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ROTTERDAM.

PAPER BY

W. GUSTAV TRIEST,
New York City, U. S. A., May, 1894.

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INTRODUCTION.

The majority of the great ports of the world are situated on large rivers, either some distance inland or at their mouths. The advent of steam navigation and the subsequent revolution in the size of sea-going vessels have imparted an ever-increasing importance to the improvement of the river outlets and of the rivers up to the centres of commerce, as the natural waterways are rarely sufficient any longer to accommodate modern vessels. Each lengthening of the waterway, and the resulting reduction of the transit by rail, diminishes essentially the freight charges and consequently the price of goods. In the struggle for superiority in the maritime trade all ports are bound to succumb which do not allow the deepest draft ships to go up to their docks. Vast sums have been expended during the last few decades to deepen and enlarge the natural waterways, but only recently the building of artificial ways of access has been begun. One of the earliest undertakings of this class which can consequently be best judged as to its success is the so-called „new waterway" to Rotterdam. This work, together with harbor improvements, will doubtless raise Rotterdam to that prominent place among the European ports to which it is entitled from its favorable location at the mouth of the Rhine as an *entrepôt* of the commerce of a large part of Holland and central and southern Germany.

NATURAL COMMUNICATION WITH THE SEA.

Rotterdam is built on the banks of the „Nieuwe Maas", or New Maas, one of a remarkable system of outlets by which the waters of the Rhine, the Meuse and the Scheldt, unite and discharge into the North Sea. The ancient arm of the Rhine which alone, through the Netherlands, bears the name of the Rhine, has long since ceased to be an outlet of the river waters, being closed by guard locks. The main body of the Rhine flows by Rotterdam under the name of the New or „Nieuwe" Maas. The natural mouth of the Maas, entering the sea at Brielle, had a sufficient depth until the beginning of this century, so that even the deepest vessels of that time could ascend it as far as Rotterdam. There appears to have been at that time a greater depth on its bar than now. It still accommodates ships drawing not more than 10 to $11^1/_2$ feet (3 to 3.5 m), but with strong Westerly winds the sea runs so heavy upon the entrance bar that the passage becomes impracticable. Access for vessels of larger draft had to be sought by way of the distant harbors of Brouwershaven or Goeree and through intricate shoal-beset channels. Owing to the unsatisfactory character of the natural routes of navigation, from 1827 to 1829 a canal was dug through the island of Voorne from Hellevoetsluis to Nieuwesluis. This canal is about 8 miles (13 km.) long, has locks at each end and affords passage at any tide to vessels of 230 feet (71 m.) length, 45 feet (14 m.) width and 17 feet (5.15 m.) draft. The ordinary surface level corresponds to low water at Hellevoetsluis, but it can be raised 6 feet (1.8 m.) above that level. With the increase in the size of ships the depth of water on the bar and shoals of the Goeree Pass and the restricted length of the canal locks soon became insufficient. Large vessels of great draft entered the Brouwershaven Pass, discharged part of their cargoes into lighters, sometimes outside by the Goeree Pass, but oftener by the interior passage, to Hellevoetsluis and through the Voorne Canal to Rotterdam.

It may here be mentioned that the national hydraulic works of Holland with the supervision over the river and ocean dikes is in charge of a permanent board, the „Waterstaat". As organized in 1848 this board consists of two inspectors, five engineers-in-chief of the first class, and four of the second, fifteen engineers of the first class and fifteen of the second. After the completion of the Voorne Canal the engineers devised various projects for removing the defects of that route. Mr. Greve, a former chief-engineer of the Waterstaat, proposed a jetty starting from the island of Voorne in a North-westerly direction, then, making an elbow, running parallel to the Goeree Shore and terminating in the sea at the line of $16^1/_2$ ft. (5 m.) depth below low water. This jetty would have been nearly 9 miles (14.5 km.) long and would have cost $ 30,000.000. Mr. Greve and Mr. Conrad, engineer of the Waterstaat, recommended also the construction of a new canal through the Western point of the island of Goedereede, connecting the Springers-deep with the Haringvliet. The locks of the Voorne canal were to be lengthened and the river navigation bettered in various ways.

The question of improving the waterway became so urgent that, in

1857, the Government appointed a committee of engineers of the Waterstaat to consider the projects of improvement. By order of the Government Mr. Greve made a report in the same year in which he advised improving the entrance of the Nieuwe Maas by a pair of dikes of fascine work, at a cost of $ 3,600,000. The dikes were to start from either shore, paralleling each other for the greater part of their length and terminating at a depth of 18 feet ($5^1/_2$ m.) below low water. They were to reach to a height of 9 feet ($2^3/_4$ m.) above low water and their combined length was to be about $11^3/_4$ miles (18.9 km.) A very similar plan, but contemplating lower and shorter dikes, was proposed about the same time by Mr. P. Caland who was then engineer of the Waterstaat. A year later Mr. Caland submitted a project which differed considerably from the two above mentioned. Instead of attempting to obtain an outlet through the old mouth, the Northern arm of the Nieuwe Maas and the Scheur, were to be followed and then extended by a channel cut through the Hoek van Holland, with a dam across the old outlet of the Scheur just above the proposed cut. The plan also contemplated improving the whole river from Krimpen to the new cut by means of lateral dikes which would modify the directions of the currents and correct the channel widths. A cut was to be made through the Easterly point of the island of Rozenburg so as to throw the waters of the Old Maas into the Scheur. A uniform depth of 21.3 feet (6.5 m.) at low water was to be obtained from Rotterdam to the sea. The great advantage of this last project was mainly that a depth of 18 feet (5.5 m.) below low water could be obtained with jetties of a total length of 8530 feet (2600 m.) Furthermore, the Scheur branch of the Nieuwe Maas is more regular and better adapted for a great navigable channel than the Southerly branch which passes by Brielle.

The Waterstaat made the following criticisms on the above propositions. Mr. Greve's plan for the improvement of the Goeree Pass involved a very great expense, while the desired result could not be regarded as certain. To the Goedereede canal the objection was made that in addition to the admitted inferiority of canal to open river navigation, there existed in the Haringvliet directly in the route of vessels, a shoal which was doubtful of removal. The objections to the Greve plan for the improvement of the Brielle Pass were as follows: It does not provide for the free admission of the tidal flow which is mainly influential in maintaining depth in the outlets of rivers; further, the jetties are given the height of storm-tides, thus increasing the expense and needlessly exposing the work to injury. The construction of the excessively long jetties would be difficult as they would be built upon the existing shoal on which the breakers are violent during moderately strong Westerly winds. The last remarks apply also to the first plan of Mr. Caland with the qualification that the lesser height diminishes the expense and affords less exposure to injury from wave force. The commissioners adopted Mr. Caland's second plan with some slight modifications, and a law passed in January 1863 provided for its execution. Thus was to be realized the project of the Dutch engineer CRUQUIUS who, in 1739, had proposed to open a shorter outlet to the waters of the New Maas by cutting through the Hoek van Holland. In endorsing the plan the commission presented some „general considerations" on the improvement of navigation into the mouths of tidal rivers. A short abstract of the same follows:

„Theory and experience have taught that the most powerful agent in maintaining the depths of the Dutch tidal outlets is to be found in the velocity with which the water moves through the section of the navigable channel. If the velocity and volume of water required cannot be obtained, resort must be had to dredging or to artificial canals.

