

REPORT

ON THE

STATE AND REQUIREMENTS

OF THE

Kurrachee Harbour Works,

BY

COLONEL H. ST. CLAIR WILKINS, R. E.,

A. D. C. TO THE QUEEN.

WITH PREFACE BY COLONEL SIR A. CLARKE, R. E.

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Preface by the Hon'ble Member in charge of the Public Works Department.

IN July 1875 the Government of Bombay in forwarding certain Surveys and Reports connected with the Karachi Harbour Works, also submitted a communication from the Superintendent regarding the injurious action said to have been in progress in certain parts of the harbour, and observed that it was possible further reports would tend to show that the effect on some of the works was not so harmful as the previous ones would seem to indicate, for the deterioration brought to notice was due to a temporary cause only.

Further investigation did not, however, confirm this hopeful view, and in submitting its subsequent proceedings, the Government of Bombay remarked that the subject was one of serious consideration, and one on which an early decision with respect to future operations was very desirable.

It appeared to me that the subject was of paramount importance, for not only was it desirable to obtain some tangible benefit for the large sums of public money that had been expended on the harbour, but the construction of the Indus Valley Railway then approaching completion was calculated to bring a large increase of trade demanding increased facilities for entering the port and more conveniences for the shipping lying within it. The Government of India accordingly on my recommendation decided that a Committee should be appointed to take the matter into consideration, and to ensure the subject being properly investigated, the following general instructions were laid down for the guidance of the Examining Officers :—

- (a).—To ascertain what were the chief features of the natural harbour previous to any efforts at improvements being made.
- (b).—To compare the present state of the harbour with the former taking care to discriminate those changes which are due to natural causes from those created by artificial means, and from those produced by combined natural and artificial action.
- (c).—To state the nature of the remedial measures that should be undertaken in those spots where it was ascertained that either natural or artificial causes or both combined have had an injurious influence.
- (d).—To ascertain, in detail, the result of each artificial work whether beneficial or injurious.
- (e).—To consider the further improvements of the harbour whether by the extension of existing artificial works or by the addition of new ones for the purpose of creating scours or to maintain the depth by the natural ebb and flow of the tide, or to influence existing currents.
- (f).—Also the probable effects of such artificial works.
- (g).—To consider the probable advantages or disadvantages of endeavouring to effect the same results by better and more economical dredging apparatus.
- (h).—To make an approximate calculation of the cost by both methods with the relative advantages of each.
- (i).—To give full attention to the further treatment of the Chinna Creek, and of the other estuaries debouching past Manora Point.
- (j).—To consider whether any beneficial result can be obtained by deflecting the course, or the currents of the Pahi Baka or of the Gaini.
- (k).—To take careful observations of the influence of Manora Point and of East Pier.
- (l).—To offer opinions as to the stability and structural arrangements of the break-water.

The prosecution of this enquiry was entrusted to Colonel Wilkins, R. E., whose report, full of valuable and interesting information regarding the harbour, now forms the bulk of these papers. I have, since its receipt, visited Karachi, and have discussed on the spot with Mr. Price, the Superintendent of the Harbour Works, the various proposals for additional groynes and piers made by Colonel Wilkins and himself for diverting and regulating the scour from the tidal waters. I cannot fail to recognise the value and possible efficiency of those proposals, but the element of extreme uncertainty as to whether they will prove efficient or the reverse, cannot be eliminated from them, and I have arrived at the opinion that better and more permanent results can be secured by well devised and continuous dredging than can be obtained by any of the other means suggested.

I would here mention that I have come to this opinion not guided by the facts and observations afforded by the works at Karachi alone, but from a pretty large experience and from results I have either personally obtained or have seen obtained by other Engineers in harbours in various parts of the world,* some under conditions not dissimilar to those with which we have to deal in the present case.

* I may here quote the instance of the bar at the entrance to Portsmouth harbours which I deepened by dredging alone. Adverse opinions and predictions of failure were not wanting at the commencement of the work, but the experience of 15 years, doubtless but a short span of a harbour's life, has fully borne out my views, and not one inch of depth over the bar has, up to this time, been lost.

A. C.

The artificially formed harbour of Karachi is, so far, doubtless a very fair success, but like all artificial works of whatever nature they may be, from a beaver dam to first class harbour of refuge, it must be maintained, and we should be prepared to spend on it annually a certain sum, not only to keep it efficient, but still further to improve it, and so meet the demands of the rapidly increasing trade following on the opening of the Indus Valley Railway. In advocating this system of dredging, I have not lost sight of the value of the spoil and the means it affords of reclaiming the ground lying between Keamari and the Chinna Creek. Sites for buildings and the various offices connected with the shipping operations are very restricted, and I believe this reclamation will give the much needed space for extension in the busy part of the town, and that every rood of it will in time be occupied in some manner connected with the business of the port and will ere long become a valuable property.

When reviewing the annual outlay for Imperial services under the head of "Miscellaneous," I stated that, including cost of establishment, we must be prepared to assign for the next ten years an annual fixed sum of at least a lakh of rupees for the maintenance and improvement of this harbour. This amount does not include any of the additional works to which I have alluded, but the construction of which I have deprecated, until, at any rate, we have had very much more experience of the features which the harbour will assume, and shall be better able to ascertain with tolerable certainty the results we may expect from carrying out these proposals.

This uncertainty is more or less removed when we confine our operations merely to deepening and widening the existing natural channels, and to increasing the ebb and flow of the water through them; for in this case we can calculate with some degree of accuracy that the outlay will effect an immediate benefit, and we shall not, as is too often the case when trying to guide or control nature, be called upon to use fresh expedients to neutralize the results of a previous project.

This is by no means an unimportant point in the consideration of this subject, and it induces me the more confidently to advise that our operations should be limited, at least for some years to come, to dredging on a consistent although not very extensive plan. The dredging operations should be undertaken in the following order:—

- 1.—Deepening the entrance along the western run.
- 2.—Deepening the water off "Deep water rock." I admit I should like to see the rock at this point removed, and the 3-fathom line carried over its centre; but the expense of this would be so considerable that I hesitate to advocate its being done at present.
- 3.—Improving and widening the Manora anchorage, the Eastern Channel and the Keamari anchorage generally.

Accepting the above programme, the next consideration is the best plant and machinery

* From information subsequently obtained from England it has been ascertained that the self-moving steam dredger does not realize the expectations formed of it, and the outturn of the Patent Hopper Dredger "Greenock" now working in the Clyde falls far short of that reported to have been done on its trial trip on which the estimate of its capabilities was based. A steam dredger with two steam hopper barges of from 400 to 500 tons has accordingly been substituted.

8-10-78.

A. C.

There is no doubt that if the results of the trials published in the engineering papers are reliable* and are confirmed by the every day working of the vessel, the single, self-moving, powerful hopper steam dredger is by far the most effective, as it is the most economical machine yet introduced, more especially in a narrow and restricted anchorage. There is the set-off of having all our eggs in one basket, and the attendant risk of having the machine for excavating combined with the carriers to convey the spoil to sea or for the reclamation of sites alluded to above but, subject to the proviso that it stands the test of experience, I am inclined to adopt this dredger although I am prepared to admit the risk. The economy of working and the convenience of the machine seem, I think, sufficient compensation.

The expenditure in the creation of Karachi Harbour having been defrayed from Imperial revenues, these grants may be regarded as a primary charge on the Provincial revenue when the harbour is ultimately transferred to the Local Government, which should consequently bear the interest on that outlay, with sinking fund to repay its first cost. We may hope in the meantime by a revision of the dues on shipping to obtain at least sufficient to meet the annual maintenance and improvements now proposed.

I take this occasion to record my impression that the success that has hitherto attended this work is largely due to the able labours of Mr. Price.

The 10th July 1877.

A. CLARKE.

No. 699 C—W—1858, dated 3rd November 1876.

From—Major-General M. K. Kennedy, R. E., Secy. to the Govt. of Bombay,
P. W. Dept.,

To—Secretary to the Government of India, P. W. Dept.

With reference to your letter No. 101 M of the 27th of March last, conveying instructions to Colonel Wilkins, R. E., in respect to the points on which the Government of India require his report and opinion in reference to the Kurrachee Harbour operations, I am now directed to forward a copy of Colonel Wilkins' report, together with a copy of a report by Commander Hand, R. N., and notes of evidence by Mr Price, Superintendent of Harbour Works, Mr. Hart, C. E., late Acting Superintendent of Harbour Works, and Lieutenant Parker, I. N., Acting Master Attendant.

2. This report, which is accompanied by various appendices, illustrating the past progress and present state of the Kurrachee Harbour Works, is a very clear and able document, and from it the Government of India will, no doubt, be able to derive all the information they require to enable them to arrive at a decision as to the future progress of the works

3. When forwarding the Government of India's letter of instructions to Colonel Wilkins, this Government added subsidiary orders, drawing his attention to three practical points which appeared to have a direct bearing on the subject of his enquiry; a copy of a Resolution No. 251 C—W—653 of the 3rd of April last, containing these instructions, is attached to this letter.

4. I am, in forwarding these documents, to say that this Government concur generally in the conclusion at which Colonel Wilkins has arrived. They think with him that, with the exception of the dredging operations and the completion of the break-water recommended at the close of his report, Chapter VIII, nothing should be done at present, or until after January 1877. After that date, should no improvement take place, or should the deterioration, which has been caused by the Chinna Creek scour, increase, it will be advisable to try first the inexpensive arrangement suggested by Colonel Wilkins of opening the notch in the Napier Mole, to be followed, should this plan in course of time be found to be ineffectual, by further efforts to obviate the effects of the scour, and eventually, should all palliative measures fail, by shutting off the Chinna Creek water altogether from the harbour, and opening the original natural communication between the creek and the sea.

5. As regards the question, which is now under consideration, relative to a ship pier at Keamari, I am directed to draw attention to paras. 39 and 40 of Chapter IV of Colonel Wilkins' report.

Dated Belgaum, 4th October 1876.

From—Colonel H. St. Clair Wilkins, R. E.,

To—The Hon'ble Major-General M. K. Kennedy, R. E., Secy. to the Govt. of Bombay,
P. W. Dept.

I had the honor to receive, in April last, Government Resolution No. 653, dated 3rd April 1876, enclosing a copy of letter No. 101 M, dated 27th March 1876, from the Secretary to the Government of India, which contained detailed instructions for my guidance in respect of an enquiry into the state and requirements of the Kurrachee Harbour Works to which I had been deputed.

2. His Excellency the Naval Commander-in-Chief, at the desire of the Government of India, placed one of Her Majesty's Ships at disposal for the examination of the harbour of Kurrachee. Her Majesty's Ship *Vestal*, a 9-gun Steam Sloop, Commander Henry Hand, was detailed for the duty on her way to the Persian Gulf. I embarked on the *Vestal* on the 8th April, when the ship proceeded on her voyage, and anchored off Keamari in the Kurrachee Harbour on the 11th idem.

3. During the time I remained on board Her Majesty's Ship *Vestal* in Kurrachee Harbour for the purpose of examining the harbour and its works, Mr. Price, C. E., Superintendent of the Harbour Works, afforded me every information and assistance in his power. Mr. Price accompanied me over the harbour and backwaters, and personally explained the nature of the works undertaken with the view of improving the harbour, and the results obtained by natural and artificial causes. The Chinna Creek backwater was examined, as also the breakwater, dredging operations, and sub-marine rock blasting.

4. The Commissioner in Sind, Colonel Sir William L. Merewether, K. C. S. I., and C. B., gave me every facility for the conduct of my enquiry on shore. I gratefully acknowledge his kindness in this and every other respect; and I am indebted to several official and non-official gentlemen at Kurrachee for much information with regard to the port and its trade, which, at the Commissioner's request, they so freely afforded me.

5. I have now the honour to submit my report on the state and requirements of the Kurrachee Harbour. For the convenience of reference I have divided the report into chapters under the different headings of my instructions.

6. I desire to express my obligations to Commander Hand, R. N., Commanding Her Majesty's Ship *Vestal*, and his Officers. Commander Hand took great interest in the subject of the condition of the Kurrachee Harbour, and he was good enough to express his opinion on various subjects connected with it in a report which is attached to the papers I have the honour to forward for the information and consideration of Government.

CHAPTER I.

DESCRIPTION OF THE NATURAL HARBOUR.

The reports and opinions which have already been published on the Kurrachee Harbour Works are so voluminous and varied, little or nothing of real value to a further consideration of the question would be gained by a discussion, at this time, of the theoretical principles which have guided, or should guide, Harbour Engineers. These principles, as applied to the harbour of Kurrachee, have formed a wide field of argument, not to say dispute, for the last twenty-four years. The time has now arrived when the results of the principles adopted should be investigated and reviewed, and advantage be taken of the data which the executed works afford, to determine the future course of procedure. There is no such thing as finality in harbour works. There are periods, therefore, when it becomes a matter of great importance to take stock, as it were, of the public works property in a harbour; and with a view to economy to the State, and convenience to trade, to estimate and provide for its future requirements. The harbour works of Kurrachee have now reached such an advanced state of completion, that, happily, the practical questions yet to be determined lie not so much in the region of theory as in the domain of fact.

2. The instructions of the Government of India are very comprehensive. They embrace all that has as yet been done at Kurrachee, and all that remains to be accomplished. It will be impossible, therefore, to do justice to the important subject in hand by simply giving an outline sketch of its history, and an abstract of recommendations for the completion of the harbour works. An endeavour will be made to present in a practical form the whole features of the Kurrachee Harbour works question from the very commencement up to close of the official year 1875-76. The recommendations to be made will be based on the facts of the case as they now present themselves.

3. The instructions direct that the present enquiry should embrace twelve heads:

1.—What were the chief features of the natural harbour previous to any efforts at improvements being made?

Before any works of improvement to the port of Kurrachee were undertaken, the harbour was simply a creek of the sea running inland between Manora Point, a rocky headland ninety feet in height on the west, and Keamari Island, a long and elevated sandy ridge on the east. This island, 300 to 500 yards in width, and 4,000 yards in length, ran east and west, across the centre of a shallow bay, the waters of which penetrated at high tides far inland over the low-lying ground of Kurrachee. Keamari Island, thrown back across the head of the bay some 3000 yards from Manora Head, and with its length almost perpendicular to the headland, acted as a kind of breakwater, and shut out the waves of the bay from the Kurrachee shore behind it. The creek between Manora headland and the west end of Keamari formed the natural harbour, and the tidal waters, after passing Keamari on the west, and also up the smaller Chinna Creek on the east, opened out like a fan over the low land of Kurrachee, and at high water spring tides covered an area of 18 square miles. This large expanse of backwater was intersected by several minor creeks which mostly joined the main creek above Keamari Island.

4. The bay of Kurrachee from Manora on the west to the Ghizri headland on the east had a breadth of 5 or 6 miles, and a depth to the town of Kurrachee of about 4 miles. Keamari Island, however, cut the depth almost in half, and formed itself the beach of the bay-head with an extensive backwater behind it.

5. Manora headland on the western side of the harbour creek was the termination of a very narrow promontory $9\frac{1}{2}$ miles in length from the mainland, and was distant about 4 miles seawards from the high-water line near the native town of Kurrachee.

6. Manora on the west, and Clifton on the east, with the Oyster rocks rising up in the bay between the two, have the same formation of conglomerate rock overlying stiff clay.

7. Only one river, the Layari, discharged into the lagoon behind Keamari Island. This river was dry excepting for a few days in each year.

8. On the eastern side of the creek, opposite Manora, a long sandy spit ran out seawards from Keamari Island in a direction parallel to Manora, and formed, in fact, the eastern bank of the creek.

9. From Manora Point a spit or bar ran out due east across the creek entrance, and joined the sand in the shallow bay opposite. This bar had a general depth of water over it of from 8 to 10 feet at low water ordinary spring tides. It had, however, two depressions; one on the west next to Manora Point with 11 feet, the other to the east with 15 feet of water at low water ordinary springs. These depressions formed the entrances for vessels over the bar into the creek. The bar was composed of sand.

10. The average range of tides over the bar was springs $9\frac{1}{2}$ feet, and neaps 3 feet, and the velocity of the ocean tide from $\frac{3}{4}$ to 1 knot per hour. The maximum velocity of the flood tide within the creek was $1\frac{1}{2}$ knots, and of the ebb at its most contracted section $2\frac{1}{2}$ knots per hour. The tidal wave approached Manora headland from the south-west, and entering the bay swept round to the west over the Keamari spit into the creek with a velocity of $1\frac{1}{2}$ knots per hour, the velocity of the ebb tide being the same.

11. At high water, from the anchorage in the large creek off Keamari, the so-called harbour must have presented in 1845, as it does now—though diminished in size by the area of the Keamari backwater cut off by the Napier Mole—an imposing appearance. Eighteen square miles of water in the lagoon and estuary, the former completely land-locked with the exception of the entrance channel 1000 yards in width between Keamari and Manora, portended ample accommodation and shelter for the shipping likely to visit to the port of the newly acquired Province. The view, however, was then, as now, very delusive; for the vast expanse of water in the lagoon was too shallow to admit ships of the lightest draught. The innermost anchorage for ships was situated then, as now, in the estuary itself off Keamari Island.

12. Before any works were undertaken, the anchorages for ships were in number and extent as follows:—

- 1.—Keamari anchorage 26·85 acres
- 2.—West Channel anchorage 23·76 acres
- 3.—Manora anchorage 14·46 acres

giving a total anchorage area of 65 acres within a 20-foot contour below datum; that is, below low water springs.

13. Besides this area of anchorage there were 35 acres at the anchorages within the 20-foot contour which were considered as useless from being unsheltered during the south-west monsoon, subject to eddies, or too narrow. The total area within the 20-foot contour thus amounted to about 100 acres.

14. The anchorages above described, situated at Keamari, and in the creek and estuary, with channels of approach from within the bar, have always formed what has been called the "Lower Harbour." At this time the Lower Harbour had an area at low water of 778 acres. The shallow back-water, or lagoon, with its intersecting creeks situated north or inland from Keamari Island, and covering an area of 14½ miles, has been termed the "Upper Harbour."

15. Before any works of improvement were commenced, the anchorages above detailed were capable of berthing 20 loaded vessels of from 500 to 900 tons only. This limit of tonnage, however, was most probably dependent, not upon the size and depth of water at the anchorages, but rather upon the shallow channels of access to them.

16. The flood tide after rounding Manora Point circled round to the west over Keamari spit into the creek. This caused a movement of sand from the spit into the creek. The ebb current ran in a more direct line to sea down the creek.

17. In this condition of the harbour ships drawing 20 feet of water could enter the port during the fair season at high-water spring tides; drawing 18 feet vessels could enter at high-water neap tides. During the three or four months of the south-west monsoon, ships drawing from 15 to 17 feet, could enter at high-water neap and spring-tides, respectively. The mail steamers had to time their arrival and departure according to tide.

18. The tortuous course of the east channel entrance to the harbour caused the services of a steam tug to be frequently required for ships. The lighter vessels could sail in by the more direct, but shallower, west channel during the south-west monsoon.

19. For native vessels the harbour was available for eight months in the year, but the entrance channels were dangerous for them during the south-west monsoon.

20. At this period, the scouring action of the flood and ebb-tides appears to have been the cause of the depressions in the bed of the creek which formed the anchorages of Keamari, West Channel and Manora. It may be surmised the action of the tides was somewhat as follows:—The flood tide after rounding Manora Point and sweeping into the bay curved round to the west, and entered the creek over Keamari spit, causing strong eddies at the Keamari anchorage. The flood-tide also set up the western side of the creek, and may have had some effect in scouring the west channel anchorage. But the depressions in the bed of the creek were formed mainly by the stronger action, and river-like direction, of the ebb, or outward current. After the turn of high-water in the backwaters, and creeks inland of Keamari, the run of the waters from the Baba, Puh, Soti and Tooker Creeks would be against the projecting west end of Keamari Island, which would result in the excavation of the bed of the channel at this point. The main current uniting at Keamari with the waters from the east, or Chinua Creek backwater behind Keamari Island, then became deflected across the main creek to its western side. Here the same action would take place resulting in the formation of the west channel depression, or anchorages. The united currents of the main creek then passed through the gut of deep-water point, and with the increased volume of water, and narrower passage, resulted in the scouring of the deep depression which still exists at this place. The Keamari spit, no doubt, maintained its position by being constantly fed with sand by the action of the flood tides and sea waves. Thus the tidal ebb-current of the creek was the main excavator of the anchorages.

21. If a comparison be made between the Kurrachee creek and lagoon with other estuaries and backwaters of the Indian coast, it will be found that the natural processes known to be in action at the mouths of numerous rivers and creeks are in a measure reversed at Kurrachee. On the south-western coast of India sand bars are formed at the mouths of rivers and estuaries by the action of the sea wave during the north-east monsoon, and these

bars are breached by the land flood-waters during the south-west monsoon, lasting from June to October. At the same time there is a small deposit of silt from the heavily laden river floods in the creeks themselves, although the larger proportion is carried out to sea. At Kurrachee, although a sand bar is formed as usual at the mouth of the estuary by the sea wave acting in shallow water, yet the tidal currents, owing to the size of the lagoon, are sufficient to prevent the creek from being completely closed up. Sind is however an almost rainless district, and consequently the tidal currents, flood and ebb, are not counteracted and assisted by flood waters which, in other instances, breach the bars with irresistible force. The result is, that in this respect the harbour of Kurrachee is at a disadvantage. The heavy sea wave of the south-west monsoon is but little interrupted in its labour of throwing up sand on the bar which is always at its worst at the close of that season. On the other hand, if the bar is not breached yearly by flood waters, neither is the creek subject to the silting inside the bar which, in ordinary cases, is occasioned by the yearly passage of silt-laden floods.

22. Thus the natural process of silting in this harbour is very slow. That some silting must occur is evident, for westerly winds prevail for seven months, and when the wind is high, which is of frequent occurrence, a constant stream of sand pours into the harbour from the neck of land which connects Manora with the mainland.

23. The harbour anchorages or depressions are dependent upon the rise and fall of the tide. The bar is formed by the stroke of the sea wave in shallow water and by the arrest of the harbour silt-laden currents by the comparatively still water of the sea.

CHAPTER II.

COMPARISON BETWEEN THE PRESENT AND FORMER STATES OF THE HARBOUR.

2. Comparison of the present state of the harbour with the former, taking care to discriminate those changes which are due to natural causes, from those created by artificial ones, and from those produced by combined natural and artificial action.

4. The results whether beneficial or injurious, on each artificial work, should be ascertained and stated in detail.

In drawing a comparison between the original and present states of the harbour, it will be desirable, and indeed necessary, to a full comprehension of the subject, that the condition of the harbour in certain intermediate stages should be brought into comparison.

The improvement in the harbour has not been progressive throughout. It has of late years been retrogressive; consequently, it becomes a matter of importance that the history of the progressive and retrogressive periods should be traced in this report.

2. The plans A and B attached to this report, which have been reduced from larger charts, illustrate the comparison to be drawn between the former state of the harbour previous to any works of improvement having been carried out, and its condition and physical aspect, at the present time, as also at certain intermediate dates. The two maps on Plan A, bearing the dates 1858 and 1876, show the harbour as it was in 1858, before the commencement of the design for its improvement proposed by the late Mr. Walker, C. E., and as it is now in the present year, after the completion of the works affecting the harbour regimen projected by Mr. Walker, and his successor, Mr. Parkes, C. E.

3. The reduced maps on Plan B show the anchorage areas below the 20 feet contour in—

1838.—Chart of Lieutenant Carless, I. N., before any works were commenced.

1854.—Chart of Lieutenant Grieve, I. N., before Mr. Walker's harbour works were commenced, but after the completion of the Napier Mole.

1858.—Mr. Parke's, C. E., (deputed by Mr. Walker) survey of the harbour.

1869.—Mr. Price, C. E., Superintendent, Harbour Works. This shows the harbour at its best between 1838 and 1876. The "Notch" had not been opened, and the Chinna Creek had not been closed.

1876.—Mr. Price, C. E., shows the harbour at the present time.

4. The question of improving the Kurrachee Harbour was first raised in the year which followed the conquest of the country by Sir Charles Napier in 1843. Under his government the Napier Mole was projected and carried out. The object of this work was to join the island of Keamari to the mainland by a broad roadway, and thus to facilitate communication between the town of Kurrachee and the port. The Mole was a solid causeway of earth about 2 miles in length, and of ample breadth. It was completed in 1850. Sir Charles Napier also initiated a timber pile pier at Keamari for native craft and lighters, and this work was completed in 1853 when Mr. Bartle Frere was Commissioner in Sind. Mr. Frere, now the Right Honorable Sir Bartle Frere, Bart., G. C. B., and G. C. S. I., after a protracted discussion and enquiry by local officers, brought the question of the harbour improvement before the Home Government which resulted in the reference in 1856 of the whole subject by the Directors of the Honorable East India Company to Mr. Walker, C. E., an eminent Harbour and Hydraulic Engineer.

5. The Napier Mole, therefore, was the only harbour work of importance which was not a part of the designs of the Home Engineers. It does not appear that any objection was made at this time to the Napier Mole as a harbour work, or to its position. The work was accepted as it was; only, to take advantage of the Keamari backwater behind it, which at high water covered 1,800 acres, and at half flood 900 acres, two or three openings in the Mole "of sufficient width to afford a free passage to the ebbing and flowing waters through the Napier Mole" were included in the first proposals of Mr. Walker.

6. The Napier Mole brought the land communication close up to the Keamari anchorage and closed, with the exception of a small opening near the Obelisk, the Keamari backwater from the harbour. The position of the Mole was probably selected with reference to the shortest, and most direct, line from the native town to the island. Whether, or not, any consideration was given to the effects which were to be produced upon the harbour by the causeway is not known. Sir Charles Napier did not contemplate closing the Chinna Creek at its mouth, though the causeway closed it on the harbour side, because he considered it indispensably necessary for the salubrity of the neighbouring cantonments that the extensive marshes eastward of the Mole should be covered regularly by the tide. Sir Charles predicted that the town of Kurrachee would in time be removed to Keamari, and a plan was prepared on which the quays and streets of the new town were projected. It is not clear why this excellent project was abandoned. Good and sufficient reasons may have existed at the time, but they have not been recorded in the harbour correspondence, and the probability is, that the scheme was abandoned when the harbour works were proposed, because it was intended by those works to reverse the usual process, and to carry the part up to the native town in place of moving the town or mercantile portion of it, down to the sea. This part of the harbour works scheme, it should be mentioned, was subsidiary to the main object to be effected by those works, which was the scouring of the bar and entrance channels, by closing the Chinna Creek at its mouth, and so forcing the flow and ebb of the waters of the Keamari backwater through the harbour by way of an opening in the Mole. Advantage was to be taken of this flow of water through the Mole to form a navigable channel up to the town which would be available for native craft.

7. As mentioned above, the position of the Mole was most likely decided on the double grounds of convenience to the merchants and economy to the State. The result proved that the selection had been an unfortunate one. The effect produced on the harbour during the four years which followed the completion of the Napier Mole, will be seen by a reference to Lieutenant Grieve's chart of 1854, No. 2 Map, Plan B. The Keamari anchorage was almost entirely destroyed. Its anchorage area within the 20-foot contour was reduced from 26·85 acres to 4·49 acres. The other anchorages at West Channel and Manora were not altered, or injuriously affected; but the injury at Keamari, the most valuable anchorage of the three, must have been very serious at the time. Turning, however, to the next map on Plan B, that of Mr. Parkes, made in 1858, or four years subsequently to the date of Lieutenant Grieve's chart, it will be observed, the Keamari anchorage had then partially recovered itself. It had regained in 1858 two-thirds of its area before the Mole was built.

8. The comparison of anchorage areas in acres good for moorings within the 20-foot contour is as follows:—

Dates.		Keamari.	West Channel	Manora.	Total acres.
Before Napier Mole was built	...	26·85	23·76	14·46	65·07
1854.—Four years subsequently	...	4·49	25·95	13·81	44·25
1858.—Eight years	„	17·20	22·63	18·82	58·65

Besides these totals of anchorage areas good for moorings, there were also areas within the 20-foot contour which are not included in the above table, not being available for ships from various causes.

Dates.				Keamari.	West Channel.	Manora.	Total acres.
Before Mole	...	...	...	...	2·58	32·58	35·16
1854	...	...	..	4·09	...	30·35	34·44
1858	...	...	...	1·72	·98	34·10	36·80

The total areas, therefore, at each date were—

Before construction of Mole—

	Acres.
1838-1850	100·23
1854	78·69
1858	95·45

So that the Mole resulted in a total loss of 4·78 acres below the 20-foot contour. Its real loss was, of available anchorage, 6·32 acres ; but at Keamari it had lost 9·65 out of 26·85 acres, or one-third, which was a serious loss in the best anchorage. In the upper harbour, the Napier Mole caused the Tookar Creek, see map of 1858, Plan A, to silt up, and thus diminished the capabilities of access to the town wharf for native craft.

9. The Napier Mole shut off the east, or Keamari backwater from the harbour, and consequently the ebb currents from the west side of the main creek, which resulted in the gradual reduction of the west channel anchorage. The great reduction which occurred at the Keamari anchorage was attributed to the deposit of material scoured out of the head of the Mole bank as the work proceeded. When completed, and the filling up of the anchorage from this cause subsided, the ebb currents from the waters above Keamari resumed their action on the anchorage, and in 1858 had increased its area within the 20-foot contour from $4\frac{1}{2}$ to $17\frac{1}{2}$ acres. The position of the anchorage was somewhat changed, the new excavation occurring at its southern end.

10. The construction of the Mole was followed by an increase in the height and size of the Keamari sand spit. The actual quantity of tidal water passing Keamari was diminished by the Mole shutting off the east backwater, and this appears to have given the sea wave increased power to add to the sand spit. The spit so raised confined the currents between Deep-Water-Point and Keamari, and although their currents were reduced in volume, yet the channel leading up to Keamari improved in depth from 1854 to 1858 by about a foot.

11. To the construction of the Napier Mole, then, must be laid the very serious deterioration of the harbour anchorages which occurred between 1850 and 1858, and the slight improvement in the navigable depth of the channel up to Keamari from Deep-Water-Point.

12. The Kurrachee Harbour was in the condition described above when Mr. Walker, C. E., was desired to propose a scheme for its improvement.

Mr. Walker's proposals were as follows :—

	£
1st.—Manora breakwater	110,000
2nd.—Keamari groyne	42,000
3rd.—Napier Mole Bridge	40,000
4th.—Native Jetty or Quay	28,000
5th.—New Channel	18,000
6th.—Chinna Creek stoppage	9,000
7th.—East pier (if required)	40,000
Total	287,000
In round numbers	300,000

Mr. Walker also proposed—

	£
8th.—Tidal Basins and Quays	300,000
9th.—Graving Dock	60,000
	360,000

but these works were not sanctioned.

The seven works enumerated above, estimated to cost £300,000, were for the improvement of the harbour. Omitting the 4th work, the remaining six works, estimated at £259,000, were for the improvement of the harbour entrance alone. The objects to be attained by the six works were thus stated by Mr. Walker—

1st.—*Manora breakwater.*

“A breakwater from Manora Point to prevent the passage of sand from the westward, and to afford shelter from the west seas at the entrance, and which would also serve to protect the foot of Manora cliff from the washing by the sea. The breakwater pier to be 1,500 feet long. The body of the pier to be raised 6 feet above monsoon high water, and to have an elevated footway sheltered by a parapet 17 feet above high water to give access to all times of the tide to the end of the pier, and to a proposed lighthouse there.”

2nd.—*Keamari Groyne.*

“A bank or groyne from Keamari southward upon the sand spit to prevent the waste of water to the eastward, and to confine the ebbing and flowing currents to the harbour channel so as to direct them upon the bar. This work would also serve to stop the movement of sand from the eastward. The groyne to be 7,400 feet long and the top $2\frac{1}{2}$ feet above monsoon highwater.”

*3rd—Napier Mole Bridge.**5th—New channel.*

"The water—backwater on closing of Chinna Creek—is proposed to be conveyed through the Napier Mole by an opening 1,200 feet long to be crossed by a bridge on piles. A wrought iron bridge 1,200 feet long and 40 feet in width. Between this opening and Keamari I expect there will be maintained by the assistance of the ebb and flow of the Chinna Creek waters a channel of sufficient capacity for the largest native craft at almost all times of the tide."

6th—Chinna Creek Stoppage.

"The closing of the Chinna Creek by a solid embankment, and conveying through the harbour and its entrance the flowing and ebbing waters to and from the portion of the estuary which lies to the eastward of the Napier Mole, thereby obtaining their scouring power upon the bar, and entrance channels, and forming an extension of the navigable channel up to near the town which would be available for native craft."

7th—East Pier.

"In continuation of the Keamari Groyne, 2,600 feet in length, and 2½ feet above monsoon high water. This work was to be postponed till the last, until the sufficiency of the other works should be tested. This should be done previous to carrying it out to any considerable length."

4th—Native Jetty or Quay.

This work was for the convenience of the port, not for the improvement of the harbour. As regards this work it was stated in the proposals that the additional wharfage and accommodation for the native craft was also provided near the town which enables the quay to be entirely removed from the roadway upon the Mole. Mr. Walker recommended in his report, but in so vague a manner as to leave it open to question, the order in which the works proposed should be undertaken. This order seems to have been as under—

Napier Mole Bridge.
Chinna Creek closure.
Keamari Groyne.
Manora Breakwater.

13. Mr. Walker further stated in his report—

"I entirely agree in the opinion that no permanent good can be expected from dredging upon the bar itself: its removal is to be effected by other means which are—

"*Firstly.*—Preventing the ebbing tide from spreading and wasting its force until it has carried the sand of the bar into deep water, or into a stronger cross tide.

"*Secondly.*—Giving the water that passes through the entrance to the harbour at each flowing and ebbing tide the right direction.

"*Thirdly.*—Increasing the quantity of water that passes through the entrance at each tide by dredging the shoals that are in the way of navigation, or otherwise.

"*Fourthly.*—Shutting off as much as possible the heavy southerly and south-westerly seas from the mouth of the harbour, and either preventing any sand that may be brought from the westward from coming at all in front of the harbour, or at least carrying it out into deep water before it can do so.

"If these objects be kept steadily in view, and if these works be done to effect them (as I think they can be), Kurrachee will, in my opinion, be of easy access, free from bar and of increased depth.

"I am strongly of opinion that the works I have already named, combined with the general deepening and improving of the harbour by dredging, will remove the bar, deepen the entrance to not less than 20 feet at low water (if the bottom to this depth is of sand), render the harbour of easy access, tend to quiet it at and above the entrance, and thus prevent ships from being obliged to remain in the roadstead exposed to the heavy and dangerous seas and breakers that have been described to me. Therefore, I think, they should be tried before going to any other more expensive work for the removal of the bar. I do not, however, pledge myself to this, or that an east pier also may not be required."

14. Orders were issued early in 1860 for the execution of the—

2nd.—Keamari Groyne,
3rd.—Napier Mole Bridge,
4th.—Native jetty and quay,
5th.—New channel,
6th.—Chinna Creek stoppage,

and the works were continued without interruption till December 1863 when orders were received to postpone the stoppage of the Chinna Creek which was just about to be completed. This was in consequence of Mr. Parkes' opinion, that the increased scour which resulted from the construction of the Keamari Groyne, which had been finished six months, should be allowed time to deepen the entrance to such an extent that any possible small temporary deposit should not be injurious.

15. Mr. Walker, C. E., died in 1862, and Mr. Parkes, C. E., who had been deputed by Mr. Walker to survey the Kurrachee Harbour in 1858, and to report on it generally with respect to Mr. Walker's proposals, was consulted by the Secretary of State in 1863 regarding the scheme which had met with persistent opposition on the part of Colonel Tremenhare, R. E., Chief Engineer in Sind. Mr. Parkes visited Kurrachee in 1864, and submitted a further report with his recommendations. He again visited Kurrachee in 1868, and after a full re-consideration of the whole subject, he reported his conclusions as to the effect of the works already executed, and his recommendations as to future proceedings. Mr. Parkes was appointed Consulting Engineer for the Kurrachee Harbour Works for five years from September 1868.

16. The works at their commencement in 1860 were confided for execution to Mr. Price, C. E., an Executive Engineer of the Sind Canal Department, and this Officer has continued, with one interval of two years, and another of shorter duration, in charge of the harbour works up to the present time. Mr. Price has been a consistent supporter throughout of Messrs. Walker and Parkes' designs for the improvement of the harbour.

17. The Keamari Groyne was commenced in November 1861, and completed in April 1863 to a length of 2,516 yards, which was about 50 yards in excess of the length proposed by Mr. Walker.

The immediate effect produced by this work was as follows :—

The velocity of the currents in the harbour increased, and resulted in a scour from the harbour of $23\frac{1}{2}$ millions of cubic feet of silt. As the cubic foot unit is so small when millions of feet are in question, in future in this report the unit of an acre, one fathom, or six feet in depth, in addition to the solid feet, which will be retained for reference, will be employed. The $23\frac{1}{2}$ millions of solid feet mentioned above is equivalent to 90 acres one fathom deep. A portion of this amount of silt was deposited inside the bar, and in the the eastern entrance channel. There was a greater depth of water over the crest of the bar of from half a foot to five feet ; but the available depth for navigation was diminished. The material in the bar was changed from light to coarse heavy sand, and the total result produced by the groyne was, on the hand, increased harbour space, and on the other, a deposit of silt at the bar, which was injurious to the navigation of the entrance to the harbour.

18. The south-west monsoon of 1863 followed, and the results were at its close as under—

1st.—The characteristic form of the bar was restored, a high bank of sand being piled up as a barrier immediately in front of the entrance, while the circuitous channel round the tail of this bank was re-opened to the same depth as formerly, but to a less width and consequently a less depth available for navigation.

2nd.—A considerable quantity of sand was washed into the harbour channel, partially replacing that which had been washed out previous to the monsoon.

19. On the recommendation of the Consulting Engineer, the following works were sanctioned for execution :—

1st.—The extension of the Keamari Groyne for 1,500 feet, called the East Pier. Commenced May 1864, and completed October 1865.

2nd.—The removal of Deep-Water-Point. Commenced in 1864, and carried on by artificial means, and by natural scour, during 1864, 1865 and 1866.

3rd.—A training groyne, running for 1,000 feet northward from Deep-Water-Point, constructed in 1866.

20. Colonel Tremenhare, R. E., continued his opposition to Mr. Walker's scheme, and the questions at issue between Colonel Tremenhare and Mr. Parkes were referred by the Secretary of State for India to Messrs. Stevensons of Edinburgh, Harbour Engineers.

Messrs. Stevensons reported that on the evidence laid before them they came to the conclusion that Colonel Tremenhare's fears as to the ultimate success of the design of Mr. Walker were well founded.

21. Accordingly the Secretary of State in April 1866 ordered that the works should be stopped. At this time, however, all the works sanctioned, excepting the Deep-Water-Point removal, which had been in progress three years, had been completed.

The Government of India acquiesced in the decision of the Secretary of State.

22. In 1866 the Government of Bombay called for, and received, a report from a local Committee convened at Kurrachee, which was favourable to the prosecution of the designs of Messrs. Walker and Parkes. This report was forwarded to the Secretary of State by the Bombay Government with the suggestion that a further reference to Messrs. Stevensons should be made, and in the event of the Messrs. Stevensons adhering to their former opinions, that some other Engineers of standing should be consulted.

The Secretary of State did not adopt the recommendation made from India, but in 1867 referred the question back to the Government of Bombay. The Bombay Government in January 1868 advised the resumption of the works designed by Mr. Walker.

23. In June 1868, Mr. Parkes again proceeded to Kurrachee to inspect the state of the harbour, when he recommended—

- 1.—The construction of the Manora Break-water to be carried out 1,500 feet from low water mark.
- 2.—The admission of the Chinna Creek water into the harbour at the Napier Mole Bridge.
- 3.—Dredging the new west entrance channel close to Manora Point; in the shoal water Deep-Water Point; in the new channel between the Native Jetty and Keamari.

24. The works were resumed in the early part of 1869, a memorable year in the history of the Kurrachee Harbour Works, for it marks the epoch when the harbour improvement works had produced their most beneficial results. The years which note the eventful periods in the history of the harbour and progress of the works are—

1838-43.—Before commencement of any works.

1854.—Before Mr. Walker's designs were commenced, but after completion of Napier Mole.

1858.—Ditto state of harbour at Mr. Parkes' Survey.

1869.—Best year.

1876.—Present time.

The first three dates have been sufficiently dwelt upon, but before proceeding to review the state of the harbour in 1869, its best year, it will be as well to make a few observations on the condition of the harbour and entrance at the time the Consulting Engineer visited Kurrachee in 1868, which resulted in his making his proposals stated above.

25. In the sections of the harbour between 1 and 16 A, see Charts, that is between the lower centre of Keamari anchorage and the end of the groyne, up to October 1867, there had been an increase in water space at low water since 1858 of 32,889,861 cubic feet, equal to 125·841 acres one fathom deep, which was an increase of 12½ per cent. Every year showed an increase, except the year from October 1864 to October 1865, which showed a slight decrease. But the increase was not continuous throughout the year. During the south-west monsoon in each year a quantity of sand was washed into the harbour which more or less neutralized the results of scour.

26. The results of five monsoons were as under—

Monsoon of 1863.—	Decrease of	6,500,114=	24·870	acres a fathom deep.
„ of 1864.—	Increase of	21,821=	·083	„ „
„ of 1865.—	Decrease of	1,942,091=	7·430	„ „
„ of 1866.—	„	292,404=	1·118	„ „
„ of 1867.—	„	852,774=	3·262	„ „

The results of 1863 and 1865 were attributed to the sudden contraction of the channel by the construction of the Groyne and East Pier respectively. The flood tide was forced to take its course with an accelerated velocity before entering the harbour over an area of water in which the sandy bottom was disturbed by heavy surf.

