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VIDEO TAPE SEMINAR

HEC-6

Scour and Deposition in Rivers and Reservoirs

U.S. Army Corps of Engineers

prc

PRC Toups

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VIDEO TAPE SEMINAR

HEC-6

Scour and Deposition in Rivers and Reservoirs

U.S. Army Corps of Engineers

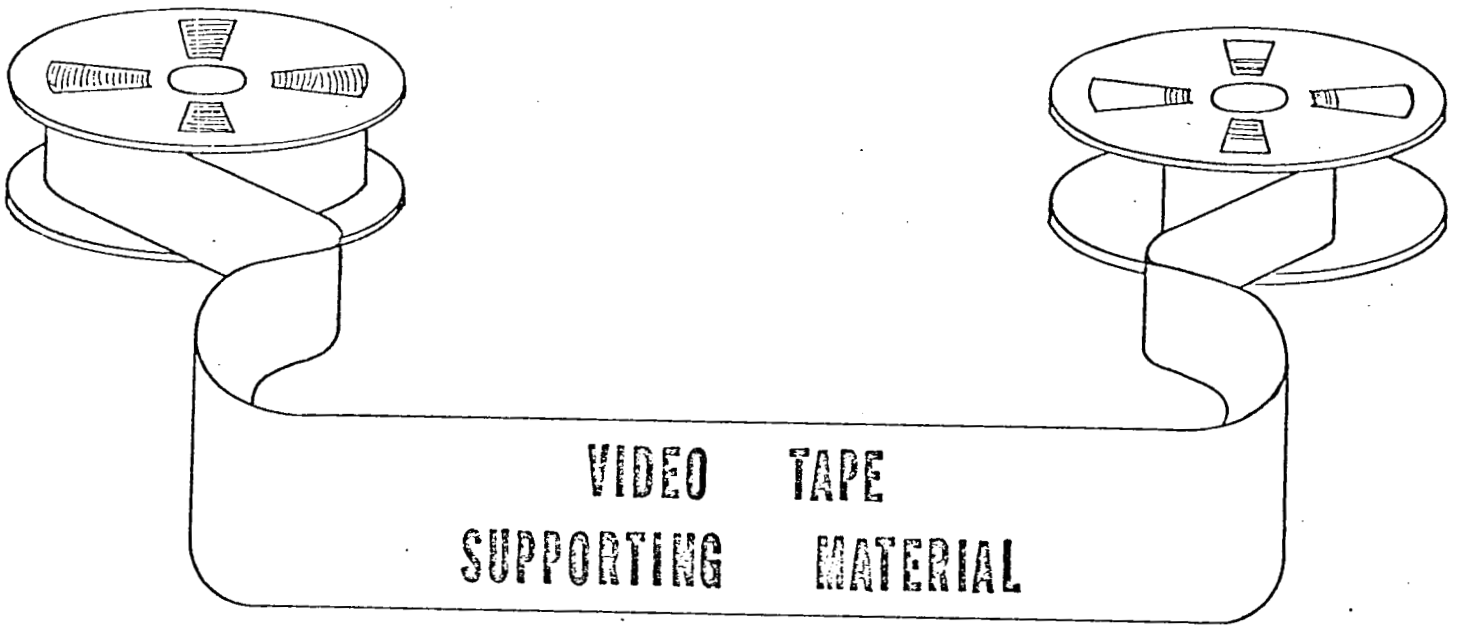
TIME: October 30, 1980
Thursday, 12:30 p.m. to 5:30 p.m.

PLACE: PRC Toups
4131 North 24th Street
Suite 110
Phoenix, Arizona 85016
(602) 954-9191

AGENDA:

TAPE NO.	DESCRIPTION	TAPE RUNNING TIME	INSTRUCTOR
164-RR1	Introduction to Fluvial Hydraulics	56 minutes	Nordin
165-RR1	Physical Properties of Sediments	41 minutes	Nordin
166-RR1	Analysis of Sediment Data, Part I & Part II	63 minutes (I) 08 minutes (II)	Nordin
184-RR1	Localized Scour	26 minutes	Fletcher
188-RR1	Estimating Sediment Yield	43 minutes	Livesey

TAPE No. 164



INTRODUCTION TO FLUVIAL HYDRAULICS

The views and conclusions expressed on video tapes are those of the individual instructors and are not intended to modify or replace official guidance or directives such as Engineering Regulations, Manuals, Circulars, or Technical Letters issued by the Office of the Chief of Engineers.

THE HYDROLOGIC ENGINEERING CENTER
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609 SECOND STREET
DAVIS, CALIFORNIA 95616
(916) 449-3292

INTRODUCTION TO FLUVIAL HYDRAULICS

A. STREAM CLASSIFICATION

I. Alluvial Channels

a. Define alluvium
b. Self-formed boundaries
c. Regime channels
d. Channel response to imposed variables

II. Non-Alluvial Channels

a. Sediment transport always below stream capacity
b. Rigid-boundary hydraulics apply

III. Stream Topology

a. Stream length and channel profile
b. Stream order, branching
c. Drainage density, basin characteristics

B. CHANNEL FORM-BRAIDING, MEANDERING, STRAIGHT

I. Meandering Streams

a. Typical cross sections
b. Flow patterns in bends
c. Meander wave length
d. Radius of curvature
e. Meander cut-offs
f. Natural levees, channel migration, and residual features

II. Braided Channels

a. Chutes, islands, divided flows
b. Relation of braided channels to slope and sediment load

III. Straight Channels

a. Typical cross sections
b. Stable channel design

    1. No sediment movement
    2. With sediment transport

c. Bank stabilization and channel maintenance

C. FLOW IN ALLUVIAL CHANNELS

I. Forms of Bed Roughness

a. Flat bed, no sediment movement

1. Criteria for incipient motion
2. Grain roughness

b. Ripples

1. Properties
2. Criterion for occurance
3. Roughness

R_e 10

c. Dunes

1. Properties
2. Criterion for occurance
3. Roughness

d. Flat bed with high transport

1. Properties
2. Criterion for occurance
3. Roughness

e. Antidunes in phase

1. Properties
   (a) Fine sand
   (b) Coarse material
2. Criterion for occurance
3. Roughness

f. Transitional and residual forms

II. Large-Scale Features

a. Point bars

1. Mechanics of formation
2. Properties

b. Middle bars, island formation
c. Alternate bars
d. Local obstructions, local scour

III. Resistance to Flow in Alluvial Channels

a. Grain roughness and form roughness
b. Flow resistance and bed forms
c. Problems of prediction

D. SEDIMENT TRANSPORT IN ALLUVIAL CHANNELS

I. Classification of Transported Sediment

a. According to transport mechanism

1. Bed load – continuous contact with bed
2. Suspended load – suspended by turbulence

b. According to source

1. Bed material
2. Fine material (wash load)

c. According to method of observation

1. Measured load
2. Unmeasured load

Modeling of Rivers

HSIEH WEN SHEN

CSU

Wiley-Interscience Publication

John Wiley & Sons

1979

- Field Methods for Measurement of Fluvial Sediment

by Harold P. Guy & Vernon W Norman

Book 3 Applications of Hydraulics

Superintendent of Documents
U.S. Government Printing Office
Washington D.C.
20402

Publication #1266
Depart of Agri.
Sediment Yield Data

SEDIMENT PROBLEMS IN WATER RESOURCES PROJECTS

A. TRADITIONAL PROBLEMS

I. Reservoir Sedimentation

a. Historical significance
b. Methodology
c. Some case histories
d. Current problems

II. Erosion

a. Estimating sediment yield
b. Accelerated erosion

III. Local Scour

a. Bridge crossings
b. Pipeline crossings
c. Spur dikes
d. Contractions

IV. Aggradation - Degradation

a. Above and below reservoirs
b. Control structures
c. Channelization

B. CURRENT TRENDS IN SEDIMENT STUDIES

I. Water Quality and Environmental Aspects

a. Sediment as a pollutant

1. Effects on biota
2. Water treatment
3. Turbines
4. Recreation

b. Sediment as a transporting agent

1. Radionuclides
2. Trace metals
3. Persistent chemicals

c. Lake eutrophication and related problems

II. Flow and Sediment Routing

a. "Black box" models
b. Hydraulic models

1. Unsteady flow equations
2. Boundary conditions

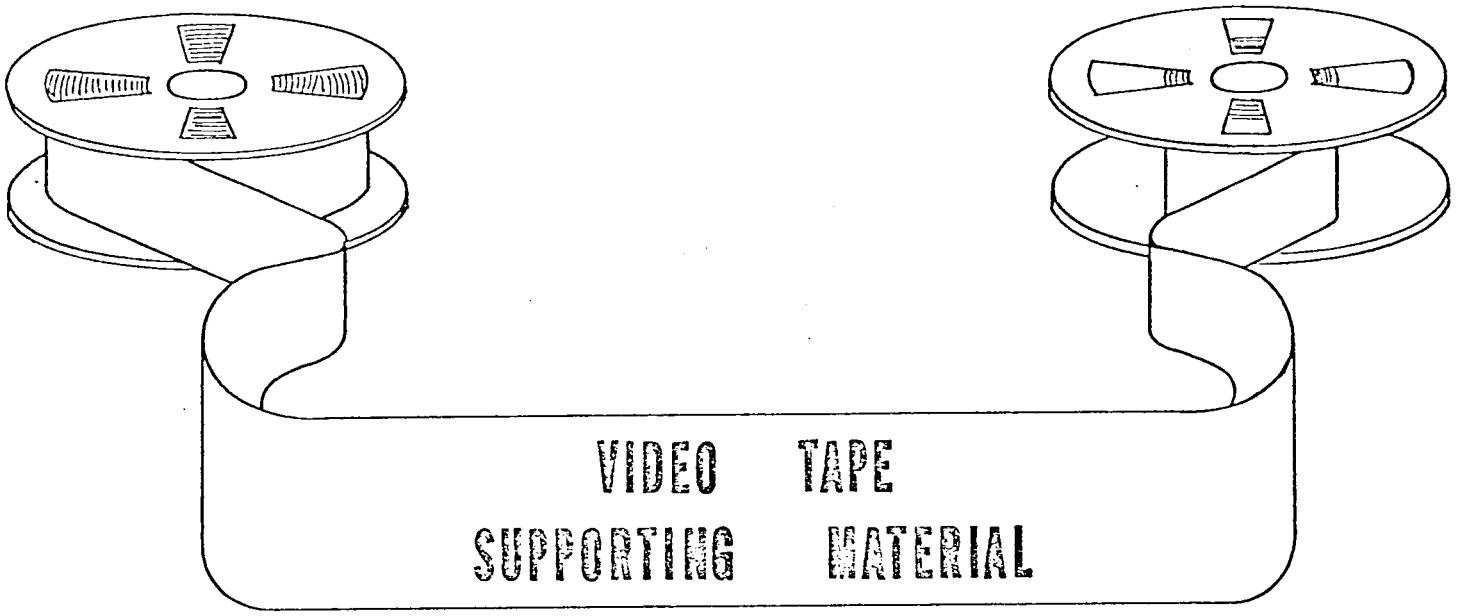
III. System Response

a. Small watersheds
b. Large watersheds

IV. Worth of Sediment Data

a. Bayesian-decision framework
b. A case study

TAPE No. 165



PHYSICAL PROPERTIES OF SEDIMENTS

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PHYSICAL PROPERTIES OF SEDIMENTS

