# A CONTRIBUTION ON THE HYDROGRAPHIC RESEARCH AND DEVELOPMENT OF THE YANTLET DREDGED CHANNEL IN THE THAMES ESTUARY

by

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## PREFACE.

The Port of London Authority is an autonomous, partly elected, partly nominated body, charged by Act of Parliament with the duty of carrying on and improving the dock undertaking transferred to it on its inception.

The Authority is also charged with the administration, conservancy and dredging of the whole of the tidal portion of the River Thames from Teddington to the sea.

Financially the Authority are self-supporting by their publicly issued capital, their dues, rates and charges — they receive no subsidy from either Government or Municipality.

Such profits as accrue to them in their trading activities must be either employed in port improvement works or used for the purpose of making reductions in their dues, rates and charges.

## SHIPPING

| | |
|---|---|
| 1909 ......... | 35,510,989 net register tons |
| 1938 ......... | 62,000,000 net register tons (approx.) |

## THE HYDROGRAPHIC RESEARCH AND DEVELOPMENT OF THE YANTLET DREDGED CHANNEL OF THE THAMES ESTUARY.

When the autonomous Port of London was formed in 1909 a statutory duty was laid upon the new authority to improve the channels of the tidal Thames and in particular to develop an approach channel between the seaward limit of the Port and Gravesend — a distance of 24 miles (English statute). The requirement for this channel was a dimension of 30 feet deep and 1,000 feet wide at Low Water Ordinary Spring Tides.

Concurrently it was decided by the enterprise of the Authority to improve the dock facilities near London and the large King George V Dock was designed. It therefore became necessary to expedite the channel improvements at the mouth of the Port and 40 miles from the King George V Dock in Galleons Reach.

To navigate vessels of considerable draft and tonnage limits the speed on passage to about 8 knots (37 feet draft has occured and the new " Mauretania " has a tonnage of 35,000 gross). During the passage through a waterway which varies from 1,400 feet to 2,000 feet in width the vessel must ease speed at Gravesend for Customs, Pratique and change of Pilots — and in consequence it is desirable that large vessels should arrive at Gravesend 1 hour before high water at that place, leaving 2 hours for comfortable passage of the remaining 16 miles and for docking operations at London. The time lag of the progressive high waters enables shipping to precede the tidal crest at the speed indicated above.

The tidal Thames has an accurately balanced semi-diurnal tide of exceptional regularity with a period of rise 5.8 hours and a period of fall of 6.5 hours in Galleons Reach where the principal dock entrance is situated. High water occurs in Galleons Reach one hour later than at Southend-on-Sea under normal conditions.

The duration of rise and fall varies as the river is ascended or descended as also does the range of tide, King George V Dock being situated in the tidal compartment where the range of tide is greatest.

When the Thames is in flood there is a predominating down stream irrespective of rise and fall for one-third of its tidal course (24 miles).

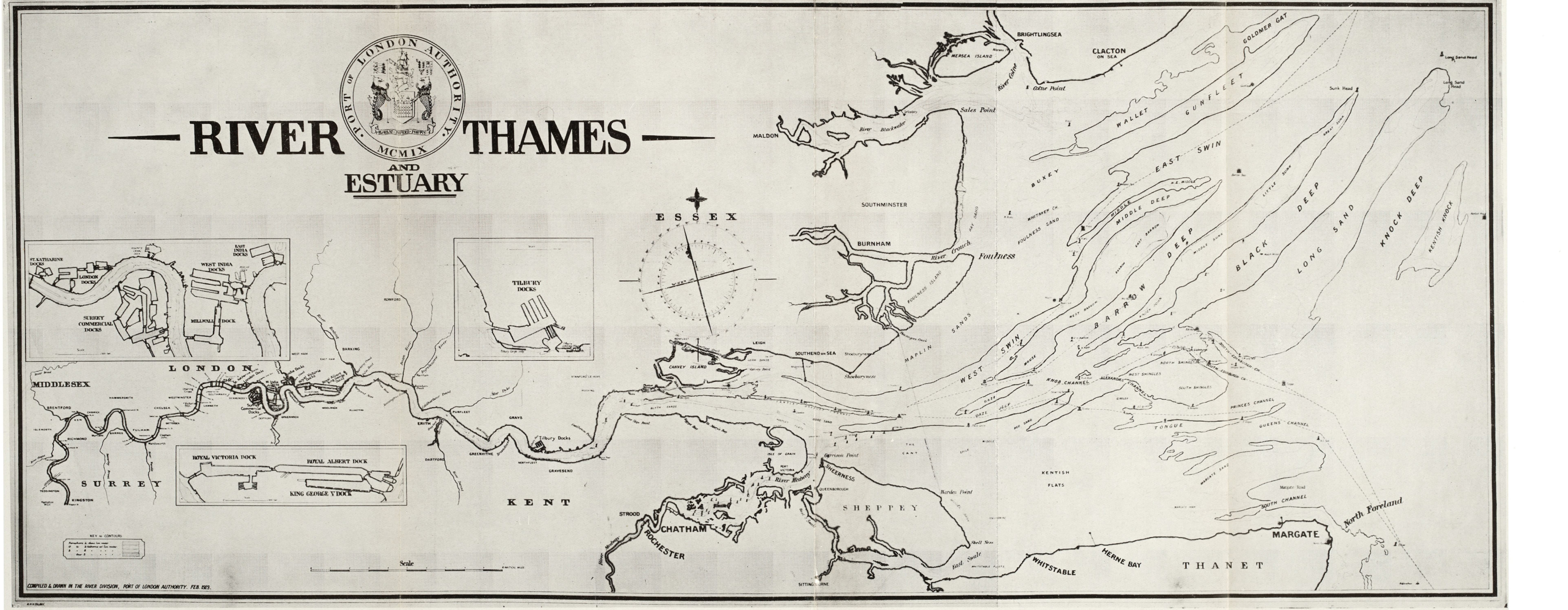
At Southend — the mouth of the Port — the duration of the tides is as follows — from automatic tide gauge records.

| | | |
|---|---|---|
| Duration of rise | Spring Tides 5 hrs. 57 mins.<br>Neap Tides 6 hrs. 17 mins. | Mean difference |
| Duration of fall | Spring Tides 6 hrs. 19 mins.<br>Neap Tides 6 hrs. 2 mins. | 17 1/2 Minutes<br>rise and fall |

| | | | | |
|---|---|---|---|---|
| h.m. | | h.m. | | *Total Tide Curve* |
| Spring rise 5.57 | + | Spring fall 6.19 | = | 12 hrs. 16 mins. |
| Neap rise 6.17 | + | Neap fall 6. 2 | = | 12 hrs. 19 mins. |

On spring tides the lateral drainage stream runs out about 30 minutes longer in the central channel than the actual fall of tide level indicates by the curves at Southend-on-Sea. This longer duration of the Spring tide on the outgoing stream is an important factor in the regime of the Thames Estuary.

