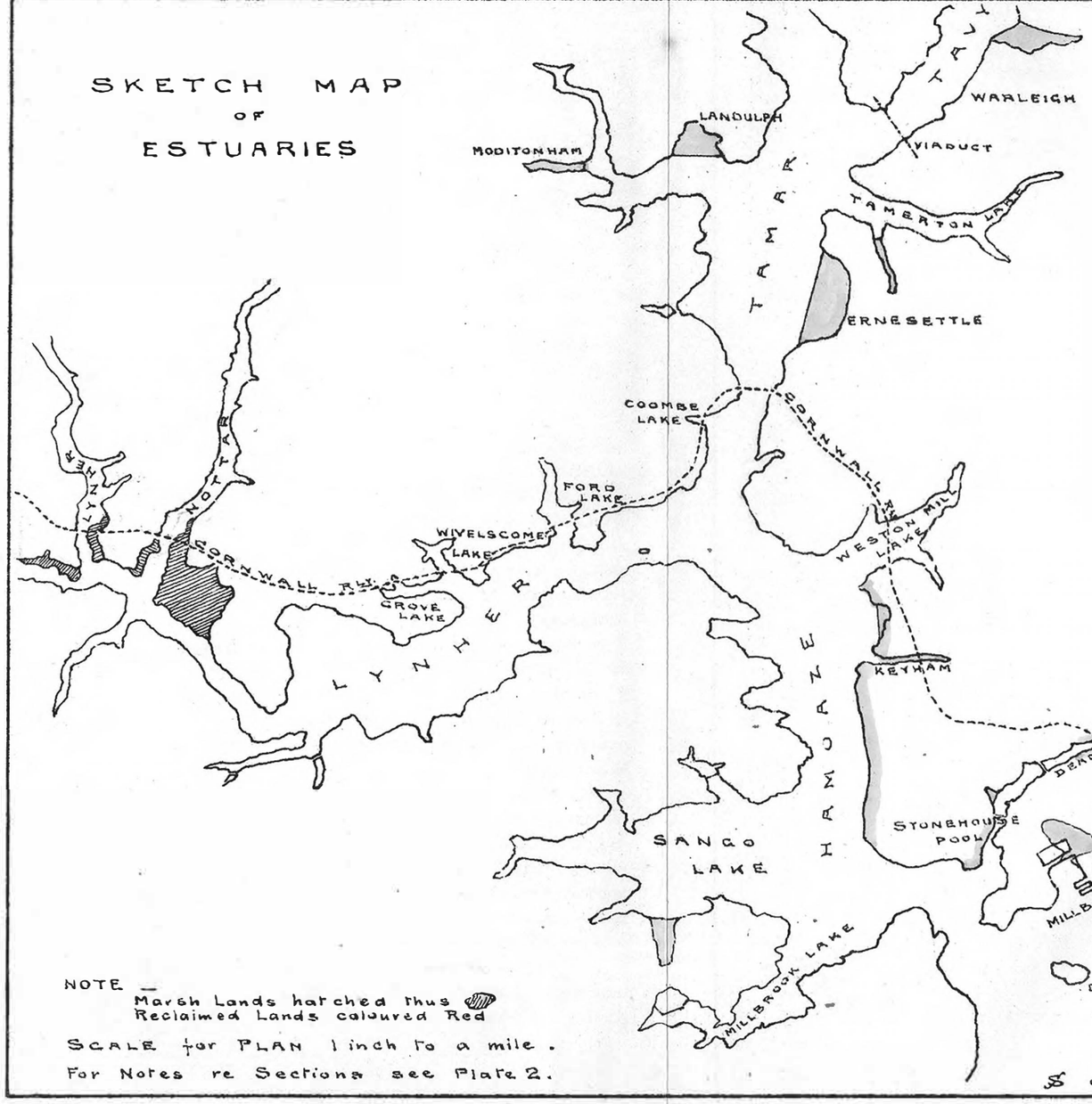
SKETCH MAP OF ESTUARIES



NOTE —
Marsh Lands hatched thus
Reclaimed Lands coloured Red

SCALE for PLAN 1 inch to a mile.

For Notes re Sections see Plate 2.

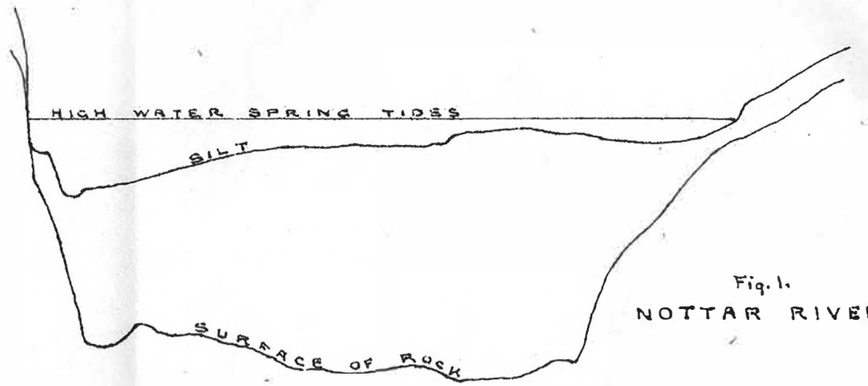


Fig. 1.
NOTTAR RIVER

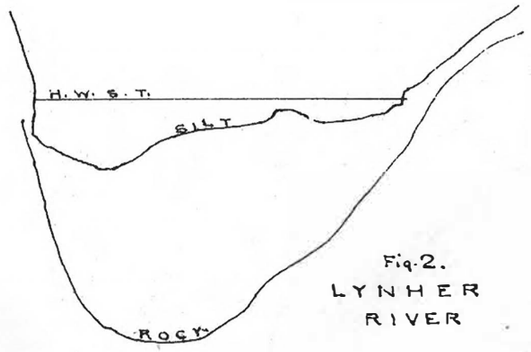


Fig. 2.
LYNHER RIVER

A. Hansford Worth del.

ESTUARIES AND TIDAL LANDS OF PLYMOUTH.

BY MR. R. HANSFORD WORTH, C.E.

(Read 22nd January, 1891.)

PLYMOUTH SOUND is bounded to the south by a line drawn from Penlee Point to the Shagstone, a distance of three and a quarter miles.

The length of a line drawn northwards from the centre of this boundary to the nearest land would be a trifle over three miles.

Although several small streams fall into this bay from the east and west, they do not affect the shore-line, which continues its bold, sweeping curves on either side until the northern extremity is reached. Here the coast-line is divided in three places. To the north by the indent known as Millbay; to the east by the strait opening into Cattewater; and to the west by the entrance to Hamoaze.

