United States
Department of
Agriculture

**Soil
Conservation
Service**

National Engineering Handbook

Section 3

Sedimentation

Chapter 8

Sediment—Storage Design Criteria

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Chapter 8 Sediment-Storage Design Criteria

General

For a reservoir to be fully effective, its capacity must be large enough to offset depletion by sediment accumulation during the reservoir's design life. This chapter describes the principles and procedures for designing sediment storage in reservoirs proposed for SCS watershed or other program work plans.

Form SCS–ENG–309, Reservoir Sedimentation Design Summary (fig. 8–1), has been prepared to facilitate recording and computing the data needed for design. Examples of how to complete this form are presented for several types of reservoirs. Methods and procedures referred to but not included in this chapter are to conform to national procedures or to procedures approved by the national technical center (NTC) sedimentation geologist.

Form SCS–ENG–309 should be completed by a geologist familiar with sedimentation processes. When the form is properly filled out, the design criteria for sediment storage have been met. A copy of the completed form should be filed with other design information for each reservoir. The data then are available for use in the final design of reservoirs proposed for SCS work.

Sediment Yield

The several methods of determining sediment yield or rate of sediment accumulation in reservoirs are discussed in Chapter 6.

Sediment Delivery Ratio and Gross Erosion

The method most often used in SCS work, especially in the more humid areas of the country, is to determine sediment yield from the gross (total) erosion and the sediment delivery ratio. It works well for estimating current sediment yield and predicting the effects of land treatment and other measures on future sediment yield.

Procedures for determining quantitative values for each type of erosion are outlined in Chapter 3. The sediment delivery ratio (ratio of sediment yield to gross erosion) is estimated from the relationships discussed in Chapter 6. The product of gross erosion and the sediment delivery ratio is the sediment yield used in computing the design requirements.

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RESERVOIR SEDIMENTATION DESIGN SUMMARY

WATERSHED ____________ SITE NO. ________ DRAINAGE AREA ________ Sq. Mi. ________ Acres

LOCATION ____________ STATE ________ PURPOSE ____________

DATA COMPUTED BY ____________ DATE ________

SEDIMENT YIELD BY SOURCES (AVERAGE ANNUAL)

		PRESENT CONDITIONS			FUTURE (AFTER CONS. TREATMENT)			
		ACRES	SOIL LOSS (TONS/AC)	TOTAL (TONS)	ACRES	SOIL LOSS (TONS/AC)	TOTAL (TONS)	
SHEET EROSION	CULTIVATED LAND							
	IDLE LAND							
	PASTURE - RANGE							
	WOODLAND							
			DELIVERY RATIO (%)		TONS DELIVERED	DELIVERY RATIO (%)		TONS DELIVERED
SHEET EROSION - TOTAL								
GULLY EROSION								
STREAMBANK EROSION								
FLOODPLAIN SCOUR								
CONSTRUCTION								
				TOTAL			TOTAL	

DEPOSITION

TEXTURE INCOMING SEDIMENT		
% CLAY	% SILT	% COARSE
VOLUME WEIGHT DEPOSITED SEDIMENT LBS/CU. FT.		
SUBMERGED		
AERATED		

SEDIMENT DELIVERED TO SITE (TONS/YR)		TRAP EFFICIENCY (%)	ANNUAL DEPOSITION (TONS)	DESIGN PERIOD (YRS)	PERIOD DEPOSITION (TONS)	SEDIMENT PASSING (TONS)
PRESENT						
FUTURE						
FUTURE						
			TOTALS			

SEDIMENT STORAGE REQUIREMENTS

CONDITION OF SEDIMENT	% OF TOTAL	DEPOSITION (TONS)	VOLUME WEIGHT	STORAGE REQUIRED		STORAGE ALLOCATION (ACRE FEET)		
			TONS/AC.FT.	ACRE-FEET	WATERSHED INCHES	SEDIMENT POOL	RETARDING POOL	OTHER
SUBMERGED								
AERATED								
	TOTALS							

Figure 8-1.—Summary sheet for reservoir sedimentation design.

Reservoir Sedimentation Surveys

Reservoir sedimentation surveys are excellent sources of data for establishing sediment yield to reservoirs (see Chapter 6, Measured Sediment Accumulation).

Results of available sedimentation surveys should be reviewed for design purposes. Miscellaneous Publication No. 1362 (Agricultural Research Service 1978) provides data obtained from many reservoir surveys. Information about the rates of sediment deposition in reservoirs typical of the area under consideration can be obtained from this publication. If no such information is available, it could be helpful to make sedimentation surveys of any reservoirs in the area. It is important that the sedimentation record for reservoirs surveyed or scheduled for survey be long enough to ensure that the data represent average conditions. It is also important to know the history of reservoirs considered for sedimentation surveys. Removal or drying of sediment and changes in spillway elevation affect volume and distribution of sediment.

In mountainous areas differences in sediment yield rates are often inconsistent with differences in size of drainage area. Also, if channel-type erosion increases downstream (for example, from main stem channel-bank cutting), the sediment yield rate may increase with increasing size of drainage area. Therefore, judgment must be used in establishing the relationship between sediment yield and size of drainage area.

Suspended-Load Records

Time seldom is available to establish a suspended-load station at a proposed site and obtain enough data before design information is required. If suspended-load records are available from nearby locations representative of the areas for which the information is required, however, these data can be useful (see p. 6–6).

Direct Predictive Equations

Predictive equations based on watershed and reservoir characteristics have been developed in some areas to estimate sediment yield or sediment accumulation in reservoirs. Such equations must be restricted to the specific area they represent.

The amount of sediment accumulation in a reservoir depends on the sediment yield to the reservoir and the trap efficiency. How the accumulated sediment is distributed within the reservoir depends on the character of the inflowing sediment, the operation of the reservoir, and other factors.

