SURVEY

OF

TIDES AND CURRENTS

IN

CANADIAN WATERS

REPORT OF PROGRESS

BY

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OTTAWA
GOVERNMENT PRINTING BUREAU
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SURVEY OF TIDES AND CURRENTS IN CANADIAN WATERS.

OTTAWA, 26th January, 1897.

W. P. ANDERSON, Esq., C.E.,
Chief Engineer,
Department of Marine and Fisheries.

SIR,—I have the honour to submit the following report on the progress of the Survey of Tides and Currents in Canadian waters. During the year, substantial progress has been made in both branches of this survey. The principal tidal stations have been maintained; and they have also been utilized for the determination of tidal differences in an important region in the Gulf of St. Lawrence. A series of tidal differences for the St. Lawrence River has been worked out, and supplied with the tide tables for publication in the leading almanacs for 1897. In the other branch of the survey, an examination of the currents has been made in the north-eastern half of the Gulf of St. Lawrence from Anticosti to the Strait of Belle Isle; and for this work the SS. "Lansdowne" was again placed at my disposal for three months during last season. It may be best to describe first the progress made in the "Tidal branch" of the work; and then give the results obtained in the "Survey of the currents" this season, and also some account of the general movements of the water in the Gulf, with relation to the Gulf entrances.

THE PRINCIPAL TIDAL STATIONS.

In establishing these stations originally, a careful selection was made of the most commanding points on the Atlantic coast, at the Gulf entrances, and on the St. Lawrence. The stations, therefore are not only of direct value to our principal harbours, but they also serve as reference stations from which to determine tidal data in the regions lying between them. There are now seven stations in operation, situated at St. John, N.B., Halifax, St. Paul Island in Cabot Strait, Forteau Bay in the Strait of Belle Isle, South-west Point of Anticosti, Father Point and Quebec. The tide-gauges at these stations are so designed that they can be heated in winter to secure a continuous record of the tide throughout the year. They are provided with self-recording tidal instruments, and other necessary appliances; and the more isolated stations are also furnished with dipleidoscopes, where there is no means of obtaining the time except by telegraph from some distant observatory, which during the first two years entailed considerable expense. These stations have been in continuous operation during the past year, without any interruption of consequence, and the tidal record obtained will serve to improve the accuracy of the tide tables as soon as the expense for the necessary calculations can be met.

The recording instrument at the station in the Strait of Belle Isle was replaced by another in September; as its driving clock required cleaning. Also at St. Paul Island, the hair-spring of the clock of the instrument broke; and with the type of tide-gauge now in use, any such accident involves the entire removal of the recording instrument, and interruption to the record. In this instance, it was imperative to avoid interruption, as the gauge was being used at the time for comparison with simultaneous observations at Pictou and Charlottetown. St. Paul Island can only be reached fortnightly, and then a landing can only be made in fine weather; it was fortunately possible to replace the instrument temporarily within three days, while it was sent away for repairs.

After extensive inquiry and careful consideration of the requirements, a form of recording instrument has been devised by myself, which obviates the uncertainty and expense connected with the use of the ordinary type of instrument. The essential point is to have a driving clock which can be readily detached from the rest of the instrument. This is secured by placing the driving clock inside of the revolving cylinder which carries the sheet of paper on which the tidal record is marked; as is done in some types of self-registering instruments of smaller size, used for meteorological purposes. In case of failure of the clock, a duplicate cylinder with clock inside can be substituted in less than two minutes, as it is released by a single screw. The defective clock can then be sent away for repair without interruption to the record. This new form of instrument is also provided with interchangeable gearing by which any one of four scales can be used; corresponding to a range in the tide of 9 feet, 18 feet, 27 feet or 36 feet. Our tides have such a variety in their range, that when an instrument requires to be changed to a new position, it has usually been first necessary to return it to the makers in Britain to have the gearing altered to another scale. There are also several minor improvements, especially in so arranging the carriage of the marking pencil, that the point of the pencil is readily accessible. This is important in making the comparisons on which the datum depends to which the observations have ultimately to be reduced. A recording instrument of this new type, manufactured by Messrs. A. Légé & Co., Covent Garden, London, has been in use at Pictou during last summer with very satisfactory results. This type of instrument should be substituted as soon as possible for those now in use at the more isolated stations, because of its reliable character. Its cost, including the duplicate clock, is also considerably less than the Lord Kelvin instrument, as there are no patent rights upon it.

TIDE TABLES; THEIR PREPARATION AND IMPROVEMENT.

The improvement which can be made in the tide tables each year has to depend upon the balance remaining after the charges of first importance are met. Out of the small vote available for this survey, the special appliances for deep-sea anchorage, and all current meters and other marine instruments required for the survey of the currents have to be provided; as well as the salaries of assistants and of the tidal observers, and maintenance and supplies for the tidal stations. The question of expense made it necessary to choose between these and improvement of the tide tables. The tide tables for Halifax were based upon old records obtained at the Dock Yard in 1860 and 1861; and it was found that an additional record also existed for the years 1851 and 1852. The reduction of this record to extend the basis of the Halifax tables had already been postponed. Sufficient record had also been obtained from the tide gauge at St. John, N.B., to enable tide tables to be prepared which are much needed; as such tables as are now published are based upon a fixed difference from ports on the other side of the Atlantic and are far from accurate; and they give only the time of high water without reference to the height of the tide, which at St. John is of special importance. The tide tables for Quebec were based upon observations for one complete year only, and there is now record sufficient to improve their accuracy. On considering these various claims in view of the money available, it was thought best to give the preference to the preparation of tide tables for St. John and the improvement of the Halifax tables; and to postpone the improvement of the Quebec tables.

The tide tables for Quebec for 1897 are still based therefore upon observations during one complete year obtained from the tide gauge at the dry dock at Lévis, namely, from 7th November, 1893, to 15th January, 1895. These tables are nevertheless far in advance of anything heretofore published. The basis on which the Halifax tables rest has been extended to include the four years for which the record existed; namely, 1851, 1852, 1860 and 1861. The datum to which the tides are at present referred is the one used in the old observations themselves which were taken at the Dock Yard; but exact levels were taken in Halifax last autumn to connect the former datum with the new observations now in progress, and also with the dry dock, and when these are worked out a more definite result will be arrived at.

At St. John much difficulty has been met with, because of the want of a satisfactory datum for the reduction of the observations; as explained in a former report. It has been necessary therefore to redetermine the low water datum from the new observations themselves. This determination is being made with great care. Comparisons were made last June, with the co-operation of Mr. E. T. P. Shewen, C.E., of the Department of Public Works, to ascertain as nearly as is now possible the low water datum used in the survey of the harbour, on which the chart is based. The result when brought into relation with the present tidal observations, and the tables based upon them, will enhance the value of the chart of the harbour; and will also afford a reliable datum for future harbour works there. Tide tables for St. John are now in preparation for 1898; and they will be based upon two full years of observation in that harbour, namely, 30th April, 1894, to 18th May, 1896. They will give the height as well as the time of both high and low water.

In preparing these tide tables, the height of the tide at every hour throughout the year is taken from the record received from the tide station; and these heights are reduced to a datum as determined or selected by this survey. There are thus 8,760 actual observations of the tide obtained from any one station during the course of the year. The results thus condensed serve for the computation of future tides as given in the tide tables. This computation is made by Mr. E. Roberts, F.R.A.S., of the Nautical Almanac Office, London; by means of the latest methods of harmonic analysis and with the assistance of a tide-predicting machine, built for the government of India.

PUBLICATION OF THE TIDE TABLES.

Tide tables for Halifax and Quebec for 1896 were supplied without charge to the almanacs; and this was the first year that reliable tide tables for any Canadian ports were thus widely available. A "Notice to Mariners" drawing attention to them was issued by this department in January, 1896.

The tide tables for 1897 were again offered to all the leading British and Canadian almanacs willing to publish them; and the harmonic constants derived from the observations were also supplied to the United States Coast and Geodetic Survey, as a basis for their tables for Halifax. The tide tables for both Halifax and Quebec appear in the *Canadian Almanac*, published by the Copp, Clark Co. of Toronto; and in *Greenwood's Almanac*, published by Mr. W. N. Greenwood of Lancaster, England. The *Star Almanac* which published them last year, has not been issued for 1897. A summary of the tables for Halifax, also appears in *Belcher's Almanac*, published by the McAlpine Co.; and in *Cogswell's Almanac*, published by Mr. R. H. Cogswell of Halifax. The tide tables for Quebec are also given in a publication prepared by the Montreal Harbour Commissioners for the use of the pilot service. In all the above, due acknowledgment is made to the Tidal Survey branch of this department for the tables supplied. Three British almanacs, *Brown's*, *Jefferson's* and *Holden's*, have not yet arranged to publish them; and *McMillan's Almanac* of St. John, N.B., is only willing to publish tables for St. John itself, which will not be ready till next year. In order, therefore, to make the tide tables for this year more widely known, an arrangement was made with the Copp, Clark Co., to reprint them from the *Canadian Almanac* as an 8-page pamphlet; and copies have been sent to the agencies of this department, to collectors of customs, the secretaries of corporations of pilots and boards of trade, harbour commissioners, and the leading steamship companies; and also to thirty-six vendors of almanacs and marine publications in Great Britain, Europe, the United States and Canada.

TIDAL DIFFERENCES.

With the tide tables for Halifax and Quebec, tidal differences are given, by which the time of the tide can be found for other places along the St. Lawrence, and on the Atlantic coast of Nova Scotia. The tidal differences for the St. Lawrence have been extended, and now include the whole of the tidal portion of the river, from Three Rivers to Gaspé, a distance of 420 nautical miles.

The differences for the Lower St. Lawrence are based upon a comparison of the observations from the tide stations at Father Point and Anticosti, with the simultaneous observations at Quebec, throughout one year. The observations used for the purpose extend in all from 12th November, 1894, to 13th January, 1896. This comparison shows that the differences are very constant throughout the course of the lunar month; so that the tide at Father Point and Anticosti can thus be correctly deduced from Quebec. It was, therefore, justifiable to base tidal differences for intermediate places upon the differences between their establishments as given in the Admiralty list; and these will serve in the meantime until direct observations can be obtained throughout this region. This uniform progress of the tidal undulation up the estuary of the St. Lawrence from Anticosti to Quebec is in marked contrast to the great irregularity which is found elsewhere in the Gulf of St. Lawrence. It is, therefore, quite unsafe to assume that the difference in the time of the tide between one point and another is constant; unless it can be proved to be so by direct observation.

The differences between Quebec and places above, as far as Three Rivers where the tide ceases to be felt, are based upon two series of observations taken by Mr. R. Steckel, C.E., of the Department of Public Works, in October, 1887, and May, 1888. These observations were taken simultaneously at seven points along the river; and each series occupied one complete month, at the seasons of lowest and highest level of the water in the St. Lawrence river itself. These observations show that on the whole the tidal undulation travels more slowly up the river when the water is at its highest; it being then from eight to twelve minutes later on the average than when the level is lowest. The reason of this appears to be that the current in the river is stronger in the high level season, and thus keeps the tide back. The differences published are the mean values for the two seasons, and these should be practically exact. On the other hand, the high tide makes its way up the river much faster than the low tide, the difference in speed making the time of low water more than an hour late relatively to high water, as far up as Grondines and Champlain. It is, therefore, necessary in the tables, to state separately the tidal differences for high water and low water respectively, for places above Quebec. A comparison was also made between these observations, and the time of the tide as noted throughout the season of 1895, by the semaphore operator at Lotbinière.

The tide tables themselves are in Standard time for the 60th and 75th meridians respectively: and the tidal differences for the other places are computed to give the time of high and low water in Standard time also. In this way the master of a vessel can know the time of the tide directly from his chronometer, by allowing an even number of hours from Greenwich time, without the trouble of looking up his longitude. Standard time is also the most convenient for harbour purposes as it is now used all but universally on shore.

SPECIAL OBSERVATIONS FOR TIDAL DIFFERENCES.

In the Gulf of St. Lawrence there are regions in which the tides show great irregularity, and where constant differences with ports on the Atlantic will not apply. This will be better understood from the following comparison, which shows the great irregularity in the difference in the time of the tide across the open Gulf, as contrasted with the even progress of the tidal undulation up the Lower St. Lawrence, when once it has entered the mouth of the river between Gaspé and Anticosti:—

Difference in the time of high water between St. Paul Island in Cabot Strait, where the tide enters the Gulf, and South-west Point of Anticosti at the entrance to the St. Lawrence. Distance, 190 nautical miles. From simultaneous observations in six months during the years 1893 and 1894. Difference in absolute time ranges from 4 h. 30 m. to 6 h. 50 m.

Difference in the time of high water between South-west Point of Anticosti and Quebec, omitting irregularities due to wind. Distance, 360 nautical miles. From simultaneous observations during eleven months in 1894 and 1895. Difference in absolute time ranges from 5 h. 13 m. to 5 h. 39 m. Mean = 5 h. 26 m.

The wide range in the difference of time across the open Gulf, is chiefly due to an unusually great diurnal inequality in Cabot Strait itself; that is, a long interval and a short interval of time between the tides of the same day. It is remarkable, when this inequality is so great in the main entrance to the Gulf by which the tide comes in from the Atlantic, that it should so disappear that scarcely a trace of it is to be found in the tides of the Lower St. Lawrence or at Quebec. On the other hand, this inequality is very marked in Northumberland Strait and the neighbouring regions. It is probable that this is due to tidal interference, occasioned by some contrary tidal undulation which over-runs the main tide entering through Cabot Strait.

The practical results of this inequality are very evident, however. On account of the importance of St. Paul Island in the main entrance to the Gulf, many endeavours have been made to establish a constant difference between it and some port on the Atlantic coast of America or in Europe; but the inequality is there so great that these endeavours have been without result. This diurnal inequality is also very marked at Pictou and Charlottetown in the region referred to.

The diurnal inequality varies with the declination of the moon north or south of the equator; and not with the moon's phases as in the case of the ordinary change from spring tides to neaps. This change still goes on, while the other variation is superadded; and as it takes place in a different period, it is continually overrunning the former. The resulting irregularities are, therefore, very great, unless these two causes are carefully distinguished from each other.

These conditions made it necessary to obtain direct tidal comparisons between the important harbours of this region and the tides as they enter Cabot Strait. For this purpose, the tide-gauge at St. Paul Island was essential, and as it has been twice destroyed by winter storms in three years, on account of its exposed situation, it was necessary to obtain the required observations without delay. A tide-guage had also been erected at Halifax in the previous season, and the gauge at Anticosti had been put in good order; and as any of these might prove necessary for purposes of comparison, it was advisable to obtain the new observations while they continued in good working order. It was also important to determine how far south of Gaspé in the Bay des Chaleurs and along the New Brunswick coast, the tides could be referred by constant differences to Anticosti and Quebec; and where the irregularities due to diurnal inequality first manifested themselves.

Arrangements were therefore made to take special observations in the region extending from Gaspé along the south-western side of the Gulf, through Northumberland Strait, and around Prince Edward Island. As this comprises some 580 miles of coast-line, it was necessary to select places which were reasonably accessible, to avoid undue delay in travel. The principal harbours in the region had the first claim; and consideration had also to be given to the relative importance of places from a tidal point of view, so as best to obtain tidal differences for intermediate points. The choice of the following places as temporary tidal stations was accordingly made: Carleton, as near the head of the Bay des Chaleurs as possible, while avoiding the local influence of the Restigouche River; Lower Neguac, near the mouth of Miramichi Bay, to obtain the open tide unaffected by the bars and rivers of the bay; Charlottetown, where the tide in Northumberland Strait has the greatest range; Pictou, in line with the open channel between Prince Edward Island and Cape Breton Island, up which the tides pass; and Souris, the nearest port to Cabot Strait which is readily accessible, as there is no railway communication on the west side of Cape Breton Island.

The erection of temporary tide-gauges at these places and the superintendence of the observations was entrusted to Mr. H. M. Mackay, who carried out the work very efficiently. By the use of self-registering instruments, more than twice as much information was obtained as could have been got by direct or personal observation with four to five times the expense.

At Pictou, the recording instrument of new design, already referred to, was used. At the other stations the instruments were of a smaller type than those at the principal tidal stations; they were of the Richard pattern, supplied by Casella of London, and were made with a scale specially adapted to this region. They are strong and simple in construction, so that the manipulation presented little difficulty to inexperienced observers. The complete tide-gauge was as follows:—firstly, a vertical plank box, to serve as a tide well, which could be strapped to the side of a wharf; holes were bored in the lower end sufficient to admit the water freely, but not to allow of inconvenience from wave motion. A shelter box containing the registering instrument, was placed directly on top of the tide well. As these tide-gauges were in operation during the summer months only, they did not require to be built in the same substantial manner as when they have to withstand the severity of the winter and to be provided with heating. They could thus be set up at small expense wherever a wharf or pier was found running out beyond the low-water line.

The readings of the instrument as regards elevation were checked by comparison with a graduated staff set up beside it; and the elevation of the zero of the staff was referred to a bench mark on shore. At most of the stations, time could be obtained from railway telegraph offices; but where there were no such facilities a meridian mark was placed, and the observer was supplied with a table giving the "Sun on meridian" in 60th standard time.

The results obtained at these five stations were supplemented by observations at places which stood next in importance, in obtaining correct tidal differences. On the coast between Miramichi Bay and Pictou, short series of staff readings were taken at Richibucto, Buctouche and Pointe du Chêne; and a gauge record during two months in all, was obtained at Cape Tormentine, where the strait is narrowest. Also, on the north coast of Prince Edward Island, a short gauge record was obtained at St. Peter's Bay and at Alberton, and staff readings at Rustico.

The total amount of tidal information obtained is shown in the following list. Throughout the progress of this work, a simultaneous record of the tide was obtained at the principal stations at Halifax, St. Paul Island and Anticosti. Also, where the observations were obtained by self-registering instruments, they were continuous day and night during the time indicated. The only interruption of consequence occurred at Charlottetown, where the partial chokage of the inlet made the observations unreliable for a time.

Carleton..................	June 29th	till	Nov. 9th.	Gauge record.
Neguac....................	July 20th	do	Nov. 6th.	do
Richibucto................	Aug. 5th	do	Aug. 8th.	Staff readings.
Buctouche	Sept. 15th	....		do
Pointe du Chêne...........	Sept. 8th	till	Sept. 11th.	do
Cape Tormentine...........	July 25th	do	Aug. 10th.	Gauge record.
do	Aug. 31st	do	Oct. 10th.	do
Charlottetown.............	June 20th	do	June 29th.	do
do	July 18th	do	Nov. 25th.	do
Pictou	June 3rd	do	Nov. 27th.	do
Souris....................	June 11th	do	Nov. 24th.	do
St. Peters Bay............	Oct. 27th	do	Nov. 24th.	do
Rustico...................	Oct. 20th	do	Oct. 24th.	Staff readings.
Alberton..................	Oct. 13th	do	Oct. 23rd.	Gauge record.

Such tide tables as are now published in local almanacs for ports in this region, are based on constant differences from Halifax or some other Atlantic port; and it is, therefore, evident that they must necessarily be far from correct. Their error is greatest when the moon's declination is at its maximum, north or south of the equator. The observations of this season show that the time of high water as given in the local almanacs now published, is in error by the following amounts:—At Pictou 1 h. 25 m. early or late; at Charlottetown, 1 h. 12 m. early or late. These errors correspond approximately with the half-range of diurnal inequality, which at Pictou amounts to 1 h. 15 m.; and at Charlottetown also it is nearly as great.

It has been possible to obtain from the present observations a variable difference with Halifax in terms of the moon's declination, which has enabled tide tables to be prepared for Charlottetown and Pictou in time for the season of navigation of 1897. Tables prepared in this way will be sufficiently accurate to be practically serviceable; and they will answer in the meantime until better data can be obtained from a more thorough analysis of the present records, or from a longer series of observations. The observations obtained at the other places will be used to extend the tidal differences supplied with the tide tables for next year.

The tidal differences which have been published, with the tide tables up to the present time are limited to regions in which their accuracy can be depended upon, as proved by direct observation; as otherwise serious errors might be made. It is therefore, very important to extend these differences each season as far as possible; and this can now be done at a relatively small expense, while the principal tidal stations are available for comparison. Observations are now much required around Cape Breton where there are several important coaling ports; also on the southwestern coast of Nova Scotia, and throughout the Bay of Fundy; as well as along the Lower St. Lawrence at intermediate points between Quebec, Father Point and Anticosti.

