APPENDIX 7-11

As-Built Calculations for
Diversions and Culverts

I hereby certify that the design contained herein was prepared by myself and is true and correct to the best of my knowledge.

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2/10/88

AS-BUILT REVIEW OF DIVERSIONS AND CULVERTS - CRANDALL CANYON MINE -

Undisturbed Areas

No alteration occurred to watersheds draining to proposed undisturbed-area diversions. Thus, check to determine that correct sizing was used.

Diversion NO.	Proposed Size	Actual Size
UD-1	42" CMP	42" CMP
UD-2	V-ditch, 1.5:1 sides, 1' deep	See below
UD-3	18" CMP	18" PVC

Summary:

UD-1 → Constructed as designed OK

UD-2 → See cross sections F-F' and G-G' on Plate 3
In both cases, the actual cross section is larger than the design cross section. Thus, the actual velocity will be lower than the design velocity. OK

UD-3 → PVC has a lower roughness than CMP. Thus the diversion as installed has a higher capacity than the design condition, making the diversion adequate. OK

Stilling Basin at Downstream End of UD-2

Item	Design	Actual	
Surface area (ft^2)	150	152	OK
Depth (ft)	3.0	4.4	OK
Volume (ft^3)	130	660	OK
Overflow device	12" CMP	12" CMP	OK

Basin is adequately sized.

Disturbed Areas – Diversion Ditches

Model input:

Diversion No.	Watershed Area (ac)				Average Curve Number [a]
	Undisturbed	Disturbed	Reclaimed	Total	
DD-1	0.11	0.00	0.10	0.21	72
DD-2	0.00	0.06	0.11	0.17	80
DD-3 [b]	0.27	0.59	0.34	1.20	81
DD-4	0.00	0.09	0.13	0.22	81
DD-5 [c]	3.70	1.46	1.10	6.26	75
DD-6 [d]	3.70	1.58	1.10	6.38	75
DD-7	0.05	0.09	0.31	0.45	77
DD-8	3.36	0.44	0.23	4.03	72
DD-9	0.00	0.13	0.13	0.26	82
DD-10 [e]	5.74	2.45	1.94	10.13	75
DD-11	1.94	0.02	0.15	2.11	70

[a] Based on CN = 69 → undisturbed
CN = 90 → disturbed
CN = 75 → reclaimed

[b] Includes WSDD-1 thru WSDD-3 (see Plate 7-5c for Watershed)

[c] Includes drainage to DD-3, DD-4 & DD-8 plus WSDD-5

[d] Includes drainage to DD-5 plus WSDD-6

[e] Includes drainage to DD-6, DD-7, DD-9, and DD-11 plus WSDD-10

Design storm → P = 2.50 in (10-yr, 24-hr)
Storm distribution → SCS Type II

Time of concentration calculations (use CN and upland methods):

DD-1 → $\ell = 165$ ft
$\bar{CN} = 72 \Rightarrow S = 3.89$
$Y = 39.9\%$

$$L = \frac{(165)^{0.8}(4.89)^{0.7}}{(1900)(39.9)^{0.5}} = 0.02 \text{ hr}$$

$T_c = (1.67)(0.02) = \underline{0.03 \text{ hr}}$

DD-2 → Travel distance = 140 ft (NNW to SSE)
Velocity = 3.5 ft/s (see attached chart for "short pasture grass" 25% slope)

$$T_c = \frac{140 \text{ ft}}{3.5 \text{ ft/s}} = 40 \text{ s} = \underline{0.01 \text{ hr}}$$

DD-3 → $\ell = 330$ ft
$\bar{CN} = 81 \Rightarrow S = 2.35$
$Y = 29.8\%$

$L = 0.02$ hr

$T_c = (1.67)(0.02) = \underline{0.04 \text{ hr}}$

DD-4 → Travel distance = 210 ft (down channel)
Velocity = 6.4 ft/s (see attached chart for "small upland gullies") 0% slope

$$T_c = \frac{210 \text{ ft}}{6.4 \text{ ft/s}} = \underline{0.01 \text{ hr}}$$

DD-5 → To the end of DD-8, $T_c = 0.13$ hr (see DD-8 calcs.)