Trap Efficiency

Trap efficiency is the amount (percentage) of the sediment delivered to a reservoir that remains in it. It is a function of detention storage time, character of the sediment, nature of the inflow, and other factors. Trap efficiency can be readily estimated on the basis of the ratio of the capacity of the reservoir to the average annual inflow (Brune 1953, Gottschalk 1965) by using the following procedure:

1. Estimate the total capacity required of the reservoir in watershed inches (see page 8–13), including the total capacity allocated to floodwater detention, sediment storage, and other uses. Since an actual value cannot be obtained until final design is completed, estimate the total capacity as follows:
   a. Assume, for the particular physiographic area, a reasonable sediment-storage volume that might be required for the design life of the structure; e.g., 1.5 in.
   b. Obtain from the hydrologist an estimate of the required floodwater-detention storage; e.g., 4.5 in.
   c. Add the values for 1a and 1b to get an estimate of the total capacity of the reservoir; i.e., 1.5 + 4.5 = 6.0 in. Include any additional storage for water supply, recreation, and other uses in the total. If an estimate of the total required storage in acre-feet is available, convert this value to watershed inches to simplify the calculation.
2. Determine the average annual runoff in inches. This value can be determined from the hydrologic analysis of the watershed, from Hydrologic Investigation Atlas HA–212 (Busby 1966) or from other available information. In this example, the average annual runoff is 17.5 in.
3. Divide the aproximate total capacity in inches (item 1c) by the average annual runoff in inches (item 2) to obtain the capacity-inflow ratio (C/I); i.e., C/I = 6.0 ÷ 17.5 = 0.343.
4. Obtain the trap efficiency for a given C/I from the vertical scale of figure 8–2. To do so, estimate the texture of the incoming sediment on the basis of the character of watershed soils and the principal sediment sources. If the incoming sediment is predominantly bedload or coarse material or is highly flocculated, use the upper curve of figure 8–2 to determine trap efficiency. If the incoming sediment is primarily colloids, dispersed clays, and fine silts, use the lower curve. If the incoming sediment consists of various grain sizes widely distributed, use the median curve. The texure also affects the distribution and allocation of the sediment in various pools.

The curves in figure 8–2 cannot be applied directly to dry reservoirs. If water flows through ungated outlets below the crest of the principal spillway, trap efficiency is likely to be lowered. If the inflowing sediment is predominantly sand, reduce the trap efficiency by about 5 percent; if the sediment is chiefly fine textured, reduce the trap efficiency by about 10 percent.

If the incoming sediment is composed essentially of equal parts of clay, silt, and fine sand and the proposed structure is to have a submerged sediment pool, use the median curve of figure 8–2 without adjustment. In the example (C/I = 0.343) trap efficiency would be 95 percent. In a situation similar except that the structure is designed as a dry reservoir, trap efficiency would be 85 percent.

Design Life

The design life of a reservoir is the period required for the reservoir to fulfill its intended purpose. Structures designed by SCS in the watershed protection and flood prevention programs usually are designed for a life of 50 or 100 years. Provision must be made to ensure the full design storage capacity for the planned design life. This may mean cleaning out deposited sediment at predetermined intervals during the design life or, as is generally the situation, providing enough capacity to store all the accumulated sediment for the reservoir's design life without domininshing the design water storage.

Land treatment (conservation) measures seldom are fully effective in reducing erosion and sediment yield in less than 5 years. Often a longer time is required. This delay in effectiveness during the

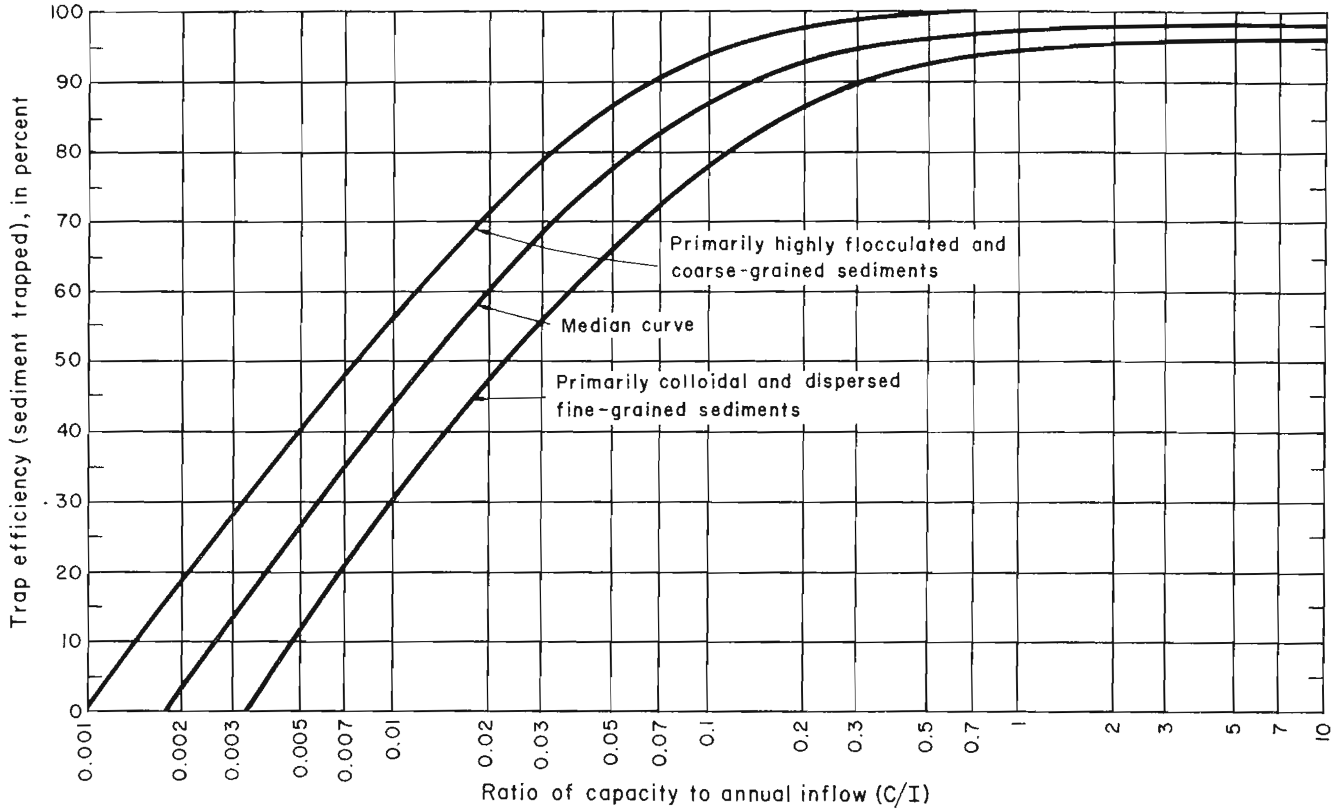

Figure 8-2.—Trap efficiency of reservoirs.

early part of a reservoir's life (Present Conditions on SCS-ENG-309) must be recognized in design. Determine, in consultation with the state program staff and the area and district conservationists, how many years will be required for the proposed land-treatment measures to be installed and become effective.

Distribution of Sediment

The total storage capacity of a reservoir must include capacity for all water storage plus capacity for the sediment expected to accumulate during the reservoir's design life. Consequently, the amount of sediment that will be deposited above the elevation designated for the sediment pool must be estimated. Such deposits may materially affect the proper functioning of the structure.

