water, and arrives at Framilode, 3 miles distant, at about 1¼ hour ebb at that place: the time of this period of the ebb, on 7th May, 1845, was 47 minutes past 10; allowing three-quarters of an hour to pass along the canal, it would leave the canal at half-past eleven, when, on that day, the tide had yet 4½ feet to fall, which would give ample depth. This canal would also enable trows and barges to reach the Stroud Canal at neap tides.*

The paper is illustrated by Thomas's Chart of the Severn, No. 4320, and by a diagram showing a longitudinal section of the river from Gloucester to Sharpness Point.

Mr. WALKER cordially concurred in the vote of thanks to Mr. Parkes for his paper, which evinced much observation, and a laudable desire to contribute to the interest of the meetings, by communicating the result of an examination of a locality to which he had been sent, for purposes connected with professional labours. Mr. Walker had formerly strongly enforced, from the Chair, the advantages that would result to the Institution, from such a course being pursued by its members of all classes, and he was gratified to find his advice had been followed so successfully by one of his assistants.

The paper was full of interesting matter, and it was not possible to examine the phenomena described, without allowing, that the river Severn afforded a wide field for observation, and for discussion, upon subjects comparatively untouched, and which, although of great importance, were but imperfectly understood.

At Worcester the river nearly resembled a canal; a few miles below Gloucester it was pent up by natural weirs; while the lower

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* It has been suggested to the Author by Mr. J. R. McClean (M. Inst. C. E.), that the present opportunity should not pass, without calling the attention of the Institution to the necessity of having one datum for tidal reference, all round the coast of England.

The observations on the tides have hitherto been insufficient to determine the cause of the great variation between high and low water, at many places on the coast; but if all the registers referred to the same horizontal line, much valuable information might be afforded, both as regards the effects of the various forms and depths of estuaries, and of the operation of the prevailing winds on the tidal wave.

In many cases it might be found, that the great rise was only relating to the low water of the place, and that the low water was under the level of places less affected by the tides, and, in fact, during part of the time of ebb, running up an incline, when referred to the level of these places.

portion presented a tortuous course, filled with shifting shoals and impediments to the navigation, which was only carried on by a remarkable and sudden rise of the tide. Of the works designed for the improvement of the upper part of the river, Mr. Walker hoped the Institution would have a good account from Mr. Cubitt, under whose direction they were executed; he would not, therefore, do more than allude to them at present. With respect to the portion between Gloucester and Sharpness Point, there had been many projects for its improvement; but the only one of importance which appeared feasible, was that of cutting a canal through the neck of the Horse-shoe at Framilode, whereby some time might be saved in the navigation for small craft. Some local improvements might also be made without much expense; but it would be impracticable to remove the rocks forming natural weirs, as, if the channel was rendered quite clear of impediments, the velocity of the stream would be so much increased, that the upper part of the river would be nearly drained, and rendered unfit for navigation. The dimensions of the lower part of the river, and its peculiar locality, rendered inapplicable any of the systems of improvement which had been so extensively practised in the Clyde and other important rivers. Perhaps the principal amelioration of which it was susceptible, would be to increase the dimensions of the Berkeley Canal, so as to render it capable of conveying larger vessels up to Gloucester, and thus still further to augment the importance of that port; for although, within a few years, it had been raised, by means of the ship canal, from an unimportant place to considerable eminence as a mercantile city, its peculiar locality would permit a still greater extension of its rapidly increasing trade; but this could only be accomplished by facilitating the access to it.

Mr. J. Scott Russell accorded with the views given in the paper, relative to the phenomenon of the breaking "bore," which he attributed to unequal velocities in the wave, the under part being retarded by the friction against the bottom, and the upper part being rolled over it, and breaking like the surf on a flat shore.

In making tidal observations, such as he had directed very extensively in the Firth of Forth, for the British Association, he had found it essential, that they should be taken simultaneously at numerous stations, at intervals of not more than 5 minutes apart, that they should be continued for a considerable period, and, if possible, be made at the mouths of several rivers at the same time. The observers should be relieved after being on duty for 8 hours; and the observations should be continued day and night. Thus no opportu-

nity would be afforded for the men absenting themselves for any time, and making up false records, as he had found had been done, when the observations were made at intervals of 15 minutes.

The fixing of a general datum-line for Great Britain was an object of great importance, and well deserved the attention of the Institution. The mean low-water mark had been proposed, and, he believed, had been used in some surveys; but although that varied but little some distance out at sea, it was liable to great variation on the coasts and at the mouths of rivers, which were exactly the spots whence the datum could be gained.

Sir JOHN RENNIE, *President*, stated, that between the years 1815 and 1818, Mr. Giles conducted for the Admiralty an extensive series of tidal observations on the Tyne and the Wear, whilst he was surveying those rivers. Gauges and stations were established, from the mouth of the river, up as far as the run of the tide extended, and, he elieved, the observations were made at intervals of 5 minutes. The work was extremely well done, and Sir John Rennie thought the credit of the introduction of this kind of observation, combined with surveying, was in a great degree due to Mr. Giles.

The fixing one general datum-line was such an important measure, that Sir John Rennie thought it was incumbent upon the Institution to bring the subject forcibly before the Government, and request some legislative enactment relative to it.

Mr. WALKER said, that Mr. A. Comrie had recently completed, for him, a survey of Plymouth Sound, in the same manner as the surveys by Mr. Giles, which had been mentioned, and he believed that few charts in existence were so accurate and yet so comprehensive. Mr. Walker thought the general datum-line was a very important subject, and he believed the present Hydrographer to the Navy was so keenly alive to everything of real utility, that it required only a hint to induce his best attention to the subject. He thought, however, that the work would be more easily and quickly accomplished by the railway engineers, whose surveys now extended in all directions throughout the length and breadth of the land. It would only be necessary to verify the accuracy of the actual datum-lines of all the surveys, extend them to the mouths of all the rivers, and reduce them to one standard—say Trinity high-water mark; such a mark being recorded in a permanent manner, there could be no difficulty in correcting any levels, or any series of observations, and in railway matters it would be found of great advantage. He thought this ought to occupy seriously the attention of the Institution.

Mr. HEMANS stated, that throughout Ireland the datum-line re-

ferred to the mean of low-water level in Dublin Bay; this had been settled after a lengthened series of observations; and great uniformity existed in the Irish surveys in consequence of its adoption.

Mr. W. Bald believed that a datum-line had been observed, for the purposes of the general trigonometrical survey of Ireland; he was not aware whether the trigonometrical survey of England referred to a similar datum.

With respect to Mr. Parkes' Paper, Mr. Bald thought there was an omission, in its not stating whether any observations had been made by rain-gauges, as to the quantity of rain falling upon the extent of 4,400 square miles, stated to be drained by the Severn. This he had found to be of great importance, in considering the question of the drainage of a country, consequent upon the improvement of its rivers.

Mr. Brunel said, there was not any fixed standard for the trigonometrical survey of England; he believed, however, that some lines had been laid down for particular tidal surveys, but no general mark had been adopted. It was a measure of great utility, and one in which the members of the Institution were so deeply interested, that he trusted they would use every effort to carry it into effect. It would be more quickly and better done by their individual exertions, than if they waited to have it done by the Government.

