SEDIMENT STORAGE REQUIREMENTS FOR RESERVOIRS

All sediment sources must be considered when determining sediment storage requirements for reservoirs. The most common sources are sheet and rill erosion. Gully erosion, valley trenching, streambank erosion, floodplain scour, and roadside erosion can be significant sources.

Form Iowa-PDM-1 is used for computing average annual soil loss from sheet and rill erosion. Instructions for preparation of Form Iowa-PDM-1 are found on the reverse side of the form and in Part 504, Subpart C, National Watersheds Manual. Soil loss from sheet and rill erosion is evaluated using the Universal Soil Loss Equation (USLE). C values for cropland, pastureland, rangeland, woodland, and idle land and other factors to be used in the USLE are found in Section I-C-1, Field Office Technical Guide.

Special erosion hazards that are not included in the soil loss calculations must be considered. These may include waterways in poor condition, gullying, roadside erosion, large areas of inadequate vegetative cover, streambank erosion, and floodplain scour. The volume of sediment from gully erosion and other sources will be evaluated with guidance from the geologist.

Field studies and observations show that only a part of the sediment removed by sheet erosion may actually travel very far from its source. Some of it may deposit on flatter areas, along fences, roads, waterways, and on the floodplains of the larger streams. The amount of sediment which reaches a given point downstream (sediment yield) will be influenced by such factors as soil texture; travel distance; relative velocities; shape, size and topography of the watershed; the extent of gully development; and character and distribution of cover. If the floodplain is narrow with a drainageway extending to the foot of steeper sloping areas, the percent of sediment delivered to the reservoir may be relatively large. If the floodplain is wide or is covered with heavy vegetation, a large part of the sediment load will drop before reaching the reservoir.

Form SCS-ENG-309 has been prepared to facilitate recording and computing the volume of sediment accumulation and its allocation above and below the crest elevation of the principal spillway. This form can be prepared for each reservoir that is being designed. It must be used for each reservoir with drainage area greater than 250 acres and for reservoirs governed by Technical Release 60 (TR-60).

The gross or total erosion in the drainage area of a reservoir is the summation of all erosion occurring in the drainage area. The sediment delivery ratio (the ratio in percent of sediment delivered to the reservoir to gross erosion) is estimated from Figure 1. The predominant texture of the sediment should be used in making this estimate.

Factors affecting sediment yield cited above should be taken into consideration when estimating the sediment delivery ratio. **An appropriate adjustment should be made in the ratio if any of these factors significantly differ from an average condition.**

Since sheet erosion estimates are based on plot data, the estimated sediment delivered to the site from sheet and rill erosion will be increased by the product of the tons delivered from this source and the following sheet erosion factors:

LRA	Sheet Erosion Factor
102 and 107	0.5
All Others	0.3

Terraced fields, where terraces are in good conditon and well maintained, may be given credit for sediment control in lieu of that computed from USLE as follows:

1. Graded terraces - 20% of soil loss in terrace interval but with a minimum of 1 ton/acre/year leaving the field.

2. Open end level terraces - 15% of soil loss in terrace interval but with a minimum of 1 ton/acre/year leaving the field.

3. Closed end level and tile outlet terraces - 10% of soil loss in terrace interval but with a minimum of 1 ton/acre/year leaving the field.

The trap efficiency is the amount (in percent) of the sediment delivered to the site that will remain in the reservoir. It is a function of detention storage time, character of the sediment, nature of the inflow, and other factors. Trap efficiency is estimated on the basis of the ratio of the capacity of the reservoir to the average annual inflow by using the following procedure:

1. Estimate the total capacity required of the reservoir in watershed inches, 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 drainage area, a reasonable sediment storage volume that might be required for the design life of the structure; e.g. 1.5 inches.

   b. Obtain from the preliminary design an estimate of the required floodwater detention storage; e.g. 4.5 inches.

   c. Add the values for 1a and 1b to get an estimate of the total capacity of the reservoir; i.e. 6.0 inches. 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 from Figure 3. In this example, the average annual runoff is 7.0 inches.

