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APPENDIX 7-7

Diversion Calculations

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

REGISTERED PROFESSIONAL ENGINEER
NO. 2102
RICHARD B. WHITE
STATE OF UTAH

Richard B. White, P.E.

Mid-Term Revisions 5-30-1986

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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

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

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

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

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

$$T_c = (1.67)(0.03) = 0.05\text{ hr}$$

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

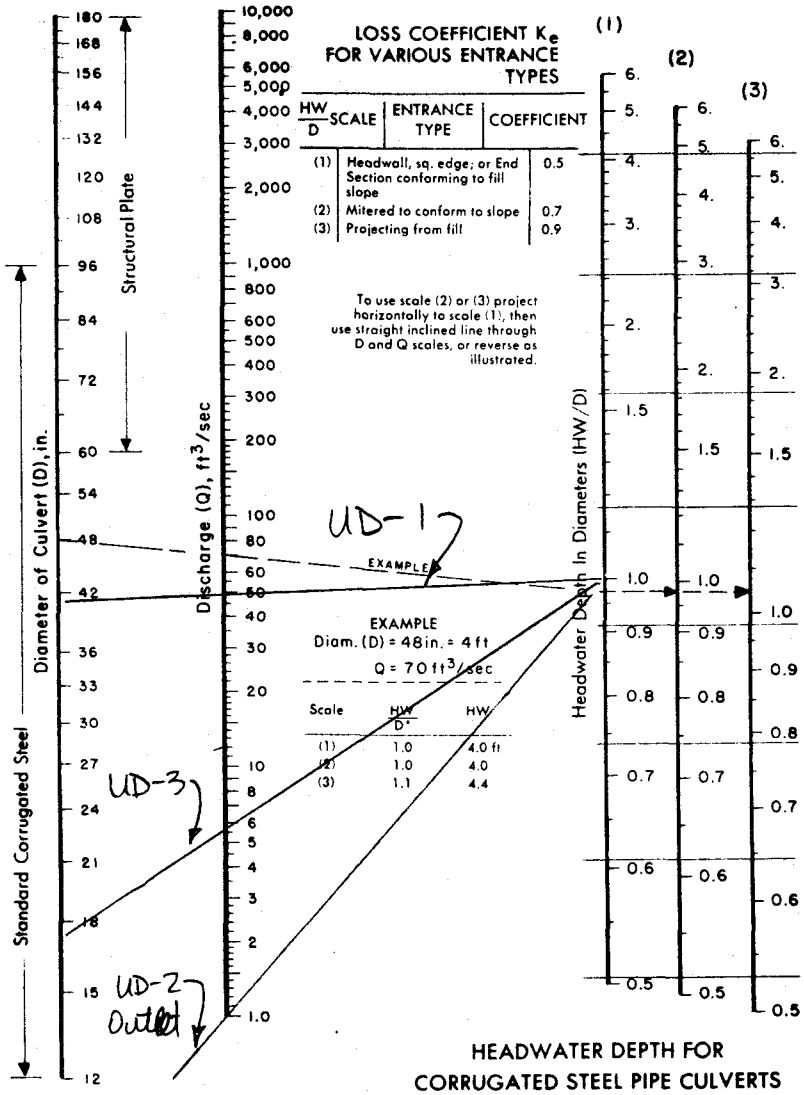
Rainfall distribution → SCS Type II

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:



Use 42" CMP w/ flared end section

HEADWATER DEPTH FOR CORRUGATED STEEL PIPE CULVERTS WITH INLET CONTROL

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

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

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

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:

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

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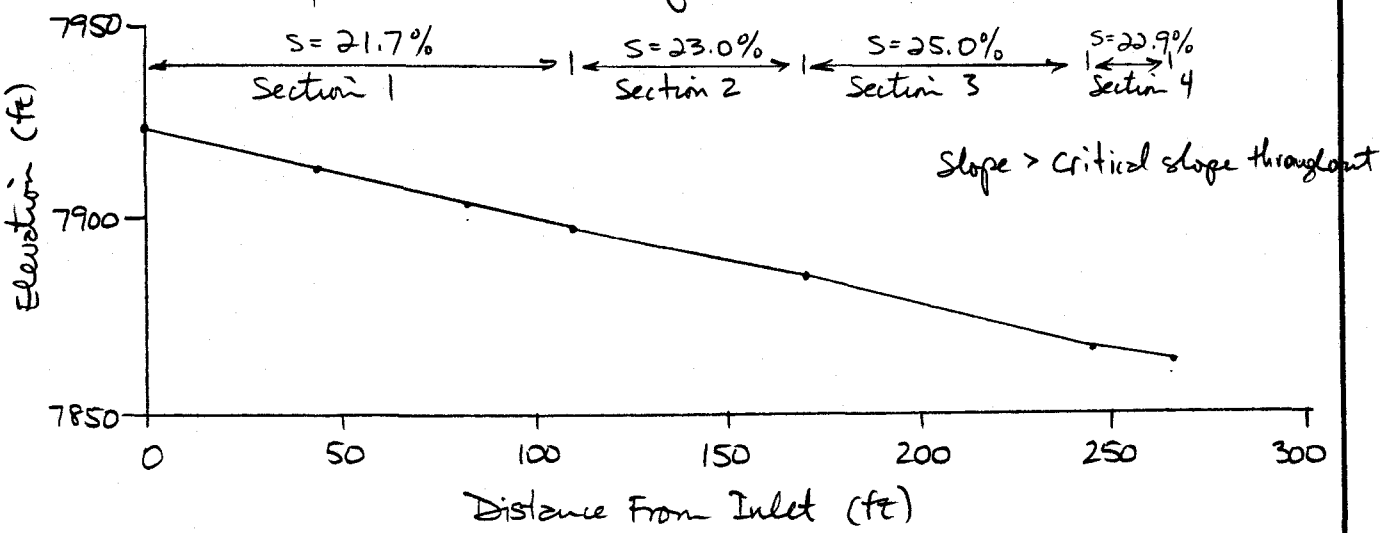
When $\frac{d_n}{D} = 0.616$, $\frac{nQ}{D^{8/3} S_c^{\frac{1}{2}}} = 0.324$

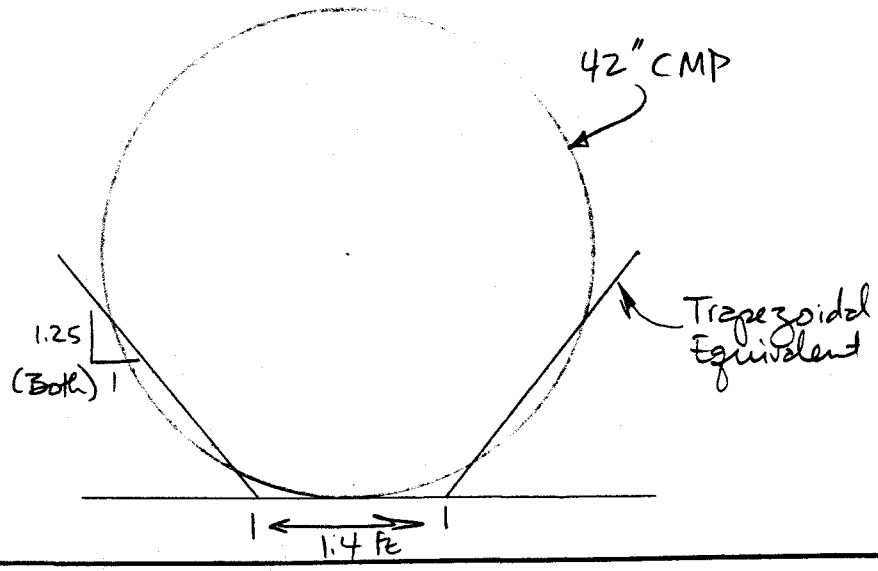
With $n = 0.024$, $Q = 2025$, $D = 2.5$

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

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:



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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	

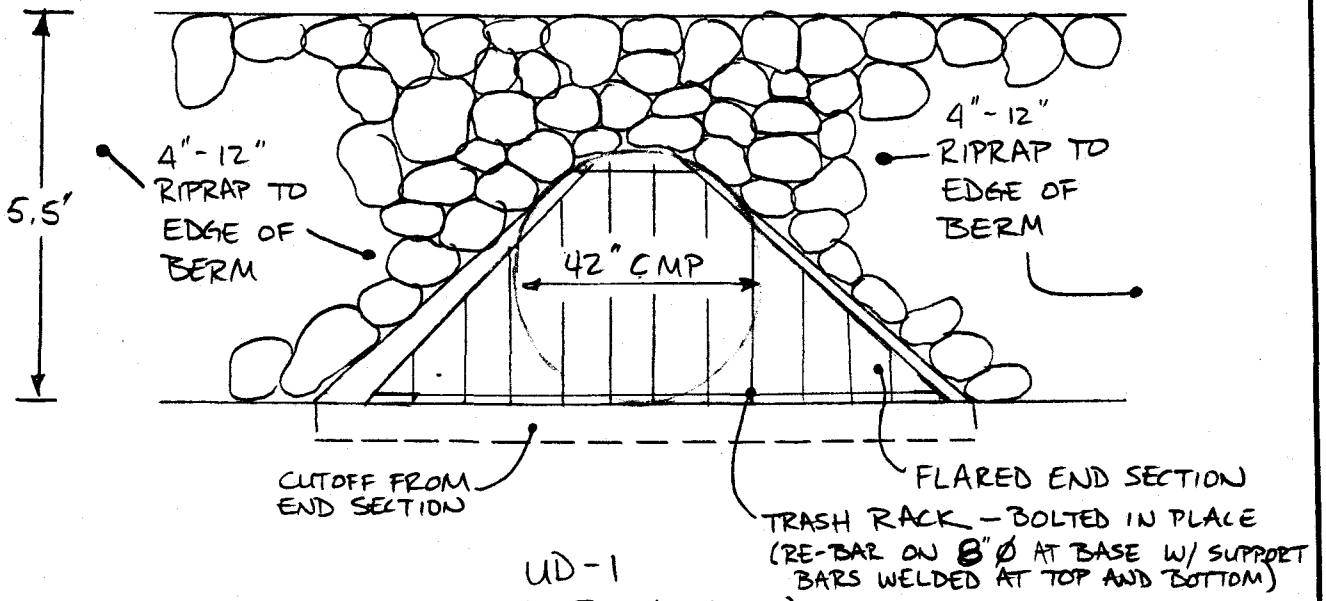
Section 3:

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	

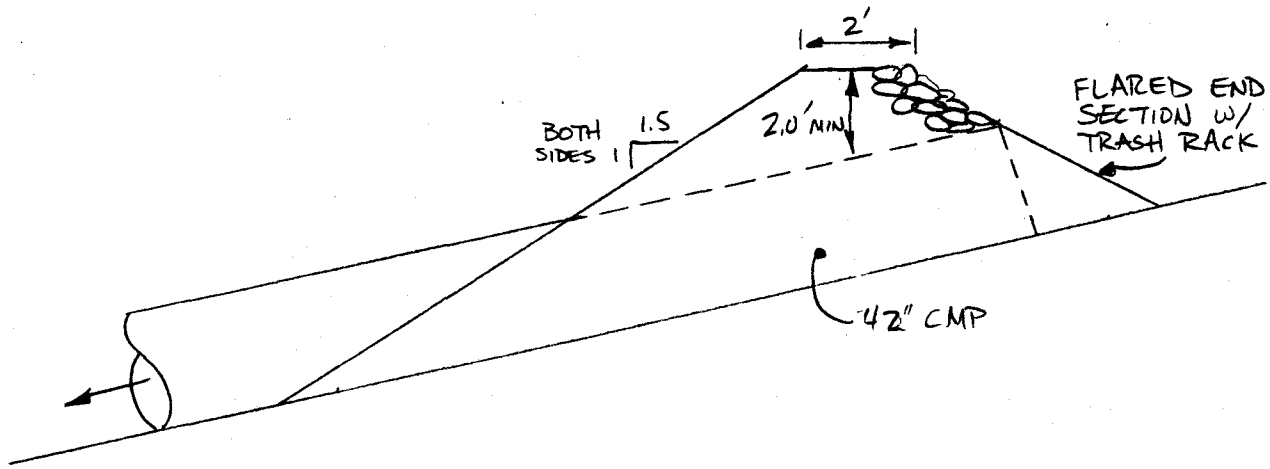
Section 4:

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

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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 pg. 8 of this calc. A flexible downspout will be added to dissipate energy down the Crandall Creek embankment. However, due to a lack of data concerning the roughness of flexible downspouts, a roughness coefficient equivalent to CMP will be assumed.