Mr. J. Taylor thought, that in fixing a general datum-mark, it should be borne in mind, that a general elevation of the coasts of some countries was proceeding: he alluded particularly to that of Sweden, as mentioned by Lyell.* Early in the last century, the Swedish naturalist, Celsius, expressed an opinion that the waters of the Baltic and of the Northern Ocean were gradually subsiding; upon which theory a fierce controversy ensued, and the fallacy of the proposition was at length generally admitted.† Playfair, in his "Illustrations of the Huttonian Theory," in 1802, admitted the sufficiency of the proofs adduced by Celsius, but attributed the change of level to the movement of the land, rather than to a diminution of the waters; as, in order to depress, or elevate, the absolute level of the sea, by a given quantity, in any one place, it must be depressed, or elevated, by the same quantity over the whole surface of the earth.

Von Buch, after very careful examination of the subject, during his travels in Scandinavia, in 1807, declared his conviction of the rising of the land in that country. Subsequently, lines, or grooves,

* Vide Lyell's Principles of Geology, vol. ii, page 409 (12mo. edition, 1840.)

† Vide Von Hoff. Geschichte, &c., vol. i, page 439.

were cut in the rocks, indicating the level of the sea at given points, on calm days, and it was found, that in 14 years there had been an elevation of the land of between 4 and 5 inches.

Now, as Sweden was not more subject to earthquakes, or similar convulsions of nature, than Great Britain, there was no valid reason why there should not be the same gradual upheaving of our shores; and in that case, particularly if the rising was partial and unequal, any correct datum-line of to-day, would, in a century, be entirely erroneous.

Mr. WALKER replied, that such might undoubtedly be the case, but the fixing of such a general datum mark would materially assist in detecting any movement of the land which might otherwise escape observation; so that, for geological purposes, the proposed measure was equally important as for engineering ones, and he trusted the geologists would lend their powerful aid.

Seeing Mr. Leslie present, he asked what methods he had adopted, in the recent valuable surveys he had made of the Tyne and the Tay.

Mr. LESLIE replied, that his tidal observations were made at numerous stations, at intervals of 5 minutes, and extending over a lengthened period. These precautions he found absolutely necessary to insure accuracy.

Mr. BATEMAN agreed in the advantage of having a general datum-line fixed, to which all surveys could refer. Captain Denham had stated, that the mean of high and low water at Liverpool was the same under all circumstances. Mr. Rendel, in his examination of the action of the tides in the Mersey, in reference to the Birkenhead Docks, found material differences in the rise of the tide. Runcorn appeared to be the apex of the tidal flow, although the influence of the tide was felt up to Warrington. At Liverpool the tide rose higher than at Formby; at Runcorn it rose still higher than at Liverpool; but, owing to the expansion of the channel, after the contraction at Runcorn, the rise was less at Warrington. It appeared, also, that the tide assumed a kind of pendulous action in that estuary; for at Liverpool, on particular occasions, it fell as much below low-water mark as it had risen above high-water mark on the same tide.

Mr. SCOTT RUSSELL did not find Captain Denham's observations of the mean between high and low water corroborated in other situations. For instance, in the Forth there was no uniformity of action, nor could there be, unless the tide was a single one, or where two equal tidal waves met regularly at given periods, as at London, Liver-

pool, and Aberdeen. In the Forth, where there was diurnal inequality, and the water of the two tides did not travel with the same relative velocity, it was evident Captain Denham's rule would not apply, as at one time there would be agreement, and at another, discrepancy.

Mr. J. THOMSON had tried experiments for the purpose of ascertaining a mean tide level, but his attempts had been unsuccessful. At the south end of the Crinan Canal, the observations gave a mean result totally different to those at the west end: there was a difference of 4 feet between the two means. In continuing his experiments along the coast, in both directions, he found, that there was no uniformity in the levels, and that the mean was influenced in all cases by local causes.

With regard to a general datum-line, he would suggest one line being carefully levelled between two extreme points, from sea to sea; and, diverging from that, other lines should be extended to given points around the coast. This would demand time and an expenditure of money; but the object was of such importance, that if the Government would not undertake it, the work ought to be accomplished by the public, whose money would frequently be saved, by having such a standard of reference in railway and other matters.

Mr. W. BALD found, by experiments in the Clyde, at Glasgow, that, notwithstanding the influence of the fresh water, Captain Denham's rule for the mean-tide level was nearly correct. It was a curious fact, that the morning tide in the Clyde always rose higher than the evening tide, and the harbour-masters always took advantage of this to berth the large ships in the morning. Mr. Bald approved of Mr. Thomson's proposal of running one main line of levels, and carrying out ordinates right and left from it, in order to establish a general datum-line throughout the kingdom.

Mr. BEAMISH said, that in some surveys, Mr. R. Stephenson and Mr. Giles had adopted the Trinity high-water mark as a datum, and reference to it was marked on the bridges. For instance, at Birmingham, Worcester, and Northampton, and also at Southampton, and some intermediate places on the South-Western line.

Sir JOHN RENNIE, *President*, hoped that the question of the present state of important rivers, and their capability of improvement, having been so well commenced by Mr. Parkes, would be kept up by an account of the original surveys and plans of Mr. Rhodes, in which he was assisted by Mr. Renton; and also by a description from Mr. Cubitt of the works in the upper part of the river Severn,

which had been so successfully executed from his designs. These were subjects well worthy the attention of the members, and he trusted that they would be soon brought forward.

Mr. W. BALD stated, in answer to questions from the President, that the difference between the level of low water in the Clyde, in the harbour of Glasgow, and down at the sea, varied from 2 feet to 3 feet 6 inches, when the water was low; but the difference was greater, when there was much water in the river. He was of opinion, that the navigation might be improved, by removing all the obstacles which impeded the free flow of the tidal waters into the upper and lower recesses of the Clyde, the river Cart, and also all the other tributary waters connected with those rivers; this would increase the scouring power, and tend to diminish the deposition which took place in the harbour and the river, and which amounted annually to about 160,000 cubic yards, of which amount about 80,000 cubic yards were deposited in the harbour of Glasgow by the river-floods and from the sewerage of the city, which stood on an area of about 2,000 acres. At Bowling, there was annually a deposition of about 70,000 cubic yards, which was partly owing to the great width of the Clyde at that place, and also to the Clyde Trustees not being empowered to form a tide dyke opposite Lord Blantyre's estate, which would confine the water and increase the ebbing scour, as in other parts of the river. The parallel dykes, designed by the late Mr. Rennie, had greatly improved the navigation of the Clyde, and, combined with the dredging power, might be said to have achieved all that had been done effectively for deepening the navigation; but Mr. Bald was of opinion, that the designs of that great and able engineer had not been executed correctly. For example, in one of his Reports, in 1807, he stated, that the Clyde at Dunglass Castle should be 536 feet wide between the dykes; now, between Dunglass and the existing parallel dyke, it was only about 400 feet wide. This contraction had been injurious to the tidal flow. Then, again, at the west end of the Newshot Isle, the Clyde at high water had been suddenly narrowed in width from 940 feet to 360 feet, which, it could not be denied, had seriously diminished the volume of the tidal waters in the Clyde.

The removal of the weir at Stockwell-bridge, and the improvement of the river above the city of Glasgow to above Rutherglen, would give an additional quantity of about 30,000,000 cubic feet of water moving up and down through the Clyde, and which would add greatly to the scouring power, and would be felt in the lower parts of the river.