The amount of sediment that will be deposited above the principal spillway varies with the nature of the sediment, shape of the reservoir, topography of the reservoir floor, nature of the approach channel, detention time, and purpose of the reserovir. The coarse sediment settles quickly as the velocity of the water decreases. Generally, sediment inflow is greatest when detention capacity is being used and some sediment is deposited at elevations above the principal spillway. Usually, more coarse material than fine material is deposited above this elevation. The texture of the incoming sediment is the basis for estimating the percentage of incoming sediment that will be deposited above the elevation of the principal spillway. Use the following guidelines for estimating this percentage.

1. For watersheds of low to moderate relief in which the predominant sources of sediment are silty and clayey soils, sheet flow is the principal eroding agent, and the sediment is transported primarily in suspension: 10 percent.

2. For watersheds of low to moderate relief in which the incoming sediment consists of nearly equal amounts of medium to fine sands, silts, and clays; sheet flow and channel erosion are the principal agents; and the coarser material is

transported along the bed and the fine materials are transported in suspension: 20 percent.

3. For watersheds of moderately high relief in which channel-type erosion is the primary source of sediment, coarse sands and gravel transported as bedload make up a large part of the incoming sediment, and smaller amounts of fine-grained sediment are transported in suspension: 30 percent.

4. For watersheds of high relief in which the primary sediment load consists of boulders, cobbles, and sand: more than 30 percent.

Adjust these percentages upward or downward according to local watershed and reservoir conditions.

Capacity Requirements for Sediment

The incoming sediment that is deposited under water is called submerged sediment. The sediment deposited above the elevation of the principal spillway is subject to alternate wetting and drying and is called aerated sediment. Submerged sediment is the sediment in the sediment pool and aerated sediment is the sediment in the retarding pool in all single-purpose floodwater-retarding structures except dry reservoirs. In dry reservoirs all sediment is considered aerated.

The distinction between submerged sediment and aerated sediment is important in determining the capacity that each will displace. The volume occupied by the deposited sediment depends on its texture and whether it is submerged or aerated. If field measurements are not available, use table 8–1 as a guide to estimating the volume-weight of sediment in pounds per cubic foot.

Estimate the volume-weight of each kind of sediment according to whether it is submerged or aerated. Any sediment volume determined on the basis of aerated volume-weight retains that same volume even though the sediment may be submerged later.

Table 8–1.—Volume-weight of sediment by grain size

Grain size	Volume-weight of sediment	
	Submerged	Aerated
	lb/ft³	*lb/ft³*
Clay	35–55	55–75
Silt	55–75	75–85
Clay-silt mixtures (equal parts)	40–65	65–85
Sand-silt mixtures (equal parts)	75–95	95–110
Clay-silt-sand mixtures (equal parts)	50–80	80–100
Sand	85–100	85–100
Gravel	85–125	85–125
Poorly sorted sand and gravel	95–130	95–130

Sediment Storage Allocation

The required sediment storage must be allocated among the various reservoir pools. Certain design elevations and flood-routing procedures depend on the expected distribution of the sediment within the reservoir. Keep the following definitions in mind in making the allocations. *Sediment storage* is the volume allocated to the total accumulation of sediment. The *sediment pool* is the reservoir space allocated to the accumulation of submerged sediment during the design life of the structure. The *sediment pool elevation* is the elevation (on the stage-storage curve) corresponding to the expected volume of submerged sediment.

The following general guidelines will help in allocating the sediment storage in several situations. These guidelines are primarily for reservoirs in which most of the sediment is submerged. For structures designed as dry reservoirs, the same guidelines apply except that all the sediment is aerated.

Single-Purpose Floodwater-Retarding Reservoirs

Single-stage principal spillway.—The sediment-pool elevation is the crest elevation of the principal spillway. Since water is expected to fill this space until it is displaced by sediment, compute this sediment volume by using the submerged volume-weight. Compute the volume of the sediment expected in the retarding pool by using the aerated volume-weight.

Two-stage principal spillway.—The sediment-pool elevation is the elevation of the low-stage inlet of a two-stage principal spillway. Since water is expected to fill this space until it is displaced by sediment, compute this sediment volume by using the submerged volume-weight.

Some sediment is deposited between the elevations of the low-stage and high-stage inlets. Compute this sediment volume by using the aerated volume-weight. Compute the sediment volume expected in the retarding pool by using the aerated volume-weight.

Multiple-Purpose Reservoirs

The sediment pool volume in multiple-purpose reservoirs will be based on submerged volume-weight. Add the volume of beneficial water storage to that of the submerged sediment. Compute the sediment volume that will be deposited above the elevation of the principal spillway by using the aerated volume-weight.

Multiple-purpose structures can be designed with either a single-stage or a two-stage principal spillway. If a two-stage principal spillway is used, the sediment deposited between the elevations of the low- and high-stage inlets must be considered as well as that deposited above the elevation of the high-stage inlet. Compute the volume of this sediment by using the aerated volume-weight.

Other Procedures

Any procedures for allocating sediment storage capacity not specifically covered in this chapter should be developed in consultation with the st of the national technical centers (NTC's).

Certain background information is necessary for every reservoir being designed. Indicate the location of the structure on an aerial photograph, a U.S. Geological Survey quadrangle, or other suitable map so that the watershed, including any problem areas above the site, can be delineated and measured. Estimate the total reservoir capacity required for all purposes. Several major parts of Form SCS–ENG–309 are considered in the following paragraphs.

Heading

State the purpose of the reservoir as in these examples: single-purpose—flood prevention; multiple-purpose—flood prevention and water supply. Note any other pertinent information about the structure, such as single or two-stage riser, in the space to the left and below the heading. The rest of the information required in the heading is self-explanatory. A completed heading is shown in example 1.

Sediment Yield by Sources (Average Annual)

Gross Erosion and Sediment Delivery Ratios

Form SCS–ENG–309 was designed to show the relationship of gross erosion and sediment delivery ratios to sediment yield (see Chap. 6). Use this part of the form to record estimates of the erosion occurring in the drainage area of the reservoir and the sediment delivery ratios. Estimates of the annual amounts of erosion must be realistic and reasonable, for both "Present Conditions" and "Future (After Conservation Treatment)." Usually, these estimates are made by delineating problem areas in the drainage area and computing sheet erosion and other components of the total erosion individually. Separate worksheets are generally used for this purpose; therefore, enter only totals for each erosion component on the form. It is preferable, however, to show the acreage and rate of soil loss for each land use listed under "Sheet Erosion." Compute the "Soil Loss (tons/acre)" for sheet erosion according to the procedures in Chapter 3, using the guides and releases prepared by the NTC staffs. The basic information required for this computation can be obtained from soil survey data available in field offices or from supplementary investigations.