From DD-8 to end of DD-5, travel distance = 370 ft @ 10% slope
Velocity = 6.4 ft/s

$$(T_c)_2 = \frac{370 \text{ ft}}{6.4 \text{ ft/s}} = 0.02 \text{ hr}$$

$T_c = 0.13 + 0.02 = \underline{0.15 \text{ hr}}$

DD-6 → Travel distance from DD-5 thru DD-6 = 220 ft
Velocity = 4.5 ft/s (see attached chart for "small upland gullies", 5% slope)

$$T_c = 0.15 \text{ hr} + \left(\frac{220 \text{ ft}}{4.5 \text{ ft/s}}\right) / 3600 \text{ s/hr} = \underline{0.16 \text{ hr}}$$

4/16

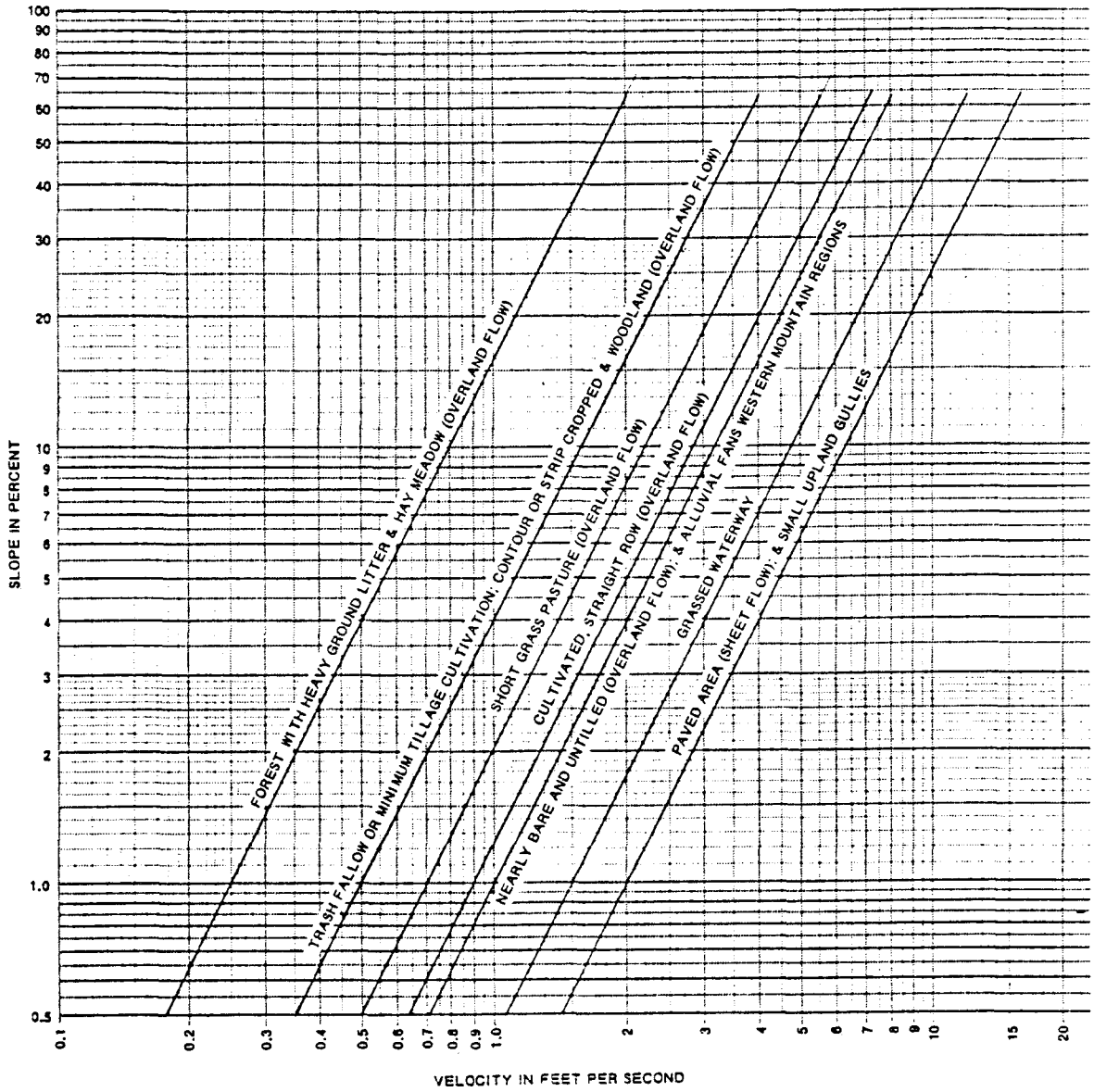

Figure 15.2.--Velocities for upland method of estimating T_c

Source: NEH-4

DD-7 → Travel distance = 110 ft
Velocity = 5.8 ft/s (see attached chart for "short pasture grass", 70% slope)

$$T_c = \frac{110\,ft}{5.8\,ft/s} = \underline{\underline{0.01\ hr}}$$

DD-8 → Undisturbed travel distance = 750 ft @ 66.1% slope
Velocity = 2.1 ft/s ("Forest w/ heavy litter")

$$(T_c)_1 = \frac{750\,ft}{2.1\,ft/s} = 360\ s$$

Disturbed travel distance = 540 ft @ 5.4% slope
Velocity = 4.6 ft/s

$$(T_c)_2 = \frac{540\,ft}{4.6\,ft/s} = 120\ s$$

$$T_c = (360\,s + 120\,s) = 480\,s = \underline{\underline{0.13\ hr}}$$

DD-9 → Travel distance = 310 ft @ 6.7% slope
Velocity = 5.2 ft/s ("small upland gullies")

$$T_c = \frac{310\,ft}{5.2\,ft/s} = \underline{\underline{0.02\ hr}}$$

DD-10 → To the end of DD-6, T_c = 0.16 hr

From DD-6 to end of DD-10, travel distance = 160 ft @ 33.3% slope
Velocity = 12 ft/s ("small upland gullies")

