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Report of Commissioners on Cape Cod Harbor - 1868



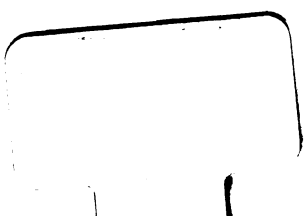
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HOUSE..... .....No. 50.

# REPORT OF THE COMMISSIONERS

APPOINTED UNDER

*Chapter 86 of the Resolves of 1867,*

IN RELATION TO

# CAPE COD HARBOR

AT

# PROVINCETOWN.

BOSTON:
WRIGHT & POTTER, STATE PRINTERS
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1868.

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James R. Baldwin

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# Commonwealth of Massachusetts.

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EXECUTIVE DEPARTMENT, BOSTON,
January 23, 1868.

*To the House of Representatives.*

I have the honor to forward the Report of the Commissioners appointed under the Resolves relating to Cape Cod Harbor at Provincetown.

Appended thereto will be found a communication from Professor Benjamin Peirce, Superintendent of the United States Coast Survey, and the able report of Assistant Henry L. Whiting, together with a map of the harbor. A model which accompanied the report of the Commissioners cannot conveniently be sent in with these documents, but will await the order of any committee which shall call for it.

ALEXANDER H. BULLOCK.

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## COMMISSIONERS' REPORT.

*To His Excellency the Governor, and the Honorable Council.*

In accordance with a provision of the Resolves concerning Cape Cod Harbor at Provincetown, approved June 1st, 1867, requiring the Commissioners under the same to submit to the governor and council for their approval, any plans of a "sea-wall, dike, or other solid and permanent structure, across the opening of East Harbor Creek," for the protection and preservation of Cape Cod Harbor, we have the honor to present for your approval, a plan for a dike across the mouth of East Harbor, with an estimate of the cost of the same.

Immediately after our appointment we endeavored to ascertain, by personal examination and inquiry, the dangers which threatened the harbor, and the changes, if any, which had already taken place within the memory of persons now living. The results of these inquiries strongly confirmed the general tenor of the numerous former reports on this subject by committees of the legislature, boards of commissioners and others, to the effect that the harbor was constantly suffering serious encroachments from accumulations of sand. From such inquiries, however, we found it impossible to arrive at any definite conclusions as to the amount of such encroachments, and as this appeared to be an essential preliminary to any large expenditure, we arranged with Professor Benjamin Peirce, Superintendent of United States Coast Survey, for a comparative survey of the harbor. Assistant Henry L. Whiting, who was detailed by him for this purpose, has made a very careful resurvey and comparison with the former elaborate survey of Cape Cod Harbor, by Major James D. Graham of the United States Corps of Topographical Engineers, made in 1833, '4 and '5.

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The results of Mr. Whiting's comparative survey are embodied in a report by him to the Superintendent of the United States Coast Survey, a copy of which we submit herewith.

By reference to Mr. Whiting's report it will be seen that very serious encroachments have been made in the harbor during the last thirty-two years, by accumulations of sand. On the western side of the harbor, Long Point has advanced more than two hundred feet, making dry land at low-water now, where there was a depth of seventy-five feet thirty-two years ago. The flats, dry at low-water, have also encroached on the west side of the harbor to an extent of about thirty acres in the same time. On the east side of the harbor, opposite the mouth of East Harbor, Mr Whiting also finds serious encroachments of the sand, extending for a distance of more than a mile in length, and into a depth of thirty feet at low tide, and evidently caused by sand carried out of East Harbor by the ebb tide.

The undersigned are not now prepared to make any suggestions for the protection of the western side of the harbor. The United States government are now erecting some works on Long Point for its protection.

To prevent the accumulation of sand on the east side of the harbor caused by the efflux of sand from East Harbor, we recommend the construction of a solid dike across the mouth of East Harbor, near the bridge, as authorized by the Resolve.

Much apprehension has been felt of the disastrous effects on the harbor which would be caused by the breaking through of the higher waters of the Atlantic, near the head of East Harbor meadows, where the ridge is low and only a few rods in width. The construction of this dike would be the best protection from such a catastrophe.

The channel to be closed by the dike is about one thousand feet in width at high-water, with a depth of water at high tide of about ten to fourteen feet. Through this channel the tide flows in and out of East Harbor, which is nearly all dry at low-water, but at high water covers a surface of from about five hundred acres at common tides to nearly a thousand acres at very high tides. From observations made by Mr. A. Savary, under our direction, it appears that during parts of a common

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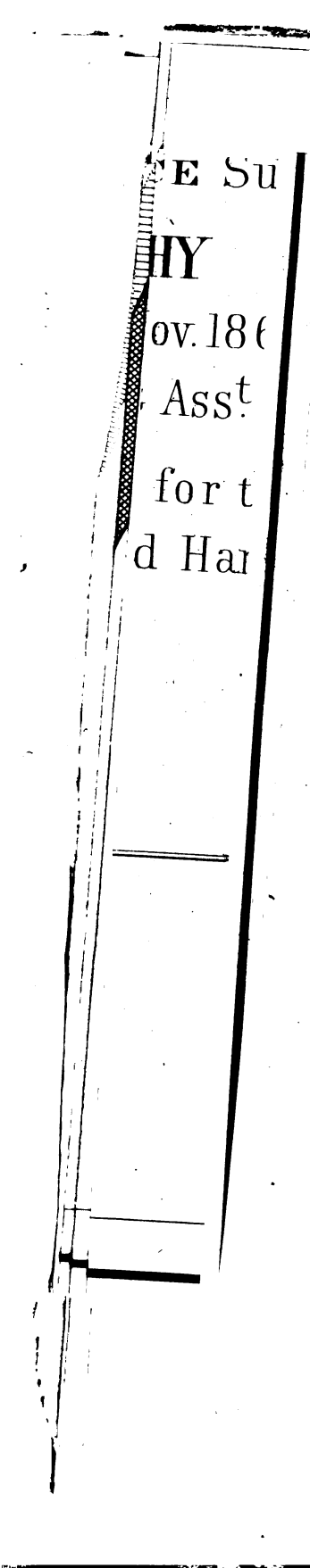
tide, the flow of water into East Harbor, through this channel, was at the rate of about 13,700 cubic feet per second; and the flow out at the rate of about 10,000 cubic feet per second. In a high course of tides the flow must sometimes be as great as 20,000 cubic feet per second, which is five or ten times the quantity of water flowing naturally in the Connecticut or Merrimack Rivers, in times of low-water.