Compute the "Future (After Conservation Treatment)" estimates from the most realistic information available. Predictions of reductions in erosion rates from the various sediment sources should reflect the land treatment data provided by the district conservationist. These future reductions must be realistic.

Estimate the total amount of material eroded by channel-type processes (gullies, streambanks, etc.) for both present and future conditions on the basis of a field reconnaissance or detailed study with aerial photographs and soil survey data. The volume of sediment produced by gullying can be determined by the procedure given in Technical Release No. 32 (Soil Conservation Service 1966) or by those given in Chapter 3. Information concerning streambank erosion and flood-plain scour can be obtained from the flood-plain damage survey. If the streambed is degrading and is a source of sediment, plan the procedures for determining the annual amount of streambed erosion in consultation with the staff of the appropriate NTC. Enter the total amount of material eroded by channel-type

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RESERVOIR SEDIMENTATION DESIGN SUMMARY

WATERSHED Wett Creek SITE NO. 7 DRAINAGE AREA 3.44 Sq. Mi. 2,200 Acres

LOCATION 42°50'10",87°07'30"W STATE MY PURPOSE Single Purpose - FP

DATA COMPUTED BY A. Competent, Geologist DATE 7/4/82

Example 1.

obtain the erosion information with Form SCS–ENG–309 as supporting data.

See "Channel Erosion: Factors Involved" in Chapter 3 for information on estimating long-term streambank erosion.

Construction sites and strip-mine areas can be major sources of sediment. The effectiveness of erosion control measures must be evaluated realistically in estimating sediment yield from these areas.

In evaluating any probable construction during the project life, do not underestimate highway construction. During a 100-year project life, most highways will be rebuilt and major relocations and new construction are likely.

To complete this part of the form, estimate the sediment delivery ratios and the sediment yield to the structure site. For each erosion component, estimate the percentage of eroded material that reaches the site. Various guides for estimating sediment delivery ratios in terms of watershed characteristics have been prepared by the NTC's. Consult these guides, as well as those listed in Chapter 6, to obtain values to enter on the form. Each entry under "Tons Delivered" is the product of the total soil loss for one erosion component and the corresponding "Delivery Ratio (%)." Add the entries under "Tons Delivered" to get the sediment yields for "Present" and "Future" conditions.

If upstream structures control sediment, add the sediment passing these structures to the sediment yield (determined by the foregoing procedure) for the net uncontrolled drainage area. The expected effective life of the upstream structures (e.g., debris basins) must be considered.

Data from Reservoir Sedimentation Surveys

If the sediment yield rate determined from reservoir sedimentation surveys is used, enter the values as the total "Tons Delivered."

State on the form that sedimentation surveys were used to develop the values. Identify the source of the data and file all worksheets with the form.

Data from Suspended-Load Records

Enter sediment yield information obtained from suspended-load records in the same manner as information obtained from reservoir sedimentation surveys. State on the form that suspended-load records were used. File the supporting data, including identification of the stations used, with the form.

Data Developed by Direct Predictive Equations

If a predictive equation is used to determine sediment yield, enter the computed sediment yield in the appropriate spaces for total "Tons Delivered." Note the equation used on the form, and file the worksheets with the form.

A completed section "Sediment Yield by Sources (Average Annual)" is shown in example 2.

If future land use includes developments such as urbanization or strip mining, it may be necessary to subdivide "future" conditions to delineate the land-use changes. This can be done on Form SCS–ENG–309 by completing only the heading and sediment yield section on one form and then continuing on a second form. See example 3.

Texture and Volume-Weight

Enter the estimated texture of the incoming sediment in the spaces provided. Determine the volume-weight (pounds per cubic foot) for submerged and aerated sediment on the basis of the data from measured reservoir sediment samples or the estimated texture, using guidelines presented in table 8–1. Enter these values in the appropriate spaces.

Deposition

Use this section to compute the amount of sediment that will be deposited in the reservoir.

Sediment Delivered to Site (Tons/Yr)

Enter the sediment yield values (the total tons delivered) in the appropriate "Present" and "Future" spaces.

To allow for gradual improvement of watershed conditions during the installation period of land treatment measures and the period during which these measures become effective in reducing erosion, use an average of the calculated present and future rates of sediment yield for the "Present" value.

Trap Efficiency

Estimate trap efficiency on the basis of the discussions on page 8-4. Data now available are not sufficient to predict how increasing age of a reservoir affects trap efficiency. Use the same value for the trap efficiency of a given reservoir under both "Present" and "Future" conditions.

Annual Deposition (Tons)

"Annual Deposition (Tons)" is the product of "Sediment Delivered to Site (Tons/Yr)" and "Trap Efficiency (%)" for each line.

Design Period (Yrs)

The design period for "Present" conditions is the expected number of years required for the proposed land treatment measures to be installed and to become fully effective in reducing erosion and sediment yield.

Period Deposition (Tons)

"Period Deposition" is the product of "Annual Deposition" and the number of years in each design period. The sum of the "Period Deposition" values entered in the "Total" space of the "Period Deposition" column, represents the total amount of sediment, in tons, that will be deposited in the reservoir during the design life of the structure.

Sediment Passing (Tons)

"Sediment Passing" is the product of the sediment delivered to the site (tons/yr) and the number of years in the design period minus the deposition in the design period. Use the result as a basis for reporting the effects of structures on downstream sedimentation, for environmental impact statements, and for estimates of the reduction in sediment damage.

SEDIMENT YIELD BY SOURCES (AVERAGE ANNUAL)

		PRESENT CONDITIONS			FUTURE (AFTER CONS. TREATMENT)			
		ACRES	SOIL LOSS (TONS/AC)	TOTAL (TONS)	ACRES	SOIL LOSS (TONS/AC)	TOTAL (TONS)	
SHEET EROSION	CULTIVATED LAND 1/	540	18.5	2/ 9,990	500	12.9	2/ 6,450	
SHEET EROSION	IDLE LAND	150	8.1	1,215				
SHEET EROSION	PASTURE - RANGE	880	4.1	3,610	950	2.9	2,755	
SHEET EROSION	WOODLAND	630	2.3	1,450	750	1.5	1,125	
SHEET EROSION								
			DELIVERY RATIO (%)		TONS DELIVERED	DELIVERY RATIO (%)		TONS DELIVERED
SHEET EROSION - TOTAL			20	16,265	2/ 3,255	20	10,330	2/ 2,065
GULLY EROSION			80	6,600	5,280	80	3,160	2,530
STREAMBANK EROSION			90	1,200	1,080	90	1,200	1,080
FLOODPLAIN SCOUR								
CONSTRUCTION			50	2,000	1,000	50	800	400
				TOTAL	3/ 10,615		TOTAL	4/ 6,075

[1]Includes row crops, small grains, meadow.
[2]Product of proceding two columns rounded to nearest 5 tons.
[3]Enter under "Sediment Delivered to Site" in "Present" space of "Deposition" section.
[4]Enter under "Sediment Delivered to Site" in "Future" space of "Deposition" section.