A. MAJOR PROPERTIES

I. Size Distribution

a. Sieve analysis
b. Size classifications
c. Statistical measures

II. Fall Velocity

a. Theoretical considerations
b. Empirical measures

1. In quiessent water
2. In native water
3. Effects of turbulence
4. Effects of fine sediments

c. Fall diameter

III. Other Properties

a. Density
b. Shape
c. Surface texture and roughness

B. SIZE DISTRIBUTIONS OF NATURAL SEDIMENTS

I. Approximate Distributions

a. Log-normal
b. Bagnold's analysis

II. Some Emperical Findings

C. DEPOSITIONAL PROCESSES

I. Sorting

a. Natural streams
b. Stilling basins

1. Trap efficiency
2. Elementary design criteria

II. Deltas

a. Location and growth
b. Hydraulic models
c. Empirical evidence

1. Laboratory studies
2. Field data

III. Deposition in Reservoirs

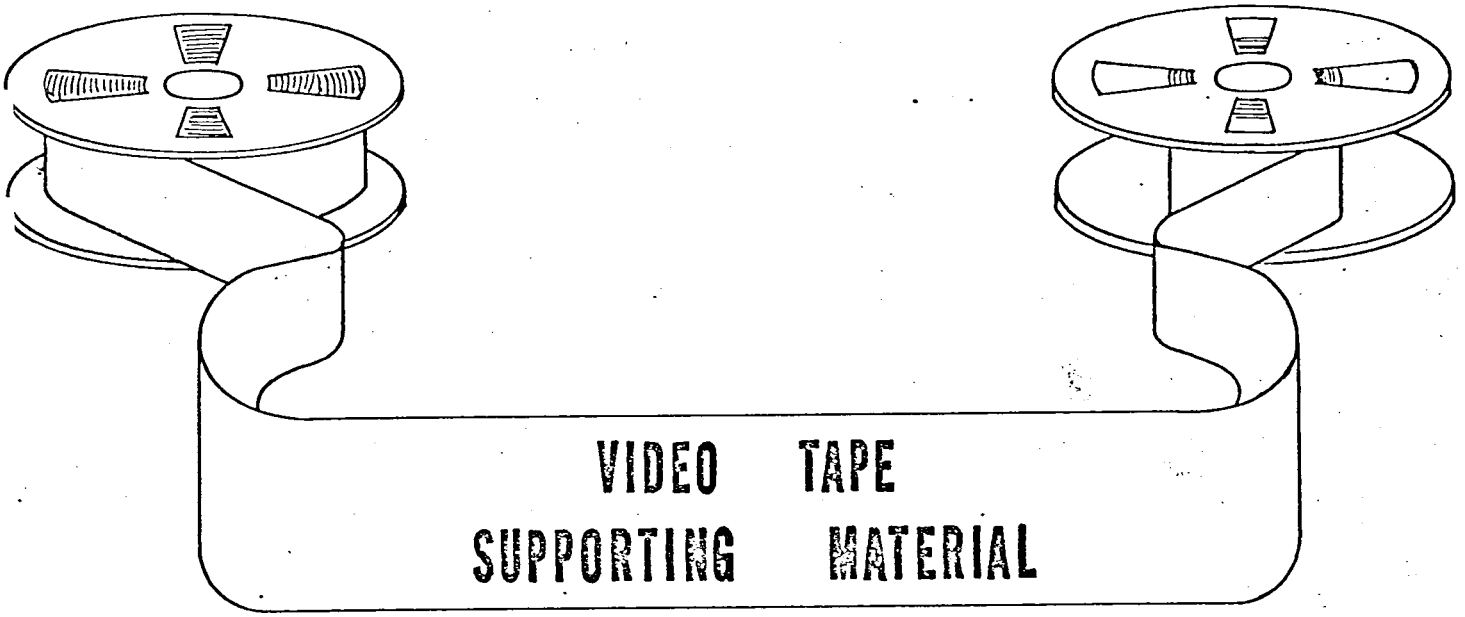
a. Major variables
b. Idealized deposition pattern
c. Density of deposited sediments

1. Initial density
2. Variation with time
3. Other factors

d. Reservoir surveys

1. Sampling deposited sediments
2. In-situ density determinations

TAPE No. 166, No 7



ANALYSIS OF SEDIMENT DATA

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THE ANALYSIS OF SEDIMENT DATA

A. SUSPENDED SEDIMENT

I. Suspended Sediment Equation

a. Theoretical distribution
b. Exact solutions
c. Some approximations
d. Limitations

II. Suspended Sediment Sampling Programs

a. Field data

1. Point samples
2. Equal centroid
3. Width-depth integration
4. Pump samplers
5. Other

b. Laboratory analysis

1. Concentration
   (a) By weight
   (b) By volume

2. Particle size distribution

c. Computational procedures

III. Design of Sampling Programs

a. Frequency of sampling

1. Sample variability
2. Sample size

b. Spatial coverage
c. Transferring sediment data

B. BED MATERIAL AND BED LOAD

I. Bed Material Samples

a. Sand beds
b. Gravel and coarser
c. Special cases

1. Cohesive beds
2. Estuaries

II. Bed Load

a. Samplers
b. Computational techniques
c. Tracer techniques
d. Mapping

C. SPECIAL STUDIES

I. Reconnaisance Studies

a. Small watersheds
b. Large watersheds

II. Data Needs for Specific Studies

a. River crossings - local scour
b. Stable conveyance channels
c. Channelization and river training
d. Other

III. Adequacy of Existing Data

WORKSHOP: SEDIMENT DATA ANALYSIS

Objective: To develop inflowing sediment load data for the reach of Cache Creek between Rumsey and Capay, California. This information will be utilized when simulating the behavior of this reach with HEC-6.

Given Data:

a. Measured concentrations of suspended sediment and associated water discharges for a wide range of flows are shown in Table 1. The distribution of grain sizes for several of the suspended load samples is also shown.

b. The grain size distribution representative of the bed material is shown in Table 2.

c. The equipment used to sample suspended load does not capture larger particles or those moving near the bed. It is estimated that for Cache Creek, this "unmeasured" load is 7% of the total load.

Solution Procedure:

a. Calculate the transport rate of suspended material in tons per day for each flow given in Table 1. Necessary conversion factors may be found in IHD Volume 12, p. 4-04.

b. Plot, on log-log paper, water discharge vs. suspended sediment concentration and water discharge vs. suspended sediment load.

c. Develop a relationship between water discharge and total sediment load. (Usually a straight line on log-log paper.)

d. Determine a representative average grain size distribution for the total load.

Questions: Please provide written answers to the following.

a. One of the two data plots exhibits more scatter than the other. Why?

b. What steps were used in determining the grain size distribution of total load? What assumptions were made?

c. How might an improved (i.e., more representative of long-term behavior) total load grain size distribution be developed from the given data?

d. Note that some grain sizes appear in both the suspended load and bed material gradations. What are the implications of this when determining total load and gradation of total load?

Table 1: Suspended Sediment Data
Cache Creek Above Rumsey, California*

Date	Qw (cfs)	C (mg/l)	Qs (tons/day)	Grain Size Distribution % Finer, size in millimeters										
				.002	.004	.008	.016	.031	.062	.125	.250	.50	1.0	2.0
mo day yr														
Jan 12 60	114	34												
Jan 25 60	588	485												
Feb 9 60	8,300	2,340												
May 2 61	336	42												
Sep 13 65	180	21												
Nov 19 65	550	146							99	100				
Dec 29 65	1,660	577			54		83		97	98	99	100		
Jan 5 66	11,400	5,300												
Feb 4 66	6,390	3,060							49	66	83	96	100	
Feb 24 66	370	22							97	99	100			
Mar 18 66	2,920	545							56	68	82	100		
Nov 22 66	749	156							99	100				
Jan 27 67	4,460	1,370		23	32	42	54	64	72	84	93	97	100	
Jan 31 67	7,160	1,530			24		44		61	72	86	93	99	100
Mar 17 67	4,320	530							74	82	93	100		
Apr 6 67	2,640	291							69	74	81	88	93	100
Dec 6 67	251	102		44	57	73	82	87	98	100				
Feb 17 68	2,990	1,490		36	43	57	68	79	84	92	97	100		
Jun 5 68	560	19		25	41	54	61	63	82	90	94	98	100	

*Source: USGS, "Quality of the Surface Waters of the U.S.", Part 11.

Date	Qw (cfs)	C (mg/l)	Qs (tons/day)	Grain Size Distribution % Finer, size in millimeters										
				.002	.004	.008	.016	.031	.062	.125	.250	.50	1.0	2.0
mo day yr														
Jan 13 69	10,800	6,040		21	23	28	37	45	55	69	81	93	100	
Jan 21 69	18,600	6,430		30	33	37	50	60	70	84	93	98	100	
Feb 14 69	5,950	556		17	26	33	40	43	58	69	84	94	98	100
Mar 18 69	1,000	57		23	43	58	70	74	84	92	97	98	100	
Dec 12 69	118	150							89	91	94	100		
Jan 12 70	1,080	144		24	29	43	54	65	74	84	93	99	100	
Jan 16 70	20,100	6,260		30	31	40	54	65	75	88	97	99	100	
Jan 24 70	21,300	2,880		31	41	51	67	80	89	97	100			
Feb 2 70	5,280	454		25	33	42	50	59	66	74	87	99	100	
Mar 5 70	3,620	308		26	34	42	50	54	64	76	90	98	100	

Table 2: Grain Size Distribution of Bed Material, Cache Creek, California*

Size in mm	% Finer
0.062	0
0.125	0
0.25	5
0.5	20
1.0	30
2.0	40
4.0	50
8.0	75
16.0	95
32.0	100

*Source: Lustig, L.K., and Busch, R.D., "Sediment Transport in Cache Creek Drainage Basin in the Coast Ranges West of Sacramento, California," U.S.G.S. Prof. Paper 562-A, 1967.

WORKSHOP II - SEDIMENT DATA ANALYSIS

Solution

Discussion: Use of numerical modeling techniques, such as HEC-6, to predict future trends of aggradation and degradation within a reach of stream requires that the quantity and gradation of sediment entering that reach be known. Experience has shown that calculated values of scour and deposition can be quite sensitive to the inflowing load. Typically, the data from which the inflowing load values are developed are sparse or incomplete.

To obtain proper reproduction of historical trends of aggradation and degradation, it has often been necessary to adjust the inflowing load curve somewhat. When this becomes necessary, however, it is usually not sufficient to modify only the volume of inflowing load; the gradation must also be adjusted. This process is complex and little guidance is available on how to proceed in a step-by-step, rational, fashion.

The importance of the inflowing load curve to the application of analytic techniques to the prediction of future stream behavior has motivated the rather detailed examination of inflowing load in this workshop.

Solution:

a. The conversion factor given in IHD Volume 12 (p. 4-04) is calculated as follows:

$$\frac{\text{tons}}{\text{day}} = \frac{\text{ft}^3}{\text{sec}} \cdot \frac{\text{mg}}{\text{l}} \cdot \frac{\text{lbs}}{\text{mg}} \cdot \frac{1}{\text{ft}^3} \cdot \frac{\text{sec}}{\text{day}} \cdot \frac{\text{tons}}{\text{lb}}$$

$$= Q \cdot C_s \cdot (2.205 \times 10^{-6})\ (28.32)\ (86400)\ (0.0005)$$

$$= Q \cdot C_s \cdot 0.0027$$

b. See Figures 1 and 2.

c. Figure 2 was developed by plotting (suspended load)/0.93, yielding total load.

d. First, an average distribution is developed for the suspended load. Two approaches may be taken.

1. Direct sample averaging

2. Sediment discharge weighted averaging

The procedures used to obtain these averages are illustrated in Table 1. The results of these techniques are shown in Table 2 and plotted on Figure 3. It is suggested that the sediment discharge weighted distribution provides more representative data.

In summary, the measured load is composed of 31.8% clay, 39% silt and 29.2% sand, but only a portion of the available sand sizes appear in the measured samples as evidenced by the relationship between the bed material gradation and the suspended sample gradation curves on Figure 3. The remaining sizes move as unmeasured load. Although only 7% of the total load in this case, these size fractions have a pronounced effect on sediment problems. Consequently, calculation techniques have been devised to determine quantities (Toffaleti, Modified Einstein or Einstein). HEC-6 may also be used to make such calculations by separating silt and clay from the measured load and calculating the total sand and gravel load. The calculated values will contain both measured and unmeasured loads and the results, by grain size class, may be printed out by selecting the C-Level print option (column 6 on the *-card, Hydrologic Data).

