Comprehensive Survey of Sedimentation in Lake Mead, 1948-49

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P. AMOUNT OF SEDIMENT

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The amount of sediment accumulated in Lake Mead may be expressed in terms of either volume or weight. The sediment volume is the space occupied by the accumulated material, which includes both the solid constituents and the interstitial water. The sediment weight, however, includes only the solid particles.

VOLUME

The volume of sediment accumulated in Lake Mead has been computed by Speert, Ames, and Kennon (p. 84–87). In December 1948, the sediment that had accumulated in Lake Mead had a total volume of 1,426,000 acre-feet, of which 1,418,000 acre-feet was stored below the level of the permanent spillway crest.[19] If this volume were confined to an area of 1 square mile it would form a block some 2,220 feet, or almost one-half mile, in height. As compared with the capacity of Lake Mead, however, the total volume of sediment is less impressive. It has reduced the usable water storage capacity of the reservoir below the level of the permanent spillway crest from 25,571,000 to 24,756,000 acre-feet, a reduction of about 3.2 percent.

To determine the areal distribution of sediment volume, the lake was divided into eight areas (fig. 17), and the volume of sediment in each area was computed separately (table 6). These areas conform in general to the major geographic divisions of the lake, and divide the accumulated sediment insofar as practicable into similar sedimentary units. For example, area 1 is Boulder Basin, where the finest grained and least compacted material has accumulated; and area 7 is Lower Granite Gorge, where the sediment is made up predominantly of firmly packed sand.

The Colorado delta (areas 1–7) contains 97.6 percent of the total volume of sediment; the Virgin delta (area 8) contains only 2.4 percent. The greatest volume of sediment in the Colorado delta has accumulated in Lower Granite Gorge (area 7), but Boulder Basin (area 1), at the other end of the reservoir, contains more than twice as much sediment as Virgin Basin (area 2.)

[19] These totals do not include the sediment, estimated about 20,000 acre-feet, which was deposited after the closure of Hoover Dam but before the completion of the reservoir survey in 1935. (See p. 167.)

WEIGHT

To obtain the total weight of the solid mineral particles, the volume of sediment in each 10-foot increment of elevation was multiplied by its average specific weight. These weight increments were then added together to obtain the total weight of solid mineral particles in each of the eight selected areas. As mentioned previously (p. 180), the specific weight of the sediment accumulated in Lower Granite Gorge and the eastern part of Pierce Basin (area 7 and part of area 6) was obtained largely by extrapolation of specific weight data from surface layers of this part of the deposit and from the bottomset beds west of the Colorado delta front. Owing to insufficient sediment data from the topset and foreset beds of the Virgin delta, the specific weight of the sediment accumulated in area 8 also was derived in part by extrapolation. However, in areas 1–5 little extrapolation was required.

These computations (table 27) show that slightly more than 2 billion tons of sediment has accumulated in Lake Mead during the 14-year interval 1935–48. Of this total, 97.2 percent is contained in the Colorado delta (areas 1–7) and 2.8 percent in the Virgin delta (area 8). The greatest weight of material was deposited in Lower Granite Gorge (area 7) where 55.3 percent of the total has accumulated. A further estimate based on delta structure reveals that about 50 percent of the total weight of sediment in the Colorado delta (areas 1–7) is contained in the topset and foreset beds and about 50 percent is accumulated in the bottomset beds. Because of inadequate data, no attempt was made to estimate the relative quantities of material in the topset, foreset, and bottomset members of the Virgin delta.

A comparison between the weight and volume of sediment in each of the selected areas is also presented in table 27. More than 55 percent of the total weight of sediment was deposited in Lower Granite Gorge (area 7), but its volume is only 37.9 percent of the total volume of accumulated sediment. In contrast, only 10.9 percent of the total weight of sediment has been deposited in Boulder Basin (area 1), but it has a volume of almost 21 percent of the total. This

TABLE 27.—*Volume, weight, and particle size of sediment in individual basins, Lake Mead*

