also been paid to the filling and hand-packing of stone pitching. The gate-caisson was opened and shut by means of chains attached to hand-power winches. Most of the piers of the old Tay Bridge were still in existence. A strong desire had been expressed by the Harbour Trustees to have them all removed before the building of the new bridge was commenced, but on the representations of the railway engineers that the foundations of the new bridge would be imperilled by their removal, they had been allowed to remain, on the railway company agreeing to place and maintain a light on each pier. The Author.

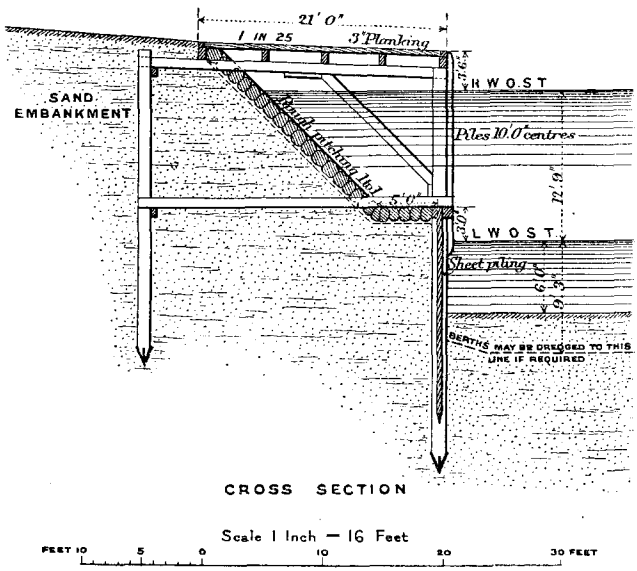
Correspondence.

Mr. T. JOHNSTONE BOURNE remarked that it would be interesting if the Author could give for the several critical periods at which increase of accommodation had proved necessary, viz., 1829, 1848, 1865, 1876 and 1891, the tonnage of goods, inward and outward, dealt with per lineal yard of quay. The length of quayage at those dates was given in the Paper, as were also the dimensions of the locks controlling the size of the vessels using the port; and the completion of the figures as suggested should show the increase of efficiency of unit length of quay as the average size of vessels increased. The shed-accommodation appeared to be about 8·6 square yards per lineal yard of quay, which seemed a low ratio, especially as the transit-sheds were of one floor only, which must serve for both export and import, and as there were no railway lines on the face of the quay. The design of the landing-wharf (*Figs. 9*) appeared to be of an eminently economical character. Perhaps the Author would state the nature of the material in which the piling was driven, and of the filling; and whether the anchor-rods occurred at every frame: also whether the anchor-block was continuous along the back of the quay. The figures given for the maximum and the average rate of discharge by hydraulic jiggers seemed to prove them to be as efficient as electric cranes for the kind of work required at Dundee, and their first cost was probably less. Mr. Bourne.

Mr. W. DYCE CAY observed that the section of the north wharf of the tidal basin for trawlers was the same as that of a wharf he had designed and erected in 1875 for herring-fishing boats at Mr. Cay.

Mr. Cay. Aberdeen (*Fig. 21*), except in the use of iron tie-rods at Dundee to carry the pressure of the embankment, and in the greater depth now required at low water. The requirements of the fishing-industry had been steadily progressive in the matter of depth of water and area of harbour. When he erected the above-mentioned wharf at Aberdeen, 6 feet at low water of spring tides had been considered sufficient to keep the boats always afloat; but, anticipating progress, he had made the work strong enough to admit of dredging the berths to 9 feet 3 inches. At that time the fishermen in many places had been contented with harbours dry at low

Fig. 21.



