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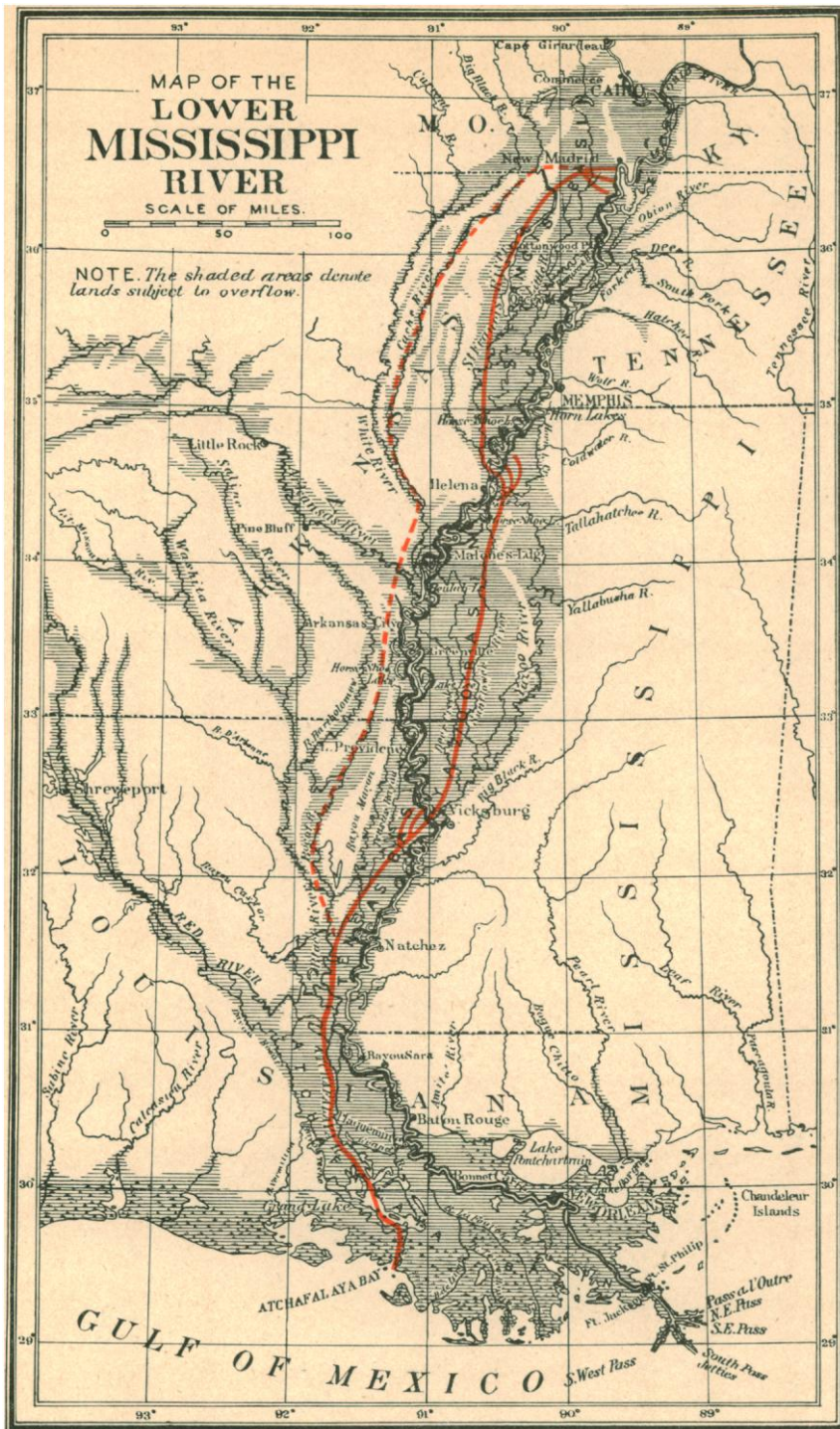
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LEVEES, OUTLETS AND RESERVOIRS AS MEANS FOR PROTECTION AGAINST OVERFLOW OF THE ALLUVIAL LANDS OF THE MISSISSIPPI VALLEY BELOW CAIRO.

