THE PROBLEM OF THE MISSISSIPPI.

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Engineers have expressed the opinion that the Mississippi challenges their profession as no other single problem. Geologists, with an equal regard for truth, might very well make an equally strong assertion. There is this difference, however, the engineers have studied their particular difficulties for nearly half a century; the geologists, on the other hand, have been busy elsewhere, seemingly, and have not produced a single high-grade study on the Mississippi that brings us any nearer to a solution of the problem. This seems the more strange since, unquestionably, the control of the Mississippi involves far more than engineering principles, and a permanent solution can be hoped for only when geologic principles are likewise taken into account.

Roughly, the suggested solutions of the problem, or problems, for their number is legion, may be thought of as falling into two main groups. The one tries to retard the waters before they reach the master stream. The soundness of this type of reasoning has been recognized, but much doubt has been expressed as to the feasibility and effectiveness of the various measures proposed, such as reforesting certain steep slopes, the building of storage reservoirs, and the like. The other group stands for a control of the waters after they once have started to move between high embankments down toward the Gulf. The river itself, by its building of natural levees, gave the suggestions for the present methods of control advocated and applied by the Army during the last 50 years. So tenaciously have the Army engineers held to the idea of "levees only" that to the popular mind the levee system is the only possible method of control. In the beginning it was undoubtedly the only method for the engineers to follow. It is perfectly natural also that with all the solicitation and care expended by them, for so long a time, that they should look upon the doctrine of "levees only" almost reverently. However, since the latest, not last, great disaster, the Mississippi River Commission has adopted an extension of the "levee only" policy. There are to be in addition spill ways, also controlled by levees, which are to be used only when the first line of defense shows signs of weakening. Whatever we may

think of this method of control, it nevertheless places the engineer and all his work wholly on the defensive. There is no aggressive attack which looks to the time when man and not the river shall be master of the situation, and one seriously questions the possibility of ever finding a solution so long as this defensive attitude of mind prevails.

Based on geological principles, this policy should be replaced by a more aggressive policy. Nothing short of a complete solution should be sought and planned for. To this end the geologists, probably, will find no efforts so fruitful as those which look to the speeding up of the waters within the main channel. This possibility comes strikingly to the fore, with a study of the so-called improvements made by man, many of which unquestionably, have had the effect of slowing and piling up of the flood waters.

To appreciate the situation fully it must be remembered that the primary purpose of the Mississippi River Commission, organized in 1879, has been to keep a navigable channel during low water stages, and not to control the high waters. During the earlier period the Commission was definitely forbidden to use any funds for such a purpose unless by doing so a direct aid to navigation resulted. All the work done has been directed from that angle, and although effective in this, has disregarded the effect on the flood waters. The increasing heights of these recurring floods may and probably are due in part to uncontrollable causes; but, just as truly, are they due also to the efforts of maintaining at all hazards, and in all places, navigable depths.

To make this clear it may be permissible to bring to mind a few fundamental facts. We speak of a river being at grade when, on the whole, it is neither aggrading nor degrading. Such a stream, however, must have a certain amount of fall or gradient to do its work. Besides the work of moving the silt, it also expends some of its energy in friction and in overcoming obstacles. Having only a certain definite amount of energy to expend, determined by the volume and altitude of the water, the river's gradient, is determined by the energy expended. If this balance is disturbed for any reason the river at grade then becomes either an aggrading or a degrading stream.

Other things being equal the greater the gradient of a stream, the faster the water flows, the velocity increasing as the

square root of the gradient, but the velocity in the various streams at grade does not bear a definite relation to the gradient. There are other controlling factors also, such as volume, friction, obstacles met, and the load carried. In whatever way energy is expended, it tends to slow up the velocity of streams flow no matter what the gradient, and if there is an additional expenditure, the river must silt up its bed and thus raise its waters to a sufficient height to maintain enough energy for the work required. A study of a number of rivers at grade shows that the gradients are strikingly unlike, because of the influences of some of the factors mentioned above.