27. The Consulting Engineer in his report said:—“It is clear that every monsoon a large quantity of sand is set in motion both by the action of the waves and of the wind both within the harbour and outside, and the most sheltered resting place for this sand is, for the time being, the deep water of the harbour. Here it rests till the slower, but not less certain, action of the tidal currents expels it.”

28. Between Section 16 A and 24—see Charts—that is, between the section across the channel at the end of the groyne, and that just outside the ends of the East Pier and Manora Point, the increase of water space from 1858 to October 1867 was 11,685,540 cubic feet, equal to 44·71 acres a fathom deep, or 20 per cent., making with the 12½ per cent. in the channel above an increase of nearly 14 per cent. on the whole length.

29. Besides the sand removed from below low water level 15,458,583 cubic feet, equal to 59·146 acres a fathom deep, had been removed from above low water level, principally from Deep-Water-Point and the Keamari sand spit, making in all a quantity of 229·697 acres a fathom deep expelled from the harbour.

30. At this period, then, it is to be noted, sand was washed into the harbour channels up to and even beyond Deep-Water-Point.

The flood and ebb currents set up and down the harbour in the same channel.

The West-Channel anchorage was silting up, and yielding its anchorage space to the more favorably situated East channel; and the improvement extended up the East channel to the most valuable anchorage of all, that at Keamari.

31. The Master Attendant of the Port said—

"I do not think ships could have possibly been placed at fixed moorings at Keamari before the groyne was built, as this anchorage was then full of violent eddies, and cross tides caused by the run of water along the south shore of Keamari on flood spring tides meeting at right angles the main stream in the harbour just at the point (Keamari); moreover, the anchorage space then, with a depth of 20 feet, was very narrow hardly permitting room to berth and swing large vessels. We could not then have berthed in 1858, with every appliance, above 20 loaded ships of from 500 to 900 tons, 8 of them at Keamari, 12 at Manora.

"I am of opinion that from 40 to 45 vessels could now with screw moorings be placed at Keamari with 12 at swinging moorings in the lower part of the harbour, say in all 55 loaded ships of from 500 to 1,200 tons."

According to the Master Attendant, therefore, the capacity of the harbour was in 1868 virtually trebled.

32. As regards the entrance to the harbour, no improvements had taken place. If anything, it had deteriorated from what it was before the harbour works were commenced.

In the early part of 1863 the entrance became choked with sand, which obliterated the 14-foot East Channel. Later in the year East Channel was re-opened to 14 feet, but was very narrow and tortuous.

In January 1865 the East Channel had a width of only half what it had in 1858, but its depth was 17 feet. With this extreme depth the channel was in its worst state for navigation.

After the monsoon of 1865 the East or main navigable channel became much what it was in 1858.

In 1868 the East Channel entrance was inferior in point of convenience and safety to what it was in 1858. The channel had doubled in width; but the bar had lengthened, so as to neutralize the advantage.

33. The bar itself greatly increased in width in 1863, and in 1864 lengthened out to the eastward. In 1865 it was 1,300 feet longer at the 14 feet line than in 1858.

In 1865-66 the force of the scour seemed to be concentrated at a point on the bar near Manora Head. The width of the bar at 14 feet was reduced to 200 feet, a little more than half its width, the year before. In the monsoon of 1866 this part of the bar was again covered with sand, apparently from the westward, and was increased in bulk. Further eastward the effect was reversed, and the bar was lowered 2 to 3 feet. In 1866-67 the eastward depression was filled in again. In 1866-67 the ebb tide, which had been previously diverted to the eastward, now set nearer to Manora which was attributed to the removal of a portion of Deep-Water-Point. In the monsoon the wave ceased to break at this Western Channel, but the depth was only 10 feet at low water. The original Western Channel had 11 feet in 1858.

34. The condition of the bar in 1868 was such that the entrance to the harbour through it was in a worse state than before the commencement of the works which were intended to improve it. It is clear that the tidal scour from the harbour had insufficient power to contend with its adversary the stroke of the sea wave. The ebb tide current increased in velocity by the construction of the groyne and east pier, in the execution of its work of altering the regimen of the harbour channels, carried on its duties as excavator when out of the reach of its opponent. At the flood tide the sea wave met the silt laden ebb, and not only made it drop a portion of its burden at the bar, but scattered sea sand up the creek almost to Keamari.

It is to be observed that the operation of dredging in aid of the harbour works first finds a place, with an exception to be mentioned in the recommendations of 1868, as an item to be estimated for as a distinct work. In Mr. Walker's report he made mention of dredging, and it will be as well to re-quote here from para. 13 what he wrote on this subject—

"I entirely agree in the opinion that no permanent good can be expected from dredging upon the bar itself: its removal is to be effected by other means which are :—

* * * *

Thirdly.—Increasing the quantity of water that passes through the entrance at each tide by dredging the shoals that are in the way of navigation, or otherwise.

Fourthly.—

* * * *

I am strongly of opinion that the works I have already named combined with the general deepening and improving of the harbour by dredging will remove the bar.

* * * *

It is clear, therefore, that Mr. Walker anticipated the necessity of dredging in the harbour, but did not contemplate any dredging at the bar. In his proposals Mr. Walker however gave no place to dredging as a work, and his estimates contained no provision for such work.

35. The exception referred to above was the dredging of the centre of the bar for two months in 1867-68 at the recommendation of the Consulting Engineer. The narrow channel gained by this means, 14 feet in depth, shoaled up at once at the burst of the monsoon of 1868.

36. The condition of the harbour in its best year, 1869, must now be described in detail, and be compared with its state in 1858 before Mr. Walker's works were commenced. On the resumption of the works in 1869 Mr. Parkes' proposals were approved. A commencement was made of the breakwater in March 1869. Dredging was carried on at the new West Entrance Channel over the bar, and also at Deep-Water-Point, and a "Notch" of 175 feet in width was opened in August at the North or main land end of the Napier Mole under the Napier Bridge. A connection was thus made between the waters of the harbour and those of the Chinna Creek backwater. This connection resulted after a time in a serious deterioration of the most valuable anchorage ground, that at Keamari; consequently the results obtained by the works up to this time should now be set forth in detail. Three charts accompany this report—

✱ No. 1.—A chart, date 1858, of the harbour previous to the commencement of any works of improvement.

✱ No. 2.—A chart, date 1869, when the groyne was completed, but the opening of the "Notch" in the Napier Mole had not been made.

✱ No. 3.—A chart, date 1875, from the latest survey.

37. The progressive changes in the anchorage areas up to 1858 have been given. The comparison of anchorage areas in acres, good for moorings within the 20-foot contour, between the year 1858, and 1869, is as follows:—

Dates.			Keamari.	West Channel.	Manora.	Total.
1858	...	...	17.20	22.63	18.82	58.65
1869	...	...	30.44	21.44	25.69	77.54

Besides these totals of anchorage areas good for moorings, there were also areas within the 20-foot contour which are not included in the above table, not being available for ships from various causes—

Dates.			Keamari.	West Channel.	Manora.	Total.
1858	...	...	1.72	0.98	34.10	36.80
1869	...	...	None.	0.71	54.05	54.76

The total areas, therefore, at each date were—

1858 95.45 acres.
1869 132.30 "

And at the conquest of Sind, 1843 or 1838—50, the total area was 100½ acres. So that the improvement works had resulted up to 1869 in an increase of anchorage for ships of 18.89 acres, and in a total increase of area below the 20-foot contour of 36.85 acres.

38. As regards the beneficial results of the harbour works obtained for the channels and harbour generally up to 1869, the details of cubic spaces gained and lost in the entrance and harbour are given in Appendix C, illustrated by Plan C, which are attached to this report.

Appendix C gives in detail the cubic spaces gained and lost in each portion of the harbour. The harbour is divided into upper harbour and lower harbour. The upper harbour includes the new channel, or channel leading from Keamari to the Native jetty and the

west and east sides of Napier Mole, with the channel limits and flats. The lower harbour includes the entrance area—see Plan C—the Manora anchorage and channel; the east channel leading to Keamari; the west channel anchorage, and the Keamari anchorage.

39. In Appendix C, which has been very carefully prepared by Mr. Price, Superintendent of the Harbour Works, the totals of the cubic spaces gained in the two periods shown in the table are the totals gained in the whole harbour, upper as well as lower. As the upper harbour spaces have no immediate bearing upon the harbour anchorages and channels proper, and the lower harbour alone constitutes the harbour for shipping, it will be as well, while considering the practical results, to keep the two portions of the harbour distinct.

40. Lower harbour or harbour proper—

1858 to 1869.	Keamari anchorage No. I, Plan C.	West channel and anchorage, No. IV, Plan C.	East channel No. III, Plan C.	Manora No. II, Plan C.	Entrance No. I, Plan C.	Total cubic feet.
Scoured ..	b 5,883,320	none	$\left\{ \begin{array}{l} a\ 4,409,240 \\ b\ 13,421,060 \end{array} \right.$	$\left\{ \begin{array}{l} a\ 8,320,490 \\ b\ 24,215,577 \end{array} \right.$	$\left\{ \begin{array}{l} \\ 13,758,543 \end{array} \right.$	$\left\{ \begin{array}{l} a\ 12,729,730 \\ b\ 57,278,502 \end{array} \right.$
Dredged and excavated.	none	none	$\left\{ \begin{array}{l} \\ \\ b\ 42,900 \end{array} \right.$	$\left\{ \begin{array}{l} a\ 2,270,040 \\ \\ \end{array} \right.$	$\left\{ \begin{array}{l} \\ \\ none \end{array} \right.$	$\left\{ \begin{array}{l} a\ 2,270,040 \\ \\ b\ 42,900 \end{array} \right.$
Silted ...	none	b 356,647	none	none	none	b 356,647
<p>NOTE. a.—Above low water. b.—Below " "</p>						a 14,999,770
						b 56,964,775
Total gain ...						71,964,525

Therefore the total gain in the lower harbour was 71,964,525 cubic feet, equal to 275·34 acres one fathom deep. Of this amount 210·30 acres a fathom deep were below low-water spring tides.

Consequently the total results up to 1869 may be stated thus—

	Acres.
Increase from 1858 in good anchorages below 20-foot contour	18·89
" " in are a below 20-foot contour	... 36·85
" in harbour capacity below L. W.	... 210·30
" " below H. W.	... 275·34
} a fathom deep.	

These results appear to be opposed to the blue 1869 section line shown on the general harbour longitudinal section Plan 5th so far as regards the Manora anchorage. The Manora gain below low water of 93 fathom acres is opposed by the section line. The Superintendent has explained in reply to a reference made to him on this point that the gain does not show on the longitudinal centre section. *Not published.*

41. Upper harbour.—New channel and flats—

1858 to 1869.	East side of Mole.	West side of Mole.	Total cubic feet.
Scoured ...	None	142,410	142,410
Dredged ...	8,302,742	9,019,795	17,322,537
Silted ...	2,532,742	5,391,970	7,924,712
Total A and B gain ...			9,540,235

Equal to 36.50 acres one fathom deep. This amount of 36½ acres one fathom deep was for the new channel for native craft proceeding up to the Native jetty from Keamari, and a continuation on the east side of the Mole preparatory to letting the waters of the Keamari backwater into the harbour through the notch at the Napier Bridge.

42. This period, then, which ended in 1869, had been one of progress towards the general improvement of the harbour, the entrance over the bar excepted. The Keamari anchorage, the most valuable of all, which starting in 1838 with 26.85 acres, had, by reason of the Mole work, been almost entirely obliterated; which had partially recovered itself by natural causes in 1858 by 18.92 acres, had in 1869 more than recovered its whole area. It contained an area of 30.41 acres within the 20-foot contour, and moreover its area was in a better and more regular figure than it had been originally. The natural causes which enlarged this anchorage between 1854 and 1858 no doubt continued at work; but, as its area had now become larger than it was in the earlier days of the British occupation of Sind, the groyne must be credited with having been an agent of value in producing so satisfactory a result. In this period also the harbour channels had been much improved.

43. Mention may be made of the effects produced by the groyne in 1863 and 1864 which are not recorded in the table. In 1863, 25 millions of cubic feet had been scoured out of the upper channel between the end of the groyne and Keamari. In 1864, 15 millions of feet were washed back. From the groyne to the bar the effect produced in 1864 had been an increase of the sections.

44. As previously described, no improvement had been effected at the bar; on the contrary the entrance over the bar had deteriorated.

45. One period, the last, now remains to be dealt with. This period is from the resumption of the works in 1869 up to the latest survey, November 1875.

The breakwater base was commenced in March 1869, and the breakwater itself in November 1870. The work was completed in February 1873. Its length was 1,503 feet, and its head terminated in 30 feet below low water.

The New West Entrance Channel was dredged in each year. The results were:—

1869.—Channel proved of great value during the monsoon, but shoaled to 3½ feet at the outer end, chiefly up to the period of the next season's dredging.

1870.—Channel of great use during the monsoon. Shoaled a foot at the outer end during the monsoon. This shoaling increased during the fair season up to the next dredging by 2½ feet.

1871.—Proved of increased value, completely superseding the old East Channel entrance. Shoaled 2 feet at the outer end, less than in any previous year.

1872.—Shelter of half length of breakwater. Shoaled 2 feet at outer end. Accumulation less than in previous years. Dredged to 220 feet least width and 17 feet least depth.

1873.—Channel now main entrance to the harbour. Mail steamers leaving at fixed hours independent of the tide. At the close of season the dredged channel 175 to 350 feet wide at 20 feet depth, excepting two or three soundings at inner end, the least of which gave 18½ feet. Quantity dredged 224,398 tons of 20 cubic feet, equal to 17.171 acres one fathom deep. This included 434 tons of boulders and rocks, shingle and stone, removed by divers. The dredged channel showed the good effects of the completed breakwater by keeping quite clear at the outer end which improved during the monsoon. At the inner end a shoaling of about a foot took place. The *Atalanta*, 3,000 tons, drawing laden 23½ feet, passed through the channel on a medium tide. The channel now to be dredged to a width of 500 feet at 20 feet in depth.

1874.—Information incomplete. Two-thirds of a million of cubic feet accumulated between sections 34 to 18, which include entrance. What portion of this amount accumulated in the entrance channel itself is not known. As regards the ridge or bar intervening between the 20-foot sea contour and the 20-foot harbour contour, the improvement of any good navigable passage through it by the aid of scour was given up in 1868. Its form by the action of the sea appears to have been constantly changing. The crest of the bar in 1875 was where the deepest part of the East Channel existed in 1869. In 1869 the crest of the bar had a slope of about 1 in 50 on both sides. In 1875 this slope had become about 1 in 100.

1875.—By the commencement of the monsoon of 1875 the maintenance of the Entrance Channel without constantly dredging was spoken of hopefully by the Superintendent of the Harbour Works.

By the end of the year, however, it was found that the dredged West Entrance Channel had become contracted by accumulations having found on both sides; and further, that an inner bar of narrow width had formed in the channel. This narrow bar is clearly delineated in Chart No. 4. In this channel 2,700 feet in length, 500 feet wide, and 20 feet deep, 744,779 tons of materials were removed.

Not published

46. A "notch" of 175 feet in width was made in August 1869 at the Napier Mole to connect the water of the Chinna Creek with the harbour. By this opening one-ninth of the ebb discharge of the creek passed into the harbour by the New Channel. This was increased in 1870-71 by widening the notch to 275 feet, and by the construction of a stone bank to 5 feet above low water across the mouth of the Chinna Creek. This, however, did not add much to the harbour ebb discharge. In 1871-72 the creek mouth was further contracted by the raising of the stone bank to 6½ feet above low water. The scour of the creek now greatly enlarged the New Channel. In December 1871 the maximum discharge at the notch was 400,000 cubic feet per minute at one-third ebb. This only added one-twenty-fourth to the harbour discharge. No further contraction of the Chinna Creek mouth was made during 1872-73, but the scour continued its work of excavation in the New Channel.

47. The completion of the stoppage of the Chinna Creek mouth, recommended by the Consulting Engineer, was commenced in May, and completed in July 1874. This work closed in the large Keamari backwater to the east end of Keamari Island, where the Chinna Creek debouched into the bay. The Chinna Creek backwater was entirely cut off from connection with the sea excepting by the notch and bridge in the Napier Mole. This produced an increased scour in the New Channel through the Mole, and caused a large quantity of silt to pass down to the lower harbour.

48. It should be mentioned that the flood and ebb tides were not entirely confined to the 275 feet notch. The screw pile bridge at the Mole was 1,200 feet in length, and for the 925 feet water-way remaining; besides the 275 feet notch, a rough stone bund was placed which rose to a foot above half-tide level. Bunds were also formed above the bridge across minor creeks to drive the scour into the New Channel.

49. The scour thus brought to bear on the New Channel deepened it to 5 feet below low water for 2½ miles length, which proved of the greatest value to the lighterage traffic by giving access to the Native Jetty and Quay, a fine solid work which had been completed in 1872. Lighters could now pass up and down the New Channel to the Jetty at almost all times of the tide, and sea-going country craft, by taking advantage of the tide, were enabled to discharge at the Native Jetty instead of, as formerly, by lighters at Keamari.

50. This result of the backwater scour was undoubtedly most satisfactory, as far as the native coast traffic was concerned. The success in the Upper harbour was not accompanied by a corresponding result in the Lower harbour, or Harbour proper. The scour, which was an active excavator of silt in the New Channel and backwater, lost its power at Keamari anchorage, and resulted in a deposit of silt in that anchorage to such an extent as to cause a loss of four good anchorages.

The Keamari anchorage in 1869 could accommodate 13 ships at swinging moorings. Two moorings were silted up by 1872, and at the present time the moorings are 8 in number, thus:—

In 1858	...	...	...	8 moorings.
„ 1869	...	...	...	13 „
„ 1876	...	...	...	8 „

including one mooring for very small ships. Seven moorings are now available for ships drawing from 17 to 21 feet.

Practically, as very small ships seldom visit Kurrachee now, including one mooring removed to give more room for larger ships, the Keamari anchorage is now diminished by six moorings.

51. The effects of the Chinna Creek scour appear to have been limited to the upper portion of the Keamari anchorage. The discharge at maximum ebb at Deep-Water-Point has not been perceptibly increased by the Chinna Creek diversion. The cause of the deposit of silt at Keamari is doubtless to be found in the fact that the velocity of the ebb down the New Channel is checked when it reaches the open harbour at Keamari. Moreover on the 27th and 28th March 1876, on the occurrence of a spring tide of 9½ feet range, it was observed that the time and height of low water at the head of the new channel were 2 hours 35 minutes later and 2 feet 11 inches higher than those at the lower end near Keamari. At low water at Keamari there was a slope of 4½ feet up to the head of the new channel, equivalent to a slope of 2 feet per mile. Thus the silt-laden ebb current down the channel meets the flood at Keamari, and results in the deposit of a portion of that silt, not only in the most valuable anchorage, but also at the mouth of the new channel itself where a small bar is formed. This bar had to be dredged in 1875. It was dredged out from 2½ to 4 feet. The cut made by the dredge did not maintain itself. This was to be expected, as though the effect was obviated, the cause was not removed.

52. The practical results which attended the operations of the harbour scheme in the period under notice have already been stated in respect to the Keamari anchorage. The 13 moorings of 1869 were reduced last year to 4 good moorings, 3 fair ones and one for small ships. As in the previous periods it will be as well to compare the anchorage areas of 1876

with those of 1869. The comparison of anchorage areas in acres good for mooring within the 20 feet contour between 1869 and 1875, stands thus :—

Dates.				Keamari.	West Channel.	Manora.	Total acres.
1869 ...	...	...	...	30·41	21·44	25·69	77·54
1876 ...	...	...	...	18·80	8·39	51·49	78·68

Besides these totals of anchorage areas good for moorings there were areas within the 20-foot contour unavailable from various causes, thus :—

Dates.				Keamari.	West Channel.	Manora.	Total acres.
1869 ...	...	...	...	None	·71	54·05	54·76
1876 ...	...	...	...	None	4·44	38·20	42·64

The total areas therefore at each date were—

						Acres.
1869	...	...	...	...	...	132·30
1876	...	...	...	...	...	121·32

so that the improvement works in this period, combined with natural causes, effected a loss at Keamari of 11·61 acres, 38·17 per cent., of good anchorage ground ; a loss of 13·05 acres, 60·86 per cent., of good ground at West Channel anchorage, and a gain of 25·8 acres, or 50·1 per cent., of good ground at Manora. There was thus a total gain of harbour anchorages good for moorings of 1·14 acres during this period, but the total area within the 20-foot contour was reduced by 10·98 acres, or 8·29 per cent., on the total of 1869.

53. The loss and gain in the harbour spaces during this period were as follows :—

Lower Harbour, or Harbour proper.

1869 to November 1875.			Kenmari anchorage No. V, Plan C.	West channel and anchorage No. IV, Plan C.	East channel No. III, Plan C.	Manora No. II, Plan C.	Entrance No. I, Plan C.	Total cubic feet.
Scoured	...	{	A ...	...	48,770	1,845,772	...	1,894,542
			B ...	...	5,180,600	...	...	5,180,600
Dredged and excavated	...	{	A ...	...	...	31,868	...	31,868
			B 222,960	...	...	1,003,977	14,019,350	15,246,287
Silted	...	{	A ...	...	...	...	...	...
			B 12,130,960	8,976,110	...	835,952	4,017,535	25,960,557
Gain ...								A 1,926,410
Loss ...								B 5,533,670
Total Loss ...								3,607,260

NOTE.—A. Above Low-water.
B. Below „

So that the total loss in the lower harbour below high water was 3,607,260 cubic feet, equal to 13·80 acres one fathom deep, and the total loss below low-water was 21·17 fathom acres. An analysis of this table shows that the total silting in the harbour during this period amounted to 25,960,557 solid feet, equal to 99·32 acres a fathom deep. Of this amount

12,130,960 cubic feet, equal to 46·41 acres a fathom deep, were deposited in the valuable Keamari anchorage; 8,976,110 cubic feet, or 34·34 acres a fathom deep, were dropped into the West Channel anchorage; 4,853,487 cubic feet, or 3·19 acres a fathom deep, fell into the Manora anchorage, and 15·38 solid fathom acres remained at the entrance.

54. Against the silting of 99·32 solid fathom acres is the quantity 58·45 solid fathom acres dredged and excavated, leaving 40·87 fathom acres deposited. The scour was 27·07 solid fathom acres, of which 20 solid fathom acres were cleared out of the important East Channel. Thus a deposit of 13·8 solid fathom acres remained in the harbour.

55. As the Manora anchorage was only increased by 168,025 cubic feet, or 0·64 solid fathom acres, below low-water, the increase of good anchorage area given in the table para. 52 requires explanation. That increase is given as $51·49 - 25·69 = 25·8$ acres, against which is to be placed the loss of $54·05 - 38·20 = 15·85$ acres of bad anchorage ground below low-water. The total increase, therefore, of area below low water at the Manora anchorage amounts to $25·8 - 15·85 = 9·95$, or 10 acres nearly. The solid fathom acres have been given as 0·64 gain only. These quantities do not appear to tally very well, because 0·64 fathom acres distributed over 10 acres area would only give a depth gained of about one-third of a foot. The explanation is that the anchorage at Manora did not gain 10 acres nearly; but the gain in capacity at that part of the anchorage was cancelled by a reduction in the depth of the Deep-Water-Point channel which is included in the Manora anchorage. In 1858 the deepest part of the Deep-Water-Point channel was towards the Manora moorings as distinguished from the Deep-Water-moorings which are below the Point. Between 1858 and 1869, the Deep-Water-Point channel increased in length both above and below, but decreased in depth nearly 3 feet. Between 1869 and 1875 it silted considerably at its upper end, and its depth at that part was reduced by 6 feet, in all nearly 9 feet from 1858. But its greatest depth at the lower end of the hole was increased during the last period by about 11 feet, and the lower end of the deep channel, which increased slightly between 1858 and 1869, increased in the last period by 5 or 6 feet. On the whole the Deep-Water-Point channel, about 1,000 feet in length, filled up very considerably during the last period which accounts for the apparent discrepancy between the Manora anchorage large gain in area, and small gain in capacity. Plan No. 5, a longitudinal section of the harbour channels and anchorages, illustrates very clearly the longitudinal changes which occurred in the different periods.

56. The entrance to the harbour gained 10,001,815 cubic feet, equal to 38·22 solid fathom acres by the dredger in the last period.

57. The spaces gained in the upper harbour, *i. e.*, new channel and flats, are given in the following table:—

January 1869 to November 1875.				East side of mole.	West-side of mole.	Total cubic feet.
Scoured	...	...	... { A } B	18,170,925	19,862,851	38,033,776
Dredged	...	...	... { A } B	137,719	562,225	699,971
Silted	...	...	... { A } B	...	...	...
Total A and B gain						38,733,747

Therefore the total gain was equal to 148·20 solid fathom acres, nearly the whole of which quantity was excavated by scour from the new channel on the west, and from the new channel and Chinna creek flats on the east side of the mole; 148 solid fathom acres of silt therefore passed down the new channel into the harbour. Of this amount it has been shown that 99·32 solid fathom acres were deposited in the lower harbour, and a considerable deposit took place in the lower end of the new channel itself; consequently $148·2 - 99·32 = 48·88$ solid fathom acres, have only to be divided between the new channel, the bar and the open sea. The greater portion doubtless passed out to sea on the ebb tide, which was, and is, discoloured; but the fact remains, that as near as can be determined, from two-thirds to four-fifths of the scour from the upper harbour found a resting place in the lower harbour.

58. No account has been taken of the silting which may have, and which indeed did, come from the sea. This silting may have been new material from the sea side, or harbour silt washed back. The results given would not be affected in any material manner, though it may be said some of the silting in the entrance and lower part of Manora came from the sea, and not from the new channel.

59. The results produced by the combined natural and artificial actions in the harbour during this last period 1869 to 1875 were, therefore, as under—

			Acres.
Decrease of good anchorage at Keamari	..	...	11·61
" " " West channel	...	...	13·05
Increase of " " Manora	...	...	25·8
Total increase of good anchorage	...	...	1·14
Decrease of good and bad anchorage at Keamari	...	...	11·61
" " " West channel	..	...	9·32
Increase of " " Manora	...	...	9·95
Total decrease of good and bad anchorage	...	...	10·98
			Solid fathom acres.
Decrease of harbour capacity below L. W.	..	...	21·17
" " " H. W.	...	...	13·8

Consequently this period is marked by, on the one hand, an increase of good anchorage ground of 1·14 acres; an increase in the capacity of the direct channel leading to Keamari; the provision of an excellent native jetty and quay; the excavation of a channel for native craft proceeding to and fro the native jetty near the town; the invaluable convenience of a direct channel of entrance to the harbour, and the shelter of that entrance by a breakwater. On the other hand the harbour lost 10·98 acres below the 20-foot contour, and its capacity below low water was reduced by 21·17 acres a fathom deep. Unfortunately the valuable Keamari anchorage was reduced by 11·61 acres, or 38·17 per cent.; the West channel anchorage also suffered severely, losing 13·05 acres, or 60·86 per cent. This, though a real loss of anchorage ground, and anchorage ground is the harbour convenience most needed, yet is not regretted by the Harbour Works Engineers who consider the closure of the West channel must produce a corresponding improvement in the East channel.

60. That the harbour in this period only lost an area of 10·98 acres, and a capacity of 21·17 solid fathom acres below low water is due to the enormous amount of dredging which took place at Manora and at the entrance. No less than 57·48 solid fathom acres were dredged out at these places; 20 solid fathom acres were removed by scour, but the period is chiefly marked by the fact that by the Chinna Creek Diversion, 100 solid fathom acres of silt from the Keamari backwater and New channel found an abode in the deep waters of the harbour, two-thirds of which it was beyond the power of the tidal currents to expel.

61. If this statement is not absolutely correct as respects the source of all the silt: if some of the silt, or sand, came from the sea, although the Chinna Creek Diversion may have a claim put forth in this respect to a re-credit of this sea silt, yet the scouring power of the ebb current cannot claim any credit on this head. At any rate the ebb current was so laden with silt as to be unable to scour any more out of the entrance and lower part of Manora, which it might have done had it been clean water.

62. The detailed results of each of the periods ending the years 1854, 1858, 1869 and 1876 have been given. As a summary of those results it may be stated that in the period ending 1854, the Napier Mole work had caused the almost entire destruction of the Keamari anchorage. The gain was the convenience of a good land communication between the town and the port.

63. In the period ending 1858, no works were undertaken in the harbour. The Keamari anchorage under the influence of natural action in the harbour recovered two-thirds of its former area. The Napier Mole had at this time caused a loss of harbour anchorage of about 5 acres. It had also caused silting in the upper boat channels communicating with the town wharf. There was also a deposit of silt in the West channel anchorage.

On the other hand, the mole was the indirect cause of an increase in the Keamari sand spit which confined the currents more to the east channel which improved in depth to a foot.

64. In the period ending 1869, Mr. Walker's works—

- 2nd—Keamari Groyne,
- 3rd—Napier Mole bridge,
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Increase of " " Manora	25·8
Total increase of good anchorage			1·14
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			Solid fathom
			acres.
Decrease of harbour capacity below L. W.	21·17
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Consequently this period is marked by, on the one hand, an increase of good anchorage ground of 1·14 acres; an increase in the capacity of the direct channel leading to Keamari; the provision of an excellent native jetty and quay; the excavation of a channel for native craft proceeding to and fro the native jetty near the town; the invaluable convenience of a direct channel of entrance to the harbour, and the shelter of that entrance by a breakwater. On the other hand the harbour lost 10·98 acres below the 20-foot contour, and its capacity below low water was reduced by 21·17 acres a fathom deep. Unfortunately the valuable Keamari anchorage was reduced by 11·61 acres, or 38·17 per cent.; the West channel anchorage also suffered severely, losing 13·05 acres, or 60·86 per cent. This, though a real loss of anchorage ground, and anchorage ground is the harbour convenience most needed, yet is not regretted by the Harbour Works Engineers who consider the closure of the West channel must produce a corresponding improvement in the East channel.

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- 5th—New channel,
- 7th—East Pier,

were in progress and completed, the native jetty and New channel excepted. These two works had no direct bearing on the improvement of the harbour proper.

65. The beneficial results attending these harbour works were 53 solid fathom acres scoured out of the entrance; 275 solid fathom acres expelled from the whole harbour; an increase of area below the 20-foot contour of 37 acres; and an increase of anchorage ground of 19 acres. The Keamari anchorage more than recovered itself. Its area had become 30½ acres against 27 acres in 1838.

66. Moreover, the groyne by giving a direct set to the harbour currents cured the evils which formerly attended the anchorage of ships at Keamari which had been affected by cross currents over the Keamari spit, causing strong eddies in the anchorage. The removal of a portion of Deep-Water Point, and the training groyne running up the harbour parallel to the channel, are works said to have improved the direction of both flood and ebb currents. An eddy in the bight above the Point was removed.

67. The injurious results were deterioration of the channel of entrance through the bar into the harbour, and a tendency to the formation of shoal patches in the channel between the end of the East Pier and Manora. This tendency was occasioned by the cross rush of the flood tide off the end of the pier which formed eddies in the sand laden currents during the monsoon.

68. In the period ending 1876, Mr. Walker's works—

- No. 1.—*Break-water.*
- „ 4.—*Native jetty and quay,*
- „ 5.—*New channel,*
- „ 6.—*Chinna Creek stoppage* and Mr. Parkes' work,
- „ 8.—*New west entrance channel,* were executed.

The beneficial results attending these works have been—

- No. 8.—A good entrance to the harbour dredged.
- „ 1.—The shelter of that entrance during the South-West monsoon by the break-water. The break-water also shelters a portion of the Manora anchorage ground so as to make it available during the monsoon.
- „ 4.—An excellent and substantial native jetty and quay.
- „ 5.—A channel of access to the native jetty from the harbour for native craft and lighters. Also a reclamation of 44½ acres of land, chiefly at Keamari.
- „ 6.—The Chinna Creek stoppage or diversion has not produced any beneficial results upon the harbour proper. It has only benefitted the New Channel. It has afforded a bank of great length across the creek mouth which is utilized to carry the Sind Railway line from Keamari to the mainland.

69. The injurious results attending these works have been,—

- No. 1.—*Breakwater.*—This work causes the flood tide to take a more circuitous course before entering the harbour. It deprives the New Entrance Channel of flood scour, and probably intensifies the present action of the flood tide round the end of East Pier.
- No. 4.—No injurious results from the *Native Jetty.*
- No. 5.—The *new Channel* affects the harbour indirectly by its silt.
- No. 6.—*Chinna Creek Diversion.*—This work has affected the harbour proper most injuriously. It did not cause any loss in the total area of good anchorage ground according to the Superintendent of the Harbour Works, but the valuable Keamari anchorage was reduced in area by 38 per cent., and it returned to the same area it had occupied in 1858 before the works of improvement had been commenced. In 1869 it had 13 moorings. In 1876 it has 7 good and fair moorings. The West Channel anchorage was reduced 60 per cent., and lost 3 moorings out of 6, which must be attributed almost entirely to the action of the Chinna Creek Diversion. The total area within the 20-foot contour was reduced by 11 acres, or 8½ per cent. It forms or helps to form a narrow inner bar across the entrance channel after the monsoon. An accumulation also takes place in the channel itself during the same season.

The Chinna Creek Diversion appears to have entirely neutralized the favourable scouring action in progress in the period ending 1869. In that period it has been recorded the Lower Harbour gained by scour 275 solid fathom acres, 210 acres of which were below low water level. In the last period, in place of a continuance of the favourable action, aided and brought into full play by Mr. Walker's works, the scouring action stood still, and was overpowered by the silt laden currents, which, unable to bear the increased burthen forced upon them, threw down their loads in the harbour to the amount of 99 solid fathom acres below low water.

70. The operations of each important period in the history of the Kurrachee Harbour Works have now been described in detail and summarized. Owing to the unequal progress of the harbour works, producing at times converse results, it became advisable to distin-

guish, and to trace those results to their several causes. This has been done, but the practical results of the whole of the works undertaken from the very commencement up to the present year have yet to be given.

71. The harbour contained the following acres of anchorage ground at the dates of the respective periods :—

Dates.			Total of good anchorage.	Total of 20-foot contour unavailable.	Total area within 20-foot contour.
1838	...	...	65·07	35·16	100·23
1854	...	...	44·25	34·44	78·69
1858	...	...	58·65	36·80	95·45
1869	...	...	77·54	54·76	132·30
1876	...	...	78·68	42·64	121·32

Thus in 1838, and it may be presumed at the time of the British occupation of Sind in 1843, the total area within the 20-foot contour below low water was 100 acres. In 1854 it was reduced to 78½ acres. The Napier Mole work produced this deterioration. In 1858 the 20-foot contour area had from natural causes recovered within five acres all it had lost. In 1869, from a combination of the natural causes with the artificial action arising from the works of improvement which had been undertaken, the 20-foot contour area increased to 132 acres, of which 77½ were good for anchorage. In 1876 the 20-foot contour area was reduced to 121 acres, but the anchorage ground was increased to 78½ acres.

72. Taking the works as a whole from the earliest days in 1843 to the present year 1876, the practical result as regards anchorage ground has been an increase of 13½ acres; but, as will be explained, the harbour only accommodates the same number of ships, 20, as it did before any works were commenced, though as the size of ships varies as the cubes of their depths, and the channels of entrance and passage are now deeper than they were in former times, larger ships can now be accommodated at the anchorages. The harbour works of Messrs. Walker and Parkes, combined with natural causes, produced an increase of anchorage ground of 20 acres, or one-fourth of the whole nearly. The increase in anchorage ground in 1876 above what it was in 1838 has been given as 13½ acres.

73. The reason why the harbour could not accommodate more ships in 1875 than it did in 1858, although the good anchorage area was increased, is due to the fact that the space gained at Manora, south of Deep-Water-Point, being wide and deep, has been taken up by two swinging moorings for vessels of a large class, such as in former years never visited the port.

74. From the evidence of the Acting Master Attendant, Captain Parker, I. N., (Appendix J.) the number of ships which can now be accommodated in the harbour, as compared with the years 1838, 1858 and 1869 is as follows :—

Date.	Keamai.	Draught, feet.	West Channel.	Draught.	Manora and Deep-Water-Point.	Draught.	Total ships.	REMARKS.
1838	...	...	...	...	...	...	20	Probable number.
1858	8	...	...	12	...	...	20	500 to 900 tons.
1869	13	17 to 21	6	21 to 24	5	...	24	} 700 to 2,000 tons.
1876	8	17 to 21	3	21 to 24	8	17 to 23	19 or 20	

The Acting Master Attendant in his evidence gives the anchorages as four in number. The Superintendent of the Harbour Works includes "Manora" and "Deep-Water-Point" under the one Lead of "Manora."

75. Captain Giles, Master Attendant of the Port in 1868, expressed his opinion of the harbour anchorages which has been quoted in this chapter para. 31. He said he could put 55 loaded ships of from 500 to 1,200 tons into the harbour; 40 to 45 at screw moorings at Keamai, and 12 at swinging moorings in the lower part of the harbour. The inference drawn from this was, that the capacity of the harbour had been virtually trebled by Mr.

Walker's works It is not very easy to reconcile Captain Giles' statement with actual facts, for it has been shown that, although the Keamari anchorage in 1869 was 11·61 acres larger than it is now in 1876, yet the total anchorage area in the harbour is 1·14 acres larger now than in the year 1869. The true explanation of the matter must probably be sought in the nature of the moorings referred to. The Keamari Moorings are swinging moorings, while Captain Giles may have meant fixed fore and aft moorings, his ships to be packed like in the London "Pool."

76. The alterations in the capacity of the lower harbour from 1858 to 1876 are given in the following table :—

January 1858 to November 1875.	Keamari, No. V.	West Channel, No. IV.	East Channel, No. III.	Monsoon, No. II.	Entrance, No. I.	Total cubic feet.
Scoured ... {	A	...	4,458,010	10,166,262	...	14,624,272
	B 5,883,320	...	18,601,660	24,215,577	13,768,545	62,459,102
Dredged and Excavated. {	A	...	...	2,301,908	...	2,301,908
	B 222,960	...	...	1,046,877	14,019,350	15,289,187
Silt ... {	A	...	...	...	...	...
	B 12,130,960	9,332,757	...	835,952	4,017,535	26,317,204
Note— A Above low water B Below „						Gain { A 16,926,180 B 51,431,085 68,357,265

Thus the capacity of the lower harbour, including the entrance channel, was increased below high water by 68,357,265 cubic feet, equal to 261·54 solid fathom acres. Below low water the capacity was increased by 51,431,085 cubic feet, or 196·78 solid fathom acres.

77. An analysis of this table gives the following results :—

					Solid fathom acres.
Scoured—					
Above low water	...	...	...	...	55·95
Below „	...	...	...	...	238·97
Total scoured				...	294·92
Dredged and excavated—					
Above low water	...	...	...	...	8·80
Below „	...	...	...	...	58·49
Total dredged				...	67·29
Dredged and excavated—					
Entrance channel	...	...	...	...	53·64
„ Manora	...	...	...	...	12·81
Silt	...	...	...	...	100·69

or put in another form, omitting decimals—

Process.	1858 to 1869.	1869 to 1875.	Total solid fathom acres.
Scoured ...	268	27	295
Dredged ...	9	58	67
Silted ...	1	99	100
Results in solid fathom acres ...	+275	—14	+261

for the Lower Harbour.

78. The alterations in the capacity of the Upper Harbour from 1858 to 1876 are noted in the table given below :—

January 1858 to November 1875.				East side of Mole No. VII.	West side of Mole No. VI.	Total cubic feet.
Scoured	...	...	... {	A } 18,170,925 B }	20,005,261	38,176,186
Dredged and excavated	...	...	... {	A } 8,440,461 B }	9,582,047	18,022,508
Silt	...	...	... {	A } 25,32,742 B }	5,391,970	7,924,712
Total gain A and B						48,273,982

NOTE. A.—Above low-water.

B.—Below „

The capacity of the new channel, or what is termed the Upper Harbour, was increased by 184·7 solid fathom acres.

						Solid fathom acres.
Scoured	...	...	...	...	...	146·06
Dredged	...	...	...	...	...	68·95
Silted	...	...	..	...	...	30·32
						+ 184·69

79. Thus the harbour works projected by Mr. Walker were, with the exception of the completion of the new channel excavation by scour, duly completed in the last period ending 1875. As previously mentioned, six of the seven works projected by Mr. Walker had for their object the improvement of the entrance to the harbour. The Napier Mole bridge, New channel, Chinna Creek stoppage, were designed for that purpose, although subsidiary objects were to be obtained by these works. Of the objects Mr. Walker had in view when he designed his works there can be no doubt. He wrote,—

“I am strongly of opinion that the works I have already named, combined with the general deepening and improving of the harbour by dredging, will remove the bar, deepen the entrance to not less than 20 feet at low-water (if the bottom to this depth is of sand) render the harbour of easy access, tend to quiet it at and above the entrance.

* * * * *

Therefore I think they should be tried before going to any other more expensive work for the removal of the bar.”

80. Mr. Walker then expected that his works would effect the desired improvement to the harbour entrance, and that dredging would be necessary in the harbour. The results have inversed those expectations. The works have scoured the harbour, and dredging has been an imperative necessity at the bar. So far from having had any beneficial effect upon the bar, the works have produced injurious results in that part of the harbour. They have rendered the harbour entrance worse than it was before. The silting caused by the passage of the Chinna Creek waters through the harbour, which has frequently been termed a temporary injury, an injury to cease when the harbour channels have attained a natural regimen, is not responsible with having been the cause of the failure of the works to cut through the bar: for the hopes of attaining such a result from the harbour scour were given up in 1868, before the Chinna Creek waters were admitted into the harbour.