The determination of tidal data for the north shore of the Gulf, from Point de Monts past the Mingan Islands and Cape Whittle to the Strait of Belle Isle, has not yet been attempted by this survey; but this is a region which is relatively of less importance.

OTHER INFORMATION AND RECORDS OBTAINED.

With a view to future work in the Bay of Fundy, copies were made last season by permission of the late H. G. C. Ketchum, C.E., of the tidal information obtained by the Chignecto Marine Railway Co. The accurate levels carried from Chignecto Basin to Bay Verte, serve to connect the mean sea level in the Gulf and in the Bay of Fundy, and the levels of high and low water on both sides of the isthmus have been obtained with reference to the marine railway datum.

The level reached by the exceptionally high tide of October 8th, 1896, was also obtained at Chignecto and Moncton, with reference to railway datum planes; and in relation to the Saxby tide of 1869. This high tide in October overflowed the dykes of the hay lands in the neighbourhood of Amherst and along the Petitcodiac River, and did much damage. If a tide of this height proves to be due to astronomical causes alone, as appears probable, its recurrence under similar conditions will be subject to prediction in future, as the level reached has now been ascertained; and warning may thus be given.

It would be a great value if warning could be given for exceptionally high tides at Quebec and St. John, which occur during storms and often do much damage. It is not impossible that the effect of meteorological conditions upon the tide may eventually be arrived at, from a careful comparison of wind and barometer with the exceptional tides recorded by the tide gauges. The necessary data for the purpose are being collected as time goes on.

A request has been received from the pilot service to prepare a tide table for the pilot station at Father Point. To save expense in printing, this has been made out in manuscript only, in time for the opening of navigation.

Copies of the tidal record for two leading points in British Columbia have been received regularly since January, 1895. These are from self-registering gauges erected by the Department of Public Works at Victoria, and at Sand Heads at the mouth of the Fraser River, in the Gulf of Georgia. Observations are also received from New Westminster, and from a point intermediate between it and the mouth of the Fraser River. These records will soon be sufficient for the preparation of tide tables for these points, when office time can be given to it, and the expense of the computations can be met.

Some tidal data for the St. John River were kindly supplied by Professor A. W. Duff, of Purdue University, LaFayette, Indiana, in exchange for information regarding secondary tidal undulations at St. John, N.B., which he is investigating. Professor Duff obtained these data last season while at his country residence on the St. John River.

Tidal information from the gauges at Quebec, Father Point and Halifax has been supplied to Mr. R. Steckel to facilitate the work of geodetic levelling which he is carrying out for the Department of Public Works; and copies of the tide curves from those stations have been of value to him in the determination of mean sea level.

SURVEY OF THE CURRENTS.

The region examined this season was the north-eastern portion of the Gulf of St. Lawrence, from the eastern end of Anticosti to the Strait of Belle Isle. It forms an arm which lies between Newfoundland on the south-east, and Saguenay County in the province of Quebec on the north. This north shore is often termed "Labrador," which is both incorrect and misleading; as no part of the Gulf is bordered by Labrador, and it is also a territory belonging to Newfoundland and not to Canada. The length of this arm of the Gulf is 220 miles, and in area it is nearly equal to the English channel. It is traversed by all the steamship lines which use the St. Lawrence route; which makes the investigation of its currents of the first importance.

The region under consideration has a width of 100 miles between Cape St. George (Newfoundland) and East Cape (Anticosti) and runs in a north-eastward direction to the Strait of Belle Isle, where its width narrows down to 10 miles. From this main arm of the Gulf, a side channel runs off to the north-westward, between Anticosti and the north shore. This channel has a width of 60 miles between the east end of Anticosti and Natashquan Point, and narrows down to 16 miles at the Mingan Islands, in a length of 115 miles. Around the greater part of the shores which bound these areas, the water increases gradually in depth to 60 or 80 fathoms at about 20 miles from the shore; and along the middle of the main arm and the channel north of Anticosti, there is a deep channel of 100 to 150 fathoms in depth. This deep channel continues through Cabot Strait with increasing depth to the Atlantic. (See outline chart, Plate 1).

For the investigation of the currents in this region the SS. "Lansdowne," of the lighthouse and buoy service, was placed at my disposal for three months—July, August and September, 1896. From this time considerable deduction has to be made for interruption to the work in obtaining supplies, and for rough weather; and also a necessary visit to the tide-gauge in the Strait of Belle Isle. The nearest port for coal and supplies was North Sydney, C.B., but there were places along the shore where water could be obtained from the natural streams. When shelter was required it was usually necessary to make a long run to obtain it. The investigation of the currents was carried on by myself, with the assistance of Mr. G. G. Hare, who also took continuous meteorological observations. The commander of the vessel, Captain G. W. J. Bissett, and the first officer, Mr. J. B. Sutherland, gave valuable co-operation in furthering the work; and also the second and third officers, N. McKellar and A. Lane, in noting the direction of the current during the night.

As the steamship route traverses the region in question on a direct line from Heath Point, Anticosti, to the Strait of Belle Isle, it was decided to give most attention to the study of the currents met with along this route itself. It was important to ascertain whether any general set existed either with or against vessels on this route: and also whether there was any cross-set making out or in through the channel north of Anticosti. A set of either character, if found to exist, might put a vessel seriously out of position in rounding Anticosti or making the Strait of Belle Isle. Little was known with respect to what currents were likely to be met with in this region, beyond what had been already ascertained by this survey. It was thus known that the current in the Strait of Belle Isle itself was tidal in its character, with a flow nearly equal in each direction, and that the difference of flow inwards towards the Gulf was very slight; and consequently it was not to be expected that a constant current of any considerable strength would be found to run through this region towards Cabot Strait. It had also been ascertained that the current at the other extreme angle of this region, namely, in the Mingan channel, was likewise tidal in its character, with a flow which was practically equal in the two directions. (See Report of Progress on this survey, 13th April, 1896; page 17.) On the Admiralty charts two currents were indicated locally, in the channel north of Anticosti; one setting to the south-east round Natashquan Point; and the other near the eastern end of Anticosti from Table Head to East Cape, setting to the southward. Such currents, if they proved to be constant in their character, might furnish a valuable indication; as they might be the shore edges of a general outward set in that channel; or on the other hand they might imply a return flow inwards up the middle of the channel. A set in either of these directions would be directly across the steamship route from the offing of Cape Whittle to Heath Point. It was, therefore, important to obtain continuous observations at the points where these currents were shown; to ascertain whether they were really constant, and for comparison with the currents as found in the open channel. For this purpose two pairs of flag-buoys were made and provided with suitable moorings; the larger buoy carried a white flag and was fastened directly to the moorings; and the other was attached to it by a line 200 feet in length and carried a red flag. As these buoys swung round on their moorings, the direction of the current could be readily observed from shore at a distance of two or three miles. Arrangements were made with two men to take these observations, and they were brought from North Sydney on the steamer. One of them was landed at East Cape, and provided with a tent and camp outfit. A pair of buoys was placed off the cape, where they were also in view of the lighthouse at Heath Point. As this observer left his post after a short time, the observations were continued from the lighthouse itself, until the buoys went adrift during a gale. The other observer was landed at Natashquan Point, and took up his quarters in a shed, the only building remaining at the abandoned Hudson Bay post. He was also provided with a boat, which could be anchored out to ascertain the direction of the current. This was very useful, especially during fog when the flags could not be seen. The time of change in the current was taken on a watch, which was regulated during the season by a table giving time of sunset. The positions of the two pairs of buoys are shown on the chart, Plate I. The results obtained will be referred to when the nature of the currents in the various localities is described.

In addition to the direct observations above referred to, information was requested from the leading steamship companies traversing this region, in reply to circulars prepared for the purpose and supplied to their captains, on which the character of the current met with on each voyage could be entered. Much useful information, especially as to the character of the currents at other seasons of the year, was obtained from fishermen and others acquainted with these waters.

GENERAL METHODS EMPLOYED.

The general method used to ascertain the nature of the currents, was to anchor the steamer at various points or stations carefully chosen. The steamer itself was thus a fixed point from which to determine the direction and velocity of the currents. As these currents are all influenced by wind and tide, it is important to have good meteorological and tidal data for comparison with the observations obtained at the various stations themselves. The only permanent meteorological stations at which continuous observations of wind and barometer could be obtained for comparison, are at the extreme ends of the region in question; namely at South-west Point, Anticosti, and on the island of Belle Isle; distant 360 miles from each other. The local wind record obtained on board, was not always satisfactory; as sometimes during the heaviest winds, the steamer lay close to the coast, or was anchored in some bay for shelter. The tidal data required are better given: as two of the principal tidal stations established by this Survey, are at South-west Point, Anticosti, and at Forteau Bay in the Strait of Belle Isle. These tide stations are within about 100 miles of the localities where tidal influence in the current was most distinctly detected.

In addition to the regular observations of the currents, the density of the water and its temperature were taken at regular intervals along all the courses which there was occasion to run. In this way an extensive series of densities and temperatures were obtained; and some of the same lines were run twice at different dates for comparison. This method has often been found useful in tracing the direction of the movement of the water. Also, at anchorage stations where the current was found to veer widely in its direction, the temperature of the water was taken every half hour in the hope of finding some difference to accord with the varying direction of the current itself.

The depth at which it was necessary to anchor at the various stations, ranged from 30 to 150 fathoms; and the holding ground was often very poor; as the bottom was sometimes flat rock lying horizontally, or soft mud. This mud was usually met with at the greater depths. The steamer itself is too heavy for the purpose, and difficult to hold. Its sides are so high, especially towards the bow, that the wind pressure alone is often enough to make it drag anchor on such bottom; especially when the current holds it broadside to the wind. In many cases the rough weather only lasted a few hours, as the sea falls very quickly in the Gulf; and if the vessel could have been held while it lasted, much time would have been saved. On one occasion in endeavouring to do so, the mooring hawser of steel wire one inch in diameter was parted, and the best anchor for holding was lost. The available shelter was so far distant, it was usually more advantageous to "lie to" in the open and keep in the vicinity of the station, even if the heavy weather lasted a day or two. The anchorage appliances used, which are of a special character, have been described in previous reports. They were improved and re-inforced as much as possible for this season's work.

METHOD OF OBSERVING THE CURRENTS.

It soon became evident that the methods employed in previous seasons would require much modification, owing to the difference in the character of the currents. The currents examined in former seasons had considerable strength, from one to three knots, and generally a uniform direction for at least some hours at a time. Their chief variation was in velocity, which fluctuated with the tide, or fell off with the depth. But the currents in the region examined this season varied chiefly in their direction. They usually veered in direction from hour to hour, often going completely round the compass, and the direction at any depth was often different from the surface direction. Their speed was always low, seldom exceeding one knot per hour. Hence the direction of the current, both at the surface and below, was of much more importance relatively, than the accurate determination of velocity. At the first station occupied, where the depth was 155 fathoms, a number of careful measurements of the velocity were made, with a current meter, as far down as 80 fathoms. The velocity was found to vary very irregularly at different depths, and as the meter did not indicate direction, these observations proved of little value. To understand these currents, it was found quite as necessary to examine the under-current as the surface current itself, as will be more fully explained when the influences that affect them are discussed. The methods adopted to arrive at their nature were, therefore, as follows:—

The direction of the current on the surface was obtained by a float attached by a line to the stern. This float was made of a board painted white, with short pieces standing out vertically from its under side to give it a good hold in the water; and weighted with lead to bring it even with the water and prevent the wind from having any hold upon it. The direction of the current was read by taking its bearing on a dumb compass at the stern; which was set to the heading of the ship at each observation. The direction of the surface current was thus obtained every half hour, continuously, day and night. The velocity of the current was measured by a current meter, registering electrically by means of a counter on board. This meter was placed at a depth of 18 feet (three fathoms) which is the standard depth adopted in this survey from the beginning; as it is necessary for accuracy to measure the velocity below the level of the keel of the steamer, which has a draught of 13 feet 6 inches. The direction of the current at 18 feet was readily observed during the day time, by noting the position of the meter in the water. This direction often differed as much as two points from the direction at the surface. The direction in which the current would set a vessel of ordinary draught was, therefore, better given by taking the average between the direction on the surface, and the direction at 18 feet. This average is given in the results shown in the plates, whenever the double observations were obtained, as there noted. The velocity of the current was noted from the counter attached to the meter, every half hour during the day time; but the importance of the velocity measurements did not warrant the continuance of these observations during the night; and the direction at 18 feet could not then be seen. The meter was, therefore, kept at work for 12 hours a day only.

The under-currents were examined by means of a "deep fan," consisting of two sheets of galvanized iron passing through each other at right angles, and thus forming four equal wings; and suspended in the water by patent sounding wire. This appliance was used with a Thomson sounding machine, on which the depth at any moment could be read off very conveniently. The fan was 26 inches deep, and each wing was 9 inches wide; and its area, which was practically the same in any position in the water, was 3·25 square feet. The fan itself weighed 14½ pounds, and in these slow currents it was used without the addition of any further weight or sinker. The sounding wire by which it was supported consisted of three strands of fine wire braided over; its thickness over all being a little less than one-tenth of an inch. This simple appliance was found to afford a very delicate means of determining both the direction and strengh of the under-current at any depth, where the currents themselves were so low in their velocity. The fan would swing out from the vertical in the direction of the current, and the supporting wire was so fine that the current nearer the surface had practically no hold upon it. In this way the direction could usually be found to the nearest point. The velocity could also be ascertained very closely by reading the inclination of the supporting wire to the nearest degree with a clinometer. The velocity corresponding to each inclination was determined by direct experiments, from which a table was made to reduce the observations. To obtain the correct depth, the fan was lowered to the surface of the water and the dial of the sounding machine set at zero. The reading on the dial then gave the depth below the surface correctly if the inclination of the wire did not exceed 15° from the vertical. When the angle was higher than this, additional wire was let out to allow the fan to reach the true depth. The amount required was found in a moment by means of a table of cosines of angles. This was carefully attended to in making the experimental observations for the velocity corresponding to the inclination.

For this purpose the calmest days were chosen, and the fan was lowered to 18 feet, the same depth as the meter. The meter register for the velocity and the inclination of the wire of the fan were taken at exact intervals of five minutes. In this way 43 determinations were obtained of the velocities corresponding to the various inclinations from 10° to 30°. These were first classified according to the inclinations, and the average velocity for each inclination was obtained. The velocities so found were then plotted graphically, and a mean curve drawn through the points. This curve was a parabola, for which the best form of equation is as follows:

$$v^2 = 1{\cdot}067 \tan i,$$

in which v is the velocity in knots per hour, and i the inclination of the wire from the vertical. The form of the curve shows also that for inclinations beyond 30°, which sometimes occurred, proportional values may be correctly used. A few values may be given as samples, from the tables thus obtained, which will serve to show that the velocities of the under-current, which are given in tabular form with this report, are quite reliable to the tenth of a knot, which is as closely as they are given. With so light a fan, flaws in the current itself were often noticeable, which gave different inclinations, especially near the surface. When this was the case a mean value was obtained, in taking the observations.

Inclination i, in degrees.	4°	6°	8°	10°	15°	20°	25°	30°
Velocity v, in knots per hour.....	0·27	0·33	0·38	0·43	0·53	0·62	0·71	0·79

In using the deep fan for the observation of the under-currents, it was generally best to lower it first to the greatest depth, where the inclination was usually nearest the vertical; and in raising it the inclination would increase towards the surface, as the current became stronger. In this way a set of observations from a depth of 30 or 40 fathoms to the surface could be obtained quickly, which was often important when the current was veering and changing.

It would have been very helpful in understanding the currents in this region, if the direction of the under-current could have been obtained at regular intervals at some standard depth, say every half hour at 30 fathoms. This was attempted, but found to be impracticable owing to the swinging of the vessel on its hawser. This swinging was the chief difficulty; and to obtain reliable results much patient watchfulness was required, to take advantage of times when the vessel was most steady. The swinging was partly due to the slowness of the currents themselves, as the vessel lay "between wind and current," and every flaw of wind drove it against the current or allowed it to swing back. When the current was strongest, it would lie the most steadily even in a stiff breeze. The trouble was largely owing to the unsuitable character of the vessel itself. With a length of 180 feet, it has an area above water on a longitudinal section of 2,980 square feet. Its high sides, especially towards the bow, give the wind a great hold upon it; and this appears to explain the worst kind of swinging that occurred, when the vessel would head first to one side and then to the other, after the manner of a kite in the air. Under certain conditions this would continue for two or three hours at a time, until a change occurred in either wind or current. The change of heading amounted to two or even four points, in a corresponding period of ten to twenty minutes; and the extent of the swing was therefore great, as the depth of anchorage usually ranged from 40 to 80 fathoms, and the length of hawser was twice to three times the depth, which gave a long radius for swing. The trouble was sometimes mitigated by hoisting a try-sail aft. But while any serious amount of swinging went on, the under-current observations by the method described were not attempted, as then also the closest attention was required to find the correct direction of the surface current itself. To obviate any uncertainty in the under-current observations, a reflector was attached to the binnacle compass which enabled it to be watched constantly while standing by the deep fan, and in this way any swinging of the vessel could at once be detected.

All directions and bearings given throughout this report, are magnetic. The variation in this region ranges from 29° to 34° west.

The methods used for accuracy in the determination of densities, and temperatures, were the same as those already described in last year's report. (See Report of Progress, April, 1896; pages 9 and 10.)

SELECTION OF STATIONS.

The stations for the observation of the currents were chosen to ascertain the actual nature of the currents met with on the main steamship route already referred to; and also whether there were any currents of a constant character, or any general circulation in the north-eastern portion of the Gulf of St. Lawrence. As the first question requiring examination, was whether there was any cross-current on the route from Cape Whittle to Heath Point, the first station occupied in the early part of July, was station A between these points, and at the middle of the channel lying between Anticosti and the north shore. (See chart, Plate I). This station is at an equal distance from the nearest shores on the two sides of that channel; being 35 miles off Table Head, Anticosti; and also 35 miles off Kegashka Bay on the north shore. It is also a little within the line joining Cape Whittle and Heath Point; and is, therefore, well placed to ascertain whether there is any indraught or outflow of current along the line of this channel. The depth of water is 155 fathoms. The weather was exceptionally quiet and favourable; and as spring tides occurred while there, any tidal influence in the current should be at its maximum.

Station B is 24 miles S.E. of Heath Point, and lies on the centre line or axis of the island of Anticosti; and it is also at the intersection of lines lying tangent to the 30 fathom banks, off the south-west and north-east sides of the island at its eastern end. It is thus well situated to obtain the direction of currents which may be guided by the trend of either shore of the island, or the edges of the outlying banks. The depth of water is 52 fathoms.

It was desirable to occupy this station again in September; but as the weather was then more broken, a position was chosen at station H, nearer to Heath Point. In this way it could be more quickly reached whenever the weather was sufficiently moderate to hold at anchor. During nine days anchorage was made four times at this station; and two of these days were too rough to make the attempt. Although the position made was closely the same each time, the depth ranged from 35 to 42 fathoms. This was still sufficient for good under-current observations.

Station C is 18 miles off Cape Whittle, where the main bend in the north shore occurs. It affords a good position to ascertain any relation between currents that may follow the trend of the shore in either direction; and also to detect any tidal element which may influence the currents.

Stations D and E are situated further to the eastward along the north shore. They are 13 to 15 miles from the coast, which makes their situation similar to station C, with reference to any current which may follow the direction of the coast itself. Station E is so placed also, as to be away from the vicinity of the inlets on that part of the coast, and thus to avoid any local cross-currents of a tidal character. The depth at station D is 45 fathoms, and at E, 98 fathoms. These six stations all lie in the vicinity of the steamship route from Belle Isle to the St. Lawrence.

Stations F and G are similarly situated with respect to the coast of Newfoundland; and the same considerations influenced the choice of their positions. Station G is quite beyond the influence of any local current from Bonne Bay. The depth at these stations is 40 and 42 fathoms respectively. It was found better, owing to the irregular character of the currents themselves, to occupy these eight stations for a longer time, rather than to attempt observations at a greater number of points, in the time available for the work.

GENERAL CHARACTER OF THE CURRENTS.

