ASSESSMENT OF NONPOINT SOURCES OF POLLUTANTS

Nonpoint sources discharge pollutants in such amounts that an abatement program for the Ohio River compact district is necessary if the national goals of water quality which provide for the protection and propagation of fish and for recreation in and on the water are to be met by 1983. A number of studies have been made as part of the national program under PL 92-500 and several documents have been issued by the U. S. Environmental Protection Agency to help define the problem and to estimate the pollutants in nonpoint sources, their significance and the effectiveness of possible means of control.

This report was prepared at the request of the ORSANCO Engineering Committee to assist the compact states and their respective local water quality management agencies by providing recommended means of identifying and characterizing the nonpoint sources of pollution from rural and urban areas with limited data generation. Applicable methodology or techniques are discussed to provide a guide to sources of information for the more detailed methodology.

ORSANCO

Staff Report

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METHODOLOGY FOR ASSESSMENT OF
NONPOINT SOURCES OF POLLUTANTS

SUMMARY

Nonpoint sources of pollutants which result from runoff of precipitation from the land to surface waters, are of two types -- diffuse runoff directly to streams and intermittent point sources from stormwater collection systems. NPDES permit regulations have been promulgated by U. S. EPA for storm sewer discharges in major urban areas, and runoff from concentrated animal feeding operations and silviculture.

The principal nonpoint sources are agriculture (cropland and pasture), silviculture, concentrated animal feeding operations, construction, stream bank erosion, mining and urban or developed areas.

Of the approximately 204,000 square mile area of the Ohio River Basin (including the Tennessee River Basin), 89 percent of the drainage area is in the major tributary basins, six percent in minor tributary basins and less than five percent drains directly to the Ohio River. Approximately five percent of the total land area in the Ohio Basin is classified as urban or developed and over 87 percent is devoted to major rural uses -- cropland (33 percent), pasture (15 percent) and forest (39 percent). The remaining eight percent includes stream, lake and impoundments and non-classified idle land.

The Universal Soil Loss Equation (USLE) was developed to estimate average annual soil loss from agricultural land. Several of the factors in the equation -- area classified by specific land use, soil erodibility, topography, conservation practices and sediment delivery ratio -- may be determined by land use surveys and, once determined, are essentially constant values. The cover factor varies with the type of crop and season of the year. The rainfall factor, erosion index, varies with the intensity and duration of individual storm events or the summation of storm events over a period of time. Nutrient, organic matter and pesticide loadings are estimated as functions of the sediment load.

The USLE has been adapted to estimate sediment and associated pollutant discharges from forest land, feedlots, construction, and urban areas. Although the equation can also be applied to land disturbed by mining operations, chemical

reactions -- oxidation of pyrite to form sulfuric acid -- and solution of exposed minerals must also be considered in evaluating the impact of mine area drainage or runoff on stream quality. Methodology has not been developed to estimate the impact of stream bank erosion on water quality.

Assessment of the impact of rural or urban runoff on quality conditions in the receiving stream requires estimation of the pollutant load (sediment, BOD, nutrients) in the runoff from individual storm events rather than as average daily pollutant loads estimated from the long-term average annual load. Using a defined 1,000 acre hypothetical small watershed (cropland, pastures, and forest), application of the USLE is applied to illustrate the procedures and variation in pollutant load resulting from average annual precipitation, seasonal differences or single storm events. Additional details of applicable methodology are presented in a separate chapter for several land uses.

The USLE provides a method for estimating the total average annual discharge of sediment or other pollutant from a defined agricultural area. Applying the equation for other land uses, such as woodland or mine sites, involves less well defined runoff coefficients. In any application, the use of the USLE to estimate seasonal or single storm event runoff characteristics requries the recognition that the calculated loads offer qualitative rather than quantitative estimates.

Compared to the average annual sediment load, the maximum seasonal sediment load occurs in June and July with the discharge for each month representing about 20 percent of the annual load. For 24-hour single storm events, the sediment loads (May - June seeding period) vary from 23 to 71 percent of the average annual load for the one to the twenty year recurrence intervals respectively. Other pollutants would vary in the same proportions as a function of the sediment load. Similar load variations would be shown for runoff from other land use categories.

The methodology presented in this report provides a first approximation of the magnitude of nonpoint source pollutants from various land uses for the initial assessment of the possible impact of these pollutants on stream quality. The methodology is not intended to be used as a basis for the design of nonpoint source control or abatement projects.

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Nonpoint sources of pollutants which result from the runoff of precipitation from the land to surface waters are of two types -- the diffuse runoff directly to streams and the intermittent discharge from stormwater collection systems. The areawide waste treatment management planning provisions of Section 208 of PL 92-500 require detailed consideration of the water quality impacts of nonpoint sources of pollutants and, where necessary, the development of implementation of control procedures.

Sources of Nonpoint Pollutants

The principal nonpoint sources of pollution are agriculture, silviculture, construction, mining and urban runoff. The following summarizes significant factors for each of these land use categories:

Agriculture

Nonpoint sources of agricultural pollutants fall into the following broad classes:

1. Cropland
2. Animal wastes
3. Farmland in grass and pasture

Of the several pollutants discharged from nonpoint sources, the major impact on water quality is caused by sediment from soil erosion. Agricultural lands, particularly crop lands, are the largest contributors of sediment. Approximately two billion tons of sediment per year are eroded from the cropland in the United States (1). In the Ohio River Basin over 50 million acres are devoted to cropland or pasture. These two land uses represent 48 percent of the 105 million acres in the Compact District and constitute the major source of sediment discharged to the basin streams.

Besides sediment other pollutants from agricultural runoff include nutrients, pesticides, organic material and bacteria directly or indirectly associated with the sediments.

The factors which affect nonpoint source pollution from rural or agricultural areas are:

1. General topography
2. Precipitation characteristics; frequency, intensity and duration.
3. Soil properties including erodibility
4. Vegetative cover, including type, density and permanence
5. Cultural and supporting conservation practices
6. Application of fertilizer and manure

Silviculture

Sediment is the principal pollutant associated with silviculture activities or commercial management of trees. Since timber harvesting alters or disrupts surface cover, surface soil is subjected to erosion and subsequent transport into adjacent streams. Surface runoff also carries pollutants such as pesticides and fire retardent chemicals used in forest management. Approximately 39 percent of the land area (105 million acres) in the Compact District are classified as forest land.

However, on a per acre basis the water from forest lands is of high quality and low in sediment as compared to agricultural or grazing lands.

Livestock in confinement

The volume of animal wastes produced in the United States is about 10 times that produced by the human population (20). Pollutant loading to waterways is significant with the primary impact coming from confined animal populations.

Livestock wastes, in addition to increasing the nutrient and organic load in waterways, are also a source of coliform and other bacteria.

Feedlot wastes are quite variable by region, season, type of animal, and lot management practices. The Compact states have classified most concentrated animal feeding operations as point source discharges and have generally required treatment or land disposal of these wastewaters.

Construction

The construction of highway, housing and other projects is a significant source of sediment in urban areas. The acreage of land disturbed in construction is small compared to other nonpoint sources such as agricultural loads, but the rate of soil erosion is generally quite high.

Maryland and Pennsylvania have pioneered in sediment control programs and have issued technical guides to erosion and sediment control design for use by developers and planners (21, 22).

Stream bank erosion

Stream banks erode either by runoff flowing over the side of stream banks or by scouring and undercutting below the water surface. Stream bank erosion is ofter increased by the removal of vegetation or by tilling too near the banks. It is influenced by the velocity of flow, depth and soil texture.

This is quite a serious problem along the Ohio River and its major tributaries where variations in water level cause slumping as result of rapid changes in water level. Waves generated by river traffic also cause a significant amount of bank erosion.

Mining

Water pollution problems created by mining activities are both physical and chemical. Increased erosion caused by land disturbance results in increased sediment load especially in strip mining areas. Chemical pollution is caused by exposing minerals to oxidation or leaching.

One of the serious problems arising from mining activities is the formation of iron compounds and sulfuric acid by oxidation of pyritic material. Resulting mine drainage is a mixture of iron salts, other salts and sulfuric acid.

Acid mine drainage has been and is one of the major water pollution problems in the Ohio River Basin. According to 1969 Ohio River Basin Comprehensive Survey by the U. S. Corps of Engineers, nearly 2.5 million tons of acid is estimated to enter the streams of the basin each year.

Urban runoff

The significance of pollution caused by storm runoff has been recognized in many recent studies. The National Council on Environmental Quality in its annual report of 1974 emphasized the importance of sotrmwater runoff.

The stormwater problem involves three typas of discharges:

1. Combined sewer overflow
2. Surface runoff through separate storm sewers
3. Sanitary sewer overflows caused by storm water inflow and infiltration

Sanitary and combined sewer overflows have similar characteristics with 5-day biochemical oxygen demand averaging approximately one-half the strength of untreated domestic sewage. Surface runoff from urban areas has a BOD_5 approximately the strength of secondary effluent.

In the Compact area some 5 million acres are classified as urban or developed areas. Storm water runoff from the larger metropolitan areas constitutes the major part of nonpoint discharges from all urban areas; however, stormwater runoff from smaller communities may have a significant impact on quality conditions in minor tributary streams.

Methods for estimating nonpoint source pollutant loads range from simple rules of thumb to computer models of varying degrees of complexity. Salient features of applicable procedures for each of the major types of nonpoint sources are summarized in the following section. Subsequent chapters illustrate application to rural runoff and present more detailed discussions of the procedures.

Overview of Nonpoint Source Methodology

Agriculture

The Universal Soil Loss Equation (USLE) was developed to estimate average annual sediment (soil loss) in runoff from agricultural land. Several of the factors in the equation -- area classified by specific land use, soil erodibility, topography, conservation practices, and sediment delivery ratio -- may be determined by land use surveys and, once determined, are constant values. The cover factor varies with the type of crop and the season of the year. The rainfall factor, erosion index, varies with the intensity and duration of individual storm events or the summation of storm events to provide an average annual erosion index. Nutrient, BOD and pesticide loadings are estimated as functions of the sediment load.

Since the factors related to individual field uses do not change, the extension of use of the USLE from the average annual load to estimation of individual storm events at various periods of the year requires a minimum of additional computation.

Silviculture

Since soil erosion and surface water runoff result in the discharge of nutrients, pesticides and other pollutants, the USLE is used for estimating quantities of these pollutants based on sediment delivery ratio and chemical analysis of sediment or enrichment ratio of soil, etc. as discussed earlier under agriculture.

Disseyer (3) has developed a method called the First Approximation of Suspended Sediments (FASS) which can be used to evaluate the impact of disturbances or control practices on suspended sediment in surface water.

Livestock in Confinement

Wastewater from confined animal feeding operations varies seasonally by region, type of animal and management or control practices. The volume and rate of storm water runoff, number and species of animal and sediment delivery ratio are major factors in estimating pollutant loads from these operations.

The USLE can be used, with appropriate factors, to estimate sediment and other pollutant loads in runoff from animal feeding operations (see page 2)

Construction

Maryland and Pennsylvania have pioneered in sediment control programs and have issued technical guides to erosion and sediment control design for use by developers and planners.

Approximate yield from construction site can be estimated as the multiple of sediment yield from pasture land (8). The pasture land sediment yield data has been developed in an EPA report (4) or can be estimated by use of the USLE. The sediment yield from pasture loads is multiplied by the following factors to obtain yield from construction:

Urban residential = 100 x pasture land

Urban non-residential = 200 x pasture land

Highway and rural = 300 x pasture land

Sediment yield from controlled construction site is calculated in a percent of yield estimated for uncontrolled site depending upon the design of the retention basin.

Stream Bank Erosion

In 1969, U. S. Corps of Engineers with the cooperation of U. S. Soil Conservation Service conducted a study "National Assessment of Stream Bank Erosion". However, specific methodology to estimate the rate of stream bank erosion is not currently available.

However, methodology is not yet available for accurately predicting the contribution of sediment loading from bank erosion, it can be estimated from historic data and research results from Army Corps of Engineers and U. S. Soil Conservation Service.

Mining

Numerous models for predicting the acid mine drainage and leachate from refuse/soil profile are primarily directed to pyritic oxidation (9) or to sulfur contents of the source material (10).

The anion-cation balance method which has been described in the 13th Edition of Standard Methods for the Examination of Water and Wastewaters is a very useful tool for estimating the acid drainage in streams. Hen (10) has also described several models which use anion-cation balance concept in interpreting the water quality data.

Urban runoff

Numerous analytical techniques of varying degrees of sophistication have been developed to assess the water pollution characteristics of urban runoff. The most accurate and definitive methods utilize complex mathematical models.

Estimating techniques can be used for preliminary analysis of urban runoff to obtain approximate characteristics of urban runoff based on limited data including:

1. Study area characteristics
2. Contaminant loading rates
3. Storm event characteristics and runoff rate

More refined estimates require use of one of several urban runoff models described in literature (12). They range from relatively simple models to highly complex models that utilize the complete dynamic equations of motion to simulate every aspect of drainage system. The most generally used urban runoff models are Storm Model (13), developed by the U. S. Corps of Engineers Hydrologic Engineering Center and U. S. EPA Storm Water Management Model (14). (see pp.3-4)

Nonpoint Sources in the Ohio Basin

The Ohio River, formed by the confluence of the Allegheny and Monongahela rivers at Pittsburgh, Pa., flows in a northerly direction for 40 miles then in a south westerly direction for 941 miles to its confluence with the Mississippi River downstream from Cairo, Illinois. Distribution of land area within the many tributary basins and land use within the major basins are determining factors in consideration of the impact of nonpoint sources on stream quality.

Tributary drainage area

Drainage areas of the twenty-one major tributaries to the Ohio River range from 1,000 square miles for the Tradewater River to 40,000 square miles for the Tennessee River. The Ohio Basin drainage area is classified as:

Classification	Drainage Area Square Miles	Percent of Basin Area
Major tributaries	182,370	89.4
Minor tributaries	12,292	6.1
Ohio Main Stem	9,278	4.5
Total	203,940	100.0

With less than five percent of the land area drainage directly to the Ohio River, the most significant water quality problems related to stormwater runoff occur in the tributary basins. Major tributary drainage areas are tabulated in Table 1 and minor tributaries in Table 2.

Land Use

Land use plus land management determines the sediment load in the runoff of the surface waters of the Ohio Basin. The land area in the Ohio Basin (exclusive of the Tennessee River) is classified as:

Use	Millions of Acres	Percent of Total
Cropland	34.2	33
Pasture	16.4	15
Forest	40.8	39
Urban and built-up	4.9	5
Lakes & impoundments	1.1	1
Miscellaneous (includes stream and non-classified idle land)	7.0	7

TABLE 1

DRAINAGE AREAS OF THE MAJOR TRIBUTARIES TO THE OHIO RIVER

Tributary	Miles below Pittsburgh: Northern Tribs.	Miles below Pittsburgh: Southern Tribs.	Length of Main Stream Miles	Drainage Area (square miles)
Allegheny	0		325	11,700
Monongahela		0	128	7,400
Beaver	25.4		21	3,130
Muskingum	172.2		112	8,040
Little Kanawha		184.6	160	2,320
Hocking	199.3		100	1,190
Kanawha		265.7	97	12,200
Guyandot		305.2	66	1,670
Big Sandy		317.1	27	4,280
Scioto	356.5		237	6,510
Little Miami	464.1		90	1,670
Licking		470.2	320	3,670
Great Miami	491.1		161	5,400
Kentucky		545.8	255	6,970
Salt		629.9	125	2,890
Green		784.2	370	9,230
Wabash	848.0		475	33,100
Saline	867.3		27	1,170
Tradewater		873.5	110	1,000
Cumberland		920.4	693	17,920
Tennessee		934.5	652	40,910
Total				182,370

TABLE 2

DRAINAGE AREAS OF THE MINOR TRIBUTARIES TO THE OHIO RIVER

Tributary	Drainage Area (square miles)	Length of Stream (miles)	Miles from Pittsburgh
Upper Ohio River			
Chartier Creek, Pa.	277		2.5
Raccoon Creek, Pa.	200		29.6
L. Beaver R., Ohio	510	51	39.5
Yellow Creek, Ohio	240	34	50.4
Cross Creek, Ohio	128	27	71.6
Buffalo Creek, W. Va.	160		74.7
Short Creek, Ohio	147	29	81.4
Wheeling Creek, Ohio	108	30	91.0
Wheeling Creek, W. Va.	300		91.0
McManon Creek, Ohio	91	28	94.7
Grave Creek, W. Va.	75		102.5
Captina Creek, Ohio	181	39	109.6
Fish Creek, W. Va.	250		113.8
Sunfish Creek, Ohio	114	31	118.0
Fishing Creek, W. Va.	220		128.3
Middle Island Creek, W. Va.	560		154.0
L. Muskingum River, Ohio	315	70	168.3
Duck Creek, Ohio	228	52	170.7
L. Hocking River, Ohio	103	18	191.8
Middle Ohio River			
Shade River, Ohio	221	38	210.6
Shady Creek, W. Va.	115		220.6
Mill Creek, W. Va.	230		231.5
Leading Creek, Ohio	151	30	254.2
Raccoon Creek, Ohio	684	109	276.0
Symmes Creek, Ohio	356	70	209.0
Twelvepole Creek, W. Va.	440		313.3
Pine Creek, Ohio	185	48	346.9
L. Scioto River, Ohio	233	41	349.0
Tygarts Creek, Ky.	336		353.3

TABLE 2 - (cont'd)

Tributary	Drainage Area (square miles)	Length of Stream (miles)	Miles from Pittsburgh
Kinniconnick Crk. Ky.	253		368.1
Ohio Brush Crk., Ohio	435	57	388.0
Eagle Creek, Ohio	154	31	415.7
Whiteoak Creek, Ohio	234	49	423.9
Mill Creek, Ohio	166	28	472.5
Tanner Creek, Ind.	136		494.8
Laughory Crk., Ind.	350		498.7
Lower Ohio River			
L. Kentucky River, Ky.	147	35	546.5
Indian Ky. River, Ind.	150		550.5
Silver Creek, Ind.	225		606.5
Big Indiana Creek, Ind.	249		657.0
Blue River, Ind.	466		663.0
Sinking Creek, Ky.	199		700.9
Anderson Creek, Ind.	276		731.3
Blackford Creek, Ky.	124		742.2
L. Pigeon Creek, Ind.	415		773.0
Pigeon Creek, Ind.	375		792.9
Coche River, Ill.	720		975.7
Total	12,292		

Approximately five percent of the total land area is classified as urban or developed and over 87 percent of the area is devoted to major rural uses -- cropland, pasture and forest. Land use classification of the drainage areas of the major tributaries is shown in Table 3.

