Appendix F.2

Surface Water Hydrology Design

SWC
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CALCULATION TITLE PAGE

CLIENT Cripple Creek & Victor Gold Company	JOB NO. 1125	TASK NO. A100	PAGE 1 OF 2
PROJECT Arequa VLF	CALCULATION No. 1	REV. No. 1	
SUBJECT/ TITLE Triangular Diversion Channel Design			

REV. NO.	PREPARER/ DATE	REVIEWER/ DATE	QA REVIEWER/ DATE	CONFIRMATION REQUIRED (Y/N)
1	Amanda L. Dolezal 2/8/08	Derek T. Wittwer 2/8/08	[illegible signature] 2/8/08	

CALCULATION OBJECTIVE

Design a surface water diversion channel to keep runoff from flowing onto the South end of the leach pad.

CALCULATION METHODOLOGY/ LIST of ASSUMPTIONS

- The size of the surface water diversion channel is based on a 100 year 24 hour Type II storm.
- The watershed to the South impacting the leach pad consists of undisturbed ground, curve number (CN) = 71.

REFERENCES

CONCLUSIONS

- A triangular diversion channel with the following dimensions can handle the expected runoff:
- Total depth = 2 feet
- Sides slopes = 2H:1V
- Area = 8 ft^2
- Wetted Perimeter = 8.94 ft

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PROJECT: Arequa VLF	JOB NO: 1125	SHEET 2 OF 2
FEATURE: Triangular Diverion Channel	BY: ALD	DATE: 2/8/08
DETAILS: Channel Sizing	CHKD BY: DTW	DATE: 2/8/08

- Criteria: 1) Size of surface water diversion channel is based on precipitation equal to a 100 year 24 hour Type II storm event.

- Analysis:

Total Area of Watershed = 586,434 ft^2 = 0.0210 mi^2 = 13.46 acres
CN = 71

Sheet Flow = 300 feet
Average Sheet Slope = 37%

Shallow Flow = 204 feet
Average Shallow Slope = 47%

Channel Flow = 926 feet
Average Channel Slope = 25%

Peak Flow = 29.3 cfs
Precipitation Volume = 1.61 inches = 0.13 feet

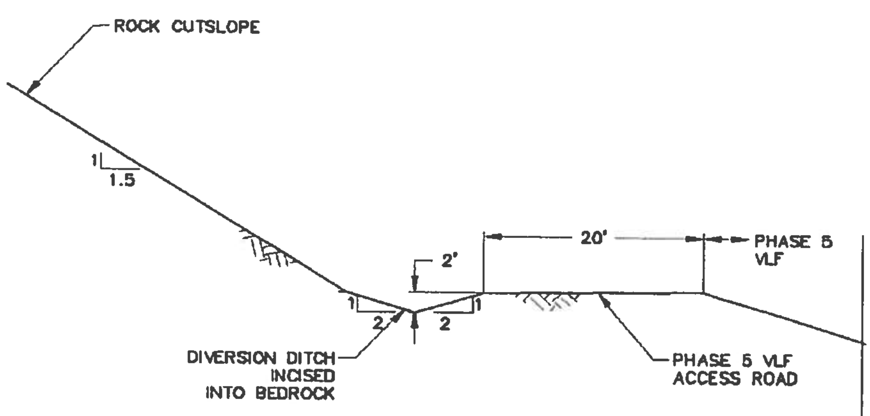
Total volume from storm = precipitation volume * total are of watershed

= 0.13 ft * 586,434 ft^2 = 76,236 ft^3 = 570,288 gallons

A triangular diversion channel with the following dimensions can handle the expected runoff.

Triangular diversion channel dimensions:

Total depth = 2 feet
Sides slopes = 2H:1V
Area = 8ft^2
Wetted Perimeter = 8.94 ft



Triangular Diversion Trench

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.25000	ft/ft
Normal Depth	2.00	ft
Left Side Slope	2.00	ft/ft (H:V)
Right Side Slope	2.00	ft/ft (H:V)

Results

Discharge	157.65	ft³/s
Flow Area	8.00	ft²
Wetted Perimeter	8.94	ft
Top Width	8.00	ft
Critical Depth	3.29	ft
Critical Slope	0.01754	ft/ft
Velocity	19.71	ft/s
Velocity Head	6.03	ft
Specific Energy	8.03	ft
Froude Number	3.47	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	2.00	ft
Critical Depth	3.29	ft
Channel Slope	0.25000	ft/ft
Critical Slope	0.01754	ft/ft

Project: CC&V Upper Watershed Simulation Run: Run 3

Start of Run: 01Jan2008, 00:00
End of Run: 02Jan2008, 00:05
Compute Time: 12Mar2008, 16:51:50

Basin Model: CC&V Upper
Meteorologic Model: 100 year 24 hour storm
Control Specifications: 24 hour event

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-1	0.021	29.3	01Jan2008, 12:00	1.61

```
Basin: CC&V Upper
     Last Modified Date: 12 March 2008
     Last Modified Time: 22:51:49
     Version: 3.1.0
     Unit System: English
     Missing Flow To Zero: No
     Enable Flow Ratio: No
     Allow Blending: No
     Compute Local Flow At Junctions: No
End:

Subbasin: Subbasin-1
     Canvas X: -1675.7493188010903
     Canvas Y: 3569.482288828337
     Area: 0.021

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
     Curve Number: 71
     Initial Abstraction: 0

     Transform: SCS
     Lag: 6.29

     Baseflow: None

     Erosion: None
End:

Basin Schematic Properties:
     Last View N: 5000.0
     Last View S: -5000.0
     Last View W: -5000.0
     Last View E: 5000.0
     Maximum View N: 5000.0
     Maximum View S: -5000.0
     Maximum View W: -5000.0
     Maximum View E: 5000.0
     Extent Method: Elements
     Buffer: 0
     Draw Icons: Yes
     Draw Icon Labels: Yes
     Draw Gridlines: Yes
     Draw Flow Direction: No
End:
```

```
Meteorology: 100 year 24 hour storm
     Last Modified Date: 15 January 2008
     Last Modified Time: 23:37:23
     Version: 3.1.0
     Unit System: English
     Precipitation Method: SCS Storm
     Snowmelt Method: None
     Basin Model List: CC&V Upper
End:

Precip Method Parameters: SCS Storm
     Storm Depth: 3.5
     Storm Type: Type II
End:

Subbasin: Subbasin-1
End:
```

```
Control: 24 hour event
     Last Modified Date: 15 January 2008
     Last Modified Time: 23:37:16
     Start Date: 1 January 2008
     Start Time: 00:00
     End Date: 2 January 2008
     End Time: 00:05
     Time Interval: 1
End:
```

Cripple Creek and Victor
Arequa VLF
Lag Time Calculation Using Natural Resources Conservation Service TR-55
Small Southern Watershed

Watershed Contribution Area

Sheet Flow

Mannings n (table 3-1) =	0.15
Flow Length (ft, max 300 ft) =	300
24 hr Rainfall, P_2 (in) =	1.8
Land Slope, s (ft/ft) =	0.370
Tt (hr) =	0.163
Tt (min) =	9.8

$$T_t = \frac{0.007(nl)^{0.8}}{P_2^{0.5} s^{0.4}}$$

Shallow Concentrated Flow

Flow Length, L (ft) =	204
Watercourse Slope (ft/ft) =	0.470
Average Velocity, V (ft/sec, fig 3-1) =	11
Tt (hr) =	0.005
Tt (min) =	0.3

$$T_t = \frac{L}{3600V}$$

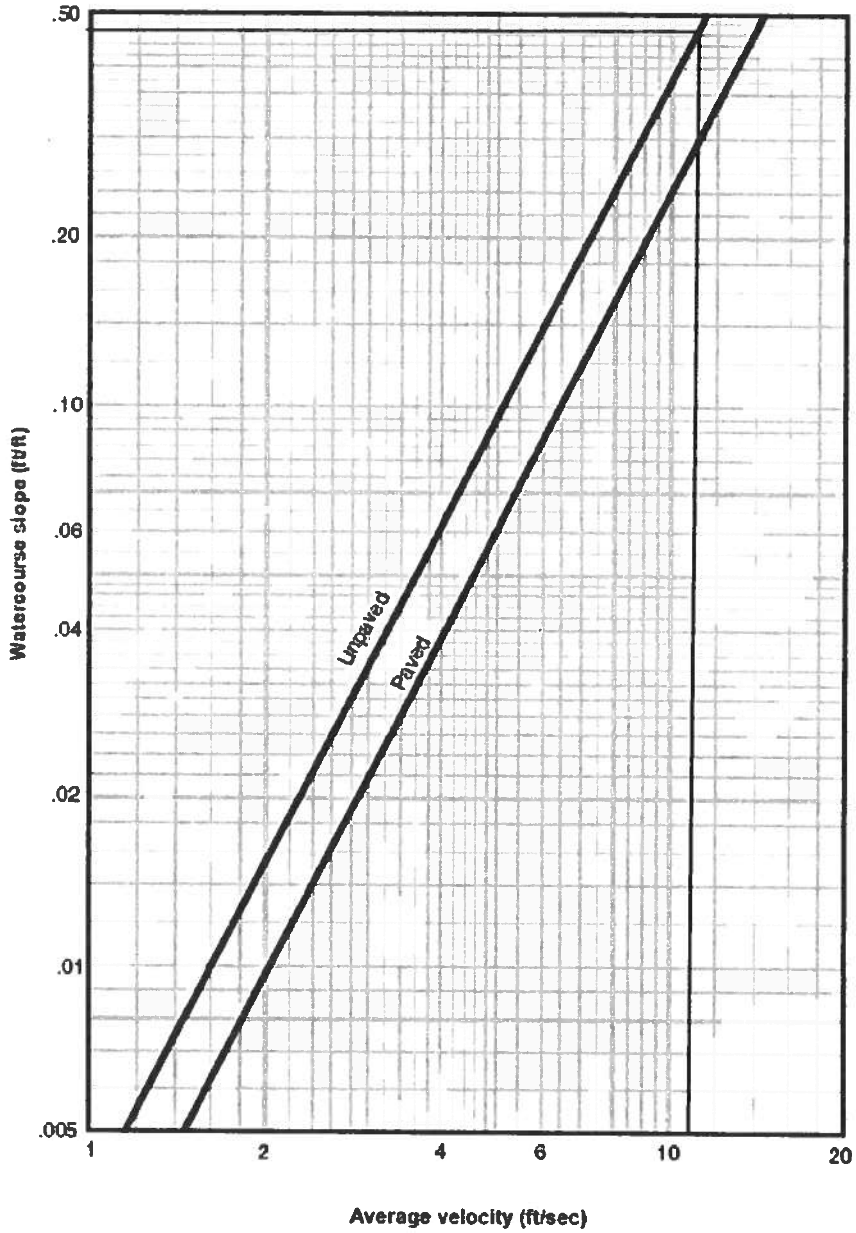
Channel Flow

Cross Sectional Flow Area, a (ft^2) =	8
Wetted Perimiter, p_w (ft) =	3
Hydraulic Radius, r = a/p_w (ft) =	2.67
Channel Slope, s (ft/ft) =	0.25
Manning's n =	0.035
V (ft/sec) =	40.93
Flow Length, L (ft) =	926
Tt (hr) =	0.006
Tt (min) =	0.4
Watershed or subarea Tc =	0.175
Lag time (hr) =	0.105
Lag time (min) =	**6.29**

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

$$T_t = \frac{L}{3600V}$$

Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow



Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

Table 3-1 Roughness coefficients (Manning's n) for sheet flow

Surface description	n [1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses [2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1] The n values are a composite of information compiled by Engman (1986).
[2] Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3] When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overtop and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5} s^{0.4}} \qquad \text{[eq. 3-3]}$$

where:

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1)
L = flow length (ft)
P_2 = 2-year, 24-hour rainfall (in)
s = slope of hydraulic grade line (land slope, ft/ft)