Dr. Thompson, of Glasgow, had stated to Mr. Bald, that he had measured the quantity of water passing at the Broomielaw-bridge, during a dry summer, when the water was low in the Clyde, and he found the flow to be 76⅔ cubic feet per second. He further stated, that the mean quantity of rain falling in Glasgow, for 30 years, was 21¼ inches; at Greenock, by observations extending over 3 years, it was found to be double, or equal to 42·66 inches; and at Edinburgh, 24½ inches.

The basin of the Clyde, including those of the Kelvin, White Cart, Black Cart, and Leven, contained an area of about 1,408 square miles. The Clyde, above Glasgow, with its basin of about 782 square miles, delivered, in the summer season, 220,050 cubic feet per second, 345,668 cubic feet per second, and 408,000 cubic feet per second. These observations of the quantity of water passing through the Clyde, were made at Glasgow, and a little above that city, in places of which Mr. Bald promised to produce the sections, and to give the calculations in detail.

Mr. WALKER said, that having been consulting engineer to the River Clyde Trustees for the last 12 years, and having advised the principal operations to which Mr. Bald had referred, he must, without meaning to doubt the correctness of the statement of the amount of cubic feet of water, guard the meeting from supposing, that the trustees had done anything with the view of preventing the tide from going to its full extent up the river, or which had that effect. The tide now rose as high in the river above the city, as in the harbour, and it fell as low there as ever it did, but not so low as it did in the harbour. The fact was, that by artificial widening and deepening in the harbour, and partially in the river below the harbour, what was naturally a shallow stream, had been converted into a great deep pool, or harbour, for large ships. The natural tendency of the land freshes, which were considerable in the Clyde, would be to carry the sand, or natural bed, of that part of the river which was above the city, down into the harbour, and thereby to increase enormously the cost of dredging, as well as to undermine the bridge, and to interfere with interests of numerous parties, including the Water Company, which by law and otherwise, the trustees were prevented from doing. All that had been done was, not to raise the water, but to keep up the original level of the bed of the river, and of the water, until power was obtained to alter the whole. This was the weir that had been referred to; and perhaps the use of the term weir was apt to mislead. In his Reports and Evidence on the Clyde, Mr. Walker had shown that, so high as Glasgow, or the harbour, the tide was almost valueless;

that it always would be so; that the scouring power there depended on the land freshes and the dredging, and certainly no tidal effect would ever practically lessen the quantity of dredging in that part of the river. When Mr. Bald named the contracted width down the river at Newshot Isle, he must have referred to the present width, which, with the other parts of the river, was designed to be deepened and enlarged, the whole being, as was well known, too small for the present trade.

Mr. Walker stated, that to the best of his recollection, under the last Act, the prohibition to make any dyke opposite Lord Blantyre's estate was removed. No navigable river had been improved on so extensive a scale, and perhaps, he might say, with greater success, than the Clyde; but the trustees could not do all at once. They had a Bill, now before Parliament, for docks and river improvements to the amount of £700,000. He did not expect, that Mr. Parkes' Paper on the Severn would have produced any observations on the Clyde, but as they had been induced by the discusssion, he felt called upon to give the explanation which the circumstances demanded.

Mr. BALD said, that after several years of experience, in conducting the works for the improvement of the river Clyde, it was his conviction, that it was not only wrong, but practically injurious and detrimental to the navigation, not to remove every obstruction, whether natural or artificial, which in any manner impeded the free passage of the tidal waters into that river, into all its upper recesses above the city of Glasgow, and to the fullest extent into all its tributary streams.

The great necessity and value of a still further improvement of the navigation of the Clyde, by a more abundant tidal flow, would not warrant an opposition to the removal of those impediments which now existed in the main channel of that river, at the Newshot Isle, upon a mere conjecture, or an assumption, that their removal would be injurious, and would involve an expense greater than any benefit which would be rendered to the navigation; because he was prepared to maintain, that the obstructions which remained in the channel of the Clyde, at that place, were injurious; and besides, that they could be removed to a sufficient extent, at such a reasonable expense, as would be more than compensated by the great improvement of the navigation, from an increased tidal flow.

After a careful examination, in 1839, of the state of the Clyde, the speed, level, and movement of its waters, the artificial works which had been constructed, the character of the strata in its bottom and of its banks, the extent of the existing natural and artificial

obstructions to the tidal flow, and considering that the dredging alone, from deposition, had been costing annually many thousands of pounds; and, contemplating how the harbours of Rye, Wells, Southwold, &c., in England, had been injured by the formation of embankments, shutting out the tidal flow; looking at the great expense which had been incurred to procure a back-water sluicing power, for deepening several of the continental harbours; and, lastly, reading over all the Reports which had been written on the Clyde, wherein a most anxious desire had been expressed, by several of the engineers, to facilitate the flow upwards of as great a body of water as possible from the sea, he became deeply aware of the great importance and value of the ebbing tidal power, and would give a few extracts relative to it from the Reports on the Clyde.

The late Mr. John Rennie, to whom the Clyde was so much indebted for its improvement, stated in his Report, 1807:—"Having, therefore, given the opinions I did in the year 1799, I cannot for a moment hesitate to advise, that a plan such as I have mentioned, should be continued; and that the best means of bringing up more tide to the Broomielaw, and improving the depth of water in the river, as well as lessening the effects of land-floods, opposite the city of Glasgow, is by the following up of this plan."

Report, 1799.—"All that, therefore, can be done, is to clear away the obstructions in the river as much as possible," &c.

The late Mr. Telford, in his Report on the Clyde, 1806, stated as his first recommendation:—"The leading or bringing up a greater quantity of tide water."

And again,—"First, in order to obtain a greater quantity of tide water in the upper part of the river, the general principle is to reduce the bed of the river to that form which shall afford the most direct course, oppose the fewest obstacles, and render the friction the least possible in regard to the section of the flowing water."

"Besides the leading up more tide water, it may be expected, when the channel is regulated and rendered more direct, that the river will deepen its bed."

The Clyde Trustees, deeply impressed as to the benefits of an abundant tidal flow up the river, consulted Mr. Whidby, who, in his Report, in 1824, said,—"I exceedingly regret that so much has been recommended in the Reports, and so much done, to ruin the river Clyde. The object appears to me to have been the obtaining of land from the river in preference to preserving the latter."

He condemned the contraction of the channel as tending to reduce the tidal flow; and stated his fears that the Clyde would share the

fate of other rivers and harbours where the tide had been shut out by embankments. He anticipated the formation of banks and bars below Port Glasgow, though he was unable to state whether any alteration in depth had taken place since the commencement of the works. He considered there never ought to have been more done to the Clyde, than paring away the points and filling the deep indents of the shores, so as to have allowed the tide to flow along the land without interruption. He recommended the jetties, especially those below Newshot Isle, to be broken through, the dams at the bridges, or weirs, to be removed, so as to allow the tide to flow above the town, and to considerably enlarge the capacity of the river.

The late Mr. David Logan, in his Report on the Clyde, 1835, also expressed his conviction of the importance of the flow of as great a body of water as possible.

Mr. Walker, in his Report on the Clyde, 1836, under the head "Navigation upwards," said, "The removal of this weir (Glasgow-bridge weir), and the deepening above it, that will be the consequence, will form another important addition to the reservoir for tidal water, as every tide will ebb several feet lower than it does at present."

For all the foregoing reasons, expressed in the Reports he had quoted, Mr. Bald had become deeply impressed with the importance of a fuller and freer passage of the tidal waters into the Clyde and its tributaries.

