April 27, 1869.

CHARLES HUTTON GREGORY, President,
in the Chair.

No. 1,216.—“On the Outfall of the River Humber.” By WILLIAM SHELFORD, M. Inst. C.E.

SMEATON's Appendix to his 'Narrative of the Edystone Light-house,' in which he describes the operations in the erection of the Spurn Lights, contains some important details relative to the condition of the Spurn Point at the time he wrote, and a sketch of his views on its previous history. With this exception, all historians of the locality have regarded the numerous interesting events at the mouth of the Humber from the antiquaries' point of view, and have evidently been conscious of their inability to deal with the physical causes of the events which they were recording. Under the impression that there is much to interest and instruct engineers in the history, not only of Spurn Point, but of the Humber Outfall, the Author presents to the Institution the facts which have come under his notice professionally.

The Estuary of the Humber is the outlet for the fresh waters from a larger drainage area than that of any other estuary in England, including, with some trivial exceptions, the whole of the district which is bounded by the watershed of the Tees on the north; by the eastern hills of Westmoreland and the watersheds of the Ribble, Mersey, and Severn on the west; by the watershed of the Avon on the south; by the watersheds of the Welland and the Witham on the south-east, and by the sea on the north-east; embracing, amongst others, the rivers Hull, Derwent, Nidd, Wharf, Ouze, Aire, Don, Idle, and Trent, with their tributaries, and the drainage of Ancholme, and containing an area of about 10,500 square miles, or one-fifth of the whole area of England. As the treatment of so large a subject must necessarily extend beyond the limits of one Paper, the Author proposes for the present to confine his remarks (except incidentally) to the district suggested by the positions of the towns of Bridlington, Hull, and Grimsby, and for convenience to arrange them under the following heads:—

- I. The facts in connection with the past and present condition of the outfall, and of its peculiar feature—Spurn Point.
- II. The ascertained alterations in the tidal régime.
- III. The relative value of tidal and fresh water at the outfall.

IV. The relation of the operations of Nature and of engineering works to the facts recorded.

I. The facts in connection with the past and present condition of the outfall and of its peculiar feature—Spurn Point. The geological structure of the district consists of diluvial clay and gravel resting upon a substratum of chalk, which crops out and forms the range of hills called the Yorkshire Chalk Wolds, crossing the Humber into Lincolnshire at Hessle and Barton-on-Humber. A boring taken by Messrs. Easton and Amos (M.M. Inst. C.E.) in 1846 at Sunk Island shows that the top of the chalk is there about 110 feet below high-water spring tides, and Professor Phillips in his ‘Geology of Yorkshire,’ considers the “dip” to be eastward, at the rate of 20 feet per mile. The boring proves that the chalk is 20 feet below the bed of the estuary opposite to Sunk Island.

The principal of the diluvial accumulations which rest upon the chalk is “a mass of clay and pebbles which forms most of the hills and hard land in Holderness.”¹ Of these the highest is Dimlington Height, rising 139 feet above the mean level of the sea. The surface of the country north of the Humber slopes for the most part downwards from the sea and drains into the Humber. Some of the clay hills have now become points of resistance to the force of the tides and waves; such are Dimlington Height, Clee Ness, and others.

There are marshes and fen lands of large extent adjoining and draining into the Humber, Plate 20. The first to require notice is from Patrington westward, to and beyond the river Hull, where about 60 square miles were formerly open to the flow of the tide. Its present level near the Humber is about 3 feet below high-water ordinary spring tides at sea, and at some points further inland it is 5 feet below. This marsh or fen was embanked at an early date, for a Royal Commission was appointed to see to the repair of its banks in 1313.²

Above Hull the first important fen is the narrow valley of Ancholme, containing about 50 square miles below the sea level, which Sir John Rennie supposes to have been embanked by the Romans. The surface of the ground near the Humber is now about 3 feet below high-water spring tides, while in the centre of the district it is 9 feet below.³ This valley was shut out from tidal influence by a sluice made under the powers of an Act passed in 1769.

¹ Phillips’ “Geology of Yorkshire.”

² Dugdale’s “History of Imbanking and Draining.”

³ Vide Sir J. Rennie’s Paper “On the Drainage of the Ancholme,” Minutes of Proceedings Inst. C.E., vol. iv., p. 186.

The great level at the confluence of the Ouze and the Trent contains an approximate area of 160 square miles below the sea level. The land near the Humber is 2 feet below high-water spring tides at sea, and 6 feet below it at some points farther inland. A Royal Commission was appointed for the repair of the banks in Hatfield Level as early as 1295, and subsequently for about a century Royal Commissions were issued for the repairs of the banks along the Ouze, the Humber, and the Trent,¹ probably enclosing nearly the whole of the land now under cultivation.¹

On both the Yorkshire and the Lincolnshire shores of the estuary other tracts of marsh land have been enclosed from time to time, and notably Sunk Island and Cherry Cobb Sands. They contain 9,500 acres, or about 15 square miles, at a level of 2 feet below high-water spring tides. The area of the Humber at high-water spring tides is 110 square miles, and the total area of reclaimed land in the estuary below high-water spring tides at sea is about 290 square miles.

Amongst other interesting information in connection with the Humber, it has been recorded by Mr. James Oldham (M. Inst. C. E.), in his Paper on the reclamation of Sunk Island,² and is otherwise known, that the whole of the east coast of Holderness, from Bridlington southwards, has been from the earliest historical times abraded and destroyed by the sea, and that the average width of land thus lost is $2\frac{1}{4}$ yards per annum. The cliffs consist of the clay and shingle before alluded to, which fall in large masses and are broken up by the heavy waves which on that coast accompany the north-east gales and act obliquely on the shore, transporting the shingle southwards³ to the end of Spurn Point, where it meets with the powerful ebb of the tide from the Humber, and is carried out to sea.

