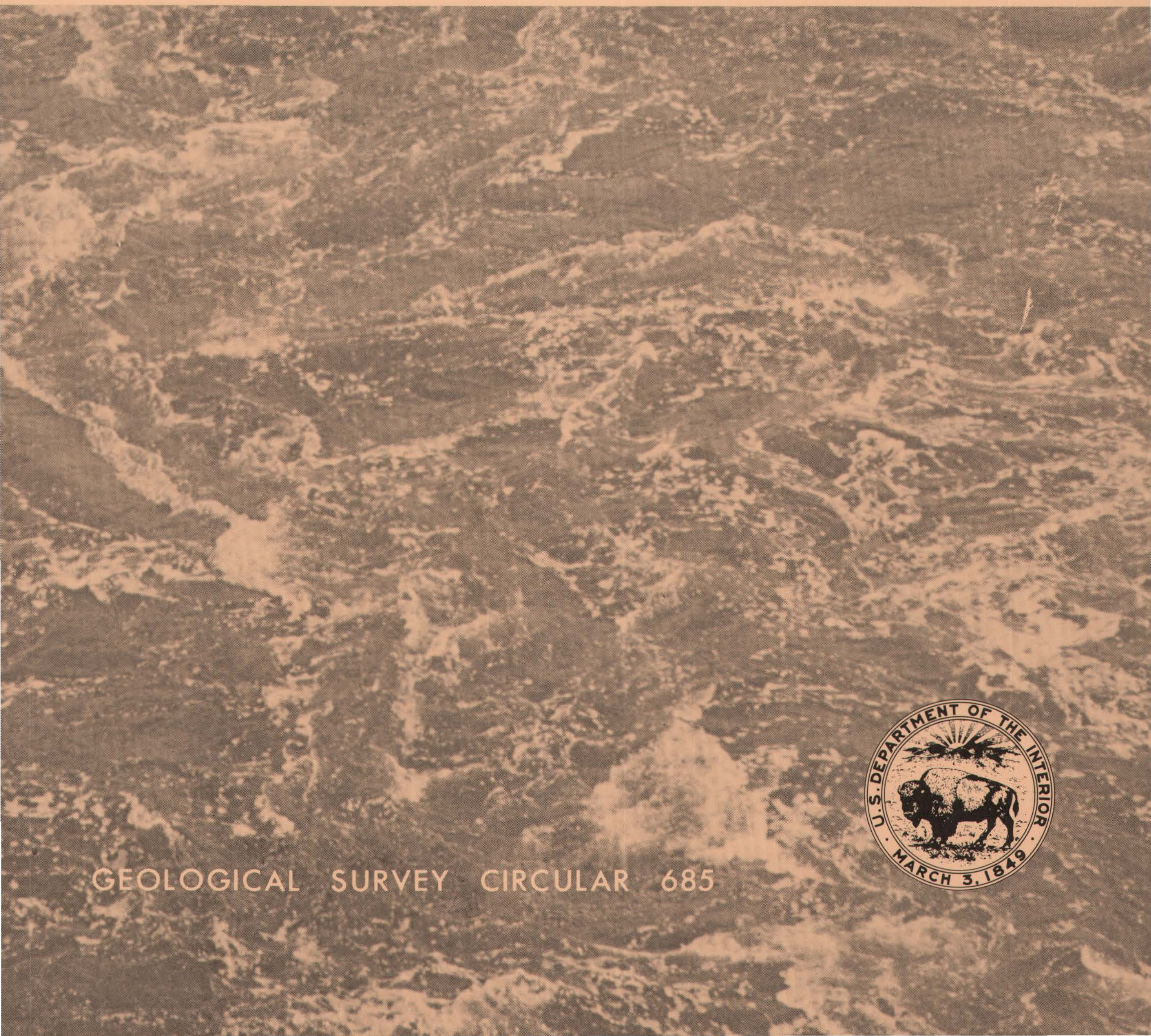
DISSOLVED-SOLIDS DISCHARGE TO THE OCEANS FROM THE CONTERMINOUS UNITED STATES

A contribution to the International Hydrological Decade



GEOLOGICAL SURVEY CIRCULAR 685

Dissolved-Solids Discharge to the Oceans From the Conterminous United States

By Donald K. Leifeste

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1974

United States Department of the Interior
ROGERS C. B. MORTON, *Secretary*

Geological Survey
V. E. McKelvey, *Director*

Free on application to the U.S. Geological Survey, National Center, Reston, Va. 22092

