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“Sand-Movements at Newcastle Entrance, New South Wales.”

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THE works at the entrance to Port Hunter, on the east coast of Australia, have now been completed as far as arranged for in the original scheme, and have been on their trial for the last few years, during which the trade of the port has increased considerably. It would seem opportune at this stage, therefore, to review the effect of the breakwaters already constructed on the sand-movements, with a view to determine the relative advantage of the different walls, and the total effect of the works constructed, taken in conjunction with the dredging-operations. The Author has therefore endeavoured, by a series of contour-plans, to indicate these different results, which are the net outcome of an expenditure, up to the present time, of £277,425.

Port Hunter, or Newcastle Entrance, is at the mouth of the Hunter River, which drains about 8,000 square miles of country. Owing to the projection of Morna Point 20 miles to the north-east, the southward Australian current is of such diminished velocity that its effect on the tidal currents of the entrance is inappreciable. The area of the tidal basin is 6,500 acres, and the tidal waters extend up to 40 miles from the mouth, into the tributary Williams and Paterson rivers. For 10 miles from the mouth the river is divided into two main channels with various subsidiary channels, through deltaic country, which continues to make up during the high floods that carry down large quantities of silt in suspension.

Experiments made by the Author showed that this silt takes 3 to 7 days to settle in perfectly still water, and with any current in the harbour, it requires 4 to 6 months to become solid enough to be dredgable. This circumstance, coupled with the fact

that all sand dredged from the bar is perfectly clean, shows that the silt itself is not accountable in this instance for any shoaling in the entrance-channel, but that, on the contrary, in high flood, when the velocity attained is about 13 feet per second, the silt and large quantities of sand are swept well out to sea and dispersed in deep water.

To the north-east of the old original entrance, as shown on the plan dated 1816 (Fig. 1, Plate 6), there existed an island called "Nobby's," 130 feet high. Between this island and the mainland there was at that time a channel 10 feet deep, which the colliers then used as an entrance in southerly weather. In 1835 a breakwater, built by convict-labour, was commenced across this entrance, to train the current on to the present channel. This wall was completed in 1848. The sailing vessels then met with difficulty in entering during southerly weather, as they lost the wind under Nobby's and at that time steam-tugs were not obtainable. It was therefore decided to blow up this hill, and undermining operations were completed, but, fortunately, wiser counsels prevailed and the explosives were never fired. Nobby's remains to this day, and carries a fine lighthouse 115 feet above sea-level.

Before the closing of this old channel the southerly seas swept round the island, rolling large boulders fallen from the sea-face of Nobby's, which is to-day a perpendicular wall of stratified argillaceous rock. These boulders have been rolled round to the lee of Nobby's, and since the sand has been removed from them during the last 2 years, they are found to be packed closely together. They extend across the channel, gradually increasing in depth from water-level at Nobby's and Stony Point to 30 feet at the north breakwater. These stones, which weigh up to as much as 5 cwt., are now being removed by a clam dredger, and below this layer the Author expects to reach a bed of shale, which will require blasting for its removal.

CHART OF 1816.

This is the earliest plan of the entrance which gives any detailed information about the depths (Fig. 1, Plate 6). It was surveyed before any works for the improvement of the channel had been undertaken, and, in addition to the channel to the north of Nobby's, it shows the channel 10 feet deep between Nobby's and Signal Hill which small sailing vessels frequently used. The dangerous character of the entrance at this date is clearly indicated by the number of wrecks charted on the plan at even this early period of the Colony's history.

CHART OF 1866 (Fig. 2, Plate 6).

This chart shows the 10-foot channel cut off by a breakwater, and the existing line of leading fairway-towers defined. The 21-foot channel was only 150 feet wide off Stony Point. Attention may also be drawn to the sand-spit to the north of Nobby's, running 80 feet north of the fairway-line, and to the two additional wrecks shown on this plan.

CHART OF 1887 (Fig. 3, Plate 6).

In this plan part of the south breakwater is shown as constructed, and also the present inner, or old north, breakwater. It will be observed that the 21-foot channel has improved perceptibly up-stream from opposite Nobby's lighthouse, and the large sand-spit off the Stockton shore is nearly scoured away; this latter action was fully explained by Mr. C. W. Darley, M. Inst. C.E., then Engineer-in-Chief, in evidence before the Public Works Committee in 1895. Opposite the commencement of the south breakwater there is clearly shown the bar, on which at this time there was a depth of 20 feet. It will be observed also that the deep-water channel is tending to follow the south breakwater, and is working over to the south of the fairway-line, which action will be observed to continue till the 1909 plan.

CHART OF 1896 (Fig. 4, Plate 6).