THE alluvial valley of the Mississippi River below Cairo contains 29,790 square miles of land subject to overflow in its natural state. It is all capable of protection and reclamation by levees except a small area at the foot of each closed drainage basin, which must be left open for the escape of surface water, and a fringe of sea marsh along its southern border. It has been in course of progressive reclamation by that method for nearly two hundred years. For the last twenty years the United States government has been assisting in the work and its progress has been rapid. The existing lines of levee are about 1,350 miles long. About 80 miles remain to be constructed to complete in length the main river system, not including some areas so small that they are not worth the cost of reclamation at the present time. In only a few places, however, are the embankments as high and strong as they should be for the greatest safety. It is not known, in fact, just how high they ought to be in order to accomplish that purpose. The work of building them began at the lower part of the river and has been carried up stream progressively. As they advanced they confined within the channel more and more of the water of great floods which had previously escaped over the bank and made its way to the sea by other paths. This process raised the flood levels within the levees higher as they were extended up



C.W. Clark, Del

stream, and they had to be raised and strengthened to meet the added load. These additions were made as the need of them developed. These needs were forecast from time to time as nearly as possible. It was a difficult problem. The 'potential high water' of floods to come has been the subject of much study and discussion. The nearest approach to a standard has been that the levee should be three feet above the highest previous flood line in that locality. In order to ascertain this line it has been the practice to record extreme high-water levels by marks on trees at intervals of a few miles along the bank. These records show such irregularity of behavior in the great floods as to make it necessary to fit the grades of the levee to local conditions. One element of disturbance and uncertainty yet remains in the completion of the closure of the St. Francis front, where about 60 miles of embankment remain to be built. That great basin, 6,700 square miles in area, has exercised in the past a profound influence on the channel along and below it. In its natural state it received a vast volume of overflow which it returned to the main stream again at and about the mouth of the St. Francis, immediately above Helena. This abstraction of water from the river along the upper and central portions of the front of that basin weakened the stream and so tended to shrink the channel in those parts; while its return at the foot of the basin augmented the stream, with a resulting tendency to enlarge the channel. Consequently, when we come to confine the flood discharge by levees along the St. Francis front, the water, in passing down, finds a channel of more ample dimensions in the neighborhood of the foot of the basin than that which it finds above. It is to be expected, therefore, that a great flood will reach a higher elevation in those parts of the channel where, for ages past, the flood volume

has been depleted by overflow than in those parts where, during the same ages, the flood volume has been augmented by return of the overflow.

Still other circumstances enter in to complicate the problem, so that, upon the whole, only the actual confinement of a series of great floods without a break from Cairo to the sea will give us the ultimate high-water profile.

But we are making rapid progress toward that information. The great floods of 1897 and 1903 carried more water to the sea between banks than any of their predecessors. They have left records of gauge readings and discharge measurements which afford a great field of interesting study into which I can not enter within the time and space at my command. Those limitations will permit only the briefest summary of what the levees accomplished and what they failed to accomplish toward the protection of the lands behind them. They were floods of the first rank and may be taken as typical of what may be expected to occur at intervals of a few years in the future.

The flood of 1897 made 38 crevasses, having an aggregate width of about 8 miles; the flood of 1903 made 9 crevasses, having an aggregate width of about 3 miles. The levees in place in 1903, if no crevasses had breached them, would have protected about 26,000 square miles from overflow. Of that area a total of about 3,000 square miles was overflowed in consequence of the crevasses which took place, which is less than one eighth of the entire area which the existing levees could and would have protected if they had all been high enough and had held their places. In the phrase of the target shooters, they accomplished 87½ per cent. of success out of a possible 100.

