

# KURRACHEE HARBOUR

1858

By  
WILLIAM PARKES, ESQ., C.E.



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# KURRACHEE HARBOR.

## SECOND REPORT

OF  
JAMES WALKER, LL.D., F.R.S. L. & E.,

CIVIL ENGINEER,  
LONDON,  
DATED 28<sup>TH</sup> OCTOBER, 1858.

AND  
REPORT OF THE SURVEY OF 1857-8,

BY WILLIAM PARKES,

CIVIL ENGINEER,

ADDRESSED TO MR. WALKER.  
WESTMINSTER:  
VACHER & SONS, 29, PARLIAMENT STREET.  
1858.

## **KURRACHEE HARBOR.**

### **MR. WALKER'S REPORT.**

**23, GREAT GEORGE STREET,**

**28th October, 1858.**

SIR:

I have the honor to transmit herewith Plans, Sections, Description, and Estimates for the improvement of Kurrachee Harbor, which have been made since Mr. Parkes' return from that place.

Mr. Parkes is, as you are aware, the Engineer who, under the authority of the Directors of the Honorable the East India Company, and upon my recommendation, which was fully approved by Mr. Frere (then in England), was sent out to Kurrachee, after my Report, dated 8th September 1856, was delivered, to make further surveys of the Harbor, and to collect such information as respects the levels and stratification of the ground, the tides, and the nature and prices of building materials, &c., as would enable me, on his return, to confirm or modify the general views I had expressed in my first Report, and, with the assistance of the more extended data he would furnish me, to make more detailed designs and estimates of the works I might think suitable for effecting the above important object.

Mr. Parkes left England in September, 1857, and returned in May, 1858. The time since his return has been principally occupied in the consideration of the matters arising from his Survey, and in the preparation of the designs and estimates sent herewith. The results of his Survey are given in the seventeen sheets, and the diagrams of the borings and tides which accompany this Report, and are described in the Appendix. I also send a copy of the Report I received from him on his return. It contains much useful and interesting information as to the physical features of the Harbor and neighboring coasts.

Mr. Parkes has expressed to me the obligations he was under to Mr. Frere; to Colonel Scott, the Superintending Engineer in Sindh; and to the gentlemen who were appointed to cooperate with him in the details of his Survey; and that he was also specially indebted to the excellent Chart made by the late Commander Grieve, I.N., and to the valuable cooperation of that officer in Mr. Parkes' own Survey, up to the time of Captain Grieve's sudden death in January last.

I have appended some extracts of letters to me on the subject of the Harbor and the plans for improving it, from Mr. Frere and Colonel McMurdo, who was Quartermaster-General to Sir Charles Napier, in Sindh. They will be interesting, as showing, not only the opinion of the writers, but also of the late Sir Charles Napier, whose views of the subject appear to have been large and enlightened.

It has been very satisfactory to me to find that the opinions expressed in my Report above referred<sup>1</sup> to, as to the capability of improving the Harbor, including the removal of the Bar and the deepening of the entrance generally, and also as to the means of effecting the other improvements, have been strengthened by Mr. Parkes' Survey and observations, and by the opinions of the eminent individuals I have just named, and also by Colonel Turner, for several years Superintending Engineer in Sindh, who is now in England. He has kindly called upon me to inspect the Plans, has favored me with his own opinions upon them, and has expressed his general approval.

The works recommended in my first Report were 1st. A Breakwater from Manora Point, to prevent the passage of sand from the westward, and to afford shelter from the worst seas at the entrance, and which would also serve to protect the foot of Manora Cliff from the wasting by the sea, which Colonel Turner and Mr. Parkes consider to be injurious, and, if allowed to continue, dangerous.

2nd, A Bank or Groyne from Keamari south-ward upon the sand spit, to prevent the waste of water to the eastward, and to confine the ebbing and flowing currents to the Harbor channel, so as to direct them upon the Bar. This work would also serve to stop the movement of sand from the eastward, which, Mr. Parkes states, is taking place to a considerable extent, and is narrowing the channel upon its eastern shore, south of Keamari.

3rd. The closing of Chinna Creek by a solid embankment, and conveying through the Harbor 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.

4th. New Docks and Basins for ships of large tonnage.

I beg now to refer you to the accompanying plan A, on which are represented the general lines of my amended design.

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<sup>1</sup> The Report was printed with a reduced copy of the plan, and a number of the copies were sent to the India House.

With regard to the two first of the before-mentioned works, *viz.*, the Manora Breakwater and the Seamari Groyne, the additional data collected by Mr. Parkes confirm me in my original views as to their utility, and in my present designs they stand as formerly shown and reported on.

With regard to the third, *viz.*, the diversion into the Harbor of the water which now passes in and out through Chinna Creek, Mr. Parkes' observations as to the quantity of water, &c., show this part of the design to be of even greater importance than I had anticipated, and the details of the present amended design have been prepared so as to take advantage of the great capabilities thereby afforded. By it the water is proposed to be conveyed through the Napier Mole by an opening 1,200 feet long, to be crossed by a bridge on piles. 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 passage of the largest native craft, at almost all times of tide. Additional wharfage and accommodation for the native craft is also provided near the town, which enables the Quay to be entirely removed from the roadway upon the Mole. Colonel Turner agrees in the expediency of this arrangement.

As the new channel above-named will be about 500 yards westward from the Mole, the intervening space will be available for the construction of Basins and Docks, and is, I think, on the whole, preferable for these purposes to the east side of the Mole, where I at first proposed to place the Basin and Docks, as they will be between the new channel and the Napier Mole, and thus leave the ground near the Railway terminus open for buildings connected with the Railway or with the shipping, or for the extension of the town to Keamari, which, Colonel McMurdo says, was predicted by Sir Charles Napier as likely to take place.

Such are the general features of the designs. The several works in connection therewith are Designs. shown more in detail in the accompanying Plans, B, C, D, E, upon which the Estimates are formed.

Sheet B shows a Breakwater Pier from Manora Point, 1,500 feet long. The body of the Pier is 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 at all times of tide to the end of the Pier and to a proposed Lighthouse there.

Sheet C shows a stone bank, or groyne, upon Keamari Sand Spit, 7,400 feet long, the top feet 6 inches above monsoon high water.

Upon the same sheet is shown the cross section of an East Pier, in continuation of the Keamari Groyne, 2,600 feet in length, and 2 feet 6 inches above monsoon high water. I think (as stated in my first Report) that this great length of pier might be postponed to

the last, as I consider that the sufficiency of the other works may be tested previous to carrying it out to any considerable length.

I may mention here, that borings were made by Mr. Parkes to 21 feet below low water on the Bar, and that sand, and sand only, was found in all of them.

Sheet D contains an elevation and section of a wrought-iron bridge over the proposed tidal opening in the Napier Mole, 1,200 feet long, and 40 feet in width of roadway.

I stated in a letter, dated 15th July last, addressed to the Secretary of the Sindh Railway Company, that a space of 1,000 feet long would be required in the Railway embankment across the Estuary, in order to pass the tidal waters under it in the same way as it is proposed to pass them under the Mole.

Sheet E contains a longitudinal and cross section of a stone-faced embankment across Chinna Creek.

MR. WALKER'S REPORT.

		£
Sheet B	Manora Breakwater	110,000
Sheet C	Keamari Groyne .	42,000
Sheet D	Napier Mole Bridge .	40,000
Sheet D	Native Jetty, or Quay	28,000
Sheet D	New Channel .	18,000
Sheet E	Chinna Creek stoppage .	9,000
	Making a total of	£ 247,000
	To this add, for the East Pier, if required.	40,000
	<b>TOTAL</b>	<b>£ 287,000</b>

Or, in round numbers, £300,000 for the improvement of the Harbor, exclusive of the Basins and Docks.

I have shown, upon Sheet A, the lines for a Tidal Basin 1,200 feet long by 830 feet wide, and 22 feet deep, at low water of spring tides. This would give 3,700 feet of available quayage, and room for twelve vessels of large tonnage at moorings in the centre of the Basin. There would be also 2,400 lineal feet of Quay in the line of the channel, outside and below the entrance to the Basin.

