Technical Reclamation Memorandum

TRM # 11

Kentucky Department for Surface Mining Reclamation and Enforcement

Date: May 27, 1983

From: Robert E. Nickel, Director
Division of Permits

Subject: New Interpretation of the EPA Settleable Solids Effluent Limitation

Background

The U. S. Environmental Protection Agency has notified the department that the settleable solids effluent limitation should now be interpreted as a 24-hour average rather than an instantaneous peak. EPA's new interpretation means that sediment ponds can be designed to meet a maximum 24-hour arithmetic average settleable solids concentration of 0.5 ml/l rather than an instantaneous peak concentration of 0.5 ml/l. In general, the new interpretation will allow smaller sediment ponds.

The new interpretation by EPA resulted from a legal controversy regarding the specific regulatory language which defines the term "maximum daily discharge" (40 CFR 122.3) which was used in relation to the settleable solids effluent limitation (40 CFR 434). EPA has not advised us whether they intend to stay with the new interpretation permanently or revise their regulations to define the settleable solids limitation as an instantaneous peak.

This TRM provides supplemental information which will allow engineers to use design procedures discussed in previous TRM's (SEDIMOT II, TRM #2 and #6; use of existing or new monitoring data, TRM #8; and hand calculator procedures, TRM #10) to size a sediment pond to meet the new maximum 24-hour arithmetic average settleable solids effluent limitation.

Use of Existing or New Monitoring Data

Applicants who elect to use the TRM #8 procedures for demonstrating that a pond will meet the settleable solids effluent limitation can use a settleable solids concentration of 4.4 ml/l for conduit and riser principal spillways or 2.8 ml/l for trickle tube principal spillways instead of a peak of 0.5 ml/l. Consequently, if the discharge-settleable solids extrapolation presented in TRM #8 produces a settleable solids concentration less than or equal to 4.4 ml/l for conduit and riser principal spillways or less than or equal to 2.8 ml/l for trickle tube principal spillways, the department will accept the design as adequate to meet a 24-hour arithmetic average settleable solids concentration of 0.5 ml/l.

Procedures for Hand Calculators

The Sediment Pond Design Guideline - Procedures for Hand Calculators (TRM #10) which was recently released by the department has been modified to calculate an arithmetic average settleable solids concentration by revising the settleable solids regression equations. In addition to providing new coefficients for the regression equations, additional changes and corrections suggested by various reviewers of the guideline have been included with this TRM. All additions and corrections to the Sediment Pond Design Guideline - Procedures for Hand Calculators have been provided as updated pages which can be inserted in the guideline. Since some applicants may wish to continue to design for a peak settleable solids concentration, the department is providing (1) correction pages for the April 1983 edition of the guideline to design for peak settleable solids, and (2) update pages to convert the equations, example, and hand calculator program to design for an arithmetic average. To enable users to easily identify those pages which were revised for designing to meet an arithmetic average settleable solids concentration, the term "average settleable solids" has been placed at the bottom of all pages which were revised for that reason. In addition, where corrections were made as a result of review comments, the symbol "R1" was placed in the right margin to designate the revised material and the date of the revision was noted at the bottom of the page. The following specific correction and update pages are included:

Correction Pages

(1) Discussion of sediment storage volume; p. 20.

Equation 15 which converts the 10-year, 24-hour sediment load in tons to sediment volume in acre-feet also contains the 1.5 multiplier for determining the minimum sediment storage volume. The original text did not indicate that the 1.5 factor was incorporated in the conversion constant. Additional explanation has been added to correct this inconsistency.

(2) Table 4 - Minimum allowable Heads for Full Pipe Flow; p. 22.

The spillway diameter abbreviations for conduit and riser principal spillways were reversed. The new page contains the correct abbreviations.

(3) Conduit and riser settleable solids prediction equation; p. 32.

The constant for equation 21 was $6.871 \times \underline{10^{-7}}$ in the original edition. This constant should be $6.871 \times \underline{10^{-5}}$. The hand calculator program GRASP presented in Appendix C has the correct constant, (register 100) and is not affected by this change.

(4) Example contained in Appendix B; pp. B-6 through B-8, B-14 through B-17, and B-21.

The sediment storage volume of 2.63 acre-feet used in the example is greater than that needed to meet the minimum of 1.5 times the 10-year, 24-hour storm sediment volume. The correct minimum sediment storage volume is 1.76 acre-feet. The discussion on pages B-6 and B-7 and worksheets 4, 5 and 6 have been updated to reflect this change.

(5) GRASP program corrections; p. C-7.

To eliminate an incorrect error message, the constant in lines 12 and 16 of subroutine "TTRF2" (top of left column on page C-7) should be <u>0.4</u> rather than 0.3.

(6) Description of the register contents for registers 14 and 15; p. C-12.

The contents of registers 14 and 15 for the hand calculator program GRASP are missing from Table 4. The corrected page includes the register contents.

<u>Update Pages for Average Settleable Solids Design</u>

(1) New coefficients for the settleable solids regression equations; pp. 32 and 33.

(2) Revised table of contents for Appendix B to include a second design example.

(3) Modified sediment pond design example in Appendix B illustrating a design for average settleable solids; pp. B-6 through B-8, B-14 through B-17, and B-21.

(4) An additional design example illustrating a sediment pond design to meet the average settleable solids effluent limitation. For comparative purposes, a design for peak settleable solids has also been provided; pp. B-22 through B-37.

(5) Modified hand calculator program (GRASP) example; p. C-4.

(6) Updated regression equation coefficient registers for GRASP; p. C-8.

<u>SEDIMOT II</u>

The University of Kentucky Department of Agricultural Engineering is currently modifying SEDIMOT II to calculate an arithmetic average settleable solids concentration. Until program modifications are available, engineers who elect to use SEDIMOT II may (1) calculate the maximum 24-hour arithmetic average concentration using the effluent suspended solids sedigraph contained in the SEDIMOT II output, or (2) calculate the arithmetic average settleable solids concentration by making a correction to the discharge-weighted storm average suspended solids concentration currently produced by SEDIMOT II.

SEDIMOT II users who wish to calculate the maximum 24-hour average settleable solids concentration from the effluent suspended solids sedigraph should (1) select the 24 consecutive hourly concentration values (time increment of one hour) which will produce the greatest average, (2) sum these 24 values, and (3) divide the total by 24 to generate an average suspended solids concentration in mg/l. The average suspended solids concentration can be converted to average settleable solids by multiplying the average suspended solids by the ratio of peak settleable solids in ml/l to peak suspended solids in mg/l. The calculations can be represented by the equation

$$\overline{C}_{se} = \frac{C_{pse}}{C_{psu}} \left(\sum_{i=1}^{24} C_{su,i} \right) / 24$$

Where $\overline{C}_{se}$ is the calculated maximum 24-hour arithmetic average settleable solids concentration in ml/l, C_{pse} is the peak settleable solids concentration in ml/l from the SEDIMOT II output, C_{psu} is the peak suspended solids concentration in mg/l from the SEDIMOT II output, and $C_{su,i}$ are hourly instantaneous suspended solids concentrations in mg/l from the SEDIMOT II output effluent sedigraph.

In those cases where outflow from the sediment pond does not extend over a 24-hour time period, the actual outflow duration rounded to the nearest hour should be used in calculating the average settleable solids. For example, if outflow from a sediment pond occurred over a 20.5 hour time period, the average settleable solids would be computed using 20 rather than 24 values.

SEDIMOT II users who do not want to make the above calculation may use the discharge-weighted storm average suspended solids concentration ("storm average effluent concentration" in SEDIMOT II output) which is calculated by the current version of SEDIMOT II. The storm average suspended solids must first be converted to settleable solids using the relationship

$$\overline{C}_{qse} = \frac{C_{pse}}{C_{psu}} \overline{C}_{qsu}$$

where $\overline{C}_{qse}$ is the calculated discharge-weighted storm average settleable solids concentration in ml/l, $\overline{C}_{qsu}$ is the discharge-weighted storm average suspended solids concentration in mg/l from the SEDIMOT II output, and the other terms are as previously defined. If the discharge-weighted storm average settleable solids calculated with the above equation is equal to or less than 1.6 ml/l for conduit and riser principal spillways or equal to or less than 1.1 for trickle tube principal spillways, the department will accept the sediment pond design as adequate to meet a 24-hour arithmetic average settleable solids concentration of 0.5 ml/l.

The department appreciates all those who have provided review comments and suggestions for improving the sediment pond design guideline. Questions related to the corrections and revisions included in this TRM may be addressed to Richard Rohlf or John Drake at (502) 564-2377.

Enclosures

The total watershed sediment yield can be obtained by simply summing the contribution from each sub-watershed:

$$Yi = \sum_{j=i}^{n} Y_j \tag{14}$$

where Yi is the sediment pond inflow sediment load in tons and n is the number of sub-watersheds. Worksheet 3 in Appendix A can be used with equations (13) and (14) to compute the sub-watershed and watershed sediment loads.

Design Step 4 - Principal Spillway Design (worksheets 4 and 5)

The principal spillway should be sized and placed at an elevation which will meet the settleable solids effluent limitation of 0.5 ml/l while keeping the routed 10-year, 24 hour storm maximum water surface elevation as low as possible.

In addition to the input parameters calculated with equations (1)-(14), sediment pond stage-area and stage-volume curves are required for design of the principal spillway. The principal spillway design process can be divided into the following general steps:

(1) Determine the amount of sediment storage required and incremental stage needed for the sediment pool,

(2) Select a spillway type and size and locate the crest or invert of the spillway at some point above the sediment pool elevation (the final crest or invert elevation must be located at an elevation above the sediment pool which is at least 40% of the elevation difference between the sediment pool and the maximum 10-year storm water surface),

(3) Determine the routed 10-year, 24 hour storm peak discharge and corresponding water surface elevation (check to see that the above 40% depth criterion is satisfied and raise the spillway if the crest or invert elevation is less than 40% of the maximum stage),

(4) Calculate the settleable solids concentration for the selected spillway size and location, and

(5) Repeat steps (2)-(4) if the settleable solids concentration is greater than 0.5 ml/l or is sufficiently below 0.5 ml/l to indicate that a more cost-effective pond can be designed.

The following material will provide a more detailed discussion of the above general steps.

Sediment storage volume

An appropriate sediment storage volume should be provided consistent with the sediment load expected over the life of the mining operation and a reasonable pond cleanout schedule. The Universal Soil Loss Equation may be used to predict average annual sediment production and to determine an approximate pond cleanout schedule. As an alternative to using the Universal Soil Loss Equation, engineers may determine the sediment pond cleanout elevation by sizing the sediment storage volume to contain 0.075 acre-foot per acre of disturbed area. At a minimum, the sediment pond cleanout elevation should be located at an elevation which will store 1.5 times the 10-year, 24 hour storm sediment volume. The 10-year, 24 hour storm sediment load in tons can be calculated with the Modified Universal Soil Loss Equation as discussed in the previous section.

Assuming a specific gravity of 1.25 for deposited sediment, the sediment storage volume can be calculated from

$$V_s = 8.83 \times 10^{-4} Y_i \qquad (15)$$

where V_s is the minimum sediment storage volume in acre-feet (1.5 times the 10-year, 24-hour storm sediment load) and Y_i is the inflow sediment load in tons for the 10-year, 24 hour storm. R1

The design engineer should be aware that a relatively small sediment storage volume may commit the mining operation to a frequent pond cleanout schedule.

Selection of a principal spillway type and size

These design procedures are applicable to conduit and riser and trickle tube principal spillways. The conduit and riser design incorporates a 3 inch diameter dewatering orifice in the riser pipe at a stage of one-half the distance between the sediment pool and the crest of the riser. Due to the dewatering orifice, conduit and riser principal spillways will generally produce smaller ponds than trickle tube principal spillways.

To prevent bottom scour and to satisfy the assumption of uniform withdrawal under which the settleable solids prediction equation was developed, the crest or invert of the principal spillway must be located at an elevation above the sediment pool which is at least 40% of the elevation difference between the sediment pool and the maximum 10-year storm water surface. This minimum stage requirement for the principal spillway can be expressed by the following relationship:

$$P_f = \frac{\Delta E_{sp}}{\Delta E_{sp} + \Delta E_{pm}} \geq 0.40 \qquad (16)$$

where P_f is the principal spillway fractional depth, ΔE_{sp} is the incremental elevation between the sediment pool and the principal spillway crest, and ΔE_{pm} is the incremental elevation between the

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principal spillway crest or invert and the maximum water surface elevation. Since the maximum water surface elevation is initially unknown, the initial principal spillway elevation must be estimated.

Since the sediment pond design process is a trial and error procedure, the user must make an initial selection of a principal spillway configuration and then check to see that the selection was adequate. If the initial spillway size is too large, the pond will not provide sufficient detention time to meet the settleable solids limitation. If the spillway is too small, the pond may produce a settleable solids concentration significantly below 0.5 ml/1, and the resulting water surface elevation will likely be excessive.

Calculation of a Routed 10-year, 24 hour peak discharge

The peak outflow from the sediment pond for the 10-year, 24 hour storm for conduit and riser or trickle tube principal spillways can be determined by using the routing functions contained in Figure 8 or Figure 9 in combination with the stage discharge curves contained in Figures 10 and 11. The routing functions contained in Figures 8 and 9 were based on procedures developed by the U.S. Soil Conservation Service and provide a relationship between the dimensionless ratios of peak outflow from the sediment pond to peak inflow, and the sediment pond maximum storage volume to inflow volume. To reduce the time required for performing the iterative calculations for determining peak outflow, two volume relationships were used (after Soil Conservation Service, 1975):

$$V_{rv} = \frac{\Delta V_{pm}}{Q_{vi} - \Delta V_{op}} \tag{17}$$

and

$$V_{rs} = \frac{A_p \, \Delta E_{pm}}{Q_{vi} - \Delta V_{op}} \tag{18}$$

where V_{rv} is a dimensionless volume ratio based on the incremental sediment pond volume between the principal spillway and maximum water surface elevation, V_{rs} is a dimensionless volume ratio based on the sediment pond area at the principal spillway and the incremental stage between the principal spillway and the maximum water surface elevation, ΔV_{pm} is the incremental volume between the principal spillway elevation and the maximum water surface in acre-feet, A_p is the sediment pond area at the principal spillway in acres, ΔE_{pm} is the incremental elevation between the principal spillway elevation and the maximum water surface in feet, Q_{vi} is the sediment pond inflow volume in acre-feet, and ΔV_{op} is the incremental volume between the riser dewatering orifice elevation and the principal spillway crest in acre-feet. Since the trickle tube design procedures contained in this guideline do not incorporate a dewatering orifice, ΔV_{op} is equal to zero (0) for trickle tube principal spillways.

As explained in more detail in the following paragraphs, the use of equation 18 allows an approximate routing to be performed without using the sediment pond stage-storage curve to determine the water-surface elevation. As a final check, the routing can be performed using equation 17 which requires that stage values be obtained from the stage-storage curve.

The peak outflow to peak inflow ratio used in Figures 8 and 9 is represented by (Soil Conservation Service, 1975):

$$Q_r = \frac{Q_{po}}{Q_{pi}} \tag{19}$$

where Q_r is a dimensionless discharge ratio, Q_{po} is the peak sediment pond outflow in cubic feet per second, and Q_{pi} is the peak sediment pond inflow in cubic feet per second.

The routing functions contained in Figures 8 and 9 are applicable to full pipe flow only. Consequently, the head above the riser or above the trickle tube invert must be greater than certain minimum values to insure that weir flow does not occur for risers and partial pipe flow does not occur for trickle tubes. The minimum allowable heads are contained in Table 4.

TABLE 4

Minimum Allowable Heads for Full Pipe Flow

Conduit and Riser		Trickle Tube		
Diameter(1) (in)	$H_r^{(2)}$ (ft)	Diameter (in)	$H_t^{(3)}$ (ft)	
12 C - 18 R	0.6	12	1.5	R1
15 C - 24 R	0.7	15	2.0	
18 C - 30 R	0.8	18	2.5	
24 C - 36 R	1.1	24	3.0	
30 C - 42 R	1.6	30	4.0	R1

(1) 12 C - 18 R - 12" conduit and 18" riser
(2) H_r - Head above the riser crest, (ft.)
(3) H_t - Head above the trickle tube invert, (ft.)