CONTENTS

ILLUSTRATION

TABLES

Dissolved-Solids Discharge to the Oceans From the Conterminous United States

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ABSTRACT

Dissolved-solids data from 54 river basins for 1966–69 were used to compute the amount of dissolved material contributed to the oceans from the conterminous United States. The computations show that about 264,000,000 tons are discharged annually. The Gulf of Mexico receives the largest load, about 183,000,000 tons, of which about 157,000,000 tons are contributed by the Mississippi River. The Atlantic Ocean receives about 37,500,000 tons, and the Pacific Ocean about 43,400,000 tons.

Average yearly yields range from 26 to 231 tons per square mile and average about 100 tons per square mile.

INTRODUCTION

The scientific community constantly endeavors to utilize improved technological methods and expanded data-collection programs to understand in more detail the global natural systems of water, air, and soil and the recycling that occurs between them. Inventories, such as this one, attempt to improve the accounting of the materials transfer between the various parts of these systems, and help explain how the global system is affected by man. They provide him with information useful in developing, managing, and conserving our resources.

PURPOSE AND SCOPE

Although surface streams carry both dissolved and suspended material, the patterns of transport and the sources of the two types of material differ. These two types of material are, therefore, best appraised separately. This report considers only those inorganic chemical constituents that are present in the dissolved state. The amount of suspended material may be large, however, and at high flow, in many streams may greatly exceed the dissolved load. The quantity of suspended material discharged to the oceans from U.S. streams has been summarized by Curtis, Culbertson, and Chase (1973).

The calculations presented in this report are for gross dissolved solids, uncorrected for salts reaching the land in precipitation; the values, therefore, reflect the effects of man's agricultural, industrial, and urbanization activities.

No detailed study has been made of submarine discharge or dissolved composition of that discharge. Computations herein concern only surface flow.

Chemical denudation has long been a matter of scientific interest. Dole and Stabler (1909) and Durum, Heidel, and Tison (1960) made regional computations of dissolved-solids discharge to the oceans. This study updates these previous investigations and provides current information that might be a basis for showing changes that have occurred in the past 60-years.

CONTRIBUTING BASINS

For purposes of this study the conterminous United States was divided into three major regions—drainage to the Atlantic Ocean, Gulf of Mexico, and Pacific Ocean. These regions were further subdivided into 27 drainage areas as follows (fig. 1):

Atlantic Ocean Drainage—10 basins (areas 1–10)
Gulf of Mexico Drainage—9 basins (areas 11–19)
Pacific Ocean Drainage—8 basins (areas 20–27)

The contributing basins correspond to those used by Wilson and Iseri (1969), and the reader is referred to that report for details concerning the water discharge and drainage area figures.