Without going back to the time of the Romans, there can be no doubt that a thousand years ago, at the landing of the Danes in Holderness, Spurn Point projected much further to the eastward than at present, and if the average waste of $2\frac{1}{4}$ yards per annum be adopted (which is most likely insufficient), the projection must have been 2,250 yards at least beyond the present coast-line. The promontory might then have been a short point, having an ebb channel close to it, and if so there would be a good roadstead on its west side.

It is thought that at or near this spot the Danes landed in 867, and planted their standard, 'the Raven;' and here afterwards

¹ *Vide* Dugdale's description of their positions.

² *Vide* Minutes of Proceedings Inst. C.E., vol. xxi., p. 454.

³ *Vide* Paper "On the Motion of Shingle Beaches," by H. R. Palmer, Esq., F.R.S., C.E., Phil. Trans. 1834, p. 567.

gradually rose the town of Ravensburg, or Ravenser, or Ravenseret —(syret, in Saxon, meaning a place of shelter),—within Spurn Head. This town is remarkable as having been one of the most wealthy and flourishing ports of the kingdom. It returned two Members to Parliament, assisted in equipping the navy, had an annual fair of thirty days, two markets a week, is mentioned twice by Shakespear,¹ and considered itself honoured by the embarkation of Baliol with his army for the invasion of Scotland in 1332; by the landing of Bolingbroke, afterwards Henry IV., in 1399; and by the landing of Edward IV. in 1471—not long after which it was entirely swept away. The only trace of it which now exists is a stone cross of very elegant design, in decorated Gothic, about 16 feet high, supposed to have been first erected on the spot where Bolingbroke landed. After several removals, it is now in the grounds of Mr. Watson, of Hedon.

One peculiarity in the history of this place is the great number of names by which it was known at different dates; and a closer examination suggests that these names indicate corresponding changes in the condition of Spurn Point.

In 1251 some monks obtained half an acre of ground on which to erect buildings for the preservation of fish in the burg of Od, near Ravenser (Od meaning in Saxon a distant or out-of-the-way place). The Chronicler of Mœux Abbey,² near Hull, says, “Od was in the parish of Esington, about a mile distant from the mainland. The access to it was from Ravenser by a sandy road covered with round yellow stones, scarcely elevated above the sea. By the flowing of the ocean it was little affected on the east, and on the west it resisted in a wonderful manner the flux of the Humber.” The two places were subsequently spoken of as one, and increased in importance, for in 1273 there was a dispute about a chapel at Od, in which the Archbishop of York was arbitrator. In 1285 the merchants speak of *Ravensroad*; and in 1289 the Grimsby people are jealous, and claim certain privileges, calling it an island, and probably basing their claims upon its previous insular character. In 1310 the three shipping ports of the Humber whose merchants contributed to the navy were Hull, Grimsby, and Ravensness. In 1332 Baliol “took the sea at *Ravenspurgh*.” In 1346 a grant to the abbey at Mœux specifies the manors of Salthagh, Tharles-thorpe, Frismersk, Wytheflet, Dymelton, and *Ravensrodde*, the termination *rodde*, or *rood*, a cross, being more in accordance with the ideas of the monkish chronicler than the “road” of the merchants. The grant also says that they were on the bank of the Humber and on the sea-shore, and complains that their annual

¹ In 3rd part of King Henry VI., act 4, scene 7; and in Richard II., act 2, scene 1.

² Liber Melsæ. Vide Poulson's “History of Holderness.”

value was reduced from £250 to £20, and, "what is worse, from day to day these places become so far waste, being tossed by impetuous waves every day and night, that within a very short time it may be feared that they will be altogether destroyed and consumed." And this must have occurred, for the only trace of their position is Salthagh Grange.

In 1347 "Ravensrod, in Holderness," was often inundated by the sea. In 1355 the bodies were washed out of their graves in the chapelyard of Ravenser. In 1360 "Ravenser Odd"¹ was totally annihilated by the floods of the Humber and inundations of the great sea." In the reign of Richard II., 1376—99, Ravenser no longer sent Members to Parliament. In 1399 Bolingbroke landed at Ravenspore, or Ravenspurgh.² In 1413 a monk obtained a grant to erect a hermitage at Ravenscrosbourne, but this name is only interesting in connection with the cross previously mentioned. In 1428, Richard Reedbarowe, the hermit of the chapel at Ravenserspore (Sporne, Spurn, Spuren, Spyrian—in Saxon—to look out), obtained a grant to take tolls from ships for the completion of a tower which he had already begun as a lighthouse.

In 1471 Edward IV. landed "within Humber, on Holderness side, at a place called Ravenspurgh, even in the same place where Henry Earl of Derby, after called King Henry IV., landed."³ About 1552 Ravenspur is alluded to by Leland in his "Itinerary"; but Holinshed, in mentioning Kelsie Cliffe, Patenton Holmes, Pall, Hidon, and many other "ports and creeks," omits Ravenspurn, which probably then had no existence. Holinshed died about 1580.⁴

In 1622, Callis, in his Lectures on Sewers at Grays Inn, says that, "Of late years parcel of the Spurnhead in Yorkshire, which before did adhere to the continent, was torn therefrom by the sea, and is now in the nature of an island."

In 1676 a patent was granted by Charles II. to a Mr. Angell for the erection and maintenance of certain lights at Spurn Point, which lights were erected at the request of those interested in the northern trade, who represented that a broad long sand had been thrown up at the mouth of the Humber six or seven months before. Smeaton thought that this sand had afterwards become connected with the mainland, and so formed the Spurn Point of his day.⁵

About 1684, Captain Greenville Collins, hydrographer to King Charles II., made surveys and charts of fifty British ports, and,

¹ Liber Melsæ. Poulson's "Holderness."