water. About 10 years later the size of the boats had been increased to 45 feet to 50 feet in length by 15 feet beam; and now the Moray Firth boats, of the "Zulu" type, were 60 feet long on the keel and 80 feet long by 20 feet beam on deck, and drew 9 feet to 9½ feet aft. As the hull cost £500, and steam-winch, sails, etc., a further £250, the owners naturally objected to putting the boats in harbours where they had to lie aground, especially if the bottom was rocky, or where they could not get in or out at all states of the tide; so that 10 feet at low water of spring tides was required. Also, with these deck-dimensions, twenty-seven boats filled 1 acre, or, say, twenty-two boats, to leave a little room for

working. The trawlers at Aberdeen and Dundee required, as stated in the Paper, 14 feet of water. With regard to the silting in front of the docks, he agreed with the second remedy proposed by the Author, viz., dredging through the sandbank called "My Lord's Bank," above the bridge, so as to lead more of the current on the ebb to the north side, and to make it sweep the face of the docks. He had noticed recently, when crossing the bridge, that on the flood there was a strong current passing through it at the smaller 130-foot spans objected to, so that he did not despair of the effect of the bridge if the channel above-mentioned were formed; and he thought that, by judicious dredging, the rate of silting and formation of the banks might be much reduced. Mr. Cay.

Mr. W. LEIGHTON JORDAN desired to point out, in reference to the Author's statement that the body of the tide ebbed on the south side of the river, and that there was a strong set of the flood-tide on the north side, that this course of the flood- and ebb-tides accorded with what he had lately described [1] as the normal course which they must have a tendency to take respectively. The estuary of the Tay, however, was a tidal river rather than an enclosed harbour of the character to which his arguments were intended to apply. The flood-tide from the north, after passing the headland on the north side of the river and taking its course southward in the offing, swirled back and recrossed the river's course at the bar in a northerly direction. The momentum of the flood gave it in fact several rebounds across the river's course before it reached Dundee, where the tendency of the ebb to the south side of the river, combined with that of the flood to the north side, seemed to show some controlling action of the normal tendency to cyclonic circulation. Mr. Jordan.

Mr. JOHN ROBINSON remarked that for the development and prosperity of a port the equipment and the arrangement of the sidings, including their connection with the railways, were of great importance. The equipment of a port with the most efficient mechanical appliances was, in these times of quick despatch, necessary for dealing with the traffic, even although it might be somewhat costly; and an expenditure of as much as £12,500 or £15,000 in the construction of a hydraulic coal-hoist and the approach thereto might be justified. The hoist or tip referred to in the Paper as in course of construction by the side of the Tay, for shipping bunker-coal, provided for a Mr. Robinson.

[1] Minutes of Proceedings Inst. C.E., vol. cxlvii. p. 145.

Mr. Robinson. maximum height, between high water of ordinary spring tides and the discharging end of the shoot, of 37 feet, and at low water of 53 feet 6 inches; 40 feet above ordinary high water to the lower end of a coal-shoot was not uncommon inside docks, and 50 feet had been contemplated where bunker-coal was required to be tipped into the hatchways of large modern steamships when light. Wagons with end doors were used in the Dundee district, there being no hopper-wagons like those on the North Eastern Railway system, where the coal was dropped through the bottom doors of the wagons; in the present and similar cases the table, hinged in front of the cradle on which the wagons were lifted within the hoist, had to be tilted up at the back, after releasing the end door-catches, in order to discharge the coal. He had noticed on the ground that gradients were to be adopted for the full- and empty-wagon sidings leading to and from the hoist, the wagons entering and leaving the hoist at or near quay-level. This would lead to a saving in the working-expenses which would be well worth the cost of the gradients anywhere where the nature of the site available would admit of the necessary side slopes. He thought the curved sidings leading to the hoist for the full wagons would have been better laid out from the opposite or east side, so that locomotives, on bringing a train of coal-wagons from the collieries, would at once back them into the sidings with falling gradients towards the hoist, leaving them to be drawn forward by the hydraulic capstans when the coal was needed for shipment. Should the space not be required for other purposes, the sidings for empty wagons, being well located, could remain as they were instead of being altered to run alongside the suggested full-wagon sidings, but at a lower level. He had not noticed any provision for weigh-bridges, which many traders now considered indispensable for weighing both full and empty wagons as they went on and came off the cradle. The proposed method of placing the hydraulic lifting-cylinders vertically against one side of the framing, instead of under the cradle in a well below quay-level, would, he thought, fully answer the purpose. There were other situations, however, differing from Dundee, where a hoist erected on a quay-wall with telescopic side cylinders would be preferable to projecting, for a temporary convenience, a staging into the fairway in order to get the lifting-cylinders underneath the cradle, where the staging interfered with the entrance and departure of vessels. In any situation cylinders fixed on the framing had the advantage of being more accessible for examination and repairs. About 11 years ago, after the Barry Dock had been opened for traffic, divers had

