Whetstone Associates

Technical Memorandum

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Date:	January 15, 2020	
Subject:	Runoff Modeling, Parkdale Quarry Project	

Potential impacts to surface water flow rates in Currant Creek and Tallahassee Creek resulting from proposed mining at the Parkdale Quarry Project were evaluated using the Natural Resources Conservation Service (NRCS) TR-55 method and HydroCAD® modeling software. The models estimate the surface water runoff from the proposed quarry expansion area (Sale Area) under existing conditions, which are then compared to the potential runoff after mining and reclamation.

1. SITE DESCRIPTION

1.1 Surface Water Flow

The Sale Area is located on the flank of Cactus Mountain and drains southwest toward Currant Creek and Tallahassee Creek. All drainages within the proposed pit disturbance are intermittent or ephemeral and flow for limited periods during most years in response to direct precipitation and snowmelt.

The proposed mining operation would remove vegetation and overburden soils to expose the granite deposit. Granite would be blasted, excavated, and hauled to an existing onsite processing facility. Final reclamation of the Sale Area would create a landscape that substantially mimics the landscape in Webster Park, south of and bordering the Sale Area. After mining is complete, the topography of the quarry would generally slope in the same direction and drainage channels would be excavated into the quarry floor to maintain the current general patterns of runoff. The drainage channels would be constructed with a channel profile and sinuosity similar to that of natural drainages in Webster Park that feed into the south side of the Arkansas River.

1.2 Precipitation

Lower areas of the watershed receive about 13 inches of annual precipitation and higher elevation areas receive about 19 inches, with most of the rainfall events occurring in July and August. The average precipitation at the site is about 17 inches annually (BLM 2017) with recharge to groundwater being estimated to be about 0.16 inches per year (ERM 2019).

The precipitation frequency (magnitude and recurrence interval) of storms for the site are shown in Table 1. The rainfall intensity for 24-hour storms with 2-year to 100-year recurrence intervals were interpolated from the online NOAA Atlas 14, Vol. 8, version 2 (NOAA 2020, **Error! Reference source not found.**), for the purpose of runoff calculations.

Table 1. Design Storm Parameters

Recurrence Interval	Duration (Hours)	Storm Magnitude NOAA Atlas (inches)
100-year	24	4.35
50-year	24	3.73
25-year	24	3.17
10-year	24	2.52
5-year	24	2.12
2-year	24	1.69

Rainfall is assumed to follow the 24-hr Type II rainfall-time distribution curve which is applicable to this area of the United States (USDC, 1973).

1.3 Hydrologic Characteristics of Local Soils

The dominant soils in the Sales Area are Ustic Torriorthents, which are shown as soil type 120 in Figure 1. Additionally, the southern third of the drainages are mapped as the Roygorge very gravelly sandy clay loam, shown as soil type 98 in Figure 1 and Table 2. Soils in the lower reaches of the drainages, just north of Tallahassee Creek, are mapped as Shanta loam (104), Kim loam (50), Louviers-Travessilla complex (64), Otero fine sandy loam (81), and Riverwash (92) (**Error! Reference source not found.**).

The Ustic Torriorthents and Roygorge gravelly sandy clay loam occupy the majority of the area and are mapped as Hydrologic Soil Group D. Much smaller areas are mapped as Hydrologic Group A and Group B. These soil groups are defined by the NRCS (2007) as:

> ***Group A.*** *Soils having a low runoff potential (high infiltration rate) when thoroughly wet. Water is transmitted freely through the soil.*
>
> ***Group B.*** *Soils having a moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures.*
>
> ***Group C.*** *Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.*
>
> ***Group D.*** *Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. Water movement through the soil is restricted or very restricted. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.*

