UNITED STATES

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

MEMORANDUM TO CHIEF DESIGNING ENGINEER

SUBJECT: THE FUTURE SILT LOAD IN THE COLORADO RIVER AND ITS EFFECT ON THE OPERATION OF THE ALL-AMERICAN CANAL

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by

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MEMORANDUM TO CHIEF DESIGNING ENGINEER
(H.R. McBirney, E.W.Lane, C.P. Vetter)

Subject: The Future Silt Load in the Colorado River and Its Effect on the Operation of the All-American Canal.

1. The silt load in the Colorado River and its exclusion from the waters diverted to All-American Canal is a problem that has been given consideration for many years. Much inconvenience, with resulting high expenditures, has been experienced by the Imperial Irrigation District and water users in the removal of silt from canals, distribution systems, and lands, due largely to inadequate facilities at their headworks for exclusion of the silt, that one of the primary considerations for their favoring the All-American Canal construction was the thought that an adequate desilting system would be constructed by the Government and the district relieved for all time from the great burden of silt removal.

2. In anticipation of this problem a comprehensive plan of silt sampling was inaugurated, both by the Bureau and by the Geological Survey many years ago. Daily records are now available of the silt content in the Colorado River at Yuma, Arizona, for a period of over 20 years. Other records of measurements at Topock and elsewhere are also available. While these records are of inestimable value, it is apparent that they cannot be used as representing the future loads that will come to the All-American Canal heading after Boulder and Parker dams are in operation. This fact was not overlooked by those giving consideration

to the desilting problem. It now appears, however, that too much weight should not be given to the probable immediate or future benefits to be derived from the reservoirs created by these dams, one of which is about 300 miles and the other 150 miles above the Imperial Dam headworks for the All-American Canal.

3. An extensive program of borings in the river bottom and on the banks, supplemented by accurate mechanical analyses of the materials has demonstrated that there is in the river bed and the adjacent banks of the river even below Parker Dam, not to mention the numerous dry washes between the Parker and Imperial dams, readily transportable materials sufficient to furnish a very objectionable silt load for many years to come, even though no silt should find its way past the Parker Dam.

4. Since the impression seems to be somewhat prevalent that with construction of the Boulder and Parker dams the silt problem of the lower river will be forever solved, an attempt is here made to bring together certain facts based largely on observations and analyses and not on theoretical considerations alone, that will demonstrate the necessity of adequate desilting works and the inconvenience and embarrassment that may ultimately follow if such works are not provided at the time of initial construction.

5. A further difficulty may arise if the construction of the desilting works is temporarily deferred in that it is probable that funds will be difficult to obtain should the construction later be found necessary.

6. The subject may logically be divided into the following four major problems which will be considered separately:

A. The magnitude of the future silt load entering the Imperial Reservoir after Boulder and Parker dams have been placed in operation,

B. The influence of the Imperial Reservoir on the amount of silt which will reach the All-American Canal headgates,

C. The effect on operation and maintenance of the canal of the silt entering the All-American Canal if no desilting works are constructed, and

D. The disposal of silt below Imperial Dam assuming that the major portion of the silt passing the headgates of the canal is removed in desilting works and returned to the river.

A. The Future Silt Load Entering Imperial Reservoir

7. Observations of retrogression below large storage dams give abundant evidence that clear water, discharged from a reservoir into an alluvial stream bed which has previously adjusted itself to water carrying a considerable silt load, will pick up material from the stream bed and carry it along as bedload, suspended load or both.

8. Recent observations of conditions in the Colorado River below Boulder Dam indicate that considerable retrogression takes place immediately below the dam. Six sets of observations have been made over a period of 67 days since closure of the outlet gates. The observations indicate that with an average flow of 5,500 sec. ft. material has been removed from the river bed at the rate of over 5,000,000 cu. yds. per

year. It has been estimated that with a future average flow of 18,000 sec. ft. the corresponding rate of removal will be 47,700,000 cu. yds. per year. Up to the time of the last observations the major portion of the silt, almost one million cubic yds., was removed from a stretch of river about six miles long immediately below the dam.