As the first approximation, assume the unmeasured load has the same gradation as the bed material and estimate the gradation of total load as shown in Table 3. Code an inflowing sediment load for HEC-6 by selecting two water discharges and their corresponding total loads from Figure 2. Code the estimated fraction of material from the last column in Table 3 and execute HEC-6 with a C-Level print option in the Sediment Calculations. Average the load passing each cross section (excluding the first and the last sections) for each sand and gravel class. Calculate a new total load by adding the average loads for sand and gravel to previously determined silt and clay quantities. (Adjust if significantly different from the total load from Figure 2, and calculate the new gradations.) The results may have to be refined later during verification, but usually any such refinement is minor.

Response to Questions:

a. The concentration versus water discharge plot exhibits more scatter than sediment load versus water discharge. This is typical of most measurements. It comes from the fact that the sediment load moves at the velocity of the water whereas water waves move at higher velocities. Since flow in natural streams is usually unsteady, (i.e. waves of water as illustrated by stage hydrographs) the water tends to out-run the sediment in transport. Concentrations of sediment changes whereas total mass of sediment does not.

b. The steps to follow are shown in the Solution Procedure, above. Assumptions are:

1. The selected bed gradation data is representative of the full range of discharges.

2. The amount of silt and clay that moves in the unmeasured zone is small compared with that in the measured zone.

c. By fine tuning the inflowing load curve during model verification.

d. The Modified Einstein technique requires information from the suspended load measurements to calculate the quantity of material which moves in the unmeasured zone. Consequently, only those grain sizes in the suspended samples are included in the calculations. Larger particles are missed altogether.

Table 1: Example, Averaging of Suspended Load Gradations

Consider percentage finer than 0.008 mm
(Refer to Table 1 of Workshop Statement)

Date	Q_s (tons/day)	P, % finer than 0.008 mm
Jan 27 67	16,500	42
Dec 6 67	69	73
Feb 17 68	12,000	57
Jun 5 68	29	54
Jan 13 69	176,000	28
Jan 21 69	323,000	37
Feb 14 69	8,930	33
Mar 18 69	154	58
Jan 12 70	420	43
Jan 16 70	340,000	40
Jan 24 70	166,000	51
Feb 2 70	6,470	42
Mar 5 70	3,010	42

Calculations:

1. Direct sample averaging:

$$\bar{P} = \frac{\sum^{N} P}{N} = \frac{42 + 73 + 57 + \ldots\ldots 42}{13} = 46.2$$

2. Sediment discharge weighted averaging:

$$\bar{P} = \frac{\sum^{N} Q_s \cdot P}{\sum^{N} Q_s} = \frac{(16500)\ (42) + (69)\ (73) + (12000)\ (57) + \ldots\ldots (3010)\ (42)}{16500 + 69 + 12000 + \ldots\ldots 3010}$$

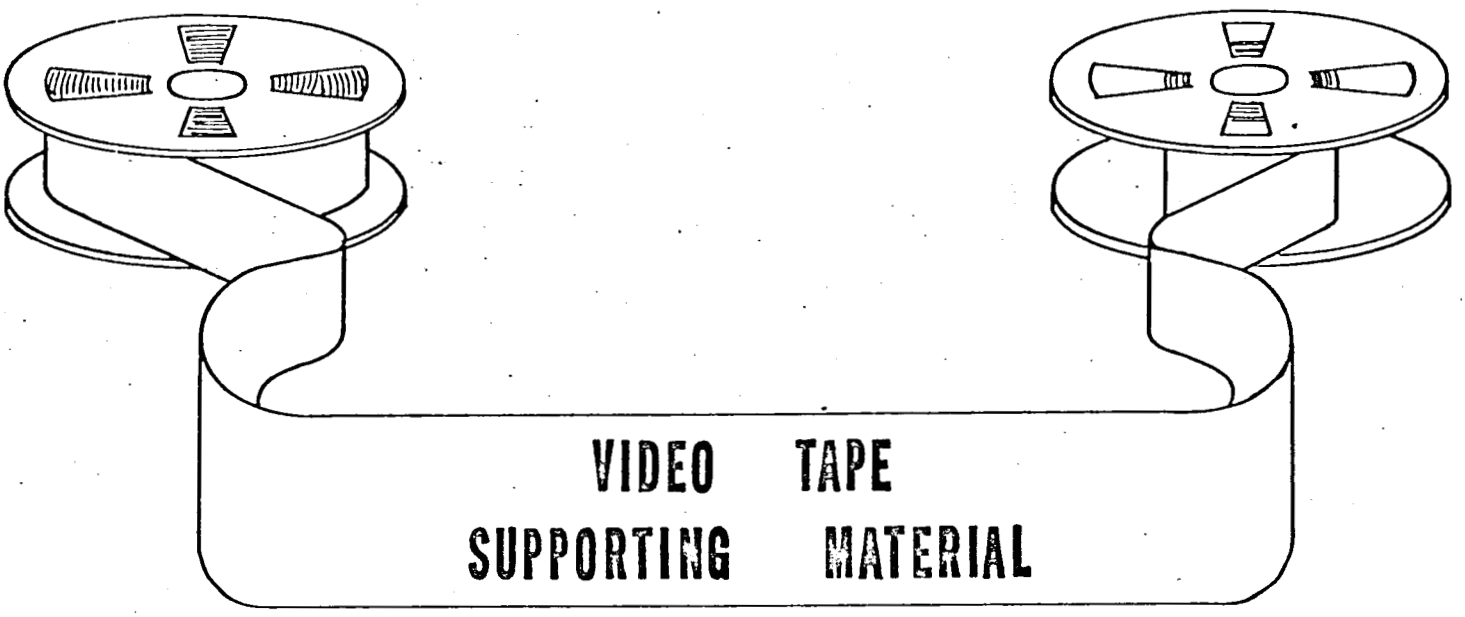
$$= 39.0$$

Continue as above to develop values for other grain sizes, results are shown on Table 2.

Table 2: Average Suspended (Measured) Load Gradation Calculated Two Ways

Grain Size (mm)	% Finer	
	Sample Averaging	Sediment Discharge Weighted Averaging
0.002	27.3	28.5
0.004	36.3	31.8
0.008	46.2	39.0
0.016	57.6	51.8
0.031	64.5	62.4
0.062	76.2	70.8
0.125	84.3	83.5
0.25	91.9	92.6
0.5	97.4	97.6
1.0	99.3	99.9
2.0	100.0	100.0

TAPE No. 184



LOCALIZED SCOUR

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Tape No. 184

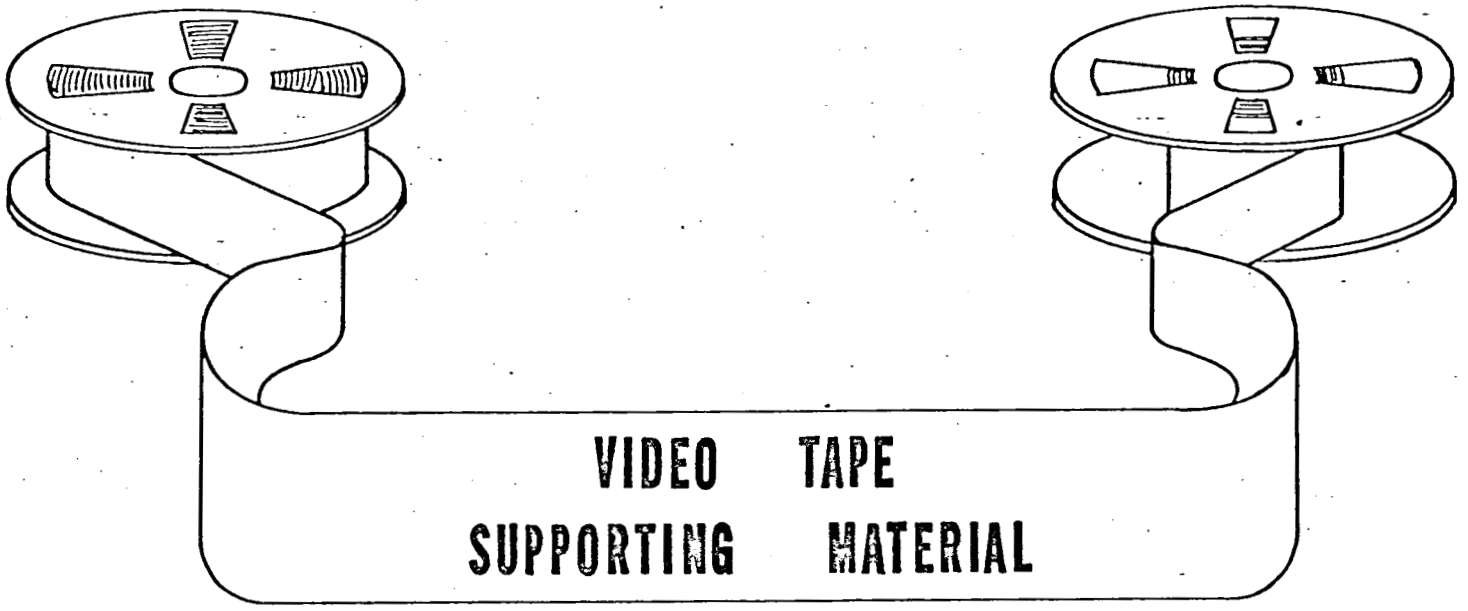
OUTLINE FOR HEC TRAINING COURSE PRESENTATION

TITLE: Methods for Estimating and Controlling Localized Scour

I. Culvert Outlets - Types of Scour
   A. Gully
   B. Localized
      1. Methods of Estimating
      2. Methods of Controlling
         a. Cutoff Wall
         b. Horizontal Blanket of Riprap
         c. Preformed Scour Hole Lined with Riprap
         d. Lined Channel Expansion
         e. Flared Outlet Transitions
         f. Commonly Used Energy Dissipators

II. Bridge Piers
   A. Localized Scour
   B. Willow Mattresses and Riprap Protection

TAPE No. 184



LOCALIZED SCOUR

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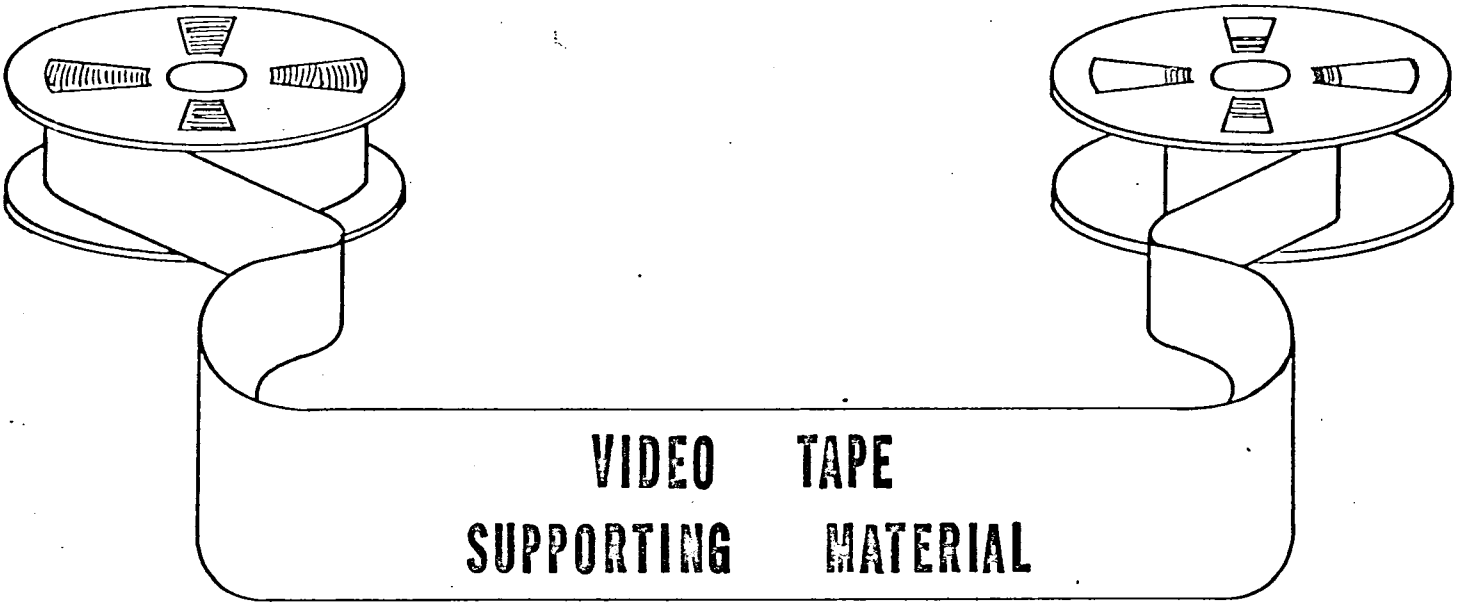
TAPE NO. 188