The estimate for these Basins and Quays, including the necessary dredging is £300,000. From the soft nature of the ground, a very expensive mode will be required for founding and constructing the Basin walls, and other similar works.

A Graving Dock ought to be made in some convenient spot near the Basin. I have shown two sites, with the lines for two Docks in each. That which, from local considerations, should appear the most eligible at the time the point comes to be decided on, may be chosen.

I have not estimated the Graving Dock in detail, but my experience justifies me in saying that the cost would not be less than £60,000.

Thus the estimate of all the works that are recommended in this Report, in order to make Kurrachee suitable for an extensive trade in shipping of large tonnage, is –

	£
For the Harbour and its Entrance	300,000
For the Basins and Quays	300,000
For the Graving Dock	60,000
Making in all .	£ 660,000

The result of every consideration I have given to the subject is, that at least 20 feet at the low water of spring tides, 23 feet at the low water of neap tides, 25 feet at the high water of neap tides, and 29 feet at the high water of spring tides, with an ample width of entrance sheltered from the worst winds, may be depended upon.

The expenditure of this sum would necessarily be spread over several years. It is probable, even if the whole were contracted for at once, that the execution would require at least six or eight years, in which case the annual expenditure would be about £100,000.

In my first Report, I referred to the value of Docks in which the heaviest and sharpest ships would always be kept afloat and at the same level; and I beg now to add, that if a detailed estimate of a Dock be desired, I have the data for making it. The lines upon Sheet A show a dock space 2,000 feet long by 900 feet wide, giving an area of 40 acres, and are only meant to prove that there is ample space; the width, 900 feet, being, with one or two exceptions, about twice the width of any Dock in this country. As respects the immediate necessity for Wet Docks, it is right to observe, that as the bottom is soft, and the depth, even at extreme low water, will never be less than about 20 feet, a heavy sharp ship would not suffer by touching the ground in the Basin.

The Dock or Docks, as I have shown them, would afford room for extensive Quays round all their sides, with sites for large sheds and warehouses, and branch lines from the Sindh Railway, which would give great facility for the loading and unloading of ships, storing their cargoes, or conveying these into the interior.

Colonel Turner and Mr. Parkes inform me, that the important question of a supply of pure fresh water for the town of Kurrachee is not being neglected by the authorities upon the spot, and that various plans are under their consideration.

If the Layari is to be the source, the Napier Mole would afford a convenient channel (as suggested by Sir Charles Napier) for extending the supply to the shipping at Keamari.

Mr. Parkes speaks in strong terms of the necessity of an improvement upon the present supply, which necessity will increase as the Port becomes more frequented by shipping.

If it be resolved to proceed in the execution of any considerable portion of the before-named works, detailed or working drawings, with specifications of the materials to be used, and conditions for contracts, will be required. Colonel Turner and Mr. Parkes agree with me in the opinion, that the most satisfactory and expeditious way will be to apply to several respectable and substantial contractors – including such of the above character as have at present Railway or other contracts in India – for tenders to execute the whole that may be specified for a fixed sum; the tender to be accompanied by a schedule of prices to regulate the allowances to be made for any additions to, or deductions from, the contract; the tenders to specify also the time within which each party would undertake to execute the work.

I have the honour to be, SIR,  
Your most obedient Servant,  
J. WA LKE R.



## KURRACHEE HARBOR.

### APPENDIX TO MR. WALKER'S REPORT.

Dated 28th October, 1858.

*List of Plans of Mr. PARKES' Survey of Kurrachee Harbor.*

No. 1 is a general or index Plan, showing the relative position of the parts which were the subjects of detailed surveys, and the exact lines in which the several sections were taken. It contains references to the numbers of the drawings in which the detailed surveys and sections are given. It also contains some soundings of the main channel of the Harbor, and a survey of a channel within the Chinna Creek not given elsewhere.

No. 2 is a Plan of Manora Point and the entrance of the Harbor, with soundings over the Bar and entrance-channels, to a scale of 200 feet to an inch.

Nos. 3, 4, and 5 are Sections of the shores around the Point, of which the lines are shown on No. 2.

(These four drawings contains all the details necessary for laying down works so far as they extend, and form also a record of the present state of the ground, which may be referred to if change should hereafter take place.)

Nos. 6 and 7 give the results of experiments upon the direction and force of the tidal currents into and out of the Harbor.

No. 8 contains cross sections of the spit of sand which extends southward from Keamari, on which a stone bank for confining the water to the main channel is proposed to be constructed.

No. 9 contains sections of the Keamari Beach, or eastern shore of the Harbor, from Keamari public jetty southward to the point at which the sections on No. 8 commence. Future sections, taken in the same lines as these, will show the changes which take place in this beach.

No. 10 is a Plan, to a scale of 200 feet to an inch, of the whole space, embracing the sites for the proposed works for conveying the Chinna Creek waters through the Harbor, and of the Docks or Basins.

Nos. 11 and 12 are Sections over such portions of the ground shown on Drawing No. 10 as are likely to be occupied by works.

No. 13 contains six cross sections of the Napier Mole in its present state.

No. 14 is a detailed Plan of Chinna Creek to a scale of 200 feet to an inch, giving the details necessary for laying down the line of the proposed embankment.

No. 15 contains sections of Keamari Island, showing its present state.

No. 16 is a Plan, with sections, of the present state of the sand-bank which, extending several miles westward from Manora Point, divides the Harbor from the sea. It also shows the changes in the line of high-water mark since 1854.

No. 17 contains a longitudinal and cross sections of the lower part of the bed of the Layari River, with the levels to which the flood of 1857 rose.

There are also appended –

A Diagram, showing the results of the borings made; the positions of the borings being given on the Plan No. 1.

Diagrams of the tidal observations made at Manora Point, from 5th December, 1857, to 15th March, 1858.

*Extract from MR. FRERE'S Letter to MR. WALKER, dated 14th October, 1856.*

I am very certain that, had Sir Charles Napier been alive, no one would have been a warmer admirer of your plan than the conqueror of Sindh. I do not say this at random, because the very first things he began to talk to me about when we met in Sindh, were his plans for the Mole and for the improvement of the Harbor, which he explained at great length; and I feel assured your arguments would have convinced him. I always honestly did my best to carry out his views, not merely from the high respect and warm regard I felt for him personally, but because I always found that when the information before him was full and accurate, it was very rarely possible to improve on any project of his.

As regards the Mole, it is clear from the memoranda, which Sir W. Napier enclosed in his note to you, that Sir Charles wished it to have had bridges across the creeks. He was doubtful of the propriety of closing the creeks, and only refrained from bridging them because the senior naval officer who was there, thought that by closing them up the rush of water along the side of the Mole would be increased to an extent sufficient to deepen the boat channel. The result

has shown, what you would no doubt have predicted, that it would have been better to have adhered to Sir Charles' first plan, and made the bridges at once. But it is quite certain they were always a part of his original plan; and, as I mentioned to you, Capt. Hill (the officer who began the Mole under Sir Charles, and who afterwards finished it) left behind him a rough estimate of the cost of erecting one after the Mole was finished. So far, therefore, from injuring that great work by the openings you propose, you are only completing it as Sir Charles originally intended it.

With regard to the Bar, it was marked on the old charts, sand and rock.' Sir Charles argued, and, no doubt, very justly, that if there were rock there, it would be like that of Manora, soft and friable, and easily removed, and that when once removed, the Bar would not reform. He, therefore, ordered the Bar to be carefully examined, but his orders had not been carried out before he left. This he explained to me; and when Colonel Turner and Lieutenant Leeds carefully examined the Bar, it was found that the charts were incorrect; not a particle of rock could be found on or near the Bar. Had Sir Charles known this, I am satisfied he would at once have seen that other means must be adopted to remove the Bar, and I think he would have fully concurred with you as to the mode of doing it.

I hope you will have time to see Colonel McMurdo, and to explain your views to him, as he is a very able officer, and deeply interested in all that concerns Sindh.

