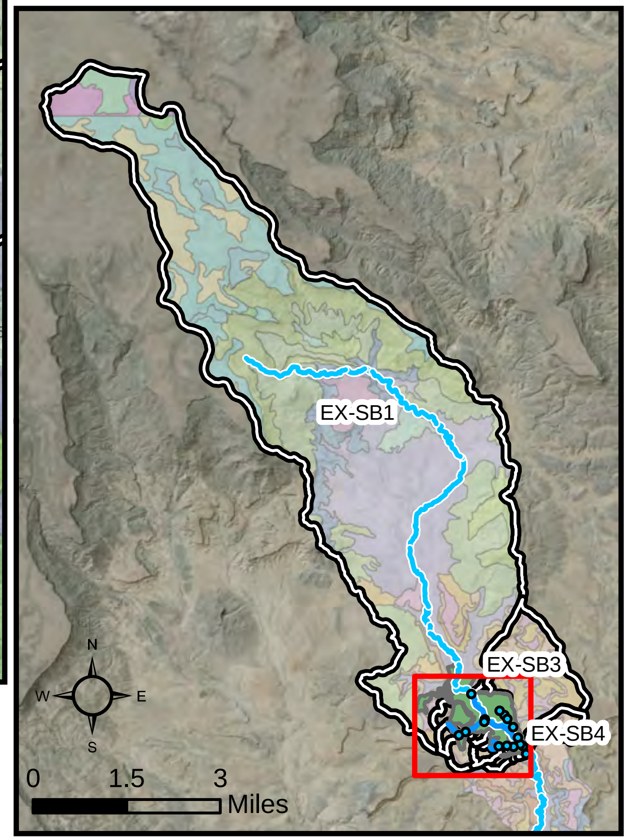
General Electric
St. Anthony Mine Closeout Plan

Attachment A
Watershed Delineation Map
Existing Conditions

DATE: 1/28/2019

PROJECT NO: 233001076





Legend

- Arroyo del Valle
- Design Sub-basins
- Design Flow Paths
- Basin Outlets
- Post Remedial Mine Areas

HUC12 Soils Mapunit

56858, 56863, 56865, 56866, 56867, 56868, 56870, 56871, 56872, 56873, 56902, 56903, 56909, 56948, 57298, 57299, 57300