81. It is not known whether it is expected on the attainment of the harbour regimen, that then the Chinna Creek scour, added to that of the harbour, will cut through or remove the bar, or even maintain a dredged entrance channel. Such expectations based on the harbour works executed, or even on the proposals of the Superintendent of the Works contained in Appendix D, are not likely to be realized, and if held should be abandoned for ever. Tidal scour will never remove the sea-bar under the conditions presented, because that bar is formed by a force which must ever, in such a position, be more powerful than the

velocity of a current produced by the variation of the tides at Kurrachee. And not only this, but the greater the scour the greater the bar, because more material is carried down to it by the ebb-current, which is retarded at the harbour mouth by the sea. Moreover the bar is not a passive obstacle, a mere bank of sand to be cut through. It is an active opponent to scour, and if driven back at any point, or even if its line be broken through to a certain extent, so long as its general position is unassailed, it has an unfailing reserve to draw upon to restore its original formation.

CHAPTER III.

REMEDIAL MEASURES.

3. Where either natural or artificial causes, or both combined, have had an injurious influence, the nature of the remedial measures that should be undertaken.

That the Chinna Creek Diversion has had an injurious influence upon the harbour is beyond doubt. Whether or not that injurious influence is to be permitted to continue at work for a longer or shorter period, or whether it is to be put a stop to at once, has therefore to be determined.

2. The Chinna Creek Diversion was effected by closing the creek at its mouth, and by opening out a channel at its head—tail, would perhaps be a more expressive term. In fact, the flow of the waters of the creek was reversed. The course to be followed to meet the evils which have occurred, which most naturally suggests itself, is to endeavour to restore the creek to its original physical condition by re-opening its mouth so as to permit its waters to advance and recede as before.

3. To such a proposal there are, however, two objections. In the first place an important part of the harbour works project, irrespective of the lower harbour, is dependent, according to the scheme, upon the flow of the Chinna Creek waters in their present direction. The treatment of what has been called the “upper harbour” was subordinate to that of the “lower harbour,” or harbour proper; but it was so intimately connected with it that, to attempt a complete severance at this date between the two is not a matter of easy accomplishment. Mr. Walker's and Mr. Parkes' scheme was that the new channel between Keamari and the Native Jetty should be scoured out to a depth of 20 feet. The Consulting Engineer in his report of August 1868 said—

“The *object* which I have always placed before me is simply this—to obtain the best possible navigation from the deep water at sea to the new Native Jetty at the head of the harbour; and the *means* by which I hope to attain this object is the removal of all obstructions to the natural and equable flow and ebb in one capacious channel of the largest possible body of tidal water;” and again in his report of March 1874 he wrote—

“As the trade of Kurrachee increases and more wharfage accommodation (whether to be provided by Government or private enterprise) is called for, the development of the channel, which is now being formed by the Chinna Creek waters between the Native Jetty and Keamari, will become an important element in the decision of what works shall be undertaken or permitted. It is of the utmost importance that such decision should be in harmony with the principles on which the general design has been formed. That channel, although sometimes called the ‘Boat channel’ (a term which gives an inadequate idea of its capabilities,) may be made, by persistence in the system of training which has hitherto been so successful, ultimately and at small cost, navigable for vessels of 20 feet draught. It appears at present by no means improbable that further wharfage accommodation, for which the line of this channel will be a favourable site, may be called for at no distant time.”

4. This was a grand idea. To carry the port, inland as it were, for a distance of $2\frac{1}{2}$ miles, and place vessels drawing 20 feet of water at the very doors of the Custom House on the mainland was a project of vast proportions, and beyond what it is now considered the works of the scheme are able to attain, at all events, within any reasonable period of time. It appears from the report of Mr. Hart, C. E., Acting Superintendent of the Harbour Works in 1875, that he considered, not 20, but 8 feet should be taken as the limit of depth to be attained in the New Channel. Mr. Price, C. E., Superintendent of the Harbour Works, in his report No. 272, dated the 10th April 1876, endorsed Mr. Hart's view with the difference of a foot, and proposed a depth of 9 feet based on the depth of the jetty foundations which are $9\frac{1}{4}$ feet below datum.

5. To obtain this depth of 9 feet in the New Channel, which Mr. Price considered would amply meet the requirements of the country sea-going and harbour lighterage trade, Mr. Price estimates would take without the aid of further additional works ten years, in which time 14 millions of cubic feet, or $53\frac{1}{2}$ solid fathom acres, would be scoured out of the channel limits. The grander scheme would have necessitated the expulsion of 643 solid fathom acres, which, at the rate mentioned above, would require a period of 120 years for its accomplishment.

6. The desire therefore to increase by scour the present depth of the channel, which is about 5 feet to a depth of 9 feet, at the rate of 5 inches per annum, is the first objection to the re-opening of the Chinna Creek mouth.

7. The second objection is one of much weight, because it involves a heavy expenditure. The Chinna Creek has been closed at its mouth by a solid bank of stone 2,780 feet in length. This bank has been deposited on the soft natural bed of the creek, and, although it might easily be removed, yet, as it carries the line of the Sind Railway, that course cannot be followed without providing the Railway with a substitute which must take the form of a bank and bridge. When the Chinna Creek backwater was cut off from the harbour by the Napier Mole embankment, the mouth of the creek increased very considerably in size. An iron screw pile bridge 1,000 feet in length would have to be constructed for the Railway, the cost of which would not probably be less than four lakhs of rupees. Such a bridge could not be erected in the line of the present embankment, because the stone in the creek would prevent the piles being driven; the bank, therefore, could not be utilized in its present position for the Railway.

8. It has been shown that the Chinna Creek Diversion in its work of excavation of the New Channel to its present depth—at its head—of 5 feet, has wrought only mischief to the harbour; that its waters only add one-eighth to the harbour discharge, an advantage for which the Guardian of the harbour at Manora Castle may well exclaim—

Timeo Danaos et dona ferentes.

Is it possible, therefore, to regard this work in any other light as respects the practical efficiency of the harbour than as a mistake? The native craft and lighter channel may be purchased at too heavy a price when the deterioration of the best anchorage and channels for ships in the harbour is the cost thereof. Was it not for the heavy probable cost of providing a new passage for the Railway from Keamari to the mainland, the adoption of that plan as an effectual remedy against the existing evils might be recommended. The Chinna Creek mouth might be opened, and the Railway line be carried from Keamari to the mainland by a new embankment constructed without a bridge somewhere near the present Napier Mole. This would cost, probably, $3\frac{1}{2}$ lakh of rupees at the least, as the Napier Mole, without the bridge, cost Rs. 3,36,320 in earlier and cheaper days, and other expenses would be attendant on the change in direction of the line.

9. The most perfect way of dealing with the backwater and Railway line would be by re-opening the Chinna Creek mouth, and passing its waters under a bridge with sluices to regulate the in-flow and discharge. This would necessitate the construction of sluices at the Napier Mole also. The expense of such works would be heavy.

10. As the re-opening of the creek mouth would in one case cost $3\frac{1}{2}$ or 4 lakhs, and on the other plan, without sluices, cost probably not less than 5 lakhs of rupees, and therefore places on one side, at present at least, even the cheaper design of the three mentioned, some more economical method of procedure must be devised.

11. The claims of the two harbours cannot be reconciled as the means to satisfy them. They are so antagonistic, it is unfortunate Sir Charles Napier's first idea of founding a new town close to the harbour at Keamari in place of carrying up the port to the old town was not carried through. The horse is taken to the trough; the well is not carried up to the stable.

12. The scheme of the Chinna Creek Diversion seems to have been regarded with great favour by the Harbour Engineers. The advantages which were pronounced would accrue to the trade of the port by enabling the local trade to be conducted at the head of the Napier Mole, in place of Keamari, have been reiterated in every possible form. There is no doubt the native merchants of Kurrachee are united in their opinion of the advantages afforded to them in the conduct of their business by having a landing quay so close to the town. They argue the water carriage from the harbour is so much cheaper than the land carriage would be by the Napier Mole. Mr. Price, in his reply to question XL, has given some details showing the benefits derived by the merchants, and the Municipality from having their goods landed at the Napier Jetty. The Landing Company and Municipality are said to save a lakh of rupees a year by having their goods conveyed up the New Channel. Nevertheless the advantage so obtained may be dearly purchased in other respects. If the saving by water carriage up the New Channel over the cost of land carriage up the mole can only be secured at the expense of serious deterioration in the harbour anchorages, which are small enough for the local and foreign trade of the port, and also of the entrance channel, which alone will cost some Rs. 42,000 per annum to keep clear of silt, why then the advantages are overborne by the disadvantages. The alloy altogether depreciates the true metal. But as Mr. Price very justly remarks in the same reply, arrangements would be made to facilitate the carriage of goods to and from the town of Keamari if the landing place came to be moved to that island.

13. The fact is, the Chinna Creek Diversion has placed the Harbour Works in a dead lock. Like the situation in Sheridan's "Critic" where uncles, nieces, and hero, each threaten, and are threatened, with daggers, and each one is afraid to let go first, so at Kurrachee the difficulty rests in determining which work of improvement is to be foregone. If the creek waters continue to flow, the harbour is obliterated. If the currents be stopped, the New Channel is ruined.

14. The backwater could be cut off from the harbour by simply filling up the notch and raising the weir at the Napier Mole, which could be accomplished at small expense; but this plan would render the backwater a stagnant pool and marsh, which could not fail to be detrimental to the salubrity of the town and camp. There are other objections to this plan which need not be described.

15. A second inexpensive method of cutting off the scouring action of the backwater would be by raising the notch to half tide level. This procedure would probably be effective as a measure of sanitation in the interests of the inhabitants of Kurrachee, as the backwater would be kept filled up nearly to the height to which the weir might be raised, and there is very little drainage into the backwater from Kurrachee.

16. If it was considered desirable to retain the power of draining off the backwater, the notch might be closed by moveable boards technically called "stop planks." The New Channel might silt a little in process of time with the adoption of this plan; but it is not at all certain the injury to the Napier Mole and Chinna Creek bank by percolation, mentioned by Mr. Price in his reply to question XXX, as attending the adoption of a proposal of this nature to rectify which would, in his opinion, cost Rs. 13,000, would occur. On the contrary, percolation of this nature has been found to improve, by capillary attraction, the surfaces of causeways similarly situated.

This plan is well worth a trial should any other fail.

17. A third plan of dealing with the creek would be to open the 275 feet notch to the full width of the bridge, which is 1,200 feet in length. This would free the ebb, and reduce the scour in the New Channel. It may be anticipated that if the notch opened, such a proceeding would eventuate in a decrease in the amount of silt which is now brought down into the harbour. At first a quantity of light silt would be brought down; this must be expected; but the expansion of the passage would diminish the velocity of the currents, and so reduce their power to carry silt.

18. The Keamari anchorage has, in this year, shown signs of improvement at its lower end—see Appendix K. The natural action in the harbour which forms the anchorage has thus, apparently, the power to contend in a small measure with the silt-laden current of the creek. The filling up of the head of the anchorage proceeds; but the harbour currents attack with some success the bed of the lower part of the anchorage. When the first effects of the expanded notch opening may have passed away, the creek ebb current will be less laden with silt, and the harbour currents may regain an ascendancy.

19. At all events, particularly as the dredging of the East channel, advised by the Superintendent of the Harbour Works, will be recommended, the proposal is worth a trial. The more so, as the cost—see Appendix E—would only be a few hundred rupees. Mr. Price, it will be seen from the Appendix E, would prefer the adoption of other somewhat costly measures, which he considers will be cheaper in the end, in preference to this one suggested by him, and now proposed for adoption subject to a contingency to be stated below. Mr. Price considers better results may be obtained from other works proposed by him which will be found detailed in Appendix D. He is loath to relinquish the reduced scheme of obtaining 9 feet of water at the Native Jetty by the Chinna Creek scour; but it is satisfactory to observe that the Superintendent of the Works considers the present state of the New Channel may be tolerably maintained; that the injury to the Keamari anchorage may be stopped, and probably its improvement be early resumed by the adoption of this third plan which will only cost the few hundred rupees mentioned. That any proposal for the solution of the general harbour problem, how to mitigate, if not avert from the Lower Harbour, the evils arising from the present condition of the forces at work in the upper harbour, without completely sacrificing the original harbour scheme, effects upon the new channel, should meet the approval not only of Mr. Price, Superintendent of the Harbour Works, but of Mr. Hart, C. E., Acting Superintending Engineer in Sind, who acted as Superintendent of the Harbour Works during Mr. Price's absence in England, and, also, with the support of Captain Parker, I. N., Master Attendant of the Port, is a fact to be regarded as one of great weight. From the evidence of these Officers, which is attached to this report, it will be observed that they approve the adoption of the third plan above described.

20. This third plan, or proposal—Plan 8—to open the notch at the Napier Mole to the full width of the bridge by the gradual lowering of the rough stone weir—at present 1 foot above half tide level—which now blocks up its waterway, is then with the opening of the training bunds, the remedial measure proposed to be first tried to meet the injurious influence of the Chinna Creek Diversion which has done so much harm. But in consequence of the improvement which appears to have set in the last fair season at the lower part of the Keamari anchorage, in consideration of the new work about to be recommended of dredging the Keamari Channel, and the doubts which must still exist as to the entirely satisfactory results to be obtained by the adoption of a half measure, it is advisable, before carrying out the alterations proposed, that the effect produced on the Keamari anchorage ground in the present year should be ascertained.

21. If the improvement at Keamari, see Appendix K, is found at the end of the year, or in January 1877, to have progressed, and if the Master Attendant of the Port is satisfied

to accept the accommodation of the harbour, assisted as it will be by the Keamari and East channel dredging as sufficient to meet his requirements, then the proposed measure in relief may even be placed in abeyance.

22. Before, therefore, any expensive works for dealing with the Keamari backwater in the direction of re-opening the Chinna Creek mouth be contemplated, the third and second plans described above, which are of easy accomplishment at small cost, should be given a trial. The second plan will cost more if carried out after the third than if adopted at once, as the present weir would have to be reformed. But if the weir, which is only of rough loose stone, be wheeled back like a regiment from line formation into columns, the cost of replacing it would not be very great. The weight of opinion is in favour of the third plan which should therefore be tried first; but the second plan will be a good one in reserve.

23. The practical proposal, therefore, to meet the injurious influence exerted upon the harbour by the Chinna Creek Diversion is simply to do nothing immediately. Should the soundings in the Keamari anchorage at the commencement of 1877 not have improved, and the trade of the port increase to any material extent, which is unlikely until the last link of the Railway line be forged, then an inexpensive project, which is generally approved, if only as an experiment, is ready for adoption.

24. The injurious effect of the Chinna Creek Diversion upon the entrance to the harbour must not be lost sight of. The shoaling of the entrance channel sides and inner end, which took place in 1875, is partially, but probably not wholly, attributable to that work. This inner bar and shoaling can be, and has been, removed by the dredge. The necessity of dredging in the fairway of the harbour entrance is not only inconvenient, but also an expensive operation. Nevertheless, taking into consideration all the circumstances of the case, it is recommended for the present at least that the test which has been laid down in para. 23 be held to be the guide by which future dealing with the creek scour should be directed.

25. Dredging to a certain extent will always be required at the harbour entrance. After a time, therefore, supposing the Keamari anchorage to improve, either under present conditions or by the adoption of the third plan, it will become a question whether the value of the excavation by scour on the New Channel should not be compared with the cost of dredging at the harbour entrance necessitated by that scour, and a balance be struck between them.

26. Injurious influences have been at work in the harbour irrespective of those already dealt with. These injurious influences have arisen from artificial works combined with natural causes, and from one purely natural feature in the harbour, thus—

1st.—*Break-water.*

2nd.—*East pier or groyne.*

3rd.—*Deep-water Point.*

1st.—*The break-water* causes the flood tide to take a more circuitous course before entering the harbour. It is said to deprive the new entrance channel of flood scour, and probably to intensify the present action of the flood tide round the end of East pier.

27. The break-water may, and no doubt does, cause the flood tide to sweep further round Manora Point than was the case previous to its construction; but, as the flood only sets in at the rate of 2 miles an hour, spring tides, its action at the groyne end can only be increased over the natural action of the flood at that point to a very small degree indeed.

28. As respects the deprivation of the entrance channel from the flood scour by reason of the break-water, this effect may be considered rather an advantage than otherwise.

29. No remedial measure is proposed, therefore with respect to the break-water which is a most valuable work.

30. With regard to the second artificial work, the groyne, and the third a work of nature, the Deep-Water-Point, their treatment falls more within the scope of the next chapter on "harbour improvements" than under "remedial measures."

CHAPTER IV.

FURTHER IMPROVEMENTS OF THE HARBOUR.

5. The further improvements of the harbour, whether by the extension of existing artificial works, or by the addition of new ones, for the purpose of creating a scour, or to maintain the depth by the natural ebb and flow of the tide, or to influence existing currents, should be considered.

6. Also the probable effects of such artificial works.

Further improvements to the harbour by the extension of existing artificial works, and by the additions of new ones have been proposed from time to time by the Consulting Engineer, by the Superintendent of the Harbour Works, and other authorities. The Superintendent of the Works has prepared, in Appendix D, a list of the further works proposed for the improvement of the Kurrachee Harbour which have either been proposed by him, or which meet with his approval. Estimates of the probable cost of the works are also given.

2. If the first two items in the list of works given in Appendix D, which are sanctioned works in progress to cost Rs. 28,850 are omitted, it will be seen that the further works of improvement are estimated to cost 23 lakhs of rupees. The works in question are divided under two heads, thus—

- 1.—*To perfect existing works.*
- 2.—*To provide further accommodation.*

Under the first head are included—

- 1.—*Dredging in Entrance channel.*
- 2.—*East pier (groyne) extension.*
- 3.—*Deep-Water-Point removal.*
- 4.—*Auxiliary dredging, and construction of training groynes in the New channel.*

These four works are estimated to cost with share of Tools and Plant and Establishment Rs. 8,66,080.

3. Under the second head are included—

- 1.—*Blasting and dredging a cut along the centre of the Manora anchorage, and providing six fixed moorings.*
- 2.—*Dredging in East channel of lower harbour.*
- 3.—*Ship Pier at Keamari.*
- 4.—*Graving dock at Manora.*

These four works are estimated to cost with share of Tools and Plant and Establishment Rs. 14,34,090.

4. Before entering into a consideration of the several works above named, the cost of which would no doubt be found in execution to approach a quarter of a million sterling, it will be well to review the expenditure which has already been incurred on the Harbour Works, to record the advantages gained, and to value the results. If this course be followed, a better comprehension of the scope of the "further works proposed" will be obtained, and the advisability or otherwise of carrying out some, or all of those works, will be more apparent.

5. A list of all the works executed at Kurrachee for the improvement of the harbour will be found, with the exception of the Mole, in Appendix A. Appendix A contains the list of works projected by Mr. Walker in 1858 which received the sanction of Government. Mr. Walker's other proposals for tidal basins, quays and a graving dock were not entertained in 1858, probably because it was considered premature to decide on such purely conveniences for trade until the harbour was itself ready to receive and shelter ships. Mr. Walker's design for the improvement of the harbour comprised, as has already been mentioned, seven works. Six of those works were for the improvement of the harbour entrance. One, the native jetty, was for the conveniences of the native craft and lighter trade. The six works include the new channel; it would probably, therefore, be more correct to say that five of the works were for the improvement of the harbour entrance, one was for the convenience of landing operations, and one, the new channel, was common to both.

6. Mr. Walker's works were estimated to cost £ 300,000. The following table shows the estimated amounts and actuals :—

No.		Estimated cost, 25 per rupee.	Actual cost, 2s. per rupee.
		£	£
1	Break-water	110,000	69,634
2	Keamari Groyne	42,000	30,175
3	Napier Mole bridge	40,000	49,012
4	Native Jetty and Quay	28,000	43,067
5	New Channel	18,000	62,602
6	Chinna Creek stoppage	9,000	18,827
7	East Pier groyne	40,000	18,142
		287,000	291,459
	or, according to Mr. Walker, say	300,000	291,462

Taken in this manner the estimated and actual cost of the works show a very close and rare agreement.

7. The actual cost of the works, however, up to March 1876, has been much in excess of 30 lakhs on account of the following items :—

					Rs.
Ten small extra works and charges ...	...	..	...	...	25,595
Tools and Plant ...	...	..	..	...	7,42,075
Workshops, quarters ...	...	...	...	...	1,37,575
Harbour Survey ...	...	...	..	...	48,469
					<hr/> 9,53,714
<i>Less—</i>					Rs.
Value of Tools and Plant $\frac{1}{2}$ ...	...	..	..	1,85,518	
Reclamation of ground, at Re. 1 per yard ...	...	...	...	2,15,000	
Sundry property ...	...	..	...	15,000	
					<hr/> 4,15,518
					<hr/> 5,38,196
<i>Extra works.</i>					
Bar dredging ..	...	...	...	...	3,70,846
Deep-Water-Point removal ...	...	...	...	...	1,96,045
Dredging, &c., New channel ...	...	...	..	...	11,666
					<hr/> 11,16,753
Establishment ...	...	..	..	...	5,97,610
					<hr/> 17,14,363

This expenditure added to the cost of Mr. Walker's seven works, makes a total of Rs. 46,28,984 expended on the Harbour Works since 1858. For this expenditure, added to the cost of the Napier Mole Rs. 3,36,320, in all Rs. 49,65,304, which borders closely in half a million sterling, the Indian Government have obtained at the Port of Kurrachee the following results :—

- 1.—Shelter to the harbour entrance during the South-West monsoon.
- 2.—Shelter to the shipping in the Manora anchorage during the same season.
- 3.—The stoppage of the travel of sea sand from the west on to the bar and harbour entrance.
- 4.—A direct harbour entrance channel for the largest ships.
- 5.—Shelter for the Keamari and West Channel anchorages from the sea in the bay to the east, and protection from the travel of silt over Keamari spit.
- 6.—Improvement in the Keamari and Manora channels.
- 7.—Improvement in the Manora anchorage.
- 8.—Increase in the anchorage area for ships of $13\frac{1}{2}$ acres, and of area within the 20-foot contour of 21 acres. (Mr. Walker's works produced an increase of 20 and 26 acres, respectively.)
- 9.—Accommodation for 20 ships of from 500 to 2,000 tons in place of 20 ships 500 to 900 tons, a gain of 78 per cent. in the capacity of ships harboured.
- 10.—A causeway two miles in length forming a land communication between Kurrachee and the port.
- 11.—A bridge 1,200 feet in length for passage of backwater through the causeway.
- 12.—Boat piers at Keamari.
- 13.—Wharfage for large native craft of 1,736 feet, and for small craft of 1,070 feet. Also 515 feet of quay wall for vessels of light draught on the south of the mole,—an area within wharves of 5 acres. The bulk of the trade of the port passes over these wharves, the exceptions being Railway material and Government stores.
- 14.—A channel of access to the wharves $1\frac{1}{2}$ miles long, 300 to 500 feet in width, and average depth of 5 feet at low water springs.
- 15.—Reclamation of 44 acres of land, chiefly at Keamari, which is likely to be worth eventually a rupee a square yard.
- 16.—An embankment across the Chinna Creek 2,870 feet in length carrying the Railway line, saving $3\frac{1}{2}$ lakhs to the Railway Company or Government.

The Harbour Works have not secured—

- 1.—An entrance to the harbour by scour.
- 2.—Accommodation at the anchorages for a larger number of ships.

8. From the first list above given which contains, probably, all the chief results of a beneficial character, and they are many, the one fact that the harbour will not conveniently accommodate a greater number of ships, though of far greater tonnage than it could in earlier days, is that which cannot fail to be deemed unsatisfactory. The cause of this halting in the improvement of the harbour has already been sufficiently dwelt upon in this report. In fact, this is the point, which, in conjunction with the obstinate and apparently intractable character of the entrance to assume a favourable regimen, is the origin of the present investigation. The treatment proposed to remedy the somewhat scanty accommodation for ships in the port has been fully described. It remains only, therefore, to dispose of the entrance question, which, however, itself seems to involve the consideration of the berthing of ships of a large class.

9. The injurious results which have arisen at the harbour entrance resulting from the works undertaken are these. The Keamari groyne, although it terminates, as designed, yet end somewhat abruptly. The flood tide sweeps round the bay from Manora Head, and enters the harbour obliquely across the groyne head. This causes a cross rush of the flood tide and eddies, and the shoaling of a patch inside the end of the groyne close where the largest ships which visit the port are berthed. The patch and ground here are easily dredged, but the shoaling is said to reform quickly. This spot is near the outermost or No. 3 Deep-Water, mooring between 19 and 20 section lines; and it appears, although in February last the place was dredged out, the B. I. S. *Canara* grounded in 17½ feet, during a very low tide, at this mooring in May. It is not unlikely the mooring may have been a little too near the east limit of the channel which under any circumstances must shoal gradually; but the fact remains, that owing to the action of eddies caused by the cross run of the flood and the presence of silt from the backwater and bar, this berth is not a pleasant one for large ships. There is a screw mooring on section line 16 which is deep enough for any ship, however large, but which is under the influence of such strong eddies caused by the promontory, called Deep-Water-Point, that it is a matter of damage, if not danger, for ships to lie there.

10. To remedy the evils which have been in a measure described above, two works have been proposed. These works the "extension of the East Pier," and the "Deep-Water-Point removal" have been entered by the Superintendent of the Harbour Works in his list of "further works proposed," Appendix D, and numbered 2 and 3 in the list under the first head, para. 2.

11. It will be more convenient to take the "further works proposed" in their order under the two heads in place of commencing with Nos. 2 and 3, so setting these aside for the moment, the work holding the first place is—

1.—*Dredging the Entrance Channel*.—This work is entered to cost Rs. 2,14,000, but this is hardly a fair way of putting it forward. Dredging the entrance channel has become a necessity. The probability is, that dredging to some extent at the entrance to the harbour will always be required. At any rate for the next few years the charge must be a recurring one, and it therefore should not be regarded as a new work, but rather as an annual repair to the harbour works. The Rs. 2,14,000 is for dredging the harbour entrance for five years at an annual charge of Rs. 42,800. Consequently this latter sum should be provided for expenditure in the current year 1876-77.

12. 2.—*East Pier Groyne extension* entered at Rs. 98,875, but without its share of Tools and Plant, and 14 per cent. Establishment. This work illustrated in Plan D with the other "further works proposed" is a proposed extension of the groyne running south from Keamari along the sand spit. The extension is designed to take a curved form with an arc of 1,100 feet length, and radius 1,500 feet. The top surface of the extension is to be brought up to low-water level only, so as to allow the tides a free entrance and exit. The top of the extension is to be 40 feet in width. The object of this work is stated to be the prevention of injury to the entrance channel and anchorage by eddies, and shoaling from the cross-rush of the flood tides.

13. From the persistent way in which this work, and the next on the list the "Deep-Water-Point removal," have been for a long time urged upon the attention of Government, it might be supposed, upon their execution depended the whole fate of the works or rather the results of those works. To carry out the extension to a short distance of the East Pier, and to remove a natural promontory of rock which causes a contraction of the harbour channel, and its excavation to an inconvenient depth, not to speak of eddies and increased velocity of currents, would appear to be the acme of human wishes in respect of this harbour. But is it quite clear that these two works would prove the panacea of harbour ailments?

14. It is only just and proper to state that the weight of Harbour authorities is arrayed in favour of the two works named. Mr. Parkes, C. E., lately Consulting Engineer for the Kurrachee Works, a gentleman holding an eminent position in his profession, and as it will be seen from the evidence in the Appendices to this report, the Superintendent of the Harbour Works, the lately Acting Superintendent, and the Master Attendant of the Port, are all in favour of the adoption of the measures proposed. Nevertheless it is incumbent that those who are called upon to decide whether or not certain works should be undertaken on both engineering and financial grounds, should be placed in possession of all the evidence to be obtained on each side of the question.

15. In the first place the Keamari Groyne was designed to end some 1,500 feet short of its present termination; but it was at the same time considered that this work might require lengthening, and provision was made for that extension. The groyne was built, and the position of its end was said to be critical. The extension, called the East Pier, was then built; and no sooner was this done, and some ill-effects were said to be produced at the groyne end occasioned, it was averred, by the action of the tidal currents, than the final length of the work was pronounced to be an unknown quantity to be decided only by experiment. This could scarcely be regarded as a matter of satisfaction, particularly as an opponent to the scheme of the Harbour Works, Colonel Tremenhare, R. E., had repeatedly expressed the grounds of his objections to the groyne as follows:—

“The tidal water to fill the harbour being now drawn from the vicinity of the breakers on the bar, and carried at a high velocity through a narrow deep funnel, is much more laden with sand, silt and mud than it was formerly; and the amount of such sedimentary matter brought in by the flood during the monsoon, much exceeds what can be lifted and carried out by the ebb-tides, so that the amount of deposit within the harbour must annually increase.

“The result of extending the groyne still further must be to draw water during the flood-tide still more heavily charged with sand, and to cause still more rapid injury to the harbour.”

16. Mr. Parkes, in his report of 1868, said, with reference to active measures which would be required to assist the scour in effecting a deepening of the entrance, and when suggesting a further extension of East Pier and dredging —

“The last steps in an undertaking of this description must necessarily be *tentative*. We are dealing with forces of which we know the general direction and character, but which cannot be brought within the scope of numerical estimate.”

This is all very well, and many persons would doubtless be inclined to agree with the opinion expressed. But no such cautious and judicious reticence was observed when the groyne was projected, unless it is to be found in Mr. Walker's.

“I do not however pledge myself to this, or that an East Pier also may not be required,” when he was expressing his opinion, when first proposing his works, that they would effect the objects desired—(see Chapter II, para. 13).

17. If the length to which the groyne should be carried is only to be decided by experiment, it may be a judicious caution which suggests the present extension of the East Pier to a further length of 1,100 feet. But why 1,100 feet? Why not only 1,000 feet? Why not 2,000 feet? Some good reasons should be apparent why the groyne should be brought to a complete termination, not 1,100 feet further out, but 1,100 feet further on, the direct line hitherto followed being abandoned.

18. The object of the extension is stated to be to secure the entrance channel and anchorage from eddies and from the shoaling, which is occasioned by the cross rush of the flood tides. But are these objects at all certain of attainment by means of the work in question? The original object of the groyne was to compress the tides into a narrower channel, and thus to carry down to the bar a current of greater velocity and directness which should have sufficient power to cut through the bar; or, latterly, at all events, have power to keep a dredged channel open. Now in the curved bell-mouthed shape of the proposed extension, if the objects hoped for are not realized, it may follow that the extension should have taken, in the interests of the ebb action, a more direct line in prolongation of the East Pier. The curved extension, though adapted to the interests of the flood action, is not in furtherance of the interests of the action of the ebb. With a groyne such as this, terminating in shallow water, it may be impossible to reconcile the means by which favourable action within the scope of both flood and ebb currents are to be secured. But is there a sufficiently strong reason why the extension should be made in the interests of the flood action and for abandoning the power at hand of still further contracting the ebb?

19. The design for this groyne extension in the interests of the flood action is supposed to be so far in favour of improvement at the harbour entrance as to remove from the fair way the disturbance which is now caused by the groyne end, and the shoaling at the “patch” and inner bar. This shoaling is not so detrimental as first appears from an examination of the chart for 1875. The “patch” has 18 feet of water over it, two feet less only than the entrance channel; and the inner bar has 19½ feet over it nearly across, so that with a little caution on the part of the Pilots, and dredging for a few days twice or thrice a year, but little inconvenience will be caused by the cross rush of the flood. The real fact is, that this is a spot used for berthing large ships drawing from 21 to 22 feet, a ship draught for which the harbour in its present incomplete condition, owing to the disturbance of its regmen caused by the Chinna Creek Diversion, is scarcely ready to receive. Doubtless the Master Attendant is anxious his directions to mariners visiting the port should be consistent with facts; and probably his desire to see the groyne lengthened is connected with his wish for additional berths for ships of large size. The groyne extension would be likely to move on one side of the fairway the first cross rush of the flood, and the patch might follow it out of harms way; but, at the same time, the sand bank on the harbour side of the groyne would extend itself further down, and would be liable to new complications; and the inner bar would still exist, for the causes of its formation would not be removed.

20. To prolong the groyne in the interests of the scour effect upon the entrance channel, it should take its present direction, and be carried out into deep water. If the groyne could be prolonged into about 26 feet, or even 20 feet, at low water, then, and then only, would the ebb-scour produce its full effect on the bar entrance. Even then the scouring power might not be sufficient to save all dredging, and some inconvenience might be experienced south of Deep-Water-Point arising from the reflex of the sea wave into the harbour mouth.

21. The question, then, resolves itself into this consideration. Which is the most valuable, or the most destructive,—the flood, or the ebb? The whole scheme of the Harbour Works has been based on the valuable ebb effects. The Superintendent of the Harbour Works has himself called attention to a tendency to shoaling out side the 20-foot sea contour, and has ascribed this action to the want of ebb scour. To prolong the groyne, as proposed, would not be to further directly the principle of obtaining, against all other considerations, the full force of the ebb on the bar. A little dredging about the patch might be saved; but even this is doubtful, and an additional berth or two for ships be gained; but the more important work to be done in the entrance channel would experience no relief. To prolong the groyne at all must further compress the flood tide. This might not matter so much did not the proposed groyne end terminate closer to the bar from the neighbourhood of which the flood waters must be drawn.

22. The groyne extension is estimated to cost a lakh of rupees very nearly, which would be a high price to pay for two ships' berths. It would be better to prepare two berths for large ships at Manora or Keamari. This should be done. To dredge a berth for a ship would *per se* cost about Rs. 9,000. Two berths Rs. 18,000. If it is found the East Channel dredging, hereafter to be dealt with in this chapter, is insufficient for the purpose, an additional grant might be given to assist that work to provide two berths for large ships, and so meet the wishes and requirements of the Master Attendant. This Officer must have room for his ships; and it would be better to give him what he requires above Deep-Water-Point than to continue the present practice of berthing ships off the end of a groyne, and over the inner bar of the entrance channel, where disturbances and shoaling, arising from flood water and ebb silt, must continue to occur for, at least, some time to come.

To continue the subject of the groyne extension, there is no certainty of improvement resulting from the proposed work; but the effects of the dredger are sure, if not very permanent.

23. The Superintendent of the Harbour Works, in his reply to question XIV, allows that the least unfavourable application of direct unaided dredging would be, in substitution for the action of the proposed east pier extension and deep-water-point removal in keeping the entrance open. Reliance can be placed with certainty upon the dredger for effecting the object in view. There is nothing certain, but uncertainty in the effects which may be produced by lengthening the groyne a few feet in another direction. To carry out the groyne into 26 feet of water, by which alone are the chances of success in favour of its prolongation at all, would be to incur an expense not to be thought of in this generation.

After all, it would seem to be a mistake to endeavour to work out the scour theory on highly scientific principles. It is unnecessary to go very far to seek for an example of the action of scour in a channel. What has occurred in the new channel and harbour entrance, is exactly what may be seen any day in roadside gutters after a thunderstorm. The notch and the groyne compress the current like newly cut drains. A volume of water rushes down the channels, scouring them out at their heads, and depositing the silt at their mouths. The longer this goes on, the larger the deposits at the channel mouths, for the currents are arrested by the accumulations of what they carry themselves until at last the channels become pools barred in front by their own silt. In this condition a channel ceases to be self-acting. A cooly removes the deposit from the gutter with a phoura. A dredge is required to perform the same operation in a harbour.

24. On the whole, therefore, unless it can be shown more clearly that the groyne prolongation would, with any certainty, effect a cure upon the present condition of the harbour at this spot, the work is not recommended.

25. The next work on the list is—

3.—Deep-Water-Point removal.

This work is entered to cost Rs. 2,14,333, or with the special plant required, but without a share of Tools and Plant, or 14 per cent. Establishment, Rs. 2,37,721.

26. This work, illustrated on plan D, but fully shown in detail on the traced plan No. 6, is for the removal of a promontory projecting in a perpendicular direction from Manora into the Creek channel. This proposed removal is the second attack which has been made upon the rocky projection called Deep-Water-Point. In Appendix A, under the head of "Supplementary works found necessary," the same work appears, and to judge of the extent of the first attack it is only necessary to observe that 50,317 cubic feet of rock, and 2,938,468 cubic feet, equal to 11½ solid fathom acres of sand and shingle were removed from the promontory on that occasion at a cost of nearly two lakhs of rupees. It should, however, be added, that this expenditure appears to cover the cost of a training groyne of, it is supposed, loose stone run out from the point to the north.

Not published.

27. If this "further proposed work" be sanctioned, the cost of removing a portion only, and really a very small portion—see plan No. 6—of the promontory, will amount in the aggregate to Rs. 4,33,766, or, with Tools and Establishment, close on 4½ lakhs. This is a large sum to pay for removing only a portion of the obstruction, and Mr. Hart, in his reply to question XXIV, where he expresses a doubt that the proposal goes far enough, is probably correct in his opinion.

28. The effect of Deep-Water-Point on the harbour channel appears to be this:—It causes a contraction of the channel which results in an increased velocity of the currents passing it, which, again, not only form eddies, particularly at a screw mooring on section line No. 16, but also excavate the channel to such a depth, 46 feet at low water, that the use of that portion of the harbour as an anchorage is impossible. Besides these effects, the point diverts the ebb current from the Manora side, and throws it out of the desired direction of the entrance channel. There may be other reasons than those stated, such as the danger ships may occasionally encounter in passing the point, why the gut in the channel should be opened out; but the principal objects to be attained by executing this work have been given. The question is this: Are these objects to be secured by the proposed partial removal; and are they worth the further expenditure of upwards of 2½ lakhs of rupees? Supposing the objects gained, are they worth the money; is it at all certain the result of the expenditure will prove successful?

29. There can be no certainty about the matter. A small improvement in the direction aimed may, and no doubt would, be made; but it would only be small. From an inspection of the Plan No. 6, this is obvious. To get rid of the eddies, and to secure the ebb current to the Manora side would necessitate the removal of, at the very least, double the quantity proposed to be excavated.

30. What might be done at a much smaller cost would be the blasting away by a few heavy charges of the extreme end of the rock which appears to be pointed. It might be rounded off somewhat, and as the depth of water is so great, if the charges are not very heavy, no damage would follow on the deposit of the debris in the deep hole opposite, now some 45 feet below low water springs. This suggestion is offered for Mr. Price's consideration.

31. No mention has been made of the effect on the groyne side of a cutting on the Manora side of the channel. Considering the stolid resistance offered by the Deep-Water-Point rock to the scouring of the tidal currents, and the gradual closure of the deep water in the west channel anchorage, how is it that the groyne side is not cut away? Unless the groyne shore is of pretty solid formation, it might be supposed that the currents would have made more room for themselves. No doubt Captain Parker is correct in his opinion expressed in his reply to question No. 19, No. 4, that there must be hard sand-stone in the channel.

32. It is not intended to deny that it would be a good thing to remove the obtruding promontory if it could be thoroughly accomplished at reasonable cost. As Mr. Parkes expressed himself in his report of 1872—

"There is no doubt that the removal of the rock would be an advantage, but it is one which might be purchased at too great cost." He further adds: "I wish therefore to defer any recommendation with regard to it until there are more materials for judging, not only as to the cost of its removal, but more definitely than at present as to the effect it will be likely to have on the entrance channel if allowed to remain."

33. It is a coincidence that the above quoted opinions only came under notice after the previous portion of the paragraph had been written. The opinion expressed in this report on the subject of the treatment of Deep-Water-Point has therefore received the independent support of an eminent authority. Mr. Parkes counted the cost. So must the Government of India, supposing the balance of testimony to be in favour of the undertaking.

34. 4.—*Auxiliary dredging and construction of training groynes in the new channel.* (See Appendix E for alternative arrangement.)

This work is not required, as the alternative arrangement of dealing with the New Channel and Chinna Creek has been recommended. This is the last work under the first head "to perfect existing works."

35. The "further works proposed" under the second head of "to provide further accommodation" have now to be reviewed.

1.—*Blasting and dredging a cut along the centre of the Manora anchorage and providing six fixed moorings.*

This work entered to cost Rs. 1,65,000, without share of Plant and Establishment, is not recommended. The excavation of sand stone rock and dredging of shingle at a depth of 25 feet below datum for a width of 200 feet, in order to accommodate six steamers of the largest class, such as Her Majesty's Indian Troop-ships, is a heavy work not required as yet. It may be put on one side at present, until it is seen to be absolutely necessary.

36. 2.—*Dredging in East Channel of lower harbour.*

This work for dredging the Keamari Channel, entered to cost Rs. 1,20,000, without Plant and Establishment, is recommended. It is of the greatest importance that not only should the Keamari anchorage regain its former area, but also that that area should be extended by all possible means. The lower part of the Keamari anchorage is now being beneficially acted upon by natural causes. This work will aid that natural action, and, moreover, effect a junction between the 20-foot contours at Keamari and Manora. It is not at all unlikely that this work may relieve the Manora anchorage in a manner which the Master Attendant may consider satisfactory. The work will take two years to carry out, therefore Rs. 60,000 should be provided for this next season's work, 1876-77.

37. 3.—*Ship Pier at Keamari.*

This work, entered in Appendix D, to cost Rs. 2,91,550, is for the erection of a screw-pile pier for ships at Keamari. The pier, proposed to be run out from the shore 234 feet, is to have a T shaped head 307 feet in length and 55 feet in breadth. The pier is to reach a depth of water in front of 22½ feet at low springs, and to be raised 5 feet above high water. It is to have a line of rails in connection with the adjoining Sind Railway, and also a public road approach. The pier is to be constructed similarly to the Calcutta piers. The object of the pier is to facilitate the loading and discharging goods direct from ships without the intervention of lighters, and to minimise the labour attendant on the transit of through goods on their way up-country, and *vice versa*.