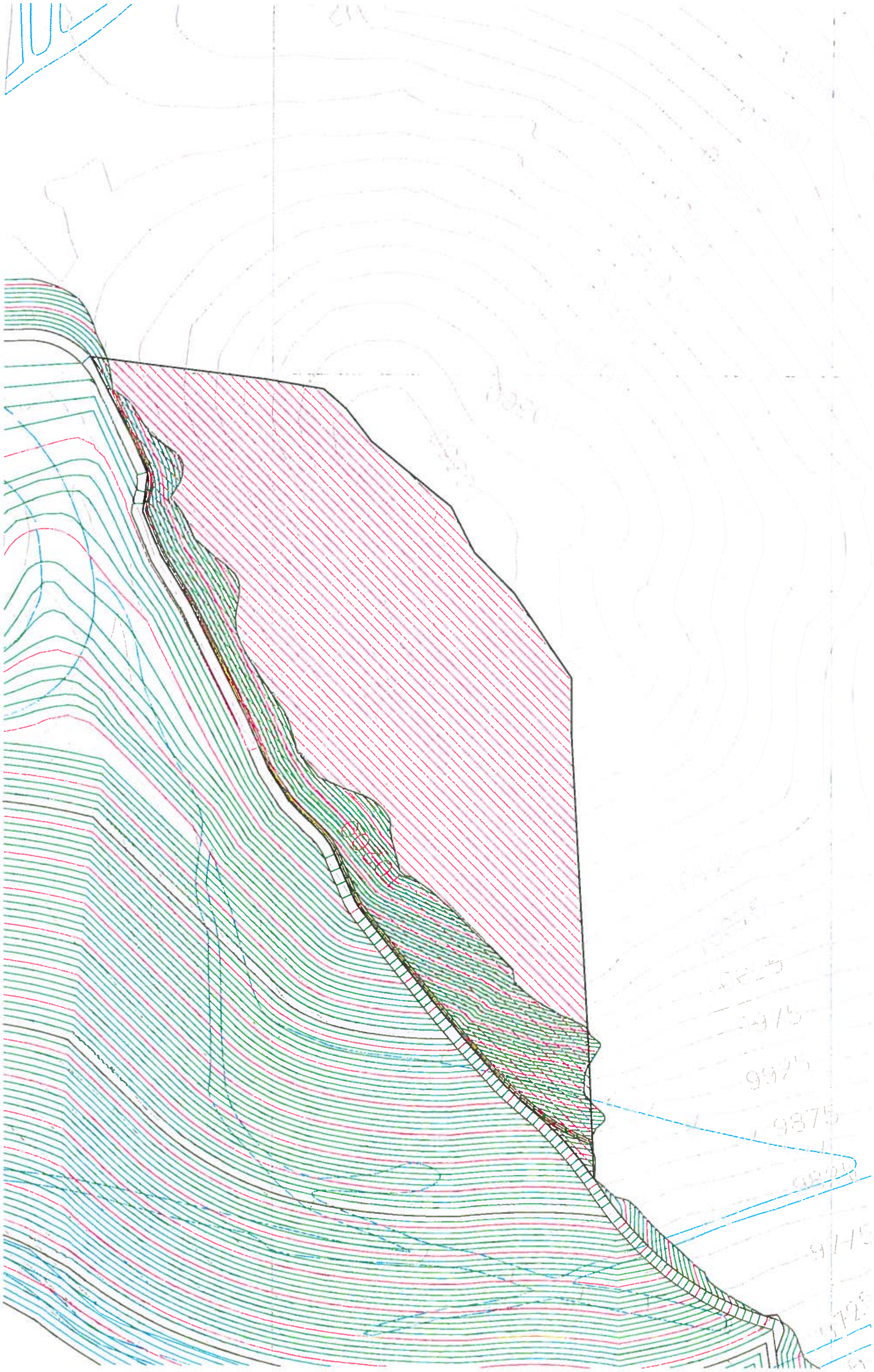
This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels


9925
9875

Cripple Creek and Victor
Arequa VLF
Lag Time Calculation Using Natural Resources Conservation Service TR-55
Sediment Pond - Runoff from North

Watershed Contribution Area

Sheet Flow

Mannings n (table 3-1) =	0.15
Flow Length (ft, max 300 ft) =	300
24 hr Rainfall, P_2 (in) =	1.8
Land Slope, s (ft/ft) =	0.280
Tt (hr) =	0.182
Tt (min) =	10.9

$$T_t = \frac{0.007(nl)^{0.8}}{P_2^{0.5} s^{0.4}}$$

Shallow Concentrated Flow

Flow Length, L (ft) =	2752
Watercourse Slope (ft/ft) =	0.090
Average Velocity, V (ft/sec, fig 3-1) =	4.8
Tt (hr) =	0.159
Tt (min) =	9.6

$$T_t = \frac{L}{3600V}$$

Watershed or subarea Tc =	0.342
Lag time (hr) =	0.205
Lag time (min) =	**12.30**

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CALCULATION TITLE PAGE

CLIENT Cripple Creek & Victor Gold Company	JOB NO. 1125	TASK NO. A100	PAGE 1 OF 2
PROJECT Arequa VLF	CALCULATION No. 1	REV. No. 1	
SUBJECT/ TITLE Sediment Collection Pond Design			

REV. NO.	PREPARER/ DATE	REVIEWER/ DATE	QA REVIEWER/ DATE	CONFIRMATION REQUIRED (Y/N)
1	Amanda L. Dolezal 2/1/08	Derek T. Wittwer 2/8/08	JECooper 2/8/08	

CALCULATION OBJECTIVE

Design a sediment collection pond to handle the runoff from the watershed to the North of the leach pad.

CALCULATION METHODOLOGY/ LIST of ASSUMPTIONS

- The size of the sediment collection pond is based on 2 x a 10 year 24 hour Type II storm.
- The watershed to the North that may impact the leach pad consists of both disturbed and undisturbed land.
- Curve Number (CN) for disturbed land = 90
- Curve Number (CN) for undisturbed land = 71

REFERENCES

Brater et. al, "Handbook of Hydraulics", 7th ed., 1996, McGraw-Hill Companies, Inc.

CONCLUSIONS

- A trapezoidal shaped pond with a total volume of 290,000 ft^3 will provide protection for the leach pad from the runoff from the watershed to the North.
- Total depth = 11 feet
- Side slopes = 2H:1V

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PROJECT: Arequa VLF	JOB NO: 1125	SHEET 2 OF 2
FEATURE: Sediment Collection Pond	BY: ALD	DATE: 2/1/08
DETAILS: Pond Sizing	CHKD BY: DTW	DATE: 2/8/08

- Criteria: 1) Size of pond based on precipitation equal to 2 x a 10 year 24 hour Type II storm event.
  2) Allow for 1 foot of freeboard in pond.

- Analysis:

Total Area of Watershed = 2,661,602 ft^2 = 0.0955 mi^2 = 61.1 acres
Area of disturbed land = 359,079 ft^2
CN = 90
Area of undisturbed land = 2,302,523 ft^2
CN = 71
Average CN = [(359,079ft^2 * 90) + (2,302,523ft^2 * 71)] / (2,661,602 ft^2)
Average CN = 73.6 ≈ 74

Sheet Flow = 300 feet
Average Sheet Slope = 28%

Shallow Flow = 2752 feet
Average Shallow Slope = 9%

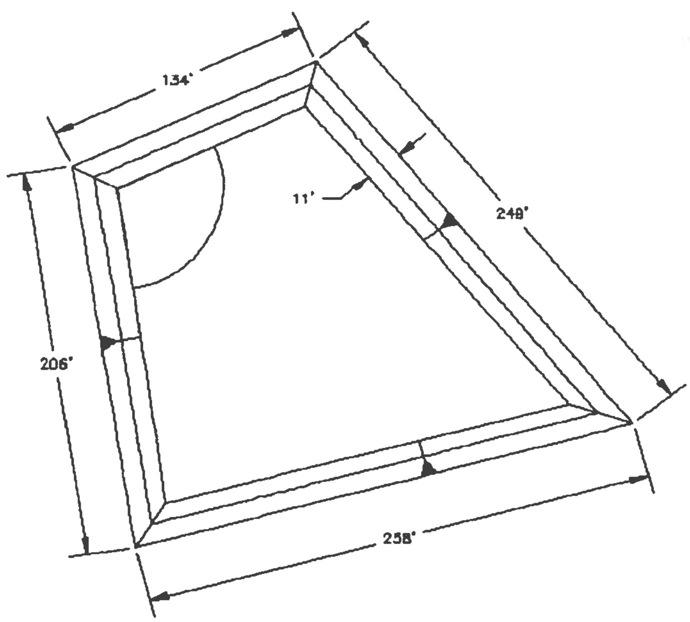
Lag Time = 12.30 minutes
Peak Flow = 33.3 cfs
Precipitation Volume = 0.55 inches = 0.0458 feet

Total volume from storm = precipitation volume * total are of watershed
= 0.0458 ft * 2,661,602 ft^2 = 121,901 ft^3 = 911,886 gallons