It results from the movement of this great volume of water, that sand is carried by every ebb tide from East Harbor into Cape Cod Harbor, the velocity of the flow of portions of the ebb tide being greater than any portions of the flood tide. The greatest velocity found by Mr. Savary in the tide above referred to, when flowing in, was at the rate of two and a half feet per second, and when ebbing, at the rate of about three feet per second. According to different authorities, the velocity of water required to move sand is from six to twelve inches per second.

The only material on the spot, available for the construction of the dike, is sand, and that of a kind perfectly free from any cohesive quality. If it should be attempted to build the dike by filling in this material in the ordinary mode of making an embankment, after contracting the channel to a certain amount, the sand would be carried away by the tide as fast as it could be put in. If any other material but sand is used for the dike, it must be brought from a distance, which would involve an enormous expense. In order to use the sand for the main body of the dike, the flow of the tide must be stopped by some other means. In the published accounts of similar works in Europe, this is described as the critical point; but we do not find that any such work of this magnitude has been attempted in such material as this.

By the plan presented herewith, the tide is designed to be shut out by a timber dam. Timber abutments are proposed to be built on each side of the channel, leaving a space of not less than five hundred feet between them for the flow of the tide; the abutments to be connected with the shores by embankments of sand; the space between the abutments to be prepared for closing up by driving two rows of sheet piling as deep as they can be driven, and twenty-five feet apart, connected by an apron of plank just above the level of low-water, and the sand on each

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side protected from scouring by rip-raps or rubble stone. Upon this apron is to be constructed a timber dam to shut out the tide, after which a sand embankment can be made, to form the main body of the dike.

From the nature of the work, it is impracticable to make a reliable estimate of its cost. In making the following estimate, we have consulted those having most experience in the details of such works, and have endeavored to make allowance for all ordinary contingencies, but this work will be subject to extraordinary contingencies and uncertainties, for which we can make no estimate; such as great storms, scouring of the bottom, depth to which the sheet piling can be driven, &c.

There are some weak places in the tongue of land called Beach Point, over which the road to Provincetown runs, and which divides East Harbor from Cape Cod Harbor; these are now being attended to by the United States authorities, and for the sake of the road, by the local authorities, and we have accordingly not considered them in the estimate. A breach here, after the construction of the dike, will be a more serious matter than at present, as it would involve the possibility of a new channel into East Harbor, which would render the proposed dike useless; and it is probable that a more complete protection will be found advisable, to guard against a breach, than has been thought necessary heretofore.

*Estimate of the cost of a Dike across the mouth of East Harbor at Provincetown, if built according to the Plan of this date.*

| | | |
|---|---|---|
| 693,913 feet B. M., of spruce lumber, at $30, | | $20,817 39 |
| 500 round spruce piles, 28 feet long, 14,000 feet, at 10 cents, | | 1,400 00 |
| Lumber for staging, shanties, track, &c., 100,000 feet, at $26, | | 2,600 00 |
| Driving 2,660 piles, at $5, | | 13,300 00 |
| 4 pile drivers, with engines and screws, at $2,500, | $10,000 00 | |
| Less value of same when work is finished, | 2,500 00 | |
| | | 7,500 00 |
| Cutting of 1,800 piles under water, at $1, | | 1,800 00 |
| Receiving, taking care of and delivering to the work 900,000 feet of lumber, at $5, | | 4,500 00 |
| Framing and placing all the lumber, except the piles, 378,763 feet, at $10, | | 3,787 63 |
| Iron work, 25,000 pounds, average price, at 13¼ cents, | | 3,312 50 |
| Stone for rip-rap at apron and bridge, 6,300 tons, at $3, | | 18,900 00 |
| Sand bags to prevent sand scouring, 22,500 bags, at 13 cents, | | 2,925 00 |

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| | |
|---|---|
| Filling bags with sand and placing them, 22,500 bags, at 20 cts., | $4,500 00 |
| Sand filling for embankment, 50 feet wide on top, slope 2 to 1 on East Harbor side, and 8 to 1 on Cape Cod Harbor side, 140,000 yards, at 20 cents . . . . . | 28,000 00 |
| Protecting surface of dike from the action of the wind, 10,000 square yards, at 10 cents, . . . . . | 1,000 00 |
| Ropes, anchors, boats, smith's work, &c., . . . . . | 5,000 00 |
| Wharf for landing materials, 500 feet long, 30 feet wide, . . | 4,700 00 |
| Shanty boarding-house for 50 men, . . . . . | 1,000 00 |
| 6 horses, to be used for other work than the embankments, carts, harnesses, horse keeping, &c., . . . . . | 4,640 00 |
| | $129,682 52 |
| Add for engineers, inspectors, overseers, and the ordinary contingencies of the work, 15 per cent., . . . . . | 19,452 37 |
| Estimated cost of dike, . . . . . | $149,134 89 |

Which is respectfully submitted.