The two great estuarine expanses, the lower reaches of which are known as Cattewater and Hamoaze respectively, have many features in common; in fact, their characteristics may be said to be identical; and the distinctions are mainly in relation to depth and area, more in degree than in kind. Each opens into the Sound by a narrow strait—barely 450 yards in width in the case of Cattewater, and only about twenty yards wider between Wilderness and Devil's Points.

Beyond this first constriction there follows in each a rapid expansion, more marked in Hamoaze than Cattewater; and each is joined by a lesser inlet from the north, in the one case Sutton, in the other Stonehouse Pool.

A second contraction takes place in each, at Turnchapel Rock and Torpoint respectively; and in each the area once more widens, terminating again at the Laira and Saltash Bridges with narrow straits. Above these last a third and final expansion takes place;

and then both estuaries divide to take two main streams, the Tamar and Tavy, the Plym and Torry.

In the Lynher the same alternate constriction and expansion are seen, although on a smaller scale.

So much for a rapid preliminary survey of the area to be dealt with.

The present state of these estuaries, with their deep centre channels, and wide bordering flats, dry at low-water, gives no clue to the actual form of the rock surface underlying.

To attempt to acquire some idea of the features of these creeks before the present accumulation of silt was deposited, we must review the evidence at our disposal.

Fortunately this has been considerably added to of recent years. The construction of the new railway bridge at Laira has afforded information as to the section of the rock channel at that point, which would not otherwise be obtainable. Perhaps the erection of costly bridges on cylinder foundations may be regarded as a somewhat expensive method of obtaining geological information, but it has the merit of giving accurate results.

The diagram annexed shows the depths attained by the pier cylinders of this structure. Owing to the curvature of the bridge on plan, the slope of the rock on the left-band or western side is really steeper than represented. The distance between the piers is uniformly 106 feet; and the first pier at the west or Plymouth end is founded upon rock at a height of 3 feet above low-water of spring tides. The next or second pier reaches a deptb of 30 feet below low-water spring tides, giving a fall of 33 feet in 106 feet, or at the rate of 1 in 3¼. The third pier reaches a depth of 80 feet below low-water spring tides, giving a fall of 50 feet in 106, or practically 1 in 2. The fourth pier reaches 87 feet 6 inches, and the fifth 86 feet 6 inches, below low-water spring tides, thus showing that, for about a breadth of 212 feet at the centre, the chaunel in the rock is practically level at 87 feet below low-water. Between the fifth and sixth piers there is a rise of 50 feet at the rate of 1 in 2, being precisely the same slope as the corresponding length at the other side of the section. The slope of the bottom from this point to the masonry abutment on the east bank is about 1 iu 3¼, again corresponding with the other side. This deep trough is not really the full extent of the matter we have to consider, for we must add the height of the adjoining

cliffs in order to obtain the full excavation which has here been executed by natural means. From present appearances, these cliffs must have risen to a height of at least 60 feet above low-water spring tides, but may not have been very bluff, rising probably much more rapidly on the western side at Prince Rock than on the eastern side. From an examination of Figure 1, Plate 2., it will be seen that the surface of the silt bears no relation to that of the underlying rock, the greatest depth of water at low-tide being only 5 feet.

The deposit at this part of the estuary consists to a great extent of sand of varying sized grains; and contrary to what might perhaps be thought, it was by no means au easy matter to induce the cylinders to sink into it.

Those that were sunk by the aid of the pneumatic apparatus invariably refused to start until all the air was exhausted; while even in those fixed by dredging in the open, a considerable disincliuation to move was observed. On one occasion one of these cylinders, weighing in all with ballast about two hundred tons, remained fixed for nearly two days, although the ground was excavated to a depth of 6 feet below the cutting edge. The only supporting power was the skin friction between the iron of the cylinder and the sand. Finally, when it did start, it dropped through 47 feet in considerably less than as many seconds. This was by no means an isolated instance.

In sinking these foundations, layers of oyster shells of considerable depth were met with, the oue at about 30, and the other at between 60 and 70 feet below low-water. Reudel, in making a survey preliminary to the erection of his bridge, undoubtedly mistook this layer of oyster shells for the rock, and the mistake—a perfectly natural one—was, I believe, repeated in taking details for the new bridge. The rock bed across the whole width of the Laira at this point was found to be limestone.

The new quay at Priuce Rock was founded on cylinder foundations, and these attained a very considerable depth. The various railway banks which have at times been constructed along the shores of Cattewater and the Laira, all add corroboratory evidence as to the great depth of the deposit, even comparatively near shore. Directly a spoil bank of any kind is tipped on the surface of the silt it commences to sink, and displaces the silt, which at the same time rises in level. Presently a condition of equilibrium obtains

—due either to the material of the bank reaching and resting on the rock bed, or to its reaching a bed of compact sand, or finally it may sink sufficiently far, and spread over a wide enough area, to compact and displace the silt, and maintain a condition of what might almost be called floating equilibrium.

Thus a certain amount of evidence as to the depth of deposit can be obtained from the behaviour of a bank tipped on its surface.

At Cattedown pile driving has shown that in places at least the rock surface is as much as 40 feet below low-water quite close to shore. It is necessary to add, however, that at other places it reaches a level within about 20 feet of low-water for some distance out. In Hooe Lake I have reason to believe that a very considerable depth of deposit exists, although my actual knowledge of that creek only extends to 12 feet below low-water or thereabouts. What the actual depth of the rock surface may be in the centre of Cattewater I am unable to say, and any attempt to ascertain it would involve considerable expenditure. Between Queen Anne's Battery and Fisher's Nose, 64 feet below low-water failed to find rock. Off the West Pier at Sutton Pool, on the outside, 60 feet below low-water failed to find rock, and this within 120 feet of shore. Even inside the piers of Sutton Pool very considerable depths were found, not however connectedly, but in pits and patches with shallower gullies running between. At one place the drop from 4 feet to 30 feet below low-water is practically perpendicular. An elaborate survey of the bed of Sutton Pool has been made, and the results are interesting, but cannot be quoted in detail here, especially as I have not obtained the permission of the Directors of the Company to make them public. Some day, if those gentlemen give the requisite permission, it would make an interesting geological study.

At the Great Western Docks there is 60 feet depth of silt on the line of the quay forming the dam between the floating and the outer basin. This is at a point to the westward of the present entrance.

In Firestone Bay, off Eastern King, soundings of 25 fathoms or 150 feet at low-water are obtained. The bottom is rocky, and probably represents the actual rock bed of the harbour. There is no absolute proof that such is the case, however, so that it would be best to consider this depth as a minimum, which might possibly, on further examination, be found to be exceeded.