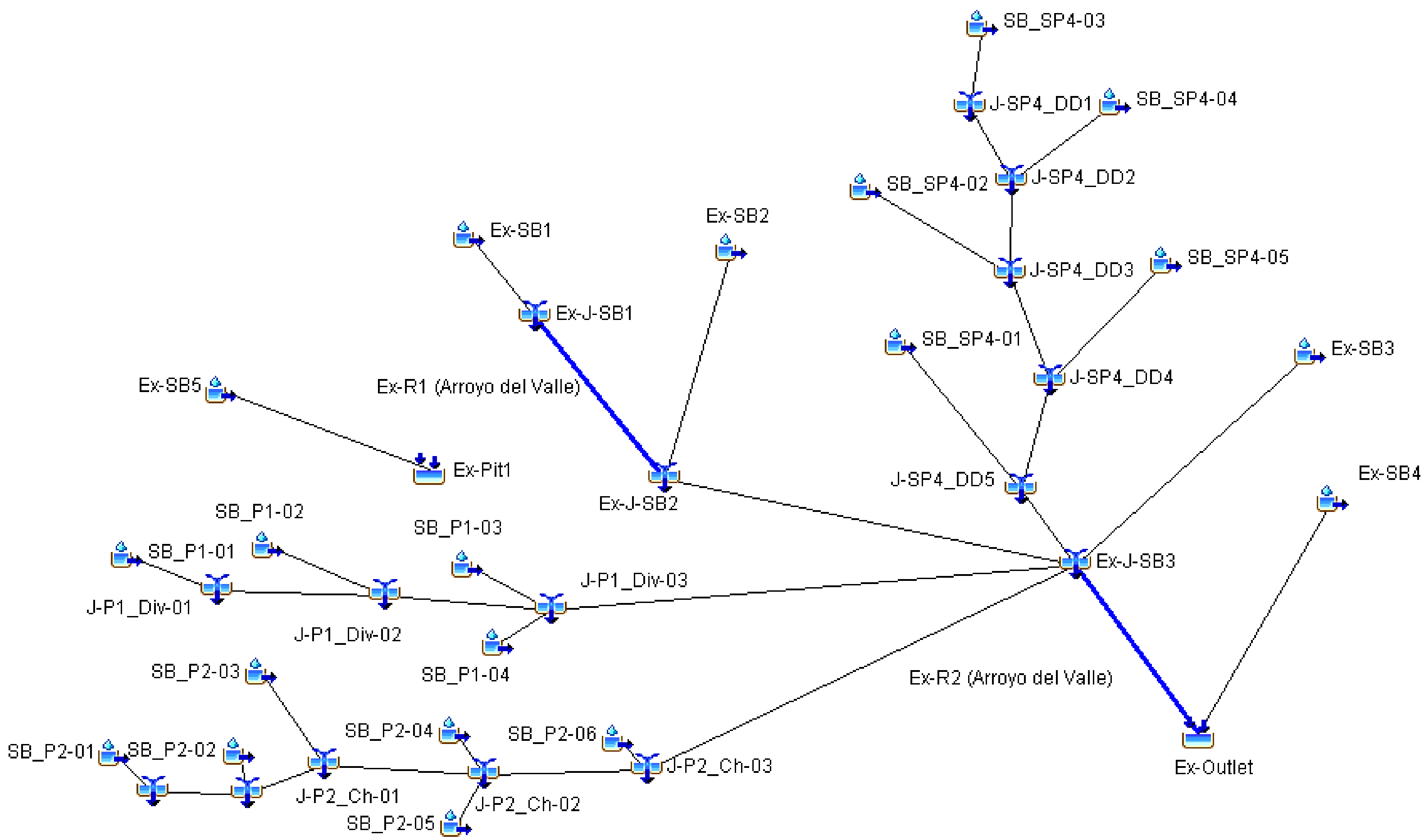
Stantec

General Electric
St. Anthony Mine Closeout Plan

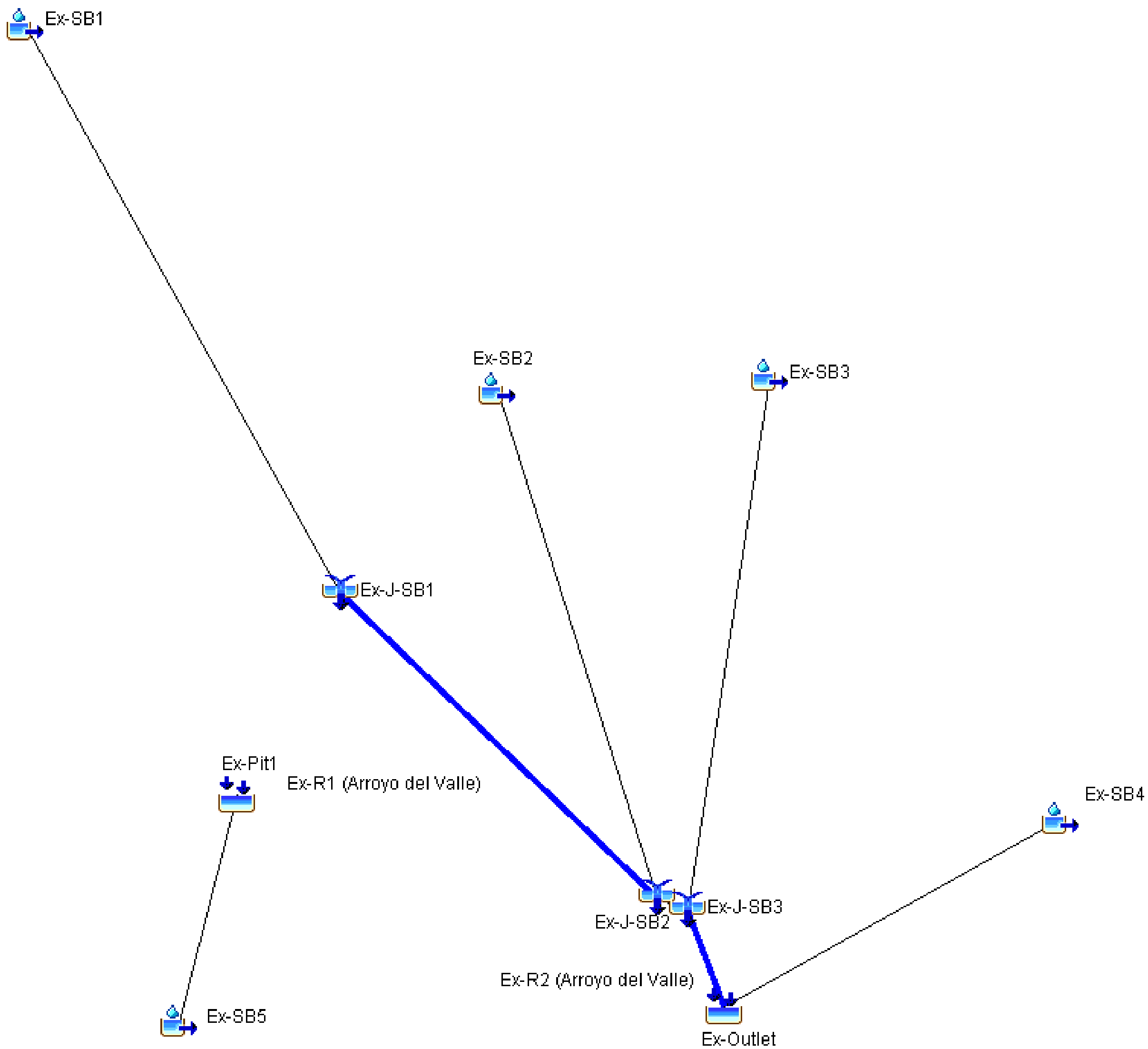
Attachment A
Watershed Delineation Map
Proposed Conditions

DATE: 1/28/2019

PROJECT NO: 233001076



HEC-HMS Basin Model Schematic – Proposed Conditions



HEC-HMS Basin Model Schematic – Existing Conditions

Existing Conditions	
Subbasin	Area (mi^2)
Ex-SB1	26.626
Ex-SB2	0.491
Ex-SB3	1.876
Ex-SB4	0.335
Ex-SB5	0.571