„The incessant action of the tides and waves keeps the sands in constant motion along the Dutch coasts, establishing such a slope that a depth of 18 feet ($5^1/_2$ m.) below low water cannot be found nearer than 2600 to 4300 feet (800 to 1300 m.) from the shore line. The drainage water of the rivers is quite inadequate to maintain, through this slope, a channel of a depth sufficient for large vessels, owing to the great width of the river mouths. But the tide enters the mouths and, during ebb, is discharged with the accumulated drainage water, than which, however, its volume is many times greater. Hence the maintenance of depth in the Dutch river outlets is principally due to the action of the tides. This action increases with the tidal range. To increase the latter is not within the power of man, but the direction and form of the entrance may be regulated. The outlets of the Dutch rivers in the North Sea all have a curve to the Southward whereby they better guide the tidal current which flows from out the channel. The shortest line to the required depth is nearly North-west because the coast trends North-east but as the tide-stream comes from the South-west, the direction should lie, at least, East and West.

„The volume of rivers grows as they approach the sea. To maintain an equal depth, the width must hence be the greatest at the outlet, diminishing funnel-wise in ascending.

„For the protection of the outlets externally, jetties must be used. Inland, the width of the rivers is often regulated by jetties of cribwork. For the lower rivers this method is undesirable, as between the cribs there remain basins which the tide must fill, thus diminishing its upward flow. The further the tide reaches the more powerful will be the ebb, and preference is therefore given to lateral dikes."

The law of 1863 established the width of the tidal stream at 740 feet (225 m.) at Krimpen, gradually increasing to 1480 feet (450 m.) at Vlaardingen and to 2960 feet (900 m.) at the sea end of the jetties. These widths were fixed on the assumption that, owing to the removal of the existing contractions, particularly those at Rotterdam and Charlois, the tide would ascend higher and need larger cross sections. Such are required also between Rotterdam and Krimpen to relieve the flow of the Lek. For the heights of the lateral dikes the mean between high and low water was taken; a greater height would diminish the quantity of tide-water while a less height would decrease the effects of the ebb currents. The following sections of the dikes from Krimpen to the Hoek were determined upon, as far as they are not a part of the shores themselves. The top width is 10 feet (3 m.) with slopes on the river side 1 to 1, on the land side $^1/_2$ to 1. The landward berms are $6^1/_2$ feet (2 m.) wide, while the berms on the river side are 16 feet (5 m.) at Krimpen increased to 48 feet (15 m.) at the outlet. Along the cut through the Hoek and connecting with the „downs" high dikes on each side were planned with the double object of making suitable connections with the sea jetties and providing areas of land protected from overflow, where men and goods would be in security during storm-tides. The two sea jetties were to consist of fascine work with stone. The new cut was calculated at a width of 164 feet (50 m.) and a depth of 10 feet (3 m.) at low water in the expectancy that the river, after the damming of its old outlet, would scour a bed of sufficient depth and width. The cost of the whole improvement was estimated at only $2^1/_2$ million dollars, the work to be completed in 6 years. The construction of the North jetty was begun in 1863 and finished in 1874, while the South jetty was started in 1864 and completed in 1876.

Construction of the Jetties.

The length of the Northern jetty is 6560 feet (2000 m.), while the South jetty is 7550 feet (2300 m.) long. The jetties begin at the high dikes on the shore above mentioned, at an elevation of 3 feet 3 inches (1 m.) above mean high water at the high water shore line. They are well connected with these dikes so that the water cannot scour behind them and tear them off. From the shore their top descends in an easy curve to a height of about 3 feet 3 inches (1 m.) above low water. The ordinary tidal range is 5 feet 7 inches (1.7 m.) more or less.

The jetties consist of mattresses of fascine work covered with stone, of the dimensions as given by the drawings. Their top is curved 20 inches (0.5 m.) and paved with large blocks. They were constructed on the sea-beach between high and low water so that after completion they could be floated off at high tide. They were towed to their location and anchored with sinking lines, loaded with stone and sunk to the bottom. The mattresses were loaded wiih at least half a ton ($^3/_5$ ton) of stone per cubic yard (cu. m.) of fascine work. The mattresses consisted, in the first place, of a grillage of fascines, the bottom layer of which lies crosswise at distances of 36 to 40 inches (0.9 to 1 m.) between centres. The fascines were 4 to 6 inches (100 to 150 mm.) in diameter and were composed of small branches of willow trees. The upper layer of fascines crosses the first one at right angles; they are laid not more than 36 inches (0.9 m.) centre to centre, and are made as long as possible, as longitudinal strength is needed. Where jointed they are spliced by short fascines bound to them, or they are united by cutting open the end binding-withes and interlocking and binding the ends together for a length of 5 to 6½ feet (1½ to 2 m.). The two layers are connected at the intersections with flexible withes, while along the circumference and at alternate inside joints they are bound together with tarred ropes. These ropes are cast around stakes so that they can, after the filling up of the mattresses, be made fast to the upper grillage. On and perpendicular to the bottom layer are then placed loose layers or bundles of osier willow, in which the longitudinal fascines are thus embedded. A second layer, called the filling layer, is put crosswise. Over this filling layer are placed the longitudinal fascines of the upper grillage, between which is put down a second filling layer. A final cross layer of fascines is then so laid that their intersections with the longitudinal fascines coincide with those of the lower grillage, which are marked by the above mentioned stakes. These intersections are bound with the same cords, so that the osier filling is compressed as tightly as possible between the two grillages. The other intersections are stiffly bound with withes. The stakes are then withdrawn. The three layers make a mattress 16 to 24 inches (40 to 60 cm.) thick. The upper surface of the mattresses is provided with enclosures of hurdle work in order to keep the ballast in place should the bottom be sloping. The size of the mattresses depends on the convenience of transportation and of sinking; they should contain not less than 480 sqare yards (400 sq. ft.). The largest mattresses sunk have a breadth of about 50 feet (15 m.) and a length of from 490 to 590 feet (150 to 180 m.).

Above low water the fascine work is laid in separate fascines by hand. These, like the mattresses, are loaded with stone.

The jetties are consolidated by oak piles, 30 to 38 feet (9 to 11½ m.) long, which are driven through all the layers into the bottom. The tops of these are framed together, thus forming the supports of a platform on which a track was laid during construction. The foreshore berms and slopes surrounding the pier head are further secured by three rows of oak piles framed together as shown on the drawing, Fig. 5.

As soon as a portion of the jetty was completed to above low tide, ballast stone was thrown in upon the base berms and sides to an amount of 56 to 64 tons per running yard of jetty (60 to 70 tons per running metre). No stone of less than 110 lbs. (50 kg.) weight was used, and above low water they were carefully laid and their joints packed with smaller stones, spawls and quarry refuse. Between the piles around the fore-shore berm of the pier head, stones were placed weighing at least half a ton (500 kg.), and on the outside of the outer row of piles of that berm at least one row of stones was deposited of a minimum weight of one ton (1000 kg.)

No artificial stone has ever been used on these jetties. The largest natural stone weighed only about one ton and a half (1500 kg.). The secret of the success in maintenance has been that the jetties have been kept low enough to allow the storm waves of high tides to go over them, and the protection of the most exposed slopes by flat stone of good dimensions placed over each other like shingles on the roof of a building; the lines of shingling being laid at right angles to the direction of the sea as it strikes the slopes of the jetties. A railroad track extends the entire length of the jetties, the rails being laid on longitudinal timbers embedded in the stonework, and above this stonework rising above the tops of the rails on either side between the tracks so as to protect it from the waves.

The annual cost of keeping the jetties in order is but $ 7200, a proof that it is feasible to maintain such works in an exposed situation.

Construction of the New Waterway.