² Thompson's "Holderness."

³ Quotation, Thompson's "Ravenspurn."

⁴ Thompson.

⁵ Smeaton's "Appendix to Narrative of Edystone Lighthouse."

among others, of the Humber from the sea to Hull. This chart is in several hands at the present day, and, as it forms an epoch in the history of the Humber, it will be well to pause and refer to other points of interest, antecedent to the date of its publication.

Of these the first is—

Sunk Island.—In 1667 it was first spoken of as a novelty, and was then “reported to have been at first a great bank of sand (of which there are still many to be seen in the Humber at low water), that thereat other mud and matter stopt, and then still more and more, until it arrived at its present bigness.” This was written in 1711,¹ and Greenville Collins’s survey nearly represents its condition at that time. It is now the property of the Crown, and it is said that the title rests on the fact of its having been an island.

Frismersh, Frismersk (Fresh, or New Marsh), is supposed to have been on the site of Sunk Island, or eastward of it. In 1341 a Commission was appointed for viewing and repairing the banks on the coast of Humber in the towns of Patrington, Frismersh, Ottringham, &c.; and again in 1343.² In 1345 the charge of supporting the banks and sewers in Frismersh had become very burdensome, and the inhabitants petitioned the King that their lands were often overflowed by the tides of the Humber.

In 1361, Commissioners were appointed to view the banks on the coast of the Humber between Hessle and Ravensere.³ Frismersh was probably not destroyed before 1362.

Clee Ness.—This promontory no doubt formerly projected farther into the Humber than at present. The cliff consists of stiff clay, and receives now, as it must have done for hundreds of years, the full force of the flood tide as it enters the Humber. One of the townships of Clee has gone to decay,⁴ and it may be inferred that it has fallen a victim to the waves of the estuary.

The Old Den (Den, in Saxon, a valley or dale), is a hard bank of shingle within Spurnhead and at half-tide level. It has been supposed that Ravenser-Od stood there, or near to it,⁵ but this is doubtful, and the Author is of opinion that it may consist of shingle which has been brought round the point by the flood tide, and has not been returned by the ebb.

GREENVILLE COLLINS’S CHART, 1684. (PLATE 20.)

This chart shows Angell’s Lights at Spurn, a low-water channel between Sunk Island and the north shore,—the main channel,

¹ Thompson.

³ Dugdale.

² Dugdale.

⁴ Allen’s “History of Lincolnshire.”

⁵ Thompson’s “Ravenspurn.”

broad, and deep, running to the north of the Bull Sand, a small and shallow channel to the south of the Bull Sand. Sand Haile, Clee Ness, The Den, Trinity Sand, Long Middle, Burcum and others are shown. The soundings in deep water are generally few, but eastward of the Spurn they are very close, and show a depth of 3 fathoms to 9 fathoms.

After 1684 the Point continued to increase in length, and the lights consequently became useless. An application was therefore made to Parliament in 1766, by the Trinity Houses of Hull and Deptford-Strond, for power to erect and maintain other lights, and was passed. At this juncture Mr. Smeaton was consulted, and recommended the erection of two lighthouses.

MITCHELL'S CHART, 1778. (Plate 20.)

Twelve years after Smeaton was called in, a chart was published by a Robert Mitchell, and dedicated to the Trinity House of Kingston-upon-Hull. It shows the old lights extinguished, and two temporary lights erected at the Point, which has extended a mile further south. The low-water channel between Sunk Island and the mainland has silted up. The channel to the north of the Bull Sand has diminished, while that to the south of it has increased in importance. The Den, Trinity, and other sands have undergone great changes, while to the eastward of Spurn, large sands and shoals have formed.

In 1771, Smeaton reported that Spurn Point had extended 280 yards since 1766, and that it had increased on the Humber side, but diminished on the sea-side to the extent of 50 yards. In the same year Smeaton's small lighthouse was founded, and in 1772, his great lighthouse, which is the present "high light," was commenced. The small light appears to have been in danger from the first.¹

In 1786, Smeaton made a survey of the Spurn, from which it appears that the high light was 1,840 yards south of the position of one of Angell's lights, and was then 480 yards from high-water mark at the end of the point, and that the Point had also moved westward throughout its length. Smeaton concluded that Spurn Point was a necessary appendage to the cliffs of Holderness, and was in a continual state of travel southward and westward; the southward movement being accompanied by a corresponding encroachment of the river on the Lincolnshire coast, and the westward movement by the abrasion of the coast of Holderness by the sea.²

¹ *Vide* Smeaton's "Reports."

² *Vide* "Appendix to Narrative of Edystone Lighthouse," and the plates and notes in explanation of them.

HEWETT'S CHART, 1828. (Plate 20.)

The next chart of value is the Admiralty chart, from the survey of Captain Hewett, R.N., and dated 1828. It shows that about 7,000 acres of the accretions at Sunk Island had been reclaimed, that the Point had advanced, and that the capacity of the channel to the south of the Bull Sand had again increased. Other changes had taken place, especially seaward of Spurn, where the accumulations of sand and stones had increased, and a light vessel had been moored in 1820. There is also a note on the chart, that a portion of the Spurn Neck, north of the lighthouses, is overflowed at high spring tides.

In 1849, a large breach occurred in the Spurn Neck, north of the lighthouses, and in 1850, Captain Vetch, R.E., held an Admiralty inquiry on the spot. He reported in favour of strengthening the point on its seaward face, by means of groynes placed at right angles to its length, for the purpose of intercepting the shingle in its passage southward, and on the Humber side by the further reclamation of the accretions east of Sunk Island.

Some of the groynes have been executed since 1863 by Mr. Coode (M. Inst. C.E.), and Captain Vetch's anticipations have been so far realized. But his plan has not been completed, and it is thought that the ultimate effect of converting the natural westward, or retiring movement of Spurn into an eastward or advancing one will be to bring about its destruction.