Proposed Conditions	
Subbasin	Area (mi^2)
Ex-SB1	26.618
Ex-SB2	0.311
Ex-SB3	1.898
SB_P1-02	0.202
SB_P1-01	0.084
SB_P1-03	0.054
SB_P1-04	0.022
SB_P2-01	0.094
SB_P2-02	0.047
SB_P2-03	0.010
SB_P2-05	0.086
SB_P2-04	0.010
SB_P2-06	0.007
SB_SP4-05	0.056
SB_SP4-02	0.029
SB_SP4-04	0.018
SB_SP4-03	0.009
SB_SP4-01	0.064
Ex-SB4	0.319
Ex-SB5	0.248

ATTACHMENT B

Storm Hyetograph Tables

Cumulative Rainfall Depth (inches)				
Time (min)	2-Year	5-Year	10-Year	100-Year
0	0	0	0	0
5	0	0	0	0
10	0.001	0	0	0
15	0.001	0	0	0
20	0.002	0	0	0
25	0.002	0	0	0
30	0.003	0	0	0
35	0.004	0	0	0
40	0.004	0	0	0
45	0.005	0	0	0
50	0.005	0	0	0
55	0.006	0	0	0
60	0.006	0	0	0
65	0.007	0	0	0
70	0.007	0	0	0
75	0.008	0	0	0
80	0.008	0	0	0
85	0.009	0	0	0
90	0.009	0	0	0
95	0.01	0	0	0
100	0.011	0	0	0
105	0.011	0	0	0
110	0.012	0	0	0
115	0.012	0	0	0
120	0.013	0	0	0
125	0.013	0	0	0
130	0.014	0	0	0
135	0.015	0	0	0
140	0.015	0	0	0
145	0.016	0	0	0
150	0.016	0	0	0
155	0.017	0	0	0
160	0.018	0	0	0
165	0.018	0	0	0
170	0.019	0	0	0
175	0.02	0.001	0	0
180	0.02	0.002	0	0
185	0.021	0.003	0	0
190	0.022	0.004	0	0
195	0.022	0.004	0	0
200	0.023	0.005	0	0
205	0.024	0.006	0	0
210	0.024	0.007	0	0
215	0.025	0.008	0	0
220	0.026	0.009	0	0
225	0.026	0.01	0	0
230	0.027	0.011	0	0
235	0.028	0.012	0	0
240	0.028	0.013	0	0
245	0.029	0.014	0	0
250	0.03	0.015	0	0
255	0.031	0.016	0	0
260	0.031	0.017	0	0
265	0.032	0.018	0	0
270	0.033	0.019	0	0
275	0.034	0.02	0	0
280	0.034	0.021	0	0
285	0.035	0.022	0	0
290	0.036	0.023	0	0
295	0.037	0.024	0.001	0
300	0.038	0.026	0.003	0
305	0.039	0.027	0.004	0
310	0.039	0.028	0.005	0
315	0.04	0.029	0.007	0
320	0.041	0.03	0.008	0
325	0.042	0.031	0.01	0
330	0.043	0.033	0.011	0
335	0.044	0.034	0.013	0
340	0.045	0.035	0.014	0
345	0.046	0.036	0.016	0
350	0.047	0.038	0.017	0
355	0.047	0.039	0.019	0
360	0.048	0.04	0.02	0
365	0.049	0.041	0.022	0
370	0.05	0.043	0.023	0
375	0.051	0.044	0.025	0
380	0.052	0.046	0.027	0
385	0.053	0.047	0.028	0
390	0.054	0.048	0.03	0
395	0.056	0.05	0.032	0
400	0.057	0.051	0.034	0
405	0.058	0.053	0.035	0
410	0.059	0.054	0.037	0
415	0.06	0.056	0.039	0
420	0.061	0.057	0.041	0
425	0.062	0.059	0.043	0
430	0.063	0.061	0.045	0
435	0.065	0.062	0.047	0
440	0.066	0.064	0.049	0
445	0.067	0.066	0.051	0
450	0.068	0.067	0.053	0
455	0.07	0.069	0.055	0.003
460	0.071	0.071	0.057	0.007
465	0.072	0.073	0.059	0.011
470	0.074	0.075	0.062	0.014
475	0.075	0.077	0.064	0.018
480	0.077	0.079	0.066	0.022