Example 2.

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RESERVOIR SEDIMENTATION DESIGN SUMMARY

WATERSHED Wett Creek SITE NO. 7 DRAINAGE AREA 3.44 Sq. Mi. 2,200 Acres

LOCATION ____ STATE ____ PURPOSE Page 2 of 2

DATA COMPUTED BY A. Competent DATE 7/4/82

SEDIMENT YIELD BY SOURCES (AVERAGE ANNUAL)

		PRESENT CONDITIONS			FUTURE (AFTER CONS. TREATMENT)		
		ACRES	SOIL LOSS (TONS/AC)	TOTAL (TONS)	ACRES	SOIL LOSS (TONS/AC)	TOTAL (TONS)
SHEET EROSION	CULTIVATED LAND				400	11.7	4,680
	IDLE LAND						
	PASTURE - RANGE				950	2.9	2,755
	WOODLAND				750	1.5	1,125
					100		

	PRESENT DELIVERY RATIO (%)		PRESENT TONS DELIVERED	FUTURE DELIVERY RATIO (%)		FUTURE TONS DELIVERED
SHEET EROSION - TOTAL				20	8,560	1,710
GULLY EROSION				80	1,500	1,200
STREAMBANK EROSION				90	1,000	900
FLOODPLAIN SCOUR						
CONSTRUCTION				50	800	400
		TOTAL	xxx		TOTAL	4,210

Example 3.

As noted earlier, direct predictive equations can be used to determine sediment yields. Predictive equations are sometimes developed to estimate total deposition in a reservoir. Sediment yield, trap efficiency, and life of the reservoir usually are among the variables incorporated in these equations. If such an equation is used, enter only the estimated deposition and the sediment passing the site for the required time periods in the last two columns of this section.

Examples

Examples 4, 5, and 6 illustrate the use of this section of the form for several different situations.

DEPOSITION

TEXTURE INCOMING SEDIMENT 1/		
% CLAY	% SILT	% COARSE
30	40	30
VOLUME WEIGHT DEPOSITED SEDIMENT LBS/CU. FT.		
SUBMERGED	50	
AERATED	82	

	SEDIMENT DELIVERED TO SITE 2/ (TONS/YR)	TRAP 3/ EFFICIENCY (%)	ANNUAL 4/ DEPOSITION (TONS)	DESIGN PERIOD (YRS) 5/	PERIOD DEPOSITION 6/ (TONS)	SEDIMENT PASSING 7/ (TONS)
PRESENT	10,615	95	10,085	8	80,680	4,240
FUTURE	6,075	95	5,770	42	242,340	12,810
FUTURE						
			TOTALS	50	323,020	17,050

[1]See page 8–9.
[2]Sediment yield entries.
[3]See page 8–9.
[4]Product of [2] and [3] to nearest 5 tons.
[5]See page 8–10.
[6]Product of [4] and [5].
[7]See page 8–10.

Example 4. 50-Year-Life Reservoir

DEPOSITION

TEXTURE INCOMING SEDIMENT		
% CLAY	% SILT	% COARSE
30	40	30
VOLUME WEIGHT DEPOSITED SEDIMENT LBS/CU. FT.		
SUBMERGED	50	
AERATED	82	

	SEDIMENT DELIVERED TO SITE 1/ (TONS/YR)	TRAP EFFICIENCY (%)	ANNUAL DEPOSITION (TONS)	DESIGN PERIOD (YRS) 2/	PERIOD DEPOSITION (TONS)	SEDIMENT PASSING (TONS)
PRESENT	10,615	95	10,085	8	80,680	4,240
FUTURE	6,075	95	5,770	92	530,840	28,060
FUTURE						
			TOTALS	100	611,520	32,300

[1]Entries from "Sediment Yield."
[2]See page 8–10.

Example 5. 100-Year-Life Reservoir

DEPOSITION

TEXTURE INCOMING SEDIMENT		
% CLAY	% SILT	% COARSE
30	40	30
VOLUME WEIGHT DEPOSITED SEDIMENT LBS/CU. FT.		
SUBMERGED	50	
AERATED	82	

	SEDIMENT DELIVERED TO SITE [1] (TONS/YR)	TRAP EFFICIENCY (%)	ANNUAL DEPOSITION (TONS)	DESIGN PERIOD (YRS) [2]	PERIOD DEPOSITION (TONS)	SEDIMENT PASSING (TONS)
PRESENT	10,615	95	10,085	8	80,680	4,240
FUTURE	6,075	95	5,770	42	242,340	12,810
FUTURE	4,210	95	4,000	50	200,000	10,500
			TOTALS	100	523,020	27,550

[1]Entries from "Sediment Yield."
[2]See page 8–10.

Example 6. 100-Year-Life Reservoir–Major Land-Use Changes Expected During Second 50-Year Period

Sediment Storage Requirements

Use this section to estimate total amount and distribution of sediment storage capacity in the various pools of the reservoir.

Condition of Sediment

This column provides headings indicating whether the sediment is expected to be submerged or aerated.

Percent of Total

Use this column to record estimated percentages of the incoming sediment deposited in submerged and aerated environments. The values used should conform with the guidelines previously discussed.

Deposition (Tons)

In this column enter the estimated amount of sediment deposited (tons) previously recorded in the "Deposition" part of the form. Enter the total "Period Deposition" in the "Total" space of this column.

Multiply the total "Deposition" by the percentages to determine how many tons of sediment will be submerged and how many aerated. Enter these values in the appropriate spaces of this column.

Volume-Weight (Tons/Acre-Foot)

The sediment deposited in the reservoir must be expressed in terms of the volume it will displace. Convert the volume-weights entered in the small box "Volume-Weight, Deposited Sediment (lbs/cu.ft.)" to tons per acre-foot by multiplying them by 21.78.

Enter the values derived for both submerged and aerated sediment in the corresponding spaces of this column.