The conduit and riser stage-discharge curves contained in Figure 10 were developed using the default energy loss coefficients contained in TRM #6 (Department for Surface Mining Reclamation and Enforcement, 1982) and a conduit length of 140 feet. Discharge correction factors for lengths other than 140 feet can be obtained from Figure 12. The stage-discharge curves are applicable to standard corrugated metal pipe risers and conduits. The head used in Figure 10 is total head and is computed as

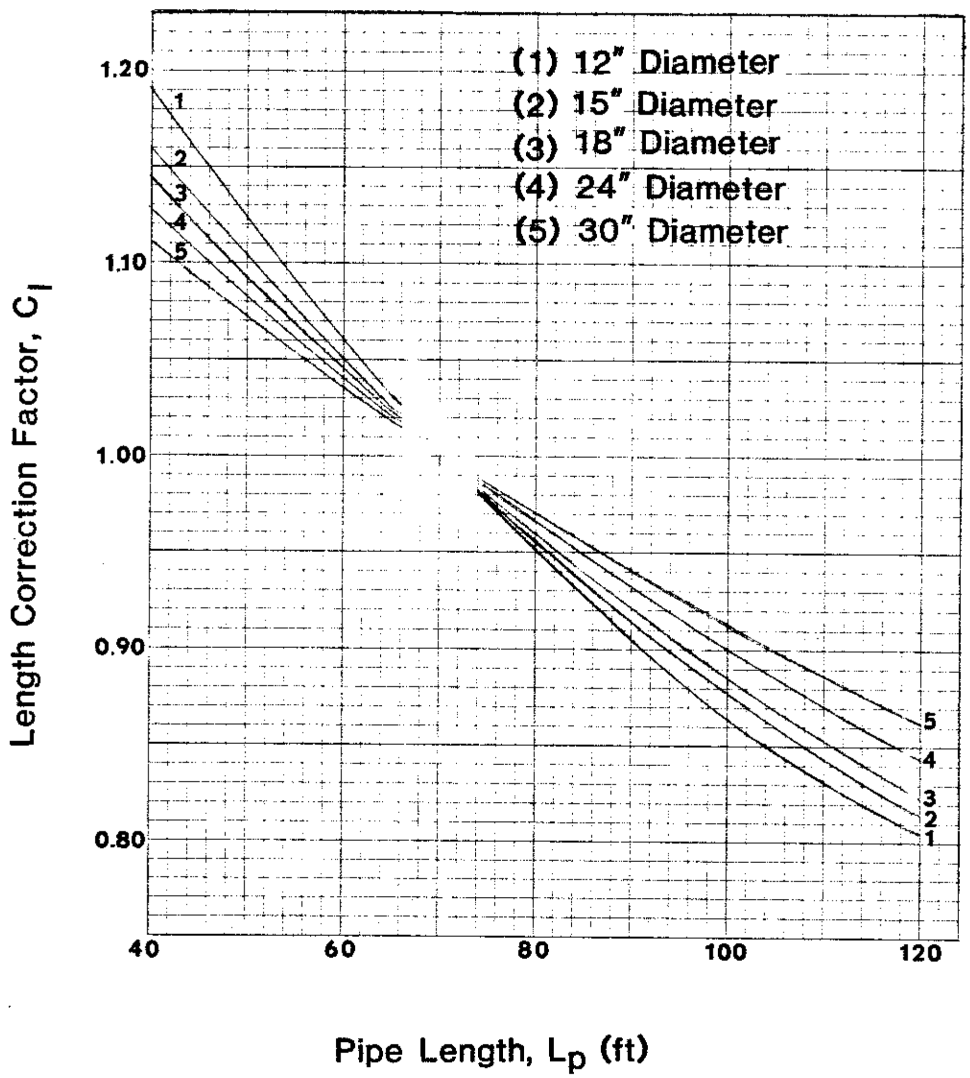

Figure 13 Pipe length discharge correction factors for trickle tube principal spillways.

Calculation of settleable solids concentration

The maximum settleable solids concentration for conduit and riser principal spillways is given by:

$$C_{se} = \frac{6.871 \times 10^{-5}}{1250} D^{2.694} \frac{Q_{vi}^{2.000}}{\Delta V_{sp}^{1.189}} \left(\frac{Q_{po}}{Q_{pi}}\right)^{2.399} C_{su}^{0.9396} \quad (21)$$ R1

and for trickle tube principal spillways by:

$$C_{se} = \frac{1.738 \times 10^{-4}}{1250} D^{1.222} \frac{Q_{vi}^{2.796}}{\Delta V_{sp}^{1.541}} \left(\frac{Q_{po}}{Q_{pi}}\right)^{2.076} C_{su}^{0.9587} \quad (22)$$

where C_{se} is the settleable solids concentration in ml/l, D is the pond depth in feet measured from the sediment pool elevation to the maximum water surface elevation, Q_{vi} is the watershed runoff volume in acre-feet, ΔV_{sp} is the pond storage volume in acre-feet at the principal spillway crest or invert (incremental volume between the sediment pool and principal spillway), Q_{po} is the peak outflow in cubic feet per second, Q_{pi} is the peak watershed inflow in cubic feet per second, and C_{su} is the average inflow suspended solids concentration in mg/l.

The average inflow suspended solids concentration is given by:

$$C_{su} = 735 \frac{Y_i}{Q_{vi} + 2.94 \times 10^{-4} Y_i} \quad (23)$$

where Y_i is the pond inflow sediment mass in tons and Q_{vi} is the inflow runoff volume in acre-feet. All other terms in equations 21 and 22 are given by previous equations and figures or can be obtained from the stage-area or stage-storage relationships for the sediment pond.

Equations 21 and 22 were developed by a regression analysis of data generated for watershed drainage areas which ranged from 23 acres to 101 acres, average inflow suspended solids concentrations which ranged from 2,800 mg/l to 574,000 mg/l, and effluent settleable solids which ranged from approximately 0.019 ml/l to 2.8 ml/l. The R^2 values for equations 21 and 22 were 0.65 and 0.62, respectively. The standard errors ranged from 0.30 ml/l to 0.82 ml/l for equation 21 and 0.27 ml/l to 0.91 ml/l for equation 22 (the standard error ranges are based on a settleable solids concentration of 0.5 ml/l).

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Inspection of column 16 of worksheet 2 revealed that the largest sub-watershed peak discharges occurred at $T_c + T_t$ values of 0.10 and 0.15 hours. Consequently, it was only necessary to calculate hydrograph ordinates for $T_c + T_t$ values of 0.10 and 0.15 hours.

Peak discharge to hydrograph conversion factors, F_h, were obtained from Figures 5 and 6 for the corresponding sub-watershed adjusted unit discharge, q_t, (column 15) and at time increments of 0.05 hour on either side of the peak discharge and entered in column 13 of worksheet 2. For example, the peak discharge for sub-watershed 1 occurred at a $T_c + T_t$ time of 0.15 hours and a hydrograph ordinate value was needed at .05 hours before the peak ($T_c + T_t = 0.10$ hr.). A value of F_h was obtained from Figure 5 at - .05 hours (rising limb of hydrograph or time prior to the peak discharge) and placed in the corresponding section of column 13, worksheet 2. The conversion factor, F_h, (0.93) was then multiplied with the peak discharge for sub-watershed 1 (10.4 cfs) and the result entered under a $T_c + T_t$ time of 0.10 hour (-0.05 hr. prior to the peak) in column 16. Other hydrograph ordinates in column 16 were determined in a similar manner.

After all hydrograph ordinates were calculated, the peak discharge for the watershed (inflow to the sediment pond) was determined by summing the hydrograph ordinates for $T_c + T_t$ equal to 0.10 and 0.15 hours and selecting the maximum discharge (eq. 6).

Determination of Sediment Load

Worksheet 3 (Table B-5) was used with equation 8 to calculate the sediment load for each sub-watershed. The sub-watershed sediment loads were summed to generate the pond inflow sediment load.

Area weighted erosion slope lengths, L_e, were determined for each sub-watershed by visually dividing the sub-watershed into approximately equal areas and averaging the slope lengths for all areas in the sub-watershed. The LS factors were obtained from Figure 7 and entered in column 5 of worksheet 3 (Table B-5). Soil erodibility, K, and control practice, CP, factors were obtained from Table 3 and entered in columns 6 and 7, respectively. Sediment loads were determined with equation 8 and entered in column 8 of worksheet 3.

Principal Spillway Design

The required sediment pool storage volume was determined first and then worksheets 4 and 5 were used to design the principal spillway.

Sediment storage volume

As previously noted, the Example 1 operation has a disturbed area of 18.8 acres. Providing a sediment pool volume of 0.075 acre-feet per acre disturbed yields a sediment pool storage volume of 1.41 acre-feet. However, using equation 15 to determine the minimum sediment storage volume (1.5 times the 10-year, 24-hour storm sediment load of 1990 tons) produces a sediment pool of 1.76 acre-feet. The sediment pool elevation corresponding to a volume of 1.76 acre-feet is 13.0 feet (Figure B-2). R1

Selection of a principal spillway size and type

Worksheet 5 (Table B-7) was used to begin the principal spillway design process. An initial principal spillway elevation of 14.5 feet was assumed for a 18"-30" conduit-riser spillway (1.5 feet above the sediment pool) and basic information concerning the pond was entered at the top of worksheet 5 and in columns 1-9. Equation 24 was used to calculate the discharge ratio, Q_r, needed to meet the settleable solids effluent limitation of 0.5 ml/l. The discharge ratio of .215 (column 10) was used with Figure 8 to produce a volume ratio, V_{rs}, of 0.273 (column 11) and an H_r of 2.50 feet (column 12). The H_r value in column 12 is the estimated head needed to meet the effluent limitation as determined from equation 24. An H_r of 2.50 yields a fractional depth, P_f, of 0.38. Since the fractional depth for the estimated head was only slightly less than the minimum allowable of 0.40, the calculations were continued to determine a final head and settleable solids concentration. The initial H_r was entered in column 2 of worksheet 4 (Figure B-6) to perform the routing using the V_{rs} routing function. Two iterations produced a ΔE_{pm} (H_r) of 1.67 feet and a P_f of 0.47. The final routing using the V_{rv} routing function also produced an H_r of 1.67 feet (column 9-14) and a peak discharge of 16.9 cfs. The settleable solids concentration was 0.46 ml/l (column 23 of worksheet 5) and the maximum water surface elevation (pond height) was 16.2 feet (column 17 of worksheet 4). R1

Emergency spillway design

R1

Procedures summarized in worksheet 6 were used to design the emergency spillway to control the total sediment pond outflow for the 25-year, 24-hour storm such that the pre-mining 25-year, 24-hour peak discharge was not exceeded. The pre-mining 25-year peak discharge (37.8 cfs) was calculated for a forested condition with equation 1 and worksheets 1 and 2 (Tables B-8 and B-9). The resulting discharge was entered in column 11 of worksheet 6 (Table B-10). The during mining 25-year, 24-hour storm peak discharge was calculated using worksheet 2 (Table B-9). The same time of concentration and travel time values initially used with the 10-year storm were used with the 25-year storm. The maximum routed 25-year discharge, (T_c and T_t used in calculations) was 66.7 cfs (column 16, worksheet 2, Table B-9) while the peak discharge calculated without considering the effects of travel time and time of concentration (equations 3-5) was 68.3 cfs, only 2 percent higher (column 9, worksheet 2, Table B-9). The 25-year, 24-hour during mining runoff and peak discharge were used to calculate ΔQ_{vi} and ΔQ_{pi} (top of worksheet 6, Table B-10). Following the calculation procedures summarized in worksheet 6, an initial head above the emergency spillway crest of 0.80 feet produced a peak outflow (principal plus emergency) of 29.6 cfs for an emergency spillway with a bottom width of 5.4 feet and 2:1 side slopes. Since the maximum outflow was well below the pre-mining discharge of 37.8 cfs, a lower water surface elevation, H_e, of 0.60 feet was assumed. A lower water surface means that less water is stored and a higher discharge will result due to a wider spillway bottom width. The resulting discharge was 33.2 cfs, still well below the pre-mining peak discharge of 37.8 cfs, and the spillway bottom width was 11.8 feet. R1

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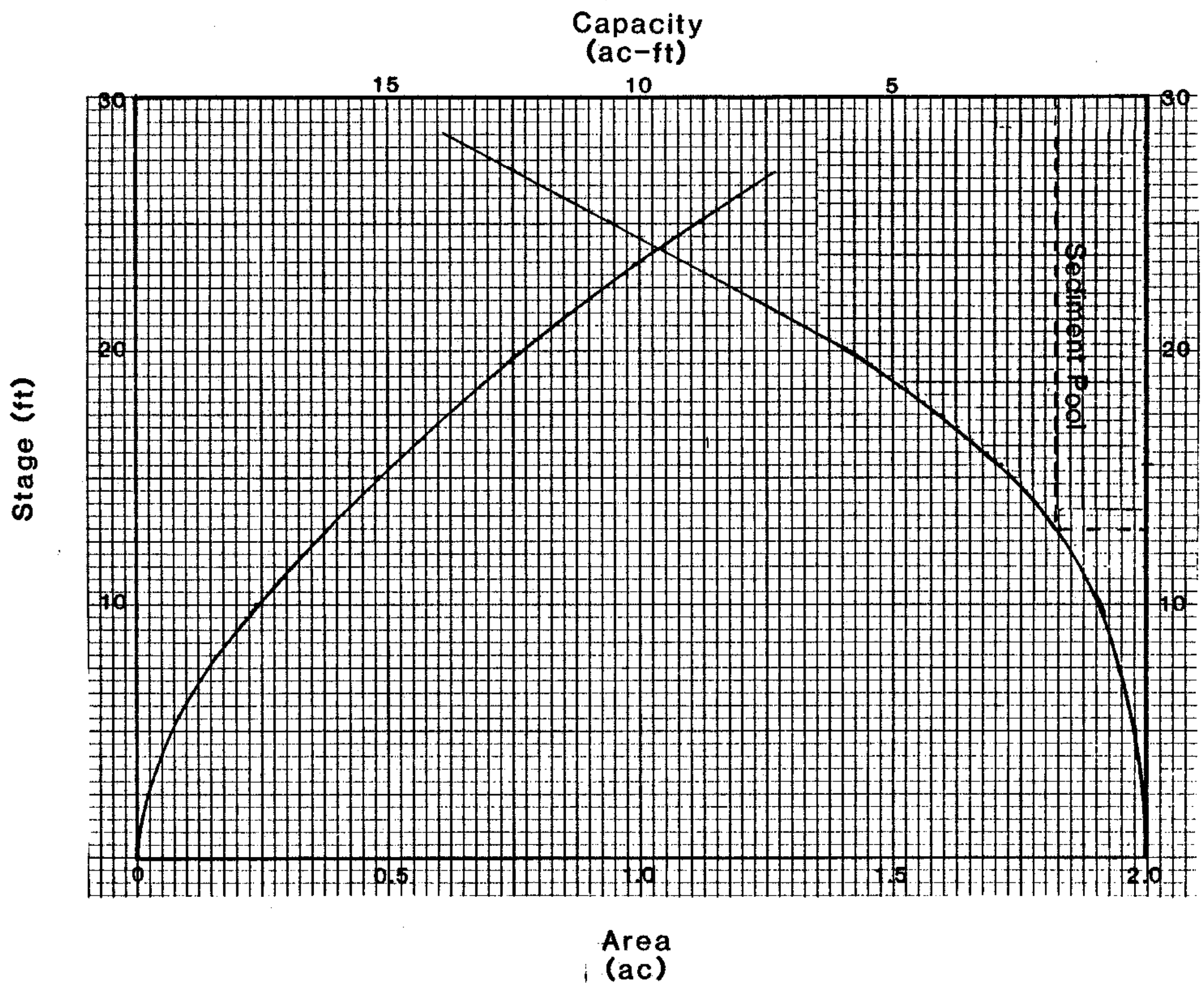

R1

Figure B-2 Sediment pond area-capacity curves.