Simultaneously with the construction of the jetties the damming of the Scheur was begun and carried up to high water in 1872. The profile of the dam, as designed, had to be greatly altered during construction. The total width of the Scheur at the location of the dam was about 1000 feet (300 m.). This outlet could not be stopped before the new channel was cut through the Hoek. While this latter work was going on, jetties were built out from the embankments of either shore contracting the channel to 420 feet (128 m.) and confining it to the deepest existing portion. Between the ends of these jetties a bottom revetment of fascine work and ballast stone was sunk to prevent the accelerated tidal currents from scouring the bottom of this opening. Later it was found that the bottom along the edges of the revetment had greatly deepened, undermining them and letting it extend across the river like a ridge. The subsequent construction of the dam was thereby rendered more difficult as the regular process of sinking mattresses could be applied only after the great inequalities of the bottom had been levelled up by laying successive small mattresses.

The contracts for the construction of the channel through the Hoek were awarded in March 1863, but as acquiring the right of way occupied much time, actual work on the excavation was not begun until 1866. In the years to 1868 a canal of a bottom width of 33 feet (10 m.) and of a depth of 6½ feet (2 m.) below low water was excavated through the Hoek. Thus a new outlet of the Scheur into the sea was created. The canal was enlarged to a width of 164 feet (50 m.) in 1870, and after the old mouth had been closed the river began to actively scour out its new bed. The current is said to have carried away not less than $6^1/_2$ million cubic yards (5 million cu. m.) of material within one year.

The new waterway was opened to navigation in 1871, though the required width and depth had not yet been attained. On July 10th of that year two fishing boats passed through the cut as the first vessels; they were followed in March 1872 by a steamer of 10 feet (3 m.) draft.

A few years were now spent in seeing how the new cut would develope, but it soon became evident that, under the existing conditions, the scouring force of the current alone would not create a channel of sufficient dimensions. A great part of the scoured material had settled between the jetties. This is explained by the fact that the narrow sections of the cut of a width of about 820 feet (250 m.) suddenly changed there to 2950 feet (900 m.). Over 5 million dollars had been expended on the cut, the jetties and the regulation of the river, without attaining the desired end.

A careful survey, made in April 1877, showed the situation as follows. In the new cut there had formed a narrow channel of more than 23 feet (7 m.) depth to within about 4000 feet (1200 m.) from the jetty heads; but through the bar between the latter there was a channel, near the North jetty, of only 15½ feet (4.7 m.) at high water, thus prohibiting large vessels from entering.

The project of the commission of 1858 had counted on the action of the sea currents to widen and deepen the waterway between and in front of the jetties as well as inside of the cut, but it now became apparent that it would be necessary to assist nature or the whole enterprise would collapse. Consequently in May 1877 a law was enacted which required the bar between the jetty heads to be removed by dredging. The government did not rest contented with this measure, as experience taught that an artificial channel through the bar shoaled again very rapidly. It appointed a committee which should examine the original project and report on the necessary changes so as to insure the success of the undertaking. The committee made a preliminary report in 1878 and submitted a definite project two years later. The essential features of the plan were retained, but some changes were recommended, especially with regard to the standard widths, the improvements at the Eastern point of Rozenburg and the jetties. The commissioners further proposed a different method of execution, abandoning the principle that a channel could be developed by the natural force of the current and advising to place reliance solely on artificial means. The following standard widths were recommended: 820 feet (250 m.) at Krimpen, 1110 feet (340 m.) at Rotterdam, 1470 feet (450 m.) at Vlaardingen, 1740 feet (530 m.) at Maassluis, 2060 and 2160 feet (630 and 660 m.) at the beginning and end of the cut respectively. The width was to be 2250 feet (685 m.) at the existing sea end and 50 feet (15 m.) more at the proposed sea end of the North jetty, which was to be lengthened. The above widths exceed the previous ones above Vlaardingen and are less below it. The old Maas and Scheur were to be separated by a dam which should reach from the dikes of the Eastern point of Rozenburg across to those of the island of Ysselmonde, communication between the two rivers to be had by means of a lock in the dam. The commission finally proposed to extend the existing jetties to a depth of 29½ feet (9 m.) at low water and to raise them to 13 feet (4 m.) above low water by means of concrete blocks on a foundation of basalt rocks. In order to reduce the width between the existing jetties from 2950 feet (900 m.) to 2290 feet (700 m.), the construction of a pair of low dams of fascine work about parallel and between the old jetties was suggested. The crown of these dams should be at the elevation of low water. A lengthening of the jetty was considered necessary as it was the opinion of the commission that between and in front of the existing jetties the required depth at low water for ships of 21 feet (6.5 m.) draft could not be obtained; the sea currents landwards of the 28 feet (8.5 m.) depth line would not be powerful enough to remove the sand which was carried out by the tidal stream.

The cost of execution of the new plan, including the regulation of the Maas up to Krimpen, was estimated at 12 million dollars. The city of Rotterdam promised to contribute 10 percent of this sum, up to a maximum amount of $ 1,200,000. The report of the commission was submitted by the Government to the „Generalstaaten", the legislative body, but it never came up for discussion. The excessive cost formed a great obstacle, especially as nearly 4 million dollars had already been spent up to the end of 1880. Moreover, the succes of the improvement was greatly doubted. The Government declared it indispensable that the dredging of the cut be energetically pushed, and in 1881 the appropriations were made for dredging the cut and building the inner South jetty. The method of annually appropriating sums for executing single parts of the project of the commission without the plan having been adopted and without the Government pledging itself to carry it out, was vigorously opposed in the Upper Chamber. The Government then decided to complete the work for a maximum sum of 6 million dollars, omitting the lengthening or raising of the jetties and not bringing the river between Rotterdam and Krimpen to a continuous channel depth of 21 feet (6.5 m.) at low water. The Upper Chamber appropriated this sum under condition that each year not more than $ 600.000 should be expended; and the last of the appropriations was expended in 1893.

In the meantine the conditions at the mouth had changed considerably. In 1877 a contract was made for excavating 6.760.000 cubic yards (5.170.000 cu. m.) in the cut and 915.000 cubic yards (700.000 cu. m.) on the bar between the jetty heads. This work was pushed vigorously. In dredging the bar it was the intention to divert the ebb current from the right hand shore and bring it to bear against the bar midway between the jetties. The result was that a deep channel, the so-called „West Channel", formed near the South jetty. Where in 1877 there was only a depth of 6½ feet (2 m.) at low water, in 1880 it was 10½ feet (3.2 m.) deep, so that the new channel could be opened to navigation. The contraction of the width between the jetty heads to 2300 feet (700 m.) by the inside South jetty and extensive dredging operations succeeded, by the fall of 1883, in creating a channel between the jetties with depths varying from 15 to 20 feet (4.5 to 6 m.). In the spring of the following year a continuous depth of 18 feet (5.5 m.) at low water was attained. This depth has since increased steadily. In 1887 the least depth between Maassluis and the Hoek was 25½ feet (7.8 m.) at high water, while the 18 foot (5.5 m.) channel was nowhere less than 430 feet (130 m.) in width. The soundings of October 1889 give 27 feet 7 inches (8.4 m.) as the least depth between the North Sea and Maassluis and 26 feet 11 inches (8.2 m.) between the latter place and Rotterdam. Since March 1890 navigation finds a minimum depth of $28^1/_4$ feet (8.6 m.) at high water with a width of 430 feet (130 m.) at that depth. The map of soundings of June 1891 gives in the line of the „range lights" a least depth of 31½ feet (9.6 m.), and that of August 1893 gives even a little more. This result has been accomplished without lengthening or raising the jetties, showing that the fears of the commission that otherwise a bar would form in front of the jetties were groundless. There is no trace of a bar in the sea at present. Nearly all vessels of deep draft enter at flood tide and ascending the river with it, reach Rotterdam within two hours. Deducting from the available channel depth at high water 20 inches (0.5 m.) in summer and 32 inches (0.8 m.) in winter for keelwater and for sea-swells, leaves a safe entrance in summer for vessels of 30 feet (9.1 m.) draft and in winter for 29 feet (8.8 m.)