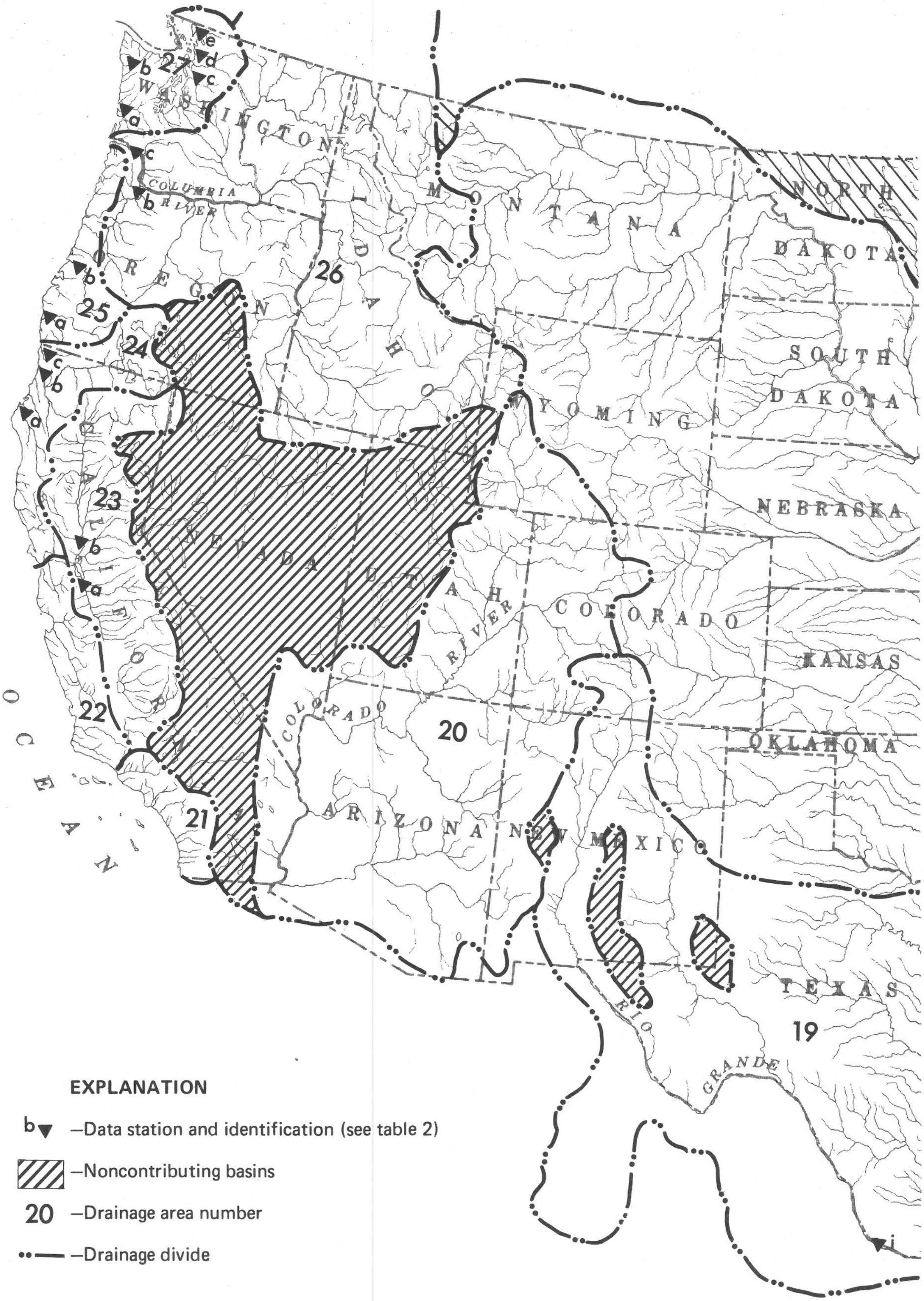

Figure 1.—Contributing basins and location of data stations.

