**APPENDIX 7-11**

**Calculations for Existing Diversions and Culverts**

REGISTERED PROFESSIONAL ENGINEER
No. 7933
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STATE OF UTAH

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

R. Jay Marshall

**2/25/94**

# 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.

Areas and Curve Number Determination
for
Diversion Ditches

Model Input: (a)

Watershed Area (ac)

| Diversion No. | Undisturbed | Disturbed | Reclaimed | Paved | Total | Average Curve Number |
|---|---|---|---|---|---|---|
| DD-1 | 0.11 | 0.00 | 0.10 | 0.00 | 0.21 | 72 |
| DD-3[b] | 0.28 | 0.60 | 0.36 | 0.00 | 1.24 | 81 |
| DD-4 | 0.00 | 0.00 | 0.00 | 0.18 | 0.18 | 95 |
| DD-5[c] | 3.70 | 1.46 | 1.10 | 0.00 | 6.26 | 75 |
| DD-7 | 0.05 | 0.09 | 0.31 | 0.00 | 0.45 | 77 |
| DD-8 | 3.36 | 0.44 | 0.23 | 0.00 | 4.03 | 72 |
| DD-9 | 0.00 | 0.13 | 0.13 | 0.00 | 0.26 | 82 |
| DD-11 | 1.94 | 0.02 | 0.15 | 0.00 | 2.11 | 70 |

(a) Based on: CN=69 for Undisturbed
CN=90 for Disturbed
CN=75 for Reclaimed
CN=95 for Paved

(b) Includes WSDD-1 through WSDD-3 (See Plate 7-5c)

(c) Includes drainage to DD-3, DD-4 and DD-8 plus WSDD-5.

Design Storm = P=2.50 in. (10yr. - 24hr.).
Storm Distribution = SCS Type II.

# DESIGN OF DIVERSIONS AND CULVERTS — CRANDALL CANYON MINE

## Design of UD-1

Watersheds draining to UD-1 ⟶ WS-1 and WS-2

WS-1 ⟶ Area = 95.2 ac = 0.149 mi²

$l = 3850$ ft

CN = 69 (undisturbed)

$$S = \frac{1000}{69} - 10 = 4.49$$

$$Y = \left[\frac{(55{,}600\text{ ft})(40\text{ ft})}{(95.2\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100)$$

$$= 53.6\%$$

$$L = \frac{(3850)^{0.8}(1+4.49)^{0.7}}{(1900)(53.6)^{0.5}} = 0.17\text{ hr}$$

$$T_c = (1.67)(0.17) = 0.29\text{ hr}$$

WS-2 ⟶ Area = 0.9 ac undisturbed
+ 0.3 ac reclaimed
1.2 ac = 0.002 mi²

$l = 650$ ft

CN = 69 for undisturbed area
= 75 for reclaimed area

$$\overline{CN} = \frac{(69)(0.9) + (75)(0.3)}{1.2} = 71$$

$$S = \frac{1000}{71} - 10 = 4.08$$

$$Y = \left[\frac{(1000\text{ ft})(40\text{ ft})}{(1.2\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 76.5\%$$

$$L = \frac{(650)^{0.8}(1+4.08)^{0.7}}{(1900)(76.5)^{0.5}} = 0.03\text{ hr}$$

Design storm → use 25-yr, 24-hr storm. P = 2.92 in (Miller et al., 1973).

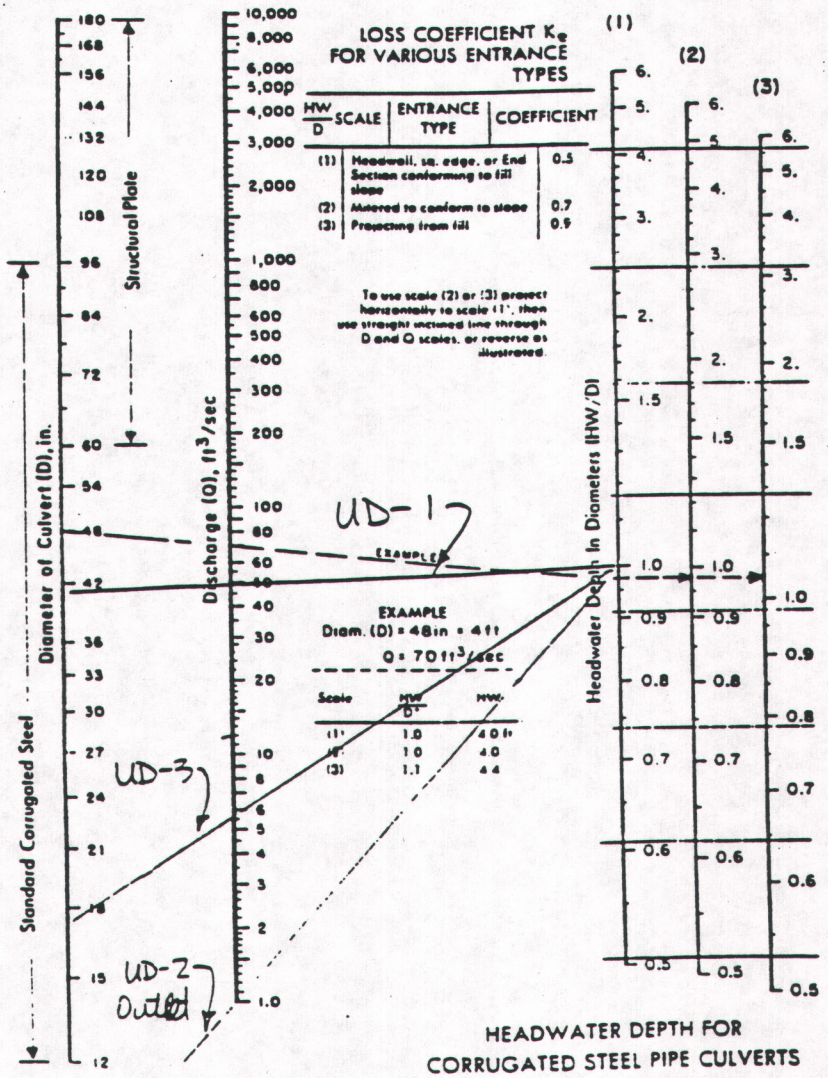
Rainfall distribution → SCS Type II

Hydrograph results (from Hawkins & Marshall model) – see page 3 of this calc.:

WS-1 → q = 46.7 cfs @ 12.08 hr
WS-2 → q = 1.0 cfs @ 12.00 hr

→ $q_{Total}$ = 46.7 + 1.0 = 47.7 cfs

This flow will be diverted into a CMP. Required size:




HEADWATER DEPTH FOR CORRUGATED STEEL PIPE CULVERTS WITH INLET CONTROL

Use 42" CMP w/ flared end section

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

IDENTIFICATION: WS-1 - TYPE II

INPUT SUMMARY:

```
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II           AREA =  0.149 SQ. MI.
        DEPTH =  2.92 IN.             CN = 69.0
        DURATION = 24.0 HR.           TIME OF CONC. =  0.29 HR.
*************************************************************
```

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

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.6273 INCHES
     INITIAL ABSTRACTION =  0.8986 INCHES
     PEAK FLOW =     46.72 CFS  ( 0.4858 IN/HR)
     TIME TO PEAK =  12.08 HOURS
     RUNOFF VOLUME CHECK =  0.6285 INCHES
*************************************************************
```

IDENTIFICATION: WS-2 25-YR 24-HR STORM

INPUT SUMMARY:

```
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II           AREA =  0.002 SQ. MI.
        DEPTH =  2.92 IN.             CN = 71.0
        DURATION = 24.0 HR.           TIME OF CONC. =  0.05 HR.
*************************************************************
```

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

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.7148 INCHES
     INITIAL ABSTRACTION =  0.8169 INCHES
     PEAK FLOW =     0.99 CFS  ( 0.7637 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.7163 INCHES
*************************************************************
```

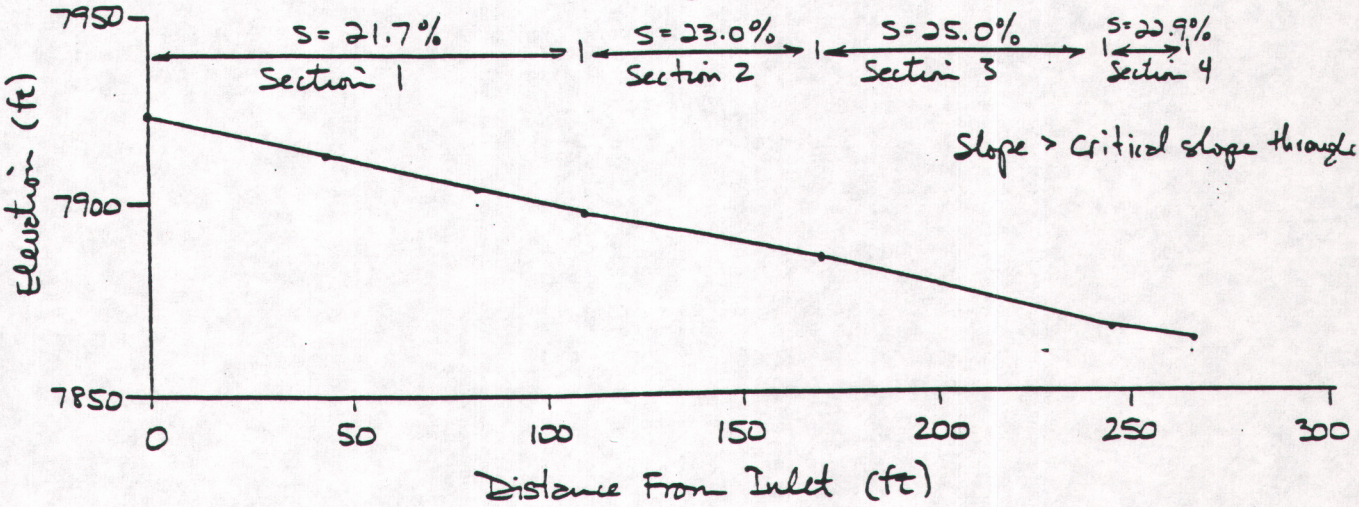
Determine critical slope for UD-1 – From nomographs in NEH-5:

$$\frac{Q}{D^{2.5}} = \frac{47.7 \text{ cfs}}{(3.5)^{2.5}} = 2.081 \Longrightarrow \frac{d_c}{D} = 0.616$$

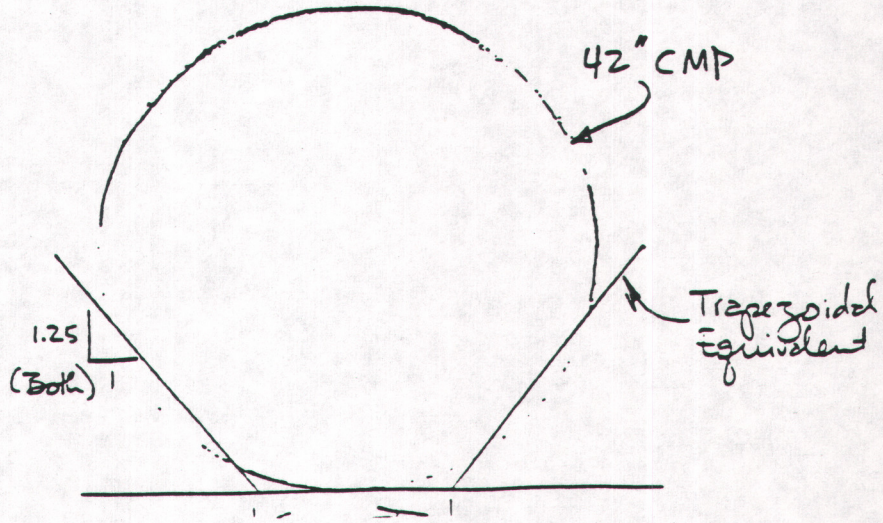
When $\frac{d_n}{D} = 0.616$, $\frac{nQ}{D^{8/3} S_c^{\frac{1}{2}}} = 0.324$

With $\left.\begin{array}{l} n = 0.024 \\ Q = 2025 \\ D = 2.5 \end{array}\right\}$ $S_c = \left[\frac{(0.024)(47.7)}{(3.5)^{8/3}(0.324)}\right]^2 = 0.016$ ft/ft

Culvert profile (from survey):




Approximate flow depths in each section → treat the culvert as a trapezoidal channel and use TRAP1 from the OSM Hydro. package:



Section 1:

| | | |
|---|---|---|
| Bed Slope = | .217 | |
| Manning's N = | .024 | |
| Bottom Width = | 1.4 | feet |
| Channel Side Slope = | 1.25 | |
| Flow Depth = | 1.056449 | feet |
| Cross Sectional Area = | 2.371896 | square feet |
| Wetted Perimeter = | 4.105829 | feet |
| Hydraulic Radius = | .5776898 | feet |
| Discharge = | 47.7 | cubic feet/sec |
| Velocity = | 20.1105 | feet/sec |
| Froude Number = | 3.448027 | |