What could be more useful and beneficial to a large city, like that of Glasgow, than to have a tidal river flowing directly up from the sea, to a distance of some miles above it, unimpeded by obstacles of any kind, and running freely, unfettered by lock, dam, or weir, and in its ebb, scouring the whole river channel, and sweeping away everything discharged by the city sewers, the contents of which remained at present for lengthened periods on the ground, dry at low water, between the bridges, tending to produce the miasma, and induce typhus fever, which had become so prevalent and so fatal in the city of Glasgow. He would say, that to accomplish these desirable objects, no expense should be spared, to obtain as early and as abundant a tidal flow of water as possible, into the highest recesses of the Clyde, or above the city of Glasgow.

With a view to this important object, but principally to obtain a greater depth of water for navigable purposes, a channel was cut through the Port Glasgow Bank, which was the greatest natural barrier to the navigation in the lower Clyde. This channel was about

700 yards long, by 100 yards broad, and the depth of the cutting was about 2 yards. At high-water springs the depth was 22½ feet, and at low water it was only from 5 feet to 5 feet 6 inches deep. This work was commenced in 1841, and finished in 1842. Since this channel was formed, it had not shown any tendency to silt up. The material cut through consisted of sand and mud, mixed with shells and marine decomposition. A thin bed of a calcareous rock crust, about 3 inches thick, was cut through for a length of about 100 feet. Some anchors, in a state of great decay, were dredged up. The forming of a channel through this bank was allowed to be of the greatest importance for the improvement of the navigation in the lower Clyde; indeed it might be said to have been the key which opened the lower navigation; for formerly vessels were daily to be seen lying grounded upon that bank. This cut, or channel, being in the open estuary, where the river was about 2 miles broad, it had been buoyed along its western edge to guide vessels up and down. Three dredgers were employed in cutting this channel.

The second bank cut through was the Puddle Deep Bank at Garmoyle, and which was also cut in line, conformably to the plan and sections. The third was the Dumbarton Bank; and the fourth, the bank at the head of the Long Dyke. These banks were cut through to a depth of from 10 to 11 feet at low water. Their material consisted of fine and coarse sand, mud, and some clay.

Plans were made and agreed to by the Trust, for widening the channel opposite to Dunglass Castle, to even greater dimensions than were specified by Mr. Rennie; but so many things had to be done, that this great improvement still remained untouched. Mr. Rennie assigned a width of 530 feet, but it was left at only 400 feet.

On the south side of the Clyde, below Erskine Ferry, two jetties were partly removed; and above the ferry, on the south side, a parallel dyke, nearly 500 yards long, and another on the north side, below the Newshot Isle, were also removed. These jetties and dykes considerably obstructed the tidal flow.

Between Erskine Ferry and the Newshot Isle, the bed of the Clyde, for a distance of 2000 yards, was greatly encumbered with stones and stone boulders, which were highly injurious to vessels if they grounded there; and frequently, large ships, in being tugged through this part of the river channel, had their copper bottoms injured when they touched the rocky channel-bed.

In deepening and clearing this part of the river, two diving-bells were employed, and one, and sometimes two, steam-dredgers. The

clearing and deepening of this channel was exceedingly severe on the machinery and working gear of the steam-dredgers; the speed of the engines were therefore governed by the nature of the material in the bottom, and although the iron work frequently gave way, yet spare links and buckets being always ready to replace those which broke, there was little interruption to the continuous working of the dredgers. When the dredgers had cleared away the material which covered the boulders in the bottom of the channel, the diving-bell boats were worked over the ground so cleared, removing all the large boulders, and when that part of the channel had been cleared of them, the dredgers went again over the same bottom, removing all the lighter material from the heads of the lower boulders, preparatory to the bells commencing again, and these operations were continued until the necessary depth was attained.

The buckets of the steam-dredgers, in working along the bottom, always slipped over the head of the large boulders, which the diving-bells alone could lift and remove. Some of those masses of trap, or whinstone, were 4 and 5 tons in weight, and from their rounded forms and smooth surface, it was evident, that they had been brought from some distance. Some of them were of sandstone, but they were more angular than the trap boulders. Quantities of these boulders, lifted from the bed of the channel, might be seen lying along the sides of the river; and many of them had since been split and broken up by gunpowder for repairing the river dykes. The tops of some of the large stone boulders lifted from the bed of the channel, were found grooved, to a depth of about an inch or more, by the ships' keels having been rubbing over them, and metallic particles were distinctly to be seen upon their surface. In removing these stone boulders from the bed of the channel, the diving-bell men found numerous fragments of copper and iron, which had been torn off the ships' bottoms and keels by the large stones; but latterly this had not been the case, as great progress had been made in the removal of the boulders and the deepening of the channel.

Having arrived at the river channels which formed the Newshot Isle —one of the most important parts of the Clyde for the improvement of its navigation—it was quite evident that the south channel of the Newshot Isle was the main channel of the Clyde, and that the north channel of the Newshot Isle had been formed by the united waters of the rivers Gnyfe, White and Black Cart. No description could illustrate so forcibly those inductions regarding the formation of these channels at the Newshot Isle as the river plan, and more parti-

cularly as showing the position and direction of the south channel, as being the best and most favourable, for obtaining an abundant flow upwards of the tidal waters, and as being also the most direct and best line for the navigation of the Clyde.

The influx of the tidal flow, through the deepenings and widenings which had been made in the lower Clyde, was greatly diminished, in reaching the higher recesses of that river and its tributaries, while the south, or main channel of the Clyde, at the Newshot Isle, remained dyked up, and the tidal flow was forced to pass through the narrow and crooked northern channel. It should be noticed, that the Clyde, from being 900 feet wide below the Newshot Isle, was suddenly reduced to a width of only 360 feet at the west entrance of the north channel; while the south, or main, channel had been completely shut up by a stone dyke and a pier, extending for a length of 2450 feet. He was of opinion, nothing could be more injurious to such a river navigation.

The Report of Mr. Scott Russell on the tidal wave of the Clyde, in 1838, clearly pointed this out; for he stated that the wave moved at the following speeds:—

"From Port Glasgow to Bowling	20	miles per hour.
,, Bowling to Clyde Bank	8	,,
,, Clyde Bank to Glasgow	13·63	,,

"It is, therefore, between Clyde Bank and Bowling that the greatest loss at present takes place. These observations point out, quite decidedly, where the loss exists and how it is to be remedied."

Mr. Bald's own observations gave—

From Port Glasgow to Bowling	13	miles per hour.
,, Bowling to Clyde Bank	6·4	,,
,, Clyde Bank to Glasgow	10	,,

Mr. Bald had strongly urged on Mr. Walker and on the Trustees, the expediency of opening the south channel. The first objection which had been made was, that the river could not maintain two channels, and that if the south channel were opened, the north channel would silt up; but no proofs had been given to support such an assertion; while the old maps of the Clyde, executed 46 years ago, exhibited two channels formed by nature—the northern channel being, at high water, at an average, about 710 feet wide; while the south channel presented a remarkable configuration, being trumpet-mouthed, opening at its western, or seaward extremity, with a width

of 840 feet, and at its eastern entrance, 530 feet, giving an average width of about 790 feet. The area of the southern channel was larger by about 6½ acres than the northern channel.