Exit velocity from the flexible downspout → use the pipe flow equation:

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

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 side view on 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

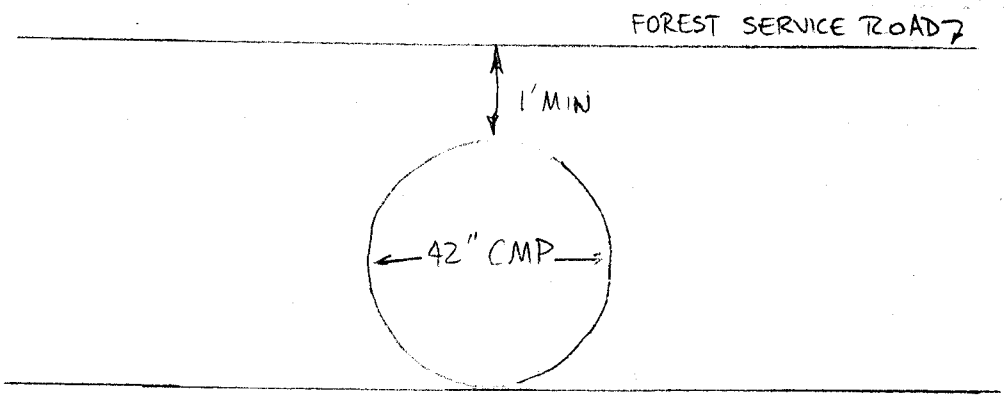
H = 22.5 + 6.5 = 29.0 ft

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

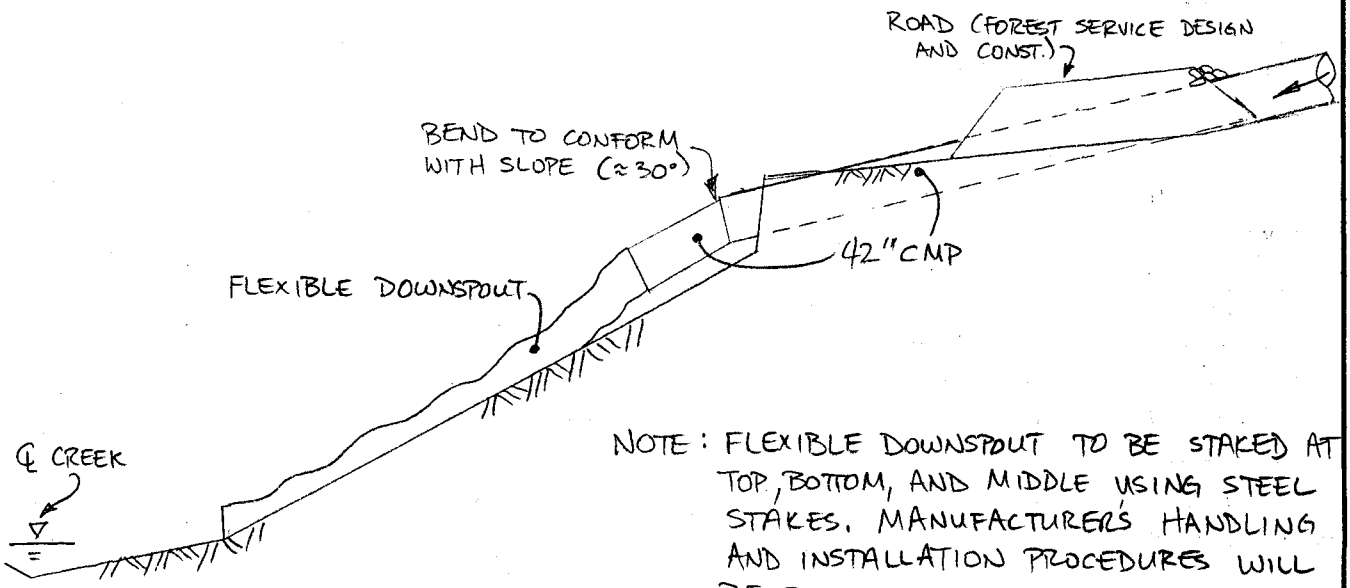
$$K_c = \frac{5087\, n^2}{d_i^{4/3}} \quad \text{(Assume } n = 0.024\text{)}$$

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

Diversion outlet:



UD-1
DOWNSTREAM INLET ELEV. VIEW



NOTE: FLEXIBLE DOWNSPOUT TO BE STAKED AT TOP, BOTTOM, AND MIDDLE USING STEEL STAKES. MANUFACTURER'S HANDLING AND INSTALLATION PROCEDURES WILL BE FOLLOWED.

UD-1
DOWNSPOUT SIDE VIEW
SCALE: 1" = 10'

$$V = \frac{[(2)(32.2)(29.0)]^{\frac{1}{2}}}{[1+1.0+0.5+(0.020)(25)]^{\frac{1}{2}}} = 25.0 \text{ ft/s}$$

The downspout will discharge onto rock and natural alluvial boulders. Hence, this velocity is acceptable and no additional energy dissipation will be required.

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.)

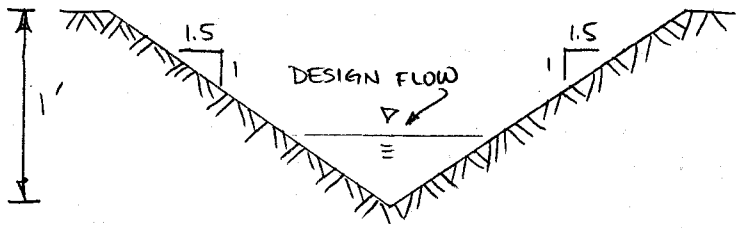
Slope along substation pad = (2.8 ft / 115 ft)(100) = 2.4%

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 TRAP1:

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

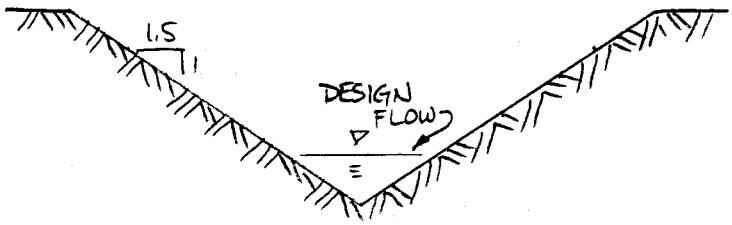


UD-2 AT SUBSTATION PAD - ELEV.

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

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

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

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

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

Area = 8.8 ac = 0.014 mi^2

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

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*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

IDENTIFICATION: WS-3 25-YR 24-HR STORM

INPUT SUMMARY:

```
*************************************************************
     STORM:                          WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.014 SQ. MI.
        DEPTH =  2.92 IN.               CN = 69.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.12 HR.
*************************************************************
```

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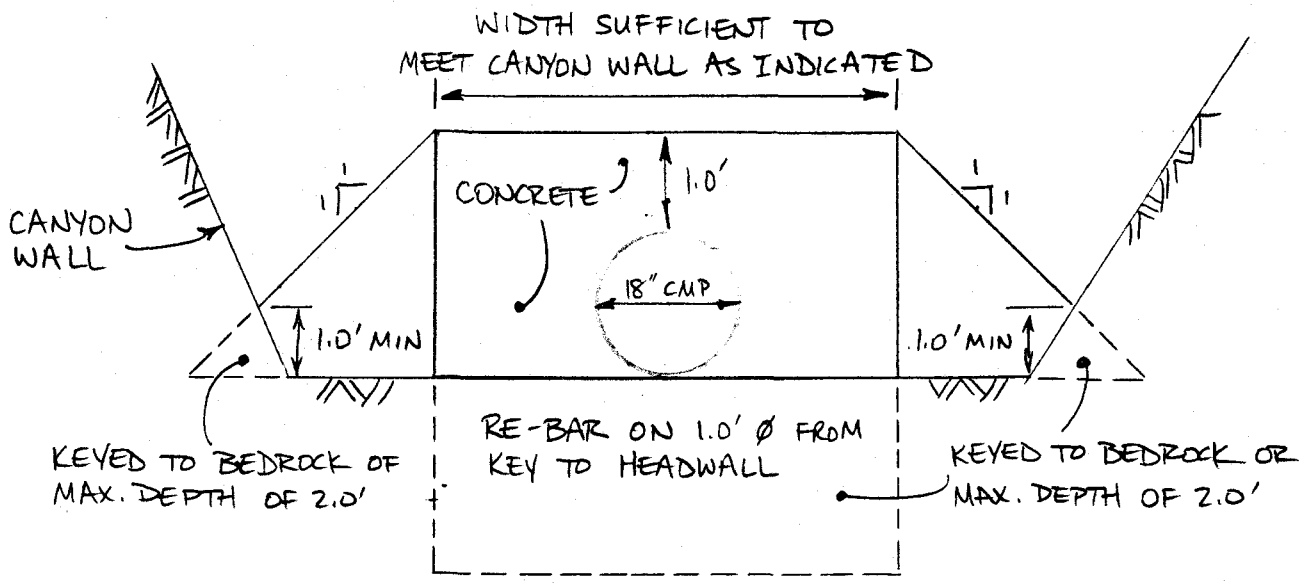
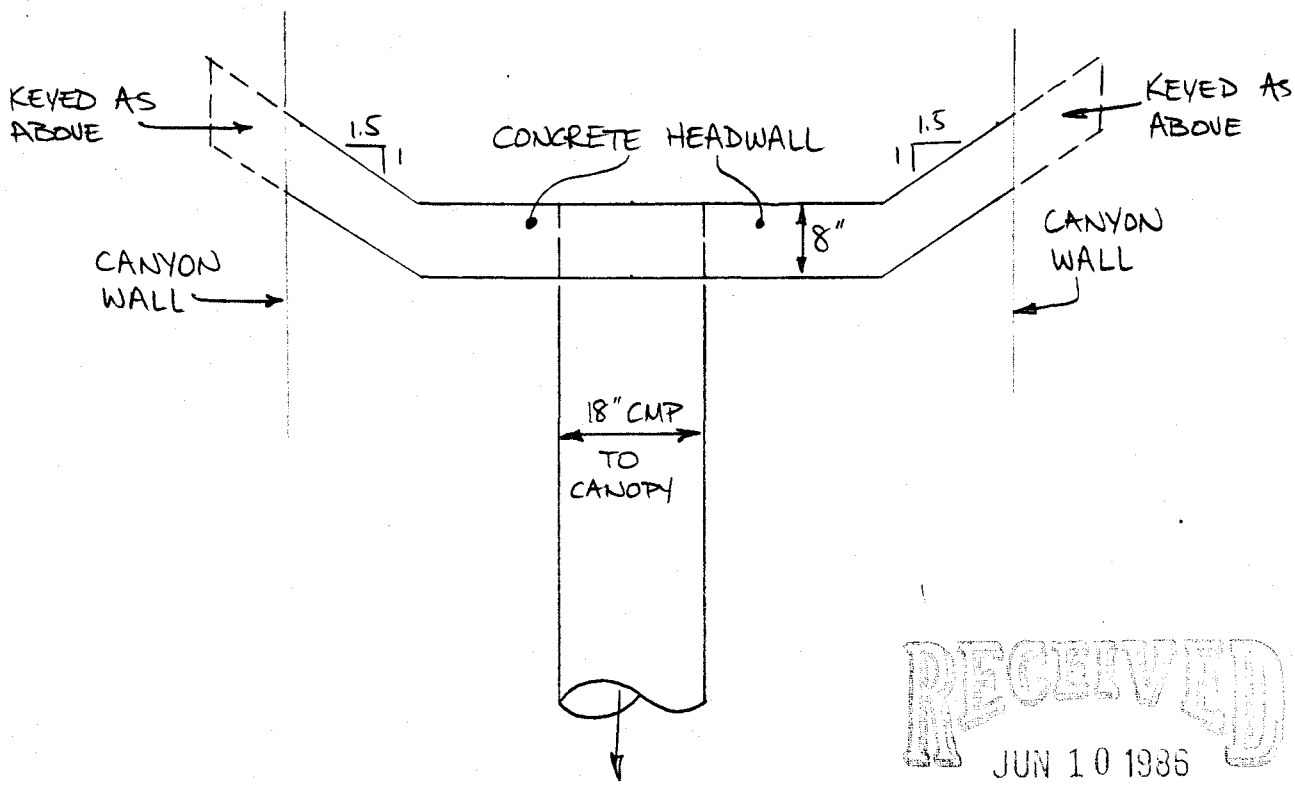

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.6273 INCHES
     INITIAL ABSTRACTION =  0.8986 INCHES
     PEAK FLOW =      5.55 CFS  ( 0.6138 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.6285 INCHES
*************************************************************
```

From nomograph on page 2 of this calc. → minimum culvert size is 18". Use 18" CMP at the inlet. Run the culvert to the top of the highwall and install a 60° bend to head down the face of the highwall. Anchor the culvert at this bend with a metal strap and roof bolts. Run the culvert down the highwall to the top of the portal canopy. Install a 90° bend, taking the culvert to the east. Again anchor this bend with a metal strap and roof bolts. Keep the culvert as an 18" CMP across the top of the canopies and along the side of the hill east of the portal pad. This diversion will discharge into an existing channel east of the portal pad.



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



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

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

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

$H = 57.0$ ft

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

$$K_c = \frac{(5087)(0.024)^2}{(18)^{4/3}} = 0.062$$

$L = 430$ ft

$$V = \left[\frac{(64.4)(57)}{(2.5+[0.062][430])}\right]^{\frac{1}{2}} = 11.2 \text{ ft/s}$$

At this velocity, riprap protection will be required at the outlet. Using the figure provided on page 27c of this calc., with the culvert discharging onto the bottom of the existing stream channel, riprap with a d_{50} of 0.80 ft (9.6 inches) will be required. This riprap will be graded as follows:

Diameter (in)	Percent Passing
19.2	100
9.6	50
4.8	20
1.9	0

} Adapted from Barfield et al. (1981)

This riprap will be placed along the bottom and sides of the existing channel to a depth of 20 inches. The riprap blanket will extend 10 ft downstream from the outlet of UD-3. The filter blanket designed for RD-2 (pg 27h thru 27m) will be placed to a depth of 6 inches below the riprap required for outlet protection.

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

Total area = 0.21 ac = 0.0003 mi² (use A = 0.001 mi²)
Undisturbed = 0.02 ac
Reclaimed = 0.19 ac

$l = 180$ ft

$\overline{CN} = \frac{(0.02)(69) + (0.19)(75)}{0.21} = 74$

$S = \frac{1000}{74} - 10 = 3.51$

$Y = 40.0\%$

$L = \frac{(180)^{0.8}(4.51)^{0.7}}{(1900)(40.0)^{0.5}} = 0.02$ hr

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$T_c = (1.67)(0.02) = 0.03$ 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:

Bed Slope =	.4	
Manning's N =	.04	
Bottom Width =	1	feet
Channel Side Slope =	.6667	
Flow Depth =	.1082605	feet
Cross Sectional Area =	.1258402	square feet
Wetted Perimeter =	1.390325	feet
Hydraulic Radius =	9.051131E-02	feet
Discharge =	.6	cubic feet/sec
Velocity =	4.767954	feet/sec
Froude Number =	2.553695	<5 — Acceptable

IDENTIFICATION: DD-1 DIVERSION DITCH

INPUT SUMMARY:

```
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II           AREA =  0.001 SQ. MI.
        DEPTH =  2.92 IN.             CN = 74.0
        DURATION = 24.0 HR.           TIME OF CONC. =  0.03 HR.
*************************************************************
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*************************************************************
```
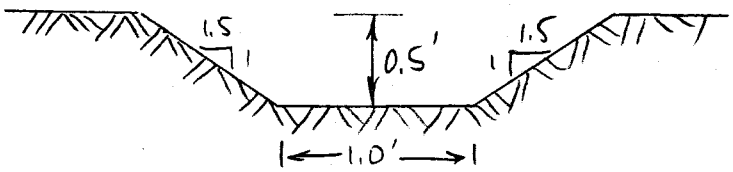

OUTPUT SUMMARY:

```
*************************************************************
     TOTAL RUNOFF DEPTH =  0.8579 INCHES
     INITIAL ABSTRACTION =  0.7027 INCHES
     PEAK FLOW =      0.60 CFS  ( 0.9297 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.8596 INCHES
*************************************************************
```



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

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Design of DD-6

Undisturbed area = 5.50 ac (CN=69)
Reclaimed area = 1.57 ac (CN=75)
Disturbed area = 1.22 ac (CN=90)

Total area = 8.29 ac
= 0.013 mi²

$$\overline{CN} = \frac{(5.50)(69) + (1.57)(75) + (1.22)(90)}{8.29} = 73$$

T_c = 0.21 hr (same as inlet to sed. pond – see pond calcs. for undisturbed drainage)

Hydrograph & TRAP1 results:

IDENTIFICATION: DD-6 DIVERSION DITCH

INPUT SUMMARY:
****

STORM:	WATERSHED:
DIST. = SCS TYPE II	AREA = 0.013 SQ. MI.
DEPTH = 2.50 IN.	CN = 73.0
DURATION = 24.0 HR.	TIME OF CONC. = 0.21 HR.

****

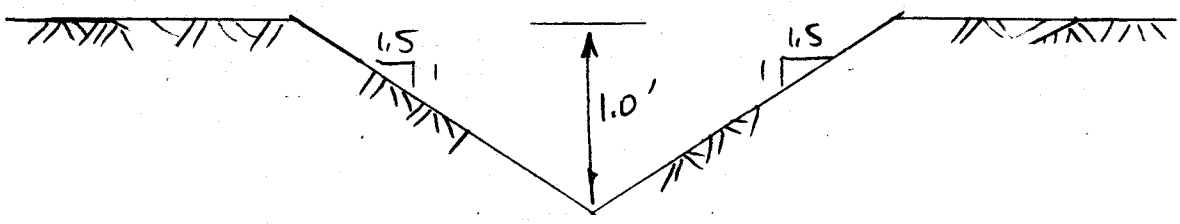
****

OUTPUT SUMMARY:
****

TOTAL RUNOFF DEPTH = 0.5676 INCHES
INITIAL ABSTRACTION = 0.7397 INCHES
PEAK FLOW = 4.15 CFS (0.4950 IN/HR)
TIME TO PEAK = 12.04 HOURS
RUNOFF VOLUME CHECK = 0.5688 INCHES

****

Bed Slope =	.07	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.6667	
Flow Depth =	.7742366	feet
Cross Sectional Area =	.8991185	square feet
Wetted Perimeter =	2.791453	feet
Hydraulic Radius =	.322097	feet
Discharge =	4.15	cubic feet/sec
Velocity =	4.615632	feet/sec
Froude Number =	.9244138	



DD-6
TYPICAL ELEVATION
SCALE: 1" = 1'

Design of DD-2 thru DD-5

DD-2 → Drainage area < DD-6
Slope < DD-6

DD-3 → Drainage area < DD-6
Slope < DD-6

} Use DD-6 cross section

DD-5 → Undisturbed area = 5.42 ac (CN = 69)
Reclaimed area = 1.52 ac (CN = 75)
Disturbed area = 0.64 ac (CN = 90)

Total area = 7.58 ac = 0.012 mi^2

$$\overline{CN} = \frac{(5.42)(69) + (1.52)(75) + (0.64)(90)}{7.58} = 72$$

T_c = 0.20 hr (same as for DD-6 minus 0.01 hr for section from DD-4 to DD-6).

Peak flow = 3.59 cfs (see printout on page 18 of this calc.)

Channel design by TRAP1 → see page 18 of this calc.

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IDENTIFICATION: DD-5 DIVERSION DITCH

INPUT SUMMARY:

****

STORM:	WATERSHED:
DIST. = SCS TYPE II	AREA = 0.012 SQ. MI.
DEPTH = 2.50 IN.	CN = 72.0
DURATION = 24.0 HR.	TIME OF CONC. = 0.20 HR.

****

****

OUTPUT SUMMARY:

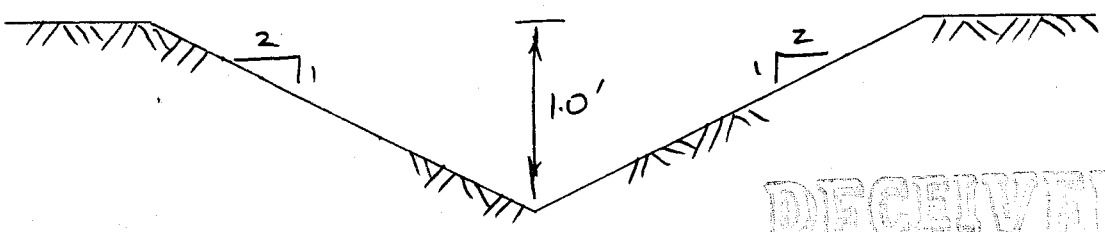
****

TOTAL RUNOFF DEPTH = 0.5286 INCHES
INITIAL ABSTRACTION = 0.7778 INCHES
PEAK FLOW = 3.59 CFS (0.4631 IN/HR)
TIME TO PEAK = 12.04 HOURS
RUNOFF VOLUME CHECK = 0.5297 INCHES

****

Bed Slope =	.1	
Manning's N =	.04	
Bottom Width =	0	feet
Channel Side Slope =	.5	
Flow Depth =	.6046139	feet
Cross Sectional Area =	.731116	square feet
Wetted Perimeter =	2.703916	feet
Hydraulic Radius =	.2703916	feet
Discharge =	3.59	cubic feet/sec
Velocity =	4.910302	feet/sec
Froude Number =	1.112862	<5 — Acceptable

Design of DD-4 → Drainage area < DD-5, Channel slope = DD-5 } Use DD-5 cross section



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

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Design of DD-7, DD-8

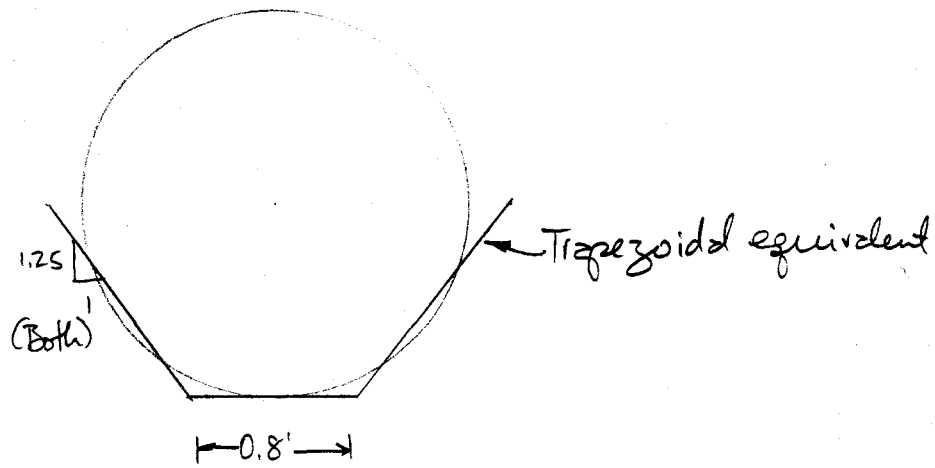
Both channels → Drainage area < DD-6
Disturbed area drainage negligible
Slope < DD-6

→ Use DD-6 cross section

Design of In-Yard Culverts

Design of C-3 → Peak flow = 4.15 cfs (see DD-6 calcs.)

This culvert currently exists as a 24" CMP with projecting inlet. From the nomograph on pg. 2 of this calc., the capacity of C-3 is 12 cfs. Hence, this culvert is adequate.



"Channel" slope = 0.10
n = 0.024
Q = 4.15 cfs (same as for DD-6)

Bed Slope =	.1	
Manning's N =	.024	
Bottom Width =	.8	feet
Channel Side Slope =	1.25	
Flow Depth =	.4447861	feet
Cross Sectional Area =	.5140965	square feet
Wetted Perimeter =	1.939208	feet
Hydraulic Radius =	.2651064	feet
Discharge =	4.15	cubic feet/sec
Velocity =	8.072415	feet/sec
Froude Number =	2.133045	

Design of C-4 → Disturbed area = 0.25 ac (CN=90)
Reclaimed area = 0.29 ac (CN=75)

$$\text{Weighted avg. } CN = \frac{(0.25)(90)+(0.29)(75)}{0.54} = 82$$

Total area = 0.54 ac = 0.001 mi^2

$T_c \Rightarrow$ 90 ft @ 67% $\xrightarrow{\text{Reclaimed section}}$ V = 5.6 ft/s

$(T_c)_1$ = 0.004 hr

130 ft @ 1% $\xrightarrow{\text{Road}}$ V = 2.0 ft/s

$(T_c)_2$ = 0.018 hr

→ Upland method of U.S. SCS (1972)

$(T_c)_{TOTAL}$ = 0.004 + 0.018 = 0.02 hr

Hydrograph results:

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IDENTIFICATION: C-4 CULVERT

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

****

C-4 is currently a 24" CMP. Determine exit velocity as trapezoidal equivalent.

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Exit velocity from C-4 (trapezoidal equivalent)

Bed Slope =	.1	
Manning's N =	.024	
Bottom Width =	.8	feet
Channel Side Slope =	1.25	
Flow Depth =	.1530165	feet
Cross Sectional Area =	.1411444	square feet
Wetted Perimeter =	1.191913	feet
Hydraulic Radius =	.1184183	feet
Discharge =	.67	cubic feet/sec
Velocity =	4.746912	feet/sec
Froude Number =	2.138524	

Design of channel from C-3 & C-4 to sed. pond:

$Q = 4.15 + 0.67 = 4.82$ cfs

Bed slope = 0.33 (10 ft / 30 ft)

Side slopes = 2h : 1v

Assume $n = 0.037$ (riprap w/ $d_{50} = 8''$)

TRAP1 results:

Bed Slope =	.33	
Manning's N =	.035	
Bottom Width =	2	feet
Channel Side Slope =	.5	
Flow Depth =	.2379983	feet
Cross Sectional Area =	.5892829	square feet
Wetted Perimeter =	3.064361	feet
Hydraulic Radius =	.1923021	feet
Discharge =	4.82	cubic feet/sec
Velocity =	8.179434	feet/sec
Froude Number =	2.954666	

> Exit velocity from both C-3 and C-4. Design for this velocity.

Acceptable velocity – use the Isbach eq. (U.S. Army Corps of Eng., 1970):

$$W = 2.44 \times 10^{-5} V^6$$

$$D_s = \left(\frac{6W}{\pi \gamma_s}\right)^{1/3} \Rightarrow \text{Based on } d_{50}$$

where W = stone weight (lb)
V = velocity (ft/s)
D_s = equivalent stone diameter (ft)
γ_s = specific weight of stone = 165 lb/ft^3

$$W = (2.44 \times 10^{-5})(8.2)^6 = 7.4 \text{ lb}$$

$$D_s = \left[\frac{(6)(7.4)}{(\pi)(165)}\right]^{\frac{1}{3}} = 0.44 \text{ ft}$$

$$= 5.3 \text{ in} < 6 \text{ in} \Rightarrow d_{50} = 6 \text{ in acceptable}$$

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.

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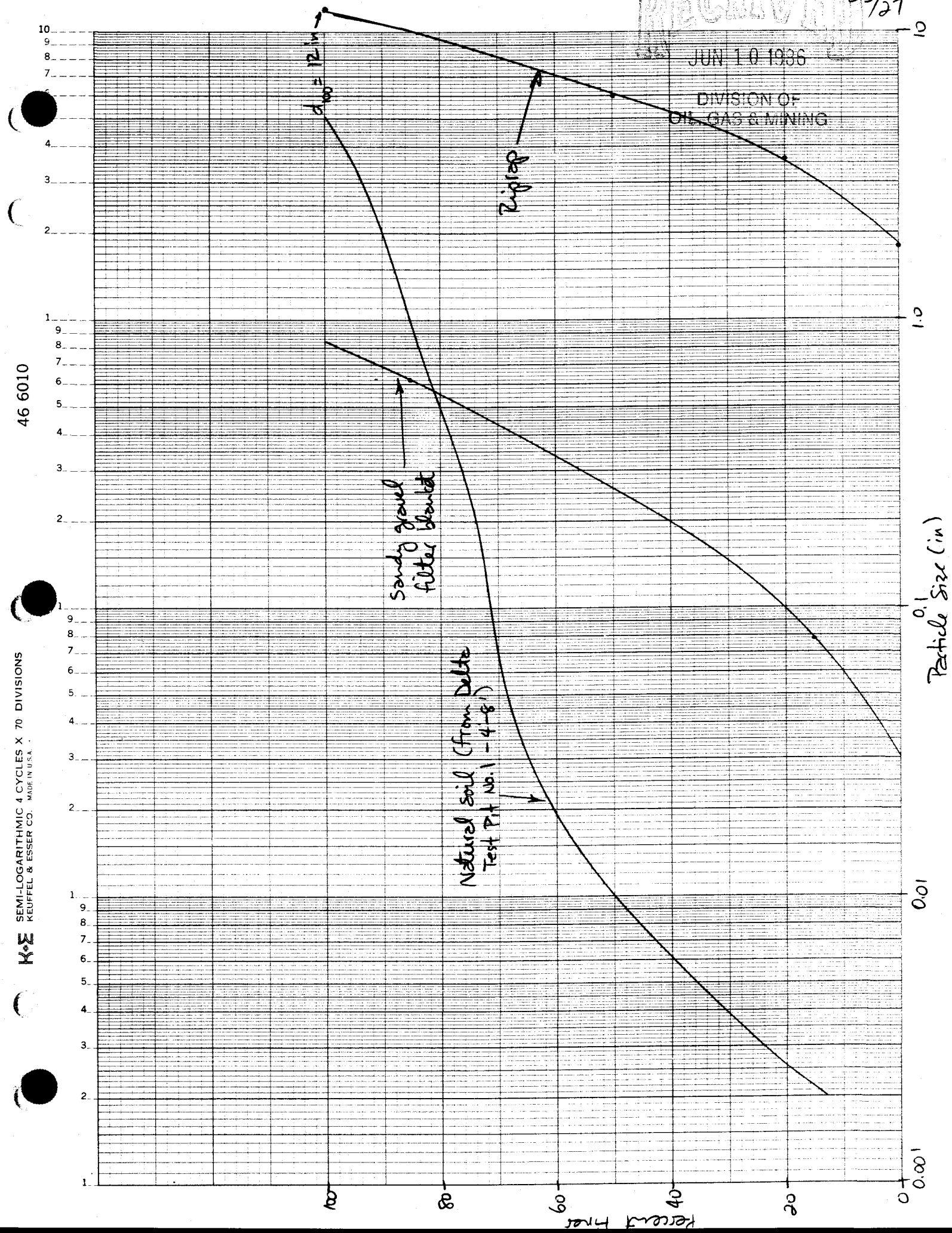

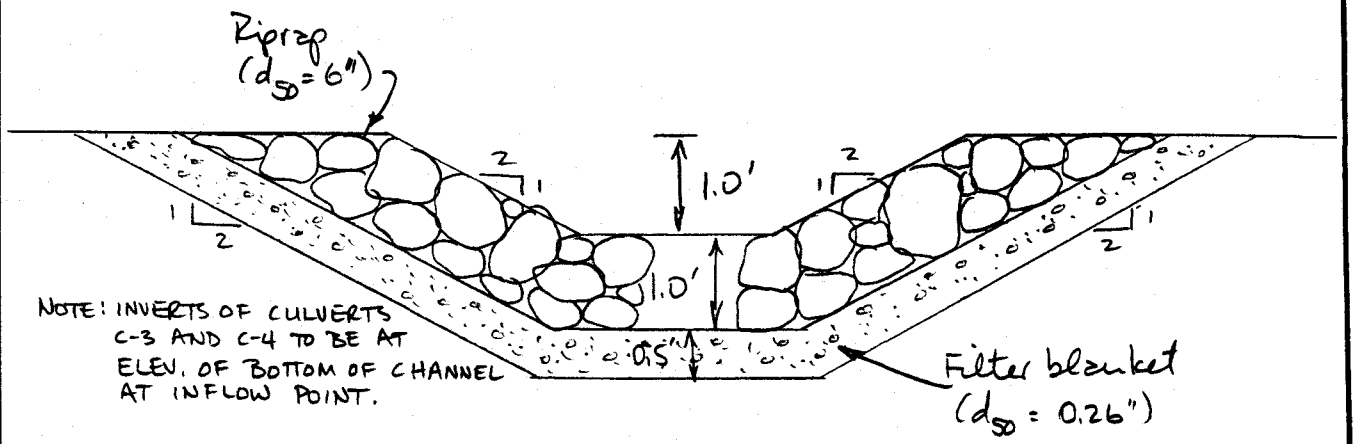

SEDIMENTATION POND INLET CHANNEL
ELEVATION VIEW
SCALE: 1" = 2'

Design of culvert C-2 → Currently exists as a 24" CMP. Since the drainage area to this culvert is smaller than to C-3 and 24" CMP is adequate at C-3, 24" CMP is also adequate at C-2.

Design of culvert C-1 → Since this culvert is upstream from C-3, it need not be larger than C-3. According to the nomograph on pg. 2 of this calc., an 18" CMP is adequate to pass the C-3 design flow of 4.15 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 portal 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 mi²

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

See hydrograph summary on page 26 of this calc.

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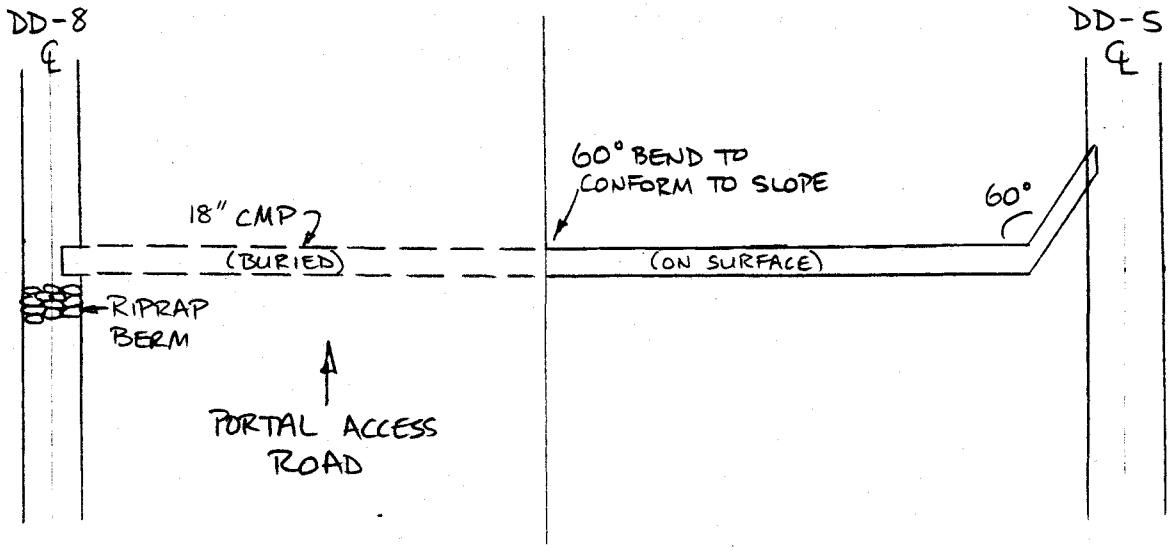
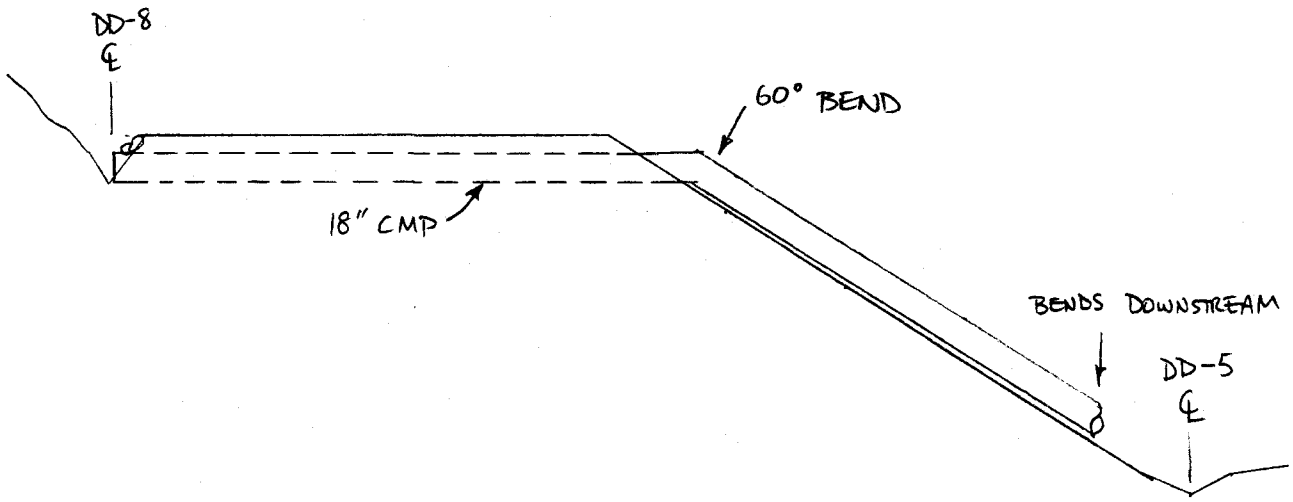
COMPUTED TBW DATE 6 Jun 1986
CHECKED DATE



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



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

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```
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*   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.

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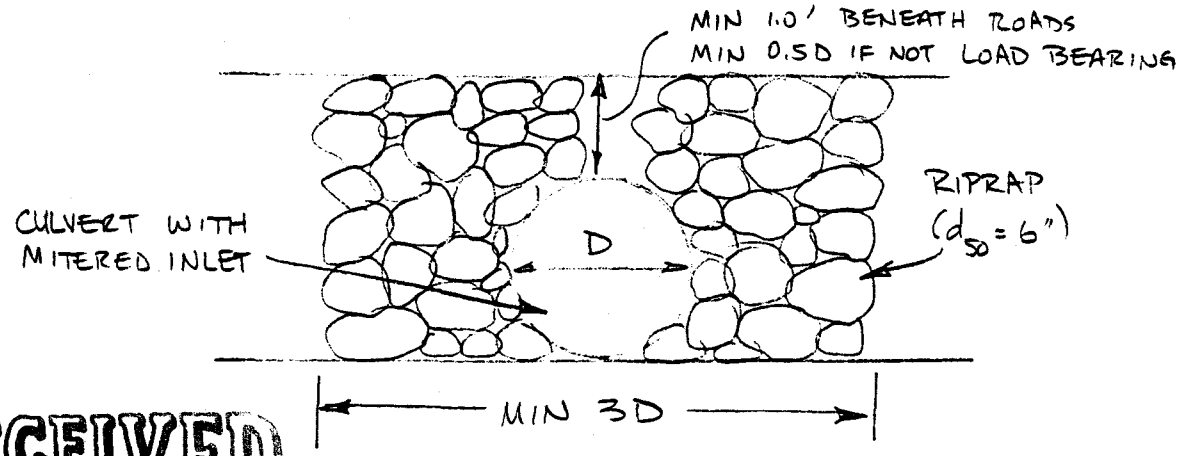

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TYPICAL CULVERT INLET
(APPLIES TO CULVERTS C-1 THRU C-5)
ELEV. VIEW

NO SCALE

— 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 mi^2

$l = 4110$ ft

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

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

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

$$L = \frac{(4110)^{0.8}(1 + 4.49)^{0.7}}{(1900)(53.4)^{0.5}} = 0.18\ hr$$

$$T_c = (1.67)(0.18) = \underline{0.31\ hr}$$

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:

```
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*                             *
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*   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

27c/

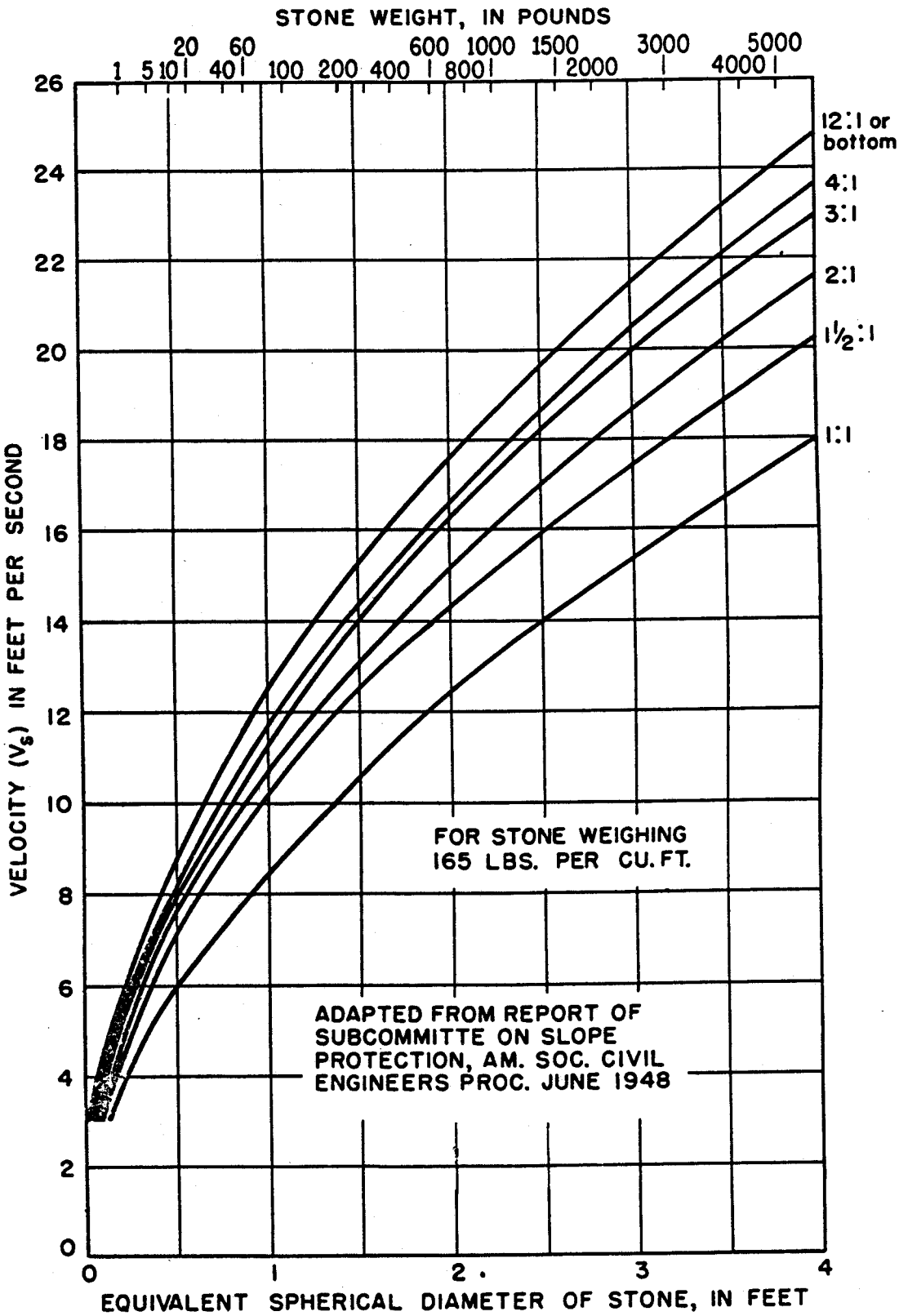

FIG. 2-SIZE OF STONE THAT WILL RESIST DISPLACEMENT FOR VARIOUS VELOCITIES AND SIDE SLOPES

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 → d_{so} = 2.1 ft, n = 0.045
For b = 5 ft → 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 → 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).