*Extract from COLONEL MCMURDO'S Letter to MR. WALKER, dated 24th October, 1856.*

I have many apologies to offer you for the delay that has occurred in answering your note of the 7th instant; but I have had more to do than I could accomplish, and perhaps more to think about still; which has prevented me from giving that attention to the interesting subject of your pamphlet which is its due.

I have never seen any of the Reports or Correspondence of the gentlemen you mention at the foot of the 4th page: I am only acquainted, generally, with the views and opinions of Sir Charles Napier respecting the Harbor of Kurachee, formed 12 years ago— long before some of the gentlemen named ever saw Scinde, and others of them India itself.

These views and opinions were confirmed by subsequent Surveys and Reports, which were transmitted by the General to the Supreme Government of India.

I am, therefore, naturally surprised to see the name of the great originator of the whole plan omitted among the authorities furnished you as materials for your Report. Be that as it may, however, I am happy to find, in your general opinion of capability, so emphatic a confirmation of Sir Chas. Napier's opinions—enhanced, too, by the same appreciation of the national importance of the Harbor of Kurrachee.

With regard to the plan you have suggested for deepening the Bar, which comprises three important works—*viz.*, the Groyne at Manora Point, the Bank and East Pier, and the stoppage of the Chinna Creek—I am not competent, at this distance of time (and having had no official connection with his plans), to state how far these points were considered by Sir C. Napier; whether as a whole, or as separate plans conceived at different times, bearing upon the great object he had in view—*viz.*, securing a strong and undivided scour in and out of the main mouth of the Harbor: but that two out of the three were entertained by him, I am almost certain.

If I recollect rightly, he abandoned the stopping of the Chinna Creek because he considered it indispensably necessary, for the salubrity of the neighboring cantonments, that the extensive marshes eastward of the Mole should be covered regularly by the tide; and I do not think that the openings you suggest through the Mole would be sufficient to effect this end, when I consider that the immense extent to be covered requires the capacity of the Chinna Creek at its mouth to accomplish. And this Creek is very deep and rapid. I have crossed it with a regiment of cavalry at night, and I found it necessary to place the guiding torch on one side much lower down than the other on the opposite bank, in order to allow for the current carrying the men and horses along with it.

The General secured a certain benefit from the vast body of water thrown in through this Creek by an opening through the Mole near the Obelisk, which caused a scour at ebb tide in the direction of Keamari.

I consider your suggestion of the Bank and East Pier a most important one. There is, no doubt, a vast body of return water wasted in that direction. How far this idea was also entertained by Sir Charles Napier, I do not recollect; but I shall put myself in communication with the naval officer who made the surveys for him at the time, as I am curious to learn what were his precise views on this point, as well as concerning any work at Manors.

I do not, however think he had any intention respecting the latter; because I think it was reported to him that the Bar was not composed altogether of sand, but a soft rotten stone, which would not have rendered the work you suggest necessary.

I think that Mr. Frere's fears regarding the safety of the spit of sand westward of Manora groundless. I have seen the sea break over occasionally in heavy monsoon gales; but the beach is too shelving to admit of any serious injury to the spit; in short, the prevailing gales have themselves formed this great bank u of sand.

Your suggestions regarding the situation of the Docks conform with Sir Charles Napier's views also; and, indeed, it is difficult to understand on what grounds it is proposed to take ships up to the old town to be u repaired. As you truly observe, a canal would have to be dug to admit of ships being so taken, and materials brought there also from Keamari for everything comes to Kurrachee from the sea-board.

The General predicted that the town of Kurrachee would in time be removed to Keamari, and that the new town and shipping should be supplied with water by pipes laid along the Mole from the Layari River; and I remember a plan in which the quays and streets of the new town were projected. Keamari itself is high and safe from the sea.

## **KURRACHEE HARBOR.**

### **MR. PARKES' REPORT.**

**19, PARLIAMENT STREET, WESTMINSTER, 5th June, 1858.**

SIR,

Immediately on my arrival at Kurrachee, on the 27th October last, I reported myself to Mr. Frere, the Commissioner in Sindh, and also to Colonel Scott, the Superintending Engineer, and consulted with those gentlemen as to the means of carrying out, with as little delay as possible, the operations which the Court of Directors, under your recommendation, had entrusted to me.

From Mr. Frere I received introductions to the heads of all the Government establishments at Kurrachee who were likely to be able to render me assistance; and notwithstanding that I was placed under some disadvantage by the departure of Mr. Frere himself for the Districts only a few days after my arrival, his directions that all possible aid should be afforded me were most fully carried out.

Colonel Scott immediately proceeded to make arrangements for supplying me with professional assistance; and as soon as I had made sufficient general observations to enable me to determine upon the details required, he placed at my disposal the services of Lieutenant Finch, of the Bombay Engineers, and of Mr. Gujamun Sudashew, a very intelligent native Surveyor attached to his own establishment.

Subsequently, Lieutenant Pym, of the Engineers, and at Mr. Frere's desire, Mr. Elander, the Deputy Collector of Canals for the Kurrachee District, were also directed to give me their assistance.

Commander Grieve, I. N., who had made in 1854 the very excellent Chart which has been laid before you, arrived in December, and rendered important service to the Survey up to the time of his sudden death on the 17th of January. His duties were, within a very short time, taken up by Commander Barker, I.N., who was dispatched from Bombay immediately on my informing the Commander-in-Chief of the Indian Navy of the melancholy death of Captain Grieve.

The whole of the gentlemen I have named carried out the intentions with which they were detached for the survey of the Harbor with much zeal, and I trust that the results of their labors, which I have the honor to lay before you, will be satisfactory to you.

Besides the gentlemen who were constantly engaged with me, I wish to express my obligations to the successive Executive Engineers, Major North and Lieutenants Finch and Merriman, who were always most ready in responding to my demands for materials, or for any assistance that their establishment could afford: also, to Mr. Maher, the Deputy Collector in charge of the Treasury; Captain Daniell, the Commandant of the Indus Flotilla, who permitted me to make use of all the facilities afforded by the building-yard at Keamari, under his charge; and especially to Lieutenant Giles, the Port Officer of Kurrachee, from whom I received not only much valuable information, but much assistance, both personally and through the subordinates of the establishment under his command.

I mention these gentlemen, to show you what full cooperation I met with from the Company's officers at Kurrachee; and in the hope that, in any Report you may make to the Court of Directors upon my Survey, you will mention the obligations I am under to them.

The principal parts of the Survey made under my direction are given in a series of seventeen drawings, now presented to you, and of which, as a security in case of accident to the originals, I left tracings with Mr. Frere.

From the communication I had constantly with the late Captain Grieve for upwards of five weeks, as well as from a comparison of his Chart with the ground, I was perfectly satisfied that his Chart might well be taken as a general basis of the Survey; and that what remained for me to do was, to add more particular observations on those points which come more especially in the department of the Engineer, *viz.*, the direction of the tidal currents into and out of the Harbor; comparative tidal observations at different parts of the Harbor referred to a datum; the movements of the sand or silt by waves or currents; the nature of the ground, ascertained by boring and surface observation; and more detailed surveys, to a larger scale, of those parts where works are likely to be carried out.

The drawings and documents I now lay before you will speak for themselves; but I propose, in this Report, to call your attention to what appear to me the most important points, adding thereto freely my own conclusions—believing, by that means, you will be the better able to judge whether I have been involuntarily led to give undue weight to any points.

The general features of the Harbor of Kurrachee have been already so well described to you that it is unnecessary for me to repeat them here, and I therefore proceed at once to those particulars which were the objects of my own observation.

The first point which claims attention, as Tides. being the very means by which the Harbor exists, is the rise and fall of the tide. The laws which govern this are very peculiar in the neighborhood of Kurrachee; and I thought I should be justified in extending my observations a little beyond what was absolutely required for the engineering part of my Survey, in order that a Register might be formed, which should, at any rate, give some data for forming practical rules to guide pilots and others in their predictions; and this opinion was so strongly confirmed in my mind, as the materials accumulated, that I recommended to Mr. Frere the re-establishment of a self-acting gauge, of which the machinery was already on the ground, for the purpose of continuing the Register. This recommendation is now being carried out, under Mr. Frere's authority, by Lieutenant Merriman, the Executive Engineer of Kurrachee.