9. The fact that clear water is discharged from a reservoir does not mean, therefore, that the stream, at some distance below the dam, will carry clear water. As long as retrogression takes place material must necessarily be transported by the stream.

10. Careful determinations have been made of the total silt load in the Colorado River and of the composition of the material in the river bed and banks which will be subject to erosion in the future. Based thereon an estimate has been made of the magnitude of the part of the future silt load coarser than 300 mesh or 0.05 m.m. that will enter Imperial Reservoir. The estimate indicates that if no steps are taken to artificially control the erosion above Imperial Dam this coarser part of the load will be about 100.000 tons per day or 20,000 ac. ft. per year at a river flow of 21,000 sec. ft.

11. In order to determine the effect of the closure of Boulder Dam on the amount of silt passing the Imperial Damsite regular observations are being taken of the silt load at this point. Results based on the few observations available serve to confirm the above estimate.

12. The part of the future silt load finer than 300 mesh, is far more difficult to estimate. It is expected that it will be materially less than before the regimen of the river was disturbed and so far

observations at Imperial Damsite have been in agreement therewith. The future load, coarser than 0.01 m.m., entering Imperial Reservoir has been estimated to be approximately 200,000 tons per day or 39,000 acre ft. per year during the early years.

13. There are several factors which may tend to modify these estimates but the fact remains that even though clear, or almost clear, water will be discharged below Parker Dam there will be very large quantities of silt entering the Imperial Reservoir for many years in the future.

B. Influence of Imperial Reservoir on Silt Load Reaching All-American Canal Headgates

14. After closure of the cofferdam at Imperial Damsite and, later, after the All-American Canal has been placed in operation a reservoir will be created upstream from the dam. The incoming silt load will settle in this reservoir and gradually build up the bed. Due to the extreme fineness of the silt load it is expected that the deposited silt will, at first, be somewhat uniformly distributed over the reservoir area rather than exclusively deposited at the upstream end as is the case in some reservoirs on rivers carrying much coarser loads.

15. Surveys are in progress to determine the storage capacity of the Imperial Reservoir. Until the final data are available it is estimated that the storage capacity to the sills of the headgates of the All-American Canal (El. 171.00) is approximately 21,000 acre ft. and to normal water surface (El. 179.50) approximately 75,000 acre ft. If the

silt load enters the reservoir at the rate of 39,000 acre ft. per year the reservoir will silt up to the sills of the headgates in a relatively short period of time. There are several factors which would tend to prolong this period, primarily the storage of silt in the river bed upstream from the reservoir above reservoir level, but even allowing for these factors it seems evident that large quantities of silt will begin to enter the All-American Canal headgates within a very few years after the water level at the dam site has been raised.

16. It is anticipated that the very fine, colloidal part of the silt load will pass through the headgates long before the accumulated silt reaches the elevation of the sills and this fact will be of considerable aid during the priming period of the canal. If desired, during the initial period of operation, the amount of silt entering the canal may be increased by keeping the reservoir at a low level and by causing the flow to by-pass the desilting basins.

17. It is not expected that the rate at which the load enters the headgates will suddenly and materially change as soon as the accumulated silt reaches the elevation of the sills, rather it is expected that it will gradually increase and approach the rate at which the silt enters the upper end of the reservoir.

18. It is possible to estimate, approximately, the amounts of silt passing through the headgates at various times after closure of the Imperial Dam. After approximately 5 years of operation and at 12,000 sec. ft. diversion it is estimated that 37,500 tons of coarse silt per 24 hours will enter the All-American Canal. After 7 years

operation the amount of silt passing through the headgates will have increased to 49,000 tons per day and after 50 years operation, when the maximum diversion has probably reached 15,000 sec. ft., the load passing through the headgates is estimated to be 70,000 tons per day. The latter quantity corresponds to 1,800,000 cu. yds. per month. As compared herewith the total excavation of the All-American Canal by contract and by force account for the month of April, 1935, amounted to 2,200,000 cu. yds.

19. These figures are not claimed to be exact, they represent, however, the result of careful studies carried out by the design and research staff over a period of years. They are believed to indicate beyond any doubt, that very large quantities of silt will pass through All-American Canal headgates for many years in the future.