Therefore required pond storage = 911,886 gallons x 2 = 243,802 gallons

Trapezodial pond:
Total depth = 11feet
Side slopes = 2H:1V

Total volume = 290,000 ft^3



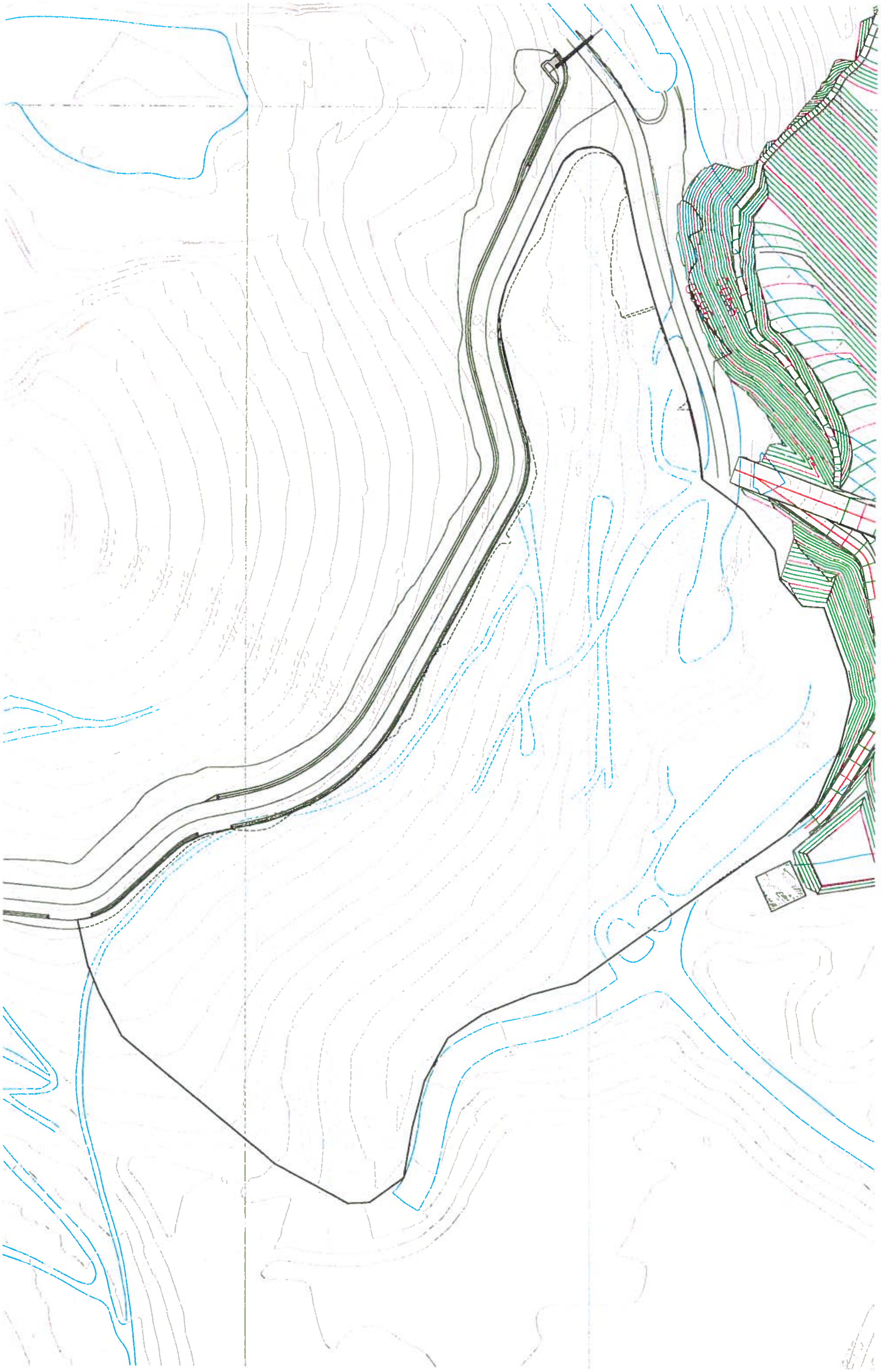
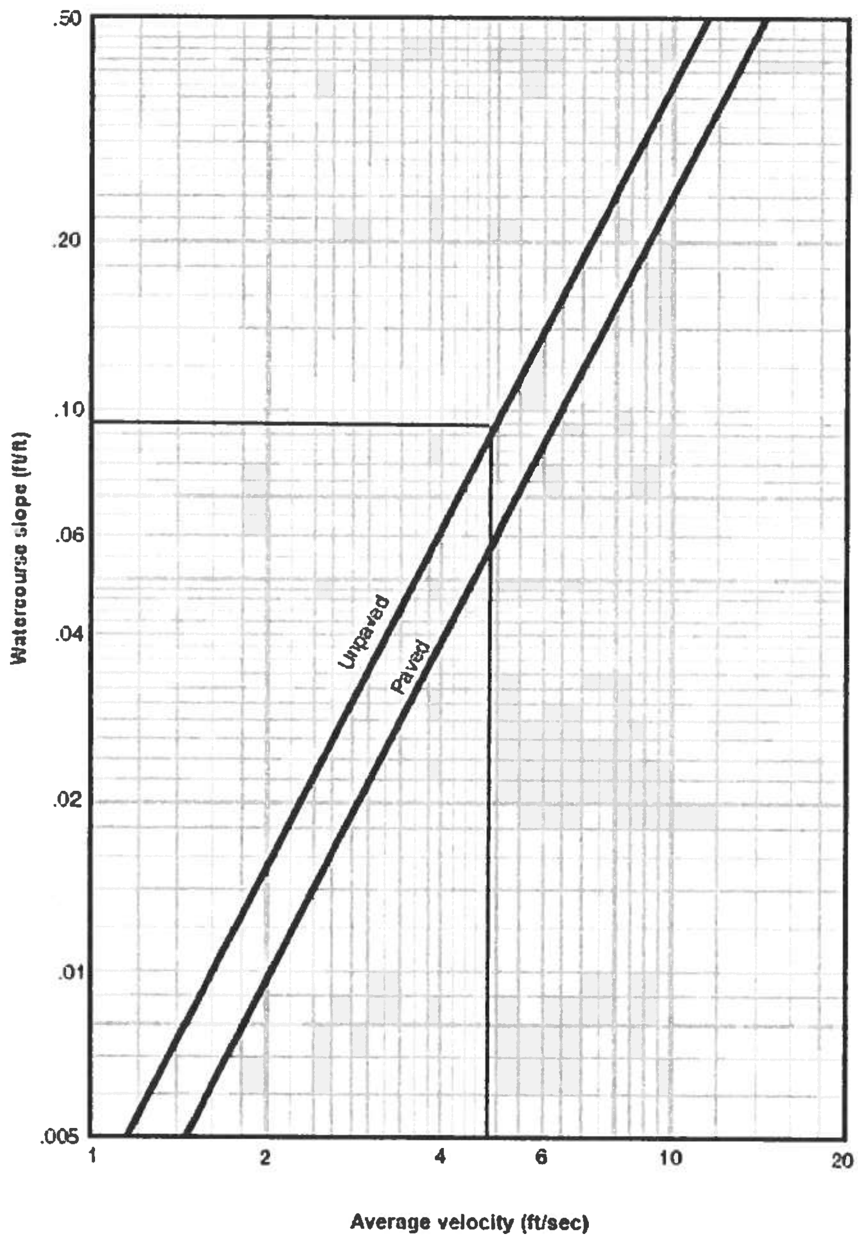


Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow



Sheet flow

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Table 3-1 Roughness coefficients (Manning's n) for sheet flow

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Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses [2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods: [3]	
Light underbrush	0.40
Dense underbrush	0.80

1 The n values are a composite of information compiled by Engman (1986).
2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
3 When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overtop and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5}\, s^{0.4}} \qquad \text{[eq. 3-3]}$$

where:

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1)
L = flow length (ft)
P_2 = 2-year, 24-hour rainfall (in)
s = slope of hydraulic grade line (land slope, ft/ft)

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Project: Runoff near Pad   Simulation Run: Run 4

Start of Run: 01Jan2007, 00:00   Basin Model: Basin 1
End of Run: 02Jan2007, 00:05   Meteorologic Model: Met 1
Compute Time: 13Mar2008, 14:06:33   Control Specifications: Control 1

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Runoff Watershed	0.0955	33.3	01Jan2007, 12:07	0.55

```
Basin: Basin 1
     Last Modified Date: 13 March 2008
     Last Modified Time: 20:06:32
     Version: 3.1.0
     Unit System: English
     Missing Flow To Zero: No
     Enable Flow Ratio: No
     Allow Blending: No
     Compute Local Flow At Junctions: No
End:

Subbasin: Runoff Watershed
     Canvas X: -1497.6958525345617
     Canvas Y: 2388.6328725038406
     Area: 0.0955

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
     Curve Number: 74

     Transform: SCS
     Lag: 12.3

     Baseflow: None

     Erosion: None
End:

Basin Schematic Properties:
     Last View N: 5000.0
     Last View S: -5000.0
     Last View W: -5000.0
     Last View E: 5000.0
     Maximum View N: 5000.0
     Maximum View S: -5000.0
     Maximum View W: -5000.0
     Maximum View E: 5000.0
     Extent Method: Elements
     Buffer: 0
     Draw Icons: Yes
     Draw Icon Labels: Yes
     Draw Gridlines: Yes
     Draw Flow Direction: No
End:
```

```
Meteorology: Met 1
     Description: 10yr 24 hr Event
     Last Modified Date: 8 February 2008
     Last Modified Time: 01:21:58
     Version: 3.1.0
     Unit System: English
     Precipitation Method: SCS Storm
     Snowmelt Method: None
     Basin Model List: Basin 1
End:

Precip Method Parameters: SCS Storm
     Storm Depth: 2.4
     Storm Type: Type II
End:

Subbasin: Runoff Watershed
End:
```

```
Control: Control 1
     Description: 24 Event
     Last Modified Date: 22 January 2008
     Last Modified Time: 18:40:48
     Start Date: 1 January 2007
     Start Time: 00:00
     End Date: 2 January 2007
     End Time: 00:05
     Time Interval: 1
End:
```

Culvert Calculator Report
Worksheet-1

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	9,739.00 ft	Headwater Depth/Height	0.75
Computed Headwater Eleva	9,737.63 ft	Discharge	33.30 cfs
Inlet Control HW Elev.	9,737.51 ft	Tailwater Elevation	0.00 ft
Outlet Control HW Elev.	9,737.63 ft	Control Type	Entrance Control

Grades

Upstream Invert	9,735.00 ft	Downstream Invert	9,733.80 ft
Length	235.00 ft	Constructed Slope	0.005106 ft/ft

Hydraulic Profile

Profile	S2	Depth, Downstream	1.60 ft
Slope Type	Steep	Normal Depth	1.60 ft
Flow Regime	Supercritical	Critical Depth	1.79 ft
Velocity Downstream	7.78 ft/s	Critical Slope	0.003478 ft/ft

Section

Section Shape	Circular	Mannings Coefficient	0.012
Section Material	Corrugated HDPE (Smooth Interior)	Span	3.50 ft
Section Size	42 inch	Rise	3.50 ft
Number Sections	1		

Outlet Control Properties

Outlet Control HW Elev.	9,737.63 ft	Upstream Velocity Head	0.71 ft
Ke	0.20	Entrance Loss	0.14 ft

Inlet Control Properties

Inlet Control HW Elev.	9,737.51 ft	Flow Control	Unsubmerged
Inlet Type	Beveled ring, 33.7° bevels	Area Full	9.6 ft²
K	0.00180	HDS 5 Chart	3
M	2.50000	HDS 5 Scale	B
C	0.02430	Equation Form	1
Y	0.83000		

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CALCULATION TITLE PAGE

CLIENT Cripple Creek & Victor Gold Company	JOB NO. 1125	TASK NO. A100	PAGE 1 OF 2
PROJECT Arequa VLF	CALCULATION No. 1	REV. No. 1	
SUBJECT/ TITLE LOB Haul Road Diversion Channel			

REV. NO.	PREPARER/ DATE	REVIEWER/ DATE	QA REVIEWER/ DATE	CONFIRMATION REQUIRED (Y/N)
1	Derek T. Wittwer 11/25/07	Amanda L. Dolezal 3/10/08	[signature] 3/10/08	

CALCULATION OBJECTIVE

Delineate watershed impacting the LOB Haul Road, determine contribution from the watershed, and design surface water controls to accommodate the runoff.

CALCULATION METHODOLOGY/ LIST of ASSUMPTIONS

- The size of the surface water diversion channel is based on a 100 year 24 hour Type II storm.
- The watershed impacting the LOB Haul Road consists of undisturbed ground, curve number (CN) = 71.

REFERENCES

CONCLUSIONS

- A triangular diversion channel with the following dimensions can handle the expected runoff:

- Total depth = 1.5 feet
- Sides slopes = 2.5H:1V
- Area = 5.63 ft^2
- Wetted Perimeter = 8.08 ft

SMITH WILLIAMS CONSULTANTS, INC.

PROJECT: Arequa VLF	JOB NO: 1125	SHEET 2 OF 2
FEATURE: LOB Haul Road Triangular Diversion Channel	BY: DTW	DATE: 11/25/07
DETAILS: Channel Sizing	CHKD BY: ALD	DATE: 3/10/08

- Criteria: 1) Size of surface water diversion channel is based on precipitation equal to a 100 year 24 hour Type II storm event.

- Analysis:

Total Area of Watershed = 2,294,804 ft^2 = 0.0823 mi^2 = 52.7acres
CN = 71

Sheet Flow = 300 feet
Average Sheet Slope = 20%

Shallow Flow = 790 feet
Average Shallow Slope = 34%

Channel Flow = 2944feet
Average Channel Slope = 10%

Lag Time = 11.13 minutes
Peak Flow = 62.8 cfs
Precipitation Volume = 1.06 inches = 0.09 feet

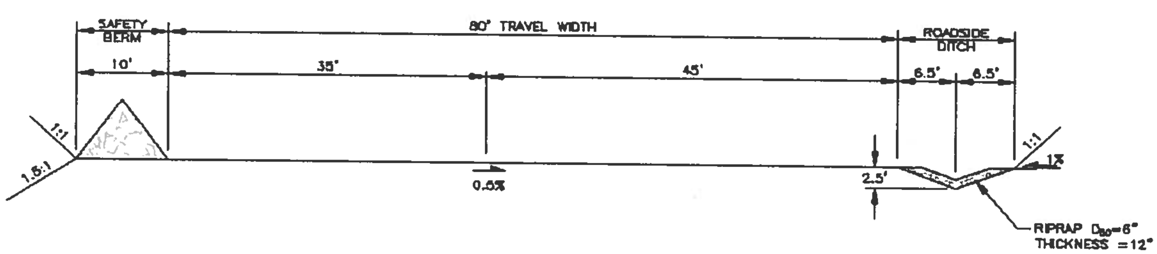
Total volume from storm = precipitation volume * total are of watershed

= 0.09 ft * 2,294,804 ft^2 = 206,532 ft^3 = 1,544,970 gallons

A triangular diversion channel with the following dimensions can handle the expected runoff.

