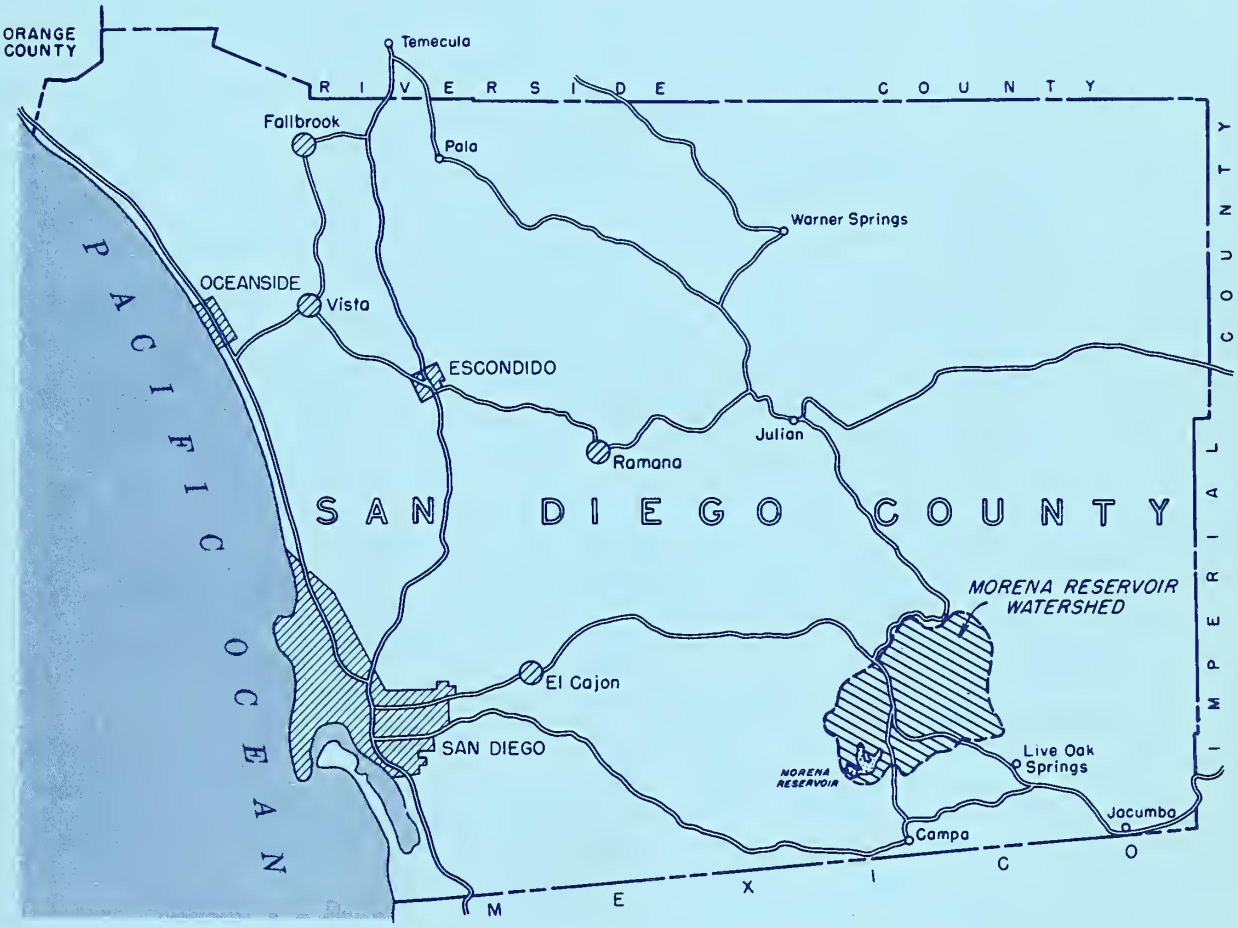
MORENA RESERVOIR WATERSHED

SAN DIEGO COUNTY, CALIFORNIA

NOVEMBER 1953



A study to determine needed watershed erosion and sediment control practices.

Prepared Jointly by THE CITY of SAN DIEGO

SOIL CONSERVATION SERVICE and FOREST SERVICE ··· UNITED STATES DEPARTMENT of AGRICULTURE

AGR-SCS-PORTLAND, ORE NOV 1953

A STUDY TO DETERMINE NEEDED WATERSHED EROSION AND SEDIMENT CONTROL PRACTICES ABOVE MORENA RESERVOIR SAN DIEGO COUNTY, CALIFORNIA

****

Prepared Jointly by

THE CITY OF SAN DIEGO

SOIL CONSERVATION SERVICE and FOREST SERVICE

of the

UNITED STATES DEPARTMENT OF AGRICULTURE

November 1953

REPORT

Index

Table

Map

APPENDIX

Index

APPENDIX

Tables

Tables

APPENDIX (Continued)

Figures

Maps

SUMMARY

The Morena Reservoir, which is an important storage reservoir in the water supply system of the City of San Diego, is losing its capacity through sedimentation at the rate of about 200 acre feet per year. This has become a matter of concern to the city officials since military and industrial expansion have caused greatly increased water demands during the war and subsequent years. In order to determine the sources of sediment in the watershed and to develop and appraise the feasibility of control practices, an investigation has been made by the City of San Diego in cooperation with the Soil Conservation Service and the Forest Service of the U. S. Department of Agriculture. The findings of this investigation are reported herein.

The investigation determined that certain practices are needed to reduce reservoir sedimentation to a minimum and to benefit watershed users. These practices include dams for the purpose of stabilizing gully systems or valley trenches in mountain meadows and such fire control practices as increased fire protection forces, fire breaks, truck trails and water developments to reduce erosion on mountain slopes. Installation of those practices found to be economically feasible is recommended with the costs to be shared in proportion to expected benefits. The quantities of feasible practices include 5 dams or dikes, 27 miles of firebreaks, 650 acres of strip burning, 3 miles of road rehabilitation, 6 water developments, increased manning of three fire guard stations and 300 small gully plugs.

INTRODUCTION

The City and County of San Diego have experienced an enormous increase in population since 1940. Military and industrial developments have increased many fold, as a result of the war and subsequent years of international unrest. The population of the City of San Diego increased about 114 percent between 1940 and 1952 and the County by 138 percent during the same period. In order to maintain an adequate water supply for a more slowly developing pre-war population, the City purchased or constructed six major impounding reservoirs between 1910 and 1943. The occurrence of extended dry periods, as well as an increasing demand, caused the City to file for a permit to divert flow from the Colorado River. This diversion was accomplished in 1947 when Colorado River water was first delivered through the San Diego County Aqueduct of the Metropolitan Water District and the San Diego County Water Authority.

A series of dry years, beginning in 1946, resulted in withdrawal of most of the native water from impounding reservoirs, while creating increasing demands for imported Colorado River water. The Navy and San Diego County Water Authority, which includes the City as a member agency, have sponsored the addition of a second barrel to the San Diego County Aqueduct. However, the use of native water from impounding reservoirs, when available, results in a savings of about $12.00 an acre foot over the cost of imported Colorado River water.

Surveys of the storage capacity of City-owned reservoirs were made in 1948. These and earlier surveys showed that certain reservoirs were losing their capacity at a significant rate, particularly Morena Reservoir. In recognition of the relationship between accelerated watershed erosion and reservoir sedimentation, the City of San Diego entered into an informal agreement with the Soil Conservation Service and Forest Service of the U. S. Department of Agriculture in 1951 to make a survey of the sediment sources and possible control practices. This agreement, which is shown following page 3 of the Appendix, outlined agency responsibility for determining existing and potential sources of sediment and the feasibility of an action program designed to reduce sedimentation in Morena Reservoir and improve watershed conditions. Before entering into an agreement, the proposal was discussed with the Directors of the Mountain Empire Soil Conservation District, which includes the Morena watershed. The Directors expressed the interest and desire of the Soil Conservation District to participate in the investigation and its findings.

DESCRIPTION OF MORENA RESERVOIR AND WATERSHED

Morena Reservoir is on Cottonwood Creek, in T. 17 S., Rs. 4 and 5 E., 35 miles east of San Diego in San Diego County, California. The dam was built in 1910 and is a rock-fill structure, 506 feet long and 167 feet in maximum height above the stream bed. The maximum length of the reservoir was originally about 3.9 miles; the surface area 1,687 acres, and the original capacity 66,403 acre feet.

The watershed of about 115 square miles is a mountainous area lying on the west slope of the Peninsular Range. Elevations vary from about 3000 feet at the dam to 6000 feet on the northern divide. Two principal sub-watershed streams, Cottonwood and La Posta Creeks, join at the head of the reservoir. The two predominant topographic features consist of sharply dissected to moderately rounded mountainous slopes and gently sloping inter-mountain alluvium filled valleys. Rocks of igneous and metamorphic origin have given rise to only thin to moderately well developed soils ranging in texture from sandy clay to coarse sand. About 86 percent of the area is in brush, chiefly chapparral, about 7 percent open pine and oak forest, and 4 per cent in meadow and cultivation.

The climate is warm and temperate with dry summers and moderately wet winters. Almost all the precipitation, usually rain at lower elevations and snow near the higher divides, falls during the period from November to April. The average annual precipitation is 22 inches near the dam and 30 inches in the Laguna Mountains along the northern divide. Cyclonic storms from the northwest provide most of the rainfall and when these storms encounter large air masses from the tropical Pacific region, precipitation of long duration and high intensity occurs. The precipitation over a long series of years is roughly cyclic in pattern, with predominantly dry and wet years grouped in series of from 6 to 21 years.

RESERVOIR SEDIMENTATION

The total accumulation of sediment in Morena Reservoir during the period from 1910 to 1948 amounted to 7,652 acre feet. The average annual accumulation over the 38 years is about 201 acre feet, or at a rate of approximately 1.8 acre feet per square mile of watershed per year. By 1948, sediment had depleted the storage capacity by 11.5 percent. The sediment consists largely of fine, medium and coarse sand, with less than 30 percent in the silt and clay sizes. Most of the sediment has been lodged in the delta of the Cottonwood Creek arm although the proportion depositing in the broad central basin is increasing. Laboratory tests were made to determine the specific yield of the sediment deposits. These tests indicated that under optimum conditions about 2500 acre feet of water could be extracted by pumping from the sediment deposits in the reservoir after withdrawal of free stored water. Further field investigations would be needed to determine the amount of usable water the deposits would yield by free drainage.

SOURCES OF SEDIMENT

The watershed may be divided into two zones, based on the nature of the erosion problem and its control. The meadows, as one, were homestead sites for the first permanent settlers in the years shortly after the Civil War. The mountain watershed, as the other, was withdrawn from the public domain in 1890 and the area is now a part of the Cleveland National Forest. Almost from the beginning of early settlement, intensive grazing has reduced the effectiveness of plant cover on both mountain slopes and in meadows. Periodic burning of the brushy uplands in an attempt to increase the amount of forage, and accidental fires during the long fire-danger season from May to December, have lowered the resistance of most land to erosion. Few records are available on the amount of watershed burned over prior to 1910, but since that time an average of 4 percent per year has been burned, and in some areas the cover has been destroyed several times. The Laguna Junction Fire of 1945, the largest of record, burned over 70 percent of the watershed. Fire and intensive grazing not only cause accelerated erosion and runoff for a number of years afterward, but also impair the site for effective regrowth. Fire damage appraisal studies have shown that the volume of soil removed from mountain slopes by erosion during the life of the reservoir has amounted to about 7750 acre feet. Assuming that similar conditions will be maintained without a more intensive erosion control program, approximately 20,000 acre feet of soil will be eroded from mountain slopes during the remaining useful life of the reservoir which is estimated to be 108 years. This estimate is based not only on loss of capacity but obsolescence, deterioration of structural material, etc.

While mountain slopes are affected by sheet and shallow gully erosion over broad areas, the deep soils of the meadows are cut by vertical walled trenches up to several miles in length and as much as 40 feet in depth and 265 feet wide. They are reported as starting about 1895 and by 1951 had engulfed some 340 acres of meadow. Local inhabitants believe that much of the erosion damage occurred during the 1916 and 1927 floods. Field investigations have revealed that about 4920 acre feet of material have been removed from the valley trenches. Studies of their probable future growth were based on the meadow slope, area and soil type, on the stability of the channel outlet and of the present head of the trench. Estimates of their development during the remaining useful life of the reservoir show that approximately 9000 acre feet will be removed during the period unless the valley trenches are stabilized.

Not all of the material from eroding mountain slopes and meadows will reach Morena Reservoir during the period with which this report is concerned. Some of the soil moves only to a lower position on a slope. Buried fence posts and tree crowns and sand washes with surface elevated above the surrounding plain, are evidence of deposition of sediment in channels and meadows. Ponding of water near the head of the reservoir has created broad zones of deposition above the reservoir. Measurements and reconnaissance estimates indicate that about 4060 acre feet of sediment have been deposited in the valleys above the reservoir since accelerated erosion began.

Available information indicates that about 58 percent of the soil eroded on watershed slopes and 80 percent of the soil eroded from mountain meadows will reach the reservoir during its remaining useful life, as estimated by the City of San Diego. This was determined by comparison of the mechanical analysis of 11 samples of upstream channel deposits, mountain meadow and watershed slope soils with those of reservoir deposits. An average of 4 percent of the channel deposits are silt and clay, the remainder being chiefly coarse sand with some fine gravel and fine and medium sand. Mountain meadow soils, on the other hand, average 17 percent silt and clay, 40 percent fine and medium-sized sand and 43 percent coarse sand. Samples of only two watershed slope samples were analyzed, but these averaged about 10 percent silt and clay and 68 percent coarse sand, with the remainder fine and medium-sized sand. Because of the finer texture of mountain meadow soils, a proportionately large amount of the eroded material will be carried to the reservoir.

EFFECT OF EROSION ON WATERSHED LAND OWNERS OR USERS

Livestock enterprises within the watershed are largely dependent on the forage produced in the mountain meadows. Where the meadows are not dissected by valley trenches, the water table remains near the surface, supplying moisture to the vegetation. Palatable and nutritious forage is thereby available to stock during the fall, winter and spring. When the meadows are cut by valley trenches, the water table is lowered and the moisture is no longer available for plant growth. This has resulted in a decrease in volume and palatability of forage and, if some instances, a replacement of wet meadow by dry sagebrush flats. The loss of income producing land through valley trenching is also important in the already limited meadow areas.

In addition to the adverse effect of erosion and sedimentation on the reservoir and livestock enterprises, other damaging effects of watershed deterioration occur. These include the acceleration of runoff and probable increase in reservoir spillway water loss during flood flows and the impairment of the reservoir as a resort for fishing and other recreation. The value of the watershed for hunting and camping is impaired by destruction of vegetation by fire and site deterioration through erosion.

REMEDIAL PROGRAM AND COSTS

The remedial program considered for the Morena Reservoir watershed is one designed to stabilize sediment sources while improving the condition of the watershed as a land and water resource. The only proposals considered, however, were those having the stabilization of a sediment source as one primary function. The mountain meadow stabilization practices considered involve the construction of earth fill dams with spillways below the tops of the valley trenches. These will serve as key stabilization structures in the event supplementary check dams may eventually be necessary at some point in the trench to induce sediment aggradation to the desired grade. Cost estimates of the key structures are summarized in Table 1, and their location is shown on Map 1. These estimates are based on cross sections and profiles at the dam site and for a distance upstream. Purpose of the dams is to impound sediment behind the structures on a grade probably approaching the present meadow slope. Other functions will include stabilization of the bottom and upper end of the trench.

The slope treatment practices are designed to give maximum protection to existing vegetative cover against large fires and to improve cover types wherever soil moisture makes this possible. The practices set forth in this report are expected to reduce the total average burned area per year from 4 percent to 0.1 percent. They include such fire control measures as fire breaks, both motorized and non-motorized, development of water storage facilities, and an increase in fire protection forces. The location of these measures is shown on Map 1. Erosion control structures in small gullies and for control of road slope erosion are also included but are not shown on Map 1.

An increase in the capacity of Morena Reservoir by raising the dam offers one possibility of alleviating the effects of sedimentation for the time being. The cost or benefit of this type of program has not been evaluated.

PROGRAM EVALUATION

The benefits to be derived from the program are those subject to monetary evaluation and those generally considered to be social values not easily subject to evaluation. The former benefits include those affecting Morena Reservoir through reduction in sediment volume and those accruing to the sites on which the measures are installed. The monetary value of the increased water yield that may be expected was adopted as the most suitable measure of the benefits from reducing sedimentation in the reservoir. During the 38 year life of the reservoir, to 1948, sedimentation has reduced the safe yield by .45 million gallons per day. Assuming that this rate can be projected into the future, the average annual loss in safe yield without the needed program will be about 13.3 acre feet per year. An acre foot of reservoir sediment will not only reduce the safe yield the year of accumulation, but for the remaining life of the reservoir. The present value of an increasing annuity of one for the estimated remaining life was therefore used in determining the monetary worth of preventing one acre foot of sediment accumulation. Details of the economic evaluation are given on pages 25 to 29 of the Appendix.

The savings in use of water from reservoirs already constructed rather than from the Aqueduct is $12.00 per acre foot. The City of San Diego estimates that increased costs will raise this sum to $35.00 per acre foot after about 18 years. This saving was capitalized at 3 percent for the remaining 108 years of useful reservoir life. The present value of the savings accumulating over that period of time would be worth $470,800 to the City of San Diego, if it were possible to prevent all sedimentation. However, some sediment will continue to enter the reservoir with full implementation of the practices considered. Not only will normal geologic erosion in the watershed continue, but a large volume of alluvial material in the channels throughout the watershed is subject to entrainment and eventual deposition in the reservoir.

Watershed treatment practices consisting of a single or a series of meadow stabilization structures were evaluated separately since they function independently of other practices. An evaluation of on-site benefits associated with meadow stabilization structures was also made. These evaluations are listed separately on Table 1. Mountain slope treatments, on the other hand, function as a dependent group of practices whereby the failure of one may nullify the value of others. Such practices cannot, therefore, be evaluated separately but only as a group.

In addition to the benefits obtained through reduced reservoir sedimentation, the stabilization structures built in mountain meadows will substantially improve the quality and quantity of forage. These benefits were determined from estimates of the difference in pounds of beef gain per month under present and under future improved conditions. The possible variation in annual cow months of forage in this watershed range from about 0.6 acres required per cow for an 8 months' grazing season on excellent wet meadows to about 7 acres per cow required on poor condition meadow that is wet only in the spring. The variation in beef gain per month per animal unit is from 45 pounds on good quality to 20 pounds per animal unit month on poor quality forage. The value of the improved forage possible with a meadow stabilization program is listed on Table 1 as on-site benefits.

To reflect more adequately the different rates at which public agencies and private interests can borrow money, the estimated costs and benefits were computed using 3.0 percent interest for public agencies and 4.0 percent for private interests.

The social values associated with both reduced reservoir sedimentation and improved watershed conditions are of considerable significance. Recreational values about the reservoir result from the opportunities for fishing and enjoyment of a pleasant climate throughout the year. The great expansion of population in Southern California causing over-crowding of recreational facilities has greatly increased the patronage of such surroundings as afforded by Morena Reservoir and watershed.

In addition to the social values about the reservoir, hunting and other recreational facilities in the watershed would be appreciably enhanced by a program designed to hold fires to a minimum. Such protection will afford better cover for game and insure maintenance of their numbers in the area. Improvements in the economy of local ranch operations will also have a value beyond that of increased income. These large benefits to watershed users, which are in addition to those measureable by increased income, have not been evaluated in this report.

RECOMMENDATIONS

The survey made jointly by the City of San Diego, Soil Conservation Service and Forest Service of the U. S. Department of Agriculture shows the need for installation of certain erosion and sediment control practices in the watershed above Morena Reservoir. The costs of these practices and their tangible benefits to the City of San Diego and to other watershed users have been evaluated. On the basis of this evaluation, certain practices were found to be economically feasible. It is recommended that these, and others in which the benefits to the community are large, be installed. The practices recommended include the following: (1) Structures to prevent further erosion and restore Coogan Meadow, Crouch Meadow and Thing Valley and (2) Slope treatment practices including fire control, protection forces and minor gully stabilizers. Other practices considered in the report are to be included if the community determines that the public interest outweighs presently unfavorable economic ratios. The information on which the latter is based should be reconsidered from time to time as water supply costs and watershed conditions change.

Additional study, including cost-benefit evaluation, is recommended on the effect on reservoir sedimentation of higher dams than those considered in this report. At Cameron Narrows, for example, a dam extending above the meadow level would necessitate acquiring rights-of-way in the area to be flooded or covered with sediment. Further information is also needed on the effect of erosion and sediment control practices on watershed water yields. Presently available but limited information indicates that they would have little effect on decreasing or increasing total yields.

TABLE 1 - COSTS AND EVALUATED BENEFITS

MORENA RESERV

Site No. on Map 1	Practice	Quantity Number	Unit	Total Instal. Cost Dollars
	<u>MOUNTAIN SLOPE TREATMENT</u>			
	Fire Control Practices			
	A. Fire breaks, etc.	27	Miles	13,500
	B. Rehabilitate Truck Trail	Lump	Miles	40,000
	C. Strip Burning	650	Acres	3,000
	D. Water Developments	7	Tanks	10,250
	Protection Forces			
	Increased Manning of Guard Stations	39	Pay Periods	
	Minor Erosion Control Structures	300	Gully Plugs, etc.	3,000
	Subtotal			69,750
	<u>MOUNTAIN MEADOW STABILIZATION</u>			
1 & 2	Deposits Immediately above Reservoir	2	Rock Dams	29,800
3	Coogan Meadow	1	Earth Dike	3,200
4	Glencliff Meadow	1	Earth Dike	32,300
5	Crouch Meadow	1	Earth Dike	10,400
6, 6A	Cameron Meadow	1	Concrete Dam *	169,200
7, 8, 9	Foster Meadow	3	Earth Dams	33,400
10, 11	Thing Meadow	1	Earth Dam	31,150
		1	Earth Dike	
	Subtotal			309,450
	Grand Total			379,200

* Includes small earth fill upstream from concrete dam.

ROSION AND SEDIMENT CONTROL PRACTICES

ATERSHED

COSTS			BENEFITS			
Average Annual Instal. Cost Dollars	Annual Operation and Maintenance Cost Dollars	Total Annual Cost Dollars	Average Annual Reservoir Benefits Dollars	Average Annual On-site Benefits Dollars	Total Average Annual Evaluated Benefits Dollars	Ratio of Total Average Annual Benefits to Annual Costs Ratio
423	700	1,123				
1,252	600	1,852	Not Evaluated Separately			
94	225	319				
321	650	971				
	6,240	6,240				
94	1,000	1,094				
2,184	9,415	11,599	7,164	Not Evaluated	7,164	Not Evaluated
933	745	1,678	381	136	517	0.31 - 1.0
100	100	200	499	251	750	3.75 - 1.0
1,011	380	1,391	445	235	680	0.49 - 1.0
326	280	606	146	528	674	1.11 - 1.0
5,296	1,550	6,846	1,157	2,139	3,296	0.48 - 1.0
1,045	880	1,925	749	720	1,496	0.76 - 1.0
975	700	1,675	2,263	907	3,170	1.90 - 1.0
9,686	4,635	14,321	5,640	4,916	10,583	
11,870	14,050	25,920	12,804	4,916	17,747	

LEGEND

A	||||||||||||	Fire break
A	|||||||||||||||||	Discway
C		Strip burns
B	|||||||||||||||	Road rehabilitation
	———————	Meadow boundary
5	▬	Structure
D	○	Water development

MAP I

NEEDED EROSION AND SEDIMENT CONTROL PRACTICES

MORENA RESERVOIR WATERSHED

SAN DIEGO COUNTY, CALIFORNIA

NOVEMBER 1953

1 0 1 2 3

SCALE IN MILES

AGR-SCS-PORTLAND, ORE NOV 1953

APPENDIX

APPENDIX

INTRODUCTION

During and subsequent to World War II, the City of San Diego and surrounding communities have had a phenomenal increase in population. The population of San Diego in 1940 was 203,341 and, according to a March 17, 1952 special census, had increased to 434,924, or 114 percent. This includes personnel of large military establishments in the area. County-wide, the population has increased from 289,348 in 1940 to an estimated 688,000 in 1952, or 138 percent during the same period.

