

paid by the Witham Outfall Board. The area benefited by the works was certainly not less than 200,000 acres, and over this area the aggregate cost of the works, described in the Paper, represented a capital sum of only 21·2*s.* per acre. The large area affected by the works was not only materially enhanced in value, but the owners and occupiers were relieved of the anxiety and loss which attended frequent and disastrous floods. An ordinary spring-tide in Clayhole rose 23 feet 4 inches, and flowed for five and a half hours. Before the opening of the new channel, spring-tides rushed up to Boston with a bore 3 feet in height, heavily charged with silt, and flowed for two hours. On the completion of the works, the bore disappeared and the tides flowed gently in and comparatively clear from the estuary. Spring-tides now flowed for three hours and neaps from four to six hours, according to the force and direction of the wind. With reference to the slopes of the new channel, a slope of 4 to 1 was a successful and economical one in so exposed a position. It saved in a great measure costly works of protection; the same slope had been adopted on the Norfolk Estuary Works by Sir John Rennie and Mr. Robert Stephenson, many years ago. It was the first time he had heard Mr. Smeaton mentioned as the engineer of the Grand Sluice, local history credited Mr. Langley Edwards alone with the work. He could bear testimony to the great labour and care bestowed by Mr. Symons in compiling rainfall statistics, the perusal of which often afforded him much valuable aid. Mr. Hurtzig, like himself, preferred granite to sandstone; but no granite whatever was used in the construction of any of the sea sluices. Quoins of Bramley-fall ashlar were sufficiently hard and durable for such works, and their cost was less than one-half that of granite. The new channel was designed to catch the flood-tide, and at the same time to ensure the free flow of the ebb current into deep water. He might state in reply to Mr. Duff-Bruce that no special appliances had been used for landing the material dredged from the river between the Grand Sluice and Tattershall Bridge. The cost of landing the material dredged averaged 5*d.* per cubic yard.

Correspondence.

MR. P. CALAND considered the cutting of a new outfall at the mouth of the Witham to be an important work of river-improvement. It comprised at once the widening and deepening of the Grand Sluice above Boston, the draining of the lands formerly

Mr. Caland. exposed to flooding, the reinforcement of the action of the tide, and with it the improvement of navigation, the two last mentioned features being the purpose of every scheme of river-improvement in the estuary. Not every scheme of river-improvement was so fortunate. It appeared from the Paper that while formerly the depth of water at the mouth of the River Witham at high-water spring-tides was barely 15 feet, and the navigation difficult, if not impossible, for vessels of more than 300 tons, the result of the works had been to add 8 feet to the effective depth; so that now vessels of 2,000 tons, and drawing 23 feet, could reach Boston. As the level of the low-water had been lowered not less than $5\frac{1}{2}$ feet at Hobhole Sluice, and 4 feet at Grand Sluice, the tidal action had been greatly intensified, and the period between slack-water and high- and low-water had been correspondingly lengthened, thus greatly benefiting the navigation at flood-tide, and the drainage at the ebb. And not only the depth of the river, but the direction of the fairway, had been much improved by the construction of the new outfall between Clayhole and Boston. In future, both on the ebb and at the flood, the navigation of the channel would be available at a much earlier period of the tide, owing to the avoidance of the tortuous narrows, and channel encumbered by sandbanks, which formerly rendered the navigation difficult, and at times impossible.

Mr. FitzGerald. Mr. M. F. FITZGERALD observed that the Paper brought out strongly the importance, where low-lying lands about a flat reach of river were to be dealt with, of securing a free outfall at the lowest possible level. Where such was not provided, the increase of surface slope, which necessarily occurred during floods, might cause flooding at a moderate distance above the discharging sluices, even when this area was so great as to prevent any rise, during floods, at the sluices themselves. He would like to suggest, with reference to the great weight of floods referred to in the Appendix, that the flow of rivers had sometimes been observed notably to exceed that due to the rainfall, not only for a week or a day, but for several weeks together, especially in winter floods after long-continued wet weather. This point had been alluded to in a Paper by Mr. Robert Manning, M. Inst. C.E.,¹ and observations of river flow giving such a result had been sometimes treated as anomalous and necessarily incorrect. Fig. 3 represented the average flow of the Shannon for a period of ten years, along with the flow which would have taken place if the rainfall had been

¹ Minutes of Proceedings Inst. C.E., vol. xxv. p. 459.

discharged as fast as it fell. In this river the flow considerably exceeded the rainfall for the greater part of January and February. The ratio of river to rainfall-flow for the months of November, December, January, and February together was 1·2 to 1; for the remaining months of the year it was, however, only 0·39 to 1; and for the months of May, June, July, August and September, taken together, 0·33 to 1. Evidently the flow of a single month could not be compared with the rainfall of the same month, any more

FIG. 3.