Triangular diversion channel dimensions:

Total depth = 1.5 feet
Sides slopes = 2.5H:1V
Area = 5.63ft^2
Wetted Perimeter = 8.08 ft



Cripple Creek and Victor
Phase 5 VLF
Lag Time Calculation Using Natural Resources Conservation Service TR-55
Phase A

Watershed Contribution Area 4

Sheet Flow

Mannings n (table 3-1) =	0.15
Flow Length (ft, max 300 ft) =	300
24 hr Rainfall, P_2 (in) =	1.8
Land Slope, s (ft/ft) =	0.200
Tt (hr) =	0.209
Tt (min) =	12.5

$$T_t = \frac{0.007(nl)^{0.8}}{P_2^{0.5} s^{0.4}}$$

Shallow Concentrated Flow

Flow Length, L (ft) =	790
Watercourse Slope (ft/ft) =	0.340
Average Velocity, V (ft/sec, fig 3-1) =	9.5
Tt (hr) =	0.023
Tt (min) =	1.4

$$T_t = \frac{L}{3600\,V}$$

Channel Flow

Cross Sectional Flow Area, a (ft^2) =	5.63
Wetted Perimiter, p_w (ft) =	8.08
Hydraulic Radius, r = a/p_w (ft) =	0.70
Channel Slope, s (ft/ft) =	0.1
Manning's n =	0.035
V (ft/sec) =	10.58
Flow Length, L (ft) =	2944
Tt (hr) =	0.077
Tt (min) =	4.6

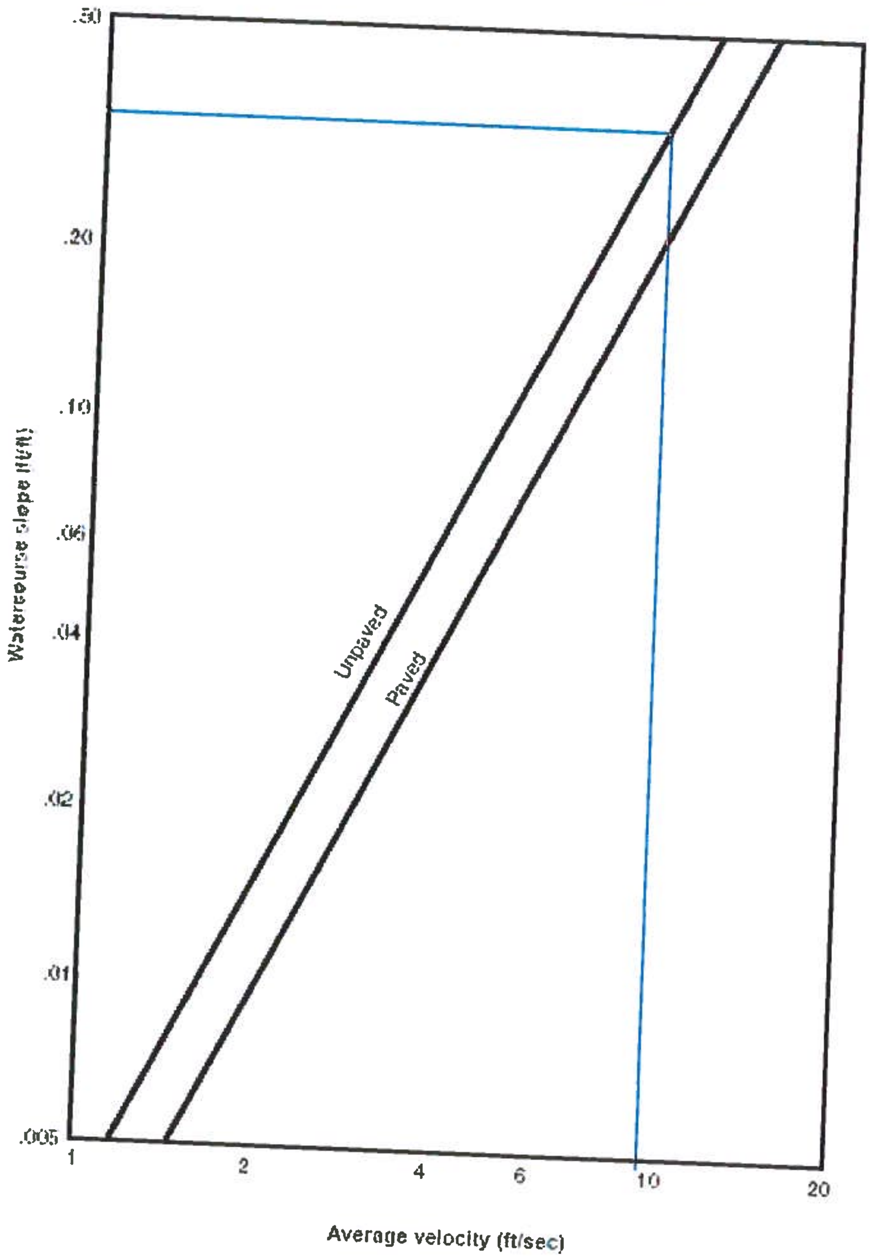
$$V = \frac{1.49\, r^{2/3} s^{1/2}}{n}$$

$$T_t = \frac{L}{3600\,V}$$

Watershed or subarea Tc =	0.309
Lag time (hr) =	0.185
Lag time (min) =	**11.13**

Note: Figure 3-1 and table 3-1 are on sheet 2

Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow



Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

Table 3-1 Roughness coefficients (Manning's n) for sheet flow

Surface description	n [1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses [2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods: [3]	
Light underbrush	0.40
Dense underbrush	0.80

1 The n values are a composite of information compiled by Engman (1986).
2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
3 When selecting n , consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overtop and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5} s^{0.4}} \qquad \text{[eq. 3-3]}$$

where:

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1)
L = flow length (ft)
P_2 = 2-year, 24-hour rainfall (in)
s = slope of hydraulic grade line (land slope, ft/ft)

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Project: CC&V LOB Simulation Run: Run 3

Start of Run:	01Jan2008, 00:00	Basin Model:	Basin 1
End of Run:	02Jan2008, 00:01	Meteorologic Model:	100 year 24 hour
Compute Time:	13Mar2008, 16:38:48	Control Specifications:	Control 1

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-1	0.0823	62.8	01Jan2008, 12:05	1.06

```
Basin: Basin 1
     Last Modified Date: 13 March 2008
     Last Modified Time: 22:38:47
     Version: 3.1.0
     Unit System: English
     Missing Flow To Zero: No
     Enable Flow Ratio: No
     Allow Blending: No
     Compute Local Flow At Junctions: No
End:

Subbasin: Subbasin-1
     Canvas X: -806.4516129032254
     Canvas Y: 1221.1981566820277
     Area: 0.0823

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
     Curve Number: 71

     Transform: SCS
     Lag: 11.13

     Baseflow: None

     Erosion: None
End:

Basin Schematic Properties:
     Last View N: 5000.0
     Last View S: -5000.0
     Last View W: -5000.0
     Last View E: 5000.0
     Maximum View N: 5000.0
     Maximum View S: -5000.0
     Maximum View W: -5000.0
     Maximum View E: 5000.0
     Extent Method: Elements
     Buffer: 0
     Draw Icons: Yes
     Draw Icon Labels: Yes
     Draw Gridlines: Yes
     Draw Flow Direction: No
End:
```

```
Meteorology: 100 year 24 hour
     Last Modified Date: 10 March 2008
     Last Modified Time: 20:18:40
     Version: 3.1.0
     Unit System: English
     Precipitation Method: SCS Storm
     Snowmelt Method: None
     Basin Model List: Basin 1
End:

Precip Method Parameters: SCS Storm
     Storm Depth: 3.5
     Storm Type: Type II
End:

Subbasin: Subbasin-1
End:
```

```
Control: Control 1
     Last Modified Date: 10 March 2008
     Last Modified Time: 20:19:59
     Start Date: 1 January 2008
     Start Time: 00:00
     End Date: 2 January 2008
     End Time: 00:01
     Time Interval: 1
End:
```

LOB Triangular Diversion Channel

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Roughness Coefficient	0.035	
Channel Slope	0.10000	ft/ft
Normal Depth	1.50	ft
Left Side Slope	2.50	ft/ft (H:V)
Right Side Slope	2.50	ft/ft (H:V)

Results

Discharge	59.33	ft³/s
Flow Area	5.63	ft²
Wetted Perimeter	8.08	ft
Top Width	7.50	ft
Critical Depth	2.04	ft
Critical Slope	0.01959	ft/ft
Velocity	10.55	ft/s
Velocity Head	1.73	ft
Specific Energy	3.23	ft
Froude Number	2.15	
Flow Type	Supercritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	1.50	ft
Critical Depth	2.04	ft
Channel Slope	0.10000	ft/ft
Critical Slope	0.01959	ft/ft

Culvert Calculator Report
Worksheet-2

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	9,886.59 ft	Headwater Depth/Height	0.94
Computed Headwater Eleva	9,884.80 ft	Discharge	63.00 cfs
Inlet Control HW Elev.	9,884.19 ft	Tailwater Elevation	9,880.13 ft
Outlet Control HW Elev.	9,884.80 ft	Control Type	Outlet Control

Grades

Upstream Invert	9,881.50 ft	Downstream Invert	9,880.13 ft
Length	137.30 ft	Constructed Slope	0.000000 ft/ft

Hydraulic Profile

Profile	H2	Depth, Downstream	1.74 ft
Slope Type	Horizontal	Normal Depth	N/A ft
Flow Regime	Subcritical	Critical Depth	1.74 ft
Velocity Downstream	6.62 ft/s	Critical Slope	0.013738 ft/ft

Section

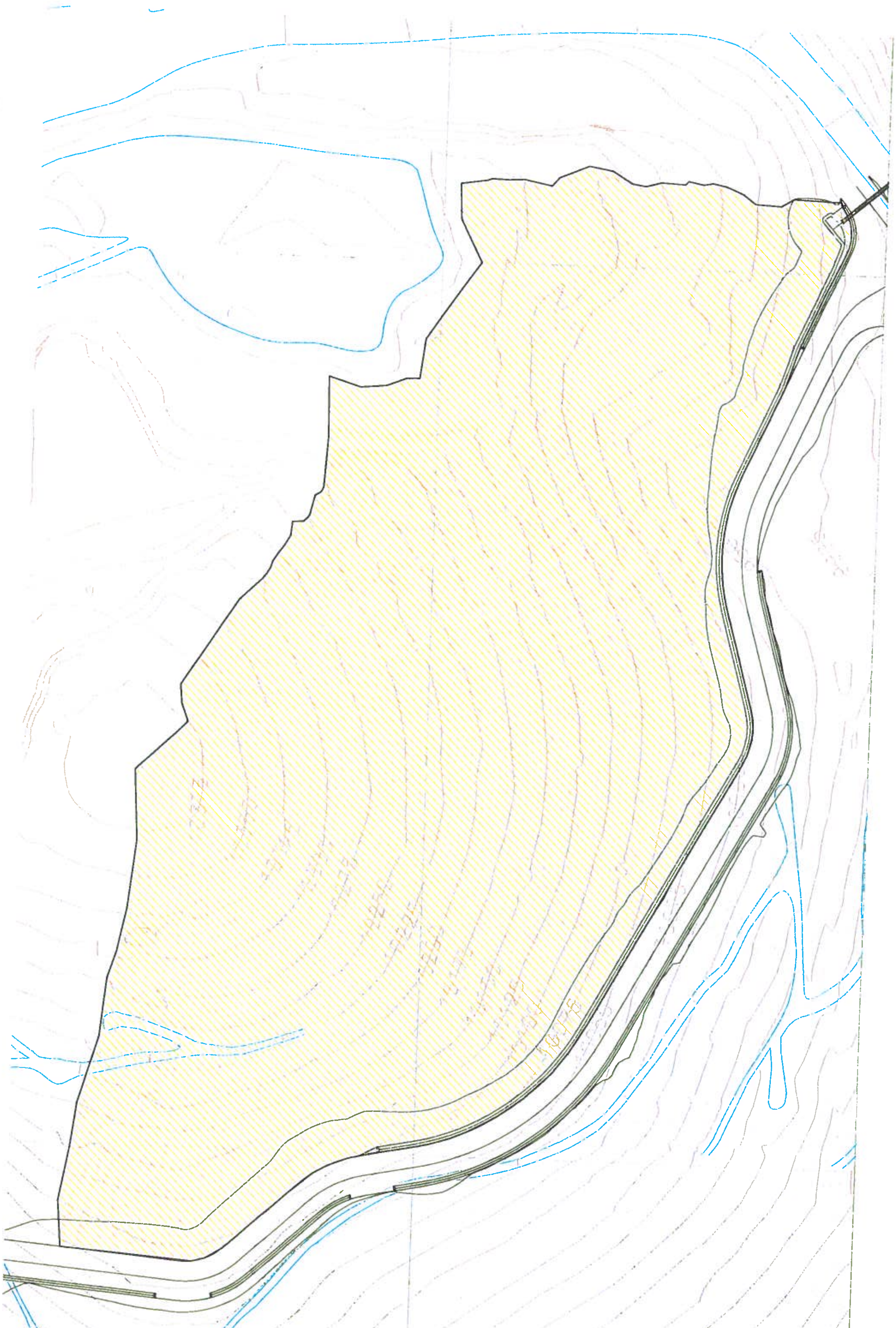
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	3.50 ft
Section Size	42 inch	Rise	3.50 ft
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	9,884.80 ft	Upstream Velocity Head	0.21 ft
Ke	0.90	Entrance Loss	0.19 ft