38. This ship pier would, without doubt, be a very useful public work, in which the Railway and Commissariat Departments and the travelling public would most benefit. So long as the native trade is carried on at the new jetty that trade, or rather the pier interests, would not benefit by the local trade. Nevertheless, the pier would probably be a success over and above paying interest on capital and expenses. The Government of India in July last directed that the Engineer-in-Chief of the Indus Valley State Railway should prepare a design and estimate for a suitable pier or jetty along which vessels can lie, and embark and disembark their cargoes. It has been decided that the pier should be a State, and not a Railway Company, work, therefore a suggestion may without impropriety be offered respecting the department of Government which should be entrusted to carry it out. The Superintendent of Harbour Works may give all the information in his power to the Engineer-in-Chief of the Railway; but, nevertheless, the success of the pier must entirely depend upon considerations which are wholly within the province of the Harbour Engineers. It would be far easier for the Railway Engineers to give their requirements as to land position, dimensions and strength, than for the Harbour Engineers to convey their knowledge of the harbour conditions at Keamari to the Officer of the Railway who may be called upon for the pier design; and it would, further, be better for the Harbour Works Department to be entrusted with the responsibility of constructing the work which is to be set up in the harbour in over 22 feet of water, low tides.

39. But apart from the responsibility of designing and constructing this pier, there are other considerations affecting its success, which should be borne in mind at the time when the project is laid before Government for final decision. These considerations are connected with the present condition of the Keamari anchorage. That anchorage ground is in a state of transition. The causes producing that state have already been sufficiently dwelt upon, and the fact only requires mention here. If a reference be made to Plan No. 5, it will be seen, in a measure only, how the Keamari anchorage ground has been affected of late years. This plan, which is a longitudinal section of the harbour taken through the anchorages, shows the changes which have taken place at Keamari in the periods ending 1869 and 1875. The section, however, does not show the lateral contraction of the anchorage which has been considerable. Until, therefore, the Keamari anchorage ground may assume, under future treatment, a more permanent regimen in length, breadth and depth, the erection of a ship pier must be considered premature. The anchorage is not ready for the pier. In the papers on this subject it is stated that the estimate already prepared includes dredging over an area of 800,000 square feet. But dredging up in the anchorage will not maintain itself so long as the cause of the silt deposit exists; and it is not proposed for reasons of economy to treat that cause in such a radical manner as will at once cure its entire action. Therefore, it must not be forgotten that the dredged pier ground may re-fill with silt, and that it cannot without much difficulty be re-dredged after the construction of the pier.

40. Moreover, there is another point which requires consideration, and that is, whether or not such a ship pier would interfere so much with the fairway as to cause a loss of moorings in the Keamari anchorage. At present ships at this anchorage have only just room to swing with the tide, and a pier run out to 22 feet at low water would inconveniently project into the fairway. The anchorage is long and narrow; the breadth is sufficient to allow a ship to swing, but is insufficient to permit two ships to be moored abreast.

41. The head of the pier already designed is to accommodate two ships at one time. If one berth is retained, as is probable, for the mail steamers, only one berth remains. This may or may not be sufficient; but supposing two ships entering the harbour the same day, the second ship left in the Keamari tide-way would be able to discharge her cargo before the first ship at the pier could accomplish the same operation. The second ship would discharge into lighters on both sides; the first ship on to the pier from one side.

42. 4.—*Graving Dock at Manora*, Rs. 6,00,000.

This work would be a convenience for ship masters, and an encouragement to trade with the port. No recommendation is made, as, on the one hand the work is not an absolute necessity, and on the other the great benefits such a dock would confer on the trading public are manifest. The project requires not so much engineering as financial treatment.

43. In concluding this chapter on "further works proposed," a recommendation is brought to notice which may, after a time, if not very soon, be considered a necessity. It is the provision of a small dredger suitable for the shallower water of the new channel. Such a dredger would cost Rs. 35,000 only according to the estimate of the Superintendent of Harbour Works. He has entered the dredger in his Appendix D under the head of Tools and Plant required for No. 4 work, "auxiliary dredging in the new channel," of the first series of works.

CHAPTER V.

DREDGING APPARATUS.

7. Also the probable advantages or disadvantages of endeavouring to effect the same results by better and more economical dredging apparatus.

8. To make an approximate calculation of the cost by both methods with the relative advantages of each.

In the last chapter dredging operations have been recommended in place of adding to existing works, or constructing new ones. Whether, or not, those dredging operations should be performed by means of the existing plant, or by new dredgers of later and better invention, and more economical application, is not only a financial question, but that financial question divides itself into two considerations: for it may on the one part be the most economical course in the end to expend a large sum on improved dredging apparatus, while, on the other part, it may be easier to provide a certain amount for expenditure in each year on dredging with old available plant, which lifts spoil at a higher cost than would be the case with new dredgers.

2. There are two dredgers at Kurrachee, each 25 H. P., which cost Rs. 2,20,511 in 1856. Each dredger lifts 70 tons per hour, or seven hundred tons per diem. These dredgers, including the cost of the deposit of the spoil outside the harbour, work at a rate of 8 annas per ton of 20 cubic feet. It is estimated an improved dredger would effect a saving of 2 annas per ton.

3. Mr. Price mentions in his reply to question XII, that dredging plant, lately ordered for the Bombay Harbour, is to cost some 6½ lakhs of rupees. This may be for two dredgers, or for one of great power. But a single dredger costing over £30,000 in England, say £35,000 delivered at Kurrachee, could, according to a notice lately published in the "Engineering" journal, which was probably furnished by the dredge builders, lift 160 to 200 tons of mud, gravel, and free sand per hour from a depth of about 20 feet below water level. Makers are generally complimentary to their manufactures, and this is particularly the case with those who deal in mechanical appliances, and in machines where steam is the motive power. Nevertheless, if the new dredger, now under notice, could do very much less work than stated, yet still it would perform more work than the two old Kurrachee dredgers.

4. Notwithstanding what has been said, the Kurrachee dredgers will do very well for the purposes required. They are capable of doing the work required of them, and there is great advantage in having two dredgers in place of only one. They are not self-propelling, which is a great drawback, but they have hitherto managed very well. They are not required to work excepting in fine weather.

5. The cost of dredging with the old apparatus is estimated, with repairs to dredgers, at Rs. 42,000 per annum. This is for dredging at the Harbour entrance. A new dredger, costing 3½ lakhs, would, it is estimated, perform the same work for Rs. 31,500. To this sum must be added 4 per cent. on the prime cost which would bring the annual charge to Rs. 45,500.

6. The Kurrachee plant has still some life in it left. Mr. Price has stated that the plant may be good for use during the next five years. It is therefore recommended that no new dredging apparatus be purchased at present.

7. A recommendation has already been made in Chapter IV as respects the purchase of a small dredger, costing Rs. 35,000, for use in the new channel. As this item of plant has been inserted by the Superintendent of Works in Appendix D in connection with a work which is not recommended for execution, it will not appear in the summary of expenditure which will be given in this report. The Superintendent may deal with the subject hereafter should there be occasion for him to do so, independent of his work No. 4 under the head of "*To perfect existing works.*"

CHAPTER VI.

FURTHER TREATMENT OF CREEKS AND RIVERS DEBOUCHING PAST MANORA POINT.

9. The further treatment of the Chinna Creek, and of the other estuaries debouching past Manora Point, should receive full attention.

10. The consideration of whether beneficial results can be obtained by deflecting the course or the currents of the Pahi Baka, or of the Gaini (Lyari), especially the latter.

11. Careful observation should also be taken of the influence of Manora Point and of the East Pier.

The treatment of the Chinna Creek has already received full notice in this report. Of the other creeks of the lagoon which are fed from the Lower Harbour, and discharge their waters past Manora Point, the principal ones are, the Soti, Puhi, Baba and Yarari. These creeks of course play an important part in the economy of the harbour; and, fortunately, the influence of three of these upon the harbour anchorage is favourable to their development. It is in fact to the direction of the Soti, Puhi, and Baba Creeks, that the harbour is indebted for its Keamari anchorage, and the influence of the fourth creek is probably neutral as respects that anchorage. The influence of the fourth creek, the Yarari, cannot be readily traced. The natural resulting action which might be looked for from the position and direction of Yarari would be a silting at its mouth, and a deepening of the harbour bed at the first point of contact between the creek water and the shore. Probably its ebb current does not extend across the harbour, but becomes absorbed in the volume of the general ebb from the creeks in the upper lagoon. In 1838, from Lieutenant Carless' Chart, it will be observed the head of the West Channel anchorage appears to have reached very nearly to the mouth of the Yarari Creek. At present this West Channel 20-foot contour does not go so far up the harbour by 1,000 yards. This alteration in the harbour is due to the Napier Mole and Chinna Creek Diversion, and not to the influence of the Yarari Creek.

2. The waters of the Baba Creek, the largest of all, appear to keep very much to the west side of the harbour, and to hug the shore near the village of Baba. The tidal current has here excavated the bed of the harbour to a 17-foot contour of small and a 14-foot contour of large area. This excavation extends below the village of Baba, and even across the mouth of the Yarari Creek. In 1858, see Map of 1858, Plan A, there was only 11 feet depth of water off Baba village, and the 14 and 17-foot contour excavation was situated up in the mouth of the Baba Creek. As has been mentioned above the Soti, Puhi and Baba Creeks are favourably situated as respects the harbour, and no treatment is necessary with respect to them.

3. The Superintendent of the Harbour Works has, in his reply to question XVI, mentioned that the influence of the Yarari Creek might be improved by closing its mouth, and diverting its waters into the Baba Channel. He, however, explains, that the operation would cost about Rs. 70,000, and the change might so alter the regimen of the Baba Creek as to cause further temporary inconvenience by setting fresh material in motion. In this opinion Mr. Price is no doubt correct. The regimen of the Baba Creek is established, and any increase made to the waters passing through it which would follow the closure of the Yarari Creek mouth would only result in upsetting that regimen to the immediate damage of the harbour. The experience of the past is a sure guide in this respect, and there can be no desire to encounter the effects of another creek diversion.

4. As regards the influence of the Layari River upon the harbour, this river is not a perennial stream, nor do its waters flow with any regularity during any portion of the year. In fact it is seldom in flood for more than a few days in the year; consequently it can have no influence upon the lower harbour, or harbour proper. Mr. Parkes, when surveying the harbour in 1858, took sections of the bed of the Layari River, and calculated its discharge when in flood. The result of his investigation was, that the power exerted by the river waters in scouring the lower part of the harbour was quite insignificant. He calculated the discharge of the Layari when in flood to be as 1 to 16 of the harbour discharge, and only that for five or six tides during the year. The Layari brings down a quantity of sand into the upper harbour when it is in flood, and it was said in 1865 to increase the quantity of material which had to be moved from the new channel during its excavation before the Chinna Creek waters were admitted. Mr. Parkes stated in his report of 1858—

"Its floods bring down a great quantity of gravel and sand, of which the larger portion is now deposited just below the point at which the narrow channel joins the open estuary, where it is little injurious to navigation. The heavier material never reaches the navigable channels. If the course of the river were defined and embanked, the solid matter would be carried down to the end of the defined channel, and there deposited, probably, in a more injurious position."

5. No recommendation for any treatment of the Layari River bed and currents is proposed.

6. Manora Point and East Pier are the works which direct and compress the tidal currents of the harbour. The promontory of Manora is an admirable natural breakwater to the harbour which is placed completely under its lee during the heavy weather which prevails from June to September. The promontory being lofty at its outer end increases the shelter it otherwise provides; and now the point has been artificially lengthened by the

construction of a breakwater, which terminates in 30 feet of water at low tides, every thing has been done to extend the advantages the headland naturally affords. Under the present circumstances of the harbour, an increase in the length of the breakwater is not desired or required.

7. The flood tide does not approach the harbour mouth direct from the open sea: it comes round Manora headland from the west, and after taking a wide semi-circular sweep enters on the east side from an almost opposite direction. The flood enters the centre of the harbour mouth by a simple curve round the breakwater, and this curve encloses in comparatively still water the dredged west entrance channel which is thus not subject to strong flood tidal action. This is just as well, because the movement of sand at the bar, caused by the stroke of the sea wave, does not receive any strong impetus to traverse the entrance channel during the flood. If it be said the flood should scour the entrance channel as well as the ebb, then it may be replied, that if the flood effected a scour in the channel, the resulting sand or silt must be deposited in some portion of the harbour fairway and inner channels, and nothing would be gained.

8. For the ebb current the breakwater is well placed as its length lies parallel to the entrance channel. It thus confines the ebb current to that channel on one side.

9. East pier is the lee groyne or breakwater of the harbour. It compresses the tidal currents inside the harbour, and acts beneficially as respects the harbour channels. Its prolongation on its present alignment into deep water would probably be attended with great advantage to the harbour, but the expense would be very heavy. The length of the groyne would have to be enormously increased, and a great portion of the increase would require as solid a construction as the breakwater. The position of the harbour entrance and the bay as respects the cardinal points is adverse to the groyne prolongation; for the bay trends in a curve to the south of east, which causes the deep sea contour, which commences to leeward of the breakwater and entrance channel to follow that direction, and thus gradually to open out the shore to the full influence of the heavy gales which prevail for three months in the year. To prolong the lee groyne, therefore, to obtain the advantages usually sought by such works would be to expose its terminal to the full force of the westerly gales. Such a lee groyne would not be sheltered by Manora Points and the breakwater from the fury of the south-west monsoon.

10. The effect of the flood tide on the end of the east pier is to scour out the bed of the creek in its neighbourhood for a width of 1,000 feet at its narrowest part. The excavation is 35 feet deep at low water close up to the groyne end, and varies from 24 feet to 32 feet in other parts. A narrow bar, about 3 feet in height, forms across the harbour channel from the shoal water just inside the east pier to the Manora shore opposite, and an elliptical patch rising up in the centre of the pool, some 6 or 10 feet above the channel, makes its appearance from time to time. The patch is caused by the eddy in the floodtide at the groyne end, and probably has a nucleus of rock about which the sand collects. The small narrow bar is formed either by the sand washed into the entrance from the bar the floodtide, or is occasioned by the arrest of the silt-laden ebb current at the turn of the tide, and by the loss of velocity in the ebb current at the harbour entrance. The probabilities are all in favour of the silting in the entrance channel, and the inner bar being the resulting effects at the harbour mouth of the Chinna Creek Diversion. Those effects should not, however, be magnified as respects the harbour entrance. They are inconvenient, but do not present any very formidable obstruction, for it must be remembered, that although at the present time the dredging at the harbour entrance is estimated at Rs. 42,000 per annum, yet all that expenditure is not to be laid at the door of abnormal silting occasioned by the diversion of the Chinna Creek. It has been before stated that the filling up of the entrance channel may be occasioned, partially at least, by the natural action of the sea on the Manora ridge, spit, or bar, whichever it may be called; and an opinion has been given that whatever treatment may be applied to the Chinna Creek, yet, nevertheless, some dredging at the harbour entrance will, reasoning from analogous cases, always be required.

11. On account of the expense and other complications of the case, it is not proposed that, at the present time, the east pier or lee groyne should be prolonged into deep water.

CHAPTER VII.

BREAK-WATER.

12. Opinions may be offered as to the stability and structural arrangements of the Breakwater.

The Breakwater, including its rubble base, was commenced in March 1869, and completed in February 1873. The object of this work was to shelter the entrance to the harbour from the heavy seas of the south-west monsoon, and, at the same time, to prevent the sand from the sea bottom from being deposited as a bar to the entrance. Kurrachee is said to be north of the limit of cyclones; but the south-west monsoon occasions a very heavy sea, which lasts with full force for three months, from the middle of June to the middle of September. During the rest of the year easterly winds prevail, but do not cause heavy seas.

The sea at Kurrachee has an offing of 500 miles, and a depth of 100 fathoms within 77 miles of the port. The waves in deep water off Manora were estimated to have an extreme height of 15 feet, and trough of 600 feet, and to move at the rate of from 15 to 30 nautical miles per hour. Although the south-west monsoon gales are tolerably heavy, and long continued, yet their power was much less than that experienced further south. The Kurrachee monsoon has been compared with weather experienced during a mild winter on the English coast.

2. It was considered necessary to meet these conditions at Kurrachee that the breakwater should be constructed of artificial blocks of concrete masonry, founded on a rubble-stone base. Twenty-seven tons was fixed upon as the weight of the artificial blocks, the dimensions of such blocks being 12 feet by 8 feet and $4\frac{1}{2}$ feet in thickness.

3. The design of the breakwater, see Plan No. 9, was to lay the blocks of concrete at a slope of $\frac{1}{2}$ to 1 inclined towards the shore, the section to contain six blocks, two in width and three in height. This gave the cross-section the dimensions of 24 feet each way; width and depth of the structure alike. Mr. Price in his interesting account of the design and construction of the breakwater published with minutes of proceedings of the Institution of Civil Engineers on the 9th November 1875, says—

“The bottom of the lowest course of blocks was shaped so as to set level on the rubble base. For 108 feet from the shore the breakwater is levelled off on the top with concrete to 4 feet above high water of spring tides, to which latter level it was gradually dropped in the next 468 feet, and so continued to the end, but it has since settled, more or less, in the middle or outer portions as much as 3 feet. Between 108 and 1,180 feet from the shore the heads of the top blocks were left square, so as to form a jagged top, which, it was thought, would afford a better bond for a concrete capping, if required. For the outer 323 feet, however, as the top did not then seem likely to require raising, the heads of the upper blocks were made oblique, so as to finish with a level top.”

4. The first block was set in November 1870, and the last in February 1873, the length of the breakwater being 1,503 feet.

5. The action of the sea at the breakwater during the south-west monsoon is as follows. The wave which breaks near the shore end of the breakwater is crested with spray which rises at high water to 35 feet above the superstructure, or nearly 40 feet above sea level; while at the breakwater end the wave rises about half as high, and in an unbroken mass plunges into the water on the other side. At low water the sea wave rises nearly 30 feet above the sea level throughout.

6. The wave action on the breakwater appears to have shown itself in 1871 and 1872 during the progress of the work. Shortly after the commencement of the monsoon of 1871 the centre joint opened, and the sea-side row of blocks beyond 100 feet from the shore overhung more or less, especially at 206 feet where the top course projected $2\frac{1}{2}$ feet. The blocks on the harbour side settled more uniformly, and the sea displaced some of the blocks of the top course.

7. After the first burst of the monsoon of 1872, 18 blocks were washed out from the harbour side top course, the breakwater being then 793 feet in length. The course of blocks below the breach also shifted. At the same place the two upper courses of the sea-side row were driven inwards. Seven single blocks were also washed out from the top course of the harbour side. The large breach was repaired, when the monsoon was over, in seven days.

8. During the monsoon of 1873, the first after the completion of the breakwater, damage occurred in four places, all to the harbour side top course. In two cases a single block was washed out; in one, a mass of concrete occupying the place of two blocks, and in another, a concrete mass filling the space of three blocks.

9. In the monsoon of 1874, the outer end of the breakwater, which had been uninjured in the previous monsoon, lost five blocks, two from the harbour side, one from the sea side of the top course, and two from the second course. This damage occurred during a gale in July, the wind coming from the south-east with a velocity of 46 miles an hour. This gale brought up a sea from an unusual quarter, and seems to indicate that Kurrachee is not, as has always been stated, entirely beyond the reach of cyclones.

10. During the working season of 1874-75, the six outer tiers of the top course were connected together by chains. The beacon which had been carried away at the breakwater head was also re-erected.

11. The breakwater sustained no injury during the monsoon of 1875, and the Superintendent of the Harbour Works reports, under date the 2nd October 1876, that, although a close examination of the breakwater was not then practicable, it was apparently uninjured. The head of the beacon, 25 feet above high water, had, however, been carried away.

12. It would appear from the above account that the breakwater blocks had now settled down fairly upon the rubble base, and if no serious damage occurs to the work during the next few years, every block will find its true bearing on the foundation. The slight lateral rocking of some of the blocks on the sea side face caused by the sea swell acting on blocks which had not set down perfectly true from unevenness in the bed, and which was perceptible in April last will probably disappear in the course of time.

13. The design of the breakwater is excellent, but would have been better still if the blocks had been larger, and the central joint could have been avoided. It is not intended by this remark to mean that by making the blocks of different sizes, a good horizontal bond could have been obtained in place of a central joint, but that, if larger blocks of different form could have been employed, which would have obviated the central joint, or have given to any block, or blocks, in either face, subject to extraordinary pressure from the blow of the sea-wave coming from the opposite side, the assistance transversely of its neighbour's weight, supposing the blocks not to be through blocks, that, under those circumstances, the strength of the structure would have been greater than has been obtained by the present structural separation of the two halves of the breakwater.

14. The breakwater is formed of loose blocks of 27 tons placed at an angle in tiers, the structure having a breadth of two blocks. Consequently the breakwater has an open central vertical joint along its whole length. The design is novel, and Mr. Parkes has evidently given the greatest consideration to the question of the size of his blocks, and where bond should, and should not, be given. To the absence of horizontal and transverse bond must be attributed the success which has hitherto attended the completion of the breakwater; displacement of blocks was, of course, to be anticipated during the time of construction.

15. Had the blocks been arranged to secure perfect bond, there cannot be much doubt that, founded as the structure has been on a rubble base, dislocation arising from settlement must have occurred. Considerable settlement of the blocks took place as much as 3 feet in one place; but the subsidence of the blocks on their beds caused no rupture to the superstructure, which possesses the uncommon properties of being elastic as well as solid. Like a chain it retains its strength whether its figure be rigid or undulating. If it be said that larger blocks could and should have been employed, there is the answer, that, doubtless, at an enhanced cost larger blocks could have been used; that weightier blocks should have been employed must remain a matter of opinion until time shall have, one way or the other, transformed opinion into fact.

16. As usual the question of cost doubtless formed an important element in the considerations of the designer of the work. The breakwater was down on the list of harbour works prepared by Mr. Walker in 1858 for £110,000. The cost of the work, including establishment, has been £109,000, or £1,000 within the estimate. This shows a closeness of working to estimates which is alike creditable and unusual.

17. The time has now arrived when the upper surface of the breakwater should be finished off. For more than two-thirds of the length of the work the top surface is serrated longitudinally, owing partly to settlement, but principally to the blocks being of rectangular form laid at an inclined angle: transversely, also, the surface is uneven owing to settlement. It was advisable the breakwater should be allowed to settle before completing the top surface; but at the same time the irregularity of top surface has increased the effect of the sea-battering. It must be remembered that the top of the breakwater is for the greater portion of its length rather lower than high water springs; consequently, although by its low structure it does not present much surface to the sea-wave, yet volumes of water are for ever dashing over it, and the waves get a hold, as it were, of the top surface instead of being suffered to glide away.

18. The top surface of the breakwater, therefore, should be filled up with concrete to a slight curve. This work is now recommended, and its probable cost will be Rs. 6,000 per annum for five years, or Rs. 30,000 altogether.

CHAPTER VIII.

SUMMARY.

Subsidiary Instructions.

1st.—Is it advisable or necessary that any new works should be constructed, or any existing works added to, with a view to bring about improvement in the harbour by means of natural scour?

2nd.—Should any existing works be altered or modified with the same object?

3rd.—Should the dredge be wholly or partially depended on for maintaining the advantages that have already been secured, or for extending those advantages?

The three subsidiary questions, which have been added to the instructions received from the Government of India, are of such a practical character as to require brief and simple replies. Therefore

To the 1st question the reply is:—No.

To the 2nd question the reply is:—No, not at present; but a slight modification of one work may become necessary in next year, 1877.

To the 3rd question the reply is:—Yes, the dredge should as an active measure be wholly depended on for maintaining the advantages that have already been secured, and for extending those advantages.

2. A brief summary of the state and requirements of the Kurrachee Harbour as detailed in the previous chapters will now bring this report to a conclusion.

As respects the present state of the Kurrachee Harbour and its works, it may be said that the conditions of the harbour at the present time is one of transition. Whether, when the works of improvements were first designed and inaugurated, it was foreseen and understood that the alterations in the constitution of the harbour (that is, in the regimen of its anchorages, channels and entrance through the bar) would extend over so long a period as has elapsed since the completion of the works, is not known. Such changes as were contemplated could not occur with any great degree of suddenness ; but it is now eleven years since the groyne and east pier were completed, five years since the Keamari backwater was turned on to the harbour, and three and a half years since the backwater was completed, and the establishment of the harbour regimen still only looms in the distant future.

3. It is clear that the effects which the authors of the Kurrachee Harbour Works intended, or hoped, to produce, have not been realized up to the present time. The whole effects anticipated will never be produced, and even partial results, it is now seen, can only be secured by means of additional help. As events have happened, the Chinna Creek Diversion has not proved a success. On the one hand, to the backwater was attributed a potentiality it by no means possessed ; on the other, a force was raised which could not be regulated. In it the harbour engineers have created a very Frankenstein which they are powerless to control. It did not excavate a new channel for itself with any rapidity on account of the distance of its new mouth from the sea. The ebb-current excavator could only work for a limited time in each twenty-four hours. Some of its work was undone by the flood ; and, by the contraction of its section at its head, anything but a satisfactory regimen was established in the new channel. The creek diversion into the harbour, which was to aid the harbour currents to force a way through the bar, has proved but a feeble friend ; for the volume of its waters was reduced to a fraction by the constriction established for other purposes at the notch.

4. It has been mentioned in this report in Chapter III, how the Chinna Creek Diversion has placed the harbour regimen in a sort of dead-lock. That part of the scheme which was intended to make a port for native craft far up the harbour, by means of scour, has resulted in the ordinary effects which are produced by scour in a channel, namely, a deposit of silt at the channel mouth ; but whereas a large pool existed at the end of the channel, not only has the channel mouth silted, but a large quantity of silt has been carried beyond into that pool. The groyne itself has occasioned a similar result at its mouth, which is the harbour entrance, and has thus placed this part of the harbour at a disadvantage ; for it has become a very knotty point indeed to determine, apart from the question of expense, how and where the groyne ought to terminate. Bars are fed from within, and however the channel may end its mouth must eventually debouch in comparatively still water, and then the bar will reform. A strong natural littoral current would seem to be the only remedy, and where there is no such current all idea of effacing a bar from a harbour mouth must be abandoned.

5. The Chinna Creek portion of the harbour scheme has been a mistake. It would have been a better plan to have left the backwater alone, and to have had the Railway line along side the Napier Mole. The whole trade of the port should have been carried on, as originally projected by Sir Charles Napier at Keamari. Had this been done, a sum of no less than 11 lakhs of rupees would have been saved. The new channel and Napier bridge have cost Rs. 11,16,148, not counting Plant and Establishment. The Rs. 4,30,677 expended upon the Native Jetty and Quay at the head of the new channel could have been spent in providing accommodation for that trade at Keamari. Had this course been followed, the Railway would have been at hand with its line passing close to the Native town, and the awkward loop in the present line would have been avoided. The Keamari anchorage would have improved still further than it had done in 1869, and a good deal of the silting which now occurs at the entrance would have been spared to the harbour.

6. These observations are not made in a captious spirit of criticism, but simply as a historical record, for future guidance, of an interesting example of harbour engineering. He would be a bold man who could assert that he would have done better under the circumstances. If one part of the scheme has been somewhat disappointing in the results hitherto attained, it should not be forgotten that other portions have been followed with a good measure of success. The Government of India may be satisfied the harbour of Kurrachee promises ere long to secure, very fairly, all the advantages desired for a provincial port situated 500 miles from the chief port of the country. The coasts of India are not prolific in harbours, it is a matter for congratulation, therefore, that one so good as Kurrachee should occupy so important a position with respect to direct communication between Europe and the upper provinces of India.

7. The designers of the Kurrachee Harbour Works were placed at this disadvantage that they had in 1858 to forecast the results of their works, while the critic of 1876 has certain effects before him which afford good data on which to base his recommendations for subsequent proceedings. The one proficiencies ; the other is the judge of events which have occurred.

8. The questions which from a consideration of the statements made in this report arise for settlement with respect to the Kurrachee Harbour Works are two in number—

1stly.—Is the future treatment of the harbour to be such as will ensure the accomplishment of the objects sought in the most expeditious manner at considerable cost? or

2ndly.—Is the same end to be attained in a longer period; or, at least, is an attempt to be made to that end, at a small expenditure?

9. By the first question is meant:—Is the Chinna Creek mouth to be opened, a bridge built across it with a newly formed embankment for the purpose of carrying the Railway line; the notch at the Napier Bridge to be closed; and an expenditure on dredging in the new channel, not for clearance only, but also for excavation, to be incurred, the whole scheme involving great expense?

Or, by an alternative still more costly:—Is the Chinna Creek mouth to be opened, involving a new bridge and embankment; the notch to be closed; the new channel and native jetty to be abandoned, and a new quay and accommodation for the native trade to be constructed and prepared at Keamari?

Or, again, by another alternative less expensive, but still costly:—Is the Chinna Creek mouth to be opened, the new channel to be dredged, and the notch closed by the construction of a new embankment from Keamari to the mainland for the Railway line?

10. By the second question is meant:—Is the present arrangement, supplemented by dredging, to be permitted to continue till January 1877, at which date if fair prospects of eventual success, based on an improvement having taken place up to that date, are not forthcoming, a certain inexpensive alteration be made to an existing work? And further:—Is the present arrangement, supplemented by dredging, to be permitted to continue in operation should the above mentioned inexpensive experiment fail, a second comparatively inexpensive plan of treatment being ready for, and worthy of, trial, before one of the radical and expensive treatments involved in the first question be adopted?

11. The recommendations made in this report are in favour of a negative answer to the first, and an affirmative reply to the second question. It is safer and better in every way to proceed cautiously, and to give inexpensive remedies a fair trial before entering upon any further costly undertakings in the Kurrachee Harbour. Provided the Kurrachee trade can be accommodated in the port, as it doubtless may be, with the aid of the works recommended in this report, that is, all that is imperatively needed at this time. The harbour is naturally and artificially sheltered at all seasons, and its entrance presents no difficulties. All it requires is a little additional anchorage accommodation for ships. If the recommendations of this report are carried out, sufficient accommodation for ships for the next few years will be provided, and, after a while, increased accommodation will result from the action of natural causes aided by some dredging. Should the trade of the port advance with more giant strides than has hitherto been the case, and urgently call for the adoption of more prompt and decisive measures by an expenditure which that increased trade may justify, further aid can be given.

12. The recommendations made in this Report as respects expenditure are these—

1.—*Dredging the harbour entrance.*—Estimate for five years at Rs. 42,800 per annum, Rs. 2,14,000.

2.—*Dredging East Channel.*—Rupees 1,20,000 in two years.

3.—*Completing the Breakwater*, by rounding off the top with cement concrete, Rs. 30,000 in five years.

Grants required for expenditure in 1876-77.

	<i>Annual repair.</i>			Rs.
1.—Dredging Entrance	42,800
	<i>New works.</i>			Rs.
2.—Dredging East Channel	60,000	
3.—Completing breakwater	6,000	
				<u>66,000</u>
Total	...			1,08,800

13. The undermentioned expenditure may become necessary during next year, irrespective of the continuation of the works above mentioned.

	<i>New works.</i>			Rs.
4.—Opening notch	1,000
5.—Small dredger	35,000
6.—Berths for two large ships	18,000
Total	...			<u>54,000</u>

14. In concluding this report the writer would desire to express his appreciation of the difficulty of the problem the authors of the Kurrachee Harbour Works had to solve. While the features of the natural harbour seemed to secure to the new port the most advantageous disposition of land and water which could possibly be desired, yet, in reality, that disposition above water was so involved below the surface as to present difficulties of an intricate character with which even harbour engineers are not often called upon to contend.

15. As respects the execution of the harbour works, Government appears to have been fortunate in having placed them in charge of very efficient Officers. Mr. W. H. Price, C. E., has been Superintendent of the Works from their commencement in January 1860 up to the present time, a period of nearly 17 years. Mr. Price was absent twice on leave for three and a half years altogether, during which intervals the works were in charge of Lieutenant, now Major, Merewether, R. E., and Mr. J. H. Hart, C. E. Major Merewether was also Executive Engineer on the works for eight years, besides the two years he acted for Mr. Price as Superintendent. Mr. Price is now assisted by Mr. J. Humby, Sub-Engineer, who has been connected with the works for nearly as long a period as Mr. Price himself. Mr. Price has frequently acknowledged the skilful and valuable services rendered by Mr. Humby.



REPORT
ON THE
STATE AND REQUIREMENTS
OF THE
Kurrachee Harbour Works,
BY
COMMANDER HENRY HAND, ROYAL NAVY,
1876.

Dated 27th April 1876.

From—Henry Hand, Royal Navy, Commander, Her Majesty's Ship *Vestal*,

To—Colonel H. St. Clair Wilkins, R. E., A. D. C., Government House, Kurrachee.

In reply to your letter of the 24th instant in which you request me to furnish you with a report on the state and requirements of Kurrachee Harbour, with reference to the Resolution of the Government of Bombay in the Public Works Department, and the letter of the Secretary to the Government of India, No. 101 of the 3rd instant, I have the honor to enclose a report founded on my examination of the harbour and works which have been carried out for its improvement.

2. In submitting my observations I would state that many considerations of importance with regard to the existing and proposed works are without the limits of my profession, such as, the estimated costs of construction, description of works required, and especially the expediency which urges the improvement of the harbour at so large a cost in view of future trade, I therefore trust my remarks will be received with due regard to these circumstances.

Report on state and requirements of Kurrachee Harbour by Commander Henry Hand,
Royal Navy, of Her Majesty's Ship *Vestal*.

Detail of subject of Report.	Report.
<i>Existing works.</i>	
1. Breakwater at Manora Point.	1. Shelter has been afforded to the entrances of the harbour. The durability of the breakwater is doubtful.
2. Groyne running from the Keamari anchorage along the east side of the lower harbour 8,900 feet in length.	2. Has confined the flood and ebb tides to the main channel of the harbour and consequently increased their velocity. Might have produced a larger anchorage ground off Keamari by preventing the sand being silted from the eastward with the flood tide. Is of doubtful advantage.
3. Excavation of a portion of the rocky obstruction called Deep-Water-Point.	3. <i>Nil</i> .
4. The new channel, 2½ miles long, formed through the upper harbour for the passage of native craft and lighters and for the collection of tidal waters.	4. Doubtless is useful for native craft below the bridge; the deep channel above is useless. The scour has apparently produced a good passage for native craft, but this is the only benefit derived and is entirely negated by its helping to fill up the anchorage at Keamari by their lodging a large portion of the silt on its way seawards. I would suggest that the channel be blocked up at the bridge, the native passage would still remain, and a little dredging, at times, would keep it sufficiently clear (<i>Vide</i> under head 7).
5. A native jetty, 1,400 feet long, with masonry wharf walls to which access is afforded by the new channel.	5. The benefits derived are at the expense of loss of anchorage ground in the harbour. The necessary depth of water at the jetty being obtained by the scour from the Chinna Creek.
6. The Napier Mole iron bridge.	6. A bridge, one-third the length, would, in my opinion, have sufficed, even if existing works had proved successful.
7. An embankment, 2,780 feet long, which has been thrown across the mouth of the Chinna Creek and which carries the Railway.	7. I would recommend that a passage be cut through the embankment in order to carry off the water from the Chinna Creek prior to the channel at the Napier Bridge being blocked as suggested under head 4.

Detail of subject of Report.	Report.
<p><i>Existing works—(continued).</i></p> <p>8. A west channel through the bar has been dredged.</p> <p><i>Proposed works with view to further improvements.</i></p> <p>1. Proposed dredging in entrance channel for 5 years at a cost of Rs. 2,14,000.</p> <p>2. Extension of groyne on a curved line for a length of 11,000 feet at a cost of Rs. 98,875.</p> <p><i>Entrance.</i></p> <p>3. Removal of Deep-Water-Point at a cost of Rs. 2,38,218.</p> <p><i>Lower Harbour.</i></p> <p>4. Deepening the centre of Manora anchorage to 25 feet below low water so as to fit it for largest class of steamers with six fixed moorings at a cost of Rs. 1,65,000.</p> <p>5. Dredging a cut 5,200 feet long, 400 feet depth and 200 feet at 20 feet depth, giving at the latter depth an area of 24 acres to compensate for loss of 12½ acres at Keamari at cost of Rs. 1,20,000.</p> <p><i>Upper Harbour.</i></p> <p>6. Dredging and construction of training groynes to accelerate improvements to 9 feet depth within 5 years, including 35 rupees for a small dredger, at a cost of Rs. 1,60,000.</p>	<p>8. Indispensable as from my experience of a similar harbour, with a greater scour, dredging is always found necessary.</p> <p>1. This must be carried out at any price seeing that a bar existed prior to the commencement of any artificial construction of the harbour, and there still exists a tendency to fill up at this point.</p> <p>2. I cannot see the advantage that would be likely to ensue.</p> <p>3. Certainly would not advocate this expenditure, as there is no certainty that after the removal of the Point the result would be satisfactory. It is true there is stronger tide and deeper water there than at any other part of the harbour, but should this rock be cleared away, there would not be the resistance which causes ebb to be so locally strong, and by reducing the strength of the scour, there would be a greater tendency to deposit.</p> <p>4. Dredging will always be necessary; at present the moorings in lower harbour are apparently sufficient for the trade. Two of the largest, or Indian troop-ships, could, I believe, now be moored here.</p> <p>5. The necessity for this work would, I think, be obviated by opening the Chinna Creek to the sea at eastward, and increasing the more valuable anchorage at Keamari (<i>Vide head 4</i>).</p> <p>6. If employment of native craft is considered of importance, this work will be necessary, otherwise the piers and landing at Keamari are considerations of greater moment. The shipment of cargo from the latter place would probably be less expensive.</p>

General observation.

Having pronounced my opinion in regard to the works already in existence, and my views as to the expediency or otherwise of those proposed, I conclude by alluding to, what seems to me, the enormous sum the works have cost the Indian Government. The amount nearly half a million sterling is, for the advantages derived, a very large expenditure, and the trade of Kurrachee must increase to a very great extent before its value will bear a reasonable proportion to the outlay on the construction of its harbour, and without any knowledge of the *anticipated* trade, I am of opinion that dredging is sufficient to keep the harbour in every respect equal to its present requirements.

Dated on board H. M.'s Ship *Vestal* }
 at Kurrachee,
 27th April 1876.

HENRY HAND,
Commander.

APPENDIX

A.

KURRACHEE HARBOUR WORKS.

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KURRACHEE HARBOUR WORKS.

Questions by Colonel H. St. C. Wilkins, R. E., A. D. C. to the Queen, on special duty ; with replies by Mr. W. H. Price, M. Inst., C. E., Superintendent, Kurrachee Harbour Works.

I. What were the chief features of the natural harbour previous to the commencement of the improvements ?

Previous to the commencement, in 1860, of the improvements designed by Mr. Walker, the harbour had undergone some change through the construction of the Napier Mole, completed about 1850, and which will be referred to further on.

The features of the harbour generally being described in the Kurrachee Harbour Works Memoir, pages 1 to 3, and in the two Volumes of Kurrachee Harbour Works' correspondence, it will be sufficient here to refer to those parts with which the works are concerned.

Plan A accompanying shows the state of the harbour as surveyed by Mr. Parkes in 1858.

The harbour had then two channels over the Bar at its mouth, of which the circuitous East Channel [due chiefly to the ebb] was 14 feet deep at low water, and the more direct, but much smaller, West Channel [due chiefly to the flood] had a depth of 11 feet. As both were completely unsheltered, the extreme draughts at which vessels could enter or leave port during the three or four months of the south-west monsoon were [according to the official directions] from 15 to 17 feet at high water of neap and spring tides respectively.

Even at these draughts they were fortunate to cross without bumping, and there were days when the sea was so heavy that such vessels could not pass. It was a matter of frequent occurrence for ships to be detained for several days cruising off and on waiting for suitable tides [and some were wrecked while so waiting], or to be sent away to Bombay to lighten.

The mail steamers also were obliged to time their arrival and departures according to tide, thus involving constant changes in the postal arrangements of Sind and the Punjab.

In the fair season also similar inconveniences were felt, though of course in a much less degree, and the maximum draughts allowed during that season were 18 and 20 feet at high water of neap and spring tides respectively.

The circuitous course of the East Channel also caused the services of a Steam Tug to be very frequently required for ships, the chief exceptions being those which were sailed in through the West Channel during the south-west monsoon.

The anchorage space, 20 feet or more in depth, and useful at all seasons of the year [see Appendix and Plan B] consisted of 58½ acres, made up by the anchorages of Manora, West Channel, and Keamari. These were included within the space called the lower harbour, 778 acres in area, at low water, extending from the Bar to the north-west angle of Keamari Island, flanked on the west by the Manora shore and Baba Island, and on the east by the sand-spit, dry at low water, and west end of Keamari Island.

Across the Keamari spit the flood-tide set, carrying in much sand, especially during the south-west monsoon, and causing also strong eddies, especially at Keamari. The ebb-current and monsoon sea also caused much disturbance in the Manora anchorage near Deep Water Point.

Altogether the anchorages were not then capable of berthing more than 20 loaded vessels of 500 to 900 tons.

From the foregoing it will be understood that the harbour was not at that time capable of maintaining a regular trade at all seasons of the year by vessels of large size, and further, the safety of those ships that did use the port was, as regards the entrance, a constant source of anxiety to the harbour authorities.*

The above statements, with reference to navigation, are made on the authority of Captain E. Giles, I. N., who was Master Attendant here for several years, both before and during the improvements.

For native vessels the entrance of course sufficed during the fair season, though impassable to them in the south-west monsoon.

The only wharfage accommodation were the Customs and Commissariat Piers at Keamari, and one side of the narrow roadway of the Napier Mole near the town end ; neither however were suited to any except native craft, and the latter accessible only to lighters, and that at high water, though nevertheless preferred to Keamari, owing to saving in cartage, and generally to vicinity to the town.

From Keamari the shallow backwater spread out north, west and south-west for an area at high water spring tides of 14½ square miles, intersected by numerous creeks.

Formerly joined with the above, the east backwater 3½ square miles in extent, had been cut off by the Napier Mole running from Kurrachee to Keamari Island, and completed in 1850, from which time that backwater had its only vent through the Chinna Creek, and the latter consequently enlarged from 150 to 1,275, feet † in high water width at the mouth.

* As an instance may be mentioned the case of the *Jullia* which was wrecked when putting to sea with a Battery of Artillery on board in the south-west monsoon of 1857, a few of the men and many of the horses were lost.