The purpose of this Paper is to describe the hydrography tidal and


RIVER THAMES
AND
ESTUARY
PORT OF LONDON AUTHORITY
MCMIX
ESSEX
MIDDLESEX
LONDON
SURREY
KENT
SHEPPEY
THANET
ST. KATHARINE DOCKS
LONDON DOCKS
WEST INDIA DOCKS
EAST INDIA DOCKS
SURREY COMMERCIAL DOCKS
MILLWALL DOCK
TILBURY DOCKS
ROYAL VICTORIA DOCK
ROYAL ALBERT DOCK
KING GEORGE V DOCK
BRENTFORD
RICHMOND
HAMMERSMITH
CHELSEA
WESTMINSTER
GREENWICH
BARKING
ROMFORD
ERITH
PURFLEET
GRAYS
DARTFORD
GREENHITHE
Tilbury Docks
GRAVESEND
KINGSTON
TEDDINGTON
CANVEY ISLAND
LEIGH
SOUTHEND ON SEA
Shoeburyness
BURNHAM
SOUTHMINSTER
MALDON
River Blackwater
MERSEA ISLAND
BRIGHTLINGSEA
River Colne
Colne Point
CLACTON ON SEA
Sales Point
River Crouch
Foulness
FOULNESS ISLAND
MAPLIN SANDS
FOULNESS SAND
BUXEY
WALLET
GUNFLEET
GOLDMER GAT
EAST SWIN
MIDDLE DEEP
BARROW DEEP
BLACK DEEP
LONG SAND
KNOCK DEEP
KENTISH KNOCK
WEST SWIN
KNOB CHANNEL
ALEXANDRA CHANNEL
PRINCES CHANNEL
QUEENS CHANNEL
TONGUE
SOUTH CHANNEL
KENTISH FLATS
ISLE OF GRAIN
Garrison Point
SHEERNESS
QUEENBOROUGH
River Medway
STROOD
CHATHAM
ROCHESTER
SITTINGBOURNE
East Swale
WHITSTABLE
HERNE BAY
MARGATE
North Foreland
Long Sand Head
Sunk Head
KEY TO CONTOURS
Scale
COMPILED & DRAWN IN THE RIVER DIVISION, PORT OF LONDON AUTHORITY. FEB. 1923.

dredging research covering the more difficult operations in channel improvements mainly between 1922 and 1938 in the Yantlet Channel area, at the seaward limit of the Port. The major dredging difficulties were surmounted between 1922 and 1925 but until 1938 trimming to adjust curvature and small corrections to depth has taken place.

The general plan for the Authority's new channels to King George V Dock was as follows :— passing through Sea Reach, Lower Hope Reach, Gravesend Reach, Northfleet Hope, St. Clement's Reach, Long Reach, Erith Rands, Erith Reach, Halfway Reach, Barking Reach and Galleons Reach.

| | | |
|---|---|---|
| (1) | Nore Lightship (Entrance) to Erith Reach 34 miles, width 1,000 feet, depth 30 feet at L.W.O.S.T. | 40 Statute miles |
| (2) | Erith Reach to King George V Dock 6 miles, width 600 feet, depth 27 feet at L.W.O.S.T. | |

This general plan has been completed and its extension to London Bridge is in course of completion.

The Thames Estuary which influences the tidal supply of the inner waterway covers approximately 250 square miles of natural deep water channels lying N.E./S.W. passing between sandbanks which dry at low tide and stretch seawards into the North Sea to the east of the longitude of North Foreland, 35 miles from the dredged channel at the Nore.

These sandbanks lie upon a chalk base at great depths proved by borings taken under the direction of the General Lighthouse Authority for the purpose of considering the erection of lighthouses on the sand banks in recent years.

The sea-bed material consists mainly of littoral drift in the form of fine sand and shell. Alluvium and detritus has combined to consolidate the banks although some retain a quicksand or shivering character. The detritus comes from the following rivers which drain into the estuary —

| | |
|---|---|
| Thames | Crouch |
| Medway | Blackwater |
| | Colne |

with a catchment area of about 6,000 square miles.

In the outer estuary the banks and cross channels continue to change their situation and character. These changes may be of a gradual or long term type, while others are of short periodical type but none is of an acute or of violent activity.

The main channels of fixed character are the West Swin, Barrow Deep, Black Deep — and the tidal Thames receives its main supply of sea water from the West Swin and Barrow Deep because in the matter of tidal phenomena the tidal wave which passes southward through the North Sea and retreats north again accounts for our semi-diurnal high waters and low waters in the Port of London.

The main tide enters the North Sea between Scotland and Norway, the Channel tide via Dover Straits having little, if any, effect. In the Flemish bight the progress is rotary in character and an amphidromic point, where the lunar semi-diurnal constituent has zero range, occurs in the centre. The range of the semi-diurnal tide increases in all directions from an amphidromic point so that in the Thames Estuary it may reach 18 ft.

The tidal wave which arrives in the Estuary via Straits of Dover is therefore a small contribution to the whole estuarial capacity and as it arrives later it joins for a short period the retreating or north-going stream and thus creates the cross cut channels and swatchways which in some places divide the long sandbanks.

Through these approach channels the greatest Port tonnage in the World passes.

It was at the border line of the littoral drift and river silt deposits that dredging problems gave most concern because of the exposure to weather while dredging and the uncertain history of this area from previous hydrographic surveys.

It is to this embouchure area — 8 miles in length with a mean width of 3.4 miles — that the following details are directed.

For several generations proved by the geological formations to extend to 3,000 to 4,000 B.C. the Thames has been laying down its silt and spreading it over a wide area in the estuary which is of the typical bellmouth formation.

The natural corollary to such a bellmouth is the dissipation of tidal energy in this region for the discharge, and affecting the tidal stream in the course of 8 miles we had brought under study for development for a deep water channel.

It should be kept in mind that only a small fraction of the water passing out of the Thames on discharge is fresh water. As a matter of fact the figures are as follows :—

| | |
|---|---|
| Measured through a cross section at Gravesend | Salt water — Spring tide discharge 65,556,000,000 galls. per 12 hours.<br>Fresh water — Standard discharge 1,357 galls. per 24 hours. |

When a chart of Sea Reach was made in 1894 it shewed that the region referred to was encumbered with sands having no defined deep water channel and that the river and sea currents spread over it irregularly with depths for navigation which varied near the centre from 18 to 24 feet at Low Water Ordinary Spring Tides.

The situation was complicated also by the mouth of the River Medway which discharged at a central point in the Estuary. This point was also a focus for shipping entering the Port of London, a natural area for manœuvre and close to the position at which our new dredged channel now has its entrance.

This close proximity has not been found in any respect detrimental to maintenance of depth, because the two outlets have found a common point of convergence suitable to their hydraulic needs.

The material deposited in the estuary by these rivers is of very fine grain and measures —

| | *Parts per 100,000* | | *Grains per gall.* |
|---|---|---|---|
| At Barking | 11.52 | = | 8.06 |
| At Southend Pier | 1.40 | = | 0.98 |

The determination of the weight of dried sediment per unit of volume of wet silt is as follows :—

| | | | | |
|---|---|---|---|---|
| (1) | 1,500 ft. N.W. | of Nore Lightship | 1,087 | Ounces (Avoirdupois) of dry material per cubic foot of wet silt |
| (2) | 5,200 ft. E. | of N° 1 Buoy | 1,090 | |
| (3) | 5,000 ft. E. | of N° 2 Buoy | 970 | |
| (4) | 5,000 ft. E. | of N° 3 Buoy | 1,186 | |

N$^{os}$. 1, 2 and 4 are all fine silt; but N° 3 contains a slight percentage of coarse particles.

The Thames flows through chalk and the London clay. The amount in suspension is normally 8.06 grains to the gallon in the middle reaches of the River as compared with .42 grains to the gallon in the Black Deep or sea water channels.

In the year 1901 arising from a Royal Commission of Inquiry a scheme was put forward to control the area shown on the plan by training walls and by this method the principles which govern the flow of the tidal Thames from Teddington to the Chapman Lighthouse were to be extended by half-tide revetments into the sea and the entire main approach channel brought under regulation with the assistance of dredging to be undertaken after the walls or revetments were constructed. Owing to the exposed character of the estuary and the problems which the scheme raised in relation to cost accompanied by the possibility that dredging alone would be sufficient, this scheme was not favoured by the predecessors of the Port of London. By this decision a large and unnecessary expenditure was avoided.

The highly successful opening of the Gironde estuary by dredging is a recent achievement which was not available for comparison or consideration in 1922 when after the Great War the Port of London undertook their dredging tasks de novo. Our attention had been drawn to the successful completion of the Ambrose dredged channel at the approaches to New York which is devoid of revetments or artificial training walls.