ESTIMATING SEDIMENT YIELDS

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THPE 188

HEC TRAINING COURSE ON SEDIMENT TRANSPORT

1-12 November 1976

Lecture - Estimating Sediment Yields

Instructor - R. H. Livesey, P. E.
Chief, Water Quality and Sediment Section
Omaha District, Corps of Engineers

1. Introduction

   A. Scope of lecture

   B. Identification of study or report needs

   C. Application of methods and limits

2. Sedimentation Processes

   A. Sediment sources

   B. Erosional factors

   C. Climatic factors

   D. Watershed factors

3. Basic Data Requirements

   A. Definition of contributing drainage areas

   B. Design considerations

C. Hydrologic records

4. Methods for Determining Sediment Yields

A. CE experience

B. Direct measurement

C. Computation

D. Judgment extrapolation of measured data

5. Special Considerations

A. Urbanization

B. Strip mining

C. Highway relocations

6. Estimating Reservoir Depletion Volumes

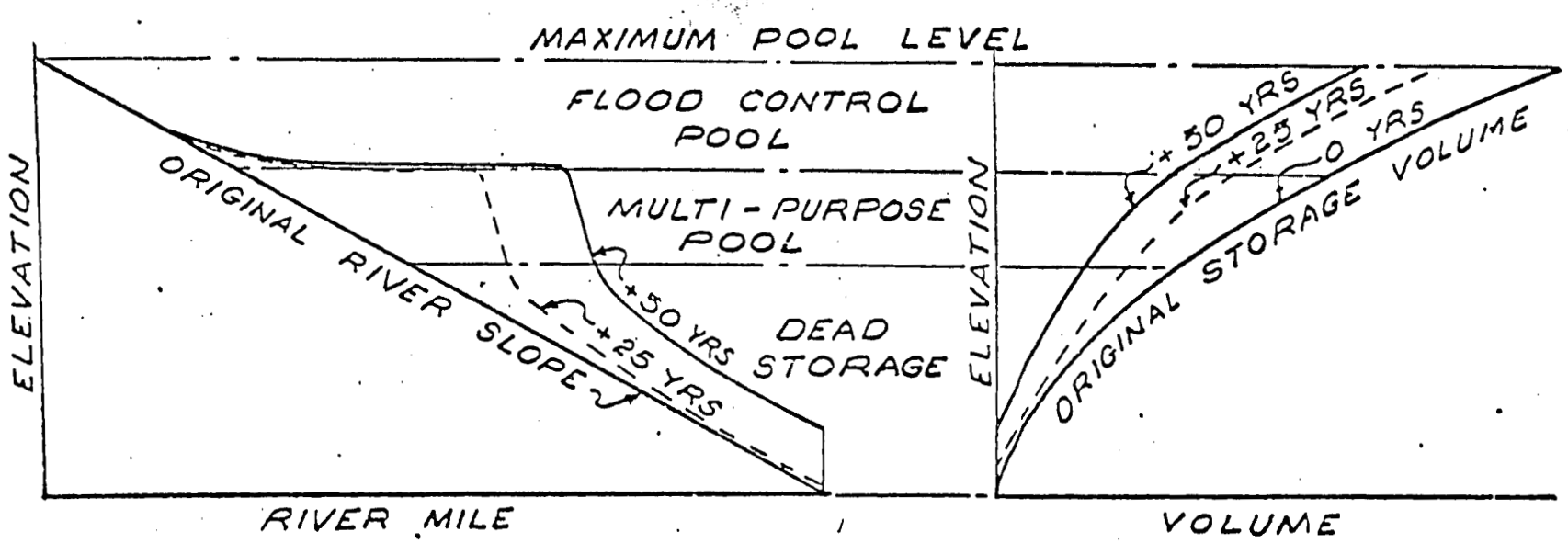
A. Computational factors and units

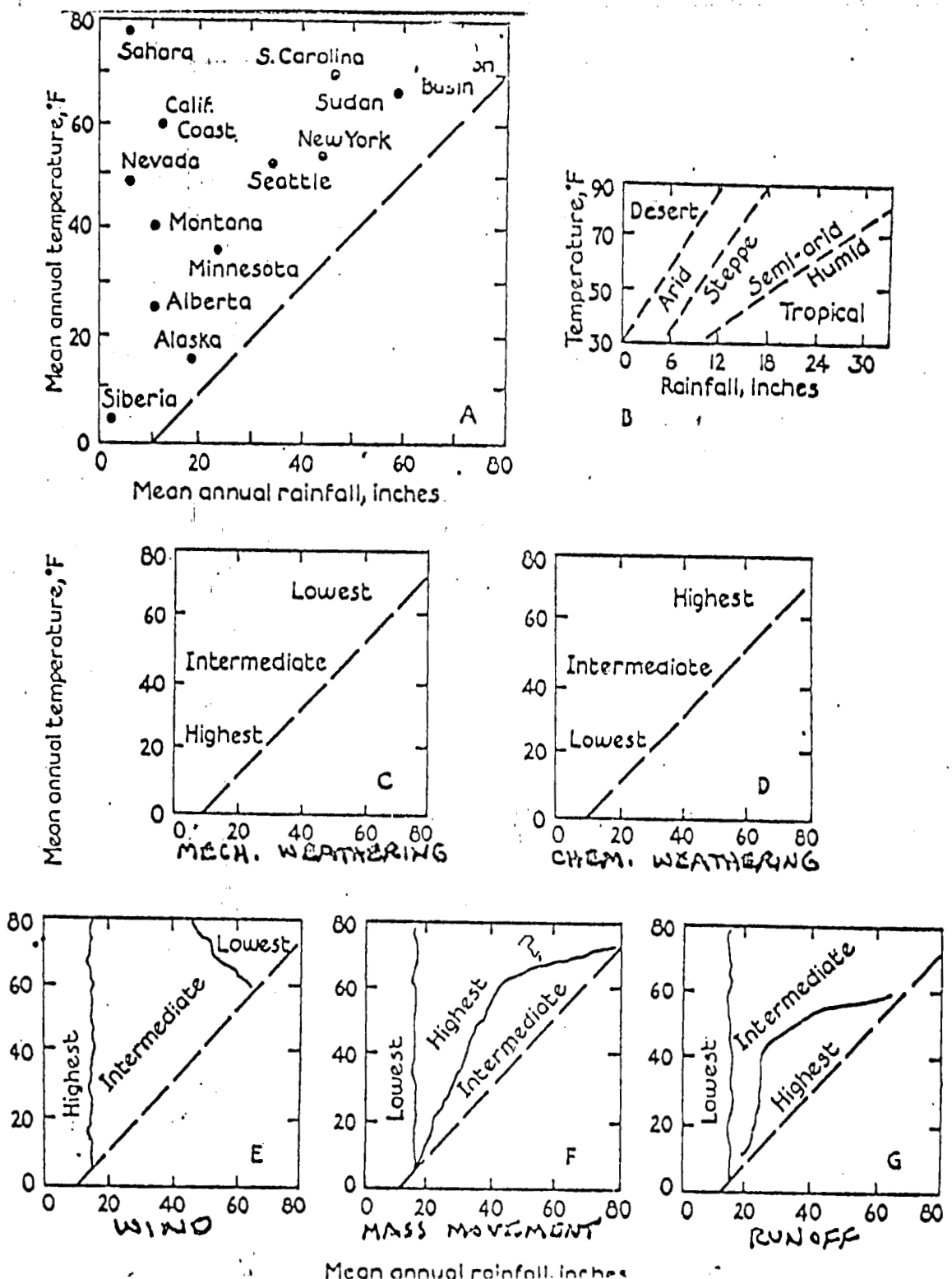
B. Reservoir trap efficiency

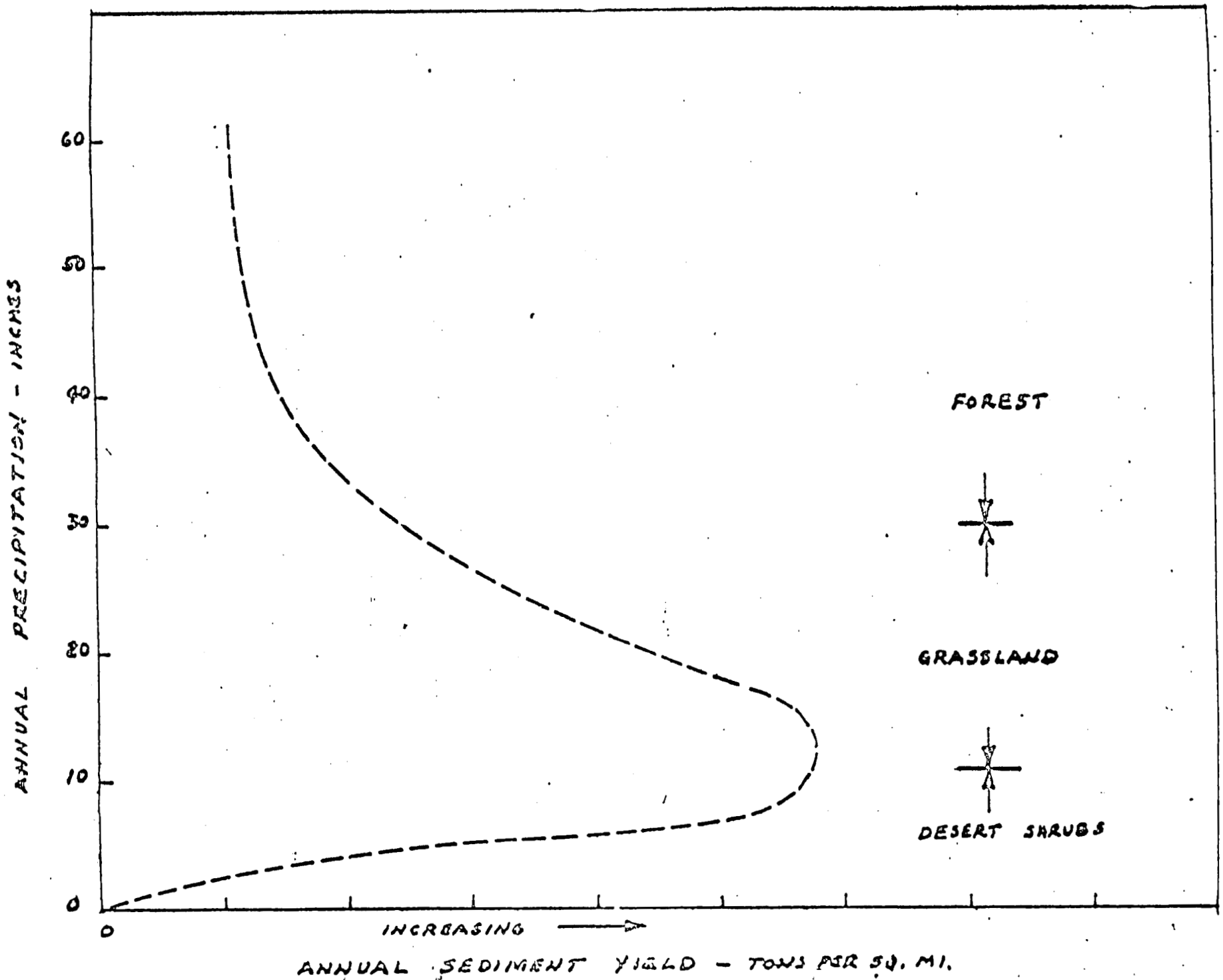
C. Deposit density

D. Depletion rate and volumes

RESERVOIR STORAGE DEPLETION




Sahara
S. Carolina
Sudan
Calif. Coast
New York
Nevada
Seattle
Montana
Minnesota
Alberta
Alaska
Siberia
A
Mean annual temperature, °F
Mean annual rainfall, inches
Desert
Arid
Steppe
Semi-arid
Humid
Tropical
Temperature, °F
Rainfall, inches
B
Lowest
Intermediate
Highest
C
MECH. WEATHERING
Highest
Intermediate
Lowest
D
CHEM. WEATHERING
Highest
Intermediate
Lowest
E
WIND
Lowest
Highest
Intermediate
F
MASS MOVEMENT
Lowest
Intermediate
Highest
G
RUNOFF
Mean annual rainfall, inches


