IX. DETAILED DESIGN EXAMPLE

The purpose of this chapter is to provide a realistic example of the design process for a sediment control system. The previous examples given for each structure and treatment groups were intended to illustrate the design procedures. Topographic, climatic, and soils data were given as background information in order to clearly present the design procedures. In this chapter the details of developing design parameters from available data are illustrated.

9.1 Site Description

A small catchment is located at the corner of a lease boundary for a mine located in central Illinois (Figure 9.1). The site has recently been regraded and topsoiled as shown on the topographic map. Planned post mining land use will be pasture and the site will be seeded with grass and legumes to support this use. It is anticipated that two growing seasons will be required to establish the permanent vegetative cover conditions which exist on the vegetative reference plot.

Access to the lease area is available from a county road. The access road within the lease boundary follows the eastern edge of the lease area. Potential areas of damage by sediment are at the culvert for the county road and at the confluence with the stream originating outside the lease area.

9.2 Hydrologic Data

Mean annual rainfall for this central Illinois site is 35 inches, the SCS type II distribution is the appropriate rainfall distribution for this area, and the 10-year, 24-hour storm volume is 4.5 inches. The mean annual rainfall is used as a guide to select vegetation and seasonal distribution of rainfall is used for timing revegetation efforts. The 10-year, 24-hour storm volume is determined from the appropriate rainfall frequency atlas, in this case the TP-40 atlas (Figure 3.2, Chapter III).

Curve numbers used for the design will be based on a case II antecedent moisture condition (see Chapter III, section 3.3). Conditions which would produce a very high antecedent moisture (case III) would be rare for a small area.

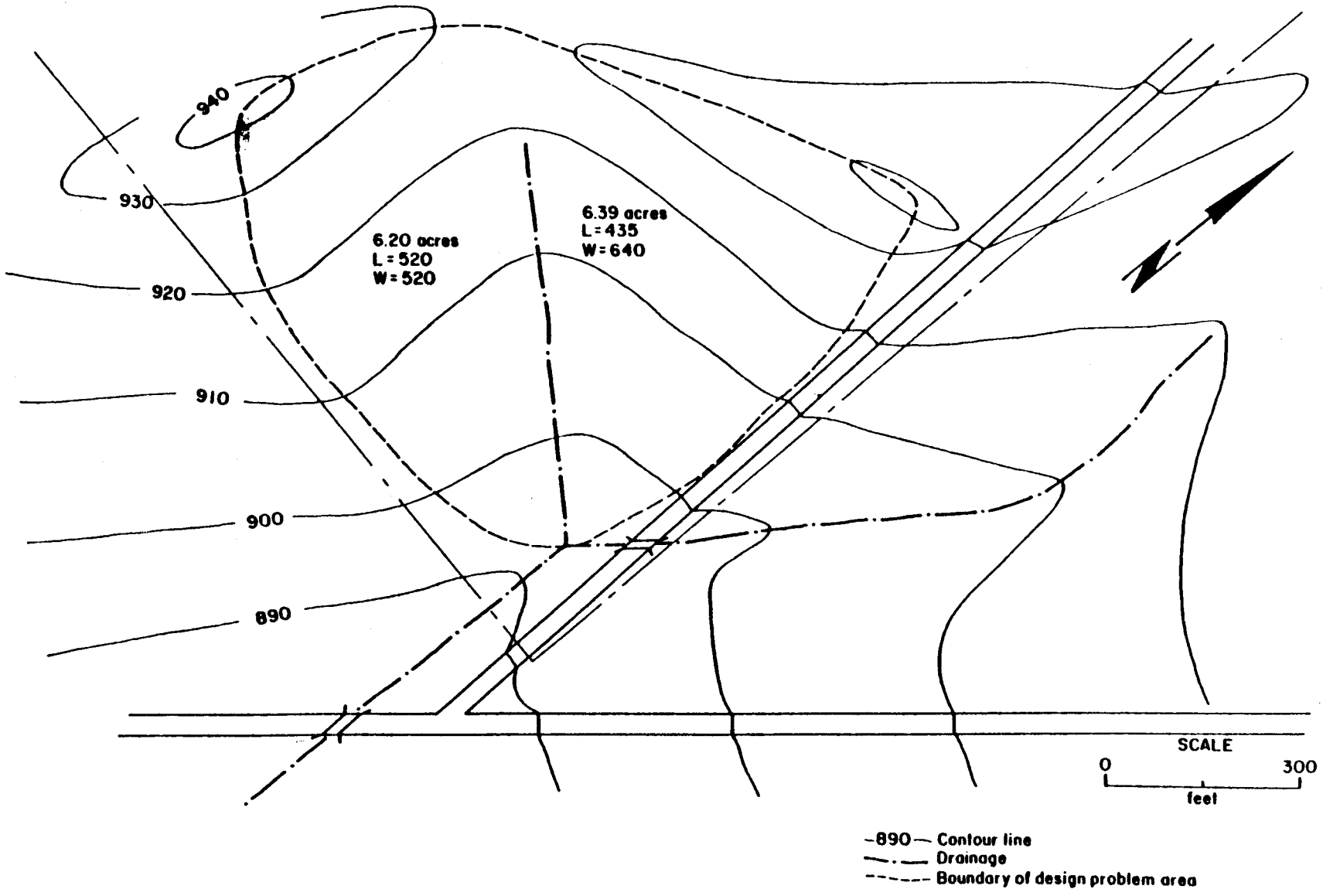

Figure 9.1. Topographic map of design problem area.