Mr. Robinson.

been employed to perform some repairs in the well of a low-level hydraulic tip, one without a water-tight iron casing enclosing the ram, etc., and a considerable amount of time had been spent in getting the tip into working-order again. It had occurred to him then that the hydraulic movable tip on the south side of the dock had its cylinders hung up in the framing; why not, he had thought, place the cylinders of a fixed tip above ground, securing them to the framing, thus obviating the necessity for any inspection and repairs being done by divers under water? He had mentioned the matter to the managing director, who, at the fixed tips subsequently erected by the side of dock No. 2, had had the hydraulic cylinders for lifting and tipping attached to the sides of the steel framing above quay-level, and the working had, he understood, given satisfaction. He had witnessed the method of discharging jute-bales by lifting them from a vessel by means of a rope attached to a hydraulic jigger stationed on the wharf and passing over a pulley suspended from the ship's derrick over the hold, and then disengaging the bales and allowing them to slide down a smooth wooden inclined plane into the shed; and he had seen that it was very expeditious. By the side of the Victoria Dock there was a 90-ton crane, and on the day of his visit a boiler weighing 83 tons had been lifted into a steamship. Transit-sheds being essential to the trade of Dundee, the Harbour Trust had not hesitated to build them of a substantial character, which had been done at a reasonable cost. He had scrutinized the granolithic flooring in the sheds recently erected, and in his judgment it was very suitable for the purpose, and equal to the traffic it had to sustain; there was, however, some danger of fracture from subsidence where the floor and walls were on made ground. In proposing to construct a new river-wall, having a dredged depth alongside of 27 feet at low water of ordinary spring tides, the Harbour Trust was providing for the accommodation of the large modern cargo-steamers which certain shipowners and merchants required for the profitable carrying on of their business. At high water of ordinary spring tides the depth of water in the Victoria Dock, the last constructed at Dundee, was 21 feet, and in the Earl Grey Dock, previously constructed, only 17 feet 6 inches at springs, and 14 feet 6 inches at neaps; there was therefore good reason for the provision of a greater depth of water. But the best way of arranging for the accommodation of vessels of a deeper draught than those making use of the existing docks, of such limited depths, required careful consideration as to whether it should be by a deep-water wharf-wall on the Tay side, or by a deeper dock;

Mr. Robinson. because the construction of a permanent wharf-wall 2,000 feet in length, with foundations more than 27 feet below low water of spring tides and 43 feet 6 inches below high water, in the situation proposed, would be very costly, and as great a depth would also have to be maintained along the navigation-channel and over the bar. Although the present timber wharf might allow the largest steamers now frequenting the port to lie and discharge at any time of the tide without inconvenience, there was a depth of only 18 feet at low water of spring tides, which limited the draught of vessels at such times, except when the level of the fresh water of the Tay happened to be higher; and at ordinary spring tides there was a variation in the level of the water at the river-wharf in one day of 16 feet 6 inches, whereas in the docks the variation in the level in a whole week was only 3 or 4 feet, that was between high water of ordinary spring and neap tides. Again, vessels lying at the proposed new river-frontage, 140 feet farther out into the Tay, would be more subject to the influence of the flow and ebb of the tides, and would be more exposed to gales of wind, which at times were very severe in the estuary of the Tay. Under these circumstances a dock would be more convenient for loading and discharging the cargoes of vessels; it would also be less difficult to construct, would probably cost no more in the end, and would be better value for the money. A timber wharf on the site proposed for the wall would not be so difficult to carry out as a wall, and consequently would be a more economical structure, taking into consideration the cost of the material as well, if the latter were not liable to destruction by the *teredo navalis*. But a deep-water dock, well equipped with up-to-date appliances, would give the most satisfaction in the management of the traffic, and be more conducive, in his opinion, to the prosperity of Dundee. With regard to improvements in the approaches to the harbour, the existing conditions would have to be studied, including the effect produced by the Tay Bridge on the tidal currents and fresh-water floods, as neither the site nor the openings could well be altered. Doubtless the conditions would have been different had there been no viaduct across the estuary, but the difficulty of devising works for the prevention of the encroachment of sand on the navigable channel had not been rendered insuperable thereby; and after giving due consideration to improvement schemes and to their various bearings, all the changes in the sandy estuary following the carrying of them out might not be foreseen. The unfavourable effects, however, might have a remedy devised for them before much mischief had been done. He did