In order to maintain an adequate water supply for an expanding population, six major impounding reservoirs were purchased or built between 1910 and 1943 by the City of San Diego. The total storage capacity of these reservoirs and several small regulating reservoirs is about 400,000 acre feet. In an area where widely fluctuating, cyclic meteorologic conditions greatly affect the watershed water yield from year to year, sufficient carryover must be available to sustain the water supply during periods of drought.

In 1926, the City of San Diego, foreseeing the need for additional dependable sources of water, filed application with the State Division of Water Resources for a permit to divert 155 c.f.s. from the Colorado River annually. The City's Colorado River water was merged with that of the Metropolitan Water District of Southern California.

In 1944, the San Diego County Water Authority, made up of nine public agencies including the City of San Diego, was organized for the operation and maintenance of the aqueduct bringing water to San Diego County. The diversion was accomplished in 1947 when the San Diego County aqueduct connection with the Metropolitan Water District was completed. Colorado River water was first delivered to the City's San Vicente Reservoir on November 24, 1947.

A series of dry years, beginning in 1945, coupled with a rapidly increasing population, created a severe draft on surface storage supplies in San Diego County. On January 1, 1952, only 14.9 percent of the capacity of City reservoirs was filled, and most of this was Colorado River water. In fiscal year 1950-51 the City purchased about 51,450 acre feet of Colorado Aqueduct water, which is equivalent to approximately one year's consumption within the City. In recent years, it has become apparent that large military and civilian requirements in the San Diego area would exceed the yield not only of surface storage but of the existing aqueduct.

In 1949 the Water Authority signed a contract with the U. S. Bureau of Reclamation for construction of a second barrel to the

Aqueduct. With present water demands, the City of San Diego is able to purchase all its requirements in excess of impounded native water from the San Diego County Water Authority through the San Diego Aqueduct. On the other hand, even if surface storage supplies in San Diego County were able to satisfy the demand for water and none was obtained from the Aqueduct, certain fixed charges continue on Colorado River water available but not used. These charges include the City's proportionate cost and operation and maintenance of the Metropolitan Water District and the San Diego County Water Authority. Under present financing, the cost of aqueduct water over and above fixed charges is about $12.00 per acre foot. Since the operation and maintenance costs continue whether water is used or not, the $12.00 per acre foot represents the savings to the City when impounded native water supplies are available.

Construction of the second San Diego County Aqueduct barrel is occurring when costs greatly exceed those in effect during construction of the first. Sometime in the future, it is expected that the demand for water by Authority agencies in San Diego County will exceed their ultimate Colorado River water entitlement. At such time, the City will be forced to obtain additional water, probably at a cost greatly exceeding that of the present. The City estimates that Colorado River water will be available for the next 18 years at a cost of about $12.00 per acre foot but thereafter the cost will rise appreciably above fixed charges. Water purchased or developed from this or other sources after that time may cost an average of $35.00 per acre foot according to estimates of the City of San Diego.

Surveys of the City of San Diego reservoirs in 1948 showed that sediment accumulation in Morena Reservoir was occurring at a rate which is significantly reducing the net safe water yield. Officials of the Water Department estimated that because of obsolescence and deterioration of equipment as well as sedimentation, that the remaining useful life of the reservoir is about 108 years. This estimate is based on an assumed total useful life of 150 years from the time of construction. One hundred eight years is the remaining life subsequent ot 1948, when the most recent sedimentation survey was made.

The City recognized the need for maintenance of a dependable and economic supply of water in the face of a rapidly increasing population, and expanding community. In May, 1950 the Director of the Water Department asked that the U. S. Department of Agriculture, represented by the Soil Conservation Service and Forest Service, make a study of the watershed above Morena Reservoir. This study was to determine existing watershed conditions and the possibilities for the control of erosion and sedimentation. After a conference, the interested agencies informally agreed to certain aims and agency responsibility for such a study. This informal agreement, dated October, 1951, is given on the following pages.

Other watershed users in addition to the City of San Diego have expressed their interest and concern with the condition of the watershed above Morena Reservoir. In 1941, a Soil Conservation District was organized in the area under an enabling act of the State of California. The District, known as the Mountain Empire Soil Conservation District, embraces about 160,000 acres including almost all the Morena Reservoir Watershed. The District has been largely concerned with the development and application of soil and water conservation measures on individual farms and ranches. Prior to the joint agreement mentioned above, representatives of the Soil Conservation Service and Forest Service discussed the proposal with the Directors and they expressed the desire of the Soil Conservation District to participate in a program which would be of mutual advantage to both resident and municipal watershed users.

C O P Y

JOINT INVESTIGATION OF THE MORENA WATERSHED

BY

THE CITY OF SAN DIEGO

SOIL CONSERVATION SERVICE

UNITED STATES FOREST SERVICE

October - 1951

PURPOSE

1. To determine existing and potential sources of sediment deposit in the Morena Reservoir.

2. To determine factors influencing water behavior, soil and debris movement and deposition in Morena drainage basin.

3. Recommend an action program which will:
   a. Stabilize sediment source areas
   b. Increase watershed values - water conservation
   c. Develop on-site watershed benefits
   d. Develop on-site agricultural resources of mountain meadows
   e. Conserve reservoir capacity

4. Prepare a report which will include full inventory of the Morena Basin and the cost benefit relationships of the action program recommended in No. 3.

It is recognized that the three agencies, The City of San Diego, Soil Conservation Service and the United States Forest Service, have a current full program of work and that neither individually nor collectively can they prosecute a full report to completion in one unbroken period, and, therefore, the job will be accomplished in stages.

None of the agencies can obligate themselves to the program of work necessary to complete this study and report beyond the current year's appropriation.

Logical stages of work toward final completion of the report must be set up currently to get the full job done as expeditiously as possible under present work loads.

STUDY PROGRAM

The Soil Conservation Service will determine the existing and potential sources of sediment immediately above the reservoir and in mountain meadows such as recent sediment deposits now lodged above spillway; valley trenches, effect of channel and flood plain deposition above reservoir in reducing reservoir sedimentation.

The Forest Service will bring up to date the data on existing and potential sources of sediment from:

1. Road development, major fire areas and other important cover disturbances.
2. Mountainous slopes in excess of 50% by age classes of chaparral

The City of San Diego and Soil Conservation Service will make engineering studies of structures designed to control erosion, such as field surveys, design and cost of dams, debris barriers, drop structures and other structural channel controls, within the limits of available facilities.

The Soil Conservation Service will recommend sites for study primarily in conjunction with mountain meadow stabilization.

The Forest Service will recommend sites for study for debris storage and channel barriers.

PLANNING PROGRAM

The City of San Diego will recommend on structures designed for the primary purpose of debris storage.

The Soil Conservation Service will recommend a program of mountain meadow stabilization including necessary vegetative planting and treatment. Included in the mountain meadow classification will be the flood plain deposition immediately above the reservoir.

The Forest Service will recommend a program of watershed development directed toward minimizing soil erosion and increasing water yields on the wild lands of the watershed, including a program of manipulation of cover in the chaparral belt, tree planting and protection.

PROGRAM EVALUATION

The City of San Diego will determine the cost benefit relation of the debris storage program: the value of Morena Reservoir storage by acre feet; tieing this in with the future costs of reservoir replacement within the watershed and/or debris removal.

The Soil Conservation Service will make evaluations of the recommended program for stabilization of valley trenches and deposits above the spillway, such as volume of sediment to be stabilized; effect of proposed structures on adjacent flood plains and mountain meadows; effect of proposed structures and existing ponds on water yield to Morena Reservoir.

The Forest Service will evaluate the cost to benefit relationships of the watershed development and protection program, based partially on the values set by the City of San Diego and Soil Conservation Service in the lower reaches of the drainage; on-site benefits and contributions to the local economy under the development program.

SUMMARY

The Supervisor of the Cleveland National Forest agrees to assume the responsibility of correlating and combining the material of the three agencies to form a comprehensive report for the individual use and needs of each agency.

To accomplish this end, it is agreed that a meeting will be held by representatives of the three agencies not less than once a month for the remaining of the calendar year, at which time each agency will report fully on the progress made on their agreed portions of the survey work.

Any changes in direction, organization, or addition to planning can be made at this time.

DESCRIPTION OF MORENA RESERVOIR AND WATERSHED

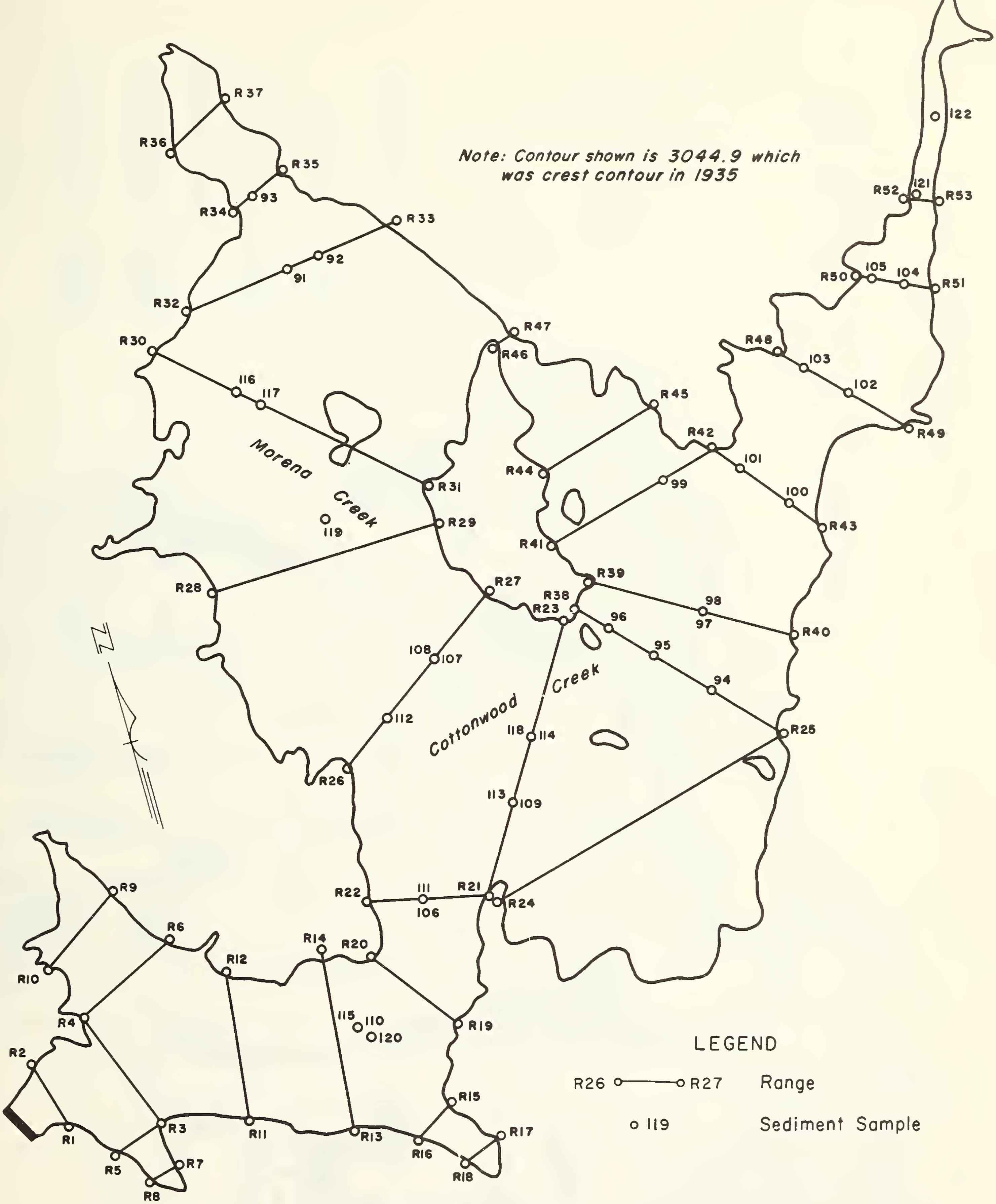
MORENA RESERVOIR

Morena Reservoir is on Cottonwood Creek, in T. 17 S., Rs. 4 and 5 E., San Diego County, California, 35 miles east of San Diego. Water is impounded not only in the valley of Cottonwood Creek, in which the dam is located, but also in Morena Creek, one of the larger tributaries. The reservoir, owned by the City of San Diego, serves as a reserve storage unit of the municipal water supply system. The dam was completed in March, 1910.

Morena Dam is a rock-fill structure 506 feet long and 167 feet in maximum height above the stream bed. Masonry faces the up-stream side of the dam. A concrete spillway extends 310 feet upstream from the dam and discharges through a channel cut from solid rock on the north canyon wall. At the time of construction in 1910, the spillway was 146 feet above the stream bed, but in 1923 it was raised to 155 feet above stream bed. Steel flash-gates raised the controlling crest level to 162.5 feet above the stream bed and 3044.9 feet above mean sea level. The gates were removed in 1945, and in 1947 a permanent sill was added to the spillway, placing the crest elevation at 157.0 feet above stream bed, or at elevation 3039.4 feet above sea level. Water is released from the reservoir through a tunnel in rock 30 feet above the stream bed.

The reservoir basin (Map 2) is about 500 feet wide at the dam, which was constructed at the upper end of a narrow, steep-walled gorge. A few hundred feet above the dam it widens abruptly to about 2000 feet and maintains this width with little variation for one mile to the Narrows, formed by the convergence of two rocky spurs. Above the Narrows, the reservoir widens again in a broad, relatively flat-bottomed basin, nearly a mile in maximum width, formed by the junction of Cottonwood Creek from the north and Morena Creek from the northwest. Above this basin both arms range between 2000 and 4000 feet in width for a mile or less and then narrow abruptly between confining canyon walls. The length of the reservoir to the crossing of the spillway crest-level contour on Cottonwood Creek was originally 3.9 miles and about 2 miles to the upper end of the Morena Creek arm. The original surface area was 1,687 acres, and the original capacity, also at the present spillway level, 66,403 acre feet.

Morena Reservoir is one of two reservoirs in the Tia Juana River Watershed. Barrett Dam is located about 8 miles downstream on Cottonwood Creek tributary. Water is released from Morena Reservoir down Cottonwood Creek and is impounded by Barrett Reservoir for distribution in the City's system. Cottonwood Creek is a tributary of the Tia Juana River which flows northwesterly in Mexico to enter the United States at the City of Tia Juana, south of San Diego.



MAP 2
LOCATION OF SEDIMENTATION SURVEY RANGES
AND SEDIMENT SAMPLES

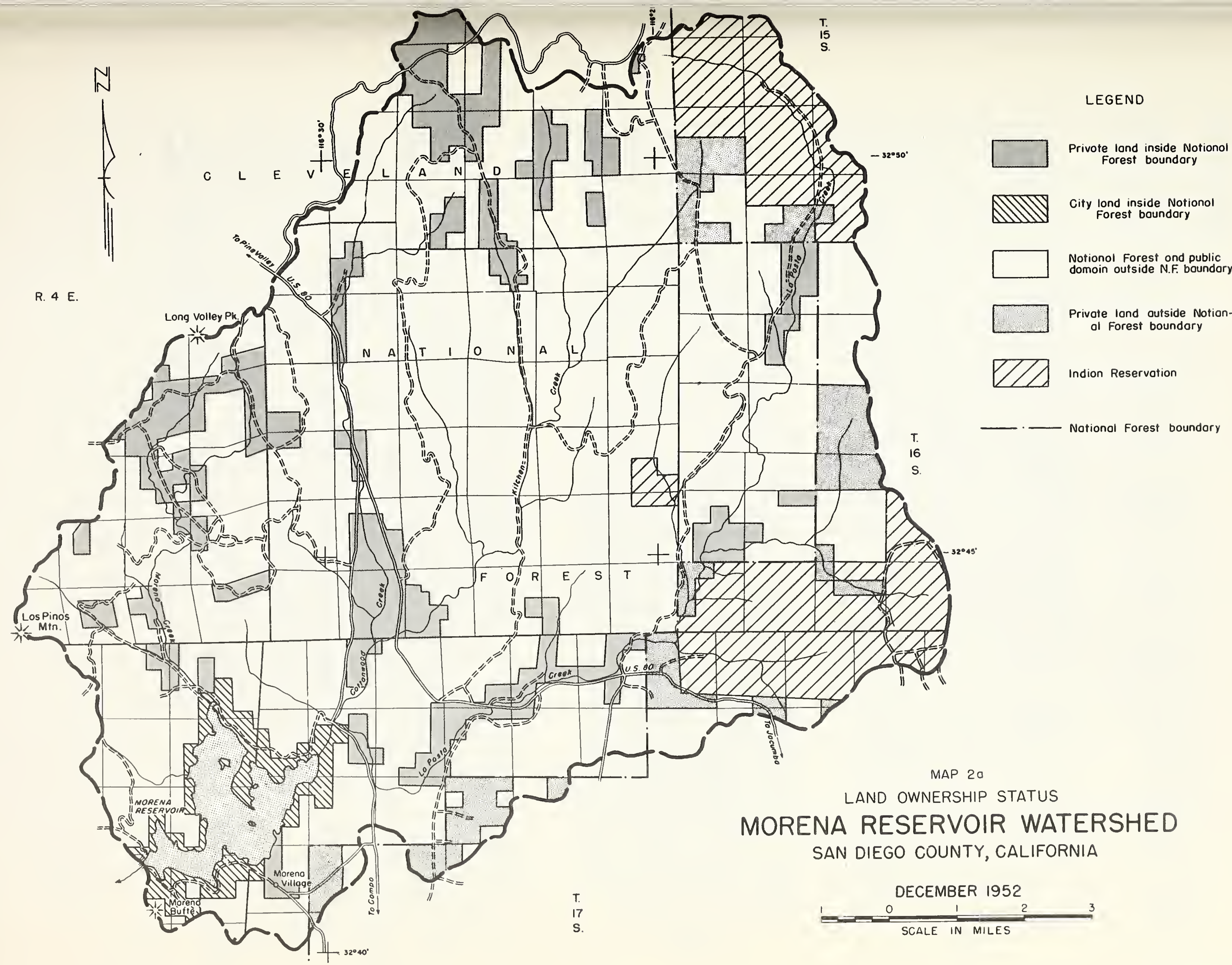
MORENA RESERVOIR

SAN DIEGO COUNTY, CALIFORNIA

NOVEMBER 1953

1500 0 1500 3000
SCALE IN FEET

SCS-PORTLAND, ORE NOV 1953



MAP 2a

LAND OWNERSHIP STATUS

MORENA RESERVOIR WATERSHED

SAN DIEGO COUNTY, CALIFORNIA

DECEMBER 1952

SCALE IN MILES (1 0 1 2 3)

AGR-SCS-PORTLAND, ORE. APRIL 1954

7-0-14497-L

MORENA RESERVOIR WATERSHED

TOPOGRAPHY

The 115 square miles of Morena Reservoir Watershed lie immediately west of the main crest of the Peninsular Range. The elevations range from 3000 feet to 6000 feet and the general direction of the drainage is south and southwest.

The drainage basin includes a portion of three dissected plateaus which stand at unequal elevations. The La Posta plateau, the southern lowland plateau, has a mean elevation of 3400 feet and is separated from the higher plateaus to the west and north by irregular scarps averaging 1600 feet in height. Corte Madera, the northwestern plateau, is between 3900 and 4200 feet elevation, with peaks projecting 300 to 500 feet higher. Laguna, the northern plateau, is the highest, averaging 5400 feet in elevation and has the highest peak in the drainage, Laguna Peak, elevation 6329 feet. Mountain watershed slopes are moderately well rounded to steep, with the steeper slopes usually adjacent to edges of the plateaus.

Mountain meadows, which lie on gentle gradients along the principal stream courses, are very important topographic features in terms of present production of erosional debris, although occupying only 14 percent of the total drainage area. Formed in comparatively recent geologic time by accumulation of erosional waste from the surrounding hills, the meadows are composed of deep alluvium. The meadows are usually terminated at their lower ends by a narrows cut through the rock outcrops by the stream. Flood flows formerly swept through and over the meadows, following shallow depressions cut in the alluvium.

GEOLOGY AND SOILS

The La Posta plateau is underlain by decomposed quartz-dioite that is weathered to great depths. The Corte Madera and Laguna Mountain plateaus are underlain by a complex of schist, quartzite, gneiss and granitic rocks. The residual soils in the Laguna Mountain area are deep and medium textured. The soils in the remainder of the watershed are thin to moderately deep and coarse textured. Rock outcrops are commonly exposed in the south and southwestern part of the watershed and the surface is sometimes littered with weathered granite boulders. The mountain meadow or potrero soils consist of alluvium eroded from the surrounding watershed. They are generally deep and dark colored and have considerable amount of organic matter. They contain an average of about 30 percent silt and clay and the remainder medium and coarse sand. They are well drained where valley trenches have dissected the meadows, and poorly drained in those areas where the meadow surface has remained intact.

CLIMATE

The Morena Watershed lies essentially within a belt of warm, temperate climate characterized by arid summers and moderately wet winters. However, the eastern half of this drainage (that portion drained by La Posta Creek) is subject to desert influences. To what extent this affects the climate of this region cannot be precisely determined because of the lack of gauging stations within the drainage. One precipitation gauging station was established during the winter of 1951-52 on the Foster Ranch, at the junction of La Posta Creek and Highway 80, and one year's record compared to the record of Descanso Station at identical elevation shows a decrease in precipitation of about 33 percent at the Foster Station. While these are insufficient data to make any definite comparison, the cover type in the La Posta drainage would indicate that this is an area of lower rainfall. The rest of the drainage follows the general precipitation pattern of the coastal areas and average annual precipitation varies from 20 inches at Morena Reservoir to 28 inches on the Laguna Plateau. In this area isohyetes roughly follow the elevation contours, with an increase of 6 inches of precipitation per year for every thousand feet elevation.

Except for occasional torrential summer cloudbursts the precipitation occurs mostly during the 4 month period of December through March. In exceptional seasons the fall in a one month period may be well in excess of the mean seasonal precipitation. The weather station in the City of San Diego is the only one in San Diego County with a long record of rainfall intensities. In the Morena drainage it is estimated that one hour intensities during winter and spring storms, however, would be around 2-1/2 to 3 inches. Rainfall intensities during the summer and fall cloudburst type rainfall are much greater.