In the region referred to, the currents in the summer months are all very moderate in their speed, usually ranging from about half a knot to one knot per hour. It is reported, however, that there are currents much stronger than this in the spring of the year; but this we will have occasion to refer to again. In their direction the currents are extremely variable and irregular, especially towards the surface; that is, in the layer of water between the surface and five or ten fathoms in depth. Below this, the under-current at 20 and 30 fathoms may sometimes show more definite characteristics; as for example a tendency to make constantly in some one direction, or to vary with the tide. The surface current often appears, therefore, to have little relation to the under-current in its direction or velocity, in the time at which it slacks, or the manner in which it veers.

The reason most probably is that the surface of the water is more directly affected and disturbed by the influence of the wind; while the under-current may continue to follow the law which dominates in any particular locality. A noteworthy example of this has already been described in the case of the current in the Strait of Belle Isle. (See annual report, Department of Marine, for 1894; page 99.) The usual tidal character of the current in that strait is maintained by the under-current, at times when the surface current is gradually acquiring a constant set in one direction under the influence of heavy and continuous wind.

It is thus essential to give careful attention to the investigation of the under-current in order to understand the surface current itself; for if it is the movement of the under-current which is more in accordance with the normal conditions of the locality, it will come up to the surface as soon as the disturbing influences which have been acting on the surface of the water, cease to operate. The study of the under-current is therefore also necessary, if any hope is entertained of arriving at the general circulation in this portion of the Gulf, or the true relation of its currents to the causes which influence them.

The general causes which act upon both the surface and the under-current, and often affect them so differently are:—1. Tidal influence. 2. The influence of the wind and barometer. 3. A cause of a wider character which shows itself as a tendency in the current to set constantly in some one direction.

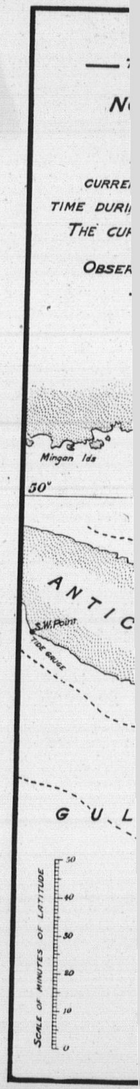
In describing the actual behaviour of the currents as ascertained from the observations taken, and from the information which was collected during the season, we will have occasion to refer to the effects of these influences upon the currents, so far as they can be traced. The observations will also show the limiting speed of the currents; their prevailing directions; and the range of direction in which they may possibly set; all of which is of direct practical value.

NATURE OF THE CURRENTS AS OBSERVED.

The positions of the stations at which the observations were made, are shown on the outline chart, Plate I. The actual directions of the surface current at the various stations are shown in Plates II. and III., in which the times of high water and low water from the tidal station at South-west Point, Anticosti, are also given for comparison. In Table I., a summary is given to show the time during which the current set in each direction at the various stations, and the time during which there was no current. This table is made from the observations of the current every half hour, by summing up the total number of half-hours during which the current set in each direction. It serves to show whether the current has any dominant direction; and also the directions through which it may veer and in which it is most prevalent. The same result is shown graphically on the chart, Plate I.; where the arrows radiating from each station in the eight leading directions, indicate the prevalence of the current in each of these directions. (The length of the arrow gives the time that the current ran in its direction, as a percentage of the total time that the station was occupied. Hence the total length of the arrows at each of the stations is the same, if the time during which there was no current, is allowed for; as this length makes up 100 per cent in each case.)

The observations of the under-current are given in Table II. The direction and velocity at the surface and three fathoms, were obtained from the surface float and the meter record. From three fathoms downwards, the results were obtained by the deep fan as already explained. Many of the individual results given at the different depths, were careful averages, or were taken twice, or checked by both meter and fan. Any results in which there was any uncertainty, from the swinging of the ship or other causes, are omitted; and in this way some of the longer intervals of time for which no observations are given, are accounted for.

In reviewing the results obtained at the different stations we may first notice those at station C, as this is a typical station in the central part of the region under consideration. It will thus serve to illustrate the nature of the currents in the open waters, as this station lies 18 miles off Cape Whittle. It was also occupied twice,



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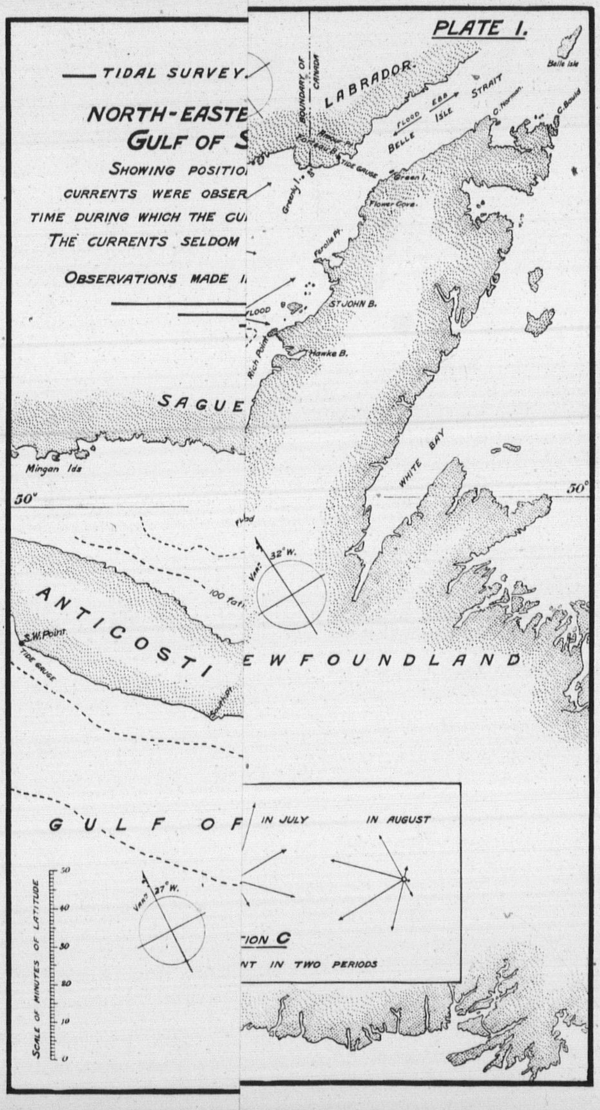

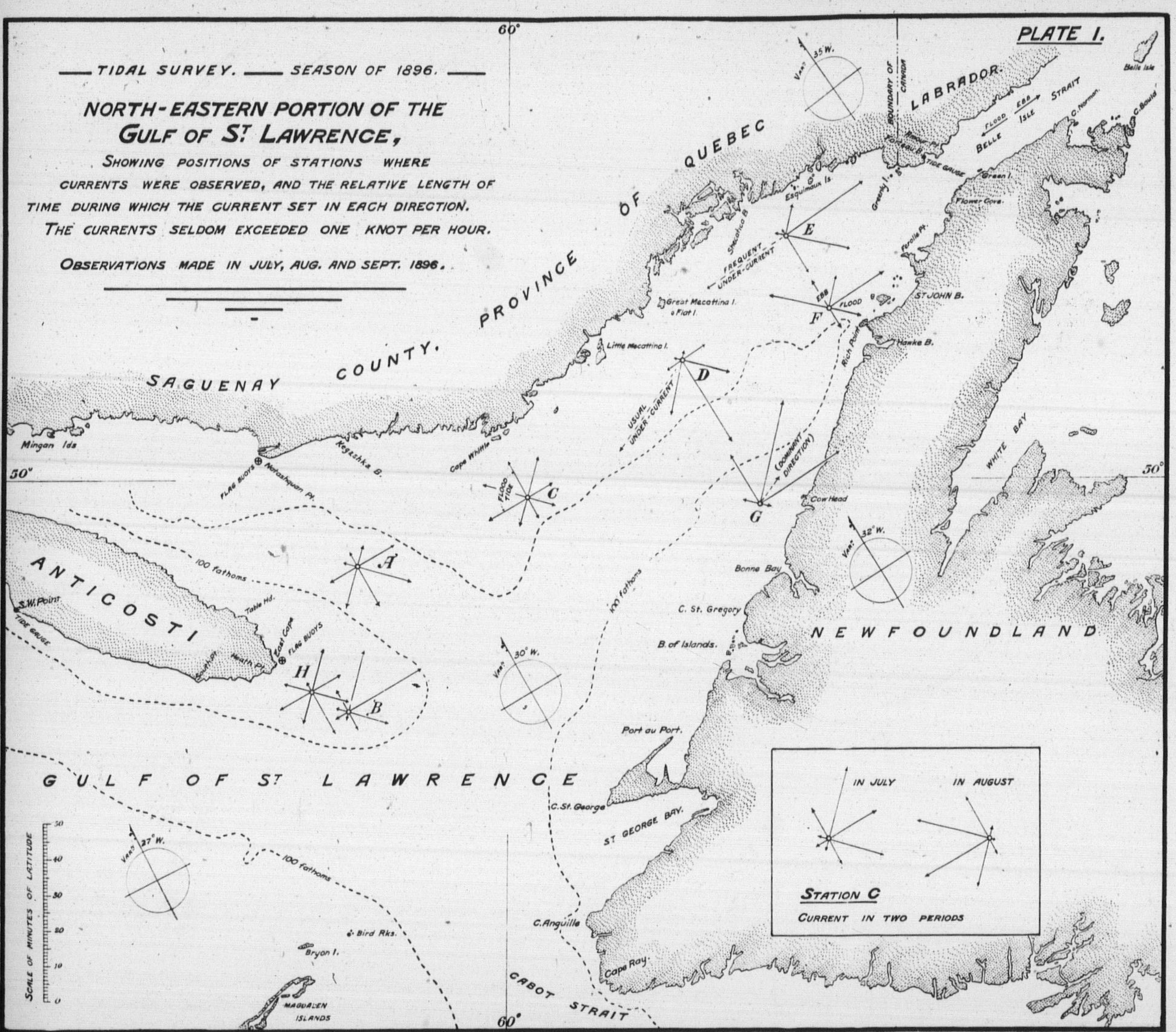
PLATE I.
TIDAL SURVEY. — SEASON OF 1896.
NORTH-EASTERN PORTION OF THE GULF OF ST LAWRENCE,
SHOWING POSITIONS OF STATIONS WHERE CURRENTS WERE OBSERVED, AND THE RELATIVE LENGTH OF TIME DURING WHICH THE CURRENT SET IN EACH DIRECTION.
THE CURRENTS SELDOM EXCEEDED ONE KNOT PER HOUR.
OBSERVATIONS MADE IN JULY, AUG. AND SEPT. 1896.
60°
50°
PROVINCE OF QUEBEC
LABRADOR.
SAGUENAY COUNTY.
BOUNDARY OF CANADA
BELLE ISLE STRAIT
FLOOD
EBB
Belle Isle
C. Norman
C. Bauld
Green I.
Flower Cove.
Esquimaux Is.
ST JOHN B.
Hawke B.
Rich Point
Great Mecattina I.
Flat I.
Little Mecattina I.
Mingan Ids
Natashquan Pt.
FLAG BUOYS
Cape Whittle
FREQUENT UNDER-CURRENT
USUAL UNDER-CURRENT
DOMINANT DIRECTION
FLOOD TIDE
A
B
C
D
E
F
G
H
Cow Head
WHITE BAY
Bonne Bay
C. St. Gregory
B. of Islands.
NEWFOUNDLAND
ANTICOSTI
S.W. Point
TIDE GAUGE
Table Hd.
East Cape
Heath Pt.
100 fathoms
Var. 35° W.
Var. 32° W.
Var. 30° W.
Var. 27° W.
GULF OF ST LAWRENCE
Port au Port.
C. St. George
ST GEORGE BAY.
C. Anguille
Cape Ray.
CABOT STRAIT
Bird Rks.
Bryon I.
MAGDALEN ISLANDS
SCALE OF MINUTES OF LATITUDE
50
40
30
20
10
0
IN JULY
IN AUGUST
STATION C
CURRENT IN TWO PERIODS

TIDAL SU

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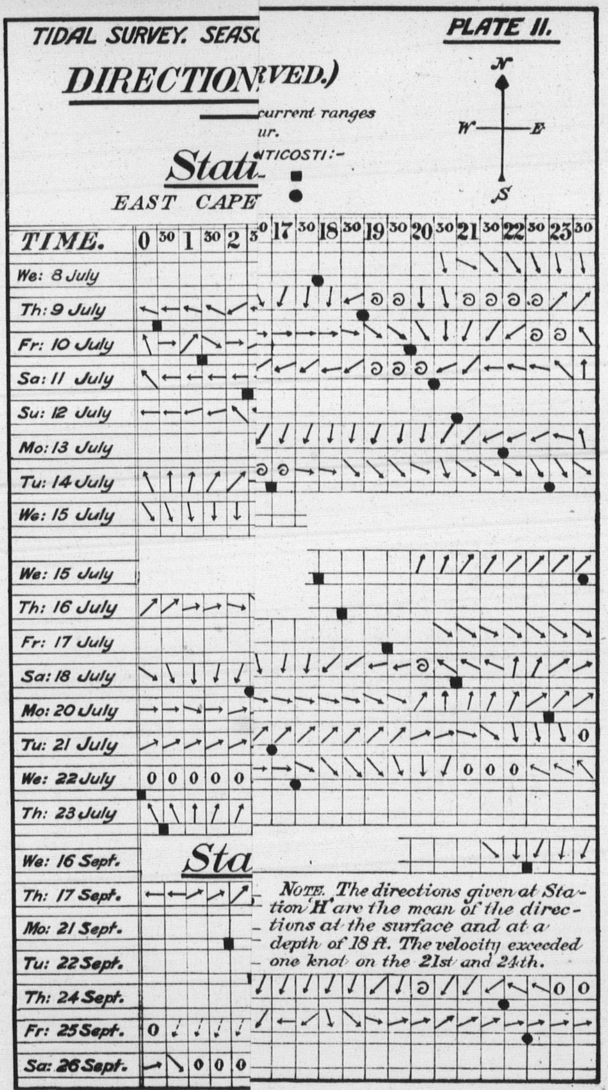
TIME.	(	
We: 8 July		
Th: 9 July	←	
Fr: 10 July	↖	
Sa: 11 July	↖	
Su: 12 July	←	
Mo: 13 July		
Tu: 14 July	↖	
We: 15 July	↘	
We: 15 July		
Th: 16 July	↗	↗
Fr: 17 July		
Sa: 18 July	↘	↘
Mo: 20 July	→	→
Tu: 21 July	↗	↗
We: 22 July	0	0
Th: 23 July	↖	↖
We: 16 Sept.		
Th: 17 Sept.	←	←
Mo: 21 Sept.		
Tu: 22 Sept.		
Th: 24 Sept.		
Fr: 25 Sept.	0	↙
Sa: 26 Sept.	→	↘



TIDAL SURVEY. SEAS
PLATE II.
DIRECTION
VED.)
current ranges
ur.
NTICOSTI:-
Stati
EAST CAPE
N
W
E
S
TIME.
0 30 1 30 2
17 30 18 30 19 30 20 30 21 30 22 30 23 30
We: 8 July
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We: 22 July
Th: 23 July
We: 16 Sept.
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Th: 17 Sept.
Mo: 21 Sept.
Tu: 22 Sept.
Th: 24 Sept.
Fr: 25 Sept.
Sa: 26 Sept.
NOTE. The directions given at Station 'H' are the mean of the directions at the surface and at a depth of 18 ft. The velocity exceeded one knot on the 21st and 24th.

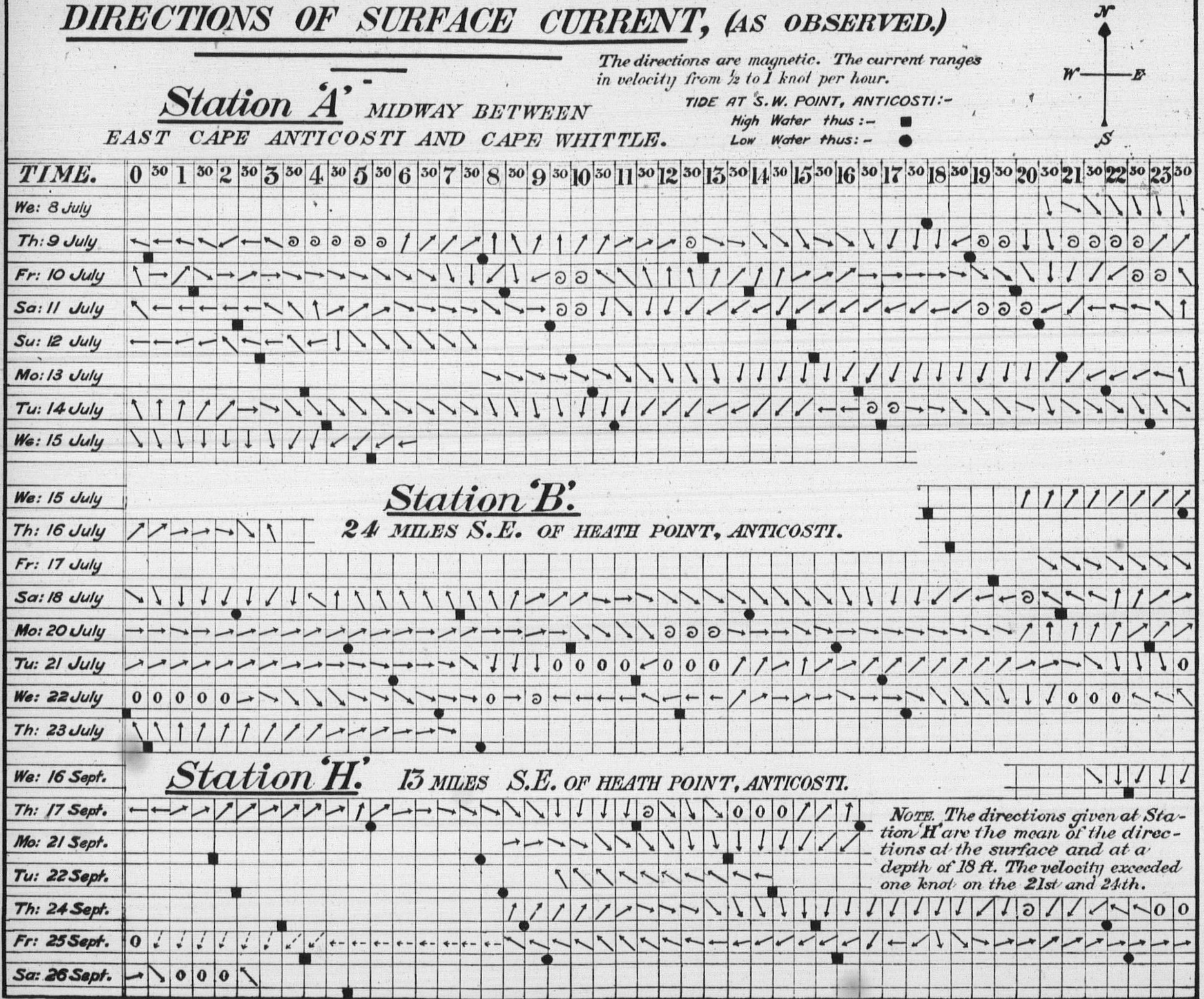
TIDAL SURVEY. SEASON OF 1896. PLATE II.

DIRECTIONS OF SURFACE CURRENT, (AS OBSERVED.)

The directions are magnetic. The current ranges in velocity from ½ to 1 knot per hour.

Station 'A' MIDWAY BETWEEN EAST CAPE ANTICOSTI AND CAPE WHITTLE.