Data for estimation of nonpoint source loads

Many types of information are required to estimate the sediment and associated pollutant loads in stormwater runoff to surface waters. Besides water quality data, this information includes:

- soil and geologic data
- climatological data
- topographic information
- aerial maps
- statistics on land use
- livestock production
- use of fertilizers and pesticides

Most of the information necessary for developing an effective plan is available from water management programs and studies such as:

- EPA studies and reports
- basin studies under the water resources planning act of 1965
- flood plain information studies of the U. S. Geological Survey and U. S. Army Corps of Engineers
- forest service and soil conservation reports
- regional planning agencies -- Cincinnati area (OKI) and Louisville area
- Bureau of Land Management
- Bureau of Reclamation
- U. S. Army Corps of Engineers reports

TABLE 3

LAND USE DATA FOR MAJOR TRIBUTARIES AND MAIN STEM

Stream	Total Area	Cropland	Pasture	Forest	Urban & built up	*Remaining
Allegheny	7,486	1,332	732	4,322	302	798
Monongahela	4,127	529	907	2,334	139	218
Beaver	1,837	617	197	564	219	240
Muskingum	5,089	1,749	1,074	1,325	306	635
Kanawha, L. Kanawha	9,117	824	1,764	6,148	233	148
Guyandot, Big Sandy, Little Sandy	3,799	152	222	3,091	92	242
Scioto	3,979	2,520	494	638	223	104
Great Miami, L. Miami	4,149	2,694	496	521	360	78
Licking, Kentucky, Salt	7,837	1,434	2,341	3,329	182	551
Green	5,148	1,712	904	2,038	122	372
Wabash	20,886	13,412	2,074	3,134	1,010	1,756
Cumberland	11,104	2,095	1,801	5,874	436	898
Ohio River & minor tributaries	18,723	5,145	3,334	7,471	1,291	1,472
TOTAL	103,281	34,215	16,350	40,789	4,915	7,012

* Includes farmstock, rural non-farm residences, cross-road service stations, rural schools, churches, etc.

ILLUSTRATIVE APPLICATION OF USLE TO RURAL NONPOINT SOURCES

The Universal Soil Loss Equation was developed to estimate annual soil loss from agricultural land. Water quality impacts on the receiving streams, however, result from individual storm and runoff events. This section illustrates the application of the USLE to a hypothetical small watershed on an annual, monthly and single event basis.

Assume a watershed (figure 1) area of 1,000 acres in central Indiana. Compute annual, average daily, seasonal and individual storm nonpoint pollution loads from the watershed in terms of:

1. Sediments
2. Nitrogen
3. Phosphorus
4. Organic matter/BOD_5

<u>Land use and other basic information</u>

Cropland 280 acres

Continuous corn

Conventional tillage, average yield 40 to 45 bu.

Corn stalks are left after harvest

Contour strip cropped

Soil -- Fayette silt loam

Slope 6 percent

Slope length 300 feet

Pasture 270 acres

No appreciable canopy

Cover at surface -- grass or grass-like plants

Percent ground cover 80 percent

Soil -- Fayette silt loam

Slope 8 percent

Slope length 200 feet

Woodland 450 acres

Medium stocked

Percent of area covered by tree canopy -- 50%

Percent of area covered by litter -- 80%

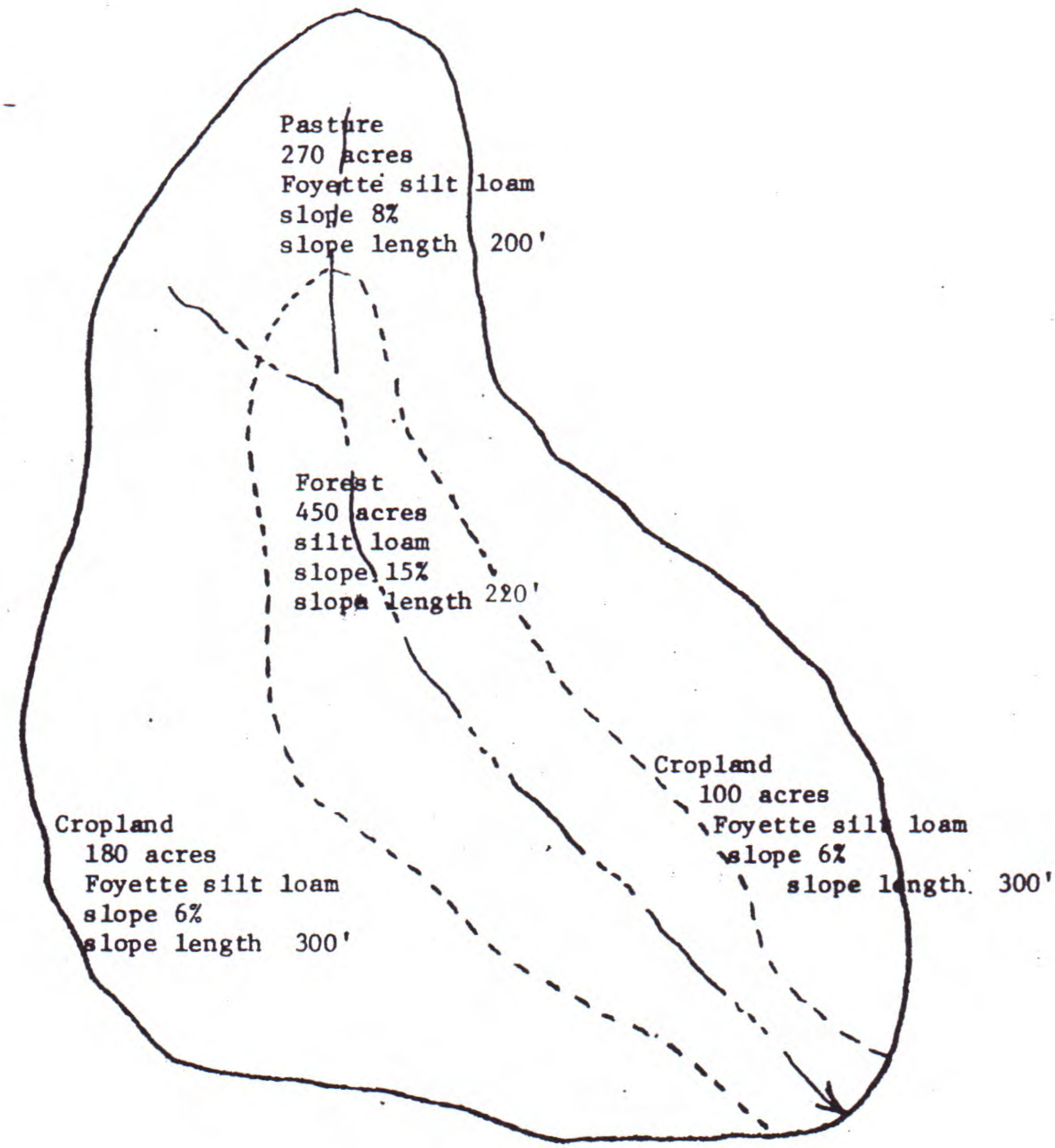

Figure 1: Hypothetical 1000 acre watershed
for use in the example

Undergrowth -- managed

Soil -- silt loam

Slope 15 percent

Slope length 120 feet

The Universal Soil Loss Equation

$$Y = A\ (R.K.LS.C.P.)\ SD$$

is used to estimate the sediment load from the watershed.

Determination of factors:

	Cropland	Pasture	Woodland
R =	175 (figure 2)	175	175
K =	0.37 (SCS)	0.37	0.37
LS =	1.2 (figure 3)	1.55	3.3
C =	0.49 (table 4)	0.013 (table 5)	0.003 (table 6)
P =	0.25 (table 7)	1.0	1.0

Sediment delivery ratio, SD, for the watershed is 0.51 (figure 4)

Calculation of sediment loading:

Cropland

$$Y\ annual = A\ (R.K.LS.C.P.)\ SD$$

$$= 280\ (175 \times 0.37 \times 1.20 \times 0.49 \times 0.25)\ 0.51\ ton/yr.$$

$$= 1,350\ tons/yr.$$

Pasture (154 ton/yr.) and Woodland (120 ton/yr.) are calculated in the same way.

Total annual sediment = 1,350 + 154 + 144 = 1,673 ton/yr.

Average daily sediment = 1,633/365 = 4.47 tons/day = 8,940 lbs/day

Individual pollutants

The following equation is used to estimate total nitrogen, total phosphorus, organic matter and 5-day biochemical oxygen demand from the sediment load:

load

$$Load\ (pounds/year) = a \times Y \times C_i \times r_i$$

where

a = dimensional factor = 20

Y = annual sediment load, pounds or tons per unit time

C_i = concentration of pollutant in soil, percent by weight

r_i = pollutant enrichment ratio

For the hypothetical field these values are:

	Nitrogen	Phosphorus	Organic Matter
a	20	20	20
Y - tons/yr	1,673	1,673	1,673
C_i	0.12 (Figure 5)	0.031 (Figure 6)	2.4*
r_i (MRI report)	2.5	1.5	2.5
Pollutant load			
pounds/year	9,800	1,509	196,032
pounds/day	26.8	4.3	537

* 20 x C_i value for nitrogen

The BOD_5 load is assumed to be 10% of the total organic matter 19,600 pounds/year or 537 pounds per day.

Computation of seasonal nonpoint pollution load

The USLE can be used to compute the seasonal nonpoint pollution loads for the watershed described in the example, assuming all factors constant except C and R, where C varies throughout the year depending upon the type and stage of the crop. The value of C can be assumed as constant for forest and pasture lands. The average monthly distribution of erosion index, R, which is computed by summing EI values of individual storms, has been determined by SCS based on long time rainfall data for different regions of the United States.

The average monthly erosion index values are expressed as percentage of the average annual values. The curves applicable to the Ohio River Basin are reproduced (2) and shown in Figures 7 to 10.

Variation in NPS load due to rainfall factor

The rainfall index, R, varies within a year. For loads where the cover factor, C, is relatively constant -- woodland and grass land, for example -- temporal distribution of rainfall factor R governs temporal variations in sediment load.

The seasonal variations of nonpoint pollution load based on R from a 1,000 acre watershed assuming constant cover factor for cropland are given in Table 8. Figure 11 shows the monthly distribution of sediment load as compared to average annual monthly load. This indicates that more than 50 percent of the total nonpoint pollution load contribution occurs during the summer.

Table 8: Average monthly non-point pollution load from the Illustrative Watershed based on erosion factor R

Month	Percent of Annual Load	Sediment (lbs)	Total-N (lbs)	Total-P (lbs)	BOD_5 (lbs)
January	1	32,600	98	15	196
February	3	98,000	294	45	588
March	4	130,000	392	60	784
April	7	228,600	686	106	1,372
May	9	294,000	882	136	1,764
June	20	653,400	1,960	302	3,920
July	20	653,400	1,960	302	3,920
August	14	457,400	1,372	211	2,744
September	10	326,800	980	151	1,960
October	6	196,000	588	90	1,176
November	4	130,000	392	60	784
December	2	65,400	196	30	392
Total Annual		3,266,000	9,801	1,509	19,603
Average Monthly		272,167	817	126	1,633

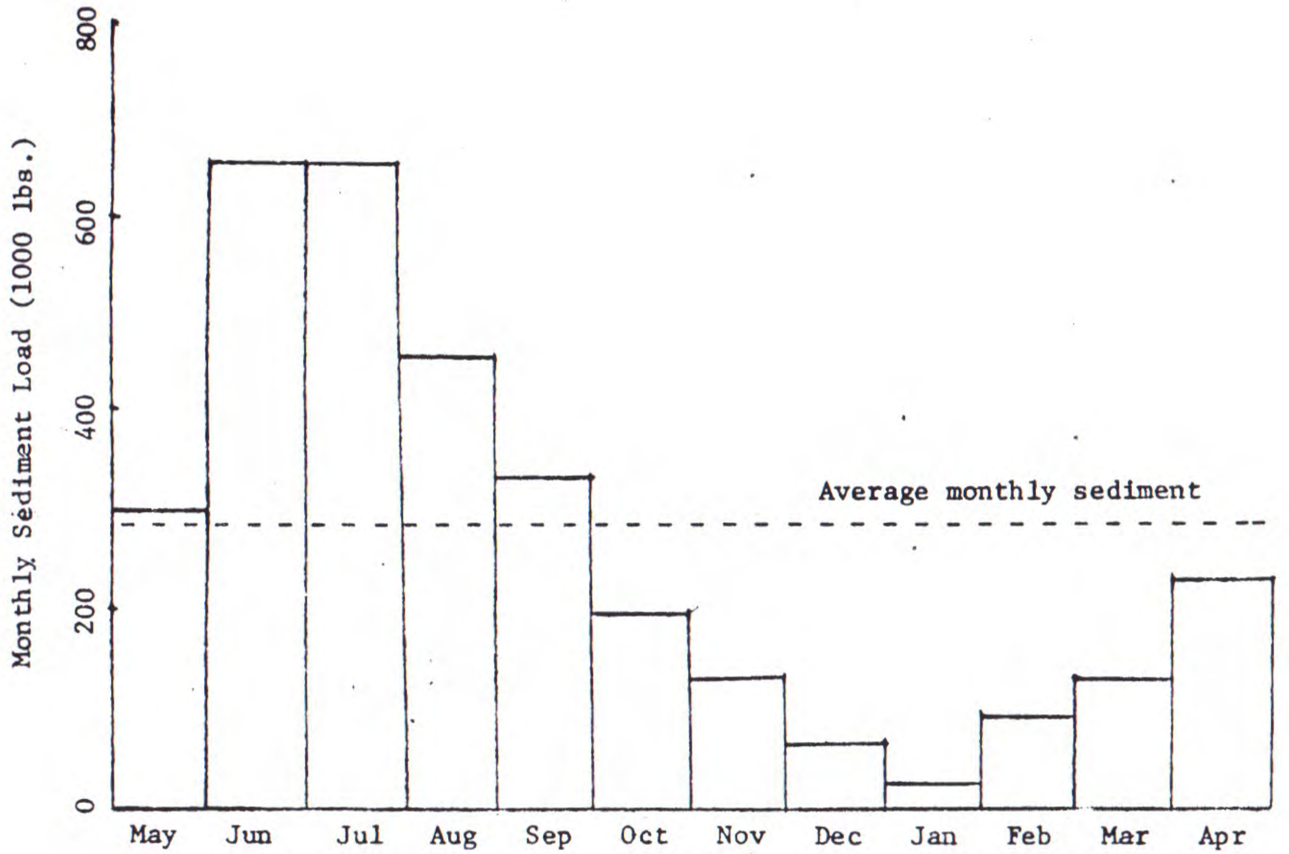

Figure 11: Monthly Variation in Sediment Based on Rainfall Factor Assuming Cover Factor Constant

Variation in NPS pollution caused by combined effects of rainfall factor and cover factor

As mentioned earlier, the cover factor C remains relatively constant throughout the year for woodland and grass land, but for croplands, where soils are tilled and surface conditions change drastically from one crop stage to another, evaluation of erosion variations should include both R and C factors.

Table 9 gives the average dates of each crop stage, cover factor and percentage of R that can be expected during each crop stage (curve 16) in addition to the average daily load in each period. Figure 12 gives a comparison of average daily sediment in each period and average annual daily sediment. It is seen that maximum erosion occurs from mid-June through July, approximately the same period of maximum erosion determined with constant cover factor.

NPS pollution from a single storm event

Table 10 enumerates the total nonpoint pollution load for selected recurrence intervals based on the erosivity of the storm for different crop stages.

The values of factor R for selected recurrence interval are available in the Agricultural Handbook 282, and are reproduced in Table 11.

Table 10 and Figure 13 indicate that a 20-year storm can produce as much as 70 percent of the total annual NPS load if it occurs from June through July.

To evaluate the impact on water quality from nonpoint source pollutants, the estimation of total annual load or annual average daily load is of limited value, since the contribution is not continuous throughout the year but occurs primarily as the result of a few intense storms. Average daily load based on the duration of the storm would be much higher than the average annual daily load.