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TABLE B-5

WORKSHEET 3

Design Step 3 -Determination of Sediment Load

Watershed	(1) Q_v (ac-ft)	(2) Q_p (cfs)	(3) L_e (ft)	(4) S_o (%)	(5) LS	(6) K	(7) CP	(8) Y (tons)
1	1.029	10.8	250	19	6.00	0.22	0.14	67.6
2	1.885	23.7	200	31	11.60	0.22	0.90	1831.8
3	0.238	3.0	120	1	0.14	0.22	0.90	2.1
4	0.152	1.9	60	36	8.19	0.22	0.90	76.8
5	0.158	1.7	110	1	0.13	0.22	0.14	0.2
6	0.127	1.3	60	36	8.19	0.22	0.14	8.7
7	1.538	10.7	180	15	3.43	0.17	0.003	0.8
							ΣY	1988.0

(1) From column 8 worksheet 2
(2) From column 9 worksheet 2.
(5) From Figure 7.
(6) From Table 3.
(7) From Table 3.
(8) From equation 13.

TABLE B-6

WORKSHEET 4

Determination of Routed Peak Discharge for the 10-Year, 24 Hour Storm
Q_{pi} 49.4 (cfs) C_1 1.00

Initial Routing Using V_{rs}							
(1) Principal size (in)	(2) H_r/H_t (ft)	(3) Q_{po} (cfs)	(4) Q_r	(5) V_{rs}	(6) $\frac{Q_{vi}-\Delta V_{op}}{A_p}$ (ft)	(7) ΔE_{pm} (ft)	
18-30	2.50	17.3	0.350	0.154	10.5	1.62	R1
	1.62	16.9	0.342	0.159	10.5	1.67	R1

(1) Selected principal size.
(2) Initial estimated value of H_r/H_t from worksheet 5 column 12.
(3) From Figure 10 or 11 multiplied by the length correction factor from Figure 12 or 13.
(4) (3)/Q_{pi}.
(5) From Figure 8 or 9.
(6) Worksheet 5 (8)/(6).
(7) (5) x (6).

TABLE B-6 (continued)

WORKSHEET 4 (CONTINUED)

Determination of Routed Peak Discharge for the 10-Year, 24 Hour Storm

Final Routing Using V_{rv}											
(8) Principal size (in)	(9) H_r/H_t (ft)	(10) Q_{po} (cfs)	(11) Q_r	(12) V_{rv}	(13) $Q_{vi}-\Delta V_{op}$ (ac-ft)	(14) ΔV_{pm} (ac-ft)	(15) V_p (ac-ft)	(16) V_m (ac-ft)	(17) E_m (ft)	(18) E_p (ft)	(19) H_r/H_t (ft)
13-30	1.67	16.9	0.342	0.200	4.33	0.968	2.45	3.42	16.17	14.5	1.67 R1

(8) Selected principal size.
(9) From (7) for first trial or (19) for subsequent trials.
(10) From Figure 10 or 11 multiplied by the length correction factor from Figure 12 or 13.
(11) (10)/Q_{pi}.
(12) From Figure 8 or 9.
(13) From column 8 worksheet 5.
(14) (12) X (13)
(15) From column 5 worksheet 5.
(16) (14) + (15).
(17) From sediment pond stage-volume relationship for V_m.
(18) Selected principal spillway elevation from worksheet 5 column 4.
(19) (17) - (18).

TABLE B-7

WORKSHEET 5

Calculation of Settleable Solids

E_s 13.0 (ft) V_s 1.755 (ac-ft) Q_{vi} 5.13 (ac-ft) C_{su} 256,000 (mg/l)

(1) Principal size (in)	(2) E_o (ft)	(3) V_o (cfs)	(4) E_p (ft)	(5) V_p (ac-ft)	(6) A_p (ac)	(7) ΔV_{op} (ac-ft)	(8) $Q_{vi}-\Delta V_{op}$ (ac-ft)	(9) ΔV_{sp} (ac-ft)	(10) Q_r	(11) V_{rs}	(12) H_r/H_t (ft)	
18-30	13.3	2.15	14.5	2.45	0.46	0.30	4.83	0.695	0.215	0.238	2.50	R1

(1) Selected principal size.
(2) Elevation at the dewatering orifice. $E_o = E_s + (E_p-E_s)/2$.
(3) From sediment pond stage-volume relationship.
(4) Selected principal spillway elevation.
(5) From sediment pond stage-volume relationship.
(6) From sediment pond stage-area relationship.
(7) (5) - (3).
(8) Q_{vi} - (7).
(9) (5) - V_s.
(10) From equation 24 or 25.
(11) From Figure 8 or 9.
(12) (11) X (8)/(6).

TABLE B-7 (continued)

WORKSHEET 5 (CONTINUED)

Calculation of Settleable Solids

(13) Principal size (in)	(14) H_r/H_t (ft)	(15) H_r/H_t (ft)	(16) P_f (ft)	(17) D (ft)	(18) Q_{vi} (ac-ft)	(19) ΔV_{sp} (ac-ft)	(20) Q_{po} (cfs)	(21) Q_{pi} (cfs)	(22) C_{su} (mg/l)	(23) C_{se} (ml/l)
13-30	1.67	1.67	0.47	3.17	5.13	0.695	169	49.4	256,000	0.46

R1

(13) Selected principal size.
(14) From column 7 worksheet 4.
(15) From column 19 worksheet 4.
(16) From equation 16.
(17) (4) + (15) - E_s.
(18) From equation 12.
(19) From column 9.
(20) From column 10 worksheet 4.
(21) From equation 9 or 10.
(22) From equation 23.
(23) From equation 21 or 22.

TABLE B-8

WORKSHEET 1

Design Step 2 - Calculation of Time of Concentration and Travel Time

(1) Watershed and Segment	(2) Surface Condition	(3) Hydraulic Length (ft)	(4) Average Slope (%)	(5) Velocity (ft/sec)	(6) Segment T_c or T_t (hr)	(7) Watershed T_c (hr)	(8) Watershed T_t (hr)	(9) $T_c + T_t$ (hr)
	25-YEAR, 24-HOUR PRE-MINING							
1-a	(1) FORREST	400	15	1.0	0.111			
1-b	(7) CHANNEL	500	8	5.7	0.024	0.135	0.	0.135

TABLE B-10

WORKSHEET 6

Determination of Emergency Spillway Routed Peak Discharge for the 25-Year, 24-Hour Storm

ΔQ_{vi} = Q_{vi} (25-yr) 6.68 ac-ft - Q_{vi} (10-yr) 5.13 ac-ft = 1.55 ac-ft.

ΔQ_{pi} = Q_{pi} (25-yr) 68.3 cfs - Q_{pi} (10-yr) 49.4 cfs = 18.9 cfs.

(1) E_e (ft)	(2) V_e (ac-ft)	(3) H_e (ft)	(4) V_{me} (ac-ft)	(5) ΔV_{em} (ac-ft)	(6) $\frac{\Delta V_{em}}{\Delta Q_{vi}}$	(7) $\frac{Q_{eo}}{\Delta Q_{pi}}$	
16.2	3.42	0.80	3.89	0.47	0.303	0.65	R1
16.2	3.42	0.60	3.78	0.36	0.231	0.85	

(8) Q_{eo} (cfs)	(9) Q_{po} (cfs)	(10) Q_{pe} (cfs)	(11) Q_{pm} (cfs)	(12) Side slope (H:V)	(13) Q_{tr} (cfs)	(14) Q_b (cfs/ft)	(15) BW (ft)
12.3	17.3	29.6	37.8	2:1	2.1	1.90	5.4
16.1	17.1	33.2	37.8	2:1	1.3	1.25	11.8

Emergency Spillway Crest 16.2 ft. Peak Stage 16.8 ft.

Bottom Width 12 ft. Side slopes 2:1 (H:V).

Pre-mining Discharge 37.8 cfs. Pond Routed Discharge 33.2 cfs. R1

(1) From column 17 worksheet 4.
(2) From sediment pond stage-volume relationship for E_e.
(3) Assumed emergency spillway head.
(4) From sediment pond stage-volume. relationship for E_{me}. ($E_{me} = E_e + H_e$).
(5) (4) - (2).
(6) (5)/ΔQ_{vi}.
(7) From Figure 14.
(8) (7) x ΔQ_{pi}.
(9) From Figure 10 or 11.
(10) (8) + (9).
(11) Pre-mining peak discharge.
(12) Selected side slope.
(13) From Figure 15.
(14) From Figure 16.
(15) ((C8) - (C13))/C14).

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Example 2 - Mountaintop Removal Operation

A mountaintop removal operation is proposed for the watershed presented in Figure B-3. The operation will disturb 14 acres and the remaining portion of the watershed (49 acres) will be left in the original forested condition. The sediment pond is located at a drainage area of 63 acres.

The following material provides an abbreviated discussion of the design process and does not include a detailed description on use of the worksheets. Those desiring a more detailed description on use of the worksheets are referred to Example 1.

Selection of Sub-watersheds

The 63 acre watershed was divided into three sub-watersheds (Figure B-3) for the purpose of calculating peak discharge, runoff volume, and sediment load. A summary of sub-watershed information representative of a "worst-case" condition is presented in Table B-11. Parameter values from TRM #6 were used for all sub-watersheds.

TABLE B-11

Summary of Sub-watershed Surface Conditions for Example 2

Watershed	Surface Condition	Area (ac)	CN	K	CP
1	Reclaimed; 0-2 months vegetation	10	79	0.22	0.14
2	Backfilled and graded; bare	4	86	0.22	0.90
3	Undisturbed forest	49	73	0.17	0.003

Determination of Peak Discharge and Runoff Volume

Time of concentration and travel time values were calculated for each of the sub-watersheds using worksheet 1 (Table B-12 and B-13). Review of the combined time of concentration and travel time values in column 9 of worksheet 1 (Table B-12) shows that the maximum combined T_c and T_t is 0.120 hours. Since the maximum T_c + T_t is less than 0.150 hours, the peak discharge can be calculated directly using equations (3) through (5), thus eliminating the need to adjust the peak discharge for time of concentration and travel time. The runoff volume and peak discharge for each sub-watershed is given in columns 8 and 9 of worksheet 2, respectively (Table B-14). The total runoff volume and peak discharge for the sediment pond are 9.07 acre-feet and 75 cfs, respectively.

```
91 6
92 -
93 X<0?
94 XEQ "ER4"
95 .726
96 Y↑X
97 RCL IND 30
98 *
99 ISG 30
100 RCL IND 30
101 +
102 RCL 08
103 *
104 STO 17
105 RTN
106♦LBL "TTSQ"
107 XEQ "R"
108 XEQ "DIA"
109 40
110 *
111 47
112 +
113 ST+ 30
114 RCL 20
115 RCL IND 30
116 -
117 X<0?
118 XEQ "ER5"
119 ISG 30
120 RCL IND 30
121 Y↑X
122 ISG 30
123 RCL IND 30
124 *
125 ISG 30
126 RCL IND 30
127 +
128 RCL 08
129 *
130 STO 17
131 RTN
132♦LBL "CRRF1"
133 XEQ "R"
134 71
135 ST+ 30
136 XEQ "RTFN"
137 RTN
138♦LBL "TTRF1"
139 XEQ "R"
140 75
141 ST+ 30
142 XEQ "RTFN"
143 RTN
144♦LBL "RTFN"
145 RCL 18
146 RCL IND 30
147 -
148 X<0?
149 XEQ "ER1"
150 ISG 30
151 RCL IND 30
152 Y↑X
153 ISG 30
154 RCL IND 30
155 *
156 ISG 30
157 RCL IND 30
158 X<>Y
159 -
160 STO 19
161 RTN
162♦LBL "PFRACT"
163 RCL 11
164 RCL 09
165 -
166 STO 25
167 RCL 20
168 +
169 RCL 25
170 X<>Y
171 /
172 STO 25
173 STOP
174 RTN
175♦LBL "DIA"
176 RCL 00
177 FRC
178 RTN
179 END

01♦LBL "ROUTE2"
02 RCL 24
03 X=0?
04 XEQ "CRSQ"
05 RCL 24
06 X>0?
07 XEQ "TTSQ"
08 RCL 17
09 RCL 03
10 /
11 STO 18
12 RCL 24
13 X=0?
14 XEQ "CRRF2"
15 RCL 24
16 X>0?
17 XEQ "TTRF2"
18 RCL 19
19 RCL 02
20 *
21 STO 21
22 RCL 14
23 RCL 12
24 -
25 STO 22
26 X>Y?
27 XEQ "ER2"
28 RDN
29 RCL 16
30 RCL 12
31 -
32 STO 23
33 X<Y?
34 XEQ "ER3"
35 RCL 21
36 RCL 22
37 -
38 RCL 23
39 RCL 22
40 -
41 /
42 RCL 15
43 RCL 13
44 -
45 *
46 RCL 13
47 +
48 RCL 11
49 -
50 STO 20
51 STOP
52 XEQ "PFRACT"
53 GTO "ROUTE2"
54 END

01♦LBL "CRRF2"
02 .3
03 RCL 18
04 X<=Y?
05 XEQ "CRR12"
06 .3
07 RCL 18
08 X>Y?
09 XEQ "CRR22"
10 RTN
```

```
11♦LBL "TTRF2"
12 .4                R1
13 RCL 18
14 X<=Y?
15 XEQ "TTR12"
16 .4                R1
17 RCL 18
18 X>Y?
19 XEQ "TTR22"
20 RTN
21♦LBL "CRR12"
22 XEQ "R"
23 79
24 ST+ 30
25 XEQ "RTFN"
26 RTN
27♦LBL "CRR22"
28 XEQ "R"
29 83
30 ST+ 30
31 XEQ "RTFN"
32 RTN
33♦LBL "TTR12"
34 XEQ "R"
35 87
36 ST+ 30
37 XEQ "RTFN"
38 RTN
39♦LBL "TTR22"
40 XEQ "R"
41 91
42 ST+ 30
43 XEQ "RTFN"
44 RTN
45 END

01♦LBL "CSE2"
02 RCL 24
03 X=0?
04 XEQ "CRSS"
05 RCL 24
06 X>0?
07 XEQ "TTSS"
08 END

01♦LBL "CRSS"
02 XEQ "R"
03 95
04 ST+ 30
05 XEQ "SLSOLID"
06 RTN
07♦LBL "TTSS"
08 XEQ "R"
09 101
10 ST+ 30
11 XEQ "SLSOLID"
12 RTN
13♦LBL "SLSOLID"
14 RCL 11
15 RCL 09
16 -
17 RCL 20
18 +
19 RCL IND 30
20 Y↑X
21 RCL 01
22 ISG 30
23 RCL IND 30
24 Y↑X
25 *
26 RCL 12
27 RCL 10
28 -
29 ISG 30
30 RCL IND 30
31 Y↑X
32 /
33 RCL 18
34 ISG 30
35 RCL IND 30
36 Y↑X
37 *
38 RCL 04
39 ISG 30
40 RCL IND 30
41 Y↑X
42 *
43 ISG 30
44 RCL IND 30
45 *
46 1250
47 /
48 STOP
49 RTN
50 END

01♦LBL "ER1"
02 110
03 STO 29
04 VIEW IND 29
05 STOP
06 0
07 RTN
08♦LBL "ER2"
09 111
10 STO 29
11 VIEW IND 29
12 STOP
13 RTN
14♦LBL "ER3"
15 112
16 STO 29
17 VIEW IND 29
18 STOP
19 RTN
20♦LBL "ER4"
21 113
22 STO 29
23 VIEW IND 29
24 STOP
25 0
26 RTN
27♦LBL "ER5"
28 114
29 STO 29
30 VIEW IND 29
31 0
32 STOP
33 RTN
34♦LBL "ER6"
35 115
36 STO 29
37 VIEW IND 29
38 STOP
39 RTN
40 END

01♦LBL "LDRG"
02 .99901
03 ST+ 30
04♦LBL 01
05 STOP
06 STO IND 30
07 ISG 30
08 GTO 01
09 END

01♦LBL "VWRG"
02 .99901
03 ST+ 30
04♦LBL 01
05 STOP
06 VIEW IND 30
07 ISG 30
08 GTO 01
09 END
```