These experiences indicate that with complete restraint of the floods by levees we shall have, as an immediate result, some further elevation of the maximum flood

level; but not very much—not enough to change any element of the problem, nor to introduce into it any new difficulty except the additional expense necessary to build and maintain the embankments at the higher grades required. The levees have done their work so well and are so far advanced toward completion that the abandonment of that system for an attempt to protect the alluvial lands in some other way is not to be considered for a moment. The interests involved are too vast to be put in jeopardy by experiment. To complete the existing system and maintain it is a duty so plain that it is not open to discussion. At the same time there is no reason why the believers in outlets and reservoirs should not continue to advocate their theories, nor why their arguments should not receive the compliment of polite refutation. There is still great lack of information on the subject in the public mind. The government has spent large sums from the United States treasury in aid of levee building, and must continue to do so if they are to be perfected and maintained; and all citizens who care to look into the subject are entitled to know why that method of protection has been and is to be pursued instead of others that are proposed.

Nothing could be more natural than the suggestion to seek relief from great floods by providing additional channels for the surplus water; and it takes some close consideration of the subject to perceive the fallacy of the proposal. But it is, as I shall attempt to show, a delusive scheme as a means of protection against overflow of general permanent practicability and utility. In the consideration of the subject I shall try to come a little nearer to it than has been heretofore attempted, so far as I know, by locating an outlet system on the only lines upon which it would be available for the advantage of the alluvial valley as a whole, and discussing its feasibility

and utility from a practical standpoint. I have indicated such a system by the continuous red lines on the accompanying map. The broken red line is to be disregarded for the present.

Such a system would necessarily begin in the St. Francis basin. Suppose we should make a group of outlets near the head of that basin and connect them with a channel of sufficient capacity to carry, say, one tenth or one fifth of the combined discharge of the Ohio and the Upper Mississippi during great floods. The water thus diverted would be returned to the main channel at the foot of the basin, and would produce a flood height there as great as though the same water had come down the main channel. What should we do with it there?

A possible answer would be to make another outlet on the other side of the river into the head of the Yazoo basin, with a channel of like dimensions down that basin to its foot at the mouth of the Yazoo. To follow up the plan it would be necessary to make a third outlet, leading this time into the Tensas basin, with a channel leading down that basin across Red River and through the Atchafalaya basin to the gulf. We would then have two rivers from the head of the St. Francis basin to the sea, of which one would cross the other twice as a canal sometimes crosses a river in a pool raised by a dam. Those parts of the river in the neighborhood of the crossings would have to carry the whole flood volume and would require levees as high as, or higher than would be required in a levee system without outlets.

Such a combination would be enormously expensive. The secondary channel would be not less than five hundred miles long. In order to carry water enough to afford substantial relief from floods of the first magnitude it would need to be of large capacity. It would pass through the central parts of the fat alluvial basins. To dig

it, with all the use that could be made of existing streams and bayous, would require the removal of earth enough to build several times its length of levee. Nevertheless, with men and money and time enough it could be done. And if it were constructed, and in order at the oncoming of a great flood, I should suppose that for once it would materially lower the high-water elevation except in those parts of the river in the neighborhood of the crossings of the main river by the subsidiary channel. So far up and down stream as that engorgement extended it would be necessary to maintain levees high enough to take care of the water, to whatever stage it might go.

It would be the extreme of folly, however, to construct so costly a work without the assurance of its permanent utility. The probability of this result may be considered from two hypothetical points of view. From the first of them would be contemplated, I may say, a subsidiary channel sufficient in capacity to carry only a small part of an extreme flood—just the two or three feet on top which produce the greatest strain and danger under present conditions. Such an outlet opening would have to be very carefully constructed and guarded, in order to prevent its indefinite enlargement; but that could be done. For that purpose it would be desirable to take the water off through a number of small openings leading to the subsidiary channel as indicated on the map.