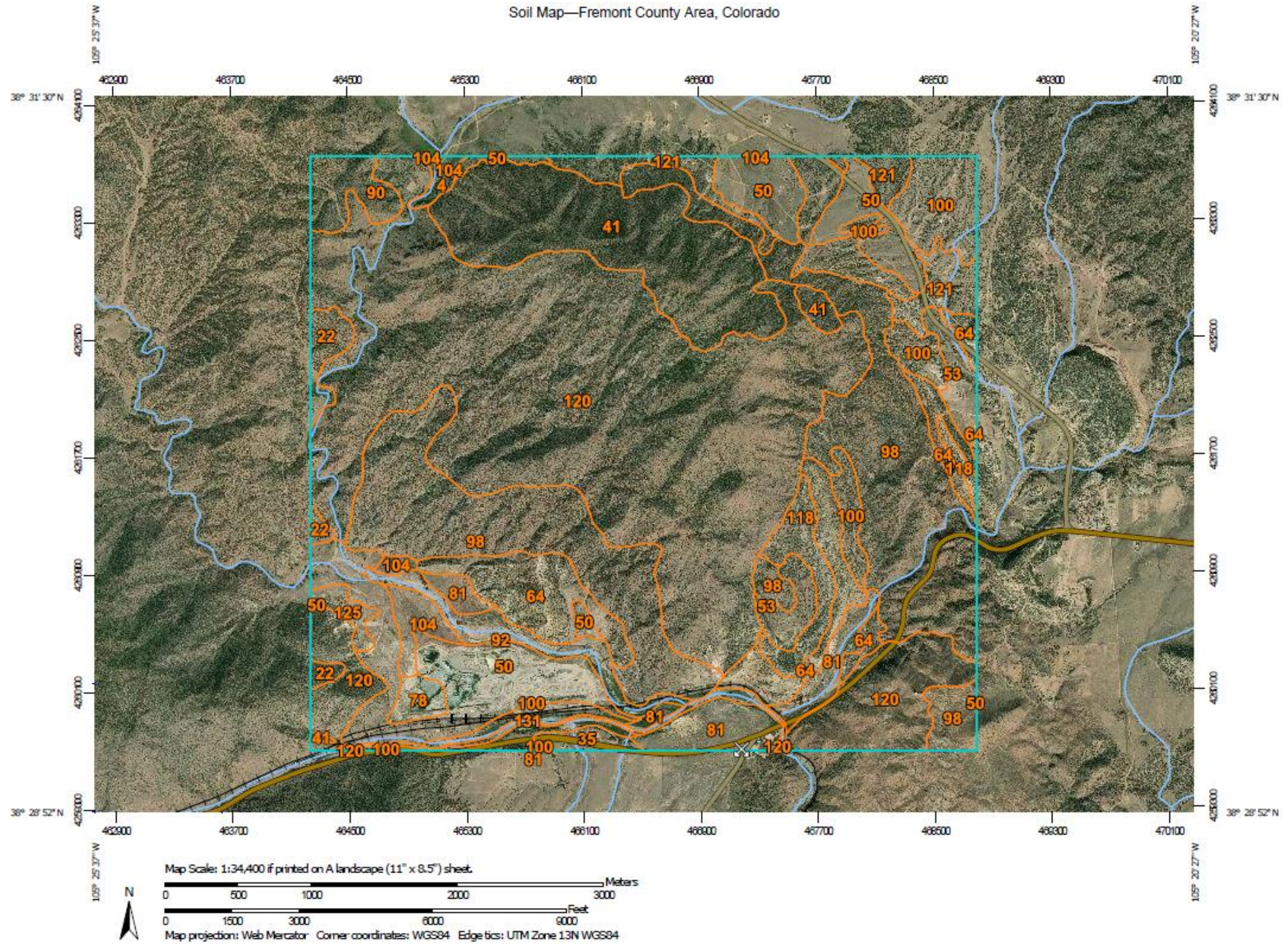


Figure 1. Soil Map

Table 2. Soils Types in Vicinity of the Sales Area

Map Unit Symbol	Map Unit Name	Acres in AOI	Hydrologic Group
50	Kim loam, cool, 3 to 8 percent slopes	377.8	B
64	Louviers-Travessilla complex, 20 to 50 percent slopes	252.2	D
81	Otero fine sandy loam, 3 to 8 percent slopes	132.2	A
92	Riverwash	71.9	n/a
98	Roygorge very gravelly sandy clay loam, 25 to 50 percent slopes	849.9	D
104	Shanta loam, 0 to 3 percent slopes	45.4	B
120	Ustic Torriorthents, bouldery-Rock outcrop complex, 35 to 90 percent slopes	1,712.70	D

The runoff curve numbers for the model were selected based on soil type, land use, and vegetative cover. A curve number of 75 was applied for pinyon-juniper with grass understory, in fair to good condition (30-70% vegetative cover) and group D soils (Table 3). A curve number of 89 was applied to areas revegetated with an herbaceous mixture of grasses, weeds, and low-lying brush in fair condition. Site curve numbers are summarized in Table 4.

Table 3. Runoff Curve Numbers for Arid and Semi-Arid Rangelands

(Table 2-2d of TR-55 [NRCS, 1986])

Cover Description (1)		Curve Numbers for Hydrologic Soil Group			
Cover Type	**Hydrologic Condition (2)**	**A**	**B**	**C**	**D**
Herbaceous-mixture of grass, weeds, and low-growing brush, with brush the minor element	Poor		80	87	93
	Fair		71	81	**89**
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory	Poor		75	85	89
	Fair		58	73	**80**
	Good		41	61	**71**
Sagebrush with grass understory	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosote bush, blackbrush, bursage, palo verde, mesquite, and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84
Gravel Road (3)		76	85	89	91

Notes:
(1) Based on average runoff condition, and Ia, = 0.2S.
(2) Poor: <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: > 70% ground cover.
(3) Source for gravel road CN is Table 2-2a of TR-55 (NRCS 1986)

Table 4. Runoff Curve Numbers for Parkdale Quarry Sales Area

Description	CN
Pinyon-juniper, grass understory, fair to good condition, Group D soils	75
Herbaceous mixture of grasses, weeds, low-lying brush, fair condition (revegetated)	89

1.4 Approach for Evaluation of Surface Water Impacts

Pre-mining and post-mining runoff rates were computed to evaluate the relative changes in surface water flow resulting from mining disturbance (changes in slope, stream lengths, and vegetation). Four drainages were simulated in the pre-mining condition (Figure 2). In keeping with scope of the analysis, the pre-mining drainage areas were limited to the area from the southern confluence of the intermittent or ephemeral stream channels with Currant Creek or Tallahassee Creek to the northern boundary of proposed disturbance.