C. Operation and Maintenance Difficulties Without Desilting Works

20. If desilting works are not constructed, the silt passing through the headgates will be carried into the main canal. With velocities of flow approximately 4 ft. per sec. the silt will probably be carried along and deposited in the laterals and ditches of the irrigation system possibly in even greater amounts than is the case at present.

21. The canal, however, is designed for a maximum flow far in excess of that which will occur for many years. It is estimated that for several years the minimum diversion may be as low as 6700 sec. ft., or about 45% of the design capacity. At other points further down the canal the minimum flow will be an even smaller fraction of the design

capacity. Since it is necessary or at least desirable to maintain the water level in the canal as high as possible above the power drops the velocity of flow in the canal for considerable distances, above the power houses, will be only a fraction of the velocity required to keep all the silt moving. Above Siphon Drop power house, if reconstructed, the minimum velocity during the first few years of operation would be 1.7 ft. per sec. and the maximum velocity 2.5 ft. per sec. It may be expected that the greater part of the silt carried into the canal will settle in this stretch. The remainder except the colloidal part will probably settle above the power houses and checks further down the canal where the velocities are even lower. The main canal will thus act as a series of settling basins.

22. To remove the silt from the canal by sluicing after it has once consolidated requires very high velocities and this method is believed to be impractical. Dredging is made difficult by bridges and wash crossings which make it impossible to move a dredger along the canal for any great distance. It would probably be necessary to remove the silt by drag lines operating either from embankments or berms. The cost of operation under these conditions would be high, and in many places, it would be almost impossible to dispose of the silt in this manner. The average yearly cost of silt removal may be as much as $1,000,000 per year for the first 10 years. As compared to this the total construction cost saved by omitting the proposed desilting works would be about $1,500,000. Furthermore, the construction of desilting works should they be found necessary after the canal has been placed

in operation, will be extremely difficult.

23. It may be possible, by operating the main canal without checking, to partially prevent silt deposits in the canal itself. The silt load would then be carried on to laterals and ditches and to the irrigated fields making silt removal even more difficult and costly. This method of operation would cause a loss of revenue from power generation particularly in plants below Pilot Knob. At Siphon Drop there would also be a loss of revenue when a new plant is constructed. Since under these conditions water diverted for the Yuma Project would doubtless carry greater quantities of coarse silt than at present, that project would probably contend that desilting basins should be constructed for their water.

24. The Imperial Irrigation District and its water users are reported to have spent as much as $1,000,000 per year for silt removal. Even then, a material portion of the silt load passing the Rockwood Heading is removed very economically by dredging. Without desilting works the silt entering the canal could not be removed at the same unit cost since dredging would not be practical.

D. Silt Disposal Below Imperial Dam

25. The disposal of the silt, returned to the river from the proposed desilting works at Imperial Dam, has been given careful consideration. A sluiceway is provided through which will be discharged all water available over and above irrigation demands. Assuming normal runoff above Boulder Dam and the construction of the first unit of the

Gila Valley Project, there is expected to be sufficient excess water available for sluicing at Imperial Dam for a considerable period of time.

26. It is planned to create a confined channel from Imperial Dam to Laguna Dam terminating in the present sluiceway for the Yuma Canal. The channel will carry all water discharged through the sluice gates at Imperial Dam and all sludge from the desilting basins. The water level at the lower end of the channel will be controlled by the three 33'-4" Stoney gates in the sluiceway. The drop between the Imperial Dam and the Laguna Dam which can be made available by fully opening the three Stoney gates is more than sufficient for carrying the sludge discharged from the desilting basins.

27. It may be found necessary, at some future time, to extend this confined channel below Laguna Dam probably as far as Yuma, or to reduce the silt load by stabilizing the river channel above Imperial Dam. No such construction is planned at the present time as it is believed that observations of the actual behavior of the river in the future will offer the best guidance as to the extent of additional construction work required.

28. Below Yuma, in the delta of the Colorado River, conditions should be materially improved, due to the reduction of the total amount of silt deposited in the delta per year.

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