CALVER'S CHART, 1852. (Plate 20.)

This is the Admiralty chart at present in use. It was surveyed in 1851—2 by Captain Calver, R.N., (Assoc. Inst. C.E.), and is an excellent survey. It shows that 700 acres had been added to the reclamations of Sunk Island, and that the bay between Sunk Island and Spurn had become further silted up. The concavity in the Lincolnshire shore, opposite Spurn, and below low water, had increased, and the Middle Sand had shifted considerably. The mariner is warned in a note that it "is liable to change," and the soundings between it and Spurn are corrected to 1862.¹ Seaward of Spurn there does not seem to have been much alteration since 1828.

The flood and ebb streams are shown by dotted lines on this chart. Their direction was ascertained by the Author, and after-

¹ Since the above was written, the Author finds that part of the chart from Spurn to Sunk Island was corrected in 1866. The deductions in the Paper are based on the chart corrected to 1862, and are not materially affected by the recent alterations.

wards confirmed by independent observations, conducted by Mr. Coode in 1867. The main stream of the flood tide sets from the north-east against the Lincolnshire shore, which it scoops out, and rebounding against Clee Ness, is thrown across the Middle Sand into the Sunk Road. At the same time, another stream sets in round Spurn Point, up the Hawk Road and the North Channel. At about quarter-flood, when the low part of the bay, to the west of Trinity Sand, is covered, a branch from the main stream sets into the bay and returns down the North Channel, forming an eddy opposite the lighthouses. This current continues for three-quarters of the flood tide, and the North Channel has consequently a "three hours' flood and a nine hours' ebb." It is this eddy also which keeps the North Channel from silting up. The main ebb stream passes through the Fairway abreast of Sunk Island, and out to sea by the end of Spurn Point, and to the north of the Bull Sand, with a velocity of about 4 knots per hour. "The set of the tide when ebbing from the bay is south-south-west, and not through the North Channel until the Trinity Sand begins to uncover, which takes place somewhat after half tide."¹

There is no perceptible current at any time of the tide on the north-east side of the line *a, a*. The land in the bay consists of warp and sand, more or less fine according to its exposure to currents. The average level is about half tide, and from careful levels taken over an area of a mile in width from the shore, under the direction of Mr. Coode, Mr. Oldham, and the Author, it appears that it rose, as a whole, $11\frac{1}{2}$ inches between 1854 and 1867.

MOVEMENT OF SPURN POINT. (Plate 20.)

The following is a summary of the known extensions of Spurn Point southward:—

1676 to 1766	1,800 ³ yards, or 20 yards per annum.
1766 " 1771	280 " " 56 " "
1771 " 1786	150 " " 10 " "
1786 " 1851	300 " " 4.6 " "
1851 " 1864	113 " " 8.7 " "

Total . 2,643 yards.

The westward movement has been nearly uniform throughout the length of the Point.

Angell's Lights are known to have been swept away by the progress of the sea, and one of them is so shown in Smeaton's

¹ Mr. Coode, in his report to the Board of Trade, 1867; also Captain Calver, in his evidence before Court of Referees, 1866.

² This is only an approximate measurement, as the exact distance from Angell's Lights to the end of the Point, in 1676, is not known.

survey of 1786. The following summary of the history of Spurn Lights will serve to prove the amount of this movement from time to time.

Smeaton's small lighthouse was built in 1771, 280 yards east of the High Light.

A second was built 70 yards farther west in 1816.

A third „ 30 „ still farther west in 1830.

A fourth „ 50 „ „ 1831.

And in 1863 the sea had reached the High Light itself, making a total westerly advance of 280 yards in ninety-two years or 3 yards per annum. The Low Light now stands on the Humber side of the High Light.

At the present time, Spurn Point consists of a bank of sand and shingle, having a top varying in width from 9 feet at its northern end to 500 feet at the Lighthouses.

By means of blown sand and 'bent grass,' it has attained a maximum height of 20 feet above high-water spring tides, but its minimum height scarcely reaches above that level. The slopes vary from 2 to 1 to 20 to 1.

II. The ascertained alterations in the tidal régime.

1st. As to range—In 1344 the roads between Howden and York and Selby and York were frequently flooded, and the banks were too low to keep out the tides.¹

In 1357 the inhabitants of Hull informed the king (Edward III.) that the tides in the Humber and the river Hull flowed higher by 4 feet than they had been accustomed to, and, in consequence, the road from Anlaby to Hull, and the lands between those places and Hessle, were continually destroyed.² About the same time, the men of Ravenspurn wished to remove to Drypool near Hull; but as Drypool and the adjoining lands had been greatly injured by the overflowing of the tides, they were obliged to go to Hull.³ Dugdale says, "How long the tides upon this coast kept their course so much higher than they had formerly done I am not able to say, but it is like that they did so for no short time after, there being scarce a year in the succeeding part of this king's reign (20 years), that one or more commissions were not issued for repair of the banks upon this great river." In 1684, Greenville Collins, in his "Sailing Directions," gave the rise of spring tides at Hull as 17 feet.

In 1725, an accurate survey was made of the Ouze from its source to the sea, by William Palmer and Partners, of York, and on

¹ Dugdale's "Imbanking."

² Dugdale's "Imbanking;" Gent's "History of Hull;" and Tickell's "History of Hull."

³ Gough's "Camden;" Thompson.
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the same sheet was engraved a diagram of the tides from the sea to York, based on the common report of the watermen. This survey and diagram are accepted as generally authoritative. The diagram shows a rise at spring tides of 21 feet at sea and 18 feet at Hull, *i.e.*, 3 feet less at the latter. The tide in the Ouze was then free to flow. It was afterwards shut out of the upper portion of the river by the construction of Naburn Lock in 1754.