Area (fig. 17)	Area	Volume		Weight		Mean specific weight, in lb per cu ft	Median particle diameter, in microns
		Acre-feet	Percent of total	Millions of tons	Percent of total		
1	Boulder Basin [1]	295,000	20.7	219	10.9	34.1	0.95
2	Virgin Basin [1]	142,000	10.0	123	6.1	39.8	1.25
3	Temple Bar area and Virgin Canyon	59,000	4.1	54	2.7	41.8	1.40
4	Gregg Basin	114,000	8.0	122	6.1	49.4	2.45
5	Grand Bay	97,000	6.8	111	5 5	52.3	6.60
6	Pierce Basin	144,000	10.1	214	10.6	68.2	25.0
7	Lower Granite Gorge	541,000	37.9	1,113	55.3	94.5	150.0
	Subtotal, Colorado delta	1,392,000	97.6	1,957	97.2	[2] 64.6	[2] 44.0
8	Overton Arm (Virgin delta)	34,000	2.4	57	2.8	78.2	[2] 49.0
	Total	1,426,000	100.0	2,014	100.0	[2] 64.9	[2] 46.0

[1] Includes part of Boulder Canyon (fig. 17).
[2] Weighted average.

comparison further illustrates the variations in compaction of the sediment deposit, which are due to differences in the physical properties of the solid particles and to the depth of sediment burial.

The mean specific weight of the sediment in each of the eight selected areas is also given in table 27, based on the volume and weight computations. According to these calculations, the average specific weight of all the sediment accumulated in Lake Mead is 64.9 pounds per cubic foot. The mean specific weight of the sand comprising the topset and foreset beds is 93.8 pounds per cubic foot, and the mean specific weight of the silt and clay making up the bottomset beds is 51.8 pounds per cubic foot. The sediment in the Virgin delta (area 8) averages 78.2 pounds per cubic foot, whereas the material in the Colorado delta (areas 1–7) averages only 64.6 pounds per cubic foot. The higher average specific weight of the Virgin delta may be related, at least in part, to its smaller percentage of fine constituents. As noted previously, the bottomset beds of the Virgin delta are considerably coarser than the bottomset beds of the Colorado delta. This has given them a lower porosity and higher specific weight than the bottomset beds of the Colorado delta. The considerable extrapolation required in estimating the weight and volume of the topset and foreset beds of the Virgin delta may also have contributed to the difference in the average specific weights.

RATE OF SEDIMENTATION

An estimate of the rate of sedimentation is readily obtained. About 2,014 million tons of sediment was deposited in Lake Mead during the 14-year period 1935–48; thus, the average annual rate of sedimentation is estimated at 144 million tons. As indicated earlier, most of the material in the Colorado delta and the Virgin delta was supplied by the Colorado and Virgin Rivers, respectively. Consequently, a further estimate may be made of the mean annual load of detrital material carried into the lake by each of these rivers. According to this estimate, the mean annual load of the Colorado River is 140 million tons, whereas that of the Virgin River is only 4 million tons.

It is interesting to compare the above estimate of the mean annual load of sediment supplied by the Colorado River with suspended-load measurements obtained by the Geological Survey at the Grand Canyon gaging station. According to Howard (p. 103), about 1,990 million tons of suspended sediment was carried past the Grand Canyon station during the period 1935–48, of which less than 10 million tons was carried out of the reservoir. This is equivalent to a mean annual load of about 142 million tons, or about 2 million tons more than the estimated average annual deposition of sediment from the Colorado River in Lake Mead in the same period. No estimate is made of the average annual suspended load of the Virgin River, because of the short period of record.

Such close agreement between the mean annual suspended load of the Colorado River and the average annual rate of sedimentation in the Colorado delta is indeed striking. However, the material carried as bed load was not included in the measurement of sediment passing the Grand Canyon station, whereas it is included in the estimate of the amount of sediment accumulated in the Colorado delta. If the quantity of sediment carried in the bed load is appreciable, we would expect the total amount of sediment in the Colorado delta to be somewhat greater than the total suspended load passing the Grand Canyon station. Since this is not the case, it appears that the bed load of the Colorado River is extremely small, and that practically all of the sediment supplied by the Colorado River is carried in suspension. Thomas (p. 29) has cited evidence that the bed load of the Colorado River upstream from Lake Mead is not great. The absence of significant quantities of coarse constituents in the Colorado delta also suggests a small bed load.