Runoff in the drainage is extremely erratic and, except in a few locations, streambeds become dry in the summertime. Annual runoff may vary from 5 percent to 700 percent of the average yearly mean. Some authorities believe that the runoff pattern is cyclic and for the comparatively short period of record, this can be roughly substantiated. The actual sequence of several unrelated variables will determine how important this runoff rate is to the erosion rate of the drainage. These variables include fire history immediately preceding high runoff years, land management practices on the meadow type lands, storm intensity and duration.

VEGETATION

The dominant brush type which covers about 86 percent of the watershed is commonly known as chaparral. This type which is a complex of many species, is widely distributed through the southern California mountains. In this area the dominant species are chamise, scrub oak and olive-green soapbloom. When undisturbed by fire, chaparral grows very densely and reaches heights of 6 to 10 feet, thereby affording protection to the slope soils.

The principal tree types which occur above the 5000-foot level on about 7 percent of the area include Jeffrey pine, Coulter pine and California black oak. Tree growth occurs in open stands but, as most precipitation at the 5000-foot level and above occurs as snow with comparatively low rates of runoff, the erosion problem is not great.

Grassland, mixed with minor amounts of cultivated land, covers about 4.2 percent of the watershed, chiefly in the valley meadows. Perennial grasses and sedges predominate. When not highly disturbed, the meadow growth provides a densely matted but shallow root system.

LAND USE CAPABILITY CLASSES

The Department of Agriculture has developed a system of classifying land designed to indicate the use of the land and the management requirements for (1) continuous high yields (2) the retardation of runoff and (3) the prevention of erosion. Eight classes of land are recognized in the capability classification employed in planning use of land within its capability and treatment according to its needs. Table 2 of Appendix contains the estimated acreage of land in Morena Creek Watershed in each capability class.

OCCUPANCY AND USE

Morena Reservoir Watershed was first used in about 1870 by settlers homesteading lands of the Public Domain. Sheepmen also used the high mountain meadows for browse in their drives from Mexico and the desert area to the coastal areas for market. The meadows formed the key sites for homesteaders, and the majority of usable lands were taken up by 1890. At that time the area now known as the Cleveland National Forest was withdrawn from the public domain.

Indications are that a larger number of families have lived in the watershed than at the present time. During and following the pioneer period, the valleys probably supported one or more family stock ranching units centering around the 160 acre homestead, which included a portion of the choice meadowland in the locality. Since that time, suitable grazing lands have come under the ownership, lease or permit of a relatively few ranch operators. Although cattle grazing has always been the dominant use, more acreage was in cultivation in the early days than the few in grain at the present time.

Located about 50 miles by highway west of the Imperial Valley, the relatively high altitude of Morena Watershed and adjacent areas furnish the nearest relief from the high temperatures in the valley. The area also offers recreational advantages to the people of San Diego and adjacent communities in Southern California. The City of San Diego has installed facilities for picnicking and fishing on the south side of the reservoir. A community has developed on the slope adjacent to the reservoir and in the same vicinity, known as Morena Village. Home owners are either retired people or summer residents with winter homes in the Imperial Valley. The Laguna Mountains in the timbered headwaters are a favorite resort area of San Diego County. Many permittees have built cabins for summer and winter recreation.

Land ownership status is shown in Map 2a and the area in each ownership is given in the following tabulation:

	Sq.Mi.	Acres
Private land inside National Forest Boundary	15.4	9,856
City land inside National Forest	5.0	3,200
National Forest and public domain outside National Forest Boundary	76.9	49,216
Private land outside National Forest boundary	5.5	3,520
Indian Reservation	12.0	7,680
	114.8	73,472

TABLE 2 LAND USE CAPABILITY, MORENA RESERVOIR WATERSHED

CAPABILITY CLASS	ACRES	USE LIMITATION
I	1,208	Very good land that can be cultivated permanently with slight continuing limitations in use or risk of damage
II	5,402	Good land that can be cultivated safely with a systematic program of easily applied conservation protective measures.
III	2,559	Moderately good land, suitable for regular cultivation under a strong soil maintaining rotation and intensive application of supporting conservation measures.
IV.	940	Fairly good land, suitable for occasional cultivation, usually not more than one year in six.
V	1,692	Very well suited for grazing or forestry and has little or no physical limitation for such use.
VI	1,208	Well suited for grazing or forestry. It is not arable because of steep slopes susceptability to erosion, shallow soils, etc.
VII	13,008	Fairly well suited for grazing or forestry. It has major hazards or limitations for use because of very steep slopes, shallow or droughty soils, excessive erosion, etc.
VIII	45,765	Land suited only for wildlife, recreation or watershed protection. Consists chiefly of mountainous stony areas.

RESERVOIR SEDIMENTATION AND RELATED WATERSHED PROBLEMS

RESERVOIR SEDIMENTATION

HISTORY OF SURVEYS

The first survey to determine the volume and rate of sediment accumulation in Morena Reservoir was made by the Soil Conservation Service between October 25 and December 31, 1935. Soundings and direct sediment depth measurements were made on each range by the range method of survey described in U. S. Department of Agriculture Technical Bulletin 524 1/ The range system used in this survey is shown on Map 2 of the reservoir basin. The details of this survey and of the reconnaissance watershed condition survey in December 1936 were set forth in U. S. Department of Agriculture Technical Bulletin 639 2/.

In 1948, when the water level in the reservoir was at a low stage, the City of San Diego contracted for a new contour map to be made by Fairchild Aerial Surveys from aerial photography. This map was prepared with a contour interval of 10 feet and on a scale of one inch equals 500 feet. The submerged portion of the reservoir was sounded by a field party of the City of San Diego. The field party also obtained surface elevations along all ranges that were established during the 1935 survey. The Soil Conservation Service cooperated with the City Water Department in tying together the 1935 and 1948 surveys and in computing present capacities and sediment volumes at the 1935 and 1948 spillway levels.

Table 3 is a Statistical Summary of Sedimentation Data. The data is arranged by periods between surveys and by the total period between 1910 and 1948. The water and sediment volumes used include those below gauge elevation 162.5, the spillway level in 1935, and where available, similar data on the volumes below gauge elevation 157.0 or present spillway level. The 1935 datum was used in order to form a basis of comparison with the survey of that date. Information on capacities and sediment volumes below present spillway level are needed to evaluate the effects of a watershed program on the present water storage capacity.

1/ Eakin, Henry M. and Brown, Carl B., SILTING OF RESERVOIRS, USDA Tech. Bulletin 524, 142 pp., illus.

2/ Barnes, F. F., Kraebel, C. J. and LaMotte, R. S. Effect of Accelerated Erosion On Silting In Morena Reservoir, San Diego County, California. USDA Tech. Bulletin 639, 22 pp. illus. 1939

CHARACTER OF SEDIMENT

The sediment in Morena Reservoir consists of fine-textured bottom-set beds in the main lake basin and coarser sandy delta deposits in Morena and Cottonwood Creek areas. The bottom-set beds consist of very uniform, fine, dark brownish-gray to black silt and clay. The sediment is characterized by an unusually high percentage of mica flakes derived from the granite rocks that underlie a large part of the drainage basin. Delta deposits, consisting of imperfectly stratified fine sand, silty sand and sandy silt with some coarse sand and gravel, occur in Cottonwood Creek Arm and the upper part of Morena Creek Arm.

A series of undisturbed sediment samples were obtained in January, 1951 when the reservoir was almost dry. These samples were obtained with a Pomona soil sampler modified from the Uhland sampler by V. S. Aronovici. The reservoir and watershed samples taken during the same period were analyzed at the Pomona laboratory of the Division of Irrigation, Soil Conservation Service, under the direction of Mr. Aronovici. Locations of the reservoir sediment samples are shown on Map 2. Mechanical analysis of some of the reservoir samples is shown on Figure 1 and 2 and summarized in Table 4. Table 5 gives the density and observed porosity of reservoir samples. The weighted density of reservoir deposits is 69.6 pounds per cubic foot. The data on density may be used to convert sediment load measurements in the same area from tons to acre-feet of deposited sediment. The data may also be used to convert watershed soil loss measurements expressed in tons to acre-feet of deposited sediment.

DISTRIBUTION OF RESERVOIR SEDIMENT

The distribution of sediment in the reservoir and its relation to the stream profile is shown on Figure 3. Between 1910 and 1935 the heaviest deposition occurred in the Cottonwood Creek arm and near the dam. Between 1935 and 1948 most of the deposition occurred in the central and lower basin, a feature due probably to both a steepening of grade in the Cottonwood Creek area and lower discharges carrying finer sediment. If it were feasible to do so, maintenance of storage near spillway level would induce deposition of coarse sediment in the vicinity of, and above, the reservoir area, thus preserving some of the capacity otherwise lost. Otherwise, drawdown, coupled with steeper grade, would probably result in most sediment being carried to the central and lower basin. One of the features of sedimentation during the period 1935-1948 was that part of the sediment in the Cottonwood Delta has been cut away and redeposited in the central and lower basin. The area between ranges R-39 - R-40 and R-48 - R-49 actually increased in capacity by more than 200 acre-feet during the period 1935-1948. If the present channel cut in the deposits continues headward, it may remove some of the deposits presently accumulated above spillway level.

TABLE 3 --- MORENA RESERVOIR
STATISTICAL SUMMARY OF SEDIMENTATION DATA

	Quantity	Quantity	Unit
	At Gauge Elevation		
1/	2/	3/	
Age	162.5	157.0	
1935 Survey	25.7	25.7	Years
1948 Survey	38.3	38.3	Years
Drainage area including Reservoir	114.8	114.8	Sq.Mi.
Drainage area excluding Reservoir	112.2	112.2	Sq.Mi.
Reservoir Data			
Area			
Original	1,687	*	Acres
1935	1,669	*	Acres
1948	1,650	1,562	Acres
Storage Capacity at Spillway Elevation			
Original	66,767	66,403	Acre Feet
1935	60,699		Acre Feet
1948	58,933	58,751	Acre Feet
Capacity Per Square Mile of Drainage 4/			
Original	582	578	Acre Feet
1935	529	*	Acre Feet
1948	513	512	Acre Feet
Sedimentation			
Sediment Volume			
1910-1948	7,834	7,652	Acre Feet
1910-1935	6,068	*	Acre Feet
1935-1948	1,766	*	Acre Feet
Average Annual Sediment Accumulation			
1910-1948	204.5	201.4	Acre Feet
1910-1935	236.1	*	Acre Feet
1935-1948	140.2	*	Acre Feet
Average Annual Sediment Accumulation 5/ Per Square Mile of Drainage Area			
1910-1948	1.82	1.80	Acre Feet
1910-1935	2.10	*	Acre Feet
1935-1948	1.25	*	Acre Feet
Depletion of storage capacity			
To 1948	11.7	11.5	Percent
Average per year, 1910-1948	0.31	0.30	Percent
Average per year, 1910-1948	0.35	*	Percent
Average per year, 1935-1948	0.21	*	Percent

1/ Storage began in March, 1920. Average date of 1935 survey, December
Average date of 1948 survey, July
2/ Spillway level in 1935
3/ Spillway level in 1948
4/ Including Lake Area
* Not determined
5/ Excluding Lake Area

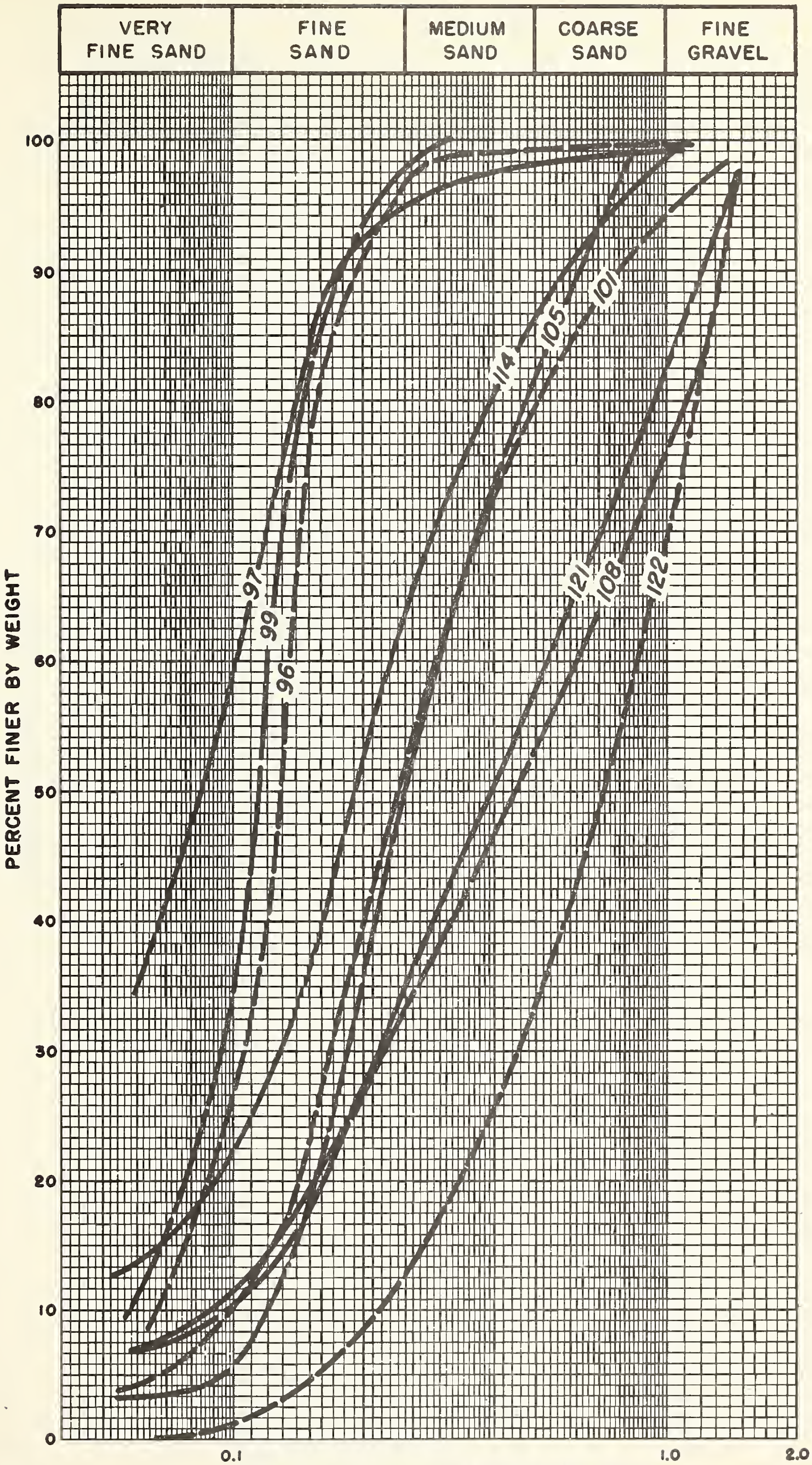


FIGURE I Mechanical analysis of sediment, Cottonwood Creek arm Morena Reservoir.

AGR-SCS-PORTLAND, ORE NOV 1953

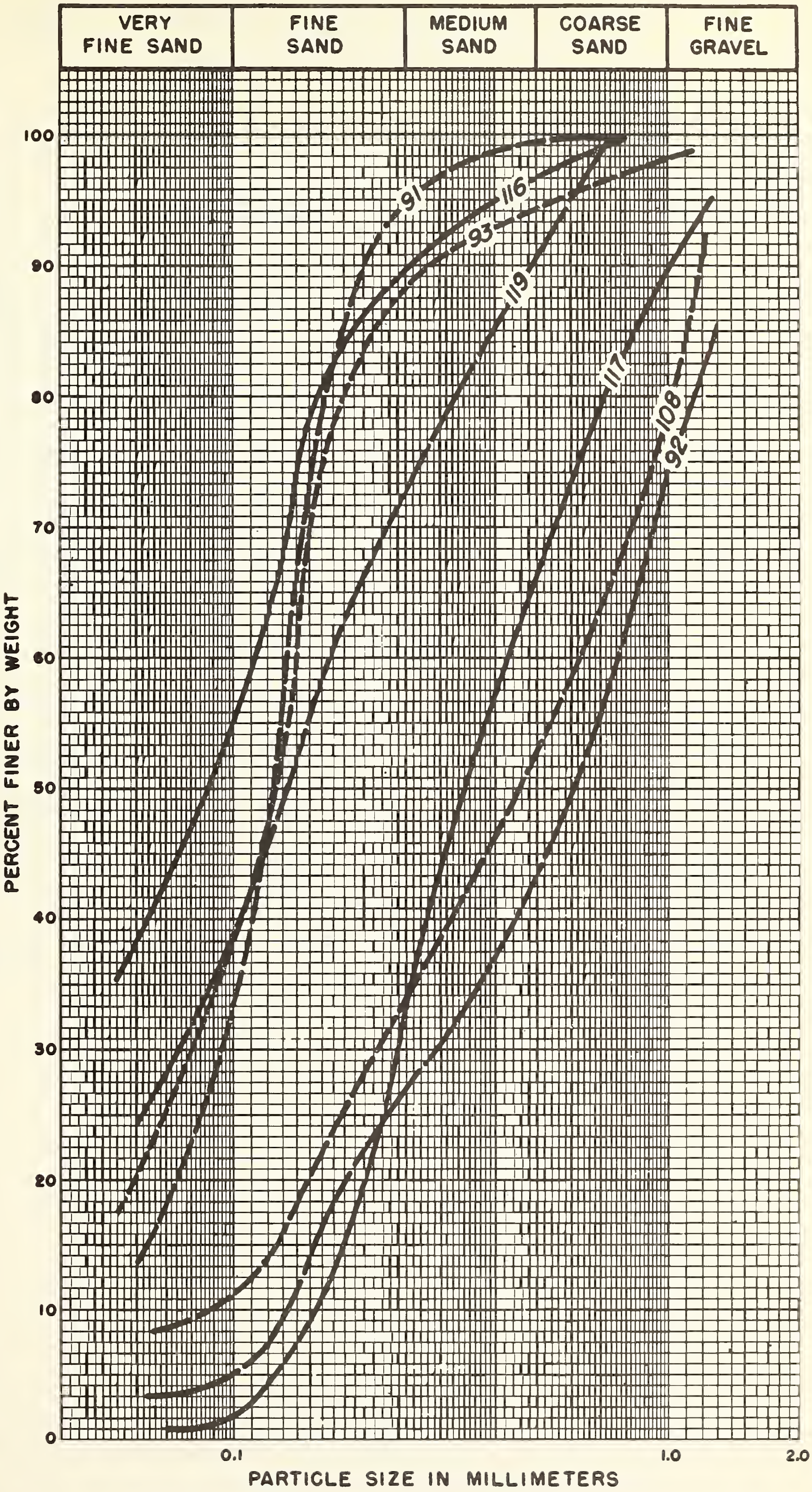


FIGURE 2 Mechanical analysis of sediment, Morena Creek arm of Morena Reservoir.

TABLE 4 - MECHANICAL ANALYSIS OF SAMPLES FROM MORENA RESERVOIR

	Sediment Sizes - Percent			
	Silt & Clay	Fine Sand	Medium Sand	Coarse Sand
Segments				
Reservoir Deposits				
Lower Reservoir	79.8	20.2	0.0	0.0
Central Basin	12.8	25.5	28.7	33.0
Morena Creek Arm	24.2	26.2	21.7	27.9
Cottonwood Creek	10.7	25.8	36.6	26.9
	Volume, Acre Feet			
Lower Reservoir	1390	350		
Central Basin	159	318	358	411
Morena Creek Arm	277	306	252	341
Cottonwood Creek Arm	392	947	1344	992
	2217	1920	1953	1744
Percent of Total	28.3	24.5	24.9	22.3

TABLE 5 - DENSITY AND OBSERVED POROSITY OF SAMPLES FROM MORENA RESERVOIR

Sample	Location	Depth Feet	Density Lbs./cu.ft.	Observed Porosity %
Reservoir Deposits				
91	Morena Creek Arm	0.4	76.9	48.8
92	Morena Creek Arm(present channel)	2.2	93.8	39.2
93	Morena Creek Arm	0.6	72.5	50.3
94	Central Basin	1.2	55.0	63.6
95	Central Basin	0.8	72.5	---
96	Central Basin	3.0	60.0	51.8
97	Cottonwood Creek Arm (present channel)	1.3	69.4	52.4
98	Cottonwood Creek Arm (present channel)	4.7	51.9	
99	Slope at margin of delta	4.7	84.4	52.4
100	Cottonwood Creek Delta	1.0	47.5	
101	Cottonwood Creek Delta	2.3	95.0	51.6
102	Cottonwood Creek Delta	4.3	65.0	59.9
103	Cottonwood Creek Delta	1.2	70.6	56.7
104	Cottonwood Creek Delta	1.2	73.8	55.7
105	Cottonwood Creek Delta	1.2	96.3	43.8
106	Lower Reservoir	1.8	73.1	56.6
107	Central Basin	0.2	68.1	56.9
108	Central Basin	4.0	71.9	48.7
109	Central Basin	2.5	73.1	54.4
110	Lower Reservoir	4.5	43.1	75.6
111	Lower Reservoir	4.3	73.1	54.4
112	Lower Reservoir	0.8	71.9	55.0
113	Central Basin	0.2	47.5	64.8
114	Central Basin	4.7	83.1	41.0
115	Lower Reservoir	0.2	33.8	---
116	Morena Creek Arm	0.8	69.4	56.2
117	Morena Creek Arm (channel area)	1.0	93.1	41.4
118	Central Basin	0.2	71.9	54.2
119	Morena Creek Arm	1.8	91.3	42.2
120	Lower Reservoir	0.2	43.1	50.2
121	Cottonwood Creek Arm	0.8	81.3	50.6
122	Cottonwood Creek Arm	1.5	90.0	42.5

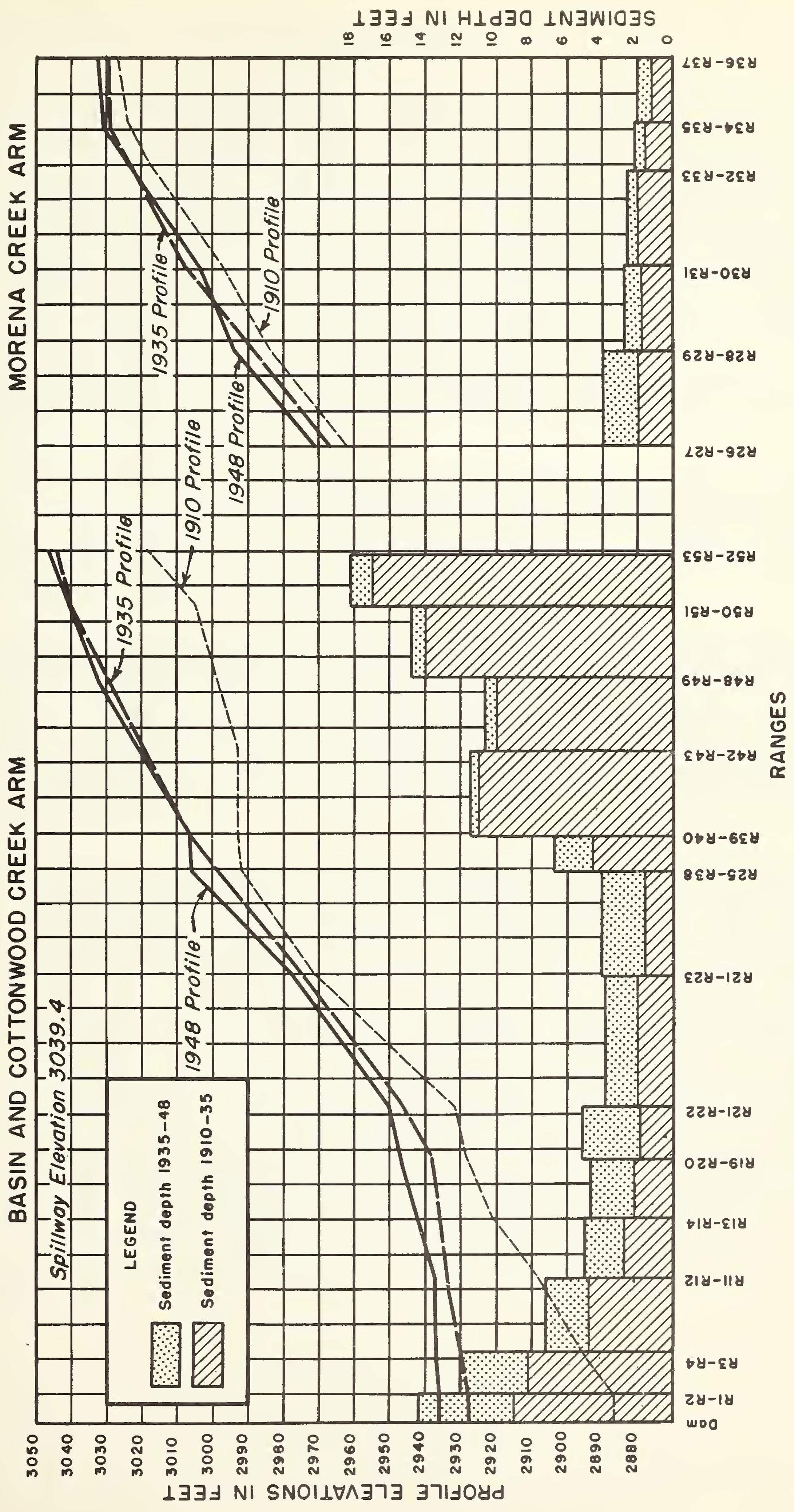


FIGURE 3 Relation of stream profiles to average sediment depths, Morena Reservoir.