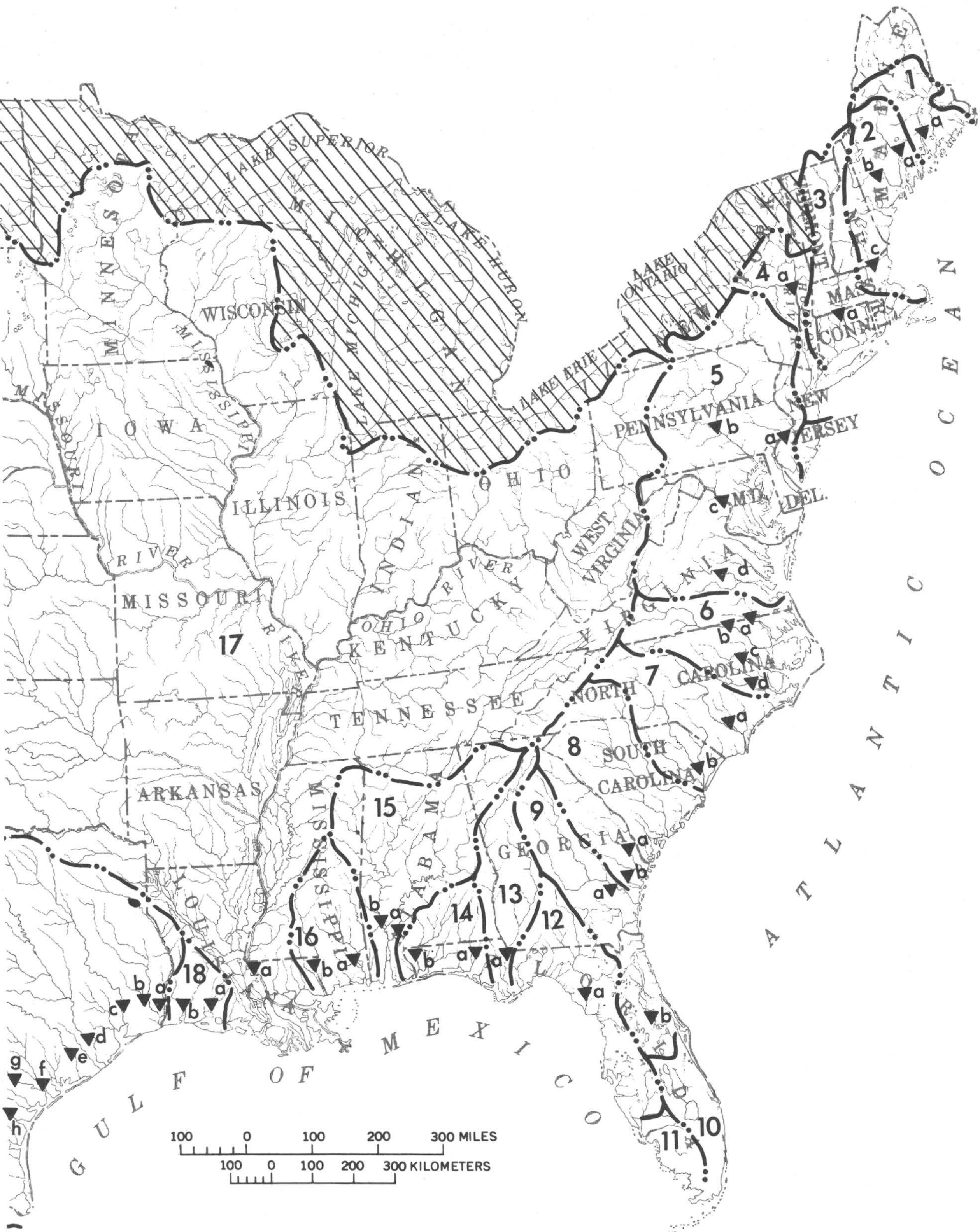

Figure 1.—Continued.

METHODS OF COMPUTATION

Computations of dissolved-solids discharge from the contributing basins are based on water-quality records of the United States Geological Survey with the exception of records furnished by the International Boundary and Water Commission for the Rio Grande. Only streams discharging directly to the oceans from the shores of the United States were considered, regardless of origin. Streams draining part of the United States but discharging into the Great Lakes or from Canadian shores were not included.

No estimates are given for the Colorado River because the river flow is nearly fully utilized for irrigation and other purposes, and only a very small residual of the natural flow reaches the Gulf of California.

Estimates for the coastal drainage of southern and central California (areas 21–23) must be considered very gross estimates because of the complex hydrology of these areas combined with very limited data. In southern California (areas 21 and 22) water is intensely, and generally very completely, developed. There are numerous reservoirs, water is transferred from one river basin to another as needed, and there is much deliberate recharge of alluvial aquifers by both locally derived and imported stream water. Because of the cultivation and drainage patterns of the Sacramento and San Joaquin River basins (area 23) and the complex pattern of canals and natural channels in their combined delta, detailed analyses beyond the scope of this report would be required to develop reasonably accurate estimates of the dissolved-solids discharge to San Francisco Bay.

Data from 54 individual river basins were used to estimate the annual dissolved-solids discharge for the 27 areas. The boundaries of the 27 contributing basins and the location of the sampling stations are shown in figure 1. Generally the sampling stations were closest to the mouth of the river, but above the estuarine zone. Daily or monthly records were used for most streams; however, for some of the smaller subareas only data from less frequent sampling were available. In order to reflect current conditions as much as possible, and yet provide a sufficient record for meaningful averages, data for 1966–69 were used.

Load values for dissolved solids were computed using the following methods.