The relative accuracy of the estimated sedimentation rates based on the amount of sediment in the Colorado delta and on suspended-load measurements cannot be evaluated quantitatively. It is noted (p. 233) that there are several possible sources of error in the determination of suspended-sediment load. Also, satisfactory techniques have not yet been developed for measurement of bed load in a stream.

The rate of sedimentation estimated from the total weight of sediment accumulated in the Colorado delta is also subject to error. Small errors have undoubtedly been introduced by assuming that cores obtained along the central part of the delta are representative of the entire cross sections. However, the chief source of error probably lies in the considerable extrapolation required in estimating the total weight of sediment in the thick part of the Colorado delta east of the delta front.

Although none of these possible errors can be evaluated quantitatively, the close correspondence of estimates of the rate of sedimentation obtained by such widely differing methods suggests that the estimates are reasonably correct.

MEDIAN PARTICLE SIZE

To obtain a quantitative estimate of the average size distribution of the constituent particles, size data for samples from each of the eight selected areas were averaged separately. In Lower Granite Gorge and the eastern part of Pierce Basin, where data are inadequate, it was assumed that the deeply buried topset and foreset beds were about the same in texture as the surface layers and that the bottomset beds were similar in texture to the bottemset beds that were sampled in Pierce Basin. Likewise, in the absence of adequate data, the texture of sediment accumulated in the Virgin delta topset and foreset beds was determined by extrapolation largely from size analyses from the topset and foreset beds of the Colorado delta. Owing to the general textural similarity of the topset and foreset beds of the Virgin and Colorado deltas, it seems probable that no great error has resulted from this extrapolation.

The results of these computations (fig. 53) show that the median particle diameter of the sediment in the Colorado delta decreases progressively from the eastern end of the lake (area 7) to Boulder Basin (area 1) and that the median particle diameter of the Virgin delta (area 8) is about twice that of the sediment accumulated in Pierce Basin (area 6).

Table 27 shows the median particle diameter of the sediment in each of the eight selected areas. The mean specific weight increases as the median particle size increases, but casual comparison suggests that the relation in areas 1–5, where the median diameter is less than 62 microns, may be different from that in the other areas, where the particles are predominantly of sand size.

In figure 54 the average textural characteristics of the material in several of the areas have been combined and weighted so as to provide an estimate of the average size distribution of various parts of the accumulated sediment. The curve for areas 1–8 shows that the median particle diameter of all the sediment accumulated in Lake Mead is about 46 microns, and the curve for areas 1–7 shows a median particle diameter of 44 microns for the material of the Colorado delta. The median diameter of the silt and clay particles of the Colorado delta bottomset beds (areas 1–5) is, in contrast, only 1.65 microns.

Except for small amounts of material contributed by ephemeral tributaries and by slumping of the reservoir walls, practically all the material in the Colorado delta (areas 1–7) was carried into the lake by the Colorado River. The cumulative curve for areas 1–7 is, therefore, an estimate of the average size distribution of the total load of sediment carried into Lake Mead by the Colorado River during the 14-year interval 1935–48. This curve shows that the average sediment load of the Colorado River during this period was made up of approximately 45 percent sand (greater than 62 microns), 27 percent silt (4–62 microns), and 28 percent clay (less than 4 microns). The most striking feature of this distribution is the virtual absence of coarse components. Only 1 percent of the material consists of particles greater than 500 microns in diameter—that is, coarse sand or larger grains.

AVERAGE CHEMICAL COMPOSITION

From the sediment weight and chemical data presented in the preceding pages, a further estimate can be made of the mass chemical composition of the sediment accumulated in the Colorado delta. The method used in estimating the average composition of the Colorado delta corresponds closely to the method of estimating the average particle-size distribution. Because of inadequate chemical data from the sediment of the Virgin delta, no attempt is made to estimate its average composition.