Table 9: Nonpoint Pollution Load Based on the Combined Effect of Cover Factor C and Erosion Factor R

Crop Stage	Cropland* Starting & Ending Date	C	Percent R	Cropland 280A	Pasture 270A	Woodland 450A	Total 1000 A	Avg. Daily 1000A
Turn plowing	5/1 -- 5/19	0.55	5.7	173,960	17,556	13,680	205,196	10,799
Seeding	5/20 -- 6/19	0.70	16.5	640,907	50,820	39,600	731,324	24,377
Establishment	6/20 -- 7/19	0.58	21.3	685,521	65,604	51,120	802,245	27,664
Growing Crop	7/20 --10/09	0.32	33.7	598,402	103,796	80,880	783,078	9,667
Harvest and Stubble	10/10 -- 4/30	0.50	22.8	632,584	70,224	54,720	757,528	3,677

* USDA -- Agricultural Research Service Handbook 282. The appropriate C values for different crop sizes in various regions can be obtained from SCS district offices.

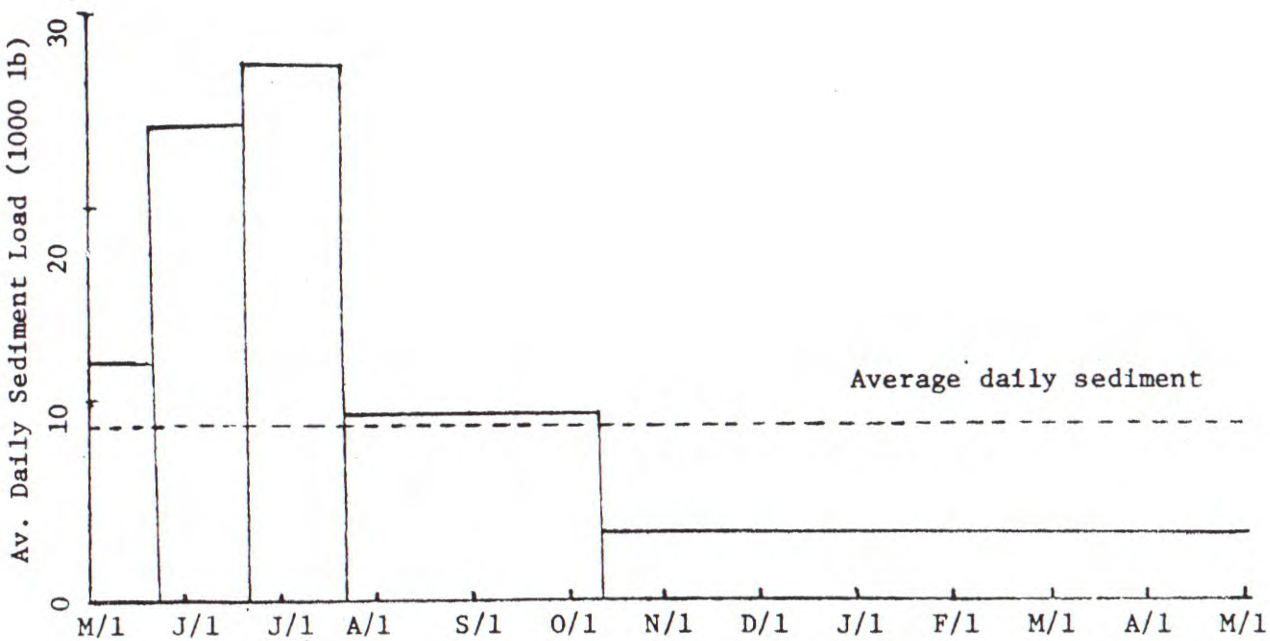

Figure 12: Variation in average daily sediment load based on combined effect of the monthly rainfall factor and cover factor

Table 10: Single Storm Event NPS Contribution
(1,000 acre watershed)

Recurrence Interval	Crop Stage	Sediment (lb) Cropland 280A	Pasture 270A	Woodland 450A	Total	Total-N (lb)	Total-P (lb)	BOD (lb)	Organic Matter	Total Annual Sediment
1	1	504,000	59,400	48,600	612,000	1,840	280	3,680	36,800	3,266,000
	2	644,000			752,000	2,260	350	4,520	45,200	
	3	532,000			640,000	1,920	290	3,840	38,400	
	4	291,200			399,200	1,200	180	2,400	24,000	
	5	453,600			561,000	1,700	260	3,400	34,000	
2	1	711,200	81,000	68,400	860,600	2,490	400	5,180	51,800	
	2	907,200			1,056,600	3,180	490	6,360	63,600	
	3	750,900			899,800	2,700	410	5,400	54,000	
	4	414,400			563,800	1,690	260	3,380	33,800	
	5	644,000			793,400	2,390	370	4,780	47,800	
5	1	1,047,200	124,200	100,800	1,272,200	3,820	580	7,640	76,400	
	2	1,332,800			1,557,800	4,680	720	9,360	93,600	
	3	1,103,200			1,328,200	3,990	610	7,980	79,800	
	4	604,800			829,800	2,490	380	4,980	49,800	
	5	946,400			1,171,400	3,420	540	7,040	70,400	
10	1	1,304,800	151,200	129,600	1,585,600	4,770	730	9,540	95,400	
	2	1,663,200			1,944,000	5,840	890	11,680	116,800	
	3	1,377,600			1,658,400	4,990	760	9,980	99,800	
	4	756,000			1,036,800	3,120	480	6,240	62,400	
	5	1,181,600			1,462,400	4,400	670	8,800	88,000	
20	1	1,568,000	183,600	153,000	1,904,600	5,720	880	11,440	114,400	
	2	1,993,600			2,330,200	7,000	1,070	14,000	140,000	
	3	1,652,000			1,988,500	5,980	920	11,960	119,600	
	4	907,200			1,243,800	3,740	570	7,480	105,000	
	5	1,416,800			1,753,400	5,270	810	10,500	105,000	

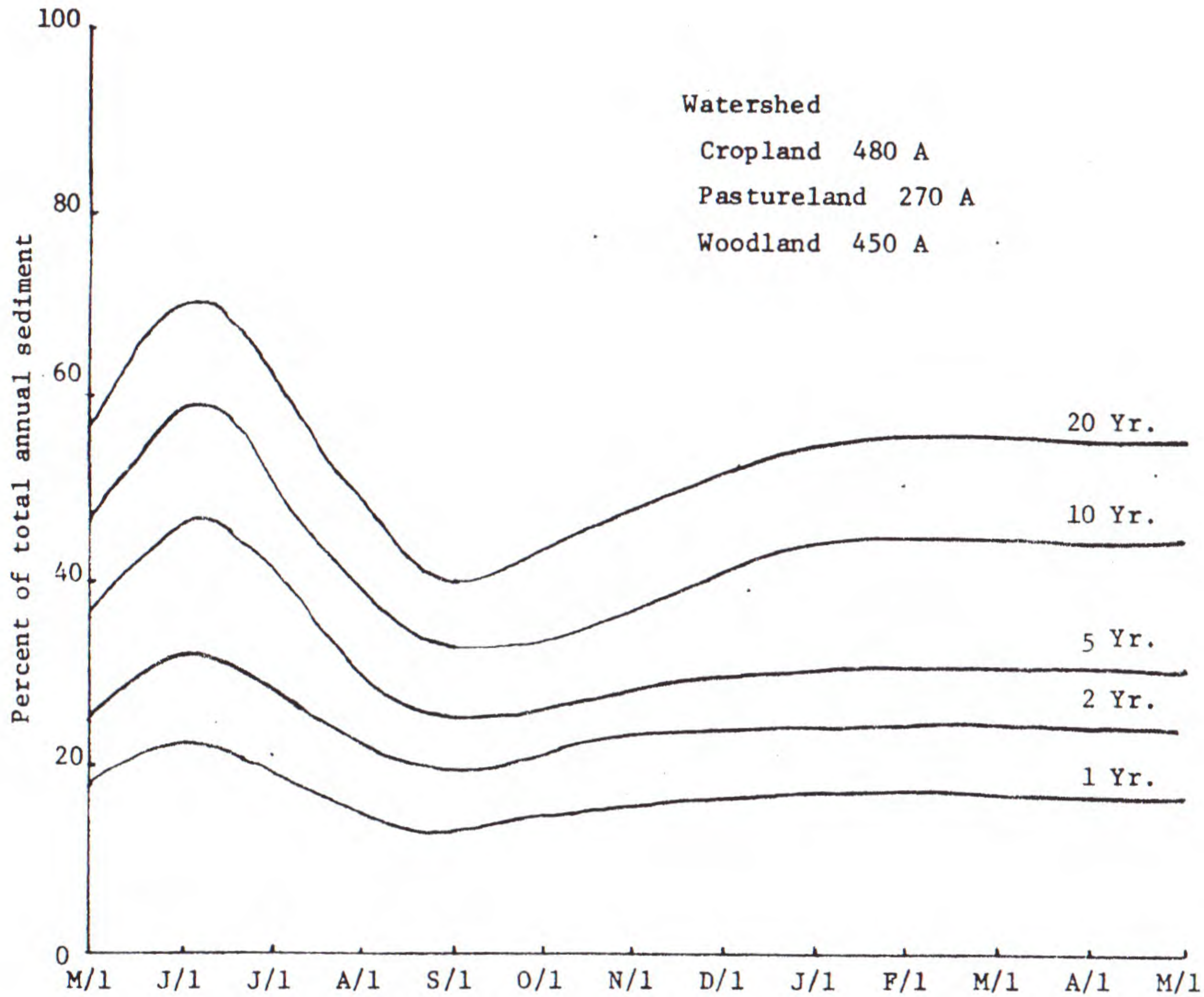

Figure 13: Comparison of 24-hour sediment load from single storm events at indicated recurrence intervals with total average annual sediment load

Limitation of "USLE"

1) The USLE can be used to predict soil losses from sheet and rill erosion but not from gully, stream bank, landslide, road ditch, irrigation or wind erosion.

2) The rainfall index measures only the erosivity of rainfall and associated runoff; therefore, the equation does not predict soil loss from snow melt or thaw.

3) The USLE was developed primarily for cropland, and the factors for application of this equation to other areas like silviculture, construction and mining are not well developed.

4) Care should be exercised in selecting the values of factors used in the equation.

5) The USLE provides an estimate of the total annual average discharge of sediment and other pollutants from a defined area. Average seasonal or monthly estimates of pollutant loads are based on more limited field data and would be more variable than the annual loads. Application of the USLE to single storm events provides an estimate of the magnitude of pollutant loads and possible water quality impacts.

Pollution Transport in the Stream

Runoff is a major mode whereby nonpoint source pollution is transported into a stream or waterway. Surface waters carry suspended solids in large quantities and many pollutants such as phosphate, pesticides and coliform bacteria are attached to the sediment and thereby carried to the stream. Subsurface drainage may also carry a significant concentration of pollutants in dissolved form.

By the time the pollutants reach the stream, they are partially oxidized so that most of the organic matter is not readily available for biological oxidation. It would degrade very slowly.

It is incorrect to assume that all the nonpoint load generated within the sub-basin will enter the main stem. The actual load to the main stem is a function of complex activities involving time of travel, reaction rate, biological activity and hydrological and hydraulic characteristics of the stream

APPLICABLE METHODOLOGIES FOR ESTIMATING NONPOINT SOURCE POLLUTION

A requisite feature of any prediction procedure is the sound data base upon which to operate. Regardless of the level of sophistication of a prediction model, the information generated can be no better than the base line data which formed the foundation for predicting future events in a given water course.

The following are some available techniques for predicting rates and types of pollutants generated by nonpoint sources of pollution.

AGRICULTURE

Among a variety of pollutants discharged from nonpoint sources, sediment is regarded as having the largest effect upon water quality, and agricultural activities, particularly of croplands, are the largest contributors of sediment. Other pollutants are associated with the sediment in one way or another.

There are numerous sediment prediction methods exhibiting varying degrees of accuracy and completeness, but the most comprehensive technique currently available is the Universal Soil Loss Equation (USLE). The gross soil erosion estimated by USLE is multiplied by sediment delivery ratio to determine the amount of solids carried out of the watershed. Nutrient and organic loading can then be estimated from the reported chemical properties of the sediments or from known nutrient levels in the soil and enrichment ratios.

1. Sediment loading
2. Nutrient and BOD loading
3. Pesticide loading

Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) was developed by Wischmeir and others (2). It is presented below, along with a brief description of its factors. A more detailed description and evaluation of various factors is given in Agricultural Handbook 282 (2) and in other references (3, 19).

The Universal Soil Loss Equation is expressed as:

$$y = A(R \times K \times LS \times C \times P)\ SD$$

where

y = Gross sediment load from the area under consideration, tons/year

A = Area in acres

R = The rainfall factor, expressing the erosion potential of average annual rainfall in the locality, is the summation of the individual storm products of the kinetic energy (E) of rainfall in hundreds of foot-tons per acre, and the maximum 30-min. rainfall intensity (I), in inches per hour for all significant storms, on an average annual basis.

Average annual R values are published as an iso-erodent map for states east of the Rocky Mountains in Agricultural Handbook 282 (2). (See Figure 2)

To compute the erosion index for a particular storm, the following relationship developed for the Eastern United States can be used:

$$R = 19.25 \frac{r^{2.2}}{H^{0.4672}}$$

where r is the storm rainfall in inches and H is the duration of rainfall in hours.

K = Soil erodibility factor, K, relates to the rate at which different soils erode. It is defined as the average rate of soil loss per unit of R for a continuous fallow on a 9% slope 72.6 feet long. The properties of importance in soil erodibility are infiltration rate, permeability, and resistance to dispersion splashing, abrasion and transport. The K values for various soils in different locations can be obtained from regional or state offices of Soil Conservation Service.

A monograph developed by Wischmeir (1), Figure 14, can be used to compute K using known values of particle distribution, organic matter, structure and profile permeability.

LS = Topographic factor that represents the combined effects of slope length and steepness is the expected ratio of soil loss per unit area on a field slope to corresponding loss from the 9 percent slope, 72.6 feet long. The ratio for specific combination of slope length and gradient may be taken directly from Figure 3 or can be computed by the following relationship:

$$LS = \sqrt{l} \quad (0.0076 = 0.0053S = 0.00076S^2)$$

where S is the present ground slope and l the length of the slope.

C = The cover factor, C, ranges from near zero for excellent sod or a well managed forest to 1.0 for the continuous fallow, construction areas or other extensively disturbed soils.

In order to evaluate the cover management factor for crops, different crop stage periods are selected for relative uniformity of cover and residue effect within each period. The values of C are highly variable with rainfall pattern, planting dates, type of vegetative cover, seeding method, soil tillage, disposition of residues, and general management level. Ranges of C values for several types of vegetation and ground cover are listed in Table H, for pasture, rangeland, and idle land in Table 5, and for woodland in Table 6.

P = Conservation practices factor, P, is the ratio of soil loss with supporting practices to soil loss with uphill and downhill culture. The supporting practices such as strip cropping, terracing and contouring reduce the erosive potential of runoff by their influence on drainage pattern, runoff concentration, and runoff velocity. The values of P for different practices have been developed by Soil Conservation Service and are given in Table 7.

SD = Sediment delivery ratio is defined as the ratio of the sediment delivered at a location in the stream system to the gross erosion from the drainage area above that point. The sediment yield is estimated by computing the gross erosion and multiplying it by the sediment delivery ratio. The sediment delivery ratio relationships are shown in figure 4. These take into account the effect of distances the soil particle must travel from the erosion site to the receptor water, expressed as reciprocal of drainage density and the effect of soil texture. The delivery ratio is higher if the soil is essentially silt or clay and lower when the soil texture is coarse.

Nutrient and BOD Loading

It has been shown that erosion is an important factor in the loss of nutrients in surface waters. Almost all of the total phosphorus and a considerable portion of the total nitrogen and organic matter is associated with the particulate matter in the storm runoff. Thus the sediment yield can be used to estimate the nutrients and organic loads in surfaee waters.

The loading functions for nutrients and BOD have a general form as:

$$Nu = a \times Y \times C_{nu} \times r$$

where

Nu = loading of nutrient or BOD to surface waters carried by sediments, lb./yr.

a = constant (dimensional factor)

= 20 (in English unit)

y = sediment loading from surface erosion, tons/yr.

C_{nu} = concentration of nutrient or BOD in soil, percent by weight

r = enrichment ratio

$= \frac{\text{nutrient or BOD in eroded soil}}{\text{nutrient or BOD in uneroded soil}}$

= 2-4 for nitrogen and BOD, and 1.5 for phosphorus (from MRI report (8))

The nitrogen content of soils in various regions can be estimated from Figure 5, MRI report (8).

The phosphorus contents of soils for the United States published by Parker, etal. (15) are reproduced in Figure 6.

For approximate values, the organic matter contents may be taken as 20 times that of total nitrogen, and biochemical oxygen demand as 10 percent of organic matter (16).

Pesticide Loading

Similar to the nutrient and BOD loading functions, the pesticide loading function is based upon sediment yield and the concentration of pesticides in the soil.

The loading function is

$$P = a \times rp \times Cp \times Y$$

where

P = pesticide yield, lb./yr.

a - constant (dimensional factor), 2×10^{-3} (in English unit)

rp = enrichment factor, 1.5 (MRI report)

Cp = concentration of pesticide in soils, ppm

Y = sediment yield for source, tons/yr.

Pesticide concentrations in soils for the Ohio River Basin (see Table 12 and Figures 15-17) were obtained from an article by Wiersma etal. (17) published in Pesticide Monitoring Journal. The data reported were monitored by EPA, office of pesticide programs. The mean residue levels (ppm) of various pesticide types for each state can be used as an input to calculate pesticide loading in the above equation.

Use of USLE for Individual Storms

Sediment erosion from a nonpoint source is a direct function of the erosive force of the specific rainfall. In practice, the erosion loss is estimated with the help of Universal Soil Loss Equation, which utilizes such factors as crop management, conservation practices, soil erodibility, length and slope and rainfall. The relation of soil loss to these is not the same from storm to storm or from year to year, even on the same field under continuing rotation.