For many years French engineers had adopted the training wall or revetment for the inner part of the embouchure of the Seine, and Liverpool had adopted similar methods for the Mersey. In the estuary of the River Ribble in Lancashire, training walls have been constructed to control the direction, depth and width of the main entrance channel. But the more comparison is made with the Thames Estuary and other seaport estuaries the more one finds absence of comparative factors whether in range of tide, velocity of currents and other phenomena. For instance although the mean seaward course of the tidal Thames is East, it has a propensity to hug its northern or left bank in the principal reaches. Whether this is some affiliation remaining from its early connection with the primordial River Rhine and which the present Thames inherits in the seaward flow, it is impossible to say.

We are told by geologists that rivers flowing northwards invariably wash their western banks and those flowing southwards like the Mississippi (below Ohio) frequently wash their eastern bluffs and rarely erode the western bluffs. Lyell and Giekie, famous geologists, ascribe this to the rotation of the earth on its axis (Lyell Ch. XIX p. 276). The deficiency of the rotary motion when a body of water is transferred from a lower to a higher latitude is probably the cause from which this effect operates — but in so far as the tidal Thames is concerned we are faced with more than one scientific paradox when these laws or facts are examined for possible application.

The tidal Thames in its course persistently runs hard on the north bank in Sea Reach before it debouches into the estuary. This causes a deep water frontage there and consequently for several miles jetties have been erected to accommodate deep drafted ships. These jetties have come to act as groins to prevent further scour of the river bank so that erosion has been arrested for the greater part. At Canvey Island however, which is the eastern terminal of the Thames river wall constructions where jetties have not until recently been constructed, there has occurred during the last 100 years a northward erosion of 400 feet by the action of the tidal stream and the river wall has been set back and reconstructed in consequence. This pressure from the tidal stream on the north bank is also connected with the history of the south bank of corresponding cross sections. When the inner main channel of Sea Reach was dredged the water level was lowered which exposed more of the Blyth Sand and thus was conducive to its consolidation and further growth. The south bank sands therefore advanced slightly to form the parallel line for the conduit of discharge also regulating the stream line on the flood, and pressing the flow over towards the north.

From ancient charts we find that the tidal river course was at one time more sinuous and that the stream on rounding the Lower Hope Point in its outward course took a penultimate swing to the south and in recurving finally discharged to the north of the present axis line. This northward course accounted partly for the old channel in the Leigh embayment which closed in the 19th century with the straightening and consolidation of the Blyth Sand. This conduit line which now fixes the general line of discharge does not control it after passing the Chapman cross section where the estuarial bellmouth is reached.

### *Model of Estuary.*

At this stage of the report the research which was undertaken in 1901 and continued until 1904 should be studied in connection with a model then made of the river and estuary from Teddington to the Nore Lightship. The upper portion of the model was a fixture, at the lower end a flexible joint connected it to a large reservoir which was alternately raised and lowered by suitable mechanism in such a manner that the water contained flowed up and down the river exactly like the true tidal currents. (Crutwell's Report, 7th January 1904). In order to make the working of the model as true to nature as possible, a continuous stream of water was introduced at the Teddington end (70 statute miles from the Nore) and another stream lower down to represent the combined inflow of the various lower streams below Teddington. The horizontal scale of the model was 6 inches to the statute mile and the vertical scale 32 feet to an inch. The time scale of the model corresponding to these scales by a mathematical law was 1-540th of the natural time. In order words, as many tides can be observed in one day's working of the model as would occur in 540 days of actual time.

The first series of experiments consisted in running the model for several consecutive days, during which period the velocities and directions of the tidal currents, and the varying periods of flood and ebb at the different points of the river, were carefully noted. Attention was chiefly directed to that portion of the river and estuary between the Chapman and the Nore.

Previous to the making of this model the remedial measures referred to on a previous page had been recommended by which training walls were carried out to sea across the sand-banks. By experimenting with miniature training walls on the model, after experiments of free flow had been conducted, a conclusion was reached that the training banks would not be of any material benefit certainly on the alignments and directions proposed. Furthermore the disproportion of the grains of sand used notwithstanding a special refining process were found to be too large to be carried along by the currents, so that no actual depositing or shifting of the shoals were discernible. With these elements unproved and the high cost of the training walls which at that time was estimated at £ 843,280 no further consideration was given to the training wall proposals.

In justice therefore to the advocates of estuarial models the mechanical results obtained by this model appear to have disproved the need of artificial training walls as a solution to the problem of a navigable outlelt in the bellmouth of Sea Reach: This paper will shew that the results 38 years later are such that the rejection of the training walls scheme was fully justified.

Reverting to the dredged Ambrose Channel at New York, it will be observed that the tidal range there is approximately one-quarter that of the Yantlet Channel. This may be regarded as a point in favour of the latter qua influx and efflux of the tidal stream. On the other hand the supply of oceanic water which enters by way of Hell Gate through Long Island Sound into New York Harbour thus adding to the outflow of the Hudson River may be claimed as an asset in tidal circulation for the Ambrose. The following details supplied by Colonel Hall of the United States Engineer Office shew the conditions :—

(1) In a complete tidal cycle having a duration of 12 1/2 hours, it has been estimated that the average flow of water through the Narrows is 12 1/4 billion cubic feet on the ebb tide and 11 billion cubic feet on the flood tide. The net excess flow out through the Narrows in each tidal cycle is 1 1/4 billion cubic feet. Long Island Sound empties into New York Harbour on each tidal cycle about 130 million cubic feet more than it receives. Approximately 100 million cubic feet of this flow, originating in Long Island Sound, passes through the East River to Upper New York Bay and the remainder, 30 million cubic feet, passes north through the Harlem River and thence south through Hudson River before it empties into Upper New York Bay. This total of 130 million cubic feet, which originates in Long Island Sound, constitutes about 1/10th of the total excess ebb flow of 1 1/4 billion cubic feet passing through the Narrows in each tidal cycle. The effect of the tide prism of the East River on the total flow through the Narrows is much more appreciable. Of the total flow through the Narrows approximately one-third of the volume is contributed by the East River. It is assumed, therefore, that the total flow from the East River is responsible for one-third the strength of the current through Ambrose Channel. It is believed that the principal effect of the flow through the East River on conditions in Ambrose Channel is only to increase the current velocities.

(2) Since the completion of the improvement in 1915 to previously authorised dimensions, 2,000 ft. width and 40 ft. depth at mean low water, the channel has to all intents and purposes maintained itself. The depths in the channel as shown by recent surveys compare quite favourably with those obtained after the original dredging. The channel is practically in a state of equilibrium. One shoal of a minor nature had been formed between buoys 6A and 8.

The River Hudson's flow lies between 1,080 million gallons per day average, and 129,600 million gallons per day in flood. The Thames' flow lies between 300 million gallons per day average and 10,000 million gallons per day in flood.

The success of the United States Engineers in dredging this channel under factors of small tidal range and exceptional curvature were encouraging as far as comparisons with the Yantlet scheme permitted. Let us compare the relevant conditions :—

| | NEW-YORK *Ambrose dredged channel* | LONDON *Yantlet dredged channel* |
|---|---|---|
| Material ...... | Alluvium and Sand | — Alluvium and Sand |
| Length ........ | 7.4 miles | — 8 miles (dredged) |
| Width ......... | 2,000 feet | — 1,000 feet |
| Depth ......... | 40 feet (Mean Low Water) | — 30 feet (L.W.O.S.T.) |
| Tidal range .... | 4 ft. 6 ins. | — 16 ft. 10 ins. Mean of Spring Tides |
| Courses ....... | 2.2 miles 169° outward A | — 2.00 92 1/2° outward A |
| | 4.5 miles 117° outward B | — 1.72 95 3/4° outward B |
| Maximum alteration of course .................. —— | A — B 52° | Total alteration of course ...... 1.90 103° C |
| | | 1.86 99 1/4° D |
| | | 1.68 97° E |
| | | 9.16 10 1/2° A — C = Maximum alteration of course. |
| | | Less non-dredged 1.16 |
| | | 8.00 |

The present dredged Yantlet Channel differs from the Ambrose and Mersey Channels chiefly by its small variation in course alteration for shipping. There are no sharp bends in the Yantlet development.