9.3 Soils Data

For the purpose of this problem, it will be assumed that only the textural classification of the soil is available. A loam soil which commonly occurs in Illinois will be used as topsoil. This soil will be assumed to have a slow infiltration rate and a moderately high runoff potential. The soil falls within the C hydrologic soil group.

9.4 Topographic Information

The catchment area shown in Figure 9.1 is complex and must be simplified in order to proceed with the sediment yield analysis. The open-book representation (described in Chapter III, section 3.5) will be illustrated here in detail. First, the catchment is divided along the main swale into two areas or planes and their respective areas determined. As shown in Figure 9.1, the right side includes 6.4 acres and the left side includes 6.2 acres.

The overland flow length and slope are then determined for each area or plane. Overland flow paths are measured and their slopes are determined at points along the main swale for each plane. An average overland flow length and slope are then determined. Results indicate lengths of 435 feet and 520 feet, and slopes of 6.8 percent and 5.5 percent for the right and left sides, respectively.

The design width for each plane is the area divided by the overland flow length. Results are 650 feet and 520 feet for the right and left sides, respectively. The slope of the main swale is determined from the actual topography and is 5.7 percent.

These data for the open-book configuration of the catchment area are summarized in Table 9.1. As can be seen from the data, the widths of the left and right planes are different. This simply indicates that the overland flow discharge per unit width of the two planes will be greater for the left plane than for the right plane. Hence, the overland flow length is the most important dimension for each phase.

Although the information in this section was developed from a topographic map of some detail, field measurements could be used. For example, the catchment area could be approximated from the mine plan and supplementary measurements of overland flow lengths and slopes could then be made in the field. Field measurements will be necessary for areas where changes in topography occur rapidly, such as stockpiles and spoil areas.

Table 9.1. Summary of Topographic Data.

	Right Side	Left Side
Area	6.39 acres	6.20 acres
Overland Flow Length	435 feet	520 feet
Slope	6.8%	5.5%
Width	640 feet	520 feet
Main Swale Slope	5%	

9.5 Sediment Control System Design

9.5.1 Selection of Alternatives

The first step in the design process is to select erosion control treatments or structures which are suitable for the site. The site terrain has mild to moderately steep slope and the soils are moderately silty. Based on these characteristics, three structure groups are selected and alternatives will be selected based on these groups. The selected groups are surface protection, diversion and conveyance structures plus surface protection, and detention and filtering structures. Individual structures which will be selected are straw mulch at 2 tons/acre, terraces with straw mulch at 2 tons/acre and filter fence.

The design sediment yield is two tons/acre/year. The allowable sediment yield for the 10-year storm can be found using the Mean Annual Sediment Yield Worksheet from Chapter VIII (Worksheet 8.1) and determining the sediment yield factor, C_{rt}, and expected water yield, P_{pt}. These factors are determined in Worksheet 9.1 with $C_{rt} = 0.438$ and $P_{pt} = 1.036$. The average annual water yield is 9.0 inches. Using Equation 8.6 and solving for the sediment yield for the 10-year, 24-hour storm gives

$$G_y = \left(\frac{P_{pt}}{P_w}\right)\left(\frac{\bar{G}_y}{C_{rt}}\right)$$

$$= \left(\frac{1.036}{9.0}\right)\left(\frac{2.0}{0.483}\right)$$

$$= 0.53 \text{ tons/acre}$$

The sediment concentration is determined using Equation 4.14. The rainfall excess is 2.13 inches for a storm of 4.5 inches and a CN value of 76.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Return Period (years)	24-Hour Rainfall, P (inches)	Rainfall Excess, P_e (inches)	Rainfall Excess Ratio R_p	R_p^b	Weighting Factor W_p	Sediment Yield Factor, C_r	Expected Water Yield, P_p
100	6.5	3.82	1.79	2.21	0.01	0.022	0.038
50	5.8	3.21	1.51	1.75	0.01	0.018	0.032
25	5.2	2.70	1.26	1.37	0.02	0.027	0.054
10	4.5	2.13	1.0	1.0	0.06	0.06	0.128
5	4.0	1.74	0.82	0.76	0.10	0.076	0.174
2	3.3	1.22	0.57	0.47	0.50	0.235	0.61
					C_{rt} =	0.438	1.036

Curve number, CN = 76

Roughness-slope ratio, K_g/S = 133,333

Rainfall ratio exponent, b = 1.36

Average annual water yield, P_w = 9.0

Sediment yield for 10-year, 24-hour storm, $G_{y_{10}}$ = ---- tons

Mean annual sediment yield $\overline{G}_y = (P_w/P_{pt})C_{rt}G_{y10}$

= ---- tons

Worksheet 9.1. Mean Annual Sediment Yield.

$$G_s = \frac{8830\ G_Y}{P_e\ A}$$

$$= \frac{8830(0.53)}{2.13(1.0)}$$

$$= 2{,}200 \text{ ppm}$$

9.5.2 Maximum Area for Structures and Treatments

The maximum area for designing a surface protection measure is a function of the roughness coefficient, K_g, the percentage of silt in the soil, P_1, The slope, S, the sediment concentration, C_s, the rainfall excess, P_e, and the width of the area, W. For the straw mulch treatment and the site these values are:

K_g = 6,800
P_1 = 0.30
S = 0.06
C_s = 2,200 ppm
P_e = 2.13 inches
W . 450 feet

The overland flow length coefficient (Figure 8.2) is 500 which gives a maximum overland flow length of 235 feet (from Equation 8.1). The maximum area for the mulch treatment is 2.4 acres. This is about 40 percent of either the left or right plane.