In a particular rainstorm, the factor relationships are influenced by such variables as antecedent moisture, tillage, tractor and implement compaction, soil crusting by prior rains, and progressive changes in the plant cover. Since the positive and negative effects tend to balance out over a long time period, they do not invalidate the equation for predicting long-term average soil losses from specific land areas and management conditions.

Prediction of individual storm soil losses will be less accurate; however, a valuable estimate can be computed by the following procedure:

Two important factors which affect the soil loss estimates by USLE are rainfall--R--and cover--C.

Instead of taking an average annual value of R, compute R values for a specific rainstorm as:

1) $R = EI$

where E = kinetic energy of the storm (Table 13)

I = maximum 30-minute intensity of that particular storm

or 2) Rainfall erosion factor R can be computed directly by a formula developed for the states east of the Rocky Mountains as

$$R = 19.25 \frac{r^{2.2}}{H^{0.472}}$$

where r is the storm rainfall in inches and H is the duration in hours

SILVICULTURE

The principal pollutant associated with silviculture activities or commercial management of trees is the sediment. Universal Soil Loss Equation has been found very useful for estimating the soil erosion from forest areas, as discussed on page 5.

CONCENTRATED ANIMAL FEEDING OPERATIONS

Feedlot wastes are quite variable by region, season, type of animal, and lot management practices. The following factors are considered to estimate wastes from feedlot operations:

a. quantity of runoff

b. concentration of pollutants (type and number of livestock)

c. delivery ratio

The 1975 requirements for NPDES permits for concentrated Animal Feeding Operations were published in the Federal Register, November 20, 1975. According to these requirements, the following categories of animal feedlot facilities are included under the NPDES program:

Slaughter and feeder cattle steers and heifers	--	1,000
Dairy cattle	--	700
Slaughter pigs	--	4,500
Feeder pigs	--	35,000
Sheep	--	12,000
Turkey	--	55,000
Laying hens	--	180,000
Broiler chickens	--	290,000
Animal within a facility	--	1,000 animal units

The following multipliers are used to calculate the number of animal units in lots with more than one type of animal.

Slaughter steers and heifers	--	1.0
Dairy cattle	--	1.4
Swine	--	0.4
Sheep	--	0.1

The formula to estimate the loading rate from feedlots is suggested by an EPA report (4) as:

$$Y\ (i) = a.\ Q.\ C_{(i)}.D_f.A$$

where

Y_i = loading rate of pollutant i from livestock facility, lb/day

Q = direct runoff, in/day

C_i = concentration of pollutant i in runoff (mg/l)

D_f = delivery ratio

A = area of livestock facility

a = a dimensional constant, 0.23 (English units)

a. Quantity of runoff

Runoff volume is dependent upon many factors, e. g.

(i) amount and intensity of precipitation

(ii) soil moisture conditions

(iii) topography including slope and surface cover

(iv) soil characteristics

Based upon the above, the U. S. Soil Conservation Service has developed the following method for estimating direct runoff from small agricultural lots due to single storm events:

$$Q = \frac{(P-0.2S)^2}{P+0.8S}$$

where

Q = direct runoff, inch

P = storm rainfall, inch

S = potential infiltration, inch

S is defined in terms of runoff curve number (CN) as:

$$S = \frac{1000}{CN} - 10$$

For given values of P and CN, direct runoff can be estimated directly from Figure 18.

b. Pollutant concentration

Some of the reported data on feedlot runoff characteristics are presented in Tables 14 and 15 and can be used as a guide for selecting concentration for feedlot operations.

c. Pollutant delivery ratio

Pollutant delivery ratios were developed by EPA (4) based on the following considerations:

1. The majority of the pollutant load is carried away in the first part of runoff.

2. Feedlot solids are fine textured and tend not to settle out of the overland flow.

3. Buffer strips have limited value for permanent retention of runoff-contained sediments.

These delivery ratios, therefore, tend to be higher than delivery ratios for sediments from similarly located cropland.

Recommended delivery ratios are:

Case I -- Feedlot 0.1 mile from an unobstructed waterway

$D_f \geq 0.9$

Case II -- Feedlot located more than 0.1 mile from stream or unobstructed waterway

$D_f = 0.7$ to 0.9

CONSTRUCTION - (See Page 5)

STREAM BANK EROSION

As mentioned above, methodology is not yet available for accurately predicting the contribution of sediment loading from bank erosion. (See Page 6)

MINING

According to Ohio River Basin Comprehensive Survey of the U. S. Corps of Engineers, nearly 2.5 million tons of acid are estimated to enter the streams of the basin each year. Methodologies for predicting the acid mine drainage and leachate from refuse/soil profile have been established and are referenced on Page 6.

URBAN RUNOFF

Analytical techniques which have been developed to assess the water pollution characteristics of urban runoff can be grouped into:

A. Simple technique

B. Mathematical modeling

A. Simple Technique

For preliminary analysis of urban runoff simple techniques can be used to obtain approximate characteristics.

1. Study area characteristics: Physical characteristics of the study area required include:

   - Size of the study area.
   - Impervious area within the study area.
   - Street surface area.
   - Length of main drainage channel.
   - Average slope of the main channel.

   This information can be obtained from topographic maps, aerial photographs or engineering maps, etc.

2. Contaminant loading rates: The loading rate for different land uses of the study area can be obtained from Table 16 which was prepared by URS Research Company for the U. S. EPA based on the analysis of the existing published data in the United States at 95% confidence level.

   The loading rates in Table 16 are expressed as lbs. per curb mile per day which can be converted to lbs/acre/day of street surface from the following Table 17.

Table 17: Equivalent curb mile per acre of street surface, arranged land use type

Land Use	Equivalent curb mile per acre of street surface
Open land	0.53
General residential	0.54
General commercial	0.41
Light industrial	0.43
Heavy industrial	0.40
All land use type	0.46

The solid loads per acre are calculated as:

solid load = rate of accumulation x Eq. days of accumulation

(lbs/acre) (lb/acre/day)

The equivalent days of accumulation (EDA) factor is necessary to account for residual amount of pollutant left on the streets after the last sweeping. The EDA is determined using the following relationship:

$$EDA = (D_r - D_s)(1 - E_s) + D_s$$

where

EDA = equivalent days of accumulation

D_r = days since last substantial rainfall

D_s = days since last sweep

E_s = effectiveness of sweeping procedure

3. Storm characteristics and runoff rate; Characteristics of a storm, i.e., duration, intensity and frequency influence the pollution potential of runoff.

The following durations and intensities are considered to remove 90% of the road particulate:

. 0.1 in/hr for 300 minutes

. 0.33 in/hr for 90 minutes

. 0.50 in/hr for 60 minutes

. 1.0 in/hr for 30 minutes

(also see Table 7)

The simplest method to compute runoff rate from an impervious area is the runoff coefficient method which is expressed as:

$$q = kr$$

where

q = runoff rate in in/hr

r = precipitation in in/hr

k = runoff coefficient

Values of runoff coefficient k, for impervious surfaces are given in Table 18.

Table 18: Values of runoff coefficient k

Impervious surfaces	k (Approx.)
Flat (2% slope)	0.80
Moderate (2-7% slope)	0.85
Steep (7% slope)	0.90

The percentage of contaminant removed from street surfaces by various combinations of runoff rates and runoff durations is given in Table 16 prepared by URS Research Company (11). Examination of this table reveals that the contaminant removal is a direct function of the total inches of runoff. Consequently, a runoff rate of 0.5 inches per hour which lasts for one hour will remove the same percentage of contaminant as a runoff rate of 1.0 inch per hour which lasts for 30 minutes.

B. Mathematical Modeling

Numerous urban runoff models have been described in literature (12). They range from relatively simple models to highly complex models that utilize the complete dynamic equations of motion to simulate every aspect of drainage system. The most widely used urban runoff models are Storm Model (13) developed by the U. S. Corps of Engineers Hydrologic Engineering Center and U. S. EPA Storm Water Management Model (14).

U. S. Corps of Engineers Storm Model: The model can simulate hourly stormwater runoff and its quality for a single catchment for several years. Five water quality constituents are computed for different land uses - suspended and settleable solids, biochemical oxygen demands, nitrogen and phosphorus.

Runoff is computed from hourly precipitation data of a single rain gauge. The rainfall excess is defined as the difference between available rainfall and losses to depression storage. A constant recovery rate for depression storage accounts for evapotranspiration.

A weighted average of the runoff coefficients for the pervious and impervious areas defines the fraction of rainfall excess which becomes surface runoff. Runoff from snow melt is computed by degree-day method.

The stormwater quality is computed from non-linear functions considering the daily rate of dust and dirt accumulation, the percent of each pollutant contained in the dust and dirt, street sweeping practices, and days between runoff events. The BOD, N, and PO_4 runoff rates depend also on the rate of runoff of suspended and settleable solids. Land erosion is computed with the Universal Soil Loss Equation.

The model appears useful, primarily for preliminary planning studies to evaluate urban runoff pollution lands from small urban areas.

Stormwater Management Model: The Stormwater Management Model of the U. S. Environmental Protection Agency is one of the most comprehensive models for the simulation of storm and combined sewered system. It computes the combined storm and sanitary runoff from several catchments and routes the flow through a converging branch sewer network.

Suspended and settleable solids, biochemical oxygen demand, carbonacous oxygen demand, coliform bacteria, nitrogen, phosphorus, and oil and grease are modeled, and the performance and cost of nine unit treatment processes can be computed. The model is limited to the simulation of single runoff event.

Runoff for both pervious and impervious areas begins when the available depression storage is filled. Infiltration of pervious areas is computed with Horton's equation. Overland and gutter flow routing is accomplished by a kinematic wave formulation.

Stormwater quality is computed from non-linear function considering different land uses, as in the U. S. Corps of Engineers Storm Model.

Table 4 . RELATIVE PROTECTION OF GROUND COVER AGAINST EROSION
(In order of increasing C factor)

Land-use groups	Examples	Range of "C" values
Permanent vegetation	Protected woodland Prairie Permanent pasture Sodded orchard Permanent meadow	0.0001-0.45
Established meadows	Alfalfa Clover Fescue	0.004-0.3
Small grains	Rye Wheat Barley Oats	0.07-0.5
Large-seeded legumes	Soybeans Cowpeas Peanuts Field peas	0.1-0.65
Row crops	Cotton Potatoes Tobacco Vegetables Corn Sorghum	0.1-0.70
Fallow	Summer fallow Period between plowing and growth of crop	1.0

Table 5 . "C" VALUES FOR PERMANENT PASTURE, RANGELAND, AND IDLE LAND[19, a]

Vegetal canopy Type and height of raised canopy[b]	Canopy cover[c] (%)	Type[d]	Cover that contacts the surface					
			Percent ground cover					
			0	20	40	60	80	95-100
Column no.	2	3	4	5	6	7	8	9
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	0.45	0.24	0.15	0.090	0.043	0.011
Canopy of tall weeds or short brush (0.5 m fall height)	25	G	0.36	0.17	0.09	0.038	0.012	0.003
		W	0.36	0.20	0.13	0.082	0.041	0.011
	50	G	0.26	0.13	0.07	0.035	0.012	0.003
		W	0.26	0.16	0.11	0.075	0.039	0.011
	75	G	0.17	0.10	0.06	0.031	0.011	0.003
		W	0.17	0.12	0.09	0.067	0.038	0.011
Appreciable brush or bushes (2 m fall height)	25	G	0.40	0.18	0.09	0.040	0.013	0.003
		W	0.40	0.22	0.14	0.085	0.042	0.011
	50	G	0.34	0.16	0.085	0.038	0.012	0.003
		W	0.34	0.19	0.13	0.081	0.041	0.011
	75	G	0.28	0.14	0.08	0.036	0.012	0.003
		W	0.28	0.17	0.12	0.077	0.040	0.011
Trees but no appreciable low brush (4 m fall height)	25	G	0.42	0.19	0.10	0.041	0.013	0.003
		W	0.42	0.23	0.14	0.087	0.042	0.011
	50	G	0.39	0.18	0.09	0.040	0.013	0.003
		W	0.39	0.21	0.14	0.085	0.042	0.011
	75	G	0.36	0.17	0.09	0.039	0.012	0.003
		W	0.36	0.20	0.13	0.083	0.041	0.011

a/ All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists.

b/ Average fall height of waterdrops from canopy to soil surface: m = meters.

c/ Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

d/ G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 5 cm (2 in.) deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds) with little lateral-root network near the surface and/or undecayed residue.

Table 6 . "C" FACTORS FOR WOODLAND[19/]

Stand condition	Tree canopy percent of area[a/]	Forest litter percent of area[b/]	Undergrowth[c/]	"C" factor
Well stocked	100-75	100-90	Managed[d/]	0.001
			Unmanaged[d/]	0.003-0.011
Medium stocked	70-40	85-75	Managed	0.002-0.004
			Unmanaged	0.01-0.04
Poorly stocked	35-20	70-40	Managed	0.003-0.009
			Unmanaged	0.02-0.09[e/]

a/ When tree canopy is less than 20%, the area will be considered as grassland or cropland for estimating soil loss.

b/ Forest litter is assumed to be at least 2-in. deep over the percent ground surface area covered.

c/ Undergrowth is defined as shrubs, weeds, grasses, vines, etc., on the surface area not protected by forest litter. Usually found under canopy openings.

d/ Managed - grazing and fires are controlled.
Unmanaged - stands that are overgrazed or subjected to repeated burning.

e/ For unmanaged woodland with litter cover of less than 75%, C values should be derived by taking 0.7 of the appropriate values in Table 3-4. The factor of 0.7 adjusts for the much higher soil organic matter on permanent woodland.

Table 7. "P" VALUES FOR EROSION CONTROL PRACTICES ON CROPLANDS[18/]

Slope	Up- and down-hill	Cross-slope farming without strips	Contour farming	Cross-slope farming with strips	Contour strip-cropping
2.0-7	1.0	0.75	0.50	0.37	0.25
7.1-12	1.0	0.80	0.60	0.45	0.30
12.1-18	1.0	0.90	0.80	0.60	0.40
18.1-24	1.0	0.95	0.90	0.67	0.45

TABLE 10
Expected Magnitudes of Single Storm Erosion Index Values

Location	Index values normally exceeded once in 1 yr.	2 yrs.	5 yrs.	10 yrs.	20 yrs.
Illinois					
Cairo	39	63	101	135	173
Chicago	33	49	77	101	129
Dixon Springs	39	56	82	105	130
Moline	39	50	89	116	145
Rantoul	27	39	56	69	82
Springfield	36	52	75	94	117
Indiana					
Evansville	26	38	56	71	86
Fort Wayne	24	33	45	56	65
Indianapolis	29	41	60	75	90
South Bend	26	41	65	86	111
Terre Haute	42	57	78	96	113
Kentucky					
Lexington	28	46	80	111	151
Louisville	31	43	59	72	85
Middlesboro	78	38	52	63	73
Ohio					
Cincinnati	27	36	48	59	69
Cleveland	22	35	53	71	86
Columbiana	20	26	35	41	48
Columbus	27	40	60	77	94
Coshocton	27	45	77	108	143
Dayton	21	30	44	57	70
Toledo	16	26	42	57	74
Pennsylvania					
Franklin	17	24	35	45	54
Harrisburg	19	25	35	43	51
Philadelphia	28	39	55	69	81
Pittsburgh	23	32	45	57	67

TABLE 10(cont'd)

Location	Index values normally exceeded once in 1 yr.	2 yrs.	5 yrs.	10 yrs.	20 yrs.
Reading	28	39	55	68	81
Scranton	23	32	44	53	63
Virginia					
Blacksburg	23	31	41	48	56
Lynchburg	31	45	66	83	103
Richmond	46	63	86	102	125
Roanoke	23	33	48	61	73
West Virginia					
Elkins	23	31	42	51	60
Huntington	18	29	49	60	89
Parkersburg	20	31	46	61	76

Table 12: Pesticide residues in cropland soil from Ohio River basin states -- FY 1969