This shows further improvement in the channel, but unfortunately further wrecks on the Oyster Bank and Stockton shore. It may be mentioned, however, that before 1896 very heavy floods occurred in the Hunter River, that of 1893 being the greatest ever known, and these heavy discharges undoubtedly had a good effect in clearing away large quantities of sand. A very ugly shoal, though, is shown as formed to the north-east of the old north breakwater. Another shoal was beginning to form on the fairway-line opposite the end of the south breakwater at that time, where the 8-fathom contour had come in 600 feet, and the depth had decreased from 48 to 24 feet. It was about this time that the Public Works Committee recommended the construction of 3,000 feet of north breakwater and the extension of the south breakwater by 300 feet,

CHART OF 1903 (Fig. 5, Plate 6).

This plan, from the Author's own survey, shows three additional wrecks on the north, and the construction of the breakwater to 2,000 feet out. Two very important sand-spits are clearly defined, which were becoming a source of danger to navigation, both having only 18 feet depth of water at 80 feet from the line. The ebb- and flood-tide used to rush round the end of the north breakwater at the high velocity of 3 knots per hour, forming the channel shown, and deepening the tip-head to 36 feet. The entrance at this time was a dangerous one in heavy weather, the ships entering being liable to be swept over by the seas into shallow ground to the north. A deep channel was still available, however, by keeping close to the south breakwater, outwards from Stony Point.

1904.

In September of this year the barque "Adolphe" was wrecked on top of the old wrecks of "Wendours," "Lindus," "Colonist," and "Cawarra": and an advisory Board of Engineers decided to close the gap between the end of the north breakwater and the "Adolphe," in order to stop the flow of sand from the Stockton Bight, and to keep the ebb-tide current in a straighter course. This was effected by the sinking of the old steam-hulks "Elamang" and "Katoomba," and also of thirteen iron hopper-punts loaded with stone. The positions of these hulks and punts are shown in the next plan.

CHART OF 1905 (Figs. 7 and 8, Plate 6).

During this year the channel caused great anxiety, owing to the perpetual formation of various small shoals at different places. The sand was all alive, but gradually working away, owing to the blocking action of the fan-shaped currents to and from the north; and during this process the shoals kept changing in position and depth, thus requiring constant watching and attention. There was at times as little as 18 feet on the fairway-towers line. In this and the following year good work was done by the sand-pump dredgers "Antleon" and "Tethys" in removing the shoals, but these dredgers were of too small a capacity to effect any permanent improvement.

CHART OF 1907 (Fig. 9, Plate 6).

This survey, taken before the work of the bar-dredger "Jupiter," shows the effect of the north breakwater without any appreciable dredging having been done. The 21-foot channel had now widened out to 450 feet off the end of the north breakwater, and the sand-spit in that portion of the entrance was slowly but surely disappearing. The ebb now ran out in a straight direction, with a velocity of 2·4 knots per hour, carrying the sand seaward; but the flood-tide still came round the end of the north breakwater, carrying large quantities of sand (about 430 tons per day), though with the diminished velocity, at the end of the breakwater, of 2·4 knots per hour instead of more than 3 knots, as in 1904. The south breakwater extension had also the beneficial effect of diverting the force of the heavy seas to the north, instead of in the direction of the "Regent Murray," thus reducing the danger to navigation. It will be observed also that the constant shoaling of the various parts of the channel as in 1905-6 has practically ceased. Unfortunately, however, the outside shoaling, which, in reality, is now the "bar" in the usual acceptance of that term, shows a steady increase below the 4-fathom contour-line.

CHART OF 1909 (Fig. 10, Plate 6).

This plan shows the contours of the entrance in March, 1909, due to the combined action of the north breakwater as far as at present constructed, and the dredging at the bar of 944,050 tons by the sand-pump dredger "Jupiter." The 21-foot contour has widened out opposite Nobby's to 800 feet, as against 200 feet in 1866, and the rocky bottom of the shallow parts of the channel on the fairway-marks line has been completely cleared of sand, leaving the stone bare and allowing marine growth to appear thereon. The removal of a portion of these rocks has now been taken in hand, as already mentioned. The shoal opposite the end of the south breakwater is still in evidence, as indicated by the tongue of the 5-fathom contour coming down to the fairway-line, but during the last 12 months this has deepened from 24½ feet to 29 feet, and is therefore not increasing, though how much of this negative effect is due to the "Jupiter" it is difficult to estimate. This, however, is now the danger-point, causing the seas to break in heavy weather; the motion of the waves alters from oscillation to translation slightly south of the towers line and the seas break right across the remainder

of the channel, with such force that a vessel would have but little chance if caught, being here broadside on for entering the harbour. It is therefore highly essential that this shoal should be removed, and the proposed extension of the north breakwater would certainly assist materially; but it will probably be necessary, in the first instance, to dredge to the maximum depth obtainable, when the breakwater would have a better chance of maintaining the depth (with possibly occasional dredging with a sand-pump), by arresting the flow of sand from the Stockton Bight. The highest waves outside, as measured by the Author, were 16 feet from sea-level to crest, and the corresponding maximum range in the harbour was 7 inches, whereas the range was 11 inches before the construction of the north wall and of the last extension of 300 feet to the south wall, together with the two wave-traps. This substantial decrease is of much importance to vessels lying alongside wharves which are in such close proximity to the ocean.