The maximum overland flow length is about half the actual overland flow length for either the left or right plane and a straw mulch treatment will be inadequate to meet the required design sediment yield. A reasonable terrace spacing would divide each plane in half. Some sediment deposition will occur in the terraces which will allow for an increased overland flow length to the terrace.

The maximum area which can be treated by a filter fence depends on the slope of the area, S, the duration of rainfall excess, t_e, the flow rate through the fabric, K_a, and the amount of rainfall excess, P_e. The structure length coefficient, C_f, is 86.4 from Figure 7.2 for a detention parameter of 37.4 (Equation 7.2). This gives a maximum allowable overland flow length to the structure of 485 feet. The longer the filter fence becomes, the larger the area which can be treated. However, it can be seen from the

topography (Figure 9.1) that the larger the area becomes, the less contour length is available in the catchment. A plot of contour length versus area and filter fence length versus maximum area (Figure 9.2) shows the optimum filter fence length to be 790 feet or an area of 8.8 acres. The contour length at elevation 910 is 800 feet, so the filter fence should be located at approximately this contour. The remaining 4.6 acres could be treated with straw mulch.

9.5.3 System Design

In the last two sections we identified three alternative structures and treatments and were able to quickly determine that two alternatives, terrace with straw mulch and filter fence, were feasible. At this point a cost analysis should be conducted to identify which structure is most cost-effective. Maintenance requirements for each structure should be assessed. The best structure for the site could then be selected and a detailed design conducted to estimate the actual sediment yield, determine a channel lining and other requirements.

The next two sections will illustrate the detail design of both feasible alternatives.

9.6 Detailed Design of a Terrace System

It was shown that a reasonable terrace spacing would divide the catchment in half. These terraces would be located as shown in Figure 9.3, basic data on the topography of each subarea are:

	Upper Right Side	Lower Right Side	Upper Left Side	Lower Left Side
Area	3.60	2.77	3.50	2.70
Overland Flow Length	300	250	320	250
Slope	0.068	0.058	0.055	0.045
Width	522	482	476	470

The average slopes, S, for the lower areas are somewhat flatter than the upper portions of the catchment. This is because the hillslopes are concave upward.

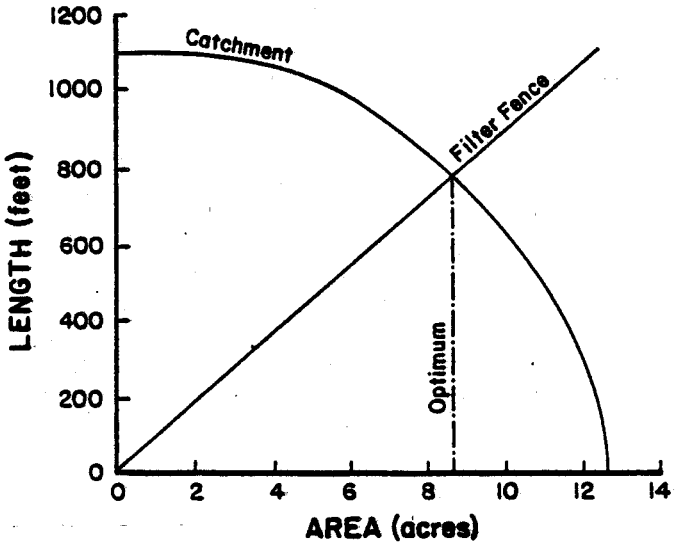

Figure 9.2. Optimum filter fence length.