Cumulative Rainfall Depth (inches)				
Time (min)	2-Year	5-Year	10-Year	100-Year
485	0.078	0.081	0.069	0.026
490	0.08	0.083	0.071	0.03
495	0.081	0.085	0.074	0.034
500	0.083	0.087	0.076	0.038
505	0.084	0.089	0.079	0.043
510	0.086	0.091	0.082	0.047
515	0.088	0.094	0.084	0.052
520	0.089	0.096	0.087	0.056
525	0.091	0.099	0.09	0.061
530	0.093	0.101	0.093	0.066
535	0.095	0.104	0.096	0.071
540	0.097	0.106	0.1	0.076
545	0.099	0.109	0.103	0.082
550	0.101	0.112	0.106	0.087
555	0.103	0.115	0.11	0.093
560	0.105	0.118	0.113	0.099
565	0.108	0.121	0.117	0.105
570	0.11	0.124	0.121	0.111
575	0.112	0.127	0.125	0.118
580	0.115	0.131	0.129	0.125
585	0.117	0.134	0.134	0.132
590	0.12	0.138	0.138	0.139
595	0.123	0.142	0.143	0.147
600	0.126	0.146	0.148	0.155
605	0.129	0.151	0.153	0.163
610	0.132	0.155	0.158	0.172
615	0.136	0.16	0.164	0.181
620	0.139	0.165	0.17	0.191
625	0.143	0.17	0.176	0.201
630	0.147	0.176	0.183	0.212
635	0.152	0.182	0.19	0.223
640	0.156	0.188	0.198	0.236
645	0.161	0.195	0.206	0.249
650	0.166	0.202	0.215	0.263
655	0.172	0.21	0.225	0.279
660	0.178	0.219	0.235	0.296
665	0.185	0.228	0.247	0.315
670	0.193	0.239	0.26	0.335
675	0.202	0.251	0.274	0.358
680	0.211	0.265	0.291	0.385
685	0.223	0.28	0.31	0.415
690	0.236	0.299	0.332	0.451
695	0.252	0.321	0.359	0.494
700	0.272	0.349	0.393	0.548
705	0.298	0.386	0.438	0.619
710	0.334	0.439	0.501	0.719
715	0.393	0.522	0.603	0.879
720	0.514	0.697	0.815	1.212
725	0.737	1.021	1.206	1.83
730	0.817	1.136	1.346	2.05
735	0.862	1.201	1.425	2.174
740	0.893	1.244	1.477	2.257
745	0.916	1.276	1.516	2.319
750	0.933	1.301	1.546	2.367
755	0.948	1.321	1.571	2.406
760	0.96	1.338	1.592	2.439
765	0.97	1.353	1.609	2.467
770	0.98	1.366	1.625	2.492
775	0.988	1.377	1.638	2.513
780	0.995	1.387	1.651	2.533
785	1.002	1.396	1.662	2.551
790	1.008	1.405	1.672	2.567
795	1.013	1.412	1.681	2.582
800	1.018	1.42	1.69	2.596
805	1.023	1.426	1.697	2.609
810	1.027	1.432	1.705	2.621
815	1.032	1.438	1.712	2.632
820	1.035	1.443	1.718	2.642
825	1.039	1.449	1.725	2.652
830	1.043	1.453	1.73	2.662
835	1.046	1.458	1.736	2.671
840	1.049	1.462	1.741	2.679
845	1.052	1.467	1.746	2.688
850	1.055	1.471	1.751	2.695
855	1.058	1.474	1.756	2.703
860	1.061	1.478	1.76	2.71
865	1.063	1.482	1.764	2.717
870	1.066	1.485	1.768	2.724
875	1.068	1.488	1.772	2.73
880	1.07	1.491	1.776	2.736
885	1.073	1.495	1.78	2.742
890	1.075	1.497	1.783	2.748
895	1.077	1.5	1.787	2.754
900	1.079	1.503	1.79	2.759
905	1.081	1.506	1.793	2.764
910	1.083	1.508	1.797	2.769
915	1.085	1.511	1.8	2.774
920	1.086	1.513	1.803	2.779
925	1.088	1.516	1.806	2.784
930	1.09	1.518	1.808	2.789
935	1.092	1.52	1.811	2.793
940	1.093	1.523	1.814	2.798
945	1.095	1.525	1.816	2.802
950	1.096	1.527	1.819	2.806
955	1.098	1.529	1.821	2.81
960	1.099	1.531	1.824	2.814