Compound	Number of Samples Analyzed[1]	Number of Positive Samples	Percent Positive Sites[2]	Mean Residue Level (PPM)	Range of Detected Residues (PPM)
ILLINOIS					
Aldrin	142	60	42.3	0.13	0.01-2.24
Arsenic	142	142	100.0	8.05	1.54-33.40
Atrazine	43	2	4.7	<0.01	0.02-0.10
Chlordane	142	36	25.4	0.23	0.02-5.20
p,p'-DDE	142	16	11.3	<0.01	0.01-0.05
o,p'-DDT	142	4	2.8	<0.01	0.01-0.02
p,p'-DDT	142	12	8.5	<0.01	0.01-0.06
DDTR	142	16	11.3	0.01	0.01-0.29
Dieldrin	142	87	61.3	0.11	0.01-1.42
Heptachlor	142	31	21.8	0.03	0.01-0.59
Heptachlor epoxide	142	36	25.4	0.02	0.01-1.08
Isodrin	142	2	1.4	<0.01	0.02
o,p'-TDE	142	1	0.7	<0.01	0.06
p,p'-TDE	142	5	3.5	<0.01	0.01-0.16
Trifluralin	142	2	1.4	<0.01	0.05-0.16
INDIANA					
Aldrin	78	13	16.7	0.07	0.01-3.06
Arsenic	78	78	100.0	7.88	1.28-19.65
Chlordane	78	4	5.1	0.02	0.07-0.53
p,p'-DDE	78	1	1.3	<0.01	0.03
o,p'-DDT	78	2	2.6	<0.01	0.01-0.03
p,p'-DDT	78	2	2.6	<0.01	0.02-0.09
DDTR	78	2	2.6	<0.01	0.06-0.14
Dieldrin	78	21	26.9	0.03	0.01-0.58
Heptachlor	78	2	2.6	<0.01	0.02-0.08
Heptachlor epoxide	78	1	1.3	<0.01	0.02
Isodrin	78	1	1.3	<0.01	0.03
p,p'-TDE	78	2	2.6	<0.01	0.01
Trifluralin	78	1	1.3	<0.01	0.03
KENTUCKY					
Aldrin	31	8	25.8	0.03	0.01-0.42
Arsenic	31	31	100.0	8.41	2.60-12.80
Chlordane	31	4	12.9	0.02	0.06-0.27
o,p'-DDE	31	1	3.2	<0.01	0.03
p,p'-DDE	31	5	16.1	0.01	0.01-0.17
o,p'-DDT	31	3	9.7	0.02	0.01-0.34
p,p'-DDT	31	6	19.4	0.04	0.02-1.00
DDTR	31	6	19.4	0.08	0.03-1.84
Dieldrin	31	17	54.8	0.06	0.01-0.65
Heptachlor	31	2	6.5	<0.01	0.01
Heptachlor epoxide	31	1	3.2	<0.01	0.02
Isodrin	31	2	6.5	<0.01	0.01
o,p'-TDE	31	1	3.2	<0.01	0.02
p,p'-TDE	31	4	12.9	0.01	0.02-0.28
WEST VIRGINIA					
Arsenic	6	6	100.0	6.33	4.36-8.17
Chlordane	6	3	50.0	0.21	0.19-0.78
p,p'-DDE	6	2	33.3	0.02	0.02-0.10
p,p'-DDT	6	2	33.3	0.01	0.01-0.07
DDTR	6	2	33.3	0.04	0.05-0.17
Dieldrin	6	1	16.7	0.04	0.23
Heptachlor epoxide	6	3	50.0	0.06	0.08-0.18

Table 12(cont'd)

Compound	Number of Samples Analyzed[1]	Number of Positive Samples	Percent Positive Sites[2]	Mean Residue Level (PPM)	Range of Detected Residues (PPM)
OHIO					
Aldrin	68	10	14.7	0.03	0.01-0.74
Arsenic	69	69	100.0	11.23	1.15-41.49
Chlordane	68	3	4.4	0.01	0.01-0.71
o,p'-DDE	68	1	1.5	<0.01	0.20
p,p'-DDE	68	11	16.2	0.03	0.01-1.77
o,p'-DDT	68	2	2.9	0.01	0.19-0.22
p,p'-DDT	68	6	8.8	0.04	0.01-1.27
DDTR	68	11	16.2	0.08	0.01-3.38
Dieldrin	68	19	27.9	0.02	0.01-0.30
Endosulfan (I)	68	1	1.5	<0.01	0.07
Endosulfan (II)	68	1	1.5	<0.01	0.29
Endosulfan sulfate	68	1	1.5	0.01	0.40
Heptachlor	68	2	2.9	<0.01	0.01
Heptachlor epoxide	68	1	1.5	<0.01	0.01
Isodrin	68	2	2.9	<0.01	0.01-0.03
Lindane	68	1	1.5	0.01	0.35
p,p'-TDE	68	3	4.4	<0.01	0.04-0.12
Trifluralin	68	1	1.5	<0.01	0.06
NEW YORK					
Arsenic	37	35	94.6	9.38	1.24-43.90
Chlordane	38	1	2.6	0.08	3.19
o,p'-DDE	38	3	7.9	<0.01	0.01-0.06
p,p'-DDE	38	15	39.5	0.23	0.01-3.70
o,p'-DDT	38	11	29.0	0.07	0.01-1.45
p,p'-DDT	38	13	34.2	0.53	0.02-7.67
DDTR	38	15	39.5	0.91	0.01-13.29
Dieldrin	38	13	34.2	0.05	0.01-0.96
Endrin	38	1	2.6	0.01	0.56
Endrin ketone	38	1	2.6	<0.01	0.05
Lindane	38	3	7.9	0.01	0.01-0.23
Methoxychlor	38	1	2.6	0.01	0.28
o,p'-TDE	38	2	5.3	0.01	0.06-0.37
p,p'-TDE	38	10	26.3	0.07	0.01-1.49
PENNSYLVANIA					
Arsenic	29	29	100.0	10.80	2.96-64.94
Chlordane	29	6	20.7	0.07	0.02-0.92
o,p'-DDE	29	1	3.5	<0.01	0.08
p,p'-DDE	29	9	31.0	0.07	0.01-1.52
o,p'-DDT	29	5	17.2	0.03	0.01-0.67
p,p'-DDT	29	8	27.6	0.12	0.01-2.99
DDTR	29	11	37.9	0.27	0.01-5.50
Dicofol	29	1	3.5	0.02	0.53
Dieldrin	29	10	34.5	0.02	0.01-0.14
Endosulfan (II)	29	1	3.5	<0.01	0.02
Endosulfan sulfate	29	1	3.5	<0.01	0.01
Heptachlor epoxide	29	4	13.8	<0.01	0.01-0.03
Ethyl parathion	3	1	33.3	<0.01	0.01
o,p'-TDE	29	4	13.8	0.01	0.03-0.20
p,p'-TDE	29	7	24.1	0.04	0.01-0.55
Trifluralin	29	2	6.9	<0.01	0.0[illegible]
VIRGINIA					
Aldrin	21	1	4.8	<0.01	0.01
Arsenic	20	20	100.0	3.34	0.69-12.34
Chlordane	21	5	23.8	0.01	0.01-0.11
p,p'-DDE	21	11	52.4	0.02	0.01-0.22
o,p'-DDT	21	4	19.1	0.01	0.01-0.17
p,p'-DDT	21	8	38.1	0.11	0.01-1.31
DDTR	21	11	52.4	0.17	0.01-1.75
Dieldrin	21	6	28.6	0.08	0.01-1.60
Heptachlor epoxide	21	4	19.1	0.01	0.01-0.05
Malathion	1	1	100.0	0.04	0.04
Ethyl parathion	1	1	100.0	0.90	0.90
o,p'-TDE	21	1	4.8	<0.01	0.07
p,p'-TDE	21	7	33.3	0.02	0.01-0.19
Toxaphene	21	1	4.7	0.01	0.28

TABLE 13 KINETIC ENERGY OF NATURAL RAINFALL*

Intensity, in./hr	Kinetic Energy, ft-tons/acre-in.									
Increment	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	254	354	412	453	485	512	534	553	570
0.1	585	599	611	623	633	643	653	661	669	677
0.2	685	692	698	705	711	717	722	728	733	738
0.3	743	748	752	757	761	765	769	773	777	781
0.4	784	788	791	795	798	801	804	807	810	814
0.5	816	819	822	825	827	830	833	835	838	840
0.6	843	845	847	850	852	854	856	858	861	863
0.7	865	867	869	871	873	875	877	878	880	882
0.8	884	886	887	889	891	893	894	896	898	899
0.9	901	902	904	906	907	909	910	912	913	915
Increment	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	916	930	942	954	964	974	984	992	1000	1008
2	1016	1023	1029	1036	1042	1048	1053	1059	1064	1069
3	1074	1079	1083	1088	1092	1096	1100	1104	1108	1112
4	1115	1119	1122	1126	1129	1132	1135	1138	1141	1144
5	1147	1150	1153	1156	1158	1161	1164	1166	1169	1171
6	1174	1176	1178	1181	1183	1185	1187	1189	1192	1194
7	1196	1198	1200	1202	1204	1206	1208	1209	1211	1213
8	1215	1217	1218	1220	1222	1224	1225	1227	1229	1230
9	1232	1233	1235	1237	1238	1240	1241	1243	1244	1246

* Source: Wischmeier and Smith

Table 14.: RUNOFF CHARACTERISTICS FROM CATTLE FEEDLOTS IN KANSAS*[12/]

	Concrete	Nonpaved
Ammonia-N		
Winter	1.3-7.0 mg/ℓ	1.0-3.8 mg/ℓ
Spring-fall	20-77 mg/ℓ	13-45 mg/ℓ
Summer	50-139 mg/ℓ	26-62 mg/ℓ
NH_3-N: Kjeldahl-N, %		
Winter	0.01-0.05	0.02-0.6
Spring-fall	0.3-0.4	0.06-0.2
Summer	0.1-0.4	0.1-0.3
Nitrite-N		
October-November	1.0-5.0 mg/ℓ	1.0-2.3 mg/ℓ
July-August	1.0-6.0 mg/ℓ	1.0-7.0 mg/ℓ
Suspended solids		
July-August		
Moist - 1 in/hr	6,000 mg/ℓ	5,000 mg/ℓ
Dry - 0.4 in/hr	3,000 mg/ℓ	1,500 mg/ℓ
Dry - 2.5 in/hr	1,400 mg/ℓ	2,000 mg/ℓ
Wet - 2.5 in/hr	3,000 mg/ℓ	3,000 mg/ℓ
Wet - 0.3 in/hr	12,000 mg/ℓ	10,500 mg/ℓ
October-November		
Wet - 1 in/hr	2,000 mg/ℓ	1,800 mg/ℓ
Wet - 0.5 in/hr	2,500 mg/ℓ	-
Bacterial densities (in millions of organisms per 100 ml), 70% limits		
July-November		
Total coliform	33-348	22-348
Fecal coliform	35-240	8-79
Fecal streptococci	13-240	8-79

* Kansas data shown here are typical for Midwestern states. These values tend to increase in the West and decrease in the East.

Table 15: BEEF CATTLE FEEDLOT RUNOFF CHARACTERISTICS

	Total solids	Suspended solids (mg/ℓ)	COD (mg/ℓ)	BOD_5 (mg/ℓ)	Org-N (mg/ℓ)	NH_3-N (mg/ℓ)	NO_3-N (mg/ℓ)	Total N (mg/ℓ)	Total P (mg/ℓ)	Alkalinity (mg/ℓ as $CaCO_3$)	pH
Nebraska											
Snowmelt runoff	3.0-19.8[a]	-	14,100-78,000	1,600-7,900	-	270-2,028	0-80	1,429-5,765	7-750	-	6.7-7.6
Rainfall runoff	0.024-1.74[a]	-	1,300-8,200	370-600	-	26-82	0-17	65-555	14-47	-	6.7-9.4
Texas											
Dirt lots	-	-	2,964-28,000	1,150-3,210	6-434	2-100	0-163	-	-	70-1,600	7.1-7.95
Concrete lots	-	-	5,000-48,000	2,400-10,000	35-797	33-774	0-1,270	-	-	86-2,600	5.6-7.3
Texas											
Dirt lot	3,100-28,900[b]	745-17,702	1,440-16,320	1,075-3,450	31-495	4-173	0-2.3	35-658	21-223	-	
Kansas											
Nonsurfaced lot	-	1,500-10,500	1,900-8,900	216-1,010[c]	-	1-65	0.1-6	50-540	-	-	
Concrete lot	-	1,400-12,000	2,760-19,400	314-2,200[c]	-	1-140	0.1-11	94-1,000	-	-	

a/ Percent.
b/ Mg/ℓ.
c/ Calculated using a COD/BOD ratio.

Figure 16: Urban runoff loading rates for different land uses

		Category	lbs/curb mi/day Loading	Concentrations in micrograms per gram of dry solid: BOD_5	COD	OPO_4	TPO_4	NO_3	NH_4	OrgN	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Sr	Zn	No./gram: TCOLI[b]	FCOLI[b]
Land Use	10	Open space																			
	20	Residential			$83,000_b$					$1,800_a$											
	30	Commercial	74_e	$58,700_e$						$6,430_a$					$3,400_b$						
	40	Light industry																		$8.2E5_e$	
	50	Heavy industry																			
Climate	1	Northeast										130_b			870_c		21_c		360_b		$4.4E3_c$
	2	Southeast				$2,240_a$											21_b				$7.0E4_d$
	4	Southwest	50_e			470_b							78_a				57_b	15_a			
	5	Northwest	30_e											$34,800_b$				10_c	480_a	$6.9E5_f$	$1.1E4_f$
Average Daily Traffic No./day	<	500																	252_b		
		500 - 5,000		$9,500_e$				419_b							$1,060_c$		17_d				$3.4E3_d$
		5,000 - 15,000																		$3.8E5_e$	
	>	15,000																			
Type of Landscaping Beyond the Sidewalk	1	Grass																		$8.3E5_d$	$7.4E4_d$
	2	Trees	43_b																	$1.1E7_b$	
	3	Landscaped buildings																			
	4	Hard surfaces						461_b										16_a		$7.1E3_c$	
Street Surface Material	1	Asphalt				$2,470_a$				$1,770_b$											
	2	Concrete	38_b	$72,000_c$		$3,520_b$		$2,600_b$		$6,680_b$											
		All data	186_b	$19,900_b$	$140,000_b$	$1,280_b$	$2,930_e$	904_b	$2,640_e$	$2,950_b$	3.4_a	211_a	104_a	$22,000_a$	$1,810_a$	418_a	35_a	21_a	370_a	$2.5E6_e$	$1.7E5_b$

[a] Only those subset means are shown which differ from the means of the set of all data at the 95-percent confidence level (Student $t > 2.25$, Degrees of Freedom > 10). Total number of permitted substitutions = 47. Percent Standard Error of the Mean Subscripting Code: a = 0 - 9, b = 10 - 19, c = 20 - 29, d = 30 - 39, e = 40 - 49, f = 50 - 62.

[b] Coliform counts are expressed in computer notation, i.e., E5 = 10^5.

Table 19 PERCENT OF CONTAMINANTS REMOVED FROM STREET SURFACES BY RUNOFF RATE/DURATION

Runoff Rate (in./hr)	Runoff Duration (hr) 0.25	0.5	1.0	2.0	3.0	4.0	5.0	6.0
0.1	10.9	20.5	36.9	60.1	74.8	84.1	90.0	>90.0
0.2	20.5	36.9	60.1	84.1	>90.0	>90.0	>90.0	
0.3	29.1	49.8	74.8	>90.0				
0.4	36.9	60.1	84.1					
0.5	43.7	68.3	90.0					
0.6	49.8	74.8	>90.0					
0.7	55.3	80.0						
0.8	60.1	84.1						
0.9	64.5	87.4						
1.0	68.3	90.0						

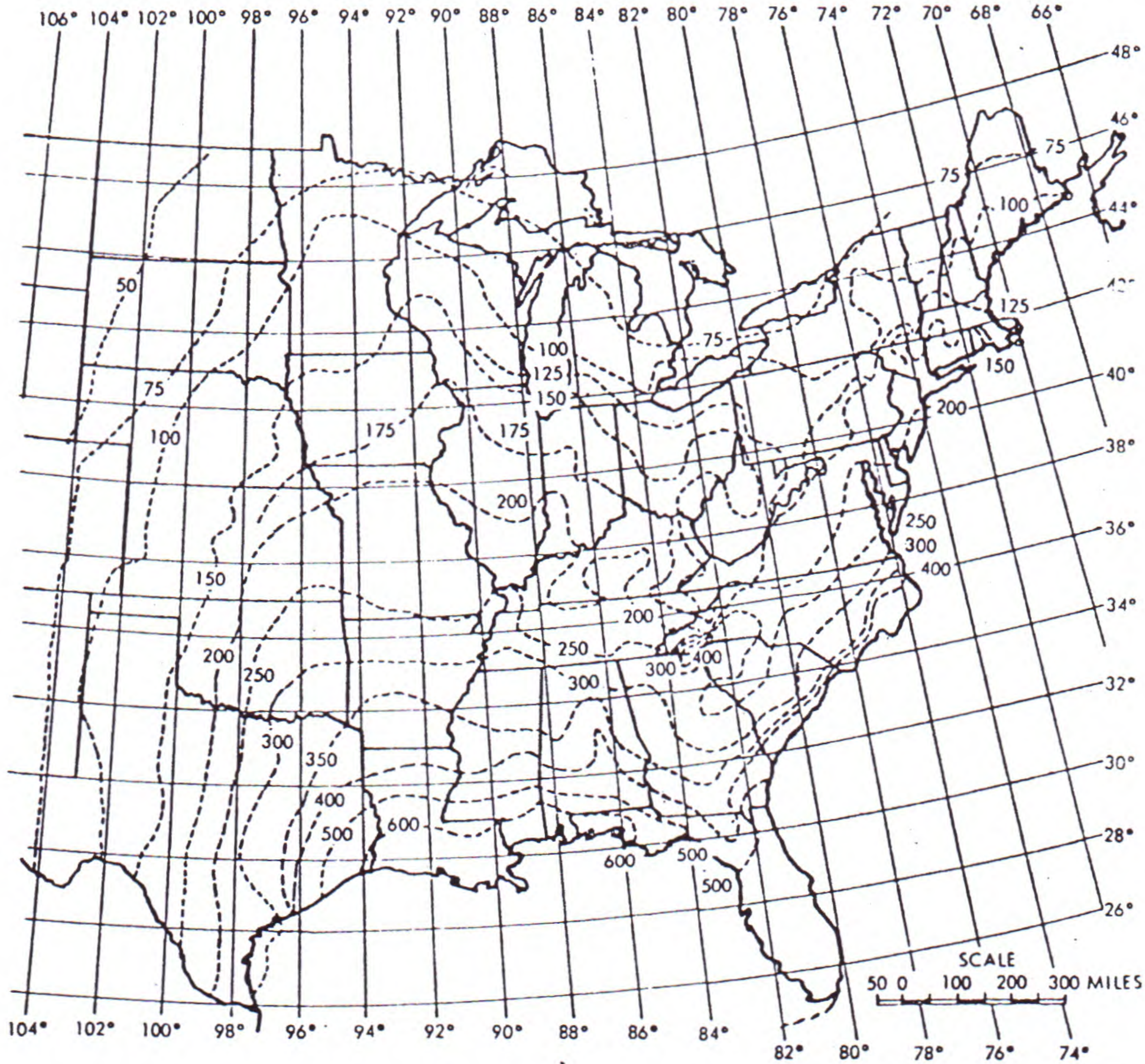

Figure 2: Mean annual values of erosion index for the (in English units) eastern United States