not think that the flow and ebb of spring tides, or the scouring action of great land-floods at the ebb of spring tides, referred to by Mr. Cunningham in his Paper, could be depended on for keeping open a deep navigation-channel and the bar at the mouth without dredging, even if the channel were properly and scientifically treated. Vast improvements might be effected in the approaches to the harbour with modern suction sand-pump dredgers, judging by the success of their employment at Liverpool and at a number of foreign ports. A greater depth of water, he considered, was requisite for the accommodation of vessels of larger size if the trade of the port was to be retained and increased. The Author had given the cost of the different works executed in a way which would be easily understood and appreciated by dock engineers. Mr. Robinson.

Mr. W. Stopford Smyth observed that the estuary of the Tay afforded a most interesting study, and was a striking object-lesson in the evolution of docks, besides being a typical instance of the rapidity with which the demands had grown for accommodation on a wider and more extended scale than even the most sanguine minds had foreseen. The Port of Dundee might also be taken as an instance of the truth of the maxim that if proper accommodation were made, adequate means employed, and due equipment provided, then successful results might be looked for with considerable confidence. It must be admitted, however, that some instances could be named of docks having been constructed with too much precipitation, on an ambitious scale and in inviting situations, where the hopes of the projectors had not yet been realised. The large volume of the upland water, the comparatively vast width of the estuary opposite Dundee, the characteristic "neck" at Broughty Ferry, and the reversed inclination of the low-water surface during neap tides were the most salient features; while the fluctuation in quantity of the upland water affected the position and extent of the shoals in front of the entrance to the docks at Dundee and the depth on the bar. The docks first constructed were so small, the entrance was so narrow, and the depth of water on the sill was so little, that at the present day they stood but as ancient records, no longer remunerative, upon which much capital had been expended. The extremely cautious steps by which the Dundee Trustees had increased their dock-accommodation were very noticeable, but the boldness with which they had abandoned the use of docks for large vessels, and were building quay-walls in the tideway at which to load and discharge, notwithstanding the strong currents and in the face of the gales to which the estuary was subject, was much to be Mr. Smyth.