Cumulative Rainfall Depth (inches)				
Time (min)	2-Year	5-Year	10-Year	100-Year
965	1.101	1.533	1.826	2.818
970	1.102	1.535	1.829	2.822
975	1.104	1.537	1.831	2.826
980	1.105	1.539	1.833	2.829
985	1.106	1.541	1.835	2.833
990	1.108	1.542	1.837	2.836
995	1.109	1.544	1.84	2.84
1000	1.11	1.546	1.842	2.84
1005	1.111	1.548	1.844	2.84
1010	1.113	1.549	1.846	2.84
1015	1.114	1.551	1.848	2.84
1020	1.115	1.553	1.85	2.84
1025	1.116	1.554	1.852	2.84
1030	1.117	1.556	1.853	2.84
1035	1.118	1.557	1.855	2.84
1040	1.12	1.559	1.857	2.84
1045	1.121	1.56	1.859	2.84
1050	1.122	1.562	1.861	2.84
1055	1.123	1.563	1.862	2.84
1060	1.124	1.565	1.864	2.84
1065	1.125	1.566	1.866	2.84
1070	1.126	1.567	1.867	2.84
1075	1.127	1.569	1.869	2.84
1080	1.128	1.57	1.87	2.84
1085	1.129	1.571	1.872	2.84
1090	1.13	1.573	1.874	2.84
1095	1.131	1.574	1.875	2.84
1100	1.132	1.575	1.877	2.84
1105	1.133	1.576	1.878	2.84
1110	1.133	1.578	1.88	2.84
1115	1.134	1.579	1.881	2.84
1120	1.135	1.58	1.883	2.84
1125	1.136	1.581	1.884	2.84
1130	1.137	1.582	1.885	2.84
1135	1.138	1.583	1.887	2.84
1140	1.139	1.585	1.888	2.84
1145	1.139	1.586	1.889	2.84
1150	1.14	1.587	1.891	2.84
1155	1.141	1.588	1.891	2.84
1160	1.142	1.589	1.891	2.84
1165	1.143	1.59	1.891	2.84
1170	1.143	1.591	1.891	2.84
1175	1.144	1.592	1.891	2.84
1180	1.145	1.593	1.891	2.84
1185	1.146	1.594	1.891	2.84
1190	1.146	1.595	1.891	2.84
1195	1.147	1.596	1.891	2.84
1200	1.148	1.597	1.891	2.84
1205	1.149	1.598	1.891	2.84
1210	1.149	1.599	1.891	2.84
1215	1.15	1.6	1.891	2.84
1220	1.151	1.601	1.891	2.84
1225	1.151	1.602	1.891	2.84
1230	1.152	1.603	1.891	2.84
1235	1.153	1.604	1.891	2.84
1240	1.154	1.605	1.891	2.84
1245	1.154	1.606	1.891	2.84
1250	1.155	1.607	1.891	2.84
1255	1.156	1.608	1.891	2.84
1260	1.156	1.609	1.891	2.84
1265	1.157	1.609	1.891	2.84
1270	1.157	1.61	1.891	2.84
1275	1.158	1.61	1.891	2.84
1280	1.159	1.61	1.891	2.84
1285	1.159	1.61	1.891	2.84
1290	1.16	1.61	1.891	2.84
1295	1.161	1.61	1.891	2.84
1300	1.161	1.61	1.891	2.84
1305	1.162	1.61	1.891	2.84
1310	1.162	1.61	1.891	2.84
1315	1.163	1.61	1.891	2.84
1320	1.164	1.61	1.891	2.84
1325	1.164	1.61	1.891	2.84
1330	1.165	1.61	1.891	2.84
1335	1.165	1.61	1.891	2.84
1340	1.166	1.61	1.891	2.84
1345	1.166	1.61	1.891	2.84
1350	1.167	1.61	1.891	2.84
1355	1.168	1.61	1.891	2.84
1360	1.168	1.61	1.891	2.84
1365	1.169	1.61	1.891	2.84
1370	1.169	1.61	1.891	2.84
1375	1.17	1.61	1.891	2.84
1380	1.17	1.61	1.891	2.84
1385	1.171	1.61	1.891	2.84
1390	1.171	1.61	1.891	2.84
1395	1.172	1.61	1.891	2.84
1400	1.172	1.61	1.891	2.84
1405	1.173	1.61	1.891	2.84
1410	1.173	1.61	1.891	2.84
1415	1.174	1.61	1.891	2.84
1420	1.174	1.61	1.891	2.84
1425	1.175	1.61	1.891	2.84
1430	1.176	1.61	1.891	2.84
1435	1.176	1.61	1.891	2.84
1440	1.176	1.61	1.891	2.84

ATTACHMENT C
Clark Unit Hydrograph Parameter Calculation and Routing Tables

Existing and Proposed Conditions - Clark UH Parameters, Tc and R by Sabol (1993)

ID	Tc (HRS)	R (HRS)
Ex-SB1	4.09	2.53
Ex-SB3	1.31	0.75
Ex-SB4	0.66	0.52

Time of Conentration								*Storage Coeff*
Method	*Area (mi2)*	*L (mi)*	*Lca (mi)*	*El_Max (ft)*	*El_Min (ft)*	*S (ft/mi)*	*Tc (hours)*	*R (hours)*
Sabol (Desert/Mountain)	26.6	16.2	7.9	8550	6024	156	4.1	2.5
Sabol (Desert/Mountain)	1.9	2.6	1.4	6305	5960	134	1.3	0.7
Sabol (Desert/Mountain)	0.3	1.3	0.7	6345	5951.9	312	0.7	0.5

Proposed Conditions - Clark UH Parameters, Tc and R by FHWA

ObjectID	Tc (HRS)	R (HRS)
SB_P1-01	0.324	0.217
SB_P1-02	0.283	0.168
SB_P1-03	0.278	0.254
SB_P1-04	0.143	0.195
SB_P2-01	0.309	0.631
SB_P2-02	0.192	0.141
SB_P2-03	0.420	0.483
SB_P2-04	0.182	0.136
SB_P2-05	0.246	0.457
SB_P2-06	0.103	0.065
SB_SP4-01	0.632	1.031
SB_SP4-02	0.362	0.497
SB_SP4-03	0.254	0.304
SB_SP4-04	0.342	0.554
SB_SP4-05	0.616	1.020
SB_Ex2	0.696	0.685