TIDE AT S.W. POINT, ANTICOSTI:-
High Water thus:- ■
Low Water thus:- ●

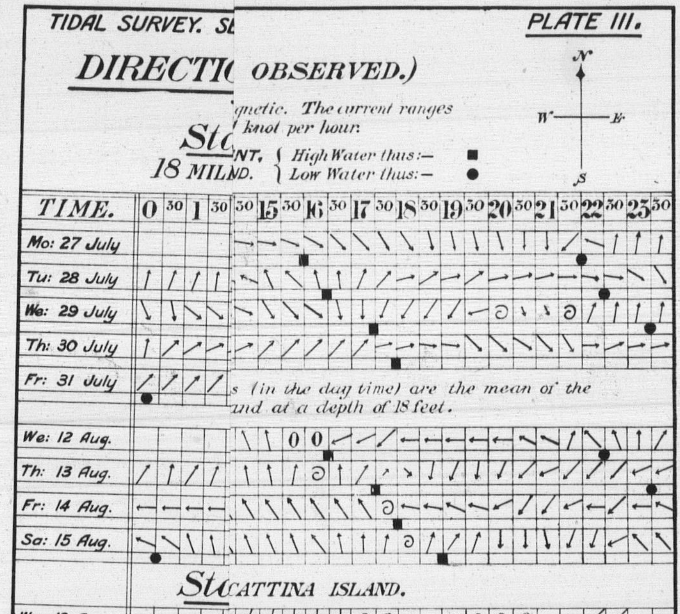


TIDAL SUR

DIRE

1

TIME.	0		
Mo: 27 July			
Tu: 28 July	↑		
We: 29 July	↘		
Th: 30 July	↑	↗	
Fr: 31 July	↗ ●	↗	
We: 12 Aug.			
Th: 13 Aug.	↗	↑	
Fr: 14 Aug.	←	←	
Sa: 15 Aug.	↖	↘ ●	
We: 19 Aug.			
Th: 20 Aug.	↙	↘	
Fr: 21 Aug.	↘	↓ ■	
Sa: 22 Aug.	↙	↙	
We: 26 Aug.			
Th: 27 Aug.	↙	↓	
Th: 3 Sept.			
Tu: 8 Sept.			
We: 9 Sept.	0	↖	↖
Th: 10 Sept.	↗	↗	
Fr: 11 Sept.	↘	↘	↘



TIDAL SURVEY. S
PLATE III.
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s (in the day time) are the mean of the
and at a depth of 18 feet.
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Th: 13 Aug.
Fr: 14 Aug.
Sa: 15 Aug.
St CATTINA ISLAND.
We: 19 Aug.
Th: 20 Aug.
Fr: 21 Aug.
Sa: 22 Aug.
St AY.
We: 26 Aug.
Th: 27 Aug.
St D. (W. COAST OF NEWFOUNDLAND.)
Th: 3 Sept.
Tu: 8 Sept.
We: 9 Sept.
Th: 10 Sept.
Fr: 11 Sept.

TIDAL SURVEY. SEASON OF 1896. PLATE III.

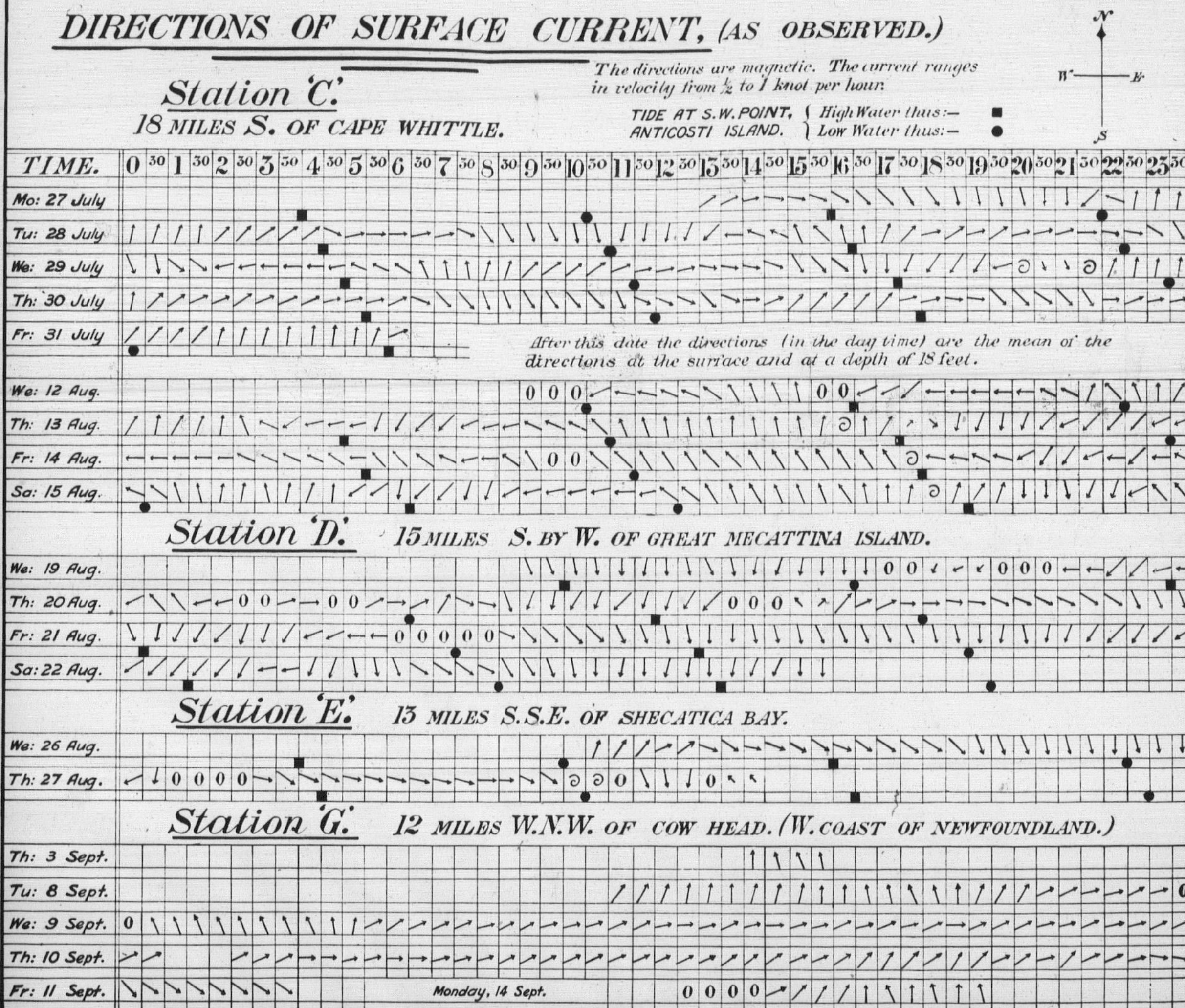
DIRECTIONS OF SURFACE CURRENT, (AS OBSERVED.)

Station 'C'.

18 MILES S. OF CAPE WHITTLE.

The directions are magnetic. The current ranges in velocity from ½ to 1 knot per hour.

TIDE AT S.W. POINT, ANTICOSTI ISLAND. { High Water thus:— ■ Low Water thus:— ●



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STATION

In July........	
In August.....	
Total........	

for five days in July and four days in August. Continuous records were thus obtained for 89 hours in July and 87 hours in August, or 176 hours in all.

The way in which the current veers completely around the compass is very noticeable. (See Plate III.) From 27th July, at 14 o'clock, till 30th July, at 5 o'clock, the current in 63 hours veered completely round *four* times. This veering was right-handed orin the direction of the hands of the clock; and the period of one complete revolution was 16 hours on the average. During the same time there were *five* complete tides from high water to high water, occupying 61 hours in all, or on the average the usual tidal period of a little over 12 hours. This was followed by three oscillations in the direction of the current from S.E. to N.E. during the succeeding 24 hours. As the veering of the current occupied a longer period than the tidal intervals, the direction of the current was necessarily out of relation with the time of the tide, but the regular character of the veering may be taken as an indication of tidal influence. This is the more probable, as the more regular veering was immediately after spring tides, and the later oscillations in the current were towards the neaps.

In August the station was again occupied from the 12th to the 15th. This was shortly after the spring tides, as the moon was new on the 9th. As the weather was also very calm, the tidal character of the current was more distinct than before. During the rise of the tide the set of the current ranged from west to north, and judging by the day observations, when the average direction between the surface and 18 feet was obtained, the dominant set during the rise of the tide was to the N.N.W. During the fall of the tide, the direction of the current is more irregular and fluctuating, but it may probably be taken as ranging usually from west to south. A time of veering and slack water is also noticeable about high water and low water. The velocity of the current did not exceed one knot per hour in any direction.

We thus find that while there is least wind disturbance, the surface current makes on the whole in westward directions, although it veers and fluctuates as just described, under the influence of the tide. But when the influence of the wind is also taken into account, the actual set of the surface current is very nearly equal in every direction. This will be seen by comparing the directions of the current during each of the two periods in July and August taken separately, with the total or combined results of all the observations. The directions in each period by itself are shown near the lower right hand corner of the chart, Plate I.; and the combination of the two periods is shown at the true position of station C on the chart. The period in August may be taken to show the direction of the set while undisturbed, and including only the veer produced by the tide, as the weather was then very calm. The prevailing direction of the wind during the summer season is south-westerly, and this season the wind was more constantly than usual in that quarter. It appears, therefore, that the influence of this wind when combined with the tendency of the current to set dominately to the westward, produces an actual set which on the whole is nearly equal in every direction.

This tendency of the current to set to the westward, is more distinctly shown by the under-current, as it is less influenced by the wind. The set of the under-current at 20 and 30 fathoms ranged usually from west to north, or in a general north-westward direction. That this was its dominant direction will be seen in the following table, which is condensed from all the under-current observations of July and August, given in Table II. The figures are the sums of the velocities in knots in each direction, whenever any current was found; which is sufficient for comparative purposes.

STATION C.—Direction of the under-current at 20 and 30 fathoms.

	S.	S. W.	W.	N. W.	N.	N. E.	E.	S. E.
In July	0·4	0·0	1·2	1·9	0·8	0·8	0·9	0·4
In August	0·4	0·3	0·4	0·4	1·0	0·3	0·2	0·0
Total	0·8	0·3	1·6	2·3	1·8	1·1	1·1	0·4

The under-current thus makes in a dominant direction, while the surface current usually veers in all directions, and during any short period there is, therefore, no relation discernible between them. The directions of the under-current, when classed according to the rise and fall of the tide, fail to show any tidal character. If there is any tidal influence it is so obscure as to be indeterminate.

Station A, half way between East Cape and Cape Whittle, in the middle of the channel north of Anticosti, was occupied without interruption from 8th to 15th July, and continuous observations were obtained during 130 hours. The current was found to veer completely around the compass, and the direction in which the veering took place was right-handed, as at station C. The period of a complete revolution was not quite so definite, but it ranged from 14 to 18 hours, which was much the same on the average. As the period is again longer than the tidal interval between successive high waters, the current at this station also is necessarily out of relation with the tide. The only other distinct feature which this current shows is the tendency to make to the southward of a line lying east and west, rather than to the northward. (See Table I.) The direction of the surface current is thus outward from the channel north of Anticosti, and a comparison will be given further on, to show its amount with reference to the influence of the wind.

Station B, at 24 miles S.E. of Heath Point, Anticosti, was occupied from 15th to 23rd July; and station H, in the same vicinity (13 miles S.E. of Heath Point), was occupied several times between the 16th and 26th September, as already mentioned. The total time during which observations were obtained here in the two months was 180 hours. It was expected that tidal influence would be more felt here, as this position is near the main entrance to the St. Lawrence. The surface current showed much the same character, however, as that already described at the other stations. The direction of the current would sometimes veer completely round the compass in about 16 hours; and it would also make a half revolution in 8 or 10 hours. This veering was usually right-handed, but there was sometimes also a left-handed veer from S.E. to E. While veering in this way, the current would sometimes set directly towards or from the end of the Island of Anticosti for as much as three hours at a time. A persistent set to the eastward for 8 or 10 hours at a time is also very noticeable. Once or twice also there was a sudden reversal of the set from the eastward to the westward. (See Plate II.) The more continuous observations of July showed the more dominant set to be between N.E. and S.E. In September the current veered much in the same way, and occupied about 9 hours in making a half revolution, either in a right-handed or left-handed direction. The velocity in July was not more than one knot; but in September it exceeded one knot on the 21st and 24th. This was probably due to the influence of the heavier winds in that month.

At Stations B and H, fifty-seven observations of the direction of the under-current at 20 and 30 fathoms, were obtained in July and September. (See Table II.) These were all classified in relation to the time of high and low water, at South-west Point, with the following result: A slack time in the under-current was found on seven occasions, which occurred at half tide, either rising or falling. For three hours before and after low water the under-current makes on the whole to the north-eastward and eastward, its direction ranging from N. by W. to E.S.E.; and for three hours before and after high water, it makes on the whole to the south-westward and westward, its direction ranging from S. to N.W. In the fifty observations in which the current had a definite direction, there were only four exceptions to the above rule; and these occurred near to the time of half tide, rising or falling.

The following table shows the relation between the tide and the direction of the under-current. The period of three hours before and after high-water is indicated as "H.W." and the remaining period before and after low-water as "L.W." The figures give the number of times that the under-current set in the directions indicated, out of the 50 observations obtained.

STATIONS B AND H. Direction of the under-current at 20 and 30 fathoms, in relation to the tide.

Period.	N.N.W.	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.
"H.W."	0	0	0	1	0	1	0	0
"L.W."	0	5	4	4	3	2	2	0
Period.	S.S.E.	S.	S.S.W.	S.W.	W.S.W.	W.	W.N.W.	N.W.
"H.W."	0	3	3	2	7	8	2	1
"L.W."	0	0	0	0	0	1	0	1

It thus appears that the under-current has a definite set in two directions in accordance with the tide, while the surface current continues to veer completely round in such a way as to be quite out of relation with the tide. The two dominant directions of this set are, to the W.S.W. while the tide is high, and to the N.E. while the tide is low. These directions are nearly across the end of Anticosti Island. To determine the true relative amounts of the set in these two opposite directions, the average velocity of the under-current towards each of the points above given, was first found from all the observations obtained at Stations B and H; the amount by which the current makes towards the N.E. and W.S.W. respectively, was then carefully computed; (by adding together the components of these average velocities as projected on axes lying in these two directions). When finally reduced to a percentage for convenience in comparison, the result is as follows:—

Amount by which the under-current makes towards the N.E. = 100.

Amount by which the under-current makes towards the W.S.W. = 116.

This shows that the amount by which the under-current makes to the W.S.W. is 16 per cent greater than towards the N.E. The water thus makes to the westward on the whole, around the east end of Anticosti; which is very significant in relation to the general circulation, and in showing also the direction from which the water comes, which forms the return flow to make up for the Gaspé Current. (See Report of Progress, April 1896; pages 27 and 28.)

Station D was situated at 15 miles S. by W. of Great Mecattina Island, and its position was fixed from the beacon on Flat Island. It was occupied during six complete tides, from August 19th to 22nd. The current was very irregular in its direction, however; and the only indication of tidal influence is that it appears to set more steadily to the southward about the time of high water, and to be slack and variable about the time of low water, but these indications are obscure owing to the irregularities which occur. The dominant direction of the set is thus to the southward, and this direction is off shore. The under-current however, at 20 and 30 fathoms, makes very constantly along shore to the south-westward. This is important with relation to the general circulation in the Gulf.

At Station E, 13 miles off Shecatica Bay, observations were only obtained during two complete tides, or 30 hours in all, owing to interruption from rough weather. Where the irregularity is so great, this time is too short to give any relation with the tide. The direction of the under-current was both to the S.W. and N.E., but more frequently to the S.W. The change in direction might prove to be due to tidal influence, as this station may be near enough to the Strait of Belle Isle to be affected by its tides.

At Station F, 10 miles N.N.W. of Rich Point, the tidal element is distinct. The ebb and flood run alternately in nearly opposite directions, as shown on the chart, Plate I. The turn of the tide is felt first in the under-current which makes its way up to the surface and replaces the former direction of the surface current, in a way that often occurs in tidal currents at some distance off shore. This station lies between the influence of the constant current which follows the west coast of Newfoundland, and the tidal influence of the Strait of Belle Isle. It is probably for this reason that the directions of the ebb and flood are nearly at right angles to the trend of the shore, and not because of the proximity of this station to St. John's Bay.

Station G is situated off the long stretch of straight coast on the west side of Newfoundland. It is at 12 miles W.N.W. of Cow Head, and was occupied several times from the 3rd to the 14th of September; shelter being found meanwhile in Bonne Bay, when the weather was too rough to obtain results. The total time secured at this station was 72 hours. The current here sets almost always to the north-eastward, and very seldom veers in direction through a wider range than from N.N.W. to E. When at the one extreme of this range, it sets directly off shore; and on one occasion it set on shore to the S.E. by E., during 3½ hours. The relative frequency of these directions is shown on the chart, Plate I.; and also the evidently dominant direction of the current along the shore to the north-east. In the under-current, this direction is even more definite. At 20 and 30 fathoms, it does not veer through a greater range than from N. to E.; and even at 10 fathoms, the dominant direction is better maintained than by the surface current. At this station, it is not unusual for the whole of the current from the surface to 30 fathoms, to set in the same direction for three hours at a time, especially when this direction is N.E. or E.N.E.; and it is then also strongest, its velocity being nearly one knot at the surface, and falling off to half a knot at 30 fathoms. This is the only station at which the current showed so definite and constant a character.

Some instances of the relation of the under-current to the surface current may also be given to illustrate the way in which changes may pass from the one to the other. These may best be taken from the observations at stations B, H and C. (See under-current observations, Table II.) There is at times a distinct difference in the current, between the surface and three fathoms, especially when the current is changing. The current may slack off first at the surface, while it still retains considerable strength at three fathoms. This could sometimes be observed very distinctly on calm days; when the surface of the water was found to be quite still as shown by floating objects, while the meter and fan agreed in showing a current of as much as half a knot at three fathoms. (See Table II., station B, 21st July; station C, 12th August; &c.) This may occur when the under-current is making its way up to the surface. At station B, on 21st July, the line at which the under-current struck up to the surface could be seen as a distinct current rip, which approached gradually, and on reaching the vessel carried objects in its current which had been floating around it for an hour previously.

On the other hand the surface current itself may consist of a comparatively thin layer, only 5 or 10 fathoms in thickness; and below this the water may be quiescent. A number of instances of this will be noticed in Table II; as it is much more usual than to have the surface layer at rest, with a distinct under-current running immediately below it. Such a surface current may even set in after a slack time, by a moving layer making its way over the surface of the water. This once occurred on 13th August at station C. The day was very calm and the edge of the moving surface water was visible as a distinct line or current rip. This came up to the point of observation at 16·30; and it was over two hours afterwards before the new current could be felt as far down as 10 fathoms. These changes are remarkable, so far from shore as 18 and 24 miles, and when the currents themselves do not exceed one knot in their speed.

When it is the surface layer only which is in motion, its thickness is sometimes very distinctly marked. At station H, on the afternoon of 24th September, when the current was as strong as ever observed, its velocity fell sharply at a depth of 12 fathoms, from over one knot to less than half a knot per hour. For over an hour the current thus remained slow at 13 fathoms and below; while very strong from 11 fathoms upwards.

It may also happen that the only movement of the water is in a layer at a depth of 10 or 20 fathoms; while the water at the surface and below is quite still. (See station G, 14th September). At times also there is a bottom current at 40 or 50 fathoms, which may have a direction of its own. As a result of these movements at various depths, the current sometimes had what may be called a spiral character;

or an apparent veering in direction with the depth from the surface downwards, at any given moment. As time went on, the under-current usually veered the same way as the surface current, although several points behind it in direction; but instances of these currents veering in opposite directions were not unknown.

These changes in the depth of the water will help to explain the changes in the surface current itself. They also show that the drift of the mere surface layer of a few inches or a foot in thickness, may not represent correctly the direction in which the current will set a vessel of ordinary draught. If the currents in such waters are ever examined by means of drifting floats, these should consist of spars floating upright in the water, and reaching to the same depth as the average draught of the vessels for which it is desired to ascertain the set of the current. Such spars would of course require to be weighted at their lower ends, and to have a hollow ball or a disc of wood at the upper end to keep them from sinking, and to avoid any exposure of surface to the wind.

Shore Currents in the Channel north of Anticosti.—The direction of the current off East Cape, Anticosti, was observed during the day time from 7th July to 10th August. The current sets north or south along the shore; and its direction was indicated by two buoys attached to each other as already explained. These buoys were placed 1½ miles off the cape, in 30 fathoms of water. The direction of the current was noted every two hours from 5 or 6 a.m. to 7 or 8 p.m. and also the time at which the currents changed in direction. The shore runs north and south; and the current was nearly parallel to it. But it was very irregular, as sometimes it set in the same direction all day, for two or three days in succession; and it was comparatively seldom that there were two changes of direction during the day, as in the case of ordinary tidal currents. A summary of the observations obtained on twenty-three complete days in clear weather, during the above time, gives the following result:—

On nine days, the current ran in the same direction all day, either north or south.

On nine days, one change in direction occurred.

On five days, the direction changed twice.