The principal measures which, since 1877, have contributed to the rapid and lasting improvement of the waterway are:

1st. *The dredging of the cut.* According to the map of 1889 the cut had been dredged to its full normal width, as urgently recommended by the commission in order to carry the flood tide inward as rapidly and as far as possible. The great influence of this work is seen from the fact that in 1882 there existed at the upper end of the cut a least depth of only 16 feet (4.9 m.) at low water which had increased to $23^1/_4$ feet (7.1 m.) in 1889.

2nd. *The narrowing of the „Noordgeul"*, as the river arm is called which branches off at the Eastern point of Rozenburg, below Vlaardingen. The interests of navigation compelled the modification of the plan to dam this branch entirely and to have a lock through it only. Instead of that the Noordgeul was very much reduced in width between 1885 and 1887. It is now only 230 feet (70 m.) wide against an original width of 1060 feet (325 m.). As a result the movement of the tidal stream has become much more regular and nearly all the water of the New Maas and its ebb tide volume flows along the Scheur and out to the sea through the new cut. The favorable effects of this show themselves in the Scheur down to the outlet.

3[rd]. *The removal of the shoal in the Scheur between Vlaardingen and Maassluis.* A little below the Noordgeul there existed a very persistent shoal which had acquired notoriety in the history of the waterway. The map of 1882 shows the channel interrupted there and giving a depth of only 18 feet (5.5 m.) at low water. This depth had increased by about $3^1/_2$ feet (1.1 m.) in 1889; periodical dredging is still necessary.

4[th]. *The dredging of the bar „het Zuiden".* About 3.7 miles (6 km.) below Maassluis where the channel changes from the right to the left shore, a bar has always existed which has been deepened by the general improvement of the waterway. Where there was a depth of $16^3/_4$ feet (5.1 m.) at low water in 1882, it had increased to $19^1/_2$ feet (6 m.) in 1889, and varies now between 19 and 20 feet (5.8 and 6.1 m.) at low water or $24^1/_2$ and $25^1/_2$ feet (7.5 and 7.7 m.) at high water. Since the amelioration of the outlet this bar has become the limiting factor in the capacity of the waterway. A sufficient depth over it can only be maintained by continuous dredging. The channel here persistently maintains its former direction towards the old outlet of the Scheur, though this has been closed for a number of years.

Besides the above principal measures two important works may be mentioned. These are restricting the width of the Scheur above and below Maassluis. This work formed part of the original project and was endorsed by the commission with some alterations. It was nearly completed in in 1887 at a cost of about $ 700,000. Further the dredging of „het Beneden-Scheur". As this had a less width above the dam across the Scheur than the closed mouth, it has been enlarged up to the point below Maassluis. Both shores are revetted and, where necessary, built out to the standard width. The dredging material was dumped into the New Maas and for its transportation a canal with locks was built through the lower end of Rozenburg. This canal also forms a navigation channel between the new waterway and the Brielle New Maas.

Cost. From the beginning of the improvement in 1863 to the close of 1893 there was expended in construction, exclusive of maintenance, $ 14,765,300. The exact amounts from 1889 to 1893 have not been available in writing this paper, and the maximum annual proportions are used. The yearly cost of maintenance of the outlet by dredging was, according to official reports of October, 1893, $ 16,000 between the jetties and $ 32,000 in the sea beyond the North jetty.

Résumé. This very important work has been successfully completed. The good results have been attained by extensive dredging operations and a skilful utilization of the scouring force of the ebb tide. A very interesting problem has thus found a solution. The problem is, on what principles must the improvement of the outlets of tidal streams be carried out, where the tidal range is small and the outlets are exposed to the depositing action of the sea, and where the tidal current becomes the principal agent and dredging operations are of secondary importance. Under such natural conditions a fan-shaped enlargement has been generally recommended in order to freely admit the flood tide. This principle was followed here at first, but was abandoned later when it was found that the force of the current, weakened by the wide sections, could neither create nor maintain the required depth.

The Maas belongs to that class of tidal streams which drain a considerable area, but have a small tidal range so that the formation of bars at the mouth can only be removed and afterwards prevented by increasing the natural current at ebb tide. Now, if on the one hand a wide mouth cannot be dispensed with, and if on the other hand the ensuing disadvantage of weakening the ebb current must be avoided by narrowing the outlet, both requirements can be satisfied only by a double profile. The larger high water section will serve the former and the low water section the latter purpose. The necessity for reinforcing the ebb current becomes more urgent as the shoaling at the mouth is caused not only by the sand which is carried down the river, but also by the sand which in stormy weather is carried in with the flood tide. The latter sand will settle after the storm has subsided and will create shoals. To remove these dredging operations would, as experiences teaches, not only be insufficient, but would be impracticable in heavy wather.

The uniform waterway, gradually widening towards the sea, has exerted a most beneficial influence in carrying off the ice. Throughout the severe winter of 1890—91 Rotterdam remained accessible to steamers and sailing vessels, while most ports of North-western Europe were closed by ice.

The dredges and their performances.

The dredging operations before 1882 deserve slight mention as the difficulties until that time were not as great as later on. The North channel was dredged under the protection of the North jetty, so that even ordinary bucket dredges had a sufficient number of working days. In dredging this channel the principal object was to render navigation possible, reserving until later the deepening of the main channel. The conditions changed in 1882. The „West Channel" from its location midway between the jetty heads, was exposed to heavy seas and to all winds from West-southwest to North-east, and it was further desirable to attain the proposed depth in the shortest time possible. Within 18 months from April 1882, 522,000 cubic yards (400,000 cub. m.) were to be dredged, making a monthly average of 29,000 cubic yards (22,000 cu. m.); while according to previous experience only a very limited number of working days could be counted on. The former suction dredges could work in a maximum wave height of 26 inches (65 cm.), while it was now necessary to operate them in a wave height of 32 inches (80 cm.). Among the existing types of dredges could be considered only a self-loading bucket dredge, PRIESTMAN's grapple dredge, the hydraulic dredge by BRUCE and BATHO, and the centrifugal pump dredges.

The ordinary bucket dredge could only be used in a wave height of 12 inches (30 cm.). It occupied much room in the channel with its dumping barges, and it must retreat to a place of safety in bad weather. To arrange a bucket dredge self-loading would be very expensive on account of the large amount of machinery required. Trials with the PRIESTMAN dredge in 1881 showed it was not adapted to the material to be dredged. Experiments with other dredges were not made, as centrifugal pump dredges had already proved themselves satisfactory, and it was expected that their efficiency could be still further increased. The principle of the centrifugal pump dredges is that the mouth of a tube which is suspended from a ship, is placed near the bottom of the sea or river. Through this tube a centrifugal pump on the vessel lifts the sand with the water and discharges it into the hold of the vessel which transports it to deep water at sea and dumps it there, or separate barges are used for taking away the dredged material. The first pump dredge for this work, Adam I, was designed by the English engineer, DORTON HUTTON, and built at Dordrecht. It had two suction tubes which operated in two wells in the longitudinal axis of the ship; it was not self-loading. A second larger self-loading dredge, Adam II, of the same type, was built soon afterwards. It was 110 feet (33.3 m.) by 26 feet (8 m.) and 10½ feet (3.2 m.) feet from keel to deck. The single suction pipe worked through a longitudinal well. On deck the pipe splits into two branches which lead into the two loading chambers, one of which is placed on either side of the well. The two chambers have a joint capacity of 180 cubic yards (139 cu. m.). Adam II made four double trips daily, removing on an average about 720 cubic yards (550 cu. m.) per day. In 1880 another dredge, Adam III, was built on the same plan, but of larger dimensions, at a total cost of $ 18,000. With a draft of 11½ feet (3.5 m.) when loaded it could carry 276 cubic yards (212 cu. m.). It made three trips daily, carrying away a total of 830 cubic yards (636 cu. m.). Several more dredges were then built of this class, but with some improvements. The suction pipe for instance was placed outside of the vessel thus giving one continuous loading chamber. Two of this kind of dredges were built with a capacity of 320 and of 208 cubic yards (244 and of 160 cu. m.) respectively. Recently dredges of 680 cubic yards (518 cu. m.) capacity have been used. A combination dredge is also in use, the suction pipe working on the side of the vessel and an ordinary endless chain bucket dredge working in an opening in the centre of the vessel. This is especially adapted to varying kinds of material, but it requires complicated and expensive machinery to thus unite the two methods.