SPECIFIC YIELD OF RESERVOIR SEDIMENT

The water level in Morena Reservoir is frequently drawn down, exposing the deposits. Since much of the sediment consists of sand which may yield an appreciable volume of water, tests were run of the reservoir samples in the Soil Conservation Service Pomona laboratory to determine the specific yield of the deposits. Specific yield is the difference between field capacity and saturation. Tensions (equivalent to depths to water table) of 40, 60, 135 and 330 centimeters were applied to the samples which were at saturation at the beginning of the experiment. Table 6 gives the total yield of water in inches per inch as related to tension. Figures 4, 5, and 6 show a plotting of these values, with the samples grouped by segments of the reservoir basin; Central and Lower Basin, Cottonwood Creek area and Morena Creek area.

In determining the amount of water the deposits would yield, it was assumed that the water table would drop to the bottom of the deposits. The average depth of deposits within segments was, therefore, the value used for determining yield under tension such as pumping.

The yield in acre-inches per inch of depth for each sample was read from Figures 4, 5, and 6, and the data are given in Table 7, together with a calculation of total yield for each segment. These data show that, providing pumping was feasible, a maximum of about 2500 acre feet of water could be extracted from the sediment. Due to stratification of the deposits, the actual yield would be somewhat less than laboratory studies indicate.

Of more significance to the present study is the amount of water the deposits will yield with free drainage as the surface water is withdrawn from storage. In January, 1951 and some months after withdrawal of water, deposits in the exposed portion of the basin near the dam and most of the central basin were still saturated with water within 1-2 feet of the surface. These deposits are not expected to yield significant amounts of water with free drainage, and potential yield under tension for the central and lower basin is only about 20 percent of the total. Most of the remaining 80 percent of potential specific water yield is in the deep sediments of Cottonwood Creek arm. The sands in this area probably contribute an appreciable amount of water by free drainage providing strata of fine material do not seal off the escape to surface storage. Further field studies would be necessary to determine with reasonable accuracy the amount of usable water the reservoir would yield by free drainage.

EROSION AND SEDIMENT SOURCES

The Morena Reservoir Watershed has apparently undergone some major changes in vegetative cover and erosion conditions during the past 80 years. The changes have been brought about by the forces of nature and man combined. Deteriorated cover from fires on watershed slopes and cultivation and other grazing in the mountain meadows have existed when severe storms swept the area, creating heavy soil losses and high sediment transporting runoff.

WATERSHED SLOPE EROSION

Evidence of major slope fires prior to 1900 are recorded in the oaks and large conifers of the area. Fire records since 1911 indicate some 4000 acres were burned in the watershed every 20 years up until 1944 when nearly two-thirds of the area was burned in the Laguna Junction fire. Map 3 shows the location and date of mappable burns since 1911, according to the fire records of the Cleveland National Forest.

Fires in chaparral increase the rate of erosion in relation to the size of fire, topography, soil structure and point of time in cyclic storm pattern. A watershed erosion source delineation primarily characterized by vegetative cover, but with consideration of other variables such as slope, exposure, soil structure and site ability to sustain plant life is shown on Map 4.

Erosion Area A is characterized by slight erosion. The area is described as (1) Where the vegetative canopy density is from 70 to 10 percent over a forest floor upwards of 2 inches in depth with adequate litter to minimize erosion, or (2) the area is meadow, exclusive of valley trenches, which has not burned or has since been rehabilitated or (3) the area is composed of rocky formations on gentle slopes. In general, the cover consists of tree forms and old-age chaparral or grassland.

Erosion Area B, characterized by moderate erosion, has a vegetative canopy comprising a 30 to 70 percent cover over a forest litter less than 2 inches in depth, with inadequate litter for erosion control. This vegetative cover consists of chaparral between the ages of 6 and 20 years old. Chamise is dominant in the plant composition.

Erosion Area C, characterized by severe erosion, has a vegetative canopy from 0 to 30 percent, with little or no forest litter. The vegetation composition is similar to Area B, but stunted and sparse, with area exposed rocks and raw areas of the parent material. Characteristic of "C" are the areas of south and desert exposure, steep slopes and a well established erosion pavement.

The average annual amount of soil loss from each erosion source type as shown on Map 4 was estimated during fire damage appraisal studies made by the U. S. Forest Service in 1948. Based on these studies, the total amount of soil loss during the 108 years the City of San Diego estimates as the remaining useful life of the reservoir, is shown on Table 8. The data, given for the 4

TABLE 6 - EXTRACTION OF WATER IN INCHES PER INCH OF SOIL DEPTH AS RELATED TO TENSION, MORENA RESERVOIR

Sample No.	Volume Weight Ratio	Ins. Water at saturation 1/ Ins./Inch	Total yield of water in inches per inch: 40 cm tension Ins./In.	60 cm tension Ins./In.	135 cm tension Ins./In.	330 cm tension Ins./In.
91	1.23	0.487	0.064	0.175	0.330	0.344
92	1.50	.375	.189	.254	.281	.288
93	1.16	.505	.078	.135	.276	.339
94	0.88	.639	.064	.071	.092	.106
96	1.24	.516	.048	.182	.401	.408
97	1.11	.522	.042	.091	.309	.407
99	1.33	.052	.032	.082	.362	.423
101	1.49	.429	.194	.265	.347	.378
102	1.14	.601	.051	.062	.259	.456
103	1.15	.569	.052	.093	.331	.424
104	1.20	.559	.042	.053	.208	.425
105	1.49	.432	.176	.247	.329	.350
106	1.17	.564	.028	.056	.337	.379
107	1.09	.567	.065	.099	.239	.302
108	1.35	.487	.247	.282	.339	.352
109	1.17	.542	.035	.042	.065	.077
110	.69	.756	.110	.131	.186	.216
111	1.17	.543	.021	.028	.091	.218
112	1.15	.550	.113	.127	.155	.176
113	.76	.644	.161	.168	.182	.196
114	1.33	.412	.106	.157	.227	.263
115			(Erratic - data not tabulated)			
116	1.11	.562	.078	.107	.198	.261
117	1.49	.414	.291	.325	.340	.346
118	1.15	.549	.036	.071	.345	.408
119	1.46	.423	.077	.105	.177	.225
120	.69	.501	.120	.127	.141	.155
121	1.30	.506	.124	.176	.159	.221
122 2/	1.50	.425	.333	.342	.408	.420

1/ This value x 100 = observed porosity. Slight differences are due to imperfect cores or loss of accuracy due to dropping decimal.

2/ Results questionable.

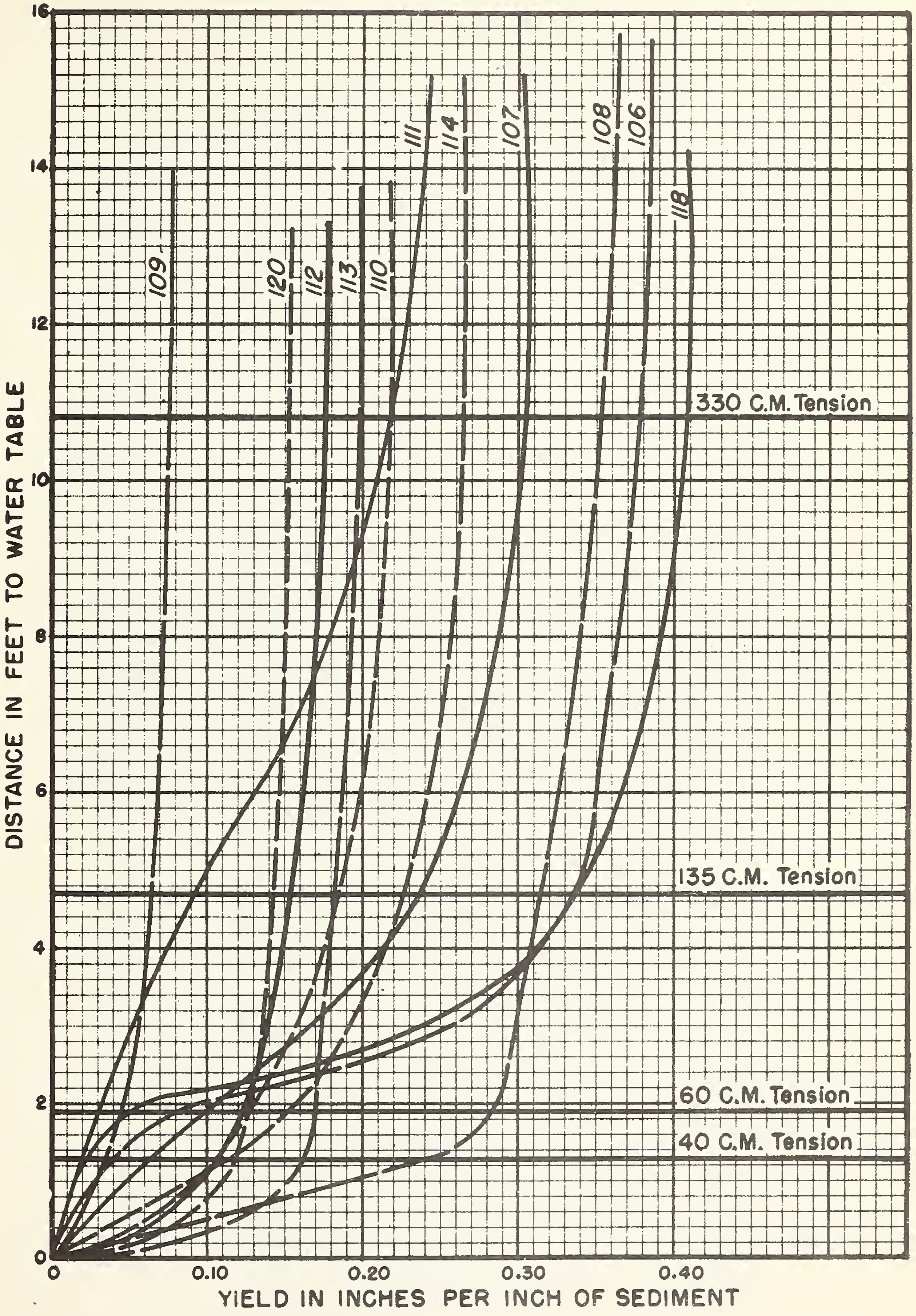


FIGURE 4 Specific yield of sediment, Central and Lower Basin, Morena Reservoir

AGR-SCS-PORTLAND, ORE NOV 1953

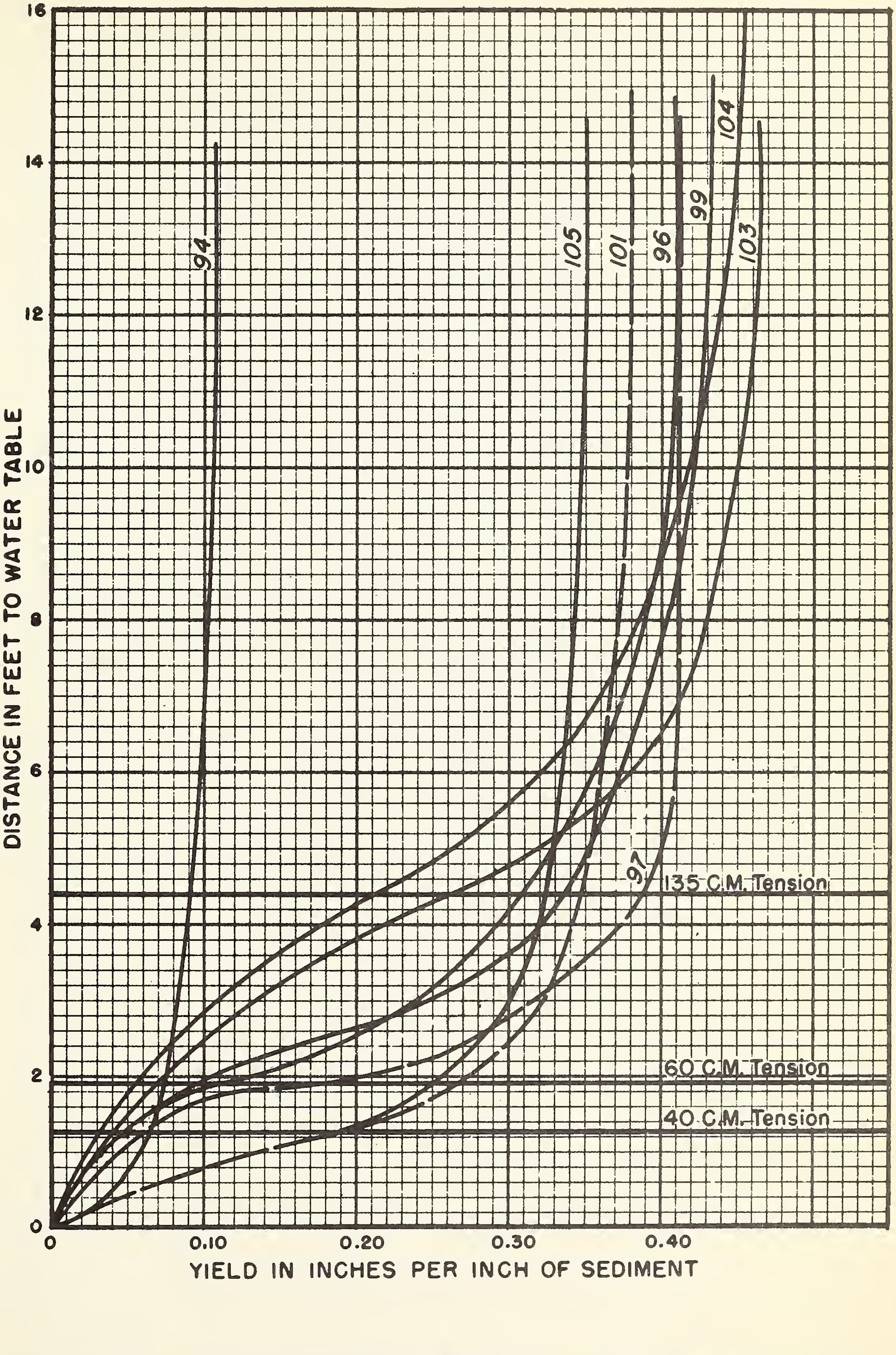


FIGURE 5 Specific yield of sediment, Cottonwood Creek Arm of Morena Reservoir

7-L-14073

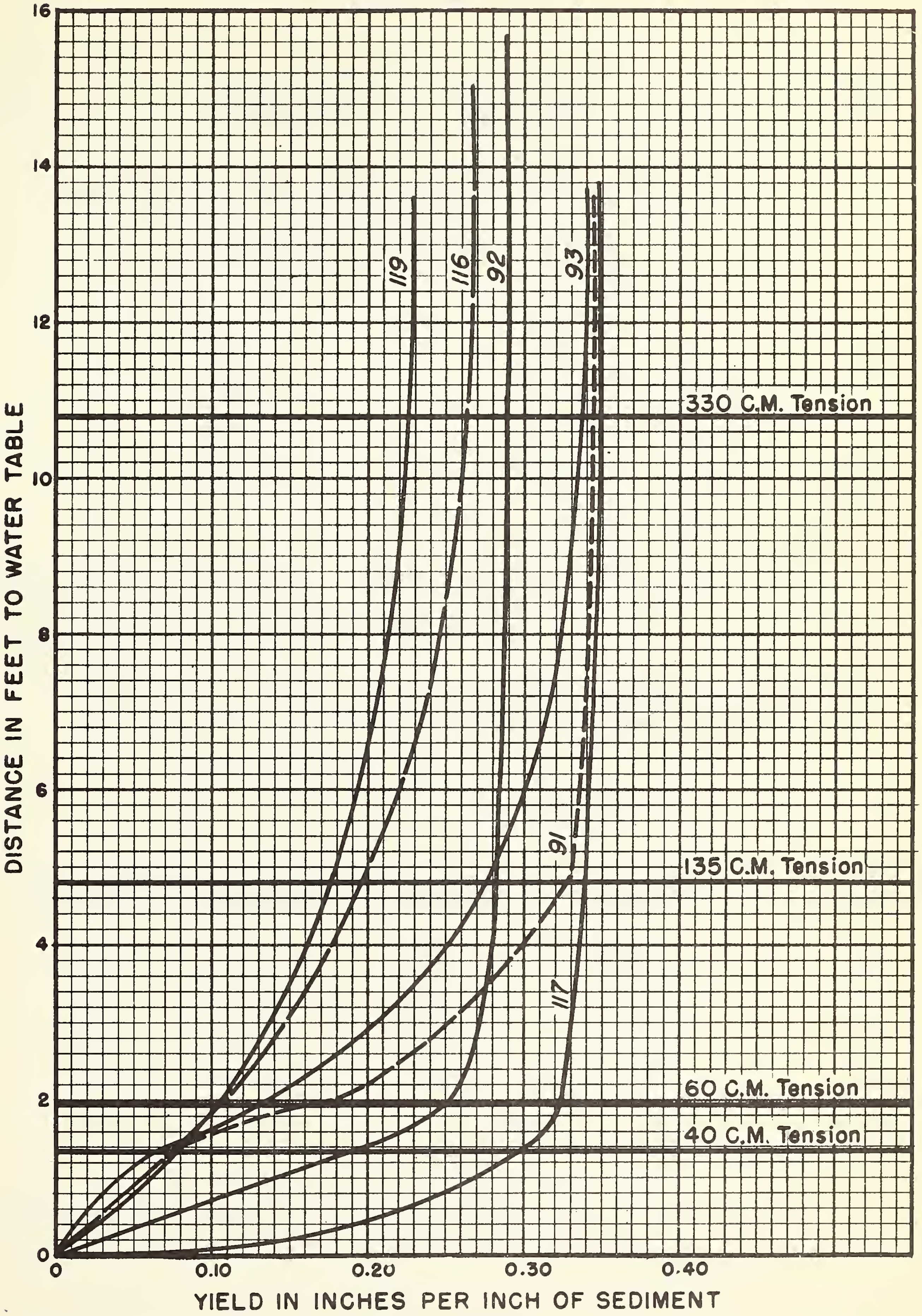


FIGURE 6 Specific yield of sediment, Morena Creek Arm of Morena Reservoir

7-L-14073

AGR-SCS-PORTLAND, ORE NOV 1953

TABLE 7 - SPECIFIC YIELD BY RESERVOIR SEGMENTS
MORENA RESERVOIR

Distance to Water Table Feet	Acre-Inches per Inch Sample 110	Acre-Inches per Inch Sample 120	Average	Acre-Inches Total

Specific Yield of Sediment between Dam and Range 11-12

Average Sediment Depth = 30 feet

Area = 26.5 acres

0 - 2	0.09	0.11	0.10	2.40
2 - 4	0.16	0.135	0.147	3.53
4 - 6	0.19	0.142	0.166	3.98
6 - 8	0.205	0.150	0.177	4.25
8 - 10	0.215	0.152	0.183	4.39
10 - 30	0.216	0.155	0.185	44.40
			Total	62.95

62.95 acre-inches x 26.5 acres = 1668 acre-inches = 139 acre-feet

Note: Sample 115 erratic; data not tabulated

Specific Yield of Sediment between Range 11-12 and Range 21-22

Average Sediment Depth = 13 feet

Area = 72 acres

	Acres-Inches per Inch Sample 110	Acres-Inches per Inch Sample 120	Acres-Inches per Inch Sample 111	Average	Acre-Inches Total
0 - 2	0.15	0.09	0.02	0.09	2.16
2 - 4	0.16	0.13	0.05	0.11	2.64
4 - 6	0.19	0.14	0.10	0.14	3.36
6 - 8	0.20	0.15	0.16	0.17	4.08
8 - 10	0.21	0.15	0.19	0.18	4.32
10 - 13	0.22	0.15	0.22	0.20	7.20
				Total	23.76

23.76 acre-inches x 72 acres = 1734 acre-inches = 144.5 acre-feet.