3. Divide the approximate 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 = 6.0/7.0 = 0.86.

4. Obtain the trap efficiency for a given C/I from the vertical scale of Figure 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 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 texture also affects the distribution and allocation of the sediment in various pools.

The curves in Figure 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 5 percent; if the sediment is chiefly fine textured, reduce the trap efficiency by 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 2 without adjustment. In the example (C/I = 0.86) trap efficiency would be 96 percent. In a situation similar except that the structure is designed as a dry reservoir, trap efficiency would be 86 percent.

For water impounding structures, provide sediment storage below the crest for 70% or more of the total sediment deposition by weight. Since sediment will accumulate on a gradient above the inlet, storage capacity will be provided above the crest for 10% or more of the total sediment deposition. The portion of sediment storage allocated above the crest may vary from 10% to 30% of the sediment deposition depending on individual site conditions. Sediment storage above the crest shall be deducted from total available storage in order to determine the volume remaining for temporary water storage. The total sediment storage volume may be allocated above the crest for dry reservoirs.

When computing sediment storage requirements, the sediment in tons deposited in the reservoir must be expressed in terms of the volume it will displace. The volume in acre-feet of sediment storage required is obtained by dividing the "Deposition (Tons)" by the corresponding "Volume Weight (Tons/Acre-Foot)" for both aerated and submerged sediment. The volume weight is obtained from Figure 4.

Example

Given: Drainage Area - 228 Acres (0.36 sq. mi.) (TR-60 governs)
Soil Types, slopes and land uses as shown on attached Form Iowa-PDM-1. LRA 107, Northwest Page County, 50-year useful life.

Steps in preparing Form SCS-ENG-309:

1. Determine the material eroded by sheet erosion frm the total drainage area above the structure using form Iowa-PDM-1 = 630 tons. It is preferable to show acreages and total soil losses on SCS-ENG-309 for each applicable land use listed under "Sheet Erosion".

2. Estimate the delivery ratio from Figure 1. For a drainage area of 0.36 square miles and silty clay soils, the delivery ratio is 64% for sheet erosion. Sediment delivered to reservoir from sheet erosion = (630)x(0.64) = 403 Tons.

3. Data for estimating sediment yield from gully erosion is obtained from surveys and estimate of annual rate of gully growth. In this example gully growth produces 1068 tons of sediment per year. The project will control 90% of the gully growth. Sediment delivered to the reservoir from gully erosion will vary from 80% to 100%. Sediment yield from gully erosion with project = (1068)x(0.10) = 107 Tons. Delivered to reservoir = (107)x(1.00) = 107 Tons. All other sources of erosion must also be estimated, but for this example there are none.

4. Multiply the total tons delivered from sheet erosion by the sheet erosion factor from Page IA11-10(2). Since this example is in LRA 107, multiply by 0.5. (403)x(0.5) = 202 Tons.

5. Total Sediment Delivered to Site is equal to the total of the Tons Delivered column. 403 + 107 + 202 = 712 Tons.

6. Trap efficiency is estimated using the procedure outlined above and Figures 2 and 3. In this example:

   Average Annual Runoff = I = 4.9 Inches
   Estimated Sediment Storage = 1.5 Inches
   Estimated Floodwater Detention Storage = 3.0 Inches
   Total Reservoir Capacity = C = 4.5 Inches
   C/I = 4.5/4.9 = 0.92
   From the Median Curve, Figure 2, Trap Efficiency = 97%

7. Annual Deposition = (Sediment Delivered)x(Trap Efficiency) = (712)x(0.97) = 691 Tons.

8. Period Deposition = (Annual Deposition)x(Design Period) = (691)x(50) = 34,550 Tons.

9. Sediment Passing = (Sediment Delivered to Site)x(Design Period) - (Period Deposition) = (712)x(50) - (34,550) = 1,050 Tons.

10. Allocate sediment storage in the reservoir. The portion of sediment storage allocated below the principal spillway crest will be submerged; the portion above the crest will be aerated. For this example, allocate 80% of the sediment deposition below crest. Volume weight of sediment is obtained from Figure 4.