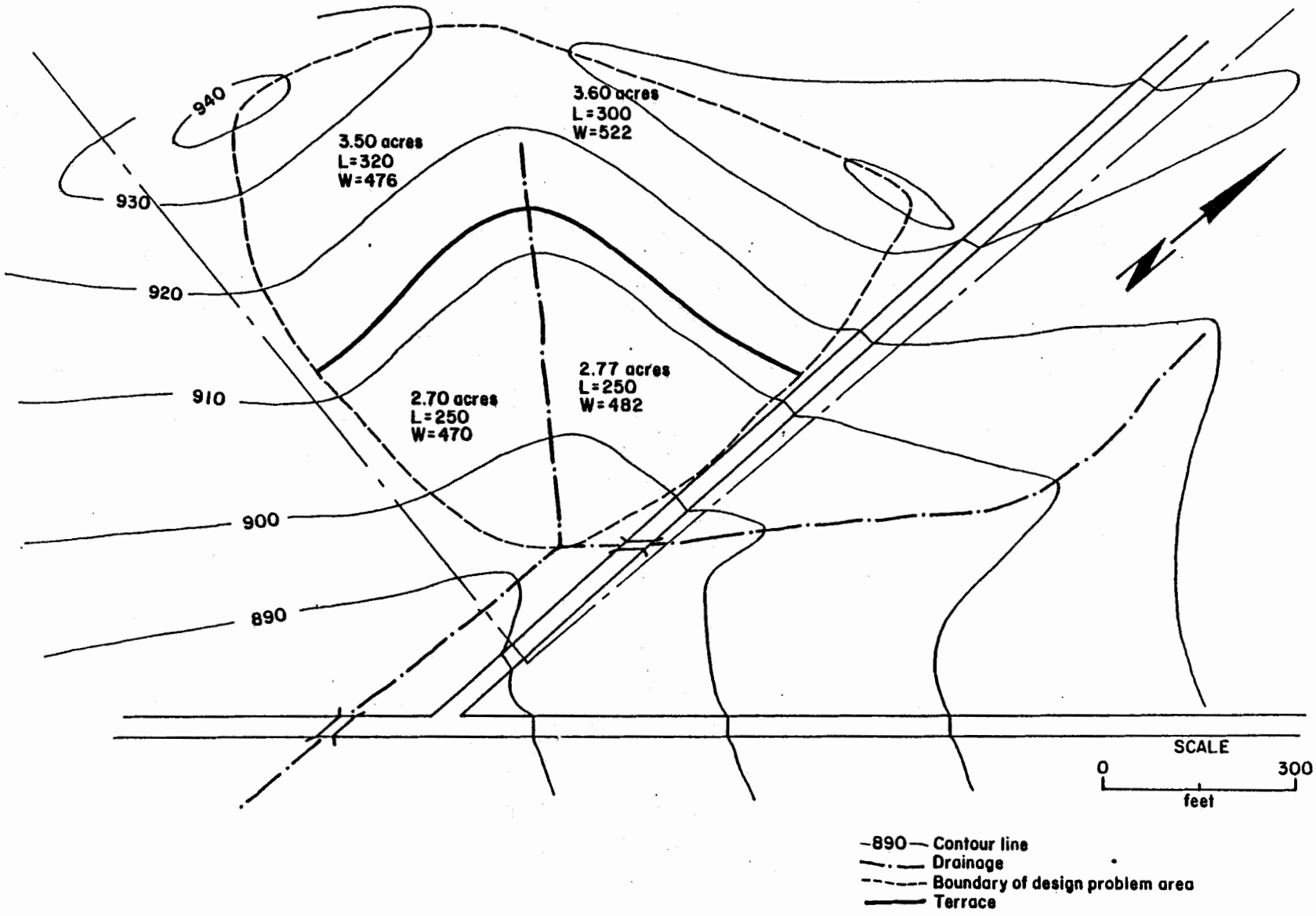

Figure 9.3. Topographic map of design problem area with terrace.

9.6.1 Terrace Design

Runoff from the upper subareas will reach the terraces. Determination of sediment yield to the terraces and the design of the terraces are given in this section.

Basic data on soil and climate are as follows:

Storm rainfall amount, P = 4.5 inches

Curve number, CN = 76

Hydrologic soil group: C

Soil texture class: Loam

Task 1. Determine the Water and Sediment Yield to the Terraces

Using the base data on soil, topography and climate, the Chapter IV sediment yield procedure is executed to determine the sediment yield from the two upper subareas. Information in steps one and two is the same for both subareas.

Step One. Particle Size Distribution

Data from Table 3.4 for a loam are as follows:

Clay:		= 10%
Silt,	P_1	= 30%
Very Fine Sand,	P_2	= 10%
Fine-Medium-Coarse Sand,	P_3	= 25%
Very Coarse Sand,	P_4	= 25%

Step Two: Cover Ratio, Roughness and Detachment Coefficients

Cover Ratio, C_g = 0.88 (from Figure 4.11)

Erodibility Factor, K_e = 0.36 (from Table 4.1)

Roughness Coefficient, K_g = 6,800 (from Figure 4.2, Table 4.2)

Detachment Coefficient, D_f = 0.55 (from Table 4.2)

Steps Three Through Seven: see attached worksheets.

Worksheets for the upper left subarea are given first and the worksheets for the upper right subarea are given next.

(1) Time (hr)	(2) Δt (hr)	(3) P/P_t	(4) P (inches)	(5) Pe (inches)	(6) ΔP (inches)	(7) ΔPe (inches)	(8) I (in/hr)	(9) Q (cfs)	(10) q (cfs/ft)
8.42		0.14	0.63	0.00					
	0.58				0.04	0.001	0.075	0.004	$.747 \times 10^{-5}$
9.00		0.15	0.68	0.001					
	2.25				0.45	0.066	0.200	0.103	$.216 \times 10^{-3}$
11.25		0.25	1.13	0.067					
	0.92				2.00	1.035	2.1766	3.938	$.827 \times 10^{-2}$
12.17		0.70	3.13	1.102					
	1.83				0.56	0.403	0.3074	0.771	$.162 \times 10^{-2}$
14.00		0.82	3.69	1.505					
	10.00				0.81	0.625	0.0810	0.219	$.459 \times 10^{-3}$
24.00		1.00	4.50	2.130					

Small area characteristics:

Area = 3.5 acres

Length = 320 feet

Width = 476 feet

Step Three worksheet - Upper Left Subarea.

(1) Δt (hr)	(2) I (in/hr)	(3) G_r (tons)
0.58	0.0750	0.01
2.25	0.2000	0.24
0.92	2.1766	11.86
1.83	0.3074	0.47
10.00	0.0810	0.18

Area = 3.50 acres

$G_r = 6.48\ \Delta t\ I^2\ A_b$ (Eq. 4.7)

Ground Cover Ratio = 88%

Width = 476 feet

$A_b = (1 - C_g)A$ (Eq. 4.8)

Step Four worksheet - Upper Left Subarea.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Δt	q	g_{t1}	g_{t2}	g_{t3}	g_{t4}	G_{t1}	G_{t2}	G_{t3}	G_{t4}	G_t
(hours)	(cfs/ft)	(tons/ ft/hr)	(tons/ ft/hr)	(tons/ ft/hr)	(tons/ ft/hr)	(tons)	(tons)	(tons)	(tons)	(tons)
0.58	$.747 \times 10^{-5}$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.25	$.216 \times 10^{-5}$	0.00009	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
0.92	$.827 \times 10^{-2}$	0.01488	0.00	0.00	0.00	1.96	0.00	0.00	0.00	1.96
1.83	$.162 \times 10^{-2}$	0.00155	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.40
10.00	$.459 \times 10^{-3}$	0.00027	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.38

Roughness Coefficient, K_g = 6,800

Slope, S = 0.055

Width = 476 feet

Step Five worksheet - Upper Left Subarea.