The extreme floods which this provision would be designed to relieve occur only rarely—not oftener, upon an average, than once in five years. During the intervals the unused channel, especially those parts of it not following the channel of some river or bayou, would be filled with a dense growth of vegetation—willows and cottonwoods, mostly. The floods have no regular periods of return, so that there would be no way to be sure that the channel would be

unobstructed except to keep it open and clean all the time. This could be done too, but it would involve an annual expense equal to the cost of clearing a right of way for a railroad from Cairo to the gulf. It would be expected, I suppose, to lay out the subsidiary channel on comparatively straight lines down the interiors of the basins. This would result in a high velocity of flow in them; and this, again, would result in more or less cutting and caving of banks, with the consequent formation of bars. There would be danger that the subsidiary channel would follow the vicious example of its parent and overflow its banks; and to be secure against this danger it would probably be necessary to restrain its inherited propensities by levees.

It follows that, even with this smallest subsidiary channel that would suffice to relieve the tension of an extreme flood, we would have on our hands a work of prodigious magnitude and cost which, at its best, would relieve us of only a small part of our present burdens and dangers. It would be necessary to continue to maintain the levees on the main stream. They would be subject to the same accidents which befall them now. Caving banks would undermine them, and muskrats would burrow in them as now. Considerations of expense would require us to build on as low grades as would be consistent with safety, just as we do now. When a great flood came there would be the same apprehension of disaster, the same necessity for incessant watchfulness, and the same occasional crevasse which attend the floods now. Assuming that our outlets and subsidiary channel were entirely successful in accomplishing the work for which they were designed, we would still be little better off than we are now with the added burden of the enormous cost of the subsidiary system to be carried forever.

This, it is to be remembered, is upon the

assumption that the outlets would be designed to take from the main channel only the surplus of an extreme flood over the discharge of an ordinary flood. To consider the subject from the other point of view referred to, we may suppose the system of outlets and channels already described to be made of sufficient capacity to carry all the surplus water above the overflow stage, so that the levees on the main stream could be abandoned. This would require channels of far greater size and cost. But as the plan would propose to dispense with all levees and so save the cost of them, we may set off that saving against the cost for the present purpose, and confine our attention to questions of maintenance and effectiveness.

In such a system the subsidiary channel would be only another river. In all floods the two channels would divide the discharge between them, and water would flow in both of them all or a large part of the time. Would the river be able to maintain for itself as ample discharge room in the aggregate by a divided flow through two parallel channels as by a concentrated flow through a single channel? To state the question is to answer it. The smaller the channel *by* which a fluid flows the greater, relatively, is the retardation due to friction. A river flows with greater velocity at high stages than at low stages because of its greater volume. A flood divided between two channels would have less power to scour out and keep open the two channels than it would have to scour out and keep open a single channel. The two channels would have a greater tendency to fill up by deposit of sediment than a single channel carrying the whole discharge would have. There can be no dispute over these propositions among engineers.

It is by reason of the immutable operation of these laws that the Mississippi River has made for itself a single great channel

from Cairo to the sea. As between two parallel streams produced by division the smaller stream is the weaker. As it shrinks in capacity by deposit, what it loses in volume of discharge the other stream gains. Thus the disparity between them in volume and energy increases at an increasing rate until the smaller channel is obliterated and the larger stream takes the whole discharge. To attempt to fight that tendency toward concentration in so great a river as the Mississippi flowing through a material so easy to erode and so ready to sink would be a futile undertaking.

I have thus discussed two imaginable outlet schemes—one a mere tapping, or blood-letting, operation to take off the top layer of an extreme flood, leaving the levees to take care of all the lesser floods; the other a true subdivision of flow complete enough to obviate the necessity of levees by providing sufficient channel capacity to carry all floods without overflow. It requires, as it appears to me, only a little close attention to the subject to make it apparent that they are both hopelessly impracticable.