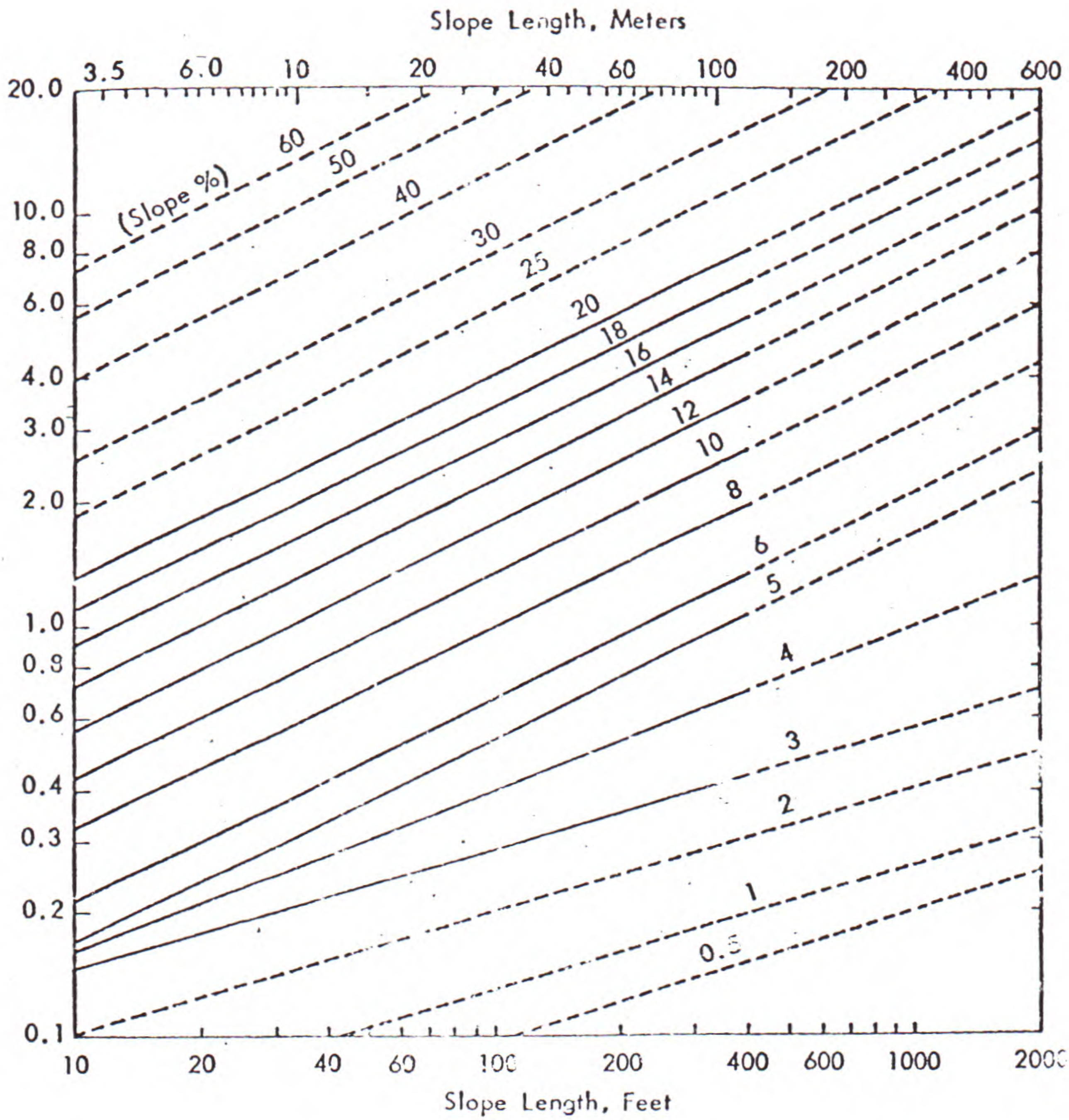

Figure 3: - Slope effect chart (topographic factor, LS) 18 /a

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a/ The dashed lines represent estimates for slope dimensions beyond the range of lengths and steepnesses for which data are available.

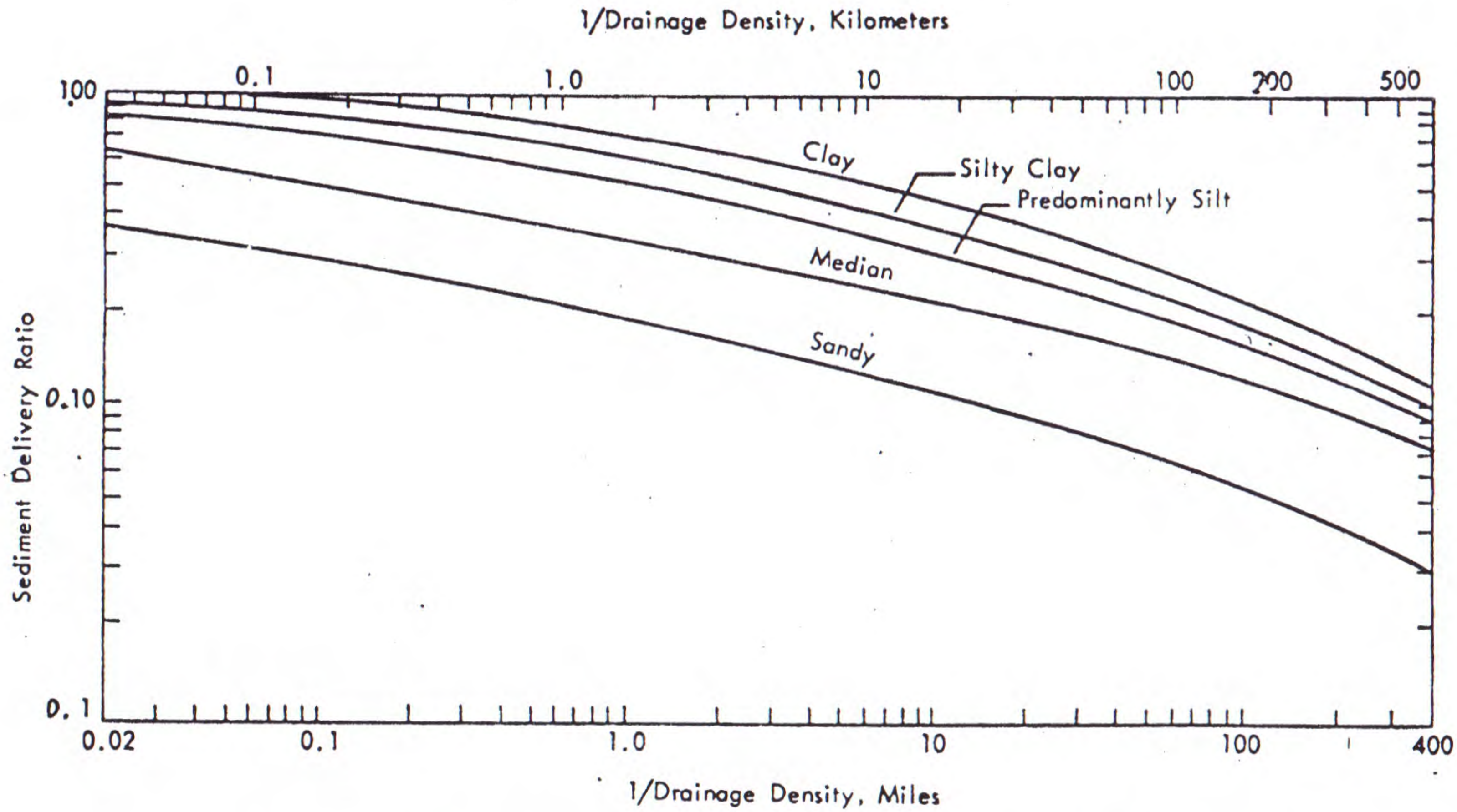


Figure 4: - Sediment Delivery Ratio for Relatively Homogeneous Basins[a]

a/ Source: Midwest Research Institute.