Section 2:

| | | |
|---|---|---|
| Bed Slope = | .23 | |
| Manning's N = | .024 | |
| Bottom Width = | 1.4 | feet |
| Channel Side Slope = | 1.25 | |
| Flow Depth = | 1.040392 | feet |
| Cross Sectional Area = | 2.32248 | square feet |
| Wetted Perimeter = | 4.064703 | feet |
| Hydraulic Radius = | .5713776 | feet |
| Discharge = | 47.7 | cubic feet/sec |
| Velocity = | 20.53839 | feet/sec |
| Froude Number = | 3.548461 | |

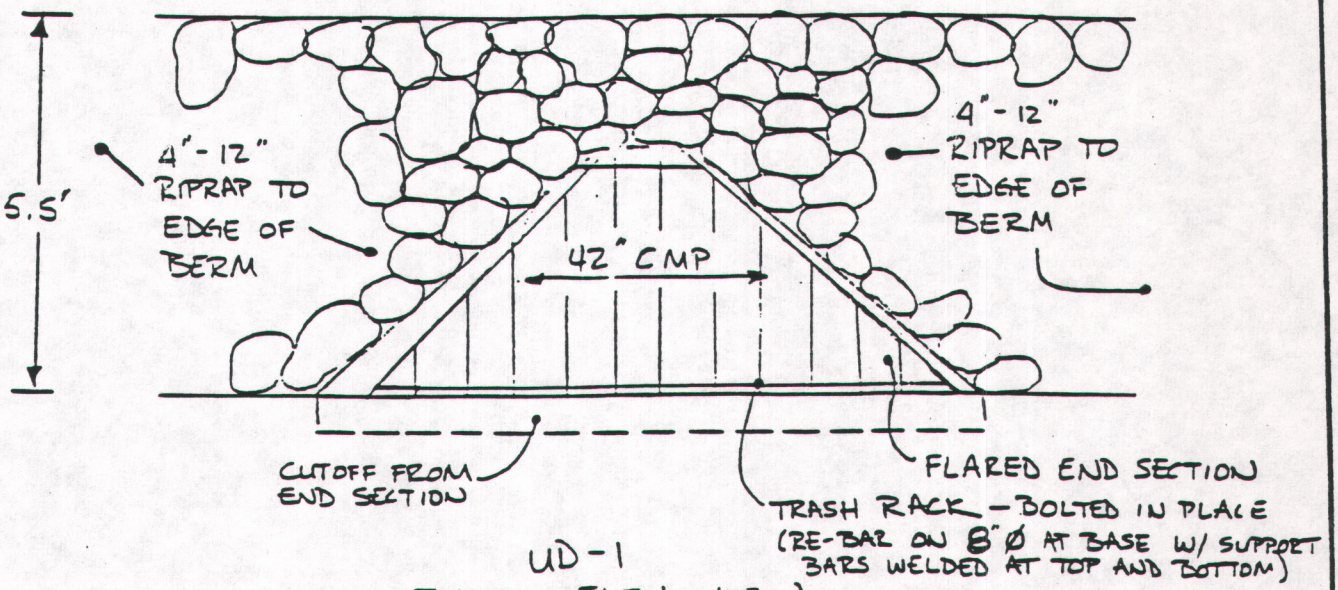
Section 3:

| | | |
|---|---|---|
| Bed Slope = | .25 | |
| Manning's N = | .024 | |
| Bottom Width = | 1.4 | feet |
| Channel Side Slope = | 1.25 | |
| Flow Depth = | 1.017745 | feet |
| Cross Sectional Area = | 2.253487 | square feet |
| Wetted Perimeter = | 4.006699 | feet |
| Hydraulic Radius = | .5624298 | feet |
| Discharge = | 47.7 | cubic feet/sec |
| Velocity = | 21.1672 | feet/sec |
| Froude Number = | 3.697566 | |

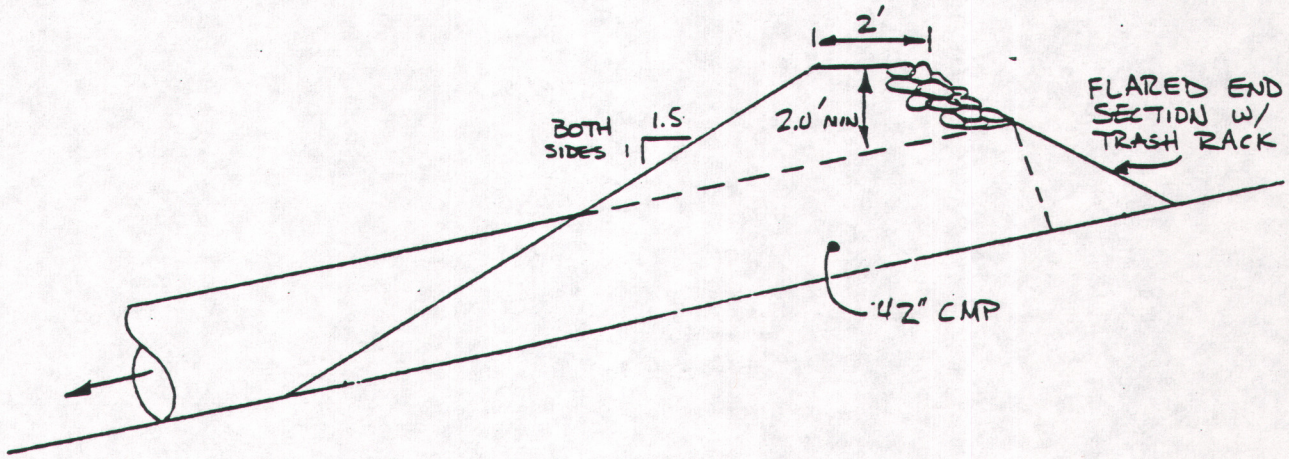
Section 4:

| | | |
|---|---|---|
| Bed Slope = | .229 | |
| Manning's N = | .024 | |
| Bottom Width = | 1.4 | feet |
| Channel Side Slope = | 1.25 | |
| Flow Depth = | 1.041587 | feet |
| Cross Sectional Area = | 2.326144 | square feet |
| Wetted Perimeter = | 4.067764 | feet |
| Hydraulic Radius = | .5718483 | feet |
| Discharge = | 47.7 | cubic feet/sec |
| Velocity = | 20.50604 | feet/sec |
| Froude Number = | 3.540839 | |

Diversion inlet:
(UD-1)




UD-1
INLET ELEV. VIEW




UD-1
INLET SIDE VIEW

UD-1 to remain as a full-round culvert through its entire length. Typical elev. and side views of the culvert at the USFS road crossing are shown on page 8 of this calc.