It is, therefore, clear that in these circumstances it is not possible to make out any relation between the current and the tide. On the other hand, the observations show that the prevailing set of the current is to the southward. The total number of times that the direction of the current was noted was 231; and out of this number the set of the current in each direction was as follows:—

Current setting to the northward	78 times.
Current setting to the southward	153 do

This may be taken as a fair comparison; as during the course of a little more than a full month, the observations are distributed pretty evenly over all the states of the tide.

At Natashquan Point on the other side of the channel north of Anticosti, the direction of the current was obtained in the same way, by means of buoys. The observations were more continuous, extending from 9th July to 19th September and including the time of daylight on each day. The direction of the current was usually north-west or south-east; although it sometimes veered two points or more from these directions. This is parallel to the general direction of the coast. The current sometimes ran in the same direction all day, for two or three days in succession; and this feature was even more noticable here than at East Cape. When a change in direction occurred, it took place at any time, without reference to the time of the tide.

In classifying the whole of the observations with relation to the rise and fall of the tide, it appears that during the rise of the tide the set of the current is very nearly equal in each direction; but during the fall of the tide, the set to the south-east largely predominates. This is, therefore, the dominant direction on the whole. The direction of the current was noted 627 times in all; and out of this number, the set of the current in each direction was as follows:—

In directions between N. and W.	218 times.
do S. and E.	409 do

The set of the current is thus distinctly outwards on the whole, in much the same proportion as at East Cape. The "constant currents" shown locally on the Admiralty charts at these points, must therefore be taken to mean that the current sets in the direction indicated about twice as often as in the contrary direction. We will refer again to the relation of these currents to the general circulation.

Influence of the Wind. In moderate weather, when the wind was light and variable, or blowing steadily in one direction, the current would veer completely round the compass as already described. The only effect, therefore, which it would be possible to attribute to the wind, in the tendency of the current to set in some dominant direction. The best comparison of this character which can be made, is at Station A. This was the most open of all the stations, as it was 35 miles from the land on either side; and the direction and mileage of the wind were, therefore, well observed on board. Also, the direction of the current as observed at this station, was the direction on the surface only, where it is most under the influence of the wind. The set of the current (see Plate I.) was mostly to the south-east; and least towards the N.W. and N. The total mileage of the wind while the station was occupied, from 8th to 15th July, was 1,967 miles during 156 hours; or only 12 miles an hour on the average. The mileage of the wind in each direction is given below, in comparison with the set of the current as observed during 130 hours. (The figures for the current are the number of half hours in each direction, as in Table I. There were 8 hours of calm, and 25 half-hours of no current, which are omitted in the comparison. The directions are magnetic throughout.)

	S.	S.W.	W.	N.W.	N.	N.E.	E.	S.E.
Station A.—Mileage of wind...	125	332	359	955	79	28	16	73
	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
Set of current.......	13	18	37	50	40	37	28	12

This comparison shows a distinct correspondence between the wind and the more usual direction of the current. It may, therefore, be taken to indicate the general influence of the wind, when a long period is taken as a whole, to cause a leading drift or set in its own direction. It is to be noted, however, that during any shorter period the current was veering round continually, while the wind often maintained a steady direction.

At station B, and at C in the month of July, the dominant direction of the surface current also accords in general with the direction of the greatest mileage of wind at the time. At these stations the tide has a greater influence relatively to the wind than at A; but the influence of the wind is still sufficient to overcome in the surface current the tendency which the water there has to move in other directions, which are indicated by the under-current. This will be seen from the following tables, which give the comparison between the wind and current in the same way as for station A. The comparison at station B is for a period of 107 hours, from 17th to 23rd July, in which 11 hours of no current are omitted; and at station C, for a period of 90 hours, from 27th to 31st July, omitting 1½ hours of no current.

	E.	S.E.	S.	S.W.	W.	N.W.	N.	N.E.
Station B.—Mileage of wind.....	0	0	311	941	355	195	87	0
	W.	N.W.	N.	N.E.	E.	S.E.	S.	S.W.
Set of current......	12	8	16	41	65	30	15	5
	E.	S.E.	S.	S.W.	W.	N.W.	N.	N.E.
Station C.—Mileage of wind....	0	0	30	1147	325	0	0	42
	W.	N.W.	N.	N.E.	E.	S.E.	S.	S.W.
Set of current.......	9	6	22	45	35	36	18	6

During the month of July, the heaviest wind at any of the stations was on the 30th at station C. From 14 o'clock on the 29th to 20 o'clock on the 30th the wind blew steadily from S.W. by W. The total mileage from that direction was 659 miles in 30 hours; yet this amount did not increase the thickness of the current beyond 10 fathoms. On the 30th, from 8 to 20 o'clock, the rate of the wind was 26 miles per hour. During that time the current set as shown below; the only exceptional feature was a left-handed veer from S.S.E. through E. to N.E. This may have been due to the wind; although it veered back to S.E. while the wind maintained the same direction, and continued to increase.

July 30th.	Hour..........	8·00	10·00	12·00	14·00	16·00	18·00	20·00
	Set of Current.	S.S.E.	S.E.	E.S.E.	E.	N.E.	E.	S.E.

The heavy winds above mentioned increased to a gale on 31st July and 1st August. There was also heavy weather in the middle of the month; but there was no opportunity to occupy a station immediately afterwards on either occasion.

In the windy weather of September, good observations could not be obtained in the early part of the month while at station G; as Bonne Bay was used as a harbour in rough weather, and the mountains around it made wind observations unreliable. There is no permanent meteorological station in that region. The off and on-shore directions of the current occurred, however, at such times as to make it possible that these were due to the effect of wind or barometer.

The best examples of heavy winds were obtained in September at station H, off Heath Point, where there is little or no shelter to be had. On 21st September there was a strong westerly wind, which changed at midnight to N.E. and veered by the morning of the 22nd to nearly E. The current on one of these days veered in the usual right-handed direction, and on the other the veer for some hours was in the reverse direction. A comparison of the wind and current are given below:—

Sept. 21st.	Hour............	9.00	11.00	13.30	16.00	Wind velocity during 8 hours; 25 miles per hour.
	Direction of wind..	W.	W. by S.	W.S.W.	W. by S.	
	Set of current......	E.	S.E.	S.	S.W.	
Sept. 22nd.	Hour............	10.00	11.00	13.00	14.00	Wind velocity during 8 hours; 26 miles per hour.
	Direction of wind..	E. by N.	E.	E. by N.	E. by N.	
	Set of current......	N.W.	N.W. by W.	W.N.W.	W.	

On the night of the 22nd and during the 23rd, the wind increased to a gale from the E. and N.E. Its rate was over 50 miles an hour; and the waves reached a height of 14 feet and a length of 180 feet from crest to crest. The total mileage of wind from an easterly direction during 32 hours, up to 16 o'clock on the 23rd, was 1,163 miles. The wind then moderated, and backed into the north; and during the following day, the 24th, it varied between N. and W.N.W. with an average rate of only 15 miles per hour. The current on that day, from 9 to 21 o'clock, veered from N.E. through S.E. and S. to S.W. It thus made half a revolution in the usual right-handed direction in 12 hours. The current in the morning was setting against the direction of the heavy wind of the previous day. It also veered during the day to the right, while the wind backed to the left; and by evening it was setting directly across the new direction which the wind then had. It is, therefore, difficult to know what effect to attribute to the influence of the wind; unless it be that in backing against the usual direction in which the current veers, it may have lengthened its period of rotation.

Throughout the night of the 24th the wind averaged 26 miles an hour for 12 hours, and it veered again from N.W. to N.N.E. On the 25th the wind fell off during the forenoon to a calm; and towards evening it set in as a light breeze from the S.W. The current in the morning was W.N.W. and from 10.30 to 18.30 it veered to the left, making a half revolution from N.W. through south-west to S.E. in 8 hours. The current in the morning was thus nearly contrary in direction to the strong wind of the previous night; and during the day it veered round in the reverse direction to that which the wind had taken. Also both morning and evening the current was setting at right angles to the direction of the wind which was blowing at the time.

From these examples, when strong winds were best observed, and stations were occupied at the time or immediately afterwards, it is quite evident that the current does not run in the same direction as the wind which is blowing locally at the time. On the contrary, the current continues to veer as usual; although its movements appear to be more disturbed; and the strength of the current was also greatest during windy weather. The current at any given time may thus set in any direction quite irrespective of the wind; while on the other hand it is to be inferred that when continuous observations can be obtained for as long a period as a week, it would be found that the greatest amount of set had taken place in the same general direction as the greatest total mileage of wind.

Usual veer of the current in relation to wind and tide.—If we look for an explanation of both features which these currents show, it might, therefore, seem reasonable to attribute the veering in the direction of the current to tidal influence; and to consider any tendency of the current to set in a dominant direction as due to the influence of the wind. The difficulty in adopting this view is, that the period in which the current veers completely round is 16 hours on the average, at the more open stations. The period is thus nearly four hours longer than the tidal period of about 12 hours; and this difference in the two periods results practically in an entire want of relation between the direction of the current and the time of the tide.

It is possible to suppose that the longer period of 16 hours is of the nature of an over-run, which is brought into harmony with the tidal period by the time occupied in veering in the reverse or left-handed direction which sometimes occurs. The observations do not favour this view; as it is during the least disturbed periods and also when the tidal influence is greatest, that the 16-hour period is most distinct. But if this should prove to be the case, some explanation might be found in the tidal interference between the tide entering the Strait of Belle Isle and the main tide of the Gulf of St. Lawrence which enters through Cabot Strait. Otherwise we must look for some cause which is capable of lengthening the ordinary tidal period by retarding the rate of veer in the current itself.

The period could not be lengthened by the combined effect of a tidal rotation and a wind drift. The effect of a steady wind on a current which was veering continually with the tide, would be to make it set more strongly and veer more slowly when it ran with the wind; and to be slacker and veer more rapidly when setting against the wind. But it would be impossible for a steady wind, or the surface drift which it produced, to alter the period of rotation, or the time which the current would take to veer completely round.

This period could only be lengthened by combination with another rotation in the contrary direction. If the wind itself were to back round continually to the left after the manner of a perpetual storm, it might produce this result. It is possible that the veering or backing of the wind may at times have an appreciable effect; and it is fair to remark that in the northern part of the Gulf of St. Lawrence, the wind as a rule backs to the left during storms, and thus tends to lengthen the period of veer in the current.

The only left-handed rotation of a constant character which we know of, is the general circulation in the Gulf itself, which we will see to be pretty conclusively proved when all the information available is considered together. It is difficult to say whether a slow circulation of this kind would have an appreciable effect on the veering of the current; but it may at least be allowable to point out that the lengthening of the tidal period which we here meet with, accords with the opposite direction in which this general circulation takes place; and so far as our information goes, these two features are consistent and help to explain each other.

DENSITIES AND TEMPERATURES.

Throughout the region under consideration, the density of the surface water is higher and much more uniform than in the remainder of the Gulf. There were times, however, when lower densities were found in the neighbourhood of the eastern end of Anticosti. With this exception, the density of the surface water in the whole area lying to the north-east of a line from Cape Ray to Heath Point, and including the channel north of Anticosti, varies only from 1·0234 to 1·0242. This is based upon 231 determinations made throughout this region on all the courses run in July, August and September. It was very rare to find densities below the lower of these limits, except locally near the mouths of rivers. In the western end of the Strait of Belle Isle itself (off Forteau Bay at the beginning of September) the surface density was 1·0239 to 1·0241. These densities are the true specific gravity of the water at 60° Fahrenheit, determined with the same precautions to ensure accuracy as formerly used.

This result is important, in showing that the lower densities found in the south-western portion of the Gulf of St. Lawrence are confined to that side; and this further confirms the conclusion already reached last season, that the general set or drift across the Gulf, as shown by the water of lower density, is in the direction of a line from Gaspé to Cape North. (See general chart of density of water in the south-western portion of Gulf of St. Lawrence, Plate III., in Report of Progress of 13th April, 1896.)

The density in the open Atlantic, from seven determinations made at the end of June off the south and south-east coasts of Nova Scotia, was found to range from 1·0237 to 1·0242, which is practically the same as in this north-eastern portion of the Gulf. It may, therefore, be stated broadly, with regard to these two divisions of the Gulf, that throughout the north-eastern portion the average surface density ranges from 1·0235 to nearly 1·0245; while in the south-western portion, the density is below 1·0235, ranging usually down to 1·0220, and falling in the Gaspé Current itself to 1·0210. The dividing line between these two portions of the Gulf, runs approximately from the east end of Anticosti, to a point in the middle of Cabot Strait, about 20 miles west of Cape Ray. The densities in the border region near this dividing line, vary to some extent just as the other lines of equal density elsewhere vary in their position.

On the other hand, the endeavour to obtain some differences locally, which would correspond with the various directions of the current, was without result; although a large number of temperatures as well as densities were taken at the various stations for this purpose.

The best observations to ascertain the amount of change in the temperature of the surface water with the season, were obtained at a series of points, five miles apart, on each of the following lines:—(1.) From 30 miles off Heath Point, to Cape St. George on 6th July. (2.) From station C, off Cape Whittle, to the offing of Cape St. George, on 3rd August. (3.) Same line as No. 1, run a second time on 28th September. The results were as follows:—

(1.) July 6th. From 49½° to 51½° Average = 50.°93.
(2.) August 3rd. From 50° to 54°. Average = 52.°68.
(3.) September 28th. From 52° to 54½°. Average = 53.°62.

The following deep densities will also serve to show how closely they correspond with those found in previous seasons in other parts of the Gulf, at the same depths. (See Report of Progress, 13th April, 1896; p. 7, and tables A. to F.) Densities at these depths were also obtained for comparison in the open Atlantic off the Nova Scotia coast. These were taken at six points, at ten to fifteen miles from shore, on a course from the offing of Liverpool Bay, past Halifax, to 13 miles east of Cape Canso.

DEEP DENSITIES in the Atlantic, and in the north-eastern portion of the Gulf of St. Lawrence.

Locality.	Surface.	10 Fathoms.	20 Fathoms.	30 Fathoms.	50 Fathoms.	100 Fathoms.
In the Atlantic off Nova Scotia, June 30th, and July 1st, 1896	1·0240	1·0243	1·0245	1·0246		
	1·0240	1·0243	....	1·0246	1·0245	
	1·0237	1·0243	1·0245			
	1·0239	1·0243	1·0244			
	1·0239	....	1·0243	1·0243		
	1·0237	1·0239	....	1·0243	1·0243	
Station A.—July 10th	1·0234	1·0240	1·0243	1·0243	1·0246	1·0253
July 14th	1·0235	1·0239	1·0242	1·0245	1·0247	1·0255
Station D.—Aug. 21st	1·0236	1·0237	1·0242	1.0245		
Aug. 22nd	1·0236	1·0239	1·0244	1·0246		
Station E.—Aug. 24th	....	1·0241	....	1·0245	1·0248	
At 7 miles south of station E.	1·0239	1·0240	....	1·0248		
At 21 miles south of station E.	1·0235	1·0241	....	1·0248		
Station F.—Aug. 28th. Morning	1·0236	1·0241	1·0245	1·0248		
Aug. 28th. Afternoon	1·0238	1·0240	1·0247	1·0247		
Across the Strait of Belle Isle. Three points, 3 miles apart, Sept. 1st, 1896	1·0239	1·0240	....	1·0245		
	1·0240	1·0240	1·0243			
	1·0239	1·0241	1·0244			
Station G.—Sept. 10th	1·0240	1·0240	1·0242	1·0246		
Sept. 14th	1·0238	1·0239	1·0243	1·0247		
Station H.—Sept. 21st	1·0240	1·0244	1·0246			
Sept. 24th	1·0235	1·0238	1·0247	1·0247		
Sept. 25th	1·0235	1·0239	1·0246	1·0247		

The deep temperatures obtained show that in this region as elsewhere in the Gulf, the cold layer occurs at a depth of about 50 fathoms. The three points in the Strait of Belle Isle are on a line running across the strait from Amour Point to Green Island; in the same part of the strait in which the detailed examinations of 1894 were made.

Depth.	Station A.	Station D.		Strait of Belle Isle, Sept. 1st. Three points, 3 miles apart.		
	July 10th.	Aug. 20th.	Aug. 22nd			
	°	°	°	°	°	°
Surface	50	54	55	52	53	57
10 fathoms	42	51	51	46	51	55
20 do	34	44	40	40	38	48
30 do	31½	36	38	....	37	39
40 do	....	31	35			
50 do	31					
75 do	31½					
100 do	36½					

INFORMATION OBTAINED REGARDING CURRENTS.

A considerable amount of information of value was collected during the season, with regard to the currents in this part of the Gulf. By taking advantage of the stormy weather, this was obtained with little loss of time to the main work in hand.

The fishermen were able to give the best information, because they anchor their boats, and thus have a fixed point from which to observe; while the masters of trading schooners have difficulty in distinguishing current from lee-way. On the other hand, sealing schooners which lie in the ice and drift with it, can often give satisfactory information. In obtaining information from the fishermen, care was taken to see that they described the currents as found at some miles off the open coast, away from the vicinity of large bays, or channels between islands, where currents of a local character might occur. By questioning the men of longer experience, and comparing their statements, reliable results could be arrived at.

Drift of the ice as an indication.—The currents in the early spring (March and April) are often well indicated by the drift of the ice, and numbers of small vessels are then engaged in seal fishing. It is necessary, however, to distinguish between the different kinds of ice which are met with, and also to keep in mind the difference in the movements of the surface water and the under-currents, as already explained; as otherwise the inferences drawn from the drift of ice may be far from correct.

The ice met with is of three kinds:—(1) Berg ice, or the true icebergs which come into the Gulf through the Strait of Belle Isle. They are also found off the south coast of Newfoundland, nearly as far west as Cabot Strait. (2) Flat or pan ice, forming fields or in broken pieces, usually not more than 6 feet in thickness, but sometimes as thick as 10 feet. This often jams or shoves along the shore or between islands, and may form masses 20 feet or more in thickness, but it can never be mistaken for berg ice. In this flat ice a distinction is sometimes made between "Northern ice," which finds its way in through the Strait of Belle Isle under certain conditions, and "Gulf ice," which forms in the Gulf itself. As the effect of the wind and current upon it is the same in either case, the distinction is not of importance for our present purpose. (3) River ice, from the St. Lawrence River and its estuary. This is also flat ice, and in the Gaspé region it can be readily distinguished by its appearance from the Gulf ice. It is not found, however, in the region which we are now considering.

The berg ice, from its great depth in the water, will evidently move with the under-current; and it will not be appreciably affected by the wind. These bergs do not necessarily indicate the direction of the current as affecting shipping, except when the surface current has also the same direction, which is not usual. They show in reality the average direction which the current has, between the surface and the depth of their draught. This draught is limited to about 35 fathoms by the depth of the strait. They are thus of much value as an indication of the general movement or circulation of the water.

The relation of the flat ice to the wind and current requires some little consideration. It is, of course, just as true of this ice as of the berg ice, that the greater part is under water; but as it is almost always in broken pieces, more or less piled and with upturned edges, the wind has a much greater hold upon it in proportion to its total weight, than on the berg ice. Even when this is allowed for, its depth in the water still gives the current a greater hold upon it than the wind has. For example, if such ice is drifting with a current in a given direction, and the wind is blowing across that direction at right angles, the ice will seldom be set more than two points, or three at the most, off the true direction of the current. When the ice becomes soggy or water-soaked and loses its edges, as it does later in the spring, it will set still more correctly with the current.

When the surface current itself is moving in the direction of long continued or prevalent winds, as it often does in this region, the ice naturally follows the same direction too. Also in regions where the current is tidal, and the ice in calm weather would drift as far in the one direction with the flood tide as in the other direction with the ebb, the direction in which it makes on the whole will depend upon the wind. It is probably for these reasons that it is so often said that the ice drifts with the wind; although this merely expresses the fact, without distinguishing between the relative influence of the wind and the current upon it.

There is also a direct effect which the ice has upon the strength of the current in regions where the direction of the surface drift is under the influence of the wind.

The broken and upturned edges of the ice give the wind a much greater hold upon the water than it otherwise would have. Hence during long continued winds the velocity of the current is appreciably greater than if the ice were not present. This is undoubtedly the explanation of the common belief which is expressed by saying that "the ice makes its own current." It may be well to recall that the weight of the ice itself is the same as the water which it displaces, and, therefore, the wind has no greater mass to set in motion in producing a surface current than if the ice were to melt and refill the hollow which it makes in the water; while the presence of the ice gives the wind a better hold than it would have upon the surface of open water, free from ice.

