INTRODUCTION.

THE development of a water-supply for irrigation in the arid West sooner or later reaches a stage where the construction of storage-reservoirs becomes a necessity. If the stream is one of considerable volume, numerous irrigation-canals will be constructed from it at all convenient points, and its entire normal flow will be utilized before the impounding of flood-volumes is thought of as a possibility. But with the varying seasons there will occasionally come a year when the best of streams are so shrunken below the normal as to limit sharply the area which can be irrigated from it, and emphasize the regret that some means had not been provided for holding back the wealth of water which at times pours into the sea without benefit to any one, so as to render it available in the drier part of the year. Other streams there are, which drain very large districts and at certain times of the year are formidable and almost impassable rivers, that in the summer and fall are dry for months at a time. If these sources are to be rendered servicable storage-reservoirs must be built as the initial step in irrigation development.

All streams, except they be regulated by nature by means of lakes or subterranean reservoirs, are subject to great fluctuation. It is the function of artificial reservoirs to equalize in a measure these variations in flow, impounding the floods for use in the season when irrigation is necessary. Were it possible to conceive of a stream flowing throughout the year without change in volume, such a stream would not have its fullest measure of usefulness without storage of the water flowing during the period of the year when irrigation is not needed.

Inasmuch as the total available water-supply of the arid region is vastly short of the quantity needed for irrigating all the land requiring artificial watering, it is evident that, under every condition and with every class of stream, storage-reservoirs are needed to develop the fullest measure of usefulness of the existing supply.

Unfortunately it is beyond the possibility of hope that all the water flowing can be stored or utilized. There is such a wide range in the total run-off of every stream from one season to another that it would rarely be possible to find storage capacity for the extremes of flow. On large rivers

the ratio between maximum and minimum years may vary as 12 to 1, while on smaller streams the total flow one year may be one hundred times as much as that of the next year. Hence the reservoirs which might be provided to catch all the flow of average years would occasionally be overwhelmed by freshets so extraordinary as to fill them several times over. This condition has an important bearing on the design of every reservoir located in the path of floods, first, in emphasizing the necessity for providing ample spillway capacity, large enough to carry safely the greatest possible or probable flow, and, second, in fixing the proportion which the capacity of the reservoir may bear to the total annual run-off of the stream, so as to minimize the ratio of silt deposited to the total volume of water impounded. It may be accepted as true that the destiny of every reservoir is to be filled with silt sooner or later. If a reservoir were created on a stream carrying silt to the extent of 1% of its volume on an average (although few actually carry so much as 1%), and the average annual flow of the stream were, for an extreme example, fifty times as great as the capacity of the reservoir, the latter would be filled and become unserviceable in two years, assuming that the greater portion of the silt carried was deposited in the reservoir. It would evidently, therefore, be unprofitable to construct such a reservoir unless provision were made for an immediate increase in height of dam, for diverting the river around the reservoir, which is usually impracticable, or for sluicing or dredging the silt from the reservoir, a process involving great expense. If, on the other hand, the reservoir capacity was made great enough to store rather more than the usual average flow for one year, the period of usefulness of the works would be vastly increased, and the consideration of the problem of silt disposal would be left for future generations to solve.

The importance of reservoir-construction and water-storage for irrigation was not so generally recognized in the arid region prior to about the year 1885 as it has been subsequent to that time, and it is only within a comparatively recent period that capital has been extensively enlisted in such works except for the storage of water for cities and towns. With a few prominent examples of successful achievement in that line as precedents, however, the subject of water-storage has awakened wide-spread attention, and each year it appears to be attracting deeper public interest. Capital has been slow to undertake the largest and most important works of this character, because of the difficulty of realizing immediate returns upon the investment. The development of a new section upon which water is but recently introduced, the construction of distributing canals, ditches, and pipes, the cultivation of the land and the planting of orchards—in fact the conversion of a desert to a condition of profitable productiveness, is the work of time, which cannot be begun until the irrigation-works are actually completed, and when begun is slow of full development. Meantime, however,

the interest account accumulates, and often is so far in excess of possible revenues as to bring discouragement, and sometimes actual bankruptcy, before a paying basis is reached. The uncertainty of the laws of the different States governing water rights in reservoirs, the difficulty of establishing fixed rates for water that will be high enough to afford an adequate revenue to the capital involved and low enough to enable the farmer to pay for the water he requires and make a living while developing his farm, and the responsibilities involved in the risk from floods, accidents, and dry seasons, have been potent in deterring capitalists from investing in the business of storing and selling water, *per se*, unless it were coupled with the ownership of the lands to be irrigated, or with the domestic supply of a growing town, or with the possibilities of generating water-power.

The recent development of electrical machinery, by which power may profitably be transmitted long distances with comparatively small loss, has indirectly benefited the irrigation development of the country by adding an incentive to the construction of storage-reservoirs for the primary and more profitable purpose of generating power. Many reservoirs are being favorably considered by capitalists for the power which they will afford that would otherwise be regarded as comparatively valueless or unprofitable investments for irrigation alone. As the great bulk of precipitation in the arid region occurs in the mountains, where it increases with some degree of uniformity with every foot of increased altitude, the mountains are coming to be regarded as indispensable to the wealth of the country, valuable not only for their precious metals, stone, and timber, but for the store of water which they are able to supply to the thirsty plains below. The mountains not only supply the water, but they usually afford the best sites for reservoirs to impound it, in ancient lake-beds, and high, cool, deep valleys, surrounded by forests; while the latter fulfil a most important function and attain a value far higher than the mere commercial one to be derived from their lumber and firewood, by serving to retard the rapid run-off of the water-supply. Forest growth is of primary importance in the preservation of the source of streams, in preventing the mountains from being washed down with destructive force to the valleys and the sea, and in creating natural reservoirs on every square mile of their surface.

That storage-reservoirs are a necessary and indispensable adjunct to irrigation development, as well as to the utilization of power, requires no argument to prove. That they will continue to become more and more necessary to our Western civilization is equally sure and certain; but the signs of the times seem to point to the inevitable necessity of governmental control in their construction, ownership, and administration. Those which private capital may undertake should only be permitted to be erected under the most rigid governmental supervision, to assure their absolute safety. Many reservoirs are needed for the development of the arid regions which

are of too great a magnitude to be undertaken by private capital or organized individual effort. In every other country such works are undertaken by the national government. In general it may be said that the lands which would be benefited by such works in arid America belong to the government. To make these lands productive and capable of sustaining population, the government of the United States should undertake their reclamation and construct and administer the reservoirs. That such a policy will ere long be inaugurated seems inevitable. The purpose of this work is to familiarize the public with the details of construction and the general features of interest appertaining to the principal reservoirs constructed or projected in the Western States and Territories which have come within the knowledge or observation of the writer, describing in a popular way their characteristics, their water-supply, the results accomplished or sought to be accomplished by them, and the methods and materials employed in the construction of the dams which form them.

TABLE OF CONTENTS.

CHAPTER VIII.

APPENDIX.

LIST OF ILLUSTRATIONS.