Inlet Control Properties

Inlet Control HW Elev.	9,884.19 ft	Flow Control	Unsubmerged
Inlet Type	Projecting	Area Full	19.2 ft²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		



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CALCULATION TITLE PAGE

CLIENT Cripple Creek & Victor Gold Company	JOB NO. 1125	TASK NO. A100	PAGE 1 OF 5
PROJECT Arequa VLF	CALCULATION No. 1	REV. No. 1	
SUBJECT/ TITLE Post Closure Watersheds and Diversion Channels			

REV. NO.	PREPARER/ DATE	REVIEWER/ DATE	QA REVIEWER/ DATE	CONFIRMATION REQUIRED (Y/N)
1	Amanda L. Dolezal 2/26/08	Derek T. Wittwer 3/1/08	JF Lyon 3/1/08	

CALCULATION OBJECTIVE

Delineate watershed impacting the post closure design, determine contribution from each watershed, and design surface water controls to accommodate the runoff.

CALCULATION METHODOLOGY/ LIST of ASSUMPTIONS

- The size of the surface water diversion channel is based on a 100 year 24 hour Type II storm.
- The watershed contribution areas can be broken into 6 separate areas.
- Watershed contribution areas 1 and 2 are grouped together to form the South watershed.
- Watershed contribution areas 3A, 3B, 4 and 5 are grouped together to form the North watershed.
- All of the watersheds consist of disturbed ground, curve number (CN) = 50.

REFERENCES

CONCLUSIONS

- Two trapezoidal diversion channels, one in the North Watershed and one in the South Watershed with the following dimensions can handle the expected runoff:

- Total depth = 2.5 feet
- Sides slopes = 4H:1V
- Area = 37.5 ft^2
- Wetted Perimeter = 25.6 ft

PROJECT:	JOB NO:	SHEET 2 OF 5
Arequa VLF	1125	
FEATURE: Post Closure Watersheds and Diversion Channels	BY: ALD	DATE: 2/26/08
DETAILS: Runoff Contributions and Channel Sizing	CHKD BY: DTW	DATE: 3/1/08

- Criteria: 1) Size of surface water diversion channel is based on precipitation equal to a 100 year 24 hour Type II storm event.

- Analysis:

Total Area of Each Watershed:

Watershed 1: Area = 328,971 ft^2 = 0.0118 mi^2

Total length of flow path = 1580 ft

Sheet Flow = 300 feet
Average Sheet Slope = 8%

Shallow Flow = 142 feet
Average Shallow Slope = 18%

Peak Flow = 0.4 cfs
Lag Time = 11.05 minutes
CN = 50

Watershed 2: Area = 724,841 ft^2 = 0.0260 mi^2

Total length of flow path = 1581 ft

Sheet Flow = 300 feet
Average Sheet Slope = 33%

Shallow Flow = 160 feet
Average Shallow Slope = 47%

Peak Flow = 1.3 cfs
Lag Time = 6.30 minutes
CN = 50

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PROJECT: Arequa VLF	JOB NO: 1125	SHEET 3 OF 5
FEATURE: Post Closure Watersheds and Diversion Channels	BY: ALD	DATE: 2/26/08
DETAILS: Runoff Contributions and Channel Sizing	CHKD BY: DTW	DATE: 3/1/08

- Analysis:

Total Area of Each Watershed:

Watershed 3A: Area = 2,234,655 ft^2 = 0.0802 mi^2

Total length of flow path = 1275 ft

Sheet Flow = 300 feet
Average Sheet Slope = 8%

Shallow Flow = 975 feet
Average Shallow Slope = 31%

Peak Flow = 2.6 cfs
Lag Time = 11.93 minutes
CN = 50

Watershed 3B: Area = 1,055,432 ft^2 = 0.0379 mi^2

Total length of flow path = 2532 ft

Sheet Flow = 300 feet
Average Sheet Slope = 8%

Shallow Flow = 2232 feet
Average Shallow Slope = 23%

Peak Flow = 13.82 cfs
Lag Time = 13.82minutes
CN = 50

Watershed 4: Area = 3,543,826 ft^2 = 0.1271mi^2

Total length of flow path = 1317 ft

Sheet Flow = 300 feet
Average Sheet Slope = 1%

Shallow Flow = 1017 feet
Average Shallow Slope = 15%

Peak Flow = 3.2 cfs
Lag Time = 26.53 minutes
CN = 50

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PROJECT: Arequa VLF	JOB NO: 1125	SHEET 4 OF 5
FEATURE: Post Closure Watersheds and Diversion Channels	BY: ALD	DATE: 2/26/08
DETAILS: Runoff Contributions and Channel Sizing	CHKD BY: DTW	DATE: 3/1/08

- Analysis:

Total Area of Each Watershed:

Watershed 5: Area = 3,945,885 ft^2 = 0.1415 mi^2

Total length of flow path = 2259 ft

Sheet Flow = 300 feet
Average Sheet Slope = 1%

Shallow Flow = 1959 feet
Average Shallow Slope = 17%

Peak Flow = 3.5 cfs
Lag Time = 28.29 minutes
CN = 50

North Diversion Channel: (Watersheds 3A, 3B, 4 & 5)

Total length of flow path = 3445 ft (Channel Flow)

Section 1 = 2022 feet @ 11% (NW)
Peak Flow = 5.4 cfs
Lag Time = 1.06 minutes
CN = 50

Section 2 = 1423 feet @ 1% (NE)
Peak Flow = 10.1cfs
Lag Time = 2.59 minutes
CN = 50

South Diversion Channel: (Watersheds 1 & 2)

Total length of flow path = 1614 ft (Channel Flow)

Section 1 = 1614 feet @ 20%
Peak Flow = 1.5 cfs
Lag Time = 0.66 minutes
CN = 50

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SMITH WILLIAMS CONSULTANTS, INC.

PROJECT: Arequa VLF	JOB NO: 1125	SHEET 5 OF 5
FEATURE: Post Closure Watersheds and Diversion Channels	BY: ALD	DATE: 2/26/08
DETAILS: Runoff Contributions and Channel Sizing	CHKD BY: DTW	DATE: 3/1/08

- Analysis:

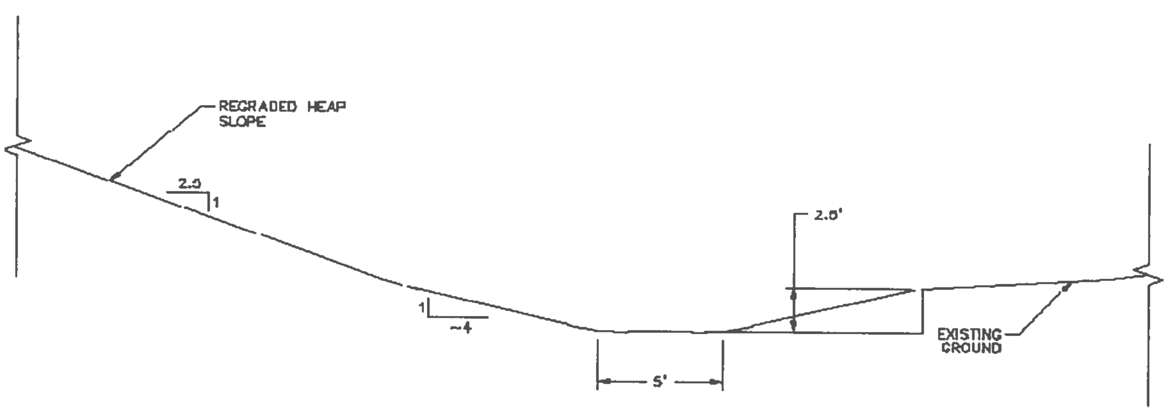
Two trapezoidal diversion channels, one in the North Watershed and one in the South Watershed, with the following dimensions can handle the expected runoff.

Trapezoidal diversion channels dimensions:

Total depth = 2.5 feet
Sides slopes = 4H:1V
Area = 37.5 ft^2
Wetted Perimeter = 25.6 ft

North Watershed Total Length = 3445 feet

South Watershed Total Length = 1614 feet



Project: CC&V Simulation Run: South

Start of Run: 01Jan2008, 00:00
End of Run: 02Jan2008, 00:05
Compute Time: 27Feb2008, 16:10:33

Basin Model: South Watershed
Meteorologic Model: 100 yr 24 hr
Control Specifications: Control 1

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Diversion Channel	0.0378	1.5	01Jan2008, 12:06	0.19
WS #1	0.0118	0.4	01Jan2008, 12:12	0.19
WS #2	0.0260	1.3	01Jan2008, 12:05	0.20