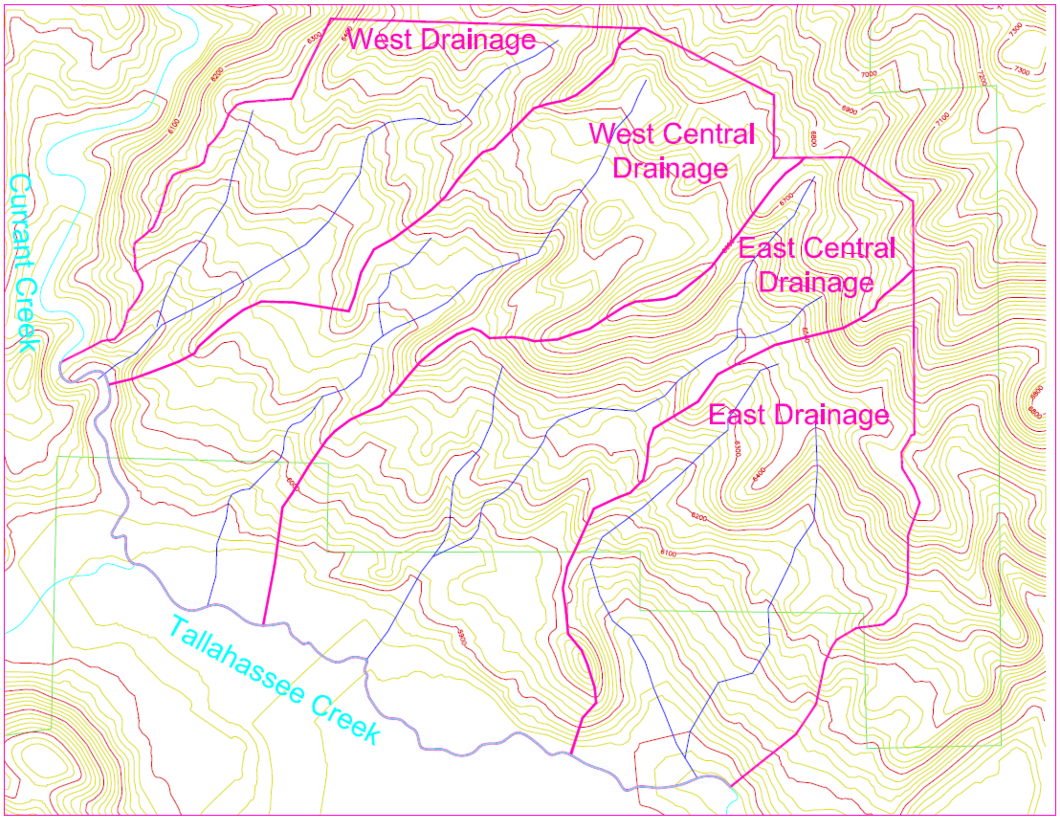


Figure 2. Pre-Mining Watersheds Evaluated

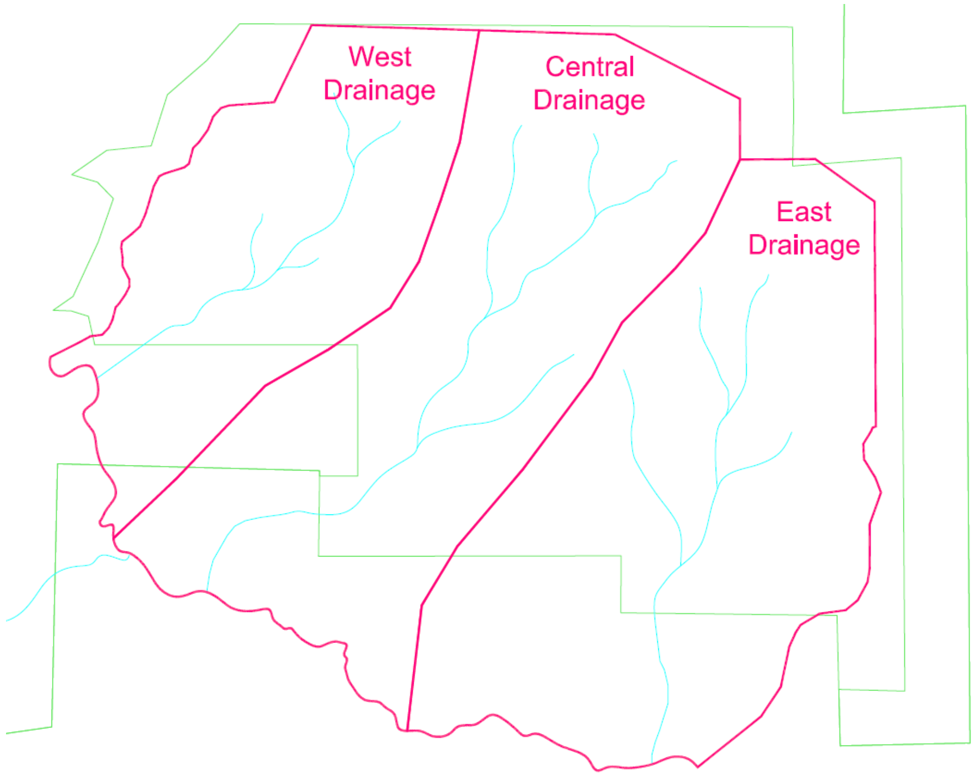


Figure 3. Post-Mining Watersheds Evaluated

2. RUNOFF MODELING

2.1 Runoff Estimation Methodology

Watershed runoff was estimated using the methods described in Technical Release 55 (TR-55), which was developed by the U. S. Department of Agriculture Natural Resources Conservation Service (NRCS, 1986). TR-55 presents simplified procedures to calculate storm runoff volume, peak rate of discharge, hydrographs, and storage volumes required for floodwater reservoirs in small watersheds.

Runoff depth (q_d) is calculated in TR-55 by the Curve Number (CN) method, using the following equation:

$$q_d = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

where: q_d = Runoff depth, inches ($q_d = 0$, if $P < 0.2S$),
P = Rainfall depth, inches
S = Potential maximum rainfall retention after runoff begins, inches

This method assumes initial abstraction (losses before runoff begins due to retention in surface depressions, interception by vegetation, evaporation, infiltration etc.) is equal to 0.2S.

The parameter S is related to curve number (CN) by:

$$S = \frac{1000}{CN} - 10$$

Site-specific curve numbers are discussed in Section 1.3.

Runoff volume (Q) is obtained from : $Q = q_d / 12 \cdot A \cdot 43{,}560$

where: Q = Runoff volume, cubic feet
q_d = Runoff depth, inches
A = Catchment area, acres

Peak discharge is calculated using Time of Concentration (T_c) which is the time it takes for runoff to travel from the most hydraulically distant point in the watershed (or sub-basin) to a point of interest. T_c is the sum of travel time for sheet flow (T_{sh}) plus the travel time for shallow concentrated overland flow (T_{sc}) plus the travel time for channel flow (T_{ch}).

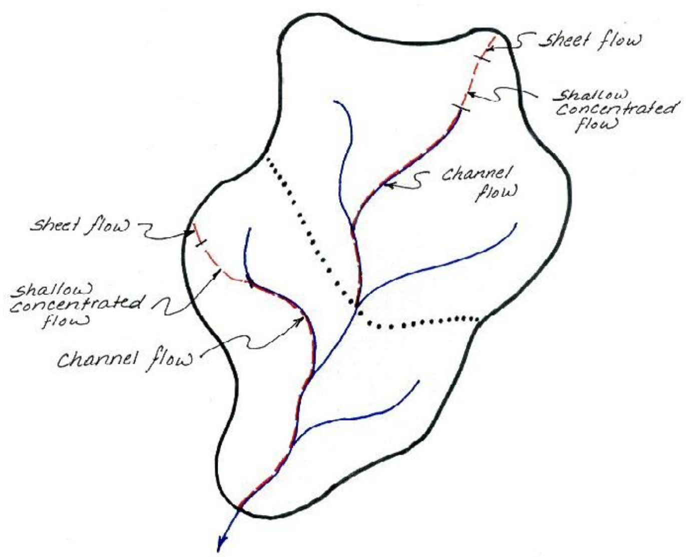


Figure 4. Location of Sheet Flow, Shallow Concentrated Flow, and Channel Flow within a Basin

Sheet flow occurs over plane surfaces in the "headwaters" or uppermost reaches of the watershed, as shown in Figure 4 above. For the pre-mining condition at the Parkdale Quarry Sales Area, sheet flow is assumed to occur in the upper 80 feet of the sub-basin. Sheet flow travel time is calculated using the simplified form of Manning's kinematic solution from Overton and Meadows (1976) which is Equation 3.3 of TR55 (NRCS, 1986):

$$T_{sh} = \frac{0.007\ (nL)^{0.8}}{P^{0.5} S^{0.4}}$$

where:

T_{sh} = sheet flow travel time (hr)
n = Manning's roughness coefficient for surface flow
L = flow length (ft)
P = 24-hour rainfall (in)
s = land slope (ft/ft)

Shallow concentrated flow has been assumed to occur from the end of sheet flow until the flow path reaches an incised intermittent stream channel. The travel time for shallow concentrated flow is calculated as:

$$T_{sc} = \frac{L}{3600 \cdot V}$$

where:

T_{sc} = shallow concentrated flow travel time (hr)
L = flow length (ft)
3600= conversion factor for seconds to hours
V = velocity on unpaved surface, interpolated from Figure 3-1 of TR-55 for land slope (ft/s) or calculated using Manning's equation:

$$V = \frac{1.49\, r^{2/3} s^{1/2}}{n}$$

where:

r = hydraulic radius = depth of flow = 0.4 ft
s = slope of the hydraulic grade line (land surface) (ft/ft)
n = Manning's n (roughness coefficient) for open channel flow = 0.05

Simplifying for unpaved conditions:

$V = 16.13\, s^{1/2}$

Channelized flow occurs in defined channels or intermittent drainages. The travel time for channelized flow is calculated using Manning's equation for channelized flow and the channel-specific geometry and hydraulic characteristics (rather than the simplifying assumptions used for shallow concentrated flow).