† This was the width in 1858, from which it altered little until 1862, when the width suddenly enlarged to 2,720 feet, under the burst of a heavy monsoon sea, helping the current to act on the narrow neck of the Keamari side.

These relative dimensions show that before the construction of the Napier Mole the east backwater must have contributed largely to the main harbour flow. In illustration of this, some particulars are given in Appendix and Plan B, as regards the bearing of the change on the anchorages, especially on that of Keamari, which is now attracting so much attention, and which, it will be seen, both suffered much and largely recovered itself, under influences similar to those which are now again affecting it.

Besides the injury to the lower harbour, in the upper harbour also the Napier Mole caused the Tookar Creek to silt up, and thus greatly diminished the capabilities of access to the town for native craft.

The only river channel discharging into the harbour is the "Layari," which debouches at the head of the backwater near the town of Kurrachee, flowing at most only for a few days each year when heavy rain falls in the hills; these floods bringing down a large quantity of sand into the upper harbour, but not having any important influence on the lower harbour or entrance as regards either scour or deposit.

II. In comparing the present state of the harbour with its former original state, what changes are due to artificial causes?

The former state of the harbour has been just described, and the present state [where altered] is as follows [see Plan A], understanding the question to refer to the results of the works as a whole.

The scour by the groyne, aided indirectly by dredging and excavation at Deep Water Point, and largely by direct dredging on the bar, has formed nearly in the line of the old West Channel, an entrance 2,700 feet long, 500 wide, and 20 deep at low water; protected by the Monora Breakwater, and through which, according to the official directions for the port, vessels with a draught not exceeding 21½ feet can now pass without difficulty during the south-west monsoon, and up to 24 feet draught during the fair season, from October to 15th May.

This is an increase of 4½ to 6½ feet during the monsoon, and 4 to 6 feet during the fair season, and it may be added that the draughts allowed are really limited more by the capabilities of the anchorage than by those of the entrance, which could pass vessels of much heavier draught at high water.

Detention of vessels off the port is now unknown, except in waiting for the Steam Tug [which is but seldom required], and the mail steamers time their entry and departure regularly, irrespective of tide.

Practically, since the capacities for tonnage of different channels vary as the cubes of their depths, * and allowing for its greater directness and certainty, the capabilities of the entrance may fairly be said to have been trebled.

As regards anchorage, though much of what was gained at Keamari up to 1869 has been temporarily lost by the operation of the Chinna Creek diversion, yet, through the effects mainly of the Keamari Groyne, and partly of the breakwater shelter, the harbour is now capable of accommodating twenty vessels of 500 to 2,000 tons, being 78 per cent. more tonnage than could have been berthed in 1858, though the increase of trade and in size of vessels makes even this insufficient.

Particulars of the anchorage areas and of the changes in these from time to time since 1838 will be found in Appendix and sketch Plan B, and details of qualities scoured or otherwise removed from the entrance and harbour, in Appendix and sketch Plan C.

The low water area of the lower harbour has increased from 778 to 868 acres.

For the native sea-going and general lighterage trade in the upper harbour a channel has been provided, 1½ miles long, 500 to 300 feet wide, and averaging 5 feet deep at low water [datum], giving access at most times of tide to the Native Jetty, a work presenting 1,736 feet of wharfage, founded at 9½ feet to 13½ feet below low water, and 1,070 feet founded at low water, comprising an area of wharf of about 5 acres.

Over this jetty passes the great bulk of the trade of the port, the exceptions being chiefly Railway material, and Government stores, which are landed at Keamari.

Eastward of the jetty, the channel passing through the "Notch" forming part of the opening in the Napier Mole spanned by the screw-pile bridge, extends for a length of one mile to its junction at head with the Chinna Creek. This part, which is 290 feet wide, and 3 deep at low water [datum], fulfils at present only the object of partially tapping the east backwater, and so directing scour into the channel below; but also offers valuable facilities for extension of wharfage when needed.†

In Appendix C will be found particulars of the quantity of material removed in forming this channel, which was effected partly by dredging, but far more by scour.

The scour was brought to bear by the opening in the Napier Mole and the closure of the Chinna Creek mouth, which have so far acted chiefly in forming the "New Channel" [and causing temporary deposit at Keamari,] but they will also tend to the general improvement of the harbour and entrance when the 3½ square miles forming the east backwater

* "Stevenson on Harbours," 2nd edition, page 247, which adds, "This result at once explains why such large sums are often cheerfully expended in securing even an additional foot of depth in harbours or river navigation."

† Except the Railway Pier at Keamari and the Harbour Works Pier at Manora, both for lighters only, no addition has been made to wharfage accommodation in the lower harbour.

shall have been thrown freely open to the tidal flow by lowering the rough weir, which up to the present has been kept up along 900 feet of the Napier Mole Bridge, so as to confine the scour to the 300 feet of "Notch."

All the above changes are due primarily to artificial causes, in the shape of the improvement works, chiefly by influencing the natural forces affecting the harbour, but partly by the direct application of those works.

III. Have any changes occurred which are due to natural causes ?

No material changes, except in so far as these have been directed by the improvement works.

IV. Have any changes occurred which are due to natural and artificial causes combined ?

The greater part of the changes described in reply to Question II, *viz.*, the general deepening and shelter of the Entrance, Anchorage and Harbour Channels, were produced by natural and artificial causes combined, in the sense of the former having been controlled, set in motion, or aided by the latter ; all will be described in detail in reply No. IX.

Some injurious changes—though generally temporary—have also been so produced ; these will be described in reply No. VII, and more particularly in reply No. IX.

V. Have any natural causes had any injurious influence upon the harbour ?

Neither before nor since the commencement of the improvement works do I consider that any natural causes *per se* had any injurious influence on the harbour, in the sense of causing progressive change.

The chief unfavorable natural influences were, the action of the south-west monsoon waves on the entrance, and in a less degree on the harbour ; the influx of sand from the Keamari spit by the waves and currents, and from the west breach and Keamari ridges by monsoon wind ; the washing of material from the land and Layari River by occasional rains, deflection of the ebb by Deep Water Point, and its waste over the Keamari spit, also eddies and disturbance of portions of the anchorages.

The favorable influences were chiefly the tidal scour from the backwater, and secondary to this, the ripple across it caused by the monsoon wind, stirring up material which passed out with the ebb-tide.

These two classes of influences counteracted each other so as practically to establish a balance, so far as they were concerned, before the commencement of the works.*

These last have since turned the balance in favor of improvement, though one removable adverse natural influence remains in the shape of Deep Water Point, which, though partially removed, presents a more abrupt and dangerous obstruction than it did when its rock was masked by sand.

VI. Have any artificial causes had any injurious influence upon the harbour ?

No artificial causes *per se* have had any injurious influence on the harbour. In explanation of this, see reply to next question.

VII.—Have any natural and artificial causes combined had any injurious influence upon the harbour ?

During the earlier operation of the groyne it caused serious temporary injury to the entrance by deposit of a portion of the sand washed out from the harbour, but this afterwards cleared away.

The breakwater and the abrupt termination of the groyne [East Pier] unfavorably affect the run of the flood-tide, the first only negatively so, as depriving the Entrance Channel of the direct benefit of the flood scour, but the other positively so, as causing eddies and shoaling at the inner end of the Entrance Channel, and in the anchorage adjoining.

Of late years also injury [which like that of the entrance formerly] may be looked on as temporary, has been done to a portion of the previously improved anchorage of Keamari, by deposit of a portion of the material scoured from the "New Channel" above. Injury has also occurred to the West Channel anchorage, this was initiated by the Napier Mole, [see Appendix B], and the material brought down from the "New Channel" has of late years somewhat accelerated the deposit there. The progressive deepening in the East Harbour Channel is connected with, and will eventually compensate for this.

VIII.—Where either natural or artificial causes, or both combined, have had an injurious influence, what remedial measures have you proposed should be undertaken ?

The remedial measures which I propose are shown on Plan D, and are described in Appendix D, under the head "To perfect existing works."

The following explanation may be added.

The deflection of the flood from the Entrance Channel by the breakwater cannot be directly remedied, but it can be compensated for by directing the ebb-scour more into the channel through the removal of Deep Water Point.

* Disturbance had however been caused by Napier Mole [see reply I and Appendix B].

To remedy the shoaling and eddies caused by the cross-rush of flood round the end of the groyne [East Pier], I have proposed an extension of that work curving to eastward, so as to ease the entrance of the flood and to remove such disturbance as may still remain beyond the limits of the channel.

These two works would also add to the anchorage space to the extent of berthing for four or five of the largest class of vessels.

For the present the dredging, which is being carried on each fair season in the Entrance Channel, may be looked on in a great measure as a temporary and partial substitute for the two works just named.

For the "New Channel" I have proposed further dredging and training, not only with the direct object of accelerating its improvement to 9 feet depth of low water, but in order also that the flow of the east backwater may be sooner set free by the improvement of the lower harbour and especially of the Keamari anchorage.

In the event of the expenditure thus proposed on the "New Channel" being deemed out of the question (though I believe in the end it would be found the best economy), I have proposed (see Appendix E) an alternative and immediately cheaper arrangement for regulating the flow at the Napier Mole Bridge, so as to give early relief to the Keamari anchorage, without any serious loss of what has been already gained in the "New Channel."

I do not propose any direct treatment of the Keamari anchorage, which I believe with time will recover itself.

Assuming, however, that increasing trade calls for an immediate extension of accommodation, I have proposed to dredge between the lower end of that anchorage and the upper end of the Manora anchorage a cut as described in Appendix D and reply No. X, which aiding the natural action would within a year or two far more than compensate for the recent temporary loss at Keamari.

IX. Please to state in detail, the results whether beneficial, or injurious, on each artificial work.

It is difficult to apportion exactly the results on each work, as they are more or less connected as regards their effects on the harbour.

The following therefore must only be looked on as approximation, and the results so far as a whole may be judged from the reply to Question II.

BREAKWATER.

Beneficial results.

Shelters the Entrance Channel from the south-west monsoon sea, so that when there is a 15 foot wave outside, this is reduced to a 5 foot wave at the outer end of the channel, lowering gradually to smooth water at the inner end. This shelter not only directly benefits the navigation, but also prevents the sea from breaking, so as to tear up sand from the bottom and to deposit it as a bar.

The Breakwater also has sheltered the outer part of the Manora (Deep Water) anchorage, so as to make it available during the monsoon (see Appendix and Plan B).

Injurious results.

The deflection of the flood-tide to a more circuitous course in entering the harbour.

This acts negatively, by depriving the Entrance Channel of flood scour. The diversion also intensifies the injurious cross-rush of flood round the end of the Groyne (East Pier).

GROYNE.

(KEAMARI GROYNE AND EAST PIER).

Beneficial results.

Acted in deepening the entrance, by scour only, up to January 1869, to the extent of 13½ millions of cubic feet,* which has however since been reduced by about 4 millions by changes during the construction of the Breakwater (see Appendix and Plan C.)

In still greater degree the Groyne by its concentration and better direction of the tidal currents, especially that of the ebb, has deepened and enlarged the lower harbour, from which up to January 1869 nearly 56 millions of cubic feet† of material were expelled by scour only (see Appendix and Plan C), which enlargement, aided by freedom from eddies, virtually trebled the capacity of the anchorage (see Appendix and Plan B). Since the division of the Chinna Creek waters was commenced in 1869, the gain in the lower harbour has been reduced, especially at Keamari, by deposit of a portion of the material scoured down from the "New Channel," so that the nett gain in the lower harbour by scour is now only 41 millions,‡ and the capacity of the anchorage is now not quite double what it was in 1858 (see Appendix and Plan B).

* Enough to cover nearly 53 acres, one fathom deep.

† Enough to cover 214 acres, one fathom deep.

‡ Enough to cover 157 acres, one fathom deep.

When the "New Channel" shall have attained its regimen (which cannot however be expected for some years yet), the former gain will it may be expected be not only recovered, but eventually far surpassed with the aid of the very Chinna Creek waters which are now doing temporary damage.

Besides its effect in causing scour, the Groyne has been highly beneficial by shutting off the movement of sand from the eastward, and sheltering the anchorage from sea and from tidal eddies.

Injurious results.

The shoaling of the inner end of the New Entrance Channel and of part of the anchorage adjoining, by the cross-rush and eddies of the flood-tide at the contraction formed by the abrupt termination of the Groyne (East Pier).

This greatly increases the dredging required annually in the entrance.

Last year a bar formed at this part right across the channel, having only 17½ feet over it at low water, and a Ship, the "Abercorn," touched on it.

This was dredged away to 20 feet by the 15th February last, but nevertheless by the end of May had already partially reformed, and a large Steamer, the "Canara," while lying at a mooring recently laid down there, grounded within the limits of the channel, into which the usual spit proved to be extending, so that near the east side it had shoaled to 17½ feet.

This will probably extend across the channel as before during this monsoon.

The particulars of this case, were communicated to Colonel Wilkins under my No. 393 of 26th May 1876.

DREDGING AND REMOVAL OF ROCK IN ENTRANCE CHANNEL.

Beneficial results.

Supplementing scour have deepened the Entrance Channel for a length of 2,700, a width of 500, and to a depth of 20 feet (at low water), within the shelter of the Breakwater.

Injurious results.

No injurious ultimate results, but during progress of work some interference with navigation and risk of collision in the channel.

DEEP WATER POINT REMOVAL.

Beneficial results.

The work done in partial removal of the Point, in straightening the high water line with a rough stone pitching, and in prolongation of this a training groyne constructed northward for a length of 940 feet, have improved the direction of the currents both on flood and ebb, to the benefit both of the anchorage and entrance.

Up to the present the flood has been the most benefited by the doing away with the eddy in the bight above the Point.

A good deal more work is however required in removal of the rocky nucleus of the Point, so as more fully to remedy its mis-direction of currents and interference with anchorage and navigation.

Injurious results.

In the present unfinished state of the work the tongue of Jagged rock laid bare is more dangerous to shipping than it formerly was when masked by sand and shingle.

NAPIER MOLE BRIDGE.

Results.

This work being merely an auxiliary to the "New Channel" and "Chinna Creek Stoppage" cannot be said to have any results apart from these works, which will be referred to presently.

NATIVE JETTY.

Beneficial results.

The Native Jetty has been for several years of great use to the harbour lighterage and native sea-going trade, by providing a commodious wharfage 2,806 feet in length, of which 1,736 feet can be used by the larger, and 1,070 feet by the smaller, native craft.

The area of the jetty bounded by these wharves is about 5 acres.

515 feet of quay-wall for vessels of light draught have also been provided south of the Napier Mole Bridge, but not yet much used, as the water-way has not yet been opened so as to bring scour to bear on its approach.

Over the Native Jetty passes all the trade of the port excepting Railway material and Government stores generally, which are landed at Keamari (by lighters) at the Railway, Customs, or Commissariat Piers.

Injurious results.

None.

NEW CHANNEL.

(TO NATIVE JETTY AND CHINNA CREEK.)

• *Beneficial results.*

Provides access to the Native Jetty, at nearly all times of tide for lighters, and at high water for the largest native sea-going craft.

The facilities to lighters are of course an advantage to the shipping by enabling loading and discharging to be expedited.

The "New Channel" also offers throughout its entire length of $2\frac{1}{2}$ miles great facilities for future extension of wharfage.

As yet the "New Channel" improvement has not advanced sufficiently to fulfil that portion of its object which consists in freely tapping the east backwater so as to increase the scour in the lower harbour and entrance.

With the material excavated from the line of "New Channel", before scour was brought to bear was filled in $44\frac{1}{2}$ acres of land, chiefly at Keamari, the greater portion of which has been reserved by Government, but which must all eventually prove of much value.

Particulars as to quantities of material excavated and scoured in forming the "New Channel" are given in Appendix C.

Injurious results.

The "New Channel" has no directly injurious effect, but indirectly, though temporarily, it causes damage by supplying, through its scour by the Chinna Creek waters, material for the shoaling of the Keamari anchorage, for particulars of which, see Appendices B and C.

CHINNA CREEK STOPPAGE.

Beneficial results.

Excepting the formation of land with excavated material, the beneficial results detailed under the head of the "New Channel" apply also to this work, the two in fact may be classed under one head as "Chinna Creek Diversion."

Injurious results.

The same applies as regards the temporary injury to the Keamari anchorage.

X. Do you contemplate any further improvements of the harbour by the extension of existing artificial works, or by the addition of new ones?

For convenience of reference, I have included in Appendix and Plan D, the additional works which I propose, to provide accommodation for trade further than what may be looked for from the existing works when perfected.

These consist of—1st, Deepening the centre of the upper Manora anchorage where the bottom in great measure consists of soft sand-stone, to 25 feet below low water, so as to provide berthing for six large vessels at fixed moorings, and to aid scour—2nd, Dredging east harbour channel in continuation of the last named between Manora and Keamari, so as to aid action of scour at that part to form additional anchorage space—3rd, a Ship Pier at Keamari—4th, a Graving Dock at Manora.

Particulars of these will be found in Appendix D.

XI. What would be the probable effect of such extension or additional works?

For convenience of reference, I have entered in Appendix D an abstract of the particular effect of each proposed work.

In looking to the general effects of the further works proposed, the "perfecting" and "additional" works cannot well be separated. Their combined effects I consider will be, with the aid of the scour already provided, though not yet fully brought to bear, to confirm and extend the improvement already gained in the entrance, and more than double the present anchorage capacity of the harbour, making it about four times what it was in 1858.

Further, they will greatly increase the facilities already given to the native sea-going and general lighterage traffic, and by the construction of the Ship Pier at Keamari and Graving Dock at Manora, will give entirely new and much needed facilities to shipping.

Further, that the enlargement gained will maintain itself without the aid of dredging, except possibly in the entrance to a slight extent.

The enlargement of the channels and anchorages comprised in the foregoing summary of general results, includes large effects of scour, and it will be convenient here to examine in some detail what those effects may be.

In Mr. Parkes' report on the survey of October 1873, dated 13th March 1876, para. 22, he assumes as an approximation that the further effects of the Chinna Creek diversion would ultimately be to increase the sectional area throughout the whole length of the harbour, so as to set in motion about 168 millions of cubic feet of solid matter, of which the greater portion would ultimately be expelled from the harbour.

Since then, in $2\frac{1}{2}$ years, only $8\frac{1}{2}$ millions have been scoured, but as the Chinna Creek diversion develops itself under the regulation and aid now proposed, it may reasonably be expected that within the next 10 years about 80 millions of cubic feet will be expelled.

This is rather less than has already been scoured from the harbour since the commencement of the works. See Appendix C.

I do not mean to convey that the ultimate enlargement will be limited by the quantity and time just named, but the further process—unless further aided—will be slow, and practically it would seem sufficient at present to confine the question within the above safe limits.

XII. Could the same results be effected by dredging with the dredgers now at your disposal, or by the employment of better or more economical dredging apparatus?

I do not consider that the above results could be obtained by unaided dredging, even with the most improved appliances.

Putting aside the Ship Pier and Graving Dock, which of course could not be replaced by dredging, of the other six works, three consist substantially of dredging, two of sub-marine blasting combined with dredging, and one is an extension of the East Pier, but all are more or less auxiliaries to aid or expedite scour.

The question therefore seems to resolve itself into this, can further dredging be substituted with advantage for the action of such scour?

Looking first to the experience of the past, I think that the figures given in Appendix C will show that dredging could not with advantage have been substituted for scour in what has been already effected.

But this can be shown even more clearly in a money form, seeing that the cost of removal of material by dredging or excavation has averaged $9\frac{1}{2}$ annas per ton of 20 cubic feet,* whereas that of the scour works has averaged only 5 annas per ton† on the material removed by their means, besides that their effects are not yet exhausted‡. Also our dredging plant should have been increased two or three-fold to execute the work in the same time, and constant dredging operations on so large a scale would have been a serious obstruction to shipping.

And after all remains the most weighty consideration, that the space so gained would not have maintained itself without extra scour.

To the future, similar considerations apply, with the addition that the works to produce the scour are already in great measure complete, though time is needed to develop their full effects.

For the works of dredging which I have proposed in Appendix D (excepting that of the "New Channel," which is specially provided for), the present dredging plant may be made to suffice, for though improved plant would save probably one-fourth in the rate of dredging, or say $1\frac{1}{2}$ to $1\frac{1}{4}$ lakhs of rupees on the works now proposed, this would not be enough to warrant the first outlay on such plant, which on the scale of that lately ordered for the Bombay Port Trust, would amount to about $6\frac{1}{2}$ lakhs of rupees.§

If however continual dredging on the bar were to be provided for on the present scale (that is, if the East Pier extension and Deep Water Point removal be not carried out), and that it were determined also by shutting off the Chinna Creek waters to look to dredging instead of scour for the further improvement and maintenance of harbour channels and anchorages, since the present plant will not last for many years longer, it would no doubt be good economy at once to order improved plant, which would save the sum above-mentioned on the works now proposed, and remain available for further dredging.

It will be obvious, however, that even with such improved plant, I do not consider that the same results could be obtained without the aid of scour.

XIII. What are the advantages and disadvantages of each method?

* Entrance dredging, spoil deposited at sea	...	...	...	8 Annas per ton.
" New Channel," dredging and excavation, spoil landed	...	...	...	11 ditto.
				Rs.
† Groyne (including East Pier)	...	...	...	4,83,174
Deep Water Point training groyne, stone facing, and other work, exclusive of direct removal of material	...	...	...	83,720
New Channel training groyne, and other work, exclusive of direct removal of material	...	...	...	36,934
Napier Mole Bridge	...	...	...	4,90,128
Chinna Creek Stoppage	...	...	...	1,88,273
			Total	12,82,229

which, divided by 4,050,882 tons of 20 cubic feet scoured (see Appendix C) gives 5 annas per ton.

‡ Plant and Establishments are excluded in the above comparison, but would not affect the conclusion as regards the past. For the future they would tell most against the unaided dredging plan, as requiring more plant, and being indefinite in continuance.

§ Our two existing dredgers (each 25 H. P.) cost Rs. 2,20,511 in 1856.

The advantages of the method of scour with auxiliary dredging is the saving of expense by taking advantage of the scour arrangements (for the most part already made), for both formation and maintenance of enlargement.

The disadvantage may be some temporary shoaling by the scour action, but this is not likely at worst to be so great as has already been encountered without serious inconvenience.

The advantage of direct and unaided dredging would be avoidance of temporary shoaling, and ability to form the enlargement at once in the exact position required.

Its disadvantages would be the extra cost, not only in formation but in maintenance and the obstruction to shipping by continual dredging operations.

XIV. Give the approximate cost by both methods ?

On a general view it would seem sufficient to state that, whereas by the auxiliary system, works proposed in Appendix D to cost Rs. 9,37,208 are calculated—besides their own direct effects—to aid scour in expelling 80 millions of cubic feet from the harbour, within the next ten years, and further to maintain and even increase the enlargement; to remove such a quantity by unaided dredging with our present plan would cost nearly 24 lakhs of rupees, and would occupy 50 per cent. more time.* With improved plant on about three times our present scale, the cost might be reduced by about one-fourth, and the time of course in still greater proportion.

Probably the least unfavourable application of direct unaided dredging would be in substitution for the action of the proposed East Pier extension and Deep Water Point removal, in keeping the entrance open.

Even there however I think that the following figures will help to show that the aid to scour could not well be dispensed with. The estimated cost of the two works just named is Rs. 3,13,208.* Of this one-third might fairly be considered a charge against anchorage improvement, leaving say Rs. 2,00,000 to set against the alternative direct dredging of the Entrance Channel.

The interest on this sum at 4 per cent. would be Rs. 8,000 per annum.

So far as can at present be judged, the dredging of the entrance, if other matters be left as at present, seems likely to cost Rs. 40,000 per annum. Of this I believe that at least two-thirds, or Rs. 26,666 per annum, would be saved by the better direction of the currents which the East Pier extension and Deep Water Point removal would give, so that the difference in their favor would be Rs. 18,666 per annum, with this additional consideration that the other alternative would not contribute to the improvement of the anchorage.

XV. Do you propose any further treatment of the Chinna Creek ?

No, except in so far as it may be now considered as merged in the "New Channel," the proposed further treatment of which is described in reply No. VIII and Appendix D.

XVI. Do you propose any treatment of the Soti, Puhi and Baba Creeks ?

No, as they converge at present in very fair directions for the Keamari anchorage and lower harbour generally.

The Yarari Creek which opens south of Baba island might be improved in direction by damming at the mouth and diverting it into the Baba Channel.

This however would be an expensive operation; roughly it would cost about Rs. 70,000, and the change might cause further temporary inconvenience by setting fresh material in motion.

XVII. Do you contemplate any treatment of the Layari River bed or currents ?

No, as my observation confirms the views set forth by Mr. Parkes at page 38, Volume I, of Kurrachee Harbour Works correspondence, as to any diversion or confinement of that river not being advisable under present circumstances, as the scour of the Chinna Creek waters is capable of carrying off any material brought down by the occasional flow of the Layari. Without such scour, however, the material brought down by the Layari would largely tend to the shoaling of the "New Channel."

XVIII. Do you consider any beneficial results can be obtained by deflecting the courses, or currents, of the Soti, Puhi, and Baba Creeks, and of the Layari River ?

I do not think any such deflection desirable. As regards the Yarari Creek, I have stated my views in reply No. XVI.

XIX. What is the influence of the Keamari Groyne and East Pier upon the harbour ?

Answered in detail in reply No. IX. These two may be looked on as one work, which directs and concentrates tidal currents, especially the ebb, so as to deepen the lower harbour and entrance, shuts out sand from eastward, and generally shelters anchorage from sea and eddies of tide, but by abrupt termination causes some local eddies and shoaling near outer end.

* More probably than the life of the dredgers.

† For clearness, Plant and Establishments are excluded. These would, of the two, tell most against the direct dredging plan.

XX. What influence has Manora Point on the harbour?

Acts as a natural breakwater and groyne, also as a landmark and elevated site for a lighthouse, being in fact the chief natural feature of the harbour.

XXI. What influence has the Breakwater on the harbour?

Answered in detail in reply No. IX. The Breakwater effectually shelters the entrance from the south-west monsoon seas, which are also prevented from tearing up sand to deposit it as a bar. Also shelters the outer part of the Manora anchorage.

The Breakwater has little or no effect on the ebb currents, but has deflected the flood to a greater circuit; this is some disadvantage as regards action in the entrance, but no injury has been done to the flood in its principal function of filling the Harbour and Breakwater.

XXII. Has the Bar made any advance towards the sea since the Breakwater was constructed?

The conditions of the Bar have been greatly changed by the formation of the New Entrance Channel, but it may be said that for half a mile from Manora, the Bar has from the very first not moved out. Eastward of that it had lengthened and advanced towards the sea, by deposit of a small proportion of the material scoured out from the harbour by the operation of the Groyne, before the Breakwater was built, but since that time this eastward part of the Bar has become flatter and moved in, scour evidently acting there which would be better employed in the Entrance Channel.

XXIII. Has it assumed a different form and dimensions?

Yes, in being completely cut through near its root by the deep Entrance Channel, and the remainder generally lowered, the least sounding on any part of it for half a mile from Manora being 14 feet, against 9½ feet in 1873.

XXIV. Has the Bar less or more water over it than before the Breakwater was built?

Much more water, not only in the line of the deep Entrance Channel, but in the general lowering of the Bar throughout, as above described. When the Breakwater and dredging were commenced, the depth of the old [East] channel was practically 15 feet, comparatively unsheltered. This is now superseded by the New Entrance Channel, 20 feet deep under shelter, where in 1869 there was a maximum depth of 9 feet.

XXV. Has the Breakwater suffered any damage since its completion?

It has suffered some, though no very serious damage, and as there has been no undermining or disturbance of the lower course, there has been no difficulty in effecting the necessary repairs, which are also likely to become lighter as settlement ceases.

During last monsoon, 1875, [which was not however a heavy one], no blocks were washed out, but it was thought desirable to shift in a few blocks of the sea-side course, where they overhung from unequal settlement over the boulders near the shore, and to level the top further with concrete for 150 feet in length, reaching to 259 feet from shore, an operation which I should like to continue on the jagged topped portion—as means admit—and as settlement ceases.

Altogether, during three years which have elapsed since the Breakwater was completed, an average of Rs. 4,342 per annum has been expended on its repairs.* This includes replacing a few washed-out blocks with concrete, re-adjusting others, the concrete capping and refixing and alterations of the iron beacon on the outer end. So far during the monsoon lately commenced [a heavy one], the Breakwater has suffered no damage.

XXVI. Do you approve the structural arrangements of the Breakwater?

I do, speaking generally, and especially of the absence of bond and the inclination of the blocks, which facilitated execution and repair, and enabled the structure to accommodate itself to the action of the sea and of settlement without serious dislocation. Were the work to be constructed over again, the only changes which I would propose are, blasting away of the projecting tops of the boulders in the foundation, some special ties and dove-tailing of the outer end, a level top longitudinally throughout, [instead of part jagged as carried out]; and as regards the cross section, to widen the base two feet and give the sides a slight batter, say 1 inch to 1 foot, and the beds a corresponding inclination towards the centre, also the top to have somewhat of a saddleback form.

Some extra difficulty might be looked for in moulding, conveying, and setting such blocks as compared with those of less complicated shape, also the sea-side would be more likely to follow the harbour side row, in the event of a breach in the latter. I believe, however, that the balance of considerations would be in favor of the modification, as aiding stability and lessening settlement.

XXVII. Do you consider the Breakwater likely to remain stable?

I do, though possibly a weak place may even yet be found out here and there, which from past experience I should anticipate no difficulty in repairing, though sea-works can never be reckoned as absolutely safe from extraordinary contingencies.

* Except last year these repairs were charged to construction.

XXVIII. With reference to Question XV, what would be the probable effect on the harbour of closing the notch at Napier Mole Bridge, leaving the Chinna Creek closed at the railway embankment as at present?

The effect on the lower harbour would be to stop the temporary shoaling of the Keamari anchorage, and probably to cause an early return to improvement there.

This benefit however [which could be obtained less objectionably by other means*] would be more than balanced by the immediate damage to the "New Channel" as an approach to the Native Jetty, and by the abandonment of the great prospective benefit to the harbour [including the Keamari anchorage], and in a less degree to the entrance, which may be looked for eventually if the diversion of the Chinna Creek waters be allowed to develop its effects fully according to the original intention.

A reference to the reports of Messrs. Walker and Parkes in the printed Volumes of Kurrachee Harbour Works correspondence will show the importance which they attached to this feature of the design, as calculated ultimately to produce effects not only greater, but more useful than even those of the Groyne.

XXIX. Would any results injurious, or otherwise, accrue from closing the notch irrespective of the Harbour Works?

Very injurious results would in my opinion accrue in a sanitary point of view by checking the tidal-flow over the east backwater marsh, which during neaps would be entirely, and at springs partially, cut off. The evil would be aggravated by the accumulation of sewage, and at times of rain by the penning up of the land waters. The percolation through the Napier Mole and Chinna Creek embankment caused by the head of water, would also cause continual damage and trouble to the road and railway traffic respectively.

The formerly proposed Canal from Ghizree into the harbour, which latterly I believe has also been contemplated in connection with the Jerruck Canal navigation, would also be interfered with by any arrangement for cutting off the east backwater.

XXX. Could any injurious results be obviated in any way, and at what approximate cost?

The immediately injurious results to the New Channel as an approach to the Native Jetty could be partially obviated [while abandoning prospects of its further improvement] by continued dredging, as a substitute for scour.

An approximation to the cost of such dredging may be arrived at as follows.

It will be seen by Appendix C, that accumulation to the extent of 5,391,970 cubic feet, or, 269,598 tons, took place in the line of the "New Channel" west of Napier Mole between 1858 and 1869, previous to the opening of the "Notch" in the latter year, that is at the rate of 24,509 tons per annum. The channel being now very much deeper would in the absence of scour form all the more of a trap for silt, so that 50 per cent. should be added to the above quantity to arrive at probable future rate of silting in the event of the "Notch" being closed, making a quantity of about 36,000 tons, to be removed annually by dredging. This, at the average rate of our past New Channel dredging, would cost about Rs. 25,000 per annum. It should be borne in mind too that the dredging vessels with their anchors and barges would cause much inconvenience and continual liability to accident in the navigation of the channel.

The less direct, but at least equally injurious result in the abandonment of prospective benefit to the lower harbour and entrance could not in my opinion be obviated by any practicable means. For detailed reasons as to this, see reply No. XII.

The cost of obviating the injurious results as regards sanitation I cannot attempt to estimate in a money form. The measure would I believe be nearly equivalent to the abandonment of Kurrachee as a station, as the prevailing wind blows to it across the east backwater.

As regards the Napier Mole and Chinna Creek embankment, the injury by percolation could only be obviated by forming a puddle bank along both, at an expense which I roughly estimate at Rs. 13,000.

The cost of remedying the interference with the contemplated Canal to Ghizree, I am not in a position to estimate, as I have had no concern with the latter project.

XXXI.—Can you give the approximate cost of re-opening the Chinna Creek embankment?

I estimate this approximately at four lakhs of rupees, including a substantial and permanent viaduct for the Sind Railway line, 1,000 feet in length, the removal of the present embankment, and the damming of the "Notch."

XXXII.—Can you give the approximate cost of removing and re-building so much of the Napier Mole bridge as would be required to give the necessary waterway at the Chinna Creek mouth?

The Napier Mole bridge having been designed for ordinary road-traffic, could only at great disadvantage be adapted for the very different dimensions and conditions required for the Railway.

* See reply No. XXXIII and Appendices D and E.

The piles, if they could be withdrawn, could not be screwed at the Chinna Creek, as the foundation would be a bank of rubble-stone.

At best, the adaptation would be patchwork, and might not be accepted by the Railway authorities.

I estimate the cost approximately at two lakhs of rupees for 1,000 feet in length, including cost of an embankment to replace the removed portion of the bridge, of removing the present Chinna Creek embankment, and of masonry abutments.

XXXIII.—On the understanding that the Chinna Creek scour has partially damaged the Keamari anchorage, could this injurious action be arrested by any means short of closing the notch at Napier Mole Bridge?

In reply No. VIII and in detail in Appendix E, I have stated that the injury to the Keamari anchorage [after some possible temporary aggravation] could be arrested, and the balance soon after turned in favor of improvement, by allowing the tide to pass freely at the Napier Mole Bridge, so as to ease the scour on the late ebb and its consequent conflict with the flood at Keamari.

For the bearings and details of this arrangement, I request a reference to Appendix E, but I put it forward only on the assumption that time and funds cannot be allowed respectively for the Keamari anchorage to recover itself, and for the New Channel to be further improved as proposed in Appendix D, previous to setting the Chinna Creek waters free for the benefit of the anchorage.

XXXIV.—What is the depth of water at the Native Jetty?

About 5 feet below datum low water, but owing to the ponding up of the ebb, the lowest tides do not usually fall lower there than $1\frac{1}{2}$ feet over datum, so that there is seldom less than about $6\frac{1}{2}$ feet of water along the south wall. This head will of course be reduced as the channel approaches a regimen.

XXXV.—What is the depth of water in the New Channel?

In the west division from Keamari to the "Notch" about 5 feet,* except on the bar at mouth just above Keamari where there is only about 4 feet below datum low water. In the east division, from "Notch" to head of channel, the depth is about 3 feet below datum, though the ponding up of the ebb seldom allows the water to fall within $2\frac{1}{2}$ feet of this.

XXXVI.—What is the depth of water desired, or necessary, in the New Channel and at the Native Jetty?

Mr. Parkes in his report on the survey of October 1873, para. 25, contemplates the Channel being ultimately navigable by vessels of 20 feet draught, and from the context he would seem to mean this to be at low water. I am however of opinion that 9 feet below datum low water, which is the limit allowable by the foundation of the Native Jetty south wall, would practically suffice for the "New Channel" as making it passable at all times of tide for native sea-going craft and harbour lighters.

XXXVII.—In what time is it anticipated the required depths will be obtained, and at what approximate cost?

At the rate of last year's deepening it would take ten years, but even that rate can hardly be looked for in future.

With help by dredging and groynes, as proposed in my report No. 272 of 10th April 1876, and Appendix D, I believe that the depth of 9 feet could be attained in about five years, provided that the weir at the bridge be kept up as at present.

XXXVIII.—Supposing the Napier Mole Notch closed, and the Chinna Creek mouth opened, what would be the probable effect on the New Channel and Native Jetty Channel?

The effect would be an early return to the state of 1869, when the channel became so blocked up that Rupees 8,002 was sanctioned as an emergency for a very partial measure of dredging, which should have been continued on a much larger scale [see reply No. XXX], but for the opening of the "Notch" in the same year.

XXXIX. Supposing as above in the previous question, what would be the probable effect on the harbour?

As regards the Keamari anchorage, an immediate check to the shoaling there, and probably an early return to improvement, but without the ultimate aid of the Chinna Creek waters, I do not think that anchorage will ever completely regain its dimensions of 1869.

As regards the rest of the lower harbour and the entrance, the closing of the "Notch" would cause no material change from their present state.

XL. What object was gained by placing the Native Jetty in its present position?

Saving of cartage, and advantage generally by proximity to the Town, Custom House, Merchants' Godowns and Offices, to supply of labour, and of fresh water.

In illustration of the saving in the one item of cartage, as compared with Keamari, it appears from information with which I have been favoured by the Collector of Customs, the Agents of the Landing and Shipping Company, and the Municipality, that 1,71,428 tons of goods passed over the jetty in 1875-76; that the extra cost of conveying this quantity to or

* At the upper end there is of course in addition the head mentioned in reply No. XXXIV.

from Keamari instead, would have been Rupees 96,423, at 9 annas per ton ; and that the probable extra annual cost for repairs to the roadway of the Napier Mole would be Rupees 3,500 per annum.

Thus, in these two items alone, a saving of about a lakh of rupees in one year appears in favor of the jetty, equal at 4 per cent. to interest on a capital sum of 25 lakhs. The other considerations, though not so easy to put into money value, are, I believe, in the aggregate of nearly equal importance.

No doubt if the landing-place were shifted to Keamari, arrangements would be made, to facilitate carriage of goods to and from the town by some modification of the Railway, or construction of a special tram-line along the Mole.

These measures however would involve a large outlay, and the result would never be so cheap or so satisfactory to the merchants, as the direct and independent cartage between the jetty and their godowns and presses, or town Railway Station.

XLI. Are there any good reasons why the native landing-place should not have been established at Keamari ?

Yes, the converse of the reasons given in last reply, and in addition the limited space at Keamari, and the crowding which would have been caused in the anchorage, by the concentration there of the native sea-going and lighterage traffic.

XLII. Required a list of the harbour works projected for Kurrachee, with the cost of each, under all heads, including plant and establishments ?

For convenience of reference I have drawn out such a list in Appendix A, giving the cost of construction to 31st March 1876, in the form under which it appears in the accounts. The works are shown on Plan A for 1876. The total amount is Rupees 46,28,984.

XLIII. Also, a brief description, with dimensions of each work, with the object to be attained by each ?

For convenience of reference I have entered these particulars opposite each work in Appendix A.

XLIV. Have all the projected works been carried out ?

No, as there still remain incomplete a portion of the East Pier extension, the removal of the rock of Deep Water Point, the Entrance dredging, and the further development of the "New Channel."

Also, it will be seen by Mr. Walker's report, [page 20, Vol I, of Kurrachee Harbour Works correspondence] that he further recommended and estimated at £360,000 considerable works in the way of Basins, Quays, and a Graving Dock, as necessary to fit Kurrachee for an extensive trade in shipping of large tonnage, and that the eventual carrying out of these was contemplated when accepting Mr. Walker's report may be inferred from the Secretary of State's Despatch No. 3, dated 16th February 1859, quoted at page 245 of Volume I, Kurrachee Harbour Works correspondence.

It may however here be remarked that the perfect shelter of the harbour will probably always enable Basins to be dispensed with, and Pile Piers or wharves to serve instead.

XLV. Have works extra to those projected been undertaken ?

No extra works,* but two works supplementary to the original design, namely, the removal of Deep Water Point, and dredging, chiefly in the entrance, both found necessary to remove hard material, and to expedite and aid scour, especially in overcoming the difficulties caused in the entrance by the postponement of the Breakwater.

XLVI. What is the probable cost of any further works proposed for execution, and what time will it take to carry them out ?

The probable cost of the further works proposed for execution, amounting to Rs. 23,29,020, is shown in detail in Appendix D, and it would take probably five or six years to carry them out, if funds were supplied for due progress.

XLVII. At what date do you anticipate the establishment of the harbour regimen ?

I should say about five or six years [if the works now proposed be carried out], that is, in so far as cessation of rapid change or disturbance.

After that time, however, it will be probably several years [it is not possible to say exactly how many] before a complete regimen is attained.

Mr. Parkes' views on this point will be found in his report on the survey of October 1873, especially paras. 3 and 22.

XLVIII. Do you anticipate a time when dredging may be dispensed with altogether ?

I think it impossible to say at present that dredging can eventually be altogether dispensed with, to maintain the Entrance Channel to its full depth of 20 feet.

It certainly never can, unless the extension of East Pier and removal of Deep Water Point be carried out, and even after that, though these works would, I believe, certainly save annual dredging to the amount of about three times the interest on their cost [see reply

* The various petty works shown as extra in Appendix A, and amounting to a total of Rs. 25,595, cannot be said to form part of the general scheme of improvement.

No. XIV], yet I think some small dredging may still be found necessary, especially owing to the patches of rock and boulders, which, though removed to the 20 feet depth, are still found to gather sand.

As regards other parts of the harbour, I do not think dredging is likely to be required further than that specially proposed in Appendix D.

XLIX. Do you consider the Harbour Works a success up to the present time ?

I do, and to save repetition, would refer to the details given in reply No. II.

There can be no doubt that the entrance is a success, even though not yet quite self-maintaining.

As regards the anchorage, the recent loss by shoaling [of a part of the previous gain] may be looked on as temporary, and up to the present seems to have caused no injury to trade, the anchorage being even now nearly double the capacity of 1858.

The wharfage accommodation has also been very greatly improved.