The Port of Rotterdam.

It may be stated for information at the outset that the city of Rotterdam including Delftshaven, which was taken into the city in 1886, has a population of about 200,000. The development, enlargement and maintenance of its port is in charge of the city, which has in this work, including all bridges, dikes, wharves &c. expended about $ 5,000,000 between 1874—1888. The State also has expended a somewhat larger sum in developing railroad facilities.

The port of Rotterdam comprises the waters of the New Maas inside of the city limits, the basins below the city on the right bank, and the new basins on the left bank. All basins, excepting those of Delftshaven, are open freely to the river. The average tidal range at the city is $46^1/_2$ inches (1.18 m.). The Delftshaven basins are closed by a lock, the gates of which remain open at ordinary tides. Among the various recent works of improvement in the harbor are levees along the left bank on lines laid out by the Commission, and a basin on the left bank called the Rhine Harbor Basin. The construction of this basin became necessary for the protection of the Rhine boats which winter at Rotterdam. All the levees are built in deep water, and with a steep slope on the river side so that even deep draft vessels can come close to the shore. Sea-walls may be built later to occupy the place of the present levees. In 1847 Rotterdam had about 65 acres (26.5 hectares) of basin area, and a wharf frontage of 6 miles (9.6 km.). In 1887 it had 172 acres (69.6 hectares) of basin area, and $12^1/_4$ miles (19.8 km.) of wharf frontage. The city is a free port for merchandise in transit. On the left bank below the city there are docks for petroleum.

Influence of the New Waterway on the Commerce of Rotterdam.

The beneficial effects of the new waterway can be readily seen from the changing methods of navigation, and the reduction in transportation charges which ensued. The distances from the sea to Rotterdam and intermediate points are as follows:

From sea to Maassluis	. . . . .	9.3 miles (15 km.).
" " " Vlaardingen	. . . . .	14.3 " (23 ")
" " " Schiedam	. . . . .	16.8 " (27 "
" " " Rotterdam	. . . . .	21.1 " (34 "

By the old waterways the distances were:

From Brouwershaven to Rotterdam via Hellevoetsluis	. . . . .	63 miles (101.4 km.)
" Zieriksee " " " "	. . . . .	65 " (104.6 ")

The voyage from Rotterdam to the sea or vice versa, can be made by the new waterway in from 2 to 3 hours, while it formerly required from 2 to 5 days. For vessels of about 23 ft. (7 m.) draft or more, that cannot make the trip in one tide, a mooring place has been provided near the Eastern point of Rozenburg. Provision has also been made there for ships to take on more cargo in going to sea. The change in methods and transportation may be seen from the fact that the tolls on the Voorne Canal, which amounted to \$ 42,000 in 1873, dropped to \$ 43 in 1886; and in addition the larger vessels had to discharge part of their cargo at Brouwershaven or Hellevoetsluis. The following abstract from the tariff of the tug company of L. Smit & Co., October 1889, gives the prices for towage by the new and old waterways:

By the old waterways:

	300 tons & less \$	per ton cts.
From Brouwershaven, innerway, to Rotterdam . .	88.66	14.5
" " outerway, " " . .	97.52	16.1
" Hellevoetsluis " " . .	34.66	6.4

By the new waterway:

	Summer.		Winter.	
	100 tons & less. \$	per ton. cts.	100 tons & less. \$	per ton. cts.
From Rotterdam to the sea, in one tide .	24.18	4.8	31.43	6.4
From the sea to Rotterdam.	30.22	7.2	39.49	9.7

Note: The "tons" are register tons of 3.7 cubic yards (2.83 cu. m.) each.

The number of vessels which use the new waterway and their draft has been growing with the increase in depth in the channel, which is shown by the following table.

Number of vessels in the new waterway, in both directions, excluding fishing boats.			DRAFT OF VESSELS.															Total no. of vessels of min. dft. of 16 ft. 5 in.
Years.	No.	Tonnage in cu. metres. 1 cu. m. = 1.308 cu. yds.	Less than 16′ 5″	16′ 5″ to 17′ 1″	17′ 1″ to 17′ 9″	17′ 9″ to 18′ 5″	18′ 5″ to 19′ 1″	19′ 1″ to 19′ 9″	19′ 9″ to 20′ 4″	20′ 4″ to 21′	21′ to 21′ 7″	21′ 7″ to 22′ 4″	22′ 4″ to 23′	23′ to 23′ 8″	23′ 8″ to 24′ 3″	24′ 3″ to 24′ 11″	24′ 11″	
1879	6946	8,314,000	6821	30	33	38	14	5	5									125
1880	7008	8,383,000	6919	37	34	15	6											92
1881	7026	8,350,000	7016	10														10
1882	7677	9,943,000	7410	69	96	72	27	3										267
1883	7788	10,829,000	7033	186	232	118	111	83	17	6								755
1884	8177	12,401,000	7212	96	216	166	216	124	80	44	22	1						965
1885	7915	12,366,000	6990	137	171	154	129	82	103	87	47	9	6					925
1886	7992	12,777,000	6958	73	162	196	142	108	128	113	67	29	10	3	3			1034
1887	8819	14,529,000	7739	90	83	181	181	113	151	85	98	54	26	12	6			1080
1888	9488	15,716,000	8538		7	211	146	102	110	91	107	89	35	30	7	4	1	950
1889	9543	16,284,000	8461	4	14	198	151	132	142	123	127	81	71	28	14	1	1	1082

The construction of the new waterway has materially developed the import commerce from the sea to Rotterdam. During the few years preceding the construction of the works the number of sea-going vessels which entered the port averaged 28 %, and their tonnage 40 % to 46 % of the total imports by sea into the Netherlands. After the new waterway came partly into use the share of Rotterdam rose gradually up to 1870 to 35 % in number and 58 % in tonnage. After 1882 only about 60 % of the sea-going vessels arriving had used the new waterway, but this percentage grew rapidly with the improvement of the latter. The following table gives some interesting details.

Years.	Rotterdam.		The Netherlands.		Percent of Rotter.	
	No. of Vessels.	Reg. tons of 3.7 cu. yds. each. (2.83 cu. m. each.)	No. of Vessels.	Register tons of 3.7 cu. yds. each. (2.83 cu. m. each.)	Vessels.	Tonnage.
1850	1970	393,000	6961	968,000	28.3	40.6
1860	2449	674,000	8714	1,459,000	28.1	46.2
1870	2987	1,190,000	8351	2,037,000	35.8	58.3
1871	3613	1,408,000	10047	2,470,000	35.	57.
1875	3435	1,655,000	7921	2,625,000	43.	63.
1880	3456	1,682,000	8164	3,438,000	42.3	48.9
1881	3673	1,742,000	8402	3,562,000	42.5	48.9
1882	3859	2,004,000	8776	4,010,000	44.	50.
1883	3634	1,640,000	8307	3,953,000	43.8	49.1
1884	3768	2,143,000	8431	4,184,000	44.8	51.2
1885	3724	2,120,000	8021	4,137,000	46.5	51.
1886	3763	2,203,000	7695	4,109,000	49.5	53.6
1887	4153	2,488,000	8089	4,601,000	51.9	54.1
1888	4528	2,721,000	8348	4,902,000	54.6	55.5
1889	4547	2,809,000	9182	5,221,000	49.5	53.8

The development of traffic is further shown by the following table, which gives the number and tonnage of all vessels which entered Rotterdam and sailed from it during the years from 1880—1889.