Shallow concentrated flow has been assumed to occur from the end of sheet flow until the flow path reaches a topographically well-defined channel. The travel time for shallow concentrated flow is calculated as:

$$T_{ch} = \frac{L}{3600 \cdot V}$$

where:

T_{ch} = channel flow travel time (hr)
L = flow length (ft)

3600= conversion factor for seconds to hours
V = velocity (ft/sec) calculated using Manning's equation for channelized flow:

$$V = \frac{1.49\, r^{2/3} s^{1/2}}{n}$$

where:

r = hydraulic radius = cross sectional area / wetted perimeter (A/Pw) (ft)
s = slope of the hydraulic grade line (channel bottom) (ft/ft)
n = Manning's n (roughness coefficient) for open channel flow (as discussed in Section 2.3.2 and Table 5)

The T_c values calculated using WinTR-55 and HydroCAD are provided in Section 2.3.3.

Runoff peak discharge is calculated from the TR-55 graphical peak discharge method. This approach graphically generates a unit peak discharge rate (Q_u) based upon the general catchment parameters of curve number (CN), initial abstraction (I_a), precipitation (P) and rainfall distribution type (type II for Colorado) and the individual catchment time of concentration (T_c). The input variables used in determining Q_u using the graphical method were determined as follows:

CN = curve number based soil type, as discussed in Section 1.3 and Table 4
I_a = initial abstraction, lookup value in Table 4-1 of TR-55 based on CN
P = Precipitation, based on design storms listed in Table 1 of this tech memo
T_c = Time of concentration, calculated as discussed above

Peak discharge (Q_p) for the catchment area is then calculated from:

$$Q_p = Q_u \cdot A_m \cdot q \cdot F_p$$

where: Q_p = Sub-basin peak discharge (cubic feet per second [cfs])
Q_u = Sub-basin unit peak discharge (cfs/mi^2/in [csm/in])
A_m = Sub-basin area (square miles)
q = Runoff (inches)
F_p = Pond and swamp adjustment factor

2.2 Computational Methods

2.2.1 NRCS WinTR-55

Peak discharge was computed using the NRCS WinTR-55 software (NRCS, 2009). WinTR-55 is a single-event rainfall-runoff, small watershed hydrologic model. The model generates hydrographs from urban, agricultural, and rural areas and at selected points along the stream system. Runoff hydrographs were generated by the model and routed downstream through channels. Multiple sub-areas were modeled within the watershed and routed to the applicable outfalls on Currant Creek and Tallahassee Creek. Although the computational methods employed in WinTR-55 are similar to the worksheet calculations in TR-55 (NRCS, 1986), WinTR-55 uses the TR-20 software engine for more accurate analysis of the hydrology of small watershed systems.

2.2.2 HydroCAD

Peak discharge for sub-basins reporting to the Stormwater Retention Pond was also computed using the HydroCAD-10 software, distributed by HydroCAD Software Solutions, LLC. HydroCAD® uses the procedures described in TR-55 and TR-20 with added features for multiple pond routing, variable pond geometry, pond pumping, exfiltration, baseflow and inflow losses (that is, inflow to and exfiltration from reaches), and an increased number of "nodes" (reaches, sub-basin, and ponds) over the limited number available in WinTR-55. The runoff results computed by HydroCAD are essentially identical to those from the NRCS WinTR-55 software, but additional graphing capability, volumetric calculations, and reporting are available in HydroCAD.

2.3 Model Input

2.3.1 Watershed Delineation

The model area was delineated into four catchments for the pre-mining simulation (Figure 2, Figure 5). These watersheds extended from the confluence with Currant Creek or Tallahassee Creek to the northern boundary of proposed disturbance, and totaled 1,040 acres. For the post-mining simulation, the total watershed area was kept constant with the pre-mining simulation (1,040 acres), but was subdivided into three catchments reflecting the proposed constructed stream channels in the mine reclamation plan (Figure 3, Figure 6).

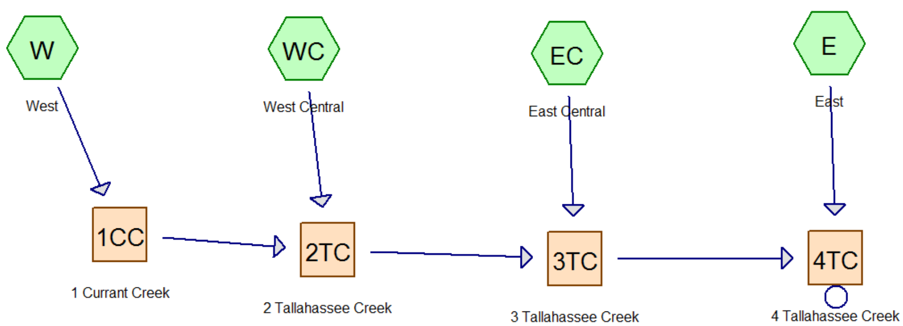


Figure 5. HydroCAD Node Routing, Pre-Mining

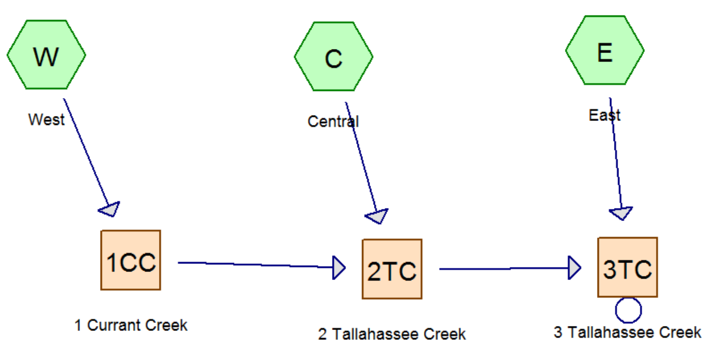


Figure 6. HydroCAD Node Routing, Post-Mining

2.3.2 Manning's n

The value of Manning's n selected for each channel affects channel velocity, conveyance capacity, and peak flows. The most important factors that affect the selection of channel n values are:

1. Type and size of the materials that compose the bed and banks of the channel; and
2. Shape of the channel.

Cowan (1956) developed a procedure for estimating the effects of these factors to determine the value of n for a channel. The value of n may be computed by:

$$n = (n_b + n_1 + n_2 + n_3 + n_4) \cdot m$$

where :

n_b = a base value of n for a straight, uniform, smooth channel in natural materials
n_1 = a correction factor for the effect of surface irregularities
n_2 = a value for variations in shape and size of the channel cross section,
n_3 = a value for obstructions
n_4 = a value for vegetation and flow conditions
m= a correction factor for meandering of the channel