Watershed Analysis Worksheet

Iowa PDM-1 3/82
(File Code 390-11-3-20)

Watershed Name *Clear Creek*
Site Number *M-1*
Township *Pierce* Sec. *9*

Total Acres *228*

Date *5-13-86*
Prepared By *VHS*
Rainfall Factor *175*

		Present Conditions										Projected Conditions									
Land Use		Rotation % Residue	K	Slope Length Feet	% Slope	Length Steep Ratio	C	P	Tons Per Acre	Acre	Total Tons	Rotation % Residue	K	Slope Length Feet	% Slope	Length Steep Ratio	C	P	Tons Per Acre	Acre	Total Tons
Pasture & Hayland			.28	250	12	2.8	.013	1	1.8	12	22										
Farmsteads									4	8	32										
Roads									5	6	30										
Woodland			.28	100	3	.29	.011	1	.16	22	4										
Wildlife																					
Cropland	A & B	ContC	.28	150	3	.32	.33	.5	2.6	17	45										
Cropland	A&B Terraced	CCOM	.32	240	3	.37	.12	.45	1.2	38	46										
Cropland	C																				
Cropland	C-Terraced	COM	.28	120	8	1.0	.08	.45	1.8	86	155										
Cropland	D	CCCOM	.32	200	10	2.0	.16	.6	10.8	22	238										
Cropland	D-Terraced	CCOM	.28	105	11	1.6	.12	.36	3.4	17	58										
Cropland	E																				
Cropland	E-Terraced																				
Cropland	F																				
Other (Specify)																					
Remarks									Total	228	630	Remarks							Total		
									90% Acres Tolerant	206									Acres Tolerant		

Remarks:
Spring plow all cropland
All cropland contoured

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SCS-ENG-309
02-85

RESERVOIR SEDIMENTATION DESIGN SUMMARY

WATERSHED *Clear Creek* SITE NO. *M-1* DRAINAGE AREA *0.36* Sq. Mi. *228* Acres

LOCATION *Page Co.* STATE *Iowa* PURPOSE *Grade Stab*

DATA COMPUTED BY *VHS* DATE *5-13-86*

SEDIMENT YIELD BY SOURCES (AVERAGE ANNUAL)

		PRESENT CONDITIONS			FUTURE (AFTER CONS. TREATMENT)			
		ACRES	SOIL LOSS (TONS/AC)		ACRES	*Soil Loss (T/Ac)*	TOTAL (TONS)	
SHEET EROSION	CULTIVATED LAND				180	4.6	542	
	IDLE LAND							
	PASTURE - RANGE				12	1.8	22	
	WOODLAND				22	0.16	4	
					14	4.4	62	
			DELIVERY RATIO (%)		TONS DELIVERED	DELIVERY RATIO (%)		TONS DELIVERED
SHEET EROSION - TOTAL						64	630	403
GULLY EROSION *10% remaining*				1,068		100	107	107
STREAMBANK EROSION								
FLOODPLAIN SCOUR								
CONSTRUCTION								
Sheet Erosion Factor			*(0.5)(403)*					202
				TOTAL			TOTAL	712

DEPOSITION

% 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	712	97	691	50	34,550	1,050
FUTURE						
				50	34,550	1,050

SEDIMENT STORAGE REQUIREMENTS

CONDITION OF SEDIMENT	% OF TOTAL	DEPOSITION (TONS)	VOLUME WEIGHT TONS/AC.FT.	STORAGE REQUIRED ACRE-FEET	STORAGE REQUIRED WATERSHED INCHES	STORAGE ALLOCATION (ACRE FEET) SEDIMENT POOL	RETARDING POOL	OTHER
SUBMERGED	80	27,640	1307	21.1	1.11	21.1		
AERATED	20	6,910	1742	4.0	0.21		4.0	
	TOTALS	34,550		25.1	1.32	21.1	4.0	