Storage Required

Determine the acre-feet of storage required by dividing "Deposition (Tons)" by the corresponding "Volume-Weight (Tons/Ac. Ft.)" for both sediment conditions. The sum of the values in this column is the total capacity required in the reservoir for sediment storage.

Use the column "Watershed Inches" to express the acre-feet of sediment shown in column 5, in equivalent watershed inches. Determine these values by using the following equation:

$$\text{Watershed inches} = 0.01875 \left(\frac{\text{acre-ft of sediment storage}}{\text{drainage area in sq miles}}\right)$$

Storage Allocation

Allocate the required sediment storage among the various pools in the reservoir. Use the guidelines previously discussed.

If equations have been used to predict the total sediment accumulation expected in a reservoir during its design life, enter the results in the total "Storage Required" space. Storage allocations can be made from this value. These equations sometimes predict the distribution and allocation of the deposited sediment. If so, enter the predicted allocations in the appropriate spaces. Note the use of such equations on the form and file with the form any sheets used in the computation.

Examples

Examples 7, 8, and 9 illustrate how the "Sediment Storage Requirements" part of the form was completed for three different designs.

SEDIMENT STORAGE REQUIREMENTS

CONDITION OF SEDIMENT 1/	% OF TOTAL 1/	DEPOSITION (TONS) 2/	VOLUME-WEIGHT 3/	STORAGE REQUIRED 4/		STORAGE ALLOCATION 5/ (ACRE-FEET)		
			TONS/AC.FT.	ACRE-FEET	WATERSHED INCHES	SEDIMENT POOL	RETARDING POOL	OTHER
SUBMERGED	80	258,415	1,089	237.3	1.29	237.3		
AERATED	20	64,605	1,786	36.2	0.20		36.2	
	TOTALS	323,020		273.5	1.49	6/ 237.3	7/ 36.2	

[1]See discussion, page 8–13.
[2]See page 8–13.
[3]See page 8–13.
[4]See page 8–13.
[5]Guidelines given on page 8–13.
[6]This capacity establishes the crest elevation of the principal spillway.
[7]Add this capacity to the required floodwater-retarding volume to establish the elevation of the emergency spillway.

Example 7. Single-Purpose Floodwater-Retarding Reservoir, 50-Year Design Life, Single-Stage Principal Spillway

SEDIMENT STORAGE REQUIREMENTS

CONDITION OF SEDIMENT	% OF TOTAL	DEPOSITION (TONS)	VOLUME WEIGHT	STORAGE REQUIRED		STORAGE ALLOCATION (ACRE-FEET)		
			TONS/AC.FT.	ACRE-FEET	WATERSHED INCHES	SEDIMENT POOL	RETARDING POOL	OTHER 1/
SUBMERGED	80	489,215	1,089	449.2	2.45	449.2		
AERATED	20	122,305	1,786	68.5	0.37		20.6	47.9
	TOTALS	611,520		517.7	2.82	2/ 449.2	3/ 20.6	4/ 47.9

[1]Retarding pool between low- and high-stage inlets.
[2]Establishes crest elevation of low-stage inlet.
[3]Add this volume to required retarding capacity above the elevation of the high-stage inlet to determine the elevation of the emergency spillway.
[4]Add this volume to the required retarding capacity between the low- and high-stage inlets to determine the elevation of the high-stage inlet.

Example 8. Single-Purpose Floodwater-Retarding Reservoir, 100-Year Design Life, Two-Stage Principal Spillway, 70 percent of aerated sediment below high-stage inlet

SEDIMENT STORAGE REQUIREMENTS

CONDITION OF SEDIMENT	% OF TOTAL	DEPOSITION (TONS)	VOLUME WEIGHT	STORAGE REQUIRED		STORAGE ALLOCATION (ACRE-FEET)		
			TONS/AC.FT.	ACRE-FEET	WATERSHED INCHES	SEDIMENT POOL	RETARDING POOL	OTHER 1/
SUBMERGED	80	489,215	1,089	449.2	2.45	382.2		2/ 67.0
AERATED	20	122,305	1,786	68.5	0.37		68.5	
	TOTALS	611,520		517.7	2.82	3/ 382.2	68.5	4/ 67.0

[1]Beneficial water storage.

[2]Allocate the part of submerged sediment to the beneficial storage pool in consultation with the national technical center sedimentation geologist.

[3]Submerged sediment in sediment pool.

[4]Submerged sediment deposited in capacity for beneficial use.

Note: Add the required capacity for beneficial use to the sum of [3] and [4] to determine the crest elevation of the principal spillway.

Example 9. Multiple-Purpose Reservoir, 100-Year Design Life

Computer Processing

If detailed erosion computations are made by use of the Universal Soil Loss Equation and other procedures, Form SCS–ENG–309 provides space for summary values only. Attach the detailed data and computations documentation to the form. An alternative procedure is computer processing.

Computer processing has the following advantages over hand computations:

1. All data are recorded in a standard format on data input forms and on computer data listings.
2. Procedures and equations are standardized.
3. The computer printout is an acceptable substitute for the data and computation documentation and the completed Form SCS–ENG–309.
4. The geologist is freed from time-consuming routine computations.
5. Computations are less subject to error.

The Appendix illustrates data input, data listing, and printout for one of the examples previously discussed. Details on computer processing capabilities are available from the NTC sedimentation geologists.

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Gottschalk, L.C. 1965. Trap efficiency of small floodwater-retarding structures. Am. Soc. Civ. Eng. Conf., Mar. 8–12. Mobile, Ala. Conf. Preprint 147.

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SCS-ENG-309A
JANUARY 1975

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

GROSS EROSION AND SEDIMENT YIELD
WATERSHED TITLE SHEET

SHEET 1 OF 5

WATERSHED NAME AND STATE	TOTAL ACRES 1/	DESIGN LIFE OF PROJECT (YEARS)	NUMBER OF FINAL SUBWATERSHED 2/	CARD NO.
SEDIMENT STORAGE PROCEDURE - EXAMPLE	———	100.	01	1

BY (NAME AND TITLE)	DATE		CARD NO.
A. COMPETENT GEOLOGIST	07/04/82		2

GENERAL INSTRUCTIONS

Card Numbers to be in consecutive numerical order, beginning with 1.

100. — Decimals are required for All numbers in "open" spaces.

7 3 — Do Not use decimals with numbers in "compartmented" spaces. Right justify numbers.

Cross out unused blanks of these forms.

INSTRUCTIONS FOR THIS FORM

1/ Insert 0. if watershed summary is Not desired.
2/ This number must be 50 or less.