1/100-Year Storm Assumed

ObjectID	SF Length (ft)	High Elevation (ft)	Low Elevation (ft)	SF Roughness Factor "n"	SF Slope (ft/ft)	Max Sheet Flow Length (ft)	Guess Intensity (in/hr)	Select Design Storm	Avg. Effective Rainfall Depth (in)	New Intensity (in/hr)	Iterate to 0	Intensity (ft/s)	Tt $_{(i*Tt)}$ (s)	SF Tt (min)
SB_P1-01	120	6399.9	6398.1	0.130	0.02	95.25	4.1	100yr 24hr	1	4.1	0.04	9.5E-05	690	11.5
SB_P1-02	62	6426.7	6426.4	0.130	0.00	48.85	4.4	100yr 24hr	1.24	4.4	0.02	1.0E-04	674	11.2
SB_P1-03	125	6402.0	6400.0	0.130	0.02	97.30	4.5	100yr 24hr	1.23	4.4	0.08	1.0E-04	673	11.2
SB_P1-04	63	6161.8	6125.0	0.130	0.58	588.14	6.1	100yr 24hr	0.87	6.1	0.01	1.4E-04	134	2.2
SB_P2-01	160	6451.8	6447.3	0.130	0.03	129.80	4.2	100yr 24hr	1.29	4.2	0.03	9.7E-05	674	11.2
SB_P2-02	112	6145.0	6143.0	0.130	0.02	102.79	5.4	100yr 24hr	1.03	5.3	0.06	1.3E-04	567	9.4
SB_P2-03	75	6061.3	6060.3	0.130	0.01	90.15	3.5	100yr 24hr	1.46	3.5	0.03	8.1E-05	573	9.6
SB_P2-04	69	6060.3	6057.8	0.130	0.04	145.45	5.6	100yr 24hr	1.00	5.5	0.12	1.3E-04	338	5.6
SB_P2-05	63	6292.5	6291.4	0.130	0.02	101.64	4.8	100yr 24hr	1.16	4.7	0.08	1.1E-04	424	7.1
SB_P2-06	60	6063.9	6059.0	0.130	0.08	219.54	6.9	100yr 24hr	0.71	6.9	-0.01	1.6E-04	225	3.8
SB_SP4-01	308	6150.0	6095.0	0.130	0.18	325.06	2.7	100yr 24hr	1.68	2.7	0.04	6.3E-05	688	11.5
SB_SP4-02	302	6215.0	6155.0	0.130	0.20	342.87	3.8	100yr 24hr	1.38	3.8	0.00	8.8E-05	574	9.6
SB_SP4-03	109	6231.6	6229.4	0.130	0.02	108.79	4.6	100yr 24hr	1.18	4.6	-0.05	1.1E-04	575	9.6
SB_SP4-04	122	6215.0	6190.0	0.130	0.20	348.21	4.0	100yr 24hr	1.34	3.9	0.07	9.3E-05	324	5.4
SB_SP4-05	325	6200.0	6135.0	0.130	0.20	344.01	2.7	100yr 24hr	1.67	2.7	-0.01	6.3E-05	687	11.4
SB_Ex2	245	6102.0	6090.7	0.130	0.06	188.42	2.5	100yr 24hr	1.73	2.5	0.01	5.8E-05	858	14.3

ObjectID	SCF Length (ft)	High Elevation (ft)	Low Elevation (ft)	k value	SCF Slope (ft/ft)	Velocity (ft/s)	Tt (min)	Tt if V=1.0 ft/s (min)	Tt (min)
SB_P1-01	837.9	6398.1	6370.0	0.457	0.033	2.76	5.06	13.97	5.06
SB_P1-02	491.0	6426.4	6326.0	0.457	0.204	6.82	1.20	8.18	1.20
SB_P1-03	1035.0	6400.0	6082.0	0.457	0.31	8.36	2.06	17.25	2.06
SB_P1-04	316.9	6125.0	6098.0	0.457	0.09	4.40	1.20	5.28	1.20
SB_P2-01	804.0	6447.3	6280.0	0.457	0.21	6.88	1.95	13.40	1.95
SB_P2-02	356.3	6143.0	6060.0	0.457	0.23	7.28	0.82	5.94	0.82
SB_P2-03	1012.8	6060.3	6045.6	0.457	0.01	1.82	9.30	16.88	9.30
SB_P2-04	245.0	6057.8	6040.0	0.457	0.07	4.06	1.00	4.08	1.00
SB_P2-05	996.4	6291.4	6110.0	0.457	0.18	6.43	2.58	16.61	2.58
SB_P2-06	421.9	6059.0	6007.0	0.457	0.12	5.29	1.33	7.03	1.33
SB_SP4-01	0.0	6095.0	6095.0	0.457	#DIV/0!	0.00	0.00	0.00	0.00
SB_SP4-02	0.0	6155.0	6155.0	0.457	#DIV/0!	0.00	0.00	0.00	0.00
SB_SP4-03	721.2	6229.4	6215.0	0.457	0.02	2.13	5.64	12.02	5.64
SB_SP4-04	0.0	6190.0	6190.0	0.457	#DIV/0!	0.00	0.00	0.00	0.00
SB_SP4-05	0.0	6135.0	6135.0	0.457	#DIV/0!	0.00	0.00	0.00	0.00
SB_Ex2	965.1	6090.7	6032.8	0.457	0.06	3.69	4.35	16.09	4.35