Mr. Smyth. commended. The fact having been generally accepted that vessels of large tonnage were, and would continue to be, the preferable means of transport across the ocean, it had been recognised that it was essential that facilities on at least an equal scale should be provided for unloading and discharging. Thus, a depth of 30 feet at least must be provided, and the loss of time consequent upon the necessity of entering docks and the delay in locking out must be avoided, the loss by such detention often amounting to a considerable sum. The Port of Dundee, by providing quays in the open, was fairly in advance of most other ports, being able to offer berths which could be reached without the delay occasioned by locking, and where large vessels could be loaded and discharged at any state of the tide without inconvenience. The mode of discharging general cargo was antiquated and far from being economical, but of course it could readily be improved by the adoption of proper methods. The question of dry docks for the use of vessels frequenting the port remained for solution. The Victoria dry dock was altogether unapproachable by large vessels, and was wholly inadequate to serve the needs of the present day. Floating docks offered advantages which the graving-dock could not afford, permitting ships' hulls to be examined at short notice when desired, and to be repaired and coated with the least possible delay. The very magnitude of a floating dock capable of taking a vessel of large size enabled it to withstand the winds and currents peculiar to what, in the case of small vessels, would be termed an exposed position. The configuration of the estuary had to be kept distinctly before the mind when considering the subject as a whole. From the mouth of the River Earn, where the width was about 600 yards, the estuary widened gradually for a distance of 10 miles, to Balmerino, where the width was $2\frac{3}{4}$ miles. The shores then converged for a distance of 2 miles, to the point where the Tay Bridge crossed the estuary, which was there $1\frac{1}{2}$ mile wide. The shores were nearly parallel for $1\frac{1}{2}$ mile below the bridge, but immediately and suddenly contracted to a width of $1\frac{1}{4}$ mile opposite the entrance to the Camperdown Dock, which was $1\frac{3}{4}$ mile below the Tay Bridge. From the dock entrance to the "neck," a distance of $2\frac{1}{2}$ miles, the shores again converged. At the neck the width was $\frac{3}{4}$ mile. From that point the estuary widened, till, at a distance of $2\frac{1}{4}$ miles farther, where the southern shore ceased, the width was $2\frac{1}{4}$ miles. The northern shore trended eastward 3 miles farther. The channel extended due east for a distance of 6 miles from the neck, then bore south-east for 2 miles to the existing bar, where the depth at low water was reduced

to 19 feet. The flood and the ebb took separate courses up the channel, as was usually the case elsewhere; the flood running unobstructedly on the north side, and the bulk of the ebb-tide on the south side, but failing to keep clear the entrance to the deeper docks, the depth there below low-water level being only 6 feet. Sandbanks necessarily occupied a zone between the two channels. Between the Tay Bridge and the dock-entrance, sandbanks occupied the north side, and the main channel was well to the south, giving a depth of 29 feet at low water for a width of 400 yards, close to Newport on the south shore. The course of the ferry-steamers between Newport and Dundee on the north was much obstructed by the tail of the Middle Bank, and by the Beacon Rocks, which were about 200 yards from the outer line of the Dundee docks. The Newcome Spit projected from the south shore half-way between Newport and the neck; the main channel was thereby driven diagonally to the north. At the neck the channel was 800 yards wide, with a minimum depth of 30 feet at low water, and was free from sand. The Horse-Shoe Spit projected from the north shore, turning the sailing-channel again southward and contracting it, at 1½ mile from the neck, to 200 yards in width, with a minimum depth, at low water, of 28 feet. The sailing-channel then expanded, and was again contracted in width to 200 yards, 2 miles farther down, by a hard patch. Beyond the patch deep water extended right away to the bar, 8 miles from the neck. The bar had been moved 1 mile seaward since the date of the first reliable survey, 1883. The material forming the banks and shoals varied. In the upper part of the estuary banks of fine sand, mainly on the north side, covered many square miles. Large quantities of such sand had been taken down by the ebb-tide. There were also sandbanks within the main channel of the upper reach, composed of coarser and cleaner sand than on the extensive flats to the north, the main channel having varied little above the Tay Bridge. Between the bridge and the dock-entrance the bank was of fine sand. The Newcome Spit, as well as the Horse-Shoe Bank and the hard ridge, consisted largely of coarse sand, full of water-worn granite boulders. Before the construction of the docks the Middle Bank had occupied that position in the centre of the channel to which it owed its name. It had been then, and as late as 1833, abreast of the bight between Newport and Woodhaven on the south shore. At the date mentioned the earlier docks had been made, but the downward movement of the ballast bank had already been apparent, the entrance to the docks having been even then impaired by the quantity of sand and silt deposited in front

Mr. Smyth.