TABLE 7 (Continued)

Specific Yield of Sediment from R 21-22 to between R 26-27 and R 28-29 and between R 21-23 and R 25-R 38

Average Sediment Depth = 6 feet
Area = 227 acres

Distance to water table Feet	Sample 107	Sample 108	Sample 109	Sample 111	Sample 112	Sample 113	Sample 114	Sample 118	Average	Total
0 - 2	0.06	0.18	0.03	0.02	0.10	0.15	0.09	0.03	0.08	1.92
2 - 4	0.16	0.30	0.06	0.05	0.14	0.17	0.19	0.25	0.17	4.08
4 - 6	0.24	0.32	0.07	0.10	0.16	0.18	0.23	0.34	0.20	4.80
								Total		10.80

10.80 acre-inches x 227 acres = 2452 acre-inches = 204 acre-feet

Specific Yield of Sediment from Vicinity of Range 28-29 to end of Morena Creek Area

Average Sediment Depth = 4.5 feet
Area = 246 acres

	Sample 91	Sample 92	Sample 93	Sample 116	Sample 117	Sample 119	Average	Total
0 - 2	0.04	0.15	0.04	0.06	0.27	0.06	0.10	2.40
2 - 4	0.25	0.27	0.21	0.15	0.33	0.14	0.23	5.52
4 - 4.5	0.31	0.28	0.26	0.18	0.34	0.17	0.26	1.30
						Total		9.22

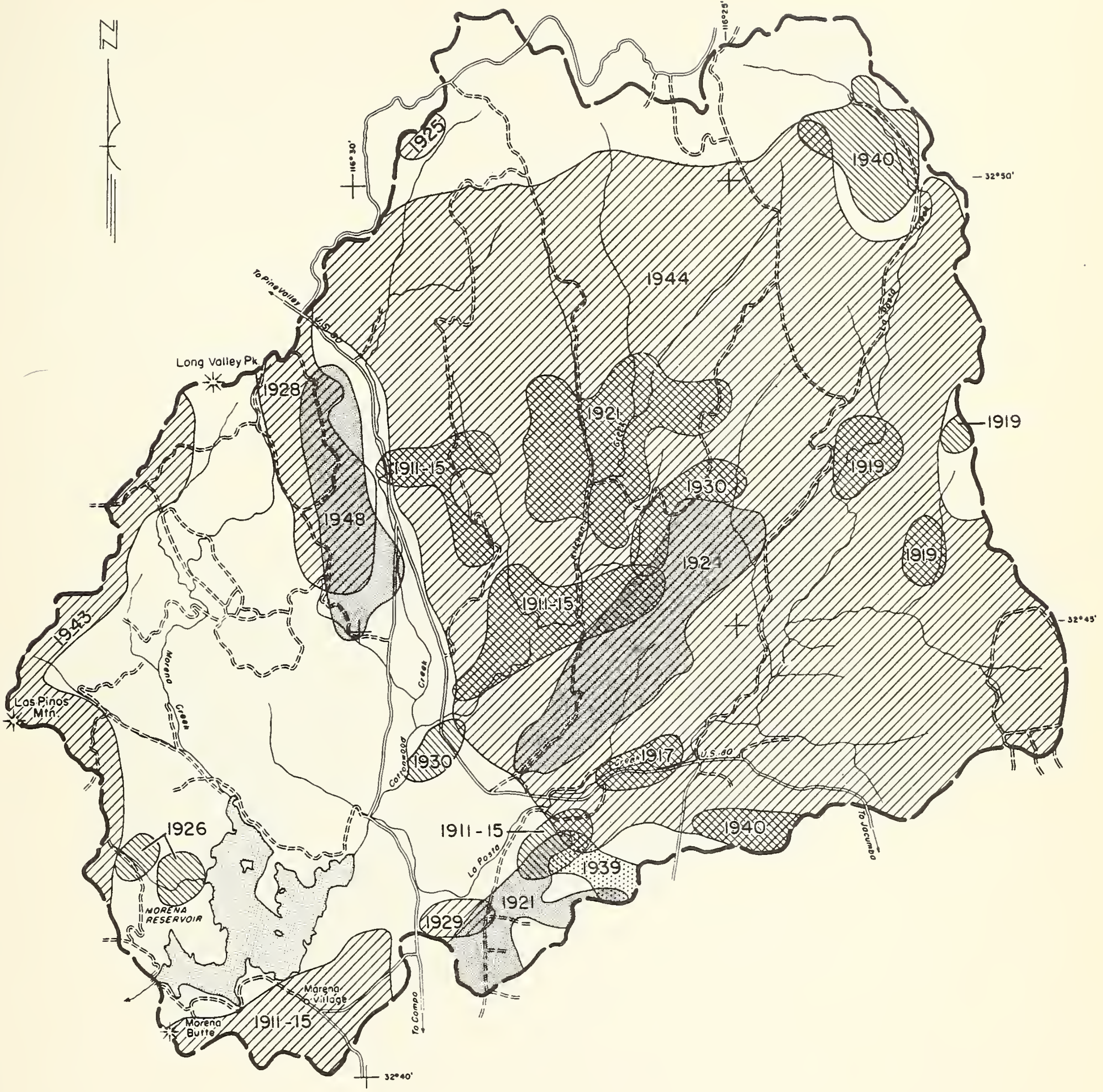
9.22 acre-inches x 246 acres = 2268 acre-inches = 189 acre feet

Specific Yield of Deposits in Cottonwood Area from below R 25-38 to head of Reservoir

Average Sediment Depth = 21.6 feet
Area = 268 acres

	Sample 105	Sample 101	Sample 96	Sample 99	Sample 97	Sample 104	Sample 103	Average	Total
0 - 2	0.14	0.13	0.04	0.04	0.10	0.03	0.04	0.07	1.75
2 - 4	0.30	0.32	0.24	0.24	0.31	0.11	0.14	0.24	5.69
4 - 6	0.33	0.35	0.33	0.35	0.39	0.26	0.31	0.33	7.97
6 - 8	0.34	0.37	0.37	0.39	0.41	0.36	0.41	0.38	9.05
8 - 10	.35	0.37	0.40	0.41	0.41	0.40	0.44	0.40	9.50
10 - 12	0.35	0.38	0.41	0.43	0.41	0.43	0.46	0.41	9.77
12 - 21.6	0.35	0.38	0.41	0.43	0.41	0.44	0.46	0.41	47.26
							Total		91.03

268 acres x 91.03 acre-inches = 24,396 acre-inches = 2,033 acre-feet.



MAP 3
AREAS BURNED

MORENA RESERVOIR WATERSHED

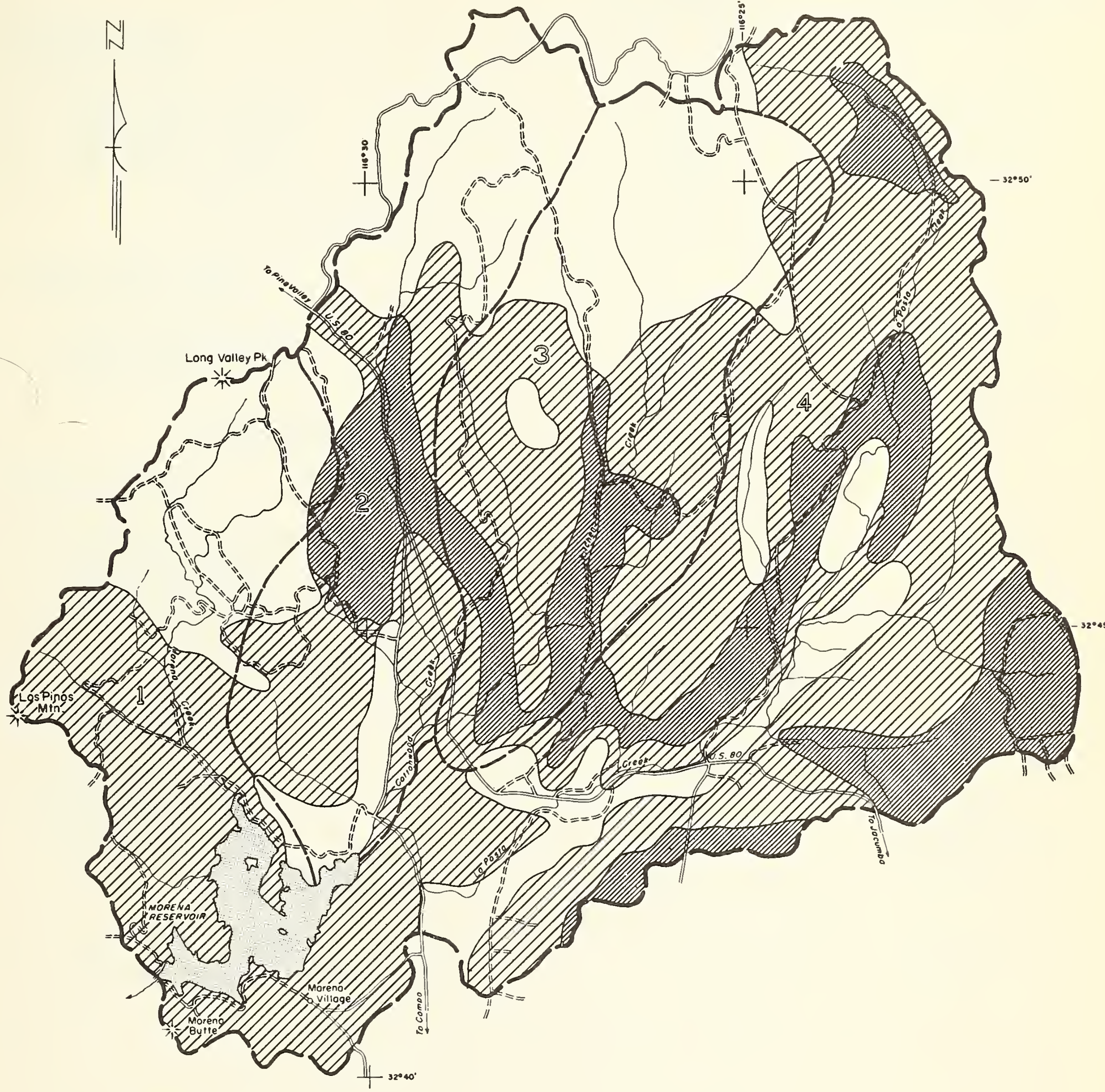
SAN DIEGO COUNTY, CALIFORNIA

NOVEMBER 1953

1 0 1 2 3
SCALE IN MILES

AGR-SCS-PORTLAND, ORE NOV 1953

7-0-14077-L



LEGEND

A — Slight Erosion

B — Moderote Erosion

C — Severe Erosion

1 — Moreno Creek Subwotershed

2 — Cottonwood Creek Subwotershed

3 — Kitchen Creek Subwotershed

4 — Lo Posto Creek Subwotershed

MAP 4

AREAS OF SLIGHT, MODERATE AND SEVERE EROSION

MORENA RESERVOIR WATERSHED

SAN DIEGO COUNTY, CALIFORNIA

NOVEMBER 1953

1 0 1 2 3

SCALE IN MILES

TABLE 8 - SOURCE OF POTENTIAL EROSION ON WATERSHED SLOPES FOR THE NEXT 108 YEARS

	Area Square Miles	Potential Erosion Acre Feet
Morena Creek		
Watershed Type A	9.0	Negligible
Watershed Type B	10.3	3,575
Watershed Type C	0.3	313
Subwatershed Total	19.6	3,888
Cottonwood Creek		
Watershed Type A	6.7	Negligible
Watershed Type B	7.1	1,242
Watershed Type C	3.8	2,527
Subwatershed Total	17.6	3,769
Kitchen Creek		
Watershed Type A	7.5	Negligible
Watershed Type B	9.5	3,402
Watershed Type C	4.4	4,730
Subwatershed Total	21.4	8,132
La Posta Creek		
Watershed Type A	4.6	Negligible
Watershed Type B	33.4	2,020
Watershed Type C	12.2	2,203
Subwatershed Total	50.2	4,223
Total Potential Slope Erosion		20,012

major subwatersheds, excludes the amount coming from valley trenches. The latter information is given in Table 9.

The sandy soil material of the Morena Watershed erodes into a relatively coarse-textured sediment, part of which deposits perhaps only a few feet from the place of origin. Other portions accumulate at the base of slopes or on flood plains and in channels above the reservoir. An approximate accounting for the amounts of soil eroded and deposited in the Morena Watershed during the life of the reservoir indicates that about 58 percent of the material eroded from mountain slopes is deposited in the reservoir. The amount of sediment from mountain slopes that is expected to deposit in the reservoir during the next 108 years without additional erosion control is, therefore, as follows:

La Posta Creek Subwatershed	2,449 Acre Feet
Cottonwood Creek Subwatershed	2,186 Acre Feet
Kitchen Creek Subwatershed	4,717 Acre Feet
Morena Creek Subwatershed	2,255 Acre Feet
Total reservoir sediment from mountain slopes in next 108 years	11,607 Acre Feet

MOUNTAIN MEADOW EROSION

Available information indicates that valley trenching in Morena Reservoir Watershed may have started at about the time of the 1895 flood, but that much of the erosion occurred, or valley trenching started, during the January 1916 flood discharge. Mention has also been made of the 1927 storm as creating significant erosion in the mountain meadows. Before the period of accelerated erosion began, some of the meadows must have had channels or depressions which carried flood flows. Since such channels have been largely erased by valley trench development, it is impossible to estimate their original volume. That valley trench development is directly related to major flood discharges is reasonably well established. A comparison of aerial photographs taken in 1929 and 1948 shows that little increase in area of the trenches occurred during the intervening period. It has been reported that the trenches were at their deepest about 1942, so it is probable that some bottom scour with subsequent aggradation occurred during the above period. One of the unpredictables related to increased trench development during the next 50 or 100 years is the occurrence of floods comparable to or greater than the 1916 or 1927 floods. Notable floods in San Diego County occurring in 1862, 1884 and 1895, in addition to the 1916 and 1927 floods, indicate that the occurrence of other major floods during the next 50 and 100 years is probable.

Measurements of valley trenches were made during January and September, 1951. Average depths of the trenches were obtained by dropping weighted tapes over the sides of the vertical walls at frequent intervals. Surface acreages were obtained both by field estimates and by planimetering of enlarged aerial photographs.

The present cavity volume of all trenches is about 4900 acre feet. The surface area and cavity volume of each trench is given on Table 9. The numbers in parenthesis to the left of the meadow locations refer to those on aerial Map 5.

In addition to the 4900 acre feet, it is estimated that an additional 1000 acre feet have been removed from the bottom of valley trenches, making a total of 5900 acre feet from valley trenches. Recent low water years have brought about deposition of coarse sand, replacing this eroded meadow soil. Table 9 (column 5) also gives an estimate of the potential volume of sediment erodible from mountain meadows during a period of about 108 years, unless valley trenches are stabilized. A certain portion of the sediment volume from mountain meadows will be deposited in channels and on flood plains before reaching the reservoir.

The potential valley trench development during the next 108 years as given in Table 9 is based on the probable dates of origin and history of flood flows during the period of development. Also considered are the size, shape and stability of remaining meadows and their position in the watershed. A lack of knowledge or data prescribes that the potential development of valley trenches be a matter of judgment, oriented by the considerations given below. In this study, the term "valley trench" is used to describe vertical walled channels that have developed in recent times in established drainageways across alluvium filled valleys.

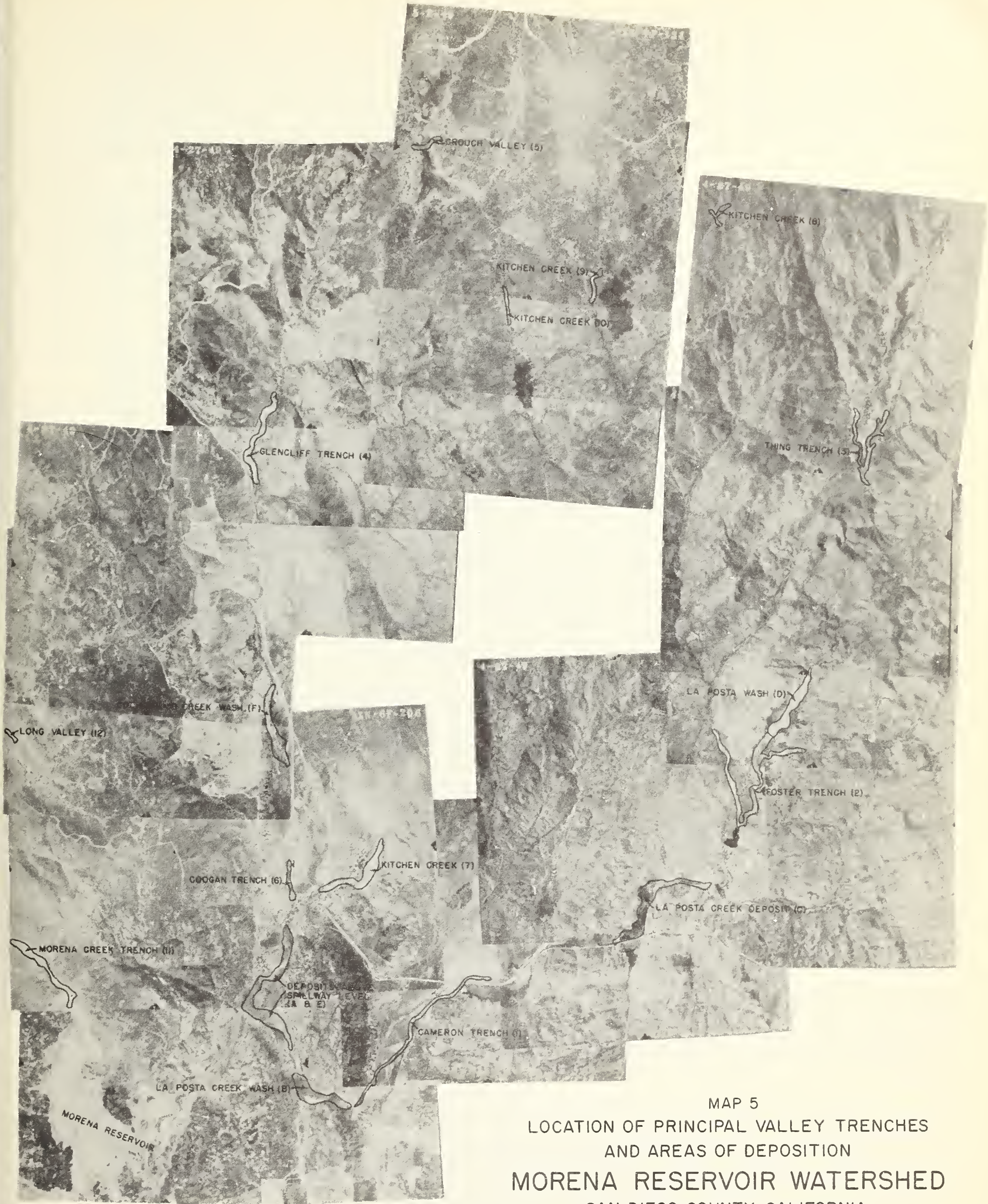
One consideration taken into account in estimating potential valley trench development is the relation of the present width of the trenches to the width of the meadow affected. Those trenches now occupying all or most of the valley between rock walls have obviously approached their maximum width. Others which occupy only a small part of the meadow still have considerable room for expansion. Examples of the second type include Cameron and Thing meadows on La Posta Creek. The location of valley trenches is shown on Aerial Map 5.

A second consideration is the present width of valley trenches in relation to the probable width when extensive meandering will give way to a relatively broad, smoothly curved channel capable of carrying flood flows without highly erodible action against the sides of the trenches. The size of the drainage area above is one factor, although there does not appear to be a direct relation between size of watershed and size of channel. Few, if any, significant trenches, however, have developed below drainage areas of 1-2 square miles, particularly at lower elevations. Some meadows either have insufficient drainage area to erode their alluvial meadows or the channel keeps to a course along the rockbound side of the valley. It is not anticipated that such meadows will become entrenched during a period of time with which this study is concerned. The nature of the soil material in channel sides has a bearing on the rapidity and extent of lateral development. Layers of loose sand contribute to the instability of banks exposed to current action.

TABLE 9 - EXISTING AND POTENTIAL VALLEY TRENCH DEVELOPMENT RESERVOIR WATERSHED

(1) Meadow and Stream Location	(2) Present Valley Trench Area Acres	(3) Present Valley Trench Volume Acre Feet	(4) Approximate Remaining Meadow Area Acres	(5) Potential Valley Trench Development Acre Feet
La Posta Creek				
(1) Cameron	31	430	285	1,580
(2) Foster	96	1,320	80	1,050
(3) Thing	39	800	420	3,850
Cottonwood Creek				
(4) Glencliff	45	1,330	29	770
(5) Crouch	9	90	300	250
(6) Coogan	9	70	360	620
Sheepshead 1/	3	30	100	70
Kitchen Creek				
(7) At Coogan Meadow	64	470	0	0
(8) Headwaters, East Branch	2	60	7	80
(9) Headwaters, Middle Branch	12	120	60	530
(10) Headwaters, West Branch	10	20	36	140
Morena Creek				
(11) Near Head of Reservoir	17	150	-	0
(12) Long Valley	3	30	15	70
	340	4,920	1,692	9,010

1/ Not shown on Map No. 5



MAP 5

LOCATION OF PRINCIPAL VALLEY TRENCHES
AND AREAS OF DEPOSITION

MORENA RESERVOIR WATERSHED

SAN DIEGO COUNTY, CALIFORNIA

NOVEMBER 1953

An example of mature development as to width of section is Kitchen Creek near its mouth. As compared to other channel sides which are near vertical, the banks of Kitchen Creek at this point are at about a 1:1 slope, are vegetated and appear stabilized. The average width of the trench is about 400 feet. The watershed area above is near the maximum for the several sub-watersheds in the drainage basin.

An example of a large meadow without gullies below a small watershed is the large Bear Valley meadow in Morena Creek watershed. This meadow has a drainage area of only 1-1/2 square miles and the channel maintains its course along the west side of the valley where the deposit of fine alluvium is shallow.

A third consideration in estimating the extent of valley trench development is the potential depth of erosion. Potential depth of erosion is determined by the nature of the material at the lower end of the trench and in the bottom of the trench. Also of importance is the slope of the meadow. The steeper the grade, the greater the potential downcutting before a critical slope is reached where more than intermittent deposition as well as scour may occur. The slope of meadows in the Morena watershed varies from about 0.6 percent in Cameron and lower Coogan meadows to between 3 and 4 percent in lower Thing meadow and almost 5 percent in Crouch Valley. Downcutting may continue to occur in a meadow trench with a steep grade even though rock or a dam controls scour at the lower end. An example is Thing meadow, where an old dam stabilizes only the extreme lower end of the channel. A rock sill or dam across a channel of comparatively low grade, however, say from 0.6 to 1 percent, should insure a considerable measure of stability to the soil material or deposits upstream. A coarse gravel and boulder train in a channel in this watershed usually mixed with considerable coarse sand and pea gravel, indicates that further significant downcutting is unlikely. An example of this type is the channel of Morena Creek above the reservoir.

A fourth consideration in estimating the probable development of valley trenches is the character of the present head or upper end of the valley trench. A vertical or near vertical drop from the meadow level to the channel bottom in unconsolidated material is a clear indication that the valley trench could erode back upstream, engulfing lands presently at the meadow surface. An example of this is the upper end of the Thing Valley Trench, which is at present intercepted by an earth dike. A valley trench terminating in a rock or boulder channel, on the other hand, has reached its maximum headward growth. An example of this type is the Glencliff meadow and trench on Cottonwood Creek.

Other valley trench headings terminate in sand-filled channels or sand washes. Due to ill-defined principal channels through these areas, it is expected that large flood flows will spread across the valleys in a comparatively shallow flow with reduced capacity for downcutting. The flow will probably enter the trench at several points with some limited head cutting at each point. The concentration of flow at any one point will probably be insufficient, however, to both move the available bedload and erode the trench heading a material distance upstream. Examples of this type are the Cameron and Foster meadow trenches on La Posta Creek.