Similarly, between Barn Pool and Devil's Point, there is a pit with 22 fathoms or 132 feet of water. To the westward of the Rubble Bank there is yet another deep sounding of 17 fathoms or 102 feet.

Through the kindness of Mr. Margary I have been enabled to obtain full information as to the sections of all the creeks crossed by the Cornish line in this neighbourhood.

Piles are second only to cylinder foundations where accuracy of information as to the rock bottom is required. All creeks of any importance are crossed by the Cornwall Railway on viaducts having pile foundations, a very fortunate circumstance, so far as we are concerned this evening. Thus I have obtained sections of Deadlake, Keyham Lake, Weston Mill Lake, the Tamar at Saltash, Coombe Lake, Ford Lake, Wivelscombe Lake, Grove Lake, Nottar River, and Lynher River. (See Plates 1 and 2.)

At the head of Deadlake the greatest depth of the deposit is only 5 feet, and the rock bed lies 9 feet above low-water.

Keyham Lake had already been to some extent reclaimed at the date of construction of the viaduct.

The coloured portion of the figure indicates the extent to which this lake had been filled in above high-water level in the year 1853; the greatest depth below low-water on this section was ascertained by boring to be 25 feet.

Weston Mill Lake has a singularly regular section; the greatest depth of deposit is 75 feet, and the depth below low-water is 66 feet.

With Saltash Bridge we will deal later on.

We next come to Coombe Lake, near Saltash. The greatest depth of deposit under the viaduct is 43 feet, reaching a depth of 36 feet below low-water.

At Ford Lake the greatest depth of silt is 73 feet, and the rock lies 67 feet below low-water. At Wivelscombe Lake, 46 feet below low-water, and 56 feet of silt, are recorded.

Grove Lake is unimportant, and has only 10 feet of silt, while the rock bottom is exactly at low-water level.

Nottar River has 57 feet of silt at the deepest point, and the rock is 44 feet below low-water. (Fig. 1, Plate 1.)

Finally, the Lynher has 18 feet of silt, over rock lying 41 feet below low-water. (Fig. 2, Plate 1.)

The great point to be observed in the above details is the fact that the small and unimportant tributary creeks maintain in many

cases the same depth as the main channel, for at least the earlier portion of their length, showing that these channels connect into the centre, and not the side, of the main channel.

The foundations of Brunel's bridge at Saltash reach a depth of 68 feet below low-water, and 13 feet of this depth consists of silt.

The cylinder foundations of the new railway bridge over Tamerton Lake indicate the following depths of deposit, commencing with the pier at the Plymouth end: 5 feet, 9 feet 6 inches, 10 feet, 11 feet 6 inches, 15 feet, 20 feet—this last being the deepest point reached—or 15 feet 6 inches below low-water. Unfortunately for our purposes the bridge was placed at the point where the low-water channel ran, and not at the point where the rock lay deepest. It will be observed that where the bridge ends and the bank recommences, the rock is still steadily shelving downward.

At the Tavy, however, the bridge extends over the whole width of the river at high-water. Starting once more at the Plymouth end we have first seven spans of masonry covering a length of 390 feet. In this length the rock surface falls from 5 feet to 24 feet below high-water in a gradual incline, covered by an increasing depth of silt, which nowhere exceeds 9 feet. Then follow eight iron spans of 120 feet each. Where the masonry ends the depth of the rock below low-water spring-tides is 9 feet. In the first span of 120 feet this increases to 33 feet, or at the rate of one in five; in the next to 43 feet, at the rate of one in twelve; then to 52 feet, at one in thirteen and a half; then 62 feet, or one in twelve; at the fifth pier 67 feet, at a rate of one in twenty-four; at the sixth pier 68 feet; at the seventh pier 67 feet. Then follows a rapid rise to 3 feet, at a rate of one to one and a quarter. Two more spans of masonry complete the bridge, which attains a total length of 1440 feet. At the abutment at the north end the rock reaches to high-water mark. (See Figure 2, Plate 2.)

This completes the evidence at present obtainable as to the depth of silt in the estuaries. Sufficient detail has, however, been gathered to enable some of the leading features of the original rock bottom to be reconstructed with fair approach to accuracy.

Taking low-water of spring tides as the datum level, the depth of the centre channel below this has been found to be greater than might have been anticipated.

In the Hamoaze this depth ranges from at least 150 feet in Firestone Bay to 132 feet and over off Devil's Point, and 102 feet and over off the Rubble Bank. Between this last point and Saltash Bridge it is reduced to 68 feet, and at the Tavy viaduct the same depth is found. It is extremely probable that the Tamar near this last point would be nearer 75 feet in depth, but such an assumption, although warrantable, might not be accurate. The channel in the rock above Saltash would be absolutely level for a little over two miles. For three miles below Saltash the incline is at least one in 515, and from the Rubble Bank to Firestone Bay it continues at the rate of one in 150. Objections might be urged against including Firestone Bay in a consideration of the Hamoaze. But although not geographically accurate, such an inclusion is warranted by physical facts, inasmuch as the bridge of rocks between Drake's Island and the main forms to all practical intent a continuation of the land at Mount Edgcumbe.

Although I have spoken of the channel as having a constantly-increasing rate of incline from the head of the estuary seawards, I must not be understood as suggesting a section lying evenly or in straight lines between the points mentioned. On the contrary, I have merely referred to a general surface-level, which we have reason to believe is subject to many minor irregularities. From general experience, it is safe to assume that the narrower parts of the estuary are relatively to their position on the length of the estuary shallower than the wider, although at first consideration the reverse might be expected.

Thus far a longitudinal section of the rock-bed has been constructed, which within reasonable limits may probably be depended on for accuracy.

Turning now to the transverse sections, one point is certain, that the channel in most cases maintains its greatest depth for a fairly level portion of some width; beyond this, on either side, the rock rises to the shore in slopes of very varied character, and speculation as to the actual form of any particular cross section would be worse than useless.

To sum up, the general conclusions to which we can safely arrive are, that the rock-bed of the Hamoaze and associated estuaries forms a channel varying from 60 feet to 150 feet in depth, steadily growing deeper seawards, and with ever-increasing rapidity, presenting constant alterations of wide-spreading basins

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and much contracted-straits. So far as our information extends, these conclusions apply also to Cattewater.

If we enquire as to the agency which would have created these singularly-shapen excavations, we must, in accordance with all modern articles of geologic faith, decide in favour of ice action.

