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UTAH DIVISION OIL, GAS AND MINING

**APPENDIX 7-7**

**Calculations**
**for**
**Future Diversions and Culverts**

**(See Appendix 7-11 for <u>Existing</u> Diversions and Culverts)**

APR 5 1994

REGISTERED PROFESSIONAL ENGINEER
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MARSHALL
STATE OF UTAH

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

R. Jay Marshall

**2/25/94**

# 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 $mi^2$

$l = 3850$ ft

CN = 69 (undisturbed)

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

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

$$= 53.6\%$$

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

$$T_c = (1.67)(0.17) = 0.29\ hr$$

WS-2 ⟶ Area = 0.9 ac undisturbed
+ 0.3 ac reclaimed
1.2 ac = 0.002 $mi^2$

$l = 650$ ft

CN = 69 for undisturbed area
= 75 for reclaimed area

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

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

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

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

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

Existing Regs Require 100 yr 6 hr 25 smaller or larger? Peak

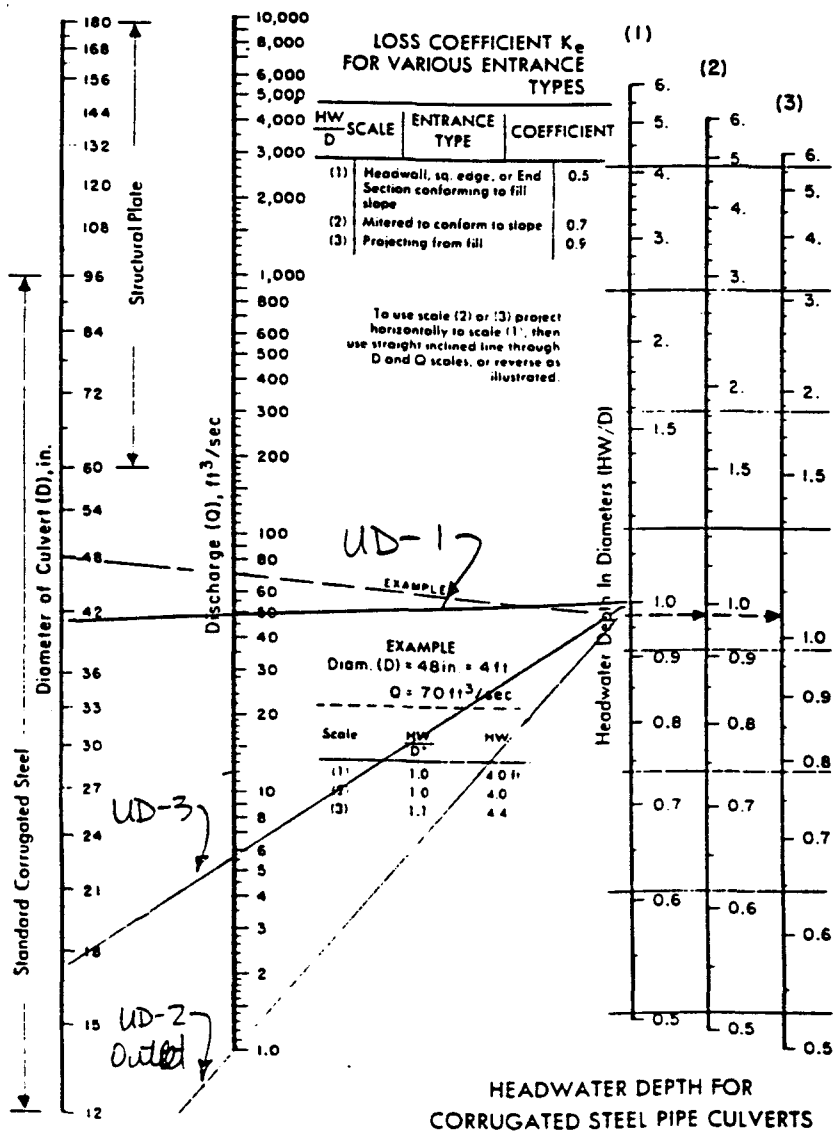
Rainfall distribution → SCS Type II

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:

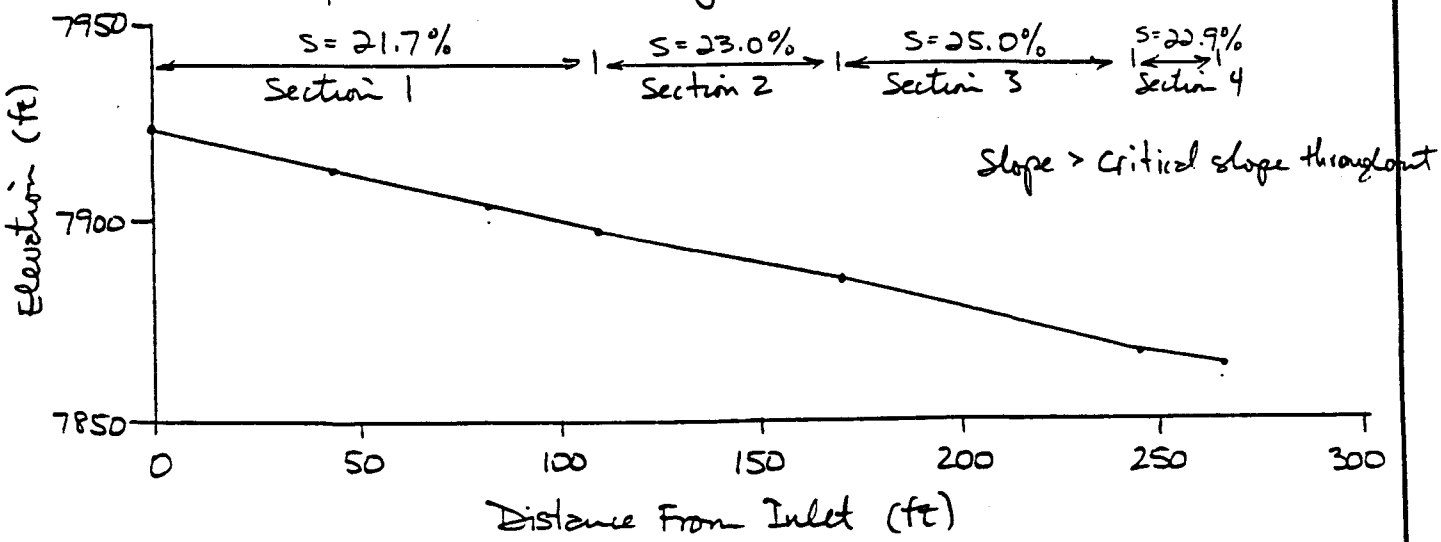
$$\frac{Q}{D^{2.5}} = \frac{47.7 \text{ cfs}}{(3.5)^{2.5}} = 2.081 \Longrightarrow \frac{d_c}{D} = 0.616$$

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

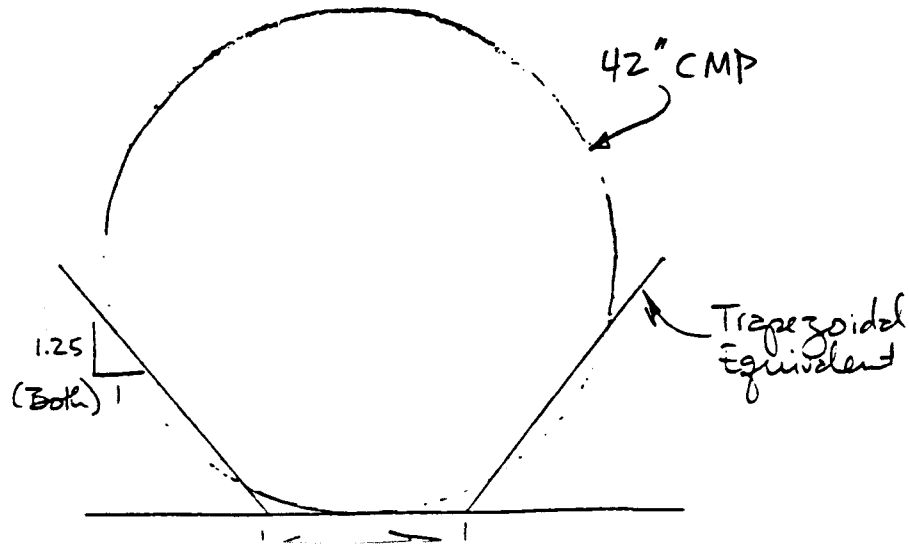
With $n = 0.024$, $Q = 2025$, $D = 2.5$

$$S_c = \left[\frac{(0.024)(47.7)}{(3.5)^{8/3}(0.324)}\right]^2 = 0.016 \text{ ft/ft}$$

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 | |

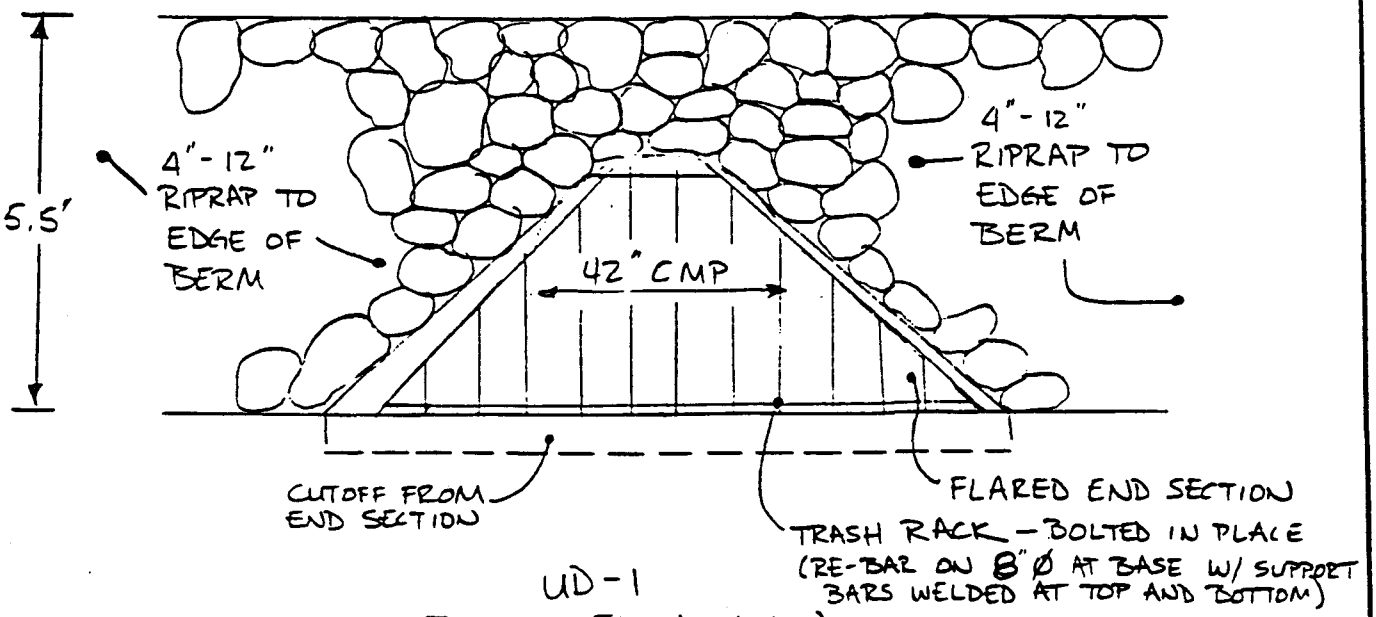
Section 3:

| | | |
|---|---|---|
| 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 | |

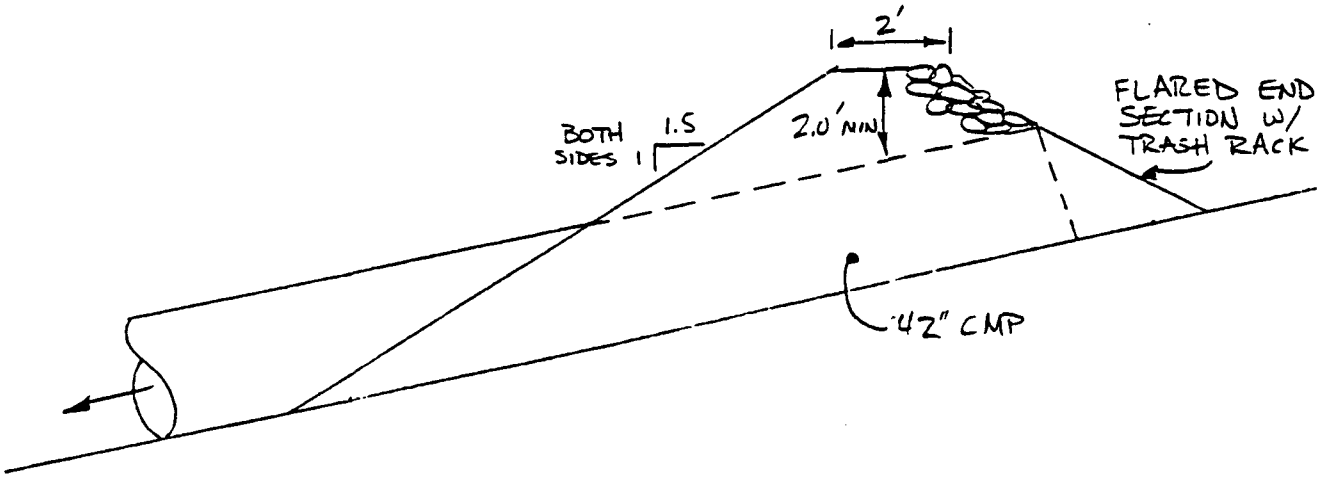
Section 4:

| | | |
|---|---|---|
| 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

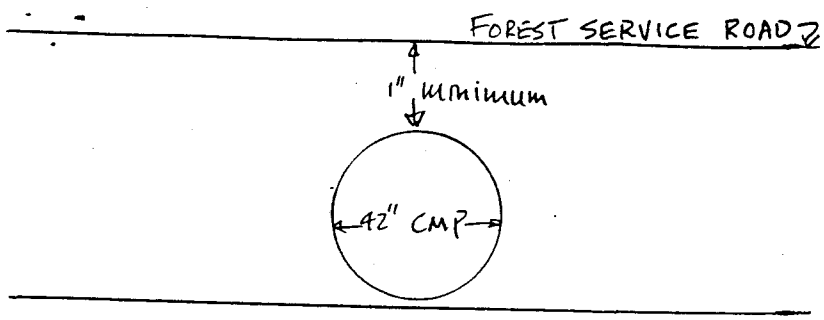
H = 22.5 + 6.5 = 29.0 ft

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

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

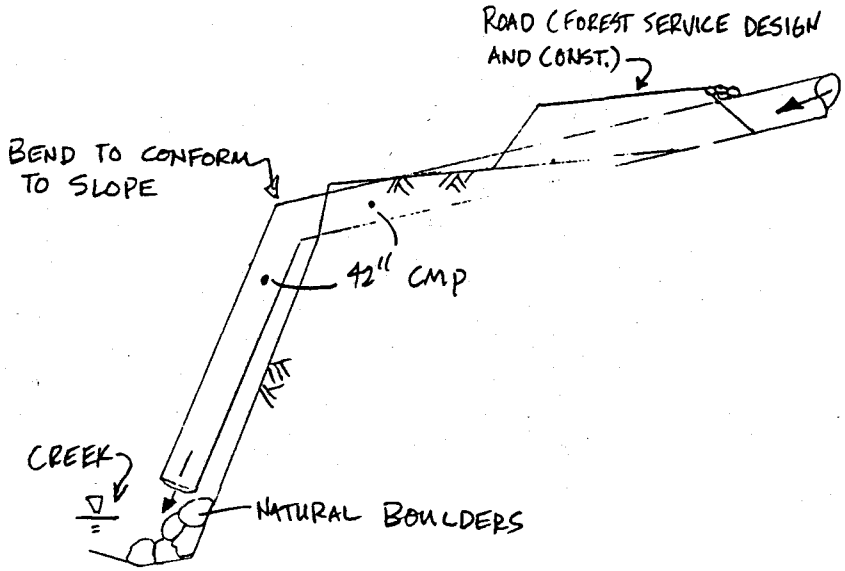
$= \frac{(5087)(0.024)^2}{(42)^{4/3}} = 0.020$

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 3 of this calc.)

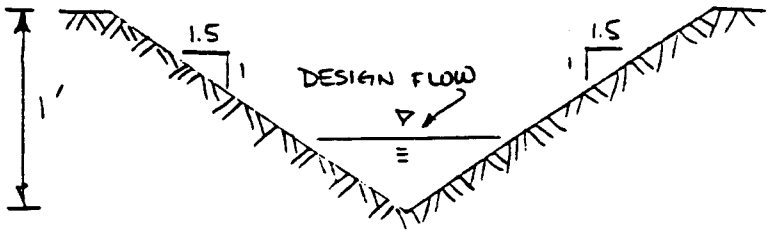
Slope along substation pad = (2.8 ft / 115 ft)(100) = 2.4%

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 4).

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 |

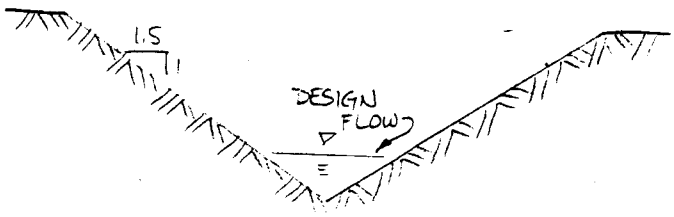



UD-2 AT SUBSTATION PAD - ELEV.

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

$l = 1320$ ft

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

$Y = \left(\frac{160 ft}{230 ft}\right)(100) = 69.6\%$

$L = \frac{(1320)^{0.8}(5.49)^{0.7}}{(1900)(69.6)^{0.5}} = 0.07 hr$

$T_c = (1.67)(0.07) = 0.12$ hr

Area = 8.8 ac = 0.014 $mi^2$

Hawkins-Marshall model output → see page 11 of this calc.