From data supplied by the Conservancy, the Thames sends into the tideway about 53 thousand tons of silt per annum descending the river by stages to the estuary, a small quantity being intercepted by dredging in the middle reaches.

For some thousands of years this sediment has been carried down stream to form the inner estuarial deposits. As an experiment we investigated the time required for silt in suspension to reach the sea in its 70 miles of tidal course with the following results.

In winter (February) with a mean fresh water discharge during the experiments of 2,350 million gallons per day the time taken for a sub-surface float to reach the sea from Teddington was about 5 1/2 days and during its progress down stream the float covered in the zig-zag of the flood and ebb tide a distance of 202 miles.

In summer (June) with a mean fresh water discharge during the experiments of 577 million gallons per day the time taken for a sub-surface float to reach the sea from Teddington was about 19 days — approximately four times longer in transit than in winter and during its progress down stream the float covered in the zig-zag of the flood and ebb tide a distance of 844 miles.

The lunar conditions and tidal selection were similar and both floats were placed at Teddington the tide head and starting point at High Water.

It is known that nature tends to augment the development artificially created in such dredged tidal channels, provided the alignment or curvature is satisfactory. Proof of this axiom is found in the Yantlet which now has definite features for natural preservation :—

(1) That the dredged cut for the greater part of its length lies parallel to the alignment of the elongated 24 feet banks on either side of it.

(2) That at its seaward end the curve is in conformity with the strong tidal stream running to and from the West Swin and Barrow Deep.

Arguments were advanced in the early days of discussion that a straight cut across the banks should prove to be successful on the principle that a projectile passing through a straight tube in the manner of the schoolboy's peashooter would be travelling in the direction of maximum energy. But tidal energy is sinuous and may be discontinuous, so that retention of the sinuous watercourse recognises the energising forces in the tidal cycle peculiar to each locality. It became apparent on study of the tidal stream the vigorous flood stream would sweep past any entrance placed transversely to it and would not feed it. Moreover, the early experiments made went to prove that if a straight East-West cut were made the mouth would be again silted up by the contours asserting their formations at the mouth. Next our study was devoted to the avoidance of convex and concave bands in the dredged channel. Previously we had experience in the upper reaches in the waterway of this tidal-hydraulic phenomenon and its variants. We in fact discovered that within limits related to the fall of the channel bed, if a change of direction less than ten degrees in channel curvature can be secured, then no appreciable convex-concave formations will develop.

In the curvatures of the Yantlet Channel the several changes of course are gradual and consecutive changes of course are less than ten degrees in variation with beneficial hydraulic results. As to gradient: The bed of the tidal Thames between London Bridge (which fixes the river bed navigation upper zero) and Gravesend falls approximately one foot to the mile. The lowest low water occurs at or near King George V Dock in Galleons Reach midway between London Bridge and Gravesend. This fall of the river bed is naturally related to the parallel land levels which required close examination in order to examine and eliminate error in land level and tide level. In this research we had at our disposal the remarkable work of Mr. Lloyd who had been employed in levelling the Isthmus of Darien. Mr. Lloyd levelled the south bank of the Thames tideway from Sheerness to London in the years of 1827-28-29. This work was published in the transactions of the Royal Society of London in 1830 and consisted of a line of levels stretching along the south bank of the tideway for a distance of about 40 miles. During the three years which occupied his time in levelling, often interrupted by weather conditions, he conducted a complete series of sea-level observations at Sheerness. In his report he states that he found a difference of 0.556 of a foot between the mean level of neap tides and that of spring tides; but as the whole of the year 1827 presented the most perfect year of observations he took that year's mean for a standard.

There followed in the years 1840-1860 the primary Government levelling of England and Wales which enabled the levels of Mr. Lloyd to be joined to the north bank. Further in 1919-1921 came the second Government geodetic levelling of England and Wales. Between 1830 and 1921 the Thames tidal levels had considerably changed, due to the excavation of approximately 60 million cubic metres of solid material from the river course by dredging. These tidal changes were affecting the low waters and high waters over the entire regimè of the river. Nevertheless the early datum levels on the land at Sheerness which is at the mouth of the river proved of considerable assistance in building up the relation between range and phase and were of the greatest assistance to us in balancing the values of low water spring tides, the datum to which our dredging is taken and in co-relating the change which has occurred in the times of high and low water with increase of range and other factors in 100 years.

The work of the Second Geodetic levelling of England in 1919-21 levels gave us accuracy for both sides of the river mouth which the earlier figures could not supply, so that the dredging plans were on a sure foundation.

Having secured the correct datum for dredging, the next problem was to consider the best possible route for the discharge conformable to nature.

In the western sections where Sea Reach Buoy N° 3 is now situated the early surveyors' charts shewed an elongated pool which retained its situation and character notwithstanding considerable changes elsewhere. This pool formed the key point or axis for the designing of the channel through the sandbanks and was associated with the stream line of the ebb discharge.

Sea Reach at this area shews three flood formations: On the north, the Warp — a deep cul de sac terminating near Leigh Creek; on the south, the Great Nore — also a deep cul de sac; in the centre, the area of the Yantlet flats where the dredged channel is now situated.

Surveys made by Admiralty Surveyors between 1775 and 1895 shewed variation in the shape of the Yantlet banks with a tendency as time went on to congestion and siltation, probably due to the estuary receiving accumulations of detritus and sewerage from an increasing population and the development of industry.

The features of these surveys were as follows :—

| | |
|---|---|
| 1775 Murdoch Mackenzie | Mid-estuary channel with narrow central drainage.<br>North (Leigh) navigation channel closed. |
| 1836-1841 Captain Bullock | Mid-estuary channel narrow irregular pools, instability evident over broad areas. |
| 1863 Captain Bullock | North (Leigh) navigation channel open and deep.<br>As for 1836/41 but shewing deterioration.<br>Loss of depth in mid-estuary and in north channel. |
| 1894-1895 Captains Pirie and Jarrad | Furthei deterioration in depth generally, but a pool remaining at the present position of N° 3 Buoy. |

We therefore had accumulated the following fundamental information :—

(1) General knowledge of geological formations.

(2) History of hydrographic surveys for approximately 150 years.

(3) Consideration of the experiments with mechanical models in forecasting estuarial behaviour.

(4) Comparison with other estuarial dredged channels where training walls were absent, with special reference to the Ambrose Channel.

(5) Precise datum levels from land surveys to establish tidal accuracy.

The remained essential hydrographic data to eliminate trial and error as far as possible.

This hydrographic research required fell under the following details:—

(1) Testing of the nature of river bed by snapper-lead, followed by soundings, charting contouring methods.

(2) Tidal research.

(3) Surface currents, their direction, duration and force.

(3) Ground currents, their direction, duration and force.

## CHARTS, SOUNDINGS, CONTOURING, etc.

Since the commencement of the surveys by the Port of London Authority, charts of Sea Reach have been drawn to the same scale as the surveyors' sheets (6" to statute mile). For accuracy a special triangulation was undertaken to remove primary inaccuracy and north and south banks have also been well co-ordinated by azimuth.