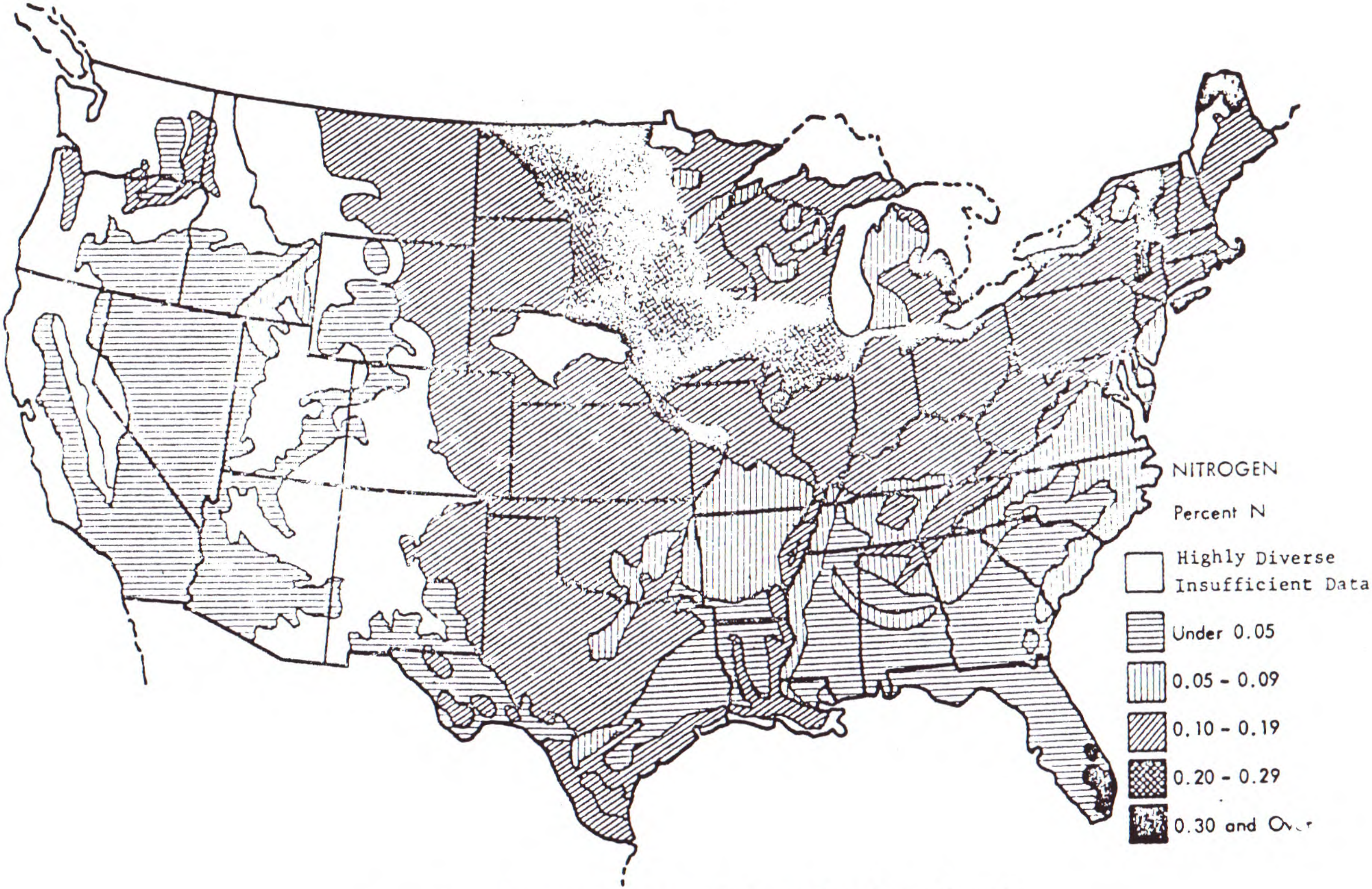


Figure 5: **Percent nitrogen (N) in surface foot of soil.**

Source: MRT 1975

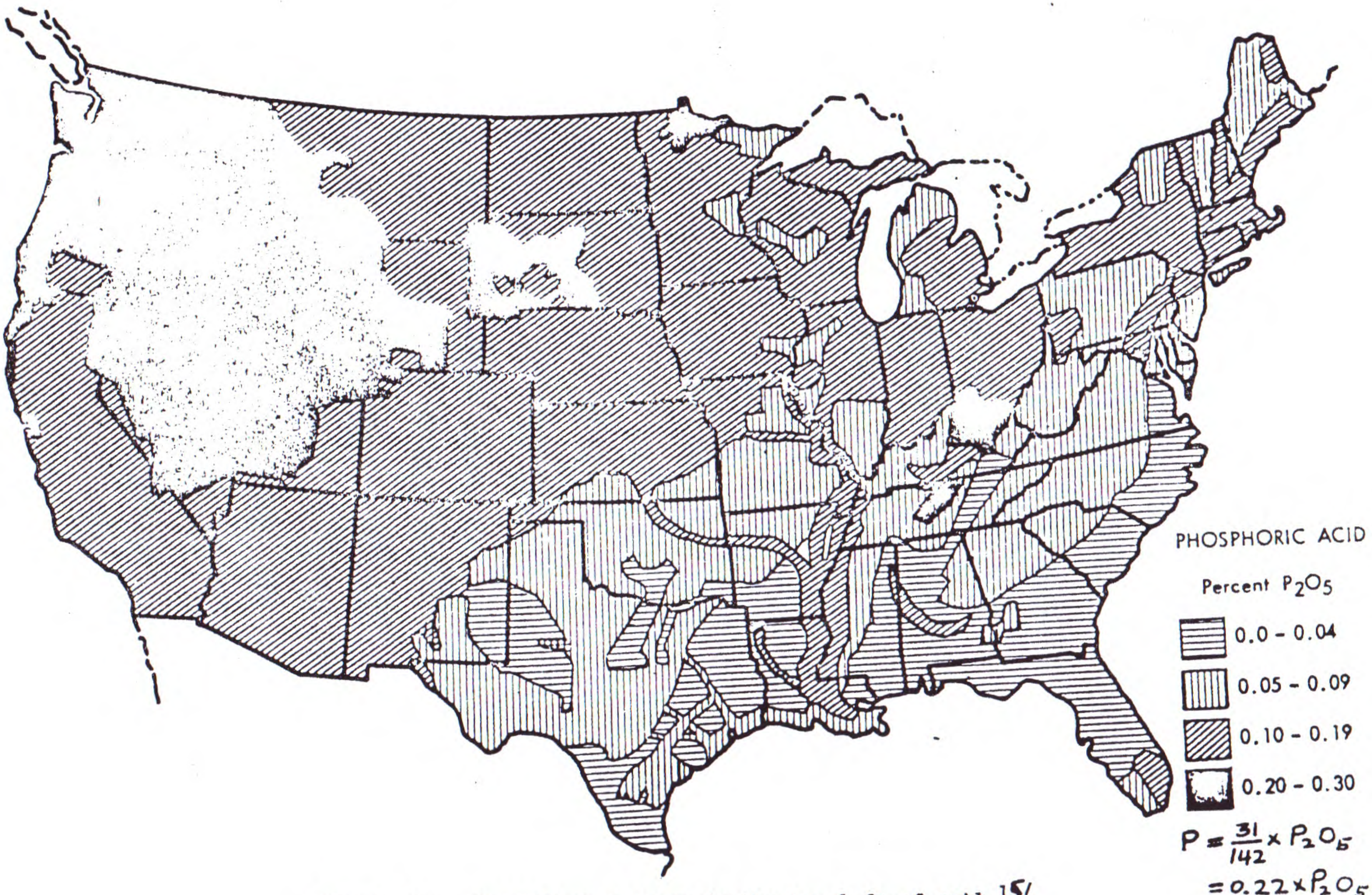


Figure 6: Phosphorus content in the top 1 ft of soil.15/

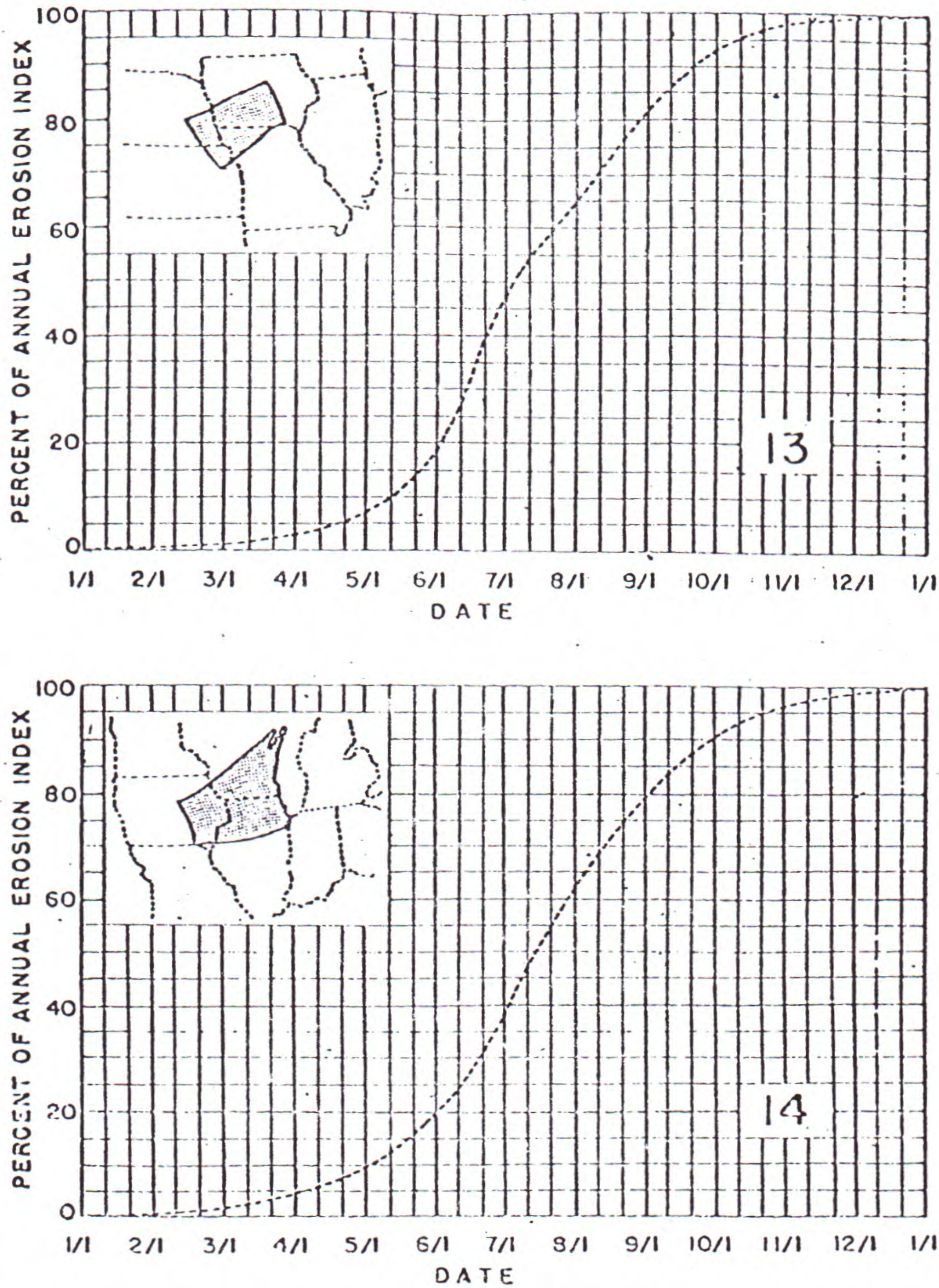
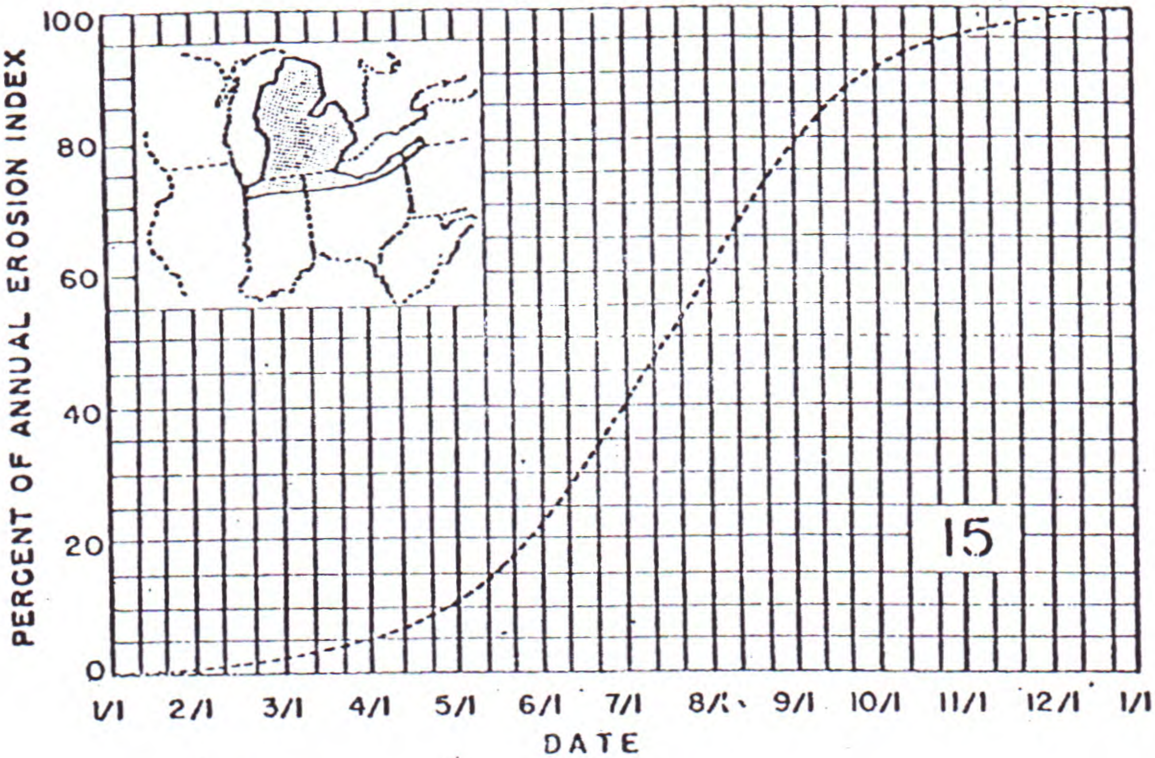


FIGURE 7.—Erosion-index distribution curves 13 and 14: parts of Nebraska, Kansas, Missouri, Iowa, Illinois, and Wisconsin.



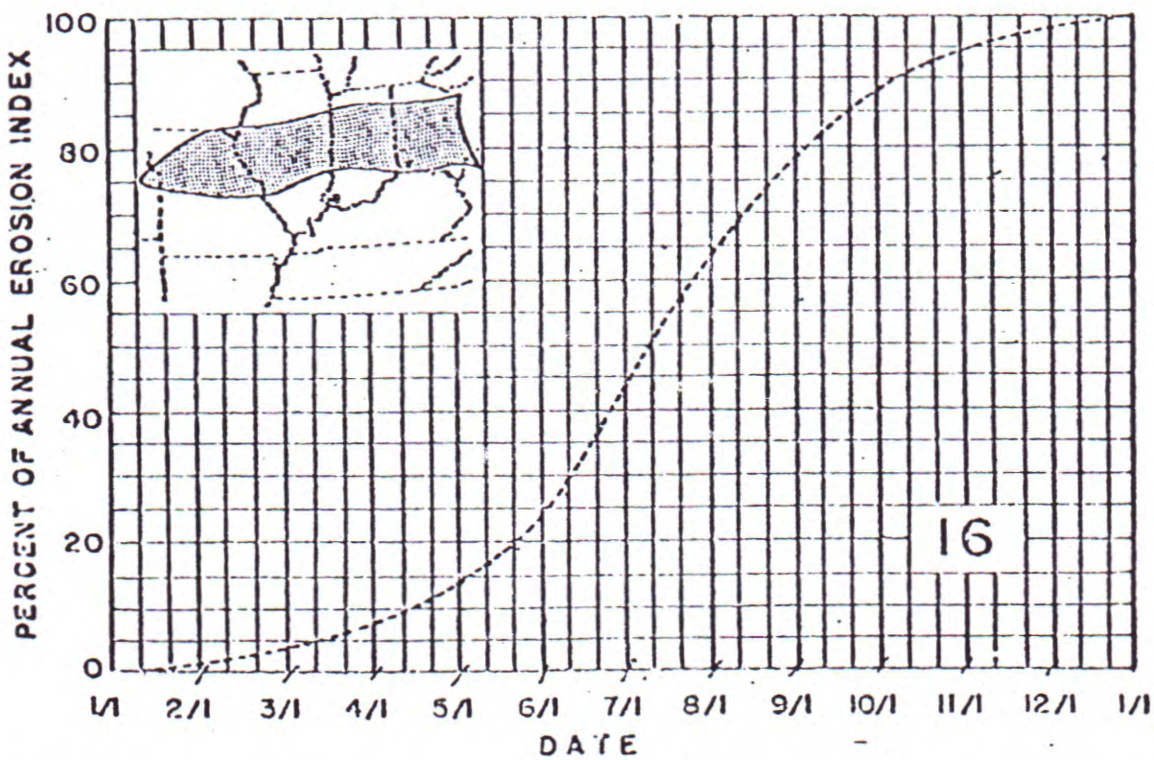
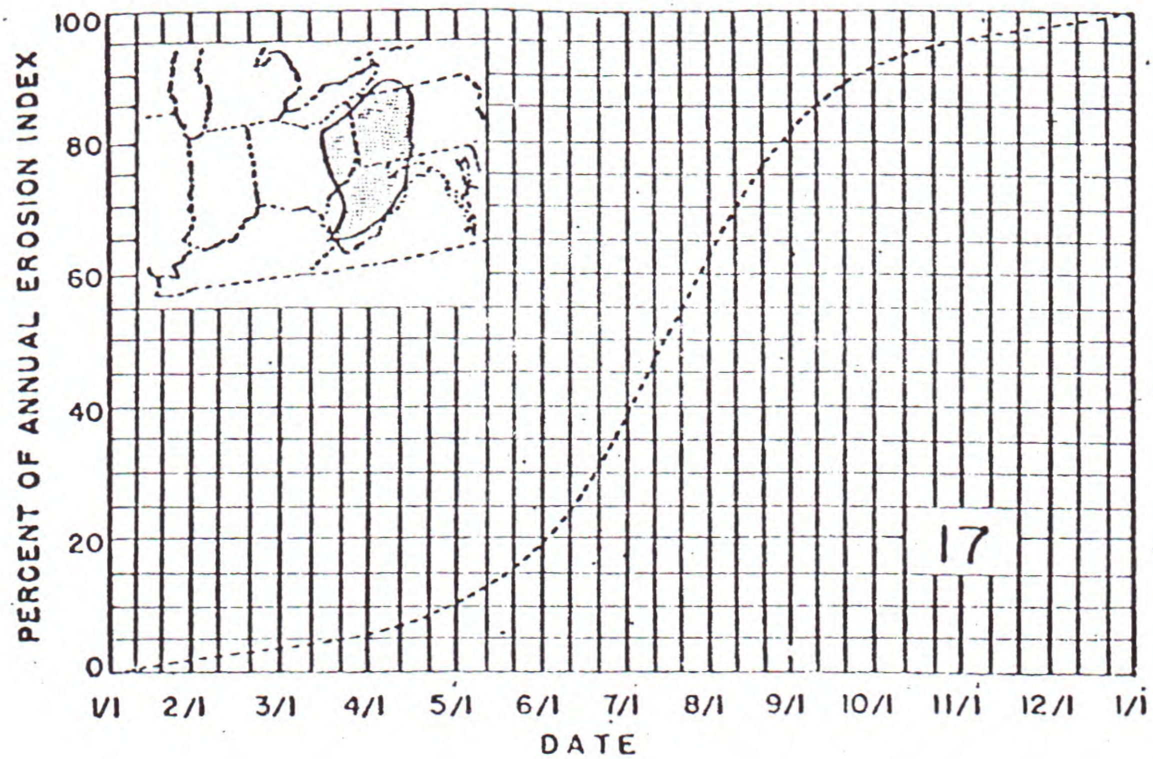


FIGURE 8:—Erosion-index distribution curves 15 and 16: parts of Michigan, Missouri, Illinois, Indiana, and Ohio.



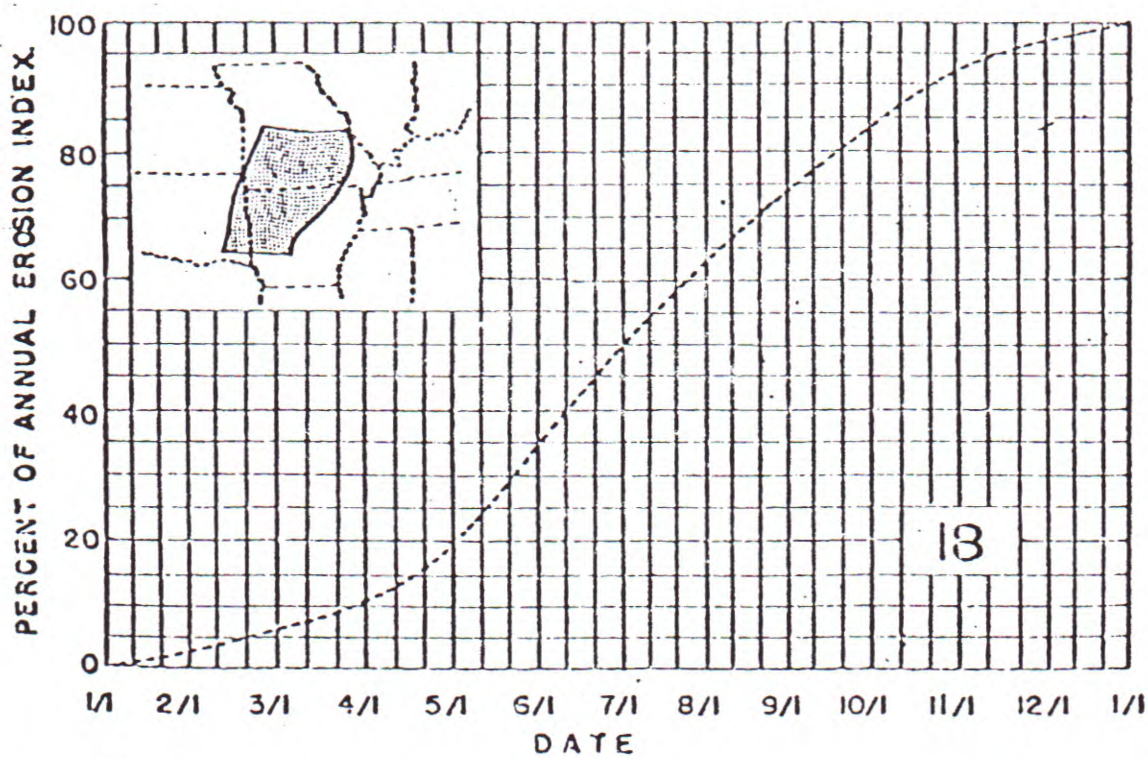
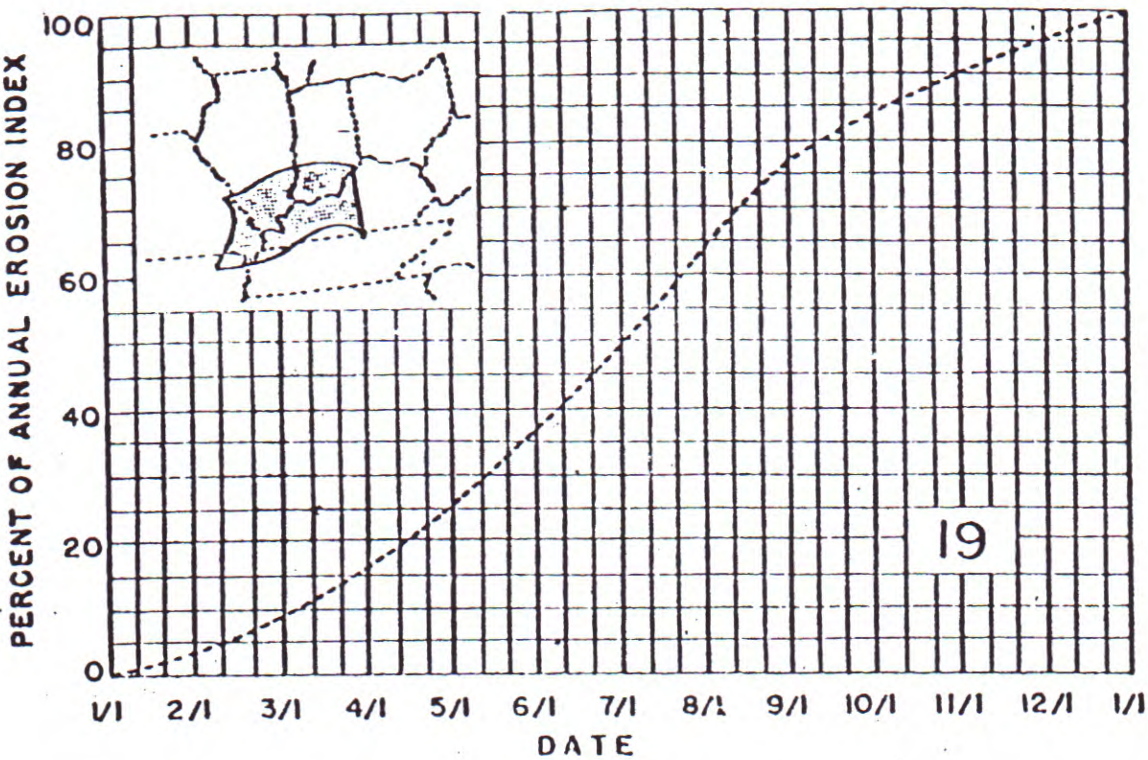


Figure 9.—Erosion-index distribution curves 17 and 18: parts of Ohio, Pennsylvania, West Virginia, Missouri, and Arkansas.