The opinions of others, who, though not responsible for the design or execution of the work, are well acquainted with and interested in the harbour, will be found in the remarks made by Sir Barrow Ellis, Mr. John Fleming, and Captain Giles, I. N., in the discussion on my Manora Breakwater paper, read this Session at the Institution of Civil Engineers, also in the following extract of a letter from the Chairman of the Kurrachee Chamber of Commerce to the Commissioner in Sind, dated 20th March 1876 :—

“I would invite attention to the fact that, including the vessels now in port with those bound for Kurrachee, it has never before happened that at any one time such an extent of sailing tonnage has been directed hither, thereby showing plainly that the anticipations of Government exhibited by the outlay in their efforts to improve the harbour are being gradually realized. At present 20 vessels are on the way here, and some of them, as also recent arrivals, are of the finest description of sailing ships afloat.”

It is, of course, impracticable to show the advantage gained by the works in the form of a direct money return, but there can be no question of the national importance and convenience of such a port in the absence of any other good harbour within 500 miles.

The comparative total values of the import and export trade in the year when the works were commenced, and during last year, are as follows :—

				Ra.	Ra.
1859-60	...	...	...	...	2,52,70,833
1875-76	{ Private trade	...	...	4,34,24,797	} 4,76,63,913
	{ State Railway material, Government	...	...	42,89,116	
	{ Stores, and Treasure	...	...	...

There can be no doubt that the increase would have been much greater, but for the disadvantages which this port has laboured under in the want of through Railway communication with the Punjab and the North West Provinces, which has of late years caused goods, stores, troops and passengers to be largely diverted for the time to other channels. These disadvantages are now in early prospect of removal; but so great have they been that the fact of the trade having in spite of them improved, instead of fallen off, speaks much for the commercial vitality of the place, and for the aid given to it by the Harbour Works.

L. At what date do you anticipate a completion of the Harbour Works ?

The works in hand and now proposed could be completed, as already stated, in five or six years,—see reply XLVI.

LL. Are you of opinion that the Harbour Works, if completed as designed, with the additional works you may have proposed, will ultimately prove successful, and provide a commodious harbour capable of receiving ships of large size, affording them perfect shelter in all seasons, and an easy exit and entrance to the port ?

I am decidedly of that opinion.

It will, in fact, be seen by reply No. 2 that a considerable portion of such results has been already attained.

LII. Adding the probable cost of future works to the actual cost of works executed, what is the total amount under all heads the Kurrachee Harbour Works will cost the Government of India ?

So far as already executed, and now further proposed, about 70 lakhs of rupees, being in round numbers the total of the works enumerated in Appendices A and D.

This (which is however only 4 lakhs in excess of what was originally contemplated on Mr. Walker's recommendation) may seem a heavy outlay, but I submit that it is not so when

measured by the national interests and the results involved, and by the outlay on Harbour Works elsewhere, though there are probably few ports where the real outlay on improvements can be ascertained so readily as in this case.

As touching on this question, I may be permitted to quote a few lines from "*Stevenson on Harbours*," 2nd edition, page 270 :—

"In concluding these remarks on harbours, it may not be out of place to state that the want of sufficient funds occasions a great national loss in the construction of many of our ports. The history of a large number of works which have been erected by private or local enterprise presents but a record of the building of piers at one period when funds were small, and of taking them down again at another, when the trade had increased and more room and accommodation were required. The difficulty of procuring capital for schemes, however beneficial in their tendency, and however likely to be ultimately productive, is fully established in the early history of many of our now flourishing ports.

* * * * *

"To such an extent has this system of partial and limited improvements prevailed, that were an Engineer called on to value many of our works, as they exist at present, his estimate however fully and fairly made out would fall far short of the actual cost.

* * * * *

"For these reasons we conceive there could hardly be a more advisable expenditure of the public money than a system of grants on a liberal scale, for supplementing the local funds. With such aid, the authorities on the spot would be enabled to protect and improve the existing physical advantages which the shores possess by preventing the construction of proposed improvements on too narrow a scale."

An opposite course to that above deprecated has up to the present time been pursued with respect to the Kurrachee Harbour, and I submit that the results already gained and those in reasonable prospect amply justify its adoption.*

Additional questions.

LIII. Required longitudinal sections of anchorages, when at their best, marked on the general longitudinal section ?

This information has been embodied in the tracing No. 5 supplied to Colonel Wilkins with my No. 340 of 5th May 1876, to para. 2 of which I would specially request a reference.

LIV. Required cross-section of Deep Water Point channel as proposed to be widened? Supplied herewith, together with plan, on tracing No. 6.

LV. Required acreage below low-water datum in best year, and in 1876 ?

The acreage of the lower harbour below low water in 1869, which may be taken as the best year with reference to anchorage space, was 850 acres, and now in 1876, it is 868 acres.

LVI. What is the desired section for the Entrance Channel, and what is the section now ?

Shown in accompanying tracing No. 7.

LVII. Required a chart with section lines marked thereon ?

The section lines are marked on the charts Nos. 1 to 4 furnished to Colonel Wilkins with my Nos. 315 and 317 of 28th and 29th April 1876.

LVIII. What are the proposals and estimates for a Ship Pier at Keamari, and Docks ?

Shown in Appendix D, and details as regards the Ship Pier given in Appendix F.

The design and estimate for the Graving Dock have not been as yet worked out in detail.

No Floating Docks or Basins are proposed, as the harbour does not seem to require them, being well sheltered.

LIX. Required cross-section of Napier Mole and New Channel ?

Given on the accompanying tracing No. 8.

*From the "*Engineer*" for March 3rd, 1876, it appears that the Netherlands' Government are about commencing, at the cost of the State, to the amount of £3,000,000, a new Harbour for Batavia in the Island of Java.

This has been found necessary to meet the requirements of the Suez Canal trade, the same which is also helping the pressure at Kurrachee, where however facilities can be provided much more easily than at Batavia.

LX. Probable cost of re-opening the Chinna Creek mouth and providing for the railway?

Replied to under Question No. XXXI.

LXI. What would general dredging, that is, dredging where you thought advisable from time to time, cost per annum?

I suppose you could dredge all you require with the two dredges you have in use?

What would an improved dredge cost?

General dredging, say in the entrance during the fair season, and during the monsoon in the anchorage [depositing the material then within the harbour, which could be advantageously arranged] could be carried on, if required, to the extent of about Rs. 1,60,000 per annum with the existing dredges, and country boats as lighters.

These dredges could be made to suffice for some years longer, perhaps ten or so.

New improved dredging plant would cost—as mentioned in reply No. XII—about 6½ lakhs of rupees. This would include one large self-propelling dredge, and three screw-barges, adapted either for depositing at sea, or for reclamation.

LXII. Required anchorage areas on each of the charts 1 to 4?

To save repetition, it is thought that the information as regards anchorage areas given in Appendix and Sketch Plan B will probably suffice for this question.

LXIII. Is there any balance of works sanctioned for which Budget allotments have not been made?

Two sanctioned works in progress, *i. e.*, Bar dredging No. 9, *i. e.*, for the season just passed, and improvements to the "New Channel," were not provided for in the Budget, but Government sanctioned their being proceeded with against the amount recoverable for plant lately transferred to Madras.

A further allotment of about Rs. 25,000 will probably be required during the current year for entrance dredging of next season, which cannot however as yet be precisely estimated.

LXIV. Prepare on any new data you may have in your possession a revised estimate of the probable cost of removing Deep Water Point?

Prepared accordingly, and the result in abstract is given in Appendix D.

The rates have been considerably reduced below those of Major Manson, owing to information about modes of working lately obtained in England, but the quantity has been increased in correspondence with the section No. 6 referred to in reply No. LIV, so that the total amount is not much under that of Major Manson's estimate.

Pending actual trial however of the arrangements proposed, the estimate now framed must be looked on as an approximation, as the work is of an extremely difficult and uncertain nature, owing to the irregularity and hardness of the rock, and the complication of the work by strong currents and eddies.

I am however of opinion that actual trial is more likely to result in saving than in excess on the estimate now put forward for Deep Water Point.

Kurrachee Harbour Works Office;

Manora, 13th July 1876.

W. H. PRICE, M. Inst., C. E.

Superintendent, Kurrachee Harbour Works.

APPENDIX A.
WORKS EXECUTED.

A P P E N D I X A .

KURRACHEE HARBOUR WORKS.

List of works executed, with cost, up to the 31st March 1876.

Name of Work.	Cost to 31st March 1876.	Total to 31st March 1876.	Remarks.	Brief description with dimensions.	Object to be attained.
ESTIMATED FOR IN MR. WALKER'S REPORT OF THE 28TH OCTOBER 1858.					
[<i>Exclusive of Basins, Quays and Graving Dock.</i>]					
Manora Breakwater ...	Rs. 6,96,349	Rs. ...	Complete ...	Extends from Manora Point on the west side of the entrance, in a south-by-east $\frac{1}{4}$ east direction for a length of 1,503', terminating in a depth of 5 fathoms at low water. The base is a bank of rubble stone levelled off for the most part to 15' below low water, but near the shore to 10'. The super-structure is of concrete blocks, each $12' \times 8' \times 4\frac{1}{2}'$, and 27 tons weight, set on edge without bond, so that two form the width and three the height, making a vertical wall of which the width and depth are alike 24'. The blocks were laid with an inclination towards the shore of 3" to 1'. At the shore end the top was raised 4' over high water of spring tides, dropping to high water at about one-third out, and so continued to the end, but it has since settled, more or less, in the middle and outer portions as much as 2 $\frac{1}{2}'$ to 3 $\frac{1}{2}'$.	Mainly to shelter the entrance from the violent and dangerous seas of the south-west monsoon, and at the same time to break them so as to prevent their tearing up sand from the bottom to deposit it as a bar.
Keamari Groyne ...	3,01,751	...	Complete ...	Runs in a slight curve, about S. S. E. from west end of Keamari island for a length of 2,516 yards. Is formed of rubble stone, tipped chiefly from wagons, but partly from boats, the size varying from hand rubble to 4 or 5 tons, the larger stone being chiefly near outer end. The mean top width is 21', with natural side slopes, and the top is 4' above high water springs. Along each side is a bench to protect the toe. The bottom is sunk more or less into the sand; 177,501 tons of stone were used in this work.	To concentrate and direct the tidal currents in the lower harbour and over the bar, and to stop the movement of sand from eastward.

East pier, 1,000 feet out of 2,000 proposed.	...	1,81,423	...	Further extension of 1,100' proposed in reply No. 8.	An extension of the Keamari Groyne and a similar work in style, but owing to the greater exposure larger stone was used generally throughout. The total length is 500 yards, the last 170 yards being sloped off longitudinally from 4' over high water to low water spring tides. The section is 20' wide at top, with side slopes as follows, from top level to datum 1½ to 1, datum to surface 2 to 1, also a bench on each side, extending from the bottom of the above slopes, 24' on each side, and 2½' in height; 125,058 tons of stone were used in this work.	Ditto
Napier Mole Bridge	...	4,90,128	...	Complete ...	An iron bridge on screw piles, with a masonry abutment at either end. Length 1,200' in 30 spans of 40', and 40' width of roadway, included in footpaths. The north abutment is founded on clay at 13' 6", and the south abutment 10' 3" below low water (datum). The piles are screwed to depths varying from 14½' to 20½' below low water.	To pass the Chinna Creek waters through the Napier Mole.
Native Jetty and Quay	...	4,30,677	...	Complete ...	Extends westward from north end of Napier Mole Bridge. The south wall is 1,400' in length, and founded at from 9½' to 13½' below low water datum, the west wall is 336½' long, founded at 10½', and the north wall 1,070', founded at low water datum. The area of wharf included by these walls is 4.93 acres. Also a quay south of bridge 515' long founded at low water datum.	Additional wharfage and accommodation for native craft and lighters near the town.
New Channel	...	6,26,020	...	Improvement still in progress by scour, and further aid to this proposed in reply No. 8.	The lower or west portion extends from near Keamari to the native jetty, and along the latter to the Napier Mole Bridge, altogether 1½ miles in length, 500' to 300' wide, and averaging 5' deep below low water datum, or 7½' below original surface of ground. The Upper or East Division extends 1 mile eastward from the "Notch" to the junction with the Chinna Creek, and 290' mean width and 3' deep below low water datum, or 9½' below original surface of ground.	To convey the Chinna Creek waters and to afford a passage for the largest native craft to the Native Jetty at all times of tide.
Carried forward	...	27,26,348	...			

Name of Work.	Cost to 31st March 1876.	Total to 31st March 1876.	Remarks.	Brief description with dimensions.	Object to be attained.
Brought forward	Rs. 27,26,348	Rs. ...			
<i>Estimated for in Mr. Walker's Report—(continued).</i>					
Chinna Creek stoppage	1,88,273	29,14,621	Complete	An embankment 2,780' long and 15' wide at top, with side slopes about 1 to 1. Formed chiefly of rubble stone, with hearting and backing of stiff mud. The base extends a considerable width and depth owing to action of scour during the gradual contraction of the opening, but the dimensions cannot be exactly given owing to the work being buried in sand.	To divert the Chinna Creek waters, and those of the east backwater generally.
SUPPLEMENTARY WORKS AFTERWARDS FOUND NECESSARY IN CONNECTION WITH THE ABOVE.				In forming the bank 65,328 tons of stone, and 1,132,166 cubic feet of mud-backing were used, but the work having been spread over a period of about 10 years was unavoidably expensive, including maintenance of staging and of unfinished bank.	
Bar dredging	3,70,846	...	In progress, see reply No. 8	A channel dredged through the bar at the entrance 2,700' long, 500' wide, and 20' deep at low water datum. This work also includes diving operations in blasting patches of rock and boulders, and removing them either by a crane barge or by the dredgers. Also some dredging in anchorage near end of groyne.	To direct and aid the tidal scour in forming and maintaining a deep and permanent entrance Channel.
In this work 744,779 tons of material were removed.					

Deep Water Point Removal	...	1,96,045	...	Incomplete, but account closed. Further work proposed in reply No. 8.	Partial removal of projection on west side of lower harbour, called Deep Water Point. Sand and shingle removed by hand labor and dredging, and underlying ridge of rock partially removed by blasting. A training groyne formed to the north of the point in order to direct the scour on it. The new high water line faced with large conglomerate rubble. Buildings which stood on the point were removed and re-erected elsewhere. 2,938,468 cubic feet of sand and shingle dredged or excavated. 50,317 cubic feet rock removed.	To improve direction of tidal currents and to ease their rush and eddies past the point, so as to benefit the scour of the lower harbour and entrance, increase the anchorage space, and add to holding ground by filling up deep rocky gut.
Dredging mouth of "New Channel"	...	8,994	...	Carried out in 1875-76, further work proposed, see reply No. 8, as part of the "New Channel" improvement.	Dredging bar at junction of "New Channel" with Keamari anchorage for a length of 1,700', quantity 22,296 tons. Pitching banks with rubble stone here and there where acted on by scour.	To aid and direct scour in forming the "New Channel."
Protecting Banks of "New Channel"		2,672	5,78,557			
WORKS, EXTRA, TO THOSE PROJECTED.						
Channel to Native Jetty. Special dredging required in 1869-70.	...	8,002	...	Complete ...	A channel cleared for a length of 2,560' from west end of south wall of Native Jetty to the level of 1' over datum, so as to partially remove accumulation which took place before opening of "Notch."	To partially facilitate access of boats to Native Jetty south wall.
Improving Channel along north and north-west walls of Native Jetty.	...	4,393	...	Complete ...	Excavation along north and west walls of the Native Jetty, 1,400' in length and 75' in width at bottom, and 2' over datum, also excavating a channel 175' in length, 20' width at bottom and to same depth, to embankment north of Jetty, also extra pitching to the embankment slope.	To improve access to north and north-west walls and (for fishing boats) to embankment north of Jetty.
Lighting Native Jetty ...	...	953	...	Complete ...	Nine cast iron lamp posts, with lanterns to burn kerosine oil, masonry foundations and ashlar plinths, and 1 spare lamp post.	To light Native Jetty.
Latrine on Native Jetty	...	729	...	Complete ...	A latrine 15' x 10' with 3 compartments, built of masonry with drain opening through south wall of Jetty, and fitted with pump, tank and apparatus for flushing.	For use by persons frequenting the Native Jetty.
Carried forward	...	14,077	34,93,178			

Name of Work.	Cost to 31st March 1876.	Total to 31st March 1876.	Remarks.	Brief description with dimensions.	Object to be attained.
Brought forward ...	Rs. 14,077	Rs. 34,93,178			
WORKS, EXTRA, TO THOSE PROJECTED— (continued).					
Chowkee at Napier Mole Bridge ...	1,316	...	Complete ...	Two rooms, each 12' x 10', one for a Chowkedar and the other for keeping stores and tools, a verandah along east side, and an iron railing with gate, round the compound, masonry of stone, and mortar, tiled roof and teakwood-work.	Quarters for Chowkedar and storage for paint, tools, &c., in use at Bridge and Jetty.
Borings in Anchorage ...	489	...	Complete ...	Ten trial borings for screw moorings, and 26 to find level of hard material.	To ascertain nature of ground with reference to proposed moorings and dredging.
Trial Borings for Ship Pier ...	575	...	Complete ...	Twelve borings at Keamari, all through sand, and averaged in depth below surface of ground 28 feet.	To ascertain nature of ground at site of proposed Ship Pier at Keamari.
New Offices to Manora Bungalow ...	981	...	Complete ...	Cook-room, quarters for servants; godown and sheds.	
Renewal and addition to roof of ditto	1,369	...	Complete ...	Renewal and strengthening of roof and addition of 2 verandahs, &c.	
Kurrachee Harbour Engineering expenses in England, a sum ordered specially to be debited in 1871-72.	6,788	...	...	Ordered to be debited by G R No. 365 of the 26th February 1872.	
		25,595		<i>Kurrachee Harbour Engineering expenses.</i> £ s. d.	
				Paid to Mr. Parkes for assistance rendered by him in connection with the discussion as to the Kurrachee Harbour Works ...	
				Paid to Messrs. J. and J. Stevens (D. and T. Stevenson ?) professional charges on account of their report on the Harbour Works ...	
				Paid to E. Fogg, Engine Driver, for 10 days' salary, gratuity and expenses ...	
				678 15 4	

SUBSIDIARY WORKS. <i>Apportionable on all the foregoing.</i>		Subsidiary to execution of main works,	
Plant and Tools	...	...	...
Office workshops and storeyard, Kurrachee.	49,109	...	Ditto ditto.
Office workshops and storeyard, Manora.	83,938	...	Ditto ditto.
Repairs to Quarters	4,478	...	Ditto
Harbour Surveys	48,469	...	Ditto
Total	...	9,28,119	To record changes produced by works and natural actions affecting the harbour.
DEDUCT—		44,46,892	
Estimated value of plant and tools after completion of works, one-fourth of Rs. 7,42,075	1,85,518		
Ditto of land filled in, with material from "New Channel," 44 acres, 1,845 yards, at Re. 1 per square yard	2,15,000		
Ditto of materials of buildings and piers and well of sweet-water at Manora	15,000	4,15,518	
ADD—		40,31,374	
Establishment	...	5,97,610	13.44 per cent. on gross expenditure, or 14.82 per cent. on nett expenditure. Enhanced by suspensions of active operations, and by the short supply of funds causing delay in works.
Grand Total	...	46,98,984	

W. H. PRICE, M. Inst. C. E.,
Superintendent, Kurrachee Harbour Works.

APPENDIX B.

ANCHORAGES.

The sketch Plan B [with statement] shows the states of the deep anchorage areas at the following important dates:—

- 1838.—Survey of Lieutenant Carless, I. N., showing Harbour in its natural state.
- 1854.—Survey of Lieutenant Grieve, I. N., showing the Harbour after changes had been caused by the construction of the Napier Mole.
- 1858.—Survey by Mr. Parkes, M. Inst., C. E., for Mr. Walker's Harbour Improvement project.
- 1869.—Survey by Mr. Price, M. Inst., C. E., after the Groyne [completed in 1865] had been some years in operation, but before commencement of Breakwater, Bar dredging, or diversion of Chinna Creek waters.
- 1876.—Survey by Mr. Price, M. Inst., C. E., after the completion of the Breakwater [completed in 1873] and the operation since 1869 of the Bar dredging, and the Chinna Creek diversion.

The anchorage spaces within the 20-foot contour at all the above dates are shown on the sketch Plan B by a dark blue tint, and to save confusion, all other contours are omitted.

The three main divisions of the anchorage are—

Manora,
West Channel,
Keamari,

the two first named of which have joined on the later surveys, but are divided in the calculations at Section 11.

Certain portions of the 20-foot area at each date not being always useful for anchorage, are distinguished by a cross hatching of blue.

The portions so crossed out, as regards the Manora anchorage, consist of those useless through disturbance by the monsoon sea, or by eddies at end of Groyne or at Deep Water Point.

In the West Channel anchorage the upper and narrow part has been crossed out, which, though it could still accommodate vessels, cannot well be got at when the lower berths are occupied.

In the Keamari anchorage the portion crossed out was narrow and subject to eddies before the construction of the Groyne.

In the accompanying statement accordingly the areas of each anchorage are divided into "Good" printed in blue; "Useless" printed in red; and "Total" printed in black.

Between 1838 and 1854 [the Napier Mole having meanwhile been made] it will be seen that the Manora anchorage slightly decreased, as also did the West channel anchorage [in its total area], and that the Keamari anchorage almost disappeared, having decreased from 27 to $4\frac{1}{2}$ acres.*

This great reduction seems clearly owing to deposit of material scoured out ahead of the Napier Mole bank during its progress.

At the same time the Mole, by shutting off the east backwater flow, transferred the preponderance of the ebb-currents from the west to the east side of the harbour, evinced not only the shoaling of the West Channel anchorage, but by the beginning in the east harbour channel of the deepening, which has of late years been largely increased by the operation of the Groyne.

Between 1854 and 1858, the Manora anchorage improved, † the West Channel continued to shoal, though not rapidly, and the Keamari anchorage without any artificial aid recovered from $4\frac{1}{2}$ to $17\frac{1}{2}$ acres [good], its position also having shifted southward.

Between 1858 and 1869 the effects of the Groyne, constructed in the interim, appear in the increase from $18\frac{1}{2}$ to $25\frac{1}{2}$ in the [good] Manora anchorage [the total increase was much more]; the West Channel anchorage continued to shoal, from $22\frac{1}{2}$ to $21\frac{1}{2}$ acres, but on the other hand the Keamari anchorage increased from $17\frac{1}{2}$ to $30\frac{1}{2}$ acres.

The aggregate increase in the good anchorage during the period was from $58\frac{1}{2}$ to $77\frac{1}{2}$ acres, and the gross total increase from $95\frac{1}{2}$ to $132\frac{1}{2}$ acres.

Between 1869 and 1876 the good Manora anchorage increased from $25\frac{1}{2}$ to $51\frac{1}{2}$ acres, partly by scour, but chiefly owing to the shelter afforded by the Breakwater having made available during the monsoon the larger space of about $19\frac{1}{2}$ acres, extending from the south side of Deep Water Point to near the end of the Groyne [East Pier].

* This is exclusive of the narrow detached pit to southward, evidently a new formation, and which later was joined by the northern portion.

† This improvement was probably caused by the raising of the Keamari sand-spit in the interim by the action of the sea—see Mr. Parkes' report, page 32, Volume I of Kurrachee Harbour Works correspondence.

The good West Channel anchorage decreased further from $21\frac{1}{2}$ to $8\frac{1}{2}$ acres, omitting the narrow gut, 100' to 150' wide, which is not conveniently accessible.

Further, the Keamari anchorage was reduced from $30\frac{1}{2}$ to $18\frac{1}{2}$ acres, by the deposit of a portion of the material scoured down from the "New Channel" by the action of the Chinua Creek waters.

The balance was slightly in favor of increase on the aggregate area of the good anchorages, which was $78\frac{1}{2}$ acres in 1876 as compared with $77\frac{1}{2}$ acres in 1869, but the gross total area decreased from $132\frac{1}{2}$ to $121\frac{1}{2}$ acres.

In 1858 the good area was $58\frac{1}{2}$, and the gross total $95\frac{1}{2}$ acres.

On a view of the figures just given, it may not at first be understood why the increase of $25\frac{1}{2}$ acres in the "good" Manora anchorage since 1869 does not compensate for the decrease of $24\frac{1}{2}$ acres in the West Channel and Keamari anchorages, but this is explained by the fact that the space gained at Manora south of Deep Water Point, being wide and deep, has been taken up by two swinging moorings for vessels of a large class, such as in former years never visited the port; also by a third mooring for a medium sized vessel.

That part also, owing to its vicinity to the entrance and to the irregular influences of Deep Water Point and of the abrupt termination of the Groyne on the tidal currents, does not admit of vessels being placed so close as they might be higher up the harbour, and so the increase of trade causes the loss on the other anchorages to be greatly felt.

General Remarks.

In 1858 Captain Giles considered that only 20 loaded ships of from 500 to 900 tons, or say 14,000 tons of shipping, could be accommodated.

Captain Parker, the Acting Master Attendant, considers the harbour as it now stands, capable of accommodating 20 ships of from 500 to 2,000 tons, or say 25,000 tons of shipping, being 78 per cent. over the capacity of 1858. This increase is in greater ratio than that of the areas, as the anchorages have also deepened, so as to accommodate larger vessels.

In 1868 Captain Giles estimated the capacity of the anchorage to have trebled since 1858, but in this he contemplated the utilisation by fixed moorings of the entire Keamari anchorage, which has since lost nearly two-fifths of its area, and as regards the remainder of which Captain Parker thinks it best to defer adoption of fixed moorings until a regimen is more nearly attained.

With the aid of time and of the further works now proposed [see Appendix D,] I believe that the present capacity of the anchorage will be more than doubled, making it about four times what it was in 1858.

W. H. PRICE, M. Inst., C. E.,
Superintendent, Kurrachee Harbour Works.

APPENDIX C.
CUBIC SPACES
GAINED IN
ENTRANCE AND HARBOUR.

APPEN

KURRACHEE HAR

Statement of cubic spaces gained in the Entrance and Harbour (Lower and Upper) both above excavation in the following periods, *viz.*, January 1858 to January 1869, January 1869 divisions into which the Entrance and Lower Harbour cubic spaces are divided.

NOTE.—The following shows the gain in the several divisions of the Harbour, first between January 1858 and between January 1869 and November 1875, being the period during which the breakwater, bar dredging, and diversion

The boundary between the entrance and lower harbour has been taken as a line drawn across at right-angles from a little higher up, *i. e.*, at Section 18, nearly up to which the so-called Bar dredging has of late years extended. As re-apportionment of water-spaces between the two adjoining divisions, but not effecting the conclusions drawn; a take in the former (and probable) future upper limit of the anchorage.

Figures prefixed with § denote silting,

Where.	How gained.	January 1858 to January 1869.
ENTRANCE.		
I.—Entrance ... Below low water ... {	Scoured ... Dredged ...	Cubic feet. 13,758,545 ...
	Total I ...	13,758,545
LOWER HARBOUR.		
II.—From off end of Groyne to 11th Section, including Manora Anchorage. {	Below low water ... { Above low water ... {	Scoured ... 24,215,577 Dredged ... 42,900 Scoured ... 8,320,490 Excavated ... 2,270,040
	Total II ...	34,849,007
East side.		
III.—Section 11 to 4 ... {	Below low water ... { Above low water ... {	Scoured ... 13,421,060 Scoured ... 4,409,240
	Total III ...	17,830,300
West side.		
IV.—Section 11 to 4, including West Channel Anchorage. {	Below low water ... {	Silted ... § 356,647 Total IV ... § 356,647
V.—Keamari Anchorage ... Below low water ... {		
	Scoured ... Dredged ...	5,883,320 ...
	Total V ...	5,883,320
UPPER HARBOUR OR "NEW CHANNEL."		
VI.—West side of Napier Mole, 8,100 feet in length. {	Within Channel { Above and below low water. { limits. { water. { From Flats ... Above low water ...	Scoured ... § 5,391,970 Dredged ... 9,019,795 Scoured ... 142,410
	Total VI ...	3,770,235
VII.—East side of Napier Mole, 5,300 feet in length. {	Within Channel { Above and below low water. { limits. { low water. { Probable from { Above low water ...	Scoured ... § 2,532,742 Dredged ... 8,302,742 Scoured
	Total VII ...	5,770,000
Total I to VII ...		81,504,760
DEDUCT.—		
Due directly to dredging and excavation as above ...		19,635,477
Balance due to scour ...		61,869,283

† January 1853 is taken for comparison, as date of Mr. Parkes' original survey, but the Groyne had not advanced far enough to affect the harbour until 1861-62.

D I X C.

BOUR WORKS.

and below low water, also showing proportions due respectively to scour, and dredging or to November 1875, and January 1858 to November 1875.—See Sketch plan C for the several

January 1869, during which period the Groyne only had been brought to bear on the scour of the Harbour, and second of Chinna Creek waters were brought into operation. The last Column shows the nett gain since 1858.†

the outer extremity of the Groyne (East Pier). In my report No. 272 of 10th April 1876 this boundary was drawn the extremity of the Groyne seems a mere convenient limit for reference, the change has been made, involving thus a similar slight re-arrangement of boundary has been made between the Keamari Anchorage and New Channel, so as to

and therefore a minus quantity.

January 1869 to November 1875.	Nett gain. January 1858 to November 1875.	Remarks.
Cubic feet. \$ 4,017,535 14,019,350	Cubic feet. 9,741,010 14,019,350	I.—The loss of about 4 millions, between January 1869 and November 1875, nearly all took place before the completion of the Breakwater, and seems mainly due to the shifting of material by the flood-tide during its diversion by that work.
10,001,815	23,760,360	
\$ 835,952 1,003,977 1,845,772 31,868	23,379,625 1,046,877 10,166,262 2,301,908	II.—About two-thirds of the dredging was at Deep Water Point, and one-third on the shoal patches off end of East Pier. The excavation was all at Deep Water Point.
2,045,665	36,894,672	
5,180,600 48,770	18,601,660 4,458,010	III.—The gain above low water is from the Keamari Sand Spit.
5,229,370	23,059,670	
\$ 8,976,110	\$ 9,332,757	
\$ 8,976,110	\$ 9,332,757	IV.—In reference to the rapid loss from 1869 to 1875, and the comparatively small amount of silting between 1858 and 1876, it may be mentioned, that from 1858 to 1863 a loss took place of about 2½ millions; 1863 to 1865 a gain of 1½ millions; 1865 to 1867 a gain of over 3 millions; and 1867 to 1869 a loss of 2½ millions. Of the further loss of nearly 9 millions, between 1869 and 1875, it will probably be fair to ascribe about 6 millions to the continuance of the shoaling previously felt, and 3 millions to material from "New Channel."
\$ 12,130,960 222,960	\$ 6,247,640 222,960	
\$ 11,908,000	\$ 6,024,680	
15,828,501 562,252 4,034,350	10,436,531 9,582,047 4,176,760	V.—The silting seems wholly due to material from the "New Channel." Dredging is about half of that done in 1875 at the junction "of the New Channel" with the Keamari Anchorage.
20,425,103	24,195,338	
9,170,925 137,719 9,000,000	6,638,183 8,440,461 9,000,000	VI. & VII.—The quantities shown in red are silting, which took place before the Chinna Creek scour was brought into action. VI.—"Flats" is that portion between the channel and Napier Mole. VII.—For "Within the channel limits," a width of 500 feet has been taken for comparison, to allow of future enlargement. The 9 millions shown as "Probable scour from flats," can be well accounted for, by the many diversions caused by change in the flow of the tide from Chinna Creek to the Notch.
18,308,644	24,078,644	
35,126,487	116,631,247	
15,978,126	35,613,603	
19,148,361	*81,017,644	* Enough to cover 310 acres, one fathom deep.

W. H. PRICE, M. Inst., C. E.,
Superintendent, Kurrachee Harbour Works

APPENDIX D.

FURTHER WORKS PROPOSED.

APPENDIX D.

KURRACHEE HARBOUR WORKS.

Further works proposed, with probable cost, from 1st April 1876.

Names of Works.	Probable cost.	Total probable cost.	Remarks.	Brief description with dimensions.	Probable effects.
<p>SANCTIONED WORKS IN PROGRESS.</p> <p>Bar dredging, completion for season of 1875-76.</p> <p>Making certain improvements to New Channel, protecting banks.</p>	<p>Rs. 22,850</p> <p>6,000</p>	<p>Rs. ...</p> <p>28,850</p>	<p>Allotment for these sanctioned in G. R. No. 925 of 15th May 1876.</p> <p>For 5 years.</p>	<p>Length 2,700 feet, breadth 500 feet, and depth 20 feet at low water, to be kept clear by dredging as accumulation takes place, pending execution of the two works next named. Includes also some further removal of patches of rock and boulders.</p>	<p>Clearance and maintenance of Entrance Channel to full dimensions.</p>
<p>TO PERFECT EXISTING WORKS.</p> <p>Dredging in Entrance Channel ...</p>	<p>2,14,000</p>	<p>...</p>	<p>Estimate submitted with No. 236 of 30th March 1876.</p>	<p>On a curve of 1,500' radius, for a length of 1,100 feet brought up to low water level. Width at top to be 40 feet. West side slope $1\frac{1}{2}$ to 1. The hearing to be of ordinary rubble-stone, faced and topped with large blocks, also 4 large beacons to mark this partly submerged work.</p>	<p>Prevention of injury to Entrance Channel and anchorage by eddies and shoaling from cross-rush of flood, also extension of anchorage space for 2 or 3 large vessels.</p>
<p>East Pier (Groyne) extension ...</p>	<p>98,875</p>	<p>...</p>	<p>Estimate with plan submitted with No. 164 of 12th March 1875.</p>	<p>Reduction of projection on west side of harbour, being a tongue of conglomerate rock (on clay), flanked and partly covered by sand and shingle. This diverts ebb from entrance, causes eddies in anchorage and danger to shipping; 1,739 lineal feet mean length, by 380 feet mean breadth, averaging $4\frac{1}{2}$ feet deep, comprising $2\frac{1}{2}$ acres of rock partly covered by shingle and $12\frac{1}{2}$ acres of sand covered with shingle. Holes to be drilled in rock by steam machinery from Barge on legs and exploded by damp Gun Cotton. Charging done by Native Divers, also the slinging of large pieces for lifting by Crane Barge.</p>	<p>To lead ebb-scour into Entrance Channel, and to improve anchorage by quieting tidal-rush and eddies, and by filling in deep rocky gut, so as to give berths for 2 or 3 large vessels.</p>
<p>Deep Water Point removal ...</p>	<p>2,14,333</p>	<p>...</p>	<p>Besides Rupees 23,338 for special plant estimated for below.</p>		

Acceleration of improvement of "New Channel" and ultimately (by giving free vent to the tide of the east backwater) that of the lower harbour and entrance by aid of Chinna Creek waters.

A

To provide additional anchorage accommodation for six Steamers of the largest class, such as H. M.'s Indian troop-ships. Also to aid scour in general improvement of the harbour.

B

Extension of anchorage space and aid to further enlargement by scour.

Remainder of work to be done by dredging, aided by scour, which will probably remove three-fourths of the softer material when the rock and surface shingle have been got away.

Dredging here and there where required, especially in hard and stiff material near head of Channel, also construction of stone groyne and pitching where required to control and direct scour, so as to bring about improvement to 9 feet depth within 5 years.

A

The improvement of Manora anchorage (A) and the dredging in East Channel (B) may be considered one work. The cut A was proposed by Captain Giles, I. N., in 1873.

A overlaps B by 420 feet, dredging the 20-foot channel left by B to 25 feet below low water.

The lowest half of A consists of soft sandstone rock too hard to be dredged, and must therefore be blasted, remainder sand and shingle will be dredged. This channel to be excavated to 25 feet below low water, 1,650 feet in length, 200 feet in bottom width, and side slopes 10 to 1, mean depth of cutting $3\frac{1}{2}$ feet. This gives $7\frac{1}{2}$ acres of deep anchorage, total area of dredging $10\frac{1}{2}$ acres. Six fixed moorings to be also provided along the cut A.

B

In this division (see Appendix C) improvement is steadily going on, to aid which dredging is proposed. Total length 4,880 feet by 200 feet in width at bottom, 20 feet below datum, and 400 feet width at 17 feet below low water, mean depth of dredging being $3\frac{1}{2}$ feet. This will join the 20' contour at Keamari anchorage to that of Manora. Area of dredging to 20 feet below low water $22\frac{1}{2}$ acres. Total area of dredging 44 acres.

Besides Rupees 35,000 for a small dredging vessel suited to the Upper Harbour, included in special plant estimated for below.

6,52,208

Estimate submitted with No. 355 of 20th April 1874.

See my No. 272 of 10th April 1876.

1,25,000

1,65,000

1,20,000

2,85,000

Auxiliary dredging and construction of training Groyne in the New Channel (see Appendix E for alternative arrangement).

TO PROVIDE FURTHER ACCOMMODATION.

A

Blasting and dredging a cut along the centre of the Manora anchorage, and providing six fixed moorings

B

Dredging in East Channel of lower Harbour.

Carried over

6,81,058

APPENDIX D.—concluded.

Names of Works.	Probable cost.	Total probable cost.	Remarks.	Brief description with dimensions.	Probable effects.
Brought forward	Rs. 2,85,000	Rs. 6,81,058			
TO PROVIDE FURTHER ACCOMMODATION—(concluded).					
B		...			B
Ship Pier at Keamari (see Appendix F).	2,91,550	...	Detailed plans, specification, and estimate submitted to the Commissioner in Sind by Mr. Hart with his No. 200 of 29th March 1875.	An iron screw-pile Ship Pier at Keamari, T shaped head 307' x 55', neck 55' wide and 234' long to shore abutment. Depth of water in front 22½ at low springs. Top 5' over high water. To have lines of rails connected with adjoining Sind Railway and adapted to carry steam travelling cranes, also a public road approach; 2 landing stairs, 12 mooring bollards, 10' lamp posts. Construction generally similar to the Calcutta Piers. For details see Appendix F.	Aid to shipping by facilities for loading and discharging goods, especially direct to or from up-country without intervention of lighters. It is believed that this work would return direct profit to Government. For details, see Appendix F.
Graving Dock at Manora	6,00,000	...	Frequently recommended and recently so by the Acting Master Attendant. Plans and estimates called for by the Commissioner in Sind, but not yet prepared, owing to pressure of other work.	Estimated approximately for a masonry dock, 330 feet long, 60 feet wide at gate, and 18 feet water on sill. The dock to be located at Manora in the vicinity of the Pier, Workshops and Store Buildings of the Harbour Works, all of which will be useful in connection with the Graving dock.	Encouragement to trade with the port by enabling vessels to be examined and repaired here, would be useful also for Government and Royal Navy vessels, except those of largest size. This would not probably at once or at a very early date pay interest on its cost, but would be a great aid to developing trade.
SUBSIDIARY WORKS.		11,76,550			
Plant and Tools.					
Plant transferred from former works. Estimated value deducted up to 31st March 1876, less Rs. 30,000 recoverable from Madras,—see Appendix A.	1,55,518	...	This will not of course be new outlay, having been already incurred, but it is included here as a fair charge against the further works.		

Special dredging vessel for "New Channel."	35,000	...	...
Special plant for Deep Water Point removal*.	23,338	...	...	*Steam drills, barge on legs, crane barge, and diving apparatus.
Total Plant	2,13,856	...	...
Harbour Surveys, 10 years	25,000	...	2,38,856	Record of changes produced by works and Meteorological Observations especially connected with navigation purposes.
Total	...	...	20,96,464	Includes the special establishment and boats' crews required for carrying out the periodical surveys of the harbour, also the tide gauge and anemometer observations. The period of 10 years is named, not as final, but as that within which it would seem likely that the present arrangement of frequent surveys will require to be continued.
DEDUCT.				
Estimated value of plant and tools after completion, one-fourth of Rs. 2,13,856.	...	...	53,464	
			20,43,000	
ADD.				
Establishment at 14 per cent. on nett expenditure.	...	...	2,86,020	
Grand Total	...	...	23,29,020	

W. H. PRICE, M. Inst., C. E.,
Superintendent, Kurrachee Harbour Works.

APPENDIX E.

NEW CHANNEL AND KEAMARI ANCHORAGE.

The proposal in Appendix D, as regards the "New Channel," is made with the special view of continuing and expediting its improvement, on the supposition that the restoration of the lost anchorage space at Keamari may be left to time, and that meanwhile it will be compensated for by other works now proposed.

Should it however be thought out of the question at present to undertake the full expenditure proposed in Appendix D, the present state of the "New Channel" might be tolerably maintained, injury to the Keamari anchorage stopped, and probably its improvement be early resumed through the action of scour, at small immediate cost, though at the same time with smaller and slower general results, by the following arrangement.

The rough stone weir at the Napier Mole Bridge might be lowered gradually, heaping up the stone at a convenient place for future use if necessary, and the "bunds" across the creeks in the East Backwater partially, or wholly removed.

This would of course give the flood greater access to the East Backwater, but in far greater degree would free the ebb and so would stop or greatly diminish the scour of material from the new "New Channel," and the conflict of ebb and flood at Keamari.

It is probable that this process might at first cause even some further shoaling at Keamari, through the fresh material set in motion on the flat between the Bridge and Channel, but this would be light and would probably soon clear away, after which not only might no further shoaling at Keamari be expected, but that anchorage would probably soon regain much of what it has lost since 1869, with prospect of still further improvement, not only there, but generally in the lower harbour and entrance, as the flow at the Bridge gained more freedom. Meanwhile of course the "New Channel" would miss the scour abstracted from it, and if the trade began to suffer from its shoaling more than was being gained by the improvement of the anchorage, the rough stone might be replaced partially, so as to raise the weir and throw more scour into the Channel.

This operation as regards the weir would cost very little, the mere lowering would be only a matter of a few hundred rupees, and it would be only in case that the weir again required to be raised, that those hundreds would mount to thousands.