Mr. Smyth. of the harbour. At the period referred to, when the bar had been nearly 1 mile nearer the shore, the entrance from the sea had been more clearly defined, and the Newcome Spit had been nearly ¼ mile higher, and had projected so far north that a curved channel, less than 500 yards wide, had caused occasional grounding of large vessels, the depth on the bar at low water being then 16 feet. The extension of the docks, the frontage of which projected ¼ mile into the estuary, and the construction of the Dundee and Perth Railway embankment, had caused, by the year 1869, some apparent reduction of the Middle Bank in midstream, but the crest had then been moving northward and eastward and the accumulation of silt in front of the docks had much increased. The first Tay Bridge, commenced in 1871 and destroyed in 1879, had been supported on the north side by piers set square to the centre line of a curve of 20 chains radius, in spans of 67 feet. The esplanade to the west of the docks, built about this time, trended, unfortunately, in a direction opposite to that most conducive to the maintenance of the requisite depth of water in front of the docks. These structures, as they existed, were detrimental and prejudicial to the interests of the docks, for although the piers of the first bridge had been removed, those of the second had been similarly placed in relation to the stream. The result was that, since 1879, the main current of the ebb had flown through the thirteen navigation-spans, while the area immediately below the twenty-five small spans had been slack water, and had permitted silting; the contour of the esplanade wall assisted in leading silt from the ballast bank to the front of the docks, there to be deposited in the slack water. In consequence of the failure of the ebb-tide to carry forward the silt, dredging had had to be resorted to in front of the docks. Notwithstanding the large amount of dredging, the Middle Bank had been in 1879 more threatening to the well-being of the docks than before the erection of the bridge. The subsequent construction of the wharf-wall to the east of Dundee, at which the largest steamers lay and were discharged at any time of the tide without inconvenience, had tended to improve the current and to reduce the accumulations in front of the docks. No doubt when the temporary timber wharf had been replaced by a quay-wall the effect of the current upon accumulations of silt would be somewhat increased, but the general conditions and consequent deposit of silt must continue unless more active measures were employed. The action of the flood and ebb on the outermost reach of the estuary influenced the whole regime, and was therefore worthy of particular attention. While the bar has been carried

Mr. Smyth.

seaward during the past 60 years, the sandbanks on each side of the main channel had been equally extended by deposits of sand brought down by the ebb from the upper reaches. The sandbanks from the points where the mainland ended were far from being in a condition to keep the channel in its proper course or to allow the ebb to have its full effect. Part of the ebb escaped over the Gaa Spit, 2 miles above the bar. The tide in entering the mouth of the estuary flowed at first in three directions, viz., over the bar, across the Gaa Spit from the north, and through an opening in the Abertay bank from the south; and it entered the last-mentioned with great force. To provide access to the docks and to allow large vessels to approach the port at all times the following modifications appeared to be necessary:—(1) The formation of an embankment of large rubble stone in front of the esplanade to half-tide level, laid so as to form, with the portion of the present esplanade wall close to the Tay Bridge railway station, one continuous straight line. (2) The removal of the Beacon Rocks. (3) The removal by dredging of as much of the Newcome Spit, the Horse-Shoe Bank, the Lady Bank, and outside it, as might be sufficient to form a channel to give a depth of 30 feet at low water. The material to be thus raised by dredging, consisting largely of coarse sand full of water-worn granitic boulders, should be applied to the following purposes:—(i.) A line of training-wall between East Newport and Woodhaven, forming the chord of the bight between those two places. The ebb-current would then have greater effect along the north shore, and the deposit of silt would be checked there. The ferry landing-place could be transferred to East Newport without causing much inconvenience to passengers. (ii.) The formation of half-tide training-walls on the flats of the sandbanks of the Gaa and Abertay Spits, so as to secure the full effect of the latter half of the ebb over the bar. With a contraction of the estuary and an unobstructed channel between the Tay Bridge and the docks, and between the neck and the sea, the full advantage of the ebb-currents during land-floods would be obtained over the bar, which would thus, in all probability, be reduced to 30 feet below low-water level. Further dredging would be required alongside the new quay-walls to the east of Dundee to allow the vessels of the immediate future to berth there. Possibly periodical dredging might be required on the bar to maintain the 30 feet at low-water level. If the half-tide rubble wall were formed west of Dundee to prevent the ballast bank from being carried down to the entrance to the docks, the dredging there would be

Mr. Smyth. reduced to a very small quantity, and the condition of the estuary would become balanced and its working almost automatic.