Exit velocity from UD-1 → use the pipe flow equation:

$$V = \frac{(2gH)^{1/2}}{(1 + K_e + K_b + K_c L)^{1/2}}$$

where H = total head (elevation head + velocity head)

$K_e$ = entrance loss coefficient

$K_b$ = bend loss coefficient

$$K_c = \frac{5087\, n^2}{d_i^{4/3}}$$

L = length (ft)

Elevation head = 22.5 ft (see page 8 of this calc)

Velocity head $= \frac{V^2}{2g} = \frac{(20.5)^2}{(2)(32.2)}$ → (from page 5 of this calc.)

$= 6.5$ ft

L = 25 ft

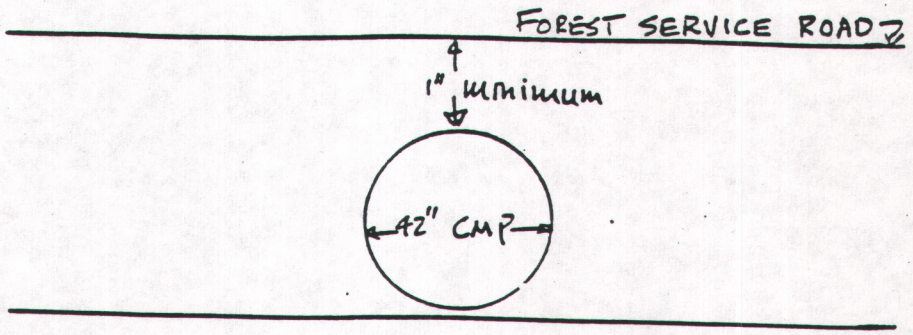
H = 22.5 + 6.5 = 29.0 ft

$K_e = 1.0$, $K_b = 0.5$ } Barfield et al. (1981)

$$K_c = \frac{5087\, n^2}{d_i^{4/3}} \quad \text{(Assume } n = 0.024\text{)}$$

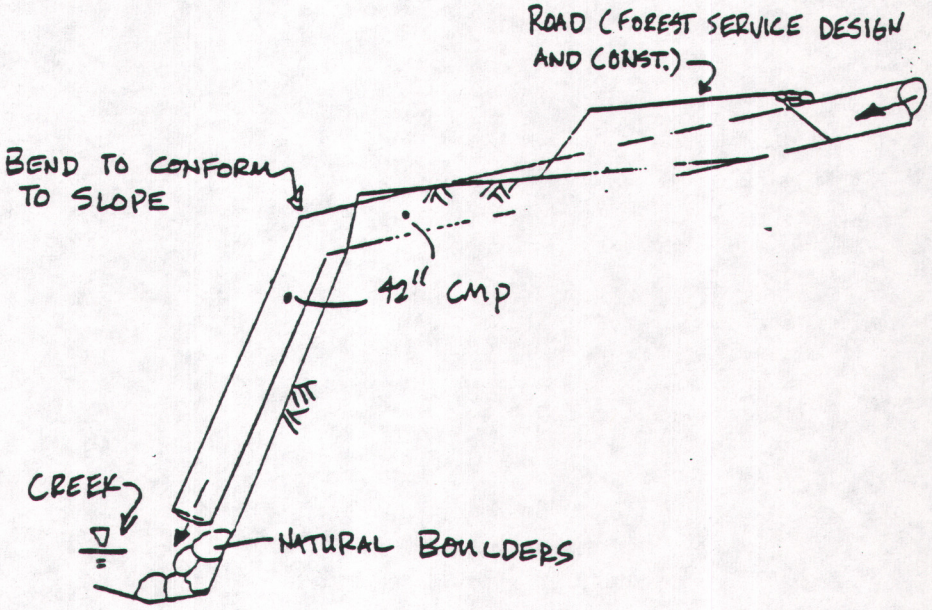
$$= \frac{(5087)(0.024)^2}{(42)^{4/3}} = 0.020$$

Diversion outlet:




UD-1

DOWNSTREAM INLET ELEVATION VIEW




UD-1

DOWNSPOUT SIDE VIEW

Scale: 1" = 10'

## Design of UD-2

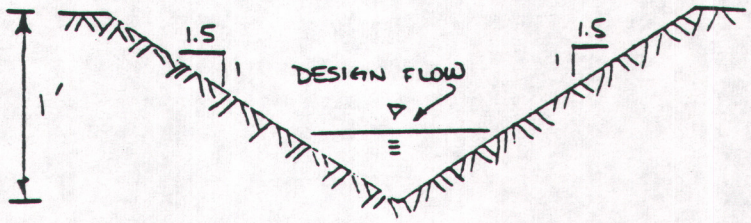
Contributing watershed → WS-2

25-yr, 24-hr storm peak flow → q = 0.99 cfs (see page 5 of this calc.)

Slope along substation pad = (2.8 ft / 115 ft)(100) = 2.4%
Assume n = 0.040 (see Barfield et al., 1981 — Their pg. 159, Table 3.1, design n value for "small drainage ditches".)
Max. permissible velocity = 5.0 ft/s (see Barfield et al., 1981 — Their pg. 162, Table 3.2, value for "graded loam to cobbles when noncolloidal. Compare with gradation curve on pg. 13 of Appendix 7 L).

DESIGN USING TRAD1:

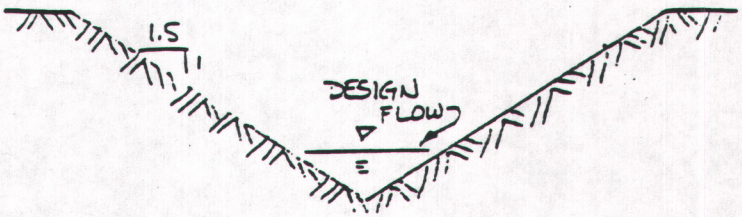
| | | |
|---|---|---|
| Bed Slope = | .024 | |
| Manning's N = | .04 | |
| Bottom Width = | 0 | feet |
| Channel Side Slope = | .6667 | |
| Flow Depth = | .5516454 | feet |
| Cross Sectional Area = | .4564462 | square feet |
| Wetted Perimeter = | 1.988917 | feet |
| Hydraulic Radius = | .2294948 | feet |
| Discharge = | .99 | cubic feet/sec |
| Velocity = | 2.168931 | feet/sec |
| Froude Number = | .5146213 | - Acceptable |




UD-2 AT SUBSTATION PAD - ELEV.
SCALE: 1" = 1'

Along the road leading to the substation pad, the slope of UD-2 will increase. Using this new slope, the following results were obtained from TRAP1:

| | | |
|---|---|---|
| Bed Slope = | .172 | |
| Manning's N = | .04 | |
| Bottom Width = | 0 | feet |
| Channel Side Slope = | .6667 | |
| Flow Depth = | .3811063 | feet |
| Cross Sectional Area = | .2178521 | square feet |
| Wetted Perimeter = | 1.374051 | feet |
| Hydraulic Radius = | .1585474 | feet |
| Discharge = | .99 | cubic feet/sec |
| Velocity = | 4.544368 | feet/sec |
| Froude Number = | 1.297246 | Acceptable |




UD-2 AT SUBSTATION ROAD – ELEV.
SCALE: 1" = 1'

Note → same size used throughout UD-2.