Ten thousand rupees would probably in any case suffice as regards the weir, but in addition to this some expenditure would be required, for training and controlling the current so as to maintain the "New Channel" as nearly as possible in its present state, say Rs. 5,000 per annum, for at least five or six years.

The arrangement thus proposed may be thought worth a trial, as saving immediate outlay and favouring the early restoration of the Keamari Anchorage, though in the end I believe that the larger measure proposed in Appendix D would be found the more advantageous for the general interests of the harbour.

W. H. PRICE, M. Inst., C. E.,

Superintendent, Kurrachee Harbour Works.

APPENDIX F.

PROPOSED SHIP PIER AT KEAMARI.

(SELECTIONS FROM CORRESPONDENCE AND REPORTS).

Letter No. 1016, dated 23rd July 1874, from the Consulting Engineer to the Government of India, for Guaranteed Railways, Lahore, to the Secretary to the Government of India, Public Works Department, Calcutta.

I have the honor to forward copy of Agent's No. 1753, dated 13th June 1874, with original enclosures (to be returned), on the subject of a proposed Ship Pier at Kurrachee, which the Home Board of the Sind Punjab and Delhi Railway have proposed to Her Majesty's Secretary of State that they should construct from the unexpended balance of the Company's Capital.

2. The subject was referred for the opinion of the Commissioner to the Deputy Consulting Engineer in Sind, and for any remarks he might wish to add; copies of the Deputy Consulting Engineer in Sind's No. 874, dated 8th July 1874, and of enclosures, are forwarded.

3. There are two questions to consider—1st, whether the pier is necessary; and 2nd, whether the Sind Punjab and Delhi Railway Company should be allowed to construct it.

4. From the correspondence it will be seen that the Commissioner in Sind warmly supports such a scheme by whomever carried out, and considers it most easy of execution, and which cannot fail to be of the greatest value to the trade of Kurrachee.

5. The Deputy Consulting Engineer shows that on an average 6,800 tons of goods are landed for the Sind section of this Railway, and for the Indus Valley (State) Railway, which can be but a small portion of what is received and despatched by merchants and Government: the total tonnage of vessels entered and cleared at Kurrachee, excluding Native Craft, during 1872-73 was 146,500 tons.

6. The value of exports and imports of Kurrachee harbour has risen as high as 6½ millions sterling, and has been about 3½ millions during the last six years.

7. The opening of through rail communication between Lahore and Kurrachee will very probably increase the trade of this port, and the proposed pier will no doubt be a work of considerable value.

8. It is impossible to treat this part of the subject properly in this department. The description and cost of such a work, its effect on the harbour, the probable return on the capital to be expended, need all to be fully weighed; and on these points Government would obtain information directly.

9. The second enquiry touches the Sind Punjab and Delhi Railway Company more immediately. My opinion is that, even if agreeable to the shareholders, it would not be advisable to allow the Company to build and possess the deep-water pier at Kurrachee.

10. The prosperity of the Indus Valley (State) Railway alone is sufficient to bind the interest of Government equally with that of the Sind Punjab and Delhi Railway in improvements to the port at the terminus of the combined system; but Government have necessarily the largest stake in such a scheme, and considering the wants of merchants and of the public, it would be unwise to place in the hands of a Railway Company the best, if not the only, available site and machinery for dealing directly with large ship's cargoes.

11. The advantages to the Company may separate widely from the best interests of the public, and the management of business concerning the jetty would be but indifferently controlled either from Lahore or London.

12. A good plan of Kurrachee Harbour will be found attached to a Memoir on the Kurrachee Harbour Works by Mr. W. H. Price, M. L. C. E., showing the railway lines to and the frontage at Keamari.

No. 1935 R, dated—August 1874.

From—The Government of India, P. W. Dept.,

To—The Government of Bombay, P. W. Dept., (Railway).

I am directed to forward in original letter No. 1016, dated the 23rd July 1874, and enclosures, with reference to the construction of a Ship Pier at Keamari for the accommodation of large vessels visiting Kurrachee.

2. The Government of India agree with Colonel Pollard that the Railway Company are not the proper people to own this pier, but at the same time as its construction may be of great public advantage, the papers are forwarded for such action as His Excellency in Council may desire to take.

II.—C. W. Harbour Improvements.

Construction of a Ship Pier at Keamari.

LOCAL.

No. 124 C W—435 of 1874.

Bombay Castle, 2nd November 1874.

PUBLIC WORKS DEPARTMENT.

Resolution in the Railway Department, No. 1456, dated 21st October 1874.

Communicates copy of a letter from the Government of India on the subject of the proposed Ship Pier at Keamari; requests the Commissioner in Sind to take the matter into his consideration; and states that if a suitable design is submitted, with any feasible suggestion for obtaining the funds, either wholly or in part, by loan on the security of Pier dues, Government will take steps to bring the matter before the Government of India.

RESOLUTION.—To be communicated to the Superintending Engineer in Sind for information.

E. L. MARRYAT, Captain, R. E.,

Acting Under Secretary to Government.

KEAMARI NEW SHIP PIER.

Report by Mr. Hart, M. Inst., C. E.

Mr. Price in his letter to the Commissioner in Sind, dated 9th May 1874, para. 29, and following, indicated a design of Ship Pier similar to those at Calcutta, reaching out to the line of 20 feet contour. It was supposed that this limit would have led to a pier extending to not more than 300 feet from high water mark; but at this distance, according to the most recent survey, it was found that the 17 feet contour only is reached. By reference however to the survey of January 1871, it is observed that at the distance above specified, a depth of about 24 feet was then to be obtained; so that since then the anchorage has shallowed through a deposit of silt from the Chinna Creek and the New Channel.

It will eventually be necessary to dredge away all this deposit, if not removed otherwise; so as this operation cannot take place after the construction of the pier, it is proposed to include dredging in the design, and thus obtain a shorter pier with a depth in front, such that vessels of 22 feet draught can lie alongside at all times of tide without touching ground. This will merely restore the Harbour bed to what it was in 1871, before the Chinna Creek was closed, and to what it is expected it will be brought again. In order to permit of vessels manœuvring about the pier, dredging over a space of 800,000 square feet has been estimated for.

This is approximately shown by red lines on the general plan with section of the site. This work forms an item in the estimate, amounting to a little over Rs. 29,000.

The Calcutta piers are in a depth of water similar to this one, and therefore similar dimensions have been used for the piles; a rather stronger class of bracing has however been adopted. The piles being very long, with a view to reduce their number, a rather larger span of girder has been designed than at Calcutta; as also concrete and asphalt for a platform flooring has been adopted. The transverse strength of the girders is also greater. In the Calcutta piers the platform is wooden planking, this is considered unsafe in the matter of fire; but if used, a saving of Rs. 6,000 might be made. Of course, it would not be either so durable, or so strong, as the construction proposed, viz., buckled plates and concrete. A construction in which the cross girders are placed between instead of on top of the main girders, has been adopted, as tending to increased strength, as well as reducing the surface of iron exposed, and thus requiring painting.

The girders are calculated to sustain with a limiting stress of 4 tons per square inch, the following load in per square foot:—

		Per square foot.	Per girder.
Concrete $4\frac{1}{2}$ " at 140 lbs. per cubic foot	...	... .023 tons	= 2.48 tons.
Buckled plates and girders	...	... .009 tons	= 0.93 "
Crowd of people, 112 lbs. per square foot	...	... .05 tons	= 5.40 "
			<hr/> 8.81

This requires a flange area of about 5" in the cross girders, and 11" in the main girders.

A crowd of people produces somewhat greater stress on the structure than a line of loaded wagons.

Taking the length of pile unbraced as 30 feet Stoney gives 7.3 tons per square inch as the breaking weight, and the weight on the piles of the structure as designed is not within 6 tons of the amount.

The timber fenders will be a constant source of expense in this harbour, and will, it is expected, have to be constantly replaced, unless saturation of the timber with Ransome's patent stone solution will protect them.* Coppering, which is found to preserve ordinary wooden pile structures, is inadmissible here, because of the galvanic action between it and iron, and because in the exposed parts the copper skin will not stand the rubbing of ships; the fender pieces are therefore designed so that they can be readily changed.

The rates for iron work are now so very uncertain that no reliable estimate can be framed. Rates adopted in the estimate are however based on the prices given by Messrs. Nicoll's Agent in Bombay, to which have been added the freight charges as mentioned by Mr. Ormiston in his Bombay pier estimate.

		English price.	Freight.	Total.
Thus :—Cast-iron	...	... 110	+ 35	= 145
		Say Rs. 150 per ton.		
Iron girders	...	... 180	+ 35	= 215

The other items of iron work in like proportion.

* Note by Mr. Price.—Enquiry in England at Mr. Hart's request makes this seem out of the question.

To this is added a rate for erecting, &c., of Rs. 40, which would bring up the rates to 190 for cast-iron, and 255 for wrought-iron. Forgings and bolts are at an higher rate, amounting to 275 when fixed.

The simplest way of finding what the market rates are for such a structure is to submit the plans to Contractors, to tender for the material, as much will depend on the economy of the design, whether high or low rates are adopted, and this point has been kept steadily in view throughout the drawings.

Regarding the probable financial position of the work, a very clear result cannot well be arrived at. The question is complicated with that of land carriage and the possibility of ships declining to make use of the pier; which, combined with the impossibility of affording pier accommodation to all vessels at all times, makes the problem one of intricacy. If the pier could accommodate the whole trade of the port, and if all vessels could be forced alongside, which powers have been taken at Calcutta, then, given the cost of lighterage per ton, it could easily be calculated what the pier might earn.

Thus it appears from a statement, kindly prepared by the Collector of Customs, that the average tonnage for the last five years entered and cleared at the port has been (exclusive of Mail Steamers) 74,000 tons, and if Re. 1 per ton be assumed to be the lighterage charges on this tonnage, we have Rs. 74,000 as the limit to the pier.

If further 30 per cent. be deducted for working expenses, there would remain over Rs. 50,000 to meet the interest on a pier. Thus warranting an expenditure of five lakhs on a pier.

The problem is, however, whether a pier costing three lakhs will pay or not.

It is impossible to procure the returns of the general public, but it appears that for the two departments most interested in a pier at Keamari, viz., the Commissariat and Railway, the average amount of disbursements on account of landing charges are Rs. 14,500, which is as nearly as possible the interest required to meet the expenditure of Capital on the pier as designed.

It is very doubtful if the Native trade would benefit much by the pier,* for there is a difference of 8 annas to Re. 1 in the cart hire between, from Keamari and from the Native Jetty, to Kurrachee; but there would no doubt be some general public trade, which would at least cover the cost of working expenses.

A rather important consideration however presents itself in favor of a new pier, which is, that there are three wooden piers now in existence, the life of which cannot be very long. Two of these belong to Government, of which one has been condemned, while the other is not very much better. These, which cost at least 2½ lakhs of Rupees, would be replaced by the much more convenient and permanent iron one now proposed, and on that ground alone, it would be to the interest of Government to erect it at once before the re-construction of the existing piers become more emergent.

The Railway Company, in consideration of the advantages offered to them, and the saving of Capital in avoiding a renewal of their pier, might also be asked to contribute towards the Capital required, on which understanding no further case for the new pier need be made.

The Collector of Customs may possibly be inclined to propose a landing fee for passengers, in which case a considerable addition to the revenue might accrue.

In estimating the cost of this pier, it is to be borne in view that about Rs. 30,000 are set down for dredging, which, by right, forms part of the necessary improvements of the Keamari anchorage.†

Statements of tonnage and charges received from the Commissariat and Railway Company, and also copy of a letter from the Chamber of Commerce accompany.‡

Manora, }
29th March 1875. }

J. HART, M. Inst., C. E.,
Acting Superintendent, Kurrachee Harbour Works.

Letter No. 1016, dated 11th April 1875, from Colonel Sir W. L. Merewether, K. C. S. I. and C. B., Commissioner in Sind, to His Excellency the Honorable Sir Phillip Edmond Wodehouse, K. C. B., Governor and President in Council, Bombay.

I have the honor to submit herewith plans and estimates for a Ship Pier at Keamari for the direct landing and shipping of goods coming to and leaving the port of Kurrachee.

* *Note by Mr. Price.*—I quite agree. The pier would be mainly for through traffic, and would not supersede the jetty for local trade.

† *Note by Mr. Price.*—This may not all now be required, but owing to depreciation in exchange, it would not be advisable to reduce the estimate.

‡ *Note.*—These accompaniments are not printed here.

2. The estimates have been very carefully prepared by Mr. I. H. E. Hart, C. E., Superintendent, Kurrachee Harbour Works, and the plan is the one approved of, after consultation with Mr. Hart, as being sufficient for the present, and at the same time admitting expansion hereafter, if found necessary. The site is the best in all respects, and was likewise decided upon after full discussion.

3. Such a pier is greatly required at Kurrachee. At present all goods and passengers have to be conveyed between Steamers and Shipping to the shore by means of barges or boats. The port of Kurrachee is admirably suited for a shipping pier being thoroughly protected, and the water still all the year round.

4. The Punjab and Sind Railway has a branch line down to Keamari which would be brought into connection with the pier, and when the link between Kotri and Multan is completed, warehouses also being established at Keamari, the traffic must be very largely increased, all of which would pass over this pier.

5. The question about cranes was lately mooted by me. Having, during my visit to Calcutta, through the kindness of the Honorable the Lieutenant-Governor and the Chairman of the Port Trust, had an opportunity of going thoroughly over the pier there, it was pointed out to me among other things that steam cranes were at first used, but on their being found not to answer well, hydraulic machinery was introduced, and the steam cranes dispensed with as they wore out. However I quite agree with Mr. Hart, that this matter may be allowed to stand over. The Honorable Mr. Schalch was good enough to cause me to be furnished with all papers and accounts relating to the Calcutta piers, and these have been handed over to Mr. Hart.

6. Of the financial success of such a scheme there can be little doubt. The disbursements by the Commissariat for seven years (omitting Abyssinian expenditure as unusual) give an average of nearly Rs. 8,210 per annum, on a yearly average of 3,800 tons of goods and 20,619 hogsheads of malt liquor. The railway payments for landing stores at Keamari for ten years give an annual average of Rs. 5,173, on average tonnage of 5,653. I have not the papers by me to show the nature of the abovementioned goods; but supposing the railway material to have been iron, and taking the Bombay Port Trust rates—8 annas a ton—the return on this item alone would be Rs. 2,826-8-0 per annum. On malt liquor for the Commissariat Rs. 5,154-12, and putting the goods at 8 annas a ton, Rs. 1,900 more.

7. Taking the Customs Returns, the average tonnage of Ships and Steamers, not including Mail Steamers, entered and cleared at Kurrachee during the past five years, is, omitting fractions, 53,135 tons.* Calculating the rate per ton

* Excluding ballast.

to be paid on this at 8 annas, there would be, taken annually a sum of Rs. 26,567-8, or nearly 9 per cent. on the outlay—3 lakhs. The whole of this shipping and steam tonnage may be expected to pass over the pier, and would probably pay higher rates than that above quoted. There is besides the certainty, that may well be depended on, of the trade of the port steadily increasing year by year, now the success of the harbour improvements has been proved, and is becoming more widely known. The increase in 1873-74 is very marked. Some of this is due to the import of railway material and larger export of wheat after removal of the duty. The former will continue until the railway is completed, and then there will be greatly increased traffic. The latter, it is hoped, will be steadily maintained from a country growing so much wheat as Sind does.

8. I would not like to see any landing fee imposed on passengers, they should be free to come and go.

9. Any private Company would be glad to carry out this scheme, but it should, I think be taken up by Government, and by Government alone; not even including the Sind and Punjab Railway Company, as suggested by Mr. Hart. The plan shows the Company could not use their own pier for shipping purposes, and they will be glad to frequent this in preference to making a new one for themselves. It is much better that Government should retain works on the foreshore in their own hands as much as possible.

APPENDIX G.

Questions put by Colonel H. St. C. Wilkins, R. E., regarding the scheme of the Kurrachee Harbour Works, and their replies by J. H. E. Hart, Esq., M. Inst., C. E.

I. Are you in favour of any further improvements of the harbour by the extension of existing artificial works, or by the addition of new ones?

I am in favour of further improvements of the Kurrachee Harbour by both extension of existing works and by the addition of new ones.

II. What would be the probable effect of such extension, or additional works?

The effect of extensions of existing works would be to strengthen in some instances the effects of such works, as in the case of the extension of East Pier and of the New Channel Groyne; in another instance to palliate evils arising from the incomplete state of the works, and to favour the natural forces at work in the maintenance of the harbour entrance. I refer to the completion of the removal of Deep Water Point. Such new works as I could propose would be more for the increase of facilities for trade, as for example Ship piers and jetties.

III. Could the same results be effected by dredging?

The effects of extensions and additions—they being preventive measures—could not in every instance be obtained by dredging. Dredging would be a recurring charge to remove silting, depending on the unfinished state of the works; but it can only remove an evil after it has been called into existence and become tangible.

IV. What are the advantages or disadvantages of each method?

The improvements obtained through the action of natural forces are permanent and progressive, and the only recurring charge is the interest of the money sunk in them. The constant use of dredging plant in the fairways of the harbour is an evil in itself of serious importance.

V. Will you compare the approximate cost by both methods?

I have not at my command just now data on which to frame comparisons of cost and anything of the sort which I might give you would to a great extent be given second-hand from Mr. Price.

VI. What is the influence of the Keamari Groyne and East Pier upon the harbour?

The Keamari Groyne and East Pier protect the harbour from the cross-set of the flood-tide, keeping back such silt as might be travelling along the Clifton shore with it.

The protection afforded by these works renders the anchorages more satisfactory and secure, while their use as training groynes is to force the tidal currents more fairly up and down the harbour.

VII. What influence has the Breakwater upon the harbour?

The influence of the Breakwater on the harbour is to protect the entrance and still the outer harbour, thus preventing the formation of a Bar by the stroke of the monsoon wave in shallow water, and adding to the anchorage of the port. The port is made more easy of access in heavy weather through the shelter afforded to the entrance channel by the work.

The theoretical effects of the work are set forth so strongly in Mr. Parkes' reports and the Harbour Works correspondence, that it is needless to enter further into an explanation of its utility, and it will suffice to say that the theoretical anticipations have been very fairly borne out by the practical results obtained by its construction.

VIII. Do you approve the structural arrangements of the Breakwater, and consider it likely to remain stable?

I approve generally of the structure of the Breakwater, although if called on to design a similar structure, I should probably advocate the use of larger blocks, and endeavour to avoid a central joint. I consider the work as a whole likely to prove stable, but at times of unusual storms we must be prepared to expect it to suffer partial or local injury.

IX. Would you propose any further treatment of the Chinna Creek?

I would not advocate any further treatment of the Chinna Creek just yet; hereafter, if found necessary, I would recommend the adoption of the measures referred to in my reply to Question XV.

X. What would be the probable effect upon the harbour of closing the notch at Napier Mole Bridge, leaving the Chinna Creek closed as at present?

If the notch were closed, the new channel would immediately silt up. After a time probably silt would cease to be deposited in the anchorages, and a possible relative improvement might at first have taken place in the entrance channel, because of the diminution of silt in the ebb-waters; but a reduction having been caused in the ebb and flood volumes, we might cease to look for any prospective improvement by natural scour in the channel.

XI. Would any injurious results be likely to follow the closing of the notch irrespective of the Harbour Works?

If the weir be reduced to half-tide level, it is possible that the daily change of water would be sufficient to keep the pond sweet; but at times of rain the flushing of the Town and Camp drains would be likely to cause a nuisance.

XII. Could any such injurious results be obviated in any way?

Except by the introduction of sluices, or by the reclamation of the space between Napier Mole bridge and the Creek bund, I do not see any way of obviating the injurious effects alluded to.

XIII. What would be the approximate cost of re-opening the Chinna Creek?

I could not give, with any attempt at accuracy, the probable cost of re-opening the Chinna Creek. I should say 3 to 4 lakhs of Rupees.

XIV. Could you give the approximate cost of removing and re-building so much of the Napier Mole Bridge as would be required to provide the necessary waterway at the Chinna Creek mouth?

It would take up more time than I could now spare to prepare such an estimate, and I think such information could be best obtained from Mr. Price who has all the necessary data at command.

XV. Understanding that the scour from the Chinna Creek has partially, but seriously, damaged the Keamari anchorage, and that at Manora also, could this injurious action be arrested by any means short of closing the notch at Napier Mole Bridge?

I think that the damage to the anchorages from the silt brought down by the Chinna Creek scour might be mitigated, if not at once arrested, by the lowering of the weir at the Napier Mole Bridge, and the judicious breaching of the training bunds inside.

XVI. Supposing the Napier Mole notch closed, and the Chinna Creek mouth opened, what would be the probable effect upon the new Native Jetty channel?

Nearly the same result as that mentioned in Question X would follow the closing of the notch and opening the Chinna Creek bund.

XVII. Supposing, as in the previous question, what would be the probable effect upon the harbour?

See latter part of Answer X for the anticipated effect of closing the notch and opening Chinna Creek.

XVIII. What object was gained by placing the Native Jetty in its present position?

The Native Jetty was built where it is, apparently, because the Native traders had selected that point on the Chinna Creek as most convenient. It is close to the Native Town, and was probably at one time the nearest piece of firm ground available.

XIX. Why should not the Native landing-place have been located at Keamari?

Water-carriage being cheaper than cartage, it is to the advantage of trade that the jetty should be at as little distance from the town as possible. The charge on the trade by a long cart mileage would be considerable, and I believe if there were no Native Jetty as it is now, and if wharfage were provided at Keamari, that all the smaller Native Boats would discharge on the nearest convenient "hard" to the town in preference to using a jetty at Keamari with its attendant inconveniences. Keamari piers can expect only to draw the Commissariat, Railway, and through traffic to themselves.

XX. At what date do you anticipate—if you anticipate it at all—the establishment of what is called the harbour regimen?

It is hard to say when the regimen of the harbour under its present design will be attained. Much will depend on *what* may be done to assist the natural action, and *when* it will be done.

Ten years would probably see a regimen established, if no assistance be given, but there will probably be more or less trivial changes for many many years to come.

XXI. Do you hold the opinion the Chinna Creek scour will ever be able to scour a Ship channel through the Bar, or even to keep open a dredged channel?

I fear I do not understand this question. If by "Bar" and "Dredged Channel" is meant that at the harbour entrance, I have to state that in my opinion the Chinna Creek scour would, of itself alone, effect nothing; but the Chinna Creek waters would be doubtless a great help to the other backwaters of the harbour, in keeping the dredged channel open, if allowed freely to ebb and flow with them.

XXII. Do you think it probable the Chinna Creek scouring process will cease its injurious effects upon the anchorages before it has obliterated and ruined them?

Yes, certainly, and I think that recent observations prove that injurious action is already on the decrease.

XXIII. Are you of opinion the time will arrive when dredging may be dispensed with altogether?

I do not think that dredging can ever be quite dispensed with, but the amounts required will probably be very slight when the harbour bed has approximately attained its regimen.

XXIV. Are you in favour of removing Deep Water Point?

I am in favour of removing Deep Water Point, and am only doubtful whether Mr. Parkes' proposal goes far enough in the matter.

XXV. If the harbour is not yet capable of accommodating Ships of the largest size, and it should be proposed—as it has been—to dredge an anchorage for such vessels, do you consider it would be wise to remove Deep Water Point—a natural work—which gives deep water in the channel, and by so straightening the channel, risk the loss of what nature has given. Do you think it expedient to remove Deep Water Point and risk the natural depth of water at a cost of from £ 20,000 to £ 30,000, just to save some trouble to Pilots and Ships' crews, and to gain—which is uncertain—an increased scour over the Bar?

I do not think the removal of Deep Water Point would produce any injurious effect on the deep water of the harbour; on the contrary, if the bed did fill up somewhat, so as to equalise the sectional area, it would be more of an advantage than otherwise.

I have never heard any complaints of trouble caused to Pilots and Ships' crews. I have heard more of the danger of Deep Water Point as being a knob of rock projecting into the anchorage and fairway, and producing uncertain and strong currents which prevent Ships steering properly when under way, or swinging safely when at anchor in its neighbourhood.

XXVI. Can you give any information bearing on the financial aspects of the whole scheme ?

I regret to say that I cannot afford any useful information, or observations on the financial bearings of the whole scheme.

I. H. E. HART.

APPENDIX H.

LIEUTENANT G. C. PARKER, I. N.

21st April 1876.

Question 1.—How long have you been acquainted with the port ?

Answer.—I have been acquainted with the port since 1854, and have been a resident at Manora, as Acting Master Attendant, for the last 2 years and 9 months.

Q. 2.—Are you aware of the fact that the anchorage areas are decreasing ?

A.—Yes; the anchorage areas are decreasing at Keamari and in West Channel.

Q. 3.—How long has this injurious effect been in force ?

A.—At Keamari since 1871, in West Channel long before.

Q. 4.—How many anchorages are there ?

A.—Four, namely—1st.—Keamari,
2nd.—Manora,
3rd.—West Channel,
4th.—Deep Water Point.

1st.—The Keamari anchorage has, since the closing of Chinna Creek in 1871, decreased by silt, caused by the ebb-tide continuing to run out after the flood has made, the effect being to deposit silt at the anchorage at Keamari. It has now swinging moorings for 8 ships, with a draught of from 16 to 20 feet. In 1868, there was space for 14 swinging moorings, but before the Harbour Works commenced, it had only 8 moorings.

2nd.—Manora anchorage is about the same as in 1868, if anything, it has improved and is still improving; the anchorage is better than it was in 1858. It has 5 swinging moorings for vessels of a draught from 17 to 21 feet.

3rd.—West Channel anchorage is fast disappearing; there was formerly space for 6 swinging moorings, we have now only 3 fixed moorings in the centre of the gut for large vessels, with a draught of from 21 to 24 feet. The decrease in this anchorage was anticipated, as a result of the scour being directed to the east side of the harbour. The West Channel began to silt up soon after the Napier Mole was built, and before the harbour improvements commenced.

4th.—Deep Water Point anchorage is increasing in width. It has two swinging moorings for large vessels, with a draught of 22 feet, and one swinging mooring for a vessel with a draught of 21 feet.

Q. 5.—How many vessels can be accommodated in the harbour at present ?

A.—About 20 ships, including 8 of the largest class, with a draught of 24 feet at fixed moorings, the rest of the size that now visit the port with a draught of 18, 19, 20, 21 and 22 feet, from 700 to 2,000 tons, at swinging moorings.

Q. 6.—Mr. Price, in his Memoir of the 8th January 1874, page 26, para. 73, states that the capacity of the harbour anchorage as respects vessels of moderate size has been nearly trebled in the ratio of 55 ships to 20. Is that statement correct ?

A.—I could not put 55 vessels of moderate size in the harbour at present; 20 of the size that now visit the port is about the number I could berth, in consequence of the silting that has taken place at Keamari.

Mr. Price's statement was, I suppose, intended to apply to the state of the anchorage when at its best, as improved up to 1871, and was made, I am informed, on the authority of Captain Giles' opinion, as quoted in Mr. Parkes' printed report dated 10th August 1868, page 4.

Q. 7.—Are you acquainted with the general scheme for improving the harbour ?

A.—Yes.

Q. 8.—Do you approve of the scouring project ?

A.—Yes, I approve of the scheme. The scour was successful as regards the harbour up to 1871, but since then, the material scoured out from the boat channel above (to the benefit no doubt of that channel) has done injury below. It requires more time before I can give a decided opinion as to the effect of the scour; the deposit of silt is decreasing in quantity, and there is a favourable action now taking place at the lower moorings at Keamari, as will be at once seen by the soundings just taken.

Q. 9.—What has been the effect of the scour project upon the channel leading up to the Keamari anchorage ?

A.—There is a favourable action taking place. We have now a 17-foot contour between the Keamari and Manora anchorage, and further improvement is expected from scour.

Q. 10.—Is there more room in the harbour now for ships than there was in 1838 ?

A.—From Lieutenant Carless' chart of 1838, there appears not so much room now ; but at that time, there was only 14 feet in the Entrance Channel, now, however, we have a sheltered channel with 20 feet at low water spring-tides.

I have not however particularly examined the chart of 1838.

(Mr. Price has since informed me, that from an examination of Carless' chart, that there is slightly more room now than in 1838.)

Q. 11.—What was the effect of the construction of the Napier Mole ?

A.—I believe deterioration has taken place ever since the Napier Mole was constructed, and before the present improvements commenced.

Q. 12.—What was the effect of the Groyne ?

A.—The Groyne improved the scour. It confined the water in a smaller space, and directed it on to the Entrance Channel ; but the scour in the channel has not been so effective as was anticipated, on account of the projection called " Deep Water Point ;" this tends to divert the ebb-tides to the eastward of the Entrance Channel.

Q. 13.—Do you think the prolongation of the East Pier a desirable work ?

A.—Yes, I do consider it most important that it should be extended in a curved direction. It would improve the direction of the flood-tide and prevent the silt which now extends across the channel, and which is caused by the flood-tide round the Groyne deflected by the Breakwater, meeting the last of the ebb. It would also give extra mooring-space for two or three large vessels.

Q. 14.—As you say the Breakwater deflects the flood-tide, would you desire it to be lengthened ?

A.—No, certainly not.

Q. 15.—What is your opinion respecting the influence on the Channels and Anchorages of the Harbour of Deep Water Point ?

A.—Deep Water Point is a rocky ridge, and extends far out into the harbour and diverts the tides, causing strong eddies and currents in its vicinity, and has the effect of making a deep hole of 9 or 10 fathoms right in the centre of the harbour. Moorings for ships cannot be placed anywhere near, and a valuable space for anchorage is thereby lost. It is also dangerous to a ship entering or leaving port during a strong ebb-tide, the violent eddies causing her to steer badly. It also diverts the ebb-tide to the eastward, so that there is little or no scour on the Entrance Channel.

Q. 16.—This rocky ridge would have to be excavated below low water ?

A.—Yes, about 20 feet below datum ; now there is 8 or 9 feet at the outer end at high water, and then it suddenly deepens to 10 fathoms.

Q. 17.—This point clearly causes a great depth of water in the Channel. Are you sure you would not lose this depth by its removal ?

A.—We should probably lose the hole and deepest water, which would I think be an advantage to the harbour, as we should get rid of the strong eddies and currents that it causes.

Q. 18.—You understand, of course, that all improvements to this harbour are costly ; to remove a promontory of rock at a depth of say 20 feet below datum must be a costly work ?

A.—Of course it would be a costly work ; but it is of great importance that a portion of it should be removed.

Q. 19.—Have you seen Mr. Price's proposals of the 10th April, amounting in total to Rs. 9,96,093.

A.—Yes, I have, a portion only of that large total is absolutely necessary in my opinion—

No. 1.—Dredging on Entrance Channel is most necessary.

No. 2.—I also strongly recommend extension of East Pier.

No. 3.—A portion of Deep Water Point I also recommend to be removed.

No. 4.—I do not recommend the deepening the centre of the Manora Anchorage, as the bottom consists of hard sand-stone, and there is no certainty about it.

No. 5.—Dredging a cut between the Keamari and Manora anchorage, I strongly recommend, as it has a tendency to deepen now, and would be likely to increase with the assistance of dredging ; this would compensate for the temporary loss at the Keamari anchorage.

No. 6.—I decline to recommend the deepening of the New Channel. I am inclined to think it would injure the Deep Water Anchorage.

Q. 20.—What was the advantage to be gained by forming a Native Jetty at its present position ?

A.—It is nearer the Town, also the space at Keamari was taken up by Government for a Commissariat Pier, &c.

Q. 21.—Was there any reason why the Native landing-place should not have been erected at Keamari ?

A.—I know of no reason excepting the distance it would have been from the Town, and also there being no available space for a Native Jetty.

Q. 22.—By the scouring project, has the harbour improved or deteriorated up to the present time ?

A.—It improved up to 1871, but since then it has deteriorated up to the present time ; but we are looking forward to improvement from scour. On the whole I think there is improvement.

Q. 23.—Supposing that the harbour does not improve in a few years' time, what then ?

A.—I would suggest the bunds under the Bridge be opened, and so allow a larger flow of water, so as to allow the ebb-tide to escape before the flood makes ; this would I think at once relieve the silting at Keamari.

Q. 24.—What would be the effect of this course upon the Native Jetty and New Channel ?

A.—It would delay the deepening of the boat channel, and might tend to decrease its present depth for a time, but the larger flow of water would have a beneficial effect on the harbour in general.

Q. 25.—What would be the effect of opening the Chinna Creek ?

A.—The effect of opening the Chinna Creek would be to greatly reduce the force of the ebb-tide in the harbour, put a stop to further deepening the Boat Channel, and prevent further deterioration to the Keamari anchorage. I would not, however, recommend this being done for some time to come. I would wait to see the effects of scour as predicted by the Harbour Engineers.

Q. 26.—What would be the effect of closing the Notch and opening the Chinna Creek ?

A.—The scour would be shut off, and the deterioration would remain as it is now, or most likely increase.

Q. 27.—What is the cause of the depression forming the Anchorage at Keamari ?

A.—I do not know how it has been formed.

Q. 28.—But it was formed originally before the Chinna Creek was allowed to flow through the Napier Bridge ?

A.—I cannot tell whether there was any deterioration in the Keamari anchorage ; but the West Channel began to silt from the time the Napier Mole was built. From Grievess' chart of 1856, the Keamari anchorage is less than Carless shows in his chart of 1838 ; some decrease must therefore have taken place after the Napier Mole was built.

Q. 29.—What have you gained in improvement to the harbour generally by the construction of the work ?

A.—We have gained a sheltered and deep water entrance, with 20 feet at low water spring-tides, in lieu of an exposed entrance with only 14 feet of water on the Bar (I remember when entering the harbour in the H. C. Steamer *Queen* in 1854, bumping heavily, the vessel only drawing 16 feet at the time) ; also some improvement in anchorage space, a boat channel to the Native Jetty, and we hope for further improvements in anchorage space ; also in directing the tides and currents.

Q. 30.—Does the harbour afford complete shelter to ships at all seasons ?

A.—Yes, it affords complete shelter.

Q. 31.—Do you want to offer any remarks ?

A.—I wish to say that I have every confidence in the scheme as it stands, and consider it only requires time to prove successful ; with the extension of East Pier, and removal of Deep Water Point, as well as dredging the Keamari and Manora Channels ; I would also remark that it is absolutely necessary that more deep water anchorage should be provided by dredging.

I would most strongly recommend that the space between Manora and the Keamari anchorage be dredged to a depth of 20 feet, and about 400 feet in width ; there is now a favourable action taking place, and dredging will greatly assist ; this work should be commenced with at once to compensate for the temporary loss at Keamari anchorage.

G. C. PARKER, Lieutenant, I. N.,

Acting Master Attendant.

APPENDIX J.

KRAMARI MOORINGS.

April 1876. Sept. 1874. Jan. 1871.			April 1876. Sept. 1874. Jan. 1871.			April 1876. Sept. 1874. Jan. 1871.			April 1876. Sept. 1874.		April 1876. Sept. 1874.	
Loss	Loss		Loss	Loss		Gain	Loss					
on	on		on	on		on	on					
1871.	1871.		1874.	1871.		1874.	1871.					
Improved.												
300' ...	4 3½	Gain.	5			10 8			8 7		13½ 11	
	4½ 6		5½ 4			11 11	Gain.		10 9		15 12	
	6 12		6½ 7½			12 12½			12 12		16 14	
	6½ 14½		7½ 8½			13½ 14			14½ 18		16½ 15½	
	7 18½		10½ 9½			16 15			15 15		17½ 17	
200' ...	7 18½ 19½	Loss.	13½ 11			17½ 16½ 20½			16 16½		19 18	
	8 23 23		16½ 13½ 24½			18 18 23½			18 18½		21 19	
	16 24 24½		19½ 16½ 24½			20 18½ 24½			18 19		23 20	
	18 24½ 26		21½ 18½ 25½			20½ 19½ 24½	Loss.		19 20		23 21	
	23 24 26		23 20½ 25½			21 20 24½			20 21		24 22	
100' ...	23 23½ 26½	Gain.	24 21½ 25½			22 21 24½			21 22		25 23	
	23 23 26		24½ 22½ 25½			23½ 23 24½			23 23		24 23	
	21½ 22½ 25½		25 23 24½			24 22 24½			24 23		24½ 22½	
	23 22 25½		24½ 23 24½			24 22½ 24½			25 23½		24½ 22	
	23 22 25		25 23½ 24½			24 23½ 25½			24½ 24		24½ 22	
	No. 1 21½ 21 24½	Gain.	No. 2 23½ 21 23½			No. 3 23 23 24½	Gain.		No. 4 23½ 23½		No. 5 23½ 21	
	19 19 23		23½ 21½ 22½			22½ 23 23½			23 23½		24 21	
	18½ 18½ 22½		22½ 21½ 22½			22 22 23½			23 23½		23½ 21	
	16½ 17 20½		21½ 23 22½			23 23 23½			22½ 22		23 20½	
	14½ 16 20½		19½ 21½ 21½			21 22 22½			22 21½		22 20	
	13 16 19½		18½ 20 20½			20 21 22½			21 21		22 19½	
100' ...	10 16 18½	Loss.	16 18½ 20½			18 20 21½			20½ 20½		21 19	
	9 13 16½		14½ 16½ 19½			16 18½ 20½			20 20		20½ 18½	
	10 11 14½		12½ 15 18½			12 18 20½			18½ 19½		20 20	
	9 9		11½ 13 17½			10 16 19½	Loss.		18 19		19½ 18	
	8 8		11½ 10			9 15 18½			17 18		19 17	
200' ...	8 6	Loss.	9½ 7			8 14			15 17½		18½ 17	
	7 4½		8½ 7			6 13			15 17		18 16	
	7 4		8½ 6½			7 12			13½ 16½		17½ 15½	
	7½ 4		8½ 6			7 11			13 16		17 15	
	7 6		9 6			7 10½			12½ 15		16 14	
300' ...												

APPENDIX J—(continued).

KEAMARI MOORINGS.

April Sept. 1876. 1874.		April Sept. 1876. 1874.		April Sept. 1876. 1874.		April Sept. 1876. 1874.		April Sept. 1876. 1874.					
Improved.		Improved.		Improved.		Improved.		Improved.					
14 12½		13 12		11 19		11 10		11 11					
15½ 13½		14 13		11½ 11½		11½ 11		12 10½					
17 14½		16 14½		12 12½		11½ 11½		12 11½					
18½ 15½		16½ 15½		13 13		12 13		13 13					
20 17½		18 17½		14 18½		14 14		14 13					
.....						
21½ 19½		19 18½		15 15		14½ 15		15 13½					
22½ 20		20 19		16½ 15½		16 16		15 14					
22½ 21½		19½ 19½		17 16½		17 17		15 14½					
22½ 21½		20 20½		18 17½		18 17		16 15½					
24 22½		21 20½		19 18		18 18		17 16					
.....						
24 22½		22 21		19½ 18½		19 18		17 16½					
23½ 22½		22½ 21		20 19		19½ 18		18 17½					
23½ 22½		23 21		21 19½		19 18		18 17					
23½ 22½		22½ 22½		21½ 20½		20 18½		18 17					
23½ 22½		22 21½		22 21½		21 19½		19 18					
No. 6 23½ 22½	Gain.	No. 7 21 21	Gain.	No. 8 22 20½	Gain.	No. 9 22 19	Gain.	No. 10 20 18					
23½ 21½		21½ 20½		22 20½		20 19		20 19					
22 21½		21 20½		21½ 20		21 19		20 19					
21½ 20½		21 20		21 19½		20½ 19		20 19					
21½ 20½		21 20		21 19½		20½ 18		20 18½					
20½ 20½		21 19½		21 19		20½ 18		20 18½					
.....						
20½ 19½				21 19½				20½ 18½		19½ 17½		19½ 18	
20½ 19½		20 19		21 18½		19 17		19½ 18					
20 19		20 18½		20½ 18½		18½ 17		18½ 17½					
19½ 18½		20 18½		20 18		18 16½		18½ 17					
19½ 18		19½ 18		19½ 17		17 16		18 17					
.....						
19½ 17½		19 17½		19 15½		16½ 15½		17½ 16					
18½ 17		18½ 17		18 15½		16 15		16½ 15½					
18½ 16½		18 16½		18 15½		15½ 14		15½ 14					
17½ 16		17 16		17 15		15 13½		14½ 13					
16½ 15½		16½ 15½		16½ 14½		14 13½		13½ 12					
.....						

APPENDIX J.

KEAMARI MOORINGS.