My own Register extends from the 5th December, 1857, to the 30th March, 1858.

The observations were made at Manora every five minutes, night and day, by three observers, relieving one another, and I afterwards reduced them to a diagram form.

Observations were made, also, in a similar manner, for upwards of a half lutation, at Keamari; at the upper end of the Napier Mole, both on the Harbor and the Chinna Creek side; and also just within the Chinna Creek outlet: each of these having the Manora diagram applied to it, shews the extent to which the tide-wave is affected by its flow into the Harbor.

Unfortunately, however, from the impossibility of getting trustworthy observers, the results of these simultaneous observations are not so satisfactory as they ought to have been, considering the time occupied by them, and the care bestowed by my assistants and myself in organizing and superintending them. The Manora observations, extending over four months, are, I believe, very good; but from those at the other stations I do not feel justified in drawing more than general conclusions.

The extent of rise and fall is very variable. The greatest rise registered in the four months at Manora, was 11 feet 6 inches; the greatest fall.10 feet; the least rise 5 inches; the least fall 4 inches. The diurnal inequality in height is so great, that on several occasions a fall of only a few inches was followed by a rise to about the same amount, and then by a fall of 4 or 5 feet and a corresponding rise.

During the greater part of the period of my observations, the highest high waters occurred when the sun was below the horizon, and the lowest low waters when it was above. In the summer months this is reversed.

The diurnal inequality of level is much greater for low water than for high water, being at times 6 feet for low water, but never more than 2 feet for high water; whereas the



diurnal inequality of time is greater for high water than for low water, being sometimes as much as three hours.

The observations now going on will show whether this is also the case in the summer months. The water at Kurrachee, and all along the neighboring coast, is heaped up during the south-west monsoon. I was not able to obtain definite observations to show the exact amount of this elevation, but it is generally considered to be about 18 inches.

The range at Keamari (one mile and a half above the point at which the Manora observations were taken) is 2 or 3 inches greater than at Manora, and the time of high water ten to fifteen minutes later; but the inclination of the water surface at the same instant seldom exceeds 3 inches either on the flood or the ebb. Sometimes, during slack tides, it is inapproachable.

The next observations were made near the upper end of the Napier Mole, and about one mile and a half above Keamari.

At this point, the bed of the Harbor being only 2 feet below half-tide level, we do not obtain the whole range of the tide. The high water, however, rises 1 or 2 inches above the level at Manora, and the time of high water is from twenty to thirty minutes later.

Comparing with these observations simultaneous ones made on the opposite side of the mole to which the tide enters through the Chinna Creek, we find that here the high water is 2 to 4 inches lower, and from half-an-hour to an hour later, showing a great obstruction to the progress of the tide-wave; and comparing these again with the observations just within the Chinna Creek outlet, we find that a part, at least, of the obstruction takes place in the outlet itself, and perhaps in the shoal water outside; for these observations show high water 1 to 3 inches lower than at Manora, and a few minutes later, while the low-water time is still more retarded, and the tide does not ebb out by (at strong tides) as much as a foot or 18 inches.

The practical deduction from all these observations appears to be, that the tide as it flows up the Harbor has a decided tendency to increase its range; and comparing this with the effect of the more obstructed flow through the Chinna Creek and over the Marsh, by which it is rather diminished, I cannot doubt that the removal of the bar, the deepening of the channel to Keamari, and the formation of new channels within the Harbor, will encourage a still greater flow of tide; although, from the water being spread over so great an area, the actual elevation of high-water mark cannot be more than a very few inches.

The observations made on the strength and direction of the tidal currents are shewn in Drawings 6 and 7. The red lines show the courses taken by floats upon the ebb tide, and the blue lines those upon the flood. The arrow heads show the position of the float at

every five minutes, and the figures attached to them the time after or before the nearest high water.

You will observe, that on the ebb the current sets with considerable force over the bar, and nearly at right angles to its longitudinal direction; that it continues its course out to sea, without material deviation from the direct line, for half-a-mile outside the bar; and that it is then gradually merged into a sea current, setting to the eastward.

This easterly current is evidently independent of tidal action, as may be seen by the two lines on Drawing 6, one taken on the early flood of a strong tide, and the other on the early ebb of a very weak tide, yet they give the same general direction, and the same speed.

This sea current is well known to the pilots and boatmen of Kurrachee, who always look for anything floated out of the Harbor, such as boats or timber, on Ghisree Beach, 5 miles to the eastward.

This current appears materially to affect the in draught of the flood tide into the Harbor, for a stream sets strongly round the end of Manora Point; but it is not until the in draught increases, by the water rising over the large expanse of the Estuary, that it sets over the Bar.

I cannot discover in these currents any eddies or sudden changes of strength, or meeting of different streams, which can give occasion to the deposit of the Bar.

Very important natural processes appear to Effect of me to be going on, by the annual long-continued the Waves. action of the waves, caused by the south-west monsoon.

There can be no doubt that the sand upon West Beach. the long beach which is exposed to the sea, to the westward of the Harbor, is in a constant state of movement from west to east. There is a great accumulation in the Bay, between Manora Point and the ledge of rocks which lies half-a-mile to the westward. There is a difference in one part of nearly 200 feet in the line of high-water mark between Captain Grieve's chart and Lieutenant Pym's survey. Sections have been taken over this part of the beach, referred to a well-marked base line, so that they may be repeated, and if the action continue, its amount for the future accurately known. At present, the action does not appear to extend to the extremity of Manors Point—the Point, in fact, as yet acts as a groyne -- but, if the accumulation of four years may be taken as a measure of what may be expected in future, it will not be very many years before the sandy beach extends to the extremity of Manora Point. Should it be allowed to pass it, the Bar will probably assume a different form, that of a spit, dry at low water, while the channel within it and round the end of it, acted on much more forcibly than at present by the contending action of the waves and the scour, will become changeable, instead of nearly constant as it now is.

The next action of the waves is one which I put forward with some diffidence, because I have not seen a monsoon, and because the evidence of it is the Bar itself—for the existence of which other theories have been advanced. I have examined the grounds upon which such of these theories as have been brought to my notice are founded, and I do not think them consistent with the facts I have observed.

You will observe, that just off Manora Point, the depth, at low water, varies from 9 to 15 feet. In this depth, the monsoon waves break, even at high water (they do so all along the Bar), and lifting up sand from the bottom, carry it on with them, until their force is spent in the space under the lee of Manora Point; there, their power of holding sand in suspension being diminished, they deposit it; and hence the nucleus of the Bar, which has gone on growing, by similar means, until the accumulating action of the waves became balanced by the force of the scour of the tidal waters of the Harbor.

This view of the formation and maintenance of the Bar, is, to my mind, confirmed by the following facts:—firstly, that the sand is of the same nature, or nearly so, as that upon the beaches; showing that they come from the same source, though there is no appearance of that of the Bar coming direct from the West Beach: secondly, that the height of the Bar does not materially—indeed, scarcely appreciably—alter by the action of a monsoon, which I can hardly imagine would not be the case, were it due to any cause so violent as that, which, in four years, has accumulated a width of 200 feet of sand.

A third action of the monsoon waves is presented in the point which lies half a mile within Manora Point, and called Deep Water Point. This appears to be the extreme point to which material is carried up the Harbor by the action of the waves—the material being in great part furnished by Manora Point itself, which consists of a crest of conglomerate, varying in consistency—some being almost solid stone, others scarcely more than gravel—about 20 feet thick, and lying on beds of softer material, sand, marl, and clay, which latter is the lowest visible stratum. The washing of the waves wears away these lower strata, the conglomerate is undermined, and large masses fall. All the loose material, and such part of the conglomerate as is disintegrated by the action of the air and sea, are driven by the waves inwards, along the east shore of Manora, up as far as Deep Water Point; and it is curious that, upon the beach around this Point, are found pebbles similar to those of which the Manora conglomerate is formed, while higher up they are not found, or only in occasional heaps, which I believe are dropping from the loads of ballast which are carried up the shore to Baba. These pebbles are collected on Deep Water Point for ballast, but continue to accumulate. I did not, however, find the same pebbles in the centre of the accumulation behind the battery, where I sunk trial pits and borings to 3 feet below low water, the material there being only fine sand. Still, I cannot account for the numerous pebbles on the beach without supposing them to be

washed by the waves from Manora. Deep Water Point does not appear to be extending to the eastward; indeed, a great part of the battery which, four years ago, was formed upon it is washed away; but this is owing to an increased scour, to which I shall presently advert. I think, however, that there is evidence, though not positive, of an increase on the side facing the sea; and I was informed by Lieutenant Leeds, I.N., the former port officer, that there is always an accumulation of sand upon the Point during the monsoon, which is afterwards washed away. The surface of the ground over the triangular space which forms the accumulation is at nearly the level of high water, which would seem to show that if it were formed by waves, it was by waves nearly spent.