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TABLE 4

Contents of Registers 00 - 30

Register Number	Contents	Number	Contents	
00	Spillway type and size (See Table 5)	16	V_2	
01	Q_{vi}	17	Q_{po}	
02	$Q_{vi} - \Delta V_{op}$	18	Q_r	
03	Q_{pi}	19	V_{rs}, V_{rv}	
04	C_{su}	20	ΔE_{pm}	
05	C_{se}	21	ΔV_{pm}	
06	A_p	22	ΔV_{p1}	
07	ΔH	23	ΔV_{p2}	
08	C_1	24	ST	
09	E_s	25	P_f	
10	V_s	26		
11	E_p	27		
12	V_p	28		
13	E_1	29	Indirect Address Register	
14	V_1	30	Indirect Address Register	R1
15	E_2			R1

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TABLE 5

Spillway Codes

Spillway Designation	Spillway Type	Spillway Size (in)
1.1	Conduit and Riser	12 C - 18 R*
1.2	Conduit and Riser	15 C - 24 R
1.3	Conduit and Riser	18 C - 30 R
1.4	Conduit and Riser	24 C - 36 R
1.5	Conduit and Riser	30 C - 42 R
2.1	Trickle Tube	12**
2.2	Trickle Tube	15
2.3	Trickle Tube	18
2.4	Trickle Tube	24
2.5	Trickle Tube	30

* 12"C - 18"R - 12" conduit and 18" riser
** 12" - 12" diameter trickle tube

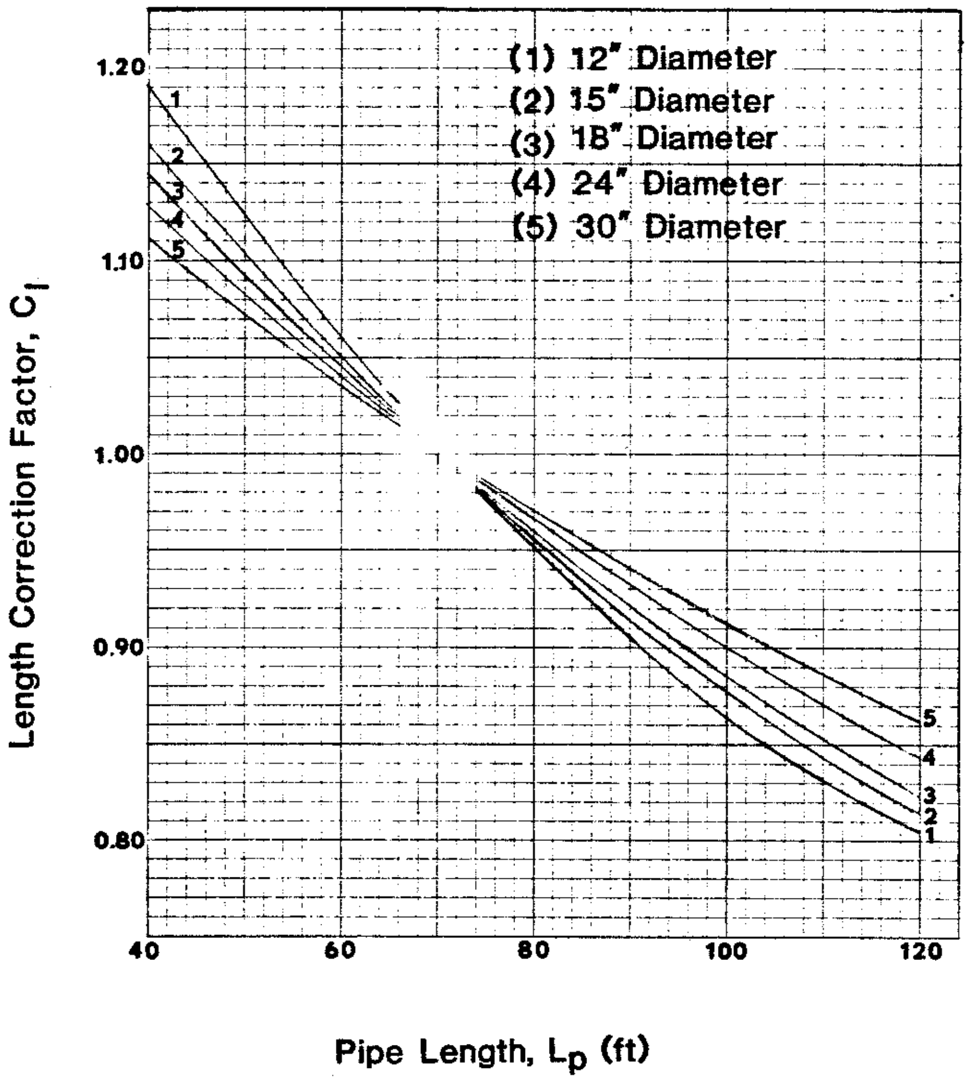

Figure 13 Pipe length discharge correction factors for trickle tube principal spillways.

Calculation of settleable solids concentration

The maximum settleable solids concentration for conduit and riser principal spillways is given by:

$$C_{se} = \frac{8.744 \times 10^{-4}}{1250} D^{1.529} \frac{Q_{vi}^{0.7746}}{\Delta V_{sp}^{0.4981}} \left(\frac{Q_{po}}{Q_{pi}}\right)^{1.555} C_{su}^{0.9132} \quad (21)$$

and for trickle tube principal spillways by:

$$C_{se} = \frac{2.048 \times 10^{-3}}{1250} D^{1.211} \frac{Q_{vi}^{1.315}}{\Delta V_{sp}^{0.6188}} \left(\frac{Q_{po}}{Q_{pi}}\right)^{1.368} C_{su}^{0.7706} \quad (22)$$

where C_{se} is the settleable solids concentration in ml/l, D is the pond depth in feet measured from the sediment pool elevation to the maximum water surface elevation, Q_{vi} is the watershed runoff volume in acre-feet, ΔV_{sp} is the pond storage volume in acre-feet at the principal spillway crest or invert (incremental volume between the sediment pool and principal spillway), Q_{po} is the peak outflow in cubic feet per second, Q_{pi} is the peak watershed inflow in cubic feet per second, and C_{su} is the average inflow suspended solids concentration in mg/l.

The average inflow suspended solids concentration is given by:

$$C_{su} = 735 \frac{Y_i}{Q_{vi} + 2.94 \times 10^{-4} Y_i} \quad (23)$$

where Y_i is the pond inflow sediment mass in tons and Q_{vi} is the inflow runoff volume in acre-feet. All other terms in equations 21 and 22 are given by previous equations and figures or can be obtained from the stage-area or stage-storage relationships for the sediment pond.

Equations 21 and 22 were developed by a regression analysis of data generated for watershed drainage areas which ranged from 23 acres to 101 acres, average inflow suspended solids concentrations which ranged from 2,800 mg/l to 574,000 mg/l, and effluent settleable solids which ranged from approximately 0.042 ml/l to 1.3 ml/l. The R^2 values for equations 21 and 22 were 0.86 and 0.74, respectively. The standard errors ranged from 0.36 ml/l to 0.69 ml/l for equation 21 and 0.36 ml/l to 0.69 ml/l for equation 22 (the standard error ranges are based on a settleable solids concentration of 0.5 ml/l).

Average settleable solids

To assist in obtaining an initial estimate of the permanent pool storage volume and discharge reduction required to meet a settleable solids concentration of 0.5 ml/l a second set of regression equations was developed by eliminating D from equations 20 and 21. The discharge ratio prediction equations are:

$$\frac{Q_{po}}{Q_{pi}} = \left(\frac{1250}{0.03808} \frac{C_{se}}{C_{su}}^{.7486} \frac{\Delta V_{sp}}{Q_{vi}}^{0.0840}_{0.7986} \right)^{1.216} \quad (24)$$

for conduit and risers and

$$\frac{Q_{po}}{Q_{pi}} = \left(\frac{1250}{0.1893} \frac{C_{se}}{C_{su}}^{0.5805} \frac{\Delta V_{sp}}{Q_{vi}}^{0.2171}_{1.055} \right)^{1.022} \quad (25)$$

for trickle tubes.

The above equations can be used in conjunction with equations 21 and 22 and the sediment pond routing procedures previously discussed to produce a sediment pond design. Worksheet 5 has been provided for calculating settleable solids.

(1) Determine the sediment pool elevation, E_s, sediment pool volume, V_s, sediment pond inflow volume, Q_{vi}, and inflow suspended solids, C_{su}, and record these parameters at the top of worksheet 5.

(2) Estimate an initial principal spillway elevation, E_p, needed to meet the settleable solids effluent limitation and obtain the corresponding volume, V_p, from the sediment pond stage-volume curve. Record E_p and V_p in columns 4 and 5 of worksheet 5.

(3) For a conduit and riser principal spillway, calculate the elevation of the dewatering orifice E_o [$E_o = E_s + (E_p - E_s)/2$] and obtain the corresponding volume, V_o. Record E_o and V_o in columns 2 and 3.

(4) Obtain the sediment pond surface area, A_p, at the principal spillway from the stage-area relationship and record A_p in column 6.

(5) Calculate ΔV_{op} ($\Delta V_{op} = V_p - V_o$) and record ΔV_{op} in column 7. ΔV_{op} is zero for trickle tube principal spillways.

(6) Calculate $Q_{vi} - \Delta V_{op}$ and record the value in column 8 (for conduit and riser principal spillways only).

Average settleable solids

(7) Using the principal spillway incremental storage volume, ΔV_{sp}, ($\Delta V_{sp}=V_p-V_s$) calculate the required discharge reduction ratio, Q_r, with equation 24 or 25. Record ΔV_{sp} in column 9 and Q_r in column 10 of worksheet 5.

(8) Enter Figure 8 or 9 with the discharge reduction ratio determined in step 7 and obtain V_{rs}. Record V_{rs} in column 11.

(9) Multiply V_{rs} by $(Q_{vi}-\Delta V_{op})/A_p$ to determine ΔE_{pm} (ΔE_{pm} = H_r or H_t for conduit and riser or trickle tube principal spillways, respectively). Enter H_r or H_t in column 12.

(10) Use equation 15 to determine if the principal spillway fractional depth, P_f, is greater than 0.40.

(11) If P_f is less than 0.40, increase the principal spillway elevation and repeat steps 2-10.

(12) Select a principal spillway size and use H_r or H_t determined in step 9, to complete steps 1-5 of the sediment pond routing procedure discussed in the previous section. Record the routed H_r or H_t in column 14.

(13) If H_r or H_t determined in step 5 of the sediment pond routing procedure (column 14) is less than H_r or H_t determined in step 9 above (column 12), the principal spillway size may need to be reduced to meet the 0.5 ml/l effluent limitation.

(14) If H_r or H_t determined in step 5 of the sediment pond routing procedure is approximately equal to or greater than H_r or H_t determined in step 9 above, complete steps 7-15 of the sediment pond routing procedure. Record the final H_r or H_t in column 15 of worksheet 5.

(15) After the routing has been completed, use equation 15 to make a final check on the principal spillway fractional depth and enter the fractional depth in column 16.

(16) Calculate D ($D = E_p + \Delta E_{pm} - E_s$) and enter D in column 17.

(17) Record the indicated parameters in columns 18-22 and calculate the settleable solids concentration using equation 21 or 22. Record the settleable solids in column 23.

(18) If the settleable solids concentration does not meet the effluent limitation or is significantly below the effluent limitation, repeat steps 2-17 with an adjusted principal spillway elevation or spillway size.

APPENDIX B

EXAMPLES

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Inspection of column 16 of worksheet 2 revealed that the largest sub-watershed peak discharges occurred at $T_c + T_t$ values of 0.10 and 0.15 hours. Consequently, it was only necessary to calculate hydrograph ordinates for $T_c + T_t$ values of 0.10 and 0.15 hours.

Peak discharge to hydrograph conversion factors, F_h, were obtained from Figures 5 and 6 for the corresponding sub-watershed adjusted unit discharge, q_t, (column 15) and at time increments of 0.05 hour on either side of the peak discharge and entered in column 13 of worksheet 2. For example, the peak discharge for sub-watershed 1 occurred at a $T_c + T_t$ time of 0.15 hours and a hydrograph ordinate value was needed at .05 hours before the peak ($T_c + T_t$ = 0.10 hr.). A value of F_h was obtained from Figure 5 at - .05 hours (rising limb of hydrograph or time prior to the peak discharge) and placed in the corresponding section of column 13, worksheet 2. The conversion factor, F_h, (0.93) was then multiplied with the peak discharge for sub-watershed 1 (10.4 cfs) and the result entered under a $T_c + T_t$ time of 0.10 hour (-0.05 hr. prior to the peak) in column 16. Other hydrograph ordinates in column 16 were determined in a similar manner.

After all hydrograph ordinates were calculated, the peak discharge for the watershed (inflow to the sediment pond) was determined by summing the hydrograph ordinates for $T_c + T_t$ equal to 0.10 and 0.15 hours and selecting the maximum discharge (eq. 6).

Determination of Sediment Load

Worksheet 3 (Table B-5) was used with equation 8 to calculate the sediment load for each sub-watershed. The sub-watershed sediment loads were summed to generate the pond inflow sediment load.

Area weighted erosion slope lengths, L_e, were determined for each sub-watershed by visually dividing the sub-watershed into approximately equal areas and averaging the slope lengths for all areas in the sub-watershed. The LS factors were obtained from Figure 7 and entered in column 5 of worksheet 3 (Table B-5). Soil erodibility, K, and control practice, CP, factors were obtained from Table 3 and entered in columns 6 and 7, respectively. Sediment loads were determined with equation 8 and entered in column 8 of worksheet 3.

Principal Spillway Design

The required sediment pool storage volume was determined first and then worksheets 4 and 5 were used to design the principal spillway.

Sediment storage volume

As previously noted, the Example 1 operation has a disturbed area of 18.8 acres. Providing a sediment pool volume of 0.075 acre-feet per acre disturbed yields a sediment pool storage volume of 1.41 acre-feet. However, using equation 15 to determine the minimum sediment storage volume (1.5 times the 10-year, 24-hour storm sediment load of 1990 tons) produces a sediment pool of 1.76 acre-feet. The sediment pool elevation corresponding to a volume of 1.76 acre-feet is 13.0 feet (Figure B-2).

Selection of a principal spillway size and type

Worksheet 5 (Table B-7) was used to begin the principal spillway design process. An initial principal spillway elevation of 14.5 feet was assumed for a 18"-30" conduit-riser spillway (1.5 feet above the sediment pool) and basic information concerning the pond was entered at the top of worksheet 5 and in columns 1-9. Equation 24 was used to calculate the discharge ratio, Q_r, needed to meet the settleable solids effluent limitation of 0.5 ml/l. The discharge ratio of .314 (column 10) was used with Figure 8 to produce a volume ratio, V_{rs}, of 0.175 (column 11) and an H_r of 1.84 feet (column 12). The H_r value in column 12 is the estimated head needed to meet the effluent limitation as determined from equation 24. An H_r of 1.84 yields a fractional depth, P_f, of 0.45. The initial H_r was entered in column 2 of worksheet 4 (Figure B-6) to perform the routing using the V_{rs} routing function. Two iterations produced a ΔE_{pm} (H_r) of 1.67 feet and a P_f of 0.47. The final routing using the V_{rv} routing function also produced an H_r of 1.67 feet (column 9-14) and a peak discharge of 16.9 cfs. The settleable solids concentration was 0.29 ml/l (column 23 of worksheet 5) and the maximum water surface elevation (pond height) was 16.2 feet (column 17 of worksheet 4).

Since the settleable solids concentration produced in the first trial indicated that a smaller pond could possibly meet the effluent limitation, a 24"-36" conduit-riser spillway at an elevation of 14.5 feet was considered. However, the calculated discharge reduction ratio, Q_r, was beyond the range of the V_{rs} routing function in Figure 8 indicating the weir flow would occur for this spillway size.