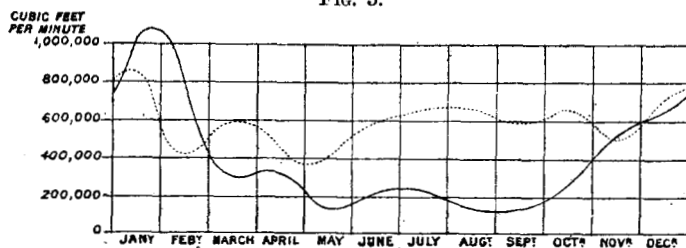
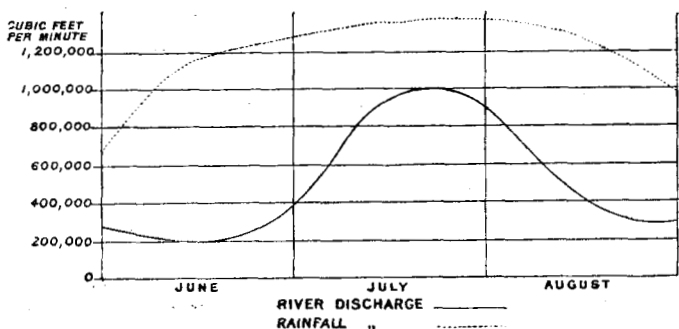


FIG. 4.



than that of a day or an hour. The effect of continued wet weather in increasing the ratio of river- to rainfall-discharge, embracing the summer flood of 1861, was shown by Fig. 4. The data for both these Figs. were partly derived from Mr. Bateman's Report on the Shannon (1866), and partly from the gauge records kept at Killaloe and elsewhere. The importance of paying regard to the seasonal variation of the rainfall-discharge coefficient was particularly great in rivers bordered by low land of a spongy nature, and it would be well if more attention were directed to this point as

Mr. FitzGerald. the conditions were different from those regarding the quantity of water which could be impounded by a given catchment area. The effect of the new outfall channel on the Welland discharge-channel should be beneficial, by diminishing the tendency of the channel between Holbeach Marsh and the Scalp to shift; but much depended on the effect of the altered direction of the flowing tide currents, about the Clayhole, reacting on those over the sands between Holbeach Marsh and the Scalp. There seemed in some instances, a tendency to produce an effect, which in this case would be represented by the pushing over of the Welland Channel in a northerly direction up to the Scalp, followed by a closing of the channel along its south-eastern border, and a deepening of that leading towards the Gat Sand.

Mr. Bloys van
Treslong.

Mr. C. BLOYS VAN TRESLONG observed that three works of different character, though nearly connected, had been almost simultaneously executed on the River Witham. By the excavation of a new outlet a serious impediment to navigation had been removed, and an unobstructed access of tidal waters obtained; by the deepening of the tidal compartment a complete filling up and emptying of the river had been assured; whilst by the enlargement of the upper part and the Grand Sluice, the area drained by the Witham had been greatly improved. He attributed these favourable results to the measures being well combined, and simultaneously executed. Measures of amelioration of the upper part of the district, taken in former years, consisted chiefly in shortening the length of the river, in the excavation of new drains, and in deepening the bottom; but these works produced only a temporary alleviation. The shortening of a river, and the subsequent acceleration of the current, generally gave rise to a more rapid erosion of the banks and bottom, and disturbed its equilibrium; and if the river was prevented from regaining its original length, the transport of materials, the result of erosion, tended to destroy the effects of the improvement. By deepening a river the regime of the stream was often injuriously affected, and the old conditions gradually re-appeared. The formation of new canals for drainage, separated from a river, frequently proved injurious by abstracting water which, by its scouring power, maintained the river. No objection, however, could, he thought, be offered to the widening of a river, as had been done in the case of the Witham; and especially was this the case where the removal of material chiefly took place above high flood-level. The erection of banks in early times reduced the sectional area of river beds during floods, and it was by neutralizing the prejudicial influence of this diminution of