Mr. Wheeler. Mr. W. H. WHEELER remarked that the Paper, taken in conjunction with that by Mr. Cunningham, afforded some instructive lessons on the effect which works of improvement carried out on the foreshore or bed of a river had on the propagation of the tidal wave and the maintenance of the navigable channel. It appeared from these Papers, that some time previous to the year 1833, works had been carried out on the foreshore of the river between Perth and Dundee with a view to the reclamation of a large tract of tidal land, which had led to the accumulation of between 13 million and 14 million cubic yards of alluvial matter, and the decrease to that extent of the volume of tidal water flowing into and out of the upper part of the river. Fears had been entertained by the harbour authority, that this large abstraction of tidal water would lead to deterioration of the navigable channel, and Mr. James Walker, who had been consulted, had confirmed those fears and had advised that no further reclamation-works should be permitted. Soon afterwards works had been carried out in the same part of the river for the improvement of the navigation by regulating the course of the channel, and removing 840,000 cubic yards of material from the bed of the river, a uniform depth of 5 feet at low water and 15 feet at high water being secured. The result of this dredging and improving the channel had been that the low-water level had become depressed 2 feet, and the velocity of the flood-tide had been increased $1\frac{2}{3}$ mile per hour, causing it to reach Dundee earlier than before the commencement of the works; the level of high water at Perth, which previously had been level with that at sea, was now 9 inches higher. The volume of tidal water flowing into and out of the river above Dundee had been increased by 20 million cubic yards. Careful surveys of the channel and sandbanks had been made before these works were carried out and afterwards, and it had been reported to the Commissioners,[1] that although large deposits had taken place on the sides of the river, this effect had been more than compensated by the increased volume of tidal water, due to the deepening of the navigable channel, and by the scour of the ebb and flow of the water being increased and intensified in action; and that the alterations which had taken place in the channel between Perth and the sea were all in the direction of improvement. Extensive encroachments had

[1] Report of Mr. David Cunningham to the Trustees of the Harbour of Dundee, 1887.

also been made on the foreshore of the river for the docks at Dundee, and in the construction of a wall and promenade 3 miles in length. The width of the waterway of the river had been reduced from $1\frac{3}{4}$ mile to $1\frac{1}{2}$ mile, the total area of land abstracted from the foreshore amounting to 328 acres. The piers of the Tay Bridge constructed in 1871–78, which crossed the channel near Dundee, further decreased the waterway by nearly $\frac{1}{8}$ mile. These encroachments and restrictions of the waterway had led to increased velocity of the current passing Dundee, and a consequent deepening of the channel and scouring away of a large middle sand, which had previously extended over an area of 130 acres, and had risen 8 feet above low water, the depth in the channel increasing to 30 feet where the sand had formerly dried at low water. The depth of the water through the piers of the bridge had been increased 8·8 feet. The greater part of the sand set in motion by the scour due to the increased velocity of the current was carried away on the ebb to sea, but owing to the piers of the bridge being so aligned as to divert the flood and ebb current away from the north side of the river, some deposit had occurred in the slack water in front of the harbour, and $1\frac{1}{4}$ million cubic yards had had to be dredged in order to obtain sufficient depth for the entrance to the docks. This depth had since been maintained. It appeared, therefore, that, contrary to the opinion so frequently expressed as to the injurious effect, on the bar and channels of a sandy estuary, caused by diminution of the area and abstraction of any part of the volume of tidal water flowing in and out of such estuary, no deterioration of the bar at the mouth of this estuary had taken place, due either to the reclamation-works in the upper part of the river, or to the abstraction of foreshore for the Dundee harbour and river-wall. On the contrary, a careful comparison of the surveys made on various occasions between 1833 and the present time disclosed the fact that the diminution in area had been more than compensated by the improvement in the channel, the depth of water over the bar having gradually increased till there was now between 3 feet and 4 feet more water over it than there had been formerly; and that it had moved nearly 1 mile seaward. Another fact disclosed in these Papers was contrary to the theory, so frequently advanced, that sand and other deposited materials was brought into estuaries from the sea by the flood-tide. Mr. Cunningham in his Paper stated that the sea-water entering the estuary on the flood-tide over the bar, was of a "clear bright-green colour," whereas the ebb-water in land-floods which it met on its course down the channel, and under which