## Design of UD-3

Contributing watershed → WS-3

$$\left.\begin{aligned} l &= 1320 \text{ ft} \\ s &= \frac{1000}{69} - 10 = 4.49 \\ Y &= \left(\frac{160 \text{ ft}}{230 \text{ ft}}\right)(100) = 69.6\% \end{aligned}\right\} \quad L = \frac{(1320)^{0.8}(5.49)^{0.7}}{(1900)(69.6)^{0.5}} = 0.07 \text{ hr}$$

$$T_c = (1.67)(0.07) = 0.12 \text{ hr}$$

$$\text{Area} = 8.8 \text{ ac} = 0.014 \text{ mi}^2$$

Design of Stilling Basin at the Downstream End of UD-2

This stilling basin will provide erosion protection during the period that vegetation is being established on the substation pad. Sufficient space exists for as basin with surface dimensions of 15'x10'. The outlet from this basin will consist of a 12" CMP that will stub into UD-1 a sufficient distance downstream from the stilling basin to ensure that the elevation of the top of UD-1 is lower than the invert of the outlet culvert from the stilling basin. See Appendix 7-9 for design details.

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

IDENTIFICATION: UD-3

INPUT SUMMARY:

```
*************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE B                AREA =  0.014 SQ. MI.
        DEPTH =  1.90 IN.                *CN = 69.0
        DURATION = 36.0 HR.               TIME OF CONC. =  0.12 HR.
*************************************************************
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*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.1825 INCHES
     INITIAL ABSTRACTION =  0.8986 INCHES
     PEAK FLOW =    0.78 CFS  ( 0.0861 IN/HR)
     TIME TO PEAK =   2.55 HOURS
     RUNOFF VOLUME CHECK =  0.1829 INCHES
*************************************************************
```

From calculations on pages 16 and 17 of this appendix a 12" pipe is adequate to handle storm runoff from WS-3. An 18" PVC inlet structure (as shown on p. 12) and a reducer (18" to 12") will be used. The 12" pipe will run along the face of the highwall and discharge into an existing channel east of the portal pad. The 12" pipe shall be fastened to the highwall with metal straps, roof bolts, and other braces as required.

* The CN of 69 for WS-3 is based on undisturbed area and is consistant with numbers used for WS-1 and WS-2 for undisturbed area.

Circular Channel Analysis & Design
Solved with Manning's Equation

Open Channel - Uniform flow

Worksheet Name: Genwall UD-3

Comment: 12" CMP - Outlet velocity

Solve For Actual Depth

Given Input Data:

| | |
|---|---|
| Diameter..... | 1.00 ft |
| Slope..... | 0.0800 ft/ft |
| Manning's n..... | 0.024 |
| Discharge..... | 0.78 cfs |

Computed Results:

| | |
|---|---|
| Depth..... | 0.26 ft |
| Velocity..... | 4.93 fps ← Outlet Velocity OK! |
| Flow Area..... | 0.16 sf |
| Critical Depth.... | 0.37 ft |
| Critical Slope.... | 0.0194 ft/ft |
| Percent Full..... | 25.54 % |
| Full Capacity..... | 5.46 cfs |
| QMAX @.94D..... | 5.87 cfs |
| Froude Number..... | 2.04 (flow is Supercritical) |

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

Circular Channel Analysis & Design
Solved with Manning's Equation

Open Channel - Uniform flow

Worksheet Name: Genwall UD-3

Comment: 12" CMP - 24-year, 6-hour storm

Solve For Actual Depth

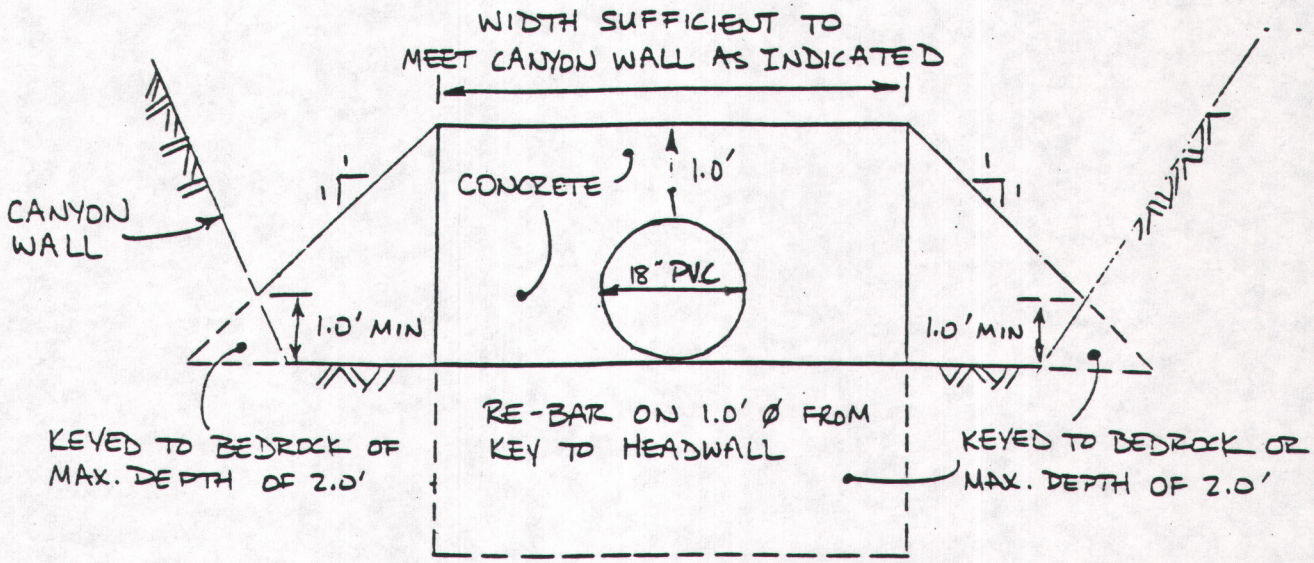
Given Input Data:

| | |
|---|---|
| Diameter..... | 1.00 ft |
| Slope..... | 0.0100 ft/ft |
| Manning's n..... | 0.024 |
| Discharge..... | 0.78 cfs |