SCS-ENG-309B
JANUARY 1975

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

GROSS EROSION AND SEDIMENT YIELD

SUBWATERSHED – GENERAL INFORMATION – DETAILED LAND USE

SHEET 2 OF 5

1 6 11 16 21 26 31 36 41 46 51 56 61 66 68 71 76 80

SITE NUMBER OR SUBWATERSHED DESIGNATION	PRESENT TRAP EFFICIENCY 1/	SUBWATERSHED DRAINAGE AREA (ACRES)	SHEET EROSION ACRES		SHEET EROSION DELIVERY RATIO %	UNIVERSAL RAINFALL FACTOR R	YEARS OF SEDIMENT STORAGE 3/	SUBWATERSHED	
			SUBWATERSHED TOTAL	SAMPLE TOTAL 2/				NO. 4/	CARD NO.
WETT CREEK W/S SITE NO. 7	——	2200.	2200.	220.	20.	100.	100.	01	3

NUMBER OF TIME PERIODS 5/	LENGTH OF TIME PERIODS (YEARS)							NO. OF SITES IN RELATED GROUP 6/	LIST SUBWATERSHED NUMBERS OF SUBWATERSHEDS IN SERIES IMMEDIATELY UPSTREAM 7/ 8/	CARD NO.
	FIRST	SECOND	THIRD	FOURTH	FIFTH	SIXTH	SEVENTH			
2	8.	92.	——	——	——	——	——	——	——	4

1/ USE 0. IF PRESENT TRAPPING EFFECT IS ZERO. USE ACTUAL TRAP EFFICIENCY (AS WHOLE NUMBER PERCENT) IF THIS IS AN EXISTING LAKE OR SWAMP.

2/ IF "SAMPLE TOTAL" IS SAME AS "SUBWATERSHED TOTAL". DO NOT ENTER "SAMPLE TOTAL".

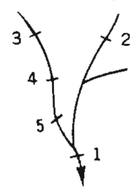
3/ USE 0. IF SEDIMENT STORAGE COMPUTATIONS ARE NOT DESIRED.

4/ THIS NUMBER MUST BE 50 OR LESS.

5/ IF "NUMBER OF TIME PERIODS" IS GREATER THAN 2, USE FORMS G AND H INSTEAD OF C AND D.

6/ SOIL LOSS, SEDIMENT YIELD, AND SEDIMENT STORAGE, FOR EACH SUBWATERSHED IN THE GROUP, WILL BE DETERMINED BASED ON RATES COMPUTED FOR THE SUBWATERSHED DESIGNATED ON THE LINE ABOVE. SEE FORM F.

7/ FOR SUBWATERSHEDS IN SERIES UPSTREAM SUBWATERSHEDS MUST BE PROCESSED FIRST, AS IN THE EXAMPLE AT RIGHT.



SUBWATERSHED 3: NONE IN SERIES ABOVE (MUST BE PROCESSED BEFORE NO. 4)
SUBWATERSHED 2: NONE IN SERIES ABOVE (MUST BE PROCESSED BEFORE NO. 1)
SUBWATERSHED 4: NO. 3 IS IN SERIES ABOVE (MUST BE PROCESSED BEFORE NO. 5)
SUBWATERSHED 5: NO. 4 IS IN SERIES ABOVE (MUST BE PROCESSED BEFORE NO. 1)
SUBWATERSHED 1: NO. 2 AND NO. 5 ARE IN SERIES ABOVE (MUST BE PROCESSED LAST)

8/ IF ANY BEDLOAD ENTERS THIS SUBWATERSHED FROM UPSTREAM SUBWATERSHEDS, A BEDLOAD DELIVERY RATIO MUST BE ENTERED ON FORM D, LINE 8.

SCS-ENG-309C
JANUARY 1975

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

GROSS EROSION AND SEDIMENT YIELD

SUBWATERSHED – SHEET EROSION DATA

SHEET 3 OF 5

LAND USE CONTROL WORD	SOIL NAME (IF APPLICABLE)	UNIVERSAL SOIL LOSS EQUATION					ACRES			CARD NO.
		K	C	SLOPE (%)	SLOPE LENGTH (FT.)	PRACTICE FACTOR 1/	PRESENT	FUTURE		
CULTIVATED	NATELY	.185	1.	9.	72.6	—	54.	0.		5
CULTIVATED	DANEEKA	.25	.516	9.	72.6	—	0.	50.		6
IDLE	ORR	.2	1.	9.	72.6	.405	15.	0.		7
PASTURE	DREEDLE	.41	1.	9.	72.6	.1	88.	0.		8
PASTURE	DUCKETT	.2	.145	9.	72.6	—	0.	95.		9
WOODLAND	AARDVARK	.2	1.	9.	72.6	.115	63.	0.		10
WOODLAND	CATHCART	.3	.5	9.	72.6	.1	0.	75		11
ENDLIST										12

Allowable Land use control words: (Do Not Abbreviate)

CULTIVATED
IDLE
PASTURE
RANGE
WOODLAND
ENDLIST

Each land use control word may be used as often as needed except "Endlist" which must be used only once (following the final data line).

1/ "P" Factors of 1. need not be entered.

GROSS EROSION AND SEDIMENT YIELD

SUBWATERSHED – – EROSION DATA (EXCEPT SHEET EROSION)

SHEET 4 OF 5

1	11	21	36	46	51	61	76	80

TYPE OF EROSION AND UNITS	AVERAGE ANNUAL RATE	DELIVERY RATIO %	ACRES, BANK MILES, OR TONS (USE ACTUAL UNITS, NOT A SAMPLE) PRESENT	FUTURE		CARD NO.
~~GULLY EROSION (T ACRE)~~						
~~FLOOD PLAIN SCOUR (T ACRE)~~						
~~URBANIZED (T ACRE)~~						
~~URBANIZING (T ACRE)~~						
~~MINE SPOIL (T ACRE)~~						
ROADBANK (T BANK MILE)	50.	50.	40.	16.		13
STREAMBANK (T BANK MILE)	20.	90.	60.	60.		14
~~BEDLOAD (TONS)~~			~~1.~~	~~1.~~		
OTHER (SPECIFY)						
GULLYS (TONS)	1.	80.	6600. ✗	3160. ✗		15
~~NON-SEDIMENT (CONTRIBUTING AREAS)~~	~~0.~~	~~0.~~				
ENDLIST						16

Rule out lines for all erosion categories not used.