ANNUAL PRECIPITATION - INCHES
60
50
40
30
20
10
0
0
INCREASING
ANNUAL SEDIMENT YIELD - TONS PER SQ. MI.
FOREST
GRASSLAND
DESERT SHRUBS

METHODS FOR DETERMINING SEDIMENT YIELDS

DIRECT MEASUREMENT

1 – SEDIMENT RATING CURVE

2 – RATING CURVE - FLOW DURATION

3 – RESERVOIR SEDIMENTATION SURVEYS

COMPUTATION

1 – UNIVERSAL SOIL LOSS EQUATION PLUS SEDIMENT DELIVERY RATIO

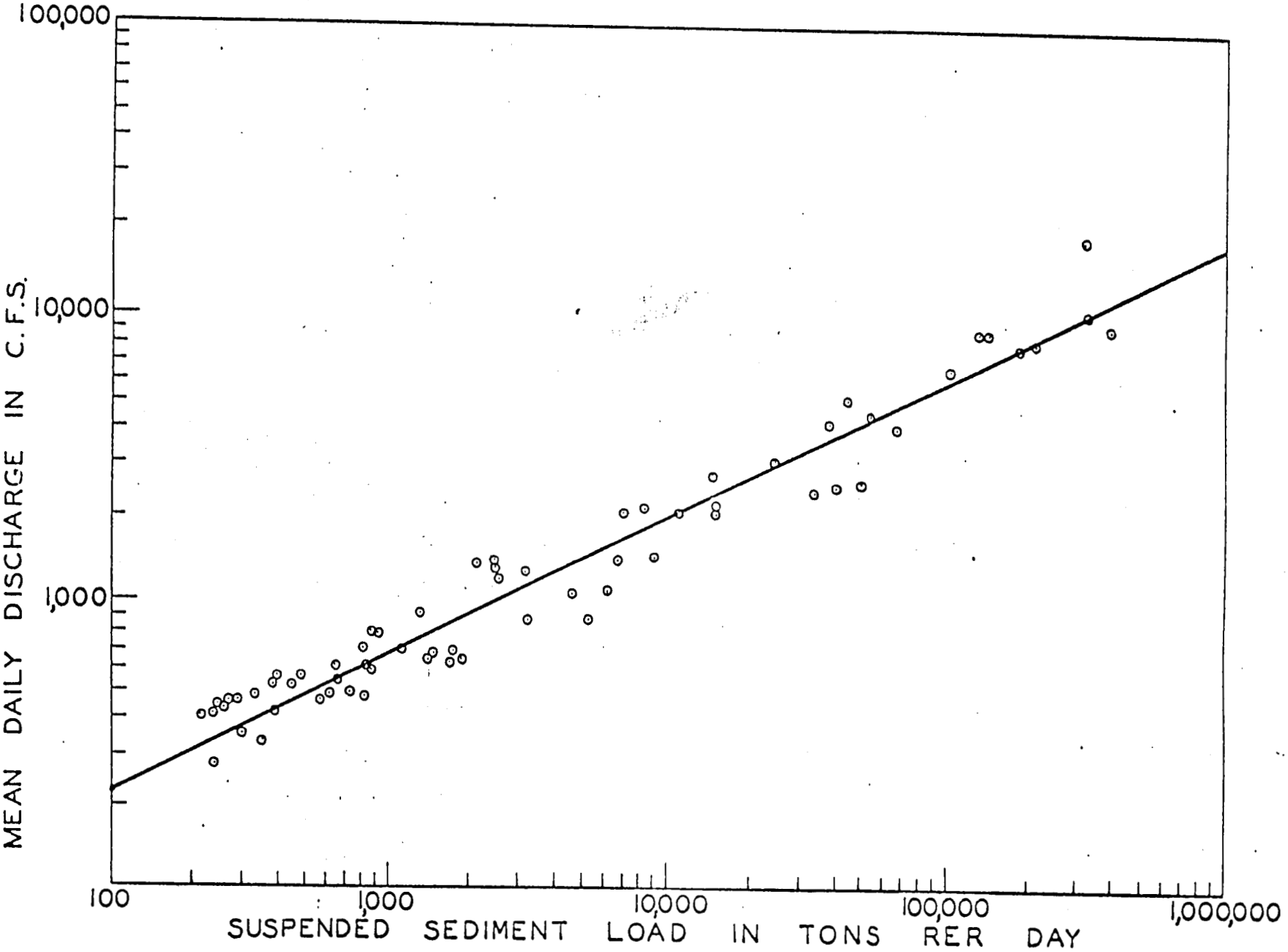
2 – SEDIMENT TRANSPORT EQUATIONS

JUDGEMENT EXTRAPOLATION OF MEASURED DATA

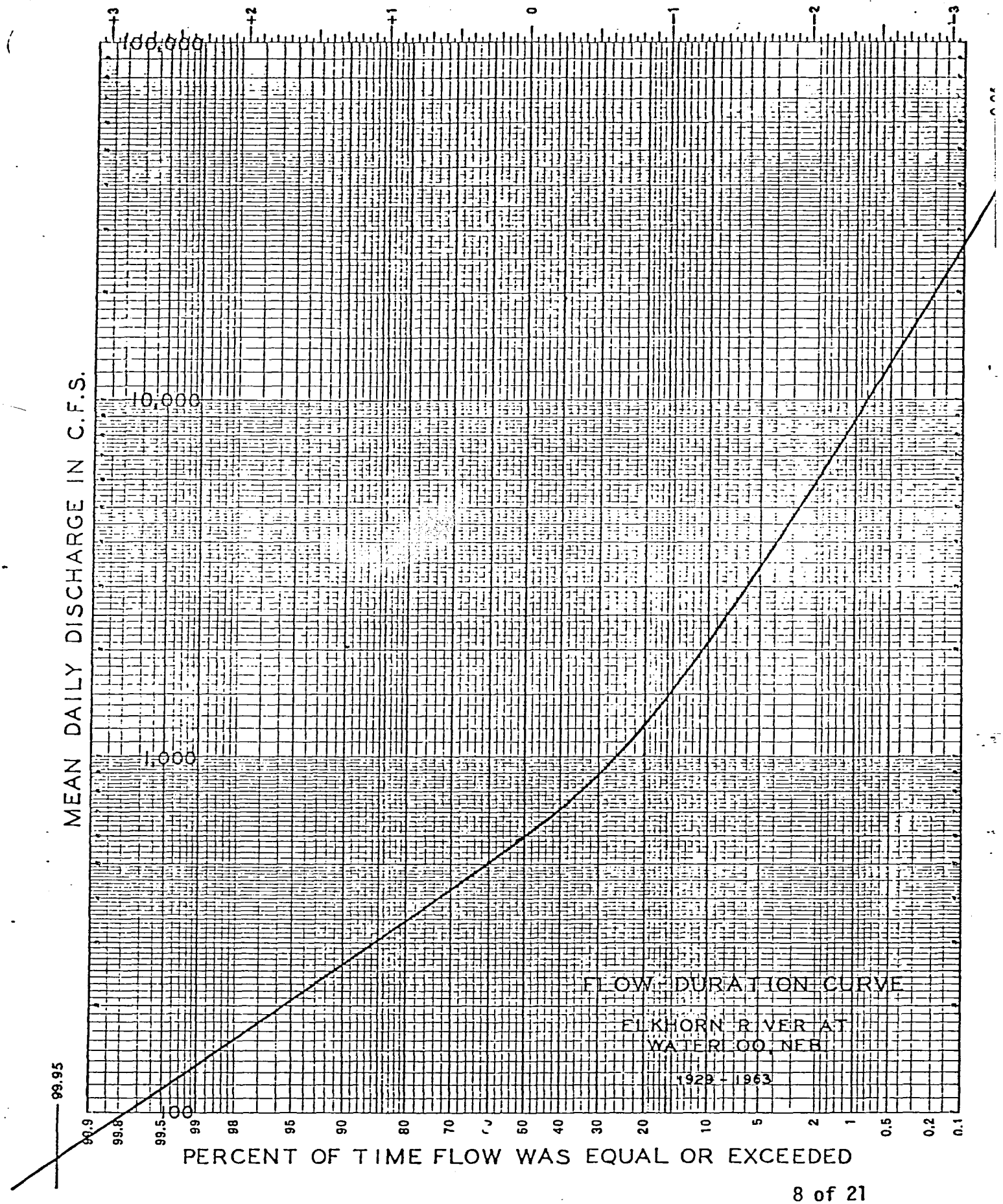
1 – DOMINANT BASIN CHARACTERISTICS

2 – SEDIMENT YIELD CONTOURS

3 – FIELD RECONNAISSANCE



SEDIMENT RATING CURVE
ELKHORN RIVER
WATERLOO, NEBR.


+3
+2
+1
0
-1
-2
-3
100,000
10,000
1,000
100
MEAN DAILY DISCHARGE IN C.F.S.
99.95
99.9
99.8
99.5
99
98
95
90
80
70
60
40
30
20
10
5
2
1
0.5
0.2
0.1
PERCENT OF TIME FLOW WAS EQUAL OR EXCEEDED
FLOW-DURATION CURVE
ELKHORN RIVER AT
WATERLOO, NEB.
1929 - 1963

RATING CURVE - FLOW DURATION METHOD

LONG TERM TOTAL SEDIMENT LOAD ESTIMATE FOR ELKHORN RIVER AT WATERLOO, NEBRASKA

STREAMFLOW RECORD - 1929 TO 1963
SUSPENDED SEDIMENT SAMPLING RECORD - AUG. 1948 TO NOV. 1950

Percent Mid Ord.	Percent Increment	Water Discharge Q_w (cfs)	Suspended Sediment Load Q_s (tons)	Daily Average Q_w (cfs)	Daily Average Q_s (tons)
0.05	0.1	37,000	4,500,000	37.0	4500
0.3	0.4	15,000	680,000	60.0	2720
1.0	1.0	9,000	230,000	90.0	2300
3.25	3.5	4,500	55,000	157.5	1925
10	10	2,100	11,000	210.0	1100
20	10	1,200	3,500	120.0	350
30	10	880	1,800	88.0	180
40	10	710	1,150	71.0	115
50	10	600	800	60.0	80
60	10	510	580	51.0	58
70	10	425	390	42.5	39
80	10	345	250	34.5	25
90	10	260	140	26.0	14
96.75	3.5	180	64	6.3	2
99.0	1.0	135	35	1.4	1
99.7	0.4	105	20	0.4	0
99.95	0.1	74	13	0.1	0
		Totals		1055.7	13,409