There is one condition of the ice which may prevent it from showing correctly the drift of the water. When it is set against an island or headland and packed together for a long distance out, with open water beyond, it may circle round as on a pivot. The outer edge of the pack may thus make a long sweep very different in its path from the true set of the current; and its movements also become irregular, as vessels caught in such ice which are near together in the evening may be ten or fifteen miles apart in the morning.

Current and wind.—There is one relation between the wind and the strength of the current which was not observed at the stations, but which is so generally stated to be the case that it must be accepted as a fact. It appears to apply chiefly, if not entirely, to currents which are fairly constant in their direction. Such a current is found to run more strongly before the wind comes, if the wind is to be in the same direction, and it slackens if the wind is to be against the current. The fishermen when anchored in their boats take these indications as warnings of the approach of heavy weather. This change in the current before heavy winds is found to occur on the south and west coasts of Newfoundland, and has also been noticed on the north shore of the Gulf of St. Lawrence. It appears to be due to the action of the wind during storms, in first holding back the water and then releasing it, and the low pressure area of the storm as it passes along also increases the result. It is also probable that the effect is more distinct in the case of confined waters, as it is very noticeable on the Great Lakes. It is from analogy with the conditions which obtain there that this explanation is suggested.

The information which was obtained with regard to the currents, was kindly furnished by the following persons:—

Captain Farquahar, of the SS. "Harlaw," which makes regular trips during the summer and autumn along the south and west coasts of Newfoundland. He has also been engaged in sealing in the Gulf in the spring.

George Curtis, for the last thirty years, has made three trips in the Gulf each season in a schooner; sealing in the spring, cod fishing in the summer, and herring fishing in the autumn.

Jonathan Noel, who has had a long experience in the Gulf as master of a sealing and trading schooner.

Also four masters of schooners, Wadman of Rose Blanche, Newfoundland; Isaac Shepherds of Bay of Islands; and two others.

On the west coast of Newfoundland, Jonas Shears, John Parsons and William Young, fishermen of long experience at Roche Harbour on the open coast at the mouth of Bonne Bay. Also fishermen of Whale Cove in Bonne Bay, Lark Harbour in the Bay of Islands, and Cow Head Harbour; who fish some miles off shore.

In the Strait of Belle Isle, Mr. T. M. Wyatt, lightkeeper at Amour Point, and Charles Davis, a resident of Forteau Bay. Also a fisherman engaged for the last thirteen years at the fishing establishment at Schooner Cove, Loup Bay.

Sam Gaumond, the only permanent resident on Great Mecattina Island. He has now lived there for many years.

Several fishermen at Natashquan Point and little Natashquan village.

Two fishermen, old residents of Fox Bay, near the east end of Anticosti; who are also well acquainted with the neighbouring coasts.

Mr. Z. Gagné, lightkeeper at Heath Point.

GENERAL CHARACTER OF THE CURRENTS IN THE NORTH-EASTERN HALF OF THE GULF.

We may now consider these currents as a whole, and trace their movements throughout the north-eastern half of the Gulf of St. Lawrence; and we will base this consideration upon the observations of this season as already detailed, supplemented by the information obtained, and the notes made by the captains of trans-Atlantic steamships. It will be best to begin with Cabot Strait itself, where the main interchange of water between the Gulf and the Ocean takes place.

Currents on the south coast of Newfoundland, and in Cabot Strait.—On the south coast of Newfoundland between St. Pierre Island and Cape Ray, the current makes to the westward, and passes around Cape Ray into the Gulf. This was found to be the case at the stations off Cape Ray where observations were taken in 1894 and 1895; and it is also shown by icebergs off St. Pierre Island, which make westward even against a north-west wind. It is stated in the Sailing Directions that when approaching the entrance to the Gulf of St. Lawrence (by Cabot Strait), the current generally sets to the southward on the Cape Breton Island side of the strait; but on the Newfoundland shore it has frequently been found setting to the northward about one knot an hour. (St. Lawrence Pilot, vol. II, 1895; page 12).

Captain Farquahar, of the SS. "Harlaw," which passes through these waters on its regular fortnightly trips throughout the summer and autumn, states that along the south coast of Newfoundland the trend is westward, and that the current sets inwards around Cape Ray. While fishing in summer, Curtis has had his schooner at anchor three or four miles off Cape Ray, and has found the current to be in wards. Anchorage cannot be had much further out, as the depth increases rapidly to 250 fathoms; but the observations and evidence show that this current is distinctly felt for a width of 8 or 10 miles out, and it must often extend considerably further, as it sometimes occupies half the width of Cabot Strait. There can be no doubt, therefore, that this is the usual current on the Newfoundland side of the strait; and that it is this which makes up for the water which leaves the Gulf in the outward current around Cape North, as already explained in former reports on this survey.

The outward current on the west side of Cabot Strait, which sets to the south-east past Cape North, is the most constant in one direction of any at the Gulf entrances, as it is rarely checked under any conditions that occur. But there is evidence to show that the inward current on the Cape Ray side, is not constant at all times. There are instances of sealing schooners in the ice about the month of March, which drifted in the opposite direction past Cape Ray. It appears, however, that while the inward current prevails, the water is usually open and free from drift ice, as it remains open off the south coast of Newfoundland throughout the winter and spring. This in itself is corroborative of the westward set of the current, as the Atlantic water must then be warmer than the Gulf water. The evidence goes to show that when there is ice in the offing of St. George's Bay and off Cape Ray, it comes from the opposite direction, with the general current which makes across the Gulf from Gaspé towards Cape North, and at times when this current or a branch of it, is driven further to the eastward than usual. It is apparently in this way that the outward drift of ice on the Cape Ray side is to be explained, as this undoubtedly occurs in the early spring of some years at least, and when certain winds prevail. The Sailing Directions remark that, in changeable weather, vessels can reach as far north as Lark Harbour, in the Bay of Islands, in any month, as it is only strong westerly winds which bind the ice in on the coast, and it soon clears away.

The ice is thus brought there under conditions which make it an indication of disturbance in the current, as otherwise the water would remain open. This disturbed condition of the current is also accompanied by circling movements in the ice. A schooner in the ice off St. George's Bay has circled around for several days between Cape St. George and Cape Ray without passing either of these capes. When there is ice in this locality, circling movements of a similar kind occur also in Cabot Strait itself, which indicate an inward current in some part of the width of that strait. There may thus be sufficient inward current to compensate for the outflowing water on the Cape North side, but it is also possible that the outflow from the Gulf may then be partly made up for by an inward flow through the Strait of Belle Isle, which is sometimes considerable in the early spring.

It is not clear what becomes of the current which passes in at Cape Ray. As a rule there is no appreciable current off St. George's Bay, and very little from Cape St. George to the Bay of Islands. We cannot thus trace this inflowing water as an actual current, but it is probable that it makes to the north-eastward, and diffuses itself over the Gulf in that region, because we find that the density of the water throughout the north-eastern portion of the Gulf is the same as in the open Atlantic, and this density could not be so maintained without some inflow of this character.

West coast of Newfoundland.—From the Bay of Islands to Rich Point the current becomes distinct, and runs along the coast to the north-eastward. It is stated by Lieut. Margesson, navigating lieutenant of H.M.S. "Buzzard," which has been stationed on this coast for three years, that the current in the summer season is always in this direction when it is felt at all, and that it usually amounts to one knot. It was stated by Lieut. Betty, navigating lieutenant of H.M.S. "Pelican," who had spent more than one season in cruising here, that there is an almost constant current running north-eastward along this coast between Cape St. Gregory and Rich Point, which is only intercepted by the flood and ebb tides running in and out of the larger bays on the coast. This is the most definite current, and the most constant, in the north-eastern portion of the Gulf, and its characteristics and the unusually steady flow of the under-current have been described from the observations at station G.

The fishermen on this coast anchor their boats as much as 10 or 12 miles off shore, in about 30 fathoms of water. They have thus an excellent opportunity of observing the behaviour of the current. It will be understood, however, that their information refers chiefly if not entirely to the surface current. They state that its prevalent direction is to the E.N.E. parallel with the shore; it will run constantly in that direction for three or four days together; and on the whole it has that direction for rather more than two-thirds of the time. For 12 to 20 hours before the arrival of a south-westerly gale, it sets more strongly in its usual direction; and before a north-easterly gale arrives, it slacks; although this is not so certain an indication of wind, as it may also slack at other times. With long continued easterly winds it may be reversed in direction. It may also set directly off or on-shore for three or four hours or even longer.

The current is stronger near the shore and weaker further out; as it is found that a schooner going westward will make better headway with long tacks; but if going eastward, with short tacks in-shore.

Flat ice, of about six feet in thickness, appears off Bonne Bay about January or February, and remains till March or April. The direction from which this ice comes is variously stated; some holding that it is formed in the Gulf, and others that it comes in through the Strait of Belle Isle; as they say that they can distinguish the Gulf ice by its appearance from the Northern ice from the strait. Icebergs have also been seen off Bonne Bay large enough to ground in 30 fathoms, but it is very seldom that they come further west on the Newfoundland side than Rich Point.

The ice serves, however, to indicate the usual direction of the current on this coast; as it drifts north-eastward in one day as far as it drifts south-westward in three days, with the same amount of wind one way or the other. A schooner caught in the ice off Cape St. George at the end of March, drifted along the coast as far as St. Barbe in about ten days; a distance of 190 miles; which gives on the average the ordinary rate of about one knot. The ice sometimes makes to the eastward all the way through the Strait of Belle Isle. In March 1896, two schooners caught off Bonne Bay, drifted with the ice eastwards through the strait, and were carried down the Atlantic side of Newfoundland to Notre Dame Bay.

Area at the western end of the Strait of Belle Isle.—Between Rich Point and the entrance of the strait, the current becomes tidal, and does not usually make in one direction more than the other on the whole. The ice may make a considerable drift when the wind is with the current; but when against it, the ice stands and shoves. The observations obtained here, also show the tidal character of the current in this locality, as already described.

On the opposite shore off the Esquimaux Islands, the fishermen when anchored six miles from shore, find that the current usually runs along the shore in one direction or the other; but there are times when it sets off or on shore for a whole tide. We thus find at the western end of the Strait of Belle Isle an area in which the tidal element predominates; but in which the currents are irregular, and cross-currents are frequent. The area in which these conditions prevail, may be considered to extend from Greenly Island westward as far as a line running magnetic north from Rich Point to the Esquimaux Islands. There is also one of these cross-currents, which sometimes runs from Greenly Island south-eastward; and forms a strong set on shore towards Flower Cove.

Strait of Belle Isle.—The usual character of the current in this strait is tidal, with a flow which is nearly equal in each direction, while the current is undisturbed by heavy or long continued winds. Its behaviour under normal conditions, and when disturbed, has already been fully described in previous reports. (See annual report, Department of Marine, for 1894; pages 95 to 104; and Report of Progress, April, 1896; Plate 1). All the information obtained goes to show that the undisturbed condition when the flow is practically equal in each direction with the tide, is the usual one throughout the summer months. This is also confirmed by the report of Mr. M. H. Warren in 1854 to the Newfoundland government, based upon his observation of the current during a season which he spent there; as already quoted in the reports of this survey. (See Report of Progress, April, 1896; page 4).

In the spring and late in the autumn, however, the disturbance is greater; and the flow may be more persistent in one direction or the other. It is usually said that there is much inward flow to the west in the early spring; but if this is inferred from the drift of icebergs, it should be remembered that bergs which are carried in through the strait by the inward flow seldom return; as most of them ground or break up and melt in the Gulf. Hence the inward flow towards the Gulf is made visible, while the outward flow may not be. It is, therefore, necessary to take with caution any statements which may be chiefly based upon the drift of icebergs.

The usual tidal character of the current, and its equal flow in each direction during the summer months is confirmed by Curtis, who has had a long experience in these waters; but in the spring and autumn in his experience, the current although it does turn, runs longer and stronger outwards than inwards; and thus makes outwards on the whole even when the winds are easterly. This is corroborated by Noel from his experience in the ice while sealing in spring; although on the other hand they know that seals on the ice may be carried inwards through the strait into the Gulf, during heavy north-easterly winds.

Such evidence as the above refers necessarily to the set of the surface current; while on the other hand the drift of icebergs shows in which direction the flow takes place on the average of the whole depth; as the bergs are as large as the strait will admit. This explains the difficulty of arriving at just conclusions from the evidence; as we now know that it is the under-current rather than the surface current which indicates the balance of flow in either direction through the strait. If the movements of the icebergs were observed at equal intervals of time, and in relation to the tide, they would give a valuable result; but there are few men who take the care or have the opportunity to do this. It is also likely that in the spring, one year may differ from another with respect to the amount of water which enters or leaves the Gulf through the strait; but a careful consideration of all the evidence obtained corroborates the conclusion which was arrived at by this survey after the first season's work; that the usual tidal flow in the strait does not give more than a small difference in favour of the inward direction towards the Gulf.

In reply to circulars issued by this survey, reports have been received from the captains of trans-Atlantic steamships of the leading lines, which state the direction of the currents as met with on each trip made through this strait, between Belle Isle and its western end. The result is as follows:—In 1895, from 11th July to 18th October only eight trips were reported. Out of this nnmber, the current set outwards to the east *six times*, with a velocity of 0·25 to 1·50 knots per hour on the average during the whole run through the strait; and *twice* there was no current or it was partly in each direction. In 1896, there are twenty-six trips reported, which were made between 27th June and 30th October. Out of this number the current set outwards *fifteen times* with a velocity of 0·25 to 2·00 knots on the average during the run. It set inwards to the west *five times*, with an average velocity of 0·75 to 1·50 knots; and *six times* there was either no current, or it was part of the time in each direction.

During the season of 1896, the fishermen at the western end of the strait, who have been there all summer, state that the current has run east and west with the tide, as it generally does. These men anchor their boats in 5 to 20 fathoms of water, or if further out, they drift up and down with the tide. They have thus an excellent opportunity of knowing the set of the current; as the strait is there only 12 miles wide. It is not so easy to gather from them in which direction the balance of flow has been the greater; but it appears that on the whole the current has made outwards to the east, rather than inwards, during the past summer. From the beginning of June to the middle of July, the winds were heavy; first, easterly, and later west and north-west. Since then there was a greater amount of south-west wind than usual throughout the summer. All kinds of weather came up with the same wind; and even fog, which is infrequent from that quarter. The winds in the early season did not bring in the ice as they generally do; but on the contrary the strait was clear of ice by 15th May which is earlier than usual. Although there was a great deal of ice at the Atlantic end of the strait throughout the summer, there were fewer bergs than usual which came into the strait itself, and none were seen west of Greenly Island. It is so reported by Captain Macauley of the SS. "Canada," Dominion line, and Captain Johnston, of the Allan line. The icebergs were numerous around Belle Isle, and many passed west of it, and out around Cape Norman; but comparatively few came up the strait west of that cape.

The temperatures of the water in the strait, taken on 1st September, when compared with the temperatures obtained during the season of 1894, show that the temperature of the water towards the surface was above the average. This corresponds most nearly with temperatures found during outward flow; but they are not so high as during the period of persistent outward flow for several days, which occurred five weeks earlier in the season of 1894. (See temperatures as observed on 21st July, 1894). The surface density on 1st September was 1·0239, which is distinctly lower than in 1894, when the average density at eight points in the strait was 1·0243 as observed early in July.

From a consideration of the evidence compared with these indications, it appears that the outward flow of this season was chiefly at the surface, and probably amounted only, to a slight difference in favour of that direction; because the observations of 1894 show that the under-current may maintain its tidal character in the two directions, even when the surface current has a dominant set in the one direction, under the influence of the wind. The under-current thus tends to make the flow more nearly equal in each direction than the surface current would indicate. This is nevertheless important to note, while tracing the general circulation.

The North Shore. (*Saguenay County, Province of Quebec.*)—From the Esquimaux Islands or the offing of St. Augustine, along the north shore to Cape Whittle, all the evidence goes to show that the prevailing movement of the water is westward, if the direction of the under-current is taken into account as well as the surface current. The unusual prevalence of south-westerly winds this season, seems to have had its effect upon the surface current at station E, as well as in the Strait of Belle Isle; but at the three stations on this shore, C, D and E, the under-current made usually to the westward. Where the dominant direction is indicated more clearly by the under-current than by the surface current, the drift of icebergs is a valuable indication. The captains of the steamship lines, have seen them as far west as the Mecattina Islands, and sometimes, though rarely, they reach Cape Whittle. There is good evidence that a small berg was once seen in the early spring as far as Natashquan. From the independent testimony of two fishermen there, this berg was thirty yards square, and as high as the masts of a schooner. It appears to require a combination of favourable circumstances to bring them as far as this, however. The manner in which these bergs make their way westward is thus described by Noel:—An iceberg off St. Augustine drifted in one day on a south-west course to Treble Hill Island, making off-shore; next day it came squarely in towards the land on a north-west course; it afterwards continued on a south-west course, and so worked its way in. It is also stated by Curtis, that within two miles of the shore, where the current runs more strongly in both directions, it still makes to the westward on the whole, and that this applies to the whole shore from St. Augustine to Cape Whittle. It will be noted that the icebergs on this shore are carried to the westward more than twice as far as on the Newfoundland side, where they are rarely found beyond Rich Point.

The master of a schooner who spent the early spring of 1896 in the offing of the Mecattina Islands, states that the current then ran westward continuously during three weeks. The wind at the time was easterly, ranging from E. S. E. to E. N. E. At other times he has also found that this is its usual direction on the whole.

At Great Mecattina Island, which is well off shore, Gaumond states that the current runs in either direction, but is strongest to the westward. In the early spring the ice passes westward at a walking pace, which he estimates at three knots an hour. The channel between this island and the mainland freezes over in winter, and if the ice is more or less packed in it, the island becomes practically a headland, which may thus increase the current. The strength of the current is also indicated by the drift of a schooner which was becalmed on 3rd June last, off Outer Island. From dark at about 20 o'clock till 4 on the following morning, it drifted from there to Little Mecattina Island, a distance of 22 miles in 8 hours or nearly three knots per hour. It is unlikely that the current in the open, ever exceeds this rate of three knots except under special conditions in the Strait of Belle Isle itself. The fishermen not infrequently speak of much higher velocities in these parts; but it is always found on inquiry that these are over-estimated, or that they refer to local rips off points or in confined channels.

A measure of the velocity of the surface current in the eastward direction or contrary to its usual set, was obtained at the end of July, 1894, at three stations lying between Rich Point and the Esquimaux Islands. These stations were occupied immediately after prolonged westerly winds; and it was stated in the report for that year, that the velocities then found were probably as great as ever occur in this eastward direction, owing to the special conditions at the time. The velocity amounted to 0·79 of a knot per hour at the middle, and 1·19 to 1·37 knots on the two sides. The layer of water in motion had a thickness of only 5 to 10 fathoms. (See conditions as described in annual report, Department of Marine, for 1894; pages 103 and 104.)

Reports have been received from the captains of trans-Atlantic steamships, in reply to the circulars, in which the Gulf was divided into several regions. On the run between Heath Point and Greenly Island, the current which was met with on each trip is described, with the following result:—In 1895, from 11th July to 18th October, only eight trips were reported. Of this number, there were *six times* when there was no current appreciable; and *twice* the current set to the westward with a velocity of half a knot. In 1896 there are twenty-four trips reported, which were made between 5th July and 30th October. *Ten times* there was no current appreciable; *nine times* the current set eastward with a velocity which ranged from 0·20 to 0·75 of a knot per hour on the average during the above run; *five times* the current set westward, with a velocity which ranged from 0·30 to 0·75 of a knot on the average.

It is clear that in dealing with such currents as these, a distinction must be made between the set of the surface water and the direction in which the general circulation takes place. There can be little doubt that when both surface and under-current are taken into account, the movement of the water as a whole is to the westward on the north shore from the Esquimaux Islands to Cape Whittle.

The surface current will also have this direction when undisturbed, or during easterly winds; but its actual set is very irregular and may be in almost any direction. On comparing the observations obtained at stations C, D and E, with the other evidence, it is found that these observations may be taken as a good illustration of the ordinary behaviour of the current, as now stated; and they show that even when the surface current sets in other directions, the under-current still makes usually to the westward.

It is more than probable that the water which makes westward along the north shore is a return current corresponding with the north-eastward set on the New foundland side. There is no other direction from which this water can come; as any inflow that there may be through the Strait of Belle Isle is quite insufficient to keep up the supply. A large volume must make to the westward if this is in reality the usual direction of the under-current from about 15 fathoms downwards, where the total depth is seldom less than 40 fathoms.

The water must make across from the Newfoundland side to the north shore in the area already referred to, lying between Rich Point and the west end of the Strait of Belle Isle. On the western confines of this area, there is a constant current setting in from the south-west, and another setting out to the westward, while on its eastern side there is the strong ebb and flow of the strait itself. There may also be times when long continued winds give the surface current a drift which is either eastward or westward according to its own direction. As the depth ranges from 30 to 70 fathoms, it is sufficient to allow the water to make across to the northern side as an under-current, as it is quite possible that it does. The irregular character of the currents in this area is thus accounted for.

On the west coast of Newfoundland, the surface current and the under-current have the same direction; but in the return current on the north shore the direction is maintained chiefly by the under-current, while the current on the surface is not infrequently to the eastward. The reason of this must be, that in these latitudes the prevailing winds are westerly; and they are with the one current, and against the other; and thus reverse its surface drift.

Although the current on the Newfoundland side is thus the more distinct, the north shore current is the better known, as it lies more directly on the route of the Atlantic steamships; and that coast is also more frequented by fishermen. The icebergs carried westward by it may also have been taken as a corrobation of the old belief in the dominant inward direction of the current in the Strait of Belle Isle; but the examination now made, points to quite a different explanation as we have seen.

Cape Whittle to Heath Point, and the Channel north of Anticosti.—From the observations of 1895, in the Mingan Strait, it appears that the current is there tidal, with a flow which is practically equal in each direction. (See Report of Progress, April, 1896, pages 17 and 18). There is, therefore, no through current to be expected in the channel north of Anticosti.

At Natashquan Point, which is half way between Cape Whittle and the Mingan Islands, the observations during the summer with the flag buoys show that the surface current makes out to the south-eastward more than inwards. The observations show this outward flow to be even more marked at East Cape, where the set is southward for two-thirds of the time. It is also stated by men who know Anticosti, that it is only on the short length of coast, from Table Head to East Cape, where the shore runs north and south, that the current has a dominant set of this character.

At station A the dominant direction of the surface current was found to be the same as the direction of the winds which had the greatest mileage at the time. As winds from the westerly quarter are the most prevalent at any time, it is probable that the surface current usually has this outward tendency. This is confirmed by the experience of Captain Macauley of the SS. "Canada," who states that in crossing from Heath Point to Cape Whittle, vessels are set more to the southward by north-west winds, than to the northward by south-east winds.

As there is no evidence of any through current in this channel, the outward tendency of the surface water must originate in the channel itself; and it appears to be balanced by an inward tendency in the under-current. The two series of observations obtained at station C, show that the current which sets to the westward along the north shore, on reaching Cape Whittle makes on the whole to the north-westward. This dominant direction is more marked in the under-current than on the surface; and this inward trend of the current around Cape Whittle is to be looked upon as an indraught to make up for the outflow on the surface.

These dominant directions of the current when taken together, point to the conclusion that the water on the whole makes across from Cape Whittle towards East Cape. It probably does so chiefly as an under-current; because the prevailing westerly winds influence the surface water in their own direction. But as the southward set is stronger on the Anticosti side, the surface water appears to be carried over against that side by the westward direction of the water off Cape Whittle; which shows that its influence is felt all the way across.

Off the east end of Anticosti, the water makes on the whole to the westward, as we have seen from the under-current observations at stations B and H. It is more than probable that this water continues westward, and contributes to the return flow which compensates for the Gaspé Current. The temperature and density of this water do not furnish any positive indication to show where it comes from; and although it may possibly be drawn from the central part of the Gulf, where the water coming in at Cape Ray diffuses itself, it appears more likely that it is water which has made its way across from Cape Whittle.

GENERAL CIRCULATION IN THE GULF.

Although there are few instances of currents in this region which run steadily enough to be termed constant, we have yet found it possible from continuous observation or long experience to arrive at a dominant direction for each locality; or the direction in which the current runs more frequently, and in which, therefore, the water makes on the whole. In reviewing these movements of the water, with a view to tracing the general circulation in the Gulf, it is the principle of the balance of flow which is the most evident. Wherever a current of a constant character occurs, there is a corresponding return current to make up for it. Thus in Cabot Strait, the outflowing water at Cape North is balanced by the inflow at Cape Ray; the north-eastward current on the west coast of Newfoundland is balanced by the contrary direction of the movement on the opposite shore; and we have fairly good indications of a return flow to compensate for the Gaspé Current.

It is this balance of flow which points to the nature and direction of the circulation of water in the Gulf. If we begin to trace it from Cabot Strait, where the balance between the Gulf and the Ocean takes place, the inflow at Cape Ray appears to diffuse itself more or less widely over the central part of the Gulf, but it regains its strength on the west coast of Newfoundland, and makes a deep bend into the north-eastern angle of the Gulf, and returns westward, as we have seen, along the north shore. On reaching Cape Whittle, it still makes westward; and, whether as an actual set, or by displacing water which comes more directly from Cape Ray, it appears to work around the eastern end of Anticosti, and so compensates for the outflow of the Gaspé Current from the estuary of the St. Lawrence. This current, after rounding the Gaspé coast, makes south-eastward as a general set or drift across the Gulf to the western side of Cabot Strait; and its waters there leave the Gulf in the outflowing current off Cape North. This current is still felt along the sweep of the north-eastern coast of Cape Breton Island, sometimes as far as Scatari, before it mingles with the waters of the Atlantic.

This general movement of the water in the Gulf is in accord with the uniform and relatively high density of the water in its north-eastern portion, already referred to; and explains why this density should be so nearly the same as in the open Atlantic; and also why there should be so small an increase in the temperature of the surface water with the progress of the season.

This must, therefore, be the usual course of the water, more especially in the summer season when the currents are least disturbed. But if at times in the spring, the outflowing water in Cabot Strait occupies the greater part of the width of that strait, the amount of water required for compensation may then flow into the Gulf through the Strait of Belle Isle. Although it is quite possible that this may occur in the early spring of some seasons, the evidence does not point strongly in that direction. On the other hand, it is now more evident than ever, that there cannot be any through current across the Gulf from Belle Isle to Cabot Strait according to the old theory; as we now see that any inflow at Belle Isle would be turned along the north shore, rather than in that direction.

It also appears that the whole of the balance or compensation in the Gulf currents takes place at the surface and in ordinary under-currents, which do not probably extend to a greater depth than some 50 or 60 fathoms. There is nothing, therefore, to show the necessity for any appreciable movement in the deep water from 60 or 80 fathoms downward, which lies in the deep channels of the Gulf. Such direct indications as have been obtained favour the belief that this deep water is quiescent.

How far the prevailing westerly winds may influence these general movements of the water, it is difficult to say. The prevailing winds over the Gulf generally, are north-westerly in winter and south-westerly in summer. These winds may have an appreciable influence in maintaining the current on the western side of Newfoundland and in carrying it further into the north-eastern angle of the Gulf before it returns. If this effect is attributed to the wind however, it makes it all the more difficult to understand why it is that the water of lower density in making its way from Gaspé to Cape North is not carried further over into the Gulf, but keeps to the south west, or the windward side. This feature has already been remarked upon in a previous report; and, although a satisfactory explanation is not yet apparent, it may be well to point out that the bias of the current in both cases accords with the rotation of the earth. Thus the Gaspé Current, after rounding the Gaspé coast, tends to the west, as its course is southward; and the inflowing water at Cape Ray, with a northward direction, tends to the east. As the Gulf of St. Lawrence lies between 46° and 52° north latitude, it is possible that the rotation of the earth may have an appreciable effect.

It is probable that the temperature and density of the water and the direction of its currents, may have important bearings upon the movements of fish, which as yet are imperfectly understood. This opinion is held by the countries bordering on the North Sea; and the information afforded by the investigation of the movements and other characteristics of the water are there used as a basis in arriving at the reasons for the distribution and migration of fish at different seasons. This information has its chief application in the North Sea to the herring fishery; and yet a practical return is expected for the outlay which is made in obtaining it; and the investigation is of such importance that arrangements are being discussed for international co-operation amongst the countries bordering on the North Sea in carrying it on. In our fisheries, the cod and mackerel have a greater importance relatively than the herring; which would warrant the expenditure of larger sums in proportion in promoting their interests by such investigations.

As an example of the importance of knowing where fish are to be found, and why they prefer one region to another in different seasons, it may be mentioned that during last season fishing schooners were returning from Labrador in September with half cargoes, while within the Gulf we found on the "Lansdowne" that cod were everywhere abundant throughout the summer on the 30 and 40-fathom banks, which no schooners were taking advantage of. It is held by fishermen that fish are never caught while the water is clear; and its clearness must have some relation to physicial conditions which could be ascertained. It is also known that the cod are caught in shallower water in the spring, and further from shore as the season advances. This may depend more directly on the movements of the herring or capelin which they follow; but these fish may themselves be influenced in their movements by the temperature or other characteristics of the water which may differ at different times.

Summary note regarding the set of the surface current in the north-eastern portion of the Gulf of St. Lawrence.—From the character of the currents as described, and the great variation in direction which they show, especially at the surface, it is necessarily difficult to lay down rules with regard to the current as it affects shipping, which will not be subject to a large amount of exception. It is of practical importance to note that the currents throughout this region are all slow, and seldom exceed one knot per hour in the summer season. It is no doubt on this account that they are so liable to disturbance, and present so much irregularity when examined in detail.

It has been possible as we have seen, when longer periods are considered, and when the under-current also is taken into account, to trace the general circulation of the water; which depends upon a greater movement in some dominant direction rather than in other directions, when long averages are taken. A knowledge of this general circulation is important to mariners, as it includes all the more constant currents, and it also shows the direction which the surface current tends to take when undisturbed.

The primary tendency in the surface current is thus to follow the direction which the general circulation has in the locality in question; but this tendency is disturbed and often overcome by the influence of the tide and the wind. The tidal influence shows itself chiefly as a veer in the direction of the current, which is either through a limited range, or completely around the compass; and it is also probable that the tides themselves are irregular in this region, owing to the interference of the tidal undulation from the Strait of Belle Isle with the main tide which enters through Cabot Strait. When the wind remains in one quarter and has any considerable strength, the drift which it gives to the surface water soon extends to a depth of five fathoms or more, and its influence thus makes itself felt throughout the thickness of the surface layer which affects shipping. As a rule these influences are all acting at the same time; and it is their combined effect which gives rise to the actual behaviour of the surface current.

It may, therefore, be of advantage to give in brief the actual behaviour of the surface current, in the various parts of the region under consideration; without distinguishing more than may be necessary, between the causes which influence its movements. It is to be understood that the currents referred to are in the offing, and do not include local currents close in shore.

On the west coast of Newfoundland, the current almost always sets along shore to the north-east. It is scarcely appreciable from Cape St. George to the Bay of Islands; but from there to Rich Point it is distinct and usually amounts to one knot per hour. Occasionally, the set may be off or on shore for a few hours at a time. It is also possible for the current to slack, or to be reversed on the surface, during heavy north-easterly winds.

From Rich Point to the western end of the Strait of Belle Isle, the currents are variable and uncertain in their direction, and cross-currents are frequent. The reasons for this have already been explained. The area in which such currents may occur, extends westward from the narrowest part of the strait at Amour Point to a line through Rich Point running magnetic north to the Esquimaux Islands. Towards the western side of this area, the currents are usually less than one knot, and seldom exceed one and a half knots; but towards the entrance of the strait their strength increases, while in direction they are more nearly in the line of the strait itself.

The characteristics of the current in the Strait of Belle Isle itself have been already fully described. (See reports already quoted; and also Notice to Mariners, No. 65 of 1895, Department of Marine and Fisheries, Ottawa).

On the steamship route running through this region from Greenly Island to Heath Point, the surface current has in general the following characteristics in the summer season, as ascertained by observations in the months of July, August and September, 1896:— From the offing of the Esquimaux Islands to the east end of Anticosti, the strength of the current usually ranges from half a knot to one knot per hour. In direction, the current veers continually, and it usually makes complete revolutions around the compass in a right-handed direction. In ordinary weather the manner in which this veering of the current takes place is such that the direction of the current is out of relation with the time of the tide. (From continuous observations of both surface and under-currents, some tidal relations have been made out, which hold good for the surface current during periods of calm weather). With regard to the influence of the wind, when a period of several days or a week is taken as a whole, it is found that the greatest amount of set has taken place in the same general direction as the greatest total mileage of wind; but at any particular time, the direction of the current is seldom the same as the wind which is blowing locally.

On the different parts of this route, it may also be noted that along the North Shore from the offing of the Esquimaux Islands to Cape Whittle, the direction of the current is more usually along the shore, than either off or on shore. Also, judging from the general movement of the water as indicated by the under-current, it is probable that on the surface the current sets more strongly to the westward during east winds, than eastward during west winds. (In the early spring, it is said to attain a speed of three knots when setting westward). In the more open waters from Cape Whittle to Heath Point, the observations make it probable that the current sets more frequently to the south-eastward than in other directions, under the influence of the prevailing winds. Also, in the offing of Cape Whittle during periods of calm weather, the current makes to the north-westward more than in other directions; and in its movement, a tidal element can be recognized. In the offing of Heath Point, the current as it veers around, sets off or on shore for about two hours at a time.

Present position of this branch of the Tidal Survey, and future work.—During the past three seasons, a general examination of the currents in the interior of the Gulf of St. Lawrence and the straits connecting it with the Ocean, has been made with special reference to the leading steamship routes which pass through it. Little attention has yet been given to the currents in the wide bay formed by the sweep of the coast from Miscou to Cape Breton, in which Prince Edward Island lies. The strong tidal currents of the Lower St. Lawrence have not yet been examined; as they are usually parallel with the shore and have less tendency to set a vessel out of its course; and also because from Father Point to Quebec, vessels have the advantage of the Pilot service. It was also necessary to obtain first some knowledge of the Gulf currents and their relation to the Ocean. No detailed examination has yet been made of the currents in the Atlantic, off the outer end of the Strait of Belle Isle, for the assistance of vessels in making the strait. On the south coast of Newfoundland, it is reported that there is a strong indraught into the larger bays; and to this several wrecks are attributed. The distance from shore that this is felt, and the conditions of wind and tide which give it the greatest strength, should be ascertained; as two of our leading steamship routes follow this coast. Some information has been collected with regard to the general set of the current on the Atlantic coast of Nova Scotia; but the currents on the south-western coast and in the Bay of Fundy are much more important. In the upper arms of the bay, the currents are probably parallel with the coast line, as in the Lower St. Lawrence; but there, the navigation is entirely dependent on the tide, and the time and height of the tide are of the first importance. Towards the mouth of the bay, the currents require investigation in the interest of the steamship lines running to St. John, and to ports in western Nova Scotia. An examination of these should be made while the principal tidal stations are still in operation; as they are chiefly tidal, and their behaviour can only be ascertained by direct comparison with a tidal record. This may serve to indicate the information which is most needed with regard to the currents on our eastern coasts, and which it is important to obtain as soon as possible in the interest of Canadian shipping.

I have, sir, the honour to remain,

Your obedient servant,

W. BELL DAWSON,
In charge of Tidal Survey.

Table I.—Direction of the Surface Current; showing the time of flow in each towards the directions indicated. The directions

Note.—After August 12th the directions of the current, during the day time, are the mean

Locality.	1896.	Total time in hours.	S.	S.S.W.	S.W.	W.S.W.	W.
Station A.							
Midway between East Cape, Anticosti, and Cape Whittle.	Wednesday, July 8..	3½	....	....	....	....	....
	Thursday do 9..	24	4	1	....	1	3
	Friday do 10..	24	2	2	2	1	....
	Saturday do 11..	24	2	2	10	4	8
	July 12-13... ...	24	9	7	1	6	5
	Tuesday, July 14..	24	2	1	6	2	2
	Wednesday do 15..	6½	3	2	3	1	....
	Totals..........	130	22	15	22	15	18
Station B.							
At 24 miles S.E. of Heath Point, Anticosti.	July 15-16	7½	....	....	....	....	....
	Friday July 17 .	3½	....	....	....	....	....
	Saturday do 18..	24	6	2	2	2	....
	Monday do 20..	24	....	....	....	....	....
	Tuesday do 21..	24	3	....	....	1	....
	Wednesday do 22..	24	1	1	....	1	6
	Thursday do 23..	7½	....	....	....	....	....
	Totals..........	114½	10	3	2	4	6
Station C.							
At 18 miles S. of Cape Whittle	Monday, July 27..	11	2	....	1	....	....
	Tuesday do 28 .	24	3	1	1	....	1
	Wednesday do 29..	24	1	4	....	4	3
	Thursday do 30..	24	....	....	....	....	....
	Friday do 31..	6½	....	....	....	....	....
	Wednesd'y, Aug. 12..	15	....	....	1	3	7
	Thursday do 13..	24	2	4	6	10	....
	Friday do 14..	24	....	2	1	3	12
	Saturday do 15..	24	3	4	4	7	1
	Totals..........	176½	11	15	14	27	24
Station D							
At 15 miles S. by W. of Great Mecattina Island.	Wednesday, Aug. 19.	15	8	2	3	2	3
	Thursday do 20.	24	1	6	2	3	....
	Friday do 21.	24	6	8	4	2	2
	Saturday do 22.	16	9	5	5	2	....
	Totals..........	79	24	21	14	9	5
Station E.							
At 13 miles S.S.E. of Shecatica Bay.	Monday, Aug. 24.	2	....	....	....	....	....
	Wednesday do 26.	13½	2	....	....	....	....
	Thursday do 27.	14½	2	....	....	1	....
	Totals..........	30	4	....	....	1	....
Station F.							
At 10 miles N.N.W. of Rich Point.	Thursday, Aug. 27.	6	1	....	....	....	....
	Friday do 28.	24	3	....	....	....	....
	Saturday do 29.	8	....	....	....	....	....
	Totals..........	38	4	....	....	....	....

direction. The figures give the number of half-hours during which the current set are magnetic. Variation, 29° to 34° W.

between the directions at the surface and at a depth of 18 feet. Compare Plates II. and III.