One sample from each of the seven delta subdivisions (areas 1–7, fig. 53) was chemically analyzed, with results as reported in table 23. In areas 1–5, where the Colorado delta is made up almost entirely of bottomset beds, it is assumed that the chemical composition of each sample is representative of the total weight of sediment in the area from which it was obtained. How-

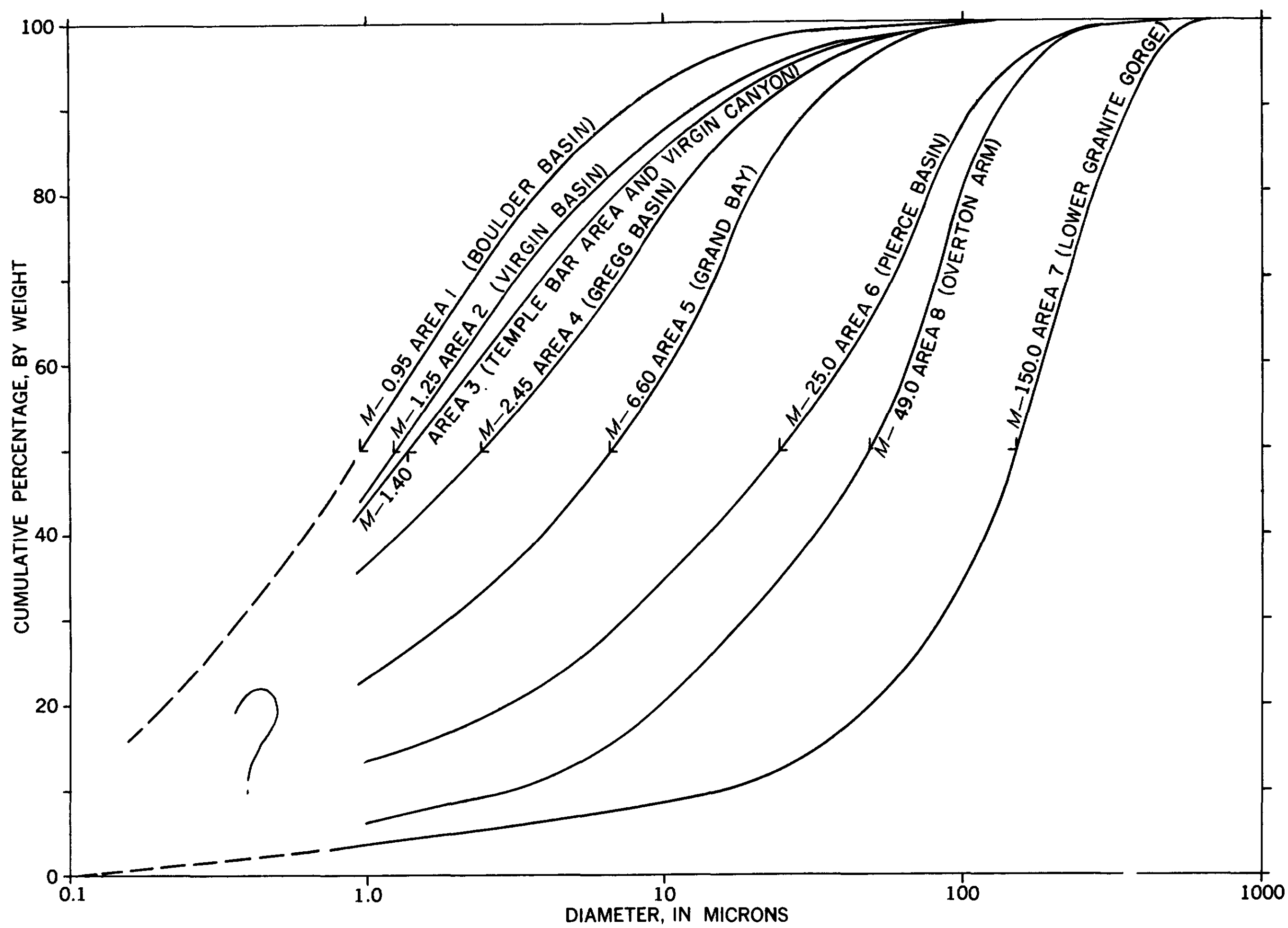

FIGURE 53.—Cumulative curves showing the estimated average size distribution of the accumulated sediment in each of the eight selected lake areas. The median particle diameter (*M*) for each curve is shown in microns.