$$(T_c)_2 = \frac{160\,ft}{12\,ft/s} = 0.01\ hr$$

$$T_c = 0.16 + 0.01 = \underline{\underline{0.17\ hr}}$$

DD-11 → Travel distance = 550 ft @ 70% slope
Velocity = 2.1 ft/s ("Forest w/ heavy litter")

$$T_c = \frac{550\,ft}{2.1\,ft/s} = \underline{\underline{0.07\ hr}}$$

Hydrograph results → attached (pg. 6-11 of this calc.)

```
*********************************
* EARTHFAX ENGINEERING. INC.    *
*                               *
* HYDROGRAPH GENERATION MODEL   *
*   USING SCS CURVE NUMBER      *
*         METHODOLOGY           *
*********************************
```

IDENTIFICATION: DIVERSION DD-1

INPUT SUMMARY:

```
*************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.001 SQ. MI.
        DEPTH =  2.50 IN.               CN = 72.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.03 HR.
*************************************************************
```

```
*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.5286 INCHES
     INITIAL ABSTRACTION =  0.7778 INCHES
     PEAK FLOW =      0.37 CFS   ( 0.5781 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.5297 INCHES
*************************************************************
```

IDENTIFICATION: DIVERSION DD-2

INPUT SUMMARY:

```
*************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.001 SQ. MI.
        DEPTH =  2.50 IN.               CN = 80.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.01 HR.
*************************************************************
```