Since the Example 1 pond is relatively small (3.2 feet above the sediment pool) and because the design procedures are limited to full pipe flow, designing for an average rather than peak settleable solids produced the same pond height of 16.2 feet. However, the predicted average settleable solids was less than the peak settleable solids (0.29 ml/l verses 0.46 ml/l).

Average settleable solids

Emergency spillway design

Procedures summarized in worksheet 6 were used to design the emergency spillway to control the total sediment pond outflow for the 25-year, 24-hour storm such that the pre-mining 25-year, 24-hour peak discharge was not exceeded. The pre-mining 25-hour peak discharge (37.8 cfs) was calculated for a forested condition with equation 1 and worksheets 1 and 2 (Tables B-8 and B-9). The resulting discharge was entered in column 11 of worksheet 6 (Table B-10). The during mining 25-year, 24-hour storm peak discharge was calculated using worksheet 2 (Table B-9). The same time of concentration and travel time values initially used with the 10-year storm were used with the 25-year storm. The maximum routed 25-year discharge, (T_c and T_t used in calculations) was 66.7 cfs (column 16, worksheet 2, Table B-9) while the peak discharge calculated without considering the effects of travel time and time of concentration (equations 3-5) was 68.3 cfs, only 2 percent higher (column 9, worksheet 2, Table B-9). The 25-year, 24-hour during mining runoff and peak discharge were used to calculate ΔQ_{vi} and ΔQ_{pi} (top of worksheet 6, Table B-10). Following the calculation procedures summarized in worksheet 6, an initial head above the emergency spillway crest of 0.80 feet produced a peak outflow (principal plus emergency) of 29.6 cfs for an emergency spillway with a bottom width of 5.4 feet and 2:1 side slopes. Since the maximum outflow was well below the pre-mining discharge of 37.8 cfs, a lower water surface elevation, H_e, of 0.60 feet was assumed. A lower water surface means that less water is stored and a higher discharge will result due to a wider spillway bottom width. The resulting discharge was 33.2 cfs, still well below the pre-mining peak discharge of 37.8 cfs, and the spillway bottom width was 11.8 feet.

Average settleable solids

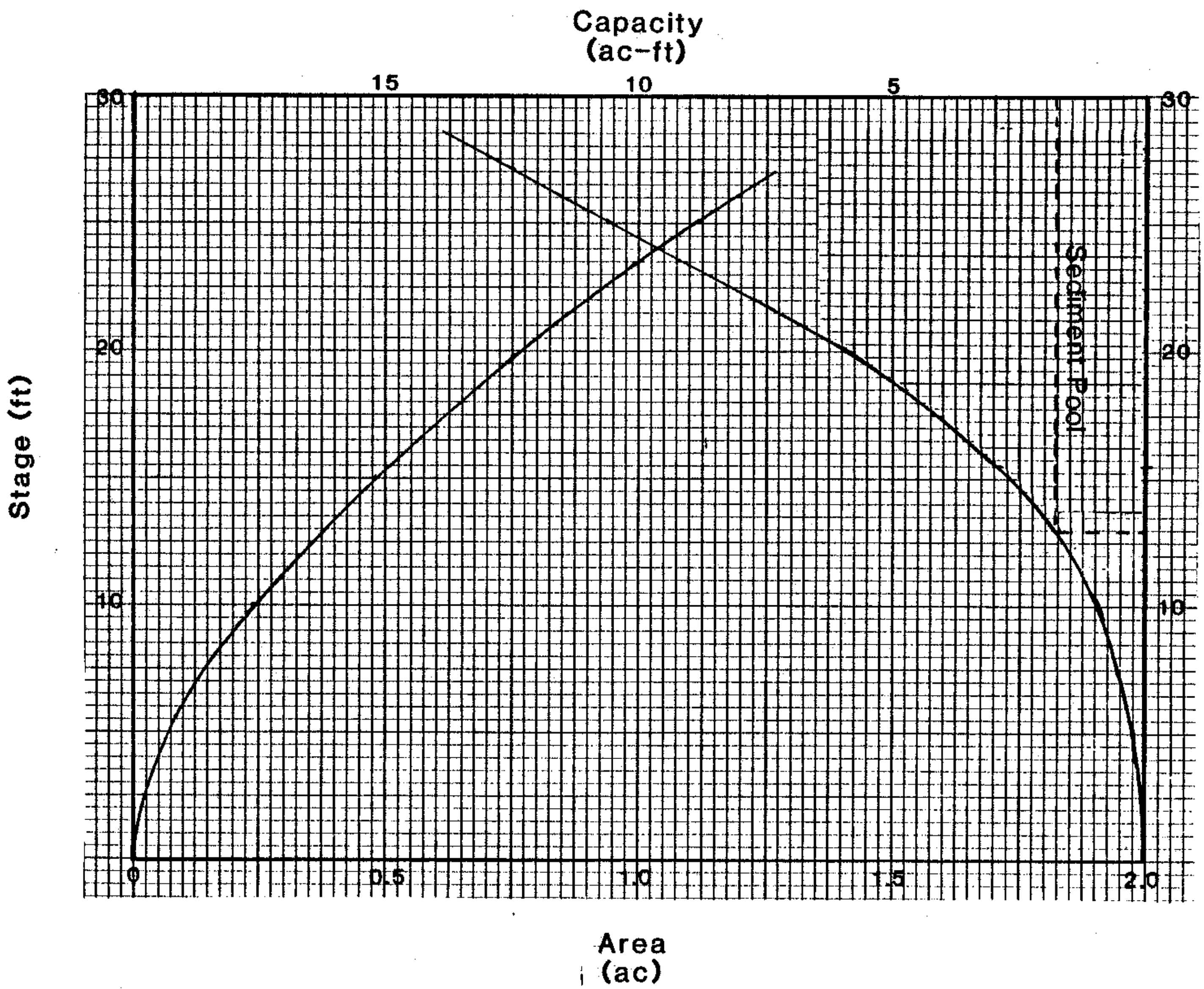

Figure B-2 Sediment pond area-capacity curves.

Average settleable solids

TABLE B-5

WORKSHEET 3

Design Step 3 -Determination of Sediment Load

Watershed	(1) Q_v (ac-ft)	(2) Q_p (cfs)	(3) L_e (ft)	(4) S_o (%)	(5) LS	(6) K	(7) CP	(8) Y (tons)
1	1.029	10.8	250	19	6.00	0.22	0.14	67.6
2	1.885	23.7	200	31	11.60	0.22	0.90	1831.3
3	0.238	3.0	120	1	0.14	0.22	0.90	2.1
4	0.152	1.9	60	36	8.19	0.22	0.90	76.8
5	0.158	1.7	110	1	0.13	0.22	0.14	0.7
6	0.127	1.3	60	36	8.19	0.22	0.14	8.7
7	1.538	10.7	180	15	3.43	0.17	0.003	0.8
							ΣY	1988.0

(1) From column 8 worksheet 2
(2) From column 9 worksheet 2.
(5) From Figure 7.
(6) From Table 3.
(7) From Table 3.
(8) From equation 13.

TABLE B-6

WORKSHEET 4

Determination of Routed Peak Discharge for the 10-Year, 24 Hour Storm
Q_{pi} 49.4 (cfs) C_1 1.00

Initial Routing Using V_{rs}						
(1) Principal size (in)	(2) H_r/H_t (ft)	(3) Q_{po} (cfs)	(4) Q_r	(5) V_{rs}	(6) $\frac{Q_{vi}-\Delta V_{op}}{A_p}$ (ft)	(7) ΔE_{pm} (ft)
18-30	1.84	17.0	0.344	0.158	10.5	1.66
	1.66	16.9	0.342	0.159	10.5	1.67
24-36	1.84	34.9	0.707			
	NOTE: Q_r IS BEYOND V_{rs} RANGE, CALCULATION STOPS.					

(1) Selected principal size.
(2) Initial estimated value of H_r/H_t from worksheet 5 column 12.
(3) From Figure 10 or 11 multiplied by the length correction factor from Figure 12 or 13.
(4) (3)/Q_{pi}.
(5) From Figure 8 or 9.
(6) Worksheet 5 (8)/(6).
(7) (5) x (6).

Average settleable solids

TABLE B-6 (continued)

WORKSHEET 4 (CONTINUED)

Determination of Routed Peak Discharge for the 10-Year, 24 Hour Storm

Final Routing Using V_{rv}											
(8) Principal size (in)	(9) H_r/H_t (ft)	(10) Q_{po} (cfs)	(11) Q_r	(12) V_{rv}	(13) $Q_{vi}-\Delta V_{op}$ (ac-ft)	(14) ΔV_{pm} (ac-ft)	(15) V_p (ac-ft)	(16) V_m (ac-ft)	(17) E_m (ft)	(18) E_p (ft)	(19) H_r/H_t (ft)
18-30	1.67	16.9	0.342	0.200	4.83	0.968	2.45	3.42	16.2	14.5	1.67
	1.67	16.9	0.342	0.200	4.83	0.968	2.45	3.42	16.2	14.5	1.67

(8) Selected principal size.
(9) From (7) for first trial or (19) for subsequent trials.
(10) From Figure 10 or 11 multiplied by the length correction factor from Figure 12 or 13.
(11) (10)/Q_{pi}.
(12) From Figure 8 or 9.
(13) From column 8 worksheet 5.
(14) (12) X (13)
(15) From column 5 worksheet 5.
(16) (14) + (15).
(17) From sediment pond stage-volume relationship for V_m.
(18) Selected principal spillway elevation from worksheet 5 column 4.
(19) (17) - (18).

Average settleable solids

TABLE B-7

WORKSHEET 5

Calculation of Settleable Solids

E_s 13.0 (ft) V_s 1.755 (ac-ft) Q_{vi} 5.13 (ac-ft) C_{su} 256,000 (mg/l)

(1) Principal size (in)	(2) E_o (ft)	(3) V_o (cfs)	(4) E_p (ft)	(5) V_p (ac-ft)	(6) A_p (ac)	(7) ΔV_{op} (ac-ft)	(8) $Q_{vi}-\Delta V_{op}$ (ac-ft)	(9) ΔV_{sp} (ac-ft)	(10) Q_r	(11) V_{rs}	(12) H_r/H_t (ft)
18-30	13.8	2.15	14.5	2.45	0.46	0.30	4.83	0.695	0.314	0.175	1.84
24-36	13.8	2.15	14.5	2.45	0.46	0.30	4.83	0.695	0.314	0.175	1.84

(1) Selected principal size.
(2) Elevation at the dewatering orifice. $E_o = E_s + (E_p - E_s)/2$.
(3) From sediment pond stage-volume relationship.
(4) Selected principal spillway elevation.
(5) From sediment pond stage-volume relationship.
(6) From sediment pond stage-area relationship.
(7) (5) - (3).
(8) Q_{vi} - (7).
(9) (5) - V_s.
(10) From equation 24 or 25.
(11) From Figure 8 or 9.
(12) (11) X (8)/(6).

Average settleable solids

TABLE B-7 (continued)

WORKSHEET 5 (CONTINUED)

Calculation of Settleable Solids

(13) Principal size (in)	(14) H_r/H_t (ft)	(15) H_r/H_t (ft)	(16) P_f (ft)	(17) D (ft)	(18) Q_{vi} (ac-ft)	(19) ΔV_{sp} (ac-ft)	(20) Q_{po} (cfs)	(21) Q_{pi} (cfs)	(22) C_{su} (mg/l)	(23) C_{se} (ml/l)
18-30	1.67	1.67	0.47	3.2	5.13	0.695	169	49.4	256,000	0.29

(13) Selected principal size.
(14) From column 7 worksheet 4.
(15) From column 19 worksheet 4.
(16) From equation 16.
(17) (4) + (15) − E_s.
(18) From equation 12.
(19) From column 9.
(20) From column 10 worksheet 4.
(21) From equation 9 or 10.
(22) From equation 23.
(23) From equation 21 or 22.

Average settleable solids

TABLE B-8

WORKSHEET 1

Design Step 2 - Calculation of Time of Concentration and Travel Time

(1) Watershed and Segment	(2) Surface Condition	(3) Hydraulic Length (ft)	(4) Average Slope (%)	(5) Velocity (ft/sec)	(6) Segment T_c or T_t (hr)	(7) Watershed T_c (hr)	(8) Watershed T_t (hr)	(9) $T_c + T_t$ (hr)
	25-YEAR, 24-HOUR PRE-MINING							
1-a	(1) FORREST	400	15	1.0	0.111			
1-b	(2) CHANNEL	500	8	5.7	0.024	0.135	0.	0.135

TABLE B-10

WORKSHEET 6

Determination of Emergency Spillway Routed Peak Discharge for the 25-Year, 24-Hour Storm

ΔQ_{vi} = Q_{vi} (25-yr) 6.68 ac-ft - Q_{vi} (10-yr) 5.13 ac-ft = 1.55 ac-ft.

ΔQ_{pi} = Q_{pi} (25-yr) 68.3 cfs - Q_{pi} (10-yr) 49.4 cfs = 18.9 cfs.

(1) E_e (ft)	(2) V_e (ac-ft)	(3) H_e (ft)	(4) V_{me} (ac-ft)	(5) ΔV_{em} (ac-ft)	(6) $\frac{\Delta V_{em}}{\Delta Q_{vi}}$	(7) $\frac{Q_{eo}}{\Delta Q_{pi}}$
16.2	3.42	0.80	3.89	0.47	0.303	0.65
16.2	3.42	0.60	3.78	0.36	0.231	0.85

(8) Q_{eo} (cfs)	(9) Q_{po} (cfs)	(10) Q_{pe} (cfs)	(11) Q_{pm} (cfs)	(12) Side slope (H:V)	(13) Q_{tr} (cfs)	(14) Q_b (cfs/ft)	(15) BW (ft)
12.3	17.3	29.6	37.8	2:1	2.1	1.90	5.4
16.1	17.1	33.2	37.8	2:1	1.3	1.25	11.8

Emergency Spillway Crest 16.2 ft. Peak Stage 16.8 ft.

Bottom Width 12 ft. Side slopes 2:1 (H:V).

Pre-mining Discharge 37.8 cfs. Pond Routed Discharge 33.2 cfs.

(1) From column 17 worksheet 4.
(2) From sediment pond stage-volume relationship for E_e.
(3) Assumed emergency spillway head.
(4) From sediment pond stage-volume. relationship for E_{me}. ($E_{me} = E_e + H_e$).
(5) (4) - (2).
(6) (5)/ΔQ_{vi}.
(7) From Figure 14.
(8) (7) x ΔQ_{pi}.
(9) From Figure 10 or 11.
(10) (8) + (9).
(11) Pre-mining peak discharge.
(12) Selected side slope.
(13) From Figure 15.
(14) From Figure 16.
(15) ((C8) - (C13))/C14).

Average settleable solids

Example 2 - Mountaintop Removal Operation

A mountaintop removal operation is proposed for the watershed presented in Figure B-3. The operation will disturb 14 acres and the remaining portion of the watershed (49 acres) will be left in the original forested condition. The sediment pond is located at a drainage area of 63 acres.

The following material provides an abbreviated discussion of the design process and does not include a detailed description on use of the worksheets. Those desiring a more detailed description on use of the worksheets are referred to Example 1.

Selection of Sub-watersheds

The 63 acre watershed was divided into three sub-watersheds (Figure B-3) for the purpose of calculating peak discharge, runoff volume, and sediment load. A summary of sub-watershed information representative of a "worst-case" condition is presented in Table B-11. Parameter values from TRM #6 were used for all sub-watersheds.