With the above factors forming the basis for estimating the potential size of valley trenches, the description and dimensions of the trenches at the present time and the dimensions expected at the end of 50 years (the year 2000) are given below. The amount of soil material expected to erode through valley trench development to the 108th year was determined by extension of a curve showing the relation between age and volume of valley trenches between 1895, 1950 and 2000. Soil losses through trench development were indicated to be somewhat less for the period after the year 2000 than before.

La Posta Creek

Cameron meadow trench. The slope in this reach of La Posta Creek is 0.6 - 1.0 per cent. The lower end of the trench is at a rocky narrows but the depth through coarse sand to bedrock is about 20 feet. The trench has vertical walls and averages 100 feet in width and 14 feet in depth. The depth gradually becomes less upstream, terminating at a sharp bend, in a sand-filled channel. Only a small part of the meadow is presently occupied by the trench. Flood flows may leave the channel and cross part of the meadow before entering the trench again. The drainage area above is about 43 square miles. The estimated dimension of the trench in 50 years is about 200 feet in width, 16 feet in depth and an overall length of 12,500 feet.

Foster meadow and trench above Foster Dam. The west or tributary trench of La Posta Creek above the Foster Dam extends from wall to wall of the canyon except in its lower 1600 feet. The trench has extended as far headward as it can go. The bottom shows some aggradation with coarse sand, part of which would probably move downstream during a major flood. The average depth is now 13 feet and the average width 225 feet. The watershed is about 6 square miles and the slope of this stream reach is about 2-1/2 percent. The trench in the main stream of La Posta Creek at this point now averages about 260 feet in width and 14 feet in depth. The slope is about 1.6 percent. The presence of Foster Dam and the energy dissipation effected by large quantities of bedload upstream will probably reduce downcutting to an average depth at the end of a 50-year period of some 18 feet. The channel width could enlarge to about 400 feet over a distance of 11,000 feet, including 1600 feet in the tributary area. The enlargement in width may be anticipated partially because of the unstable soil material through which the trench is cut.

Thing Valley meadow has a steep slope in the lower end where much of the trench development has occurred. Here it is between

3-4 percent and in the middle or upper reaches of the meadow, the slope is about 2 percent. A tributary trench enters the main channel near the lower end of the meadow. The average depth of the tributary is 27 feet and that of the main stream, 24 feet below the meadow surface. Although a concrete dam is located at the lower end of the meadow, due to the steep grade and lack of coarse material in the bottom, it is estimated that the probable average depth will reach 40 feet in a 50-year period. The trench still occupies a small portion of the total meadow width. It may expand to an average of 250 feet over a length of 10,800 feet, including tributary areas. Engineering studies indicate the earth dike in Thing Meadow (No. 11 on map showing the location of proposed structures in Morena watershed) will fail during a major flood. When this occurs, the trench heading just below this structure will erode up the valley. During the 50-year period, it is expected that the extended portion of Thing Meadow trench will attain a dimension of 12,000 feet in length, 100 feet in average width and 25 feet in depth.

Cottonwood Creek

The Glencliff meadow now has an average depth of about 30 feet and an average width of 265 feet. The trench now occupies more than half the width of the meadow. The trench has unstable soil material exposed on the sides. The slope is about 2.8 percent and the watershed area above about 9.5 square miles. The creek bottom at the lower end of the meadow is probably underlain by rock. Recession up the valley has been terminated by a boulder pavement and rock outcrop. A deposit in the bottom of the trench could be swept out during a major flood. It is estimated that the probable width of the Glencliff trench at the end of a 50-year period will amount to 400 feet and an average depth of 35 feet through the present length of 5200 feet.

Crouch Valley is at the upper part of Cottonwood Creek in the mountains along the watershed divide. Meadow slopes are between 4 and 5 percent. The total watershed area is about 3.7 square miles. The major trench crosses the center of the meadow, is about 1600 feet long, about 50 feet in average width and 15 feet in depth. Some gullies tributary to the trench have been stabilized by placed rock check dams installed by a CCC camp in 1939. The trench may cut back through the most easterly tributary about 5000 feet with a width of about 75 feet and average depth of 10 feet. Small unstabilized gullies will probably contribute an additional volume of sediment.

Coogan Meadow - This meadow is one of the largest in Morena watershed and has a slope of less than 1 percent in its middle and lower reaches. Below the mouth of Kitchen Creek the meadow is traversed by an aggraded channel (still slightly below the meadow surface) which is partly due to the ponding of the reservoir. Aggradation in the channel, combined with a low stream gradient, will probably furnish a deterrent to down-cutting unless a new channel is eroded back through the reservoir delta deposits. Some aggradation at the mouth of Kitchen Creek is evident. Cottonwood Creek above its junction with Kitchen Creek is still cutting down in unconsolidated material and at present has an average depth of 8 feet, an average width of almost 200 feet, and a length of about 1300 feet. There are two branch headings of the trench, one terminating at a dam built with the spillway on rock outcropping in the valley at this point. The other heading is a vertical one receiving overflow water from Cottonwood Creek and a tributary from the west. Assuming the dam will stabilize the one channel at this point, the other channel may deepen the whole trench to an average of 15 feet and recede up the valley to include an area of about 5000 feet in length and 250 feet in width. Further headcutting will probably be stopped by dispersed flow across the sand and gravel wash near the upper end of the meadow.

Sheepshead Meadow. This meadow is about 3 acres in area and the volume of soil eroded from it is approximately 30 acre feet. Channel slopes vary from 3-1/2 percent to 5 percent. A check dam has been installed on each of the two branches of the creek. The valley trench is estimated to contribute another 40 acre feet of sediment during a 50-year period. This estimate is based on the average rate of enlargement expected of other valley trenches in the watershed.

Kitchen Creek

Kitchen Creek at Coogan meadow is in a presently stabilized valley trench as evidenced by its weathered side slopes. The trench now averages about 400 feet in width and 10 feet in depth above Highway 80 crossing. The channel of Kitchen Creek has been aggraded in this reach. The average slope is slightly over 1 percent. This trench is not expected to widen appreciably and the present comparatively gentle grade is not expected to cut down materially unless an eroding head works back from the reservoir area. The drainage area above is about 21 square miles.

Headwaters, East Branch of Kitchen Creek. This is a narrow meadow, only about 400 feet in width and with a slope of about 4 percent. The main trench is about 75 feet wide and averages 20 feet in depth. Gullies extend through smaller valleys, entering the stream at this point. Downcutting at the upper and lower ends of this trench are controlled by rock or boulders. Most of the additional sediment is expected to come from the side tributaries cutting down to the grade of the main stream. The drainage area above this trench is about 0.8 square miles.

Headwaters, Middle Branch of Kitchen Creek. There are no roads or trails near this meadow. Estimates of present and potential erosion were made from a study of photographs and the topographic map. The present average depth was estimated as 10 feet. The slope of the meadow area is slightly less than 4 percent and the watershed area above is about 0.9 square miles.

Headwaters, West Branch of Kitchen Creek. The principal trench is about 50 feet wide, 15 feet deep and 1800 feet long in a narrow meadow and with a slope of more than 4 percent. Other erosion scars more like gullies are located in the same area. The watershed above is about 0.6 square miles.

Morena Creek

Morena Creek near head of reservoir. The narrow meadow has been almost completely removed by the valley trench which averages about 9 feet in depth and 270 feet in width. The stream slope is about 3 percent and the drainage area upstream about 13-1/2 square miles. The bed of the channel has a coarse sand and gravel pavement and the present head of the trench is at the original grade of the stream.

Long Valley. The stream and valley trench traverses only a short reach of Long Valley, which has a watershed of about 5 square miles and a stream slope of between 3 and 4 percent. The dimension of the trench is about 7 feet in depth and averages 20 feet wide. Rock sills maintain the grade at the lower and upper ends. It is expected that the width will about double during the 50-year period but that no increase in depth will occur.

SEDIMENTATION ABOVE THE RESERVOIR

Table 10 gives the estimated aggradation in channels and sand washes above Morena Reservoir. The letters under the tributary watershed names on Table 10 refer to those on aerial Map 5. To measure these deposits, soil auger borings were made in all areas of deposition. Due to the flowage of sand into the void of the boring hole, it was impossible to measure below depths ranging from 3 to 6 feet. Table 11 and Figure 7 show the mechanical analysis of these deposits which consist of sand with a minor amount of gravel in most places. Map 6 shows the location of samples plotted on Figure 7. Since most deposits were deeper than 3 or 6 feet, the estimates of volume of deposit were very approximate and were based on several factors. Maximum depths in the above spillway crest deposits and in the wash below Cameron meadow on La Posta Creek were based on thicknesses of deposits shown on the last range in the reservoir and on the closure of like contours on a profile of 1942 compared to a U.S.G.S. topographic sheet made about 1900.

Deposits on La Posta Creek below Foster Dam were not penetrable with an auger and an average depth estimate was made from the appearance of partially buried trees and fence posts. On the sand wash above the Foster meadow trench, the depth of scour channels through the deposit formed the basis for estimating average sediment depths.

On the Cottonwood Creek in the area immediately above reservoir spillway level, the depth of sediment was based partially on depths of deposit on the last reservoir range and partially on auger borings. In the wash below Highway 80 the depth was based on the foregoing and on the elevations of the wash surface above the normal flood plain level.

TABLE - 10 - ESTIMATED AGGRADATION IN CHANNELS AND SAND WASHES
MORENA RESERVOIR WATERSHED

STREAM	LOCATION	Volume-Acre Feet
La Posta Creek		
A	Deposits above spillway level	500
B	La Posta Creek wash below Cameron Meadow	430
C	La Posta Creek below Foster Dam	450
D	La Posta wash above Foster Trench	130
Cottonwood Creek		
E	Deposits above spillway level	200
F	Wash below Highway 80	250
Aggradation of valley trenches		1000
Total		2960

TABLE 11 - MECHANICAL ANALYSIS AND DENSITY OF SAMPLES
MORENA RESERVOIR WATERSHED

Sample No. & Location	Sediment Sizes - Percent				
	Silt & Clay 1/	Fine Sand	Medium Sand	Coarse Sand 2/	Density Lbs/Cu.Ft.
Channel Deposits					
123 Channel, LaPosta Creek	3	4	20	73	-----
127 Sand Wash, LaPosta Creek	3	3	16	78	92.5
128 Channel, LaPosta Creek	1	1	9	89	98.8
129 Deposit above reservoir, La Posta Creek	9	5	33	53	83.8
Average	4	3.2	19.5	73.2	91.7
Mountain Meadows					
125 Meadow Bank, Thing Valley	10	13	24	53	98.1
126 Meadow Bank, Thing Valley	21	17	24	38	72.5
131 Bank, Cameron Meadow La Posta Creek	13	11	23	53	99.4
132 Bank, Cameron Meadow, La Posta Creek	21	17	24	38	80.0
133 Cameron Meadow	19	19	29	33	81.9
Average	17	15	25	43	86.4
Watershed Slopes					
130 LaPosta Creek	9	5	15	71	91.3
135 LaPosta Creek	12	8	15	65	86.9

1/ Includes very fine sand

2/ Includes fine gravel

Estimates of the volume of sediment aggrading valley trenches was based on statements of local people and, to a slight degree, on their appearance at the present time. There are no clear-cut features that enable separating recent sediment deposition from earlier deposition in sand washes and channels. In addition to the volumes shown on Table 10, other alluvial material of much greater volume fills the valleys of Morena Watershed. Some of this material will find its way to the reservoir through erosion of mountain meadows, while most of the remainder will stay in place at least during the present erosion cycle. Of the deposits shown on the table, those in the wash area below Cameron meadow are the more stabilized by fairly dense willow growth. Some of the wash areas are too droughty to support heavy growth.

When the voids in valley trenches have become nearly filled with sediment in the years following construction of channel stabilizers, major flood flows will discharge over some meadow surfaces. In the lowest gradient meadows, Cameron and Coogan, these flows will deposit sediment of a size that would otherwise be transported into Morena Reservoir. It is estimated that the deposits in Cameron Meadow due to the proposed barriers will amount to about 200 acre feet and on Coogan Meadow to about 150 acre feet.

A portion of the soil eroded from mountain meadows will be deposited in channels and sand washes above the reservoir. It is, therefore, necessary to make some estimate of this volume. A comparison of the mechanical analysis of reservoir deposits and meadow soils, Tables 10 and 11, shows that meadow soils exceed reservoir sediment by about 20 percent in the coarsest fraction; that is, coarse sand. This fraction is the one most likely to deposit above the reservoir. The percent of medium sand is about the same in both reservoir and meadows. On the other hand, reservoir deposits of silt, clay and fine sand exceed the finer soil fractions in meadows by about 20 percent. From these data, the inference may be drawn that the depositing volume of eroded meadow sediment above the reservoir is equivalent to the proportion of meadow soil greater in size than reservoir sediment, or 20 percent.

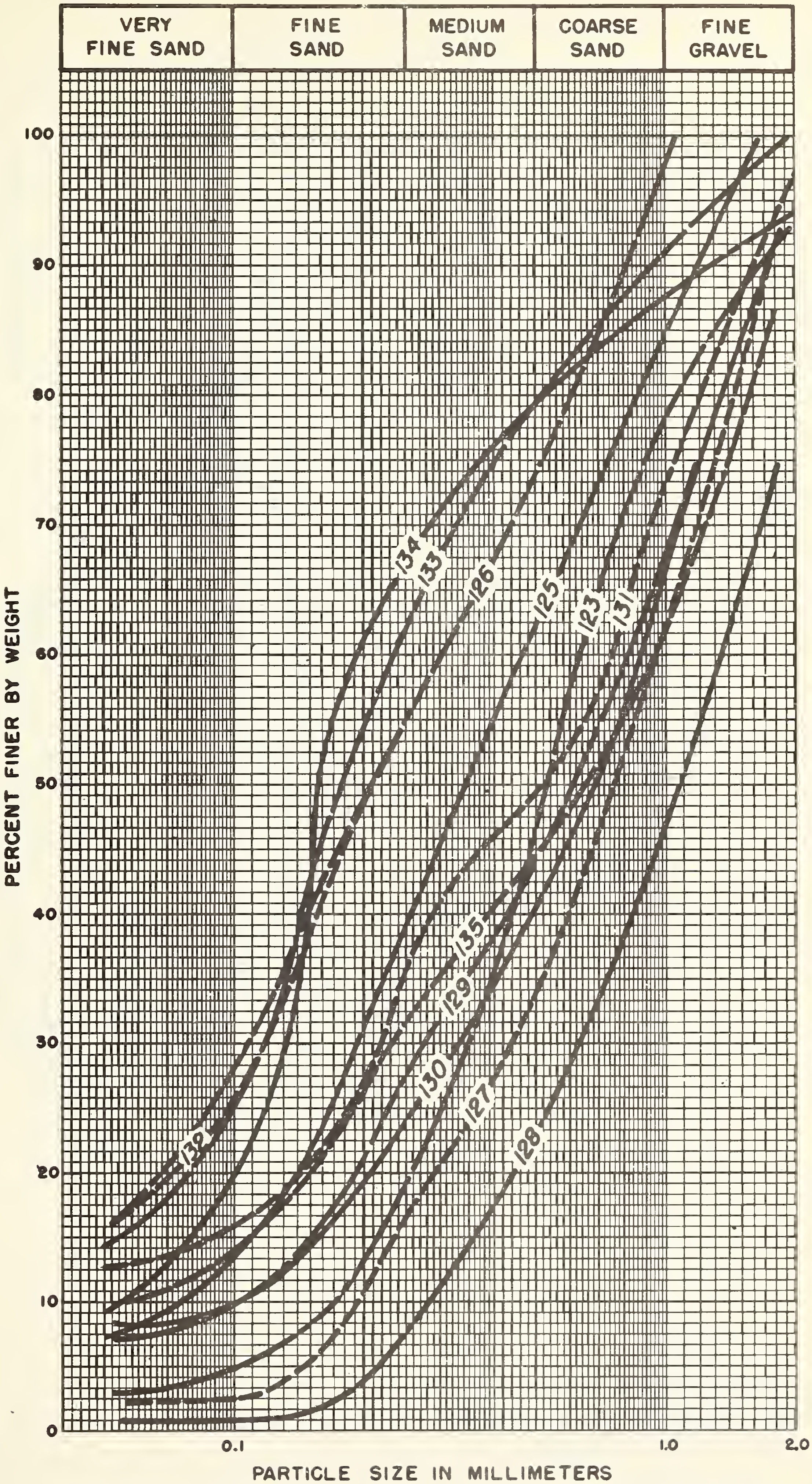
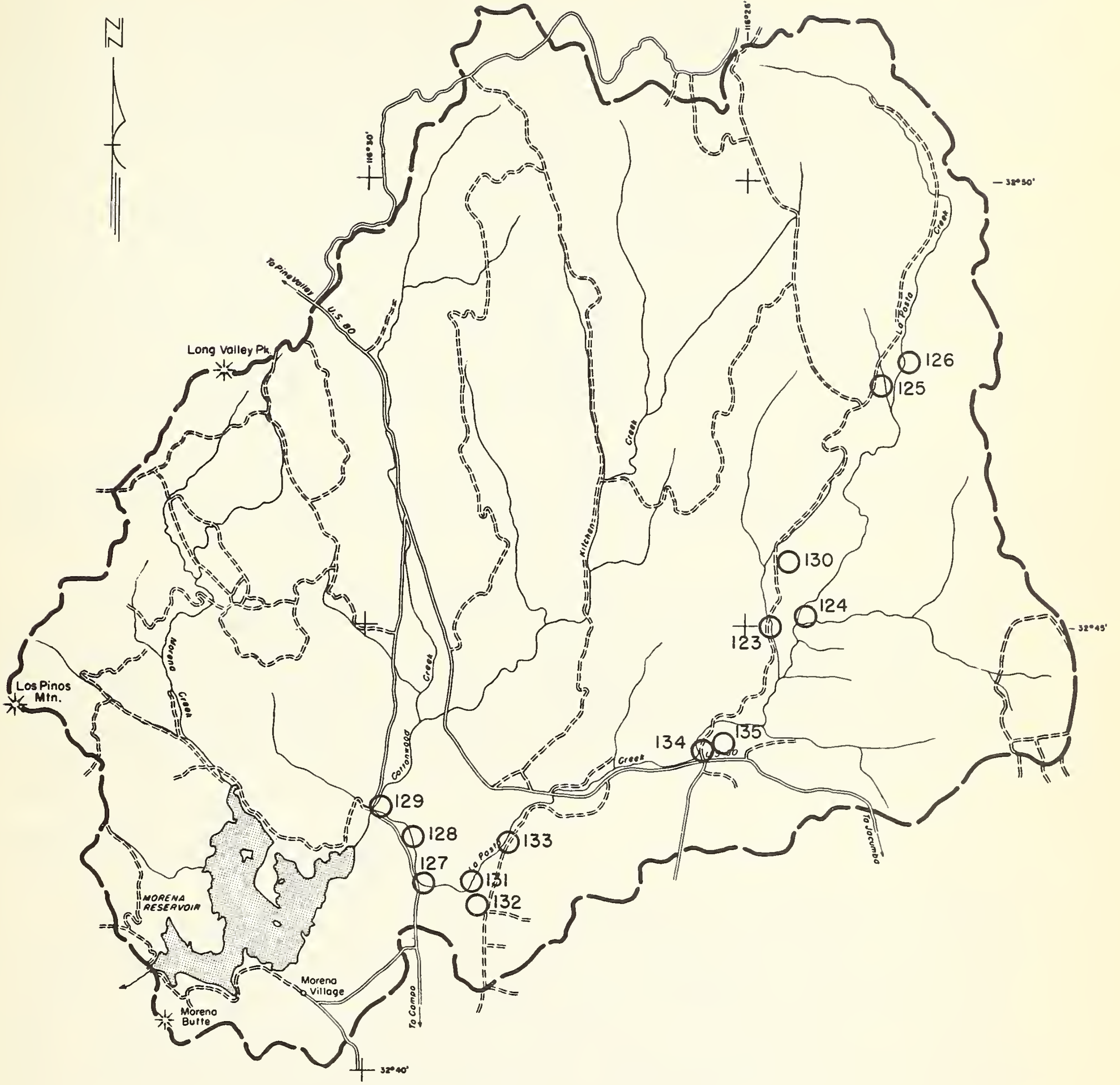


FIGURE 7 Mechanical analysis of sediment, La Posta Creek channel deposits and mountain meadow soils above Morena Reservoir including two watershed soils numbers 130 and 135.

7-L-14073

AGR-SCS-PORTLAND, ORE NOV 1953



MAP 6

LOCATION OF

CHANNEL, MEADOW AND WATERSHED SLOPE SAMPLES

MORENA RESERVOIR WATERSHED

SAN DIEGO COUNTY, CALIFORNIA

NOVEMBER 1953

SCALE IN MILES

AGR-SCS-PORTLAND, ORE NOV 1953

REMEDIAL PROGRAM AND COSTS

MOUNTAIN MEADOW STABILIZATION

Types of measures considered for mountain slope and meadow stabilization in the Morena Reservoir Watershed are those which have been generally applied in other watersheds in Southern California. Earth fill structures are considered for stabilization of most valley trenches. These are to have weeps for drainage of water through the dams in addition to side spillways for discharge of flood water. It is planned that stabilization structures shown on Map 1 will be the key stabilization structures. After the storage space is filled with sediment and a debris slope above spillway level is established, it may be desirable to build some supplementary check dams above the key structures. The dam or dams will bring valley trench aggradation to the desired level when the key structure does not do so. Temporary water storage on the meadows above the void of the trenches is not contemplated. Overland flow will occur, however, at least on Cameron and Coogan Meadows.

Structures No. 1 and 2 are intended to stabilize deposits immediately above the reservoir. Their purpose is to prevent the sediment from being carried into the main basin which remains the principal water storage area.

The site of each key structure was located in the field. Sufficient cross-sections and other engineering data were obtained to make cost estimates, but no geologic investigations were made at the sites. These reconnaissance cost estimates of types, sizes and costs are given on Table 12. The 0.1 percent occurrence flood flow discharges which determined the size of the design spillways, as well as the calculated flows of lesser storms, are given in Table 15.

WATERSHED SLOPE STABILIZATION

The proposed slope treatment program is designed to give maximum protection for existing cover against large fires, and to improve cover wherever soil and precipitation make this possible. The practices recommended are designed to reduce the total average burned area per year from 4 percent to 0.1 percent. The portion of the slope protection practices concerned with planting and wild life habitat improvements will be undertaken by the Forest Service under the regular program of that agency. This is also true for certain erosion control work now being done by fire crews on low hazard days (based on fire danger rating index). The description, cost and annual operation and maintenance of Slope Erosion Control Practices are given in Table 14.

DESIGN HYDROLOGY FOR STABILIZATION STRUCTURES

The hydrology of San Diego County was studied in order to determine probably rates of runoff at the sites of proposed structures above Morena Reservoir.