1. If a daily sampling record was available, the daily samples were usually composited on the basis of similar conductance, and the mean flow for the composite period was used to compute the dissolved-solids load for each composite period. The sum of the loads of the composite periods was used as the load for the period of record (1966–69).
2. If only monthly or less frequent sampling data were available and if annual or seasonal dissolved-solids concentrations were relatively constant, the mean concentration and mean flow for the season or year was used to compute annual loads and the load for the period of record.
3. If only monthly or less frequent sampling data were available and seasonal or annual dissolved-solids concentrations were highly variable, regression analyses were used to estimate mean concentrations for selected ranges of flow. The frequency of occurrence of each range in flow and the mean dissolved-solids concentration for each range in flow were used to compute total load for the period of record.

Although records obtained from sampling locations close to the mouth of the streams were used whenever possible, the total drainage area of the streams was not sampled. Therefore, the dissolved-solids load from the entire basin was estimated by applying the average dissolved-solids concentration of the measured portion of the basin to the entire basin and weighting it in proportion to the flow from the entire basin.

DISCUSSION OF RESULTS

DISSOLVED-SOLIDS DISCHARGE

Results of this study show that 264,000,000 tons of dissolved solids were discharged annually (1966–69) to the oceans from streams draining the conterminous United States (table 1). The Gulf of Mexico receives the largest load, 183,000,000 tons, of which 157,000,000 tons are carried by the Mississippi River. The Pacific Ocean receives 43,400,000 tons annually, and the Atlantic Ocean 37,500,000 tons.

Table 1.—*Summary of drainage area, water, and dissolved-solids discharge*

Receiving body	Drainage area		Water discharge		Dissolved-solids discharge	
	Square miles	Percent of total	Cubic feet per second	Percent of total	Thousands of tons per year	Percent of total
Atlantic Ocean	285,900	10.7	359,400	20.6	37,500	14.2
Gulf of Mexico	1,750,500	65.6	887,400	50.8	183,000	69.3
Pacific Ocean	632,500	23.7	499,060	28.6	43,400	16.5
Total	2,667,900	100.0	1,745,860	100.0	264,000	100.0

Table 2.—*Dissolved-solids discharge to the oceans*

Area No.	Contributing basin	Drainage area: Square kilometers	Drainage area: Square miles	Total discharge: Cubic meters per second	Total discharge: Cubic feet per second	Dissolved solids (mg/l): Maximum	Dissolved solids (mg/l): Minimum	Dissolved solids (mg/l): Average	Gross yield of dissolved solids: Tonnes per square kilometer	Gross yield of dissolved solids: Tons per square mile	Gross yield of dissolved solids: Thousands of tonnes per year	Gross yield of dissolved solids: Thousands of tons per year