In Thompson's history of Ravenspurn, published in 1822, the following occurs: "In late years persons who live in Hull and the neighbourhood have observed considerable variations in the flowing and ebbing of the tides in the Humber. In many instances the water has arisen above the banks within which it has usually been confined, and has done great damage to the adjacent country; and in ebbing, it has fallen so low in its channel as to leave visible wrecks of vessels and other sunken matter of various kinds, never before seen by any person now living."

Captain Hewett's chart of 1828 gives a range of 23 feet at sea, and 22 feet at Hull, *i.e.*, 1 foot less at the latter. Captain Calver's chart, now in use, gives a range of 18 feet 9 inches at sea, and 20 feet 10 inches at Hull, *i.e.*, 2 feet 1 inch more at Hull than at sea. The tidal range at Hull increased therefore 3 feet between 1852 and 1828, and 2 feet between 1828 and 1725, making 5 feet since 1725; and if the increase has been continuous since the rise of 4 feet mentioned in 1357, it would amount to a total of 9 feet in about six hundred years.

In 1864 a report was made to the British Association by a Committee, consisting chiefly of members of the Institution, on a series of tidal observations, taken between the 9th May and the 6th June, 1864, at intervals of fifteen minutes at Hull, Goole, Naburn Lock, and Gainsborough. The Author has been able, by the kindness of Mr. E. H. Clark (Assoc. Inst. C.E.), to supplement them by observations taken at high and low water on the same days at Grimsby. A copy of the latter is appended to the Paper. These observations prove the correctness of the variation between the ranges of tide at Hull and Grimsby, as shown in Captain Calver's chart.

On the 21st of April, 1866, observations were taken, under the Author's direction, at intervals of ten minutes, on the times and heights of one mean tide at Hull Docks and the Spurn Lights (Humber side), and they were connected by levels from ordnance bench-marks. Although he attaches little importance to such a limited experiment, he gives the facts in the Appendix.

In 1868, on the 8th of February, during a strong north-west wind, the tide rose higher by 2 inches than any which had been recorded in the ninety years previous. It reached 30 feet 5 inches on the Hull Dock gauge, or 15·7 feet above ordnance datum.

Fig. 2, Plate 21, is a diagram of some of the tides above referred to. Those of 1725 and 1828 are plotted from high water as a horizontal line, and those of 1864 from ordnance datum.

The effect of Naburn Lock on the tide in the Ouze is very noticeable. The tide in the Trent is shown by short dotted lines.

2nd. As to capacity.—The charts of Hewett and Calver show discrepancies in tidal range which require explanation. Captain Hewett was unfortunately lost at sea, and the datum line of his soundings is not accurately known;¹ but, as the 23 feet which he gives is about the rise of an exceptional spring tide at Spurn, and as it is obviously safer for nautical purposes to assume a low low-water line, and thus to show the depths as small as possible, his reasons may be inferred for adopting an extraordinary tide as his standard. Captain Calver, on the other hand, according to Admiralty instructions, gives the tidal range at about full and change of the moon, although it is well known that the highest tides on the east coast occur two days later. The discrepancy, which is serious, amounting to 4 feet 3 inches at sea, disappears if the mean level of each tide at sea be used as a common point by which to fix the relations of the various tides to each other with tolerable accuracy. At Hull the difference is further complicated by the improved range since 1828.

The cross sections of 1828, Plate 21, in which an approximation is required to "reduced levels," are plotted from a high-water line 2 feet $1\frac{1}{2}$ inch above Calver's high-water line, making low water 1 foot above Calver's low-water line at Hull, and 2 feet $1\frac{1}{2}$ inch below it at Spurn. But in the longitudinal section, Fig. 1, Plate 21, in which a comparison between the low-water channels is desired, a correction of 2 feet $1\frac{1}{2}$ inch has been made throughout. In corroboration of the difference which has thus been assumed, it may be stated that Captain Calver fixed low-water ordinary spring tides at 6 feet 2 inches on Grimsby Dock gauge, and that very exceptional tides ebb out to 4 feet on that gauge.

Fig. 1, Plate 21, is a longitudinal section on the deep channel lines of 1828 and 1852, plotted from the depths on the charts of those dates, after correction of the low-water line as above described. It shows a general deepening of the river, except at a point above Sunk Island and beyond Spurn Light Vessel, at both of which places the depth has diminished.

Plate 21 also contains a selection from a series of cross sections, plotted from the charts of 1828 and 1852, after correction of the low-water line as above described. These show the capacity of the estuary

¹ Captain Calver, in his evidence before Court of Reference, 1866.

below low water from Hull to the sea at the respective dates, and the results may be summarized thus :

Seaward of Spurn Point there has been no appreciable alteration. At Spurn Point, a gain since 1828 of 11·7 per cent. Between Spurn Point and Sunk Island, a gain of 6·2 per cent. Opposite Sunk Island, a gain of 32·5 per cent. Opposite Foul Holme and Paull Sands, a gain of 4·5 per cent. Between Paull and Hull, a gain of 25·5 per cent., making a total gain of 11·7 per cent. between Hull and Spurn.

The perfect accuracy of each of the above comparisons is not relied upon, but the following general conclusion is believed to be inevitable, viz.: that the tidal capacity of the Humber below low water increased between 1828 and 1852.