ever, in areas 6 and 7, where the delta is made up of topset, foreset, and bottomset beds, this assumption is not valid. Chemical data in these areas are available only for samples (1037 and G1270, table 23) from the topset and foreset beds, but it is assumed that the bottomset beds in areas 6 and 7 are similar in composition to the bottomset beds in area 5 (sample 937, table 23). On the basis of this assumption an estimate has been made of the average chemical composition of the total sediment in areas 6 and 7. The average chemical analyses of the sediment in the seven lake areas were then combined and weighted in order to obtain an estimate of the average chemical composition of all of the sediment in the Colorado delta. The results of these computations presented in table 28 represent an estimate of the average chemical composition of the total load of sediment carried into Lake Mead by the Colorado River during the 14-year period, 1935–48.

A comparison of this analysis with Clarke's composite analysis of 235 samples from the Mississippi delta shows a marked similarity in the composition of the Colorado and Mississippi deltas. The only notable differences are in the concentrations of calcium, sodium, and potassium. The Colorado delta contains about twice the calcium, one-half the sodium, and about three-fourths the potassium concentration of the Mississippi delta.

TABLE 28.—*Estimated average chemical composition of the sediment accumulated in the Colorado delta, 1935–48*[1]

Constituent	Percent	Composite of 235 samples from Mississippi delta[2]
SiO_2	72.5	69.96
Al_2O_3	7.6	10.52
Fe_2O_3[3]	3.0	3.47
MgO	1.6	1.41
CaO	4.4	2.17
Na_2O	.60	1.51
K_2O	1.66	2.30
TiO_2	.46	.59
P_2O_5	12	.18
MnO	.05	.06
Ignition[4]	7.5	
Total	99.5	92.2

[1] Weighted average of samples 332, 634, 698, 937, 1037, 1176, and G1270.
[2] See Clarke, 1924, p. 509.
[3] Total Fe expressed as Fe_2O_3.
[4] Includes loss due to oxidation of FeO.