Annual Q_w = 1055.7 x 365 x 1.98 = 762,950 AF/Yr

Annual Q_s = 13,409 x 365 = 4,894,000 tons/yr

Unmeasured & bed load = 10% Qs = 489,000 tons/yr

Total sediment load = 5,383,000 tons/yr

Total Drainage Area = 6,900 square miles

Sediment Contributing D.A. = 5,900 square miles

Average Annual Sediment Yield = 912 tons/square mile

UNIVERSAL SOIL LOSS EQUATION

Primarily small watersheds

E = RKLSCP

WHERE

E = AVERAGE ANNUAL SOIL LOSS FROM A SPECIFIC FIELD IN TONS PER ACRE

R = EROSION POTENTIAL OF AVERAGE ANNUAL RAINFALL IN LOCALITY

K = SOIL ERODIBILITY FACTOR

L = LENGTH OF SLOPE

S = SLOPE OF LAND GRADIENT

C = CROPPING MANAGEMENT FACTOR

P = CONSERVATION PRACTICE FACTOR

SEDIMENT YIELD

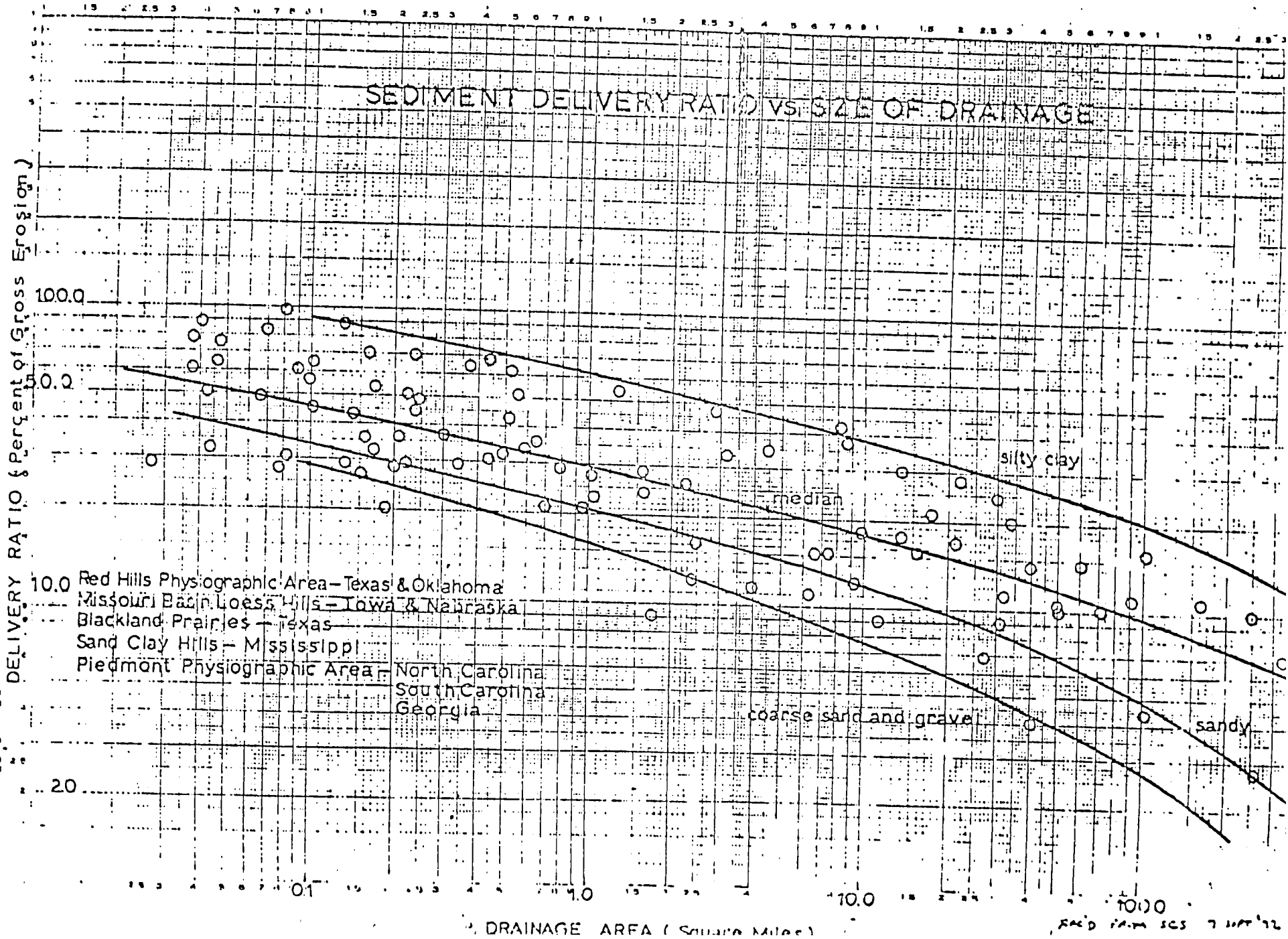
Y = T (DR)

WHERE

Y = SEDIMENT YIELD AT GIVEN DOWNSTREAM POINT (TONS/UNIT AREA/YEAR)

T = TOTAL MATERIAL ERODED FROM UPSTREAM WATERSHED - INCLUDES E ABOVE PLUS ANY CHANNEL CONTRIBUTION (TONS/UNIT AREA/YEAR)

DR = DELIVERY RATIO OR PERCENTAGE OF DOWNSTREAM MOVEMENT OF SEDIMENT FROM POINT AT T TO POINT AT Y. (%)


SEDIMENT DELIVERY RATIO VS SIZE OF DRAINAGE
DELIVERY RATIO (Percent of Gross Erosion)
100.0
50.0
10.0
2.0
silty clay
median
coarse sand and gravel
sandy
Red Hills Physiographic Area – Texas & Oklahoma
Missouri Basin Loess Hills – Iowa & Nebraska
Blackland Prairies – Texas
Sand Clay Hills – Mississippi
Piedmont Physiographic Area – North Carolina
South Carolina
Georgia
0.1
1.0
10.0
100.0
DRAINAGE AREA (Square Miles)

SEDIMENT TRANSPORT FORMULAS

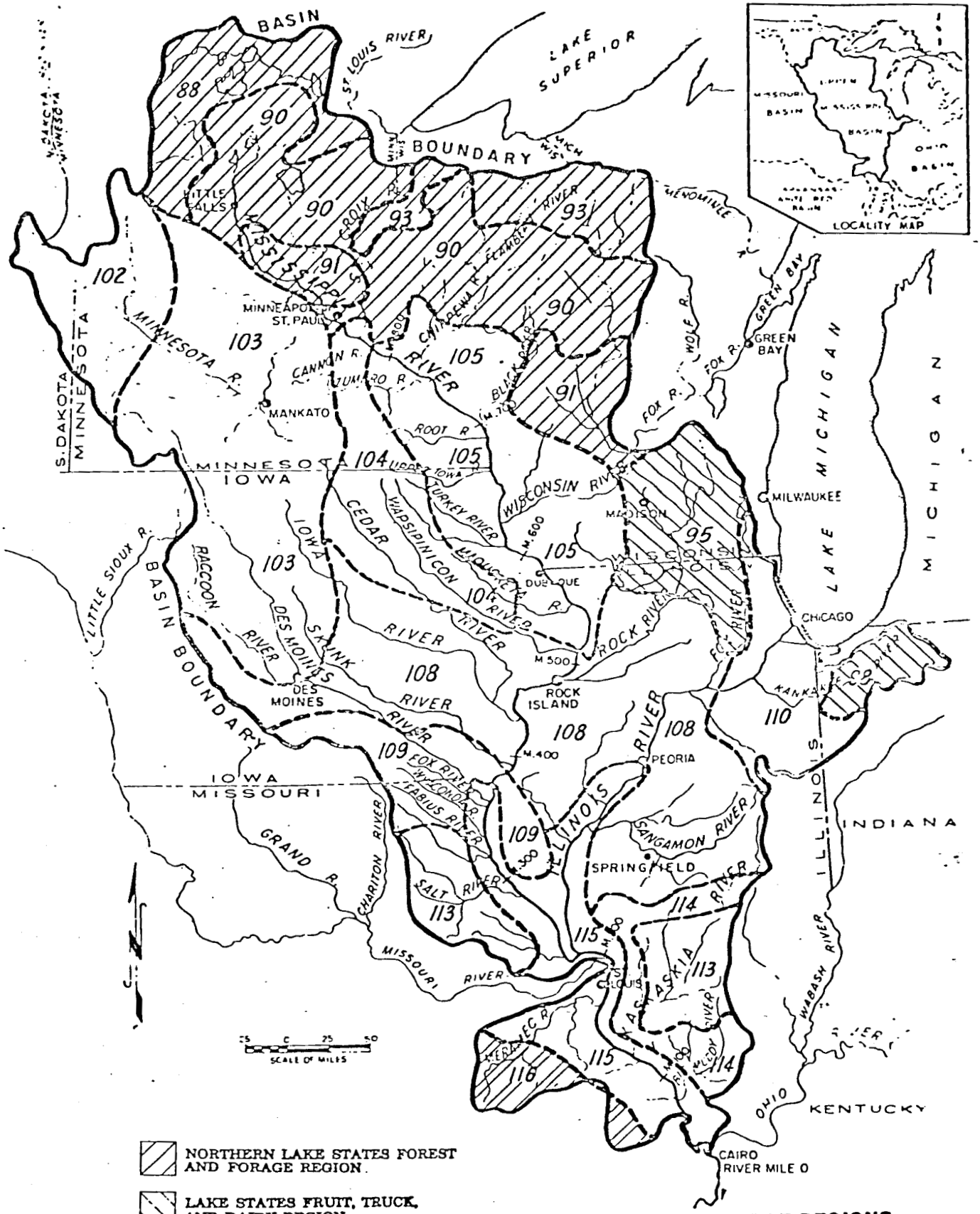
		Classification System	
		Based on mechanism of transport	Based on particle size
Total sediment load	Wash load	Suspended load	Wash load
	Suspended bed-material load		Bed-material load
	Bed load	Bed load	

BED-LOAD FORMULAS (DISCHARGE OF MATERIAL MOVING ALONG THE STREAMBED)

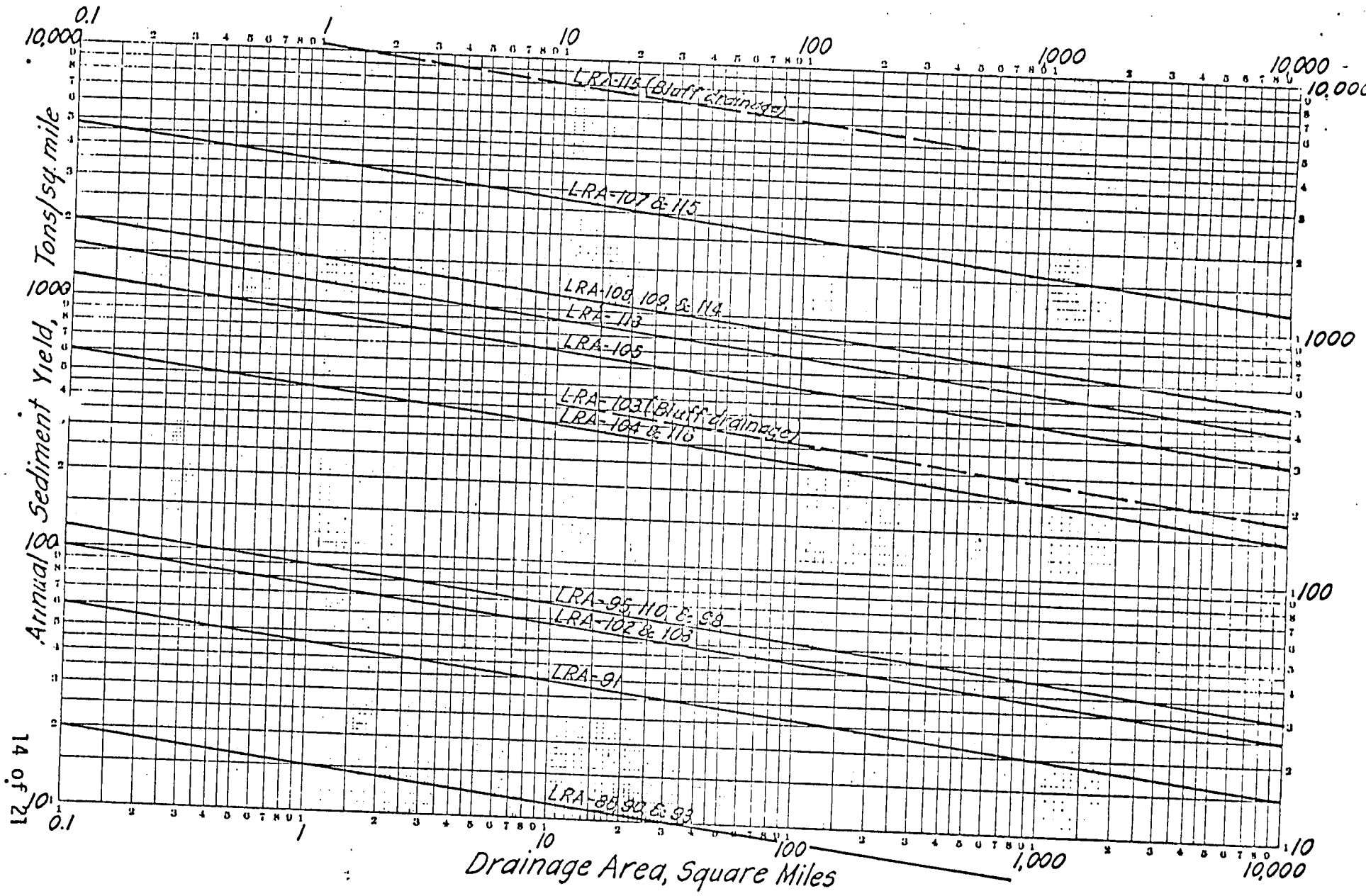
1 — SCHOKLITSCH
2 — MEYER-PETER
3 — HAYWOOD
4 — MEYER-PETER & MULLER

BED-MATERIAL DISCHARGE FORMULAS (DISCHARGE OF MATERIAL MOVING BOTH ALONG THE BED & IN SUSPENSION)