It is usual to speak of Plymouth Sound as a harbour without a bar, but personally I should rather describe it as having a bar with a great depth of water over it. The whole deposit between the twenty-fathom line in Firestone Bay and the twenty-fathom line four miles further seaward constitutes a bar with a greatest depth of water of between five and six fathoms at low-tide. It is difficult to imagine and contrary to probability that there should be no rock-channel connecting these points. The powerful tidal currents flowing to and from Hamoaze have prevented a deposit in Firestone Bay; but the comparative quiescence of the waters of the Sound have allowed of the formation of a bank, which is in its essential characteristics a drowned bar.

So far as can be ascertained the dawn of the historic period found the relative levels of land and sea in this neighbourhood precisely as they now are; and the silting up of the creeks and estuaries must have proceeded far towards its present stage. It is easy to restore the shore line of this period, and I have prepared a plan shewing what was then the geography of the district. (See Plate I.)

Commencing with the estuary of the Plym on the east, we find the Laira present a very much larger area of tidal lands than at present. All the embanked lands round Longbridge, and for some distance up the Plym river, to the highest point at present reached by spring tides, formed a long creek adding to the length of the Laira. The Torry brook had a separate estuary reaching to the present site of Plympton St. Mary Church. The land now known as Chelson Meadow was covered at each tide, and a long creek reached as far as the foot of the present Lipson Hill. The area long known as Tothill Bay was then open to the sea, as was yet another piece of tidal land lying in an indent between Great and Little Prince Rocks. Pomphlett Lake had a slightly extended area beyond its present, and Hooe Lake was much as now, except that the creek towards Radford stretched a little farther inland.

Sutton Pool was in shape much as now, only somewhat larger in all dimensions, and with a more open entrance.