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

IDENTIFICATION: UD-3

INPUT SUMMARY:

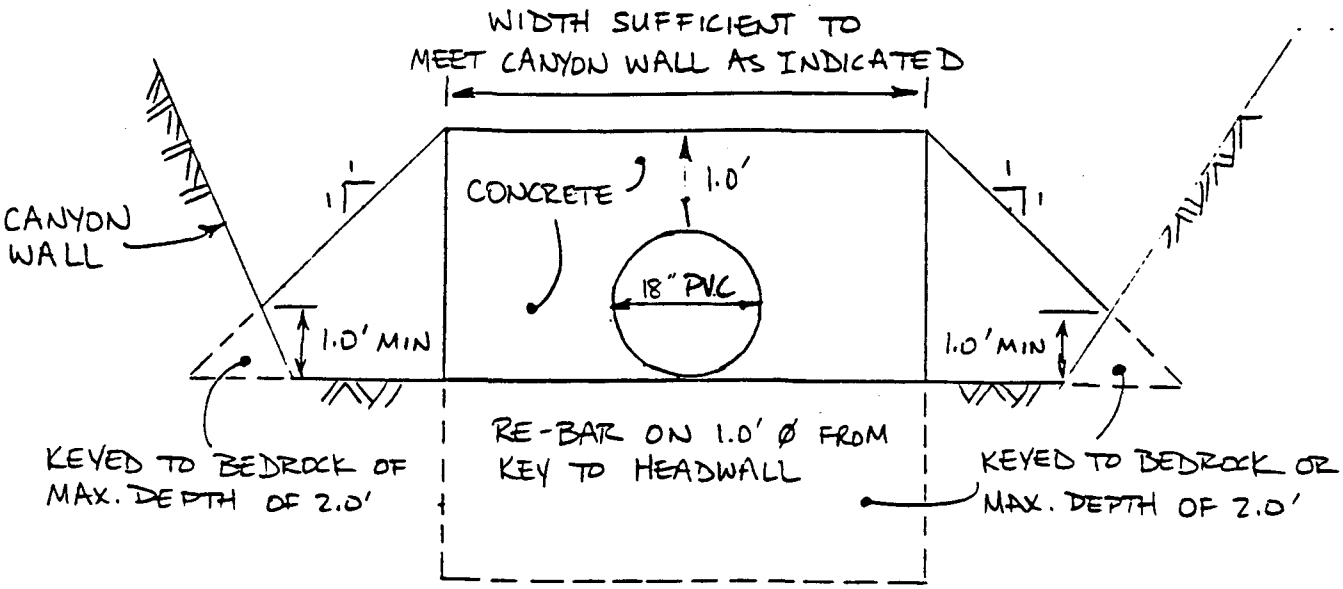
```
*************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE B              AREA =  0.014 SQ. MI.
        DEPTH =  1.90 IN.               CN = 69.0
        DURATION = 6.0 HR               TIME OF CONC. =  0.12 HR.
*************************************************************
```

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

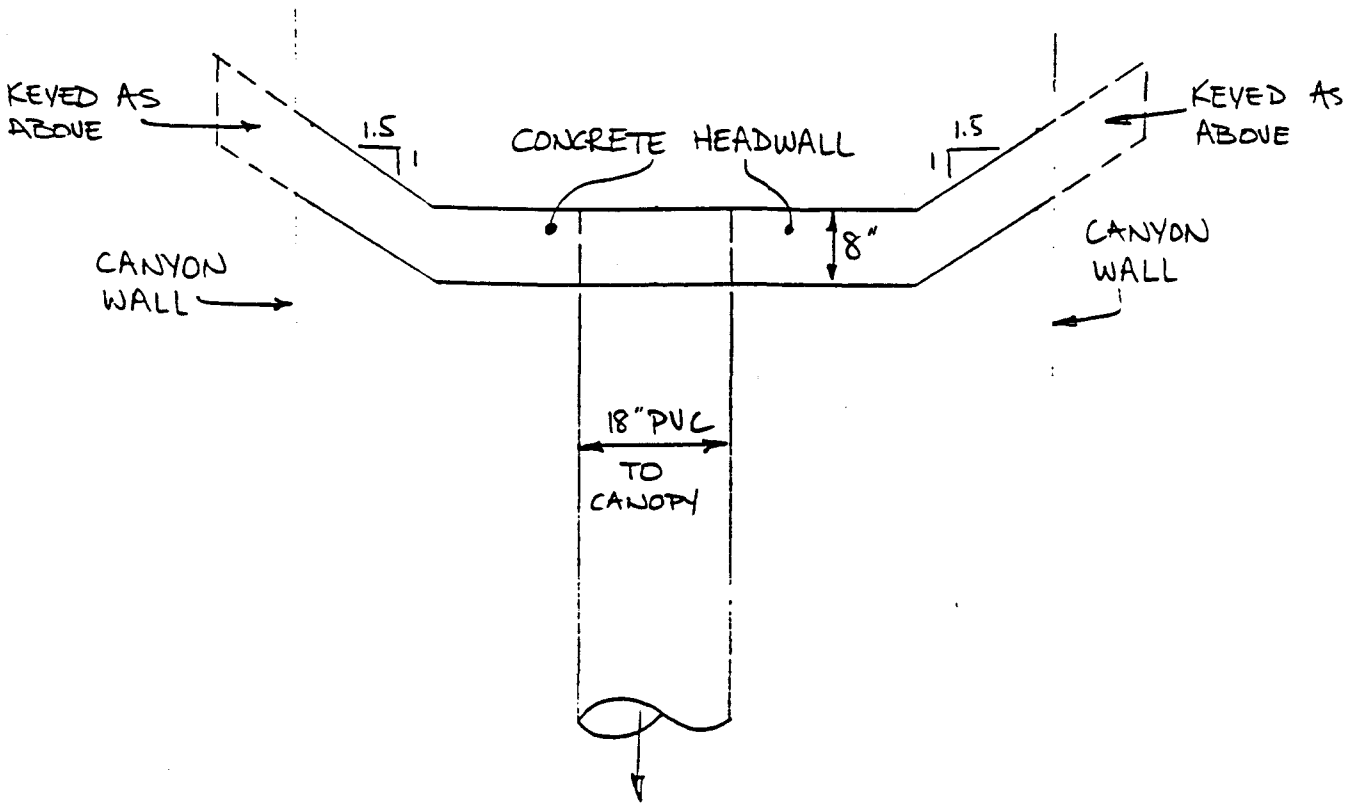
OUTPUT SUMMARY:

```
*************************************************************
     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 13 and 13a 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.




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




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

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

Determination of exit velocity from UD-3 → use pipe-flow equation:

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

$H = 57.0$ ft

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

$$K_c = \frac{(5087)(0.013)^2}{(18)^{4/3}} = 0.018 \qquad (n = 0.013, \text{assumed})$$

$L = 430$ ft

$$V = \left[\frac{(64.4)(57)}{(2.5 + [0.018][430])}\right]^{\frac{1}{2}} = 18.9 \text{ ft/s}$$

The receiving channel is cut in competent bedrock. Thus, the calculated exit velocity is not considered excessive and additional erosion protection will not be required.

## 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'×10'. 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.

## Design of DD-1

WS DD-1 Part & WS DD-2

Total area = 0.24 ac = 0.0004 mi² (use A = 0.001 mi²)
Undisturbed = 0.15 ac
Reclaimed = 0.09 ac

$l = 164$ ft

$$\overline{CN} = \frac{(0.15)(69) + (0.09)(75)}{0.21} = 71$$

$$S = \frac{1000}{74} - 10 = 4.08$$

$$Y = \left[\frac{(473\text{ ft})(10\text{ ft})}{(0.24\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 45.2\%$$

$$L = \frac{(164)^{0.8}(5.08)^{0.7}}{(1900)(45.2)^{0.5}} = 0.014\text{ hr}$$

$$T_c = (1.67)(0.014) = 0.02\text{ hr}$$

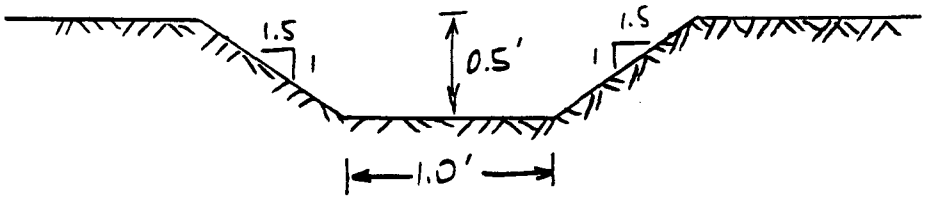
Design storm → 10-yr, 24-hr P = 2.50 in
Rainfall distribution → SCS Type II

Hawkins - Marshall model results → see page 15 of this calc.
Acceptable channel design → TRAP1 results:

| | | | |
|---|---|---|---|
| Mean Slope = | .4 | | |
| Manning's n = | .04 | | |
| Bottom Width = | 3 | feet | |
| Channel Side Slope = | .6667 | | |
| Flow Depth = | 4.604699E-02 | | feet |
| Cross Sectional Area = | 4.922731E-02 | | square feet |
| Wetted Perimeter = | 1.166019 | feet | |
| Hydraulic Radius = | 4.221828E-02 | | feet |
| Discharge = | .14 | cubic feet/sec | |
| Velocity = | 2.84775 | feet/sec | |
| Froude Number = | [illegible] | | |

<5 — Acceptable

```
IDENTIFICATION:   DD-1

INPUT SUMMARY:
*****************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.000 SQ. MI.
        DEPTH =  2.50 IN.               CN = 71.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.02 HR.
*****************************************************************


*****************************************************************


OUTPUT SUMMARY:
*****************************************************************
     TOTAL RUNOFF DEPTH =  0.4912 INCHES
     INITIAL ABSTRACTION =  0.8169 INCHES
     PEAK FLOW =      0.14 CFS   ( 0.5547 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.4921 INCHES
*****************************************************************
```




DD-1
TYPICAL ELEVATION
SCALE: 1" = 1'

## DESIGN OF DD-5

WS DD-5 +
DD-4 +
DD3 +
DD2 +

Undisturbed area = 3.52 ac (CN = 69)
Reclaimed area = 0.90 ac (CN = 75)
Disturbed area
Paved = 0.77 ac (CN = 95)
Unpaved = 0.18 (CN = 90)
Total area = 5.37 ac = 0.0084 mi²

$$\overline{CN} = \frac{(3.52)(69) + (0.90)(75) + (0.18)(90) + (0.77)(95)}{5.37} = 74$$

(S = 3.51)

$l = 1718$ ft

$$Y_{DDS} = \left[\frac{(2540\ ft)(40\ ft)}{(3.21\ ac)(43{,}560\ ft^2/ac)}\right](100) = 72.7\%$$

$$Y_{other} = \left[\frac{(3523\ (ft)(10\ ft)}{(2.16\ ac)(43{,}560\ ft^2/ac)}\right](100) = 37.4\%$$

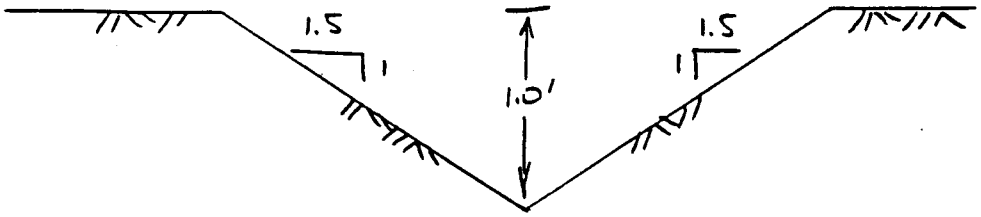
$$y' = \frac{(72.7)(3.21) + (37.4)(2.16)}{5.37} = 58.5\%$$

$$L = \frac{(1718)^{0.8}(4.51)^{0.7}}{(1900)(58.5)^{0.5}} = 0.08\ hr. \Longrightarrow T_c = 1.67L = 0.13\ hr.$$

Hydrograph & TRAP 1 results:

```
IDENTIFICATION:   DD-5

INPUT SUMMARY:
*****************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =   0.008 SQ. MI.
        DEPTH =   2.50 IN.              CN = 74.0
        DURATION = 24.0 HR.             TIME OF CONC. =   0.13 HR.
*****************************************************************


*****************************************************************


OUTPUT SUMMARY:
*****************************************************************
      TOTAL RUNOFF DEPTH =   0.6082 INCHES
      INITIAL ABSTRACTION =   0.7027 INCHES
      PEAK FLOW =       3.21 CFS   ( 0.5928 IN/HR)
      TIME TO PEAK =   12.01 HOURS
      RUNOFF VOLUME CHECK =   0.6095 INCHES
*****************************************************************
```

| | | |
|---|---|---|
| Bed Slope = | .07 | |
| Manning's N = | .04 | |
| Bottom Width = | 0 | feet |
| Channel Side Slope = | .6667 | |
| Flow Depth = | .7017343 | feet |
| Cross Sectional Area = | .7386097 | square feet |
| Wetted Perimeter = | 2.530051 | feet |
| Hydraulic Radius = | .2919347 | feet |
| Discharge = | 3.21 | cubic feet/sec |
| Velocity = | 4.346003 | feet/sec |
| Froude Number = | .9142727 | <5 - Acceptable |




DD-5
TYPICAL ELEVATION
SCALE: 1" = 1'

Design of DD-2 thru DD-4

DD-2 → Drainage area < DD-5
Slope < DD-5

DD-3 → Drainage area < DD-5
Slope < DD-5

DD-4 → Drainage area < DD-5
Slope < DD-5

Use DD-5 cross section

Note on DD-6

DD-6 formerly existed adjacent to the coal loadout at the mine site. This ditch has since been culverted. Thus, no ditch with the designation DD-6 currently exists.

Design of DD-7 thru DD-9, DD-11

Each channel → Drainage area << DD-5, slope < DD-5 } Use DD-5 cross section

Design of C-2

Peak flow = 3.21 cfs (see DD-5 calcs.)

This culvert currently exists as a 24" CMP with a projecting inlet. From the nomograph on pg. 2 of this calc., the capacity of C-2 is 12 cfs. Hence, this culvert is adequately designed.

Outlet velocity determination → use hydraulic elements graph (see pg. 19 of this calc.).

For slope = 0.08 ft/ft

$$Q_{full} = \left(\frac{1.486}{0.024}\right)(0.50)^{2/3}(0.08)^{1/2}(3.142)$$

$$= 34.66 \text{ cfs}$$

$$V_{full} = \frac{34.66 \text{ cfs}}{3.142 \text{ ft}^2} = 11.03 \text{ ft/s}$$

$$\frac{Q_{design}}{Q_{full}} = \frac{3.21}{34.66} = 0.09 \Rightarrow \text{At this ratio, } \frac{d}{D} = 0.20$$

(see pg 19)

$$\text{At } \frac{d}{D} = 0.20, \quad \frac{V_{design}}{V_{full}} = 0.61$$

$$V_{design} = (0.61)(11.03) = 6.73 \text{ ft/s}$$

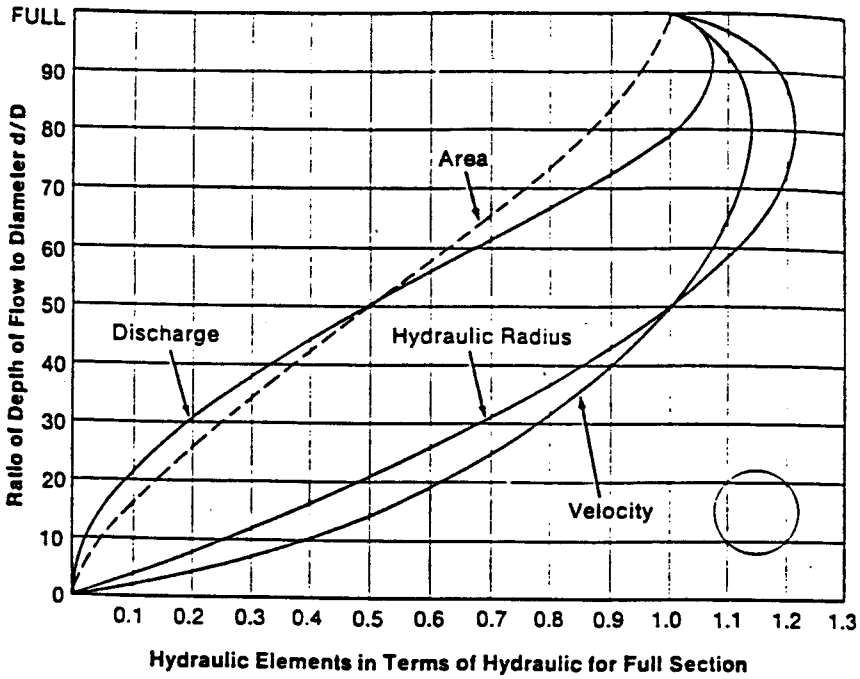



**Figure 4-37** Hydraulic elements graph for circular corrugated steel pipe.

**Table 4-14 Full Flow Data for Round Pipe**

| Diameter, in. | Area, ft² | Hydraulic Radius, ft | Diameter, in. | Area, ft² | Hydraulic Radius, ft |
|---|---|---|---|---|---|
| 12 | 0.785 | 0.250 | 156 | 132.7 | 3.25 |
| 15 | 1.227 | 0.3125 | 162 | 143.1 | 3.375 |
| 18 | 1.767 | 0.375 | 168 | 153.9 | 3.5 |
| 21 | 2.405 | 0.437 | 174 | 165.1 | 3.625 |
| 24 | 3.142 | 0.50 | 180 | 176.7 | 3.75 |
| 30 | 4.909 | 0.625 | 186 | 188.7 | 3.875 |
| 36 | 7.069 | 0.75 | 192 | 201.1 | 4.0 |
| 42 | 9.621 | 0.875 | 198 | 213.8 | 4.125 |
| 48 | 12.566 | 1.0 | 204 | 227.0 | 4.25 |
| 54 | 15.904 | 1.125 | 210 | 240.5 | 4.375 |
| 60 | 19.635 | 1.25 | 216 | 254.5 | 4.5 |
| 66 | 23.758 | 1.375 | 222 | 268.8 | 4.625 |
| 72 | 28.27 | 1.5 | 228 | 283.5 | 4.75 |
| 78 | 33.18 | 1.625 | 234 | 298.6 | 4.875 |
| 84 | 38.49 | 1.75 | 240 | 314.2 | 5.0 |
| 90 | 44.18 | 1.875 | 246 | 330.1 | 5.125 |
| 96 | 50.27 | 2.0 | 252 | 346.4 | 5.25 |
| 108 | 63.62 | 2.25 | 258 | 363.1 | 5.375 |
| 114 | 70.88 | 2.375 | 264 | 380.1 | 5.5 |
| 120 | 78.54 | 2.5 | 270 | 397.6 | 5.625 |
| 126 | 86.59 | 2.625 | 276 | 415.5 | 5.75 |
| 132 | 95.03 | 2.75 | 282 | 433.7 | 5.875 |
| 138 | 103.87 | 2.875 | 288 | 452.4 | 6.0 |
| 144 | 113.10 | 3.00 | 294 | 471.4 | 6.125 |
| 150 | 122.7 | 3.125 | 300 | 490.9 | 6.25 |

Design of C-4 → Disturbed area = 0.93 ac (CN=90) Undisturbed = 2.05 ac (CN=69)
Reclaimed area = 0.22 ac (CN=75)

$$\text{Weighted avg. } CN = \frac{(2.05)(69) + (0.22)(75) + (0.93)(90)}{3.20} = 76$$

Total area = 3.20 ac = 0.005 mi²

$l = 962$ ft

$$Y_{DD11} = \left[\frac{(1480\text{ ft})(40\text{ ft})}{(2.00\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 68.0\%$$

$$Y_{DD10} = \left[\frac{(2821\text{ ft})(10\text{ ft})}{(1.20\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 54.0\%$$

$$\bar{Y} = 62.7\%$$

$$L = \frac{(962)^{0.8}(4.16)^{0.7}}{(1900)(62.7)^{0.5}} = 0.04\text{ hr}$$

$$T_c = 1.67\,L = 0.07\text{ hr}$$

Hydrograph results:

```
IDENTIFICATION:   C-4

INPUT SUMMARY:
*****************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II              AREA =   0.005 SQ. MI.
        DEPTH =   2.50 IN.               CN = 76.0
        DURATION = 24.0 HR.              TIME OF CONC. =   0.07 HR.
*****************************************************************

*****************************************************************

OUTPUT SUMMARY:
*****************************************************************
     TOTAL RUNOFF DEPTH =   0.6945 INCHES
     INITIAL ABSTRACTION =   0.6316 INCHES
     PEAK FLOW =       2.33 CFS   ( 0.7227 IN/HR)
     TIME TO PEAK =   12.00 HOURS
     RUNOFF VOLUME CHECK =   0.6959 INCHES
*****************************************************************
```

C-4 is currently a 24" CMP. Determine exit velocity using hydraulic elements graph! Slope = 8/35 = 0.23 ft/ft

$Q_{full} = \left(\frac{1.486}{0.024}\right)(0.5)^{2/3}(0.23)^{1/2}(3.142) = 58.8$ cfs

$V_{full} = (58.8/3.142) = 18.7$ ft/s

$(Q_{design}/Q_{full}) = 2.33/58.8 = 0.04 \Rightarrow \frac{d}{D} = 0.14$

$V_d/V_f = 0.49$

$V_f = (0.49)(18.7) = 9.2$ ft/s

DESIGN of C-8

Culvert C-8 carries flow from DD-9 to sedimentation pond. From page 18 of this calc. DD-9 flow is less than DD-5 flow. Culvert C-2 carries flow from DD-5 to sedimentation pond. C-2 is a 24" CMP and is shown on page 18 to be adequate. C-8 is thereby designed as a 24" CMP also and is adequate to carry 10-YR, 24-hr storm water.

Note: DD-9 is a rip rapped trapezoidal drainage ditch.

Channel design → Assume 2:1 side slopes, bed slope = 0.33 (3:1 slope)
n = 0.04
2 ft bottom width

| | | |
|---|---|---|
| Bed Slope = | .33 | |
| Manning's N = | .04 | |
| Bottom Width = | 2 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .2493204 | feet |
| Cross Sectional Area = | .6229622 | square feet |
| Wetted Perimeter = | 3.114995 | feet |
| Hydraulic Radius = | .1999882 | feet |
| Discharge = | 4.57 | cubic feet/sec |
| Velocity = | 7.33592 | feet/sec |
| Froude Number = | 2.589093 | |

Will require 6" $d_{50}$ riprap for erosion protection (see U.S. Army Corps of Engineers, 1970).

Riprap gradation – see page 23 of this calc. (from dimensionless curve of Barfield et al., 1981).

Filter blanket sizing (see pg. 23 of this calc.):

$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{3.1\text{ in}}{0.62\text{ in}} = 5.0 \qquad \underline{\underline{OK}}$$

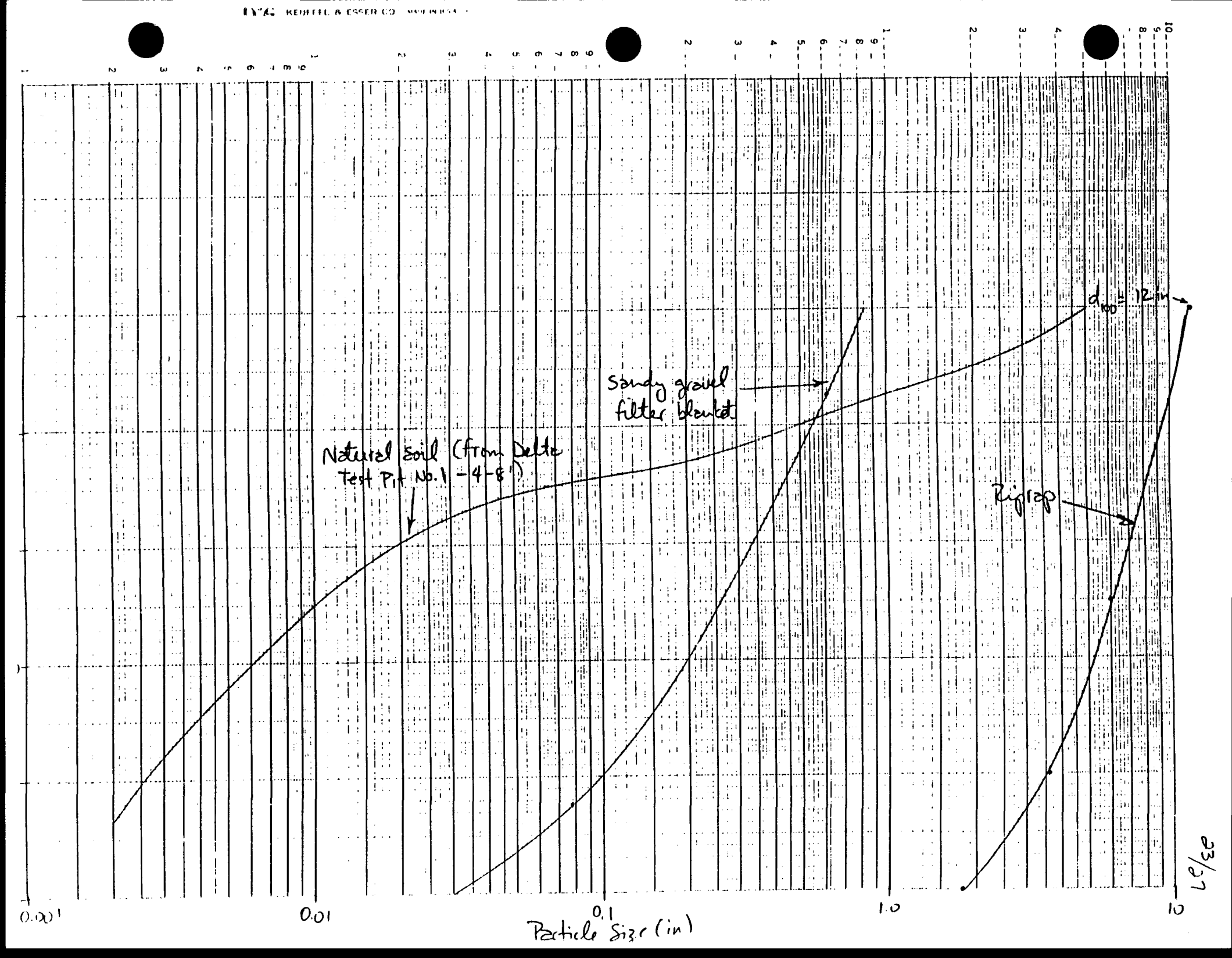
$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{3.1}{0.078\text{ in}} = 39.7 < 40 \qquad \underline{\underline{OK}}$$

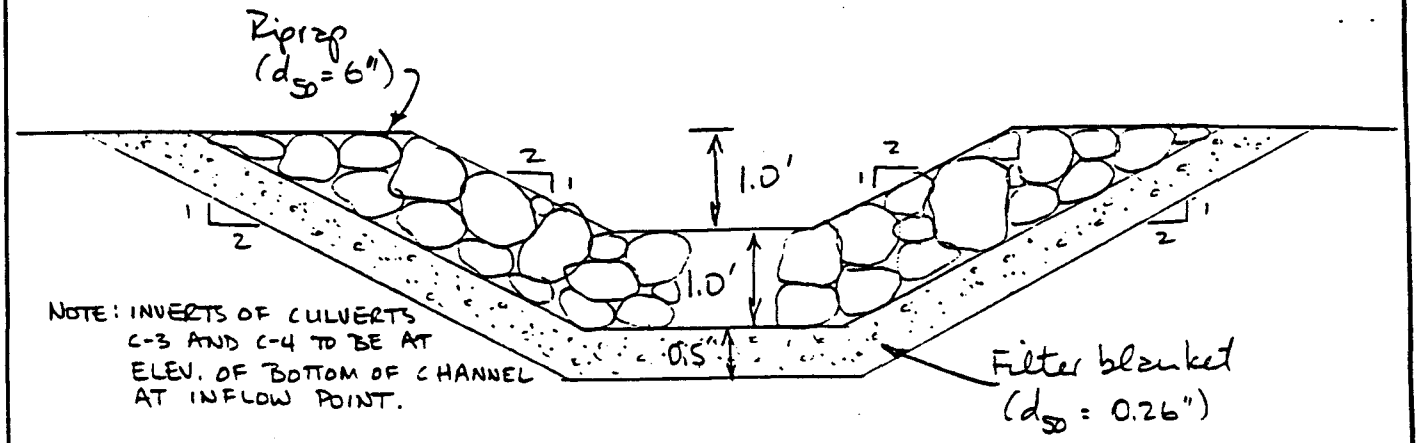
$$\frac{D_{15}\text{ (filter)}}{D_{85}\text{ (bed)}} = \frac{0.078\text{ in}}{0.94\text{ in}} = 0.08 < 5 \qquad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (filter)}}{D_{15}\text{ (bed)}} = \frac{0.078\text{ in}}{0.0021\text{ in}} = 37.1 < 40 \qquad \underline{\underline{OK}}$$

Indicated sandy gravel is sufficient for a filter blanket.

Typical elevation view of channel → see page 24 of this calc.


KEUFFEL & ESSER CO.
Natural soil (from Delta Test Pit No. 1 - 4-8')
Sandy gravel filter blanket
Riprap
$d_{100} = 12$ in
0.001
0.01
0.1
1.0
10
Particle Size (in)




SEDIMENTATION POND INLET CHANNEL
ELEVATION VIEW
SCALE: 1" = 2'

Design of C-3 → Area less than for C-2. According to nomograph on pg. 2 of this calc., an 18" CMP is adequate to handle the flow to C-2 (3.21 cfs). Thus, with a smaller expected flow, a minimum 18" CMP is adequate for C-3.

Design of culvert C-1 → Since this culvert is upstream from C-2, it need not be larger than C-2. According to the nomograph on pg. 2 of this calc., an 18" CMP is adequate to pass the C-2 design flow of 3.21 cfs (as well as smaller upstream flows). An 18" CMP will be used at C-1. Typical plan and elevation views on pg. 25 of this calc.

Design of culvert C-5 →

Undisturbed drainage = 2.13 ac from WS-5 (CN=69)
Reclaimed drainage = 0.10 ac from partial pad (CN=75)
Disturbed drainage = 0.02 ac from highwall (CN=90)

$$\overline{CN} = \frac{(2.13)(69) + (0.10)(75) + (0.02)(90)}{2.25} = 70$$

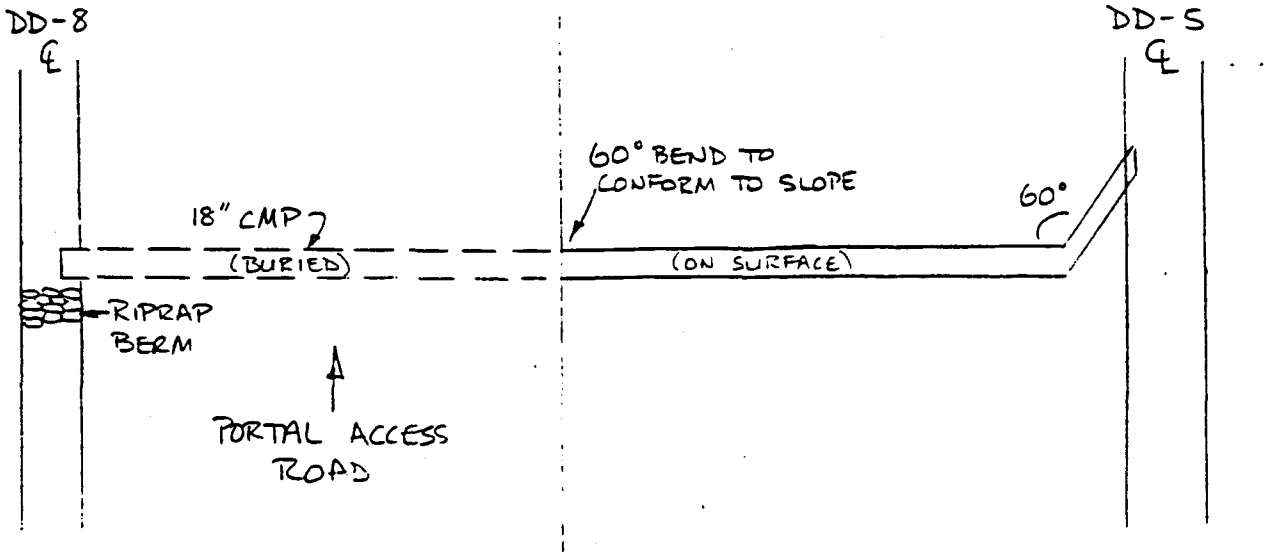
Total area = 2.25 ac = 0.004 $mi^2$

Upland method

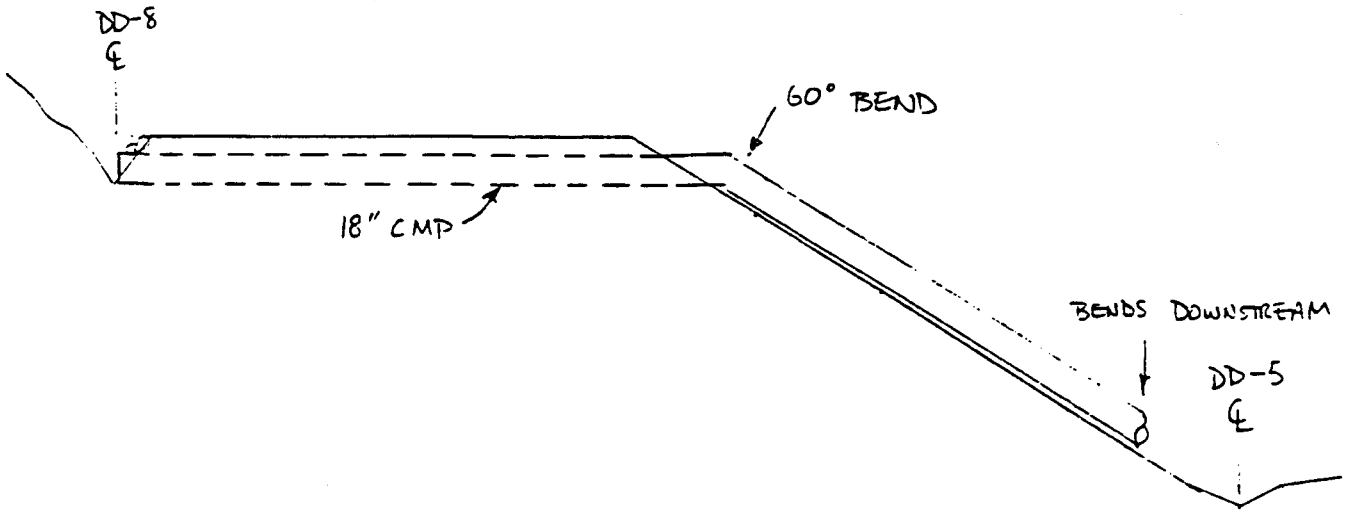
$(T_c)_{WS-5}$ → V = 1.4 ft/s, l = 550 ft } $(T_c)_{WS-5}$ = 0.11 hr

$(T_c)_{pad}$ → V = 0.7 ft/s, l = 80 ft } $(T_c)_{pad}$ = 0.03 hr

$(T_c)_{Total}$ = 0.11 + 0.03 = 0.14 hr




C-1
PLAN VIEW
SCALE: 1" = 10'




C-1
ELEV. VIEW
SCALE: 1" = 10'

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

IDENTIFICATION: C-5 CULVERT

INPUT SUMMARY:

```
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.004 SQ. MI.
        DEPTH =  2.50 IN.              CN = 70.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.14 HR.
*************************************************************
```

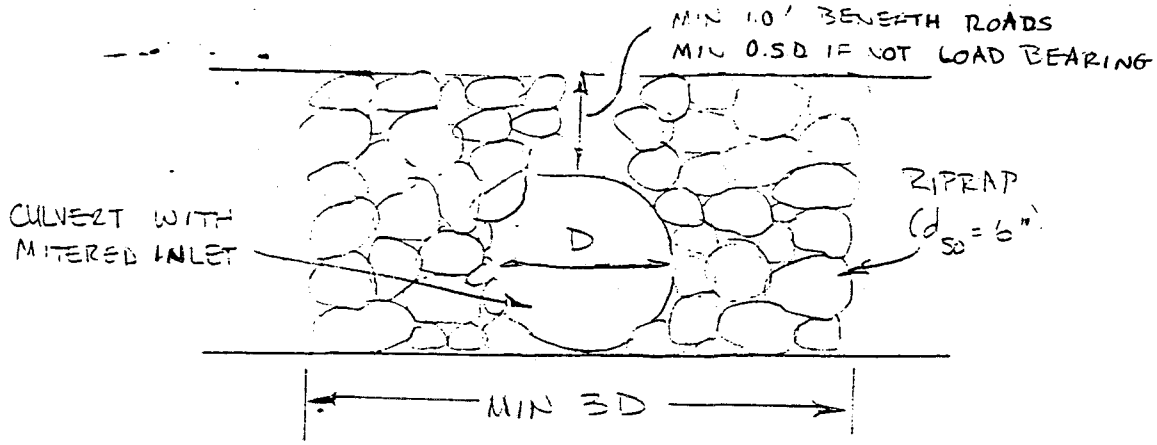
```
*************************************************************
```

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.4552 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      1.09 CFS   ( 0.4219 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.4562 INCHES
*************************************************************
```

Required culvert size → 12" (see nomograph on pg. 2 of this calc.). Collect the water in a full-round culvert, add a 60° elbow to bend the pipe down the hill, and convert the culvert to a half-round.