PAUL HILL,
JAMES GIFFORD,
*Commissioners.*

BOSTON, December 21, 1867.

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# LETTER OF BENJAMIN PEIRCE.

CAMBRIDGE, MASS., January 9, 1868.

SIR:—I take pleasure in transmitting to you the able and comprehensive report of Assistant Henry L. Whiting, upon Cape Cod Harbor. His views and conclusions meet my approbation and have my cordial concurrence.

The importance of this harbor of refuge to the commerce of Massachusetts is inestimably great. Its interests are inseparable from those of Boston Harbor, of which it is the right wing, and often in a storm thousands of tons of shipping nestle under its protection. It is in imminent peril, and it requires efficient artificial remedy or it will suffer material damage, and be put into the way of constant deterioration which will terminate in its ultimate ruin. But fortunately the danger can be arrested by skilful engineering, and postponed for many generations, at an outlay which will be moderate in comparison with the accomplished benefit. The evidence of the report of Mr. Whiting leaves no doubt that the proposed dike will secure the harbor from its two greatest dangers. It will cut off the supply of sand which is now filling up the north-eastern portion of the harbor. It will also convert the included lagoon into a receptacle for the dunes blown by the northern winds, and set up an inner line of defence which will stand for the protection of the harbor when the high tides shall sooner or later have broken down the thin spit of sand which is now the only barrier against the encroachments of the ocean from the east.

The bars by which Mr. Whiting proposes to guard the western line of the harbor are inexpensive, and deserve the favorable consideration of the Commissioners.

Yours respectfully,

BENJAMIN PEIRCE.
*Supt. U. S. Coast Survey.*

PAUL HILL, Esq., *Chairman Cape Cod Harbor Com., Lowell, Mass.*



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# REPORT OF HENRY L. WHITING.

PROVINCETOWN, CAPE COD, MASS., December, 1867.

Professor BENJAMIN PEIRCE, *Superintendent U. S. Coast Survey.*

DEAR SIR:—While engaged in my revision work on the coast of Maine, I received your letter of August 28, containing the following instructions:—

"You are authorized to concert with James B. Francis, Esq., in regard to the service expected of you by the State Commission for the protection and preservation of Cape Cod Harbor, and to proceed to the performance of that duty."

On the 6th of September I received the following letter from the Commissioners:—

HENRY L. WHITING, ESQ., *Assistant U. S. Coast Survey.*

DEAR SIR:—A communication from the Superintendent of the U. S. Coast Survey, of the 27th ult., in reply to our letter requesting a comparative survey of Cape Cod Harbor, at Provincetown, says, "Assistant H. L. Whiting has been authorized to concert with you in regard to the time and performance of the services desired."

We desire you to proceed, at your earliest convenience, to make a survey of the eastern part of Cape Cod Harbor, to include the physical conditions of that part of said harbor off the entrance of East Harbor,—stating in your report, and showing on your plans, the changes, if any, indicated by a comparison with the survey of Col. Graham, the former coast surveys, and any other surveys to which you may have access.

Also, to make such surveys of other parts of said harbor, as may be necessary to determine what changes, if any, have occurred in its physical condition.

Very respectfully yours,

JAMES B. FRANCIS,
R. A. PEIRCE,
JAMES GIFFORD,
*Commissioners for the Protection of Cape Cod Harbor.*

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On the same day I met the Commissioners, in Boston, for consultation and discussion of the details of the work desired, and thence proceeded to Provincetown, and commenced its execution.

The occasion for this call from the Commissioners, upon the Coast Survey, was to secure its result as a basis for the special duties imposed upon them by an Act of the legislature establishing their commission.

The purpose of the survey desired, is stated in the letter of the Commissioners, above recorded.

The first survey, above alluded to, was executed by Major J. D. Graham, U. S. Topographical Engineers, by order of Lieut. Col. J. J. Abert, chief of topographical engineers, for the purpose of a military and hydrographical chart of Cape Cod Harbor. The full and detailed report of Major Graham, together with his accompanying chart, establishes this survey as a standard of the first order. The triangulation and details of topography and hydrography, were accurately and elaborately executed. The field work extended through three seasons, and was completed in 1835. This is the first reliable survey, covering the ground now under consideration, and the lapse of time since it was made, makes a comparison with its results of greater value than any of which we have knowledge or possession.

In 1848 the topographical survey of Cape Cod, from Eastham to Provincetown, was ordered by the Superintendent of the Coast Survey, and executed by the party under my charge. The extremity of the Cape—Provincetown and that part of Truro embraced in Major Graham's survey—was surveyed by myself in person. The importance of Cape Cod Harbor, and the complex nature of this section of the Cape as a subject for survey, necessitated close and accurate work, which was done, in the approved mode of the standard topography of the Coast Survey, and affords important intermediate comparison of features above the water-line.

The hydrography of the Coast Survey was executed in 1856 by Commander H. S. Stellwagen, U. S. N. Assistant. This branch of the survey is for the general purposes of navigation, and in view of the great water area to be gone over, does not and cannot, develop local details with the minuteness of a

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special survey like that of Major Graham, unless such a survey is so ordered. At the time the hydrography of the Coast Survey was executed, the questions now under consideration were not anticipated. The comparison, therefore, of this survey of Commander Stellwagen's with that of Major Graham, and the one I have just completed, can only cover general, and not particular features.

In 1857, at the request, and in behalf of a former State commission, I made, by order of the Superintendent of the Coast Survey, a re-survey of the outlines of the extremity of the Cape, embracing the ground of my former survey of 1848, and including the localities now under consideration ; but no hydrography was executed at this time. This survey was based upon the same trigonometrical and topographical points of the former survey, and showed important and extensive local changes to have occurred during the intervening time.

In the spring of 1867 another survey, mainly hydrographic, was made for the board of State harbor commissioners, by A. Boschke, Esq., C. E. This survey was again, for a special but different purpose, the location of a harbor line for the limit of wharf structures, and did not, in its case, cover the ground, or develop the physical details in question.

The means, therefore, of accurate and minute comparison, had not yet been obtained. To procure this end, the present board of commissioners for the protection and preservation of this important harbor, made their call for the special survey I have just completed, under your order.

This survey has been executed in the most accurate and detailed manner, with the knowledge of the value and bearing of such results, only, as were correct. Data of projections and triangulation points have been furnished from the office of the Coast Survey. The field work is all based upon triangulation and plane table points. The outlines of high and low-water, and some interior details, have been topographically surveyed. The hydrography has been executed with special accuracy and detail. A series of water signals along the low-water and one fathom lines, and a series of flag buoys along the five fathom line, have been determined by shore observations. From these points the sounding lines have radiated, ranged and crossed, so as to give a full development of the contour of the bottom.

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Depths under three fathoms have been measured with a sounding pole, to feet and tenths; over that depth, with a sounding line, tested and corrected for shrinkage and other error, and the depths recorded in fathoms and feet. The tidal observations have been continued through four lunations. Tide gauges were located in the centre of the harbor, at the steamboat wharf, at the Inlet of East Harbor, at the centre of East Harbor Lagoon, opposite this last position, in the outside harbor, at the head of the meadows in East Harbor Creek; opposite this last point the tide was observed at high-water, without a gauge, on the outer Atlantic side of the beach.

Accurate levels have been taken by Hiram F. Mills, Esq., C. E., referring the outside ocean to the waters of East Harbor Creek, at the head of the meadows, and showing the elevation and extent of the sand beach between them. The tide gauge at the head of the meadows is referred to the tide gauge inside the lagoon; this latter gauge to the gauge in the outside harbor opposite, and to the gauge at the inlet. The tide gauges at the inlet and at Steamboat Wharf have also been referred to permament local bench marks.

I will here state, that in addition to the charts and plans of my own survey, I have received from the U. S. Engineer Bureau at Washington through the favor of General A. A. Humphreys, chief of the corps, a large scale map, copied from the *original sheets* of Major Graham's survey, showing the high-water and low-water lines of Cape Cod Harbor and East Harbor Lagoon, and the one, two, three, four and five fathom curves. The trigonometrical and topographical points of Major Graham's survey are given on this map, and afford a perfect base for bringing this survey to the same scale and base of the Coast Survey, giving a comparison of every position and detail feature with perfect accuracy.

I have also received, from the State harbor commission, through the attention of their engineer, A. Boschke, Esq., extracts, on vellum, from his large scale hydrographic chart, and a map reduced to $\frac{1}{10\,000}$, the scale of the coast surveys.

From the Coast Survey office I am furnished with a re-plotting, from original notes, of the hydrographical survey of Commander Stellwagen, also upon the scale of $\frac{1}{10\,000}$.

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Through the kindness of General H. W. Benham, I have had the loan, from him, of maps and tracings of Cape Cod Harbor, made for his use, also of manuscript and printed reports of the former commissions and board of engineers who have examined and reported upon the physical condition of Cape Cod Harbor.

The results of my own surveys are given in a general original map and chart, on $\frac{1}{10\,000}$, embracing the several localities under consideration, and showing the topographical and hydrographical features of the harbor as they now exist. A reduction, for comparison, of the large scale map from the Engineer Bureau, has been made to the scale of my own survey, $\frac{1}{10\,000}$, based upon points common to both surveys. A re-plotting of my hydrographic work has been made, on the same scale of Major Graham's large map, with the shore lines accurately enlarged. Comparative tracings, on vellum, have been made, showing the high-water, low-water, one, two, three, four and five fathom lines of all these maps. A large scale plan and chart on $\frac{1}{1000}$ has been made by original independent surveys, embracing the local ground of the Inlet of East Harbor, showing the present bridge and adjacent shores, with sounding in squares of fifty feet, given in feet and tenths and extending three hundred feet above the bridge and five hundred feet below the bridge. Upon this plan is projected the position of the proposed dike.

The special grouud of my surveys embraces three separate sections, although all are connected in their general bearing on the physique of the harbor.

The questions involved are varied. The first:—Long Point and Long Point flats, being that of change, encroachment upon area of the harbor, or the reverse.

The second:—The influences of the tidal current through East Harbor Inlet, and their change of condition, with the practicability and advisability of closing the inlet by an artifical dike.

The third:—The changes and danger of waste, of the narrow strip of beach separating the outside ocean tides and sea from the head-waters of East Harbor Creek.

In discussing these sections in detail, I classify them as above.

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## Section I.

### *Long Point.*

Long Point is the extremity of Cape Cod, and forms, by its long, crescent-shaped spit, the bulwark of the harbor, being a natural "mole," presenting a long fore-slope to the action of the sea, with a steep slope inside, declining into from sixty to seventy-five feet of water.

Between this point and the western end of the village of Provincetown, on the western side of the harbor, there are extensive flats, covered at high tide, and terminating in an abrupt decline from low-water line to about fifty feet, quite in contrast with the slope of the north side of the harbor, along the front of the village, which is long and gradual.

The survey of Major Graham shows the formation of Long Point as an irregular neck of sand flats and hommocks, broken by lagoons having several openings on the inside and one on the outside, with a high-water channel passing quite through the neck.

At the time of Major Graham's survey, Long Point Light-house was on the extremity of a spit, covered at spring high tides, and nineteen hundred and fifty feet beyond the high-water extremity of the main point.

The survey just made shows marked and important changes in the character and extent of Long Point. Some of the lagoons have filled up with sand, and the outside opening has entirely closed, and the point, generally, increased in width and substance.

By artificial structures, and the planting of beach-grass, the low-water spit between the light-house and the former end of the point has been raised to a high-water neck, now covered with beach-grass, and fifty feet wide at its narrowest part. This neck has extended beyond the light-house, in a north-east direction, and the high-water extremity of Long Point is now five hundred and ten feet beyond the centre of the light-house. (The extreme point bare at mean low-water is five hundred and seventy-five feet beyond the light-house.) This shows an *increase and extension of the point, above high-water, of two thousand four hundred and sixty feet in thirty-two years.*

The recent soundings show the base of this mole of sand to have advanced upon the floor of the harbor 250 feet, and with

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its summit now dry at low-water, where, thirty-two years ago, according to Major Graham's accurate determinations, there was a depth of water of 75 feet. The slope of the extremity of this mole or spit, like its northern side, is very abrupt; and this abrupt slope is preserved in its steady movement along the floor and into the deep waters of the harbor, like the advance of an immense dune.

Along the margin or crest of the flats between Long Point and the western end of the village, the drainage of sand off these flats had projected their low-water margin, or bank, an average distance of 275 feet, with a lateral extent of 5,000 feet, making a superficial area of increase of 1,375,000 square feet.

The outer slope of these flats,—which, as before stated, has the character of an abrupt bank—has undergone considerable change; and along its central section has encroached upon the basin of the harbor, the base of the slope or bank having advanced 60 feet.

Between the centre and southern corner of this bank there is more change than actual increase; in fact, the corner of the bank has receded at the turning point, and assumed a sharper bend. This indicates that the material of the bank itself is subject to strong under-water influences.

Between the centre and northern corner of the bank, where the curve and change from the abrupt slope is more gradual, the comparison of surveys shows more disturbance of contour than actual change; the general position of the bank in relation to the harbor outline remaining as heretofore.

The gradual slope along the front of the village also retains its former general ground.

The marked and extensive increase of the summit of this bank, between Long Point and the western end of the village, suggests the importance of arresting the moving surface material of the flats behind it.

A fence, or dike, constructed from Long Point, near the entrance of Lobster Plain to House Point Island, and from House Point Island to Stevens' Point would be a favorable line, and would shut off the greater portion of these flats, and ultimately increase the substance of the point.

A fence, or dike, might be constructed still closer to the edge of the bank, thus cutting off the entire flats, and preventing any drainage toward the harbor.

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## Section II.

### *East Harbor Inlet and Beach Point.*

Beach Point is a rift of sand which appears to have been thrown up by the dash of the sea along the outer edge of a pre-existing flat, and has thus enclosed behind it a large tide-water lagoon, known as "East Harbor."

Since the record of former surveys this rift of sand has gradually increased, and advanced in a north-westerly direction, leaving the opening that we observe; an opening which is now preserved by the persistent action of the tidal current which fill and empty the lagoon within this natural dike. This opening exhibits the usual characteristics of an inlet, with a depression at the chops, an outside bar and an inside swash.

The changes manifested by the comparison of surveys are marked and varied about the locality of the inlet, and within the range of its influence.

Above high-water the extremity of Beach Point has extended, in its general alignment, since the survey of Major Graham, 1,000 feet. On the opposite side of the inlet some waste of the main shore of the province land has occurred, amounting to 200 feet, so that the actual contraction of the width of the inlet, during the last thirty-two years, has been 800 feet.

About 2,500 feet of the end of Beach Point seems to have been affected by the dash of the sea and the action of the tidal currents of the inlet, so that the body of the beach has been beaten in, or has swung in, upon the bed of the lagoon. This retreating of the beach is an average distance of 200 feet, about its general width.

Within the inlet the changes indicated are mainly those of abrasion of the bank and bluffs on the northern shore of the lagoon; with an advance and encroachment of sand dunes upon the flats and marshes above the section of waste.

This abrasion, caused by the tidal currents, both at flood and ebb, has cut into the high sand dunes, north of the lagoon, in a deep cove about 1,200 feet in lateral extent, with an average cutting of 180 feet, showing a waste of 24,000 superficial yards. But this does not express the amount of material removed; this cut is at the base of dunes which rise abruptly above the shore to the height of at least 40 feet, and the whole mass of the



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dune has been cut away by the undermining of the tidal currents; estimating the height from low-water to the summit of the dune we have a vertical waste of 51 feet. In other figures, the removal of sand may be stated at 408,000 cubic yards.

Beyond this cove the dunes have advanced, as before stated, over the site of former high flats—otherwise unchanged—and now rise abruptly from these flats at the shore line. This extension covers an area of $800 \times 40 = 32{,}000$ square yards. So evidently is this a dune movement, that the extension and increase cannot be connected with the concave excavation and retreat of the shore at the cove below.

It would be reasonable to apply this dune advancement to the ground of the cut or cove referred to, as the whole northern shore of the lagoon is bordered by dunes of the same character, and subject to the same wind influences. This would nearly double the figures given above, as the waste and removal of material from the cut, or cove, described.

As these changes indicate, on the one hand, an advance of the shore line upon nearly the high-water plane; and, on the other, the entire removal of material between the surface and bed of the lagoon, its capacity as a reservoir, has been insomuch increased.

Above the inlet the low-water channel has changed its form and direction, but there is no evidence of any less drainage than formerly; on the contrary, the channel is deeper and extends far beyond the limit of the flats represented on Major Graham's chart as dry at low-water. Unfortunately, the sparse soundings on Major Graham's chart, within the basin of the lagoon, do not admit of a fair comparison. There is no allusion in Major Graham's report to a local plane of mean low-water in the lagoon—which differs from the plane of the main harbor. Probably no allowance for this difference was made. We have no data, therefore, by which to ascertain the relations of these planes at the time Major Graham's survey was made. Taking the data given, for comparison, a greater depth of water in the channel at low tide exists now than formerly.

The deepest water given on Major Graham's chart is $4\frac{1}{2}$ feet, at a point 300 feet above the inlet. Near this point there is now 4 feet. At 900 feet above the inlet Major Graham's chart shows $3\frac{1}{2}$ feet; at this point there is now $9\frac{3}{4}$ feet. Major Gra-

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ham's soundings gradually shoal, above this point, to 3, 2 and 1½ feet—this last sounding being 1,900 feet above the inlet. At this distance, but in a different position, there is now 4½ feet; and above it 2½, 4½ and 4¼ feet—this last depth taken being 3,400 feet above the inlet.

At the point of greatest abrasion of the shore of the lagoon, at the cove above referred to, the shore has an abrupt decline from the base of the dunes, which rise as abruptly above it, to the bed of the low-water channel. This channel, although narrower than when Major Graham surveyed it, is shown to be deeper, and has probably as much, if not greater, scouring capacity than when it was in its former condition.

The comparison of shore lines has shown the inlet to have contracted from a width of 1,700 feet in 1835 to 900 feet in 1867, —the present time. But a comparison of cross-section shows that, in this narrowing, no proportional diminution of waterway has occurred. Major Graham's chart exhibits two depressions in the cross-section not unlike those at present existing, but of much less depth. The former are respectively 3 feet and one foot, while the latter are 14 feet and 8 feet.

That the artificial structures connected with the bridge and road-way have, by confining the inflow and outflow of the tides to nearly the same pathway, aided in deepening the inlet, no one can doubt. At the period of Major Graham's survey, no bridge or other artificial obstruction existed.

The subsequent influences of these obstructions must also be given due weight in considering the changes in the positions and magnitudes of the shoals both above and below the inlet.

The drainage current of East Harbor, which may be said to approach the opening along the axis of the lagoon, impinges, as it nears the inlet, upon the bluffs of the main shore, is deflected from its course and turned off through the inlet at rather a sharp angle, after which it pursues a nearly direct course to the sea.

In studying the contours of the bottom in the section of the harbor off the entrance of East Harbor, as shown by the fathom curves, the influences of the inlet are marked in their effect.

Were there no causes for disturbance, we should expect to find the contours here, as elsewhere, *concave*, and *conforming*

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*to the general trend of the shore*, instead of which we find them *convex*.

Upon Major Graham's chart this *protrusion* of the contours off the entrance of East Harbor, is very evident, and extends from the low-water line to the muddy bed of the main harbor.

It is also evident that the projection of these contours is not alone the result of the *pushing out* of sand already existing in this vicinity, or brought here by wave and current action from distant ground; in which case, were this the prevailing action, the sands would be *thrown in* rather than protruded. But the evidence is, that supplies of sand have been brought out from the lagoon by the ebb current, and that these sands, and this tidal current, have been the prevailing causes of this local projection of the under-water shore slope of the harbor.

A comparison of the survey of Major Graham with that just made, demonstrates that this projection of sand has continued and increased during the intervening time.

We have no data by which to ascertain the increase in *elevation* of the shoals and bars off the entrance of the lagoon within the low-water line, and can therefore only compare their outlines and lateral extent. Beside the accumulation which may have occurred to increase the elevation of these shoals on either side of East Harbor channel, the tidal current from the lagoon seems to have had the power to carry material along its pathway to the crest of the decline, and project this material over the face of the outer slope. This deposit is marked and extensive, as far as the five-fathom curve, the limit of our means of comparison.

This increase may be stated in the following terms:—

The contour of the two-fathom curve shows an advance since Major Graham's survey, of an average distance of 175 feet for a lateral distance of 6,000, equalling 1,050,000 superficial feet.

The three-fathom curve has advanced in a like manner, an average distance of 160 feet by 7,000 feet, equalling 1,120,000 superficial feet.

The four-fathom curve has advanced 150 by 8,000 feet, equalling 1,200,000 superficial feet.

The five-fathom curve has advanced 110 by 5,000 feet, equalling 550,000 superficial feet.

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The total projection of these curves amounts to an area of 3,920,000 superficial feet.

To ascertain and illustrate this increased deposit we have taken only the curves of the fathom planes, which are the lines usually given on the hydrographic charts of the Coast Survey; but as each of these planes overlaps upon the other, it shows a deposit over the whole section. The distance of the overlap, indicated by the fathom curves, also shows a deposit which would probably average one foot in depth.

Estimating the section between the two and five fathom curves, which equals an average distance of 3,000 feet, and including the lateral extent of the deposit, shown upon the chart to be 6,500 feet, we have the extensive area of 30,500,000 superficial feet.

In other figures, 30,500,000 cubic feet of sand has been projected over this under-water shore slope of the harbor, covering an area of 700 acres one foot deep with sand.

The *horizontal projection* of this deposit is much greater and more important in its relation to the entrance and navigation of the harbor than this vertical shoaling would seem to indicate.

The most extended projection of the three-fathom plane—an important depth in navigation—appears at the extreme limits of the ground affected, so that at points two miles apart, we find the three-fathom curve to have advanced 300 feet.

As the intervening ground is broken and irregular, no vessel drawing eighteen feet of water should venture beyond this line within this lateral distance of two miles.

In applying the consequences of this change in the condition of the harbor to the practical question of navigation, it results: that vessels bound into Cape Cod Harbor, in standing over toward the Truro shore, within this section of two miles, must shorten their range, or tack, by a distance of 300 feet.

To vessels in distress, heavy laden and laboring, in stress of weather to make the harbor, every foot of sailing distance gained and available under the lee of the Truro shore, is of great advantage.

The present tidal power of the inlet may be further shown by a statement of the capacity of the lagoon which, at ordinary tides, has an area of 463 acres. At high spring tides—and Major Graham's tidal records show the rise of a storm tide



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with a south-east gale, to have been *sixteen feet*—the whole extent of "the meadows" is overflowed, increasing the area by 461 acres, making a reservoir capacity of 924 acres.

So long as this inlet remains open, the scour of the tidal currents, added to the other activities of nature, will have a tendency to weaken portions of Beach Point, and give a general insecurity to the locality. This has already been the occasion of large expenditures upon temporary works of defence.

In making the statements recorded in this Report, and presenting the comparative chart showing the changes which have taken, and are taking place, in the physical condition of the harbor, I will again allude to the character and accuracy of the data upon which these results are based.

The accuracy of the prepared chart furnished from the Engineer Bureau, the accuracy and detail of Major Graham's survey, and of the survey just executed, have rendered these results most satisfactory, and unusually close in their determination. In all permanent lines and features the coincidence has been most marked and perfect; as have also been the points, common to both surveys, upon which comparisons are based.

The results of these surveys unite in testifying to the encroachment of sands upon the waters of the harbor, and give no reasonable ground for assuming that these causes of injury are declining.

We will not assert that the time may not come when the action of these causes may decline or altogether cease, by the filling up of the lagoon and the sanding up of the inlet; but the data thus far obtained, afford no ground upon which to predict the ultimate result of these natural changes. The facts show *that the immediate tendencies of the present influences are decidedly injurious*, and justify the anxiety they have occasioned.

There is no seaward scour to the harbor itself, and no effort to remove sand of this description has ever proved successful. *The damage to the harbor, therefore, is irreparable.*

## Section III.

The narrow strip of outside beach, which connects the high lands of Truro and Provincetown, and stretches across the head of the meadows, is the remains of what appears to have

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been a high ridge of sand dunes, formed prior to any record or history we have of this locality. That they have been long undisturbed by wind is evident from the existence of the beach plum-tree, which covers the remaining inner slope of the highest of these dunes or hills.

Without entering into a discussion of the geology of this section of the Cape, the consideration of the probable origin and general former condition of this remarkable land is important in judging of its probable future condition, and the changes which are likely to take place.

The fact is patent, that the Truro land—or main extremity of the Cape terminating at "High Head"—was formed at an earlier period, under different influences, and contains material not present in the so-called Province land. This difference is marked by the existence of clay and of boulders, and by the peculiar form of the "bowl and dome" drift, distinguishing it from the Province land, which is of sand only—so free from all earthy matter that it will not even discolor water—while the forms which the dunes and ridges here assume, are those mainly characteristic of wind drift.

Whatever the original forces may have been that formed this part of the Cape, these forces have long since ceased, and changed from an action of *increase*, to that of constant and continued *degradation*.

The peculiar position and form of the Province land is that of a spit, thrust out by the tidal currents, and thrown up by the dash of the sea, beyond the former extremity of the Cape, and composed mainly of the insoluble material abraded from the shores of the main cape at Truro and beyond.

A cross-section of the Cape, at the Highland Light, shows an abrupt outer bank of about one hundred and twenty feet in height; proving, that at a former period, the Cape, at this section, was wider than it is now; and that probably the shore line extended far out into what is now deep water.

The remains of the *inside slope* of what were former high dunes on the Province land, shows that these dunes were formed under the lee—as it were—of this former wide and more extended portion of the Cape.

It seems to be almost a law—and certainly is the prevailing course, in the formation of such ground as Provincetown—

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that the first resultant of the creative forces is the *outer bar*, or backbone ridge, of the spit or neck so formed. It is, therefore, reasonable to assume, that the outer ridges of the peninsula of Provincetown were the earliest in date, and that the flats, marshes and ponds now existing, are subsequent accumulations and accidents, which have taken place under the shelter and eddy influences of the outer hooked bar or beach.

The waste of this beach—with its bluffs and dunes—which forms the isthmus connecting the Provincetown peninsula with the Truro land, is now going on in line with the general waste of the whole outside shore, and more rapidly, perhaps, at the main bend of the Cape along this section, than at many other points.

There are now two narrow and weak places in the strip of beach which forms the isthmus of Provincetown—as above described—which I will call in my Report, and refer to on my charts and plans, as the "oblique section" and the "cove section." At each of these points a line of levels has been run from the outside slope of the beach to the inside water-level of East Harbor Creek—as stated in the foregoing pages of my Report.

By comparison with the extreme high-water line—the one given on Major Graham's chart—a waste of 300 feet is found opposite the "oblique section;" and of 215 feet opposite the "cove section."

The outside beach, along this bend of the Cape, is swept by a strong lateral current, trending toward Race Point, and is also open to the full power of the severest storms, which bring upon the shore the heaviest breakers.

Already these breakers have dashed over the narrow strip of sand beach at what I term the oblique section. This led to some works of protection to the beach. A jetty of heavy piles was driven on the outer slope of the beach, but was torn up by the sea as soon as made. Some brush hedges have been set and beach-grass planted along the crest of the beach. These have caused some accumulation of sand, and prevented what was already there from being blown away. But nothing has been done to preserve or increase the beach at what I term the "cove section," which is now the weakest point along the line of this sandy isthmus.

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The levels taken by Mr. Hiram F. Mills, and shown upon his elaborate plan of profiles, give the following results:

At the "oblique section," the outside slope of the beach is seen to be frequently washed by the tide and sea, to within about two feet of the highest point of the ridge.

From this line of sea-dash, the distance through to the inside marsh is 437 feet—the line passing over rather irregular ground.

The difference of level between this line of sea-dash on the outside slope of the beach, and the plane of the marsh inside, is $9\frac{9}{10}$ feet.

At the "cove section," the form and character of the strip of beach is that of a single bluff, with a steep slope from its outer crest to the sea, with a more gradual, but single, inside slope toward the marsh.

The dead grass and drift at the outer edge of this bluff, show that the breakers often reach its summit.

The little cove of inside marsh—from which I name the section—reduces the width of the sand ridge constituting the entire isthmus at this point, to 90 feet.

The survey by Mr. Mills was made at a season of ordinary tides, and in ordinary weather; but there is always a heavy sea on the outside shores of this section of the Cape.

From the line of high-water sea-dash on the outer slope of the beach, to the same level on the inside slope, the distance across this strip of beach is 65 feet. The elevation of the little intervening bluff above this line, or plane, is $6\frac{6}{10}$ feet.

Opposite this cove of marsh, East Harbor Creek makes its nearest bend toward the outside beach, with a small lateral creek extending still nearer to it, so that the corresponding waters are but 301 feet apart.

The relations of these waters, in their tidal epochs, are peculiar, at this point. The long path which the inside tide has to travel, first in passing through East Harbor Inlet, then, after filling the lagoon, finding its way through the windings of the creek to nearly the head of the meadows, makes the *time* of high water in the creek 1 hour 29 minutes later than the outside ocean tide.

Our tidal observations, and the profiles of Mr. Mills, also show the level of the water in East Harbor Creek at the time



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of high-water outside, to be $11\frac{1}{10}$ feet below the plane of ordinary sea-dash on the outside beach opposite.

In these results, we have before us this physical condition of the case.

The only barrier which now prevents the waves of the outside ocean from dashing into and upon the creek and meadows of East Harbor, which are on a plane 11 feet *below* the summit of the breakers, as they come rolling in, is a strip of sand beach 65 feet wide, with a little outside bluff $6\frac{1}{2}$ feet in height.

That this strip of beach, and this little bluff is steadily diminishing, both in width and elevation, is beyond a doubt. The question seems to be simply one of time. We find in thirty-two years that 215 feet of this beach have washed away, to 90 feet now left remaining.

If it be a fact, that this outside beach, or bar, is antecedent to the flats and marshes which have formed under its protection, then, when this protection is removed, we have a condition and relation of things which has not before existed, or occurred.

In view of the vast power of ocean breakers, culminating with storm tides and gales, it is vain to predict the consequences which may result, should they break over and through this beach.

In the storm that carried away the first Minot's Light-house, a breach was made in the outside beach at Nausett, which, when the storm subsided, was over 500 feet in width, with a channel 11 feet in depth. This opening remains to this day, although the tendencies to close, by the formation of a new outside beach, are as strong, and the inside influences to keep an inlet open, less favorable, than at the ground in question,—which presents an unobstructed pathway through the entire Cape, while the calm waters of Cape Cod Harbor are always below the summit level of the breakers on the outside shore.

But assuming that no change in the existing condition of land or water should result from the wearing or breaking away of this strip of beach?

It is evident that without this barrier, at periods of high tide, the sea would dash over for many hours into the basin of the meadows. This surplus water, in its outflow at ebb tide, would tend toward the harbor as readily as it would discharge itself through the ocean inlet, should one be made.

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The scour and cutting power of East Harbor Inlet would therefore be increased at each ebb tide, by a volume of water not accumulated by its own flood tide capacity.

That this augmented water-power would increase all the evil influences of the inlet, is beyond a doubt.

In view of this contingency, the closing of East Harbor Inlet, as proposed by the present board of State Commissioners, fulfils a double purpose, in stopping the injury it is now doing, and in presenting a breakwater between the ocean and the harbor waters, should the outside beach break through.

In addition to a dike at the inlet of East Harbor—which I should strongly recommend,—a guard dike at the narrow part of the meadows, near the "wading place," would give increased protection.

It is impracticable, even impossible, to resist the forces of the ocean, on such a coast as this, at the point of its attack; security must be obtained by rear defences.

Without further comment upon the facts and questions I have above presented, I am constrained to add, that in all my knowledge of the coast, and in the results of the many surveys I have made, involving questions of harbor improvement and protection, I have found no case which, in my judgment, calls more strongly for the attention and action of the General Government and of the State, than this of Cape Cod Harbor; its value to commerce; its location; its accessibility; its shelter as a harbor of refuge are unequalled on the Atlantic, coast of the United States.

Before closing my Report, I would particularly mention the conference and consultation I have had with Henry Mitchell, Esq., of the Coast Survey, who has been twice to Provincetown during the term of my field work there.

Mr. Mitchell has personally gone over all the ground under consideration, and, with me, made some experimental tests of the Harbor and East Harbor currents. The lateness of the season, and the limited time available for such investigations, however, rendered a proper series of observations impracticable.

Mr. Mitchell concurs with me in the general views expressed, and the deductions made from the data and comparison of my surveys.

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I would also mention the services of Mr. Gershom Bradford, of the Coast Survey, who has executed the hydrographic work under my general charge; Mr. Bradford's experience and skill as an hydrographer have secured results and given data of the first order.

The extracts from the surveys of the State harbor commission, executed and furnished to this special commission, by their engineer, A. Boschke, Esq., have served to connect the detached portions of my own local surveys. The correspondence and agreement of the data given on Mr. Boschke's chart add proof and illustration consistent with the results of my own surveys.

Tidal data, references and explanations will be found in notes given upon the charts and plans accompanying this Report.

All of which is respectfully submitted.

HENRY L. WHITING,
*Assistant U. S. Coast Survey.*

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