10TH APRIL, 1890.

THE PREVENTION OF DAMAGE TO RIVER BANKS BY FLOOD WATERS AND THE REGULATION OF RIVER CHANNELS.

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THE object of the author in writing this paper is to draw the attention of the members of this Association, and to invite discussion upon a matter of considerable interest and importance to a large number of people in this colony, *i.e.*, the prevention of damage to river banks by flood waters and the regulation of river channels.

Any person who has taken notice of the alterations which are constantly occurring in the contours of river channels must also have noticed that large areas of land have been lost through such changes. It is during the periods which elapsed between the attainment of maximum flood, and the subsidence of the waters to their normal level, that these losses occur—thus a paddock having a stream for its boundary often becomes less in area after each successive freshet or flood.

To devise means of conserving the banks, and preventing rivers from changing their courses, is the business of the engineer, who must consider, in their most minute particulars, a great number of phases of the different questions which present themselves, before he can finally decide upon any definite plans for accomplishing the purpose in view.

Various methods have been adopted by engineers for the protection of river banks, and they are as follows :—

I., Fascines; II., Timber sheeting; III., Iron sheeting; IV., Crib-work; V., Stone pitching; VI., Retaining walls; VII., Groins. They are all briefly described by Professor Rankine in his valuable work on Civil Engineering—but, excepting the first (fascining) and the fourth (crib-work), all of the above methods are too expensive to apply to any but special cases. Both of these more economical plans are specially adapted for use in this colony where timber and brushwood are so plentiful.

Before fascining, the banks should be sloped according to the nature of the soil of which they are composed, after which a beard or apron of fascines should be laid as a bottom course, from the river bed upwards, the fascines lying with their length up and down the slope, the upper ends fastened by wire to stakes, and the lower ends under water held in position by loading them with stones; at a height of about three feet above water level, the fascines out should be laid horizontally along the slope-breaking joint with each other in the courses, with their bushy or leafy ends up stream, so that they may catch as much as possible of the soil and solid matter carried in suspension by the waters. For this class of work the ti-tree, she-oak and pine brushes are the best to be obtained indigenous to the colony. Fascining for this class of work is the cheapest and most effective that can be adopted. There is an avoidance of the danger attendant upon offering distinct resistance to the flow of water by means of retaining walls, timber and iron sheeting, &c., where if the up-stream ends are not carefully and often expensively secured, the water forces a passage between the work and the bank, leading to greater trouble than existed before the remedial measures were taken. Fascines admit of the water passing through them, offering only a partial resistance to the flow, at the same time retarding the velocity of the stream closest to the banks, and yet all the while they are gathering matter which assists to strengthen the latter against the action of future floods or freshes. One danger to be feared in the use of fascines is from fire, which may destroy in a short time the whole of a work of this kind.

The protection of banks with crib-work is greatly practised in

America, where such work is also extensively used for dams, abutments to bridges, &c., and is effectual in most cases. The author has used it in washaways where bridges have been endangered, and as a protection to embankments and roadways against the action of water, with most satisfactory results.

If an engineer has an unlimited amount of money at his disposal, he will probably adopt one of the other more substantial and expensive methods, but where he has to consider cost as well as efficiency, fascining presents the necessary requirements.

Having thus briefly dealt with the cheapest methods of effecting the stability of river banks, the author will now consider the best means of securing the channels and regulating the currents of rivers.

A river having a rocky bed may be said to be in a state of stability. When the bed is stony, or gravelly, it is stable in the normal state, and unstable in the flooded state of the river. "An earthy bed," Rankine states, "is in its usual condition either *just stable and no more, or permanently unstable.*" As an instance of an unstable bed during flood, may be cited the case of the Shoalhaven River, where, after a fresh, the sand scours out round the piers of the Nowra Bridge to a depth of 3 or 4 feet; but after a short period elapses, from the time the river has subsided to its normal level, the holes that have been formed gradually silt or become filled up again, so that no permanent damage has ensued.