The width of the Clyde, just above the Cart, was shown by the old maps to be about 1,020 feet at high water, and of the Cart, where it joined the Clyde, was 650 feet, making a total width of 1670 feet above the Newshot Isle. Now the mean width of the two channels of the Newshot Isle, added together, made 1500 feet; while the width of the Clyde below the Newshot Isle, and extending from its western end downwards to below Erskine Ferry, at an average, exceeded 1000 feet, but the greatest width was 1500 feet. The north channel, at its western entrance, was now, at high water, only 360 feet in width, and between the river dykes, about the centre of the north channel, it was only 270 feet wide. Looking at these dimensions, was it not, then, Mr. Bald would ask, quite possible to open the southern channel of the Newshot Isle to a dyke width of 300 feet, or more, seeing that, below the Newshot Isle, the Clyde was 900 feet wide, with a proposed dyke-width of 680 feet, and above the island, that the Cart, at high water, was 650 feet wide, and the Clyde 1020 feet, within which there was proposed to be a dyke-width of nearly 500 feet. Looking at these facts, it was quite out of the question to think of the north channel silting up, while there was such a wide entrance below the island for the tidal waters to ascend, and then such ample width in the Clyde and the Cart above the island, capable of receiving those waters. There was much more probability of the channel silting up, which had been cut through the Port Glasgow Bank, where the river estuary was 2 miles wide, and which had now been finished nearly 4 years, than that of the north channel of the Newshot Isle, by opening the southern channel.

The opening of the south channel would bring up the whole pressure of the tidal waters, directly to the embouchure of the Cart with the Clyde, and instead of a movement of the tidal wave at a rate of only 6½ to 8 miles an hour, as at present, from Bowling to Clyde Bank, it would move at a rate of 10 or 14 miles an hour to Clyde Bank. The following observations would throw additional light on this highly interesting subject:—

	Velocities in inches per second at bottom is	Velocities in inches per second at water's surface, is	The mean of four sets of observations taken upon different parts of the Clyde, between the harbour of Glasgow and the east end of the Newshot Isle, gives for the
	Inches.	Inches.	
Which will move coarse sand, the size of linseed, 8 inches per second	8·82	15·76	Descending velocity, 1,576 yards per hour.
Which will tear up fine potter's clay 3 inches per second	3·17	7·71	Ascending velocity, 771 yards per hour.
			The mean of four sets of observations taken upon different parts of the Clyde, between the west end of the Newshot Isle and Dumbarton Castle, gives for the
Which will sweep along coarse gravel 12 inches per second . . .	18·31	27·87	Descending velocity, 2,787 yards per hour.
Which will move coarse sand . .	9·00	16·02	Ascending velocity, 1,602 yards per hour.

These observations were made in ordinary fair weather, and showed, in a striking manner, how the velocity of the tidal waters were impeded in their ascent, into the reaches of the Clyde above the Newshot Isle, compared with their velocity below that island. They proved, that the velocities of both the ascending and descending currents would be increased above the island, by the south channel being opened, that a greater volume of water would ascend, and, therefore, that there would not be the slightest danger of the north channel silting up. It was quite possible to submit this question to a very rigorous investigation. The sectional area of the Clyde, 1060 yards below the west end of the Newshot Isle, was 7840 superficial feet at high water, and the sectional area of the Clyde, in the centre of the north channel of the Newshot Isle, was only 3920 superficial feet at high water; this showed that the south channel could be opened, with great benefit both to the tidal flow and the navigation.

It must have been evident, from the facts and observations which had been stated, that the opening up and deepening of the south channel of the Newshot Isle, and clearing away other obstructions, would give such an acceleration to the tidal wave upwards into the

Clyde, that there would be high water much earlier in the harbour of Glasgow than at present. There would be a greater rise of the tides in the harbour, and the tidal waters would ascend higher into the upper reaches of the Clyde, and also into those of the White Cart River, Black Cart River, and the Gnyfe River. A greater quantity of tidal water would ascend, by having a wider, deeper, and a more direct channel at the Newshot Isle; consequently, the ebbing-scouring forces would be greatly augmented, as had already been stated. This increased ebbing-scour would eminently tend to the clearing away of all shoals, or depositions, which formed in the river channel at Bowling; it would thus improve the navigation, and lessen the expense of dredging.

The shutting up of the south channel of the Newshot Isle, which was straight and direct in its course, and turning the navigation into the northern channel, which was crooked, narrow, and circuitous in its course, had diminished the tidal flow and ebbing-scour to a great extent, and had, he apprehended, tended to produce those banks and annual depositions at Bowling, which had been, and still continued to be, a great and serious expense, besides being an obstruction to the navigation.

Having attentively considered the circumstances, he had not any apprehension of the opening of the south channel, inflicting the slightest injury upon the northern channel, by depositions of any kind.

Having thus shown the injurious effects to the tidal flow, by the shutting up of the south channel of the Newshot Isle, and the benefit which the navigation would derive from its being opened, the next point was the question of the expense of the operation. After having considered this subject with some attention, it appeared to him, if the dyke at the lower entrance was removed with the other dykes and jetties at the upper entrance, that the strength and power of the descending tidal current would be so increased, that the channel would, in a very short period of time, be deepened; for it was principally filled with alluvial deposit, brought down by the floods. As an illustration of this, and showing the soft and yielding nature of the material, in the bottom of the Clyde, when the old weir was being removed from the Glasgow-bridge, the water of the river, in one night, made a channel through its bed, under the centre arch, of 11 feet 6 inches in width, extending to within about an inch of the bottom of the masonry, or nearly 14 feet 9 inches below ordinary low neap tides.

There was a portion of the south channel of the Newshot Isle, about 350 yards long, which indicated rock, according to the borings fur-

nished to him by Mr. Aird; the quantity which had been calculated in detail from the section, so as to give from 17 to 18 feet depth of water in the channel at high tide, was 60,336 cubic yards; the quarrying out of this rock would pay the expense for the annual repairing of the river dykes, if the stone material was not required for securing the sides of the south channel, in the event of its being opened. As the rock on the south shore, or the left bank of the channel, was sandstone, it might be inferred that the rock in the channel opposite to it was also sandstone; but let it be taken at the rate paid for quarrying whinstone in that neighbourhood, which was 7¾*d.* per ton, and taking two tons as being equal to a cubic yard, this would be 1*s.* 3½*d.* per cubic yard; but calling it 1*s.* 6*d.* then for—

	£.	*s.*
60,336 cubic yards, at 1*s.* 6*d.*	4,525	0
4,600 lineal yards of rubble dykes, hand thrown	1,035	4
	5,560	4
Contingencies, say	4,000	0
Total	9,560	4
Deduct 18,936 cubic yards at 1*s.* 6*d.* . . .	1,420	4
	£ 8,140	0

namely,—60,336 cubic yards to be quarried.

41,400 ,, in dykes.

18,936 ,, remain, at 1*s.* 6*d.*, was 1,420*l.* 4*s.* in value of stone.

He had allowed a sum of £4000 as a contingency, for removing any part which the power of the current might not be able to carry away, and he considered that amount ample.