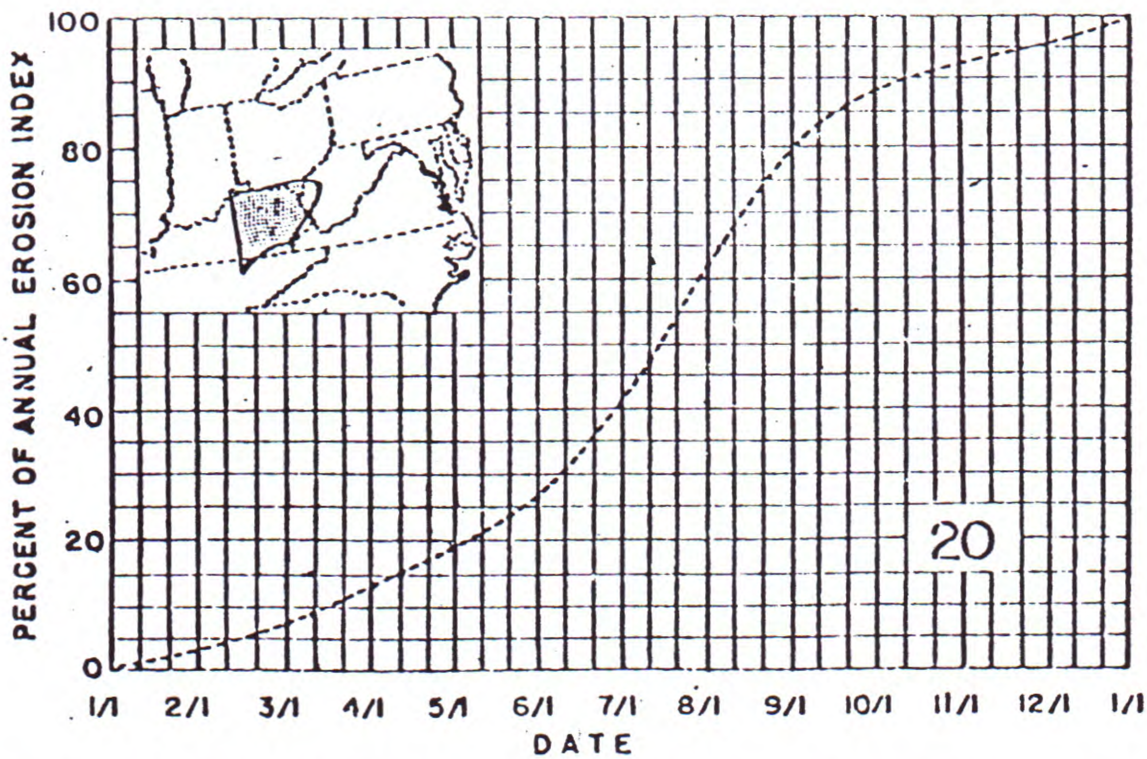


FIGURE 10.—Erosion-index distribution curves 19 and 20: parts of Missouri, Illinois, Indiana, and Kentucky.

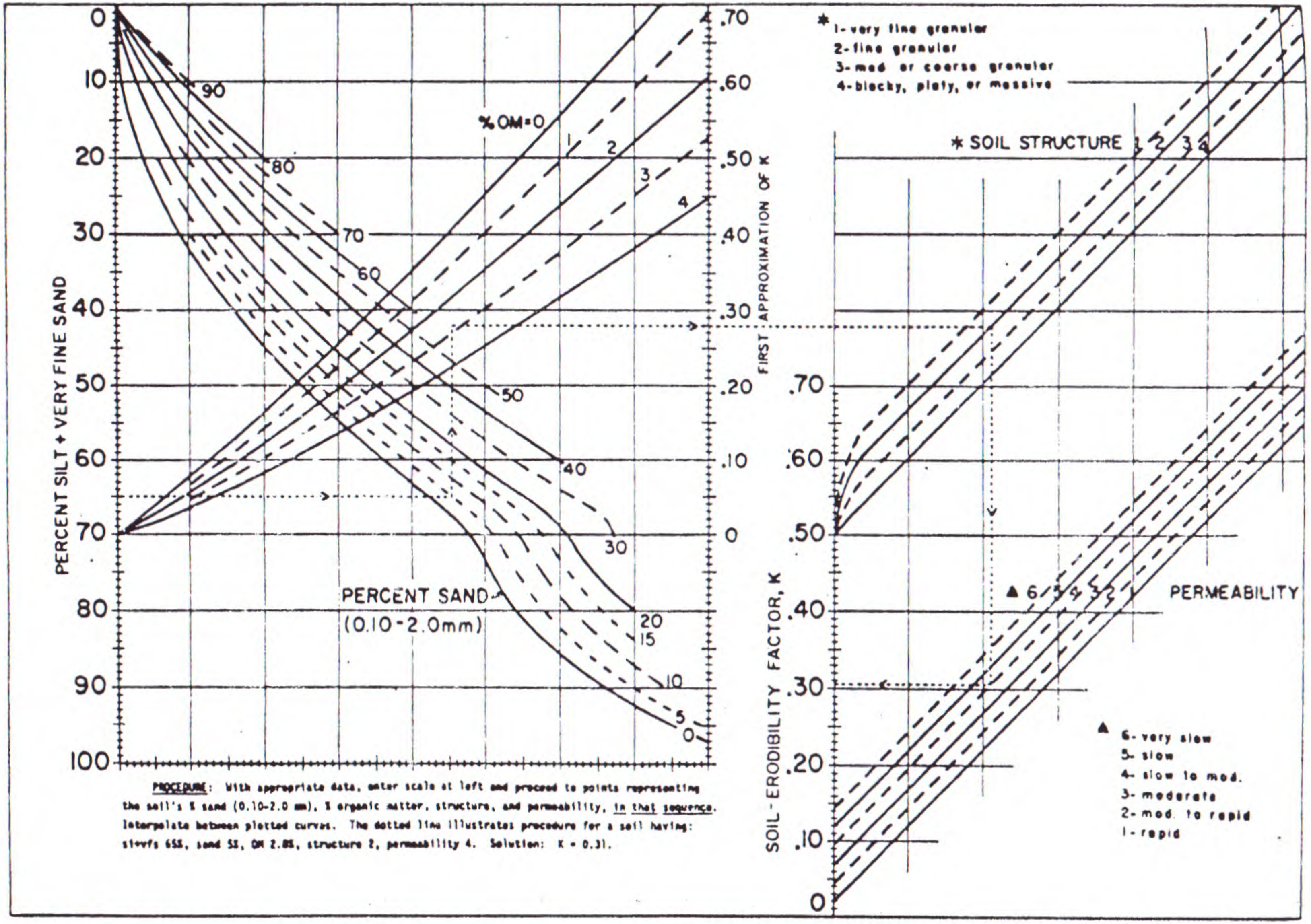


Figure 14—Nomograph for determining soil-erodibility factor, K, for U.S. Mainland soils.

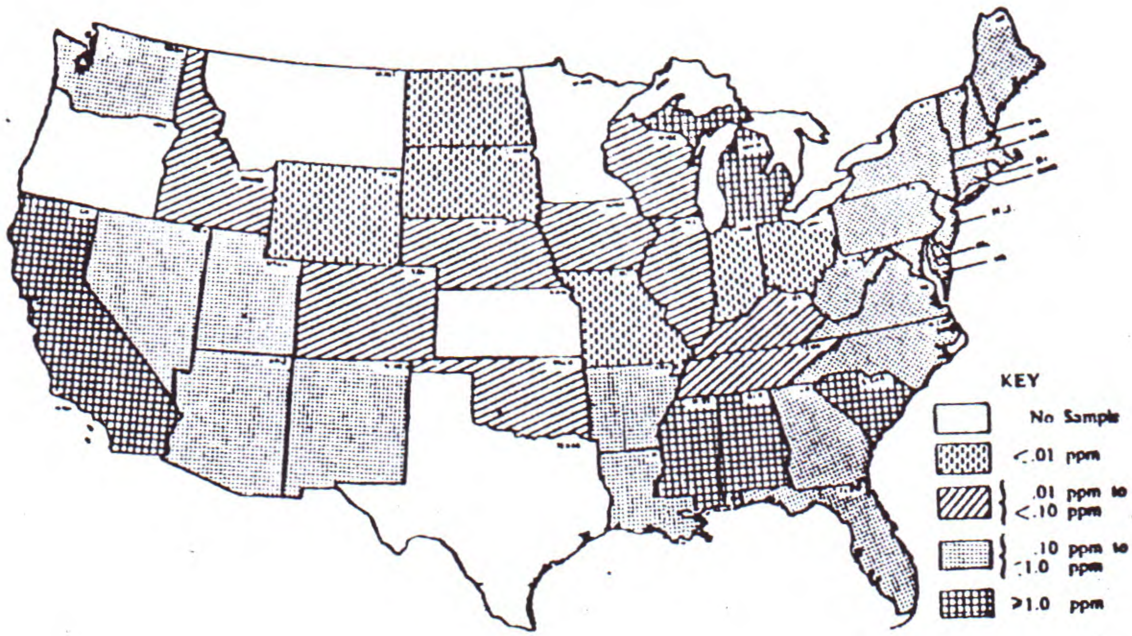


Figure 15: DDTR residues in cropland soil

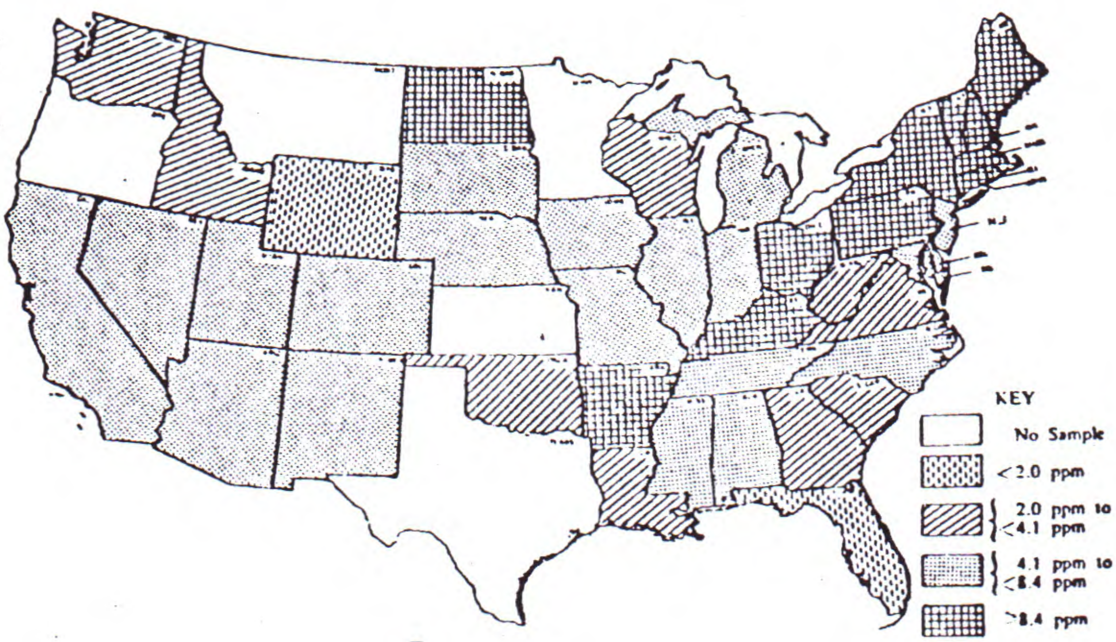


Figure 16: Dieldrin residues in cropland soil

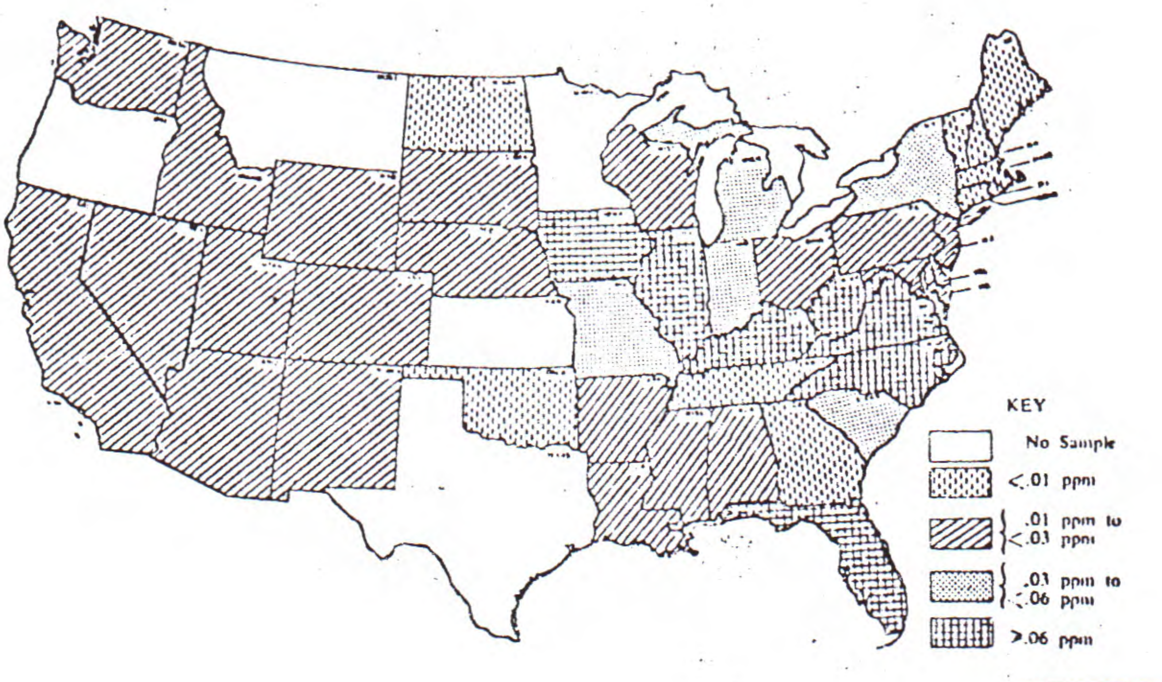


Figure 17: Arsenic residues in cropland soil

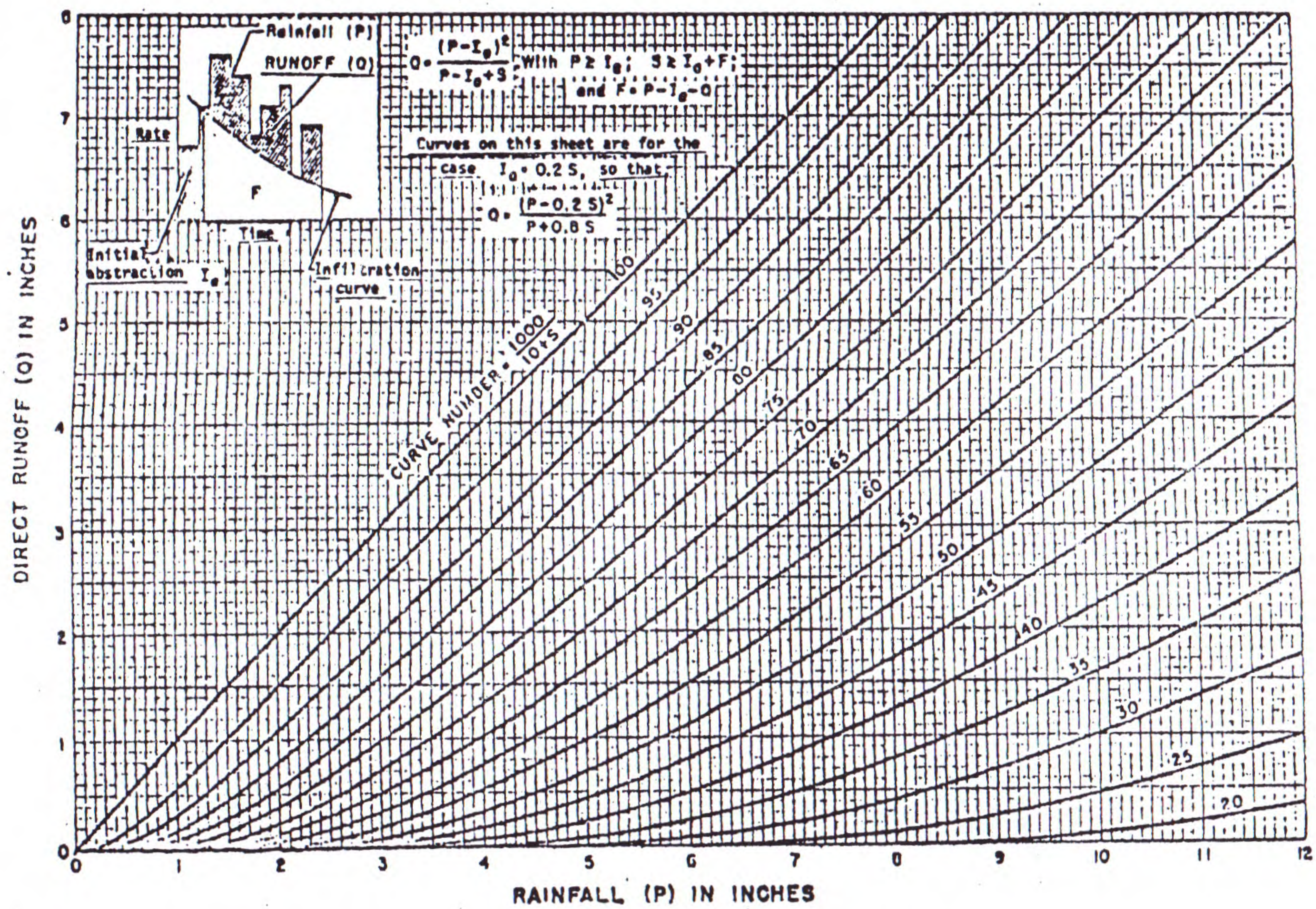


Fig. 18 —Solution of the runoff equation, $Q = \frac{(P - 0.2S)^2}{P + 0.8S}$ after Kent (1968)

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