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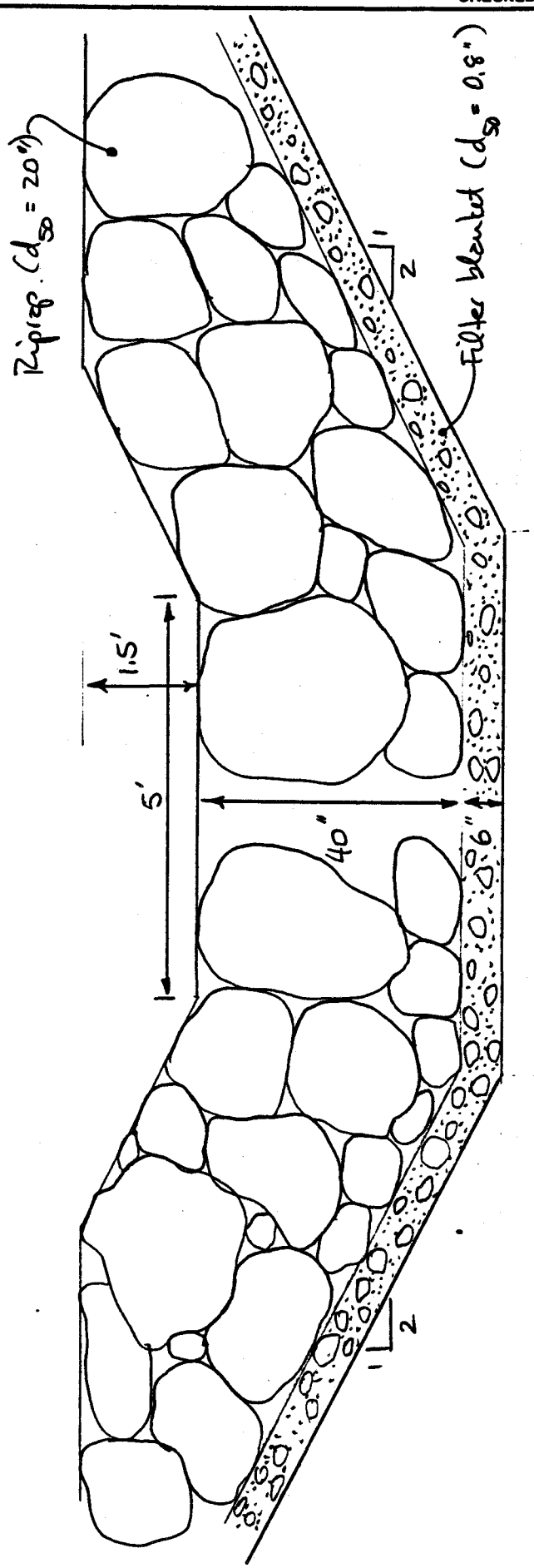
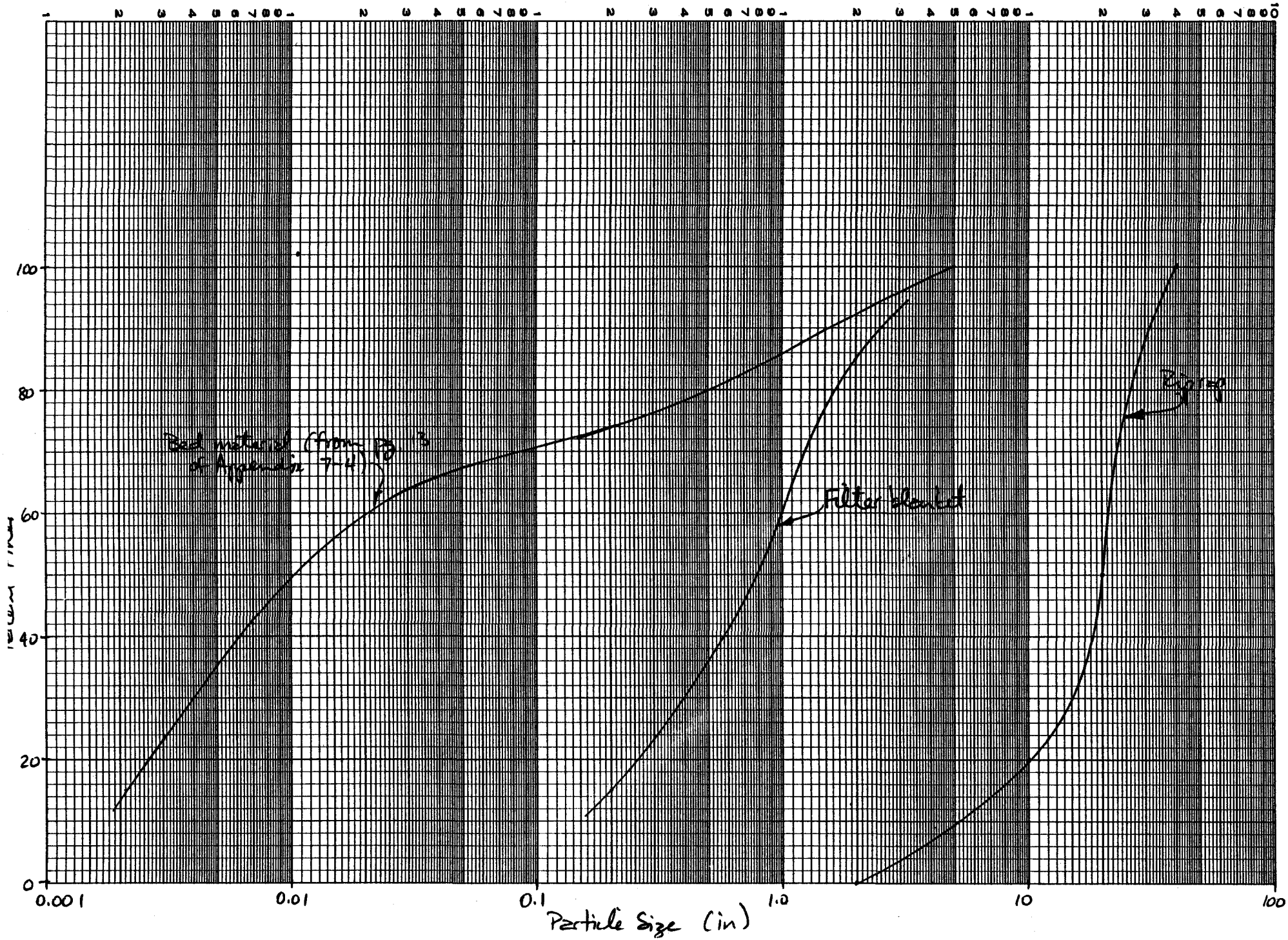


RD-1 ELEVATION VIEW
SCALE: 1" = 2'

NO. 340R-L510 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.



1 of 1

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 = $\underset{(WS-2)}{0.9} + \underset{(WS-4)}{5.5} = 6.4$ ac

Reclaimed = $\underset{(WS-2)}{0.3} + \underset{(WS-4)}{0.3} + \underset{(site)}{1.9}$ ac = 2.5 ac

Total = 6.4 + 2.5 = 8.9 ac
= 0.014 mi²

$l = 1020$ ft

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

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

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

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

$= 0.08$ hr

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

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

Hydrograph results → see pg 27i of this calc.

```
*******************************
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*   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 $\longrightarrow$ $d_{50} = 0.30$ ft $= 3.6$ in

For $b = 4$ ft $\longrightarrow$ $d_{50} = 0.25$ 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

$n = 0.033 \Rightarrow$ 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.):

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

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

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

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

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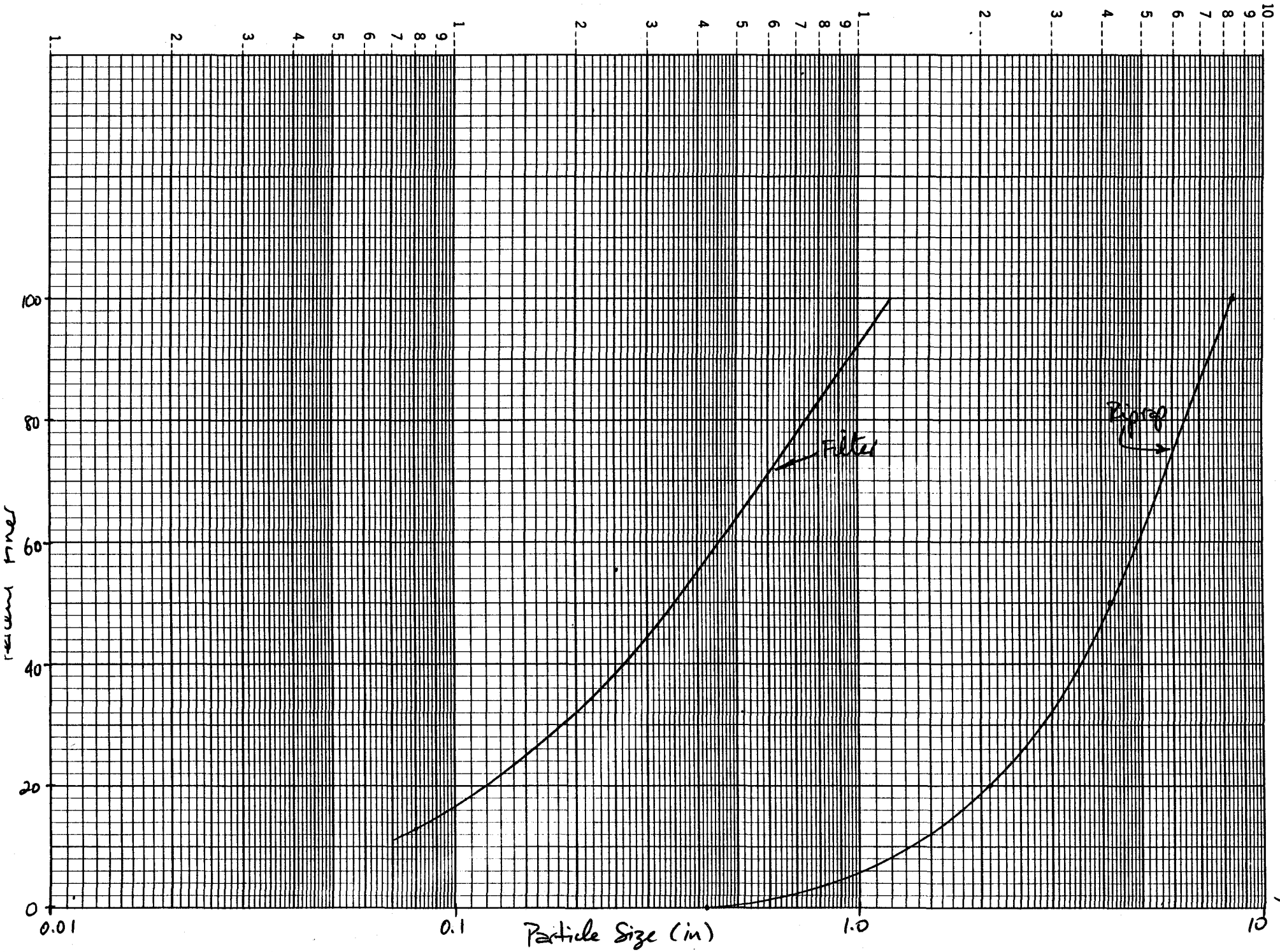
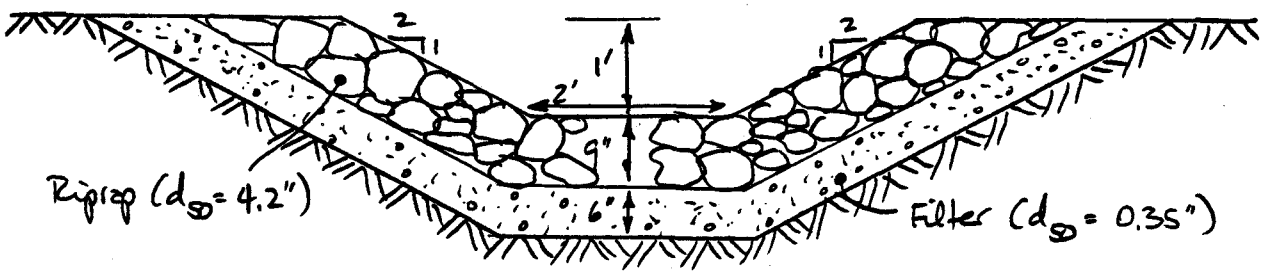


27 of



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

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

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

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

$$L = \frac{(750)^{0.8}(1+4.08)^{0.7}}{(1900)(67.7)^{0.5}} = 0.04\text{ hr}$$

$$T_c = (1.67)(0.04) = \underline{0.07\text{ hr}}$$

Design storm → 50-yr, 24-hr = 3.25 in

Hydrograph results → see pg. 27n of this calc.