Table 5. Manning's "n" Values Used in Cowan's Method for Channel Roughness

Channel Condition	n Values	Natural Channels	Borrow Ditches	Engineered Channels	Short Natural Channels
Material Involved	$\mathbf{n_b}$				
Earth	0.02				0.02
Rock cut	0.025	0.022	0.022	0.022	
Fine gravel	0.024				
Coarse gravel	0.028				
Degree of Irregularity	$\mathbf{n_1}$				
Smooth	0				
Minor	0.005			0.005	
Moderate	0.01	0.01	0.01		0.01
Severe	0.02				
Variations of Channel Cross Section	$\mathbf{n_2}$				
Gradual	0				
Alternating occasionally	0.005		0.005	0.005	0.005
Alternating frequently	0.010-0.015	0.01			
Relative Effect of Obstructions	$\mathbf{n_3}$				
Negligible	0				
Minor	0.010-0.015		0.01	0.01	0.01
Appreciable	0.020-0.030	0.02			
Severe	0.040-0.060				
Vegetation	$\mathbf{n_4}$				
Low	0.005-0.010	0.005	0.005	0.005	0.005
Medium	0.010-0.025				
High	0.025-0.050				
Very high	0.050-0.100				
Degree of Meandering	**m**				
Minor	1	1	1	1	1
Appreciable	1.15				
Severe	1.3				
Calculated Manning's n value		0.067	0.052	0.047	0.05

A Manning's n value of 0.067 was used for natural channels in the pre-mining simulation and for reconstructed channels in the post-mining simulation. These values affect the Time of Concentration (Section 2.3.3) and therefore the timing of peak flows, but do not affect the total volumetric runoff predicted by the model.

2.3.3 Time of Concentration

As described in Section 2.1, Time of Concentration (T_c) is the time it takes for runoff to travel from the most hydraulically distant point in the watershed to the discharge outlet (or other point of interest). Tc values computed for the modeled basins are shown in Table 6 and Table 7.

The area-weighted average Tc (Table 8) was 24% higher in the post-mining scenario, due the lower slopes and longer channel lengths in the reconstructed channels. The higher Tc helps to delay the arrival of peak flows from the watershed into the creek.

Table 6. Watershed Channel Length, Slope, and Time of Concentration (Pre-Mining)

Sub-Basin West (Pre-Mining)

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.8	80	0.4878	0.48		**Sheet Flow, Sheet Flow** Range n= 0.130 P2= 1.69"
0.6	375	0.3733	9.84		**Shallow Concentrated Flow, Concentrated** Unpaved Kv= 16.1 fps
32.7	5,880	0.0722	3.00	4.50	**Channel Flow, Intermittent Channel West** Area= 1.5 sf Perim= 4.2' r= 0.36' n= 0.067
36.1	6,335	Total			

Sub-Basin West Central (Pre-Mining)

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.0	80	0.4167	0.45		**Sheet Flow, Sheet Flow** Range n= 0.130 P2= 1.69"
0.5	300	0.4667	11.00		**Shallow Concentrated Flow, Concentrated Flow** Unpaved Kv= 16.1 fps
32.4	7,117	0.1075	3.66	5.49	**Channel Flow, Channel West Central** Area= 1.5 sf Perim= 4.2' r= 0.36' n= 0.067
35.9	7,497	Total			

Sub-Basin East Central (Pre-Mining)

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.1	80	0.3750	0.43		**Sheet Flow, Sheet Flow** Range n= 0.130 P2= 1.69"
0.5	325	0.4923	11.30		**Shallow Concentrated Flow, Concentrated Flow** Unpaved Kv= 16.1 fps
28.6	6,890	0.1292	4.01	6.02	**Channel Flow, Channel Flow** Area= 1.5 sf Perim= 4.2' r= 0.36' n= 0.067
32.2	7,295	Total			

Sub-Basin East (Pre-Mining)

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.6	80	0.5634	0.50		**Sheet Flow, Sheet Flow** Range n= 0.130 P2= 1.69"
1.2	730	0.4110	10.32		**Shallow Concentrated Flow, Concentrated** Unpaved Kv= 16.1 fps
21.2	5,115	0.1300	4.03	6.04	**Channel Flow, East Channel** Area= 1.5 sf Perim= 4.2' r= 0.36' n= 0.067
25.0	5,925	Total			

Table 7. Watershed Channel Length, Slope, and Time of Concentration (Post-Mining)

Sub-Basin West (Post-Mining)

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.2	40	0.5300	3.09		**Sheet Flow, Sheet Flow** Smooth surfaces n= 0.011 P2= 1.69"
0.9	650	0.5300	11.72		**Shallow Concentrated Flow, Concentrated** Unpaved Kv= 16.1 fps
13.5	3,560	0.0183	4.40	6.60	**Channel Flow, Reclaimed Channel West** Area= 1.5 sf Perim= 4.2' r= 0.36' n= 0.023 Earth, clean & winding
4.2	770	0.0779	3.07	4.60	**Channel Flow, Outside pit channel** Area= 1.5 sf Perim= 4.3' r= 0.35' n= 0.067
18.8	5,020	Total			

Sub-Basin Central (Post-Mining)

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.2	40	0.5300	3.09		**Sheet Flow, Sheet Flow** Smooth surfaces n= 0.011 P2= 1.69"
1.1	775	0.5300	11.72		**Shallow Concentrated Flow, Concentrated Flow** Unpaved Kv= 16.1 fps
61.0	5,310	0.0169	1.45	2.18	**Channel Flow, Reclaimed channel Central** Area= 1.5 sf Perim= 4.2' r= 0.36' n= 0.067
7.7	1,520	0.0888	3.28	4.91	**Channel Flow, Channel outside pit Central** Area= 1.5 sf Perim= 4.3' r= 0.35' n= 0.067
70.0	7,645	Total			

Sub-Basin East (Post-Mining)

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.6	40	0.5300	0.43		**Sheet Flow, Sheet Flow** Range n= 0.130 P2= 1.69"
1.0	708	0.5300	11.72		**Shallow Concentrated Flow, Concentrated** Unpaved Kv= 16.1 fps
14.0	3,820	0.0196	4.55	6.83	**Channel Flow, Reclaimed Channel within Pit East** Area= 1.5 sf Perim= 4.2' r= 0.36' n= 0.023 Earth, clean & winding
5.4	1,490	0.1711	4.62	6.93	**Channel Flow, Channel outside pit - East** Area= 1.5 sf Perim= 4.2' r= 0.36' n= 0.067
22.0	6,058	Total			

Table 8. Area-Weighted Average Time of Concentration

Watershed Catchment	Phase	Tc (hydroCAD) (min)	SubBasin Area (acres)	Weighted Average Tc (min)
West	Pre-mining	36.1	180	
West Central	Pre-mining	35.9	290	
East Central	Pre-mining	32.2	320	
East	Pre-mining	25.00	250	32.2
West-Reclaimed	Post-mining	18.8	235	
Central-Reclaimed	Post-mining	70.0	400	
East-Reclaimed	Post-mining	22.0	405	39.7

3. MODEL RESULTS

3.1 Results

Model results are provided in **Error! Reference source not found.**. Runoff hydrographs for the 100-year storm are shown in Figure 7 and Figure 8. The cumulative peak flows for the 100-year storm after reclamation (2,750 cfs) are 67% higher than before mining (1,650 cfs). Cumulative peak flows for the more frequent recurrence interval storms (2-yr, 5-yr, 10-yr, 25-yr, and 50-yr) are similarly higher in the post-mining model than in the pre-mining model. This implies that the mining project would result in higher flow rates in the intermittent drainages reporting to Currant Creek and Tallahassee Creek after major storm events.