ObjectID	CF Length (ft)	High Elevation (ft)	Low Elevation (ft)	Channel Roughness Factor "n"	Channel Slope (ft/ft)	Guess Flow Depth (ft)	Channel Bottom Width "B" (ft)	xH:1V-1	xH:1V-2	Flow Area "A" (ft2)	Channel Hydraulic Radius "Rh" (ft)	Calculated Discharge (cfs)	Modeled Discharge	Modeled Discharge (cfs)	Iterate to 0	Tt (min)
SB_P1-01	2011.8	6370.0	6081.0	0.04	0.144	1.02	5.00	2.0	2.0	7.16	0.75	83.24	83.2	83.20	0.04	2.9
SB_P1-02	3115.5	6326.0	6078.0	0.04	0.080	1.71	5.00	2.0	2.0	14.34	1.14	163.61	245.5	163.67	-0.06	4.6
SB_P1-03	1315.5	6082.0	6021.0	0.04	0.046	0.98	5.00	2.0	2.0	6.78	0.72	43.71	65.9	43.93	-0.23	3.4
SB_P1-04	1855.8	6098.0	5990.0	0.04	0.058	0.70	5.00	2.0	2.0	4.44	0.55	26.64	39.8	26.53	0.11	5.2
SB_P2-01	2367.9	6280.0	6071.0	0.04	0.088	0.69	5.00	2.0	2.0	4.43	0.55	32.65	48.3	32.20	0.45	5.4
SB_P2-02	522.9	6060.0	6039.0	0.04	0.040	1.24	5.00	2.0	2.0	9.25	0.88	63.10	94.7	63.13	-0.03	1.3
SB_P2-03	470.0	6045.6	6039.0	0.04	0.014	0.16	5.00	2.0	2.0	0.85	0.15	1.05	1.5	1.00	0.05	6.3
SB_P2-04	706.0	6040.0	6014.0	0.04	0.037	0.27	5.00	2.0	2.0	1.50	0.24	4.13	6.0	4.00	0.13	4.3
SB_P2-05	1989.6	6110.0	6014.0	0.04	0.048	0.95	5.00	2.0	2.0	6.51	0.71	42.12	62.9	41.93	0.18	5.1
SB_P2-06	401.4	6007.0	5961.0	0.04	0.115	0.39	5.00	2.0	2.0	2.25	0.33	13.65	20.6	13.73	-0.08	1.1
SB_SP4-01	4760.6	6095.0	5995.0	0.04	0.021	0.84	0.00	20.0	5.0	8.72	0.42	26.13	39.1	26.07	0.00	26.5
SB_SP4-02	2141.2	6155.0	6105.0	0.04	0.023	0.75	0.00	20.0	5.0	7.03	0.37	20.69	30.7	20.47	0.05	12.1
SB_SP4-03	0.0	6215.0	6105.0	0.04	#DIV/0!	0.00	0.00	20.0	5.0	0.00	#DIV/0!	#DIV/0!	12.9	8.60	#DIV/0!	0.0
SB_SP4-04	2296.0	6190.0	6140.0	0.04	0.022	0.63	0.00	20.0	5.0	4.96	0.31	12.55	18.4	12.27	0.08	15.1
SB_SP4-05	4414.0	6135.0	6045.0	0.04	0.020	0.81	0.00	20.0	5.0	8.10	0.40	23.35	34.8	23.20	0.02	25.5
SB_Ex2	7000.0	6032.8	5955.0	0.04	0.011	3.09	0.00	3.0	3.0	28.64	1.47	144.75	214.4	142.93	3.29	23.1

ObjectID	Tc (min)	Tc (hrs)	A	L(mi)	Storage Coefficient "R" (hrs)	R/Tc
SB_P1-01	19.45	0.32	0.13	0.56	0.22	0.67
SB_P1-02	16.99	0.28	0.21	0.69	0.17	0.59
SB_P1-03	16.68	0.28	0.06	0.47	0.25	0.91
SB_P1-04	8.59	0.14	0.02	0.42	0.20	1.36
SB_P2-01	18.54	0.31	0.02	0.63	0.63	2.04
SB_P2-02	11.54	0.19	0.02	0.19	0.14	0.74
SB_P2-03	25.19	0.42	0.02	0.30	0.48	1.15
SB_P2-04	10.90	0.18	0.02	0.19	0.14	0.75
SB_P2-05	14.77	0.25	0.02	0.58	0.46	1.86
SB_P2-06	6.18	0.10	0.02	0.17	0.06	0.63
SB_SP4-01	37.93	0.63	0.06	0.96	1.03	1.63
SB_SP4-02	21.70	0.36	0.03	0.46	0.50	1.38
SB_SP4-03	15.22	0.25	0.01	0.16	0.30	1.20
SB_SP4-04	20.52	0.34	0.02	0.46	0.55	1.62
SB_SP4-05	36.97	0.62	0.06	0.90	1.02	1.66
SB_Ex2	41.74	0.70	0.31	1.55	0.68	0.98

Existing Conditions - Clark UH Parameters, Tc and R by FHWA

ObjectID	**Tc (HRS)**	**R (HRS)**	1/100-Year Storm Assumed
Ex-SB2	**0.743**	**0.664**	