The Hunter and Goulburn Rivers afford instances of gravelly beds, which are always in a state of instability during even small freshes. In each of these rivers, the current of to-day may be running close to the right bank; to-morrow there may be a fresh, and, after the water has subsided, it will frequently be seen that the channel has been transferred to the left bank. When a river has both unstable banks and bottom, the channel is constantly altering its course; this is notably the case with the Hunter River. The banks of this stream being, for the most part, composed of rich friable alluvial soil, are easily eroded and undermined even by slight freshets, but when a heavy flood has subsided, leaving the banks highly saturated, the latter begin to show signs of yielding, and, mostly when the water is within 2 or 3 feet of its normal level, large masses of earth become detached and flop into the stream, which carries the soil away in suspension to deposit somewhere lower down stream, generally at a point next or in proximity to the convex bank of a turn in the river, where the velocity of flow is less than it is next to the concave bank. Rankine states that "a channel tends to become continually more and more curved," and this the author has noticed with regard to all rivers he has yet had to do with. As an instance of an encroachment made by the Hunter River upon its bank, at one particular turn near the township of Denman may be cited the following:—In the year 1886, at a point between the Denman Bridge and Denman, a strip of land in the turn shown on sketch disappeared. This strip was about 500 feet long and 30 feet wide. The next serious encroachment took place in February, 1887, after which the author had a protecting fence erected about 20 feet distant from the edge of the bank. In August, 1887, it became necessary to remove about 20 rods of the fence to prevent it from falling into the river, so that in the short space of six months a piece of land at this one point of about 17 perches in area had been swept away. It will be seen from sketch that the river at this point has changed its course considerably—for what is now a dry bed of shingle on the convex side of the curve was twenty years ago the deepest part of the channel. The author proposed that the concave bank should be battered and protected by fascining; that a cut should be made through the old bed of the river, and that brushwood spurs should be thrown out into the stream diagonally, but in the direction of its flow. By these means it was considered that the following results might be obtained:—I. The prevention of further damage to the river bank. II. The formation of silt banks caused by the deposition of sand and particles of soil carried in suspension by the water, both up and down stream of the spurs. III. The diversion of the stream from its present course into its old channel by coaxing it into the cut made through its old bed, which cut would, as the present channel silted up, scour out and enlarge itself.

In India various rivers have been successfully treated in this manner, and in America, the use of brushwood for dams in connection with irrigation works is common amongst engineers. In this colony also, valuable work has been carried out with the use of brushwood, on the Moruya River and elsewhere, by Mr. Williams, Assistant Engineer of the Harbours and Rivers Department. But the practice does not obtain sufficiently, although we have such enormous quantities of ti-tree, pine, she-oak and other scrubs handy to most of our rivers. The method is cheap and effective, giving the very best results when properly carried out, and it is deserving of more attention at the hands of engineers. The spurs, suggested in the case of the Hunter River, might be constructed in various ways, but the method adopted as the best in connection with the River Oomla, in India, consists in driving into the bed of the river stout stakes or light piles, at distances of ten or twelve feet apart; these stakes should be securely stayed and anchored to prevent them from being swept away, and then connected by strong ropes or wires upon which brushwood or leafy branches of trees are to be fastened.

The author made some experiments with miniature spurs in a rapid mountain stream and obtained exactly the result he required, viz.:—A deposit of silt or sand, both up and down stream of the spurs, the greatest amount of deposit being at the shore ends, and diminishing gradually towards the centre of the stream, where considerable scour took place at the points of the spurs. The amount of scour and the deposits varied according to the angle formed by the spur with the direction of flow of the stream.

In different streams this angle would vary according to their velocities and depths; but without making a great number of experiments of a thoroughly practical nature, the ratio which the angle of a spur should bear to the velocity and depth of a stream, could not be determined. These spurs should not be built more than five or six feet above ordinary water level, as most of our rivers, after rising the heights mentioned, carry enormous quantities of timber and débris, which would accumulate against the spurs, and carry them away. Another simple method of causing the deposition of silt is to dispense with the use of stakes, and, instead, fasten large branches of trees by ropes to wooden crates, filled with stones, which act as anchors. Many of these floating spurs were used by Mr. Tufnell, Assoc. M. Inst., C.E., on the river Tangri, in India, with most satisfactory results. In conclusion, the author only regrets that he cannot give account of practical experiments with works of this kind, which he is conscious of having but poorly described; he trusts, however, that the subject will evoke that amount of discussion amongst the Members of this Association which its importance warrants. He also trusts that the unavoidable plagiaristic tendency of his paper will be charitably overlooked, when it is considered that the subject has been already so ably dealt with by many writers with large and varied experience in works of the kind in other countries—especially the author may mention a a paper by Mr. C. F. Tufnell A.M.I.C.E.,* on "Economical River Training in India," to which he is indebted for a great amount of information on the subject which he has presumed to lay before you to-night.

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* See Vol. LXXII. Minutes of Proceedings of the Institution of Civil Engineers.