Soundings have always been taken by means of a manganese bronze wire marked every 6 inches on the hand lead system. In recent years this method has been supplemented by the Echo Sounder. The nature of the river bed was explored to verify its quality and for this work a snapper-lead was used. This implement saves dredging when it is desired to obtain a sample of the bottom. It consists of a heavy weight sliding over a tube with two brass spoons at its base, these being kept open by a set spring until the weight falls on the river bed when the spoons close and bring a sample to the surface.

By this method a complete series of surface bed samples were obtained which shewed that the material was too fine and flocculent for sand pumps but ideal for bucket dredging. These determinations were continued seaward until the sand and shell of the littoral drift were encountered.

We found that the deposits laid down by the Thames and those of the littoral drift were easily identified.

Geologically the lower Thames basin is not difficult to dredge, the following being the over-lay on chalk :—

1. Alluvium — Modern to the Bronze Age and post Roman deposits 45 feet thick.
2. Clay and Peat — Neolithic — 2000 B.C. / Mesolithic — 3000 B.C. } 40 feet thick.
3. Gravel — Pleistocene — about 15 feet thick lying about 30/45 feet below Low Water.

The variations of the current in the modern tideway have removed most of the Bronze Age and Mesolithic deposits, so that the modern sewage-laden detritus lies low on the surface.

## TIDAL RESEARCH.

### *Southend-on-Sea.*

(a) The range of tide at mean springs = 16.8 feet.

(b) The range of tide at mean neaps = 10.8 feet.

These ranges are taken at the seaward end of the dredged cut, where also the tidal stream observations were taken.

(c) Period of slack water at Nore Lightship.

From a series of observations occupying forty-four high water periods and forty-three low water periods the period of slack water from surface to ten feet below surface was found to be nineteen minutes.

*Southend-on-Sea — Tidal Levels*

Datum of Soundings Zero. (Also 20 feet below Thames High Water Level).

| | | |
|---|---|---|
| Lowest Recorded level .................. | — | 3 ft. 3 ins. |
| Mean low water Spring Tides ........... | + | 1 ft. 1 in. |
| Mean low water Ordinary Tides ......... | + | 2 ft. 6 1/2 ins. |
| Mean low water Neap Tides ............ | + | 3 ft. 10 ins. |
| Mean Tide Level ...................... | + | 9 ft. 4 1/2 ins. |
| Mean high water Neap Tides ............ | + | 14 ft. 8 ins. |
| Mean high water Ordinary Tides ......... | + | 16 ft. 4 1/2 ins. |
| Mean high water Spring Tides ........... | + | 17 ft. 11 ins. |
| Highest Recorded Level ................ | + | 22 ft. 6 ins. |

N. B. — Tides referred to as Ordinary Tides are a computation and mean of all tides.

*Tidal Constants*

Based upon time of High Water and Low Water at London Bridge.

| | *Subtract* |
|---|---|
| High Water, Southend ............ | 1 hr. 26 mins. |
| Low Water, Southend ............. | 1 hr. 56 mins. |

on Spring Tides

It is therefore High Water at Southend about 1 hour before King George V Dock which is 10 miles seaward of London Bridge.

### *SURFACE AND GROUND CURRENTS*

#### *Behaviour of flood tide currents.*

As previously described, the *surface* currents on the flood tide strike the apex of the Yantlet Channel banks and split into three parts. One part continues a northerly curved course close to Southend Pier filling the cul de sac on the north side of the estuary. The second curves southward filling the Great Nore pocket and also the River Medway. The third or middle branch flows into the Thames estuary with considerable vigour but does not have complete unity of direction until N° 3 Buoy is reached. Before reaching this position the surface currents vary from the mean or centre line of the tide by 5 to 10 degrees.

#### *Behaviour of ebb tide currents.*

On the ebb tide the *surface* currents debouch first on lines parallel with the threads of the under current and dredged channel. Secondly as the ebb tide gains momentum the stream takes a northerly run following the receding main tidal ebb through the West Swin and Barrow Deep. This run to the north may be as much as 18 degrees from the dredged channel alignment, but usually it is less, about 8 degrees.

As the tide falls the higher banks become depleted of water and the drainage area of the dredged channel draws the tributary currents towards it so that during the last quarter of the ebb tide the stream runs mainly in the dredged cut following the curves of the alignment.

*Method of observing surface and ground current data.*

In order to obtain (1) the direction, (2) duration, (3) velocity, (4) period of slack water, together with the continuous and discontinuous stream lines we have found the box-kite float the most advantageous. For this purpose a buoyant wooden frame measuring 4 feet long by 2 feet square is covered with canvas and immersed to the required depth, weighted so as to retain sufficient buoyancy and so remain at the level decided. If surface currents are being measured the float is kept under water sufficiently to escape wind pressure — the float having a small flag incapable of collecting the wind.

When ground currents are being measured the canvas box float is weighted until buoyancy just essential for floatation 1 ft. above seabed has been obtained. The surface indicator is connected to the submerged box float by a fine wire and consists of a thin pole carrying a small flag incapable of pulling the ground float by the greater velocity of the surface current.

*Tidal Predictions and Calculations*

The improved degree of accuracy which the Port of London Tide Tables now shew has been secured by careful supervision of our automatic tide gauges at Southend, Tilbury and Tower Pier. These gauges provide the dimensional data upon which predictions are founded.

Tide gauges have existed for hydrographic purposes for many years. For the pilotage of the deeper vessels special tide gauges have recently been installed. These several installations may be separated into three categories:—

1. Automatic gauges recording graphically the rise and fall of tide at suitable river stations, for hydrographic purposes.
2. Automatic gauges recording the artificially controlled river or dock levels, as at Richmond Lock and Royal Albert Dock.
3. Visual natural range gauges for pilotage night or day, the visibility of the figures being about 1/4 mile, shewing to the navigator the changing tide level continuously.

The history of tidal recording in the Thames is disconnected but interesting.

Probably the earliest recorded attempt at tidal prediction refers to the Thames, found in the Codex Cottonianus Julius DVII, at the British Museum. This work contains calendar and other astronomical or geographical information, some of which are the production of John Wallingford, who died Abbot of St. Albans in 1213. At page 456 a table on one leaf shews the time of High Water at London Bridge, thus — " flod at london brigge ".

| AETAS LUNAE | h | m |
|---|---|---|
| 1 | 3 | 48 |
| 2 | 4 | 36 |
| 3 | 5 | 24 |
| ... | ... | ... |
| ... | ... | ... |
| 30 | 3 | 0 |

In this table, column 1 gives the moon's age, columns 2 and 3 the time of high water corresponding to the age. It is evident from this table that the time of high water at London Bridge has advanced about one hour since the thirteenth century.

Flamsteed, the Astronomer Royal in 1863, friend of Isaac Newton, published a table giving times of high water at London Bridge, and so through the ages there have been tidal records of the Port of London. In 1800 Parliamentary powers were sought for the building of a dock adjoining the Pool of London when a statutory local tide level was fixed, namely Trinity Standard. Observations were then made by a committee of the Trinity House. This Committee appear to have chosen the new moon of the 20th August in that year with a meridian passage of 10 hrs. 20 mins. a.m. G.M.T. The range of this tide was measured and found to be 18 ft. 3 ins. below the level of the high water. This dimension was used for guidance in constructing the dock entrance, and a stone which commemorates and established this tidal reference exists near the Shadwell Dock at present.

Trinity Standard has come to be regarded as a horizontal tidal zero of approximately Spring Tide Level throughout the River. The statutory declaration, however, clearly intended it to be of local application only and it refers carefully to the adjustment necessary if applied to other parts of the River where the level and range would differ from the Pool of London.

Automatic gauges were apparently first tried at the Port of London in connection with further building operations for new docks. Old London Bridge, which acted as a dam to the Thames by reason of its many arches and piers, was removed in 1827 and the present one built. In order to obtain a continuous register of the changed behaviour of tide, Mr. Palmer, the Engineer to the London Dock Company, established his automatic tide gauge there in 1831. Mr. Bunt, a few years later, produced a similar machine of his own design for the Port of Bristol.