III. The relative value of tidal and fresh water at the outfall. The drainage-area of the Humber has already been stated to be 10,500 square miles. A rainfall of half an inch over it would give 450 million cubic yards. The tidal capacity of the Humber and its affluents is about 1770 million cubic yards. The Author is not aware that any connected observations of the heights and velocities of the tides in freshes and in droughts have ever been taken on the Humber. There are men, however, who, from long association, have become close observers of the condition of the estuary under all circumstances, and their evidence agrees in this; that in droughts, the sands from the Ouze and the Trent down to the Skitter Sand below Hull are raised in height and lengthened at their upstream ends, and that the flood channels are then deeper than the ebb; also that in freshes the same sands are depressed in height and lengthened at their downstream ends, and that the ebb channels are then deeper than the flood. They concur in opinion, that the height of low water from Hull to the sea is much more affected by winds than by freshes, but that in freshes the velocity of the ebb increases. They are not agreed as to the comparative velocities of the flood and the ebb.

The Author is of opinion, that whilst there is a wide field open to any one who will undertake the investigation of the phenomena connected with the discharge of so large a volume of fresh water as that which pulsates through the Humber to the sea; yet at the outfall there are other forces at work, of sufficient magnitude to throw into shade the effect produced by occasional freshes acting directly upon it.

IV. The relation of the operations of Nature and of engineering works to the facts recorded.

The Humber abounds in examples of engineering works; such as the numerous embankments, drains, and sluices, for the recla-

mation of its marshes, the lighthouses at Spurn, the docks at Grimsby and Hull, the lock at Naburn, and many others. It may be said broadly of them all, that where their intention or effect has been anything more than local, it has always been in the direction of encroachment upon the tidal area, and it may be as broadly stated that, notwithstanding this encroachment, the tidal action of the estuary has continuously improved up to the present time. Nor are the causes far to seek, or much open to conjecture.

At the founding of Ravenser about 867, the estuary was doubtless of greater width at high water than at present, and of less depth. The flood channel would then, as now, be on the south shore, and the ebb would set near to the north shore, and close past the point of the promontory. The flood tide would wear away a concavity in the south shore, and a similar action to that which made the Bull Sand would, in course of time, form a large sand, which, like Sunk Island, might accumulate till it was dry at high-water mean tides. But as the flood tide continued to wear into the Lincolnshire shore, so would the north or ebb channel become weaker; until, being no longer able to transport the shingle thrown up by the sea, it would be closed by its rapid advance, and a neck would be formed, having the sand or island, upon which Ravenser-Odd was afterwards built, for its southern termination. Sand would be blown by the wind, and shingle would be thrown up by the sea, and thus the island would be raised and strengthened for a time. The diversion of the ebb into the flood channel would deepen it, and there would be a good roadstead inside the Point.

The Author believes that Spurnhead was in this state in 1250, that neap and mean tides flowed in nearly the same channel above Hull as at present, but that up to that time spring tides overflowed the marshes, the banks of which were evidently, for the most part, neglected, and that the high-water line spring tides of the estuary scarcely attained the sea-level. But when the mouth was narrowed by the connection of the island with the land, and the ebb and flow confined to one, or, at least, to fewer channels, and when, moreover, the marsh banks had been restored and the accretions in the closed channel to the north, which were called "Freshmarsh," had formed, the high-water line in the upper reaches not only attained the sea-level but rose above it. A depression of the low-water line followed, and thus, in the next century (1350), there might easily be an increase of 4 feet in the tidal range at Hull, if low-water mark were taken as the standard from which to measure, as it probably was. The increased range produced greater depth, and, consequently, greater velocity, and the position of Ravenser-Odd became rapidly weaker. Its mercantile population removed to Hull (about 1357), and, at last, the town was carried away altogether in 1360, leaving, however, a bank of shingle called Raven-

spurgh, which might still serve as an excellent pier or landing-place to the then declining town of Ravenser; and on this Spur, or more likely in Ravenser itself, stood the cross supposed to commemorate the landing of Bolingbroke. The banks of Fresh-marsh, and the marsh itself, were probably destroyed by the increased tidal scour, and by the greater force of the current of the flood tide which the alterations at the mouth might throw upon them.

There was, however, another force at work—"the great sea." The degradation of the coast of Holderness had arrived close to the town of Ravenser, which had been protected, in all probability, hitherto, by a high clay cliff and by the Spurn Neck. But now its doom is come. The cliff is gone, and, in 1355, the Spurn Neck is attenuated. Soon the dead are washed out of their graves. The general monotony of the place is relieved by the landing, in 1399, of a duke about to take England's throne. A monk, true to his charitable profession, begins a lighthouse, in 1428, to show the mariners the way to the rival port of Hull, but has not the means of finishing it. Another king lands, in 1471, and his chronicler only calls the old town a "place." Gradually, but at last, the Spurn Point is outflanked; all trace of the town is washed away by the force of the waves, and the sea removes Spurn Point bodily a little further west. But it is a slow process. The head is again an island, in 1622, and most likely soon became a sand, invisible at high water, and the tidal action of the estuary may then have declined. The cutting into the Lincolnshire shore still goes on, and, in 1676, the sea again throws up sand and shingle, first as a shoal, afterwards by connecting it with the main land, as a neck in the form shown by Greenville Collins and described by Smeaton.

The old action is repeated as the new flood channel, south of the Bull Sand, opens, the tide in the ebb channel grows weaker, and is followed (about 1771) by the rapid lengthening of Spurn Point, increased range of tide, greater depth, greater velocity, rapid accretions in the North Channel and at Sunk Island, until the area of the estuary has become so small, and the forces at work in it so great, that the island, now Bull Sand, cannot lift its head even above low water. The same powers are at work at the present day. The channels abreast of Spurn are travelling southward. Meanwhile the sea is encroaching on Holderness, and will as surely outflank and remove the Spurn as it has done before.

The low-water channels up to Hull are now comparatively straight and confined, and the action of the ebb tide is therefore better than ever; but the shingle continues to creep along the shore to the end of the point, endeavouring still to close the estuary, but, foiled, retreats to the sea, and lies quietly out of the current, biding its time.