It might be said, that the material, consisting principally of fine alluvial river deposit, being swept out of the channel by the ebbing-scour, would be carried downwards and form shoals below. That, however, would not occur, as the greater part of the deposit in the south channel was soft fine alluvial matter, which, being once put in motion by the ebbing-scour, would be carried down to the deep and open sea, and swept off by the currents. But again: supposing that part of the material was deposited in the lower channel, it could be easily and cheaply removed by the dredgers; his opinion, however,

was, that when once the matter was set in motion by the tidal current, it would pass away, and any deposition that might take place at low water would be disturbed again by the steamers passing up and down, and would then be carried off by the next ebb. The river floods also would act most powerfully in clearing out the south channel. In the river Clyde, during high floods, immediately below the harbour of Glasgow, he had found the velocities of the descending currents to be 2 miles 1,613 yards per hour, and in the narrow parts of the river, 3 miles 1,148 yards per hour. This was in the centre of the river, and at the water's surface; then 2 miles 1,613 yards would be a velocity, at the water's surface, of 51·33 inches per second; at the bottom, 38·01 inches per second: and 3 miles 1,148 yards, at the water's surface, 64·28 inches per second: at the bottom, 49·26 inches per second. Now a velocity of even 36 inches per second, at the bottom, would sweep along stones as large as an egg. Here was a power quite sufficient to clear out and deepen the south channel, and it ought to be remembered, that it was principally owing to the application of this power, that the first deepening of the Clyde was accomplished by Mr. Golborne, and again, more successfully, by Mr. Rennie; when directed, first by jetties, and secondly by parallel dykes.

It might be stated, that by keeping the new channel closer to the Newshot Isle, and more from the south shore, the rock might be nearly divided. He had personally been down and made three borings. He was not aware, that any other means than boring had been resorted to, for testing whether the bed of the channel consisted of rock or boulders.

The borings showed, that a depth of 8 feet below high water could be obtained in the south channel, without touching the rock at all, and a depth of 13 feet with but little rock cutting. But it had already been mentioned, that by keeping the new channel close to the Newshot Isle, the rock might be almost entirely avoided.

It appeared by Mr. Logan's Report, 1835 (page 13), that he had proposed to make a dock, or ship basin, within the south channel of the Newshot Isle. It was to have been 1,200 feet long, 350 feet broad, and 20 feet deep at low water; from this fact it did not appear that he was afraid of encountering rock, as his estimate for this basin was £27,000. If the basin was to be 20 feet deep at low water, as proposed, then at high water there would have been a depth of from 27 to 28 feet, a draught of water fit to float the largest ship in the navy.

The powerful landed proprietors no doubt viewed with pleasure

the rapid progress made by the river deposits in filling up this channel. Last summer the dyke at the lower entrance was, for a length of about 500 yards, repaired and raised several feet, shutting the entrance completely up, and, as he had been informed, the reason assigned for doing so was, that the vessels had a greater tendency to run up the south channel than the north, and to prevent this it was necessary to effectually close it.

The next obstruction in the river channel was at a place called Spier's Hedge, about 5 miles below Glasgow-bridge. This shoal was composed of boulder-stones, and prior to 1841, large ships frequently grounded upon it. It was removed by the diving-bells and the dredgers, and large quantities of the large stones, which were removed from the bottom of the channel at this place, were still to be seen lying along the sides of the river.

The next improvement was cutting away the point of land at White Inch, on the right bank of the river; it was about 800 yards long, and contained about 4 acres of ground. This improvement was commenced by the late Mr. Logan; but the river dyke and cutting were terminated under Mr. Bald's direction. The Clyde was 410 feet wide at this place; while above it, between the river dykes, the width was only 200 feet, and below it, it was only about 230 feet wide. Yet the channel here, notwithstanding the great width of the river, and its being so narrow above and below, had not shown any tendency to silt up, where the water was deep.

The point at Govan, 2 miles below Glasgow-bridge, was cut away, or rather, it would be more correct to say, that a great part of it above low water, was allowed to be washed away by the river, the river dyke having fallen. This point was 250 yards long. The Clyde at Govan was formerly only 170 feet wide, it was now more than 300 feet wide. The Old Ferry slip and quay-wall were removed, and a new one built, so as to give the necessary channel-breadth. This was a great improvement to the navigation, being so close to the harbour of Glasgow.

In 1841 and 1842, the harbour of Glasgow was completely deepened and cleared out, to the full satisfaction of the harbour-masters.

In 1843, the weir at the Glasgow-bridge was removed. The average depth of water over it, at high-water neaps, in 1840, was 2 feet 6 inches.

The shipping craft could now sail through the bridge to the upper harbour, and the tidal flow passed freely up as far as Stockwell-bridge.

Such had been the general operations which had been carried on for deepening and improving the navigable channel of the Clyde from 1839 to 1845. The general aim of those works was to obtain a depth, below the low-water line, of from 10 to 12 feet, which would give a depth, at ordinary high tides, of about 18 feet in the upper part of the Clyde, and 20 feet in the lower, and at very high tides, of nearly 20 feet in the upper Clyde, and about 22½ feet in the channel cut through the Port Glasgow Bank.

It had been stated to him, that last summer, during a high and favourable tide, a ship drawing 19 feet of water had ascended the Clyde to the harbour of Glasgow. He had latterly seen a vessel, drawing 17 feet 9 inches of water in the open sea, sail up the Clyde to the harbour of Glasgow. This was a great change since 1755, when Mr. Smeaton found the depth in the Clyde, on the Hirst Shoal, to be only 3 feet 3 inches at high water; and the extent of Mr. Smeaton's views then, regarding the improvement of the Clyde, was to endeavour to obtain a depth of 4 feet 6 inches of water, up to the harbour of Glasgow, by forming a lock and dam below Marlingford, but which was not carried into execution.

Before terminating this statement, it might be necessary to mention, that the following works had been executed, since 1839, under his directions :—

1,120 lineal feet of stone quay-walls.
160 ,, ,, stone breast quay-walls.
1,032 ,, ,, wooden wharfs, including Bowling wharf.
1,447 ,, ,, new sheds.
3,703 yards of water-pipes.
101 fire-plugs.
Govan Ferry quay-wall and slip, 170 feet long.
Bowling basin, containing an area of 14 acres.
The harbour had been enlarged to an extent of more than 7 acres.
A tug boat built, with two engines of 30-horse power each.
No. 5 dredge-boat built, with an engine of 22 H.P., which could work in from 17 to 19 feet depth of water; it began to work in June, 1841.

An improvement had been introduced into the five steam-dredgers, to enable them to work forward by the power of steam instead of by manual labour, by which they were enabled to raise annually about 80,000 cubic yards, or more, than they could formerly.

The quantity of material dredged from the bottom of the River Clyde and the Harbour of Glasgow, was shown in the following Table.

Years.	Cubic Yards.	No. of Dredgers employed.					Cost per cubic yard.
							s. d.
1838	135,400	1	2	3	4	..	..
1839	142,170	1	2	3	4	..	..
1840	195,160	1	2	3	4	..	..
1841	218,810	1	2	3	4	5	1 1
1842	312,810	1	2	3	4	5	0 10½
1843	294,440	1	2	3	4	5	0 8
1844	317,660	1	2	3	4	5	0 8
Total .	1,616,450	1,481,050					

The number of Steam-Dredgers employed.