Years.	Steamers.		Sailing vessels.		Fishing boats.	
	No.	Net tonnage in cubic meters.	No.	Net tonnage in cubic metres.	No.	Net tonnage in cubic metres. In 1000 tons.
1880	5163	7,264,000	1845	1,119,000	1883	300
1881	5336	7,342,000	1670	1,009,000	1790	313
1882	6150	9,035,000	1527	908,000	2321	397
1883	6265	9,812,000	1523	1,017,000	2374	403
1884	6617	11,219,000	1560	1,182,000	3054	502
1885	6507	11,160,000	1408	1,207,000	2802	491
1886	6524	11,385,000	1468	1,392,000	3175	545
1887	7272	13,045,000	1547	1,484,000	3640	617
1888	8135	14,478,000	1353	1,237,000	3383	587
1889	8403	15,186,000	1140	1,098,000	3466	596

Rotterdam does not owe its prosperity entirely to its location as a sea-port; its situation in relation to the inland waterways secures for it a large part of the Dutch trade. Rotterdam is also the principal city for the interchange of commerce with the Rhine provinces of Germany. It handles about one-half of the total traffic between Germany and the Netherlands.

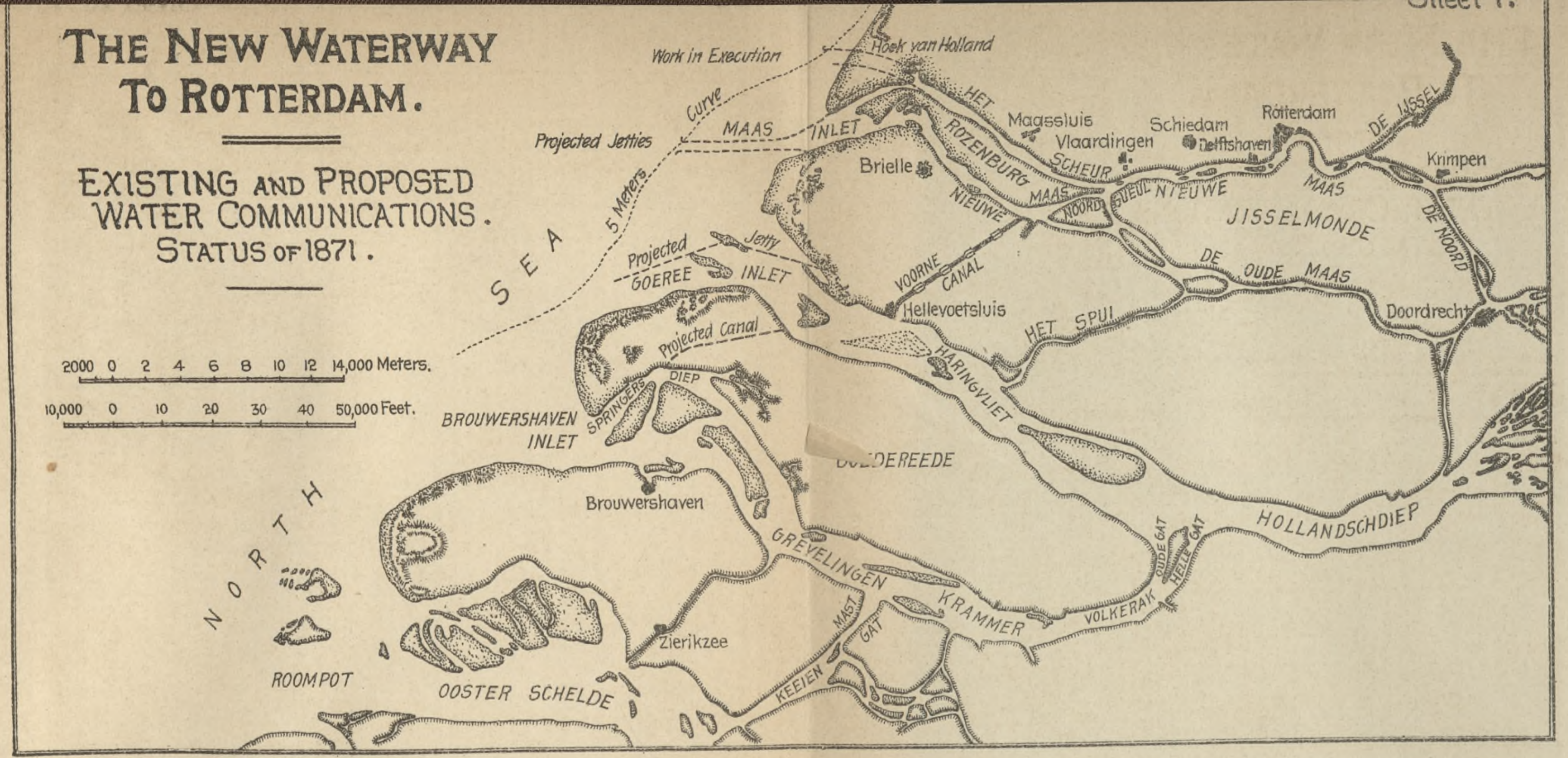
The above paper has been compiled from notes and observations of Mr. E. L. Corthell on a visit to the works in 1891, from several articles of the Dutch periodical „Tijdschrift van het Koninklijk Instituut van Ingenieurs", from the „Report on the improvement of navigation from Rotterdam to the sea" by Gen. J. G. Barnard, U. S. Army, 1872, from an article by W. Paul in the „Zeitschrift für Bauwesen", 1892, from a paper by A. von Horn, „Der neue Wasserweg von Rotterdam nach See" in the „Zeitschrift des Oesterreichischen Ingenieur- und Architekten Vereines", 1894, from two papers by J. W. Welcker on the „New Waterway", and from the book „Le port de Rotterdam" by J. H. Neiszen.