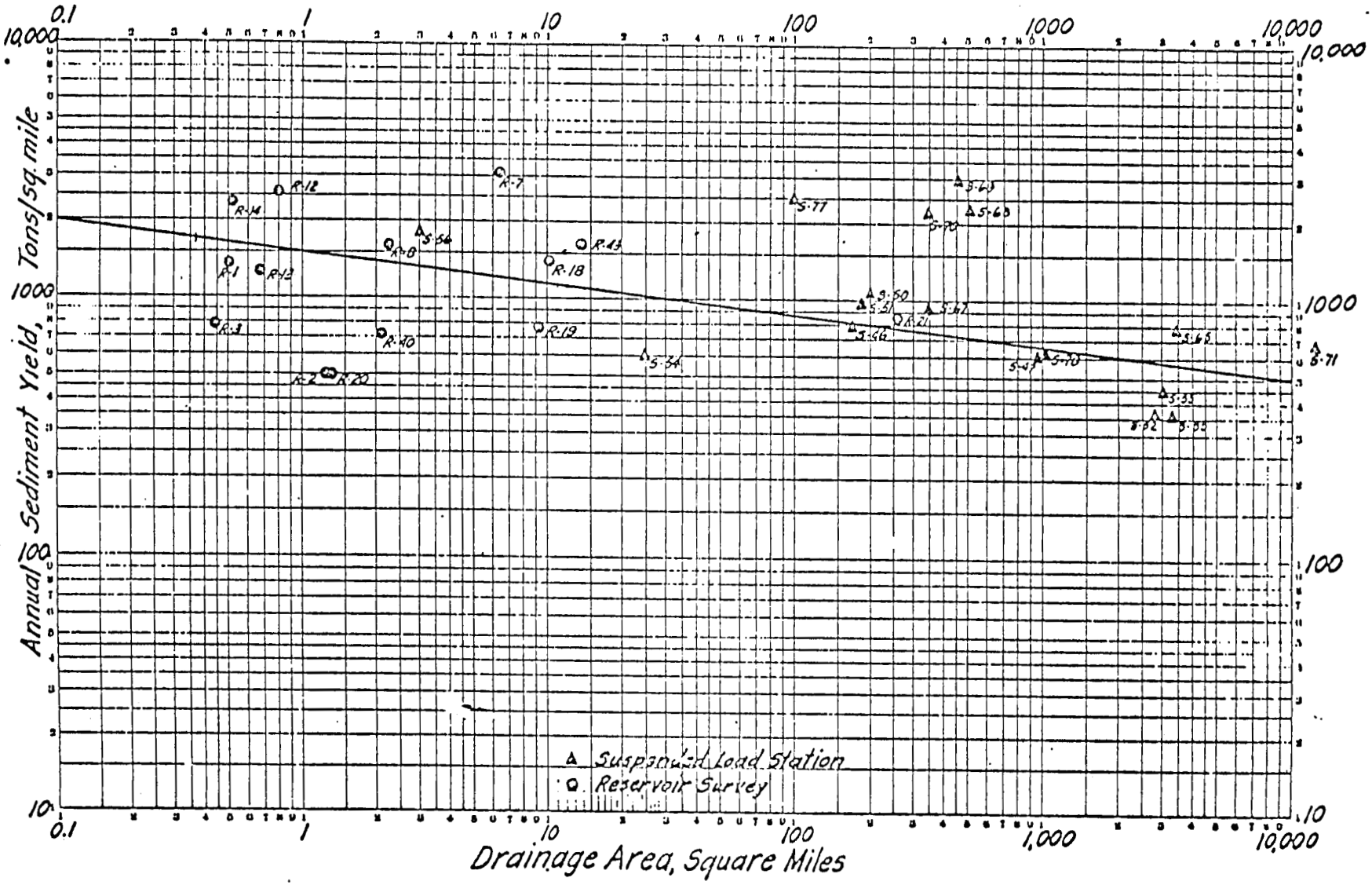
1 — EINSTEIN
2 — MODIFIED EINSTEIN
3 — COLBY
4 — ENGELUND - HANSEN



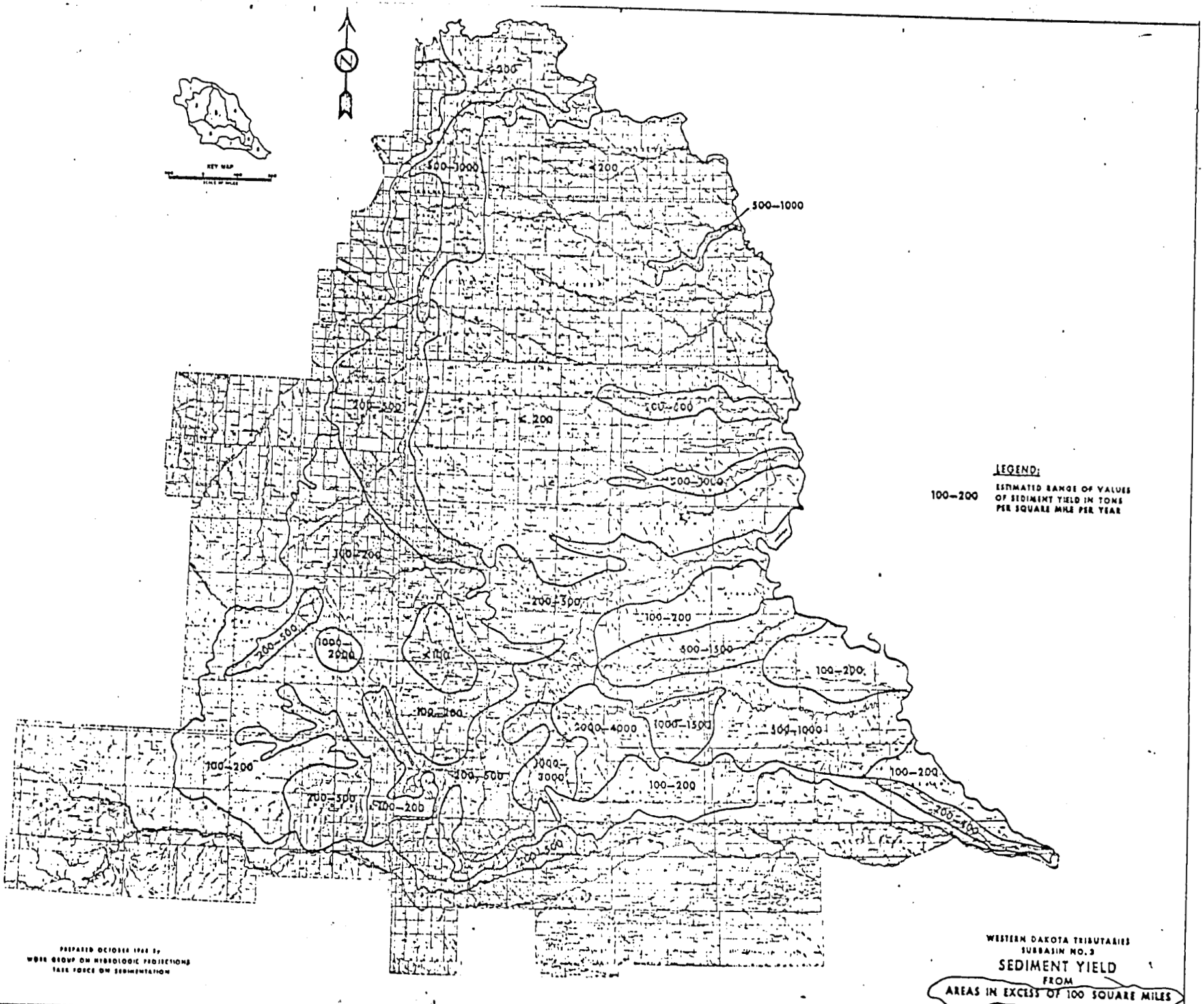
LAND RESOURCE REGIONS AND MAJOR LAND RESOURCE AREAS

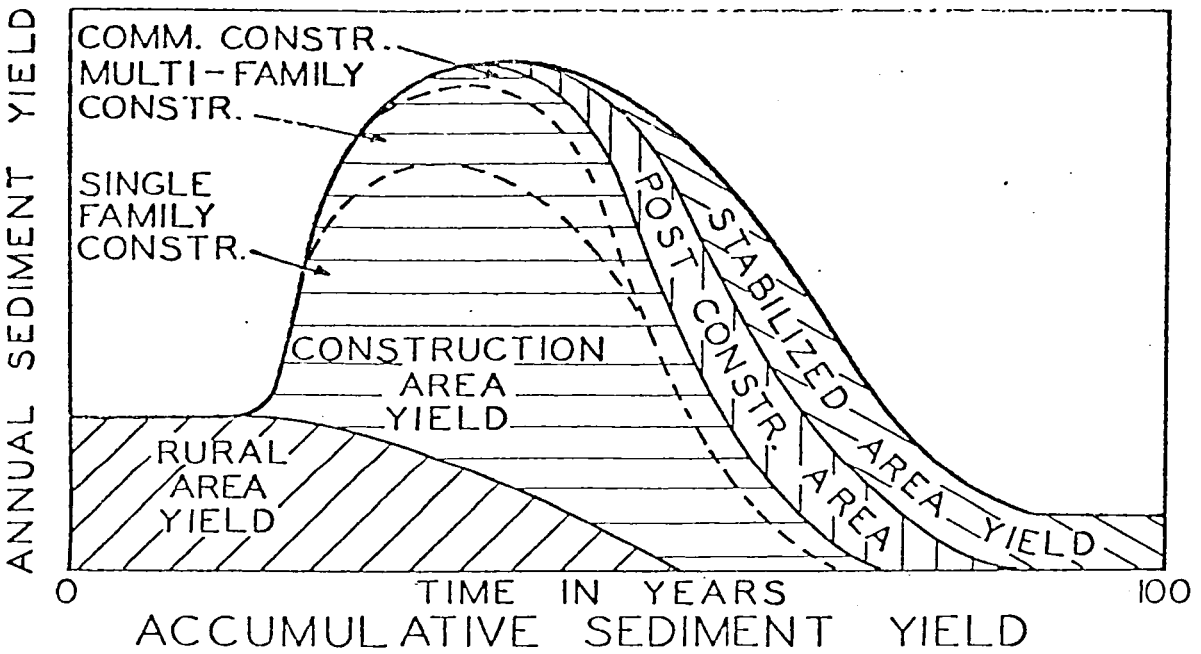


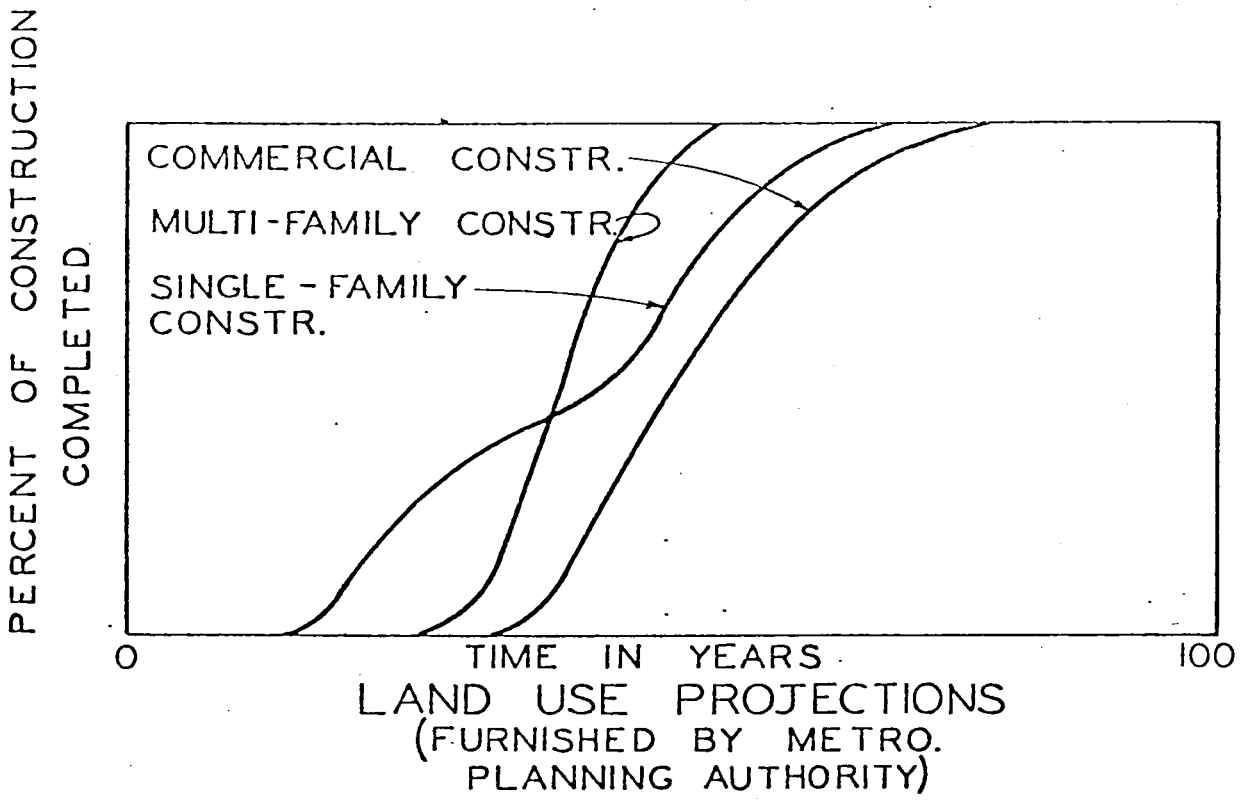
Observed Sediment Yields
All Land Resource Areas



Observed Sediment Yields
Land Resource Area 108.


KEY MAP
<200
500-1000
<200
500-1000
200-500
<200
100-200
500-1000
100-200
200-500
100-200
200-500
1000-2000
<100
500-1500
100-200
100-200
2000-4000
1000-1500
500-1000
100-200
1000-3000
200-500
100-200
100-200
200-500
100-200
200-400
200-500
LEGEND:
100-200 ESTIMATED RANGE OF VALUES OF SEDIMENT YIELD IN TONS PER SQUARE MILE PER YEAR
PREPARED OCTOBER 1966 BY
WORK GROUP ON HYDROLOGIC PROJECTIONS
TASK FORCE ON SEDIMENTATION
WESTERN DAKOTA TRIBUTARIES
SUBBASIN NO. 3
SEDIMENT YIELD
FROM
AREAS IN EXCESS OF 100 SQUARE MILES





SEDIMENT YIELDS DURING URBAN EXPANSION

SUMMATION OF TOTAL SEDIMENT YIELD DURING CONVERSION FROM RURAL TO URBAN LAND USE

ANNUAL SEDIMENT YIELD FROM SOURCE AREAS					
YEAR	RURAL	CONSTRUCTION	POST CONSTR.	STABILIZED	TOTAL
1	X				X
2	X				X
3	X				X
4	X	Y			X+Y
5	X	Y			X+Y
6	X	Y	Z		X+Y+Z
7	X	Y	Z		X+Y+Z
8	X	Y	Z	W	X+Y+Z+W
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•
n − 8	X	Y	Z	W	X+Y+Z+W
n − 7		Y	Z	W	Y+Z+W
n − 6		Y	Z	W	Y+Z+W
n − 5			Z	W	Z+W
n − 4			Z	W	Z+W
n − 3			Z	W	Z+W
n − 2				W	W
n − 1				W	W
n				W	W
TOTAL	ΣX	ΣY	ΣZ	ΣW	$\Sigma(X+Y+Z+W)$

RESERVOIR SEDIMENT DEPLETION VOLUME

COMPUTATION FACTOR	UNIT
REPRESENTATIVE SEDIMENT YIELD	TONS/SQ. MI./YR.
X	
SEDIMENT CONTRIBUTING DRAINAGE AREA	SQUARE MILES
=	
TOTAL SEDIMENT INFLOW TO PROJECT	TONS/YEAR
X	
RESERVOIR TRAP EFFICIENCY	o/o
=	
SEDIMENT INFLOW AVAILABLE FOR DEPOSITION IN RESERVOIR	TONS/YEAR
X	
DENSITY OF DEPOSITS	POUNDS PER CUBIC FOOT
=	
SEDIMENT DEPLETION RATE	ACRE FEET/YEAR
X	
PROJECT LIFE	YEARS
=	
RESERVOIR SEDIMENT DEPLETION VOLUME	ACRE FEET

TABLE
ESTIMATED SEDIMENT INFLOW
PAPILLION CREEK DAMSITE 15

URBAN EXPANSION RUNOFF

Year	Time Period (Yrs.)	Agricultural Runoff: Sediment Contrib. D.A. (Sq.Mi.)	Agricultural Runoff: Sediment Yield Rate (T/SM/Y)	Agricultural Runoff: Sediment Inflow (Tons)	Construction Runoff: Sediment Contrib. D.A. (Sq.Mi.)	Construction Runoff: Sediment Yield Rate (T/SM/Y)	Construction Runoff: Sediment Inflow (Tons)	Post-Construction Runoff: Sediment Contrib. D.A. (Sq.Mi.)	Post-Construction Runoff: Sediment Yield Rate (T/SM/Y)	Post-Construction Runoff: Sediment Inflow (Tons)	Urban Runoff: Sediment Contrib. D.A. (Sq.Mi.)	Urban Runoff: Sediment Yield Rate (T/SM/Y)	Urban Runoff: Sediment Inflow (Tons)	Total Sediment Inflow Per Period (Tons)
1976-1986		(14.2)												
Area I	10	4.0	3,500	140,000	1.0	35,000	350,000	.4	7,000	28,000	0	0	0	518,000
Area II	10	8.8	2,700	237,600	0	0	0	0	0	0	0	0	0	237,600
1986-1996														
Area I	10	2.0	3,500	70,000	2.0	35,000	700,000	1.4	7,000	98,000	0	0	0	868,000