Culvert inlet design → Typical inlet on page 27 of this calc.




TYPICAL CULVERT INLET
(APPLIES TO CULVERTS C-1 THRU C-5)
ELEV. VIEW

NO SCALE

Design of C-6 → Reclaimed area = 0.24 ac (CN = 75)
= 0.0004 mi²

$T_c \Rightarrow 110\text{ ft @ } 84\% \longrightarrow V = 6.5\text{ ft/s}$

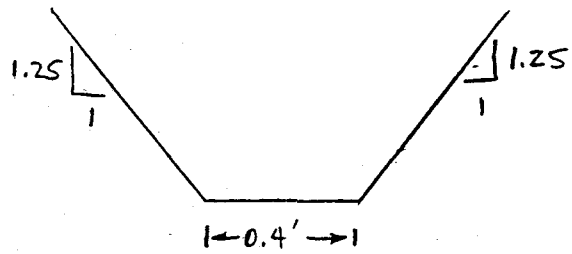
$$T_c = \frac{110\text{ ft}}{6.5\text{ ft/s}} = 16.9\text{ s} = 0.005\text{ hr}$$

SCSHYDRO results:

```
IDENTIFICATION:  CULVERT C-6

INPUT SUMMARY:
*****************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.000 SQ. MI.
        DEPTH =  2.50 IN.               CN = 75.0
        DURATION = 24.0 HR.             TIME OF CONC. = 0.01 HR.
*****************************************************************

*****************************************************************

OUTPUT SUMMARY:
*****************************************************************
     TOTAL RUNOFF DEPTH =  0.6505 INCHES
     INITIAL ABSTRACTION =  0.6667 INCHES
     PEAK FLOW =      0.13 CFS  ( 0.5000 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.6518 INCHES
*****************************************************************
```

From the nomograph on pg. 2 of this calc., a 12" CMP is adequate to pass the design flow (0.13 cfs).

Exit velocity — calculate using an equivalent trapezoidal section




Q = 0.13 cfs
Assume bed slope = 0.1 ft/ft (same as C-4)
n = 0.024 (CMP)

| | | |
|---|---|---|
| Bed Slope = | .1 | |
| Manning's N = | .024 | |
| Bottom Width = | .4 | feet |
| Channel Side Slope = | 1.25 | |
| Flow Depth = | .0870056 | feet |
| Cross Sectional AREA = | 4.085822E-02 | square feet |
| Wetted Perimeter = | .6228431 | feet |
| Hydraulic Radius = | 6.559954E-02 | feet |
| Discharge = | .13 | cubic feet SEC |
| Velocity = | 3.181734 | feet/sec |
| Froude Number = | 1.900913 | |

This design velocity is sufficiently low to minimize erosion. Discharge directly to pond.

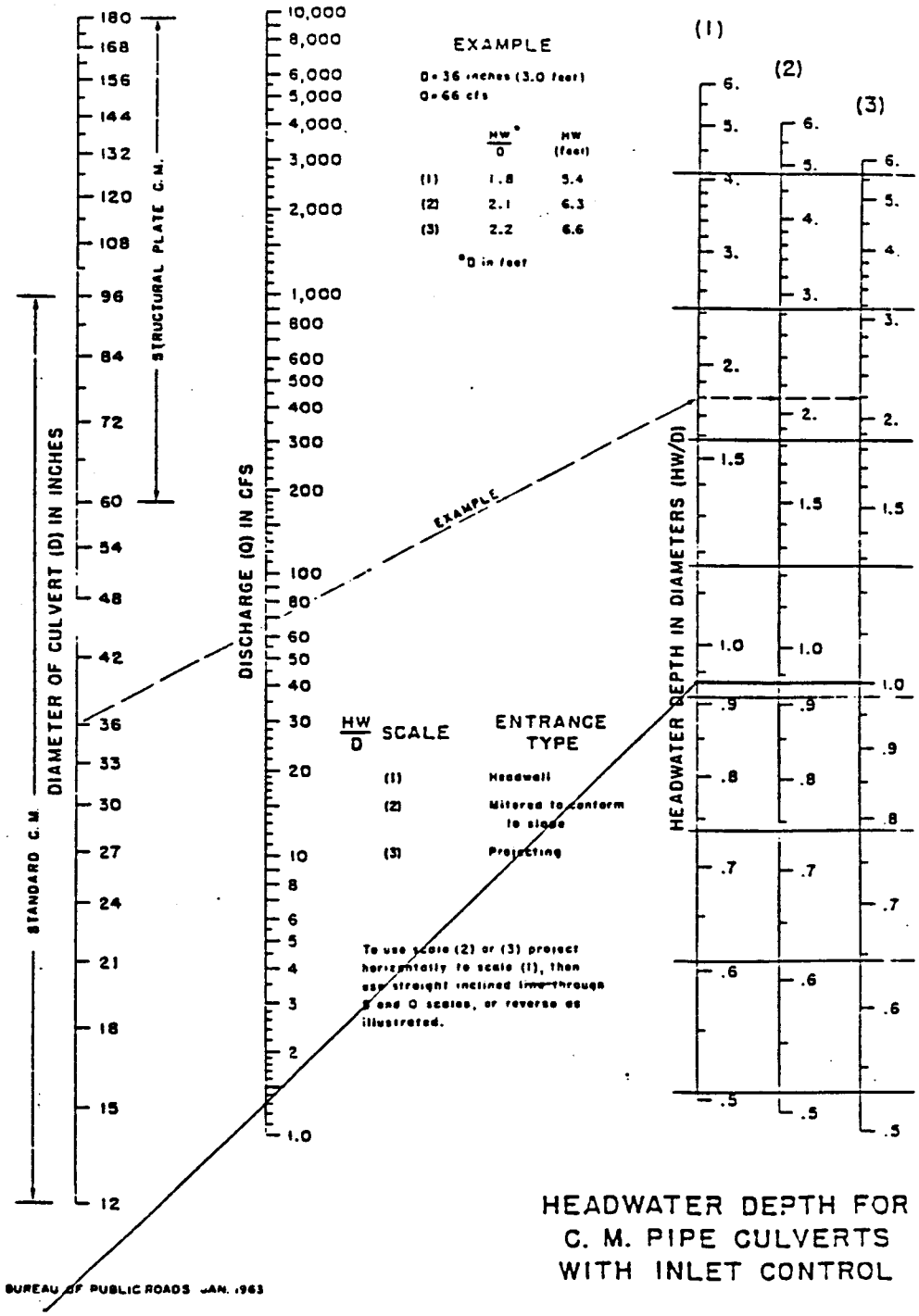
DESIGN OF CULVERT C-7

From the design flow of DD-3 (page 7 of Appendix 7-11) the runoff depth is 0.94 inches and the peak flow is 1.3 cfs.

Using the nomograph on page 26d of this appendix a 12-inch diameter CMP culvert is adequate to handle the design flow (10 yr. 24 hr.).

C-7

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.

## — DESIGN OF RECLAMATION CHANNELS —

Design of RD-1

Watershed draining to RD-1 → WS-1 + adjacent undisturbed and reclaimed area

Undisturbed area = 95.2 ac (WS-1) − 0.2 ac (Adjacent) = 95.4 ac

Reclaimed area = 0.3 ac (Adjacent)

Total = 95.7 ac = 0.150 mi²

$l = 4110$ ft

$$\overline{CN} = \frac{(95.4)(69) + (0.3)(75)}{95.7} = 69$$

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

$$Y = \left[\frac{(55{,}700\ \text{ft})(40\ \text{ft})}{(95.7\ \text{ac})(43{,}560\ \text{ft}^2/\text{ac})}\right](100) = 53.4\%$$

$$L = \frac{(4110)^{0.8}(1 + 4.49)^{0.7}}{(1900)(53.4)^{0.5}}$$

$= 0.18$ hr

$T_c = (1.67)(0.18)$

$= \underline{0.31\ \text{hr}}$

Design storm → 50-yr, 24-hr. USFS designs culverts for road crossings with 10- to 20-yr return period. Since this channel will empty into such a culvert, a 50-yr return period is a conservative design for the channel.

P = 3.25 in (Miller et al., 1973)

Hydrograph results:

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

IDENTIFICATION: WATERSHED DRAINING TO RD-1

INPUT SUMMARY:

```
-----------------------------------------------------------
     STORM:                    WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.150 SQ. MI.
        DEPTH =  3.25 IN.            CN = 69.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.31 HR.
-----------------------------------------------------------
```

```
-----------------------------------------------------------
```

OUTPUT SUMMARY:

```
-----------------------------------------------------------
     TOTAL RUNOFF DEPTH =  0.8079 INCHES
     INITIAL ABSTRACTION =  0.8986 INCHES
     PEAK FLOW =    61.21 CFS  ( 0.6323 IN/HR)
     TIME TO PEAK =  12.09 HOURS
     RUNOFF VOLUME CHECK =  0.8095 INCHES
-----------------------------------------------------------
```

Maximum slope of channel = $\frac{10}{24}$ = 0.42 ft/ft

Minimum slope of channel = $\frac{10}{75}$ = 0.13 ft/ft

Use maximum slope for design of riprap, minimum slope for design of cross section.

Run TRAP1 with bottom widths of 3 ft and 5 ft, assuming n=0.04 and sideslopes of 2h:1v. Check required riprap size, adjust roughness coefficient, and re-run TRAP1.

| | | |
|---|---|---|
| Bed Slope = | .42 | |
| Manning's N = | .04 | |
| Bottom Width = | 3 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .8082538 | feet |
| Cross Sectional Area = | 3.73131 | square feet |
| Wetted Perimeter = | 6.614621 | feet |
| Hydraulic Radius = | .5641003 | feet |
| Discharge = | 61.2 | cubic feet/sec |
| Velocity = | 16.40175 | feet/sec |
| Froude Number = | 3.215054 | |

| | | |
|---|---|---|
| Bed Slope = | .42 | |
| Manning's N = | .04 | |
| Bottom Width = | 5 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .6358769 | feet |
| Cross Sectional Area = | 3.988063 | square feet |
| Wetted Perimeter = | 7.843728 | feet |
| Hydraulic Radius = | .5084398 | feet |
| Discharge = | 61.2 | cubic feet/sec |
| Velocity = | 15.3458 | feet/sec |
| Froude Number = | 3.391368 | |

Determine riprap sizing from the figure on page 27c of this calc. Determine new n value from the equation:

$$n = 0.0395\, d_{50}^{1/6}$$

where $d_{50}$ = median stone diameter (ft)

For b = 3 ft → $d_{50}$ = 2.3 ft (ft 2:1 sideslopes)
n = 0.045

For b = 5 ft → $d_{50}$ = 2.1 ft
n = 0.045

Rerun w/ n = 0.044

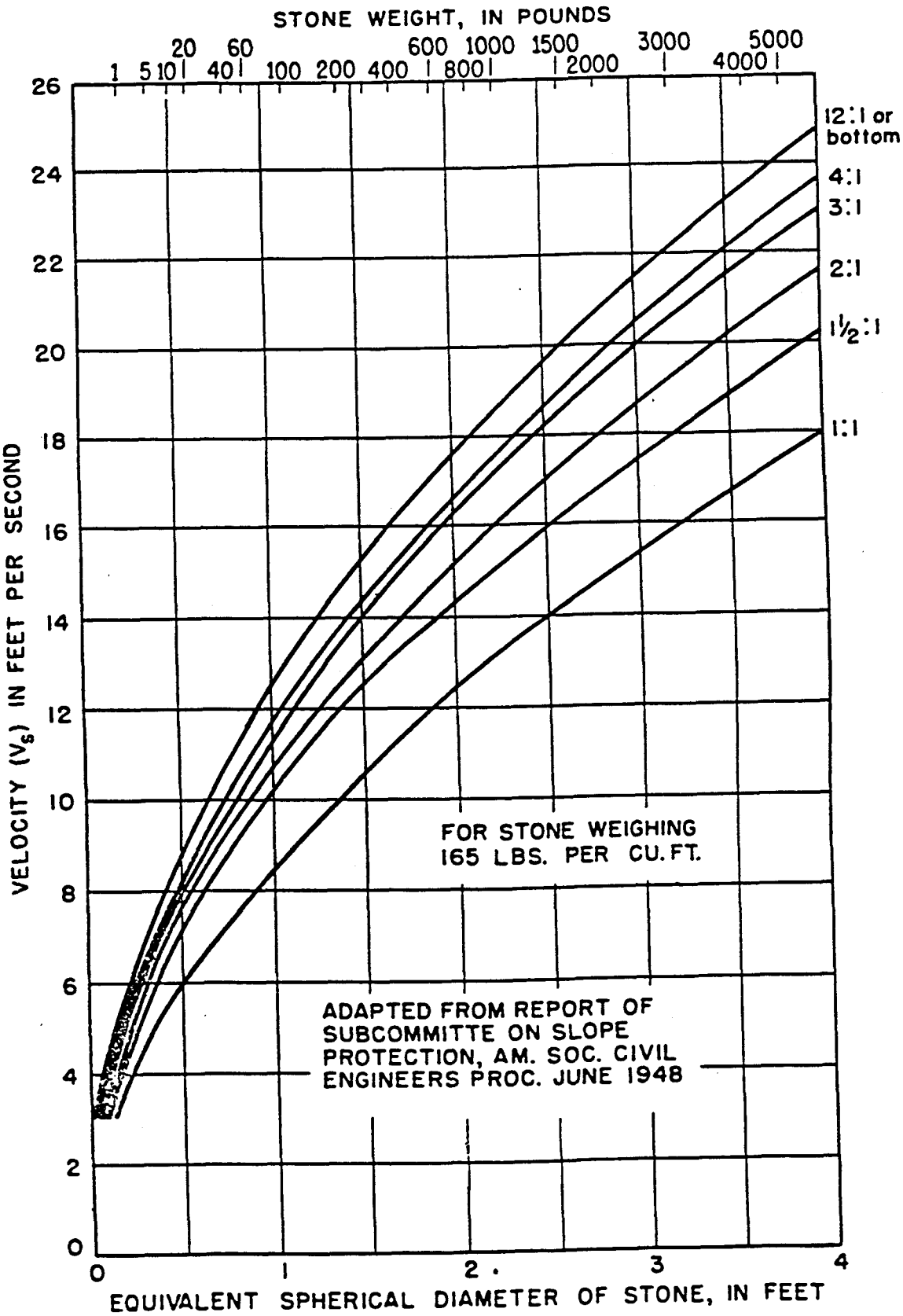



FIG. 2-SIZE OF STONE THAT WILL RESIST DISPLACEMENT FOR VARIOUS VELOCITIES AND SIDE SLOPES



Source: HEC-11

| | | |
|---|---|---|
| Bed Slope = | .42 | |
| Manning's N = | .044 | |
| Bottom Width = | 3 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .8459342 | feet |
| Cross Sectional Area = | 3.969013 | square feet |
| Wetted Perimeter = | 6.783133 | feet |
| Hydraulic Radius = | .5851297 | feet |
| Discharge = | 61.2 | cubic feet/sec |
| Velocity = | 15.41945 | feet/sec |
| Froude Number = | 2.954423 | |

| | | |
|---|---|---|
| Bed Slope = | .42 | |
| Manning's N = | .044 | |
| Bottom Width = | 5 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .6708703 | feet |
| Cross Sectional Area = | 4.254486 | square feet |
| Wetted Perimeter = | 8.000223 | feet |
| Hydraulic Radius = | .5317959 | feet |
| Discharge = | 61.2 | cubic feet/sec |
| Velocity = | 14.38482 | feet/sec |
| Froude Number = | 3.094975 | |

For $b = 3$ ft $\longrightarrow$ $d_{so} = 2.1$ ft, $n = 0.045$

For $b = 5$ ft $\longrightarrow$ $d_{so} = 1.6$ ft, $n = 0.043$

Design w/ $b = 5$ ft. Rerun w/ $n = 0.043$

| | | |
|---|---|---|
| Bed Slope = | .42 | |
| Manning's N = | .043 | |
| Bottom Width = | 5 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .6622636 | feet |
| Cross Sectional Area = | 4.188504 | square feet |
| Wetted Perimeter = | 7.961733 | feet |
| Hydraulic Radius = | .5260795 | feet |
| Discharge = | 61.2 | cubic feet/sec |
| Velocity = | 14.61142 | feet/sec |
| Froude Number = | 3.164092 | |

$d_{so} = 1.8$ ft $\longrightarrow$ $n = 0.044$

Use $d_{so} = \frac{1.6 + 1.8}{2} = \underline{\underline{1.7 \text{ ft}}}$

$= \underline{\underline{20 \text{ inches}}}$

$n = 0.043$

Channel cross section → determine from reach with minimum slope:

| | | |
|---|---|---|
| Bed Slope = | .13 | |
| Manning's N = | .043 | |
| Bottom Width = | 5 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .9184562 | feet |
| Cross Sectional Area = | 6.279405 | square feet |
| Wetted Perimeter = | 9.107462 | feet |
| Hydraulic Radius = | .6894792 | feet |
| Discharge = | 61.2 | cubic feet/sec |
| Velocity = | 9.746146 | feet/sec |
| Froude Number = | 1.792156 | |

Design cross section: Construct with finished depth of 1.5 ft (providing approx. 0.6 ft freeboard – see Barfield et al., 1981). See cross section on page 27f of this calc.

Riprap gradation → see pg. 27g of this calc. (based on dimensionless curve provided by Barfield et al., 1981).