CARDPUNCH OPERATOR: DO NOT PUNCH CHARACTERS IN PARENTHESES

SCS-ENG-309E
JANUARY 1975

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

GROSS EROSION AND SEDIMENT YIELD

SEDIMENT STORAGE 1/

SHEET 5 OF 5

1	11	21	31	41	51	61	66	76	80

SEDIMENT STORAGE OPTIONS 2/ FOR A PROPOSED DAM SITE						% OF AERATED SED. BTW. HI-LO STAGES PS	% OF SUBM. SED. IN BENEF. POOL		CARD NO.
SINGLE PURPOSE				MULTI-PURPOSE					
NORMAL POOL		DRY DAM							
TRAP EFFICIENCY	% SED. SUBMERGED	TRAP EFFICIENCY	% SED. SUBMERGED	TRAP EFFICIENCY	% SED. SUBMERGED				
95.	80.	—	—	—	—	70.	—		17

VOLUME - WEIGHT OF - SEDIMENT (LBS./CU. FT.)		TEXTURE OF INCOMING SEDIMENT					CARD NO.
SUBMERGED	AERATED	% CLAY	% SILT	% SAND	% GRAVEL		
50.	82.	30.	40.	20.	10.		18

1/ FOR THE SITE ON THE PRECEEDING FORMS B, C, AND D.

2/ IF SEDIMENT ROUTING FOR THE WATERSHED IS SPECIFIED ON FORM A, SELECT ONLY ONE OF THESE THREE OPTIONS. IF SEDIMENT ROUTING IS NOT SPECIFIED ON FORM A, YOU MAY SPECIFY ANY ONE, ANY TWO, OR ALL THREE SEDIMENT STORAGE OPTIONS.

```
SEDIMENT STORAGE PROCEDURE - EXAMPLE                              100. 01
A. COMPETENT         GEOLOGIST     07/04/82
WETT CREEK W/S SITE NO. 7      2200.      2200.      220.  20. 100. 100. 010
 2   8.   92.
CULTIVATED  NATELY         .185 1.    9.    72.6        54.        0.
CULTIVATED  DANEEKA        .25  .516 9.    72.6        0.         50.
IDLE        ORR            .2   1.    9.    72.6 .405 15.        0.
PASTURE     DREEDLE        .41  1.    9.    72.6 .1   88.        0.
PASTURE     DUCKETT        .2   .145 9.    72.6        0.         95.
WOODLAND    AARDVARK       .2   1.    9.    72.6 .115 63.        0.
WOODLAND    CATHCART       .3   `.5   9.    72.6 .1   0.         75.
ENDLIST
ROADBANK                          50.        50.  40.        16.
STREAMBANK                        20.        90.  60.        60.
        GULLYS                    1.         80.  6600.      3160.
ENDLIST
95.      80.                                                 70.
50.      82.      30.      40.      20.      10.
```

EXECUTE DATE 07/26/82

SEDIMENT STORAGE PROCEDURE - EXAMPLE BY A. COMPETENT GEOLOGIST 07/04/82

GROSS EROSION AND SEDIMENT YIELD FOR

WETT CREEK W/S SITE NO. 7 2200. ACRES (3.44 SQUARE MILES)

SEDIMENT YIELD BY SOURCES (AVERAGE ANNUAL)

FIRST 8.0 YEARS

	ACRES	SOIL LOSS (T/AC)	TOTAL SOIL LOSS (TONS)	DEL. RATIO (PCT)	SEDIMENT YIELD (TONS)
CULTIVATED	540.	18.50	9990.	20.	1998.
IDLE	150.	8.10	1215.	20.	243.
PASTURE	880.	4.10	3608.	20.	722.
WOODLAND	630.	2.30	1449.	20.	290.
ROADBANK	40.	50.00	2000.	50.	1000.
STREAMBANK	60.	20.00	1200.	90.	1080.
GULLYS		1.00	6600.	80.	5280.
NON-SEDIMENT CONTRIBUTING	0.				
TOTAL ACRES	2200.				
ANNUAL TOTALS			26062.		10612.
PERIOD TOTALS			208496.		84899.

YEARS 8.1 THROUGH 100.0

	ACRES	SOIL LOSS (T/AC)	TOTAL SOIL LOSS (TONS)	DEL. RATIO (PCT)	SEDIMENT YIELD (TONS)
CULTIVATED	500.	12.90	6450.	20.	1290.
IDLE	0.	0.0	0.	20.	0.
PASTURE	950.	2.90	2755.	20.	551.
WOODLAND	750.	1.50	1125.	20.	225.
ROADBANK	16.	50.00	800.	50.	400.
STREAMBANK	60.	20.00	1200.	90.	1080.
GULLYS		1.00	3160.	80.	2528.
NON-SEDIMENT CONTRIBUTING	0.				
TOTAL ACRES	2200.				
ANNUAL TOTALS			15490.		6074.
PERIOD TOTALS			1425077.		558807.

ROADBANK UNITS (IN ACRES COLUMN) ARE BANK MILES
STREAMBANK UNITS (IN ACRES COLUMN) ARE BANK MILES
GULLYS HAS NO AREA OR LENGTH UNITS

GROSS EROSION IS 1633572. TONS (4752. TONS/SQ MI/YR)
SEDIMENT YIELD IS 643706. TONS (1873. TONS/SQ MI/YR)
DELIVERY RATIO IS 39. PER CENT

EXECUTE DATE 07/26/82

SEDIMENT STORAGE PROCEDURE - EXAMPLE   BY A. COMPETENT   GEOLOGIST   07/04/82

SEDIMENT STORAGE FOR

WETT CREEK W/S SITE NO. 7   2200. ACRES (3.44 SQUARE MILES)

FOR A SINGLE-PURPOSE FLOODWATER DAM WITH NORMAL POOL FOR 100.0 YEARS

TRAP EFFICIENCY IS 95. PERCENT
SEDIMENT IS 80. PERCENT SUBMERGED AND 20. PERCENT AERATED

	TONS	ACRE FEET	W/S INCHES
SUBMERGED SEDIMENT	489217.	449.2	2.45
AERATED SEDIMENT	122304.	68.5	0.37
TOTAL STORED	611521.	517.7	2.82

47.9 ACRE FEET (70. PER CENT) OF THE AERATED SEDIMENT IS BETWEEN P.S. HIGH AND LOW STAGES

TEXTURE OF INCOMING SEDIMENT
- 30. PERCENT CLAY
- 40. PERCENT SILT
- 20. PERCENT SAND
- 10. PERCENT GRAVEL

DENSITY OF SUBMERGED SEDIMENT IS 50. PCF

DENSITY OF AERATED SEDIMENT IS 82. PCF

SEDIMENT PASSING THE SITE IS 32185. TONS