A fourth action of the waves is shown upon the shores of Keamari and Clifton, on either side of the Chinna Creek.

There can be little doubt, that along the Clifton Beach the sand travels to the eastward, as on the beach to the west of Manora. There are no materials to give positive evidence of this, but I see no reason to doubt that like causes will here produce like effects. You will observe, however, that the Keamari Shore is under the shelter of Manora Point; the waves do not strike with their full force to the westward of Chinna Creek, but rather spend themselves by running to the westward; and the movement of the sands is, therefore, in a direction contrary to the general direction along the shore, or from east to west. It is quite certain that there has been a very large accumulation of sand at the west end of Keamari, close to the Harbor channel; low-water mark has advanced into the channel an average of 130 feet since Captain Grieve's Chart was made; and although he gives in his Chart no clear description of what was the height of the spit extending from thence towards the entrance, it is clear, both from his own evidence and that of everyone else from whom I have asked information, that it has considerably risen. This is notwithstanding a constant and tolerably strong scour of both flood and ebb currents over it; so there can be little doubt, I think, that the accumulation is due to the action of the waves alone. I had an evidence of this at one particular spot at the extreme southwest point of Keamari. Here there has been, by a comparison of Captain Grieve's and my own plans, a great accumulation of sand; The Railway Company had set up a stone, to mark the boundary of their property, at a point which now is above half-tide level, but which formerly had, by Grieve's Chart, 3 feet at low water. Soon after my arrival at Kurrachee, I measured the height from the top of this boundary stone to the surface of the sand. It was then 2 feet; a few days afterwards, it was nearly 3 feet; and subsequently, the stone itself was washed down. The scour of the current is very considerable round this point; and, evidently, its effect, when unaccompanied by waves, is to carry away, rather than accumulate the sand.

The diversion of the two currents of sand into opposite directions in the neighborhood of the Chinna Creek, may probably have led to the formation of that opening which I have been informed took place not many years ago (by one account 80, and by another

120 years). May not some such cause as the fall of a large mass of cliff, on some part of the shore far to the westward, have temporarily stopped the supply of a sufficient quantity of sand to make up for the waste occasioned by the diversion of the sand left and right from the present site of the creek, until at last the bank of drift-sand was broken through?

If I have truly described and satisfied you, by the facts I have adduced, of the reality of the movements which are now going on through the action of the waves in the monsoon, you will, I think, be confirmed in your opinion, that the works you proposed in your Report of 1856 are calculated to reach the root of the evil. The Pier in extension of Mandra Point will, firstly, anticipate the evil of the sand beach coming round the end of the Point; secondly, it will present a head of regular form, standing in 30 feet depth of water, instead of a broken rugged one in 10 feet depth, whereby the waves will be spent under the lee of the Pier, without being so forcibly broken, and tearing up the sand from the bottom to deposit it as a bar; thirdly, by protecting the east side of Manora Point, it will prevent the foot of the cliff from being washed down and carried up the shore, to increase the accumulation at Deep Water Point.

Thus, three out of the four sources of evil will be met by this Pier; and I can see no improvement upon the direction or extent you have suggested — *viz.*, a south-by-east direction, and a length of 1,500 feet, stopping in about 27 feet of water.

The fourth evil — that of the accumulation of the west shore of the Channel at Keamari — will be directly met by the Causeway you suggest along the sand spit. It will, I have no doubt, be quickly covered by sand on the eastern side.

By means of these two works, then, the West Pier from Manora and the East Causeway from Keamari, it appears to me that the action of the sea, which has resulted in the formation of the Bar and the diversion of the full strength of the scour from it, will be effectually counteracted; so that there is no probability, after the present accumulations have been removed, of their being again formed.

The actual removal of the Bar, however, and Removal of the deepening of the entrance-channel, must be Bar. effected by increased scour; and that this will be sufficient for the purpose, I think, is clear. From three borings, made to a depth of upwards of 21 feet below low-water mark upon the Bar, — the first at 280 yards from Manora Point, the second about half-way to the tail of the Bar, and the third on the tail of the Bar itself — it appears that the whole is an accumulation of very light sand. The last foot in the first boring was of rather harder material, and a few small pebbles were brought up; but even here there was light sand to a full depth of 20 feet below low water.

If the flowing and ebbing currents were confined, so as to pass over only a certain portion of the length of the Bar, instead of spreading, as at present, half-a-mile to the

eastward, there is certainly nothing in the material of the Bar to prevent their forming a channel for themselves of a contracted width, and of a depth in the inverse ratio to the width.

A proof of this is furnished in the process now going on in the channel between Keamari and Deep Water Point. This channel has been, in the last four years, subjected to two influences; first, the actual quantity of tidal water discharged past Keamari was, about four years ago, diminished by the completion of the Napier Mole. During the same period, the raising of the sand spit, by the action of the sea, has been going on; so that, though less water passed Keamari, its course was more confined between Keamari and Deep Water Point, less escaping over the spit.

The accompanying table (see next page) shows the effects upon the channel. It exhibits the sectional area of the low-water channel, at intervals of 500 feet, from Keamari to Deep Water Point, in 1854 and 1858. No. 1, which is close to Keamari, has diminished 9 percent. Most of the others have increased, and in no case is there material diminution. The three last have increased, on an average,  $12\frac{1}{2}$  percent, and the increase extends to the Bar; although, as the channel has no defined low-water boundary the improvement cannot be reduced to figures in the same way. Lieutenant Giles, however, is of opinion that there is now at least one foot more navigable depth than is shown upon Grieve's Chart. The great decrease of No. 1 section, and the increase in No. 2, are, I think, partly owing to the existence of the strong scour round the Point, which has probably rather increased with the rising of the land below. No. 2 section is partly in the line of the scour, and sand has no doubt been deposited from it in the line of No. 1.

If the partial confinement of the channel by the natural raising of the sand-bank has had so beneficial an effect upon the depth, notwithstanding a diminution in the actual quantity of water, it is clear that the raising of the bank to above high water, and so entirely preventing the useless flow and ebb over the sand-bank, owing to which the channel near Deep Water Point is still at least one-fifth less sectional area than near Beamari, will have a still greater beneficial effect. How far this Causeway should be carried—whether only to opposite Deep Water Point or nearly to the Bar—will, I presume, depend upon how far the increasing expense will be justified by the increasing benefit. I think there can be no doubt that every increase of length will be beneficial, especially upon the scour of the flood-tide current.

I do not think any excavation will be required for the removal of Deep Water Point. Its material is a little harder than the soft sand of which the bed of the channel consisted; and thus the current, unconfined as it has hitherto been, worked rather to an increase of depth than of width; but the formation of the Eastern Causeway and Pier would so effectually direct the scour upon the Point itself, that it would soon give way.

*Comparative Table of the Sectional Areas of the low-water Channel between Keamari and Deep Water Point.*

No. of Section.	Sectional Area, 1854.	Sectional Area, 1858.	Increase.	Decrease.
No.	SuperL Feet.	Super£ Feet.	Superf Feet.	Sup. Ft.
1	38,400	34,925..	..	3,475
2	36,050	37,275	1,225	..
3	34,750	34,700	..	50
4	32,375	32,050..	..	325
5	31,100	33,250	2,150	..
6	30,700	32,225	1,525	..
7	30,800	30,975	175	..
8	28,325	29,525	1,200	..
9	28,100	31,000	2,900	..
10	28,575	28,525	..	50
11	29,700	29,650	..	50
12	27,300	27,900	600	..
13	23,800	26,800	3,000	..
14	23,925	27,925	4,000	..
15	27,675	30,075	2,400	..