TABLE B-11

Summary of Sub-watershed Surface Conditions for Example 2

Watershed	Surface Condition	Area (ac)	CN	K	CP
1	Reclaimed; 0-2 months vegetation	10	79	0.22	0.14
2	Backfilled and graded; bare	4	86	0.22	0.90
3	Undisturbed forest	49	73	0.17	0.003

Determination of Peak Discharge and Runoff Volume

Time of concentration and travel time values were calculated for each of the sub-watersheds using worksheet 1 (Table B-12 and B-13). Review of the combined time of concentration and travel time values in column 9 of worksheet 1 (Table B-12) shows that the maximum combined T_c and T_t is 0.120 hours. Since the maximum T_c + T_t is less than 0.150 hours, the peak discharge can be calculated directly using equations (3) through (5), thus eliminating the need to adjust the peak discharge for time of concentration and travel time. The runoff volume and peak discharge for each sub-watershed is given in columns 8 and 9 of worksheet 2, respectively (Table B-14). The total runoff volume and peak discharge for the sediment pond are 9.07 acre-feet and 75 cfs, respectively.

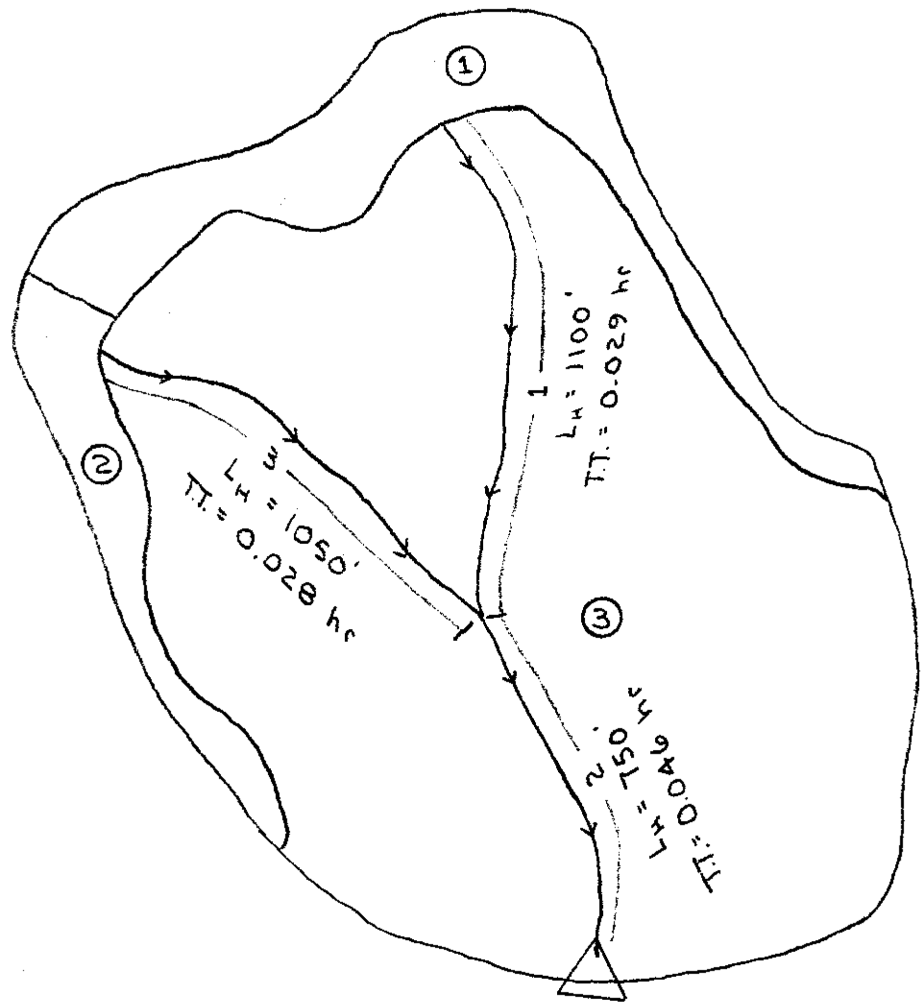

Figure B-3 Location map for Example 2

Determination of Sediment Load

Worksheet 3 (Table B-15) was used with equation 8 to calculate the sediment load for the 10-year, 24-hour storm for each sub-watershed. Area weighted erosion slope lengths, L_e, were determined for each sub-watershed using procedures described in Example 1 of this appendix.

Principal Spillway Design

The sediment pool storage volume was determined first and then worksheets 4 and 5 were used to perform the routing and calculate settleable solids.

Sediment storage volume

As previously discussed, the Example 2 operation has a total disturbed area of 14.0 acres. Providing a sediment pool storage volume of 0.075 acre-feet per acre disturbed yields a volume of 1.05 acre-feet. Using equation 15 to determine the minimum sediment storage volume (1.5 times the 10-year, 24-hour sediment load) produces a sediment pool of 0.48 acre-feet. For this example, the sediment pool was set at 1.05 acre-feet with a corresponding elevation of 9.0 feet (Figure B-4).

Selection of a principal spillway size and type

A 24 inch diameter trickle tube located at an elevation of 13.0 feet (4.0 feet above the sediment pool) was initially evaluated (worksheets 4 and 5, Tables B-16 and B-17). The predicted settleable solids concentration was 1.37 ml/l, significantly above the effluent limitation of 0.5 ml/l. For a second trial the spillway elevation was raised from 13.0 feet to 14.0 feet. The resultant settleable solids concentration was 0.95 ml/l. A third trial included an 18 inch diameter trickle tube at an elevation of 13.0 feet. The calculated water surface elevation, discharge, and settleable solids were 17.9 feet, 15.1 cfs, and 0.42 ml/l, respectively.

Emergency Spillway Design

The pre-mining and active mining 25-year, 24-hour discharges were calculated using worksheets 1 and 2 (Tables B-18 and B-19) and were 78.6 cfs and 96.4 cfs, respectively, A head of 0.60 feet (worksheet 6, Table B-20) produced an emergency spillway bottom width of 15.4 feet (2:1 side slopes) and a total discharge of 36.3 cfs. The total discharge is well below the 25-year, 24-hour pre-mining peak discharge of 78.6 cfs.

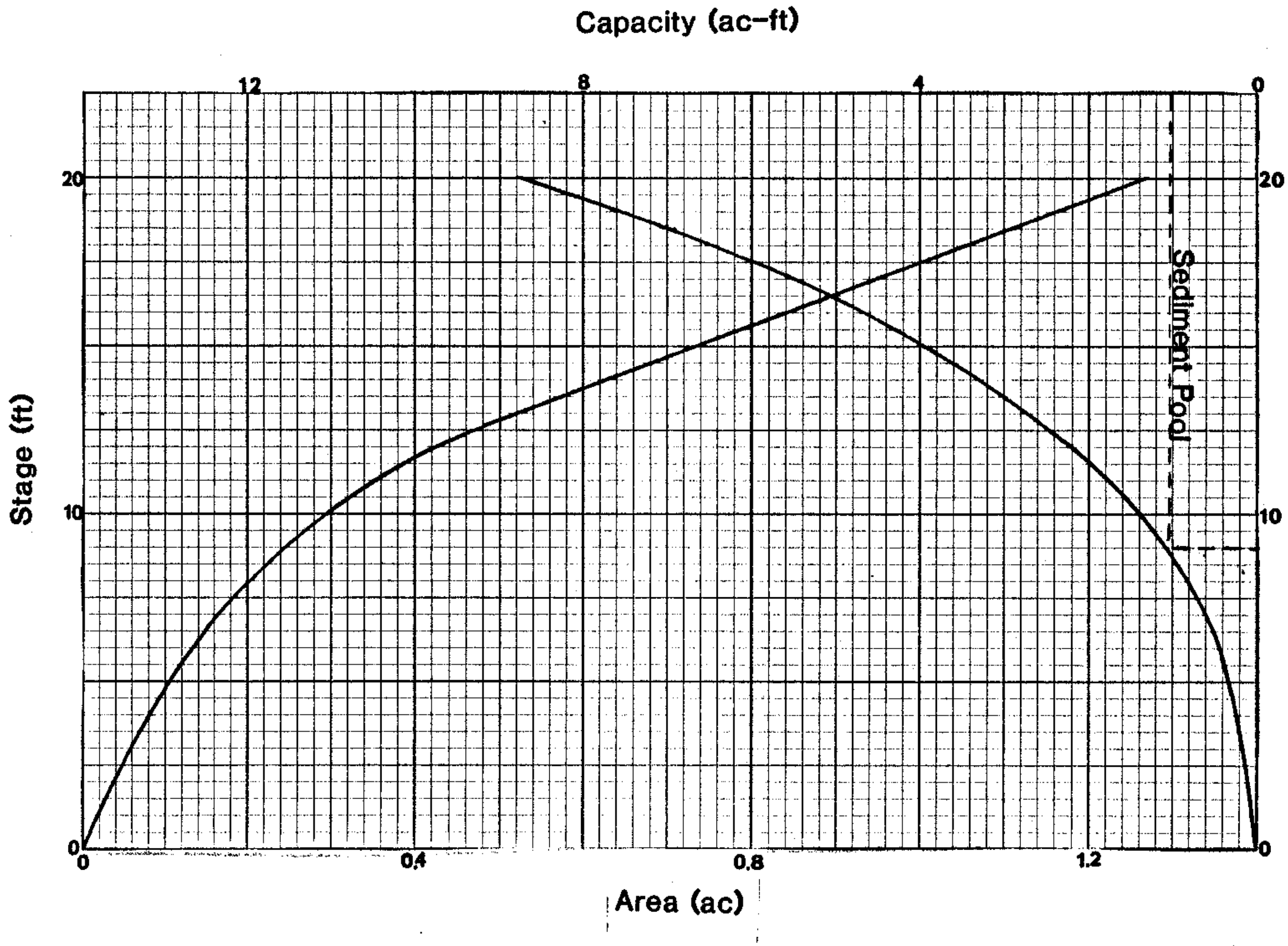

Figure B-4 Sediment pond area-capacity curves for Example 2

TABLE B-12

WORKSHEET 1

Design Step 2 - Calculation of Time of Concentration and Travel Time

(1) Watershed and Segment	(2) Surface Condition	(3) Hydraulic Length (ft)	(4) Average Slope (%)	(5) Velocity (ft/sec)	(6) Segment T_c or T_t (hr)	(7) Watershed T_c (hr)	(8) Watershed T_t (hr)	(9) $T_c + T_t$ (hr)
1	RECLAIMED	200	20	2.2	0.025	0.025	0.075	0.100
2	DISTURBED	180	28	4.7	0.011	0.011	0.074	0.085
3-a	FORREST	250	27	1.3	0.053			
3-b	CHANNEL	800	27	10.5	0.021			
3-c	CHANNEL	750	5	4.5	0.046	0.120	0	0.120

TABLE B-13

WORKSHEET 1

Design Step 2 - Calculation of Time of Concentration and Travel Time

(1) Watershed and Segment	(2) Surface Condition	(3) Hydraulic Length (ft)	(4) Average Slope (%)	(5) Velocity (ft/sec)	(6) Segment T_c or T_t (hr)	(7) Watershed T_c (hr)	(8) Watershed T_t (hr)	(9) $T_c + T_t$ (hr)
1	CHANNEL	1100	27	10.5	0.029			
2	CHANNEL	750	5	4.5	0.046			
3	CHANNEL	1050	27	10.5	0.028			

TABLE B-14

WORKSHEET 2
Design Step 2 - Determination of Peak Discharge and Runoff Volume

(1) Watershed	(2) T_c (hr)	(3) T_t (hr)	(4) CN	(5) q_{u_2} (cfs/mi²/in)	(6) Q (in)	(7) A (ac)	(8) Q_v (ac-ft)	(9) Q_p (cfs)	(10) F_t	(11) q_{t_2} (cfs/mi²/in)	(12) Rounded $T_c + T_t$ (hr)
1			79		2.0	12	1.67	17.5			
2			86		2.6	4	0.87	10.9			
3			73		1.6	49	6.53	46.6			
						Σ	9.07	75.0			

(1) Sub-watershed identification.
(2) From column 7 worksheet 1.
(3) From column 8 worksheet 1.
(4) From Table 1.
(5) From Figure 1.
(6) From Figure 3.
(8) (6) X (7)/12.
(9) (5) X (6) X (7)/640.
(10) From Figure 4.
(11) (5) X (10).

TABLE B-15

WORKSHEET 3

Design Step 3 -Determination of Sediment Load

Watershed	(1) Q_v (ac-ft)	(2) Q_p (cfs)	(3) L_e (ft)	(4) S_o (%)	(5) LS	(6) K	(7) CP	(8) Y (tons)
1	1.67	17.5	110	20	4.3	0.22	0.14	93.3
2	0.97	10.9	90	28	6.7	0.22	0.90	444.7
3	6.53	46.6	200	27	9.2	0.17	0.003	11.0
							Σ	538.5

(1) From column 8 worksheet 2
(2) From column 9 worksheet 2.
(5) From Figure 7.
(6) From Table 3.
(7) From Table 3.
(8) From equation 13.

TABLE B-16

WORKSHEET 4

Determination of Routed Peak Discharge for the 10-Year, 24 Hour Storm
Q_{pi} 75.0 (cfs) C_1 1.00

Initial Routing Using V_{rs}						
(1) Principal size (in)	(2) H_r/H_t (ft)	(3) Q_{po} (cfs)	(4) Q_r	(5) V_{rs}	(6) $\frac{Q_{vi}-\Delta V_{op}}{A_p}$ (ft)	(7) ΔE_{pm} (ft)
24	4.83	30.9	0.412	0.196	17.4	3.41
	3.41	27.5	0.367	0.212	17.4	3.70
	3.70	28.3	0.378	0.208	17.4	3.63
24	3.71	28.3	0.378	0.208	14.3	2.98
	2.98	Ht < full pipe flow, set Ht to fpf (TABLE 4)				
	3.0	26.1	0.348	0.220	14.3	3.14
	3.14	26.7	0.356	0.217	14.3	3.09
18	4.83	15.0	0.200	0.283	17.4	4.94
	4.94	15.1	0.202	0.282	17.4	4.92

(1) Selected principal size.
(2) Initial estimated value of H_r/H_t from worksheet 5 column 12.
(3) From Figure 10 or 11 multiplied by the length correction factor from Figure 12 or 13.
(4) (3)/Q_{pi}.
(5) From Figure 8 or 9.
(6) Worksheet 5 (8)/(6).
(7) (5) x (6).

TABLE B-16 (continued)

WORKSHEET 4 (CONTINUED)

Determination of Routed Peak Discharge for the 10-Year, 24 Hour Storm

Final Routing Using V_{rv}											
(8) Principal size (in)	(9) H_r/H_t (ft)	(10) Q_{po} (cfs)	(11) Q_r	(12) V_{rv}	(13) $Q_{vi}-\Delta V_{op}$ (ac-ft)	(14) ΔV_{pm} (ac-ft)	(15) V_p (ac-ft)	(16) V_m (ac-ft)	(17) E_m (ft)	(18) E_p (ft)	(19) H_r/H_t (ft)
24	3.63	28.1	0.375	0.298	9.07	2.70	2.75	5.45	16.90	13.0	3.90
	3.90	28.8	0.384	0.294	9.07	2.67	2.75	5.42	16.35	13.0	3.35
24	3.09	26.5	0.354	0.308	9.07	2.80	3.25	6.05	17.55	14.0	3.55
	3.55	27.9	0.372	0.300	9.07	2.72	3.25	5.97	17.46	14.0	3.46
18	4.92	15.1	0.202	0.398	9.07	3.61	2.75	6.36	17.89	13.0	4.89

(8) Selected principal size.
(9) From (7) for first trial or (19) for subsequent trials.
(10) From Figure 10 or 11 multiplied by the length correction factor from Figure 12 or 13.
(11) (10)/Q_{pi}.
(12) From Figure 8 or 9.
(13) From column 8 worksheet 5.
(14) (12) X (13)
(15) From column 5 worksheet 5.
(16) (14) + (15).
(17) From sediment pond stage-volume relationship for V_m.
(18) Selected principal spillway elevation from worksheet 5 column 4.
(19) (17) - (18).