Area II	10	8.8	2,700	237,600	0	0	0	0	0	0	0	0	0	237,600
1996-2006														
Area I	10	0.0	0	0	2.0	17,500	350,000	2.4	3,500	84,000	1.0	1,000	10,000	444,000
Area II	10	8.8	1,350	118,800	0	0	0	0	0	0	0	0	0	118,800
2006-2016														
Area I	10	0	0	0	0	0	0	2.0	3,500	70,000	2.4	1,000	24,000	94,000
Area II	10	6.0	1,350	81,000	2.0	13,500	270,000	1.8	2,700	48,600	0	0	0	399,600
2016-2026														
Area I	10	0	0	0	0	0	0	0	0	0	4.0	1,000	40,000	40,000
Area II	10	4.0	1,350	54,000	2.0	13,500	270,000	2.8	2,700	75,600	1.4	1,000	14,000	413,600
2026-2036														
Area I	10	0	0	0	0	0	0	0	0	0	4.0	1,000	40,000	40,000
Area II	10	2.0	1,350	27,000	2.0	13,500	270,000	2.0	2,700	54,000	4.2	1,000	42,000	393,000
2036-2046														
Area I	10	0	0	0	0	0	0	0	0	0	4.0	1,000	40,000	40,000
Area II	10	0	0	0	2.0	13,500	270,000	2.0	2,700	54,000	6.2	1,000	62,000	386,000
2046-2056														
Area I	10	0	0	0	0	0	0	0	0	0	4.0	1,000	40,000	40,000
Area II	10	0	0	0	0	0	0	1.0	2,700	27,000	9.2	1,000	92,000	119,000
2056-2066														
Area I	10	0	0	0	0	0	0	0	0	0	4.0	1,000	92,000	40,000
Area II	10	0	0	0	0	0	0	0	0		10.2	1,000	102,000	102,000
2066-2076														
Area I	10	0	0	0	0	0	0	0	0	0	4.0	1,000	40,000	40,000
Area II	10	0	0	0	0	0	0		0		10.2	1,000	102,000	102,000
TOTAL	100			966,000			2,480,000			539,200			683,000	4,673,200

TABLE ___
SEDIMENT DEPLETION RATES
PAPILLION CREEK DAMSITE 15

YEAR	TIME PERIOD (Yrs)	TOTAL SEDIMENT INFLOW PER PERIOD (Tons)	TRAP EFFICIENCY FACTOR (%)	SEDIMENT INFLOW TRAPPED IN POOL (Tons)	MULTIPURPOSE POOL DISTRIBUTION PERCENT (%)	MULTIPURPOSE POOL TONNAGE (Tons)	MULTIPURPOSE POOL DEPOSITION DENSITY (PCF)	MULTIPURPOSE POOL DEPOSITION DENSITY (T/AF)	MULTIPURPOSE POOL DEPOSIT VOLUME (Acre/Ft)	FLOOD CONTROL POOL DISTRIBUTION PERCENT (%)	FLOOD CONTROL POOL TONNAGE (Tons)	FLOOD CONTROL POOL DEPOSITION DENSITY (PCF)	FLOOD CONTROL POOL DEPOSITION DENSITY (T/AF)	FLOOD CONTROL POOL DEPOSIT VOLUME (Acre/Ft)	INCREMENT STORAGE VOLUME (Acre/Ft)
1976															
	10	755,600	95	717,820	80	574,256	55	1,198	479	20	143,412	75	1,633	88	567
1986															
	10	1,105,600	95	1,050,320	80	840,256	55	1,198	701	20	210,064	75	1,633	129	830
1996															
	10.	562,800	95	534,660	80	427,728	60	1,307	327	20	106,932	75	1,633	65	392
2006															
	10	493,600	95	468,920	80	375,136	60	1,307	287	20	93,784	75	1,633	57	344
2016															
	10	453,600	95	430,920	80	344,736	60	1,307	264	20	86,184	75	1,633	53	317
2026															
	10	433,000	93	402,690	85	342,287	65	1,416	242	15	60,404	80	1,742	35	277
2036															
	10	426,000	93	396,180	85	336,753	65	1,416	238	15	59,427	80	1,742	34	272
2046															
	10	159,000	93	147,870	85	125,690	65	1,416	90	15	22,181	80	1,742	13	103
2056															
	10	142,000	90	127,900	90	115,101	65	1,416	81	10	12,789	80	1,742	8	89
2066															
	10	142,000	90	127,900	90	115,101	65	1,416	81	10	12,789	80	1,742	8	89
2076															
TOTAL	100								2,790					490	3,280