38	2½	No. 1 Dredge Boat .	12 Horse Power .	10·6	21
38	2½	2 ,, .	16 ,, .	14·0	24
38	2½	3 ,, .	16 ,, .	14·0	24
38	2½	4 ,, .	20 ,, .	15·6	26
38	2½	5 ,, .	22 ,, .	17 to 19	27½

The material in the bed of the Clyde was found to weigh as follows:—

	Lbs. to cubic feet.	No. of cubic feet to the ton.
Fine sand and a few pebbles, laid in the box loose, not pressed, nearly dry	87	26
Pressed	92	24
Mud at White Inch, dry, and firmly packed; contained very fine sand and mica	97	23
Wet mud, rather compact and firm, well pressed into the box	115	19
Wet fine sharp gravel, well pressed	124	18
Wet running mud	122½	18·1
Sharp dry sand deposit in harbour	92	24·3
Port Glasgow Bank (sand) wet, pressed into a box . .	120½	18·6
Sand opposite Erskine House, wet, pressed	116	19·3
Alluvial earth, pressed	93	24·
,, ,, loose	67	33·

Mr. ATHERTON said, that some years had elapsed, since he was officially connected with the works for the improvement of the Clyde, under the late Mr. Telford, he was, therefore, in some degree, ignorant of what had been recently done there; still he could not help protesting against the supposition, that the effect of the tidal

wave had been overlooked, or undervalued, by Rennie, Telford, and Walker, in the works they had designed for the river. Nor should reflections be cast upon works which had been executed twenty or thirty years ago, because they were not of the magnitude of those of the present time. On the contrary, he must contend, that the economical course adopted in the commencement, had enabled the Clyde Trustees to realize their projects, and that, if they had not proceeded with caution, it was more than probable they would have been overwhelmed with debt, and could never have executed the works which had succeeded in giving such a large revenue, and enabled such extensive plans of improvement to be now carried on.

The object of the first works was to bring the river within bounds, and to confine the waters within certain limits; when this was done, the freshes were enabled to operate successfully in partially deepening the channel, and the aid of the dredging-machine was called in. The dykes were then gradually contracted, and by their action, and the judicious improvements, in several difficult parts of the river, an average depth of 12 feet of water had been obtained, and by the facilities thus afforded in the harbour and in the approaches, the present immense trade and consequent revenue had been secured.

Sir JOHN RENNIE, *President*, concurred with Mr. Atherton in his views of the necessity for the gradual improvement of rivers; for even although a general and comprehensive plan might be at first laid down, it was wiser to execute separate portions, as it frequently occurred, that the improvement of one part produced an unforeseen detrimental effect in another.

Mr. THOROLD availed himself of the opportunity of this discussion to point out the little regard sometimes paid to precedent in engineering works, as there had been actually a Bill before Parliament this Session, for authority to construct a lock upon the main channel of a river, under circumstances nearly identical with Smeaton's rejected proposition for Marlingford, on the Clyde, nearly ninety years since.

There was a prevalent opinion, that the improvements of the navigation of the Clyde were models for works of that nature; but from the tenor of the remarks of previous speakers, it must now be inferred there existed decidedly opposite opinions on the subject. If, however, attention was confined to the lower reaches of the river, he could scarcely conceive it possible there could be any difference of opinion as to the expediency of opening the south channel of the Newshot Isle; for in addition to the accepted rule of admitting the greatest amount of tidal water, this was a peculiar example of

the case; as by the slackening of the velocity of the tidal wave, immediately upon its entering the north channel, and its again increasing, on its arriving beyond the influence of the minimum section of that channel, a bank was annually thrown up between the isle and Bowling; thus producing an effect similar to that of a bar opposite a sluice.

He saw no difficulty in keeping open the north channel; it would, he thought, be kept open by the united force of the waters of the rivers Clyde and Cart taking that particular direction. The south channel might, however, he apprehended, be kept open by the operation of the flood tide, setting most favourably in the direct line of its axis, provided it was deepened in the first instance to an equal extent with the north channel, and he must attribute the tendency of that channel to silt up, entirely to its being deficient in depth, owing to the rocky obstructions, over a portion of the bottom. As soon as those were removed, the tides at the first and last quarters could act with full effect. He anticipated there being a trifling deposit at the east end, which would require, occasionally, the assistance of the dredging-machine. If both channels were kept open, the deposition of sand between the isle and Bowling would probably disappear, or, if once more removed by dredging, would never again accumulate. The necessity for opening the south channel was evident to him, from the fact, that half the annual expense of dredging that shoal, or bank, was incurred below Newshot Isle, and he contended, that means were at command by which that expense could be reduced. The cost of first opening the channel would be a minor consideration.

From what had already been experienced in removing boulders, near the Newshot Isle, it was probable the supposed rock in the south channel was of the same formation, and therefore they could be easily removed by the same means; at all events, the case could not be worse than that of the rock in the bed of the Ribble, which had been removed by Mr. David Stevenson.* If the works were commenced before the removal of the dykes, the expense of coffer-dams would be saved; and as it was in contemplation to erect a great extent of quay-walling in the harbour, he submitted that these rocks, stones, or boulders, could be economically applied to an useful purpose.

It had not been shown in what manner the ships were berthed, either in the harbour, or when waiting for the return of tide; neither was it

* Vide Trans. Inst. C. E., Vol. iii. p. 377; and Minutes of Proceedings, 1841, Vol. i. p. 81.

possible to decide how far local deposition was accelerated. These were points on which it was desirable the Institution should possess some information.

Mr. REDMAN begged to dissent, in some degree, from the statements advanced by Mr. Bald, as to the inefficiency of the late and actual works on the Clyde, and he thought some of the positions assumed were of a contradictory character. No river had undergone more extraordinary changes, or more progressive improvements, within a comparatively short period, than the Clyde. By Smeaton, Golborne, Watt, Rennie, Telford, and Walker (the present consulting Engineer), the improvements of the navigation appeared to have been as carefully watched, as the works were skilfully designed; and the consecutive resident Engineers, Messrs. Atherton, Logan, and Bald, seemed to have executed the plans with singular success.

Mr. Whidby was believed to have been the only dissentient, until the present time, when Mr. Bald entered his protest against the general direction of the works, including, it might be presumed, even those which had been executed under his own superintendence. The Tidal Harbour Commissioners, also, although the evidence contained in their Report showed the great improvement of the river, qualified their commendations by somewhat severe criticisms on the Clyde Trustees.*

Mr. Redman submitted, that if, in the progress of events, it had been found desirable to extend certain improvements, it should be remembered, as Mr. Atherton had stated, how small the trade was, which was required to be provided for, and how limited were the funds, when the works were commenced; it was somewhat unreasonable to expect those engineers who projected the first improvements, to have foreseen the present state of the commerce of the Clyde, and its consequent requirements.

It was curious to notice the progressive Reports of the engineers:—

In 1755, Smeaton reported, that at Hirst, a little below Glasgow, at low water, the depth was 1 foot 6 inches, and at high water, 3 feet 3 inches; at Point House Ford, the low water 1 foot 3 inches, and the high water 3 feet 8 inches; and at Spoydock Shoal, the river was 884 feet wide, and was only open to vessels of 4 feet 6 inches draught; in consequence, he recommended the construction of a lock, with a dam or weir, at Marlingford, so as to keep up a constant depth of 4 feet 6 inches at Glasgow.

In 1768, Golborne found the basin at Port Glasgow much filled

* Vide Report.

up with mud, and recommended two scouring basins being formed, and a pier being constructed in the basin, which might be converted into a wet dock. He found the Hirst had only one foot of water over it. The sides of the river were described as being of softer material than the bottom, and that the current had extended itself in breadth, but was deficient in depth. He recommended the removal of the hard gravel from the bottom, and the erection of jetties "to contract the width." In this manner he conceived the river might be deepened, so as to have 4 feet to 5 feet at low water, up to the Broomielaw.

In 1769, Watt placed great dependence in Smeaton's recommendation, and advocated the removal of the bottoms of the fords, which were very uneven.