I do not think that there is any occasion for carrying a wall northward from Manora jetty along the west side of the channel.<sup>2</sup> That shore shows latterly rather an increase than a diminution. Its form is more due to the flood than the ebb tide—the former sets strongly upon it, but the latter rather away from it, as is shown by the current experiments. When the Causeway on the east side is complete, so as to confine the channel, the flood and ebb will be led into the same course, and probably a still further deposit will take place in the hollow shore.

I think, however, that the crest of the sandbank on this shore should be raised, if material from excavation could be conveniently deposited upon it. At present, the water from the Tullah Creek passes through the main channel, from near Baba, downwards; but if the narrow neck of sand which separates the two should give way, a new communication would be quickly formed, to the great injury of the main channel. Such a process did, indeed, commence during my stay at Kurrachee; but, upon my calling the attention of Lieutenant Giles, the Port Officer, to it, that gentleman, and Lieutenant Merriman, the Executive Engineer, at once took measures to fill up the breach, and it was effectually done. A roadway along this shore, up to opposite Keamari, would be

<sup>2</sup> In allusion to a question raised by Mr. Walker in his instructions to me.

very convenient in facilitating intercourse between Manora and Keamari, which, during bad weather, is difficult and sometimes even dangerous.

The diversion of the tidal waters at present passing by the Chinna Creek into the Harbor, is a point of which the importance became more and more evident to me as I proceeded with my Survey. The value of this considerable body of water will be great upon the Bar and entrance-channels; but I think that its value will be still greater in forming a channel especially for native craft to near the town, and thereby saving a great amount of lighter age, which now much encumbers the Harbor.

Previous to the construction of the Napier Mole, while the division of the tidal waters to the Harbor and to Chinna Creek was determined by the ridge of the highest ground, which runs irregularly in a line between the Old Custom House at the head of the Mole, and about the centre of Keamari Island, all on the east side of this line drained through the Chinna Creek, and all on the west through the Harbor. By the formation of the Napier Mole, this line of division has been changed, and is now formed by the Mole itself; whereby a triangular area, having for its base half the length of Keamari, and for its height the length of the Mole, was taken from the Harbor and given to Chinna Creek. Owing, however, to the higher ground between it and Chinna Creek, the water never ebbs off entirely – being, at the lowest, 2 or 3 feet higher than that on the Harbor side of the Mole.

With the exception of this portion, however, the whole of the water east of the Mole passes, every tide, by the Chinna Creek, and its power is shown by the sectional area of the two channels which meet near the outlet. The westerly of the two appears to have very much increased since Captain Grieve's survey (made very soon after the Mole was closed in), for only the outlet of a small channel is shown, and he was not aware of the existence of a considerable one. I have, however, surveyed it, and I find it to be, taking a fair average of its capacity, 50 yards wide, 6 feet deep, and running 3 miles per hour on the ebb. The other, which has not materially changed since Captain Grieve's survey, is of about the same capacity. If the water of these two channels were brought into one, we should have a capacity of 100 yards wide and 6 feet deep, and this with a velocity of stream certainly more than sufficient to maintain a permanent channel.

The ground over the whole of the tidal area eastward of the Mole, is generally at a level of 6 to 8 feet above low water, or 1 to 3 feet below high water of spring tides. The surface consists of a layer, from 3 to 6 feet thick, of stiff black vegetable mud, formed of silt mixed with decayed mangrove bushes, and lying on a bed of sand of variable quality; in some places, fine and very thick; in others, coarse, approaching gravel.

The whole overlies a bed of stiff blue clay, of which I was not able to ascertain the thickness, but I drove 4 feet into it, without passing through it, at Keamari; and at Kurrachee, where it appears on the surface, it is 5 to 6 feet thick. Its depth, at Keamari, is



25 feet below low water; at the head of the Mole, 9 feet below low water; at Chinna Creek, about the same; and intermediate borings show, that its surface slopes more or less regularly over the space between the above-mentioned points.

After a consideration of all the circumstances, I have sketched out the Plan<sup>3</sup> shown on the accompanying drawing for leading the Chinna Creek waters into the Harbor. I propose to carry the Mole in a new straight line from near the Old Custom House to the bend near the Napier Obelisk, and on this line to construct a portion on piles for a length of 1,200 feet (the width of the present Chinna Creek opening), by which the tidal waters shall be passed. I propose that, from the northern abutment of this bridge, a jetty of masonry should be carried in a curved line westward, as shown, for a length of 1,400 feet; each side of the jetty to be formed with wharf walls for native craft to lay alongside, and to be provided with suitable cranes, moorings, and sheds, so that the bulk of the native trade may be carried on upon it and the portion of the present Mole between it and the Custom House, which I should propose to double in width. As soon as the new line of Mole, including the bridge, is finished, the existing line would be removed.

To lead the tidal waters through the opening above described, I propose to form a channel about one mile and a quarter in length alongside the jetty, and across a part of the marsh to the most convenient point for a junction with the main eastern channel communicating with the Chinna Creek.

To form this new channel, it would only be necessary to excavate the upper stratum of mud, of which 6 feet appears to be in this part the average depth. The sand below this would be scoured out by the current. The channel from the end of the jetty to Keamari would not, I think, require any artificial excavation, as it lies along the site of an old channel which has gradually silted up since the Napier Mole was made, and which is stated to have been formerly navigable for the largest class of native craft (drawing about 9 feet).

I have considered whether it would be advisable also to make an opening lower down the Mole for the supply and escape of the water to the triangular space before-mentioned, where the water is now penned up. By so doing, the quantity of water to be added to the channel below the opening would be increased; but, on the other hand, a considerable area of the upper part of the tide would flow through it instead of through the channel above, and so the capacity of the latter would be decreased. If the expense should appear to be justified, a new channel might be made between this space and the main new channel east of the Mole; but I think it would probably form itself in a short time. On the whole, I think the balance of advantages is against any second passage through the Mole.

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<sup>3</sup> Embodied in Mr. Walker's general design. See Plan (A).

The closing of the Chinna Creek should be undertaken when all the passages and channels for leading the water through the Harbor have been completed.

Should you approve of the mode above described, of leading the Chinna Creek waters through the Harbor, I think that the employment of the space between the Mole and the new channel (a width of about 500 yards) is worth your consideration.

It has occurred to me, that it would be a convenient site for the formation of deep Tidal Basins, which might—partially, at least—supersede the necessity for floating docks on the east side of the Mole. The determination of this point must depend, in a great measure, upon the relative merits of Tidal Basins or Docks, with a fixed water-level—for I do not think there would be room for entrance-locks on the west side—so that the basins on that side must be tidal;<sup>4</sup> while on the east side, as the communication in line of the Mole must be preserved by a bridge over a contracted entrance, the works necessary for this purpose would become part of the lock.

The level of the clay, as a foundation for the quay walls, is a little higher on the east side; but, on the other hand, it is even there (being from 19 to 25 feet below low water) unnecessarily deep for the foundation of dock walls, so that the saving of expense in the depth of foundation would not be in proportion to the difference in level of the dock water surface and low water of spring tides.

There are many points affecting the question—such as, first expense of construction, and the subsequent convenience for shipping—which will present themselves to you, but which it is unnecessary for me to indicate. There are, however, two other local points. The first is, the necessity of carrying a ship-entrance under the Mole. The Mole is now, and, it seems to me, must always remain, the great thoroughfare between the town and cantonment of Kurrachee and the steamboat landing-place, which will, doubtless, continue to be at Keamari. The traffic on this thoroughfare is now very considerable, and will no doubt increase. I think the avoidance of such an interruption as would be caused by an opening bridge over an entrance-lock a matter of great importance. It is true that, if railways were brought alongside the wharfs on the west side, the trucks must cross the road, but this would be less objectionable than ships. The second point is, the liability of the Basins to silt up. On this point I would remark, that the process of silting is very slow in Kurrachee Harbor; the tidal currents are not strong, and the entire absence of land water, except during the floods in the Layari, prevents that preponderance of a downward current, which, in ordinary cases, prevents tidal channels from ever attaining a perfect regimen. At any rate, the water in the Harbor is very clear; and there are not, so far as I have been able to observe, any evidences of

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<sup>4</sup> By the arrangement proposed by Mr. Walker (see Plan), a dock, with an entrance-lock, is placed on the west side of the Mole.

rapid accumulation (except that of sand under the influence of the waves, which does not reach above Beamari). I think, therefore, that although the tendency to silting, in the proposed Tidal Basins, should be certainly taken into account, it may be put down at less than an ordinary amount.