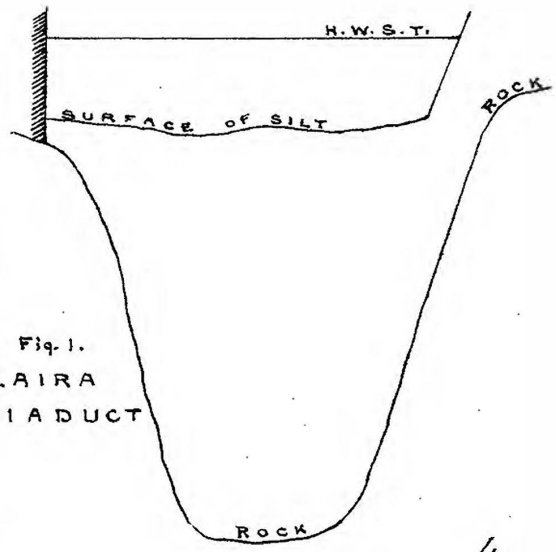


Fig. 1.
LAIRA
VIADUCT

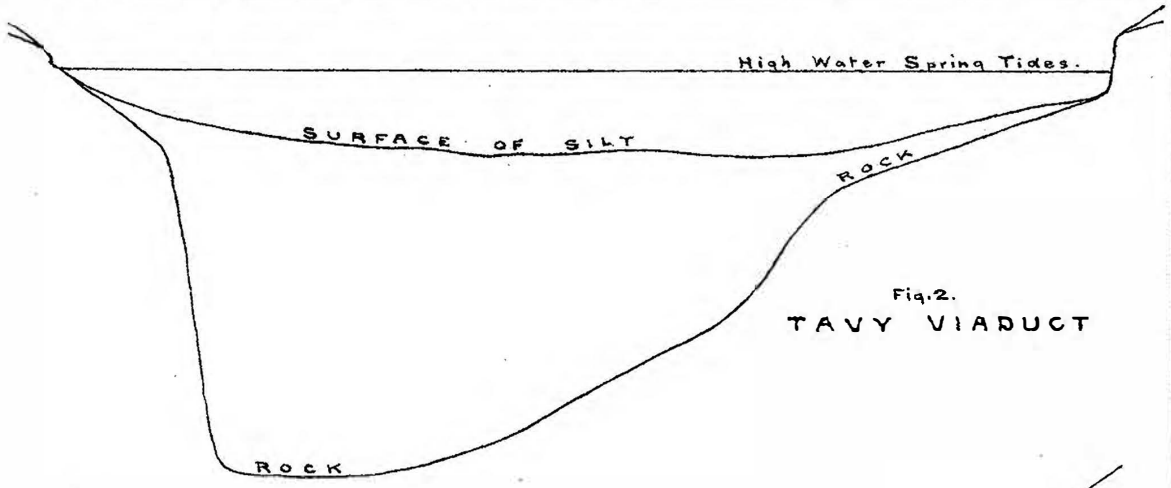


Fig. 2.
TAVY VIADUCT

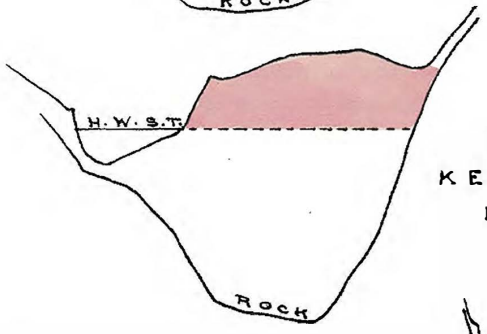


Fig. 3.
KEYHAM
LAKE

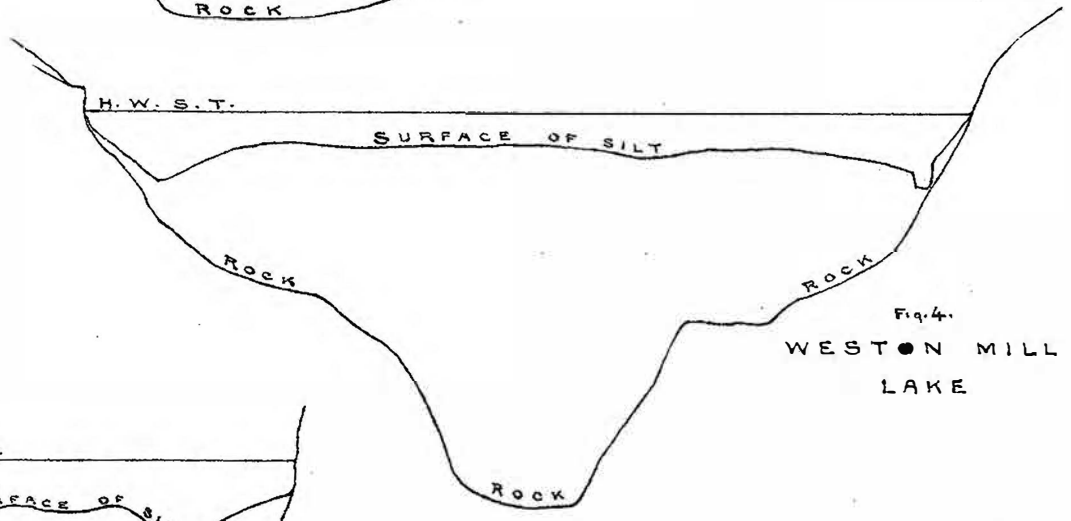


Fig. 4.
WESTON MILL
LAKE

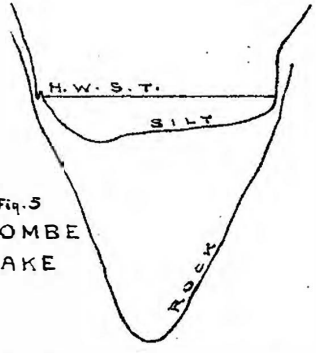


Fig. 5
COOMBE
LAKE

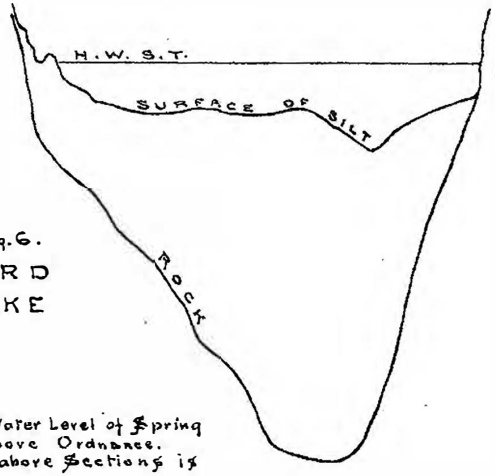


Fig. 6.
FORD
LAKE

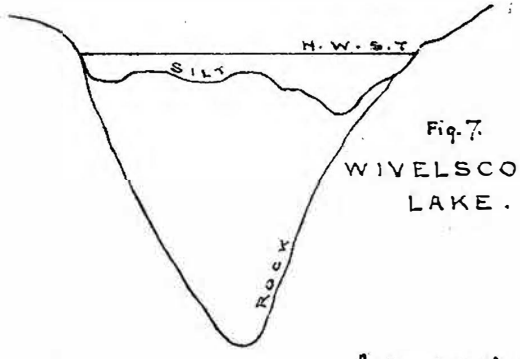
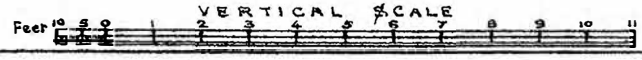


Fig. 7.
WIVELSCOMBE
LAKE.

NOTE. The Datum for Sections is High Water Level of Spring Tides, or about 7.75 feet above Ordnance. The Right Hand in each of the above Sections is the Side Toward Plymouth.



R. Hansford Worth del.

The inlet at Millbay then extended over much of the ground since occupied by Union Street and the Octagon, and the favoured inhabitants of these regions still get occasional reminders of the fact. This inlet seems to have been divided into two bays by a natural constriction, much as in the case of Sutton Harbour.

Stonehouse Pool was slightly wider, and that portion now known as Deadlake extended further inland, reaching the present position of the Saltash Road.

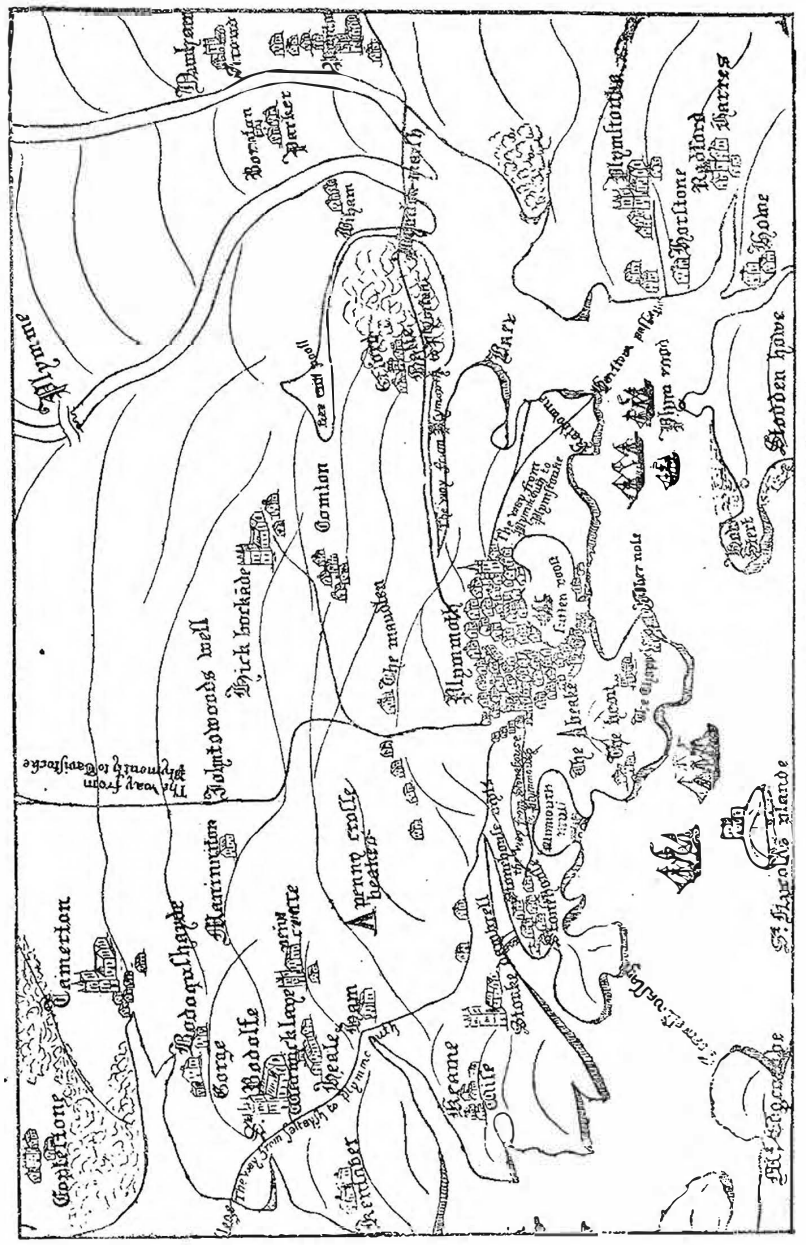
Millbrook, Sango, and St. Johns Lakes were in form and extent much as now. Keyham Lake was of considerable dimensions, and remained practically unchanged until the Dockyard extensions were undertaken.