In 1833 the Admiralty initiated what is now a worldwide practice by forecasting the tides of London, Sheerness, Portsmouth and Plymouth.

In 1892 the Thames Conservancy introduced a clockwork gauge to record the levels at Richmond Lock. This gauge made by Légé & Co. remained until 1923. When later the Port of London Authority was formed in 1909 greater attention was given to tide gauges due to the great waterway dredging scheme then contemplated. Approximately 55 million cubic yards of material in situ have since been removed from the river bed. This approximates in quantity to the first cut through the Isthmus of Suez.

The year 1912 saw several automatic gauges installed for the surveying and extensive dredging programme of the new Port Authority.

Before proceeding to describe the automatic gauges erected by the Port Authority from 1912 onwards, a description will be given of the first automatic gauge invented by Henry R. Palmer in 1831/33, when engineer to the dock under construction. The details were obtained from his paper read before the Royal Society of London by J.W. Lubbock (Phil. Trans. Volume 121, 1835). Its mechanism consisted of a float resting upon the water in a well protected against tide undulations by wire gauze. The method of suspension was by chain passing twice around a light cast-iron vessel, and provided with a counter weight. The chain of this counter weight was of such a length that both ends were always resting on the ground. A light horizontal shaft with bevel wheels was geared to an upright shaft which acted on the pencil rack. The pencil moved backwards and forwards, making its impression on graduated paper held on a drum rotated by a clock. The cylinder carrying the graduated paper had on its axis a large toothed wheel which received its rotation from the clock shaft. To control the revolutions a cam wheel, having six teeth, then raised a hammer striking the impression once in every hour so that the spaces passed through were measured as they occurred obviating any error due to expansion or contraction of materials.

Mr. T.G. Bunt's tide gauge erected at Bristol on the tidal river Avon in 1837 followed similar principles, viz :—

An eight day clock turning a vertical cylinder revolving once in 24 hours.

A float rising and falling with the tide operating a pencil to scribe the tidal curve through special gearing.

The history of artificial estuarial development shews that as dredging proceeds in a narrow tidal river or as embankments are erected to confine the water to narrower limits, tidal changes occur. By dredging the River Tyne a deepening of 10 ft. was effected in about 50 years, thus the tide levels were changed considerably.

Likewise in the Port of London above Gravesend the range of tide has altered materially due to widening and deepening the Channel over a period of 25 years. Embanking has also affected the tides by causing them to rise higher in certain parts of the waterway. We have therefore tidal complexity to consider.

Automatic tide gauges are essential to trace long period and short period effects. Mere recording of high and low water would not assist in tracing quarter-diurnal effects, for instance. These quarter-diurnals are very important in tidal research.

Throughout the tideway occasional perturbations occur in a marked degree. These are invariably due to severe meteorological disturbances sometimes operating off the Northwest coasts of the British Isles. The Straits of Dover appear to function as a sympathetic barrier to these tidal disturbances and the Thames Estuary being in close proximity registers these local reactions.

On 19th October, 1935, an intense depression travelled from the Atlantic and on that date was centred over the North of Scotland. The disturbance of the tidal levels in the lower part of the North Sea was such that the tide wave in the Port of London lost for a period its normal character with the effects seen on the curves.

The automatic Tide Gauge at Southend was made by Cary Porter and established in 1912. It is of the horizontal drum type, the float operating the pen, the clock revolving the recording drum one complete revolution in 24 hours. The gearing reduces the tidal movement to a record of half-an-inch to one foot vertical, and one inch to the hour horizontal, the scope being equal to a tidal range of 29 ft.

The automatic gauges at Tilbury, 17 miles, and at Tower of London Pier, 43 miles respectively landward of Southend are of the same design. The clocks which are lever type receive special attention owing to vibrations which are inevitable from vessels manoeuvring in the vicinity. At Galleons Reach, situated 33 miles landward from Southend, an automatic electrical recorder established in 1912 is fitted to shew by remote control the variations of water level in the Tidal Basin with reference to the river levels. These diagrams are visible to the control engineer in the pumping station. Its arrangements consist, for the river levels, of a wooden trunk 3 ft. × 3 ft. situated on the upper end of Galleons Jetty, a float having a diameter of 18 ins. is connected with a counter-weight by a copper wire passing over a grooved wheel, geared to a transmitter installed on the top and centre of the trunk. A unique feature of this trunk is the method of keeping it free from mud. The bottom consists of a flat iron plate pierced with holes, and moving over the plate but in close contact is a steel wiper. To this wiper is attached a steel rod which runs to jetty level. The top end of the rod is squared to receive a key and a few turns of this causes the wiper to move over the plate, forcing the mud through the holes in the bottom and preventing general settlement.

A movement of 2 ins. in the tide causes an electrical impulse to be transmitted along wires to the pumping station where the main instrument registers this rise or fall on the chart. Fixed to this instrument are two sets of induction coils, one for the rising tide, in which case the current causes the pen to move vertically to a scale of 2 ins.; and vice versa for the falling tide.

A plate is fixed in the river trunk at a level of 5 ft. below T.H.W. Tidal contact with this plate causes a bell to ring in the pumping station, enabling the engineer in charge to check the accuracy of the gauge and to adjust as necessary.

For dock levels a similar transmitter, sets of receiving coils, float and counter weight are used. The greatest fluctuation in dock level is 2 ft. 6 ins. compared with the maximum river range of 30 ft. The distance of the transmitter from the pumping station in the case of the river levels is some 600 ft. and in the dock level the distance is nearly half a mile.

Both the river and dock levels are recorded on the same tidal sheet which is fitted on a drum which revolves once in 24 hours and the record is changed daily. The drum is of the vertical type and consequently the pens move vertically.

The voltage used to operate this gauge is 20 volts and is supplied by a battery of 14 Leclanché cells.

From 1912, the date of installation of this gauge, to the present time, a chain passing over a sprocket wheel was used to link the float and counter weight to the transmitter, both in the case of the river levels and dock levels.

Considerable trouble was experienced by the stretching of the chain but this chain has now been replaced by a flexible copper wire which is wound round a grooved wheel.

For determining the non-harmonic constants we have recently examined the tidal slope at several points of the River from synchronous readings of the automatic gauges. From this diagram the position of maximum range of tide is clearly demonstrated as existing at Woolwich (King George V Dock).

Moreover, it will be observed that the face of the Tidal Thames is more frequently a changing sinuous surface than a direct slope.

The predictions of high and low water times and heights are based on the harmonic analysis and were previously obtained from the Old Swan Pier recordings for the year 1911-1912 and computed by Messrs, Edward Roberts & Sons, Mr Roberts having been a pupil of Lord Kelvin — the inventor of the predicting machine.

Early in 1926 inaccuracies having been noted by the tidal occurrences, a comparison was made by Roberts of the 1911-1912 figures with those of 1925 and it was found that during that interval the times of high water for Old Swan Pier situated above London Bridge had advanced 5-10 minutes and low water 3-5 minutes, also that an increase in the range of Spring tides had taken place. This acceleration of tide was probably due to dredging and other river improvements.

It should be noted that the Old Swan Pier tidal records had been used as the basis of tidal computations for the period mentioned and previously thereto. The situation of this gauge was unfavourable for tidal levels as the structure of London Bridge affected the levels so that on the ebb tide there was a slight lagging of the tide and on the flood, a weir effect, producing an untrue curve.

In 1926 the River Committee gave authorisation to transfer future tidal predicting to the Liverpool Tidal Institute relieving the Authority from the uncertainty of private computing. The Tidal Institute at this time installed a much improved tidal predicting machine and was entrusted with similar tidal prediction problems for the British Admiralty and certain important commercial ports. It was found in 1929, when the revised values were received, that the times of high and low water were still susceptible to improvement at London Bridge and to a smaller extent at Southend-on-Sea.