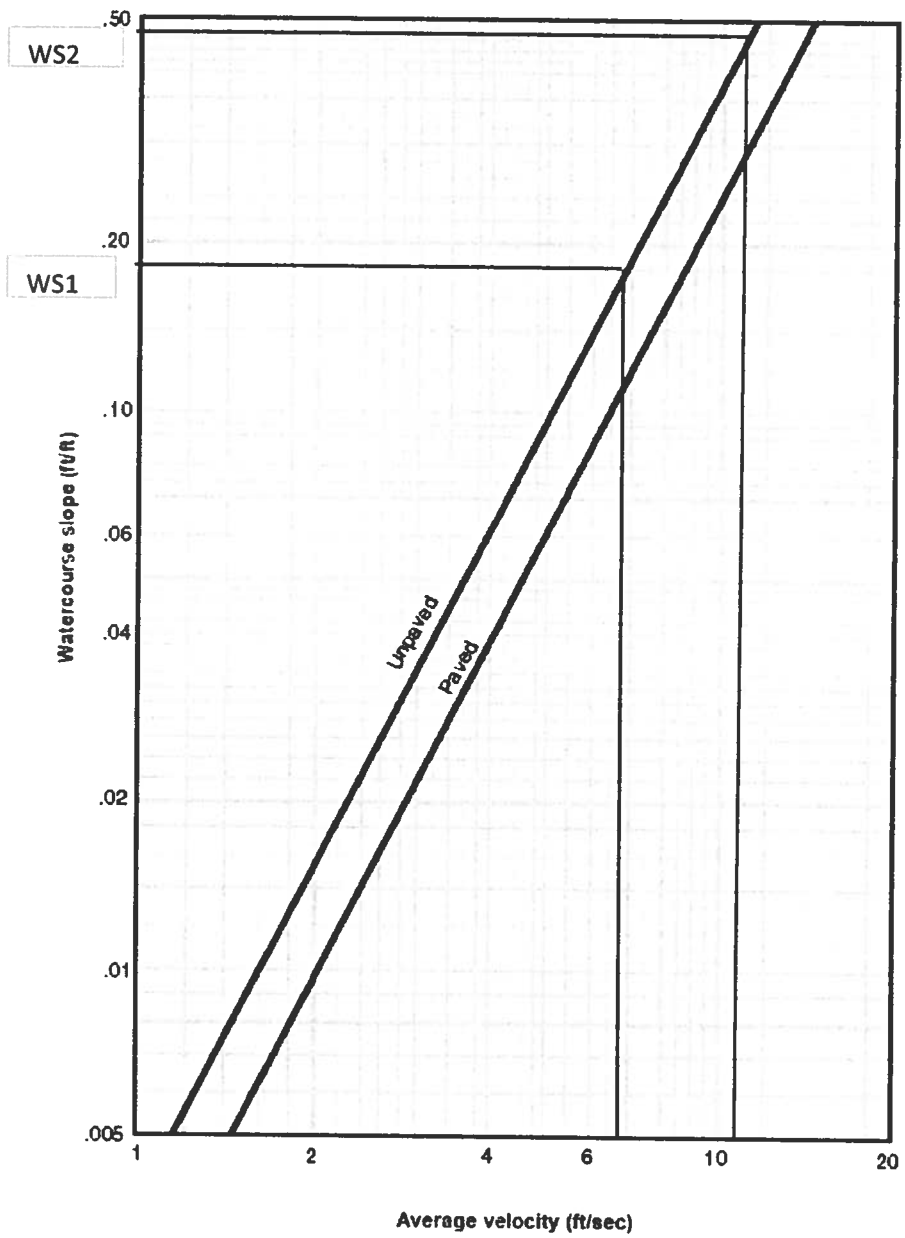
```
Basin: South Watershed
     Description: Watersheds 1 & 2
     Last Modified Date: 27 February 2008
     Last Modified Time: 23:10:03
     Version: 3.1.0
     Unit System: English
     Missing Flow To Zero: No
     Enable Flow Ratio: No
     Allow Blending: No
     Compute Local Flow At Junctions: No
End:

Subbasin: WS #1
     Description: Watershed #1
     Canvas X: 115.20737327188999
     Canvas Y: -1036.8663594470045
     Area: 0.0118
     Downstream: Diversion Channel

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
     Curve Number: 50

     Transform: SCS
     Lag: 11.05

     Baseflow: None

     Erosion: None
End:

Reach: Diversion Channel
     Canvas X: -529.9539170506914
     Canvas Y: -4539.170506912442
     From Canvas X: 115.20737327188999
     From Canvas Y: -3402.4577572964645
     Label X: -6.0
     Label Y: -10.0

     Route: Lag
     Lag: 0.66
     Channel Loss: None
End:

Subbasin: WS #2
     Description: Watershed #2
     Canvas X: 2281.1059907834106
     Canvas Y: -2188.940092165898
     From Canvas X: 1134.5659636463688
     From Canvas Y: 97.35570159258259
     Area: 0.026
     Downstream: Diversion Channel

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
```

```
     Curve Number: 50

     Transform: SCS
     Lag: 6.3

     Baseflow: None

     Erosion: None
End:

Basin Schematic Properties:
     Last View N: 5000.0
     Last View S: -5000.0
     Last View W: -5000.0
     Last View E: 5000.0
     Maximum View N: 5000.0
     Maximum View S: -5000.0
     Maximum View W: -5000.0
     Maximum View E: 5000.0
     Extent Method: Elements
     Buffer: 0
     Draw Icons: Yes
     Draw Icon Labels: Yes
     Draw Gridlines: Yes
     Draw Flow Direction: No
End:
```

```
Meteorology: 100 yr 24 hr
     Last Modified Date: 15 February 2008
     Last Modified Time: 18:40:12
     Version: 3.1.0
     Unit System: English
     Precipitation Method: SCS Storm
     Snowmelt Method: None
     Basin Model List: South Watershed,North Watershed
End:

Precip Method Parameters: SCS Storm
     Storm Depth: 3.5
     Storm Type: Type II
End:

Subbasin: WS #2
End:

Subbasin: WS #1
End:

Subbasin: WS #3A
End:

Subbasin: WS #4
End:

Subbasin: WS #5
End:

Subbasin: WS #3B
End:
```

```
Control: Control 1
     Description: 24 hour
     Last Modified Date: 15 February 2008
     Last Modified Time: 01:19:39
     Start Date: 1 January 2008
     Start Time: 00:00
     End Date: 2 January 2008
     End Time: 00:05
     Time Interval: 1
End:
```

Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow



Cripple Creek and Victor
Arequa VLF
Lag Time Calculation Using Natural Resources Conservation Service TR-55
Post Closure Watershed #1

Watershed Contribution Area

Sheet Flow

Mannings n (table 3-1) =	0.15
Flow Length (ft, max 300 ft) =	300
24 hr Rainfall, P_2 (in) =	1.8
Land Slope, s (ft/ft) =	0.080
Tt (hr) =	0.301
Tt (min) =	18.1

$$T_t = \frac{0.007(nl)^{0.8}}{P_2^{0.5} s^{0.4}}$$

Shallow Concentrated Flow

Flow Length, L (ft) =	142
Watercourse Slope (ft/ft) =	0.180
Average Velocity, V (ft/sec, fig 3-1) =	6.75
Tt (hr) =	0.006
Tt (min) =	0.4

$$T_t = \frac{L}{3600V}$$

Channel Flow

Cross Sectional Flow Area, a (ft^2) =	37.5
Wetted Perimiter, p_w (ft) =	25.6
Hydraulic Radius, r = a/p_w (ft) =	1.46
Channel Slope, s (ft/ft) =	0.26
Manning's n =	0.035
V (ft/sec) =	28.00
Flow Length, L (ft) =	0
Tt (hr) =	-
Tt (min) =	-

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

$$T_t = \frac{L}{3600V}$$

Watershed or subarea Tc =	0.307
Lag time (hr) =	0.184
Lag time (min) =	**11.05**

Note: Figure 3-1 and table 3-1 are on sheet 2

Cripple Creek and Victor
Arequa VLF
Lag Time Calculation Using Natural Resources Conservation Service TR-55
Post Closure Watershed #2

Watershed Contribution Area

Sheet Flow

Mannings n (table 3-1) =	0.15
Flow Length (ft, max 300 ft) =	300
24 hr Rainfall, P_2 (in) =	1.8
Land Slope, s (ft/ft) =	0.330
Tt (hr) =	0.171
Tt (min) =	10.3

$$T_t = \frac{0.007(nl)^{0.8}}{P_2^{0.5} s^{0.4}}$$

Shallow Concentrated Flow

Flow Length, L (ft) =	160
Watercourse Slope (ft/ft) =	0.470
Average Velocity, V (ft/sec, fig 3-1) =	11
Tt (hr) =	0.004
Tt (min) =	0.2

$$T_t = \frac{L}{3600V}$$

Channel Flow

Cross Sectional Flow Area, a (ft^2) =	37.5
Wetted Perimiter, p_w (ft) =	25.6
Hydraulic Radius, r = a/p_w (ft) =	1.46
Channel Slope, s (ft/ft) =	0.26
Manning's n =	0.035
V (ft/sec) =	28.00
Flow Length, L (ft) =	0
Tt (hr) =	-
Tt (min) =	-

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

$$T_t = \frac{L}{3600V}$$

Watershed or subarea Tc =	0.175
Lag time (hr) =	0.105
Lag time (min) =	**6.30**

Note: Figure 3-1 and table 3-1 are on sheet 2

Cripple Creek and Victor
Arequa VLF
Lag Time Calculation Using Natural Resources Conservation Service TR-55
South Diversion Channel

Watershed Contribution Area

Sheet Flow

Mannings n (table 3-1) =	0.15
Flow Length (ft, max 300 ft) =	0
24 hr Rainfall, P_2 (in) =	1.8
Land Slope, s (ft/ft) =	0.080
Tt (hr) =	-
Tt (min) =	-

$$T_t = \frac{0.007(nl)^{0.8}}{P_2^{0.5} s^{0.4}}$$

Shallow Concentrated Flow

Flow Length, L (ft) =	0
Watercourse Slope (ft/ft) =	0.180
Average Velocity, V (ft/sec, fig 3-1) =	6.75
Tt (hr) =	-
Tt (min) =	-

$$T_t = \frac{L}{3600V}$$

Channel Flow

Cross Sectional Flow Area, a (ft^2) =	37.5
Wetted Perimiter, p_w (ft) =	25.6
Hydraulic Radius, $r = a/p_w$ (ft) =	1.46
Channel Slope, s (ft/ft) =	0.2
Manning's n =	0.035
V (ft/sec) =	24.56
Flow Length, L (ft) =	1614
Tt (hr) =	0.018
Tt (min) =	1.1

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

$$T_t = \frac{L}{3600V}$$

Watershed or subarea Tc =	0.018
Lag time (hr) =	0.011
Lag time (min) =	**0.66**

Note: Figure 3-1 and table 3-1 are on sheet 2

South Diversion Channel

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Roughness Coefficient	0.150	
Channel Slope	0.20000	ft/ft
Normal Depth	2.50	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	5.00	ft

Results

Discharge	214.19	ft³/s
Flow Area	37.50	ft²
Wetted Perimeter	25.62	ft
Top Width	25.00	ft
Critical Depth	2.28	ft
Critical Slope	0.30377	ft/ft
Velocity	5.71	ft/s
Velocity Head	0.51	ft
Specific Energy	3.01	ft
Froude Number	0.82	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	2.50	ft
Critical Depth	2.28	ft
Channel Slope	0.20000	ft/ft
Critical Slope	0.30377	ft/ft

Project: CC&V Simulation Run: North

Start of Run:	01Jan2008, 00:00	Basin Model:	North Watershed
End of Run:	02Jan2008, 00:05	Meteorologic Model:	100 yr 24 hr
Compute Time:	20Mar2008, 10:49:15	Control Specifications:	Control 1

Volume Units: IN

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Reach NE	0.3867	9.7	01Jan2008, 12:39	0.19
Reach NW	0.2073	5.3	01Jan2008, 12:35	0.19
WS #3A	0.0802	2.6	01Jan2008, 12:13	0.19
WS #3B	0.0379	1.2	01Jan2008, 12:17	0.19
WS #4	0.1271	3.2	01Jan2008, 12:39	0.19
WS #5	0.1415	3.5	01Jan2008, 12:41	0.19

```
Basin: North Watershed
     Description: Watersheds 3A, 3B, 4 & 5
     Last Modified Date: 20 March 2008
     Last Modified Time: 16:49:15
     Version: 3.1.0
     Unit System: English
     Missing Flow To Zero: No
     Enable Flow Ratio: No
     Allow Blending: No
     Compute Local Flow At Junctions: No
End:

Subbasin: WS #3A
     Description: Watershed #3A
     Canvas X: -2173.5791090629796
     Canvas Y: 2296.466973886329
     Area: 0.0802
     Downstream: Reach NW

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
     Curve Number: 50

     Transform: SCS
     Lag: 11.93

     Baseflow: None

     Erosion: None
End:

Subbasin: WS #4
     Description: Watershed #4
     Canvas X: -2649.7695852534557
     Canvas Y: 775.7296466973894
     From Canvas X: -153.6098310291859
     From Canvas Y: -2350.230414746544
     Area: 0.1271
     Downstream: Reach NW

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
     Curve Number: 50

     Transform: SCS
     Lag: 26.53

     Baseflow: None

     Erosion: None
End:

Subbasin: WS #5
     Description: Watershed #5
     Canvas X: 1774.1935483870966
```

```
     Canvas Y: 545.3149001536103
     From Canvas X: -153.60983102918544
     From Canvas Y: -1920.1228878648235
     Area: 0.1415
     Downstream: Reach NE

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
     Curve Number: 50

     Transform: SCS
     Lag: 28.29

     Baseflow: None

     Erosion: None
End:

Subbasin: WS #3B
     Description: Watershed #3B
     Canvas X: 1850.9984639016902
     Canvas Y: 2050.6912442396315
     Label X: -2.0
     Label Y: -1.0
     Area: 0.0379
     Downstream: Reach NE

     Canopy: None

     Surface: None

     LossRate: SCS
     Percent Impervious Area: 0.0
     Curve Number: 50

     Transform: SCS
     Lag: 13.82

     Baseflow: None

     Erosion: None
End:

Reach: Reach NW
     Description: #1
     Canvas X: -314.9001536098308
     Canvas Y: 1205.8371735791093
     From Canvas X: -1298.0030721966214
     From Canvas Y: 1559.1397849462364
     Label X: -69.0
     Label Y: -16.0
     Downstream: Reach NE

     Route: Lag
     Lag: 1.06
     Channel Loss: None
End:

Reach: Reach NE
```

```
     Description: #2
     Canvas X: 1589.8617511520742
     Canvas Y: 1466.9738863287253
     From Canvas X: -314.9001536098308
     From Canvas Y: 1205.8371735791093
     Label X: 2.0
     Label Y: -17.0

     Route: Lag
     Lag: 2.59
     Channel Loss: None
End:

Basin Schematic Properties:
     Last View N: 5000.0
     Last View S: -5000.0
     Last View W: -5000.0
     Last View E: 5000.0
     Maximum View N: 5000.0
     Maximum View S: -5000.0
     Maximum View W: -5000.0
     Maximum View E: 5000.0
     Extent Method: Elements
     Buffer: 0
     Draw Icons: Yes
     Draw Icon Labels: Yes
     Draw Gridlines: Yes
     Draw Flow Direction: No
End:
```

```
Meteorology: 100 yr 24 hr
     Last Modified Date: 15 February 2008
     Last Modified Time: 18:40:12
     Version: 3.1.0
     Unit System: English
     Precipitation Method: SCS Storm
     Snowmelt Method: None
     Basin Model List: South Watershed,North Watershed
End:

Precip Method Parameters: SCS Storm
     Storm Depth: 3.5
     Storm Type: Type II
End:

Subbasin: WS #2
End:

Subbasin: WS #1
End:

Subbasin: WS #3A
End:

Subbasin: WS #4
End:

Subbasin: WS #5
End:

Subbasin: WS #3B
End:
```

```
Control: Control 1
     Description: 24 hour
     Last Modified Date: 15 February 2008
     Last Modified Time: 01:19:39
     Start Date: 1 January 2008
     Start Time: 00:00
     End Date: 2 January 2008
     End Time: 00:05
     Time Interval: 1
End:
```

Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow

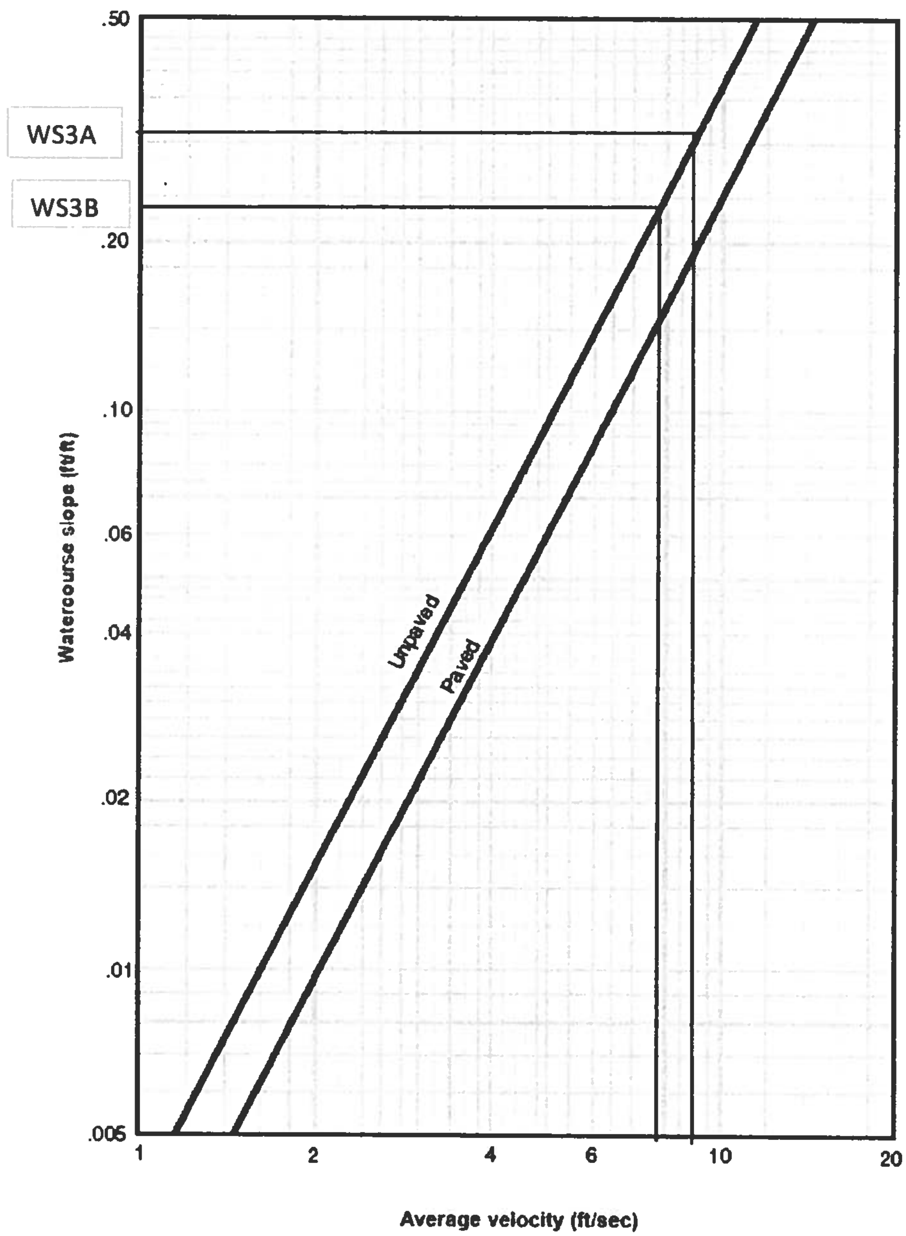
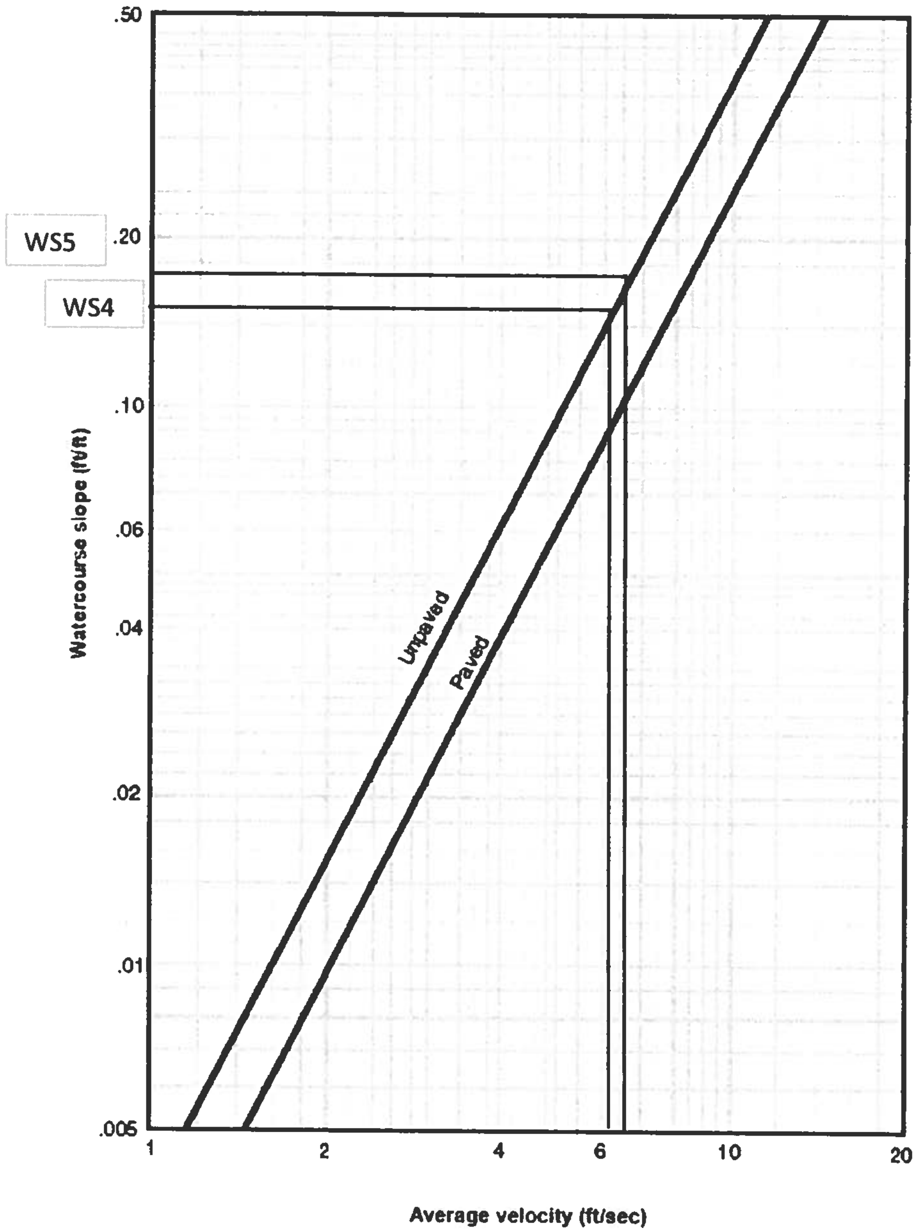


Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow



Cripple Creek and Victor
Arequa VLF
Lag Time Calculation Using Natural Resources Conservation Service TR-55
Post Closure Watershed #3A

Watershed Contribution Area

Sheet Flow

Mannings n (table 3-1) =	0.15
Flow Length (ft, max 300 ft) =	300
24 hr Rainfall, P_2 (in) =	1.8
Land Slope, s (ft/ft) =	0.080
Tt (hr) =	0.301
Tt (min) =	18.1

$$T_t = \frac{0.007(nl)^{0.8}}{P_2^{0.5} s^{0.4}}$$

Shallow Concentrated Flow

Flow Length, L (ft) =	975
Watercourse Slope (ft/ft) =	0.310
Average Velocity, V (ft/sec, fig 3-1) =	9
Tt (hr) =	0.030
Tt (min) =	1.8

$$T_t = \frac{L}{3600V}$$

Channel Flow

Cross Sectional Flow Area, a (ft^2) =	37.5
Wetted Perimiter, p_w (ft) =	25.6
Hydraulic Radius, r = a/p_w (ft) =	1.46
Channel Slope, s (ft/ft) =	0.26
Manning's n =	0.035
V (ft/sec) =	28.00
Flow Length, L (ft) =	0
Tt (hr) =	-
Tt (min) =	-

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

$$T_t = \frac{L}{3600V}$$

Watershed or subarea Tc =	0.331
Lag time (hr) =	0.199
Lag time (min) =	**11.93**

Note: Figure 3-1 and table 3-1 are on sheet 2

Cripple Creek and Victor
Arequa VLF
Lag Time Calculation Using Natural Resources Conservation Service TR-55
Post Closure Watershed #3B

Watershed Contribution Area

Sheet Flow

Mannings n (table 3-1) =	0.15
Flow Length (ft, max 300 ft) =	300
24 hr Rainfall, P_2 (in) =	1.8
Land Slope, s (ft/ft) =	0.080
Tt (hr) =	0.301
Tt (min) =	18.1

$$T_t = \frac{0.007(nl)^{0.8}}{P_2^{0.5} s^{0.4}}$$

Shallow Concentrated Flow

Flow Length, L (ft) =	2232
Watercourse Slope (ft/ft) =	0.230
Average Velocity, V (ft/sec, fig 3-1) =	7.5
Tt (hr) =	0.083
Tt (min) =	5.0

$$T_t = \frac{L}{3600V}$$

Channel Flow

Cross Sectional Flow Area, a (ft^2) =	37.5
Wetted Perimiter, p_w (ft) =	25.6
Hydraulic Radius, r = a/p_w (ft) =	1.46
Channel Slope, s (ft/ft) =	0.26
Manning's n =	0.035
V (ft/sec) =	28.00
Flow Length, L (ft) =	0
Tt (hr) =	-
Tt (min) =	-