It may be pertinent here to ask also what we mean by the gradient of a stream. Surely, not the bed over which the water flows. Were the lower Mississippi to dry up sufficiently to stop flowing the bed would become a succession of deep pools and dry stretches. It becomes manifest that not the bed of the stream, but the surface of the water becomes the datum plane for measurements of gradients. But as the water does not always stand at the same altitude in the stream bed there are an infinite number of gradients with high and low-water extremes. In the case of a river with an extremely low gradient the altitude of the body of water into which it flows must be taken into account also. As in case of the Mississippi, extreme low tide at the head of the passes is —2.5 feet with an extreme range of 3.9 feet. This must be taken into consideration when one is confronted with such facts as a low-water stage of 1.73 feet below mean gulf level at Carrollton, 111.5 miles from the Gulf. If mean Gulf level is taken as the datum plane, then this section of the river at low water would have a gradient up-stream of 0.186 inches per mile. This, of course, in general is an absurdity, but is possible under favorable conditions of tide and the special condition of a strong northwest wind blowing in the general direction of stream flow.

The variation in the gradients of streams at grade seems very large. Thus the low-water gradient of the Mississippi below Red River Landing near the mouth of the Red, a distance of 303 miles, is only 0.11 inches per mile. The Missouri of all the rivers studied has the highest gradient and strange as it may seem the lower 100 miles has the higher gradient of 12.24 inches per mile.

Certain definite conclusions, it would seem, with a good deal of confidence may be drawn from this somewhat semi-critical

study on gradients. The balance between aggradation and degradation in stream flow is very delicate. The shifting from one basis to another does not require great changes. This becomes very evident when seemingly the most minor obstructions result in the depositions of enormous beds of silt in certain sections of a stream bed. Any sort of obstruction in the lower part of the river may result in the silting up of the entire section of the river at grade above it. Conversely also a slight lessening of obstruction in the lower part of the river may also cause a desilting of the bed for the entire distance above. The elimination of one of the lesser meanders where the water travels ten miles to go one, would at first increase the gradient in the cut-off ten times, instead of a gradient of 3 inches, it would have 30 inches fall per mile. Immediately, however, the headward cutting would begin and all other conditions remaining the same, this would ultimately lower some two feet the entire base of the graded channel above the cut-off.

The question naturally arises is the river now at grade or is it slowly silting up? Unfortunately there are no data available at present which give us any positive clue to the situation. The Commission insists it is not. Others from observation insist that it is. This, however, is a most vital part of the problem and all efforts should be made to find out the actual conditions

If we trust our reasoning the bed is silting up. (1) Long before man came to modify the stream flow, the lower Mississippi, presumably, was at grade. With the recurrence of the floods the bed, somewhat silted up during the low water stages, was scoured out and the silt spread out over the flood plain. Passing down over the flood plain the quieter waters after dropping part of their load were returned to the main channel by the next tributary, there again to get another load, to repeat the process. The stopping of this has forced the river to carry this part of the load down through the passes. (2) According to the Commission they have been successful in preventing any cut-off since their control. Before man's activity many cut-offs occurred as a study of the flood plain will show. Each cut-off shortened the river by just so much and increased the gradient for the time being, ultimately de-silting the river proportionately. (3) At present, in order to keep a navigable channel, dikes are built also in channels to concentrate the waters at the outer bends where the water is already deeper. This undercuts the banks, makes the meanders larger and the river longer, re-

duces the gradient and consequently must result in silting up the river above the part affected. (4) The great problem has been to keep the passes open to navigation where the river builds out into the Gulf at the rate of about 2000 feet annually. Jetties and walls are built in this section to narrow the channel and increase the water depth. However, by doing this, there is an increase in the length of the water flow and consequently a decrease in the gradient. As silt cannot be moved on a level surface, a silting up must take place to restore the equilibrium. Time does not permit the mention of other factors.

Were there such a thing as an efficient stream from the standpoint of transporting water effectively and economically it would have certain definite characteristics. Naturally its course would be straight. Its waters would be free from silt and flow over smooth surfaces. The wetted perimeter would be semi-circular in outline, and thus the river would be twice as wide as deep. The Mississippi at present is far from this ideal. It may not be vital to philosophize on its wide departures; but it is vital to consider whether at present it is departing still farther from this ideal through man's activities. If it is, and evidence seems to show that it is, then we are farther from the solution than ever before. The geologists can point the way to a solution and their duty is clear.