Filter-blanket design:

$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{7.5\text{ in}}{2.0\text{ in}} = 3.75 < 5 \qquad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{7.5\text{ in}}{0.2\text{ in}} = 37.5 < 40 \qquad \underline{\underline{OK}}$$

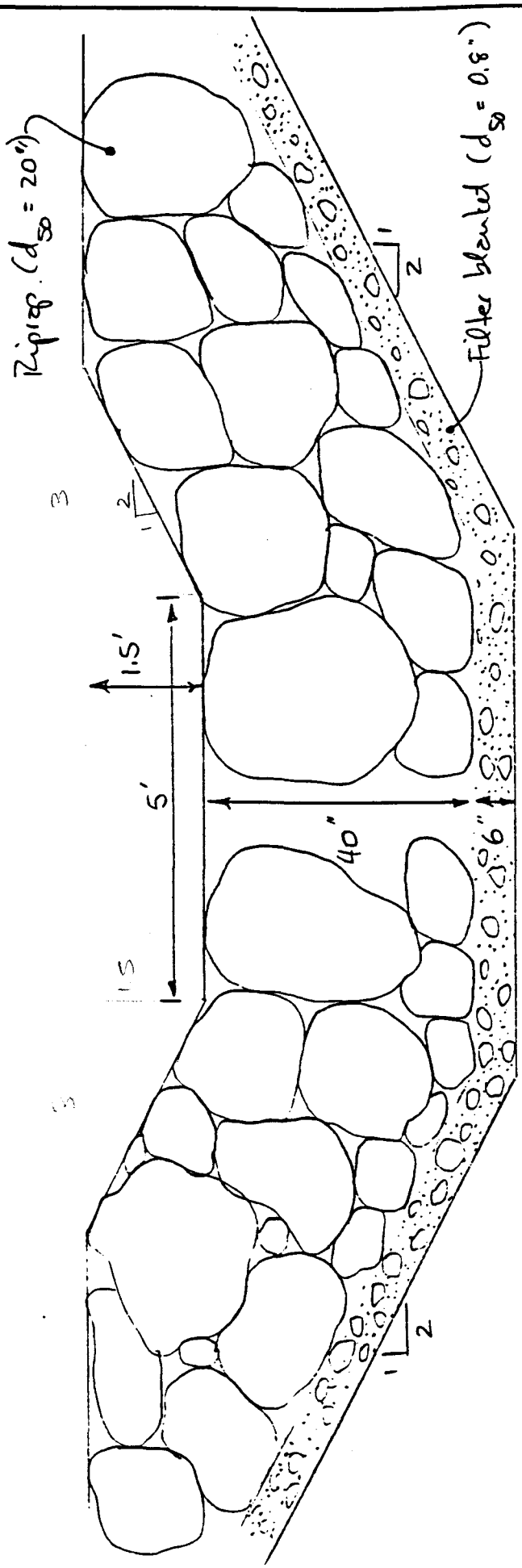
$$\frac{D_{15}\text{ (filter)}}{D_{85}\text{ (bed)}} = \frac{0.2\text{ in}}{0.94\text{ in}} = 0.2 < 5 \qquad OK$$

$$\frac{D_{15}\text{ (filter)}}{D_{15}\text{ (bed)}} = \frac{0.2\text{ in}}{0.0021\text{ in}} = 95.2 > 40$$

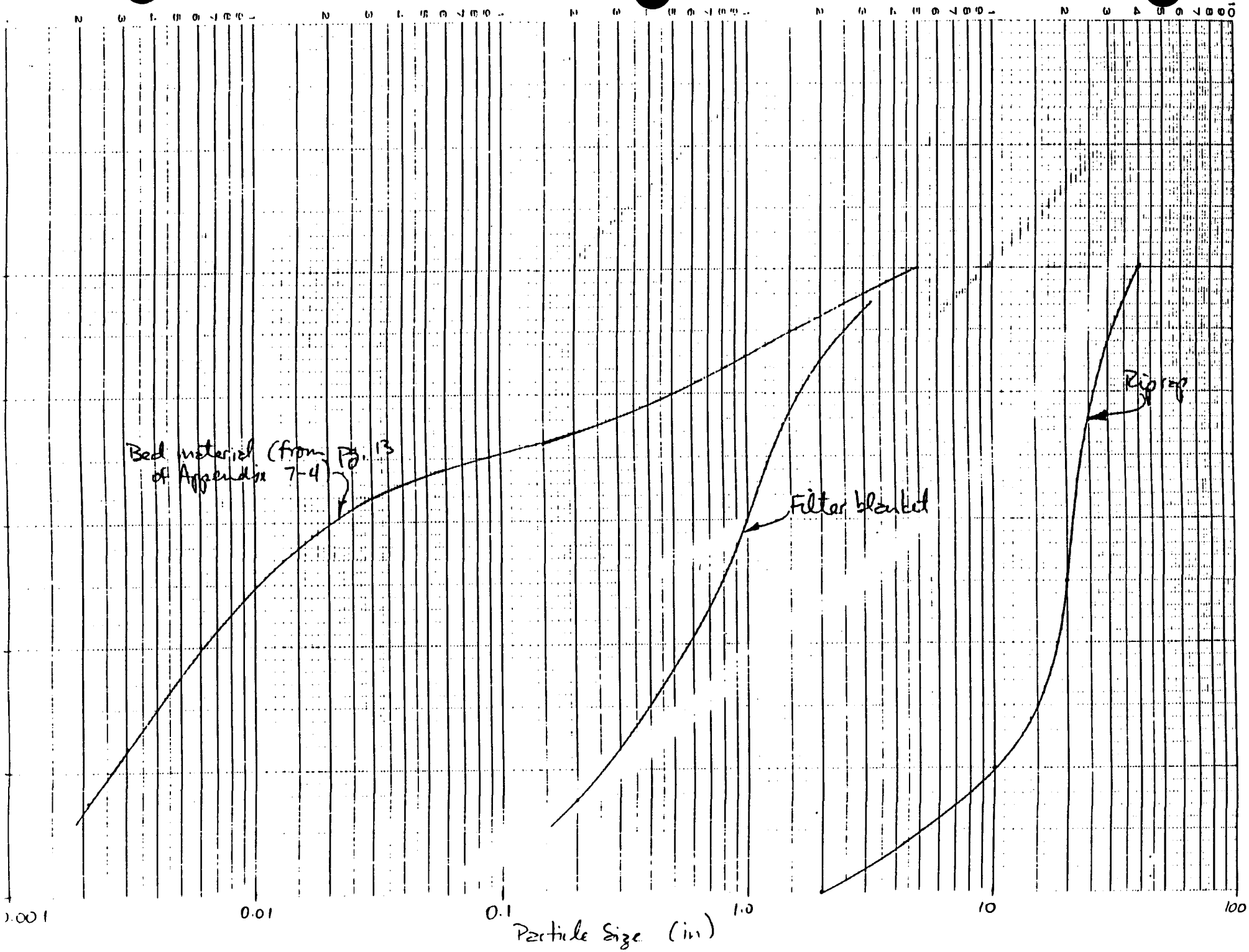
Although this final value is outside of the normal range, this filter blanket will be accepted due to the high factor of safety inherent in the runoff estimate (compare with the discussion in Appendix 7-5).

EARTHFAX ENGINEERING, INC.
ENGINEERS / SCIENTISTS

PROJECT C-27 PAGE 27f OF
COMPUTED TDW DATE 8 Jul 1986
CHECKED DATE




RD-1 ELEVATION VIEW
SCALE: 1" = 2'


Bed material (from Pg. 13 of Appendix 7-4)
Filter blanket
Riprap
0.001
0.01
0.1
1.0
10
100
Particle Size (in)

RD-1 will be constructed during Phase I of final reclamation but will divert water from WS-1 only during Phase II. WS-1 will continue to flow through UD-1 during Phase I to allow more time for RD-1 and the surrounding area to stabilize.

During Phase I, RD-1 will discharge into RD-2, thus causing site water to flow to the sedimentation pond. During Phase II, UD-1 will be removed to the USFS road and RD-1 will discharge to this culvert. The culvert will be maintained by the USFS as part of the post-mining land use. RD-1 will be extended to the head of the existing UD-1.

## Design of RD-2

Contributing watershed → WS-2 + WS-4 + portion of reclaimed area east of UD-1 and west of RD-4.

Area → Undisturbed = 0.9 (WS-2) + 5.5 (WS-4) = 6.4 ac

Reclaimed = 0.3 (WS-2) + 0.3 (WS-4) + 1.9 ac (site) = 2.5 ac

Total = 6.4 + 2.5 = 8.9 ac
= 0.014 mi²

$l = 1020$ ft

$$\overline{CN} = \frac{(6.4)(69) + (2.5)(75)}{8.9} = 71$$

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

$$Y = \left[\frac{(3010\text{ ft})(40\text{ ft})}{(8.9\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 31.1\%$$

$$L = \frac{(1020)^{0.8}(1+4.08)^{0.7}}{(1900)(31.1)^{0.5}}$$

$= 0.08$ hr

$T_c = (1.67)(0.08)$
$= \underline{0.13}$ hr

Design storm → 50-yr, 24-hr = 3.25 in.

Hydrograph results → see pg 27i of this calc.

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

IDENTIFICATION: WATERSHED DRAINING TO RD-2

INPUT SUMMARY:

```
*****************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.014 SQ. MI.
        DEPTH =  3.25 IN.               CN = 71.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.13 HR.
*****************************************************************
```

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

OUTPUT SUMMARY:

```
*****************************************************************
     TOTAL RUNOFF DEPTH =  0.9083 INCHES
     INITIAL ABSTRACTION =  0.8169 INCHES
     PEAK FLOW =      8.04 CFS   ( 0.8901 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.9101 INCHES
*****************************************************************
```

Maximum channel slope = $\frac{10}{95}$ = 0.11 ft/ft (for riprap design)

Minimum slope = $\frac{10}{160}$ = 0.063 ft/ft (for cross section design)

Initially assume n = 0.035. Run TRAP1 and compare riprap requirements with roughness coefficient.

| | | |
|---|---|---|
| Bed Slope = | .11 | |
| Manning's N = | .035 | |
| Bottom Width = | 2 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .431134 | feet |
| Cross Sectional Area = | 1.234021 | square feet |
| Wetted Perimeter = | 3.92809 | feet |
| Hydraulic Radius = | .3141529 | feet |
| Discharge = | 8.04 | cubic feet/sec |
| Velocity = | 6.515287 | feet/sec |
| Froude Number = | 1.748636 | |

| | | |
|---|---|---|
| Bed Slope = | .11 | |
| Manning's N = | .035 | |
| Bottom Width = | 4 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .3024303 | feet |
| Cross Sectional Area = | 1.392649 | square feet |
| Wetted Perimeter = | 5.35251 | feet |
| Hydraulic Radius = | .2601862 | feet |
| Discharge = | 8.04 | cubic feet/sec |
| Velocity = | 5.77317 | feet/sec |
| Froude Number = | 1.850009 | |

For b = 2 ft → $d_{50}$ = 0.30 ft = 3.6 in

For b = 4 ft → $d_{50}$ = 0.25 ft = 3.0 in

See pg. 27c of this calc

$n_2$ = 0.032
$n_4$ = 0.031

Rerun w/ n = 0.033

| | | |
|---|---|---|
| Bed Slope = | .11 | |
| Manning's N = | .033 | |
| Bottom Width = | 2 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .4175808 | feet |
| Cross Sectional Area = | 1.183909 | square feet |
| Wetted Perimeter = | 3.867478 | feet |
| Hydraulic Radius = | .3061192 | feet |
| Discharge = | 8.04 | cubic feet/sec |
| Velocity = | 6.791062 | feet/sec |
| Froude Number = | 1.851994 | |

Required $d_{50}$ = 0.35 ft
= 4.2 in

n = 0.033 ⇒ OK

| | | |
|---|---|---|
| Bed Slope = | .11 | |
| Manning's N = | .033 | |
| Bottom Width = | 4 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .2923076 | feet |
| Cross Sectional Area = | 1.340118 | square feet |
| Wetted Perimeter = | 5.30724 | feet |
| Hydraulic Radius = | .2525076 | feet |
| Discharge = | 8.04 | cubic feet/sec |
| Velocity = | 5.999472 | feet/sec |
| Froude Number = | 1.955532 | |

Required $d_{50}$ = 0.30 ft
= 3.6 in

$n = 0.032 \Rightarrow$ OK

Determine cross section using b = 2 ft, n = 0.033

| | | |
|---|---|---|
| Bed Slope = | .063 | |
| Manning's N = | .033 | |
| Bottom Width = | 2 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .4840931 | feet |
| Cross Sectional Area = | 1.436878 | square feet |
| Wetted Perimeter = | 4.16493 | feet |
| Hydraulic Radius = | .3449946 | feet |
| Discharge = | 8.04 | cubic feet/sec |
| Velocity = | 5.595464 | feet/sec |
| Froude Number = | 1.417241 | |

Riprap gradation → see pg 27l of this calc.

Filter blanket design (see also pg. 27g of this calc.):

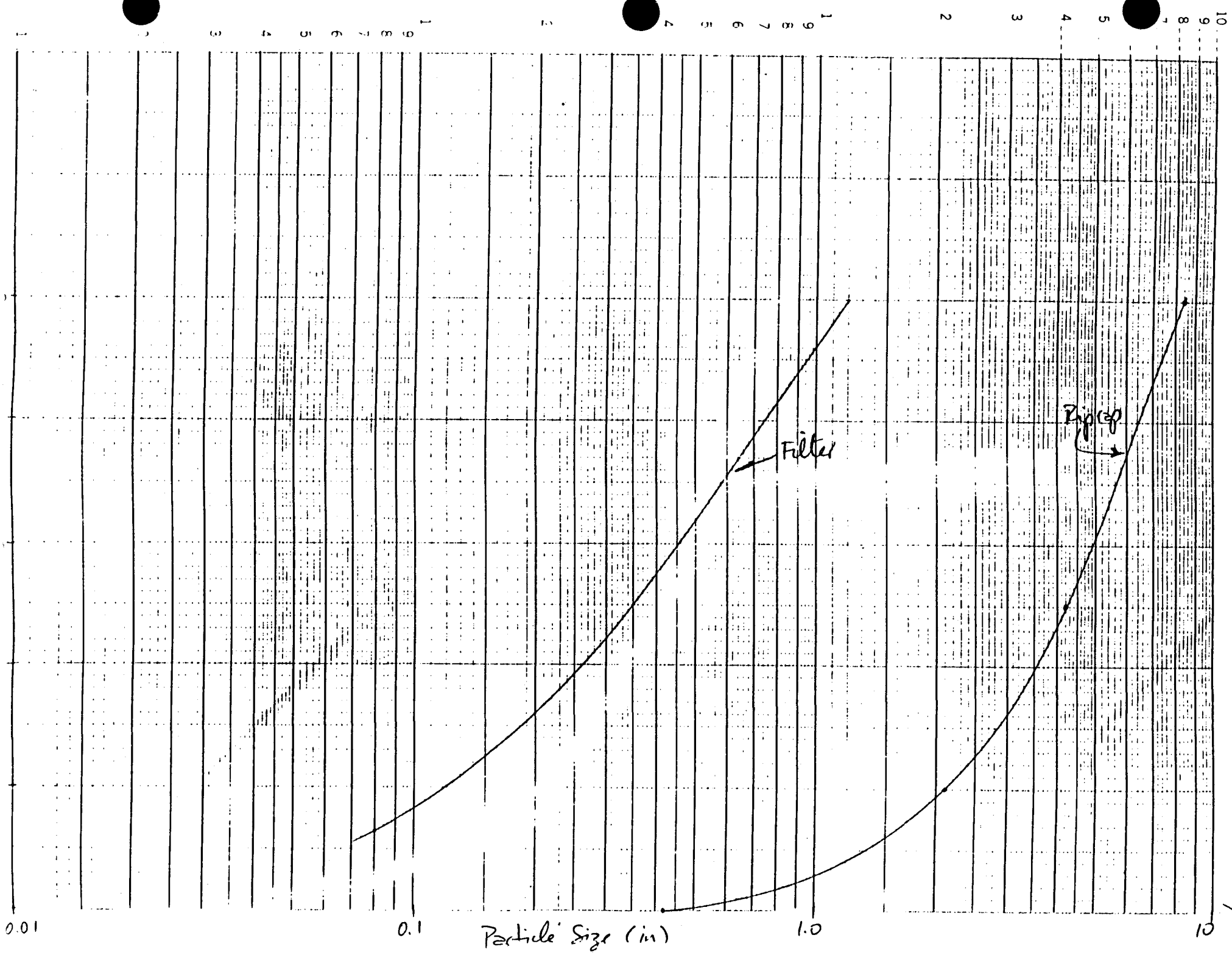
$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{1.7\text{ in}}{0.85\text{ in}} = 2.0 < 5 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{1.7\text{ in}}{0.08\text{ in}} = 21.3 < 40 \quad \underline{\underline{OK}}$$

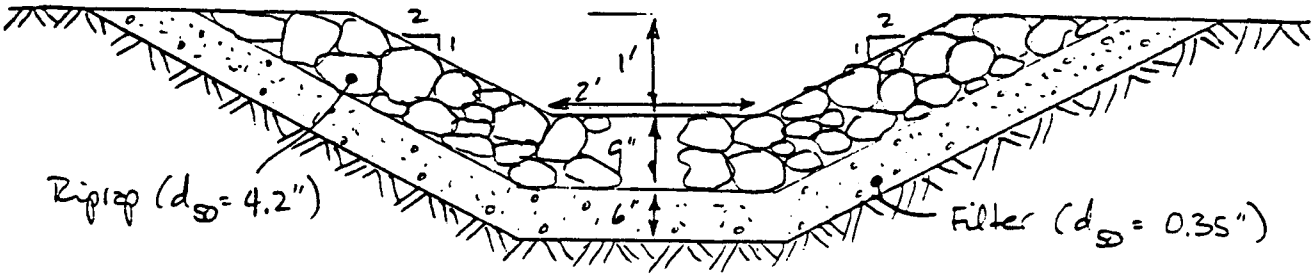
$$\frac{D_{15}\text{ (filter)}}{D_{85}\text{ (bed)}} = \frac{0.08\text{ in}}{0.94\text{ in}} = 0.09 < 5 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (filter)}}{D_{15}\text{ (bed)}} = \frac{0.08\text{ in}}{0.0021\text{ in}} = 38.1 < 40 \quad \underline{\underline{OK}}$$

KEUFFEL & ESSER CO. MADE IN U.S.A.
46 5492




278/




RD-2 ELEVATION VIEW

SCALE: 1" = 2'

Design of RD-3

Ultimate drainage area = WS-5 + site reclaimed area

Undisturbed area = 2.1 ac (WS-5)
Reclaimed area = 0.6 ac (site)
Total = 2.7 ac = 0.004 mi²

$l = 750$ ft

$\bar{C}_N = \frac{(2.1)(69) + (0.6)(75)}{2.7} = 71$

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

$Y = \left[\frac{(1990\ ft)(40\ ft)}{(2.7\ ac)(43{,}560\ ft^2/ac)}\right](100) = 67.7\%$

$L = \frac{(750)^{0.8}(1+4.08)^{0.7}}{(1900)(67.7)^{0.5}}$

$= 0.04$ hr

$T_c = (1.67)(0.04)$

$= 0.07$ hr

Design storm → 50-yr, 24-hr = 3.25 in

Hydrograph results → see pg 27n of this calc.

RD-3 no longer to be used.