```
*******************************
* 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 =	3.016158	

Required d_{50} = 0.35 ft
= 4.2 in

n = 0.033 OK

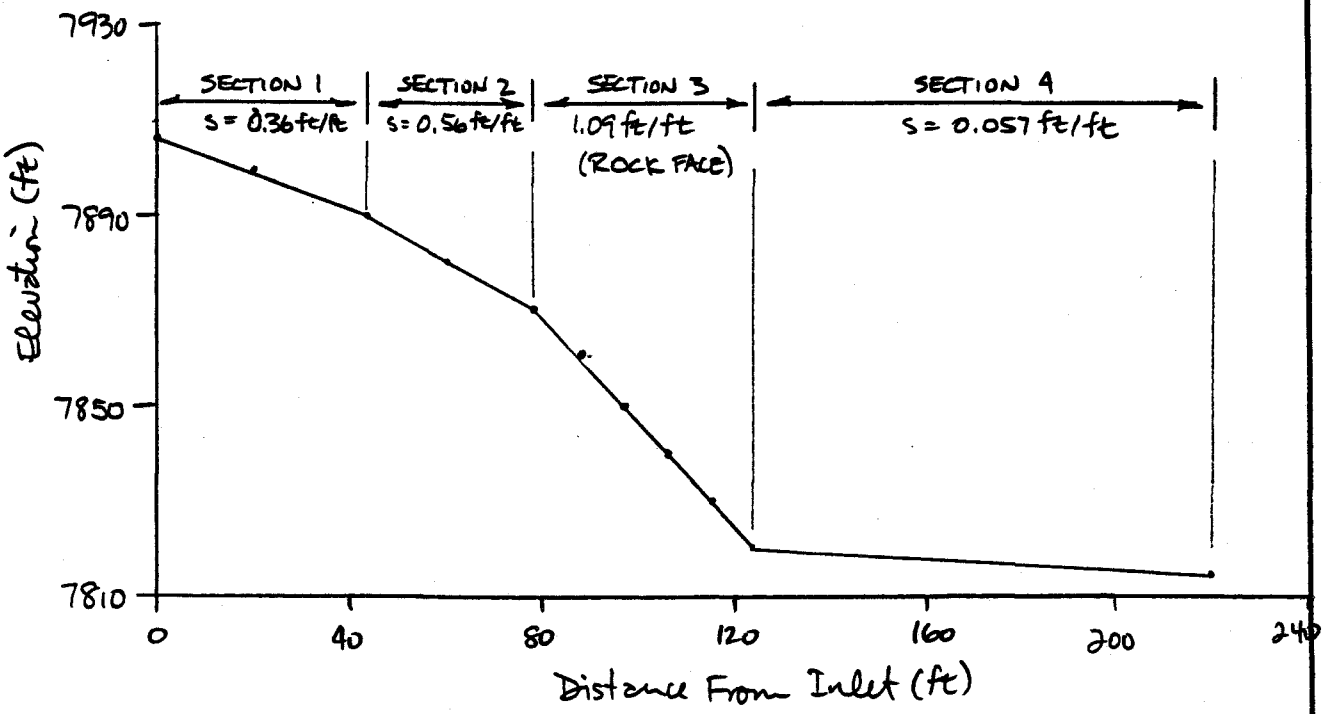
Cross section design:

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.

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

$T_c = (1.67)(0.15)$

$= \underline{0.25}$ 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.

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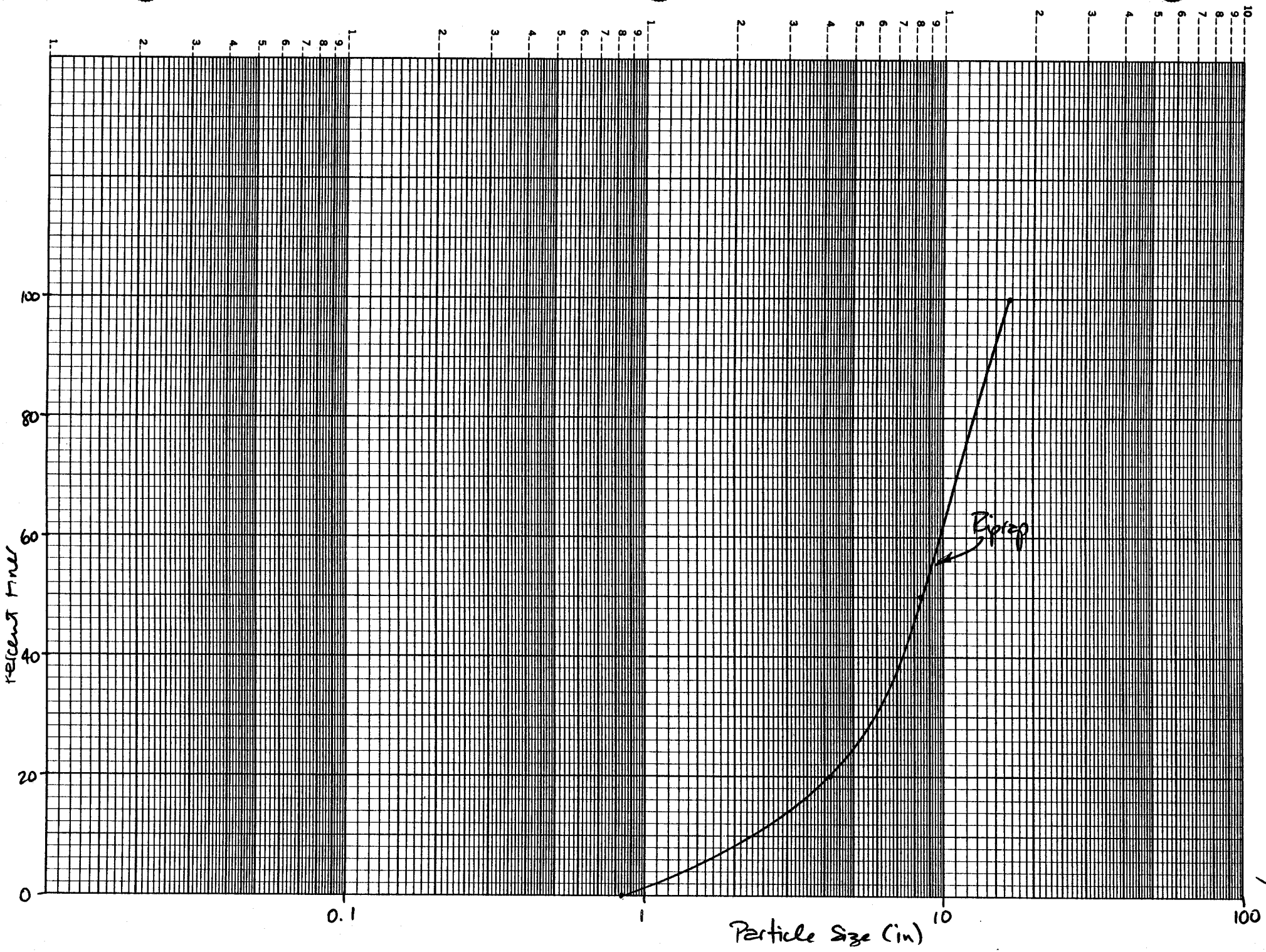
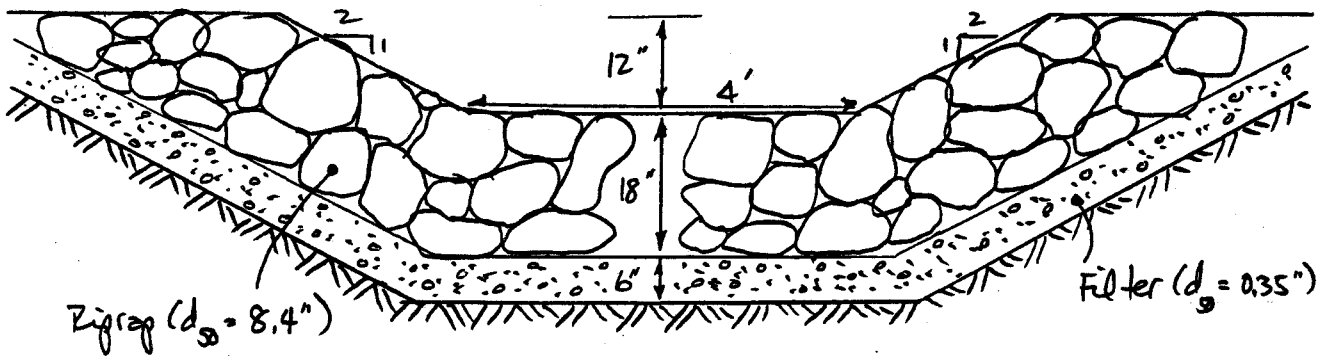


27

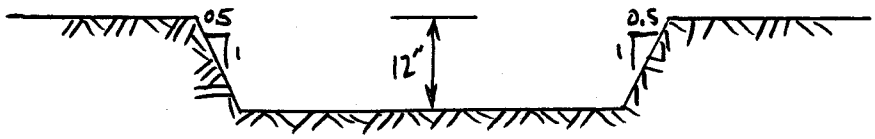


SECTION 1 / SECTION 2
RD-4 ELEV. VIEW
SCALE: 1" = 2'

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'

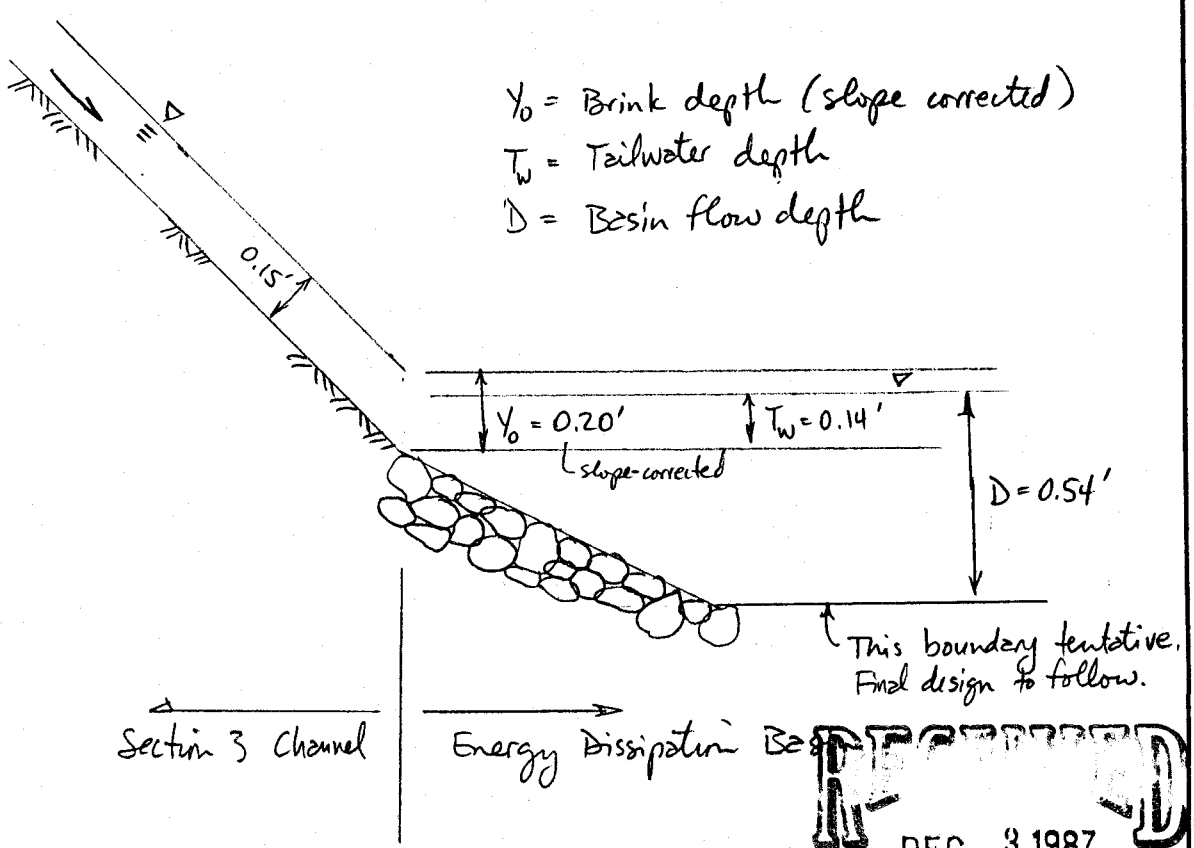
Design of Energy Dissipation Basin at Downstream Edge of Section 3 Channel (where rock face meets pad) – use the design procedure of Corry et al. (1975):
↳ HEC-14

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

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:



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$$\frac{T_W}{Y_0} = \frac{0.14}{0.20} = 0.70 < 0.75 \quad \underline{OK}$$

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 2/s4 $\rightarrow \frac{h_s}{Y_e} = 0.90 \Rightarrow h_s = (0.90)(1.59)$
$= 1.43$ 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 = $h_s + Y_o + 1.0$
$= 1.43 + 0.20 + 1.00$
$= 2.63$ ft $\Rightarrow$ Construct with depth = 2.75 ft

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

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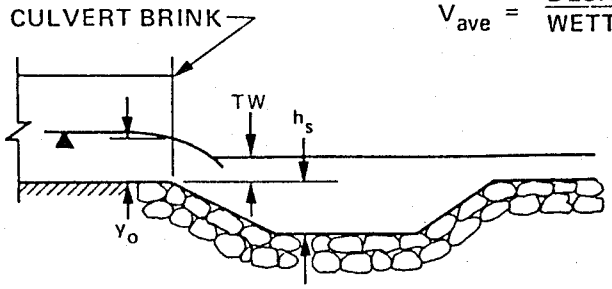


$$V_{ave} = \frac{\text{DESIGN DISCHARGE} - Q}{\text{WETTED AREA AT BRINK OF CULVERT}}$$