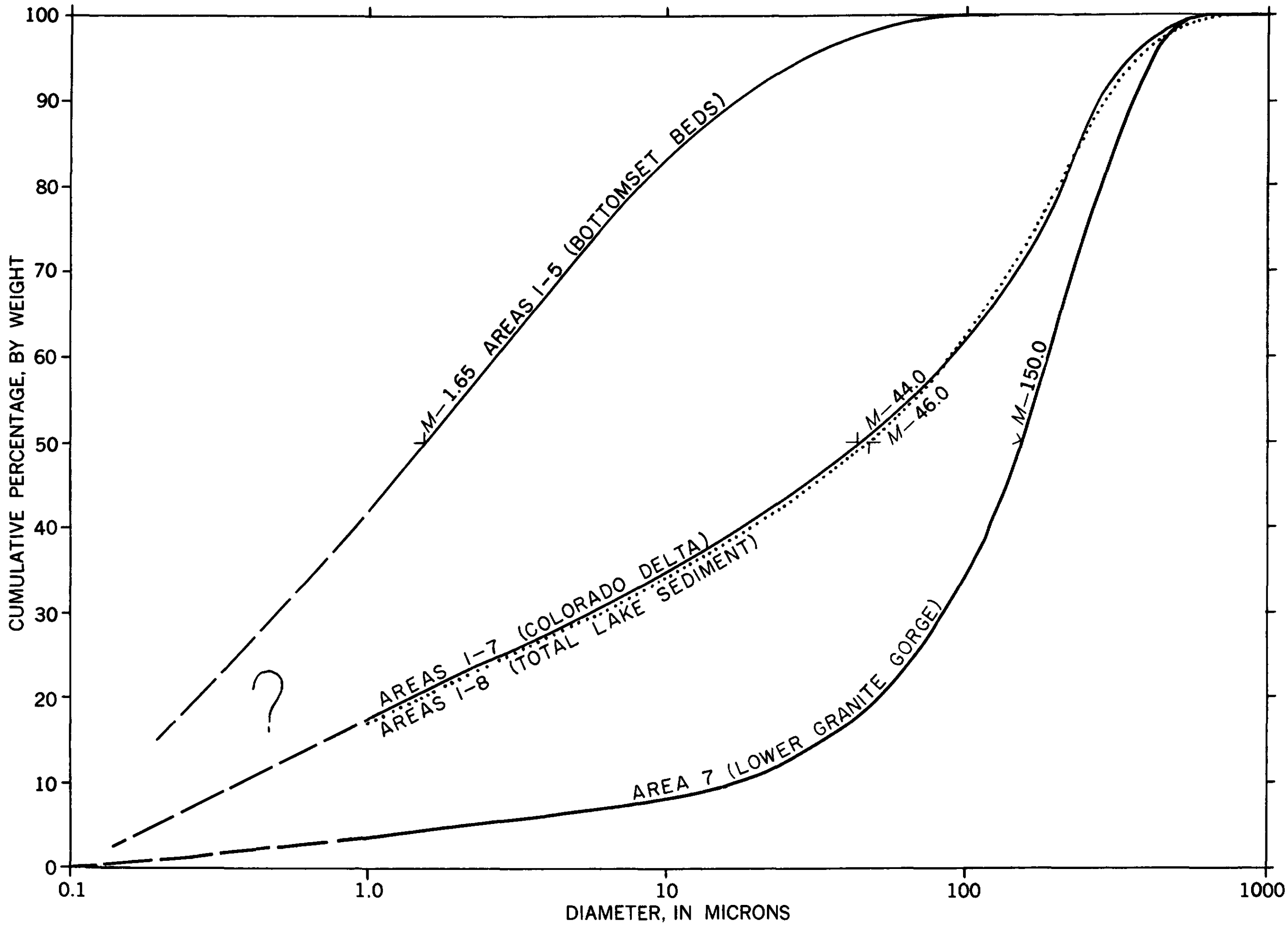

FIGURE 54.—Cumulative curves showing the estimated average size distribution of the accumulated sediment in several of the lake areas combined. The median particle diameter for each curve is shown in microns.

POTENTIAL ECONOMIC USE

With the thought that the sediment accumulated in Lake Mead might be a resource instead of a liability, the exceedingly fine grained material in the bottomset beds of the Colorado delta was investigated for its possible uses in the ceramic and petroleum industries.

Tests of the ceramic properties of the sediment were made by T. A. Klinefelter of the U.S. Bureau of Mines, who states that the clay of the bottomset beds is of the montmorillonite (nonswelling bentonite) type, as determined by X-ray patterns and physical properties. The ceramic tests were confined, therefore, to oil bleaching and heat treatment. The results of these analyses show that there is some possibility of using the Lake Mead clay in decolorizing or clarifying fats and oils. However, the clay would require activation by leaching in acid before it could be used for this purpose. There is also a possibility that the clay could be used as a catalyzer for oil cracking, but no test for this property has yet been made.

The chief potentiality of the Lake Mead sediment may be as a bloating clay for use in the manufacture of light-weight cements, building brick, and other construction materials. When flash heated to a temperature of 2,100°F, the Lake Mead clay increases from 3 to 4 times in volume, forming a fine bloat with small though somewhat uneven vesicles or blebs. The specific weight of the bloat ranges from 19 to 24 pounds per cubic foot, which is well within the commercial range of bloating clays. At lower temperatures the product would be somewhat heavier and stronger. Most of the commercial products range in weight from 45 to 55 pounds per cubic foot, chiefly because lighter bloats cannot be produced at temperatures of 1,800°F to 2,200°F from most clays used for this purpose. Hence, the Lake Mead material would be unusually good as bloating clay, although it would require care in handling in the kilns because of its narrow bloating range. As determined by slow heating (100°F per hour), bloating of the Lake Mead clay occurs at temperatures between 2,000°F and 2,200°F.

The suitability of the material as a drilling fluid was investigated by George Tchillingarian of the University of Southern California, who found that it fails to meet the specifications of the petroleum industry. The viscosity and filtration loss of drilling muds prepared with the Lake Mead clay are too high for it to compete with fresh-water clays currently used for this purpose.