TABLE B-17

WORKSHEET 5

Calculation of Settleable Solids

E_s 9.0 (ft) V_s 1.05 (ac-ft) Q_{vi} 9.07 (ac-ft) C_{su} 42900 (mg/l)

(1) Principal size (in)	(2) E_o (ft)	(3) V_o (cfs)	(4) E_p (ft)	(5) V_p (ac-ft)	(6) A_p (ac)	(7) ΔV_{op} (ac-ft)	(8) $Q_{vi}-\Delta V_{op}$ (ac-ft)	(9) ΔV_{sp} (ac-ft)	(10) Q_r	(11) V_{rs}	(12) H_r/H_t (ft)
24			13	2.75	0.52	0	9.07	1.70	0.213	0.277	4.83
24			14	3.25	0.635	0	9.07	2.20	0.251	0.260	3.71
18			13	2.75	0.52	0	9.07	1.70	0.213	0.277	4.83

(1) Selected principal size.
(2) Elevation at the dewatering orifice. $E_o = E_s + (E_p-E_s)/2$.
(3) From sediment pond stage-volume relationship.
(4) Selected principal spillway elevation.
(5) From sediment pond stage-volume relationship.
(6) From sediment pond stage-area relationship.
(7) (5) - (3).
(8) Q_{vi} - (7).
(9) (5) - V_s.
(10) From equation 24 or 25.
(11) From Figure 8 or 9.
(12) (11) X (8)/(6).

TABLE B-17 (continued)

WORKSHEET 5 (CONTINUED)

Calculation of Settleable Solids

(13) Principal size (in)	(14) H_r/H_t (ft)	(15) H_r/H_t (ft)	(16) P_f (ft)	(17) D (ft)	(18) Q_{vi} (ac-ft)	(19) ΔV_{sp} (ac-ft)	(20) Q_{po} (cfs)	(21) Q_{pi} (cfs)	(22) C_{su} (mg/l)	(23) C_{se} (ml/l)
24	3.63	3.35	0.51	7.95	9.07	1.70	28.8	75.0	42900	1.37
24	3.09	3.46	0.59	8.46	9.07	2.20	27.9	75.0	42900	0.95
18	4.92	4.89	0.45	8.39	9.07	1.70	15.1	75.0	42900	0.42

(13) Selected principal size.
(14) From column 7 worksheet 4.
(15) From column 19 worksheet 4.
(16) From equation 16.
(17) (4) + (15) - E_s.
(18) From equation 12.
(19) From column 9.
(20) From column 10 worksheet 4.
(21) From equation 9 or 10.
(22) From equation 23.
(23) From equation 21 or 22.

TABLE B-18

WORKSHEET 1

Design Step 2 - Calculation of Time of Concentration and Travel Time

(1) Watershed and Segment	(2) Surface Condition	(3) Hydraulic Length (ft)	(4) Average Slope (%)	(5) Velocity (ft/sec)	(6) Segment T_c or T_t (hr)	(7) Watershed T_c (hr)	(8) Watershed T_t (hr)	(9) $T_c + T_t$ (hr)
		25-YEAR,	24-HOUR		PRE-MINING			
1-a	FORREST	300	27	1.3	0.064			
1-b	CHANNEL	1000	27	10.5	0.027			
1-c	CHANNEL	750	5	4.5	0.046	0.137	0	0.137

TABLE B-19

WORKSHEET 2

Design Step 2 - Determination of Peak Discharge and Runoff Volume

(1) Watershed	(2) T_c (hr)	(3) T_t (hr)	(4) CN	(5) q_{u_2} (cfs/mi²/in)	(6) Q (in)	(7) A (ac)	(8) Q_v (ac-ft)	(9) Q_p (cfs)	(10) F_t	(11) q_{t_2} (cfs/mi²/in)	(12) Rounded $T_c + T_t$ (hr)
				25-YEAR, 24 HOUR PRE-MINING							
1			73		2.1	63	11.03	78.6			
				25-YEAR, 24-HOUR DURING MINING							
1			79		2.5	10	2.08	21.9			
2			86		3.2	4	1.07	13.4			
3			73		2.1	49	8.58	61.1			
						Σ	11.73	96.4			

(1) Sub-watershed identification.
(2) From column 7 worksheet 1.
(3) From column 8 worksheet 1.
(4) From Table 1.
(5) From Figure 1.
(6) From Figure 3.
(8) (6) X (7)/12.
(9) (5) X (6) X (7)/640.
(10) From Figure 4.
(11) (5) X (10).

TABLE B-20

WORKSHEET 6

Determination of Emergency Spillway Routed Peak Discharge for the 25-Year, 24-Hour Storm

ΔQ_{vi} = Q_{vi} (25-yr) 11.73 ac-ft - Q_{vi} (10-yr) 9.07 ac-ft = 2.66 ac-ft.

ΔQ_{pi} = Q_{pi} (25-yr) 96.4 cfs - Q_{pi} (10-yr) 75.0 cfs = 21.4 cfs.

(1) E_e (ft)	(2) V_e (ac-ft)	(3) H_e (ft)	(4) V_{me} (ac-ft)	(5) ΔV_{em} (ac-ft)	(6) $\frac{\Delta V_{em}}{\Delta Q_{vi}}$	(7) $\frac{Q_{eo}}{\Delta Q_{pi}}$
17.9	6.36	0.60	6.90	0.54	0.203	0.96

(8) Q_{eo} (cfs)	(9) Q_{po} (cfs)	(10) Q_{pe} (cfs)	(11) Q_{pm} (cfs)	(12) Side slope (H:V)	(13) Q_{tr} (cfs)	(14) Q_b (cfs/ft)	(15) BW (ft)
20.5	15.8	36.3	78.6	2:1	1.3	1.25	15.4

Emergency Spillway Crest 17.9 ft. Peak Stage 18.5 ft.

Bottom Width 15 ft. Side slopes 2:1 (H:V).

Pre-mining Discharge 78.6 cfs. Pond Routed Discharge 36.3 cfs.

(1) From column 17 worksheet 4.
(2) From sediment pond stage-volume relationship for E_e.
(3) Assumed emergency spillway head.
(4) From sediment pond stage-volume. relationship for E_{me}. ($E_{me} = E_e + H_e$).
(5) (4) - (2).
(6) (5)/ΔQ_{vi}.
(7) From Figure 14.
(8) (7) x Q_{pi}.
(9) From Figure 10 or 11.
(10) (8) + (9).
(11) Pre-mining peak discharge.
(12) Selected side slope.
(13) From Figure 15.
(14) From Figure 16.
(15) ((C8) - (C13))/C14).

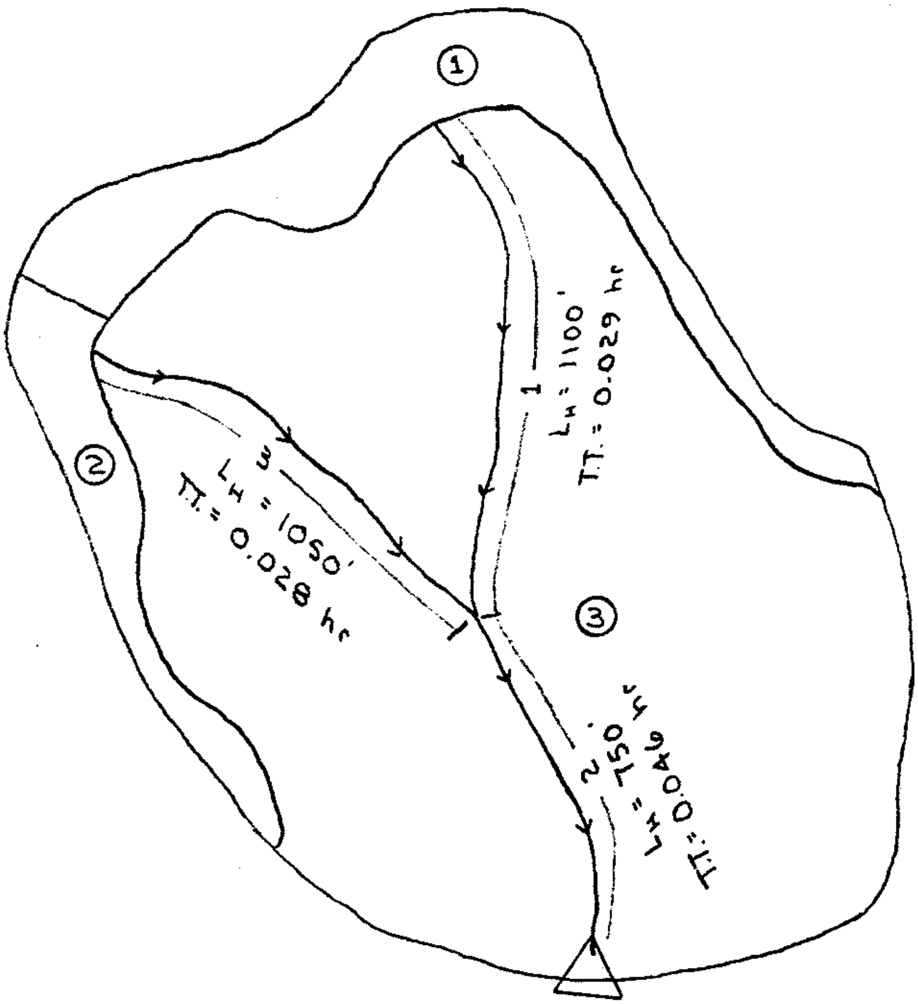

Figure B-3 Location map for Example 2

Determination of Sediment Load

Worksheet 3 (Table B-15) was used with equation 8 to calculate the sediment load for the 10-year, 24-hour storm for each sub-watershed. Area weighted erosion slope lengths, L_e, were determined for each sub-watershed using procedures described in Example 1 of this appendix.

Principal Spillway Design

The sediment pool storage volume was determined first and then worksheets 4 and 5 were used to perform the routing and calculate settleable solids.

Sediment storage volume

As previously discussed, the Example 2 operation has a total disturbed area of 14.0 acres. Providing a sediment pool storage volume of 0.075 acre-feet per acre disturbed yields a volume of 1.05 acre-feet. Using equation 15 to determine the minimum sediment storage volume (1.5 times the 10-year, 24-hour sediment load) produces a sediment pool of 0.48 acre-feet. For this example, the sediment pool was set at 1.05 acre-feet with a corresponding elevation of 9.0 feet (Figure B-4).

Selection of a principal spillway size and type

A 24 inch diameter trickle tube spillway was initially selected and analyzed. The principal spillway was located at an elevation of 11.0 feet (2.0 feet above the sediment pool). The results of the routing and settleable solids calculations are displayed in worksheets 4 and 5 (Tables B-16 and B-17).

Although the calculated settleable solids was less than 0.5 ml/l, the principal spillway fractional depth was 0.30, which is less than the minimum allowable fractional depth of 0.40. In order to satisfy the fractional depth criterion, the principal spillway elevation was raised to 12.0 feet (3.0 feet above the sediment pool). The resultant water surface elevation, peak discharge, and average settleable solids concentration were 16.2 feet, 29.5 cfs, and .01 ml/l, respectively.

Since the 24" trickle tube produced a settleable solids concentration significantly less than 0.5 ml/l, a 30 inch diameter trickle tube located at an elevation of 11.5 feet was considered. However, the calculated head was less than that required to maintain full pipe flow (Table 4).

The sediment pond size was reduced 1.7 feet (17.9 feet verses 16.2 feet) as a result of designing to meet an average rather than a peak settleable solids. The reduction in pond size would probably have been greater if the design procedures were not limited to full pipe flow.

Average settleable solids

Emergency Spillway Design

The pre-mining and active mining 25-year, 24-hour discharges were calculated using worksheets 1 and 2 (Tables B-18 and B-19) and were 78.6 cfs and 96.4 cfs, respectively. The pre-mining watershed condition was assumed to be forested. An initial emergency spillway head of 0.80 feet (worksheet 6, Table B-20) was assumed and produced a spillway width of 7.7 feet (2:1 side slopes) and a total discharge (principal plus emergency) of 48.5 cfs. A second trial with 2:1 side slopes and at an assumed head of 0.70 feet produced an emergency spillway width of 11.6 feet and a total discharge of 51.2 cfs. For both of the above trials the total discharge was well below the pre-mining 25-year, 24-hour peak discharge of 78.6 cfs.

Average settleable solids

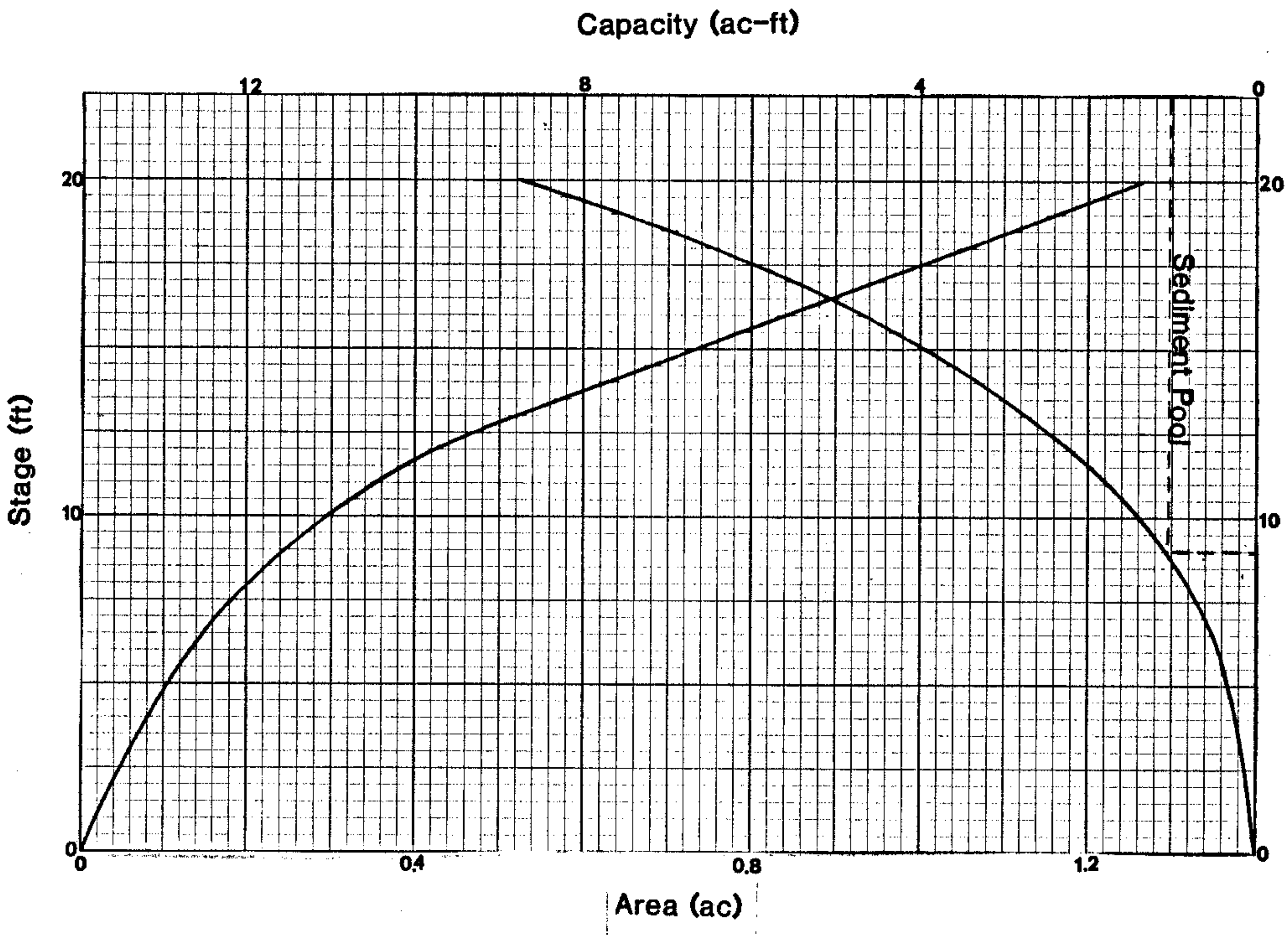

Figure B-4 Sediment pond area-capacity curves for Example 2

TABLE B-16

WORKSHEET 4

Determination of Routed Peak Discharge for the 10-Year, 24 Hour Storm

Q_{pi} 75.0 (cfs) C_1 1.00

Initial Routing Using V_{rs}						
(1) Principal size (in)	(2) H_r/H_t (ft)	(3) Q_{po} (cfs)	(4) Q_r	(5) V_{rs}	(6) $\frac{Q_{vi}-\Delta V_{op}}{A_p}$ (ft)	(7) ΔE_{pm} (ft)
24	3.23	27.0	0.360	0.215	25.5	5.50
	5.50	32.3	0.430	0.189	25.5	4.82
	4.82	30.9	0.412	0.196	25.5	5.00
	5.00	31.2	0.417	0.194	25.5	4.95
24	2.21	Ht < full pipe flow, set Ht to f.p.f. (TABLE 4)				
	3.0	26.1	0.348	0.220	20.6	4.53
	4.53	30.2	0.403	0.199	20.6	4.10
	4.10	29.3	0.390	0.204	20.6	4.20
30	2.66	Ht < full pipe flow, set Ht to f.p.f. (TABLE 4)				
	4.0	47.7	0.636	0.119	23.0	2.73
	2.73	Ht < full pipe flow			Calculation stops.	