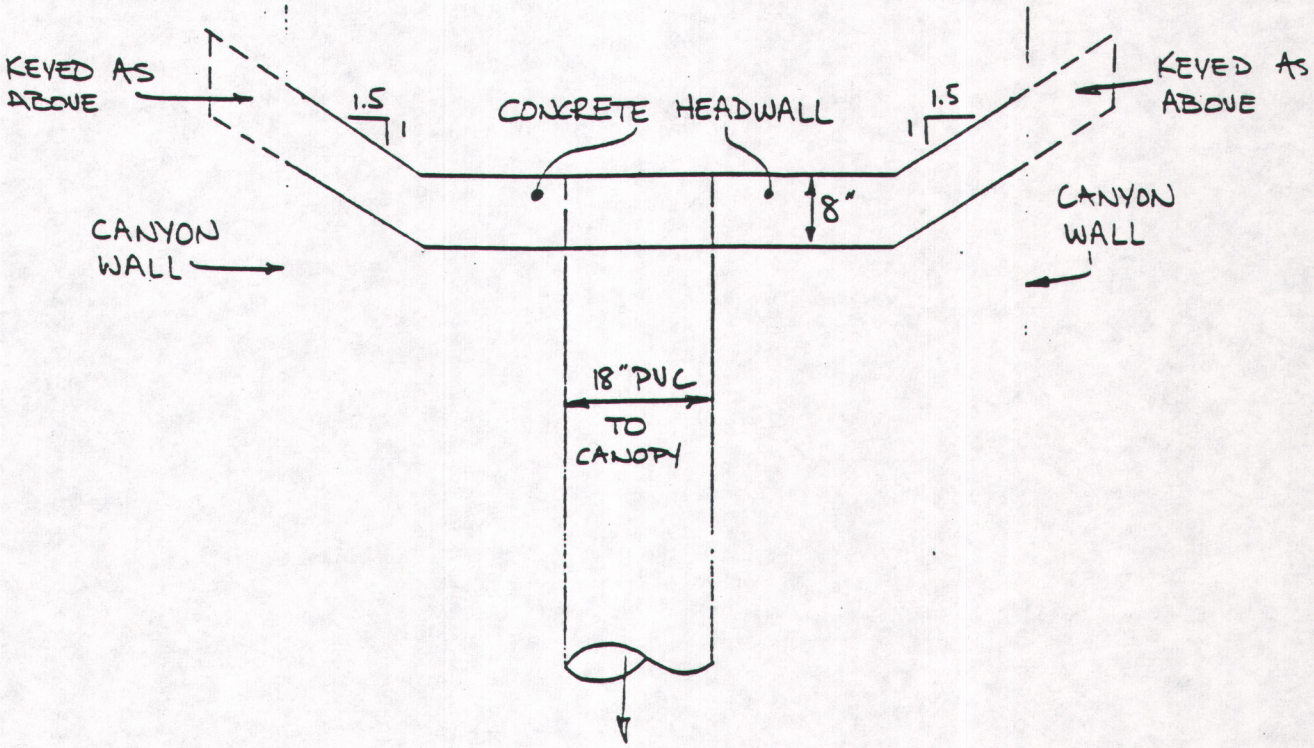
Computed Results:

| | |
|---|---|
| Depth..... | 0.44 ft ← Maximum Depth OK ✓ |
| Velocity..... | 2.33 fps |
| Flow Area..... | 0.34 sf |
| Critical Depth.... | 0.37 ft |
| Critical Slope.... | 0.0194 ft/ft |
| Percent Full..... | 44.24 % |
| Full Capacity..... | 1.93 cfs |
| QMAX @.94D..... | 2.08 cfs |
| Froude Number..... | 0.71 (flow is Subcritical) |

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




UD-3
INLET ELEVATION
SCALE: 1" = 2'




UD-3
INLET PLAN
SCALE: 1" = 2'

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

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

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

$T = (1.67)(0.02) = 0.03$ hr

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

$L = 0.02$ 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", 10% 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