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*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.8889 INCHES
     INITIAL ABSTRACTION =  0.5000 INCHES
     PEAK FLOW =      0.58 CFS   ( 0.9063 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.8907 INCHES
*************************************************************
```

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*******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*        METHODOLOGY          *
*******************************
```

IDENTIFICATION: DIVERSION DD-3

INPUT FOR: Genwall - Diversion Ditch DD-3

STORM :	WATERSHED :
Dist.=SCS Type II - 24 Hr	Area = 1.24 acres
Depth = 2.50 inches	CN = 81.00
Duration = 24.00 hrs	Time conc.= 0.040 hrs

OUTPUT SUMMARY

Runoff depth	0.94239	inches	
Initial abstr	0.46914	inches	
Peak flow =	1.30	cfs	(1.03691 iph)
at time	12.005	hrs	

INPUT FOR: Genwall - Diversion DD-4

STORM :	WATERSHED :
Dist.-SCS Type II - 24 Hr	Area - 0.18 acres
Depth - 2.50 inches	CN - 95.00
Duration - 24.00 hrs	Time conc.- 0.020 hrs

OUTPUT SUMMARY

Runoff depth	1.96325	inches	
Initial abstr	0.10526	inches	
Peak flow -	0.32	cfs	(1.77764 iph)
at time	12.002	hrs	

```
*******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

IDENTIFICATION: DIVERSION DD-5

INPUT SUMMARY:

```
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.010 SQ. MI.
        DEPTH =  2.50 IN.              CN = 75.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.15 HR.
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*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.6505 INCHES
     INITIAL ABSTRACTION =  0.6667 INCHES
     PEAK FLOW =      4.02 CFS  ( 0.6228 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.6518 INCHES
*************************************************************
```

IDENTIFICATION: DIVERSION DD-6

INPUT SUMMARY:

```
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.010 SQ. MI.
        DEPTH =  2.50 IN.              CN = 75.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.16 HR.
*************************************************************
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*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.6505 INCHES
     INITIAL ABSTRACTION =  0.6667 INCHES
     PEAK FLOW =      3.96 CFS  ( 0.6140 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.6518 INCHES
*************************************************************
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*******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

IDENTIFICATION: DIVERSION DD-7

INPUT SUMMARY:

```
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.001 SQ. MI.
        DEPTH =  2.50 IN.            CN = 77.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.01 HR.
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************************************************************
```

OUTPUT SUMMARY:

```
************************************************************
     TOTAL RUNOFF DEPTH =  0.7403 INCHES
     INITIAL ABSTRACTION =  0.5974 INCHES
     PEAK FLOW =     0.52 CFS  ( 0.8125 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.7418 INCHES
************************************************************
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IDENTIFICATION: DIVERSION DD-8

INPUT SUMMARY:

```
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.006 SQ. MI.
        DEPTH =  2.50 IN.            CN = 72.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.13 HR.
************************************************************
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************************************************************
```

OUTPUT SUMMARY:

```
************************************************************
     TOTAL RUNOFF DEPTH =  0.5286 INCHES
     INITIAL ABSTRACTION =  0.7778 INCHES
     PEAK FLOW =     1.97 CFS  ( 0.5078 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.5297 INCHES
************************************************************
```

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*******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

IDENTIFICATION: DIVERSION DD-9

INPUT SUMMARY:

```
*************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.001 SQ. MI.
        DEPTH =  2.50 IN.              CN = 82.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.02 HR.
*************************************************************
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*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.9980 INCHES
     INITIAL ABSTRACTION =  0.4390 INCHES
     PEAK FLOW =      0.67 CFS   ( 1.0313 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  1.0000 INCHES
*************************************************************
```

IDENTIFICATION: DIVERSION DD-10

INPUT SUMMARY:

```
*************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.016 SQ. MI.
        DEPTH =  2.50 IN.              CN = 75.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.17 HR.
*************************************************************
```