(1) Selected principal size.
(2) Initial estimated value of H_r/H_t from worksheet 5 column 12.
(3) From Figure 10 or 11 multiplied by the length correction factor from Figure 12 or 13.
(4) (3)/Q_{pi}.
(5) From Figure 8 or 9.
(6) Worksheet 5 (8)/(6).
(7) (5) x (6).

Average settleable solids

TABLE B-16 (continued)

WORKSHEET 4 (CONTINUED)

Determination of Routed Peak Discharge for the 10-Year, 24 Hour Storm

Final Routing Using V_{rv}

(8) Principal size (in)	(9) H_r/H_t (ft)	(10) Q_{po} (cfs)	(11) Q_r	(12) V_{rv}	(13) $Q_{vi}-\Delta V_{op}$ (ac-ft)	(14) ΔV_{pm} (ac-ft)	(15) V_p (ac-ft)	(16) V_m (ac-ft)	(17) E_m (ft)	(18) E_p (ft)	(19) H_r/H_t (ft)
24	4.95	31.2	0.415	0.279	9.07	2.53	1.80	4.33	15.47	11.0	4.47
	4.47	30.1	0.420	0.286	9.07	2.59	1.80	4.39	15.56	11.0	4.56
24	4.20	29.5	0.393	0.290	9.07	2.63	2.20	4.83	16.14	12.0	4.14

(8) Selected principal size.
(9) From (7) for first trial or (19) for subsequent trials.
(10) From Figure 10 or 11 multiplied by the length correction factor from Figure 12 or 13.
(11) (10)/Q_{pi}.
(12) From Figure 8 or 9.
(13) From column 8 worksheet 5.
(14) (12) X (13)
(15) From column 5 worksheet 5.
(16) (14) + (15).
(17) From sediment pond stage-volume relationship for V_m.
(18) Selected principal spillway elevation from worksheet 5 column 4.
(19) (17) - (18).

verage settleable solids

TABLE B-17

WORKSHEET 5

Calculation of Settleable Solids

E_s 9.0 (ft) V_s 1.05 (ac-ft) Q_{vi} 9.07 (ac-ft) C_{su} 42900 (mg/l)

(1) Principal size (in)	(2) E_o (ft)	(3) V_o (cfs)	(4) E_p (ft)	(5) V_p (ac-ft)	(6) A_p (ac)	(7) ΔV_{op} (ac-ft)	(8) $Q_{vi}-\Delta V_{op}$ (ac-ft)	(9) ΔV_{sp} (ac-ft)	(10) Q_r	(11) V_{rs}	(12) H_r/H_t (ft)
24			11.0	1.80	0.355	0	9.07	0.75	0.613	0.126	3.23
24			12.0	2.20	0.44	0	9.07	1.15	0.674	0.107	2.21
30			11.5	2.00	0.395	0	9.07	0.95	0.646	0.116	2.66

(1) Selected principal size.
(2) Elevation at the dewatering orifice. $E_o = E_s + (E_p - E_s)/2$.
(3) From sediment pond stage-volume relationship.
(4) Selected principal spillway elevation.
(5) From sediment pond stage-volume relationship.
(6) From sediment pond stage-area relationship.
(7) (5) - (3).
(8) Q_{vi} - (7).
(9) (5) - V_s.
(10) From equation 24 or 25.
(11) From Figure 8 or 9.
(12) (11) X (8)/(6).

Average settleable solids

TABLE B-17 (continued)

WORKSHEET 5 (CONTINUED)

Calculation of Settleable Solids

(13) Principal size (in)	(14) H_r/H_t (ft)	(15) H_r/H_t (ft)	(16) P_f (ft)	(17) D (ft)	(18) Q_{vi} (ac-ft)	(19) ΔV_{sp} (ac-ft)	(20) Q_{po} (cfs)	(21) Q_{pi} (cfs)	(22) C_{su} (mg/1)	(23) C_{se} (ml/1)
24	4.95	4.56	0.30	6.56	9.07	0.75	30.1	75.0	42900	0.02
		NOTE: P_f < 0.40								
24	4.20	4.14	0.42	7.14	9.07	1.15	29.5	75.0	42900	0.01

(13) Selected principal size.
(14) From column 7 worksheet 4.
(15) From column 19 worksheet 4.
(16) From equation 16.
(17) (4) + (15) - E_s.
(18) From equation 12.
(19) From column 9.
(20) From column 10 worksheet 4.
(21) From equation 9 or 10.
(22) From equation 23.
(23) From equation 21 or 22.

Average settleable solids

TABLE B-20

WORKSHEET 6

Determination of Emergency Spillway Routed Peak Discharge for the 25-Year, 24-Hour Storm

ΔQ_{vi} = Q_{vi} (25-yr) 11.73 ac-ft - Q_{vi} (10-yr) 9.07 ac-ft = 2.66 ac-ft.

ΔQ_{pi} = Q_{pi} (25-yr) 96.4 cfs - Q_{pi} (10-yr) 75.0 cfs = 21.4 cfs.

(1) E_e (ft)	(2) V_e (ac-ft)	(3) H_e (ft)	(4) V_{me} (ac-ft)	(5) ΔV_{em} (ac-ft)	(6) $\frac{\Delta V_{em}}{\Delta Q_{vi}}$	(7) $\frac{Q_{eo}}{\Delta Q_{pi}}$
16.2	4.83	0.80	5.50	0.67	0.252	0.78
16.2	4.83	0.70	5.40	0.57	0.214	0.92

(8) Q_{eo} (cfs)	(9) Q_{po} (cfs)	(10) Q_{pe} (cfs)	(11) Q_{pm} (cfs)	(12) Side slope (H:V)	(13) Q_{tr} (cfs)	(14) Q_b (cfs/ft)	(15) BW (ft)
16.7	31.8	48.5	78.6	2:1	2.1	1.90	7.7
19.7	31.5	51.2	78.6	2:1	1.7	1.55	11.6

Emergency Spillway Crest 16.2 ft. Peak Stage 16.9 ft.

Bottom Width 12 ft. Side slopes 2:1 (H:V).

Pre-mining Discharge 78.6 cfs. Pond Routed Discharge 51.2 cfs.

(1) From column 17 worksheet 4.
(2) From sediment pond stage-volume relationship for E_e.
(3) Assumed emergency spillway head.
(4) From sediment pond stage-volume. relationship for E_{me}. ($E_{me} = E_e + H_e$).
(5) (4) - (2).
(6) (5)/ΔQ_{vi}.
(7) From Figure 14.
(8) (7) x Q_{pi}.
(9) From Figure 10 or 11.
(10) (8) + (9).
(11) Pre-mining peak discharge.
(12) Selected side slope.
(13) From Figure 15.
(14) From Figure 16.
(15) ((C8) - (C13))/C14).

Average settleable solids

Example

An example sediment pond evaluation is included to illustrate the use of GRASP. The example calculations are for a 12 inch trickle tube principal spillway set at an elevation of 14.5 feet. Additional information on this example is contained in Appendix B. The contents of registers 00 - 16 are:

Register	Variable	Contents	Register	Variable	Contents
00	I_s	2.1	09	E_s	11.5
01	Q_{vi}	5.13	10	V_s	1.35
02	$Q_{vi} - V_{op}$	5.13	11	E_p	14.5
03	Q_{pi}	49.4	12	V_p	2.43
04	C_{su}	256,000	13	E_1	17.0
05	C_{se}	0.5	14	V_1	3.85
06	A_p	0.46	15	E_2	19.0
07	H	0	16	V_2	5.10
08	C_1	1.0			

Executing GRASP with the above data produces the following results.

Step	Key	Output	Description
1	XEQ CSE1	2.12	H_t
2	R/S	0.59	P_f
3	R/S	3.89	H_t
4	R/S	0.44	P_f
5	R/S	3.77	H_t
6	R/S	0.44	P_f

The difference between H_t in step 3 and H_t in step 5 is less than 0.1 ft (actually 0.03 ft) and the initial routing using V_{rs} is complete. Also note that P_f is greater than 0.40 and H_t in step 5 is greater than the initial H_t (step 1) required to meet 0.5 ml/l.

7	XEQ ROUTE2	4.27	H_t
8	R/S	0.41	P_f
9	R/S	4.23	H_t
10	R/S	0.41	P_f

The difference between H_t in step 7 and H_t in step 9 is less than 0.1 ft (actually .04 ft) and the final routing using V_{rv} is completed. Note that only two iterations were required for the initial routing and only two iterations were required for the final routing.

11	XEQ CSE2	0.097	C_{se}

The predicted settleable solids concentration is 0.097 ml/l.

Average settleable solids

TABLE 1
GRASP Program Listing

```
              CAT 1
LBL'CSE1
END        41 BYTES
LBL'CRQR
LBL'TTQR
LBL'R
LBL'QR
LBL'ROUTE1
LBL'CRSQ
LBL'TTSQ
LBL'CRRF1
LBL'TTRF1
LBL'RTFN
LBL'PFRACT
LBL'DIA
END        419 BYTES
LBL'ROUTE2
END        125 BYTES
LBL'CRRF2
LBL'TTRF2
LBL'CRR12
LBL'CRR22
LBL'TTR12
LBL'TTR22
END        163 BYTES
LBL'CSE2
END        29 BYTES
LBL'CRSS
LBL'TTSS
LBL'SLSOLID
END        117 BYTES
LBL'ER1
LBL'ER2
LBL'ER3
LBL'ER4
LBL'ER5
LBL'ER6
END        102 BYTES
LBL'LDRG
END        30 BYTES
LBL'VWRG
END        29 BYTES
.END.      09 BYTES
```

```
01♦LBL "CSE1"
02 RCL 00
03 INT
04 1
05 -
06 STO 24
07 X=0?
08 XEQ "CRQR"
09 RCL 24
10 X>0?
11 XEQ "TTQR"
12 XEQ "ROUTE1"
13 END

01♦LBL "CRQR"
02 XEQ "R"
03 31
04 ST+ 30
05 XEQ "QR"
06 RTN
07♦LBL "TTQR"
08 XEQ "R"
09 36
10 ST+ 30
11 XEQ "QR"
12 RTN
13♦LBL "R"
14 .99901
15 STO 30
16 RTN
17♦LBL "QR"
18 RCL 05
19 1250
20 *
21 RCL IND 30
22 /
23 RCL 04
24 ISG 30
25 RCL IND 30
26 Y↑X
27 /
28 RCL 01
29 ISG 30
30 RCL IND 30
31 Y↑X
32 /
33 RCL 12
34 RCL 10
35 -
36 ISG 30
37 RCL IND 30
38 Y↑X
39 *
40 ISG 30
41 RCL IND 30
42 Y↑X
43 RCL 03
44 *
45 STO 17
46 RTN
47♦LBL "ROUTE1"
48 GTO 01
49♦LBL 02
50 RCL 24
51 X=0?
52 XEQ "CRSQ"
53 RCL 24
54 X>0?
55 XEQ "TTSQ"
56♦LBL 01
57 RCL 17
58 RCL 03
59 /
60 STO 18
61 1
62 -
63 X>0?
64 XEQ "ER6"
65 RCL 24
66 X=0?
67 XEQ "CRRF1"
68 RCL 24
69 X>0?
70 XEQ "TTRF1"
71 RCL 19
72 RCL 02
73 *
74 RCL 06
75 /
76 STO 20
77 STOP
78 XEQ "PFRACT"
79 GTO 02
80♦LBL "CRSQ"
81 XEQ "R"
82 XEQ "DIA"
83 20
84 *
85 39
86 +
87 ST+ 30
88 RCL 20
89 RCL 07
90 +
```

R31= 3.800-02
R32= 7.486-01
R33= 7.986-01
R34= 8.400-02
R35= 1.216+00
R36= 1.893-01
R37= 5.805-01
R38= 1.055+00
R39= 2.171-01
R40= 1.022+00
R41= 4.380-01
R42= 3.570+00
R43= 7.740-01
R44= 6.330+00
R45= 1.227+00
R46= 1.005+01
R47= 2.525+00
R48= 2.066+01
R49= 4.368+00
R50= 3.577+01
R51= 1.500+00
R52= 7.380-01
R53= 6.330-01
R54= 3.770+00
R55= 2.000+00
R56= 7.940-01
R57= 9.210-01
R58= 7.210+00
R59= 2.500+00
R60= 7.790-01
R61= 1.568+00
R62= 1.200+01
R63= 3.000+00
R64= 8.160-01
R65= 2.917+00
R66= 2.612+01
R67= 4.000+00
R68= 8.200-01
R69= 4.797+00
R70= 4.768+01
R71= 5.000-02
R72= 6.760-01
R73= 5.710-01
R74= 4.070-01
R75= 5.000-02
R76= 7.000-01
R77= 3.880-01
R78= 3.860-01
R79= 5.000-02
R80= 6.660-01
R81= 7.880-01
R82= 5.490-01
R83= 3.000-01
R84= 7.160-01
R85= 3.450-01
R86= 2.360-01
R87= 5.000-02
R88= 4.540-01
R89= 5.660-01
R90= 6.380-01
R91= 4.000-01
R92= 9.550-01
R93= 4.510-01
R94= 2.870-01
R95= 1.529+00
R96= 7.746-01
R97= 4.981-01
R98= 1.555+00
R99= 9.132-01
R100= 8.744-04
R101= 1.211+00
R102= 1.315+00
R103= 6.188-01
R104= 1.368+00
R105= 7.706-01
R106= 2.048-03
R107= 0.000+00
R108= 0.000+00
R109= 0.000+00
R110= "ERROR1"
R111= "ERROR2"
R112= "ERROR3"
R113= "ERROR4"
R114= "ERROR5"
R115= "ERROR6"

Average settleable solids

TABLE 2

Summary of Abbreviated Program and Subroutine Names

CSE1	-	Calculate Settleable Solids 1
CRQR	-	Conduit and Riser Discharge Ratio, Q_r
TTQR	-	Trickle Tube Discharge Ratio, Q_r
R	-	Indirect Register Constant
QR	-	Discharge Ratio, Q_r
ROUTE1	-	Initial Routing Using V_{rs}
CRSQ	-	Conduit and Riser Stage-Discharge
TTSQ	-	Trickle Tube Stage-Discharge
CRRF1	-	Conduit and Riser Routing Function 1
TTRF1	-	Trickle Tube Routing Function 1
RTFN	-	Routing Function
PFRACT	-	Principal Spillway Fractional Depth, P_f
DIA	-	Spillway Diameter
ROUTE2	-	Final Routing Using V_{rv}
CRRF2	-	Conduit and Riser Routing Function 2
TTRF2	-	Trickle Tube Routing Function 2
CRR12	-	Conduit and Riser Routing Function 1, 2
CRR22	-	Conduit and Riser Routing Function 2, 2
TTR12	-	Trickle Tube Routing Function 1, 2
TTR22	-	Trickle Tube Routing Function 2, 2
CSE2	-	Calculate Settleable Solids 2
CRSS	-	Conduit and Riser Settleable Solids
TTSS	-	Trickle Tube Settleable Solids
SLSOLID	-	Settleable Solids Calculation