ObjectID	*SF Length (ft)*	*High Elevation (ft)*	*Low Elevation (ft)*	*SF Roughness Factor "n"*	*SF Slope (ft/ft)*	*Max Sheet Flow Length (ft)*	*Guess Intensity (in/hr)*	Select Design Storm	*Avg. Effective Rainfall Depth (in)*	*New Intensity (in/hr)*	*Iterate to 0*	*Intensity (ft/s)*	*$Tt_{(i*Tt)}$ (s)*	*SF Tt (min)*
Ex-SB2	141	6248.8	6244.1	0.100	0.03	182.01	6.6	100yr 24hr	5	6.6	0.00	1.5E-04	427	7.1

ObjectID	*SCF Length (ft)*	*High Elevation (ft)*	*Low Elevation (ft)*	*k value*	*SCF Slope (ft/ft)*	*Velocity (ft/s)*	*Tt (min)*	*Tt if V=1.0 ft/s (min)*	*Tt (min)*
Ex-SB2	1400.9	6244.1	6178.6	0.305	0.047	2.18	10.73	23.35	10.73

ObjectID	*CF Length (ft)*	*High Elevation (ft)*	*Low Elevation (ft)*	*Channel Roughness Factor "n"*	*Channel Slope (ft/ft)*	*Guess Flow Depth (ft)*	*Channel Bottom Width "B" (ft)*	*xH:1V-1*	*xH:1V-2*	*Flow Area "A" (ft2)*	*Channel Hydraulic Radius "Rh" (ft)*	*Calculated Discharge (cfs)*	Modeled Discharge	*Modeled Discharge (cfs)*	*Iterate to 0*	*Tt (min)*
Ex-SB2	8426.5	6178.6	5960.0	0.04	0.026	1.84	0.00	2.0	2.0	6.77	0.82	35.55	35.5	35.49	0.06	26.7

ObjectID	*Tc (min)*	*Tc (hrs)*	*A*	*L(mi)*	*Storage Coefficient "R" (hrs)*	*R/Tc*
Ex-SB2	44.58	0.74	0.49	1.89	0.66	0.89

Muskingum-Cunge Flow Routing

Reach	High Elevation (ft)	Low Elevation (ft)	Length (ft)	Slope (ft/ft)	Manning's n	Shape	Side Slope
EX-R1 (Arroyo del Valle)	6024	5960	7410	0.00864	0.04	Triangle	2
EX-R2 (Arroyo del Valle)	5960	5951.9	1492	0.00543	0.04	Triangle	2

ATTACHMENT D

HEC-HMS Model Results

HEC-HMS Model Results

Existing Conditions								
	1/100-Year Event		1/10-Year Event		1/5-Year Event		1/2-Year Event	
Hydrologic Element	Peak Discharge (cfs)	Volume (ac-ft)	Peak Discharge (cfs)	Volume (ac-ft)	Peak Discharge (cfs)	Volume (ac-ft)	Peak Discharge (cfs)	Volume (ac-ft)
Ex-SB1	4067	1627	1820	728	1206	482	412	165
Ex-J-SB1	4067	1627	1819	728	1206	483	412	165
Ex-R1 (Arroyo del Valle)	4065	1629	1822	735	1206	483	412	165
Ex-SB2	32	3	1821	739	1205	484	412	165
Ex-J-SB2	4065	1631	12	1	0	0	0	0
Ex-SB3	364	45	1819	728	1206	483	412	165
Ex-J-SB3	4082	1677	1821	735	1205	483	412	165
Ex-R2 (Arroyo del Valle)	4081	1677	1820	728	1206	482	412	165
Ex-SB4	155	12	0	0	0	0	0	0
Ex-Outlet	4081	1688	55	7	0	0	0	0
Ex-SB5	157	10	45	3	18	1	0	0
Ex-Pit1	157	10	12	1	0	0	0	0

Proposed Conditions		
	1/100-Year Event	
Hydrologic Element	Peak Discharge (cfs)	Volume (ac-ft)
Ex-J-SB1	4080	1632
Ex-J-SB2	4081	1654
Ex-J-SB3	4105	1743
Ex-Outlet	4102	1755
Ex-Pit1	172	12
Ex-R1 (Arroyo del Valle)	4077	1634
Ex-R2 (Arroyo del Valle)	4102	1743
Ex-SB1	4080	1632
Ex-SB2	214	20
Ex-SB3	409	51
Ex-SB4	154	12
Ex-SB5	172	12
J-P1_Div-01	83	3
J-P1_Div-02	321	11
J-P1_Div-03	424	15
J-P2_Ch-01	136	7
J-P2_Ch-02	203	10
J-P2_Ch-03	214	11
J-P2_Div-01	48	3
J-P2_Div-02	135	6
J-SP4_DD1	13	1
J-SP4_DD2	31	2
J-SP4_DD3	61	4
J-SP4_DD4	87	8
J-SP4_DD5	122	13
SB_P1-01	83	3
SB_P1-02	246	8
SB_P1-03	66	3
SB_P1-04	40	2
SB_P2-01	48	3
SB_P2-02	95	3
SB_P2-03	2	0
SB_P2-04	6	0
SB_P2-05	63	4
SB_P2-06	21	1
SB_SP4-01	39	5
SB_SP4-02	31	2
SB_SP4-03	13	1
SB_SP4-04	18	1
SB_SP4-05	35	4