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

$$T_t = \frac{L}{3600V}$$

Watershed or subarea Tc =	0.384
Lag time (hr) =	0.230
Lag time (min) =	**13.82**

Note: Figure 3-1 and table 3-1 are on sheet 2

Cripple Creek and Victor
Arequa VLF
Lag Time Calculation Using Natural Resources Conservation Service TR-55
Post Closure Watershed #4

Watershed Contribution Area

Sheet Flow

Mannings n (table 3-1) =	0.15
Flow Length (ft, max 300 ft) =	300
24 hr Rainfall, P_2 (in) =	1.8
Land Slope, s (ft/ft) =	0.010
Tt (hr) =	0.692
Tt (min) =	41.5

$$T_t = \frac{0.007(nl)^{0.8}}{P_2^{0.5} s^{0.4}}$$

Shallow Concentrated Flow

Flow Length, L (ft) =	1017
Watercourse Slope (ft/ft) =	0.150
Average Velocity, V (ft/sec, fig 3-1) =	6.25
Tt (hr) =	0.045
Tt (min) =	2.7

$$T_t = \frac{L}{3600V}$$

Channel Flow

Cross Sectional Flow Area, a (ft^2) =	37.5
Wetted Perimiter, p_w (ft) =	25.6
Hydraulic Radius, r = a/p_w (ft) =	1.46
Channel Slope, s (ft/ft) =	0.26
Manning's n =	0.035
V (ft/sec) =	28.00
Flow Length, L (ft) =	0
Tt (hr) =	-
Tt (min) =	-

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

$$T_t = \frac{L}{3600V}$$

Watershed or subarea Tc =	0.737
Lag time (hr) =	0.442
Lag time (min) =	**26.53**

Note: Figure 3-1 and table 3-1 are on sheet 2

Cripple Creek and Victor
Arequa VLF
Lag Time Calculation Using Natural Resources Conservation Service TR-55
Post Closure Watershed #5

Watershed Contribution Area

Sheet Flow

Mannings n (table 3-1) =	0.15
Flow Length (ft, max 300 ft) =	300
24 hr Rainfall, P_2 (in) =	1.8
Land Slope, s (ft/ft) =	0.010
Tt (hr) =	0.692
Tt (min) =	41.5

$$T_t = \frac{0.007(nl)^{0.8}}{P_2^{0.5} s^{0.4}}$$

Shallow Concentrated Flow

Flow Length, L (ft) =	2285
Watercourse Slope (ft/ft) =	0.170
Average Velocity, V (ft/sec, fig 3-1) =	6.75
Tt (hr) =	0.094
Tt (min) =	5.6

$$T_t = \frac{L}{3600V}$$

Channel Flow

Cross Sectional Flow Area, a (ft^2) =	37.5
Wetted Perimiter, p_w (ft) =	25.6
Hydraulic Radius, r = a/p_w (ft) =	1.46
Channel Slope, s (ft/ft) =	0.26
Manning's n =	0.035
V (ft/sec) =	28.00
Flow Length, L (ft) =	0
Tt (hr) =	-
Tt (min) =	-

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

$$T_t = \frac{L}{3600V}$$

Watershed or subarea Tc =	0.786
Lag time (hr) =	0.472
Lag time (min) =	**28.29**

Note: Figure 3-1 and table 3-1 are on sheet 2

Cripple Creek and Victor
Arequa VLF
Lag Time Calculation Using Natural Resources Conservation Service TR-55
North Diversion Channel - NW Reach

Watershed Contribution Area

Sheet Flow

Mannings n (table 3-1) =	0.15
Flow Length (ft, max 300 ft) =	0
24 hr Rainfall, P_2 (in) =	1.8
Land Slope, s (ft/ft) =	0.080
Tt (hr) =	-
Tt (min) =	-

$$T_t = \frac{0.007(nl)^{0.8}}{P_2^{0.5} s^{0.4}}$$

Shallow Concentrated Flow

Flow Length, L (ft) =	0
Watercourse Slope (ft/ft) =	0.180
Average Velocity, V (ft/sec, fig 3-1) =	6.75
Tt (hr) =	-
Tt (min) =	-

$$T_t = \frac{L}{3600V}$$

Channel Flow

Cross Sectional Flow Area, a (ft^2) =	37.5
Wetted Perimiter, p_w (ft) =	25.6
Hydraulic Radius, r = a/p_w (ft) =	1.46
Channel Slope, s (ft/ft) =	0.12
Manning's n =	0.035
V (ft/sec) =	19.02
Flow Length, L (ft) =	2022
Tt (hr) =	0.030
Tt (min) =	1.8

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

$$T_t = \frac{L}{3600V}$$

Watershed or subarea Tc =	0.030
Lag time (hr) =	0.018
Lag time (min) =	**1.06**

Note: Figure 3-1 and table 3-1 are on sheet 2

North Diversion Channel - NW Reach

Project Description

Friction Method	Manning Formula
Solve For	Discharge

Input Data

Roughness Coefficient	0.150	
Channel Slope	0.12000	ft/ft
Normal Depth	2.50	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	5.00	ft

Results

Discharge	165.91	ft³/s
Flow Area	37.50	ft²
Wetted Perimeter	25.62	ft
Top Width	25.00	ft
Critical Depth	2.01	ft
Critical Slope	0.31445	ft/ft
Velocity	4.42	ft/s
Velocity Head	0.30	ft
Specific Energy	2.80	ft
Froude Number	0.64	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	2.50	ft
Critical Depth	2.01	ft
Channel Slope	0.12000	ft/ft
Critical Slope	0.31445	ft/ft

Cripple Creek and Victor
Arequa VLF
Lag Time Calculation Using Natural Resources Conservation Service TR-55
North Diversion Channel - NE Reach

Watershed Contribution Area

Sheet Flow

Mannings n (table 3-1) =	0.15
Flow Length (ft, max 300 ft) =	0
24 hr Rainfall, P_2 (in) =	1.8
Land Slope, s (ft/ft) =	0.080
Tt (hr) =	-
Tt (min) =	-

$$T_t = \frac{0.007(nl)^{0.8}}{P_2^{0.5} s^{0.4}}$$

Shallow Concentrated Flow

Flow Length, L (ft) =	0
Watercourse Slope (ft/ft) =	0.180
Average Velocity, V (ft/sec, fig 3-1) =	6.75
Tt (hr) =	-
Tt (min) =	-

$$T_t = \frac{L}{3600V}$$

Channel Flow

Cross Sectional Flow Area, a (ft^2) =	37.5
Wetted Perimiter, p_w (ft) =	25.6
Hydraulic Radius, r = a/p_w (ft) =	1.46
Channel Slope, s (ft/ft) =	0.01
Manning's n =	0.035
V (ft/sec) =	5.49
Flow Length, L (ft) =	1423
Tt (hr) =	0.072
Tt (min) =	4.3

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

$$T_t = \frac{L}{3600V}$$

Watershed or subarea Tc =	0.072
Lag time (hr) =	0.043
Lag time (min) =	**2.59**

Note: Figure 3-1 and table 3-1 are on sheet 2

North Diversion Channel - NE Reach

Project Description

Friction Method	Manning Formula	
Solve For	Discharge	

Input Data

Roughness Coefficient	0.150	
Channel Slope	0.01000	ft/ft
Normal Depth	2.50	ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Bottom Width	5.00	ft

Results

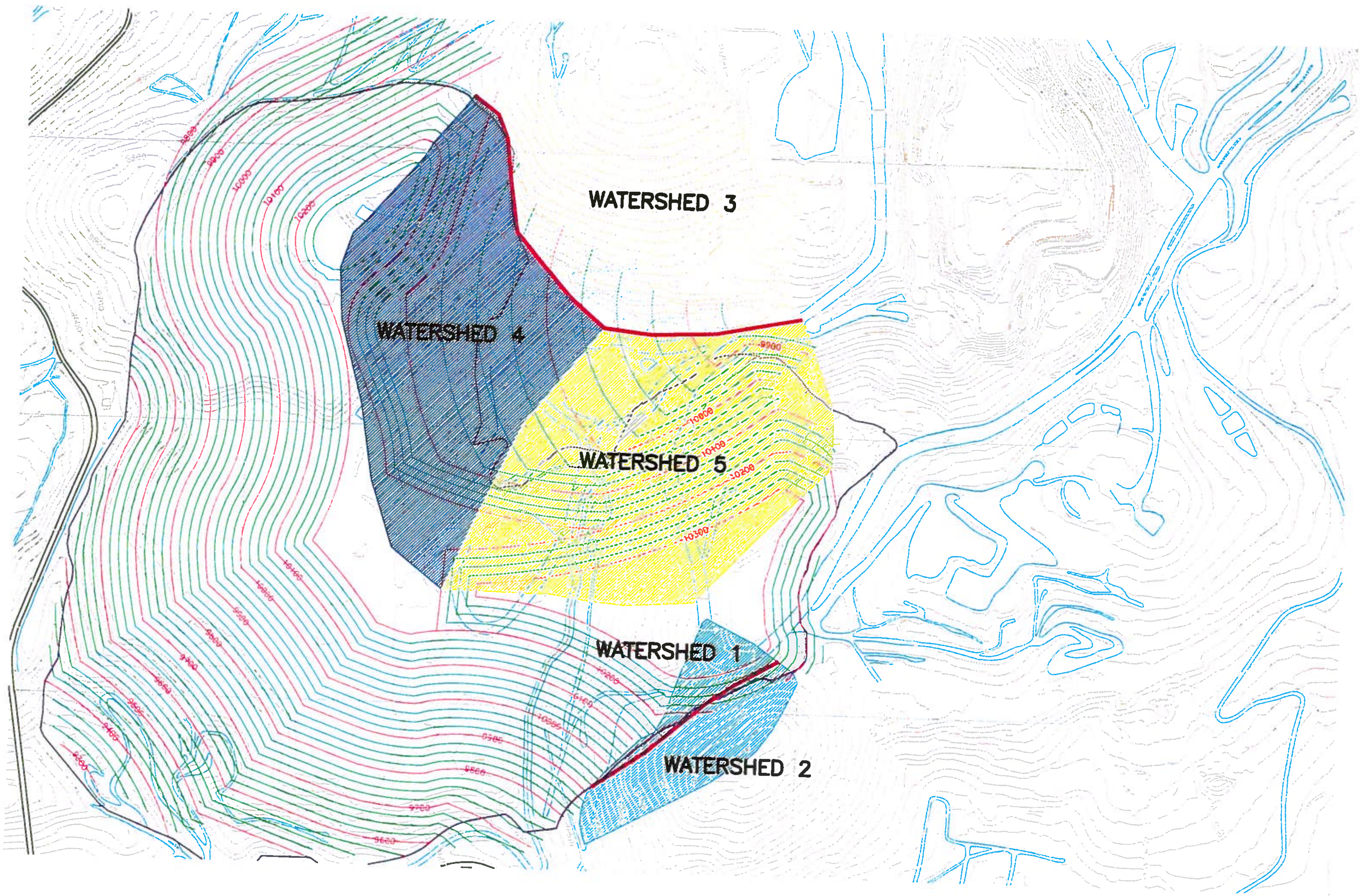
Discharge	47.89	ft^3/s
Flow Area	37.50	ft^2
Wetted Perimeter	25.62	ft
Top Width	25.00	ft
Critical Depth	1.07	ft
Critical Slope	0.37354	ft/ft
Velocity	1.28	ft/s
Velocity Head	0.03	ft
Specific Energy	2.53	ft
Froude Number	0.18	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	2.50	ft
Critical Depth	1.07	ft
Channel Slope	0.01000	ft/ft
Critical Slope	0.37354	ft/ft


WATERSHED 3
WATERSHED 4
WATERSHED 5
WATERSHED 1
WATERSHED 2

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

Table 3-1 Roughness coefficients (Manning's n) for sheet flow

Surface description	n [1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses [2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods: [3]	
Light underbrush	0.40
Dense underbrush	0.80

1 The n values are a composite of information compiled by Engman (1986).
2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
3 When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overtop and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5} s^{0.4}} \qquad \text{[eq. 3-3]}$$

where:

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1)
L = flow length (ft)
P_2 = 2-year, 24-hour rainfall (in)
s = slope of hydraulic grade line (land slope, ft/ft)

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels