JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,
FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXIV.

NOVEMBER, 1887.

No. 5.

THE FRANKLIN INSTITUTE is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

[*Contribution from the Dept. of Civil Engineering, University of Penna.*]

IMPROVEMENT OF THE PORT OF PHILADELPHIA

BY PROF. L. M. HAUPT, C.E.

Navigable water is essential to the existence of a commercial city, and it was largely due to the facilities for effecting a landing that this site was selected by the founders of Philadelphia.

But in the two centuries that have passed, the city has outgrown the limits of its deep water frontage, and although its shore line bordering a navigable river, has an extent of nearly twenty-five miles from the Poquessing Creek to Fairmount, but a limited portion of it is available without incurring great expense.*

* The importance of this discussion is confirmed by the accompanying extract found in the *Philadelphia Record*, September 23, 1887, a few days after this paper was completed.

L. M. H.

A FOREST OF SPARS.—VESSELS IN PORT THAT CANNOT BE UNLOADED.
—*The City's Growing Commerce Retarded by Inadequate Wharfage.*—*Corporations Monopolizing the River Front.*—Within the last few years the
WHOLE No. VOL. CXXIV.—(THIRD SERIES, Vol. xciv.)

The deepest water is to be found in the six mile **concavity** extending from Greenwich Point to just above Port **Richmond**. Of the remainder about eight miles are cut off by the **Five Mile Bar**, stretching from the head of Petty's Island to **Point No Point**; seven miles are included in the Schuylkill River, which is only about 400 feet wide, and the rest is covered by the **Horse-shoe Shoals**.

Above **Five Mile Point**, there are twenty-six feet of water very nearly to **Torresdale**, with the one exception of a cross-over bar opposite the **House of Correction**, having on it **over eighteen feet**. Moreover, sixteen feet of water can be carried at **mean low tide** almost to the mouth of the **Delaware and Raritan Canal**, by removing the one short **confluent bar** at **Kinkora**, thus **greatly augmenting** the carrying trade by river and reducing the **cost** of transportation. The commerce of the upper river to and from **Bordentown** for the year ending **December 31, 1885**, is estimated to have been **1,135,942 tons**, independently of the **freight and passengers** carried by the daily steamers from **Philadelphia** to **points above**.

commerce at the port of **Philadelphia** has been on a **steady increase** despite the inadequate facilities at hand for the reception of traffic, until to-day the sorry sight is presented of a harbor teeming with **heavily-laden vessels** that must wait for days before wharfage can be procured for the **discharge** of their cargoes.

At the present time there is more shipping anchored in the **Delaware River** between **Port Richmond** and the **League Island Navy Yard** than ever before in the history of the port. Looking southward from **Dickinson Street** yesterday, the eye encountered a great number of idle vessels, whose spars, looming up toward the sky, resembled a vast forest. In this great fleet of the merchant marine all the nations of the world were represented and every description of cargo included, from **East India jute** to the **common article** of commerce—**Spanish iron ore**. The detention of this vast amount of traffic at the entrance to the second city of the Union is due solely to the lack of available places at which to discharge it. The scarcity of wharf property arises mainly from the fact that nearly every foot of wharfage from **Clearfield Street** to **Moore Street** is either under corporate ownership or control, or has been rendered valueless through the refusal of the **railroad companies** to introduce the necessary sidings and connections that would prevent the necessity of handling goods a second time.

In many cases wharf charges are maintained at such an **exorbitant rate** that vessels have been driven away by the excessive tolls. Another impediment to the natural growth of the port is the contracted dimensions of many of the docks, which are too small to admit of the docking of vessels, so that they will not project into the river to the **danger of passing craft**. In other

Concerning that part of the Delaware within city limits, and lying above Petty's Island, the Advisory Board to the Harbor Commissioners, of which Capt. G. B. White, is Chairman, says,* "It is almost in a state of nature, but has great qualifications for commercial frontage. The main channel lies in great bends, but these are favorable to bold frontage. Were the river straight, the channel would be midway between the two shores, and wharves of at least 1,000 feet in length would be necessary to reach the border of the ship channel." * * * "In short, the natural advantages of this whole frontage above Bridesburg are unusual." He adds, "The city front above Richmond has been but little utilized, because of the great shoal that has accumulated in the neighborhood of Five Mile Point, and which the General Government now designs to remove in part. Should the Government be successful, the water front that the city offers above will be appreciated because of its bold banks and handy channel." In a letter to the Harbor Commissioners, dated February 13, 1886, the Advisory Board says: "The portion of the (port-warden's) line above Richmond has been located with due reference to the works of channel improvement undertaken by the General Government above Petty's Island. The improvement, while it does not conform in plan and disposition of works to that suggested in 1883 by your Advisory Board, promises to lead in the same direction, and inspires much hope of success.†

In his annual report for 1883, General Weitzel, U.S.E, then in charge, said, "It will be a matter of great expense and difficulty

cases the docks are so badly dredged that deeply-laden vessels are in peril of being strained to pieces with the flow and ebb of the tide. At the same time wharf property has risen in value until a twenty-foot front anywhere along the river would bring at public sale not less than \$30,000.

Among the large steamers lying in the river awaiting their turn to discharge are the *Kairos*, *Hungaria*, *Cid*, *Regina*, *Romanby*, *Parklands*, *Acuba*, *Pensker*, *Roseville*, *City of Newcastle*, *Cairo*, *Haverstoe*, *Madrid* and *Earnmoor*, besides a large fleet of sailing craft, composed mostly of ice schooners, with an aggregate capacity of 30,000 tons. On the steamships enumerated there are afloat 50,000 tons of iron ore alone. The Spanish steamship *Leonora*, from Havana, which arrived in port last night, with over 4,000,000 pounds of sugar, was unable to go into her dock, and was swung around lengthwise in the river, blockading the ends of three piers.

* February 25, 1886.

† See the *Supplement* to this paper.

to obtain a channel under Five Mile Point, sufficiently deep to meet the requirements of this up-river commerce."

Captain Heuer, U.S.E., in charge in 1884, reports in substance as follows: "The plans of the Advisory Board contemplated a bulk-head, wing-dam or obstruction of some kind, about 3,000 feet in length, from Fisher's Point, on the New Jersey shore, to deflect a large portion of the ebb tidal flow." * * * "To meet the increased volume of tidal flow on the Philadelphia side, and avoid too serious a scour in the wharves, it would be necessary to cut away a portion of one side of Petty's Island, and build up on the opposite side of the same, putting a bulk-head around portions of the new shore lines of the island.

"The first step would be to build out a dike from Fisher's Point, as far as necessary, and watch the effect on the channel between Petty's Island and Philadelphia; it would certainly deflect an increased tidal flow down the channel. It might scour close to the wharves on the Philadelphia side, and endanger these, and to prevent this it was deemed necessary to cut away the lower end of Petty's Island." The approximate estimate for this improvement is put at \$1,010,460, of which but \$30,000 are for the dike; the balance, or \$980,460 are then intended to counteract any injurious effects it may produce.

The suggestions reported to General Weitzel, in November, 1883, contemplated closing the south channel by a dike extending from Fisher's Point to the head of Petty's Island, and thus throwing the whole of the ebb prism into the north channel. This, it was estimated, would require a sectional area of about 55,000 square feet, and "necessitate the removal of upwards of 6,000,000 cubic yards of material."* At thirty-five cents per yard, this one item would then be over \$2,100,000, exclusive of the cost of the dike, land-damages, etc.

From this it appears that the Five Mile Bar is the key to the upper river, not only for general but for local commerce, and the opening of a suitable channel through it will render a large and valuable frontage, immediately available, yet the expense, according to the plans proposed, is almost prohibitory. A consideration of the physical features of the bar, the causes of and the efforts to remove the same, with some suggestions as to improved and more

* *Report of Chief of Engineers*, 1884, vol. i, p. 868.

economical methods of accomplishing this end, become therefore questions of great commercial and financial interest to the City as well as to the General Government.

DESCRIPTION OF FIVE MILE BAR.

This deposit of fine sand forms a submerged ridge, extending from a point in the Pennsylvania channel below the head of Petty's Island, in an easy curve to Harrison's Wharf at Five Mile Point, a distance of about 8,000 feet. It occupies the neutral ground between the paths of the flood and ebb resultants, and being composed of light material, is readily affected by the opposing forces to which it is subjected. These are the flood and ebb tidal prisms, and the fresh water drainage flowing in different paths and with variable intensities as affected by the form of the river bed above and below the bar.

How these forces have been modified by various artificial changes in the banks of the river can best be seen by examining their effects upon this plastic mass of material at different dates and comparing notes as to position, quantity and direction. Hence the great value of the accurate comparative surveys which the Government has made at various times. Such a comparison to be thorough and reveal the whole truth should be made with reference.

(1.) To the *linear features*, as the crest line, the contours, the thalwegs and the slopes.

(2.) To the *areas*, as showing the relative sizes of the sections, not only of the bar, but also of the fluid prism constantly playing upon it.

(3.) To the *volumes*, as showing the mass movement in cubic measure.

(4.) To the *dynamics*, as indicating the measure of the forces and resistances, their lines of direction, degree of relative permanence or variation, and duration of action. The resultant effect being the *difference* of movement produced by these forces, hence the slowness of the changes in tidal rivers.

"In alluvial bottoms the channel is the cast of the living waters within; it is not the independent mould into which the river is turned, but it is the trough hollowed out by the running water, and it alters its form and direction with every change that may be induced upon the flow." *

* G. B. White, Captain U.S.N.

In subjecting the bar in question to this scrutiny, it becomes necessary first to state the simple mechanical law by which the effect may be measured.

THE MATHEMATICAL PRINCIPLE.

If a flexible but straight line $A B$ be acted upon by a series of equal and opposite forces in any direction, the line will remain straight, but if any of the forces be augmented or diminished in intensity, the line will become bent in a direction away from the greater force until the equilibrium is restored or the line broken.

FIG. 1.

Thus, in the diagram (*Fig. 1*), if a system of forces in equilibrium be increased by the amounts represented in broken lines, the straight line $A B$ will become flexed in the direction of C . The same effect would result from a decrease in the intensities of the opposing forces. It is thus that the flexure of a curve as shown from a comparative chart will indicate the changes that have taken place in the forces producing these effects.

THE APPLICATION TO THE CREST OF THE BAR.

An examination of *Plate III* will show at once the marked changes that have occurred in the form and position of the axis of Five Mile

Bar, since the survey of 1843. At that date the concavity, as shown in the dotted curve, was greatest, indicating an excess of pressure from the flood tide rolling up the northern channel. During the intervening years the crest line has been gradually flattened out until the direction of its curvature has been reversed. The greatest movement having been about 810 feet. The diagram shows the relative amounts and dates of these changes.

These effects may be due to a diminution in the flood forces, an increase in the ebb, or a change in direction of either caused by auxiliary works.

As by far the larger part of the volume of the stream is composed of tidal waters, and as there is nothing to augment this volume from year to year, but on the contrary much to diminish it, we may presume at once that the ebb forces have not increased but that there has been a sensible diminution of the flood since 1843, whereby its velocity at this point has been so diminished as to produce deposits and to permit the neutral axis to recede. We must seek the cause for this effect down the river, and have not far to go, for, on examining the earlier and later maps, it will be seen that at the lower end of Petty's Island, the north or flood channel has been seriously throttled by the extensions of the pier-heads on both sides, more especially by those at the Port Richmond coal wharves and below. In response to inquiries as to the dates of construction of these wharves Mr. H. K. Nichols, Chief Engineer of the P. & R. R.R. Co., replies that "the northern tier of wharves was finished in 1843." (These are the shortest wharves, and from this it appears that they were built in the year of the survey. They are shown on the chart.) He adds:

"To the south, including No. 14, finished in 1845.

"In 1854, finished to and including No. 18.

"In 1862, Nos. 4, 6 and 8 extended." (How much is not stated.)

"In 1865, No. 14 extended." (How much is not stated.)

"In 1866, Nos. 19, 20 and 21 completed.

"In 1867, Nos. 13 and 18 extended. Several other extensions were made, the dates of which were not found."

The actual condition of these works and their relation to the channel will be seen on *Plate II*, taken from the U. S. C. S chart of 1878, scale 800 feet to 1 inch.

The wharf of the Kensington (City) Water Works, which extends to a considerable distance, was built about 1849. That of the Port Richmond Iron Works (I. P. Morris & Co.*) was built in 1839 and extended twice; the first time in 1850, 100 feet, and again in 1869, 187 $\frac{3}{4}$ feet, making a total extension of 287 $\frac{3}{4}$ feet. The original wharf extended about 520 feet from Bank (now Beach) Street. It is now 760 feet beyond the east side of Beach Street and about 380 feet beyond the low water line of 1847.

The wharf of Wm. Cramp & Son, at the foot of Norris Street, extends to a distance of 612 feet from the east line. It was prolonged 156 feet 9 inches in 1870 to the present port warden's line, which was established April 5, 1849. In 1843, none of these wharves were completed.

In addition to these extensions, there are others on the north bank of Petty's Island which have aggravated the injury to the channel above by materially reducing the flood volume and so weakening it as to destroy the former position of equilibrium between flood and ebb at the crest of the bar.†

This movement is also shown by the contours and sections which have followed the general direction of the crest. The various fathom curves of the north or flood channel have fallen back about 1,000 feet, while the corresponding south channel contours have advanced as the ebb wedged its way between the bar and the south shore, eroding and compressing the southern slope of the bar.

The cross-sections (*Plate IV*) taken on the line *A B*, of *Plate II*, at intervals of 1000 feet exhibit the shifting in the position of the fulcrum and weights, as in a scale beam. In section No. 1 there was no trace of the bar in 1843, and the flood channel was nearly the same as the ebb, there being only a difference in the slope of the two banks. In section 2, the terrace is seen at about 12 $\frac{1}{2}$ to 13 $\frac{1}{2}$ feet depth. In No. 3, a low bar with 12 feet of water, flanked by channels of equal depth. In the succeeding sections the bar becomes higher and the flood channel deeper and wider, reaching its maximum in section No. 5, 5,000 feet below the point.

* Information obtained through the courtesy of Mr. John T. Morris, President.

† On May 8, 1883, Prof. Henry Mitchell estimated the reduction of area from this cause to be eleven per cent., "with very little change of channel depth."

In the later surveys, the rapid growth of the bar, increase of ebb, and diminution of flood sections are so clearly shown as to require no further comment at this place, where it is intended merely to call attention to the relations between the flood and ebb forces.

Measurements of these sections by the planimeter also show a gradual diminution in sectional area of the water prism; that is, notwithstanding the great variations in width, there has been a shoaling which increases in the down-stream direction, indicating a diminution of the scouring forces as the head of the island is approached.

The accompanying table is confirmatory of these conclusions and contains many valuable suggestions; for example: Columns 3 and 4 show that the filaments of *maximum* flood and ebb cross each other between sections 1 and 2 (see chart, *Plate II*) and that the ebb is greater at section 1, and slightly less in 2 and 3. In section 8 it is the greater in the south channel where it reaches the unusually high value of 4.52 feet per sec., and the flood is greater in the north channel, 400 feet from shore. In column 5 it is observed that the *mean* velocities of the ebb are greater than those of the flood excepting at No. 8 north, where the mean flood velocity is 2.98, and the ebb 2.90. Hence it is safe to infer that *the volume of the ebb may be somewhat increased through this section* without producing any serious damage to the pier heads or to the channel, and without increasing the section by artificial means, but on the contrary, the result of such increase of volume would be highly beneficial. To increase the section for a small increase of ebb volume would prove injurious, as it would reduce the working power of the stream. It is also evident that there is an excess of ebb volume passing through the south channel, a portion of which may be deducted without injury to the latter, and with great benefit to the north channel.

Comparing the total area of section 8 (north and south) with those of 1, 2 and 3, as stated in column 9, it appears that at both flood and ebb, 8 is 20 per cent. greater than 1; 22 per cent. less than 2, flood; 20 per cent. less than 2, ebb; 24.8 per cent. less than 3 flood, and 23 per cent. less than 3, ebb, so that section 8 as a whole is more than large enough to pass all the water that reaches section 1, but not large enough to supply sections 2 and 3, and still maintain its velocity, hence the shoaling in the reach.

TABLE SHOWING THE ELEMENTS OF THE CROSS-SECTIONS AND DYNAMIC CURVES AT AND NEAR FIVE MILE BAR,
DELAWARE RIVER, PHILADELPHIA.*

[illegible]

* Collated and extended from the data collected and computed by Mr. Marindin, Assist. U.S.C. and G. Survey, and embodied in the Report of Prof. Henry A. Mill, on *A Physical Survey of the Delaware River*. Appendix No. 9, *U. S. Coast. Survey Report for 1878*.

† As the flood passes up over Section No. 3, the portion of its prism, 307 feet wide, lying between 2,100 and 2,407 feet from shore, has its velocity diminished to a minimum of 1.76 feet per second in passing over the foot of the bar.

† The ebb at this section passes several times from maximum to minimum values, thus dividing up into three streams.

The times of transit through the north and south channels are also different, producing some interference and deposit at both ends. Columns 10 and 11 show on which side of the mid-area the loci of mid-volumes of flood and ebb are situated, and the great divergence between these latter resultants in sections 2 and 3. In 1 and 8 their paths are more nearly coincident, and hence their useful work greater.

It will be seen that the loci of mid-volumes cross between sections 1 and 2. In 1, the locus of the resultant of the ebb stream is thirty-eight feet to the north of that of the flood, in 2 it is 563 feet to the south, and in 3 it is 371 feet distant but on the same side.

Again, if the limits of mean velocities of flood and ebb be located, as given by their co-ordinates in Column 6, it will reveal the position of the more vital part of the stream lying between them. Its breadth is stated in Column 7, where it appears that at section No. 1 the major part of the flood is 522 feet wider than the ebb.

At No. 2, these prisms are of nearly equal width, although their resultants are widely separated, being, as stated, 563 feet apart; the flood axis running near the crest of the bar, the ebb over the thalweg. What is needed there is a structure that will draw in the ebb and deflect a portion of its volume to the other side. This is more fully confirmed by an examination of section No. 3. Here it is found that the flood in the north channel is divided, by the foot of the shoal, into two parts, in which the velocity exceeds the mean (1'95). The minor prism passing over the shoal is but 307 feet wide, and has a velocity diminishing to 1'76 at 2,200 feet from the Pennsylvania shore. The ebb in the same (north) channel is also divided into two streams, having velocities above the mean (2'17), located as follows: The smaller one, between 912 and 1,444 feet from shore, with a maximum velocity of 2'81 at 1,200 to 1,300 feet. This 100-foot prism has the greatest velocity in the section. The larger ebb prism lies between 2,183 and 4,527 feet from the origin and is consequently nearly half a mile wide. It is divided near its northern limit by the head of Petty's Island (at 3,000 feet), where the greatest velocity, 2'79 feet, is found for a width of 800 feet; that is, from 2,600 to 3,400. This causes a small portion of this ebb prism to traverse the region just north of the island, and maintains the nar-

row channel it has created along its path. Between these two more rapid streams lies a retarded prism, extending from 1,444 to 2,183 feet, or 739 feet wide, in which the velocities diminish to 1'79 at 1,600 feet out, due to the bar over which it has just passed. These phenomena are characteristic of streams undergoing contraction and are produced by the reaction of the banks in causing an increased velocity near them, which produces the scour near shore and the low spur in or near mid-stream. The remedy here then consists in throwing a larger volume of the ebb into this shore channel along Petty's Island by a reaction dike, at the head of the island, which shall draw off a part of the ebb from the south channel and cause it to traverse the northern one. Such are some of the deductions from these data, which are believed to be sufficient to explain the physical phenomena of the changes produced at this site and to enable the engineer to apply the remedy.

HISTORY OF THE IMPROVEMENTS.

As the lessons of experience are of great value in projecting works and avoiding unnecessary expense, it becomes an important element to ascertain what has been done, if anything, and what have been the results. To this end the history of the work is indispensable.

In the *Report of the Chief of Engineers for 1884*, p. 794, the statement is made by the resident engineer, then in charge, that the improvement of Five Mile Bar is an important but

"At the same time a very difficult one to treat, owing to misjudgment on the part of the city authorities of Philadelphia, having allowed the wharf line to extend far beyond its proper position in rounding the point. Many wharves have been built out to this line, and have proved a serious source of shoaling in many parts of the channel below. A curtailment of these wharves will probably be a part of any thorough scheme of improvements, but as this would entail very great outlays of money at the present time, other means have been employed to enable the commerce of the river to pass this point, viz., cutting a channel during December, 1881, and January, 1882, at the upper end of Petty's Island. This channel was subsequently widened to 200 feet, with an allotment of \$4,500. It should be deepened to twelve feet at mean low water, and an appropriation of \$5,000 should be made for this purpose."

The premises in the above statements being at variance with the facts, the conclusions must be at fault, as there are believed to be but two short wharves at Five Mile Point, and these are not

used to any extent, nor are they thought to have produced any serious shoaling in the channel.

In 1881, a channel was dredged across this bar to a depth of 9 feet, with a width of 75 and length of 700, at a cost of \$2,500. The price was $38\frac{9}{10}$ cents per yard. It was regarded as a temporary expedient only, and no degree of permanence was anticipated. In fact, upon investigation, at the end of the year, the channel was found to have shoaled to within one foot of its original depth.

Subsequently, the existence of a narrow but straight channel was discovered close under the upper end of Petty's Island. It was thought that if this were improved, it would, in all probability, maintain itself. It is believed to have been caused by the building up of the submerged end of Petty's Island by a bulk-head.

This channel was enlarged in 1881-82, to a depth of 9 feet, width of 100 feet, and length of 800 feet, by the removal of 6,500 cubic yards at 41 cents, making a total of \$2,665. It was found to have silted up soon after to a width of 75 feet, and was widened in 1883, to 200 feet by the removal of 11,566 cubic yards at 35 cents, costing \$4,048.10.

These attempts to improve the channel by dredging having proved abortive, the Advisory Board to the Harbor Commissioners recommended three plans;* first, to close the south channel by a dike from Fisher's Point, and the cutting off of part of the north side of Petty's Island; second, the closing of the south channel, making a basin of that part of the river, and, third, the building of a short dike from the Jersey shore, and a cutting away of the north, and extension of the lower shores of Petty's Island, either of which would cost about \$1,000,000. The plan recommended by the Government engineer was but a slight modification of the latter and was estimated at \$955,290.

Again, in their *Preliminary Report on the Permanent Improvement of the Delaware River*, dated Philadelphia, January 23, 1885, the Board of Engineers say:

"The deepening of necessity must be done either by artificially dredging the shoal spots, or by increasing the power of the current at these points by contracting the channel, or by concentrating a larger volume of water where they occur, so that by its scouring action the obstructions may be washed away." * * *

* *Report of Chief of Engineers*, 1885, p. 805.

"After considering the various plans submitted for the improvement of the upper part of the harbor in front of the city of Philadelphia, each of which contemplates the cutting away of a part of Petty's Island, and after making a personal examination of the locality, the Board concluded that an increased tidal flow through the west (north) channel near the head of the island, sufficient to secure the increased depth and width required, could be procured by a deflecting dike, starting from Fisher's Point, and running down stream in a slightly curved direction, sensibly parallel with the pier-line of the Pennsylvania shore opposite, extending toward the head of Petty's Island, as far as might be necessary for the purpose of diverting into the west (north) channel a considerable part of the ebb tidal volume now passing down the east (south) channel." * * * "It is probable, however, that in the construction of this dike an injurious scour may occur at and beyond its outer end, to prevent this a mattress-sill of brush not more than three feet in thickness should be kept well in advance," etc.

Beyond the American Ship-Building Company's yards, "it is thought that a depth of twelve feet will be sufficient for the wants of commerce for a long time in the future."

Assuming the sill to extend all the way to Petty's Island, the Board's estimate for the dike was \$87,570, and there was added for dredging \$462,000, making a total of \$549,570 for the improvements at this bar. The dimensions finally adopted for the dike are stated in a letter of the engineer in charge, under date of October 9, 1885, as published in the *Report of the Chief of Engineers for 1886*, p. 820, as follows:

"The dike is to extend from Fisher's Point, N. J., 3,000 feet toward the head of Petty's Island, with a mattress sill about 3 feet thick, projecting 500 feet farther, leaving an open channel way of about 3,000 feet between the end of the sill and the island." * * * "The top of the dike is to be at the level of mean low water, allowing the tides to flow over it." * * * "The dike is evidently designed to throw more water into the channel west of Petty's Island. Work upon it was commenced in August, 1884, but stopped by an injunction in September."

The Board of Engineers, in reporting on the testimony taken during the injunction proceedings, under date of October 28, 1885, says: "It does not appear to the Board that there any other means available of successfully maintaining the requisite channel depth in this part of the Delaware River than those which they have heretofore proposed, and they recommend, therefore, that the construction of the Fisher's Point dike be continued and completed." This was accordingly done, and the dike was finished

in conformity with the plans and dimensions heretofore given, on June 30, 1886, at a cost of \$39,560.28.

To expedite the formation of a channel, under the influence of the dike, a cut was made in the path of the ebb and flood currents across the bar in May, June and July, 1886, when 125,000 cubic yards of material were removed at nine cents, costing \$11,250.00.

Of this work, the engineer in charge says in his report for 1886: * "The object of the dredging in progress is the formation of a channel twelve feet deep at mean low water, connecting the deep water above with the deep water below the bar. This will afford great relief to the commerce moving between Philadelphia and the river above. This channel is not supposed to be permanent, but its value is so great as to be worth some cost in maintaining it."

Thus, up to this date, there had been expended altogether in the efforts to improve this locality, \$60,023.38.

THE EFFECTS PRODUCED BY THESE IMPROVEMENTS.

To determine the results of the dredging completed in July, 1886, and of the dike finished the month before, a re-survey was made in May, 1887, when it may safely be said that not a trace of the cut, which was made 125 feet wide, 2,500 feet long, and 12 to 16 feet deep, but ten months before, remained. How much sooner it filled up is not known, but as the material is very fine, and as a lateral pressure was produced by the dike, its closure was probably very rapid. By examining cross-section No. 2, which intersected the upper, and No. 3, the lower end of the cut, it will be seen, by comparing the surveys of August, 1886, and May, 1887, that it is entirely obliterated, and the same result is revealed by the charts of the soundings and by the contours.

The effect of the dike upon the bar is also shown by these cross-sections, as well as by the plan of the crest lines already referred to (*Plate III*). On cross-section I, the crest of '87 lies to the left of all previous positions, and it is slightly higher, indicating increased shoaling at that place; on No. 2, it is slightly to the right, the point of inflection being between these sections, and it is about a foot lower than in '78 and '82 (that of '86 was cut down by the dredging); in No. 3, it is seen to the right of '86, with same depth,

* Page 805.

under '78 with a gain of a little more than three feet in depth, and a still greater gain over '82. During the interval since the completion of the dike, which is abreast of Sections 2, 3 and 4, however, there appears to have been a slight erosion from the brow of the southern, or ebb, slope, and a filling up of the cut.

The conclusion to be drawn from this is, that if a dike be intended to increase the scour through a cut, it should be placed at such a distance *above* it that the increased velocity may be acquired before the water enters the cut, and not abreast of it where the wedge-like action of the stream compresses its outer bank and tends to crowd it over into the cut.

In section No. 4, the surveys of 1886 and 1887 show the crests as nearly coincident, with an increase of deposit on the right or flood slope and shoaling in the flood channel. As compared with its position in 1843, there has been a northward movement of about 800 feet, and a loss in depth of three and one-half feet. In No. 5, below the end of the dike, there is a gain in depth on the crest of about one foot. The flood channel is very much contracted as compared with that of 1843. No. 6, shows practically no change from 1886; the salient end of the ebb channel terminates under the former crest of 1843. These cross-sections further show that in 1843, there was a good and wide twelve-foot channel on the north or Pennsylvania side of the river across the bar. In general then it may be concluded that, between the dates of the last surveys, the dike had produced a deepening of about one foot along a portion of the crest and had compressed or rolled the bar to the northward, at the point of maximum movement between sections 3 and 4, or abreast of the end about 150 feet, and changed the direction of its curvature from a line nearly straight to one which is concave. The greatest depth along the crest is now but eight feet for a short distance, with five-foot spots in the immediate vicinity.

THE PROPOSED REMEDY.

From the statements and opinions already cited, it appears that the resources of the projectors of the several plans have been limited to dredging or to current concentration by means of dikes, extending from the shore in such a direction as to canalize the channel and contract the water way, thus affecting to a greater or lesser extent the entire volumes or prisms of the flood and ebb, and

In the vicinity of Petty's Island, Philadelphia, showing depths, relative velocities and proposed improvements.

COMPILED BY
LEWIS M. HAUPT

COMPARATIVE CHART
SHOWING CHANGES IN THE CREST
OF
FIVE MILE BAR
DELAWARE RIVER,
WITH THE POSITIONS OF THE
DIKE and the CUT.
1886.

Cross-Section along the line AB (looking down stream)

Year. Frank Inst. Vol. CXXVII. November, 1897 (1896-97)

Dating Survey

1843 50 yrs
1872 28
1882 14
1886 7
1887 3

100 South Arrow. 1000
1000 East Arrow

The Sections are taken
at intervals of 1000 feet

distributing their effects over the whole section included between the dike and the opposite bank. The water is thus deflected laterally in horizontal planes and tends to scour away the *sides* of its bed, which are opposed to this contraction, but the increased resistance also raises the general level of the stream and so produces a velocity *head*, which is the effective force in scouring upon the *bottom*. It is the *additional* momentum, due to the resulting increased velocity, that produces the scouring upon the bottom, and this is relatively more effective near the sides of the stream than at the centre. It is moreover, evident, from the observed velocities, that there is a mean current over the bar amply sufficient to remove any material in that vicinity; and yet the bar remains, because of the equilibrium between the flood and ebb movements, and because the bottom velocities are but feeble as compared with those on the surface.

The whole problem, as it presented itself to me, so far as the urgent and immediate needs of commerce were concerned, required the removal only of a *sufficient amount* of material from the crest of the bar to afford a passage for vessels drawing less than twelve feet of water, and *not the removal or disturbance of the entire bar*. This result, I believed, could be accomplished in one of two ways, both of which are local and direct in their application and neither of which can be injurious to the other parts of the river.

The methods both embody the principle of the utilization of the surface currents, either by a vertical deflection or by reaction, in combination with a lateral compression and concentration of a portion of the ebb and dispersion of the flood thus producing a greater *difference* in the amount of the flood and ebb movements of the particles than exists in a natural or unimproved condition.

The means taken to effect these changes are quite different; the one, being of a movable and temporary character, the other, permanent.

The first consists of a series of wings or gates, which swing about a horizontal axis at or near the surface of the water. The gates are hinged to caissons, scows, or any suitable floats which may be anchored in any position and at any angle to the currents. The gates are also ballasted to any extent dependent upon the pressure due to the velocity, and are left to do their work. As it was doubted whether or not the water would pass under, rather than

around, the ends, and as it was desired to have the data from actual experience, without any conjectures, arrangements were made to test the efficacy of this principle on the crest of Five Mile Bar, where the dam would not obstruct navigation, and accordingly a limited company was organized and a plant erected during July of this year (1887).

EXPERIMENTS WITH CURRENT DEFLECTORS AT FIVE MILE BAR.

Two wings were put in position, the left one on the south side being 140 feet long and containing seven gates; the right wing 100 feet long with five gates, and leaving a channel way between them of 135 feet. The axes of the wings made an angle of 135° , that is, an intersection angle of 45° for the purpose of increasing the ebb prism through the channel.

The gates were twelve feet in depth, and were suspended so that at low water the lower edge was about eight feet below the surface.

Each gate was loaded with about 1,600 pounds of ballast, and, as a matter of economy, the supports were made of pile bents (as shown in the side elevation *Fig. 2*) instead of floats for this experiment. The deflectors scoured out a depth about equal to the distance from half tide to their lower edges, and increased the original depth from its average of nine to eighteen and twenty feet. This was more than I had anticipated, as it was only at the stand of the tide that they hung vertically, and I was still more surprised at the rapidity of their execution. Scarcely were they launched before the action began on the bottom, and within a few tides their immediate work was done. What the indirect effect will be upon the channel between the wings remains to be determined, as it is a question of time. Theoretically, the material from these elliptical basins would be deposited in mounds on either flank, which should aid in trailing the ebb, whilst the bottom material in the channel, being left somewhat unsupported, should gradually flow off laterally, and be carried to the mounds. The experiment confirms the supposition that such a floating plant would make an excellent current dredge, where there are sufficiently deep pools into which the dislodged material might settle without injury, as frequently occurs.*

* These devices are secured by Letters-Patent No. 339,548, issued April 6 1886.

The other or permanent device is what I have called a *reaction dike*, and is intended to be an aid to navigation, being both a day and night beacon, as well as a means for deepening and improving channels. It is, briefly, a permanent structure of such *form* as to

FIG. 2. Section Showing Position of Gates at Different Stages of the Tide.

catch, compress, deflect and train a sufficiently large prism of the ebb to give the required depth which is obtained by producing a reaction of the mid-stream velocities upon the bottom. It is so placed, also, as to defend the channel from the deposits carried up

by the flood and thus increase the differential movements between these opposing currents. Its length will be about 1,000 feet, which is much less than that of the ordinary in-shore dike, and its effects much greater on the particular part of the obstruction to be removed, hence the cost will be reduced and the efficiency increased.

If the present dike at Fisher's Point be raised to high water, it would involve an increase of base and general enlargement of cross-section. If the average height of the present submerged dike be taken at twelve feet, to add six more, the sections remaining similar, would increase the area

$$\left(\frac{18}{12}\right)^2 = \left(\frac{3}{2}\right)^2 = 2\frac{1}{4} \text{ times,}$$

and the cost in the same ratio. This would make the high water dike cost about \$50,000 more. The effect of such an enlargement on the present line of work, upon the bar 2,000 feet away, and across the deep-water channel, would be very slight, whilst the same amount expended on a structure situated directly upon the site where the channel is desired, would be more effective, definite and expeditious.

In the lowest of the estimates for improving the channel across Five Mile Bar, there was also an item of \$462,000 for dredging, to provide for the supposed increase of the ebb discharge through the north channel, thus greatly augmenting the cost of the work. The reason that dredged channels are not self-sustaining arises from the fact that whilst the area of the water way is enlarged, the prism of water remains constant, hence its velocity and consequent scouring force is diminished and the cut fills up. But a *change in the form* of the bed whereby it is deepened, locally *without increasing the area of the cross-section*, will maintain a permanent channel. This can readily be accomplished by the reaction-dikes and deflectors already described.

There are other radical improvements projected for this port, which involve a very large expenditure, but the length of this paper prevents their consideration for the present.

University of Pennsylvania.

Philadelphia, September 21, 1887.

SUPPLEMENT.

After the above-named paper was completed, there was handed me a printed description of the plans suggested by the Advisory Commission, as read at their meeting, held May 8, 1883. As this is authentic and explicit, I have appended it as a part of the history of the studies as to this part of the river. The record reads :

"After studies of the probable effect of deflecting works at and below Fisher's Point without satisfaction, because of the difficulty of accommodating such works to both ebb and flood, it is proposed to *extend the eastern point of Petty's Island*, not only over the ground lost since 1843, but beyond, so as to control the proportion of the ebb which shall seek the channels below. The crude conception of the work is a dike of fascines or cribs extended *in a straight line towards the extremity of Fisher's Point or to the left of same*, so as to leave about the same sectional area on either side, as things are now. This dike would fall to southward of the split of the ebb current, and to the southward of the line of MID-VOLUME, so that it would induce a greater proportion of flow to the northward of Petty's Island during ebb, without disturbing the relations of flood volumes, or injuriously affecting the canalized southern channel; indeed, this dike would form a part of the project for the south channel, and to its advantage, since it would probably arrest the shift of deposits which, since 1843, have caused the thirteen and one-half feet channel to wander among the shoals, and may, possibly, increase the channel depth. *It would not be less than 2,600 feet long beyond the low water point of the island.*"

The extents and locations are stated in the parts I have italicized. The object is "to control the proportion of the ebb which shall seek the channels below" and "induce a greater proportion of flow to the northward of Petty's Island during ebb, without disturbing the relations of flood volumes." It will thus be seen that the conclusions reached in the body of my communication as to the site for and object of the works are identical with those stated by the Advisory Commission more than four years earlier, yet the plans which have been executed are those to which the Advisory Board gave but a qualified approval, based upon hope of success. As to the *means* of producing the desired effects, there appears to be a material difference, for if the dike as above described, be plotted as shown on *Plate II*, by the heavy dots extending 2,600 feet from low water at the eastern end of the island in a straight line to the extremity of Fisher's Point, it will not leave the curve of mid-volumes to the north of it, but will intersect it a short distance from the island and leave it on the

south, so that the area and volume of the ebb section and prism on the north side will be diminished and the proportion of the ebb stream flowing in the *south* channel would be increased, to the further detriment of that on the north side.

The *reaction dike* (*Plate II*) jutting out from the head of the island would have a development of but little more than one-third the length of the straight one, and would withdraw a prism discharging about 15,000 cubic feet per second, or more, if it be found necessary, from the south and project it into the north channel, thus increasing the ebb velocity of the portion near Petty's Island to over three feet per second, and giving a straight channel of sufficient magnitude to satisfy all the present requirements of commerce. By extending the dike, future demands may readily be met by the same means.

University of Pennsylvania, October 7, 1887.

DESCRIPTION OF AN IMPROVED TRIPLE-EXPANSION ENGINE.

BY WM. M. HENDERSON.

[*Read at the Stated Meeting of the INSTITUTE, held Wednesday Sept. 21, 1887.*]

MR. PRESIDENT, LADIES AND GENTLEMEN :—The latest innovation in steam engineering has been the introduction of triple-expansion engines. About the year 1863, being then in the South Pacific, I remember what a furore was created by some new steamships sent out from the Clyde by Messrs. Randolph, Elder & Co., having compound or double-expansion engines, which effected a saving in fuel of about twenty-five per cent. over the existing single-cylinder engines; notwithstanding the fact that the engines in use were fitted with approved expansion gear. These compound engines, as most of you are aware, had two cylinders; the second cylinder being about twice the diameter of the first. Engineers of eminence are not wanting who still insist that all the advantages of the compound engine can be secured in the single cylinder type, provided the total ratio of expansion in the two engines is the same. Facts prove this not to be the case, to which my single cylinder friends reply, "So much the worse for the facts."