Ernesettle Bay, Warleigh Creek, Landulph and Moditonham Marshes, were then open to the tide, and the higher reaches of the rivers Tavy and Tamar were fringed with much marsh land now reclaimed.

On the whole the depth of water in the estuaries at high tide was probably not much greater than now, except in the deeper parts of the channel. Allowance of course must be made for the decrease in the range of tide caused by the construction of the Breakwater. There is reason to believe that the wide stretches or flats of mud, which have about five feet of water over them at high tide, remain practically unchanged through long periods of time. I will deal more fully with this point later on. Practically then the estuaries of early historic times were the estuaries of to-day, with the addition of a little extra depth of water, and a considerable amount more tidal land, since reclaimed, either naturally or artificially.

A chart made in the reign of Henry VIII. shows slight alteration in the estuaries beyond the erection of a bridge and mills at Millbridge, and the same at Millbay. The area of Sutton Pool, too, is somewhat restricted, and has been encroached upon by quays. A later map, prepared in the reign of Elizabeth, and for local purposes, is probably the best obtainable as showing the condition of the estuaries at that date, approximately, 1595.

The most interesting points for study here are the main roads, which, as far as possible, circumvent the creeks, and rarely seem to be provided with bridges whereby to cross them. The way from Plymouth to Plympton is shown as crossing a tract of land known as Plympton Marsh, which land seems mainly to consist



PLYMOUTH, TEMP. ELIZABETH, FROM A 'PLOT' BY SPRY.

of navigable arms of the sea, if this contradictory statement is admissible. It is evident beyond the possibility of dispute that the road at this point must have been practically impassable for foot passengers at high-water. Hence perhaps the name Efford, or the Ford of the Ebb.

A mill pool known as Dee Mill Pool has long since disappeared, but is given considerable prominence on this map. However, there is no reason to suppose that it was tidal.

In 1618–19 the following entry appears in the Corporation accounts: "Item given by a free consent towards the buylding of the lone bridge in Plympton Marsh, 40s." This amount is afterwards struck through from reasons unknown.

This fixes the date of erection of Longbridge, which superseded the old ford. Even in those days 40s. cannot have been a very large contribution to the cost of such an undertaking.

Shortly after the date of the map to which I am now referring Plymouth mill pond, also known as the Surpool, ceased to be used in connection with the mills, and with the disuse of the tidal water the reclamation of this area began. During the Commonwealth considerable encroachments appear to have been made on Sutton Pool, and legal troubles to have resulted therefrom. The Corporation seem to have been the greatest sinners in this respect, as where they did not actually aid in or direct operations they certainly encouraged them.

The judgment delivered by a Commission held at Plymouth, 28th August, 1661, after reciting the boundaries of Sutton Pool, goes on to enumerate a formidable list of encroachments recently made. Some twenty-nine cases of encroachments by houses, quays, palaces, slips, wharves, and walls are cited.

As an instance of the influence exerted by the Corporation in these matters it may be quoted that when Smart's Quay wall was erected the inhabitants of the borough were commanded to bring soil and rubbish to fill behind it.

From the end of the seventeenth century to the commencement of the present little change took plaee in the estuaries beyond a certain amount of silting up, much of which was attributed in the case of Cattewater to the action of the tin streamers.

Before considering the more extensive and recent reclamations I should like to say a word relative to the supposed channel existing within historic times between Tothill Bay and Sutton

Harbour. Nothing is more difficult to the unpractised eye, or for the matter of that to the practised eye either, than the attempt to distinguish the rise in level of gently sloping ground. Anyone, however, who cares to observe the depth of cutting necessary to carry the Great Western Railway across this land will at once understand that no such connection can have existed since the relative levels of sea and land have been near what they are now.

The opening years of the present century were marked by great activity in carrying out reclamations on the Laira and the Tamar.

Which of the many works commenced and completed between the years 1800 and 1808 came first in date I cannot say, but intend dealing in the first place with the embankment erected in the Laira by the Plymouth Embankment Company.

Through the kindness of Mr. W. H. Prance, the Secretary, I have had access to such of the papers of the Company as had interest for my present purposes.

Plans seem to have been considered as of very secondary importance in the conduct of engineering works in those days, as there are only three among the earlier papers of the Company, and one of these was evidently made after the works had been executed.

The earliest of these plans bears date 1799, and the following endorsement: "Map of the embankment and new turnpike road intended to be made from Crabtree turnpike to Plymouth."

This shows Tothill Bay as to be embanked, and 26 acres of land to be thereby reclaimed. The embankment across Tothill Bay was to be 1386 feet long. Then for 1749 feet the road was to skirt the shore until Arnold's Point was reached. From this point two alternative routes were shown. The one over a bank 2178 feet long, from Arnold's Point across Lipson Lake to Efford Quay. The other to a point on the far side of the old turnpike gate, over a bank 3960 feet long. In the one case 59 acres of Lipson Lake were to be reclaimed, in the other 93 acres.

The second plan is dated in the year 1800, and shows the new road and the embankment as separate undertakings. It is endorsed as a "design for embanking part of Lairy, and making a road from Crabtree to Plymouth instead of the present one, to avoid Lipson Hill and to make a more commodious approach to the borough of Plymouth." The new road, as shown, passes across Tothill Bay in a diagonal direction, skirts the shore to Arnold's Point, and passes thence in a straight line to Efford Quay. The intended embankment commences at Great Prince Rock, and proceeds in a straight line to Arnold's Point. Thence it follows the curve of the low water channel of the Plym, and terminates at Crabtree ten chains on the Plympton side of the old toll gate. This plan bears the name of Eveleigh as draughtsman and probably designer.[1]

The third plan is undated, but shows the completed works. These consist of an embankment from Great Prince Rock to Little Prince Rock, from Little Prince Rock to Arnold's Point, and from Arnold's Point to Efford Quay; all the banks being in straight lines.

This plan is interesting, as showing a now disused ford at Arnold's Point across the sands at low-water to Saltram Point.

The records of the Committee seem to commence in 1802, when a meeting was called to consider the direction and position to be taken by the road. Varying estimates were submitted to this meeting with more especial reference to two proposed routes. The one direct from Arnold's Point to Little Prince Rock. The other from Arnold's Point by Mount Gould House to Little Prince Rock. The estimate for the first of these considerably exceeded that for the latter.

In April, 1802, notices inviting tenders for the execution of the works were inserted in the *Sherborne Gazette*, Trewman's *Exeter Flying Post*, and Jessop's *Express*. Mitchell and Co., of Truro, and Hodge and Co., of Somerset, seem to have replied, and following this we have a contract of date 15th July, 1802, between the proprietors and the firm of Mitchell, Sampson, and Sampson, in which the latter undertake to construct an embankment from Arnold's Point to Efford Quay.