The timing of peak flows is similar in the post-mining and pre-mining scenarios, with post-mining catchments West and East peaking earlier (12.10 – 12.15 hrs) than the pre-mining peaks (12.20 – 12.35 hrs) and the post-mining catchment Central peaking later (12.70 hrs). Runoff hydrographs for all storm events modeled are provided in **Error! Reference source not found.**.

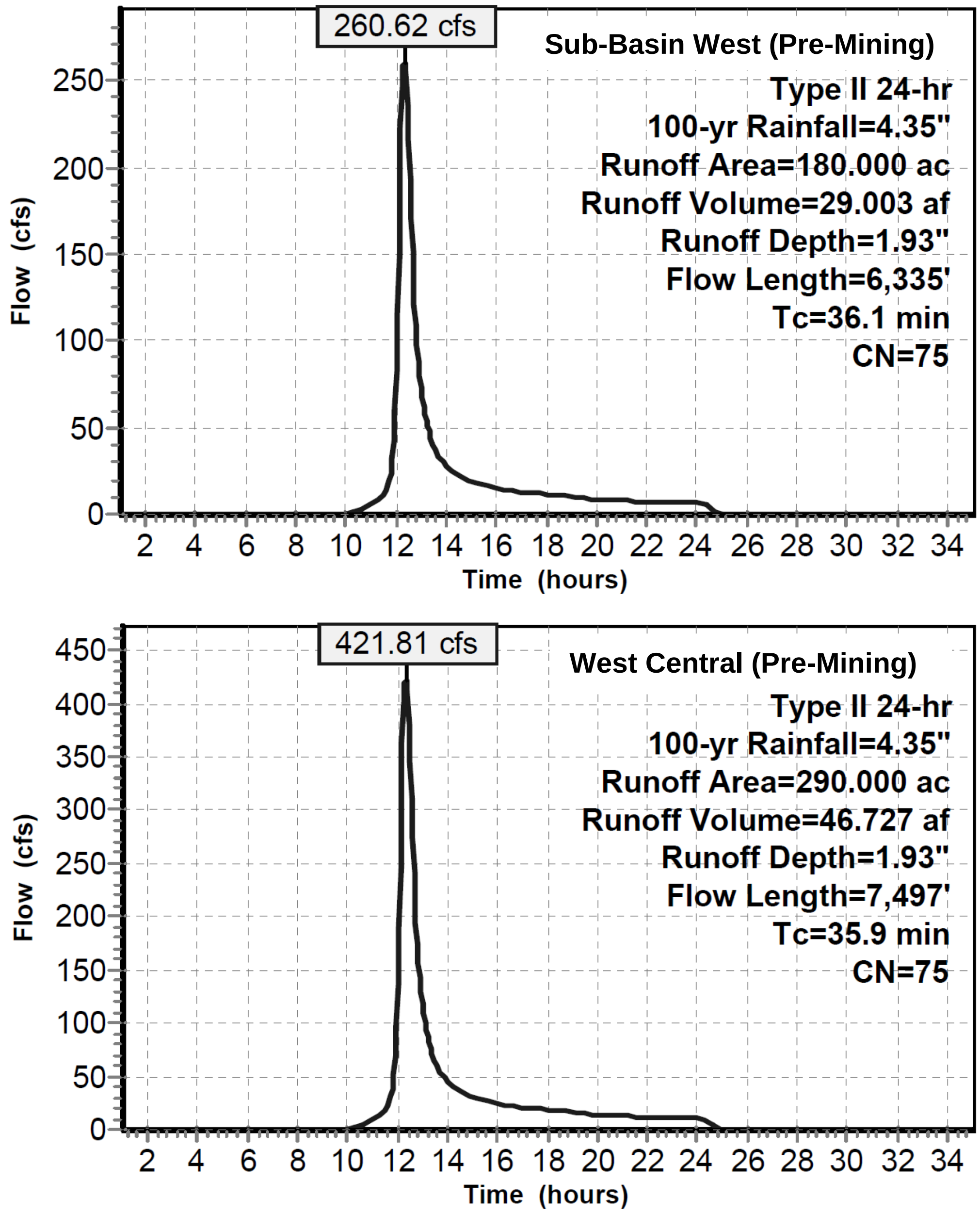
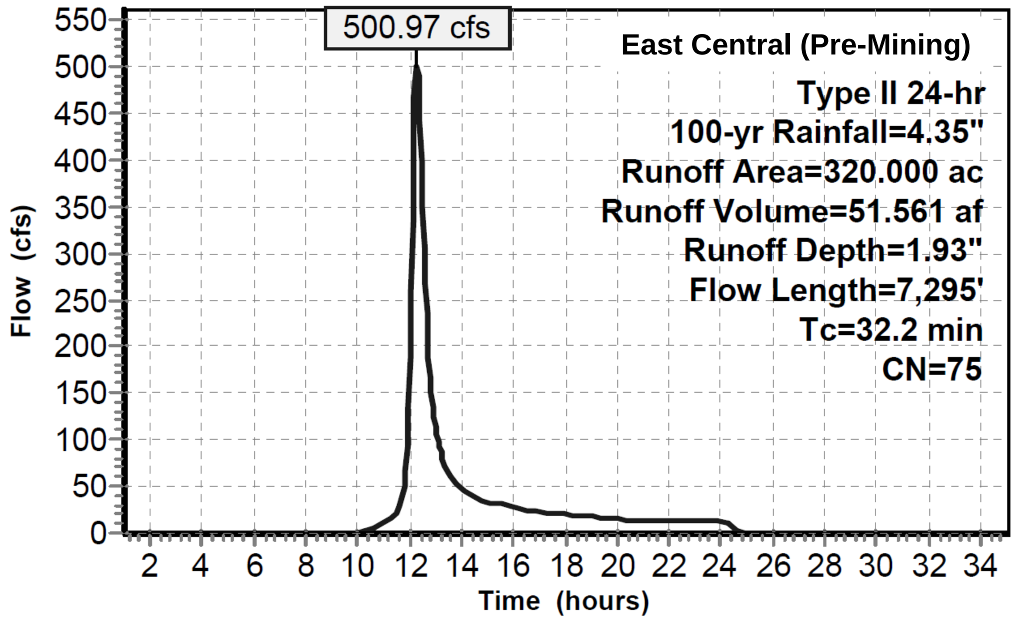