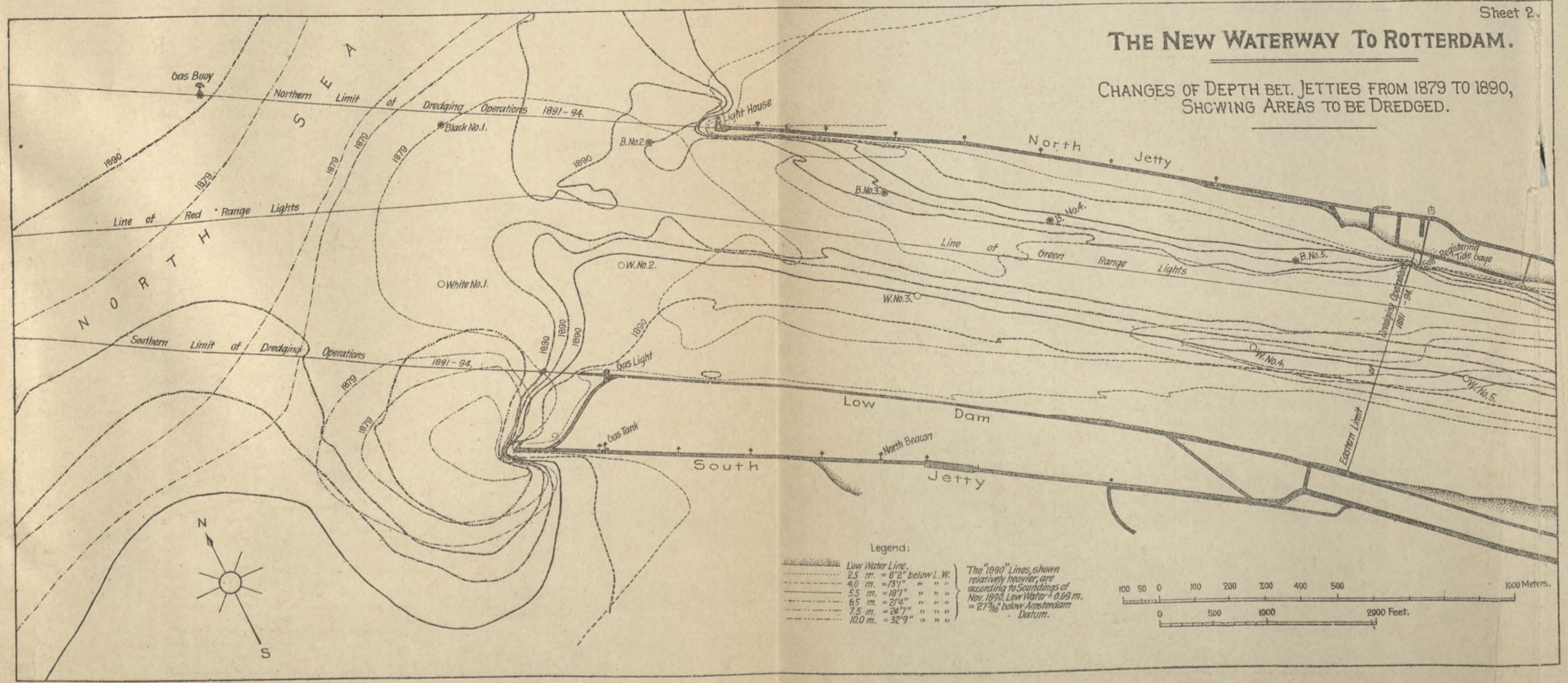
The illustrations have been prepared from the maps of the engineers of the work.

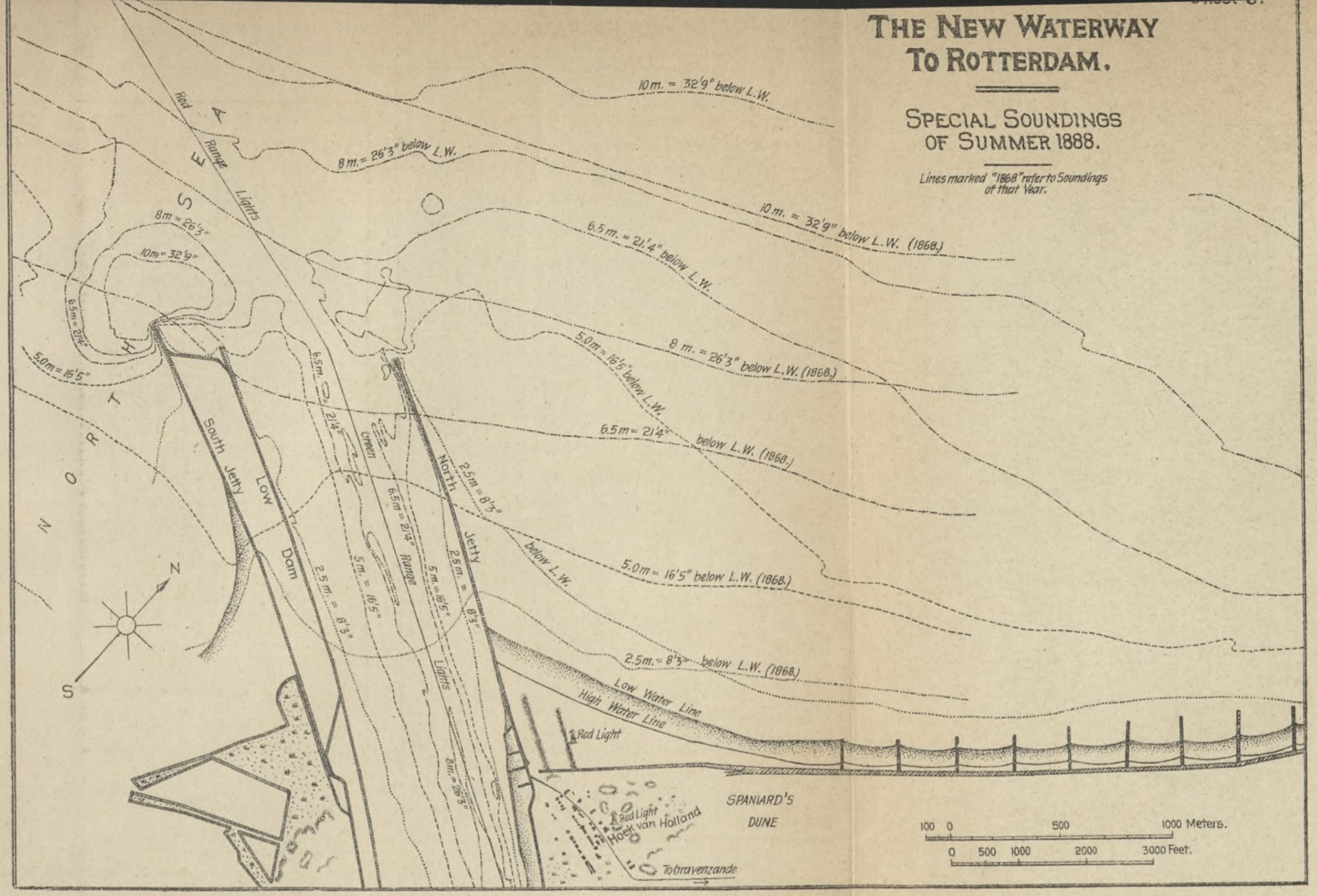
The writer takes this opportunity to express his thanks to Mr. E. L. Corthell for the revision of the article.

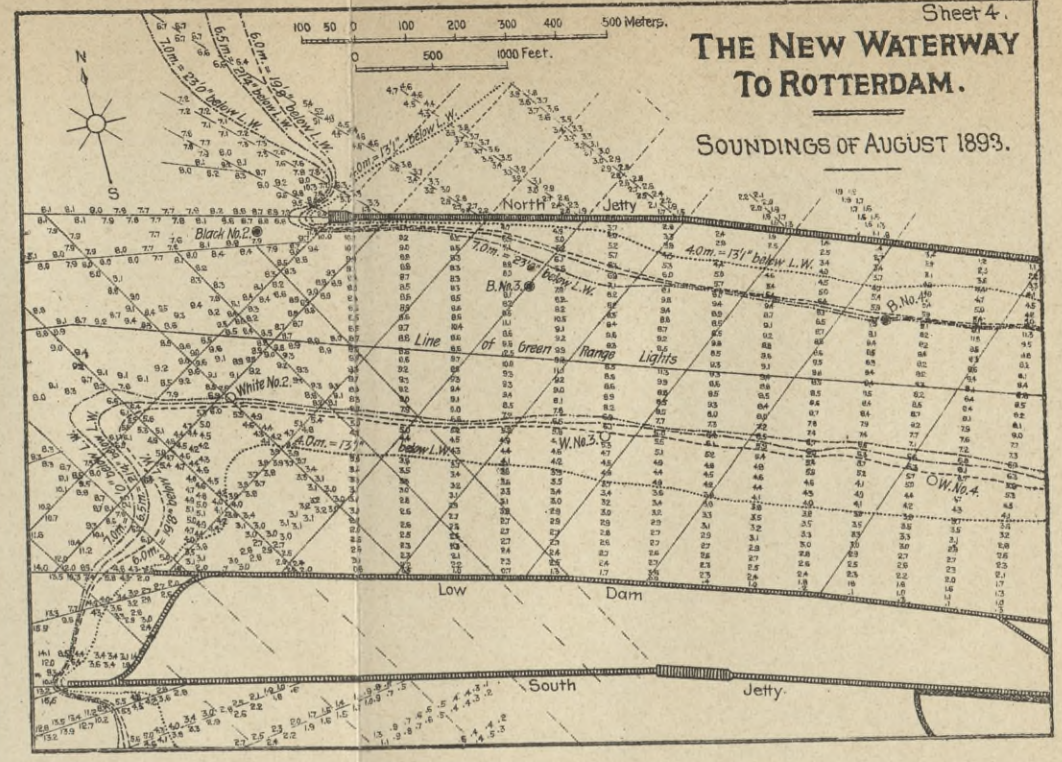
W. GUSTAV TRIEST.