Messrs. Mitchell are described as miners of Gwennap in the county of Cornwall.

In 1803 the same firm entered into a contract to construct a further embankment from the termination of the last, known as the Lipson bank, to Little Prince Rock, thus enclosing the area known at that time as Tothill Bay. The average height of this bank was to be 14 feet, with a 3 to 1 slope to seaward, and 1½ to 1 to landward; the total width at base being 69 feet. In 1805 a further contract was undertaken by the same firm to construct a turnpike road from Arnold's Point to Little Prince Rock. For this a second Act of Parliament was obtained. In 1808 William Kitto, a miner of the county of Devon, contracted for the forma-

[1] Eveleigh was also architect for the old guildhall.

tion of an embankment from Great to Little Prince Rock, and at Lord Boringdon's request the road was continued to his ferry at Great Prince Rock.

This was the last of the works executed by the Embankment Company, although they still possess much unreclaimed land in the bed of the Laira, as the rights purchased by them from the Crown extend far outside the limits of the present hanks.

I am not in a position to be able to give the commercial results of this undertaking. At first the cost of construction was certainly found to he higher than expected, inasmuch as the capital of the company was exhausted, and there is entry of a resolution to make application to the two banks of the town for a loan. I should be inclined to say that the turnpike has given a better return than the reclaimed lands.

The question as to who acted as engineer in the matter cannot be answered with any certainty. I have mentioned that Mr. Eveleigh prepared the first plan. After that, in 1807, Mr. James Adams was employed to measure the hank, and Messrs. Crossman and J. Adams seem later to have acted as arbitrators on some matters in dispute with the contractors. At another time, when a question arose as to undue leakage in the bank, Mr. Christopher Savery acted with Mr. Adams, but whether in capacity of surveyor is not stated. Mr. Savery may very likely have been solicitor.

The relations between the proprietors and the contractors seem to have been somewhat strained at times, if one may judge from the minute-book of committees.

At about the same time that these works were proceeding, Lord Boringdon was erecting an embankment to reclaim Chelson Meadow. The following particulars were kindly supplied by Lord Morley, and are given in his own words:

"The embankment was made in 1807, and in 1808 the Society of Arts gave my grandfather, the Lord Boringdon, their gold medal for reclaiming land from the sea. In his statement to the Society of Arts, he states that up to that time he had expended £9,000 on the work, and least £4,000 or £5,000 were expended in strengthening and repairing the bank hetween 1808 and 1842. The amount of land reclaimed is, according to the Ordnance Survey, 176·533 acres, of which at least ten are occupied hy the bank, roads, and canals. It was but a poor speculation, for the land is not of first-class quality, and there are considerable expenses connected with keeping the sluices in order, cleaning out canals, &c."

While the Embankment Company and Lord Boringdon were busy altering the geography of the Laira, the tidal lands on the Tamar were not neglected.

In 1808 Moditonham Marsh of twelve acres was reclaimed; in the same year Landulph Marsh of thirty-three acres was also embanked, and a creek covering twenty acres at Warleigh was converted into grass land.

The next encroachment upon the sea was at Keyham, where the Government reclaimed twenty-five acres, and the filling in of Keyham Lake has been steadily progressing until now practically complete.

Ernesettle Bay was embanked hy Mr. Elliott about the year 1860, and 100 acres were enclosed. And I must here acknowledge my indebtedness to Mr. Eustace Elliott, of Landulph, for much information as to reclamations on the Tamar.

By the courtesy of the Earl of Mount Edgcumbe, and the kind assistance of his agent, Mr. Daw Ward, I am enabled to give particulars of the last reclamation works carried on in our estuaries.

The reclamations from the Tamar in the parishes of Beer Ferris and St. Dominick were originated as relief works. The water was excluded from the tidal lands by the erection of a bank of seven feet in height, three to four feet wide at top, and with side slopes of one to one. The slopes of this hank are not pitched with stone, but simply protected by turf. The material for forming the bank wae derived from a shallow trench run just inside the bank itself. Originally the work was paid for as day-work, but it was ultimately found more economical to pay piece-work. The total cost of the bank was £500 per mile, and two and a quarter miles have been constructed, enclosing 100 acres.

The first proceeding after erecting and securing the bank was to drain the land. This was done by means of drains two poles apart, and from 2.6 to 3 feet deep. The soil was next all hand turned, as horses could not work on it. Two crops of mangolds were then grown on the land, and afterwards it was put into corn, these being necessary preliminaries to convert it into grass land. Draining cost £8 per acre, and cultivation £20. The returns amount to 4°/₀ on capital invested, and would be higher had not the low price of corn affected the sale of the early crops. It may be of interest to mention that gas lime was found to be the best

manure. I believe further works are being carried on upon the same principles.

There are one or two smaller works of which I have been unable to obtain any details, but the above include all the important undertakings of which I have any knowledge.

Turning now to the question of further reclamations from the large area of tidal lands.

Marsh lands, such as lie at the head of the creeks, present no difficulties and offer ready opportunities for reclamation. The grounds to which I refer are those in which large patches of coarse grass alternate with channels of ooze. Very shallow banks are sufficient to exclude the tide from such expanses, and the only difficulties are those connected with the shallow intersecting tidal channels. At first it might seem an easy matter to induce the suspended matter in the water to deposit in and fill up these channels, and one would think that this might be done by throwing faggot screens across them at intervals. So far as I am aware this has not yet been tried, but at the head of those creeks which receive considerable streams I should imagine it might be successful. The expedient of leaving a small opening in the bank through which the tidal waters can ebb and flow has been tried by Mr. Ward and declared against as useless. I do not think that in the case in question there was any stream falling into the main river close by, but that it was only a marsh fringing the tidal channel. This would make a great difference, as the silt held in suspension by the tidal waters is extremely minute in its particles and does not readily settle unless in absolutely quiet water. Near the mouth of a stream, however, there are always the heavier particles brought down by the fresh water, which settle before travelling far and leave the lighter matters to mingle with the main body of water in the estuary.

I might further say that the time to attempt to level up the channels is, I should consider, before the construction of the bank and not after. In those places where the deposit cannot be obtained it is only a matter of lowering the whole surface of the reclaimed ground to the extent necessary to fill in the depressions.

In the case of springs rising through the silt no amount of such filling will be of avail, and levelling up must be postponed until the land has been drained. Mr. Ward tells me of a case in which a hollow tree-trunk had been driven into the silt and a

spring thereby confined. The water then rose and stood at the level of a foot above the surrounding marsh. There was considerable difficulty in draining this spot, but it was finally done by means of faggots.