	ATLANTIC OCEAN											
1.	Passamaquoddy Bay to Penobscot River	30,046	11,601	665	23,500			55	37.5	107	1,160	1,270
	a. Penobscot River at W. Enfield, Maine	17,275	6,670	326	11,520	87	26	55				
2.	St. George River to Cape Cod Bay	54,133	20,901	1,162	41,020			55	37.1	106	2,020	2,220
	a. Kennebec River at Bingham, Maine	7,045	2,720	120	4,246	44	23	30				
	b. Androscoggin River near Auburn, Maine	8,436	3,257	167	5,899	98	34	60				
	c. Merrimack River below Concord River at Lowell, Mass.	12,005	4,635	198	7,006	112	30	71				
3.	Cape Cod to New York-Connecticut State line	46,537	17,968	986	34,810			70	47.0	134	2,210	2,440
	a. Connecticut River at Thompsonville, Conn	25,022	9,661	451	15,930	113	44	70				
4.	New York-Connecticut State line to Cape May	50,391	19,456	928	32,770			110	63.8	182	3,220	3,550
	a. Hudson River at Green Island, N.Y	20,953	8,090	353	12,480	158	78	109				
5.	Cape May to Cape Henry	205,283	79,260	2,866	101,200			135	59.6	170	12,200	13,500
	a. Delaware River at Trenton, N.J	17,560	6,780	323	11,420	117	61	94				
	b. Susquehanna River at Marietta, Pa	66,278	25,990	992	35,020	270	75	135				
	c. Potomac River near Washington, D.C	29,940	11,560	306	10,790	302	85	182				
	d. James River near Richmond, Va	17,501	6,757	204	7,205	282	61	121				
6.	Cape Henry to Neuse River	73,199	28,262	779	27,500			70	23.5	67	1,720	1,900
	a. Chowan River near Winston, N.C	12,616	4,871	131	4,626	188	40	73				
	b. Ronaoke River near Roanoke Rapids, N.C	21,782	8,410	227	8,031	98	35	72				
	c. Tar River at Tarboro, N.C	5,543	2,140	64.1	2,262	85	48	65				
	d. Neuse River at Kingston, N.C	6,967	2,690	82.5	2,914	111	28	67				
7.	Cove River Black River	75,247	29,053	805	28,440			55	18.6	53	1,400	1,540
	a. Cape Fear River near Tarheel, N.C	12,458	4,810	140	4,955	94	37	57				
	b. Pee Dee River near Pee Dee, S.C	22,870	8,830	260	9,195	84	38	57				
8.	Santee River to Sapelo Island	102,525	39,585	999	35,290			45	14.0	40	1,420	1,560
	a. Savannah River near Clyo, Ga	25,512	9,850	335	11,840	57	34	47				
	b. Ogeechee River near Eden, Ga	6,864	2,650	67.5	2,383	60	35	48				
9.	Altamaha River to Cape Kennedy	77,130	29,780	732	25,860			270	80.9	231	6,240	6,880
	a. Altamaha River at Doctortown, Ga	35,224	13,600	344	13,580	170	30	76				
	b. St. Johns River near DeLand, Fla	8,081	3,120	96.9	3,420	904	299	537				
10.	Cape Kennedy to Cape Sable			255	9,000			300			2,410	2,660
	Total or average	[2]740,480	[2]285,900	10,180	359,400			105	45.9	131	34,000	37,500
	GULF OF MEXICO											
11.	Cape Sable to Alligator Creek			71	2,500			200			446	492
12.	Peace River to New River	67,000	26,100	770	27,200			155	55.7	159	3,770	4,150
	a. Suwanee River near Wilcox, Fla	25,200	9,730	302	10,690	222	55	155				
13.	Apalachicola River	51,800	20,000	756	26,700			50	231	66	1,190	1,320
	a. Apalachicola River at Chattahoochee, Fla	44,550	17,200	623	22,010	75	32	52				