It was thereupon decided that the predictions required a broader period basis than one year's analysis. It was also proposed to use Southend, where the movement of the tide was free, as the major station instead of Old Swan Pier and consequently the records for the years 1926/1928 inclusive were analysed and form the basis of present-day predictions.

It was again proved in 1929 that the travel of the tidal wave between Southend and London Bridge had been with recent improvements accelerated by 4 mins. at high water and 8 mins. at low water, which was probably due to the removal of 1 3/4 million cubic yards by dredging in Woolwich Reach during the interval, 1925-1929. In 1931 it was further noticed that a constant difference was found between predicted tides and recorded tides for certain months of the year. The Tidal Institute was asked to investigate further and advised that corrections were necessary to the predictions for the years 1932 and 1933, reaching the maximum correction of 7 ins. on the high waters and 6 ins. on the low waters.

The recorded tides for the years 1933 and 1934 were again compared with those predicted, and it was found that 70% of the high water Springs were within 10 mins. of times and 65.9% within 6 ins. of height and the Tidal Institute furnished the following comparisons :—

| **High Waters** | | *Liverpool* | *Avonmouth* | *Southend* | *London Bridge* |
|---|---|---|---|---|---|
| Within 10 mins. of predicted Time ......... | 1933 | — | — | 76.7 % | 70.3 % |
| | 1934 | 75 % | 82.5 % | 73.6 % | 70.9 % |
| Within 6 ins. of predicted Height ........... | 1933 | — | — | 65.7 % | 65.9 % |
| | 1934 | 46 % | 49.0 % | 63.7 % | 60.0 % |
| **Low Waters** | | | | | |
| Within 10 mins. of predicted Time ......... | 1933 | — | — | 61.8 % | 66.7 % |
| | 1934 | 79 % | 80.5 % | 64.6 % | 65.2 % |
| Within 6 ins. of predicted Height ........... | 1933 | — | — | 51.0 % | 46.3 % |
| | 1934 | 42 % | 37.0 % | 65.4 % | 60.6 % |
| **Mean Range** | | 20 ft. | 28 ft. | 14 ft. | 18 ft. |

From the above it will be noted that 1934 was not a great improvement on 1933 at Southend and London Bridge and this was pointed out to the Tidal Institute.

In 1936 the Tidal Institute thereon recommended that new analyses be made for Southend and London Bridge at regular periods every three years (in place of using one year) as is the practice at Liverpool, Avonmouth and Southampton and this was done, comparing 1934 with 1931. Should it be considered desirable the question of a further analysis after this period could of course be reviewed.

During 1939 further comparisons of the actual 1938 tides for London Bridge and Southend were undertaken with the results shewn below, using the 1922 figures of Mr. Roberts for comparison, the first year that re-analysis was ordered :—

| **High Waters** | | *Southend* | | *London Bridge* | |
|---|---|---|---|---|---|
| Within 10 mins. of predicted Time ......... | 1922 | 58.6 % | | 68.9 % | (Old Swan Pier) |
| | 1938 | 81.4 % | | 72.2 % | (Tower Pier) |
| | | 22.8 % | Improvement | 5.3 % | Improvement |
| Within 6 ins. of predicted Height ........... | 1922 | 61.6 % | | 57.2 % | (Old Swan Pier) |
| | 1938 | 60.6 % | | 55.6 % | (Tower Pier) |
| | | 1.0 % | Difference | 1.6 % | Difference |
| **Low Waters** | | | | | |
| Within 10 mins. of predicted Time ......... | 1922 | 56.7 % | | 53.3 % | (Old Swan Pier) |
| | 1938 | 64.0 % | | 66.0 % | (Tower Pier) |
| | | 7.3 % | Improvement | 12.7 % | Improvement |
| Within 6 ins. of predicted Height ........... | 1922 | 65.1 % | | 52.5 % | (Old Swan Pier) |
| | 1938 | 67.0 % | | 62.4 % | (Tower Pier) |
| | | 1.9 % | Improvement | 9.9 % | Improvement |

### *TIDAL CONCLUSIONS.*

The triennial examinations should further improve the difference between predicted tides and the actual occurrences. The establishment of Southend as the standard for comparison should also increase the general accuracy.

Further embanking of the Thames such as a wall from London County Hall to Blackfriars Bridge in the narrow City reaches of the River would tend to raise the high waters in the Pool of London.

In effect the following are the approximate changes :—

*London Bridge*

Level of Low Waters has fallen 1 ft. 7 ins. in 100 years.

Level of High Waters has risen 11 ins. in 100 years.

Increase of range in 100 years = 2 ft. 6 ins.

Acceleration of tidal wave in 100 years.

Between Southend and London Bridge the amount is as follows :—

Times of Low Water have advanced 31 mins. in 100 years.

Times of High Water have advanced 38 mins. in 100 years.

## THE DREDGING FLEET.

When the Port of London Authority entered upon its responsibilities in 1909 certain dredging units were available. These were added to and by 1913/14 the main fleet stood as follows :—

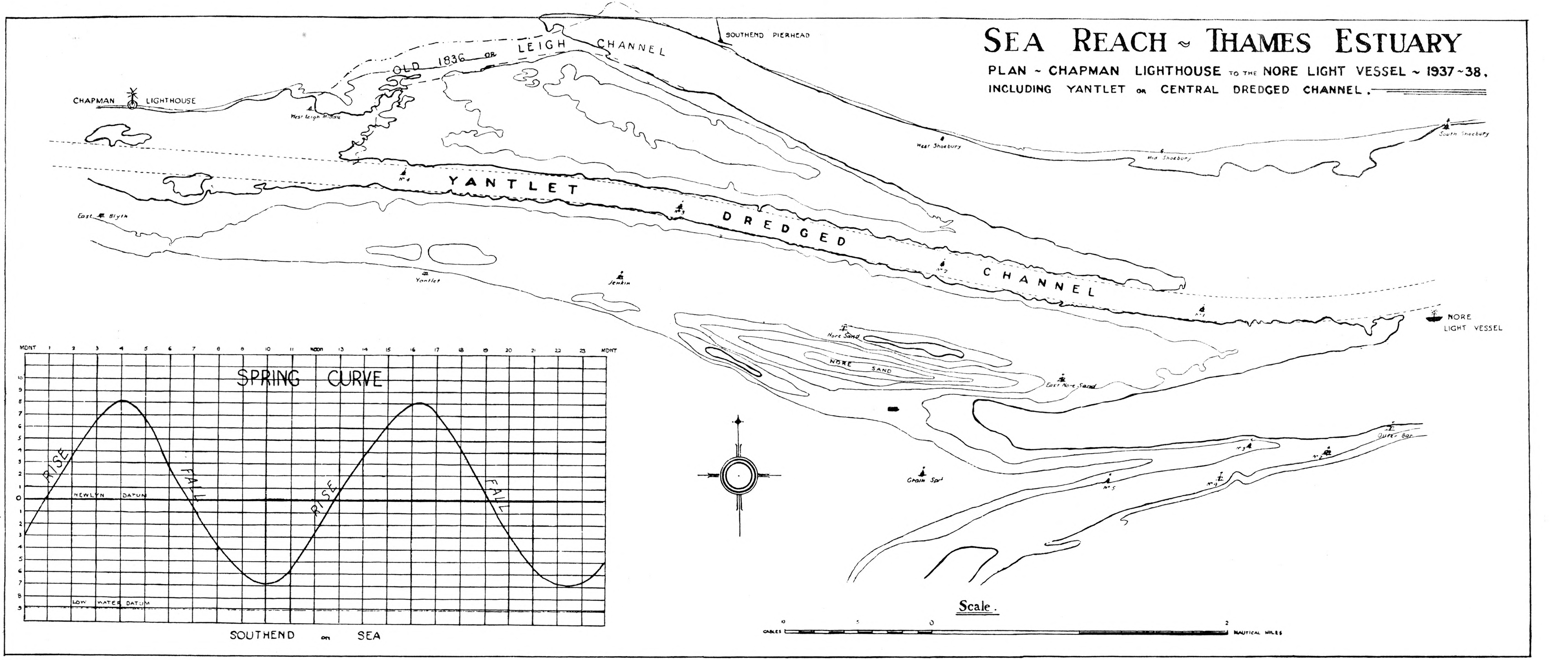
*Dredger*

N° 3. A — A steel non-propelled centre well dredger, 1,810 tons displacement.
Built by Fleming & Ferguson of Paisley in 1906.
Two sets of buckets, one of 20 cu.ft. and the other of 14 cu.ft. 350 I.H.P.
Total cost (new) £ 35,550. Dredging depth 50 ft.