(1) Δt (hours)	(2) G_t (tons)	(3) G_r (tons)	(4) G_f (tons)	(5) G_s (tons)	(6) G_{s1} (tons)	(7) G_{s2} (tons)	(8) G_{s3} (tons)	(9) G_{s4} (tons)
0.58	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00
2.25	0.03	0.24	0.00	0.24	0.07	0.02	0.06	0.06
0.92	1.96	11.86	0.00	11.86	3.56	1.19	2.97	2.97
1.83	0.40	0.47	0.00	0.47	0.14	0.05	0.12	0.12
10.00	0.38	0.18	0.11	0.29	0.09	0.03	0.07	0.07

Flow Detachment Coefficient = 0.55

$G_f = D_f(G_t - G_r)$ (Eq. 4.10)

where $G_t < G_r$

Step Six worksheet - Upper Left Subarea.

	(1)	(2)	(3)	(4)	(5)
	G_{y1}	G_{y2}	G_{y3}	G_{y4}	G_y
	0.00	0.00	0.00	0.00	0.00
	0.03	0.00	0.00	0.00	0.03
	1.96	0.00	0.00	0.00	1.96
	0.14	0.00	0.00	0.00	0.14
	0.09	0.00	0.00	0.00	0.09
TOTAL YIELD	2.22	0.00	0.00	0.00	2.22

Step Seven worksheet - Upper Left Subarea.

(1) Time (hr)	(2) Δt (hr)	(3) P/P_t	(4) P (inches)	(5) Pe (inches)	(6) ΔP (inches)	(7) ΔPe (inches)	(8) I (in/hr)	(9) Q (cfs)	(10) q (cfs/ft)
8.42		0.14	0.63	0.00					
	0.58				0.04	0.001	0.0750	0.004	$.701 \times 10^{-5}$
9.00		0.15	0.68	0.001					
	2.25				0.45	0.066	0.2000	0.106	$.202 \times 10^{-3}$
11.25		0.25	1.13	0.067					
	0.92				2.00	1.035	2.1766	4.051	$.775 \times 10^{-2}$
12.17		0.70	3.13	1.102					
	1.83				0.56	0.403	0.3074	0.793	$.152 \times 10^{-2}$
14.00		0.82	3.69	1.505					
	10.00				0.81	0.625	0.0810	0.225	$.430 \times 10^{-3}$
24.00		1.00	4.50	2.130					

Small area characteristics:

Area = 3.60 acres

Length = 300 feet

Width = 522

Step Three worksheet - Upper Right Subarea.

(1) Δt (hr)	(2) I (in/hr)	(3) G_r (tons)
0.58	0.0750	0.01
2.25	0.2000	0.25
0.92	2.1766	12.20
1.83	0.3074	0.48
10.00	0.0810	0.18

Area = 3.60

$G_r = 6.48\ \Delta t\ I^2\ A_b$ (Eq. 4.7)

Ground Cover Ratio = 88%

Width = 522

$A_b = (1 - C_g)A$ (Eq. 4.8)

Step Four worksheet - Upper Right Subarea.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Δt	q	g_{t1}	g_{t2}	g_{t3}	g_{t4}	G_{t1}	G_{t2}	G_{t3}	G_{t4}	G_t
(hours)	(cfs/ft)	(tons/ ft/hr)	(tons/ ft/hr)	(tons/ ft/hr)	(tons/ ft/hr)	(tons)	(tons)	(tons)	(tons)	(tons)
0.58	.701	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.25	$.202 \times 10^{-3}$	0.00011	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04
0.92	$.775 \times 10^{-4}$	0.01643	0.00	0.00	0.00	2.37	0.00	0.00	0.00	2.37
1.83	$.152 \times 10^{-}$	0.00174	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.50
10.00	$.430 \times 10^{-3}$	0.00031	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.48

Roughness Coefficient, K_g = 6,800

Slope, S = 0.068

Width = 522

Step Five worksheet - Upper Right Subarea.

(1) Δt (hours)	(2) G_t (tons)	(3) G_r (tons)	(4) G_f (tons)	(5) G_s (tons)	(6) G_{s1} (tons)	(7) G_{s2} (tons)	(8) G_{s3} (tons)	(9) G_{s4} (tons)
0.58	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00
2.25	0.04	0.25	0.00	0.25	0.08	0.03	0.06	0.06
0.92	2.37	12.20	0.00	12.20	3.66	1.22	3.05	3.05
1.83	0.50	0.48	0.01	0.49	0.15	0.05	0.12	0.12
10.00	0.48	0.18	0.16	0.35	0.10	0.03	0.09	0.09

Flow Detachment Coefficient = 0.55

$G_f = D_f(G_t - G_r)$ (Eq. 4.10)

where $G_t < G_r$

Step Six worksheet - Upper Right Subarea.

	(1)	(2)	(3)	(4)	(5)
	G_{y1}	G_{y2}	G_{y3}	G_{y4}	G_y
	0.00	0.00	0.00	0.00	0.00
	0.04	0.00	0.00	0.00	0.04
	2.37	0.00	0.00	0.00	2.37
	0.15	0.00	0.00	0.00	0.15
	0.10	0.00	0.00	0.00	0.10
TOTAL YIELD	2.66	0.00	0.00	0.00	2.66

Step Seven worksheet - Upper Right Subarea.