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

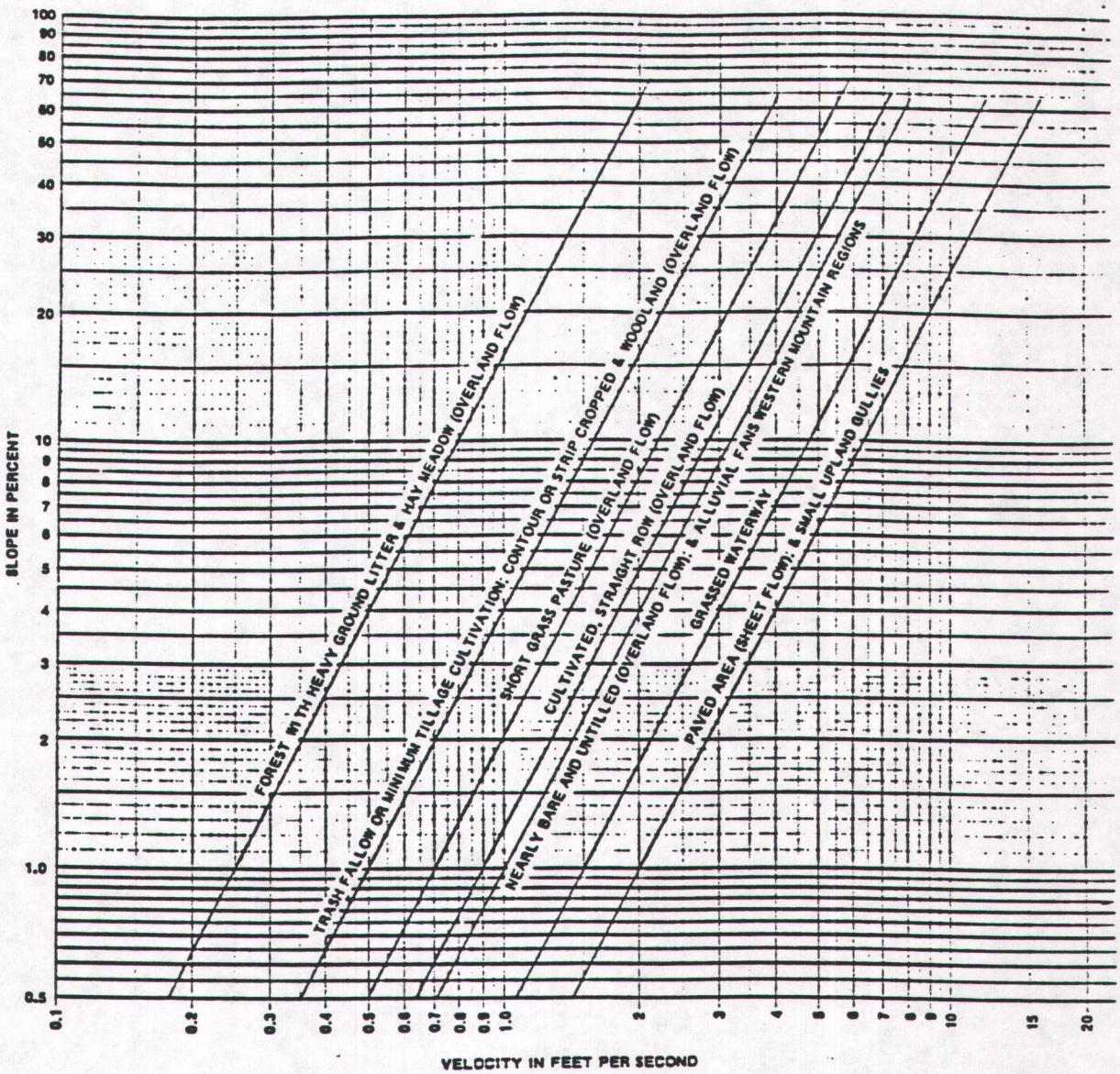



Figure 15.2.—Velocities for upland method of estimating $T_c$

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-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. 21 - 26 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
*************************************************************
```

```
*********************************
* 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.
*************************************************************
```

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

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

```
*******************************
* 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.
*************************************************************
```

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

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

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.
*************************************************************
```

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

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

```
*******************************
* 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.
*************************************************************
```

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

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

```
*****************************
* 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.
*************************************************************
```

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

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. 21-26 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 = | .9714888 | feet |
| Hydraulic Radius = | 9.714889E-02 | feet |
| Discharge = | .37 | cubic feet/sec |
| Velocity = | 3.920361 | feet/sec |
| Froude Number = | 1.482302 | < 5.0 ⇒ OK |

**Elimination of Ditch DD-2**

Disturbed Diversion Ditch DD-2 has been eliminated. The ditch previously flowed to the confluence of Ditches DD-1 and DD-3. Under the present situation, the drainage formerly in ditch DD-2, now sheet flows across the main pad area and goes into ditch DD-3, to Culvert C-7 and then to Culvert C-1. The quantity of the previous ditch DD-2 flow (0.58 cfs) is included in the existing design and calculations for ditch DD-3, and Culverts C-7 and C-1; therefore, no changes are required to the hydrology calculations. The existing ditch and culvert configuration is shown on Plate 7-5A.

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 = | 4.541907 | feet/sec |
| Froude Number = | .9723541 | <5.0 OK |

**Insert**

**Ditch DD-7**

Title of run: DITCH DD-7 (cross-section L-L')

| | | |
|---|---|---|
| Solving for..... | = | Depth Normal |
| Triangle | | |
| Flow depth (ft.)..... | = | 0.67 |
| First Side slope..... | = | 1.0 |
| Second Side slope..... | = | 1.0 |
| Slope of diversion..... | = | 0.0500 |
| Manning's n..... | = | 0.040 |
| CFS..... | = | 1.43 |
| Cross section area (soft)..... | = | 0.45 |
| Hydraulic radius..... | = | 0.24 |
| fps..... | = | 3.19 |
| Froude number..... | = | 1.16 |

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 = | 2.633479 | feet |
| Hydraulic Radius = | .233754 | feet |
| Discharge = | 1.97 | 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-11 (cross section O-O'):

| | | |
|---|---|---|
| Bed Slope = | .03 | |
| Manning's N = | .04 | |
| Bottom Width = | 0 | feet |
| Channel Side Slope = | 1 | |
| Flow Depth = | .6230584 | 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 = | .5233492 | |

## Disturbed Ditch Summary Sheet

| Ditch | Peak Flow (cfs) | Velocity (fps) | Flow Depth (ft.) |
|---|---|---|---|
| DD-1 | 0.37 | 3.92 | 0.22 |
| DD-3 | 1.30 | 2.55 | 0.65 |
| DD-4 | 0.32 | 2.63 | 0.25 |
| DD-5 | 4.02 | 4.84 | 0.77 |
| DD-7 | *1.43 | 1.04 | 0.70 |
| DD-8 | 1.97 | 3.20 | 0.51 |
| DD-9 | 0.67 | 2.74 | 0.25 |
| DD-11 | 0.91 | 2.34 | 0.62 |

* New flow with C-5

Notes:

(1) Ditch DD-2 has been eliminated. Drainage flows to DD-3, Culvert C-7 and Culvert C-1.

(2) Ditch DD-6 has also been eliminated. The ditch was replaced by Culvert C-2. Flows are included in DD-5 and Culvert C-2.

(3) Ditch DD-10 has also been eliminated. It was also replaced with Culbert C-2. Flows are carried by Culverts C-2, C-3 and C-4.

(4) Summary is based on revisions and Plate 7-5A (Revised 10/12/93).

## Re-routing of culvert C-5 to DD-7 to C-3

| Culvert | Type | Inflow (cfs) | Req'd Diam Diameter (ft.) | Adequacy |
|---|---|---|---|---|
| C-3 | 12" cmp | 1.43 (a) | 0.49 | O.K. |
| C-4 | 24" cmp | 0.52 (b) | 0.34 | O.K. |

(a) Flow from DD-7, C-5 and D-11.
(b) Flow from culvert C-10.
(c) Based on Manning's Formula: $D = \left(\frac{2.16\ Qn}{\sqrt{S}}\right)^{0.35}$

Where: D = Required culvert diameter (feet)
Q = Peak inflow (cfs)
N = Roughness factor (0.02 for cmp)
S = Slope (ft. per ft.)

Note: Slope on culverts = 0.23 ft./ft. based on C-4 (page 20 of Appendix 7-7).

## Ditch DD-7

Previous flow = 0.52 cfs.
New flow with addition of C-5 = 1.43 cfs.
New flow depth = 0.67 ft.
Ditch is adequate to handle new flow.
(See attached computer print-out).

## Addition of Culvert C-9

Disturbed area Culvert C-9, located in Ditch DD-4 to provide access to trash dumpsters.

| Culvert | Type Design | Type Actual | Inflow (cfs) | Req'd Diam. (ft.) | Slope (%) | Adequacy |
|---|---|---|---|---|---|---|
| C-9 | 12"cmp | 12"cmp | *0.32 | **0.34 | 9.50 | O.K. |

* Based on flow from DD-4

** Based on Manning's Formula: $D = \left(\frac{2.16\ Qn}{\sqrt{S}}\right)^{0.35}$

Where:
D = Required Culvert Diameter (feet)
Q = Peak Inflow (cfs)
n = Roughness Factor (0.02 for cmp)
S = Slope (ft. per ft.)