TBW
1 Dec 1989

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

IDENTIFICATION: WATERSHED DRAINING TO RD-3

INPUT SUMMARY:

```
*****************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.004 SQ. MI.
        DEPTH =  3.25 IN.               CN = 71.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.07 HR.
*****************************************************************
```

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

OUTPUT SUMMARY:

```
*****************************************************************
     TOTAL RUNOFF DEPTH =  0.9083 INCHES
     INITIAL ABSTRACTION =  0.8169 INCHES
     PEAK FLOW =      2.45 CFS   ( 0.9473 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.9101 INCHES
*****************************************************************
```

Maximum channel slope = $\frac{10}{30}$ = 0.33 ft/ft

Minimum channel slope = 0.01 ft/ft (design condition along base of cut)

Initially assume n = 0.033. Run w/ b = 2 ft.

| | | |
|---|---|---|
| Bed Slope = | .33 | |
| Manning's N = | .033 | |
| Bottom Width = | 2 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .1564641 | feet |
| Cross Sectional Area = | .3618902 | square feet |
| Wetted Perimeter = | 2.699729 | feet |
| Hydraulic Radius = | .1340469 | feet |
| Discharge = | 2.45 | cubic feet/sec |
| Velocity = | 6.77001 | feet/sec |
| Froude Number = | 3.416156 | |

Required $d_{50}$ = 0.35 ft
= 4.2 in

RD-3 no longer to be use

Cross section design:

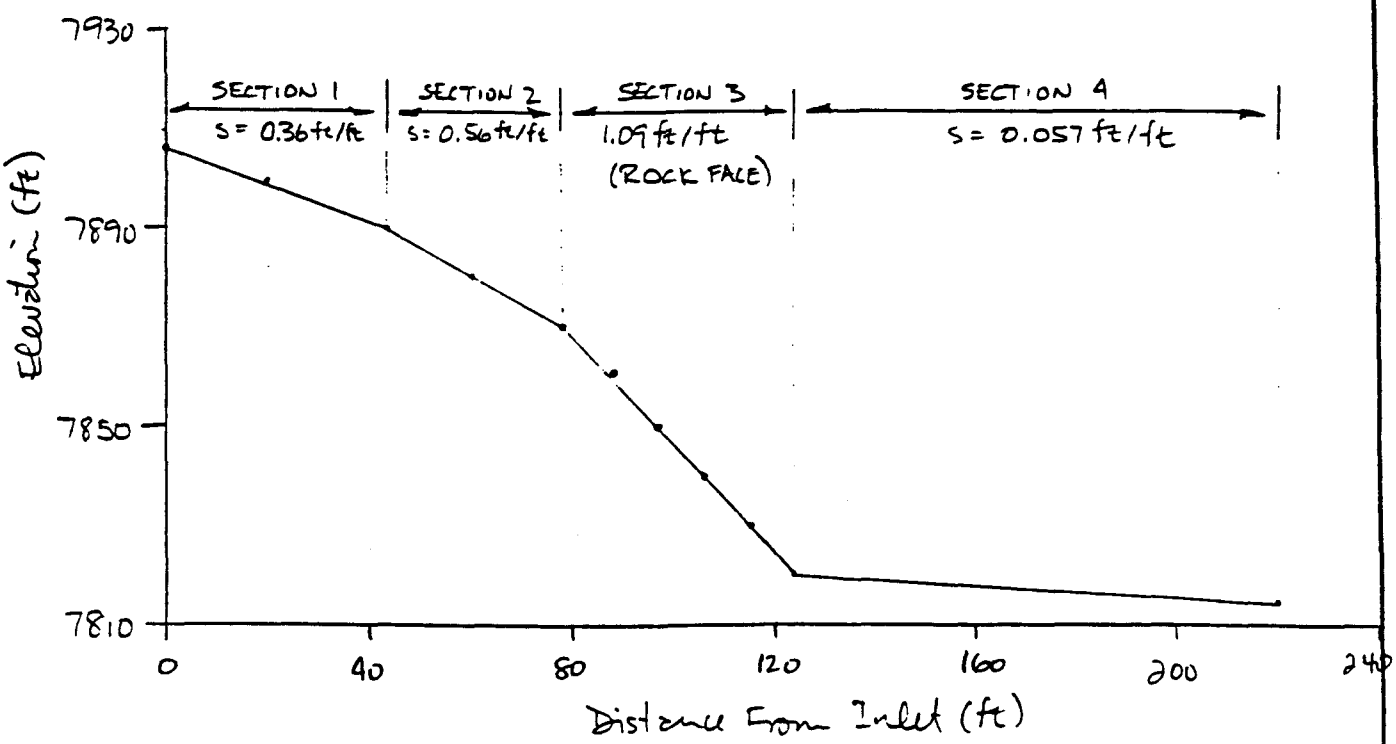
| | | |
|---|---|---|
| Bed Slope = | .01 | |
| Manning's N = | .033 | |
| Bottom Width = | 2 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .4199953 | feet |
| Cross Sectional Area = | 1.192783 | square feet |
| Wetted Perimeter = | 3.878276 | feet |
| Hydraulic Radius = | .3075549 | feet |
| Discharge = | 2.45 | cubic feet/sec |
| Velocity = | 2.05402 | feet/sec |
| Froude Number = | .5585404 | |

Use the same cross section designed for RD-2.

RD-3 no longer to be used.
RBW 12/1/89

Design of RD-4

Longitudinal profile:




Determine peak flow and design the channel by section

Watershed draining to RD-4 → WS-3 + portion of reclaimed area

Drainage area = 8.8 ac (WS-3) + 0.2 ac (site) = 9.0 ac
= 0.014 mi²

$l = 1540$ ft

$\bar{CN} = \frac{(8.8)(69) + (0.2)(75)}{9.0} = 70$

$S = \frac{1000}{70} - 10 = 4.29$

$Y = \left[\frac{(1600\text{ ft})(40\text{ ft})}{(9.0\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 16.3\%$

$L = \frac{(1540)^{0.8}(1+4.29)^{0.7}}{(1900)(16.3)^{0.5}}$

$= 0.15$ hr

$T_L = (1.67)(0.15)$

$= \underline{0.25}$ hr

Design storm → 50-yr, 24-hr = 3.25 in

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


IDENTIFICATION:  WATERSHED DRAINING TO RD-4

INPUT SUMMARY:
*************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.014 SQ. MI.
        DEPTH =  3.25 IN.            CN = 70.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.25 HR.
*************************************************************