A point to which you directed my attention, is, the security of the sand-bank which separates the Harbor from the sea to the westward of Manora Point. In order to record and to give you an idea of the present state of this bank, I had sections of it taken, and a plan made of its present position (shown on Drawing No. 16). The dotted lines show its position as given by Captain Grieve, and the lines shaded blue its present position. You will observe considerable changes; and there are indications on the ground of considerable changes having occurred. The bank, however, seems always to present the same kind of face to the sea; and a short time is sufficient for its top to be covered with a coarse jungle-grass, which collects sand drifted by the wind about the roots, and adds to its height and apparent security. I think, however, that the real security of this barrier lies in its very weakness. It consists entirely of light sand, containing a large proportion of small fragments of shell, and it offers the least possible resistance to assuming any form which the waves may tend to give it. The present form is evidently given to it by the heavy surf of the monsoon; and so long as the waste caused by the travelling westward is supplied, I conceive it will maintain its general form, though it may change its position. Occasionally, the waves seem to break over it and carry away the crest; and there is one spot where the highest part of the bank is only 5½ feet above ordinary tides, or not more than 4 feet above the monsoon high water; it is denuded of vegetation, and a great mass of sand lies within the general line of the bank – evidently carried on by the waves. I observed, however, in the same neighborhood, other places where the same thing had occurred – the mass of sand remained inside the bank, but the crest had reformed, and was again covered with vegetation.

I should, therefore, think that there need be no apprehension about the safety of this barrier, but that, on the contrary, it would be improper to place any solid mass, such as masonry or timber groynes, on the beach, which might disturb the equilibrium at present existing between the force of the surf and the mobility of the sand.

The next point is the Layari River, and its influence upon the scour of the Harbor. The information I have been able to gain on this subject is rather meager. As you are aware, the river runs above ground only for two or three days in the year; but by sinking a few feet into its gravelly bed, water is always found, so that the underground stream is constant, though probably the discharge is small.

I had a longitudinal and cross sections made of the lower two miles of the river's bed, with a view of estimating (if possible), even approximately, the discharge during floods; but the result was not satisfactory. The bed being liable to change by every flood, the formula applicable to a constant channel and constant inclination are not applicable in

this case. There is, however, in the 10,000 feet—the length of my section—a fall of 16.38 feet; and, taking the average sectional area of the channel in the last flood, as given in the cross sections, at 743 cubic feet, we obtain a discharge of 245,190 cubic feet per minute; or, 353,073,600 cubic feet in twenty-four hours. By a map shown me by Mr. Hardy Wells, the late Engineer to the Sindh Railway Company, I found the drainage area of the Layari Valley to be 224 square miles.

The above quantity—353,073,600 cubic feet per twenty-four hours—would give a depth of rather more than three-quarters of an inch over 224 square miles—a proportion of the rainfall in one flood which appears likely enough to be carried off by the river; so this may be perhaps taken as, at least, some approximation to the actual quantity.

I will now compare this quantity with the discharge of tidal water on the ebb tide. The area of the channel at half-tide, a little above Deep Water Point, is 35,000 superficial feet, and the surface velocity is 135 feet per minute (which gives 112 feet per minute as the mean velocity), upon a tide which falls 6-1 feet; whence we obtain  $(35,000 \times 112)$  3,920,000 cubic feet per minute as the tidal discharge, against 245,190 cubic feet per minute of the Layari discharge—being in the proportion of 16 to 1 nearly, and this for only five or six tides in the year.

The power, therefore, which the Layari exerts in scouring the lower part of the Harbor is quite insignificant. Its effects in the upper part are more important; but I do not think it would be advisable to confine its channel through any part of the open Harbor.

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 injury 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.

Having now submitted to you such of the results of my Survey as will enable you to decide upon the general nature of the works to be recommended; and assuming that your ultimate decision will be in favor of those recommended in your first Report, with some modifications, I will now take each of those works in turn, and lay before you such local information as, I think, will enable you to decide upon the details of their construction, and form a tolerably correct estimate of their cost.

With regard to cost, however, although I have received information as to the expense of the works of various descriptions actually executed, both at Kurrachee and at Bombay, I do not think that these furnish a correct criterion of the cost of the works you propose. At the present time, labor at Kurrachee—and in a less degree, also, at Bombay—is very scarce, and the workmen very inefficient; and I believe that in operations of the scale of

those contemplated at Kurrachee, the organization and means which would be brought to bear upon them would have an important effect, and, I think, would generally more than compensate for the increase in the nominal rate of wages which perhaps may take place. In a word, I do not think that the present cost of public works at Kurrachee, or the information gained from the limited experience of Engineers and others on the spot (though it was always most freely afforded me), will be any safe guide to you in estimating for these works. When you are sufficiently informed of the means of obtaining the materials of construction, and their nature, I think your own experience will be your best guide. I propose, therefore, at present only to lay before you in this Report information as to what materials can be procured, and how they can be brought to the spot, retaining for our future personal communications those particulars as to present cost, &c., which I think would rather tend to mislead you, unless accompanied with longer explanations than it is worthwhile to give here.

To begin with the West Pier in extension of Manora Point. This work will have to be constructed in the face of a very heavy sea, of the force of which some idea may be formed from the fact that the Bar, 18 feet below high water, causes the waves to break upon it. There will be, however, on the other hand, the great advantage of eight continuous months in every year of comparatively calm weather. During the whole of my stay (November to March), I never saw a sea of sufficient force to cause injury to moderately-strong temporary or unfinished works. What is required, therefore, is to adopt such a mode of operation as will present, at the approach of each monsoon, a portion of work complete.

The principal materials required will be (whatever section you may determine on), a considerable quantity of rough stone for the base and hearting, and of stone of good quality, and in moderately-large blocks, for face-work. Stone suitable for both these purposes can be procured at "Hand's Hill," 3 miles from Kurrachee and 5 from Keamari, the quarries being within 300 yards of the intended line of the Sindh Railway; by which, therefore, if a suitable arrangement could be made with the Railway Company, the stone might be brought to Keamari and their hand-shipped into barges for Manora.

The stone is a limestone, variable in quality, and care would be required in selecting the best beds for the Ashlar work; but its state in old buildings shows that some at least is very strong and durable. This stone has been used to a considerable extent in the formation of wharf walls along the Napier Mole: the blocks there average about 4 feet long by 1 to 2 wide and high; but, by proper means, much larger blocks might be obtained.

As a material inferior to this, but much cheaper, the Manora conglomerate might be employed as hearting where not much exposed to the wash of the waves; and I think that large blocks of this material would be found useful for at least temporary purposes

during the progress of the work. It appears to disintegrate in time by the action of the air and sea, and therefore cannot be depended on where durability is required.

For the best description of work, copings, quoins, &c., Bombay basalt would be available. The present cost varies much, according to the size of the blocks, owing to the want of proper means of quarrying; but there is every natural facility for obtaining and squaring stones of any size. I saw excellent granite close to the shore at Sudasughur, 250 miles south of Bombay; and I have been informed that it may be procured of equal quality nearer to Kurrachee.

The Hand's Hill stone above-named affords good lime; though that made from boulders of the same kind of stone found in the bed of the Layari is preferred. This lime is not naturally hydraulic, but may be made so by the mixture of a certain proportion of clay found in the neighborhood. Colonel Scott and Captain De Lisle, of the Bombay Engineers, were engaged during my stay at Kurrachee in making experiments as to the best proportions. I was not able to hear of any very quick-setting cement being used in the country; so, if such should be required, it would probably be necessary to import Roman cement from England. The ordinary mortar, however, sets very quickly, and in a few hours is hard enough to bear the wash of the waves. Freshwater sand, of all degrees of fineness, can be obtained from the Layari; and the sea sand is of good quality and more easily obtained, if the presence of a large proportion of broken shells do not prove injurious to the strength of the mortar.