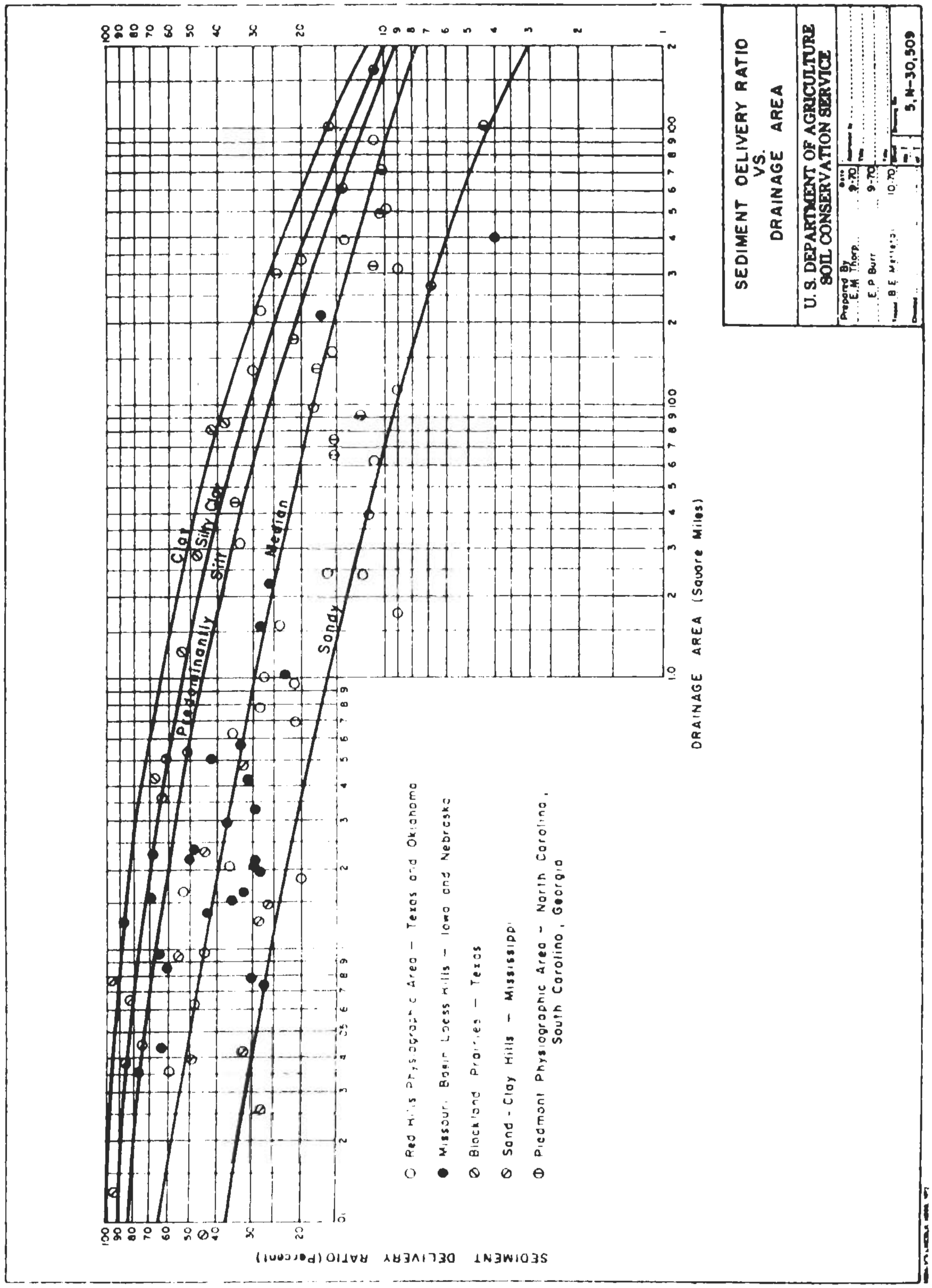

Figure 1. Sediment Delivery Ratio vs. Drainage Area

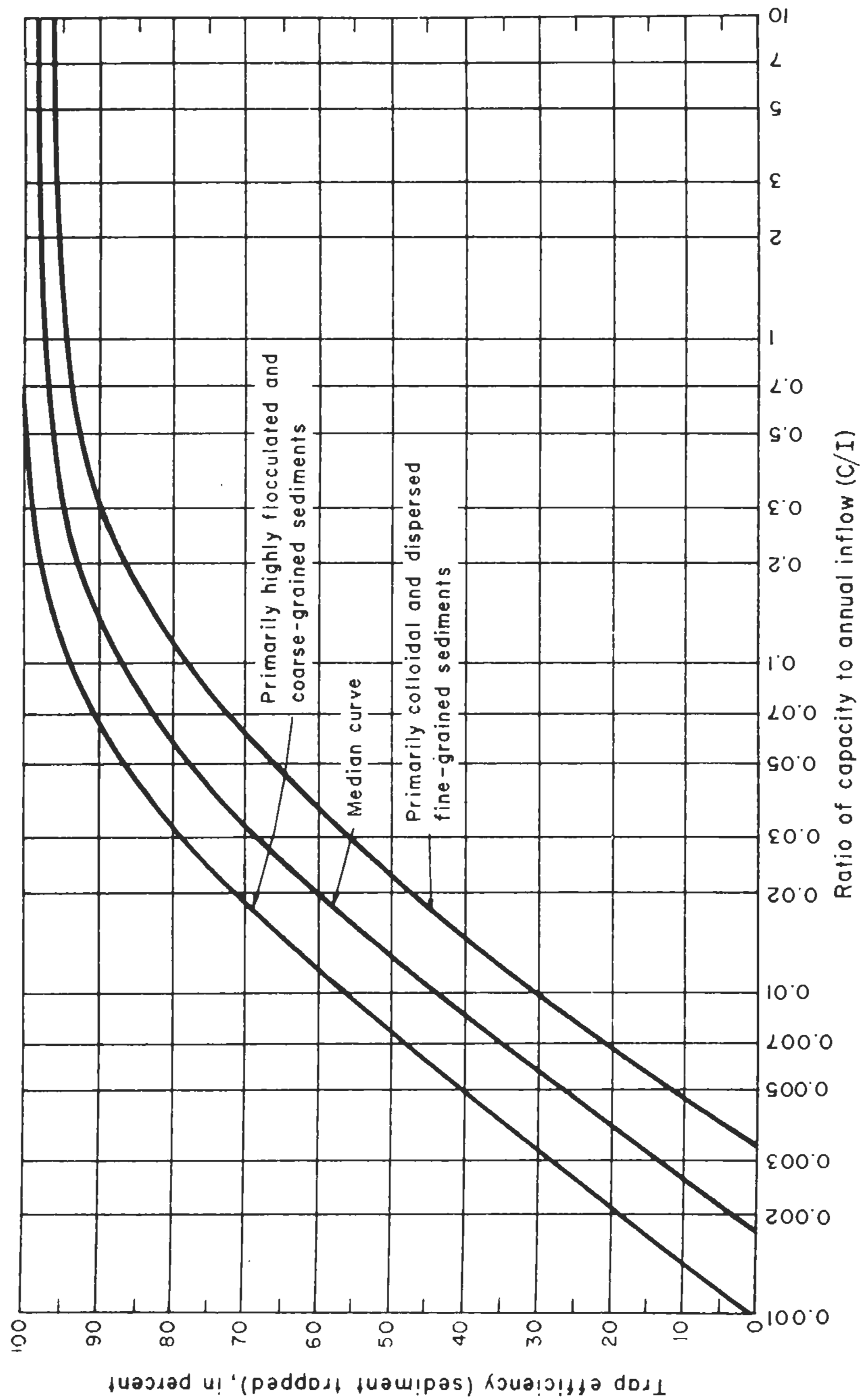

Figure 2. Trap Efficiency of Reservoirs

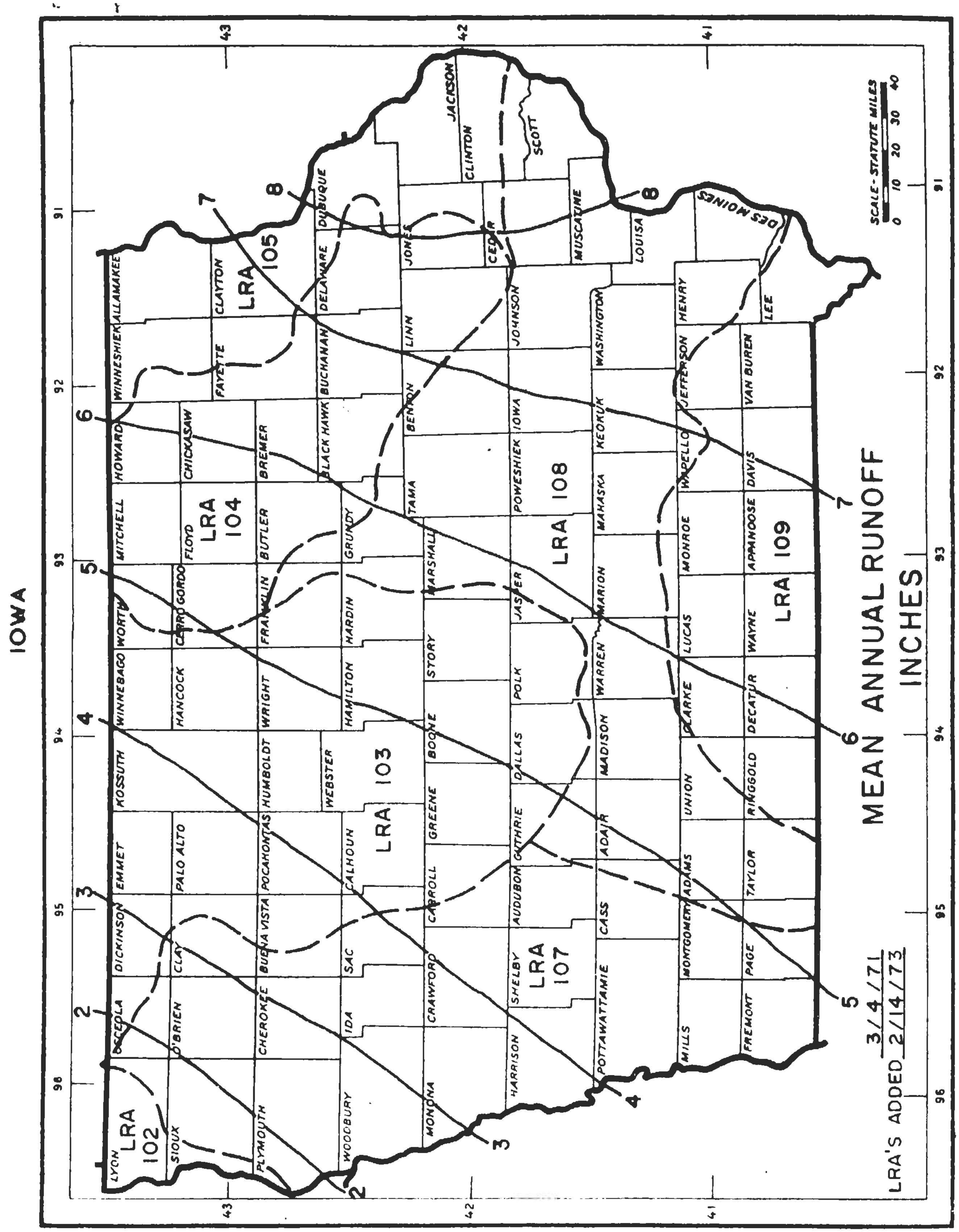

Figure 3. Mean Annual Runoff in Inches

VOLUME WEIGHT FACTOR

Lbs. Per Cu. Ft.	Tons Per Ac. Ft.	Ac. Ft. Per Ton	Ac. In. Per Ton	Tons Per Ac. In.
55	1198	.00084	.01002	99.83
* 60	1307	.00077	.00918	108.90
65	1415	.00071	.00847	117.98
70	1525	.00066	.00787	127.05
75	1634	.00061	.00734	136.13
** 80	1742	.00057	.00689	145.20
85	1851	.00054	.00648	154.28
110	2396	.00042	.00500	199.65
120	2614	.00038	.00460	217.80

* Most commonly used for submerged fine-grained sediment.

** Most commonly used for aerated fine-grained sediment.

Figure 4. Volume Weight Factor