The thanks of the Author for much valuable information, and for many opportunities of acquiring it, are due to Sir Thomas Aston Clifford Constable, Bart., the present Lord of the Seigniorship of Holderness, to Mr. Watson, of Hedon, Mr. Wyse, of Malton, Mr. E. H. Clark, C.E., of Grimsby, Mr. James Oldham, of Hull, Mr. R. T. Cussons, the Librarian of the excellent library at Hull, Mr. Luke Thompson, of York, and to many personal friends in London and elsewhere.

The Paper is accompanied by a series of Diagrams, from which Plates 20 and 21 have been compiled.

APPENDIX.

Copy of TIDAL OBSERVATIONS taken at GRIMSBY (Royal Dock) in May and June, 1864. N.B. Zero of Gauge, 15·003 feet below Ordnance datum.

1864.		MORNING.				AFTERNOON.				Observations—Barometer.
Date.	Moon's Age.	Wind.	Water at Gauge.	Time.	Height.	Time.	Height.	Wind.	Water at Gauge.	
	days hrs.		ft. in.	hr. min.	ft. in.	hr. min.	ft. in.		ft. in.	ft. in.
May 9	3 5	East; E.S.E.	25 6	1 40 7 40	8 8 25 6	2 0 8 0	7 10 25 0	E.S.E. "	25 0	17 2
" 10	4 5	E.N.E. "	25 0	2 20 8 20	9 6 25 0	2 40 8 40	8 6 24 6	E.N.E. East.	24 6	16 0
" 11	5 5	East. "	24 1	3 0 9 0	10 6 24 1	3 20 9 20	9 3 23 3	E.N.E. "	23 3	14 0
" 12	6 6	N.E. "	23 6	3 45 9 45	10 6 23 6	4 6 10 15	9 10 22 0	N.N.E. "	22 0	13 0
" 13	7 6	N.N.E.	22 3	4 30 10 30	9 8 22 3	5 0 11 0	10 9 21 3	N.E. "	21 3	10 6
" 14	8 6	Calm; thick. S.S.E.	21 4	5 25 11 30	12 3 21 4	6 0 21 2	10 10 21 2	E.S.E. W.S.W.	21 2	10 4
" 15	9 6	W.S.W. W.N.W.	21 2	0 5 6 30	21 2 12 5	0 30 7 0	21 6 11 10	W.N.W. S.E.	21 6	9 8
" 16	10 6	S.S.W.	21 5	1 0 7 40	21 5 12 3	1 40 8 10	21 4 10 0	S.S.W. S.E.	21 4	11 4
" 17	11 6	Calm; thick. S.E.	21 9	2 10 8 45	21 9 11 0	2 45 9 15	22 3 10 3	S.E. "	22 3	12 0
" 18	12 6	S.W. W.N.W.	22 10	3 15 9 35	22 10 10 8	3 35 10 0	23 0 9 6	S.S.E. S.E.	23 0	13 4

Copy of Tidal Observations at Grimsby (Royal Dock) —continued.

1864. Date.	MORNING.				AFTERNOON.				Observations—Barometer.
	Moon's Age.	Wind.	Water at Gauge.	Time. hr. min.	Height. ft. in.	Time. hr. min.	Height. ft. in.	Wind.	
May 19	13 6	S.E.	23 7	4 0 10 20	23 7 9 6	4 20 10 40	23 10 8 3	S.E. "	Light airs and fine. B. 30·20.
" 20	14 6	South. S.S.W.	24 0	4 40 11 0	24 0 8 0	5 0 11 20	24 6 8 2	W.N.W. "	Squally, with showers. B. 30·00.
" 21	15 6	N. by W. N.N.W.	25 5	5 20 11 40	25 5 8 6	5 40 12 0	25 0 7 9	S.S.E. West.	Strong gale and rain. B. 30·05.
" 22	16 6	N.W.	25 9	6 0	25 9	0 20 6 20	7 10 25 6	E.N.E. East.	Strong and squally. B. 29·95.
" 23	17 6	W.S.W. N.W.	26 2	0 40 6 40	7 6 26 2	1 0 7 0	8 10 25 8	N.E. N.N.E.	Strong breeze and squally. B. 29·92.
" 24	18 6	N.N.E. "	26 2	1 20 7 40	8 0 26 2	2 0 7 40	6 7 25 0	" S.S.E.	Fine breeze and cloudy. B. 30·27.
" 25	19 6	W. by S. N.N.W.	26 6	2 5 8 15	7 3 26 6	2 30 8 30	8 0 25 10	N.N.E. "	Strong breeze and cloudy. B. 29·95.
" 26	20 6	North. N.N.E.	25 6	2 50 8 50	10 0 25 6	3 25 9 25	7 6 24 1	" "	Strong wind and gloomy. B. 30·05.
" 27	21 6	N.N.W. N.W.	24 8	3 45 9 45	9 0 24 8	4 15 10 20	8 6 24 3	N.W. N.N.W.	Strong and squally, with rain. B. 30·03.
" 28	22 6	N.N.W. N. by E.	24 2	4 45 10 45	10 8 24 2	5 20 11 20	8 8 23 0	S.E. S.S.W.	Gale and rainy. B. 29·82.

Copy of Tidal Observations at Grimsby (Royal Dock)—continued.