April 1876. Sept. 1874. Jan. 1871.			April 1876. Sept. 1874. Jan. 1871.			April 1876. Sept. 1874. Jan. 1871.			April 1876. Sept. 1874.		April 1876. Sept. 1874.		
Loss on 1871.			Loss on 1871.			Gain on 1871.							
												Improved.	
800' ...	4 3½		Gain.	5		10 8		Gain.	8 7		13½ 11		
	4½ 6			5½ 4		11 11			10 9		15 12		
	6 12			6½ 7½		12 12½			12 12		16 14		
	6½ 14½			7½ 8½		13½ 14			14½ 18		16½ 15½		
	7 18½			10½ 9½		16 15			15 15		17½ 17		
200' ...	7 18½ 19½		Loss.	13½ 11		17½ 16½ 20½		Loss.	16 16½		19 18		
	8 23 23			16½ 13½ 24½		18 18 23½			18 18½		21 19		
	16 24 24½			19½ 16½ 24½		20 18½ 24½			18 19		23 20		
	18 24½ 26			21½ 18½ 25½		20½ 19½ 24½			19 20		23 21		
	23 24 26			23 20½ 25½		21 20 24½			20 21		24 22		
100' ...	23 23½ 26½		Gain.	24 21½ 25½		22 21 24½		Gain.	21 22		25 23		
	23 23 26			24½ 22½ 25½		23½ 23 24½			23 23		24 23		
	21½ 22½ 25½			25 23 24½		24 22 24½			24 23		24½ 22½		
	23 22 25½			24½ 23 24½		24 22½ 24½			25 23½		24½ 22		
	23 22 25			25 23½ 24½		24 23½ 25½			24½ 24		24½ 22		
	No. 1 21½ 21 24½		No. 2 23½ 21 23½		No. 3 23 23 24½		No. 4 23½ 22½		No. 5 23½ 21				
	19 19 23		23½ 21½ 23½		23½ 23 23½		23 23½		24 21				
	18½ 18½ 22½		22½ 21½ 22½		22 22 23½		23 22½		23½ 21				
	16½ 17 20½		21½ 23 22½		23 23 23½		22½ 22		23 20½				
	14½ 16 20½		19½ 21½ 21½		21 22 23½		23 21½		22 20				
	13 16 19½		18½ 20 20½		20 21 22½		21 21		23 19½				
100' ...	10 16 18½		Loss.	16 18½ 20½		18 20 21½		Loss.	20½ 20½		21 19		
	9 13 16½			14½ 16½ 19½		16 18½ 20½			20 20		20½ 18½		
	10 11 14½			12½ 15 18½		12 18 20½			18½ 19½		20 20		
	9 9			11½ 13 17½		10 16 19½			18 19		19½ 18		
	8 8			11½ 10		9 15 18½			17 18		19 17		
200' ...	8 6		Loss.	9½ 7		8 14		Loss.	15 17½		18½ 17		
	7 4½			8½ 7		6 13			15 17		18 16		
	7 4			8½ 6½		7 12			13½ 16½		17½ 15½		
	7½ 4			8½ 6		7 11			13 16		17 15		
	7 6			9 6		7 10½			12½ 15		16 14		
300' ...													

APPENDIX J—(continued).

KEAMARI MOORINGS.

April Sept. 1876. 1874.		April Sept. 1876. 1874.		April Sept. 1876. 1874.		April Sept. 1876. 1874.		April Sept. 1876. 1874.	
Improved.		Improved.		Improved.		Improved.		Improved.	
14	12½	13	13	11	19	11	10	11	11
15½	13½	14	13	11½	11½	11½	11	12	10½
17	14½	16	14½	12	12½	11½	11½	12	11½
18½	15½	16½	15½	13	13	12	13	13	12
20	17½	18	17½	14	13½	14	14	14	13
21½	19½	19	18½	15	15	14½	15	15	13½
22½	20	20	19	16½	15½	16	16	15	14
22½	21½	19½	19½	17	16½	17	17	15	14½
22½	21½	20	20½	18	17½	18	17	16	15½
24	22½	21	20½	19	18	18	18	17	16
24	22½	22	21	19½	18½	19	18	17	16½
23½	22½	22½	21	20	19	19½	18	18	17½
23½	22½	23	21	21	19½	19	18	18	17
23½	22½	22½	22½	21½	20½	20	18½	18	17
23½	22½	22	21½	22	21½	21	19½	19	18
No. 6 23½	22½	No. 7 21	21	No. 8 22	20½	No. 9 22	19	No. 10 20	18
23½	21½	21½	20½	22	20½	20	19	20	19
22	21½	21	20½	21½	20	21	19	20	19
21½	20½	21	20	21	19½	20½	19	20	19
21½	20½	21	20	21	19½	20½	18	20	18½
20½	20½	21	19½	21	19	20½	18	20	18½
20½	19½	21	19½	20½	18½	19½	17½	19½	18
20½	19½	20	19	21	18½	19	17	19½	18
20	19	20	18½	20½	18½	18½	17	18½	17½
19½	18½	20	18½	20	18	18	16½	18½	17
19½	18	19½	18	19½	17	17	16	18	17
19½	17½	19	17½	19	15½	16½	15½	17½	16
18½	17	18½	17	18	15½	16	15	16½	15½
18½	16½	18	16½	18	15½	15½	14	15½	14
17½	16	17	16	17	15	15	13½	14½	13
16½	15½	16½	15½	16½	14½	14	13½	13½	12

APPENDIX J—(concluded).

WEST CHANNEL MOORINGS.

April Nov.		April Nov.		April Nov.		
1876.	1874.	1876.	1874.	1876.	1874.	
300						
14 12½		18½ 16½		24 21½		
18½ 12½		18½ 16½		24 21½		
18½ 18		18½ 16½		23½ 22		
14 13½		18½ 16½		23 22		
15 14		18½ 16½		22½ 22		
200						
15 14½		18½ 16½		22½ 21½		
15 14½		18½ 17		22½ 21½		
15½ 14½		18½ 17		22½ 21½		
15½ 15		19 17½		22 21½		
17 15½		19½ 17½		22 21		
100						
16½ 16		19½ 18		23 21		3 Berths are available for
17 16½		20 18		23 21		20'
17½ 17		20½ 18½		23 21		24'
18 17½		21 21		23 21		21½
19 17½		21½ 20½		22½ 20½		
No. 1 18½ 17½		No. 2 22 21		No. 3 22½ 21		
19 18½		23½ 21½		23½ 21½		
19 19½		24 21½		24 22½		
20 20½		25 22½		25½ 23		
20½ 21½		24 23½		25½ 24		
21½ 21½		23 24		25½ 24½		
100						
23 21½		21½ 24		25 24		
22 21½		20 22½		24½ 24		
21½ 20½		18½ 21		23½ 23½		
20½ 19½		16 19½		21½ 23½		
20 17½		15 18½		19 22½		
200						
19 16½		12 16½		16½ 20½		
18 14½		10 13½		18 18		
17 12		8½ 10½		10 14½		
15 9½		8 8½		9 11		
13 8		7 7½		7 9		
300						

APPENDIX K.

KURRACHEE HARBOUR.

Statement showing areas of sections in January 1875 as compared with January 1858 and January 1874.

Number of Sections.	AREAS IN			AREAS IN JANUARY 1875 AS COMPARED WITH				REMARKS.
	January 1858.	January 1874.	January 1875.	January 1858.		January 1874.		
				Increase.	Decrease.	Increase.	Decrease.	
1	34,320	35,490	33,630	...	640	...	1,810	
2	37,164	34,270	33,510	...	3,624	...	730	
3	34,415	33,280	33,700	...	715	420	...	
4	33,233	32,460	32,490	...	743	30	...	
5	32,819	33,930	32,250	...	569	...	1,680	
6	32,165	33,360	32,230	75	...	...	1,130	
7	30,498	33,560	33,100	2,602	...	...	460	
8	30,117	33,430	34,390	4,273	...	960	...	
9	30,409	36,180	35,860	5,451	...	...	320	
10	27,989	37,150	36,810	8,821	...	...	340	
11	30,032	37,710	37,860	7,828	...	150	...	
12	27,552	34,190	33,980	6,428	...	...	210	
13	27,478	31,770	32,820	5,342	...	1,050	...	
14	27,532	32,900	30,990	3,458	...	...	1,910	
15	29,736	32,270	31,440	1,704	...	...	830	
16	26,736	32,400	34,570	7,834	...	2,170	...	
16 A	Not taken	35,770	35,190	...	...	...	580	
17	26,778	37,820	37,240	10,462	...	...	580	
18	23,107	36,200	37,240	9,133	...	...	960	
19	27,906	35,770	36,110	8,204	...	340	...	
20	28,707	35,620	35,820	7,113	...	200	...	
21	23,334	33,190	33,460	11,126	...	1,270	...	
22	29,495	46,350	46,440	16,945	...	90	...	
23	31,743	52,220	52,420	20,677	...	200	...	
24	41,049	48,150	50,140	9,091	...	1,990	...	
25	43,535	51,560	52,280	8,755	...	720	...	
26	43,162	53,280	54,000	10,838	...	720	...	
27	42,260	50,420	51,160	8,900	...	740	...	
28	41,349	46,790	47,480	6,131	...	690	...	
29	40,894	44,450	46,920	6,026	...	2,470	...	
30	39,321	43,620	43,670	3,249	...	50	...	
31	37,973	40,940	42,130	4,157	...	1,190	...	
32	36,400	38,130	39,630	3,230	...	1,500	...	
33	36,945	36,660	35,950	...	995	...	710	
34	36,569	35,230	34,620	...	1,949	...	610	
35	35,345	32,850	33,400	...	1,945	650	...	
36	33,540	29,730	31,430	...	2,110	1,700	...	
37	Not taken	28,220	29,690	...	...	1,470	...	
38	"	26,070	27,060	...	...	990	...	
39	"	24,620	25,700	...	...	1,180	...	
40	"	22,060	22,530	...	...	470	...	

(100)

APPENDIX K.

KURRACHEE HARBOUR.

Statement showing areas of sections in May 1875 as compared with January 1858 and May 1874.

Number of Sections.	AREAS IN			AREAS IN MAY 1875 AS COMPARED WITH				REMARKS.
	January 1858.	May 1874.	May 1875.	January 1858.		May 1874.		
				Increase.	Decrease.	Increase.	Decrease	
11	30,032	38,090	37,780	7,758	...	...	310	
12	27,552	34,080	34,400	6,848	...	320	...	
13	27,478	33,140	32,580	4,002	...	...	560	
14	27,532	32,180	32,000	4,568	...	...	180	
15	29,736	30,290	31,200	1,464	...	910	...	
16	26,736	35,700	34,420	7,684	...	...	1,280	
16 A	Not taken	35,230	36,240	...	...	1,010	...	
17	26,778	38,110	37,300	10,522	...	...	810	
18	28,107	36,030	38,800	10,693	...	2,770	...	
19	27,906	35,270	37,260	9,354	...	1,990	...	
20	28,707	35,040	36,840	8,133	...	1,800	...	
21	28,334	40,220	40,240	11,906	...	20	...	
22	29,495	48,370	49,000	19,505	...	630	...	
23	31,743	52,320	52,660	20,917	...	340	...	
24	41,049	49,070	48,460	7,411	...	...	610	
25	43,535	52,880	49,340	5,805	...	...	3,540	
26	43,135	54,490	53,320	10,184	...	...	1,170	
27	42,260	51,690	50,120	7,860	...	...	1,570	
28	41,349	47,350	46,700	5,351	...	...	650	
29	40,849	42,880	46,540	5,691	...	3,660	...	
30	39,321	42,560	43,440	4,119	...	880	...	
31	37,973	40,410	42,640	4,667	...	2,230	...	
32	36,400	37,980	39,160	2,760	...	1,180	...	
33	36,945	35,840	36,160	...	785	320	...	
34	36,569	34,170	34,600	...	2,169	430	...	
35	35,345	30,840	33,580	...	1,765	2,740	...	
36	33,540	29,970	31,660	...	1,880	1,690	...	
37	Not taken	27,480	29,500	...	...	2,020	...	
38	"	25,950	27,040	...	...	1,090	...	
39	"	23,590	25,360	...	...	1,770	...	
40	"	21,850	22,560	...	...	710	...	

No. 311 C W—880, dated 3rd July 1877.

From—Major-Genl. M. K. Kennedy, R. E., Secy. to the Govt. of Bombay, P. W. Dept.,

To—Secretary to the Government of India, P. W. Dept.

I have the honor to forward, for the information of the Government of India, a report No. 374, dated 26th May, with a Chart by the Superintendent, Kurrachee Harbour Works, on the last periodical survey of the Kurrachee Harbour, taken in January 1877. I am directed to say that, during his recent inspection of the harbour and visit to Kurrachee, His Excellency the Governor found a consensus of local opinion as to the general success of the harbour works, and an unanimous confidence in the judiciousness and professional skill of Mr. Price's management subject to the higher judgment of experts; and I am to add that His Excellency should hope that all questions may be solved in this way, and that the progressive development of the work may be effected.

No. 374, dated 26th May 1877.

From—W. H. Price, Esq., M. Inst. C. E., Superintendent, Kurrachee Harbour Works,

To—Secretary to the Government of Bombay, P. W. Dept.

I have the honor to submit report on the last periodical survey of this harbour, i. e., January 1877.

Plans and tracings accompany as follows :—

Index plan, showing divisions of water space calculations.

1. Tracing of January 1877, Chart 200' scale, 3 tracings of January 1877, Chart 500 scale (in triplicate).

(This last includes the "New Channel," which for want of space is not shown on the larger chart).

2. As the changes up to November 1875, both from the original state and from that of 1869, have recently been detailed in replies to Colonel Wilkins, it may now suffice to describe the changes between November 1875 (the previous general survey) and January 1877. The interval in this case is rather longer than it will be in future, as it is proposed to make the general survey always in January; *vide* paras. 9 and 22 of my report, No. 272 of 10th April 1876.

3. The work executed in the interval, which could materially affect the results now under report, was as follows :—

IN ENTRANCE CHANNEL.

				Cubic Feet.	Tons.
Dredging	...	...	...	1,471,485	73,574
Stone removed by Divers	...	...	...	...	516

IN "NEW CHANNEL."

For diversion of Chinna Creek waters.

					Lineal feet.
Lengthening of Training Groyne to northward between 9th and 10th Sections	...	...	...	...	126
Pitching to define scour along west side of Channel, west of Mole	...	...	...	...	1,587
Ditto ditto north side of Channel, east of Mole	...	...	...	...	1,074

4. The south-west monsoon of 1876 was above the average in force of sea; but the rainfall was unusually great, 20½ inches having fallen in the 14 months, of which nearly 15 inches fell in July.*

Entrance.

5. The general results as regards the entrance will be seen from the subjoined figures, which refer to the space (coloured green on the Index plan) nearly one mile long and ½ mile

* The above is from the registry of the Kurrachee Civil Hospital. The Manora Dispensary gauge gives only 9 inches for the same period, but the former is taken as most likely to affect the harbour.

wide, extending from deep water outside to Section 18 just within the outer end of the groyne, comprising the deep channel and such portion of the bar on either side as it is more or less an object to improve:—

DATE.		WATER SPACES BELOW KURRACHEE HARBOUR WORKS DATUM (LOW-WATER LEVEL).					
		Total cubic feet.	Increase.		Dredged in same period.	Decrease if gain by dredging be not reckoned.	
			Cubic feet.	Per cent.		Cubic feet.	Per cent.
November 1875	...	200,020,735	1,018,705	·51	1,471,485	452,780	·23
January 1877	...	201,039,440					

6. The above shows an increase of about 1 million of cubic feet, or $\frac{1}{2}$ per cent. of water space over the area in question; but as nearly $1\frac{1}{2}$ millions were dredged in the same period, this being deducted, shows a balance of nearly half a million of cubic feet, or $\frac{1}{2}$ per cent. on the side of accumulation.

7. Considering, as will appear further on, that about 4 millions of cubic feet, equal to 200,000 tons or to $15\frac{1}{2}$ acres one fathom in depth, have, in the same time, been scoured from the harbour, of which the greater part must have passed out to sea over the space referred to as the entrance, it is not matter for surprise that the latter should show for the present the above slight balance against scour.

8. But, though it may thus be said, in a general way, that scour is fairly holding its own in the division called the entrance, yet in the deep navigable channel the tendency to accumulation is found, as in previous years, counterbalancing the favourable action of scour to eastward.

9. The most marked deposit is at the inner end of the channel where the usual bar has formed by the cross rush of flood round end of the groyne.

The least sounding on this near the centre of the channel is $18\frac{1}{2}$ feet, but near the east side it has shoaled to $17\frac{1}{2}$ feet.

10. Comparing the two general surveys, the channel shows, on the whole, rather an improvement in width; but it must be recollected that a considerable quantity of dredging was done in the interim, and that the intermediate surveys or dredging purposes (submitted with my No. 893 of 29th December 1876) show the usual tendency to narrowing.

11. The sea bottom opposite the channel shows a continuance of the shoaling noticed in previous reports, which extends eastward as far as Section 34, beyond which the depths as before are well maintained.

I have before now stated my opinion that this shoaling is owing mainly to the want of ebb scour, which is deflected to eastward by Deep Water Point (while the flood is diverted by the breakwater); but whatever may be the cause, the effect calls for careful attention, and this season the dredger has been kept at work on that part for a considerable portion of her season's work, in order to keep down the accumulation.

As regards permanent remedy, I may add that the proposed deepening of the east, and contraction of the west, side of the lower harbour would help by outflanking Deep Water Point to direct the ebb into the entrance channel.

Lower Harbour from Section 18 to 11.

12. This division, which is coloured blue on the Index plan, includes the "Deep Water" and "Manora" anchorages, which are separated by the "gut" opposite Deep Water Point, and which in former reports have been classed under the one head of the "Manora Anchorage."

DATE.		WATER SPACES BELOW KURRACHEE HARBOUR WORKS DATUM (LOW-WATER LEVEL).			
		Total cubic feet.	Increase.		
			Cubic feet.	Per cent.	
November 1875	...	122,662,645	1,497,785	1·22	
January 1877	...	124,160,430			

13. The above figures show a slight gain by scour only, of about $1\frac{1}{2}$ per cent., confirming the opinion, expressed in last report, as to the slight loss then apparent in this division being only a temporary effect of the material moving outwards from the upper harbour "New Channel."

14. As stated in last report and elsewhere, this part of the harbour would be greatly improved by the curved extension of the East Pier (groyne) and removal of Deep Water Point as well as by the central dredging of the anchorage first proposed by Captain Giles.

Lately also a proposition has been submitted, on the recommendation of the present Master Attendant, to remove, at a cost of Rs. 4,000, two shoal patches of soft sandstone rock and coarse shingle, which interfere with the anchorage space about Section 13.

Lower Harbour from Section 11 to 4.

15. This space, which lies between the Manora and Keamari anchorages, may, as before, be divided longitudinally into two parts, of which, looking to ultimate improvement, the enlargement of the eastern and the contraction of the western are desirable. These divisions are coloured, respectively, red and brown on the Index plan.

Eastern Division.

DATE.					WATER SPACE BELOW KURRACHEE HARBOUR WORKS DATUM (LOW-WATER LEVEL).		
					Total cubic feet.	Increase.	
						Cubic feet.	Per cent.
November 1875	...	...	...	...	58,486,010	} 889,950	1.52
January 1877	...	...	...	...	59,375,960		

Western Division.

DATE.					WATER SPACE BELOW KURRACHEE HARBOUR WORKS DATUM (LOW-WATER LEVEL).		
					Total cubic feet	Decrease.	
						Cubic feet.	Per cent.
November 1875	...	...	...	...	71,194,690	} 71,395	.10
January 1877	...	...	...	..	71,123,295		

16. The above shows a continuance of the deepening on the east side, and accumulation on the west, which, for some years past, have characterized those divisions.

17. The shoaling of the west side during last year has been very slight, and would not require notice, but that it points to the gradual loss of the narrow "West Channel" line of anchorage, for which the deepening in progress on the east side will be, at best, a long time in forming a substitute, unless aided by the dredging proposed in the last survey and other reports, which, combined with the filling up of the hollow west shore by the dredged material, would bring the ebb and flood into one line of deep water connecting the Manora and Keamari anchorages.

Keamari Anchorage.

18. Coming now to the Keamari anchorage, which has of late years been much under notice, the following table will show the changes which have taken place during the interval in this division, which is coloured yellow in the Index plan:—

DATE.				WATER SPACE BELOW KURRACHEE HARBOUR WORKS DATUM (LOW-WATER LEVEL).		Area within 20-foot contour in acres.	
				Total cubic feet.	Decrease.		
					Cubic feet.		Per cent.
November 1875	...	...	..	62,979,725	} 1,773,190	28.1 }	18.80
January 1877	...	...	...	61,206,535			17.94

19. These figures, being for 14 months, give a rate of shoaling of about $1\frac{1}{2}$ millions, or $2\frac{1}{2}$ per cent. per annum. This is an increase on the rate of 1875, which was about 860,000 cubic feet per annum, but is less than the average rate of the 4 years from 1871 to 1874, inclusive, which was nearly $2\frac{1}{2}$ millions of cubic feet per annum.

20. On the other hand, the decrease of area within the 20-foot contour has been only .86 of an acre between November 1875 and January 1877, whereas it was 3.31 acres between January and November 1875.

This is favourable, as showing that the deposit does not now so much affect the deeper water in which a narrowing throughout is not found as in previous years, though it is still contracting at the north end, for which, however, there are signs of compensation in some slight extension to southward.

21. The increase in the cubic quantity of shoaling (*vide* para. 19) in 1876 as compared with 1875, may partly be accounted for by the increase in quantity scoured from the "New Channel," to be presently referred to, but is mainly due to a large percentage of the "New Channel" material having been dropped within the division classed as the Keamari anchorage in 1876 as compared with 1875, the proportions being, respectively, 39 and $24\frac{1}{2}$ per cent., while the average proportion for the 5 years from the commencement of the division to the end of 1874, was $32\frac{1}{2}$ per cent.

22. The reason of the large percentage of 1876 is, I think, to be found in the action of the scour straightening the channel above, aided by the dredging through the bar at its mouth, executed by Mr. Hart in 1875, and by a slight prolongation of the training groyne to northward, so that the ebb has been checked from spreading to westward, and turned more directly into the Keamari anchorage division.

23. The current which is thus causing extra shoaling in the upper end of the deep water, is at the same time doing good work in maintaining its width lower down, and even in extending it to southward, as described in para. 20, while passing about three-fifths of the "New Channel" material onward to sea.

"NEW CHANNEL."*For Division of Chinna Creek Waters.*

24. In my last report, on the survey of November 1875,* was given a sketch of the measures adopted, and progress made from the first, in the diversion of the Chinna Creek waters, so that it will suffice here to note the progress made since the previous survey:—

* No. 272 of 10th April 1876.

DATE.	WEST OF NAPIER MOLE, 8,100 FEET IN LENGTH.		EAST OF NAPIER MOLE, 5,800 FEET IN LENGTH.		Total.
	Scour within Channel limits.	Scour from Flats between Channel and Napier Mole.	Scour within Channel limits.	Scour (probable) from Flats and creeks.	
From November 1875† to Janu- ary 1877 	1,726,527	16,500	1,279,856	1,500,000	4,522,883

† In the previous report the date for New Channel was given as January 1876, but it saves confusion to refer to the same date throughout in the general survey.

25. The quantity scoured out in 1876 from the "New Channel" and flats adjoining, as shown by the above figures, is, as already noticed in para. 21, slightly in excess of the rate of 1875.

The acceleration of improvement was, no doubt, aided not only by the cut dredged through the bar just above Keamari in 1875, but by the training of the scour effected by the stone pitching to define the line at intervals, for which Rs. 8,678 was sanctioned in 1875, as a small portion of the measures then recommended by Mr. Hart.

26. On the bar just referred to between Sections 23 and 17, the narrow cut made by the dredger in 1875 has partially filled up; but, on the whole, the bar has slightly lowered, while at the same time the spreading of the current to westward of it has been checked by the gradual rising of the west bank.

27. At present there is about $3\frac{1}{4}$ feet at low water for navigation over this bar, as compared with 5 to 6 feet in the channel upwards to the native jetty, in which the quantity scoured out in 1876 gives an average increase in depth of 6 inches, while it has improved also in width and regularity, though still greatly short of the desirable depth of 9 feet throughout.

28. East of the "Notch" also the channel shows marked improvement in depth, width and regularity as far as Section $5\frac{1}{2}$, above which progress is, as usual, checked by the coarse shell and shingle near the junction with the Chinna Creek.

29. In my last survey report I gave full particulars, with diagram, in illustration of the tidal flow through the "New Channel," by which the effects just described are being produced.

30. In connection with Colonel Wilkins' inquiry some further observations of interest as regards discharge were taken in September last, which showed the maximum ebb discharge of the "Notch" to be 14,342 cubic feet per second, being about $\frac{1}{11}$ th of the main harbour maximum discharge, (but occurring 1 hour 35 minutes later), showing some improvement since September 1873, when the proportion was only $\frac{1}{15}$ th.

The total harbour discharge during the entire ebb was 2,055 millions of cubic feet, and that of the "Notch" and weir at Napier Mole Bridge combined, was 250 millions, or about one-eighth of the total harbour discharge, whereas the duty of the east backwater, if properly filled and emptied, would be at least one-fifth.

The area of the "Notch" at half tide was found to be 3,272 square feet in 1876, as compared with 2,268 in September 1873.

31. The following figures also show some, though slight, progress towards the desirable objects of a "higher flood" and a "lower ebb," at the "Notch," as compared with the lower harbour:—

DATE OF OBSERVATION.	HIGH WATER.		LOW WATER.	
	Lower Harbour.	Notch.	Lower Harbour.	Notch.
28th March 1876	9' 2 $\frac{1}{4}$ "	8' 6 $\frac{1}{2}$ "	30" B	1' 10"
30th March 1877	9' 3"	8' 10"	05 $\frac{1}{4}$ " B	1' 7"

NOTE.—The heights are with (†) referred to K. H. W. datum, and the letter B signifies below.

The slight depression of $\frac{1}{4}$ inch in the ebb at the "Notch" which these observations show, is of some importance when it is considered that the slightly higher high water in the harbour and its appreciable elevation at the "Notch," must have filled the east backwater more largely on the recent observations, so that the "Notch" must have had more to pass out on the ebb.

32. These observations all show, as remarked in last report, a large reserve of scouring power, resisted, however, here and there by hard material, especially at the neck of the "New Channel," where it leaves the Chinna Creek, so that some dredging and training, as already proposed, are required to aid the scour.

CONCLUDING REMARKS.

33. On the whole, I submit that the results of the survey are fairly satisfactory, though there are drawbacks in the shoaling of the entrance and of portions of the anchorage, also in the slowness of improvement generally, all which, however, seem susceptible of remedy, partly by moderate further measures, and partly by the lapse of time.

34. Having in my last survey and other reports, and in replies to Colonel Wilkins stated in detail the measures which I would propose, it would seem unnecessary to add to length by repeating them here.

35. I may, however, be permitted to express my gratification at finding that, though sanction has not yet been given to such further measures, at least no intention has appeared of adopting the retrograde and costly measure of re-opening the Chinna Creek.

36. The survey has, as usual, been carried out mainly by Mr. Humby, with some assistance from Mr. H. Wray, in the upper harbour work.

37. The water-space calculations have delayed the submission of this report, which would be much less definite without them, and I have now no subordinate of experience to entrust them to, except Mr. Humby, who has much other work on hands.

No. 274 M, dated 5th October 1877.

From—The Government of India, P. W. Dept.,

To—Secretary to the Government of Bombay, P. W. Dept.

I am directed to acknowledge the receipt under cover of your No. 699 C W of 3rd November 1876, of Colonel H. St. Clair Wilkins' valuable report on the Kurrachee Harbour Works, and on the steps that should be taken with reference to their satisfactory improvement and maintenance, and, in reply, to convey the following observations and orders.

2. The artificially formed harbour of Kurrachee may be considered so far to have been fairly successful, but like all artificial works of a similar nature it requires an annual outlay to maintain and keep it efficient, and in the particular case of the Kurrachee Harbour to *improve* it with a view to meet the very large increase to the trade of the port which may be looked for on the completion and opening out to traffic of the Indus Valley State Railway.

3. Various proposals for the construction of groynes and piers have been made from time to time with a view to divert and regulate the tidal scour, but though the value and possible efficiency of such methods of improvement must be recognized, yet His Excellency the Governor General in Council feels that the element of extreme uncertainty cannot be eliminated from them, and His Excellency is convinced that better and more permanent results are likely to be achieved by a well devised and continuous system of dredging, than by any of the other means that have been suggested.

4. In this view I am to say the Government of India is prepared to make an annual grant, to include the cost of establishments, of 1 lakh of rupees, for the next ten years, or such other period as future experience may suggest, to be expended wholly on dredging; and His Excellency in Council is of opinion that the most important objects to be aimed at in these dredging operations named in order of their importance, are—

(1).—Deepening the entrance to the harbour, and more especially along its western bank.

(2).—Deepening the harbour off "Deep-water Rock."

(3).—Improving and widening the Manora anchorage, the Eastern Channel, and the Keamari anchorage.

5. The next point to be considered is the means by which the dredging can be most effectively carried out. His Excellency in Council has no doubt but that in a narrow and restricted anchorage the single self-moving powerful hopper steam dredger is the proper description of machine to select, of the type recommended by Mr. Price and Sir W. Merewether, *vide* your letter No. 259 C—W—753 of 1st June last, and estimated to cost £40,000. This dredger should be at once indented for through the Secretary of State, who might be asked to contract for the machine with Messrs. Simons and Co. of Renfrew, the makers of the particular type approved, to be delivered in Kurrachee in 1879, and be paid for in 1878-79 and 1879-80. The necessary provision to be made in the Budget-Estimates of those years.

6. In thus deciding on dredging in preference to the construction of groynes, &c., the Government of India is not, I am to say, to be understood to preclude the adoption of any subsidiary and secondary proposals for the construction of such works to aid and assist the dredging operations. What is meant is that dredging shall be the primary means adopted to attain the end in view, other means being considered on their merits from time to time as occasion may demand, and experience may show to be advisable.

7. Further communication will be made to the Government of Bombay in the Financial and Revenue Departments concerning the enforcement of Provincial and Local responsibility for the expenditure now sanctioned, and the increase of local revenues in support thereof.

8. In conclusion, I am to request that the thanks of the Governor General in Council may be conveyed to Colonel Wilkins for his very able and exhaustive report.

No. 275 M.

Endorsed by P. W. Dept.

Copy forwarded to the Financial Department for information, and for the issue of an subsidiary orders that may be thought desirable.

No. 448 C W—1306, dated 7th September 1878.

From—Colonel C. J. Merriman, R. E., Acting Secy to the Govt of Bombay, P. W. Dept.,
To—Secretary to the Government of India, P. W. Dept.

I am directed to forward, for the information of the Government of India, a copy of a Report No. 879, dated 26th August 1878, with a chart, by the Superintendent, Kurrachee Harbour Works, on the last periodical survey of the Kurrachee Harbour, taken in January 1878.

No. 879, dated 26th August 1878.

From—W. H. Price, Esq., M. Inst., C. E., Supdt., Kurrachee Harbour Works,
To—Secretary to the Government of Bombay, P. W. Dept.

I have the honor to submit my report on the last periodical survey of this harbour, i. e., January 1878.

Plans and tracings accompany as follows:—

Annexed to Report.

Tracing of index plan showing divisions of water-space calculations.

By Banghy Post in Tin Case.

No.

1 Tracing of January 1878, chart, scale 200' = 1".

3 Tracings of January 1878, reduced chart, scale 500' = 1" (this last includes the "New Channel" of the Upper Harbour, which, for want of space, is not shown on the larger chart).

2 Spare copies of the index plan tracing.

2. I propose, as in last report, to confine the description mainly to the changes which have occurred in the period (of one year) since the previous survey, i. e., January 1877.

3. The work executed in the interval, bearing on the results now under report, was as follows:—

In Entrance Channel.

			Cubic feet.	Tons.
Dredging	...	...	1,020,080	51,004

In Manora Anchorage.

			Cubic feet.	Tons.
Dredging	...	...	114,672	5,734

4. The south-west monsoon of 1877 was about the average in force of sea, but the rain-fall was small, only 2.82 inches during the year, so that the harbour cannot have been much affected by material washed in from the land.*

ENTRANCE.

5. The general results as regards the entrance will be seen from the subjoined figures which refer to the space (coloured green on the index plan) nearly 1 mile long and $\frac{1}{4}$ mile wide, extending from the sea to section 18 near the outer end of the groyne, and comprising the deep entrance channel, with such portion of the bar on either side, as it is more or less an object to improve.

Date.		WATER-SPACES BELOW KURRACHEE HARBOUR WORKS DATUM (LOW-WATER-LEVEL.)					
		Total cubic feet.	Increase.		Dredged in same period.	Decrease, if gain by dredging be not reckoned.	
			Cubic feet.	Per cent.		Cubic feet.	Per cent.
January 1877	...	201,039,440	1,055,885	.52	1,020,080	35,805	.02
January 1878	...	202,095,325					

* The rain-fall in 1876, given in last report, should have been 10 $\frac{1}{2}$ and 20 $\frac{1}{2}$ inches.

The error originated in the *Bombay Government Gazette* which showed the rain-fall for July 1876 at 14 inches 83 cents instead of 4 inches 83 cents.

6. The above shows an increase of slightly over a million of cubic feet, or $\frac{1}{4}$ per cent., of water-space.

This is almost exactly the same increase as in the previous year, but is more favorable as only about one million cubic feet of dredging was done in aid of the result in 1877, against $1\frac{1}{4}$ millions in 1876.

Setting aside the quantity dredged, a decrease appears in 1877 of \$5,805 cubic feet, or .02 per cent., which is so small that scour may be said (as it has done practically of late years) to have balanced deposit in the entrance division.

7. This result cannot but appear satisfactory, considering, as will appear further on, that, as in the previous year, about 4 millions of cubic feet, equal to 200,000 tons, or to $15\frac{1}{2}$ acres 1 fathom in depth, have in the same time been scoured from the harbour, the greater part of which must have passed out to sea through the entrance division.

8. Generally speaking scour thus appears to be doing good work in the "entrance" division, but in the deep navigation channel the tendency to accumulation still continues, counterbalancing the gain effected by scour outside its limits.

9. The most marked deposit is at the inner end of the channel, where the usual bar has been formed by the cross rush of flood-tide round end of the groyne.

The least sounding on this bar near the centre of the channel is 19 feet, but near the east side it has shoaled to 17 feet.

10. Comparing the two general surveys, the channel shows, on the whole, rather an improvement in width, especially at the outer end.

It must, however, be recollected that dredging was done in the interim, and that the intermediate surveys for dredging purposes showed the usual tendency to narrowing.

11. It is most satisfactory to have to report no further continuance of the shoaling opposite the mouth of the channel, which was noticed in previous reports.

The special working of the dredger at that part during the season of 1876-77 has evidently done much good in counteracting accumulation, but nevertheless experience of the good effects of dredging for one season should not, I submit, preclude the consideration of more permanent remedies.

LOWER HARBOUR FROM SECTION 18 TO 11.

12. This division (coloured blue on the index plan), which is nearly $\frac{3}{4}$ mile long by $\frac{1}{4}$ mile wide, includes the "deep water" and "Manora" anchorages, also the "gut" separating them opposite deep water point, and which, owing to eddies is at present useless for anchorage.

DATE.		WATER-SPACES BELOW KURRACHEE HARBOUR WORKS DATUM (LOW-WATER-LEVEL)					
		Total cubic feet.	Decrease.		Dredged in same period	Decrease, if gain by dredging be not reckoned.	
			Cubic feet.	Per cent.		Cubic feet.	Per cent.
January 1877	...	124,160,430	319,545	.26	114,672	434,217	.35
January 1878	..	123,840,885					

13. The above figures show that the slight gain by scour noticed in this division during the previous year has this year turned into a still slighter loss of about one-third per cent., notwithstanding that some hard material was dredged in the interim in the Manora Anchorage, to aid in making space for long steamers to swing in.

14. The loss has chiefly occurred between the end of the groyne and "deep-water point," especially on the east side.

Such fluctuations must be looked for at this part through the irregular currents and eddies caused by "deep-water point," and by the abrupt termination of the groyne which limit and counteract improvement at this important anchorage.

LOWER HARBOUR FROM SECTION 11 TO 4.

15. This space, about $\frac{3}{4}$ mile long by $\frac{3}{4}$ mile wide, which lies between the Manora and Keamari Anchorages may, as latterly usual, be divided longitudinally into two nearly equal parts, of which the enlargement of the eastern, and some contraction of the western, are ultimately desirable, and which are coloured respectively red and brown on the index plan.

Eastern Division.

DATE.					WATER-SPACE BELOW KURRACHEE HARBOUR WORKS DATUM (LOW-WATER-LEVEL).		
					Total cubic feet.	Increase.	
						Cubic feet.	Per cent.
January 1877	...	...	...	...	59,375,960	} 1,257,850	2·12
January 1878	...	...	...	...	60,633,810		

Western Division.

DATE.					WATER-SPACE BELOW KURRACHEE HARBOUR WORKS DATUM (LOW-WATER-LEVEL).		
					Total cubic feet.	Decrease.	
						Cubic feet.	Per cent.
January 1877	...	...	...	...	71,123,295	} 25,735	·03
January 1878	...	...	...	...	71,097,560		

16. The above show a continuance of the marked deepening and slight accumulation which have for some years past respectively characterised these divisions.

17. As remarked in former reports, the accumulation on the west side is so slight as hardly to require notice, except in its connexion with the gradual and expected loss of the narrow "West Channel" line of anchorage.

For this however, a substitute will eventually be provided by the natural deepening in progress on the eastern division, which is now (for the first time) being aided by dredging and combined with the filling up of the hollow west shore by the dredged material protected by stone-pitching, will bring the flood and ebb into one line of deep water, connecting the Manora and Keamari Anchorages.

KEAMARI ANCHORAGE.

18. This division (coloured yellow on the index plan), which is nearly 1 mile long by $\frac{1}{4}$ mile wide, includes the Keamari Anchorage, the shoaling of which has of late years attracted much attention.

The following statement shows the changes in this division in 1877:—

DATE.				WATER-SPACES BELOW KURRACHEE HARBOUR WORKS DATUM (LOW-WATER LEVEL.			Area within 20 foot contour.
				Total Cubic feet.	Increase.		
						cubic feet	Per cent.	Acres.
January 1877	...	...	...	61,206,536	} 418,465	72	{ 17·94
January 1878	...	...	...	61,655,000				{ 14·55

19. In cubic quantity these figures show; for the first time since 1871 (when the Chinna Creek diversion began to affect this anchorage), a reversal of the process of shoaling which had been going on more or less from that time.

Thus, in 1876, there was a shoaling of about $1\frac{1}{2}$ millions of cubic feet, or $2\frac{1}{2}$ per cent. per annum, while in 1877 is found deepening of nearly half a million, or $\frac{1}{2}$ per cent.

20. This result is, no doubt, partly attributable to the decrease of quantity scoured from the "New Channel" above, which was under 3 millions of cubic feet in 1877, as compared with $4\frac{1}{2}$ millions in 1876.

21. But more than one-third of the $4\frac{1}{2}$ millions of 1876 was dropped in the Keamari Anchorage Division, while the (nearly) 3 millions of 1877 have passed on, and nearly half a million of gain is found in addition.

22. So favourable a result cannot, however, be looked for in 1878, owing to the temporary accumulation which may be expected from the unusually heavy rain-fall of this year.

23. But, though, so far favourable as regards general water-space within the Keamari Anchorage Division, on the other hand, decrease of area within the 20-foot contour has continued, and at a rate about 4 times that of 1876, amounting in 1877 to about $3\frac{1}{2}$ acres, or about the same as in 1875.

This decrease appears at both ends of the anchorage, but a very few inches in a very few soundings make a great difference in the area within this contour, which will soon be restored and further increased where the dredging now in progress up the east side of the harbour reaches that part.

NEW CHANNEL FOR DIVERSION OF CHINNA CREEK WATERS, AND ACCESS TO THE NATIVE JETTY.

24. The following statement shows the progress made by the "New Channel" in 1877:—

		WEST OF NAPIER MOLE, 8,100 FEET IN LENGTH.	EAST OF NAPIER MOLE, 5,300 FEET IN LENGTH.	
		Scour within Channel limits.	Scour within Channel limits, plus $1\frac{1}{2}$ millions estimated for Scour from Flats and Creeks.	Total.
		Cubic feet.	Cubic feet.	Cubic feet.
From January 1877	...	921,125	1,974,750	2,895,875
To January 1878	...			

25. These figures show, as usual, continuance of improvement, but the quantity scoured in 1877 has been less than in 1876 by rather over one-third.

This slower rate is not to be wondered at, as no assistance worth mentioning could be given to the scour during the past year, funds having admitted only of maintenance and securing of the banks in the proper line.

It may be hoped, however, with the aid of the fixed annual grant for dredging lately made by the Government of India, to give some assistance before long to the "New Channel" scour by dredging through the bar at its mouth and removal of hard material here and there.

During the current year, however, there will be no funds to spare from the dredging of the entrance and anchorage.

26. The bar just referred to, between sections 23 and 17, a distance of 400 yards, has slightly shallowed, as compared with 1876, having now about 3 feet depth over it at low-water, as compared with 5 to 6 feet in the channel thence upwards to the Native Jetty, which, on the average, has deepened about 3 inches in 1877.

27. This is only half the rate of deepening of 1876, and neither has the channel continued its rate of improvement either in width or regularity.

28. East of the "Notch" also improvement has been less marked than in 1876, but there are traces of large quantities of material being washed in from the creeks, at the upper end especially, which naturally retard the improvement of the channel, though favourable as regards general development of the east back-water.

29. The area of the "Notch" continues to increase having been 3,719 superficial feet at half-tide in January 1878, as compared with 3,508 in January 1877.

30. No observations of discharges were taken in 1877, as these give better data when repeated at longer intervals.

31. Independently of its bearing on the general improvement of the harbour, the value of the "New Channel" as an access to the Native Jetty, which has indeed long recognized, may be expected before long to assume a tangible shape in connection with the measures now in progress for enhancement of port revenue, especially in the shape of bunder fees.

32. It is however to be hoped that the levying of such dues may not be pushed so far as to check the growing trade of the port, which has still much advantage to contend with, in the incompleteness of the railway communication.

CONCLUDING REMARKS.

33. The results of the survey may, I submit, be considered, on the whole, satisfactory, though there is abundant evidence, as before, of the necessity for measures to accelerate, direct, and confirm improvement.

34. Good promise of such measures has recently been given in the orders of the Government of India, providing for a fixed annual grant for dredging, and for new and powerful dredging plant, and promising consideration to other special measures proposed on their merits, which, no doubt, may be judged of better after trial of what may be effected by dredging on a vigorous scale.

35. The unusual delay in submission of this report calls for explanation. It has arisen first from the numerous calls for surveys and charts in connection with the defences of this harbour, and next from the occupation of most of my establishment on the construction of railway lines and share of other operations in connection with the defence works.

36. Though the preparation of the charts and calculations were thus unavoidably deferred, yet the survey was completed at the usual time, the entrance portion having been carried out by Mr. Humby and the rest under his supervision by Mr. H. Wray.