In the consideration of the latter of the two plans stated—that one assuming a general abandonment of levees, and a reliance upon outlets and subsidiary channels as sole protection against floods, I have not taken into account the problems which would be presented at the intersections of the subsidiary channels and the main channel, because the argument seemed to me to be sufficient without considering them. I think, also, that it would be sufficient without considering anything but them.

Such an outlet scheme as I have supposed is the fairest one I can think of for illustration. It is not physically impossible. The soil of the alluvial valley can be fashioned in any shape you choose. There is an imaginable sum of money which would do the work. It would be a less violent contradiction of the natural course of

things than any other outlet scheme. The path of the subsidiary channel would lie wholly within the alluvial basin and over ground undoubtedly occupied in many changing locations by the stream, or parts of it, in bygone ages. It would be like what the river does now on a small scale in many places. At every 'chute' there is an outlet from the main stream and a subsidiary channel passing around an island and joining the main stream below. It may be one mile long or twenty-five. The island may be a mere 'towhead,' or it may be large enough to form a county. My subsidiary channels down the St. Francis and Yazoo basins would be only longer chutes.

Another scheme has been proposed, however, which I regard as more impracticable, if possible, than the one which I have described. It is to take an outlet channel across the upper end of the St. Francis basin through Crawley's ridge and thence to the gulf on a line lying wholly west of the Mississippi River. I have indicated one of its suggested locations by the broken red line on the map connecting the points at which it would leave and rejoin the subsidiary channel indicated by the continuous red line.

The first point to be noticed about such a plan is that it would cut off all the western confluent of the main stream below Cairo—the upper St. Francis, White, Arkansas, Black and Red. It would be an intercepting sewer for the southwestern quarter of the Mississippi valley. It would be a great big river. It would require an amount of excavation equal to several Panama canals, and levees nearly as great as those on the main river, in order to enable it to hold its own floods. Men have done a great deal in the way of improving the work of the Almighty in the creation of the earth already, but this would be a more

extensive program of reconstruction than any before attempted.

The next point to be noted is that it would permanently lessen the volume of the main stream from the location of the outlet to the gulf. It would do this to the extent of the discharge of the intercepted tributaries plus the volume taken from the channel by the outlet. What that volume would be would depend upon whether the scheme contemplated a mere tapping process, to take off the upper few feet of extreme floods, leaving the levees to take care of all ordinary floods, or such large reduction of volume as would make the levees unnecessary. If the former, then, as I have already pointed out, we should still have 1,400 miles of levee to maintain at nearly the same cost and hazard which they impose upon us now, besides a second river to take care of, with all its vicious tendencies and caprices; if the latter, we would have two Mississippi rivers to be maintained in equilibrium against the forces of nature which tend constantly in such a situation to give to that channel which hath, and take away from that channel which hath not, even that which it hath.

Such schemes necessarily take a man far afield in the domain of speculation, but this much is certain; if it should prove to be impossible to divert enough water from the main stream in that way to prevent the overflow of the natural bank, the project would have failed as a means of protecting the alluvial lands from inundation; and, on the other hand, if such diversion should be found possible and be accomplished the depleted main stream would contract its channel to correspond with its lessened discharge. A river channel through an erodible formation always fits the river as a turtle's shell fits its back. There is no reason why the channel of the Lower Mississippi is larger than the channel of the

Missouri except that the former carries the greater quantity of water.

The immediate effect of permanently diminishing the volume of flow in the river would be to impair its value for navigation. This effect would follow quickly—within a very few years. A later effect would be to diminish the capacity of the channel to hold the floods, and so raise the flood heights. How rapidly this shrinkage would take place can not be stated; but it would begin at once and go on until the relations of volume and channel capacity found an adjustment in which the natural bank level would approximate the mean annual flood height. This would mean overflow in all floods above the mean.