Where reclamation is carried out at the head of one of the smaller estuaries there is a tendency to hasten the deposit of further detritus, and the formation of further marsh land. The mouth of the stream is carried forward, and the destruction of tidal land lessens the force of the tidal currents in the immediate vicinity. The tide now flows to, and not over, the site of the bank.

Undoubtedly the best material to form the banks of in such cases is the silt or deposit itself. It is practically impervious to water, and is lighter than stone; while at the same time a bank of this material is to some extent plastic and coherent, points which tell in its favour by reducing sinkage. Such a bank, as it dries, is liable to shrink, and allowance should be made for this.

In cases where large tracts of mud lie at a depth of from three to six feet below high-water more consideration is required.

If near the mouth of a stream such tracts might probably be slowly raised in level by the reclamation of all marsh land surrounding them, when, as previously pointed out, a further deposit might be expected. But when one considers the large tracts bordering all our estuaries, it becomes evident that such a means of accelerating deposit is in many cases impossible.

It is a question too whether a mere policy of masterly inactivity would be rewarded. I am much inclined to think that, except where special causes are at work, the deposit on these banks, with from three to six feet of water at high tide, is extremely slow. It would seem that the tendency is rather to enlarge in area than to grow in height. For if we consider the large expanse of these banks, and the width to which they extend from shore, it will be seen that the tidal currents over them must be extremely swift. For the greater part of its rise the tide is confined to the centre channel. Then suddenly it reaches the level of the wide, flat bank, and instead of creeping up it, the water rushes over its surface with a velocity that must exercise some scouring action. The tide leaves these banks with the same rapidity as it covers them, as any one unfortunate enough to get caught on the mud in a boat can attest. The marvellous manner in which a vast tract

of soft, yielding mud suddenly grows up, to all appearance, between the victim and the water is under such circumstances extremely trying. Considering then the rapidity of the tidal currents, and the state of suspension in which the silt exists in the water, it seems extremely probable that little or no deposit takes place on these banks during the short period that they remain covered with water. In other words, I regard the surface of such patches as the West Mud and the mud between Sango and Millbrook lakes as fixed, although the extent of these shoals may grow.

Thus it is useless to sit down and wait until these areas of tidal land reach a level at which they can be readily reclaimed.

The question is, Can the progress of events be hastened? Anything calculated to check the extreme rapidity of the tide over these shoals should do something toward hastening the silting-up, and the only available economic means to this end would be moles or dams of faggots and hurdles.

These, carefully arranged, would do much more important work than merely checking the rapidity of the tidal currents. They would also act as breakwaters, to mitigate the force of the scour produced by wind-wash, which frequently must undo in a few hours the work of many tides.

I am thus minute in investigating this point because I do not believe that long embankments of a very considerable height are in any way economical means of reclaiming land in this neighbourhood. Chelson Meadow, I think, marks the extreme limit of possible profitable speculation. The Lipson and Tothill embankments were, I should say, only rendered financial successes by the turnpike road constructed in connection with them. Any means of bringing the shoals nearer the surface that can be attempted with economy should be tried before resorting to high banks.

With some creeks it might be possible, from their form, to reclaim a considerable area by the aid of a comparatively short high bank, and local circumstances being favourable such might be done with profit.

To recapitulate this latter portion—the following conclusions seem reasonable:

Lands already far advanced toward the marshy stage are best adapted to reclamation.

Shoals involving high banks should be raised in level, if possible, before being reclaimed. An examination of the deposit on which

the bank is to be founded should be made, and the hardest foundation selected. Banks, except of small height, should not be erected where any considerable wind-wash may be expected. What may be termed barrier banks, analogous to barrier reefs, are the most economical, and can be constructed for £500 per mile.

The above remarks apply more especially to reclamations for agricultural purposes. It might at times be advisable to undertake much more expensive works than any above referred to, but only in cases in which the land reclaimed might be required for other than agricultural uses.

And now as to the probable effect of such works, if extensively carried out, on the general depth of water in the harbour.

In the first place, if attempts were made to raise the level of the large shoals, and were successful, these would retain a considerable amount of deposit that would otherwise have settled in deeper water: this beneficial action would cease when the reclamations were complete.

Next, the loss of such shoals would not mean, as is frequently thought, the loss of extensive settling grounds for silt. I have endeavoured to point out that such a settlement as is usually considered to take place on these tracts does not really occur, but that at a certain level they become stationery—only growing in extent.

This growth in extent would not be checked, except that the deposit might accumulate rather more rapidly around the reclaimed land than elsewhere. The total deposit thrown down outside the channel might be expected to be the same.

Next, as to decreased scour in the channel, due to the encroachment on the tidal waters. Reclamations of marshes can hardly be called encroachments on the tide, and these may be neglected. Reclamations of shoals decrease the area of tidal waters, but would not, I think, in the case of the Hamoaze affect the volume for some time to come. A few feet depth of water would be shut off from certain areas, bearing no very considerable proportion to the whole; but I believe that the height of the tides would be thereby increased to an extent sufficient to supply the loss. I cannot think that at present the amount of tidal water in the Hamoaze and associated lakes and river depends solely on the depth and area of those estuaries. I believe it to be, to a great extent, governed by the contraction which takes place between Devil's

Point and Wilderness Point, and I am inclined to consider that this latter consideration would overrule any slight diminution in area. As much water passes through the strait at present as that width of opening will accommodate, and were the Hamoaze considerably greater in area it could get no more, or if a little less in area no less; so that I do not believe any loss of tidal water or the scour produced by the same would result from any reclamations likely to be attempted for some time to come. I have purposely dealt with the Hamoaze, more especially, in the last portion of my paper: because, in the first place, I consider that future reclamations in connection with Cattewater will probably be unimportant; and, in the second place, the Laira or tidal land in connection with Cattewater is subjected to so many artificial influences.

In conclusion, I have ventured to bring this subject before you this evening because it has not only an historical, but also a practical interest for us. If I have somewhat emphasized the practical considerations, I trust I have not occupied too much of your time, or trespassed on your patience. I have not been over-minute in my considerations; but to show how intimately related subjects apparently far apart may be, I would draw your attention to the fact that the extent of forest land along the course of a river may exercise a very serious influence on the fertility of the reclaimed lands in its estuary, and even to some extent affect the rate of deposition of silt.

Anyone who has noticed the scattered leaves that cover the surface of the Laira in late autumn, and also observed the extent to which their remains are mingled with the surface silt, must agree that the soil as a whole must be rendered much richer in organic matters by this cause alone.