*************************************************************


OUTPUT SUMMARY:
*************************************************************
     TOTAL RUNOFF DEPTH =  0.8573 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      6.62 CFS   ( 0.7323 IN/HR)
     TIME TO PEAK =  12.05 HOURS
     RUNOFF VOLUME CHECK =  0.8590 INCHES
*************************************************************
```

Above the rock face, design riprap size based on section 2 and channel cross section based on section 1.

Section 2 run (assume n = 0.037, b = 4 ft):

| | | |
|---|---|---|
| Bed Slope = | .56 | |
| Manning's N = | .037 | |
| Bottom Width = | 4 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .1736899 | feet |
| Cross Sectional Area = | .7550959 | square feet |
| Wetted Perimeter = | 4.776765 | feet |
| Hydraulic Radius = | .1580768 | feet |
| Discharge = | 6.62 | cubic feet/sec |
| Velocity = | 8.767098 | feet/sec |
| Froude Number = | 3.707154 | |

Required $d_{50}$ (from pg 27c) = 0.70 ft
= 8.4 in

n = 0.037 ⇒ OK

Section 1 run:

| | | |
|---|---|---|
| Bed Slope = | .36 | |
| Manning's N = | .037 | |
| Bottom Width = | 4 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .1975886 | feet |
| Cross Sectional Area = | .8684367 | square feet |
| Wetted Perimeter = | 4.883643 | feet |
| Hydraulic Radius = | .1778256 | feet |
| Discharge = | 6.62 | cubic feet/sec |
| Velocity = | 7.622893 | feet/sec |
| Froude Number = | 3.022115 | |

Riprap gradation → see pg. 27r of this calc.

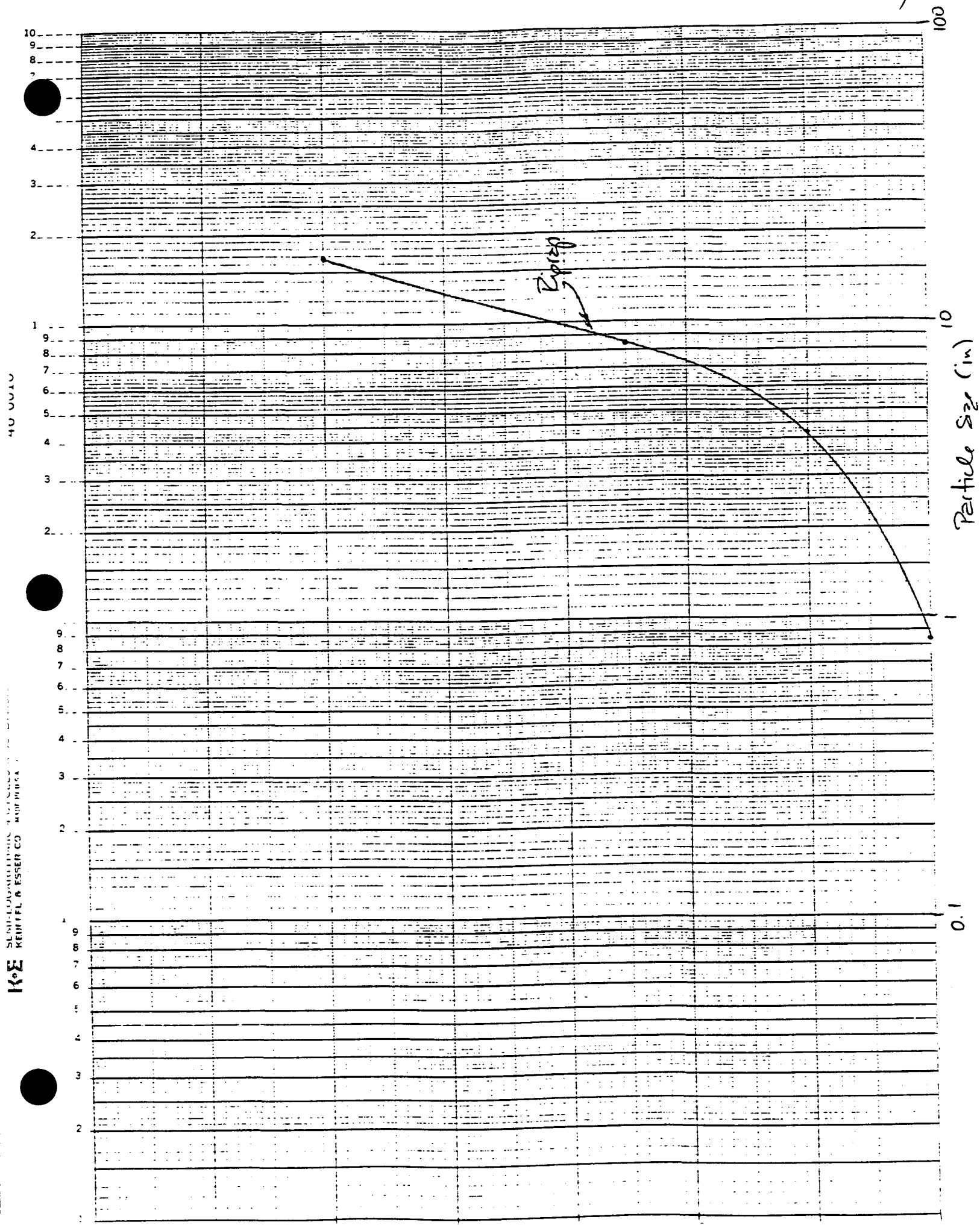
Check filter blanket design using the blanket designed for RD-2:

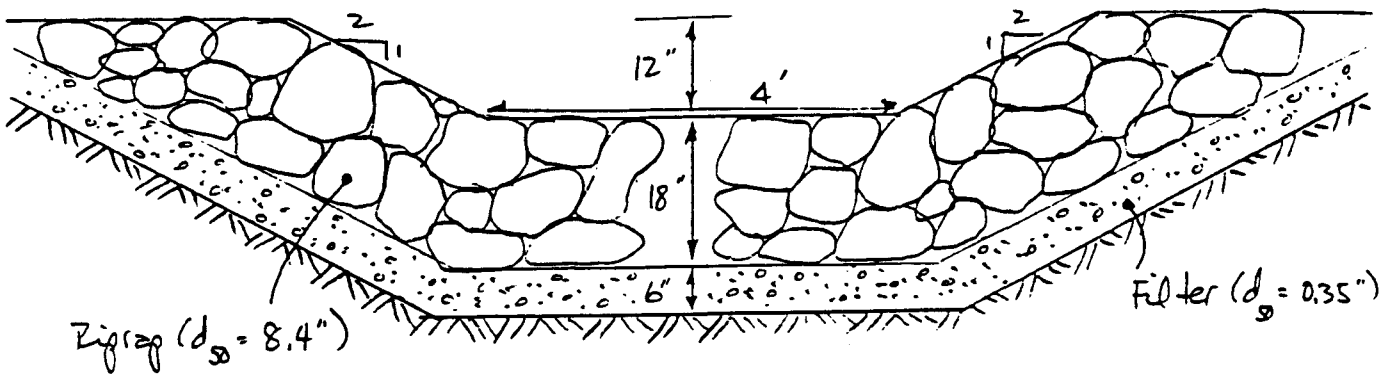
$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{3.2\text{ in}}{0.85\text{ in}} = 3.8 < 5 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{3.2\text{ in}}{0.08\text{ in}} = 40 = 40 \quad \underline{\underline{OK}}$$

Use this filter blanket.

2/12



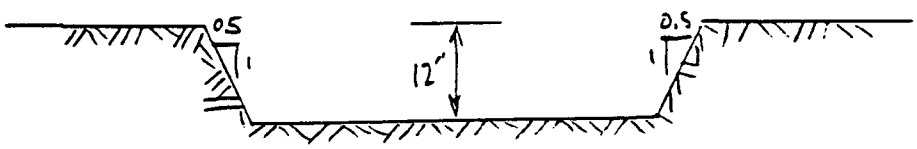



SECTION 1 / SECTION 2
RD-4 ELEV. VIEW
SCALE: 1" = 2'

Section 3 of this channel will be blasted into rock. The U.S. Soil Conservation Service (1956) suggests a range of roughness coefficients for similar channels of 0.035 to 0.045. Assume n = 0.040.

| | | |
|---|---|---|
| Bed Slope = | 1.09 | |
| Manning's N = | .04 | |
| Bottom Width = | 4 | feet |
| Channel Side Slope = | 2 | |
| Flow Depth = | .1521696 | feet |
| Cross Sectional Area = | .6202561 | square feet |
| Wetted Perimeter = | 4.340262 | feet |
| Hydraulic Radius = | .1429075 | feet |
| Discharge = | 6.62 | cubic feet/sec |
| Velocity = | 10.67301 | feet/sec |
| Froude Number = | 4.821644 | |

This velocity is considered acceptable for rock (see U.S. Army Corps of Engineers, 1970).




SECTION 3
RD-4 ELEV. VIEW
SCALE: 1" = 2'

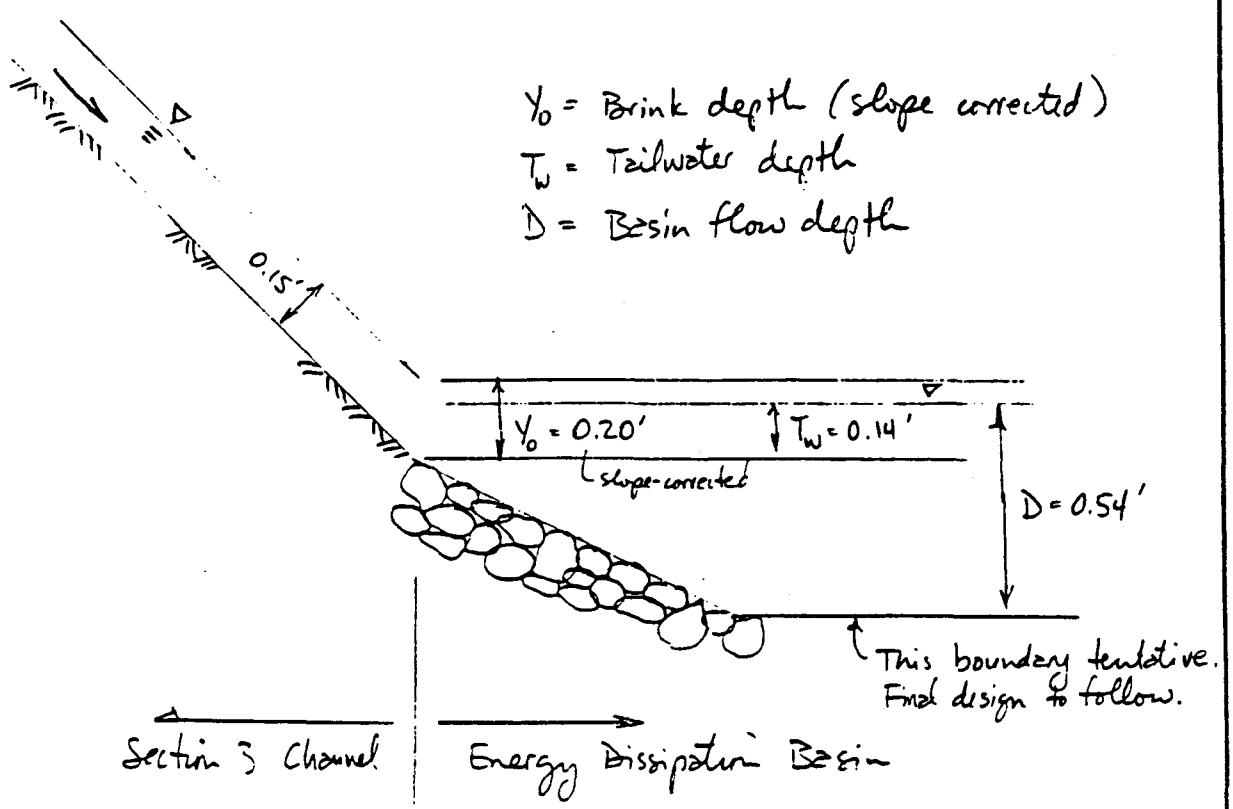
Design of Energy Dissipation Basin at Downstream Edge of Section 3 Channel (where rock face meets pad) – use the design procedure of Curry et al. (1975):
↳ HEC-14

Depth of flow in basin – Assume 1% slope on basin floor
4 ft bottom width
2:1 sideslope:

TRAP1 results:

| | | |
|---|---|---|
| Bed Slope = | .01 | |
| Manning's N = | .035 | |
| Bottom Width = | 4 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .5392388 | feet |
| Cross Sectional Area = | 2.738512 | square feet |
| Wetted Perimeter = | 6.41155 | feet |
| Hydraulic Radius = | .4271218 | feet |
| Discharge = | 6.62 | cubic feet/sec |
| Velocity = | 2.417371 | feet/sec |
| Froude Number = | .5801293 | |

General schematic:




$$\frac{T_W}{Y} = \frac{0.14}{0.20} = 0.70 < 0.75 \quad \underline{\underline{OK}}$$

Determine riprap sizing for basin — see pg 27s4 of this calc:

Select $d_{50}$ such that $0.25 < \frac{d_{50}}{Y_e} < 0.45$

AND

$2 < \frac{h_s}{d_{50}} < 4$

$Y_e$ = equivalent depth = $(A/2)^{1/2}$ where A is for Section 3 channel

$= \frac{(2.74/2)^{1/2}}{\sin 47.5°}$

$= 1.59$ ft

To meet the design criteria $(0.25 < d_{50}/Y_e < 0.45)$, select $d_{50}/Y_e = 0.35 \Rightarrow d_{50} = (0.35)(1.59') = 0.56$ ft (min)

However, the Division has requested the use of $d_{50} = 1.25$ ft (see pg 27s7) Thus, this size will be used. Filter blanket calculations included on page 27s8 of this calc.

From pg 27s4 $\rightarrow \frac{h_s}{Y_e} = 0.90 \Rightarrow h_s = (0.90)(1.59)$
$= 1.43$ ft (scour hole depth)

$\frac{h_s}{d_{50}} = \frac{1.43}{0.70} = 2.04 \Rightarrow$ OK

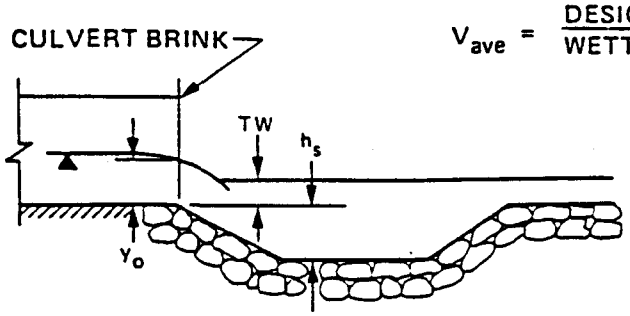
Basin length $= 10 h_s = 14.3$ ft $\Rightarrow$ use 15 ft

Apron length $= 5 h_s = 7.15$ ft $\Rightarrow$ use 7.5 ft

Freeboard = 1.0 ft

Total basin depth $= h_s + Y_0 + 1.0$
$= 1.43 + 0.20 + 1.00$
$= 2.63$ ft $\Rightarrow$ Construct with depth = 2.75 ft

Design sections $\rightarrow$ see pg 27s5 and 27s6 of this calc.




$$V_{ave} = \frac{\text{DESIGN DISCHARGE} - Q}{\text{WETTED AREA AT BRINK OF CULVERT}}$$

$d_{50}$ = THE MEDIAN SIZE OF ROCK BY WEIGHT. ROUNDED ROCK OR ANGULAR ROCK.

$Y_e$ = EQUIVALENT BRINK DEPTH

= BRINK DEPTH FOR BOX CULVERT

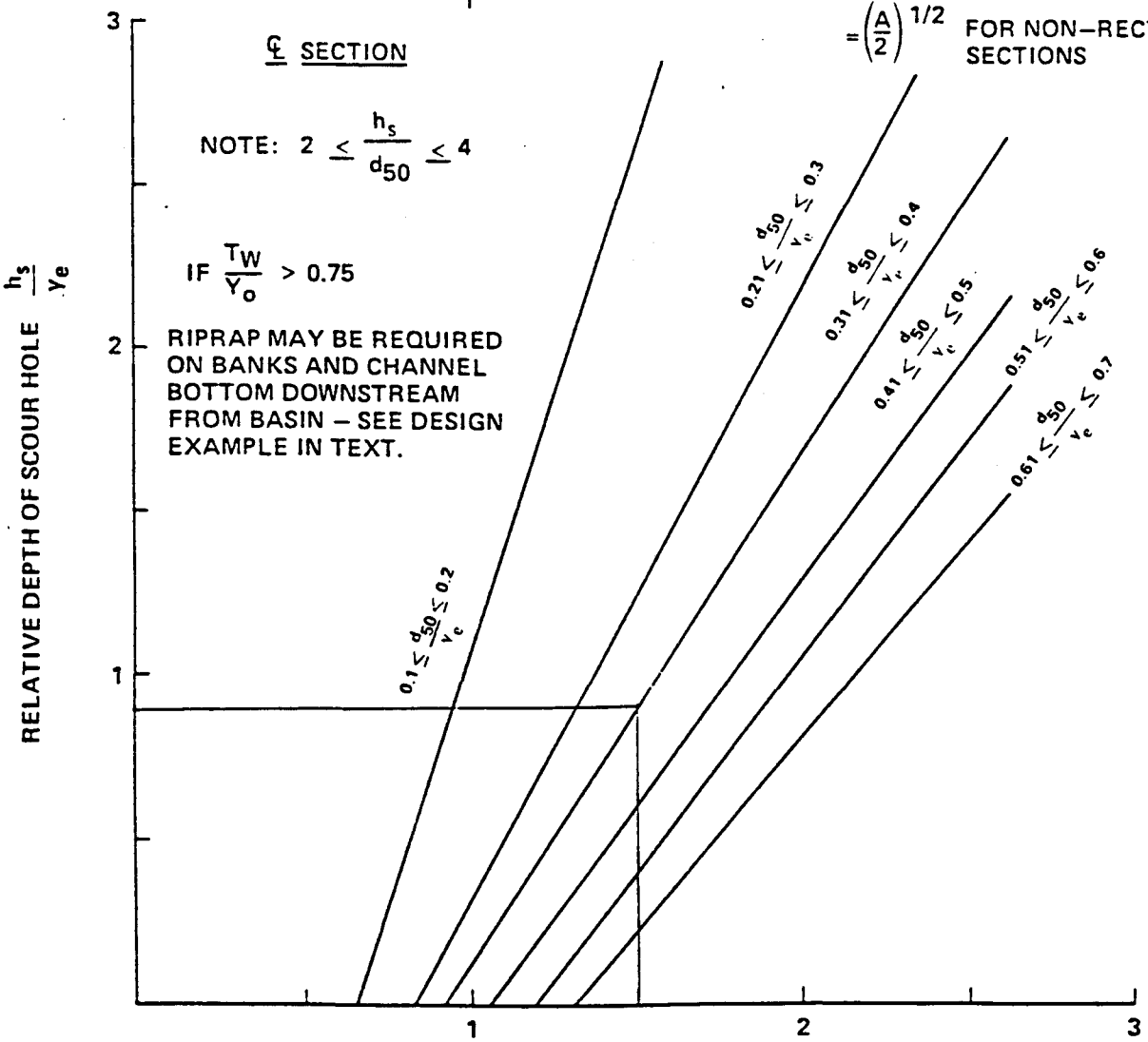
$= \left(\frac{A}{2}\right)^{1/2}$ FOR NON-RECTANGULAR SECTIONS

℄ SECTION

NOTE: $2 \leq \frac{h_s}{d_{50}} \leq 4$

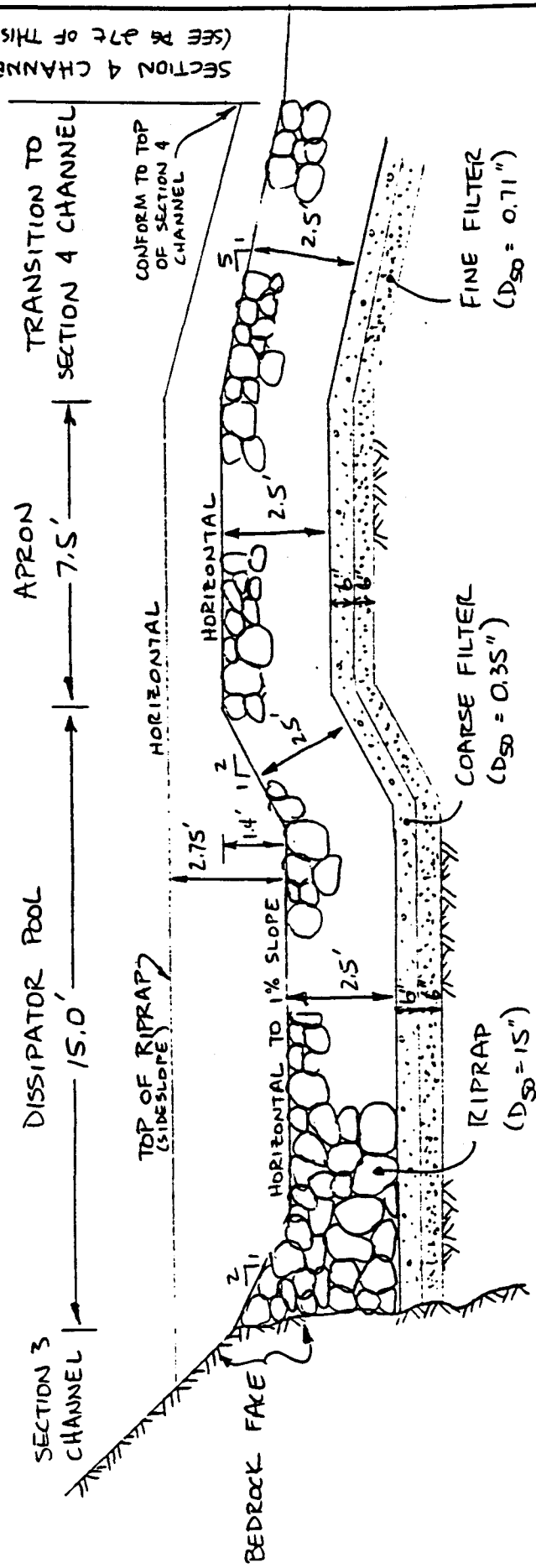
IF $\frac{T_W}{Y_o} > 0.75$

RIPRAP MAY BE REQUIRED ON BANKS AND CHANNEL BOTTOM DOWNSTREAM FROM BASIN – SEE DESIGN EXAMPLE IN TEXT.



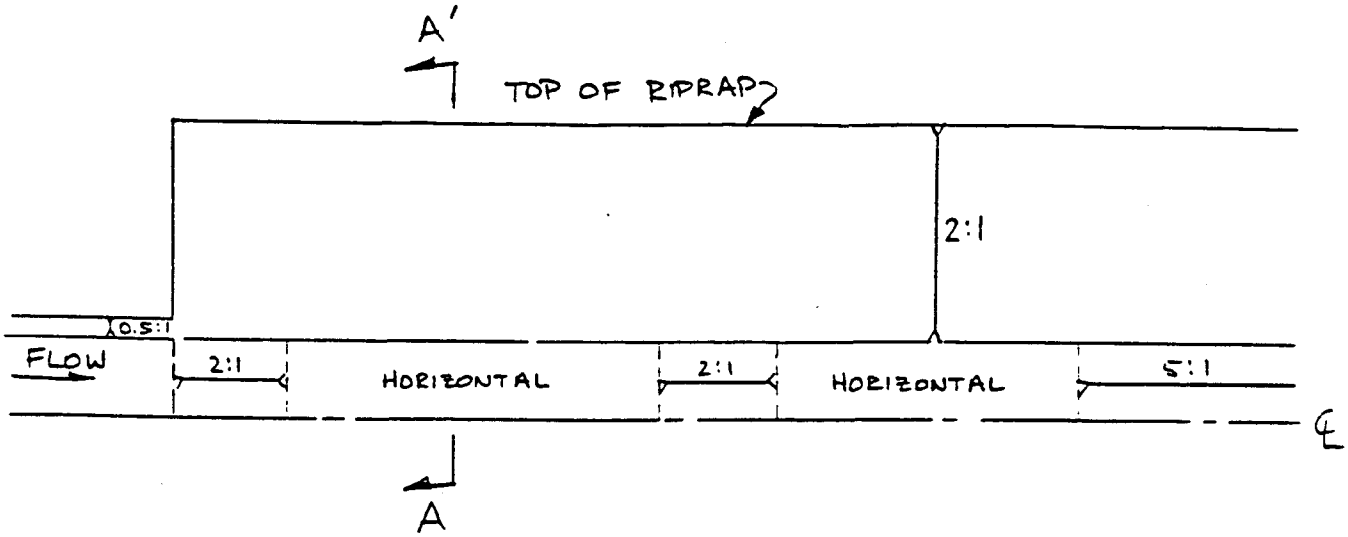

$$\text{FROUDE NUMBER} = \frac{V_{ave}}{\sqrt{(32.2)(Y_e)}} = \frac{10.7}{\sqrt{(32.2)(1.59)}} = 1.50$$ for Section 3 channel

Source: Corry et al. (1975) (HEC-14)

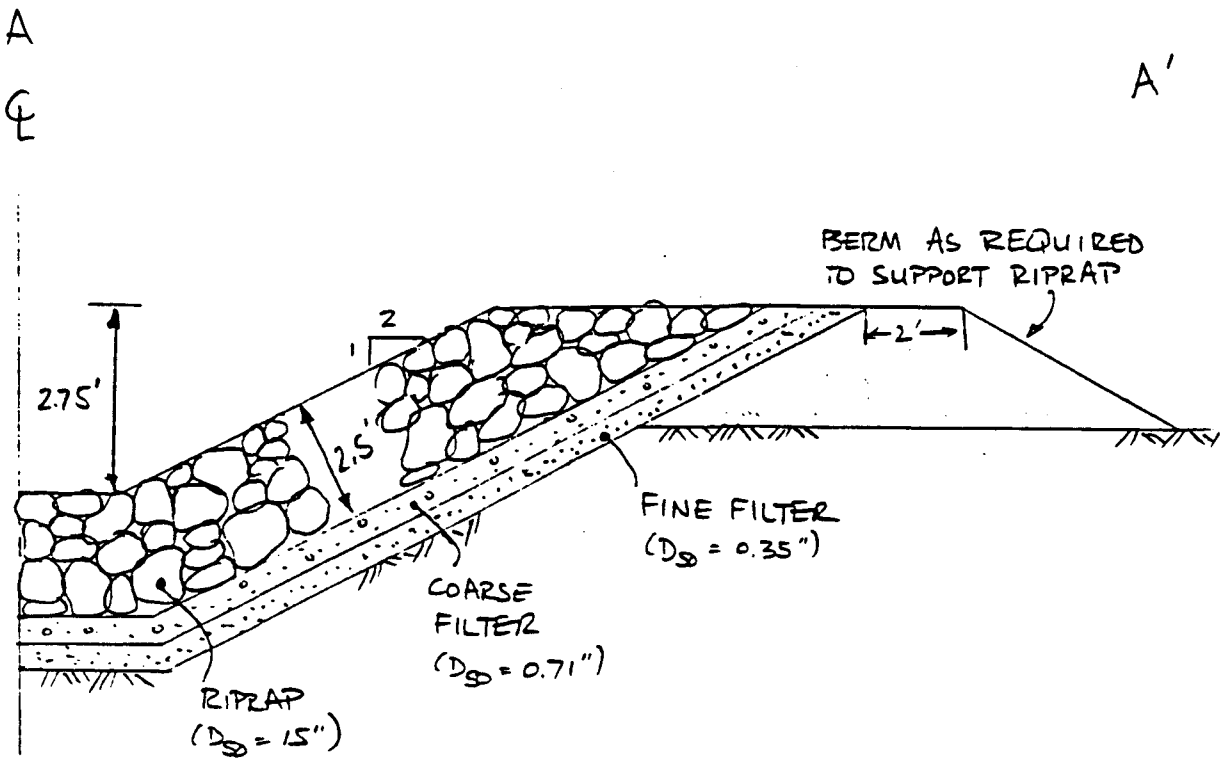



ENERGY DISSIPATION BASIN
CENTER LINE SECTION

SCALE: 1" = 4'

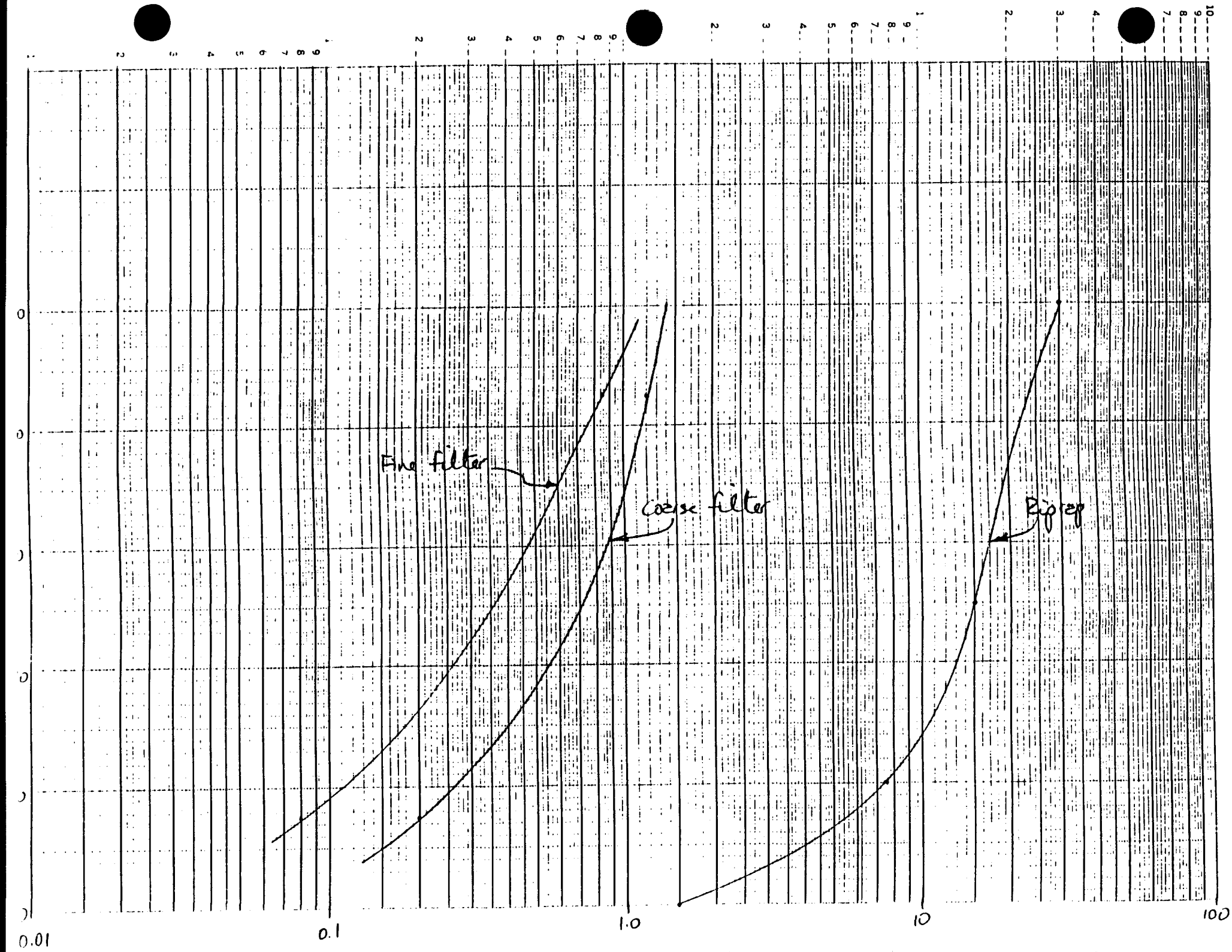



ENERGY DISSIPATION BASIN
HALF PLAN
SCALE: 1" = 50'




ENERGY DISSIPATION BASIN
SECTION A-A'

K&E KEUFFEL & ESSER CO. MADE IN U.S.A.



Check filter blanket design using the RD-2 blanket (see pg. 27l of this calc.):

$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{5.7\text{ in}}{0.85\text{ in}} = 6.7 > 5.0$$

$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{5.7\text{ in}}{0.08\text{ in}} = 71.2 > 40$$

Unacceptable

New filter blanket design (see pg. 27s7 of this calc.):

$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{5.7\text{ in}}{1.2\text{ in}} = 4.8 < 5.0 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{5.7\text{ in}}{0.2\text{ in}} = 28.5 < 40 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (filter)}}{D_{85}\text{ (bed)}} = \frac{0.2\text{ in}}{0.94\text{ in}} = 0.2 < 5.0 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (filter)}}{D_{15}\text{ (bed)}} = \frac{0.2\text{ in}}{0.0021\text{ in}} = 95.2 > 40 \quad \underline{\underline{\text{Unacceptable}}}$$

Include two filter blankets (the coarse blanket above and the RD-2 blanket). Check design between the two:

$$\frac{D_{15}\text{ (coarse)}}{D_{85}\text{ (fine)}} = \frac{0.2\text{ in}}{0.85\text{ in}} = 0.24 < 5.0 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (coarse)}}{D_{15}\text{ (fine)}} = \frac{0.2\text{ in}}{0.08\text{ in}} = 2.5 < 40 \quad \underline{\underline{OK}}$$

Section 4 → assume n = 0.031

| | | |
|---|---|---|
| Bed Slope = | .057 | |
| Manning's N = | .031 | |
| Bottom Width = | 4 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .3047183 | feet |
| Cross Sectional Area = | 1.40458 | square feet |
| Wetted Perimeter = | 5.362742 | feet |
| Hydraulic Radius = | .2619145 | feet |
| Discharge = | 6.62 | cubic feet/sec |
| Velocity = | 4.713154 | feet/sec |
| Froude Number = | 1.504646 | |

Required $d_{50}$ = 0.25 ft
= 3.0 in

n = 0.031 ⇒ OK

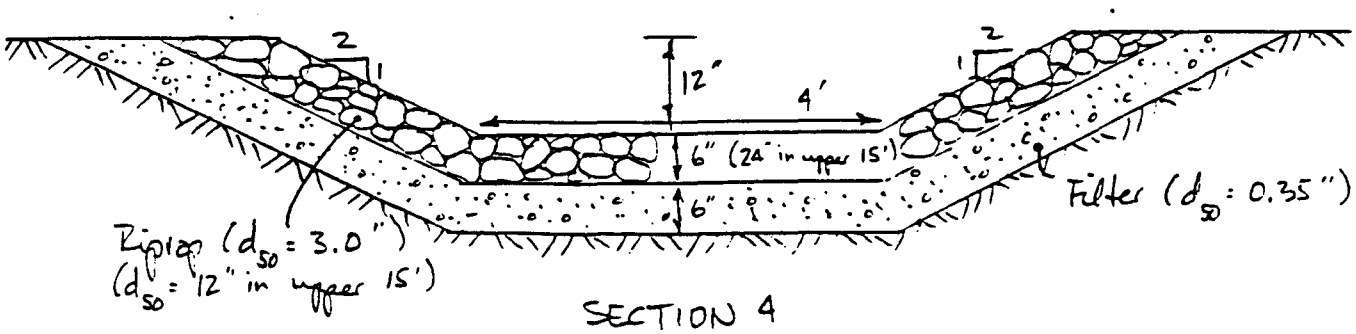
Gradation of Section 4 riprap → see pg. 27u of this calc.

Filter blanket requirement → compare with filter blanket designed for RD-2.

$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{1.25\text{ in}}{0.85\text{ in}} = 1.5 < 5 \qquad \underline{\underline{OK}}$$

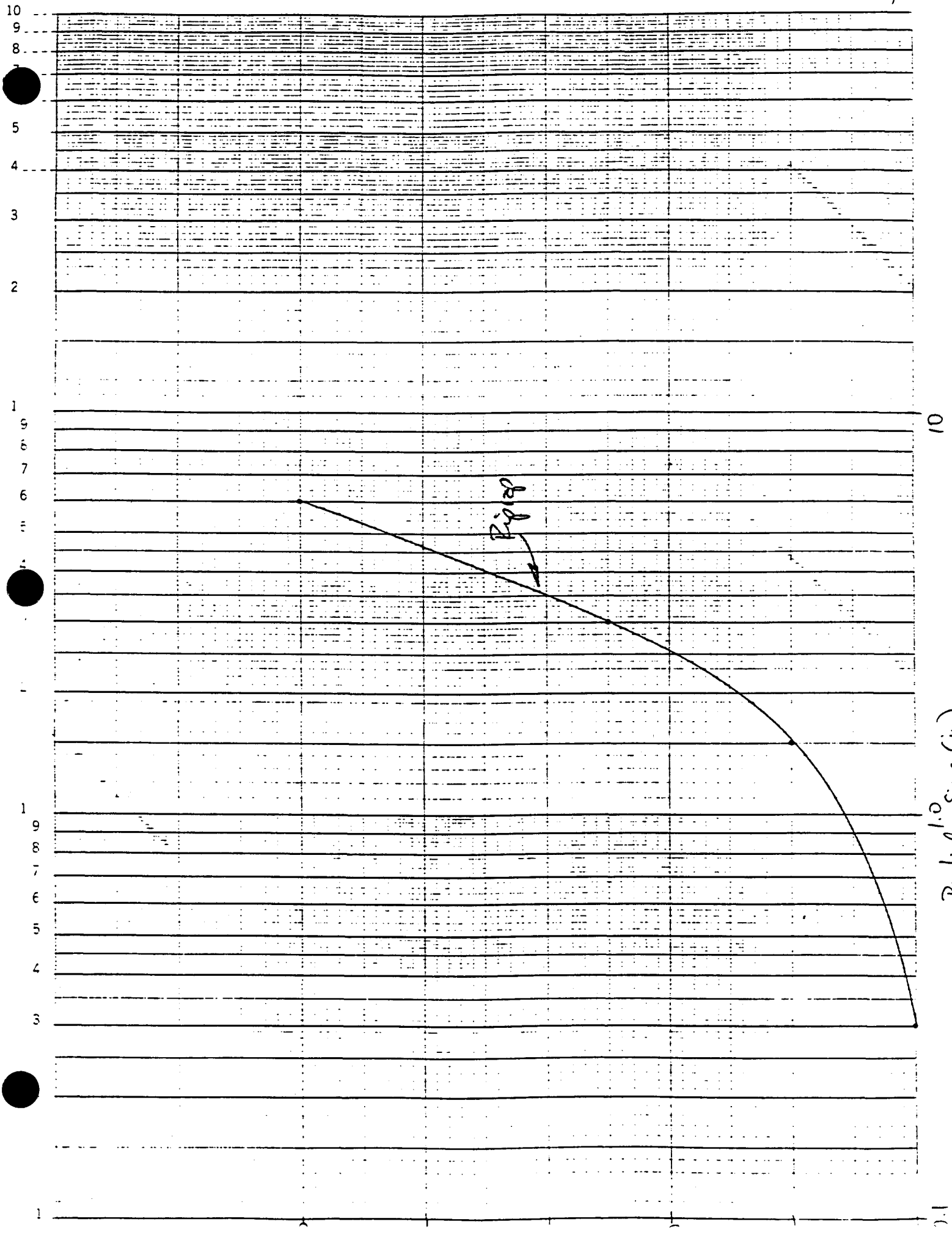
$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{1.25\text{ in}}{0.08\text{ in}} = 15.6 < 40 \qquad \underline{\underline{OK}}$$

Use the filter blanket designed for RD-2.




SECTION 4
RD-4 ELEV. VIEW
SCALE: 1" = 2'

27u/



## Design of RD-5

Contributing area → all areas contributing to RD-2 and RD-4 plus the reclaimed area between RD-3 and RD-5.

Undisturbed area = 6.4 (RD-2) + 8.8 (RD-4) = 15.2 ac

Reclaimed area = 2.5 (RD-2) + 0.2 (RD-4) + 0.3 (site) = 3.0 ac

Total = 18.2 ac = 0.028 mi²

$l = 1730$ ft

$$\overline{CN} = \frac{(15.2)(69) + (3.0)(75)}{18.2} = 70$$

$$S = \frac{1000}{70} - 10 = 4.29$$

$$Y = \left[\frac{(4770\text{ ft})(40\text{ ft})}{(18.2\text{ ac})(43{,}560\text{ ft}^2/\text{ac})}\right](100) = 24.1\%$$

$$L = \frac{(1730)^{0.8}(1+4.29)^{0.7}}{(1900)(24.1)^{0.5}} = 0.13\text{ hr}$$

$$T_c = (1.67)(0.13) = 0.22\text{ hr}$$

Design storm → 50-yr, 24-hr = 3.25 in