The *modus operandi* of the filling up process is simple enough. The flood leaves high, vertical banks on the concave sides of the bends. The enfeebled stream at low water cuts into those banks at the base. The undermined earth falls down in great masses into the pool. The weak current is unable to carry it away, and so climbs up over it and goes on gnawing at the base of the bank. By this process it grades down the bank and fills up the pool to greater or less extent. This operation goes on during every low water in the Mississippi River now. Vast quantities of earth are knocked down into the pools by the undermining of the concave banks. But when the flood follows it digs that material out again and piles it up on the convex sides of the bends. One of the striking sights to be seen on going down the river at low water after a great flood is the immense bars piled high up above the low-water line by the preceding flood. The present channel is the result of nature's adjustment between this filling-up process and this digging-out process. If the activity and energy of the digging-out process were diminished the channel would fill up until the adjustment had been restored.

If the present discharge down the main stream were reduced by one half at all stages, the energy of the excavating force would be reduced out of all proportion to the reduction of the effectiveness of the filling-up force. The low-water current would eat away the base of the high banks and fill up the pools with material which the diminished flood would be unable to remove. The result would be at last a readjustment of forces with shallower pools, lower concave banks, less filling up, less digging out, less everything that pertains to the life of a river. Then when the great flood came it would find a diminished channel to carry it and would overflow the country as before. There would be less water to take care of and it may be that the floods could be restrained by levees of less height. As against that gain, however, we would have another river to take care of with its low water and high water, its bars, floods, overflows, levees, crevasses and other burdens and calamities. All in all, our last state would be worse than our first.

As for navigation, the present large schemes for ten feet or more from Cairo down would all go glimmering. The superb advantages which nature gave us in the one great river would be thrown away in exchange for two smaller rivers, more expensive to control, more destructive and less useful.

I have been discussing the feasibility of general protection of the alluvial valley from overflow by outlets. I have endeavored to take a practical view of the question by assuming definite plans with outlets and auxiliary channels definitely located. It seems to me that it is only necessary to approach the question in this direct and practical way to make it apparent that the outlet theory is a dream impossible of realization.

It does not follow from this that there is no situation in which no outlet of any kind

can have any utility. On the contrary, I think that there is a form of outlet which might possibly be employed upon the lower part of the river with advantage in conditions which may arise hereafter. Such outlets would be confined to points in the west bank below Red River. They would consist of regulated spillways, or waste-weirs, taking off the top layer of extraordinary floods and conducting the water to the sea across the Atchafalaya basin. Their object would be to alleviate extreme flood heights through the sugar country and at the city of New Orleans. They would have no effect upon floods in the central and upper parts of the valley. They would not be outlets, as the word is usually applied, but waste-weirs in the strict sense of the word—long, shallow notches in the top of the levee, stone paved and side walled to prevent the possibility of enlargement, with secure channels leading to gulf level in the Atchafalaya lakes and bayous. Their construction would be experimental both as to benefits in relieving the strain of great floods and as to their effect on the channel below them. I speak of them now for the sake, more than anything else, of forestalling any suggestion of inconsistency on my part in case the developments of a few years to come should indicate a need of them. I do not want to be tied to a word. The outlet theory is a delusion. At the same time, a safety valve in the form of an outlet might have a certain utility in a certain situation. This would not be as a substitute for a levee system, but as an adjunct to a completed and perfected levee system.

The time has not come yet for the practical consideration of such a scheme. We do not know enough to enable us to form a reliable judgment of the probable necessity and utility of it. We must hold a flood or series of floods so effectually that we shall be surer than we can be now of the elevations to be expected. It may cost us some

dear experience—some bad breaks and disastrous overflows, but for the present nothing should be allowed to divert our money or our attention from the main work in hand—the full completion of the grand levee system of the main river. I have spoken of the possible utility of spill-ways, or waste-weir outlets, below Red River in order to mark with exactness that limited application of the outlet method which I believe to be feasible, and possibly useful, as distinguished from its general application, which I believe to be utterly impracticable.