Figure 7. Runoff Hydrographs for 100-Year Storm Event (Pre-Mining)



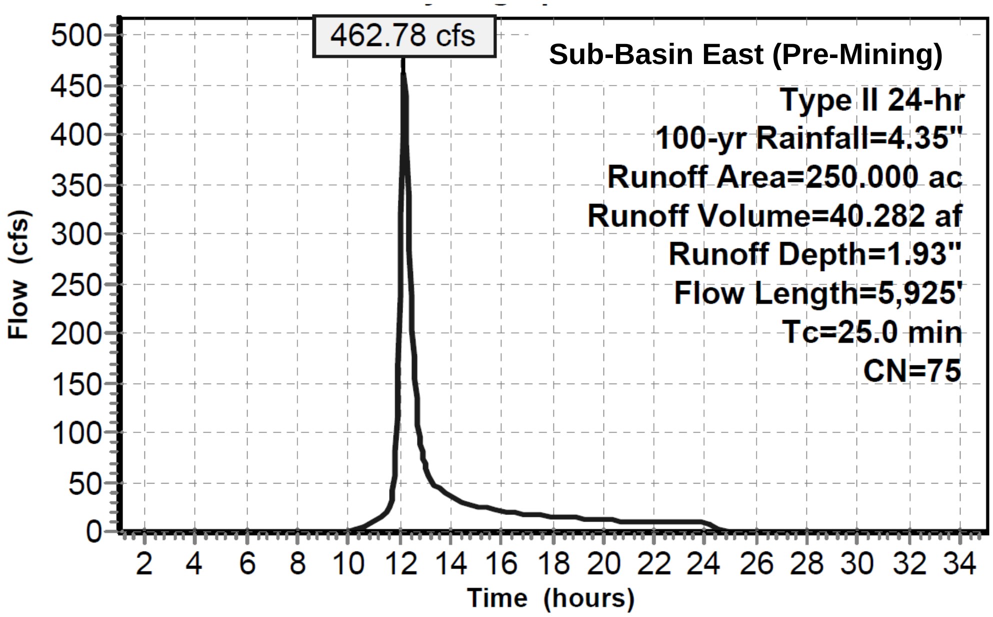
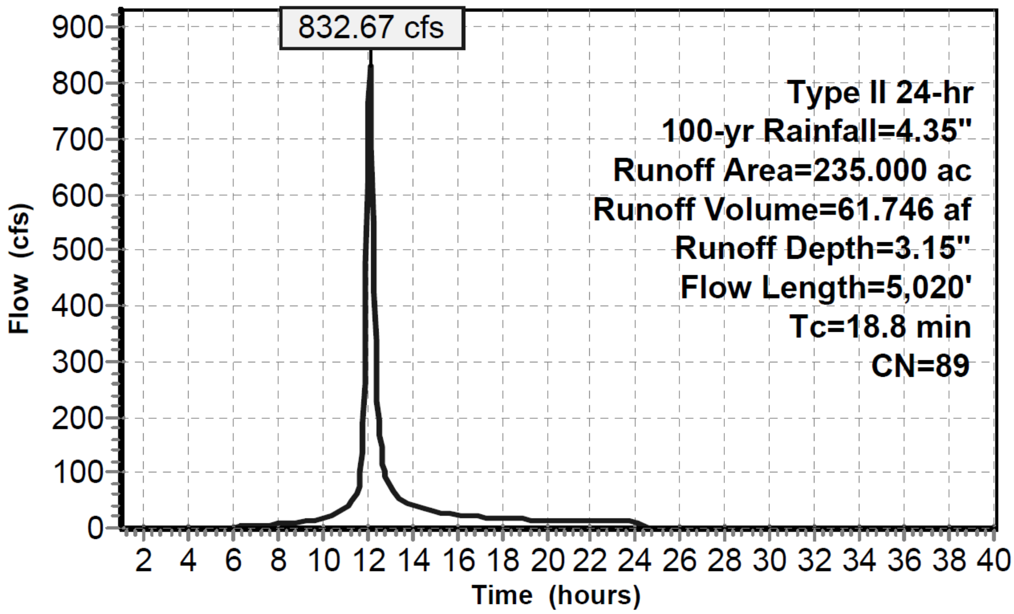


Figure 7. Runoff Hydrographs for 100-Year Storm Event (Pre-Mining) (Part 2)



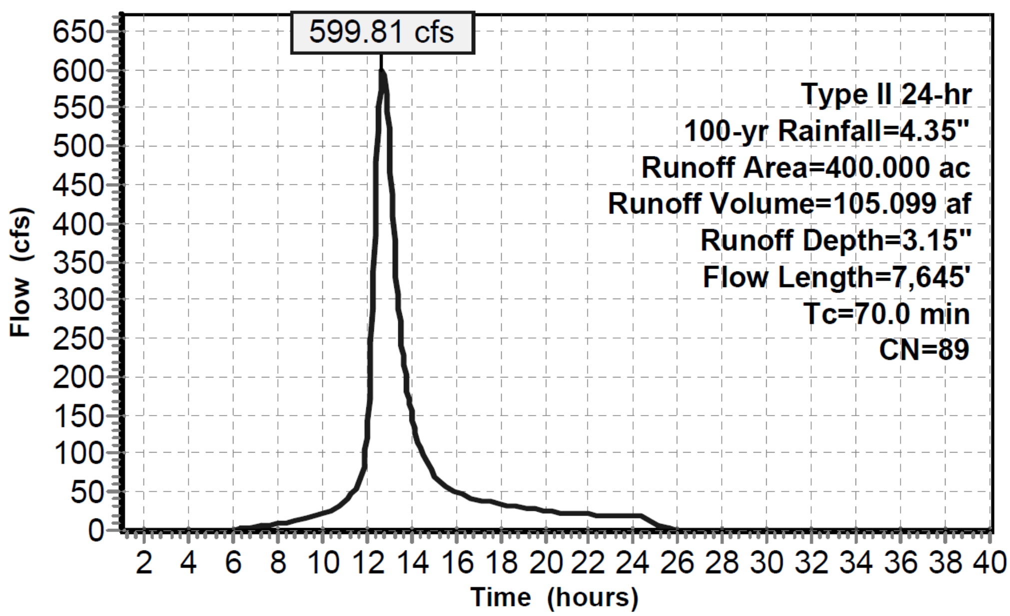


Figure 8. Runoff Hydrographs for 100-Year Storm Event (Post-Mining)