Table 2.—*Dissolved-solids discharge to the oceans*—Continued

Area No.	Contributing basin	Drainage area: Square kilometers	Drainage area: Square miles	Total discharge: Cubic meters per second	Total discharge: Cubic feet per second	Dissolved solids (mg/l): Maximum	Dissolved solids (mg/l): Minimum	Dissolved solids (mg/l): Average	Gross yield of dissolved solids: Tonnes per square kilometer	Gross yield of dissolved solids: Tons per square mile	Gross yield of dissolved solids: Thousands of tonnes per year	Gross yield of dissolved solids: Thousands of tons per year
	GULF OF MEXICO—Continued											
14.	Wetappo Creek to Perdido River	36,800	14,200	711	25,100			55	33.6	96	1,230	1,360
	a. Choctawhatchee River near Bruce, Fla	11,340	4,380	199	7,020	67	29	45				
	b. Escambia River near Century, Fla	9,890	3,820	171	6,045	119	25	66				
15.	Mobile Bay	114,700	44,300	1,818	64,200			65	32.6	93	3,730	4,110
	a. Alabama River at Clairborne, Ala	56,980	22,000	901	31,810	87	47	69				
	b. Tombigee River near Coatopa, Ala	39,890	15,400	610	21,550	138	49	53				
16.	Pascagoula River to Pearl River	51,000	19,700	883	31,200			100	34.7	156	2,790	3,070
	a. Pascagoula River at Merrill, Miss	17,090	6,600	267	9,430	418	45	144				
	b. Pearl River near Bogalusa, La	17,170	6,630	247	8,720	103	32	49				
17.	Mississippi River	3,267,700	1,262,000	18,400	650,000			245	48.4	124	142,000	157,000
	a. Mississippi River at Luling Ferry, La	3,220,900	1,243,600			326	172	247				
18.	Vermilion, Mermentau and Calcasieu Rivers	22,500	8,700	306	10,800			130	55.7	159	1,260	1,380
	a. Vermilion River near Perry, La					760	80	190				
	b. Calcasieu River near Kinder, La	4,400	1,700	73	2,570	155	20	73				
19.	Sabine River to Rio Grande	875,900	338,200	1,407	49,700			205	10.5	30	9,100	10,000
	a. Sabine River near Ruliff, Tex	24,160	9,330	234	8,270	262	30	82				
	b. Neches River at Evadale, Tex	20,590	7,950	171	6,050	138	47	92				
	c. Trinity River at Romayor, Tex	44,520	17,190	200	7,050	617	98	241				
	d. Brazos River near Juliff, Tex	114,200	44,100	160	5,640	951	128	388				
	e. Colorado River at Wharton, Tex	107,200	41,380	79	2,780	371	127	248				
	f. Guadalupe River at Victoria, Tex	13,360	5,160	44	1,550	543	111	245				
	g. San Antonio River at Goliad, Tex	10,150	3,920	23	880	822	108	379				
	h. Nueces River near Mathis, Tex	42,990	16,600	23	820	400	120	244				
	i. Rio Grande City, Tex	467,200	180,400	23	800	681	276	559				
	Total or average	[3]4,533,800	[3]1,750,000	25,120	887,400			210	36.6	104	166,000	183,000
	PACIFIC OCEAN											
20.	Colorado River	634,600	245,000									
21.	Tia Juana River to Ventura River	31,600	12,190	14	500			650	9.1	26	290	320
22.	San Jose Creek to Pescadero Creek	28,800	11,120	68	2,400			300	22	64	643	709
23.	San Francisco Bay	123,200	47,570	861	30,400			235	52	148	6,380	7,040
	a. San Joaquin River near Vernalis, Calif	35,070	13,540	126	4,450	704	58	330				
	b. Sacramento River near Sacramento, Calif	69,930	27,000	652	23,020	155	69	96				
24.	Tagunitas Creek to Smith River	56,500	21,820	1,192	42,100			115	77	219	4,330	4,770
	a. Eel River at Scotia, Calif	8,063	3,113	201	709	212	64	142				
	b. Klamath River near Klamath, Calif	31,340	12,100	483	17,060	202	55	110				
	c. Smith River near Cresent City	1,577	609	107	3,770							
25.	Oregon coastal area	43,800	16,900	1,509	53,300			65	71	203	3,110	3,430

a. Rouge River near Agness, Oreg	10,200	3,938	170	6,000	101	56	73				
b. Umpqua River near Elkton, Oreg	9,539	3,683	212	7,470	73	44	58				
26 Columbia River	668,700	258,200	7,963	281,200			85	32	92	21,400	23,600
a. Columbia River at the Dalles, Oreg	614,000	237,000	5,510	194,000	168	57	100				
b. Willamette River at Salem, Oreg	18,860	7,280	661	23,340			58				
c. Cowlitz River at Castle Rock, Wash	5,800	7,239	257	9,070			44				
27 Naselle River to Nooksack River	50,800	19,610	2,523	89,100			40	63	179	3,190	3,510
a. Chehalis River in Porter, Wash	3,351	1,294	119	4,190	75	38	57				
b. Queets River near Queets, Wash	(1)	(1)	(1)	(1)			40				
c. Snohomish River near Snohomish, Wash	4,439	1,714					30				
d. Skagit River near Mt. Vernon, Wash	8,011	3,093	463	16,350			35				
e. Nooksack River near Deming, Wash	1,513	584	92	3,260			55				
Total or average	1,638,000	632,410	14,130	499,060			85	24.2	69	39,300	43,400

[1] Average for contributing basin rounded to nearest 5 mg/l.
[2] Drainage area for area 10 estimated.
[3] Drainage area for area 11 estimated.

DISSOLVED-SOLIDS CONCENTRATION AND YIELDS

Yields of dissolved solids were computed in tons per square mile per year for each of the numbered areas (contributing basins). Results are given in table 2. Yields from the various basins, excluding the completely controlled Colorado River basin (area 20), vary from a low of 26 tons per square mile for the dry areas of Southern California (area 21) to a high of 231 for the highly watered area of southeastern Georgia – northeastern Florida (area 9), and average about 100 tons per square mile for the conterminous United States. However, much of the natural flow of streams in Southern California never reaches the Pacific Ocean, so this low figure for area 21 may not be very meaningful.

Table 2 also shows maximum, minimum, and average dissolved-solids concentration (1966–69) for each of the contributing basins.

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