Task 2. Determine Terrace Slope

The sediment yield to the terrances is silt. Since silt requires long settling times, the terrace slope should be as flat as possible to produce slow flow velocities. The terrace must provide adequate drainage and for this reason a slope of 0.3 percent is selected.

Task 3. Determination of Terrace Cross Section and Hydraulic Parameters

A triangular channel shape is used for the terrace since it is easily constructed using standard reclamation equipment (i.e. small dozers). The recommended side slopes for the terrace design are 3H:1V and 5H:1V as shown in Figure 6.3. The flow depths and areas are given by the nomographs in Figures 6.3 and 6.4, respectively. The Manning's n-value is determined for a grass-legume terrace by trial and from Figure 6.6 for a class "D" retardance (Table 6.2). When the product of velocity and hydraulic radius is less than 0.1 then the n-value should be selected as the maximum value in Table 6.1. In this case, the value is 0.28 for a good stand of grass-legume lining with a length of about 6 inches (section III, A.1.b of Table 6.1).

Results of the hydraulic calculations for both terrace are given in the following worksheets.

Task 4. Determine the Sediment Transport Capacity of the Terrace

Calculations of sediment transport capacity are shown on the following worksheets for the upper left and right terraces. Note that the sediment transport capacity of the terrace is zero except for the silt size during the peak of the storm. This indicates a good terrace design.

Task 5. Determination of Sediment Yield

Sediment yield for each terrace is shown on the Task 5 Worksheets. The length of the terrace used in determining the setting parameter, C_w, is the actual length as determined by direct measurement on-site or from a topographic map. The lengths of the terraces are 440 feet for the left subarea and 490 feet for the right subarea.

The average suspended sediment concentration is 1,600 ppm for the left subarea and 1,450 ppm for the right subarea.

1	2	3	4	5	6	7	8
Time Interval	Q (cfs)	n	d (ft)	A (ft^2)	V (fps)	T (ft)	d_h=A/T (ft)
1	0.004	0.28	0.14	0.163	0.025	1.1	0.07
2	0.103	0.28	0.48	1.86	0.055	3.8	0.24
3	3.94	0.135	1.44	16.5	0.238	11.5	0.72
4	0.771	0.28	1.03	8.41	0.092	8.2	0.51
5	0.219	0.28	0.64	3.27	0.067	5.1	0.32

Task Three worksheet - Upper Left Terrace.

1	2	3	4	5	6	7	8
Time Interval	Q (cfs)	n	d (ft)	A (ft^2)	V (fps)	T (ft)	d_h=A/T (ft)
1	0.004	0.28	0.14	0.163	0.025	1.1	0.07
2	0.106	0.28	0.49	1.90	0.056	3.9	0.24
3	4.051	0.145	1.49	17.8	0.227	11.9	0.75
4	0.793	0.28	1.04	8.56	0.092	8.3	0.52
5	0.225	0.28	0.65	3.34	0.067	5.2	0.32

Task Three worksheet - Upper Right Terrace.

$p_1 = 0.30 \quad p_2 = 0.10 \quad p_3 = 0.25 \quad p_4 = 0.25$

Time Interval	Δt (hrs)	T (ft)	g_t (tons/ft/hr)				G_t (tons)				
			1	2	3	4	1	2	3	4	Total
1	0.58	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.25	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.92	11.5	.0115	0.0	0.0	0.0	0.0365	0.0	0.0	0.0	0.0365
4	1.83	8.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	10.00	5.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
						TOTAL	0.0365	0.0	0.0	0.0	0.0365

Task Four worksheet - Upper Left Terrace.

$p_1 = 0.30 \quad p_2 = 0.10 \quad p_3 = 0.25 \quad p_4 = 0.25$

Time Interval	Δt (hrs)	T (ft)	g_t (tons/ft/hr)				G_t (tons)				
			1	2	3	4	1	2	3	4	Total
1	0.58	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	2.25	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.92	11.9	0.0101	0.0	0.0	0.0	0.0331	0.0	0.0	0.0	0.0331
4	1.83	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	10.00	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
						TOTAL	0.0331	0.0	0.0	0.0	0.0331

Task Four worksheet - Upper Right Terrace.

1	2	3	4	5	6	7	8
Time Inter	C_w	P_s	Gy_1	Gy_2	Gy_3	Gy_4	Gy
1	55.3	1.0	0.0	0.0	0.0	0.0	0.0
2	7.33	1.0	0.0	0.0	0.0	0.0	0.0
3	0.565	0.44	1.34	0.0	0.0	0.0	1.34
4	2.06	0.95	0.01	0.0	0.0	0.0	0.01
5	4.51	1.0	0.0	0.0	0.0	0.0	0.0
Total Yield			1.35	0.0	0.0	0.0	1.35

$$C_w = \frac{2.2 \times 10^{-4} L_d}{V d_n}$$ (Equation 6.5)

p_s (see Figure 6.11)

Task Five worksheet - Upper Left Subarea.