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

Y_e = EQUIVALENT BRINK DEPTH

= BRINK DEPTH FOR BOX CULVERT

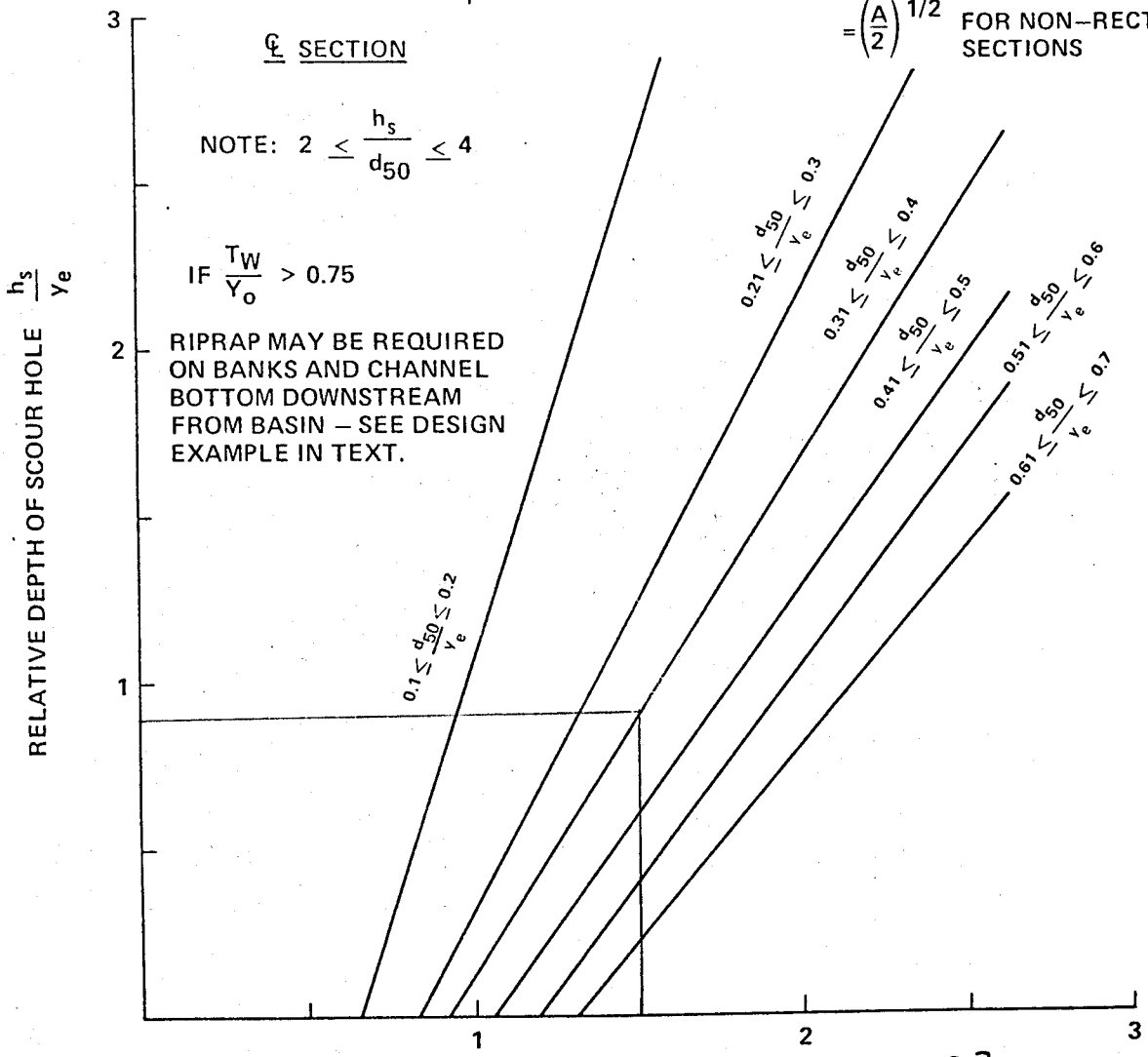
$= \left(\frac{A}{2}\right)^{1/2}$ FOR NON–RECTANGULAR SECTIONS

℄ 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

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

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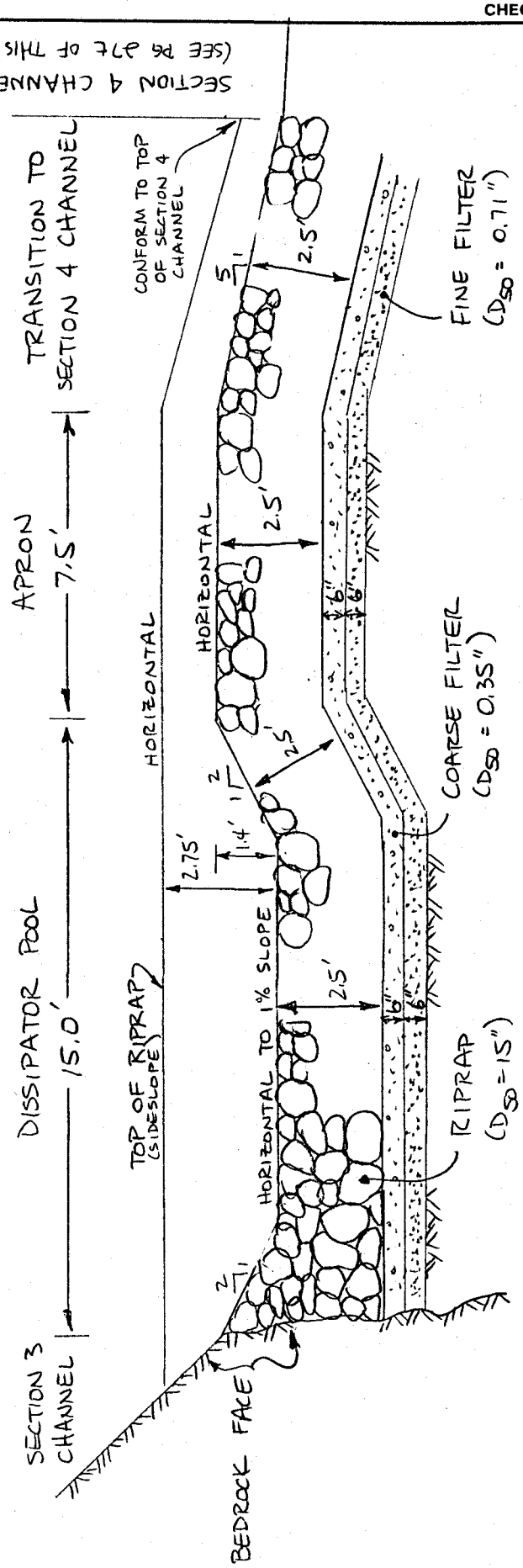

ENERGY DISSIPATION BASIN
CENTER LINE SECTION
SCALE: 1" = 4'

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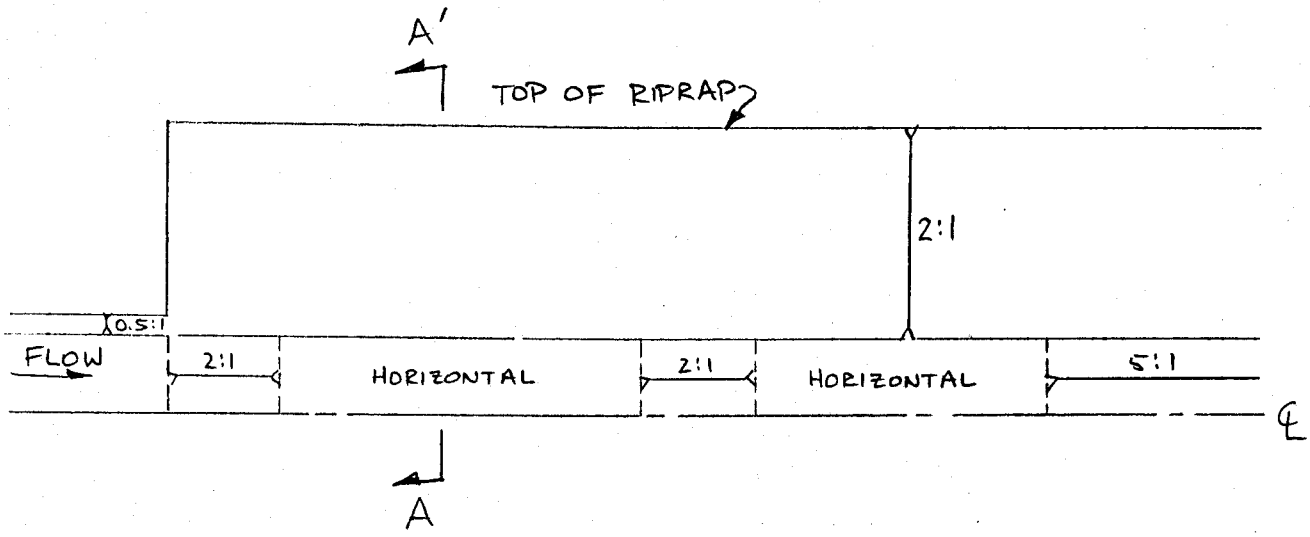

ENERGY DISSIPATION BASIN
HALF PLAN
SCALE: 1" = 50'

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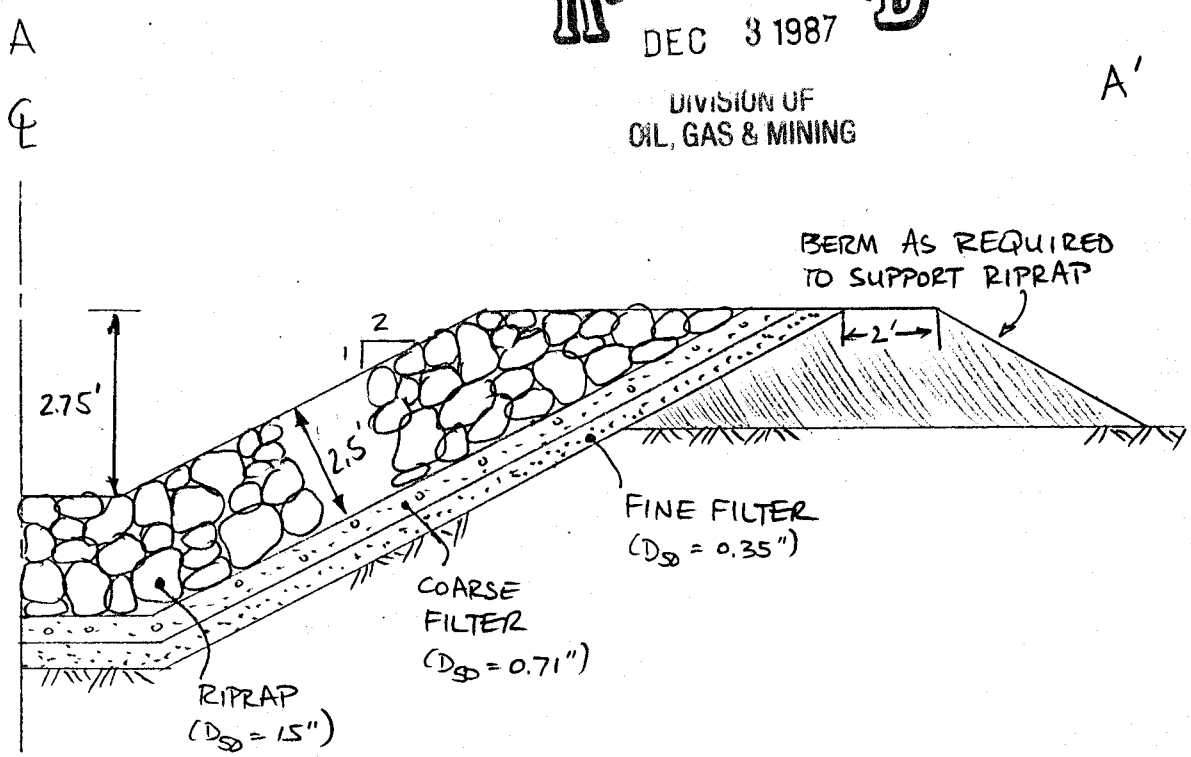
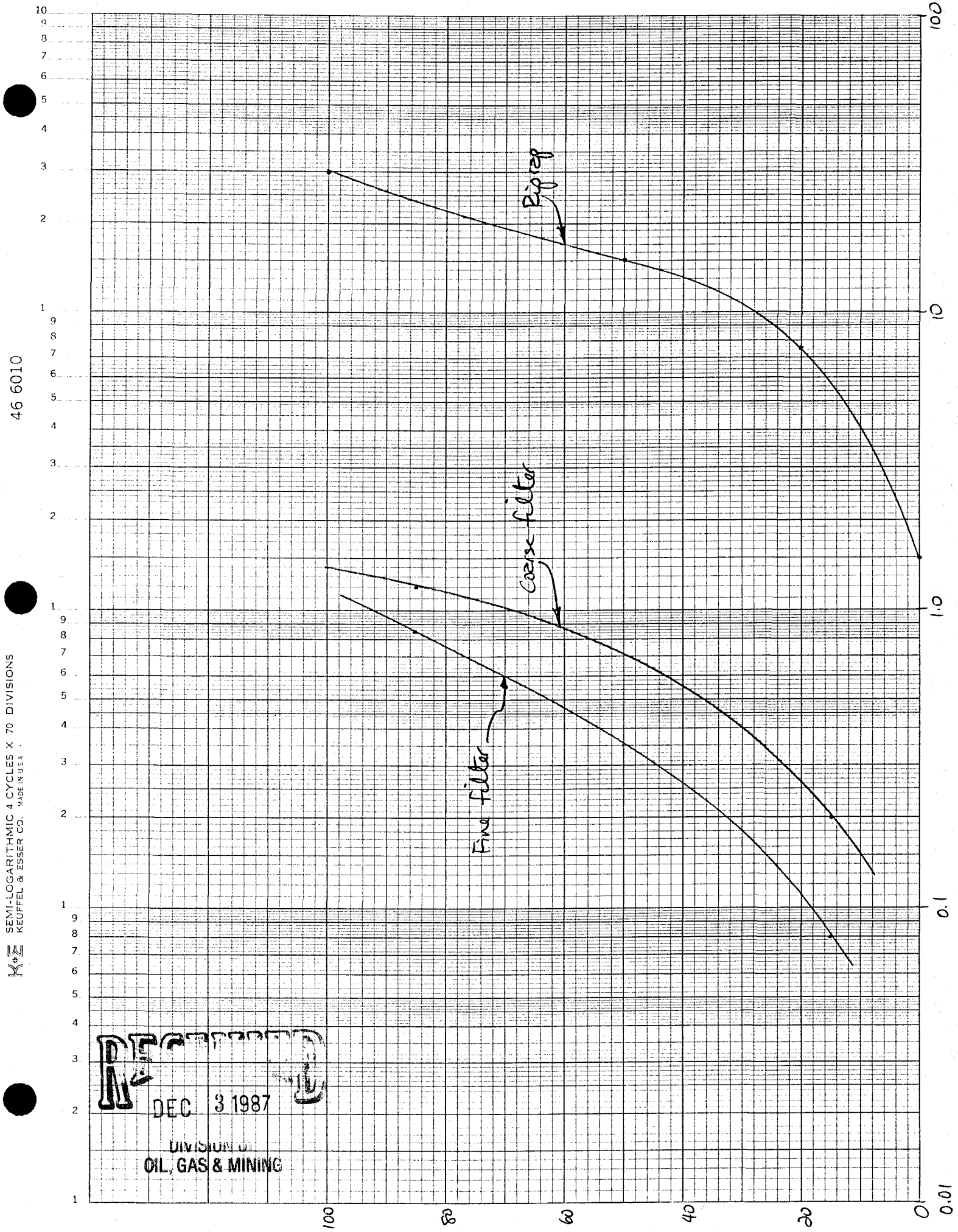