Mr. Wheeler. it forced its way like a wedge, was turbid and of a purplish-brown colour. Mr. Wheeler's own experience of examinations of the sea outside the bars of many sandy estuaries confirmed the fact mentioned in the Paper, as he had invariably found the water in these localities clear and bright, except when discoloured by heavy land-floods.

The Author. The AUTHOR, in reply to the Correspondence, regretted that, as he had now severed his connection with Dundee, he was unable to give the information as to tonnage of goods asked for by Mr. Bourne, and otherwise to reply so fully as he would wish to the remarks of correspondents. The sidings in connection with the coal-hoist, referred to by Mr. Robinson, had been designed to meet the requirements of the railway companies, and after consultation with their engineers. The 90-ton steam-crane at the Victoria Dock was admittedly behind the times, and shortly before leaving Dundee he had prepared a scheme for a 120-ton derrick-crane on a proposed new riverside wharf. The question of deep-water dock *versus* deep-water river-wharf was one which had had the earnest consideration of the Harbour Trustees and their engineering advisers for years. In 1873 the late Mr. T. E. Harrison, Past-President Inst. C.E., had prepared designs for a new dock, extending into the river and embracing the Fowler and Beacon rocks, at an estimated cost of £450,000, and in 1883 the Harbour Engineer (Mr. Cunningham) had submitted a scheme for a wet dock on the site of the present shipbuilding-yards at a cost of £405,000. In each case want of funds had been the chief obstacle to the execution of the works; and on a review of the whole situation in 1891 it had been decided that a wet dock was financially impossible. Dundee was a port which had now seen its best days and had no prospects. It was a town with practically only one trade, viz., the manufacture of jute goods; and now that Calcutta had built mills and manufactured jute goods on a large scale, Dundee was greatly handicapped and the competition became more severe every year. It might be said that Dundee was geographically the natural port for a large portion of the east coast of Scotland and should have a large import trade, but, as a matter of fact, Leith monopolized the trade, and from Leith as a centre goods were despatched by rail all over the eastern counties. Under these circumstances the Harbour Trustees had had to provide accommodation for the larger class of ocean-going steamers at the least possible cost, and deep-water river-wharves had been decided upon. The Trustees did not regret their decision, and shipowners and shipmasters were unanimous in preferring the

wharves, and grumbled if they were sent into dock; while the size of modern vessels precluded them from all danger from gales of wind in the estuary. He had recently had a similar problem before him at the Port of Rangoon, and, partly owing to the absence of any sort of foundation for dock-walls or material for building the same, and partly owing to the great success of the river-wharves at Dundee, he had decided at Rangoon in favour of river-wharves as against a dock. The remarks of Mr. Smyth were of considerable interest, but the Author doubted whether in the Tay the practical benefits of the training-walls recommended would be commensurate with the expenditure in their construction. On the North Bank he deprecated any alteration or extension of the existing esplanade, for the reason stated in the Paper. The points of resemblance between the north wharf at Dundee and Mr. Cay's wharf at Aberdeen appeared to be too remote for purposes of useful comparison. At Dundee the depth from high water to ground level was 28 feet 6 inches as compared with 18 feet 7 inches at Aberdeen; and whereas at Dundee the width of quay was 12 feet and the bank was kept up artificially, at Aberdeen the width was 21 feet with a reduced slope; further, the embankment was in the one case soft mud and in the other sand. The Author.