```
IDENTIFICATION:  WTERSHED DRAINING TO RD-5

INPUT SUMMARY:
*************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.028 SQ. MI.
        DEPTH =  3.25 IN.               CN = 70.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.22 HR.
*************************************************************


*************************************************************


OUTPUT SUMMARY:
*************************************************************
     TOTAL RUNOFF DEPTH =  0.8573 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =     13.69 CFS   ( 0.7576 IN/HR)
     TIME TO PEAK =  12.04 HOURS
     RUNOFF VOLUME CHECK =  0.8590 INCHES
*************************************************************
```

Channel slope = 0.031 ft/ft. Assume n = 0.032

| | | |
|---|---|---|
| Bed Slope = | .031 | |
| Manning's N = | .032 | |
| Bottom Width = | 4 | feet |
| Channel Side Slope = | .5 | |
| Flow Depth = | .561434 | feet |
| Cross Sectional Area = | 2.876153 | square feet |
| Wetted Perimeter = | 6.51081 | feet |
| Hydraulic Radius = | .4417504 | feet |
| Discharge = | 13.69 | cubic feet/sec |
| Velocity = | 4.759831 | feet/sec |
| Froude Number = | 1.119475 | |

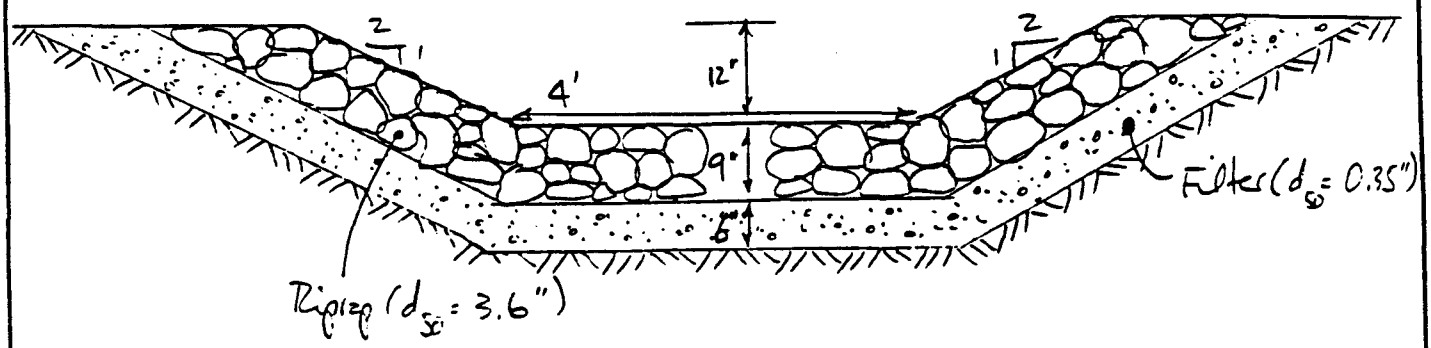
Required $d_{50}$ = 0.30 ft (from pg. 27c)
= 3.6 in

n = 0.032 ⇒ OK See gradation on pg. 27x

Check RD-2 filter:

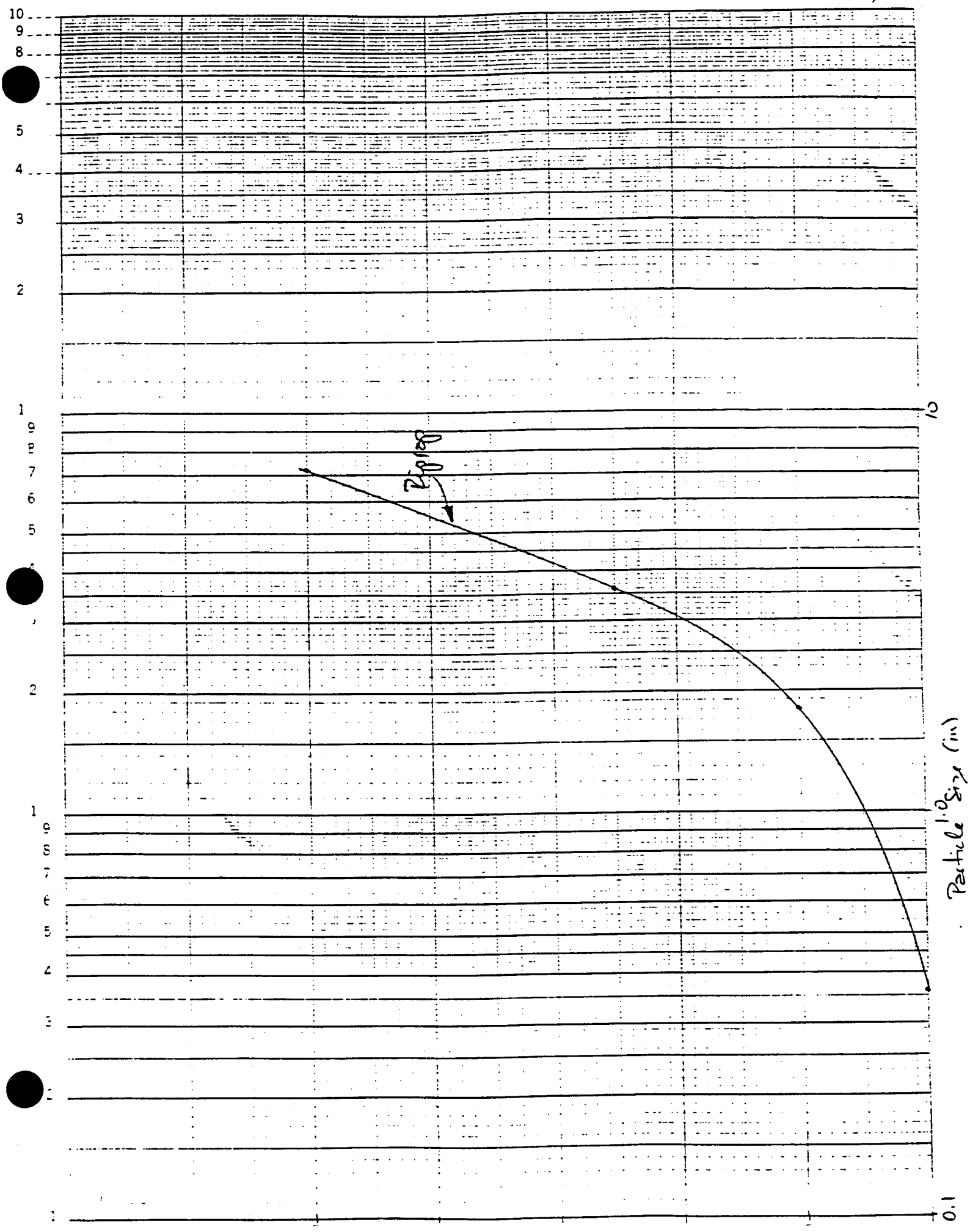
$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{1.4\text{ in}}{0.85\text{ in}} = 1.6 < 5 \quad \underline{\underline{OK}}$$

$$\frac{D_{15}\text{ (riprap)}}{D_{15}\text{ (filter)}} = \frac{1.4\text{ in}}{0.08\text{ in}} = 17.5 < 40 \quad \underline{OK}$$




RD-5 ELEV. VIEW
SCALE: 1" = 2'

27x/



## Addendum to Appendix 7-7

### Design of Culvert C-9

From the design flow of DD-4 (page 7 of Appendix 7-11), the runoff depth is 1.96 inches and the peak flow is 0.32 cfs.

Using the nomograph on page 26d of the Appendix a 12-inch diameter CMP culvert is more than adequate to handle the 10 year-24 hour design flow. In addition, using the Mannings Formula listed below, the culvert diameter required to carry the design flow of 0.32 cfs is only 0.34"; therefore, the 12" diameter culvert if further shown to be more than adequate.

$$D = \left(\frac{2.16\ Qn}{\sqrt{S}}\right)^{0.35}$$

Where:
- D = Required Culvert Diameter (feet)
- Q = Peak Inflow (cfs)
- n = Roughness Factor (0.02 for cmp)
- S = Slope (ft. per ft.)
- Note: Slope = 0.095 ft./ft. for DD-4 is shown on page 7 of Appendix 7-11.

INCORPORATED
EFFECTIVE:
NOV 12 1993
UTAH DIVISION OIL, GAS AND MINING

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