The climatic homogeneity of the areas involved was first tested. Precipitation records of all stations in and near the area were tabulated and analyzed. These records consisted of:

San Diego, 1850 to 1951
Barrett Dam, 1915 to 1951
Campo, intermittent, 1878 to 1951
Descanso, intermittent, 1897 to 1951
Cuyamaca, 1887 to 1951
Alpine, 1936 to 1945
Morena Dam, 1941 to 1951
Boulevard, 1944 to 1951

San Diego with 101 years of record was used as a key station and all the others were related to it. Correlation coefficients of seasonal precipitation at San Diego and that of other stations were as follows:

Cuyamaca	- 0.743	Boulevard	- 0.817
Descanso	- 0.806	Alpine	- 0.832
Morena	- 0.946	Barrett Dam	- 0.845
		Campo	- 0.625

All of these correlation coefficients are highly significant except that of San Diego and Boulevard which is only significant. These high correlation coefficients indicate that the area is homogeneous in so far as seasonal precipitation is concerned.

The relationship between maximum monthly precipitation at San Diego and several other stations was also significantly related. This further indicates the homogeneity of the area as regards precipitation.

Seasonal precipitation apparently varies directly with altitude in this area. Elevations of the several precipitation stations varied from 87 feet at San Diego to 4677 feet at Cuyamaca. The correlation coefficient of severn station (Boulevard was eliminated from this test because it is on the desert side of the Divide) elevations and seasonal precipitation was 0.874, being highly significant. The regression equation was $P = 0.005E + 7.7$ where P = Precipitation and E = Elevation above sea level in feet. The average elevation of the watersheds under investigation is approximately 4500 feet. Substituting this value in the above equation indicates average precipitation of 30 inches per year. Rough isohyets based on average station precipitation as somewhat modified by altitude and topographic orientation, indicate average annual precipitation is approximately 27,5 inches in the area concerned. Very probably, therefore, average annual precipitation is within these limits.

TABLE 12 - RECONNAISSANCE SURVEY ESTIMATES OF TYPES, SIZES AND COSTS OF

Structure Number	1 & 2	3	4	5	6
Location	Deposit Area immediately above Reservoir	Coogan Meadow	Glencliff Meadow	Crouch Meadow	Cameron
Type	Rock fill Barrier or dike	Earth dike w/concrete lined spillway	Earth fill dam w/spillway excavated in rock	Earth fill dam w/spillway excavated in rock	Modified arch-gravity concrete
Approximate Size (Cubic Yards in dam)(rounded) *	2,400	4,800	51,000	20,000	2,050
Approximate Construction Cost* Dollars (rounded)	25,900	2,800	28,100	9,050	145,650
Contingencies (15% of Construction Cost) Dollars (rounded)	3,900	400	4,200	1,350	21,850
Total Cost ** Dollars (rounded)	29,800	3,200	32,300	10,400	167,500
Annual Operation and Maintenance Costs Dollars per Year (rounded)	745	100	380	280	1,550

* Based on reconnaissance survey data.

** Costs for engineering, administration, overhead and supervision not estimated since they will vary according to source of funds, which cannot be determined now.

MOUNTAIN MEADOW STABILIZATION STRUCTURES - MORENA RESERVOIR WATERSHED

6A	7	8	9	10	11
Meadow	Foster Meadow			Thing Meadow	
Earth fill dam w/ excavated spillway	Raise Foster dam (earth) w/concrete lined spillway	Earth fill dam w/ excavated spillway	Earth fill dam w/ spillway excavated in rock	Earth fill dam w/ spillway excavated in rock	Earth dike diversion
5,500	9,600	12,000	10,000	30,000	6,400
1,500	9,600	10,700	8,750	24,800	2,300
200	1,450	1,600	1,300	3,700	350
1,700	11,050	12,300	10,050	28,500	2,650
Included W/No.6	290	310	280	600	100

TABLE 13 - PROPOSED MOUNTAIN SLOPE EROSION CONTROL PRACTICES
MORENA WATERSHED

	Quantity	Unit	Unit Cost Dollars	Installation Cost Dollars	Annual Maintenance Dollars
I. FIRE CONTROL PRACTICES					
A. Construct firebreak frontline from Laguna Jct. on Highway 80 west side to Morena bridge on Buckman Springs-Campo Road	8	miles	500	4000	200
B. Strip burn and motorize fire-break connecting agricultural and open lands along the Corte Madera Plateau	150	acres	10	1500	75
C. Strip burn brush areas to connect open grass and woodland areas throughout Kitchen-La Posta-Cottonwood zone.	500	acres	3	1500	150
D. Construct firebreak from Laguna Junction on NE side of highway 80 to LaPosta, connecting flats and natural openings. Discing 20' strip along highway wherever possible.	12	miles	500	6000	300
E. Hazard reduction on Laguna Road from Laguna Junction to Crouch meadows, fireproof road strip 200 feet between cuts, and plant to trees - Penny Pines planting contributed - $730.00	1	mile	500	500	50
F. Construct motorized firebreak from Crouch Meadows to Morris Ranch TT. Contribute planting $730.00	6	miles	500	3000	150
G. Morena Dam Crossing. Construct tie from dam to Forest Service TT.	(Since this work is on city property and at dam site, would be more properly done by city).				
H. Rehabilitate Kitchen Creek TT to provide a through road from Highway 80 to Laguna	3	miles		40,000	600

TABLE 13 - PROPOSED MOUNTAIN SLOPE EROSION CONTROL PRACTICES
(Continued) MORENA WATERSHED

	Quantity	Unit	Unit Cost Dollars	Installation Cost Dollars	Annual Main. Dollars
I. FIRE CONTROL PRACTICES (Continued)					
I. Replace two burned fire water storage tanks on Sheepshead TT with 2000 gal. reinforced concrete tanks.	2	tanks		3000*	150
J. Develop spring and construct 2000 gal. reinforced concrete fire water storage tank south end of Sheepshead Meadow	1	tank		1500*	75
K. Construct 1000 gal. reinforced fire water storage tank on Morris Ranch TT at east Forest Boundary	1	tank		1500*	75
L. Develop spring and construct 1000 gal. storage tank 1 mile south Morris Ranch TT on Fred Canyon TT.	1	tank		1500*	75
M. Construct 2000 gal. water tank at Glencliff Campground. (Tank to be pumped full in spring by tanker).	1	tank		1250*	100
N. Develop spring and construct 2000 gal. water storage tank at Junction Morena-Stokes TT and Kernan TT.	1	tank		1500*	75

* Labor contributed by Fire Crews.

II. PROTECTION FORCES		
A. Increase manning at Cameron G.S. Bring up to 100 percent planned strength (5 men)	13 Payperiods @ 120.00 (2 men) =	$3120.00
B. Increase manning at Laguna G.S. Bring to 100% planned strength. (5 men) Finance 50% chargeable to Morena Watershed	13 Payperiods @ 120.00 =	$1560.00
C. Pine Valley - increase manning by adding two men. Affects 50% of Morena drainage.	13 Payperiods @ 120.00 =	$1560.00

TABLE 13 - PROPOSED MOUNTAIN SLOPE EROSION CONTROL PRACTICES
(continued) MORENA WATERSHED

	Quantity	Unit	Unit Cost	Installation Cost	Annual Main.
			Dollars	Dollars	Dollars
III. MINOR EROSION CONTROL STRUCTURES AND ROAD CONTROL					
A. Construct small gully plugs, check dams, aprons and gutter checks.	300	structures	10	3000*	1000

* Labor contributed by Fire Crews.

TABLE 14 - SUMMARY OF REMEDIAL PRACTICES AND COSTS

	Quant.	Unit	Install.* Cost	Average Annual Install. Cost	Annual. Oper. & Main. Cost	Total Annual Cost
			dollars	dollars	dollars	dollars
MOUNTAIN SLOPE TREATMENT						
Fire Control Practices						
Firebreaks, etc.	27	miles	13,500	423	700	1,123
Rehabilitate TT.	3	miles	40,000	1,252	600	1,852
Strip Burning	650	acres	3,000	94	225	319
Water Developments	7	tanks	10,250	321	650	971
Protection Forces						
Increased manning of 3 guard stations	39	pay periods			6,240	6,240
Minor erosion control structures	300	Gully plugs, etc.	3,000	94	1,000	1,094
Subtotal			69,750	2,184	9,415	11,599
MOUNTAIN MEADOW STABILIZATION						
Deposits Immediately Above Reservoir	2	rockdams	29,800	933	745	1,678
Coogan Meadow	1	earth dike	3,200	100	100	200
Glencliff Meadow	1	earth dam	32,300	1,011	380	1,391
Crouch Meadow	1	earth dam	10,400	326	280	606
Cameron Meadow	1	conc. dam	169,200	1/ 5,296	1,550 1/	6,846
Foster Meadow	3	earth dam	33,400	1,045	880	1,925
Thing Meadow	2	earth dam	31,150	975	700	1,675
Subtotal Costs			309,450	9,686	4,635	14,321
Total Costs			379,200	11,870	14,050	25,920

* Based on prices in 1952

1/ Includes installation and maintenance on earth dam

A study also was made of available stream flow records in this general area. Flow records for streams within the area concerned are not available. Stream flow records analyzed were at the following stations:

Cottonwood Creek above Tecate Creek, 1937 to 1949.
Tia Juana River near Dulzura, same period.
Tia Juana River near Nestor, Ditto.
Campo Creek near Campo, Ditto.
Sweetwater River near Descanso, 1914 to1927.
San Diego near Santee, 1914 to 1949.
Santa Ysabel Creek near Mesa Grande, intermittent, 1914 to 1949.
Santa Ysabel Creek near Ramona, intermittent, 1914 to 1949.
San Luis Rey River near Bonsall, 1930 to 1949.
Short time records at several other stations.

The station record at Santee on the San Diego River was the longest available in the area. It, therefore, was utilized as a key station and the other shorter records were related to it. In order to determine whether or not the area was uniform in the production of peak rates of runoff, correlation coefficients and regression equations were determined for San Diego near Santee and other stations in the area. Most of these streams have a part of their watersheds controlled by reservoirs. In the study of peak flows, it was assumed that such reservoirs would control inflow to them and that outflow would be relatively small compared to peak flows at the stations. In other words, it was assumed that the uncontrolled drainage areas above the stations contributed peak flows. All flows were reduced to cubic feet per second per square mile. On this basis, correlation coefficients were as follows with reference to San Diego River at Santee:

Campo Creek	- 0.943
Sweetwater near Descanso	- 0.869
Cottonwood Creek	- 0.956
Tia Juana near Dulzura	- 0.952
Jamul Creek	- 0.781
Tia Juana near Nestor	- 0.848

Several other stations tested were also significantly related to San Diego. Those mentioned above, however, are the ones that surround the area under study.

The relationship between peak flows and seasonal precipitation and peak flows and maximum monthly precipitation were also investigated. These were found to be significantly related in most instances, particularly as regards peak flows and maximum monthly precipitation.

The highly significant relationship between peak flows of San Diego River near Santee and peak flows of the several streams surrounding the area under study permitted use of a frequency curve developed for the San Diego to be used in conjunction with regression equations to determine probable peak flows on the other streams that may be expected at various frequencies.

Flood flows in cubic feet per second per square mile against drainage area were plotted on logarithmic paper for each year of common record for several streams in the area. The average slope of the curves was about - 0.5. It may be concluded, therefore, that in this general area flood flows in cubic feet per second per square mile vary approximately inversely as the square root of the drainage area in square miles.

Since all of the streams under study for proposed structures were smaller to considerably smaller than any of the streams that have been gaged, it was necessary to determine the relationship between drainage area sizes and production of runoff.

Thirty-six years of record are available for San Diego River near Santee. The annual floods during this period of record were used in determining a flood frequency curve for this river at this station. The upper part of this curve is shown in Figure 8. The significant relationship between flood flows of San Diego River near Santee and Sweetwater River near Descanso, Cottonwood Creek near Tecate Creek and Campo Creek near Campo were used to prepare frequency curves for these three latter named streams that have records too short to permit determination of frequency from their own records.

The frequency curve for San Diego River, the key station, was tested for skew after Hazen and Foster. Computed points are shown on Figure 8. Extrapolation of these curves to the 0.1 percent occurrence is not warranted but, if preliminary information is desired, the relationships shown by the Foster points can be utilized. These points indicate that the 0.1 percent rate is just twice the 1 percent rate. This relationship was used to obtain the preliminary estimate figures shown in Table 15. Flows tabulated hereafter for the 1 percent occurrence should therefore be doubled to determine what might be expected once in 1000 years. These values are shown in the tabulation.

The frequency curves for Cottonwood, Sweetwater and Campo in Figure 8 were used to estimate flood flows in cubic feet per second per square mile for further use in determining flood flows for the streams under study. Probable rates of flow in cubic feet per second per square mile for 1, 2, 5, 10, and 20 percent occurrences were read from the frequency curves. These rates of flow were plotted on logarithmic paper against the drainage areas of the three streams. Curves with negative 0.5 slopes were then projected back from the points thus plotted and probable flood flows in cubic feet per second per square mile were read for these several curves for each of the watersheds in question at their respective drainage areas.

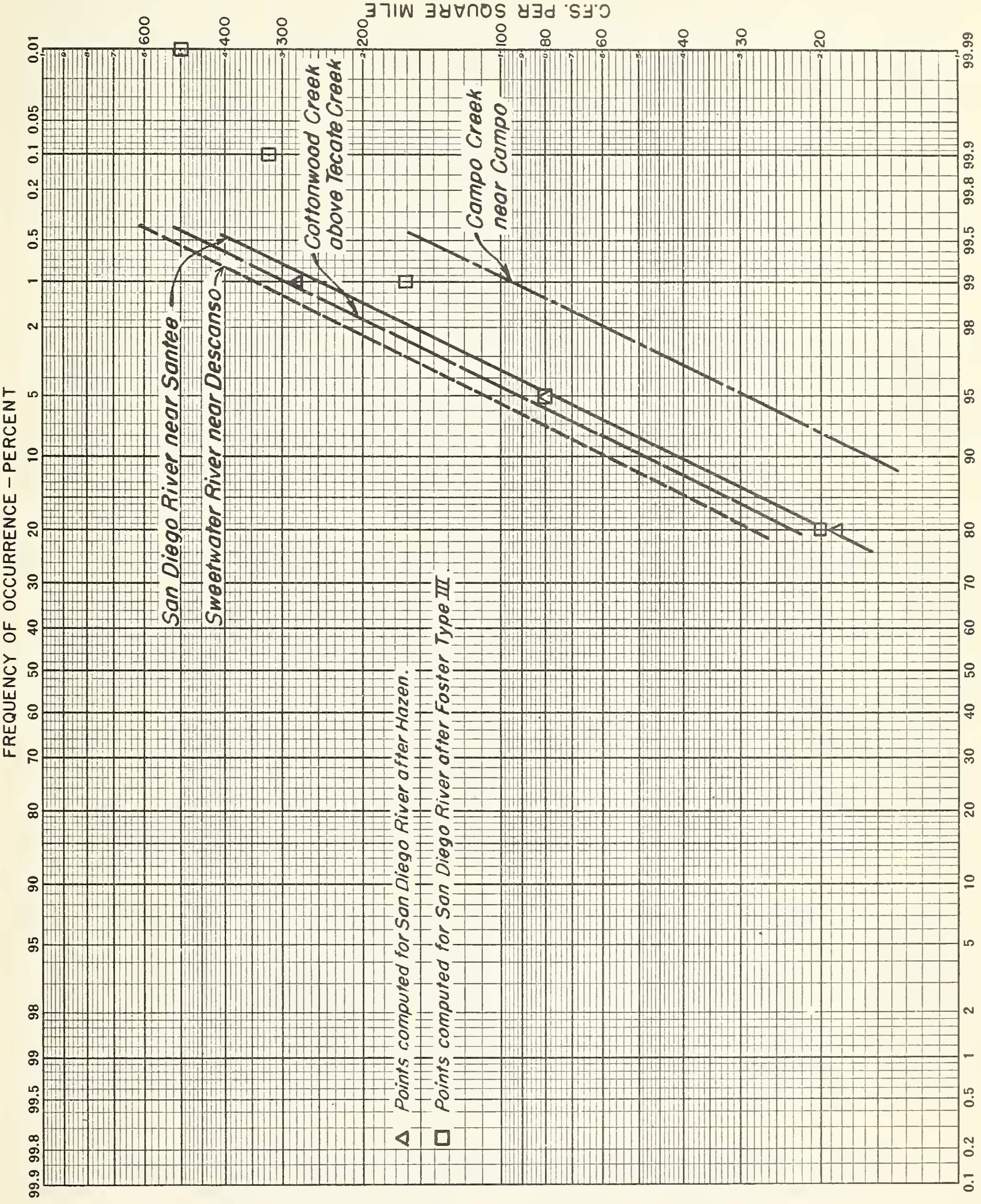


FIGURE 8 Frequency of flood flows, San Diego County Streams

Rates of flow from Sweetwater and Cottonwood drainage areas are undoubtedly higher than those to be expected from the Morena drainage area. Also, very probably, rates of flow from Campo Creek are lower than those to be expected from the areas under study. Probable watershed precipitation rates indicate that rates of flow to be expected from the area under study would be about the average of those of Sweetwater, Cottonwood and Campo. If this assumption is correct, rates of flow that may be expected at the several stations above Morena Reservoir are as shown in Table 15. An exhaustive study of storm precipitation, watershed runoff rates, and stream flow which would involve the establishing of additional rain gages and gaging stations within the area under investigation would be required to determine whether or not the above assumption is correct.

For the purpose of this study, it is believed that the flood flows tabulated in Table 15 may safely be used for preliminary design purposes. It is suggested, however, that additional recording rain gage and stream gaging stations should be installed in the watershed in order that data obtained might be used in the final design of structures if they should be built.

EVALUATION OF BENEFITS

MONETARY BENEFITS FROM REDUCTION IN RESERVOIR SEDIMENTATION

The City of San Diego has determined the dependable or safe water yield of each major impounding reservoir in the system. This determination permits calculation of the long time water supply available from watersheds within the County. The planning of additional stream impoundment or imported water requirements is thereby permitted. The term "safe yield" means the amount of water that can be safely withdrawn from the reservoir through a period of sustained drought. In determining safe yield, a number of factors are considered. These are: reservoir capacity, inflow, evaporation and spillway losses in conjunction with anticipated drawdown for use.

Based on the available information on these factors, the storage loss of 7652 acre feet by 1948 has resulted in a reduction in safe yield of from 4.60 to about 4.15 million gallons per day. The total loss of .45 million gallons per day in the 38.3 years of sedimentation is equivalent to an annual loss in safe yield of 4,288,512 gallons or 13.161 acre feet. Since the average annual sediment accumulation is 201.4 acre feet, the deposition os one acre foot of sediment results in a safe yield loss of .06535 acre foot.

Other factors used in considering the monetary value of reservoir sedimentation include the values of $12.00 and $35.00 for reservoir water per acre foot as discussed on page 2 of Appendix. An acre foot of sediment accumulating in the reservoir will not only reduce the safe yield the year of accumulation, but for the remaining life of the reservoir. An increasing annuity of one for the 108 years of estimated remaining life is therefore used in determining the monetary worth of preventing one acre foot of sedimentation. Deposition will occur throughout the remaining life of the reservoir. The reduction of the rate of sedimentation at some point in the future will have a different value than the reduction achieved this year. The present value of an annuity which increases by 1 per year was therefore used.

The meadow stabilization practices are designed to prevent erosion of valley trenches. It has been estimated that erosion of valley trenches will continue at a uniform rate for the next 50 years and then for the remaining life of the reservoir at a slightly lower rate. The steps taken in the calculations include consideration of this change in rate. On the other hand, the evaluation of the slope treatment program is based on a uniform contribution from this source. The steps shown in Table 18 are for evaluation of the reservoir benefits from a valley trench stabilization program and for an evaluation of benefits from a slope treatment program.

The watershed treatment practices described in the preceding pages are evaluated separately where they function independently of other measures. As an example, for one or a group of key valley trench structures within one trench to serve their purpose, does not require that other structures be installed, either in the one or other valley trenches, nor on the mountain slopes. Where certain measures are dependent on other measures, such as one of a series of small gully plugs which may fail if the other checks are not built, their cost and anticipated benefits are compared as a group. A fire control practice which may prevent a fire from sweeping to other parts of the watershed is considered as one of a group of dependent practices which, if not installed, may defeat the purpose of similar installations.

The benefits to be derived from the practices are two-fold; those benefits that are subject to a monetary evaluation and those generally considered to be social values not easily susceptible to monetary evaluation. The former benefits are, in turn, two-fold; those affecting the reservoir through reduction in sediment volume and those accruing to the sites on which the measures are installed. The methods and result of calculations of monetary benefits to the City of San Diego, to watershed users, of stabilizing potential reservoir deposits, are described in detail below.

The practices needed for mountain slope erosion control should reduce the average rate of burn from 4 percent to 0.1 of 1 percent per year. These practices and minor gully stabilization will ultimately result in a major reduction of erosion and reservoir sediment volumes from this source. Estimates of this reduction are given in Table 16.

TABLE 15 - RATES OF FLOOD FLOW THAT MAY BE EXPECTED AT INDICATED FREQUENCIES AT SITES FOR STABILIZATION PROGRAM

Structure No.	Drainage Area	Flood Flow in Cubic Feet per Second					
		0.1%	1%	2%	5%	10%	20%
1 & 2	87	35,000	17,400	10,800	5,400	2,870	1,350
3	16.4	15,000	7,593	2,903	2,345	1,246	525
4	9.52	11,600	5,807	3,570	1,809	952	447
5	3.66	7,000	3,587	2,196	1,098	600	278
6 & 6A	43.8	24,800	12,439	7,709	3,854	2,015	964
7	27.35	19,600	9,791	6,072	3,063	1,614	766
8	6.00	9,200	4,620	2,850	1,422	750	360
9	20.16	16,800	8,426	5,201	2,621	1,391	665
10	10.36	11,800	5,905	3,730	1,875	994	466
11	6.94	9,800	4,927	3,026	1,527	805	382

Table 16 - TOTAL VOLUME OF ERODED MATERIAL AND RESERVOIR SEDIMENT FROM MOUNTAIN SLOPES DURING REMAINING USEFUL LIFE OF RESERVOIR WITH NEEDED PRACTICES APPLIED

Subwatershed	Eroded Material Acre Feet	Reservoir Sediment Acre Feet
La Posta Creek	300	174
Cottonwood Creek	378	219
Kitchen Creek	797	462
Morena Creek	300	174
	1,775	1,029

The difference in amount of sediment from mountain slopes expected to accumulate in the reservoir without application of needed practices (11,607 acre feet in 108 years) and with needed practicas (1,029 acre feet) is 10,578 acre feet. This volume, or an average of about 97.9 acre feet per year is the amount of sediment to be prevented from entering the reservoir by the installation of mountain slope practices.

Installation of stabilization structures in the mountain meadows and reservoir will prevent further erosion of valley trenches. On page 26 it was explained that mountain meadow erosion without stabilization is expected to continue at one rate for approximately the next 50 years and at a slightly reduced rate from the 50th to the 108th year. Only those meadows are included in which stabilization structures are proposed. Structures for headwater meadows of Kitchen Creek and Morena Creek are not included with the practices considered. Cost estimates and evaluations similar to those prepared for this report should be made in these areas prior to the watershed-wide installation period.