N° 4. B — A steel non-propelled bow well dredger, 898 tons displacement.
Built by Fleming & Ferguson of Paisley in 1911.
Bucket capacity of 10 cu.ft. 225 I.H.P.
Total cost (new) £ 22,353. Improved dredging depth 60-65 feet.

N° 5. C — A steel non-propelled bow well dredger, 898 tons displacement.
Built by Fleming & Ferguson of Paisley in 1911. 225 I.H.P.
Total cost (new) £ 22,353. Dredging depth 45 feet.

N° 7. D — A steel non-propelled bow well dredger. 1,760 tons displacement.
Built by Lobnitz of Renfrew in 1911. 453 I.H.P.
Bucket capacity of 27 cu.ft.
Total cost (new) £ 42,614. Dredging depth 55 ft.


SEA REACH ~ THAMES ESTUARY
PLAN ~ CHAPMAN LIGHTHOUSE TO THE NORE LIGHT VESSEL ~ 1937~38.
INCLUDING YANTLET OR CENTRAL DREDGED CHANNEL.
SOUTHEND PIERHEAD
OLD 1836 OR LEIGH CHANNEL
CHAPMAN LIGHTHOUSE
West Leigh Middle
West Shoebury
Mid Shoebury
South Shoebury
YANTLET DREDGED CHANNEL
East Blyth
Yantlet
Jenkin
Nore Sand
NORE SAND
East Nore Sand
NORE LIGHT VESSEL
Grain Spit
Outer Bar
SPRING CURVE
RISE
FALL
RISE
FALL
NEWLYN DATUM
LOW WATER DATUM
MDNT
NOON
SOUTHEND ON SEA
Scale.
CABLES
NAUTICAL MILES

N° 6. A steel non-propelled bow well dredger. 1,760 tons displacement.
E Built by Lobnitz of Renfrew in 1913. 453 I.H.P.
Bucket capacity of 27 cu.ft.
Total cost (new) £ 42,614. Dredging depth 55 ft.

To those vessels marked A, D, E fell the work of raising four million cubic yards between 1923 and the date of final completion. The cost worked out at approximately 1.25 shillings per cube yard inclusive of depositing at sea.

Heavy weather created delays in performance and on several occasions the steam hoppers were required to circle around the bucket dredgers pouring oil on the sea surface to calm the breaking water until the storm subsided.

Wrecks of vessels sunk and destroyed by explosives were encountered in the dredging but the massive strength of dredgers D and E were able to cope with the metal and framework encountered.

Altogether four such wrecks were demolished by the dredgers.

**Comparison between Flood and Ebb Tide Current Observations in the Yantlet Channel, taken at a level of 1 foot above the river bed level Period 13th - 16th December, 1938.**

| *Position in Yantlet Channel* | *Times relating to time of Low Water* | | *Speed in Knots* | | *Tidal level at Southend above Low Water datum* | |
|---|---|---|---|---|---|---|
| | After | Before | Flood | Ebb | Flood | Ebb |
| | Hrs. | Hrs. | | | Mean of Spring and Neap Tides | |
| Mid-way | 1 1/2 | 1 1/2 | 1.4 | 1.0 | 5' 1" to 5' 8" | 3' 5" to 3' 1" |
| do | 2 | 2 | 1.7 | 1.3 | 5' 8" to 6' 4" | 4' 5" to 4' 2" |
| do | 1 1/2 | 1 3/4 | 1.4 | 1.2 | 5' 1" to 5' 8" | 4' 2" to 3' 8" |
| | 1 3/4 | · | | | | |
| Western end | 2 1/4 | 2 1/4 | 1.6 | 1.4 | 6' 4" to 7' 4" | 4' 7" to 4' 5" |
| do | 2 1/4 | 2 1/4 | 1.6 | 1.5 | 6' 4" to 7' 4" | 5' 9" to 5' 0" |
| do | 2 3/4 | 2 3/4 | 1.8 | 1.7 | 7' 4" to 8' 9" | 6' 7" to 5' 9" |
| do | 3 | 3 | 1.8 | 1.7 | 8' 9" to 9' 7" | 7' 3" to 6' 7" |

NOTE : (1) The stronger force of flood tide in all positions.
(2) Surface currents may exceed in velocity the bottom velocities by 90%.

## MARKING AND NAVIGATIONAL DIRECTIONS.

From 1797 until 1925 the Nore Light ship had occupied a position which led shipping into the River Medway rather than into the Thames because of the associations with the Royal Navy in past times with the Medway. With the development of other naval bases and the commercial rise of the Port of London the General Lighthouse Authority decided on the completion of the Yantlet Dredged Channel to alter the position of the Nore Lightship to where it now serves as the leading mark for the traffic proceeding into and out of London. At the same time the channel now dredged was rebuoyed at intervals approximately equidistant so that the navigator entering from seaward is guided by a series of buoys —

| | | | | |
|---|---|---|---|---|
| First | N° 1 | Buoy shewing | 1 | flash |
| Second | N° 2 | do. | 2 | flashes |
| Third | N° 3 | do. | 3 | flashes |
| Fourth | N° 4 | do. | 4 | flashes |

At each buoy there is a slight alteration of course due to the sinuous character of the dredged channel.

In this waterway the buoys are placed in the centre of the channel a style of marking preferred by pilots because at half tide margins extending 500 feet on either side provide a depth of 34 feet and enable the wider navigation to be used as requisite.

## THE NAME OF THE CHANNEL.

" Yantlet " is a name associated with a creek in this neighbourhood and was a short cut into the River Medway from the River Thames taking its origin from the Old English Gegnlad — a backwater. This creek has filled up and is not now fully navigable. In the Cartularium Saxonicum under the following dates 779 A.D. 789, 808 A.D. this name appears. With such an old identification spreading to the banks and vicinity the central dredged channel in Sea Reach therefore takes its name.

## CONCLUSIONS.

No fundamental laws have been assailed or the aid of expensive training walls invoked. The estuary remains free in the hydraulic sense. Since the original dredging, natural scour has increased the depth from 30 feet to 32 feet 5 inches (mean of all sections) and the natural gain from scour since the channel was formed by dredging exceeds 3 1/3 million cubic metres.

The prospect of future self-maintenance appears satisfactory and the relation of length to width and depth is apparently in sympathy with nature.

The geographical position which placed this development where the flood and ebb streams are nearly equal in duration has proved to be no disadvantage and the dissipation of tidal energy of the ebb tide due to the bellmouth has been partly counteracted by the stability of the channel bed which collects and contains the stream on the last and vital quarter of the ebb tide, without erosion of the sides.

Owing to its curvature and alignment the channel collects the full vigour of the flood stream which also helps to maintain depth, being on the average stronger than the ebb.

Those responsible for estuarial management may therefore find in this Thames research some data of service to them in coping with the problem of free flow and artificial channel development.