## Addition of Culvert C-10

Addition of Culvert C-10 under Temporary Storage Area east of Loadout.

| Culvert | Type | | Inflow | Req'd Diam. | Slope | Adequacy |
|---|---|---|---|---|---|---|
| | Design | Actual | (cfs) | (ft.) | (%) | |
| C-10 | 24"cmp | 24"cmp | *0.52 | **0.45 | 5.00 | O.K. |

* Based on previous DD-7 flow.

** Based on Manning's Formula: $D = \left(\frac{2.16\ Qn}{\sqrt{S}}\right)^{0.35}$

Where:
D = Required Culvert Diameter (feet)
Q = Peak Inflow (cfs)
n = Roughness Factor (0.02 for cmp)
S = Slope (ft. per ft.)

## Culvert Summary Sheet

| Culvert | Size | Length (ft.) | Slope (%) | Inflow (cfs) | Source | Req'd Diam (Diam.ft.) | Adequacy | Velocity (fps) |
|---|---|---|---|---|---|---|---|---|
| C-1 | 18"cmp | 60 | 16.67 | 3.27 | DD-3+DD-8 | 0.69 | O.K. | 10.12 |
| C-2 | 24"cmp | 360 | 8.00 | 4.02 | DD-5 | 0.84 | O.K. | 7.93 |
| C-3 | 24"cmp | 56 | 3.43 | 1.43 | DD-7+DD-11 | 0.68 | O.K. | 4.15 |
| C-4 | 24"cmp | 69 | 25.07 | 0.52 | C-10 | 0.34 | O.K. | 5.11 |
| C-5 | 12"pvc | 120 | 57.14 | 0.91 | DD-11 | 0.36 | O.K. | 10.63 |
| C-6 | 12"cmp | 12 | 17.20 | 0.99 | UD-2 | 0.45 | O.K. | 7.50 |
| C-7 | 12"cmp | 80 | 3.00 | 1.30 | DD-3 | 0.67 | O.K. | 4.34 |
| C-8 | 24"cmp | 97 | 17.53 | 0.67 | DD-9 | 0.39 | O.K. | 5.07 |
| C-9 | 12"cmp | 18 | 3.50 | 0.32 | DD-4 | 0.40 | O.K. | 3.00 |
| C-10 | 24"cmp | 56 | 2.53 | 0.52 | DD-7(previous) | 0.50 | O.K. | 2.56 |

Note: Summary is based on revision and Plate 7-5A (Revised 10/12/93).

* Based on Manning's Formula: $D = \left(\frac{2.16\ Qn}{\sqrt{S}}\right)^{0.35}$

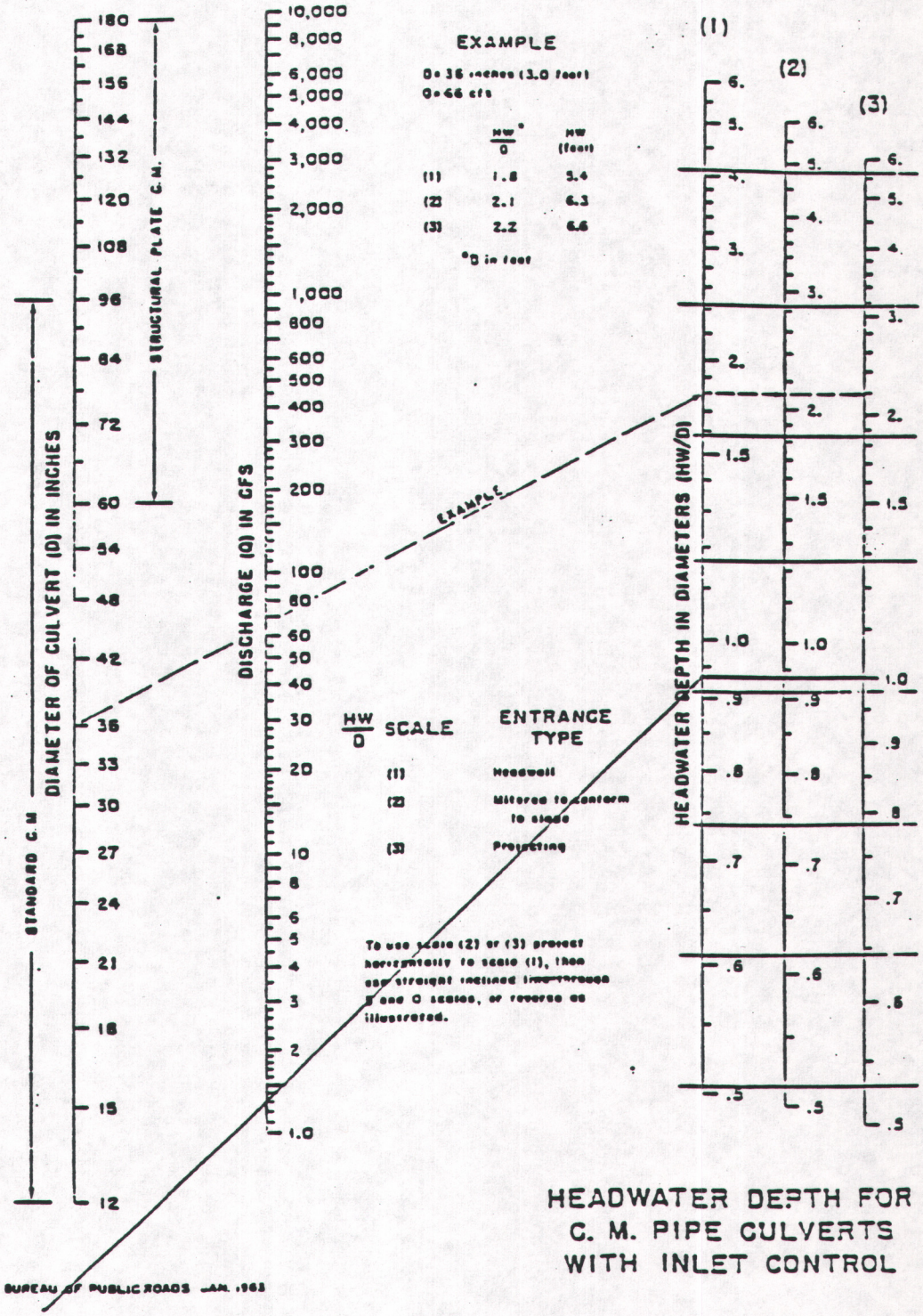
Where:
D = Required Culvert Diameter (feet)
Q = Peak Inflow (cfs)
n = Roughness Factor (0.02 for cmp)
S = Slope (ft. per ft.)

Note: Adequacy can also be checked with nomograph chart provided in this section.

C-7

O.K.

CHART 5




HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

Source: Hydraulic Charts for the Selection of Highway Culverts. U.S. Dept. of Transportation. Hydraulic Engineering Circular 5.