```
*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.6505 INCHES
     INITIAL ABSTRACTION =  0.6667 INCHES
     PEAK FLOW =      6.27 CFS   ( 0.6069 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.6518 INCHES
*************************************************************
```

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*******************************
* EARTHFAX ENGINEERING. INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

IDENTIFICATION: DIVERSION DD-11

INPUT SUMMARY:

```
*****************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.003 SQ. MI.
        DEPTH =  2.50 IN.              CN = 70.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.07 HR.
*****************************************************************
```

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*****************************************************************
```

OUTPUT SUMMARY:

```
*****************************************************************
     TOTAL RUNOFF DEPTH =  0.4552 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      0.91 CFS  ( 0.4688 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.4562 INCHES
*****************************************************************
```

Determine adequacy of actual cross sections based on flow rates presented on pg. 6-11 of this calc. See cross sections on Plate 3. For ease of calculation, initially assume equal side slopes on both sides of channel, with both side slopes being equal to the minimum actual slope (thus making the cross section conservatively small). If the velocity as calculated with this condition is acceptable, the channel design will be considered adequate. If the velocity is > 5 ft/s under this conservative condition, calculate velocity using actual non-uniform cross section.

TRAP1 results:

DD-1 (cross section H-H'):

Bed Slope =	.25	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.5	
Flow Depth =	.2172315	feet
Cross Sectional Area =	9.437906E-02	square feet
Wetted Perimeter =	.9714882	feet
Hydraulic Radius =	9.714889E-02	feet
Discharge =	.37	cubic feet/sec
Velocity =	3.920361	feet/sec
Froude Number =	1.482302	< 5.0 ⇒ OK

DD-2 (cross section N-N'):

Bed Slope =	.02	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.5	
Flow Depth =	.3813819	feet
Cross Sectional Area =	.2909044	square feet
Wetted Perimeter =	1.705592	feet
Hydraulic Radius =	.1705592	feet
Discharge =	.58	cubic feet/sec
Velocity =	1.993783	feet/sec
Froude Number =	.3589447	< 5.0 OK

DD-3 (cross section I-I'):

Bed Slope =	.03	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.833	
Flow Depth =	.650971	feet
Cross Sectional Area =	.5087193	square feet
Wetted Perimeter =	2.034179	feet
Hydraulic Radius =	.2500859	feet
Discharge =	1.3	cubic feet/sec
Velocity =	2.555437	feet/sec
Froude Number =	.558157	<5.0 OK

Triangular Channel Analysis & Design
Open Channel - Uniform flow

Worksheet Name: Genwall

Comment: DD-4 (cross section c-c')

Solve For Depth

Given Input Data:

Left Side Slope..	2.00:1 (H:V)
Right Side Slope.	2.00:1 (H:V)
Manning's n.....	0.040
Channel Slope....	0.0950 ft/ft
Discharge.....	0.32 cfs

Computed Results:

Depth.....	0.25 ft	→ FLOW DEPTH < CHANNEL
Velocity.....	2.63 fps	→ < 5.0 FPS OK
Flow Area.....	0.12 sf	
Flow Top Width...	0.99 ft	
Wetted Perimeter.	1.10 ft	
Critical Depth...	0.28 ft	
Critical Slope...	0.0524 ft/ft	
Froude Number....	1.32 (flow is Supercritical)	

Open Channel Flow Module, Version 3.2 (c) 1990
Haestad Methods, Inc. * 37 Brookside Rd * Waterbury, Ct 06708

DD-5 (cross section E-E'):

Bed Slope =	.08	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.7143	
Flow Depth =	.7700968	feet
Cross Sectional Area =	.830252	square feet
Wetted Perimeter =	2.649814	feet
Hydraulic Radius =	.3133246	feet
Discharge =	4.02	cubic feet/sec
Velocity =	4.841903	feet/sec
Froude Number =	.9723341	<5.0 OK

DD-6 (cross section J-J'):