In 1781, Golborne expressed satisfaction at the state of the works. He found the spaces between the jetties filled up and covered with grass, to the emolument of the proprietors and the improvement of the river; for in proportion as the tides filled them up and they became land, the neap tides rose higher, and the land floods being more confined, would act with greater force on the bottom. He advised raising the jetties and extending them to the land.

Rennie reported the depth of the river to be much increased by the operations subsequent to 1768. The floods were admitted to be higher; but he did not attribute that effect to the new bridge, or to the river works, but to the increased drainage of the adjoining country. In his opinion, no obstruction arose from the navigation works; but he advised the removal of all obstructions that put back the river, such as the weir below the bridge, &c. He thought, that the floods would increase with the improved drainage of the country, but that the river would become proportionately more capacious to carry them off.

In 1806, Telford recommended the leading up a greater quantity of tidal water, straightening the course, and making it of equal dimensions, &c. He objected to jetties, and recommended parallel dykes, &c.

This opinion of Telford's was no reflection on former plans, as by the jetties land was procured, and the dykes were, in fact, nothing more than a rapid execution of the system, instead of waiting till the land formed naturally between the jetties.

In 1807, Rennie advised the connexion of the ends of the jetties by low walls, and the formation of land behind them, by depositing the material from the excavation of the shoals, forming the river to a more uniform width, and lowering the weir to carry off the land floods.

In 1824, Whidby objected to the whole plan, and wished all could be undone. He apprehended, that from the reduction of the back-water, shoals would collect at the entrance of the river; although he had not the means of ascertaining any such tendency.

In 1824, Clarke reported an improved depth, resulting from the parallel dykes.

In 1836, Mr. Walker made a Report, which contained much interesting information as to the state of the works.* In reference to the floods, he said:—"Unquestionably the straightening and enlarging of the river, and the improvements hereafter stated, will do much towards the removal of all these evils; if it should reduce the rise of such a fresh as that of the 22nd of October, from 9 feet 4 inches to 4 feet, which may, I think, be depended upon, the benefit would be alike important to the city and to the low lands down the river; for further securing which, the banks, or dykes, should be raised above the highest tide, so as to confine the river to its natural channel, as the Thames is below London-bridge, where the lands, though 6 feet under spring tides, are never flooded. By thus keeping the river within its proper bounds, the scouring of the bottom will be assisted by the increased rapidity of the stream, as it has already been, wherever the current has been so confined; the land, if the dykes be properly formed, will be improved in value and also in beauty, and the excavated soil may thus, at the same time, be deposited cheaply and usefully."

On the relative effects of the land floods and the tide water, he expressed himself thus:—"I am aware that a very different opinion has been expressed by the late Mr. Whidby, a highly respectable authority on many points, but not superior to Golborne, Rennie, and Telford, who all thought differently. Mr. Whidby's opinion appears to have been founded upon the idea, that the Clyde, up to Glasgow, depends chiefly upon the tide. I think otherwise, and that the sectional area of the river, nearly as far down as dredging is wanted, is caused by, or is the effect of, the land floods, much more than of the tide water. I do not say that the latter is useless, or that it ought not to be encouraged, but only that, comparatively, it is of less consequence for scour than the land waters. I believe, that the velocity of an ebbing tide may be taken at 1½ mile an hour near the harbour. Now the fresh I saw, ran 4½ miles per hour, and at that time, it had subsided 2 feet from the height at which it had been during the night. Evidently, such a scour must have much greater effect than the tidal current of a third the velocity, and if this be not sufficient proof of

* Vide Report.

the soundness of the plans that have been pursued, it is not necessary to go to other rivers for illustration, although there are many; but only to compare the Clyde as it is, with the Clyde as it was, before the operations began, when the tide had its full range of width. Lower down the river, near Dumbarton, where the river is wider, the land floods become unimportant, as compared with the tides, and therefore it is, that the tide ought to be the chief object of care, and that I have recommended the dykes being kept down, so as to prevent, as much as possible, a diminution of the tidal water."

These extracts sufficed to show that a nearly uniform system had been acted upon.

Mr. Bald had quoted the opinions of several engineers as to the importance of tidal scour; but Mr. Redman would submit, that Whidby could not be quoted with Rennie, their opinions being totally at variance.

Whilst admitting the importance of tidal scour, it should be borne in mind, that the circumstances of each case must be taken into consideration, and that when Mr. Bald quoted the instances of Rye, Wells, &c., such cases were not analogous, and the comparison was misapplied, when put in reference to the Clyde. At Wells, and similar harbours, and also at Montrose, and in other natural estuaries, the depth depended on the flow and ebb of the tidal waters alone: this was not the case at the Clyde.

All the engineers who had been consulted on the Clyde had agreed, that the removal of the Glasgow Weir, and all other obstructions that retained the water, would be desirable.

Mr. Walker, in 1836, proposed half-tide dykes below, so that the tide might flow over them, and the tidal agency might thus be uninterrupted.

It might be advanced, that the works on the banks of the Thames had decreased the tidal scour at the entrance, yet still they must have improved the channel; the wharfs and bridges, upon rivers that were deepened and improved, were similarly affected to those on the Clyde at Glasgow.

As regarded the course of the river at Newshot Isle, Mr. Bald stated an absolute necessity for, and great advantages to be derived from, a short cut on the south side; while Mr. Walker pronounced it to be objectionable, and believed the advantages, if any, were too slight, and could be procured only at too large an outlay. This latter opinion was in accordance with those of Golborne, Rennie, and Telford, who had adopted the north and existing channel.

Mr. Bald considered the Newshot Isle as the source of the varia-

tions in the velocities of the tidal wave and the currents; but if the course of the river exercised so great an influence on the tidal velocities, which was very doubtful, Mr. Redman argued, that a very material consideration had been overlooked.

Looking at its configuration, the Clyde, from Port Glasgow to Bowling Bay, had one general direction, and from thence to Glasgow another general direction. The lines of these bore, as nearly as possible, the first N.W. by W. to S.E. by E., and the second, N.W. by N. to S.E. by S., a variation of two points of the compass, equal to 22½ degrees in the two lines of direction, or, in other words, they contained an angle of 157½ degrees; now this natural bend was nearly equal to the natural bend formed by Newshot Isle, and must, therefore, exercise a proportionate influence over the river, although Mr. Bald attributed it entirely to Newshot Isle. The deposits at Bowling would also affect the current.

It appeared that this cut would be very expensive, and its advantages, it was contended, were problematical.

It appeared, on the authority of Captain Beaufort, that even if there was not any ledge of rock, the saving of distance would be less than 100 yards in a length of 2 miles.

This straightening certainly might induce a corresponding increased velocity, but it might be doubted whether to the extent anticipated by Mr. Bald.

But supposing the new south channel to be cut, it was a question whether the effect might not be, that the north channel would silt up. It was stated, that the water of the Cart would prevent this; but if this straight channel induced the river waters to flow that way, with an increased velocity, even only for a portion of the tide, surely the more indirect, sluggish, and uncertain streams would gradually silt up, when the waters were charged with matter.

There was not any positive evidence of the south channel having ever been used for the purpose of navigation, by vessels of any considerable draught of water.

In all that had been advanced, no proofs had been given, that the north channel was not always the natural one, jetties being projected from either bank towards the centre of the river, to narrow and strengthen the current, and this, apparently, in the direction of the natural stream, and all the engineers, from Smeaton to the present time, appeared to have neglected the south, and to have adopted the north, as the natural and proper channel.