1864. Date.	MORNING.				AFTERNOON.				Observations—Barometer.		
	Moon's Age.	Wind.	Water at Gauge.	Time.	Height.	Time.	Height.	Wind.		Water at Gauge.	Rise and Fall of Tide.
May 29	days hrs. 23 6	W.S.W. N.N.E.	ft. in. 24 3	hr. min. 5 50 11 50	ft. in. 10 3 24 3	hr. min. 6 15	ft. in. 9 4	N.N.E.	ft. in. ..	ft. in. 14 0	Strong and squally. B. 29·97.
" 30	24 6	West. W.S.W.	23 4	0 15 7 0	23 4 10 6	1 0 7 30	23 3 8 6	W.S.W. "	23 3	14 9	Fresh and cold. B. 29·90.
" 31	25 6	N.N.E. N.N.W.	23 3	1 50 8 10	23 3 10 10	2 10 8 30	24 6 9 3	S.S.W. E.S.E.	24 6	15 3	Light wind and fine. B. 29·80.
June 1	26 6	West. "	23 3	2 35 9 10	23 3 9 8	3 10 9 40	24 6 9 0	N.W. "	24 6	15 6	Fine breeze and clear. B. 29·80.
" 2	27 6	N.E. E.N.E.	24 6	3 40 10 10	24 6 9 0	4 10 10 40	25 0 9 1	E.S.E.	25 0	15 6	Strong breeze and clear. B. 29·86.
" 3	28 6	S.E. "	24 10	4 40 11 0	24 10 8 3	5 0 11 20	25 3 8 0	S.S.E. "	25 3	17 3	Light wind and cloudy. B. 29·91.
" 4	New	S.S.E. "	25 2	5 20 11 45	25 2 7 10	5 45 0 0	25 2 8 7	S.S.E. West.	25 2	16 7	Light wind and fine. B. 29·90.
" 5	1 0	West. W.N.W.	25 3	0 0 6 0	8 7 25 3	0 20 6 25	7 4 25 0	W.S.W. S.W. by S.	25 0	17 8	Light winds. B. 29·85.
" 6	2 0	W.S.W. W.N.W.	25 8	0 45 6 45	8 6 25 8	1 0 7 0	7 8 25 0	W.N.W. S.S.E.	25 0	17 4	Strong breeze and showery. B. 29·85.

November, 1868.

(Signed) E. H. CLARK, C.E., Grimsby Docks.

TIDAL OBSERVATIONS taken at SPURN LIGHTS (Humber Side) and HULL DOCKS,
21st April, 1866.
N.B. The Heights refer to Ordnance Datum.

Time.	Height at				Remarks.
	Spurn.		Hull.		
H. M.	Ft.	In.	Ft.	In.	
A.M.					
4.35	..	..	- 6	6	Wind S.W.
4.45	- 4	7*	- 6	9	* Flood occurred a few
4.55	- 4	3	- 6	9	minutes before this ob-
5.5	- 3	10	- 6	9	servation was taken.
5.15	- 3	6	- 6	6	
5.25	- 3	1	- 6	3	
5.35	- 2	8	- 6	0	
5.45	- 2	3	- 5	8	
5.55	- 1	10	- 5	3	
6.5	- 1	4	- 4	7	
6.15	- 0	10	- 4	3	
6.25	- 0	4	- 3	7	
6.35	+ 0	2	- 3	3	
6.45	0	8	- 2	7	
6.55	1	2	- 1	11	
7.5	1	9	- 1	3	
7.15	2	4	- 0	7	
7.25	2	11	- 0	1	
7.35	3	7	+ 0	7	
7.45	4	1	1	1	
7.55	4	9	1	8	
8.5	5	4	2	4	
8.15	5	10	2	11	
8.25	6	3	3	9	
8.35	6	8	4	4	
8.45	7	1	4	11	
8.55	7	4	5	4	
9.5	7	7	5	10	Wind N.W.
9.15	7	10	6	3	
9.25	7	10	6	10	
9.35	7	11	7	3	
9.45	7	11	7	7	
9.55	7	11	7	10	
10.5	7	10	8	1	
10.15	7	7	8	2	
10.25	7	4	8	3	Wind North.
10.35	7	1	8	4	
10.45	6	10	8	4	
10.55	6	7	8	4	
11.5	6	4	8	0	
11.15	6	0	7	10	Wind East.
11.25	5	7	7	7	
11.35	5	0	7	3	
11.45	4	5	6	11	
11.55	3	10	6	5	
P.M.					
12.5	3	4	6	1	
12.15	2	9	5	9	
12.25	2	3	5	4	

Tidal Observations taken at Spurn Lights and Hull Docks, &c.—*continued*.

Time.	Height at				Remarks.
	Spurn.		Hull.		
H. M.	Ft.	In.	Ft.	In.	
12.35	1	8	4	10	Wind N.E.
12.45	1	0	4	4	
12.55	+ 0	4	3	10	
1.5	— 0	4	3	3	
1.15	— 0	11	2	4	
1.25	— 1	6	2	0	
1.35	— 2	2	1	4	
1.45	— 2	9	1	0	
1.55	— 3	3	+ 0	5	
2.5	— 3	9	— 0	3	
2.15	— 4	3	— 0	10	Wind S.E.
2.25	— 4	9	— 1	6	
2.35	— 5	2	— 2	1	
2.45	— 5	7	— 2	5	
2.55	— 6	0	— 3	1	
3.5	— 6	3	— 3	7	
3.15	— 6	6	— 3	11	
3.25	— 6	9	— 4	4	
3.35	— 6	11	— 4	10	
3.45	— 7	0	— 5	2	
3.55	..	..	— 5	6	
4.5	..	..	— 6	1	
4.15	..	..	— 6	4	
4.25	..	..	— 6	10	
4.35	..	..	— 7	1	
4.45	..	..	— 7	4	
4.55	..	..	— 7	8	
5.5	..	..	— 7	11	
5.15	..	..	— 8	1	Low Water at Hull.
5.25	..	..	— 8	2	

W. SHELFORD.

[Mr. SHELFORD

OUTFALL OF THE RIVER HUMBER.

PLATE 20.

W. SHELLED, DELT

W. SHELLED, DELT

OUTFALL OF THE RIVER HUMBER.

PLATE 21.

Fig. 1.

Fig. 2.