1	2	3	4	5	6	7	8
Time Interval	C_w	P_s	Gy_1	Gy_2	Gy_3	Gy_4	Gy
1	61.6	1.0	0.0	0.0	0.0	0.0	0.0
2	8.02	1.0	0.0	0.0	0.0	0.0	0.0
3	0.63	0.48	1.25	0.0	0.0	0.0	1.25
4	2.25	0.92	0.01	0.0	0.0	0.0	0.01
5	5.03	1.0	0.0	0.0	0.0	0.0	0.0
Total Yield			1.26	0.0	0.0	0.0	1.26

$$C_w = \frac{2.2 \times 10^{-4} L_d}{V d_n}$$ (Equation 6.5)

P_s (see Figure 6.11)

Task Five worksheet - Upper Right Subarea.

Task 6. Deposition Depth

The volume of deposition is computed using Equation 6.7 which gives 17.5 ft^3 for the upper left subarea terrace and 28.4 for the upper right subarea terrace. This gives deposition depths of 0.10 feet for the left terrace and 0.12 feet for the right terrace.

Task 7. Terrace Design Depth

The terrace design depth includes the sum of the depths due to flow, sediment deposition and freeboard. The design depth for both terraces is therefore 2.6 feet.

9.6.2 Determination of Sediment Yield from the Lower Subareas

The lower subareas are mulched and the procedure for determining the sediment yield from these areas follows the Chapter IV procedure. The slopes of these lower subareas are flatter compared to the upper subareas because the basic shape of the catchment is concave. The average slopes for the lower left subarea is 0.045 and 0.058 for the lower right subarea. Sediment yields are 1.12 and 1.68 tons for the lower left and right subareas, respectively.

9.6.3 Summary of Results for the Terracing Alternative

The total sediment yield from the terraced catchment is 5.41 tons for the 10-year, 24-hour storm. This gives a mean annual sediment yield of 20.6 tons or 1.63 tons/acres which is below the design objective of 2.0 tons/acre. This design produces an attractive, stable postmining landscape which is low in cost and requires little long-term maintenance.

9.7 Detailed Design of a Filter Fence System

The second design alternative is to use a filter fence to trap sediment. The fence will be placed parallel to the contour of the catchment at elevation 900 and will catch sediment from 8.6 acres of the catchment (Figure 9.4). The

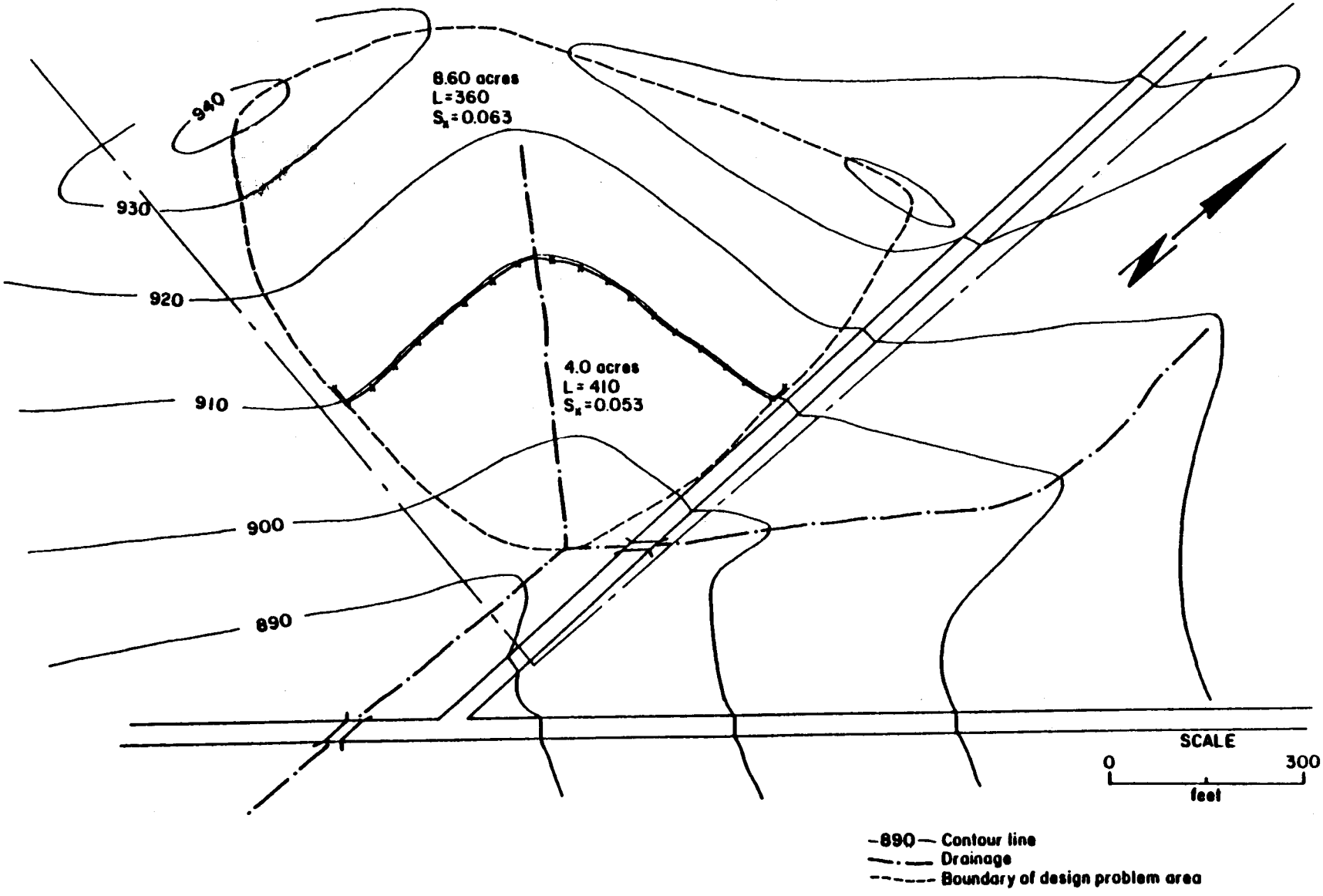

Figure 9.4. Topographic map of design problem area with filter fence.