area, that excavation beyond the navigable channel could be useful. With respect to the Grand Sluice, he considered it was difficult to decide, at present, whether its erection had been a mistake, as its former surroundings were not now known, and might have altered considerably since early days. He considered the relatively small width of the Witham an important factor in maintaining the tidal portion of its bed free from sand, which would otherwise be brought in during flood-tide, especially in stormy weather; the influence of the fresh-water flow in the last of the ebb would be especially beneficial. He approved of the cut through the Scalp. Where two rivers, such as the Witham and the Welland, joined at right-angles, and their common outlet was encumbered with shifting sandbanks, a radical remedy seemed perfectly justifiable. Moreover, by the formation of the new mouth, a prolongation of the training-works could be easily executed in the future if necessary. The cutting of the Hoek van Holland, at the mouth of the River Maas, the waterway to Rotterdam, was the most interesting instance of a similar work on the Continent. In the case of the Maas, it had been originally contemplated to resort mainly to the scouring action of tidal currents; but though there had been considerable erosion, it was found necessary, owing to the shifting and the shallowing of the navigable channel at the entrance, to undertake extensive excavation. The result was considered successful; although, probably, owing to the relatively great width and straightness of the channel, sufficient depth could only be maintained by yearly dredging. In another part of the Rhine delta, two small rivers, the Donge and the Oude Maasje, as in the case of the Witham and Welland, formerly joined nearly at right-angles to one another at the point of discharge into the Estuary of the Amer. The first-named river had in the course of time gradually altered its course in the lower part, and now occupied a position much resembling that of the Witham. At a short distance beyond the entrance, the navigable channel shallowed, and moderate dredging was required annually to maintain the depth of water equal to what it was higher up. With regard to the question of keeping the outlets of the Witham and of the Welland separate, in Holland, as a general rule, rivers were kept apart as much as possible, if their drainage areas were of a different nature, as for instance the Rhine and the Maas; in other cases, the uniting of branches was esteemed favourable to their general condition. On the point of cost he thought it would be advisable to bring the outlet of the Welland to Clayhole rather than to Lynn Deep. He found, from ancient charts, that

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formerly both the Witham and the Welland discharged alternately into Boston Deepes and Lynn Deepes, and that since the commencement of the present century neither of the Deepes had materially altered in capacity, though the latter had become narrower and deeper. The width of the Witham, in comparison with other marine waterways to an important town, was relatively small. For a commercial town of the rank of Boston, a width of channel of about 180 feet would have been adopted in Holland; its nearly straight channel somewhat resembled a canal, but the navigation was rendered more difficult by tidal currents. By the shortening of the river, consequent on the new outlet, the reservoir of tidal water had been diminished, impairing the action of the tidal scour. He was of opinion that it depended, in some degree, on the more or less rapid obliteration of the Wash, whether the results obtained by the works on the Witham would prove durable. Hitherto that had not occurred; but he thought it possible that this would occur, as soon as the reclamation of land had reached some limit, though probably not for many years. Boston Deepes was said to be maintained by tidal action. If true, this might be, to some extent, explained by the manner in which the tidal flow entered the Wash. The tidal water, following the deepest channel, did not enter Boston Deepes directly, but took the direction of Lynn Deepes, and passed across the Long Sands. As to the ebb currents, it might be deduced from the position of the banks and channels that they equally diverged at the entrance of Boston Deepes. Under these circumstances, it was evident that the raising of the banks would greatly improve the general condition as regarded navigation. To provide an outlet for the Welland into deep water, he should recommend the construction of a bank from the outer end of the Witham bank in a south-easterly direction towards Holbeach Marsh, leaving an opening at Clayhole for the discharge of the Welland waters. The space, thus partly enclosed, would be protected against the action of waves and strong currents, but filled up and emptied at every tide, and rapid silting up, especially at the angles, might be anticipated. The lands thus formed might, as soon as suitable for reclamation, be enclosed; while the banks, constructed for this purpose, would at the same time, serve to train the river. The secondary branch, leading the Welland to Lynn Deepes, would in this way be dammed off; that leading to Clayhole would remain unaltered, and would probably not need deepening, as it originally carried seawards the combined waters of the Witham and the Welland. After some time, a situation would be obtained similar

to that proposed by the Lincolnshire Estuary Company. At first, the Welland would be liable to shift its course in the large enclosed space; but not so much as at present, secondary branches being shut off, and the position of the mouth being fixed. The outlet of the Witham would, of course, be benefited by the scouring action of the water passing the entrance to the partly enclosed space.

Mr. Bloys van
Treslong.

Mr. J. EVELYN WILLIAMS, in concluding the correspondence, desired to add the following communication received from Mr. Goodwyn Archer, the Clerk and Solicitor to the Ouse Outfall Board:—"The improvement seems to be for the Boston Watershed equivalent to what was done for the Lynn Watershed by the Eau Brink Cut. Taking into account the difference of the areas of land affected, the Eau Brink Scheme cost the contributors more than twice the amount which your contributors have to bear." This statement Mr. Williams felt sure could not be other than gratifying to the land-owners in the Witham Valley.

Mr. Williams.