The timber most available for staging and temporary works, is that known as "Cutcha teak," though, in fact, it is not a teak. It can be procured of any size and scantling, at from 1s to 2s. per cubic foot, in log, according to the dimensions and quality.

Pine from the Himalayas is also being introduced into the market. The price will probably be about the same as the Cutcha teak. It will not be necessary to provide a more expensive approach to the Pier than that which the Pier will be required during the progress of the works, and which can be readily formed by roughly building up the masses of conglomerate already on the ground.

The next work is the Causeway upon the Keamari sand spit. The only difficulty likely to arise in the construction of this work will be from the scouring away of the sand immediately in advance of the end of the work by the strong currents setting across the bank, both on the ebb and flood. I am informed that there is a heavy surf upon this bank in the monsoon; but as there is so evident a tendency to accumulation, anything which would serve to collect sand would be speedily covered on the exposed side. For some distance from the shore, at any rate, I think a dyke of stakes and bushes, weighted with stone, would answer the purpose.

Small branches of Cutcha teak, 15 to 16 feet long, and 2½ inches average diameter, called in the country "*Bullees*," are easily obtained at from 6s. to 10s. per score, say 4d. to 6d. each. These would serve for stakes, and faggots of mangrove bushes can be had for the cutting.

Nothing but experience can point out for what portion of the whole length this description of work will answer the purpose. So soon as the surf is too heavy, or the accumulation of sand not rapid enough, a bank of stone from the Hand's Hill quarries may be substituted: this may be run out to the spot by Railway. For the superior description of work required for the outer end, and for the East Pier in extension, if constructed, materials similar to those of the West Pier will be available.

I now pass to the diversion of the Chinna Creek waters through the Mole. The cheapest and most advantageous plan of forming the new line of Mole will be by side-cutting. The stiff mud which covers the surface on the east side of the Mole is a good material for the purpose. The excavation might form channels in connection with the main channel.

The mode of carrying the roadway over the Opening. tidal opening will, no doubt, form matter for your consideration.

I think timber piles are inadmissible here, as everywhere else in this Harbor within the range of the tide, on account of the ravages of the shell-fish, which eat into the wood.

I suggest for your consideration the employment of cast-iron pipes of 12 to 14 inches diameter, which may be sunk through the sand by means of a valved shell, as we sunk the boring pipes. They might be driven a sufficient distance into the clay by a light monkey, and the interior filled with concrete. The roadway might be supported on beams of the best teak, which is very durable though expensive (4s. to 6s. per cubic foot in the log). I am informed, that to protect teak from the ravages of the white ant, it is only necessary to employ some other kind of timber for those parts which can be easily renewed, for the insects will not touch teak so long as any other timber is within their reach.

In order to lay dry the site of the foundations of the proposed jetty for native craft, I think a stank of earth would probably be sufficient. In boring on this spot, we found much less water than elsewhere; though there was no apparent material difference in the nature of the ground. The hard stratum of clay and gravel is found at 9 feet below low water. The channel, scoured to this depth, would be sufficiently deep for the native craft; so that, if the wall on the channel side were sunk 2 feet into the clay, and on the upper side 3 or 4 feet below the present surface, they would be quite secure.

The walls might be in part constructed of the stone of the dry wharf wall on the east side of the present Mole, which should be removed before the widening is executed. There will be no occasion for a wharf on the east side of the Mole. The 1,200 feet of the west side which will be removed, will be also available for this purpose. The facing-stones, however, will generally require redressing.

As I have before stated, I think a channel will have to be excavated from the outer end of the proposed new jetty, to join the existing channel connected with the Chinna Creek—a total length of about one mile and a quarter. The average depth of excavation should be calculated at 6 feet; below which there is probably nothing but sand, which will scour out. I think little or no excavation will probably be required beyond the end of the jetty, as this will be in the line of the old channel which has silted up. The best width for the new excavation will be matter for your consideration. I would suggest 80 yards at the upper end, gradually increasing to 100 yards at the lower end.

The excavated material should be laid in spoil on the side of the channel, from whence it might advantageously be taken in boats to form the embankment across the Chinna Creek.

The Chinna Creek would, of course, not be closed until a free passage has been provided for the tidal waters in the other direction; and, even then, I think some difficulty from the scour must be anticipated, as the tide will enter and go out rather earlier by the present route than by the new opening in the Mole. As to the site of the bank, there is no choice. The closure should be commenced and completed in one season; for, owing to the greater height of the high water during the monsoon, and the consequently greater area of flat ground covered, the current through the outlet must be greatly increased. As the shores of the Creek are, on each side, loose drift sand, while the hard substratum is at no great depth (9 feet below low water), it would, probably, be well to commence on each shore, and close between the artificial banks and the hard bottom. It has occurred to me, that it would be a good plan to form a bank of stone across first, and afterwards back and raise it with earth. Stone might be brought from the westward by Railway; and, from the eastward, conglomerate, similar to that at Manora, might be brought from Clifton (where there is a large quantity) by bullock carts, or other native means of conveyance. By such means, I have no doubt, everything might be complete between the end of one monsoon (in September), and the beginning of the next (in May).

The last division of the proposed works, are the Docks, or Tidal Basins, as you may decide upon. The first and principal point for consideration here, is the mode of founding the walls, locks, &c., and excavating below low water. The borings show the ground in this part of the Harbor to consist of a very running quicksand, so loose and full of water that I do not think the sides of the excavation will stand, at any reasonable inclination, without artificial support of some kind. It will be necessary either to



surround the whole site of the works with a coffer-dam, resting upon the clay, 19 to 25 feet below low water, or to adopt some plan of bringing the walls up to low-water mark, without laying dry the foundations. The system of sinking masses of masonry through sand, by what is generally known in India as the "well system," has been suggested to me by Colonel Scott and others. This has been practiced with success in various parts of India; but I have had no opportunity of witnessing the operation, nor have I heard of any instance similar to that of a long line of quay-wall having been attempted.

An alternative plan would be the driving rows of sheet piling, for the face and for the back of the walls, up to low-water mark, dredging the space between, and filling it in with concrete. The locks, if constructed, would still require a coffer-dam; and if they were dispensed with, it would be a question whether it would be better to lay the basin dry by closing the entrance with a coffer-dam, and so excavate the interior, or to dredge it by machinery. It would, perhaps, depend upon whether the coal lately discovered in Sindh could be supplied at a much cheaper rate than English coal or firewood.

The present cost of coal at Kurrachee is variable; vessels frequently bring it as ballast, in which case it is sometimes less than £2 per ton; but when exported express from England, it is generally about £3 per ton. Wood would be even more expensive for engines at Kurrachee, under ordinary circumstances, than coal.

As to the disposal of material from excavation, I think that a portion might, with benefit, be deposited on the shore between Baba and Manora, as I have before described. A part would be required to make up the quays; and, should there be any excess, it might be carried out to sea, and dropped well to the eastward of the entrance.

Before concluding, I wish to offer one remark as to the organization to be established for the carrying out of these works. You are, no doubt, aware that this is a more extensive operation than any which has been carried out in the neighborhood of Kurrachee, or, I believe, in Sindh. The Sindh Railway, although perhaps a larger undertaking on the whole, is spread over 100 miles of country, whereas the Harbor Improvement Works will be centered in a comparatively small space. From what I have seen of the natives, their want of enterprise, love of idleness, and general inefficiency, I feel persuaded that, to carry out these works with economy, there must be a very large infusion of foreign labor, and an almost complete introduction of foreign superintendence. This consideration will, no doubt, be an element in your decision as to what parts of the design should be recommended to be pushed forward at once, and what left for future execution, as the increasing trade of the Port may demand.

I have the honor to be, SIR,  
Your most obedient Servant,  
W. PARKES.