In addition to the soil material in mountain meadows and perhaps in some of the aggraded channels and washes, that would be stabilized by structures, the storage space behind structures will trap sediment that would otherwise be carried to Morena Reservoir. After due consideration of the sediment sizes now in Morena Reservoir (see Table 4) and the probable storage capacity of valley trench structures, it is estimated that the storage capacity behind structures up to spillway level will be filled with sediment which would otherwise be deposited in Morena Reservoir. The sediment that will come to rest on a debris slope above spillway level will be of a size comparable to sediment now found in the channels. After depositing behind structures, the stream will pick up similar material downstream if it is available. Table 10, indicates that a large volume of sediment is available, and Table 11, that the sediment is of a size likely to replace that deposited on a slope behind structures. The material deposited on a slope above mountain meadow stabilizers should, therefore, be replaced by downstream sediment without reduction in reservoir sedimentation.

Some sediment otherwise carried into the reservoir will also deposit on Coogan and Cameron Meadows once the valley trenches have been partially filled with sediment. An additional 20 percent of eroded mountain meadow soils, whose volume is not shown on Table 17, will deposit on flood plains and sand washes before reaching the reservoir.

TABLE 17 - POTENTIAL AND EXISTING RESERVOIR SEDIMENT TO BE STABILIZED BY STABILIZATION STRUCTURES

LOCATION	TYPE OF SEDIMENT RETENTION			
	Meadow or Existing Deposits	Behind Stabilization Structures	Flood Plain Deposition	Total
	Ac. Ft.	Ac. Ft.	Ac. Ft.	Ac. Ft.
Deposits Immediately Above Reservoir	600	15	--	615
Coogan Meadow	495	5	150	650
Glencliff Meadow	616	127	--	743
Crouch Meadow	200	15	--	215
Cameron Meadow	1265	82	200	1,547
Foster Meadow	840	135	--	975
Total	4,016	379	350	4,745

EVALUATION OF BENEFITS FROM EROSION CONTROL
PRACTICES IN REDUCING RESERVOIR SEDIMENTATION

TABLE 18 - FACTORS USED IN EVALUATION OF BENEFITS TO RESERVOIR FROM MOUNTAIN MEADOW AND VALLEY TRENCH STABILIZATION PRACTICES

1. Average annual loss in reservoir capacity - 201.4 acre feet

2. Average annual loss in net safe yield = 13.265 acre feet

3. Therefore the average annual loss in net safe yield per acre foot of sediment = 0.06535 acre foot.

4. The annual value of an acre foot of net safe yield for the first 18 years is assumed to be $12.00.

5. The present value of an annuity increasing by 1 per year for 18 years at 3% = 119.76718

6. Then $12.00 x 119.76718 x 0.06535 = 93.9214 = factor used in multiplying by average annual acre feet of potential reservoir sediment to be stabilized by proposed practice during first 18 years after installation.

7. The annual value of an acre foot of net safe yield after the first 18 years is assumed to be $35.00.

8. The present value of an annuity increasing by 1 per year for 32 years at 3% (between the 18th and 50th years) is 285.78811. Brought to present worth from the 18th year, this factor amounts to 285,78811 x 0.58739 = 167.86908.

9. Then $35.00 x 167.86908 x 0.06535 = 383.9585 = factor used in multiplying by average annual acre feet of potential reservoir sediment to be stabilized by proposed practice between the 18th and 50th year after installation.

10. The present value of an annuity increasing by 1 per year for 58 years (50th to 108th year) (estimated remaining life of reservoir) = 591.17056. Brought to present worth from the 50th year, this factor amounts to 591.17056 x 0.22811 = 134.85192.

11. Then $35.00 x 134.85192 x 0.06535 = 308.9120 = factor used in multiplying by average annual number of acre feet retained by proposed practice between the 50th and 108th year after installation.

12. The amount of sediment accumulating in the reservoir between the 1st and 18th year will result in a permanent loss in safe yield for the remaining life of reservoir, or 90 years. The present value of an annuity of 1 for 90 years is 31.0024 at 3% interest, but the value of 1 18 years from now is worth only 0.7002 today. Therefore, 31.0024 x 0.7002 or 21.7079 = the value of 1 for 90 years at 3%, deferred 18 years. One acre foot of sediment is equivalent to 0.06535 acre foot loss in safe yield. The value of 1 acre foot of safe yield loss per year = $35.00 after the 18th year. Therefore, 21.7079 x 0.06535 x $35.00 = factor used in computing the value of preventing sediment from entering the reservoir between the 18th and 108th year. This factor is 49.6510.

13. The amount of sediment accumulating in the reservoir between the 18th and 50th year will result in a permanent loss in safe yield for the remaining life of the reservoir, or 58 years. The present value of an annuity of 1 for 58 years = 27,3310 at 3% interest, but the value of 1 50 years from now is worth only 0.2281 today. Therefore, 27.3310 x 0.2281 or 6.2342 = the value of 1 for 90 years deferred 50 years. One acre foot of sediment is equivalent to 0.06535 acre foot loss in safe yield. The value of 1 acre foot of safe yield loss per year = $35.00. Therefore, 6.2342 x 0.06535 x $35.00 = factor used in computing the value or preventing sediment from entering the reservoir between the 50th and 108th year. This factor is 14.2590.

14. The present value of an annuity of 1 increasing by 1 per year for the remaining 90 years life of the reservoir after the 18th year equals 843.0545 at 3% interest. The value of water after the 18th year is $35.00 per acre foot and 1 acre foot of sediment reduces safe yield by .06586 acre feet. Therefore, 843.0545 x $35.00 x 0.06535 = 1928.2825. But the value of 1 18 years from now is worth only 0.7002 today. Therefore, 1928.2825 x 0.7002 = 1350.1834 = factor used in computing the value of preventing sediment from entering the reservoir through a slope treatment program between the 18th and 108th year.

FACTORS USED IN EVALUATION OF BENEFITS TO RESERVOIR FROM SLOPE TREATMENT PRACTICES

Steps 1-7 and step 12 are the same for evaluation of slope treatment practices as for meadow stabilization practices. Step 14 is used in evaluation of benefits from structures 1 and 2 and slope treatment practices.

EVALUATION OF BENEFITS TO RESERVOIR FROM STABILIZING SEDIMENT AT SPECIFIC LOCALITIES

In accord with the steps given above in determining factors to be used in evaluation of benefits to reservoir, let A = factor determine in item 6 (93.9214), B = factor in item 9 (383.9585), C = factor in item 11 (308.9120), D = factor in item 12 (49.6510), E = factor determined under item 13 (14.2590), and F = factor in item 14 (1350.1834).

The evaluation is based on the estimated average annual amounts of potential reservoir sediment to be stabilized. These estimates for the mountain meadows are given in the following table.

TABLE 19 - AVERAGE ANNUAL AMOUNT OF POTENTIAL RESERVOIR SEDIMENT IN MOUNTAIN MEADOWS TO BE STABILIZED BY INSTALLATION OF NEEDED PRACTICES

Meadow or Area of Deposit	First 50 years Acre Feet	Remaining 58 years Acre Feet
Deposits above reservoir spillway level	5.7	5.7
Coogan Meadow	8.0	4.3
Glencliff Meadow	7.0	4.6
Crouch Meadow	2.3	1.5
Cameron Meadow	18.4	10.8
Foster Meadow	12.0	6.5
Thing Meadow	35.5	24.0

The average annual amount of potential reservoir sediment from mountain slopes to be prevented from entering the reservoir by installation of needed practices is estimated at 97.9 acre feet for the remaining life of the reservoir.

An example of the method used in calculating the benefits to the reservoir by stabilization of a specific meadow and by mountain slope treatment follow. Benefits to the reservoir from structures in other meadows were evaluated similarly to that of Thing Meadow.

EVALUATION OF BENEFITS FROM STABILIZATION OF POTENTIAL RESERVOIR DEPOSITS IN THING MEADOW (Structures 10 and 11)

A	=	93.9214 x 35.5 (average annual amount first 50 years)	= 3,334.21
B	=	383.9585 x 35.5	= 13,630.53
C	=	308.9120 x 24.8 (average annual amount remaining 58 years)	= 7,413.89
D	=	49.6510 x 35.5 x 18	= 31,736.99
E	=	14.2590 x 35.5 x 32	= 16,198.22
		Total benefits to reservoir from Thing Meadow stabilization	72,303.84

The average annual equivalent value of the benefit for 108 years at 3% is : $2,263.11 (72,303.84 x .0313)

EVALUATION OF BENEFITS TO RESERVOIR FROM MOUNTAIN SLOPE TREATMENT

			Dollars
A	=	93.9214 x 97.9 (average annual amount for life of reservoir)	= 9,194.91
B	=	49.6510 x 97.9 x 18	= 87,494.99
F	=	1350.1834 x 97.9	=132,182.95
		Total benefits to reservoir from mountain slope treatment program	228,872.85

The average annual equivalent value of the benefit for 108 years at 3% is : $7,163.72 (228,872.85 x .0313)

DISCUSSION OF WATERSHED WATER YIELDS

It may be anticipated that mountain slope treatment and mountain meadow stabilization measures could affect watershed yields to Morena Reservoir. The facilities available to this study do not permit a quantitative evaluation of this phase of the problem. However, the following comments of a qualitative nature are made.

1. Effects of Mountain Slope Treatment on Water Yields. The proposed mountain slope treatment consists largely of improving protection of the cover vegetation against fire, and will result in increasing the average age and density of the cover. As cover conditions improve, losses from transpiration and interception increase. The increase, however, is largely offset by reduction of evaporation losses. The thin soil mantle of the mountain watershed slopes can retain only a limited amount of water. If the soil is without cover, the water is lost by evaporation; if with cover, the losses are caused by interception and transpiration.

Dense cover with its associated litter keeps soil pores open for rapid infiltration of water reaching the soil surface. Water going into the soil is disposed of slowly to deep underground storage, more rapidly by seepage to stream channels. Rain on the surface of bare soil, and muddy water running across bare soil, seals the pores and runs off very rapidly to build up flood peaks and carry down eroded materials as channel sediment. The chief benefit produced by good cover is, therefore, that of controlling rate of runoff, sediment load, and height of flood peaks. Water kept out of flood flows is released gradually to maintain streamflow later. The small additional use of water made by the denser vegetation is repaid both by the runoff control afforded and by the tremendous reduction in erosion losses.

"Some Aspects of Watershed Management in Southern California," CF&RES Misc. Paper No. 1, April 1951.

"Influence of Woodland Chaparral on Water and Soil in Central California," Calif. Dept. Natural Resources, 1948.

"Hydrologic Aspects of Burning Brush and Woodland-Grass Ranges in California," Calif. Dept. Natural Resources, 1947.

2. Effect of Mountain Meadow Stabilization on Water Yields. Restoration of gullied mountain meadows will have somewhat similar effects. As the gullies are filled in with sediment behind the channel barriers, water tables will rise. This improvement in soil moisture conditions will cause a return of dense meadow vegetation. The dense vegetation will use more water then the present sparse arid-type vegetation. However, present evaporation losses from the nearly bare soil surface will be considerably reduced.

Weep-holes provided in the channel barriers will permit percolation of water stored in the sediments to stream channels, and will augment summer season flow. Experience in Southern California shows that even where water-loving trees such as willow have come in on the accumulated sediments behind such barriers there is a small continuous flow produced.

Though no data are available to indicate quantitative effects of the program, again it is apparent that the additional demand on water by the change in vegetation will be largely offset by reduction of evaporation losses, and will be repaid further by reductions in sediment loads and flood peaks.

MONETARY EVALUATION OF ON-SITE WATERSHED BENEFITS FROM EROSION CONTROL PRACTICES

Structures built in the valley trenches that cut through mountain meadows will eventually improve the quality and quantity of forage. Earlier discussion has indicated that the mountain meadows furnish most of the native feed. Trenches cut in the meadows lower the water table and perennial grasses, rushes, and sedges are eventually replaced by sage and annuals. The key mountain meadow stabilization structures and supplemental fills, where necessary, will impound sediment almost to the original valley level. Filling of the trench will mean a sustained soil moisture level over much of the meadow area and maintenance of a higher water table. More water will be available for a longer period, not only from the upstream watershed but from side slopes as well.

In order to determine the value of improved forage, after valley trench stabilization, estimates were made of the present meadow condition and forage yield as well as the probable future condition and forage yield. It was found that present condition could be described by three site circumstances. These are: 1. Wet during entire season; 2. Wet and dry, mixed, and 3. Dry summer meadows wet only during the spring season. The approximate acres of meadow per cow for an eight months grazing season (April to November) are given in the following tabulation:

APPROXIMATE ACRES PER ANIMAL UNIT MONTH PER COW PER SEASON BY SITE CIRCUMSTANCES AND CONDITION

SITE CIRCUMSTANCE	CONDITION			
	Excellent Acres	Good Acres	Fair Acres	Poor Acres
Wet during entire season	0.6 - 0.7	0.7 - 0.9	0.9 - 1.4	1.4
Wet and dry meadows, mixed	1.0 - 1.3	1.3 - 1.7	1.7 - 2.5	2.5 - 5.0
Dry summer meadows, wet during spring season	1.8 - 2.3	2.3 - 3.5	3.5 - 7.0	7.0

Available information indicates that no meadow in the area can be considered in excellent condition. Also, that good wet meadow can be expected to produce about 45 pounds of beef per grazing month; fair wet 35 pounds; and fair wet and dry meadow and good dry about 30 pounds; fair dry meadow, 25 pounds; and poor, dry meadows, 20 pounds of beef per month per animal unit.

The area of each meadow subject to improvement was determined by planimetering from enlarged aerial photographs. It is assumed that upon filling of the trenches to design level that half the meadow areas will become wet during the entire season and that the other half, further removed from a source of perennial water, will be wet and dry meadow, mixed.

In order to determine the present value of an investment in meadow stabilization for improved grazing, it is necessary to estimate the number of years after stabilization that improvements in forage will start. It is also necessary to determine the length of time required to bring the meadows to maximum production. Maximum production is estimated to be either good condition, wet or mixed wet and dry meadows. Excellent condition could be achieved by careful management and fertilization.

The estimated length of time required for a meadow to produce additional forage was based on the assumption that no structures will impound water during the dry season. The storage space behind structures will therefore need to fill with debris before the water table will be raised. The rate of sediment accumulation in the valley trenches was estimated from data on sediment sources above each meadow.

An example of the method used in determining the value of improved forage in each meadow is given in Table 19. The interest rate used is 4 percent which is believed to be about the rate that on-site beneficiaries can borrow money. The gross return to the land from the increase in forage is estimated at one-third the gross value of the gain. The cost of production is about one-third the gross return to the land so that the net return from increase in forage due to installation of practices is two-thirds the gross return.

BENEFITS TO THE COMMUNITY

The benefits from enhanced recreational and aesthetic values in the watershed are difficult to adequately appraise. The benefit to the sportsman cannot be measured by the market value of the pounds of meat obtained while hunting, nor the benefit from picnicking and camping by the increased income of the local storekeeper. Such values as improved hunting, camping and scenic appearance which will be obtained by application of the practices for erosion and sediment control in the Morena Reservoir Watershed are therefore not evaluated in monetary terms. In general terms, such values include aids to the preservation of fishing and camping facilities about the reservoir and to the maintenance or improvement of Morena Village for living and recreational accommodation. Preservation and restoration of mountain meadows which are the major forage resource of livestock in the area will aid the general improvement, security and well-being of the community beyond the monetary benefit to individual ranchers. Adequate protection will minimize the damage to property and danger to life from brush fires. Improvement in vegetation will provide more plentiful food for game as well as a better habitat.

Table 20 - CALCULATION OF ON-SITE GRAZING BENEFITS FROM STABILIZATION OF CAMERON MEADOW

1. Present condition of 250 acres - fair condition, wet and dry meadow, mixed.

2. Present grazing capacity - 2 acres per cow season (8 months).

3. 250 acres divided by 2 = 125 cow seasons or for an 8-month grazing season, 1000 animal unit months.

4. The average animal unit per month gain under present condition is estimated to be 30 pounds.

5. The total beef gain in Cameron Meadow under present condition is therefore 30 x 1000 = 30,000 pounds, or at a price of $0.25 per pound, $7,500, gross value.

6. Under future improved conditions, 125 acres will be in good wet meadow and 125 acres in good condition, wet and dry mixed.

7. 125 acres of wet meadow in good condition will have a grazing capacity of 0.8 acres per cow season. 125 ÷ 0.8 = 156 cow seasons months. 156 x 8 (months) = 1,230 animal unit months. The average animal unit month gain under future improved conditions in good condition wet meadow is 45 pounds per month or 55,350 pounds per season.

8. 125 acres of meadow, good condition, wet and dry mixed will have a grazing capacity of 1.5 acres per cow season. 125 ÷ 1.5 = 83 cow seasons. 83 x 8 (months = 664 animal unit months. The average animal unit month gain under future improved conditions for 125 acres in good condition meadow, wet and dry, mixed is 35 pounds per month or 23,240 pounds per season.

9. 55,350 pounds (item 7) + 23, 240 pounds (item 8) = 78,590 pounds at $0.25 per pound = $19,648. $19,648 less $7,500 (item 5) = $12,148 gain in gross value with stabilization program.

10. The gross return to the land is estimated at 1/3 the gain in gross value, or $4,049. The cost of production is about 1/3 the gross return to the land, so that the net return from increased meadow production is $2,699.

11. The maximum benefits from meadow stabilization will accrue in 10 years. $2,699 ÷ 10 = $270 average annual gain for first 10 years.

12. The present value of an increasing annuity of $270 at 4% for 10 years = 41.992 x $270 = $11,338 = present value of the gain during first 10 years.

13. Meadow will be at ultimate improvement after 10 years Average annual net return at that time will be $2,699 or capitalized at 4% $67,475. But $67,475 deferred 10 years is worth only $67,475 x 0.676 = $45,613.

14. Then $11,338 (item 12) + $45,613 (item 13), = $56,951. But the start of benefits will not begin until second year after meadow stabilization, so $56,951 x 0.925 (present value of 1, 2 years hence) = $52,680. This is the on-site grazing benefit.

15. The average annual equivalent value of the benefit for 108 years @ 4% = $2,139.

The estimated present grazing condition and site circumstance of meadow areas and the probable condition after the full effects of stabilization have been realized are given in Table 21. The result of the calculations of on-site benefits for each meadow are given in Table 22. A comparison of costs and benefits is given in Table 23.

TABLE 21 - THE ESTIMATED PRESENT CONDITION AND SITE CIRCUMSTANCE OF MEADOW AREAS AND THE ULTIMATE CONDITION AFTER VALLEY TRENCH STABILIZATION

Meadow	Present condition	Site Circum-stance	Acres	Ultimate Condition	Site Circum-stance	Acres
Deposit Area above reservoir	Good	dry, wet during spring	45	Poor 1/	Dry 1/	45 1/
Coogan	Fair	wet & dry mixed	123	Fair 1/	Dry 1/	123 1/
Glencliff	Poor	dry, wet during spring	74	Good	Wet	37
				Good	Wet & dry mixed	37
Crouch	Poor	Wet & dry mixed	50	Good	Wet	25
				Good	Wet & dry mixed	25
Cameron	Fair	Wet & dry mixed	250	Good	Wet	125
				Good	Wet & dry Mixed	125
Foster	Poor	Dry, wet during spring	144	Fair	Wet	72
				Fair	Wet & Dry Mixed	72
Thing	Fair	Wet	175			
	Fair	Wet & Dry Mixed	175	Fair 11	Wet & Dry Mixed 1/	350 1/
	Fair	Wet & Dry Mixed	50	Good	Wet	35 2/
				Good	Wet & Dry	35 2/

1/ Extent of deterioration, if meadow not stabilized, rather than extent of improvement with stabilization.

2/ Includes 20 acres now in grain that is without net income value.

TABLE 22 - SUMMARY OF EVALUATED ANNUAL BENEFITS

	Benefits from Reduced Reservoir Sedimentation		On-Site Benefits		
	Potential Sediment Retention	Average Annual Benefits	Improved Meadow	Evaluated Monetary Benefits	Total Evaluated Annual Monetary Benefits
	Ac. Ft.	Dollars	Acres	Dollars	Dollars
MOUNTAIN SLOPE TREATMENT					
Fire Control Protection Forces Minor Erosion Control Structures	9,670	7,164	--	--	7,164
Subtotal		7,164			7,164
MOUNTAIN MEADOW STABILIZATION					
Deposits immediately above Reservoir	615	381	45	136	517
Coogan Meadow	650	499	123	251	750
Glencliff Meadow	743	445	74	235	680
Crouch Meadow	215	146	50	528	674
Cameron Meadow	1,547	1,157	250	2,139	3,296
Foster Meadow	975	749	144	720	1,469
Thing Meadow	3,170	2,263	420	907	3,170
Subtotal		5,640		4,916	10,556
Total Benefits		12,804		4,916	17,720

TABLE 23 - SUMMARY COMPARISON OF ANNUAL COSTS AND EVALUATED BENEFITS OF EROSION AND SEDIMENT CONTROL PRACTICES

Site	Practice	Total Annual Cost	Average Annual Reservoir Benefits	Average Annual On-Site Benefits	Total Average Annual Evaluated Benefits	Ratio Annual Evaluated Benefits To Costs
		Dollars	Dollars	Dollars	Dollars	Dollars
	MOUNTAIN SLOPE TREATMENT					
	Fire Control Practices, Protection Forces, Minor Erosion Control Structures	11,599	7,164	Not Evaluated	7,164	-----
	Subtotal	11,599	7,164		7,164	
	MOUNTAIN MEADOW STABILIZATION					
1 & 2	Stabilize Deposits Above Reservoir	1,678	381	136	517	0.31-1.0
3	Coogan Meadow	200	499	251	750	3.75-1.0
4	Glencliff Meadow	1,391	445	235	680	0.49 - 1.0
5	Crouch Meadow	606	146	528	674	1.11 - 1.0
6&6A	Cameron Meadow	6,846	1,157	2,139	3,296	0.48 - 1.0
7,8,9	Foster Meadow	1,925	749	720	1,469	0.76 - 1.0
10,11	Thing Meadow	1,675	2,263	907	3,170	1.90 - 1.0
	Subtotal	14,321	5,640	4,916	10,556	
	Total	25,920	12,804	4,916	17,720	

RECOMMENDATIONS

Analysis of the information on erosion and sedimentation in the Morena Reservoir Watershed, together with necessary assumptions which have been defined in the report or appendix, indicates that certain practices are economically feasible. It is recommended that these practices, and others in which the benefits to the community are large, be installed. The practices that are within this category include the following: (1) Structures to stabilize deposits in the reservoir, to prevent further erosion and restore Coogan Meadow, Crouch Meadow and Thing Valley and (2) Slope treatment practices including fire control, protection forces and minor gully stabilizers. Other practices considered in the report are to be included if the community determines that the public interest outweighs presently unfaborable economic ratios. The information on which the latter is based should be reconsidered from time to time as water supply costs and watershed conditions change.

Structural design prior to or during the construction period can be materially improved by further information on the hydrology of the watershed. Installation of stream gauging stations and continuation of 3 rain gauges which were recently installed should provide data needed for spillway design and evaluation of the consumptive use of vegetation before and after the practices have been applied.