On the subject of reservoirs little need be said. It is a delightful scheme to think of and talk about. It would beautify the map with lakes throughout the upper valley. It would bring the delights of boating, fishing and swimming within the reach of millions of us to whom they are now inaccessible pleasures. It would remove all danger of a surplus in the national treasury for a long time to come, and it might reduce the surplus in the Mississippi River somewhat.

When men think of reservoirs in this connection they commonly locate them in the headwaters of the Mississippi and the Missouri. Unfortunately, it is not there that the rains fall that furnish the stuff for great floods, but in the valley of the Ohio and its tributaries. The storms that sweep from the southwest across the Ozark Mountains and on over Kentucky, Illinois, Indiana, Ohio, western Pennsylvania, West Virginia and Tennessee are the bearers of woe to the people of the alluvial valley. One of the consequences of those rains has been to make the regions where they fall so fertile and attractive that they are filled with population, farms, cities, railroads, factories and all the adjuncts of high civilization. To occupy the country with the reservoirs necessary to hold back a great Mississippi flood would involve an incal-

culable destruction of property, to say nothing of the cost to build them.

There is one place where it would be possible, in an imaginative sense, to impound a volume of water that would be missed from the river. That place is the St. Francis basin, 6,700 square miles in area. By cutting that area up into subdivisions by dams crossing it at frequent intervals, and increasing in height progressively down stream as rapidly as the slope of the land surface would permit a vast storage of water could be secured, many feet deep at its lower border. But the only material that can be found there to make the dams of is earth. The expense of stone would be scarcely thinkable. And to imprison such a volume of water at the head of such a valley as would lie below it with only earthen walls to hold it back would be nothing less than criminal foolhardiness. The best use we can make of the reservoir theory is to keep it to talk about.

We frequently hear the present large projects for the storage of water for purposes of irrigating arid lands in the west spoken of as though valuable aid in the control of the floods of the Mississippi could be obtained from those works. For want of more accurate knowledge of the possible extent of that storage and its locality I can say no more than that while it may help a little, it appears to me that it can be no more than very little. It must be remembered that it would be of no advantage to the Mississippi River to diminish its volume at ordinary stages, or even ordinary flood stages. It is only by the power of its vast discharge that its great channel has been produced or can be maintained. A permanent reduction of its ordinary annual floods would tend to diminish its channel capacity. Better a great channel with a maximum discharge of 2,000,000 cubic feet per second than a less channel with three quarters of that volume, so the water can

be kept within the banks. If the irrigation reservoirs should operate, as I fancy they would, to store a substantially uniform quantity of water each year and distribute it over cultivated lands, to be for the most part evaporated or absorbed, they would serve no useful purpose to the Mississippi except in rare and extreme floods, when it may be said that the smallest reduction is of some value.

All this emphasizes more and more the main truth that the present levee system has been so thoroughly tested, and has been of such incalculable value, and is so near completion, that it is a sort of treason to turn aside to talk about anything else for any other purpose than to illustrate by contrast the transcendent importance of finishing up what we have in hand.

Even this phrase needs definition. In a sense the levees of the Mississippi never will be finished. But they can be extended, raised and strengthened until they will hold the water even in such floods as that of last spring. At that period they will be 'finished' in the only sense in which it will ever be possible to apply that word to them.

It is not necessary, either, to the achievement of 'success' that they shall never be broken by crevasses. I have said that during the flood of 1903 the existing levees protected from overflow seven eighths of all the lands capable of protection by them if not one had failed. Suppose we should never be able to do better than that. Suppose great floods should come once in five years, and we should always save seven eighths of the land from overflow. That would mean that, upon the whole, taking all the years and the whole valley into account, there would be an average annual inundation of two and a half acres out of every hundred. I should call that success.

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