ENERGY DISSIPATION BASIN
SECTION A-A'
SCALE: 1" = 4'

27/57



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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:

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

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

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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

Due to the higher velocities coming out of Section 3, provide riprap with d_{50} = 12 inch in the upper 15 ft of Section 4 to act as a splash basin (see pg. 27c of this calc.).

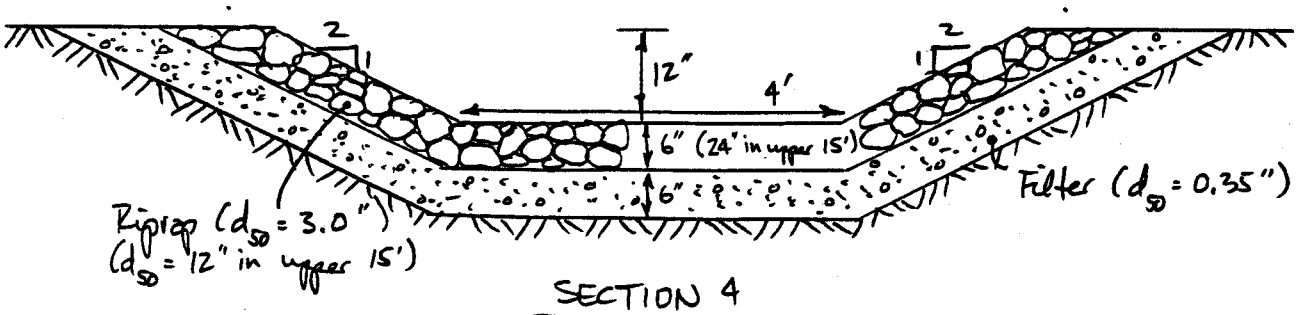
Gradation of Section 4 riprap → see pg. 27u of this calc.

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'

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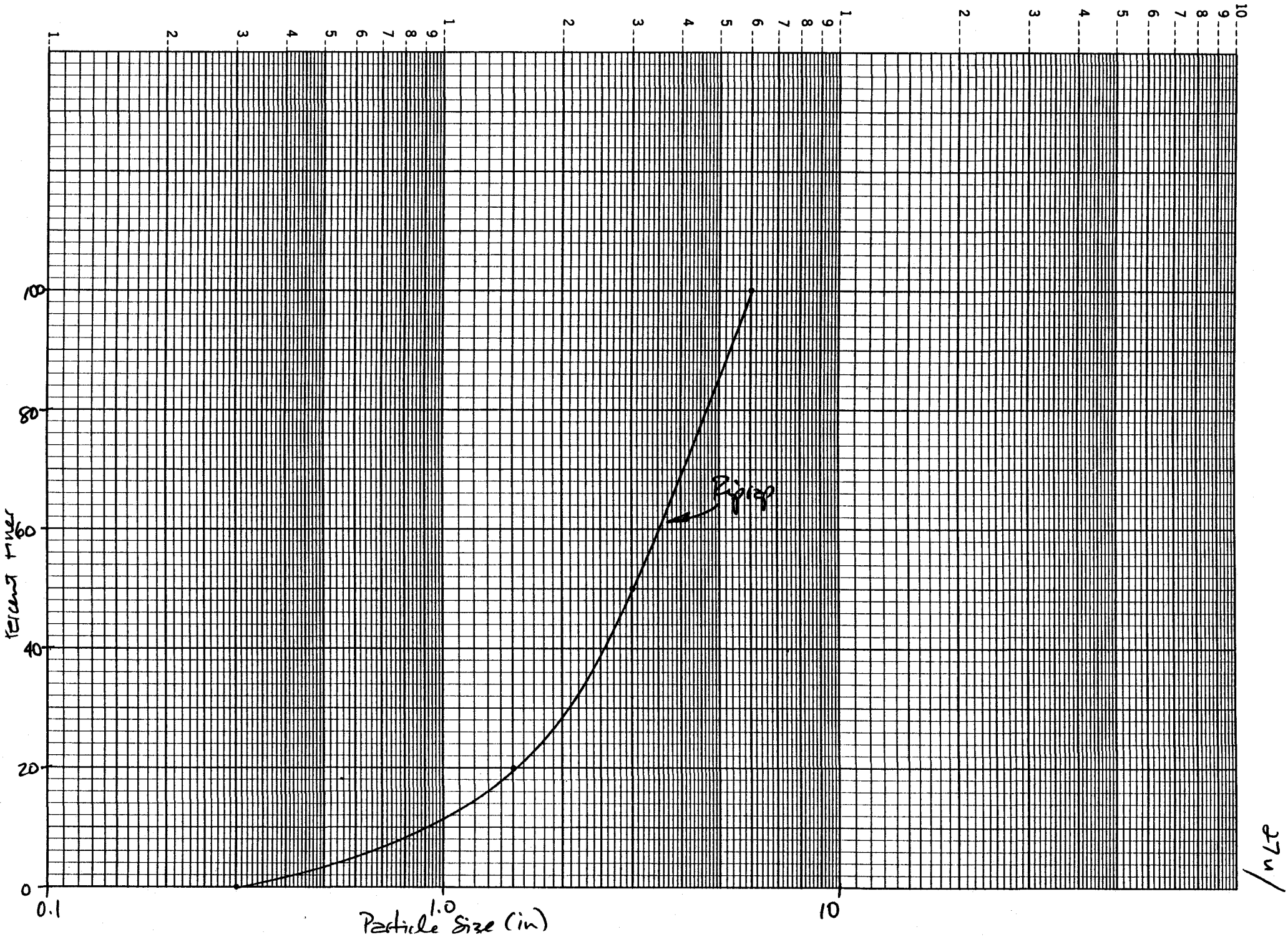


27 n/

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	

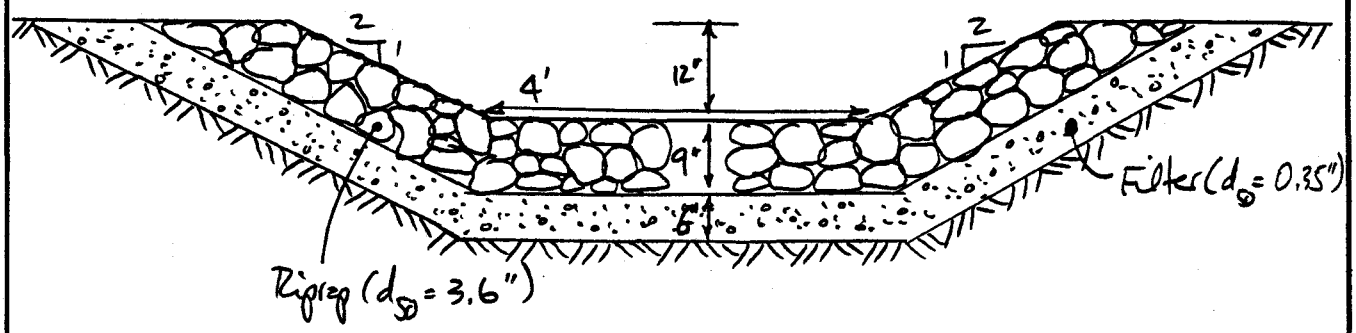
Required d_{50} = 0.30 ft (from pg. 27c)
= 3.6 in

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

Check RD-2 filter:

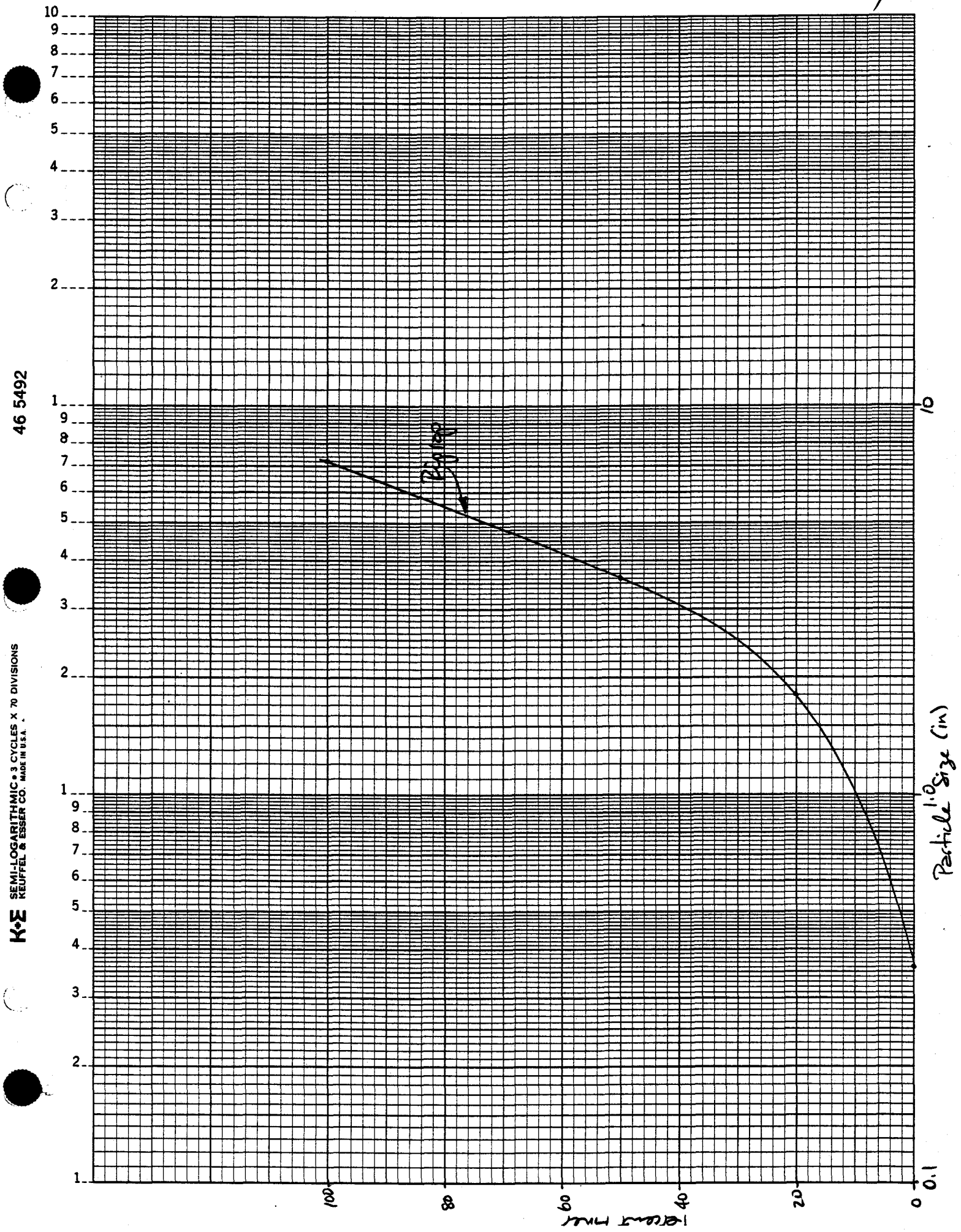
$$\frac{D_{15}\text{ (riprap)}}{D_{85}\text{ (filter)}} = \frac{1.4\text{ in}}{0.85\text{ in}} = 1.6 < 5 \quad \underline{\underline{OK}}$$

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



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

27x/



Particle Size (in)
Percent Finer
Riprap
0.1
1.0
10
100
80
60
40
20
0
46 5492
K+E SEMI-LOGARITHMIC • 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

APPENDIX 7-8

NPDES Permit

See Item 3-8