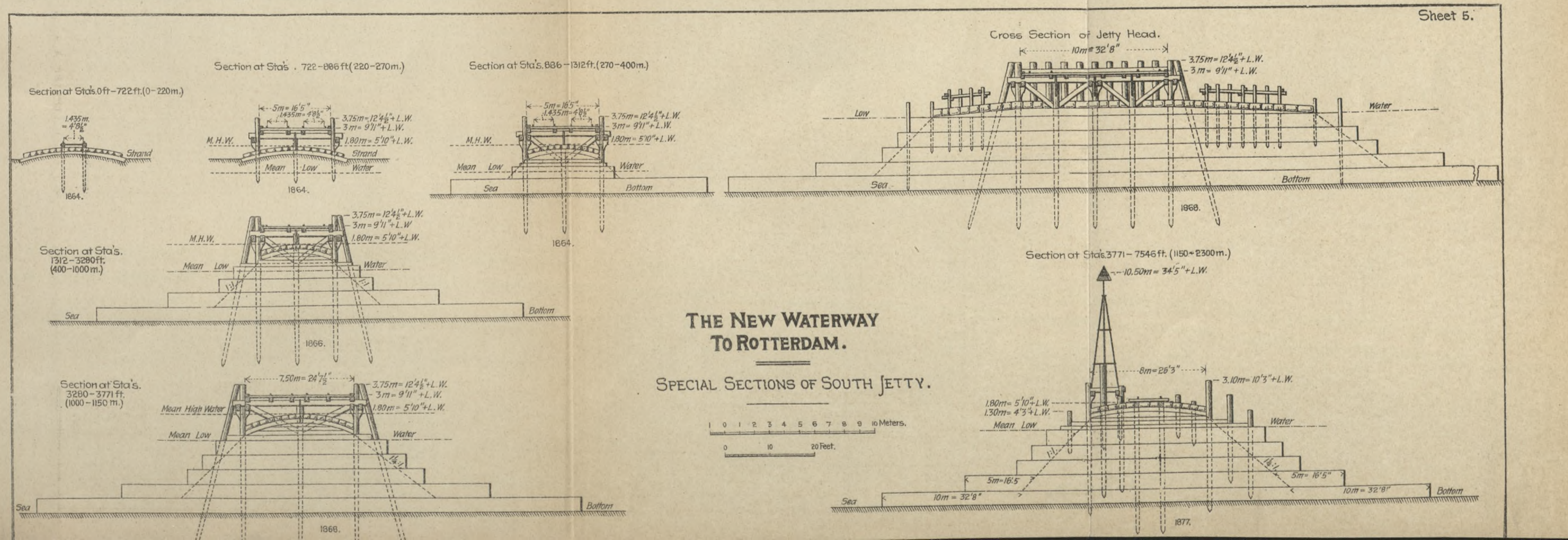
New York, June 14th, 1894.


Sheet 1.
THE NEW WATERWAY TO ROTTERDAM.
EXISTING AND PROPOSED WATER COMMUNICATIONS.
STATUS OF 1871.
2000 0 2 4 6 8 10 12 14,000 Meters.
10,000 0 10 20 30 40 50,000 Feet.
Work in Execution
Hoek van Holland
Projected Jetties
Curve
MAAS INLET
HET SCHEUR
Maassluis
Vlaardingen
Schiedam
Delftshaven
Rotterdam
DE IJSSEL
Krimpen
Brielle
ROZENBURG
NIEUWE MAAS
JISSELMONDE
DE NOORD
DE OUDE MAAS
Dordrecht
SEA
5 Meters
Projected Jetty
GOEREE INLET
VOORNE CANAL
Hellevoetsluis
HET SPUI
Projected canal
HARINGVLIET
BROUWERSHAVEN INLET
OUDDEREEDE
HOLLANDSCHDIEP
Brouwershaven
GREVELINGEN
KRAMMER
VOLKERAK
NORTH
Zierikzee
ROOMPOT
OOSTER SCHELDE


Sheet 2.
THE NEW WATERWAY TO ROTTERDAM.
CHANGES OF DEPTH BET. JETTIES FROM 1879 TO 1890, SHOWING AREAS TO BE DREDGED.
Gas Buoy
Northern Limit of Dredging Operations 1891–94.
Black No. 1.
Light House
North Jetty
NORTH SEA
Line of Red Range Lights
Line of Green Range Lights
White No. 1.
Southern Limit of Dredging Operations 1891–94.
Low Dam
South Jetty
Legend:
Low Water Line.


Sheet 3.
THE NEW WATERWAY TO ROTTERDAM.
SPECIAL SOUNDINGS OF SUMMER 1888.
10 m. = 32'9" below L.W.
8 m. = 26'3" below L.W. (1868).
6.5 m. = 21'4" below L.W. (1868).
5.0 m. = 16'5" below L.W. (1868).
2.5 m. = 8'3" below L.W. (1868).
NORTH SEA
North Jetty
South Jetty
Low Dam
Low Water Line
High Water Line
Red Light
SPANJARD'S DUNE
1000 Meters.
3000 Feet.


Sheet 4.
THE NEW WATERWAY TO ROTTERDAM.
SOUNDINGS OF AUGUST 1893.
North Jetty
Low Dam
South Jetty


Sheet 5.
Section at Sta's. 0 ft – 722 ft. (0–220 m.)
Section at Sta's. 722–886 ft. (220–270 m.)
Section at Sta's. 886–1312 ft. (270–400 m.)
Cross Section of Jetty Head.
10 m = 32'8"
Section at Sta's. 1312–3280 ft. (400–1000 m.)
Section at Sta's. 3771–7546 ft. (1150–2300 m.)
Section at Sta's. 3280–3771 ft. (1000–1150 m.)
1864.
1866.
1868.
1877.
M.H.W.
Mean Low Water
Mean High Water
Sea
Bottom
Strand
3.75 m = 12'4½" + L.W.
3 m = 9'11" + L.W.
1.80 m = 5'10" + L.W.
10.50 m = 34'5" + L.W.
8 m = 26'3"
3.10 m = 10'3" + L.W.
5 m = 16'5"
10 m = 32'8"
THE NEW WATERWAY TO ROTTERDAM.
SPECIAL SECTIONS OF SOUTH JETTY.
0 1 2 3 4 5 6 7 8 9 10 Meters.
0 10 20 Feet.

30,00