entire catchment will be mulched with straw at the rate of 2.0 ton/acre. Basic data for computing the sediment yield to the filter fence is as follows:

Roughness coefficient, $K_g = 6{,}800$

Overland flow slope, $S_x = 0.063$

Overland flow length, $L = 360$ feet

Sediment yield to the fence is 6.36 tons, all of which is in the silt size range. Below the fence, the remaining 4.0 acres have a sediment yield of 2.69 tons. Basic data on the lower area are as follows:

Overland flow slope, $S_x = 0.053$

Overland flow length, $L = 410$ feet

Details of the calculation for determining the sediment yield from the filter fence are given on the attached worksheet.

There should be a small diversion below the filter fence to control the seepage through the fence. The diversion can be designed based on the peak flow rate through the fence. This flow rate is equal to the flow rate per unit area (0.000667 ft/sec) multiplied by the maximum area

$$Q_{max} = 0.000667\ (2)(400)$$
$$= 0.53 \text{ cfs}$$

Using a grass lined diversion similar to the one used for the terrace alternative (4:1 side slopes, 0.3 percent slope, and Class D retardance) gives the following hydraulic conditions

Manning's $n = 0.28$

Flow depth, $d = 0.89$ feet

Flow velocity, $\bar{\bar{v}} = 0.08$ ft/sec

No sediment transport will occur for these conditions. The diversion channel should extend to the main swale which should also be lined with grass.

Overall the sediment yield for the 10-year, 24-hour storm on the catchment treated with a filter fence and straw mulch is 2.88 tons. This is a mean annual sediment yield of 11.0 tons of sediment or 0.87 tons/acre, which meets the design objective of 2.0 tons/acre. The filter fence design is a good short-term solution to the erosion problem, although it is moderately expensive and will require maintenance. The design life of the structure is under two years.

Worksheet - Detention and Filtering Structures.

Step One: Volume of Water and Sediment Yield

Rainfall Excess, P_e = 2.13 inches

Catchment Area, A = 8.6 acres

Actual Sediment Yield, G_y = 6.36 tons

$$\forall_{sw} = 3{,}630\ P_e A + 20.2\ G_y$$
$$= 3{,}630(2.13)(8.6) + 20.2(6.36)$$
$$= 66{,}600 \text{ cu.ft.}$$

Step Two: Minimum Structure Length

Maximum Allowable Ponded Depth, d_{max} = 2.0 feet

Duration of runoff, t_e = 15.6 hours

Flow rate per unit area, K_a = 2.4 ft/hr

Upland slope, S_x = 0.063

Detention Parameter

$$K_f = 1/2\ K_a\ t_e\ d_{max}$$
$$= 1/2(2.4)(15.6)2$$
$$= 37.4$$

Structure Length Coefficient, C_f = 85.1

Minimum Structure Length

$$L_{min} = \forall_{sw}/C_f$$
$$= 66{,}600/85.1$$
$$= 783 \text{ feet}$$

Actual structure length used, L_d = 800 feet

Worksheet (continued).

Step Three: Sediment Trapping Efficiency

Sediment Size (mm)	Actual[1] Sediment Yield G_y (tons)	Fall[2] Velocity w(ft/sec)	Trap[3] Efficiency e_s	Sediment[4] Trapped G_d (tons)
0.010	6.36	----	0.97	6.17
0.0707	0.00	----	1.0	0.00
0.316	0.00	----	1.0	0.00
1.414	0.00	----	1.0	0.00
Total	6.36	/////////	/////////	6.17

(1) From input data

(2) See Table 7.1 (Not needed for filter structures)

(3) For Filter Structures see Figure 7.2

For Detention Structures:

For Sand Sizes:

$e_s = 1 - 4\ (K_a/w)\ (L_f/L_d)\ S_x$

Rock outlet flow rate, K_a = ____----____ ft/sec

Rock outlet length, L_f = ____----____ feet

For the silt size:

$$C_w \quad \frac{2.2 \times 10^{-4}\ L_d}{K_a L_f S_x}$$

= ____----____

$e_s = p_s$ from Figure 6.11

(4) $G_d = e_s G_y$

Worksheet (continued).

Volume of sediment deposition

$$V_s = 20.2\ G_d$$

$$= \underline{125} \text{ cu.ft.}$$

Depth of sediment deposition

$$d_d = \sqrt{2V_s S_x / L_d}$$

$$= \sqrt{2 \times 125 \times 0.063/800}$$

$$= \underline{0.14} \text{ feet}$$

Step Four: Mean Concentration of Effluent

$$C_s = 8{,}830\ (G_y - G_d)/P_e A$$

$$= 8{,}830\ (6.36-6.17)/(2.13 \times 8.6)$$

$$= \underline{92} \text{ ppm}$$

Step Five: Required Structure Height

If d_d is greater than 0.5 feet then add additional freeboard, d_f

$$d_f = d_d - 0.5$$

$$= \underline{0.0} \text{ feet}$$

Total height

$$\text{Structure Height, } H_d = \sqrt{\frac{L_{min}}{L_d}\, d_{max}} + 0.5 + d_f$$

$$= \sqrt{783/800 \times 2} + 0.5 + 0.14$$

$$= \underline{2.6} \text{ feet}$$