Bed Slope =	.045	
Manning's N =	.04	
Bottom Width =	1.3	feet
Channel Side Slope =	.6667	
Flow Depth =	.4594088	feet
Cross Sectional Area =	.9138001	square feet
Wetted Perimeter =	2.756365	feet
Hydraulic Radius =	.3090959	feet
Discharge =	3.96	cubic feet/sec
Velocity =	4.333582	feet/sec
Froude Number =	1.126721	< 5.0 OK

DD-7 (cross section L-L'):

Bed Slope =	.005	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	1	
Flow Depth =	.7044704	feet
Cross Sectional Area =	.4962785	square feet
Wetted Perimeter =	1.992543	feet
Hydraulic Radius =	.2490679	feet
Discharge =	.52	cubic feet/sec
Velocity =	1.047788	feet/sec
Froude Number =	.2199979	< 5.0 OK

DD-8 (cross section B-B'):

Bed Slope =	.051	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.4167	
Flow Depth =	.5064729	feet
Cross Sectional Area =	.6155863	square feet
Wetted Perimeter =	1.633479	feet
Hydraulic Radius =	.333754	feet
Discharge =	1.87	cubic feet/sec
Velocity =	3.200202	feet/sec
Froude Number =	.7924489	< 5.0 OK

DD-9 (cross section K-K'):

Bed Slope =	.065	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.4762	
Flow Depth =	.3413474	feet
Cross Sectional Area =	.244683	square feet
Wetted Perimeter =	1.587882	feet
Hydraulic Radius =	.154094	feet
Discharge =	.67	cubic feet/sec
Velocity =	2.738237	feet/sec
Froude Number =	.825933	< 5.0 OK

DD-10 (cross section M-M'):

Bed Slope =	.0333	
Manning's N =	.04	
Bottom Width =	8	feet
Channel Side Slope =	.4	
Flow Depth =	.1367868	feet
Cross Sectional Area =	1.172389	square feet
Wetted Perimeter =	8.771234	feet
Hydraulic Radius =	.1296941	feet
Discharge =	6.27	cubic feet/sec
Velocity =	5.136706	feet/sec
Froude Number =	2.547763	> 5.0. However, channel is proposed for V = 8.2 ft/s Thus, channel OK

DD-11 (cross section O-O'):

Bed Slope =	.02	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	1	
Flow Depth =	.6230524	feet
Cross Sectional Area =	.3882018	square feet
Wetted Perimeter =	1.762275	feet
Hydraulic Radius =	.2202844	feet
Discharge =	.91	cubic feet/sec
Velocity =	2.344142	feet/sec
Froude Number =	.5233491	

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ENGINEERS / SCIENTISTS

PROJECT _____ PAGE _____ OF 18
COMPUTED TBW DATE 30 Dec 1983
CHECKED _____ DATE _____

Disturbed Areas – Culverts

Culvert No.	Type		Inflow (cfs)		Adequacy
	Design	Actual	Design	Actual	
C-1	18" CMP	18" CMP	4.15	3.25 (a)	OK
C-2	24" CMP	24" CMP	4.15	4.02 (b)	OK
C-3	12" CMP	12" CMP	4.15	3.96 (c)	OK (d)
C-4	24" CMP	24" CMP	0.67	1.43 (e)	OK (f)
C-5	12" CMP	12" PVC	1.09	0.91 (e)	OK
C-6	12" CMP	12" CMP	(g)	(g)	OK

(a) DD-3 + DD-8 flows
(b) DD-5 flow
(c) DD-6 flow
(d) DD-7 + DD-11 flows
(e) DD-11 flow
(f) Capacity of 24" CMP (w/ HW/D = 1.0) is 13.0 cfs
(g) Outflow from stilling basin. With larger actual basin than designed, outflow culvert (w/ additional routing) is considered adequate.
(h) The required headwater for adequate flow is 21.5 feet. 32 inches of headwater are present.