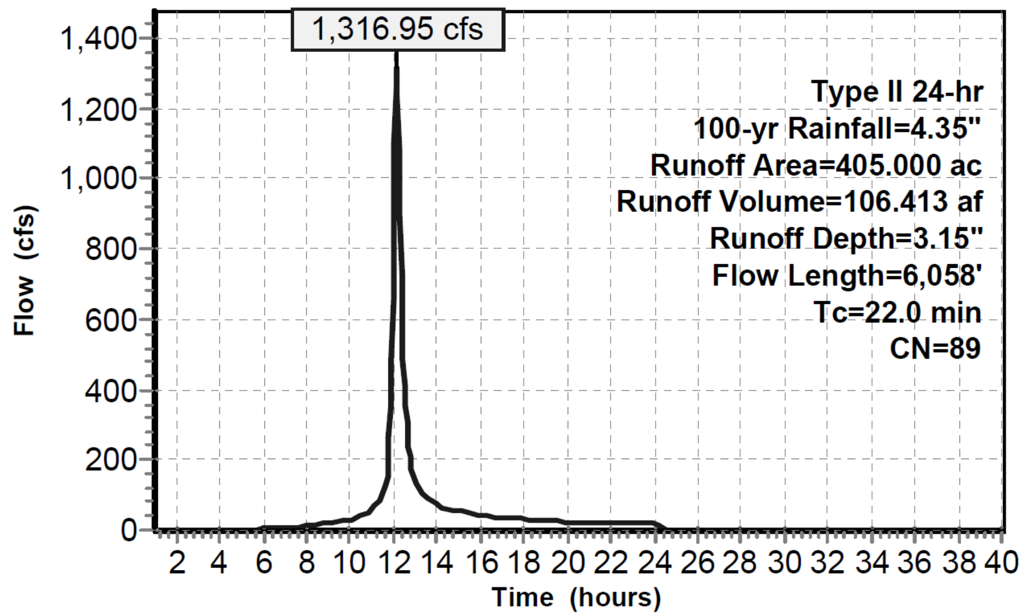


Figure 8. Runoff Hydrographs for 100-Year Storm Event (Post-Mining) (Part 2)

The total volume of runoff from major storms would increase as a result of mining and reclamation. The model results (**Error! Reference source not found.**) indicates that the volume of runoff reporting to the creeks would increase by 160% for the 100-year precipitation event and by 220% for the 10-year precipitation event (Table 9). The increased runoff is primarily due to the change in vegetation after reclamation.

Increased runoff could consequently decrease evapotranspiration and infiltration of precipitation and snowmelt to groundwater. Decreased infiltration to groundwater is expected to result in decreased baseflows to the creeks, which would be partially offset by increased streamflows during major storm events.

Table 9. Relative Comparison Pre-Mining and Post-Mining Runoff Volumes

Watershed Drainage	Phase	Runoff Volume (acre-ft) P2yr-24hr	Runoff Volume (acre-ft) P5yr-24hr	Runoff Volume (acre-ft) P10yr-24hr	Runoff Volume (acre-ft) P25yr-24hr	Runoff Volume (acre-ft) P50yr-24hr	Runoff Volume (acre-ft) P100yr-24hr
West	Pre-mining	3.6	6.6	9.9	16.1	22.0	29.0
West Central	Pre-mining	5.8	10.7	16.0	25.9	35.5	46.7
East Central	Pre-mining	6.4	11.8	17.7	28.6	39.1	51.6
East	Pre-mining	5.0	9.2	13.8	22.4	30.6	40.3
West-Reclaimed	Post-mining	15.2	22.1	28.8	40.2	50.3	61.7
Central-Reclaimed	Post-mining	25.9	37.6	49.1	68.5	85.7	105.1
East-Reclaimed	Post-mining	26.2	38.1	49.7	69.3	86.8	106.4
Total Pre	Pre-mining	20.8	38.2	57.4	93.1	127.1	167.6
Total Post	Post-mining	67.4	97.8	127.6	178.0	222.8	273.3
Increase (multiplier)		3.2	2.6	2.2	1.9	1.8	1.6

The long-term average annual change in runoff volumes was calculated using the probability of occurrence for each design storm in a given year. The probability-weighted average annual runoff volume for the pre-mining condition is 31.7 acre-ft compared to 80.3 acre-ft for the post-mining condition. The annualized increase in runoff in Tallahassee Creek below the Sale Area, calculated from the probability-weighted changes in runoff for the 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, and 100-yr storms, is 0.067 cfs

Table 10. Relative Comparison of Pre-Mining and Post-Mining Annualized Average Runoff Volumes

Watershed Drainage	Phase	Annualized Runoff (acre-ft/yr)	Outlet	% Change
West	Pre-mining	5.5	Currant Creek	
West Central	Pre-mining	8.9	Tallahassee Ck	
East Central	Pre-mining	9.8	Tallahassee Ck	
East	Pre-mining	7.6	Tallahassee Ck	
West-Reclaimed	Post-mining	18.1	Currant Creek	330%
Central-Reclaimed	Post-mining	30.9	Tallahassee Ck	
East-Reclaimed	Post-mining	31.3	Tallahassee Ck	237%
Total Pre	Pre-mining	31.7		
Total Post	Post-mining	80.3	Total	253%

3.2 Comparison to Tallahassee Creek-Currant Creek Watershed Runoff

The runoff results for the Sale Area were compared to the runoff from the regional watershed to determine the magnitude of change as a percentage of regional flows. The portion of the Sale Area modeled is 1,040 acres, or approximately 1.37% of the 108.3 square miles in the Tallahassee Creek-Currant Creek watershed (HUC 1102000111) (Table 11).

Table 11. Hydrologic Units in the Arkansas River Headwaters

4th Level Sub-Basin (HUC 8)	5th Level Watershed (HUC 10)	6th Level Sub-Watershed (HUC 12)	Sq. Mile
Arkansas Headwaters (11020001)	**Tallahassee Creek-Currant Creek (1102000111)**	Lower Cottonwood Creek (110200011108)	32.8
		Lower Currant Creek (110200011109)	35.3
		Tallahassee Creek (110200011110)	50.2
	Royal Gorge-Arkansas River (1102000114)	Five Point Gulch-Arkansas River (110200011407)	47.4
		Royal Gorge (110200011409)	26.0

3.3 Model Sensitivity

The runoff volumes predicted by the model are most sensitive to precipitation and runoff curve numbers. The curve numbers used in the model are the best engineering estimates of pre-mining and reclaimed conditions. If mine reclamation were to more nearly mimic the pre-mining condition, with respect to soils and vegetation, the post-mining runoff would more nearly resemble the pre-mining conditions.

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