DREDGING AND BREAKWATER-CONSTRUCTION.

The dredging by the "Jupiter" during the early part of 1908 was principally on the shallowest portions of the channel proper, but the Chief Engineer endeavoured to induce the main channel to move over towards the north to avoid the rock. Dredging was commenced as close up to the north breakwater as safety permitted and extended from the "Regent Murray" seaward for 1,500 feet, or in a north-easterly direction from that wreck. This had the effect of cutting off the supply of sand which continually pours in from Stockton Bight, and the ultimate result of these operations is as shown in Fig. 10, Plate 6, and mentioned previously.

The dredging-plant consists of the self-propelling twin-screw bar-dredger "Jupiter," fitted with twin suction-pumps and trailing pipes, and capable of filling its 750-ton hopper in 20 minutes; the average work per day, dredging and depositing at sea, amounts to 3,000 tons. There is also a small clam dredger engaged in removing the boulders overlying the rock in the channel.

The sinking of the hulks "Elamang" and "Katoomba" and the iron hopper-punts, in January to March, 1905, was an interesting operation. The hulks were originally passenger-steamers trading between Brisbane, Sydney, and Melbourne. The "Katoomba" had a displacement of 1,006 tons, with a length of 250 feet, a beam of 29 feet, and a moulded depth of 19 feet. The displacement of the "Elamang" was 946 tons, length 230 feet, beam 29 feet, and

moulded depth 20 feet. The hulks were first dismantled, trimmed to 9 feet draught, and moored at slack water in the positions shown on the plan; the sea-cocks were then opened and the vessels sank into the sand. The "Elamang" was loaded in position with 340 tons of stone and 1,300 tons of sand. The "Katoomba" was stiffened with 250 tons of stone and strengthened amidships with two encircling chains and struts before fixing, and 1,400 tons of sand were pumped in when she was moored into position. The "Elamang" broke athwartships 3 days after fixing, having settled down 5 feet into sand, and the "Katoomba" also gradually settled into the sand and in 4 months collapsed. The iron hopper-punts were loaded with stone packed into the air-tight compartments and hoppers, and were carefully moored into position at slack water; they were then scuttled one at a time by means of previously-prepared holes in their plates, which allowed the water to enter evenly throughout. It was necessary to moor the punts very carefully, as experience showed that when sinking each of them tried to capsize.

While the hulks and punts were being sunk, the breakwater was pushed forward day and night, and quickly covered the remains of the vessels. These hazardous operations were carried out without mishap of any kind.

The immediate effect of this rapid restriction of access for the tidal currents round the north wall is clearly shown on the contoured plans; the shifting sand was forced seaward at ebb-tide, and a large portion of the sand that came in during the flood-tide was cut off. The ultimate effect was far more pronounced, for instead of building the breakwater into a hole 36 feet deep, which continually advanced in front of the tip-head, the hulks and punts kept the depth at 15 to 20 feet, and enabled the wall to be built more expeditiously and at much less cost.

It has now been proposed by Mr. E. M. de Burgh, M. Inst. C.E., Engineer-in-Chief for Rivers and Harbours, to extend the north breakwater 420 feet, so as to cut off the sand-drift still further, and to extend the south breakwater about 200 feet, so diverting the heavy seas still more towards the north. In this proposal the Author concurs, as all the evidence he has gathered in his study of the matter points to the probability that with this increased length of wall the sand-drift will be kept within easy control, and the tip-head will not be far enough out to catch, and divert into the harbour, the heavy seas which pass the protection of the south wall. This proposed extension of 420 feet of the north wall was first recommended by Mr. C. W. Darley, M.Inst.C.E., Engineer-in-Chief in 1896, under whom the Author had the honour to serve. The ultimate

aim of the Department is to obtain a depth of 30 feet at low water, and with this in view it is anticipated that, the sand-movement question having been dealt with satisfactorily by the proposed breakwater-extension and the assistance of the dredger "Jupiter," the work of removing the rock from 23 feet down to 30 feet will be lightened appreciably.

In conclusion, the Author desires to thank Mr. E. M. de Burgh, M. Inst. C.E., Chief Engineer for Harbours and Water-Supply, for his permission to submit this Paper, and also for his kindly criticism and assistance during its preparation.

The Paper is accompanied by one tracing and a print, from which Plate 6 has been prepared; there are also two photographs.