W.N.W.	N.W.	N.N.W.	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	No current.
...	...	...	...	...	...	...	...	1	2	4	...	...
2	...	1	2	4	5	3	1	5	2	2	4	12
1	2	2	1	3	3	3	8	9	1	2	2	6
1	3	1	1	...	1	3	3	3	1	...	2	5
...	2	1	...	...	...	...	1	5	7	4	9	...
...	...	1	2	1	1	...	3	10	10	5	2	2
...	...	...	...	...	...	...	...	...	1	3	3	...
4	**7**	**6**	**6**	**8**	**10**	**9**	**16**	**33**	**24**	**20**	**22**	**25**
...	...	1	...	4	6	2	1	...	1	...	...	...
...	...	...	...	...	...	...	...	7	...	...	...	...
4	...	7	2	2	3	2	2	6	4	3	6	1
...	...	...	2	3	3	12	17	5	3	...	...	3
...	...	...	1	2	8	13	7	2	...	3	3	8
3	1	...	...	...	1	4	6	7	6	1	1	10
...	...	2	1	4	2	5	1	...	...	...	...	...
7	**1**	**10**	**6**	**15**	**23**	**38**	**34**	**27**	**14**	**7**	**10**	**22**
1	...	...	3	...	1	2	2	1	4	5	2	...
2	1	2	3	3	8	8	5	3	3	4	3	...
3	...	3	3	3	4	4	3	4	2	5	1	2
...	...	...	1	...	8	15	3	6	11	4	...	...
...	...	...	4	4	4	1	...	...	...	...	...	...
5	2	4	2	1	...	...	...	...	...	...	...	5
4	1	9	5	4	1	...	...	...	1	...	2	1
13	14	...	...	...	...	...	...	...	...	...	...	3
4	5	8	6	4	...	...	...	...	...	1	3	1
32	**23**	**26**	**27**	**19**	**26**	**30**	**13**	**14**	**21**	**19**	**11**	**12**
...	...	...	...	...	...	...	...	...	...	7	8	5
...	3	...	...	1	2	5	7	7	...	4	1	7
...	...	...	...	...	...	...	...	1	4	16	6	5
...	...	...	...	...	...	...	...	4	2	5	9	...
...	**3**	...	...	**1**	**2**	**5**	**7**	**12**	**6**	**32**	**24**	**17**
...	...	...	...	...	1	3	...	...	...	...	...	...
...	...	...	...	2	2	1	1	10	1	8	2	...
...	2	...	...	...	...	...	9	5	...	2	2	8
...	**2**	...	...	**2**	**3**	**4**	**10**	**15**	**1**	**10**	**4**	**8**
...	...	...	...	...	...	2	6	...	...	2	1	1
...	8	5	1	9	1	4	3	8	2	1	3	3
...	5	1	...	...	...	...	...	2	...	1	...	7
...	**13**	**6**	**1**	**9**	**1**	**6**	**9**	**10**	**2**	**4**	**4**	**11**

TABLE I.—Direction of the Surface Current, showing the

Locality.	1896.	Total time in hours.	S.	S.S.W.	S.W.	W.S.W.	W.
Station G.							
At 12 miles W.N.W. of Cow Head, (on the west coast of Newfoundland).	Thursday, Sept. 3.	2	....	....	....	....	....
	Tuesday do 8.	13	....	....	....	....	....
	Wednesday do 9.	24	....	....	....	....	....
	Thursday do 10.	22½	....	....	....	....	....
	Friday do 11.	4	....	....	....	....	....
	Monday do 14.	6½	....	....	....	....	....
	Totals.........	72	....	....	....	....	....
Station H.							
At 13 miles S.E. of Heath Point, Anticosti.	Wednesday, Sept. 16.	2½	2	2	....	....	....
	Thursday do 17.	16½	4	....	....	....	2
	Monday do 21.	8	2	2	2	....	....
	Tuesday do 22.	5	....	....	....	....	1
	Thursday do 24.	15½	3	8	2	....	....
	Friday do 25.	15½	....	1	1	6	3
	Saturday do 26.	3	....	....	....	....	....
	Totals	66	11	13	5	6	6

time of flow in each direction, &c.—*Continued.*

W.N.W.	N.W.	N.N.W.	N.	N.N.E.	N.E.	E.N.E.	E.	E.S.E.	S.E.	S.S.E.	S.	No current,
......	......	3	1	......	......	......	......	......	......	......	......	......
......	......	4	9	6	......	6	......	......	......	......	......	1
......	......	9	1	......	1	33	3	......	......	......	......	1
......	......	......	......	2	10	27	6	......	......	......	......	......
......	......	......	......	......	......	......	......	7	1	......	......	......
......	......	3	3	2	1	1	......	......	......	......	......	3
......	......	19	14	10	12	67	9	7	1	......	......	5
......	......	......	......	......	......	......	......	......	1	......	2	......
......	......	......	1	2	6	5	2	2	4	1	4	4
......	......	......	......	......	......	2	......	3	2	3	2	......
6	3	......	......	......	......	......	......	......	......	......	......	......
2	......	......	......	4	2	......	......	3	1	3	3	3
6	2	......	......	......	1	8	1	......	1	1	......	......
......	1	......	......	......	......	1	......	......	1	......	......	3
14	6	......	1	6	9	16	3	8	10	8	11	10

Table II.—UNDER-CURRENTS; their Velocity and Direction.

The positions of the stations are shown on the chart, Plate I. The time of the observations is Standard time for the 60th meridian, reckoned on the 24 hour system from midnight to midnight. The figures in the columns show the velocity of the current in knots per hour; and the directions are those towards which the current sets. These directions are magnetic. Variation, 29° to 34° W.

These results were obtained by means of an attached surface float, a current meter at three fathoms, and a deep fan supported by sounding wire; in accordance with the methods explained in the body of the report. The results as given are reliable. When the under-current was so slow that its bearing was uncertain, its general direction only is given. The velocity is correct to the nearest tenth of a knot; and if uncertain, it is omitted. (See pages 11 to 14).

STATION B.—OFF HEATH POINT, ANTICOSTI. DEPTH, 52 FATHOMS.

Depth.	Saturday, 18th July, 1896.							20th July.	
	10.30	13.10	14.00	15.30	16.30	17.40	18.40	9.30	10.30
Surface.....	0·5 E *b* S	0·9 SE	0·8 SE	0·8 SE	0·8 S *b* E	0·9 S *b* W	1·1 SW	0·2 E *b* S	0·3 SE
3 fathoms..	0·4 E *b* S	0·9 SE	0·8 SE	....	0·8 S *b* E	0·9 SW	0·9 WSW	None.	0·3 S'ly
10 do ..	None.	0·4 E	0·7 E	....	None.	0·3 SW	0·6 W *b* S	None.	Slack.
20 do ..	None.	0·4 E	0·4 E	0·5 NE	0·4 NNE	None.	0·5 W'ly	0·6 W *b* S	0·3 W *b* N
30 do ..	....	0·5 E	0·5 N	0·3 NE	0·6 NNE	None.	0·6 W'ly	0·4 W *b* S	....
40 do ..	....	....	0·5 N	....	0·8 N *b* W	0·4 ENE	0·6 W'ly	0·4 W *b* S	....

Depth.	Monday, 20th July—*Continued.*					Tuesday, 21st July.			
	11.30	12.10	13·50	16.15	19.15	10.15	10.50	11.30	14.20
Surface...	SE *b* E	SE *b* E	0·6 ESE	0·6 E *b* S	0·5 ESE	None.	None.	0·5 WSW	0·5 ENE
3 fathoms	0·3 SE	0·4 SE	0 5 SE	0·5 ESE	0·3 NNE	0·6 SW	0·7 W	Under-current comes up to surface.	0·5 ENE
10 do ..	None.	0·4 SE	0·5 NE	0·4 ENE	0·4 NNE	1·0 W *b* N	0·8 W		0·6 NE
20 do ..	0·3 NW	None.	0·5 NNE	0·6 ENE	0 5 NE	0·7 W *b* N	0·6 W		0·3 E
30 do ..	0·4 WNW	....	None.	0·5 ENE	0·3 NE	0·5 WSW	0·7 W		None.
40 do ..	0·4 WNW	0·2 NW	None.	0·5 NNE	0·4 NE	0·5 WSW	0·7 WSW		....

Depth.	Tuesday—*Con'd.*		Wednesday, 22nd July, 1896.						
	16.00	17.00	9.45	10.40	11.10	13.50	16.10	17.50	18.45
Surface...	0·8 NE	0·9 NE	0·1 W'ly	0·1 W'ly	None.	0·3 NE	0·3 ESE	0·3 ESE	0·4 SE
3 fathoms	0·8 ENE	0·9 NE	0·5 NW	0·5 W	0·6 WNW	0·6 —	0·7 E	....	None.
10 do ..	0·7 ENE	0·5 NE	0·5 WSW	0·5 W	0·7 W	0·3 W'ly	0·8 NE	....	0·5 E
20 do ..	0·5 NE	0·6 NE	0·2 W'ly	0·4 W	0·5 W	0·9 NW	0·6 NNE	....	0·6 NNE
30 do ..	0·5 NE	0·7 NE	0·2 W'ly	....	0·4 W	0·8 NW	0·6 NNE	....	0·6 NE
40 do ..	0·7 NE	0·7 NE	None.	....	0·4 W	0·7 WNW	....	0·9 N	0·8 NNE

TABLE II.—Under-currents—*Continued.*

STATION H.—OFF HEATH POINT, ANTICOSTI. DEPTH, 37 FATHOMS.

Depth.	Thursday, 17th Sept., 1896.					Monday, 21st Sept.			
	9.05	10.20	14.00	16.10		9.15	9.55	10.55	11.50
Surface.....	0·5 SE	0·6 S *b* W	Slack.	0·5 N *b* E	Weather very rough. Observations approximate.	1·1 E *b* N	0·9 E *b* N	0·9 ESE	1·0 SSE
3 fathoms..	0·5 SSE	0·6 S *b* W	0·4 S *b* W	0·6 N		1·1 E *b* N	0·9 ESE	0·9 SE	1·0 SSE
5 do ..	0·7 S	0·6 SSW	....	Slack.		1·1 E *b* N	....	1·0 SSE	1·0 S
10 do ..	0·3 SW	0·3 SW	0·5 WNW	None.		0·9 E *b* N	1·0 ESE	0·8 SE	0·9 S
20 do .	0·3 SSW	0·3 SW	None.	Slack.		0·8 E *b* N	0·6 ESE	0·4 ESE	0·3 S'ly.
30 do ..	None.	0·3 SSW	....	....		0·5 E *b* N	0·5 E	None.	None.

Depth.	Monday—*Continued.*			Tuesday, 22nd Sept.				
	13.25	14.50	15.40	10.10	11.10	13.00	14.10	
Surface.....	1·1 S	1·2 S *b* W	— SW	0·7 NNW	0·7 WNW	0·7 WNW	0·7 W	Heavy weather continuing Wednesday. Wind E to NNE. 1157 miles in 36 hours.
3 fathoms..	1·1 SSW	1·2 —	(Rolling	0·7 NNW	0·7 NW	0·6 NW	0·7 W *b* S	
5 do ..	....	....	heavily.)	0·5 N *b* W	0·6 NW	— NNW	....	
10 do ..	0·9 SSW	0·9 S *b* W	0·9 SW	0·6 N	0·5 NNW	0·5 W	0·9 W'ly	
20 do ..	0·4 S	0·5 S *b* W	0·5 SW	0·3 N'ly	NW'ly	1·0 WSW	1·0 WSW	
30 do ..	0·3 S	0·5 S *b* W	0·4 SW	None.	NW'ly	....	....	

Depth.	Thursday, 24th Sept., 1896.								
	9.05	10.00	11.15	11.45	13.35	14.55	16.20	16.55	17.45
Surface.....	1·1 NNE	0·9 NNE	0·8 E	0·7 ESE	0·9 SSE	1·3 S *b* E	1·3 SSW	1·3 SSW	1·0 SW
3 fathoms..	1·1 NNE	1·0 NE	0·8 E	0·5 ESE	0·9 S *b* E	1·3 S *b* W	1·2 SSW	1·2 SSW	1·0 SW
5 do ..	1·1 NE	0·9 NE	0·7 NE	0·5 E *b* S	0·7 S	1·1 —	....	1·2 SW	0·9 WSW
10 do ..	1·0 NE	0·6 NE	0·3 NNE	0·3 SSE	0·5 S *b* W	0·8 SW	....	1·0 WSW	0·8 SW
20 do ..	0·7 ENE	0·4 ENE	0·4 N	None.	0·5 W	0·8 WSW	0·5 WSW	0·5 WSW	0·3 SSW
30 do ..	0·7 E	0·4 ENE	0·4 N	None.	0·5 WSW	0·7 SW	0·5 SW	....	0·6 SE

Depth.	Friday, 25th Sept., 1896.							
	8.55	9.40	11.00	11.55	13.20	14.50	17.10	18.35
Surface.....	0·7 WNW	0·7 WNW	0·6 NW	0·6 WNW	0·7 W *b* S	0·7 WSW	0·5 WSW	0·5 ESE
3 fathoms..	0·7 WNW	0·8 NW	0·5 WNW	0·6 WNW	0·7 W *b* N	0·6 W *b* S	0·4 WSW	0·4 SE
5 do ..	....	0·8 NW	0·6 NW	0·6 WNW	0·7 W *b* N	0·6 W *b* N	0·5 W *b* S	0·5 SSE
10 do ..	0·4 NNE	0·4 NNW	None.	0·6 WNW	0·6 W	0·8 WSW	0·7 W *b* S	None.
20 do ..	0·7 NNE	0·6 N *b* E	0·4 N'ly	None.	0 4 W	0·8 WSW	0·8 W *b* S	0·4 SSW
30 do ..	0·6 NNW	0·6 NNW	0·4 NNW	None.	0·5 WNW	0·6 W	0·8 W	0·5 SSW

TABLE II.—Under-currents—*Continued.*

STATION C.—OFF CAPE WHITTLE. DEPTH, 71 FATHOMS.

Depth.	Monday, 27th July, 1896.								
	14.15	14.30	15.10	15.35	16.05	16.35	17.05	17.35	19.05
Surface.....	1·0 E*b*N	1·1 E *b*S	1·1 ESE	1·0 ESE	0·9 SE	1·0 SE	1·0 SE	SE*b*S	1·1 SSE
3 fathoms..	1·0 SE	....	1·1 SE	1·0 SE	....	....	1·0 SE	....	....
10 do ..	None.	None.	None.	0·5 ESE	None.	None.	0·3 E	0·3 E..	0·3 SSE
20 do ..	0·6 NW	....	None.	0·3 W	0·3 W	None.	None.	None.	0·3 SE
30 do ..	....	0·5 W	None.	0·4 W'ly	None.	0·3 W	None.	0·4 E	0·3 ESE
40 do ..	0·5 NW	....	....	....	....	....	....	....	....
50 do ..	0·6 NW	....	....	0·5 NW	....	None.	....	....	....

Depth.	Tuesday, 28th July, 1896.								
	9.10	9.35	10.15	10.40	11.05	11.55	13.10	13.45	15.15
Surface.....	0·8 SSE	0·8 S *b* E	0·7 S	0·7 S	0·8 S*b* W	1·0 S *b* W	Veering	0·8 WNW	0·8 NW
10 fathoms..	0·5 SE	0·3 S	0·2 S	0·2 S	0·3 S	0·4 S	None.	None.	None.
20 do ..	0·5 NNE	None.	None.	None.	None.	0·5 SSE	None.	None.	....
30 do ..	0·5 ENE	0·4 E	None.	None.	None.	0·4 S	None.	....	....
50 do ..	0·5 NNE	....	....	0·5 NE	....	....	....	....	....

Depth.	Tuesday—(*Continued*).				Wednesday, 29th July, 1896.				
	16.15	16.45	17.20	17.45	9.10	10.15	10.45	11.40	13.20
Surface.....	0·8 N*b*W	0·8 N	0·7 NNE	0·7 NE	0·9 NE	1·0 ENE	1·0 ENE	0·9 E*b*N	0·8 E*b*S
3 fathoms..	....	....	....	....	....	....	....	0·9 ENE	0·9 ESE
5 do ..	....	....	....	....	0·8 NE	....	....	0·7 ENE	0·5 ESE
10 do ..	0·6 NW	None.	None.	0·5 E	0·4 NE	0·4 E	0·4 ENE	0·3 ENE	0·3 NNW
20 do ..	....	None.	....	None.	None.	0·3 E	0·3 ENE	0·3 ENE	0·4 NNW
30 do ..	0·3 N	0·3 N	.....	None.	None.	0·3 E	0·2 ENE	0·3 ENE	None.
50 do ..	0·5 W	0·6 W	....	None.	None.	None.	0·3 ENE	....	....

Depth.	Wednesday—(*Continued*).					Thursday, 30th July, 1896.			
	14.40	15.10	16.15	17.30	19.00	9.45	17.20	17.45	19.05
Surface.....	0·5 ESE	0·5 SE	0·7 SE	0·6 SSW	0·5 SSW	* SE	* E*b*N	* E *b* N	* E *b* S
3 fathoms..	0·5 SE	0·5 SE	....	....	....	....	Uncert.	0·6 SE	....
5 do ..	0·4 SE	0·4 SE	....	....	....	....	0·3 NE	0·3 E	0·6 SE
10 do ..	0·3 NW	0·2 NNW	None.	None.	....	Slack.	None.	None.	None.
20 do ..	0·4 NW	0·5 NNW	0·3 NW	0·3 NW	None.	Slack.	....	None.	None.
30 do ..	0·4 NW	0·5 NNW	0·3 WNW	0·3 NW	....	Slack.	....	....	....
50 do ..	....	....	None.	....	....	....	* Rough	weather.	

Table II.—Under-currents—*Continued.*

STATION C.—*Concluded.*

Depth.	Wednesday, 12th Aug., 1896.						Thursday, 13th Aug.		
	10.30	11.40	13.15	15.40	17.15	19.30	9.45	10.50	11.45
Surface.....	0·2 WSW	0·4 WNW	0·4 NW	None.	None.	None.	0·3 NW	0·4 NNW	0·5 NNW
3 fathoms..	Slack.	0·2 WNW	0·4 —	0·4 W'ly.	0·4 WSW	0·4 W	0·3 NW	0·4 NW	0·5 N b W
5 do ..	Slack.	Slack.	None.	0·5 W	0·3 SSW	....	None.	....	0·4 N
10 do ..	None.	None.	None.	0·4 W	None.	0·4 SW	None.	....	0·3 N
20 do ..	None.	None.	None.	None.	None.	—W'ly	None.	0·3 NNE	0·3 NNE
30 do ..	None.	0·2 S	None.	0·3 WSW	0·2 SW	0·3 S	0·3 E	0·2 NNE	....
50 do ..	None.	None.	....	0·5 W	0·2 SW	None.	0·5 E	0·3 ENE	....

Depth.	Thursday—*Continued.*					Friday, 14th Aug.			
	14.30	15 45	17.00	19.05		9.40	10.15	11.40	13.00
Surface.....	0·4 N	0·5 N b E	Slack.	0·6 S b W	(Current to the southward begins at the surface and gradually becomes deeper).	0·3 NW	0·4 NNW	NW b N	0·5 NW
3 fathoms..	0·4 N b W	0·5 N	None.	0·5 SSW		None.	0·4 NNW	0·5 NW	0·5 NW
5 do ..	0·4 N	0·3 W	Slack.	0·4 SW		None.	0·3 NNW	0·3 NW	0·3 NW
10 do ..	0·3 N	0·3 W	Slack.	—W'ly.		0·4 W	0·4 W	0·3 NW	None.
20 do ..	0·3 N	None.	None.	None.		None.	None.	0·3 NW	0·3 NW
30 do ..	0·2 NNW	0·3 W	....	None.		None.	....	None.	None.
50 do ..	0·2 NNW	0·3 WNW	....	....		....	....	....	....

Depth.	Friday—*Continued.*		Saturday, 15th Aug., 1896.					
	16.10	19.05	9.15	11.15	13.30	15.45	16.50	17.35
Surface.....	0·6 NNW	0·5 W	0·4 WSW	0·3 W	0·6 NNW	0·6 N b W	0·4 N b E	0·3 NNE
3 fathoms....	0·6 NW	0·5 WNW	0·4 W	0·3 W b N	0·6 NNW	0·6 WNW	0·5 NNW	0·4 N
5 do	0·5 NW	0·5 NW	0·3 W	None.	0·4 NW	0·5 WNW	0·4 W	0·5 NW
10 do	None.	None.	0·4 SW	None.	0·3 N	0·3 WNW	0·2 NNW	0·3 NW
20 do	0·3 N	None.	0·4 SSW	None.	0·3 N	0·2 W	....	None.
30 do	None.	None.	0·2 SSW	None.	....	None.	....	None.
50 do	....	....	None.	None.	....	....	....	W'ly.

STATION D.—OFF MECATTINA ISLANDS. DEPTH, 45 FATHOMS.

Depth.	Wednesday, 19th Aug.				Thursday, 20th Aug.—*(Continued on next page.)*				
	10.40	11.35	13.20	15.05	8.40	9.50	10.35	11.40	13.35
Surface...	0·6 S b E	0·5 S	0·5 SSE	0·4 S	0·2 S	0·3 SSW	0·3 SSW	0·2 SW	None.
3 fathoms	0·6 S b W	0·5 SSW	0·5 S	0·3 SSW	None.	0·3 SSW	0·3 S b W	0·3 SSW	None.
5 do	0·6 SW	0·6 SSW	0·4 SW	0·3 SSW	0·3 WSW	0·3 SSW	0·4 SW	0·3 W	None.
10 do	0·8 SW	0·7 SW	0·5 SW	0·5 W	0·4 WSW	0·4 W b N	0·4 WNW	0·4 W	None.
15 do	....	....	....	....	....	0·4 W	0·4 W	0·5 WSW	0·4 W
20 do	0·6 WSW	0·5 W b S	0·4 W	0·3 W	None.	None.	None.	None.	None.
30 do	0·4 WSW	0·4 SW	0·4 SSW	0·3 SSW	None.	None.	....	....	......

Table II.—Under-currents—*Continued.*

STATION D.—*Concluded.*

Depth.	Thursday—*Continued.*			Friday, 21st Aug., 1896.				
	14.30 to 16.15	17.15	17.40	9.15	9.45	10.30	13.30	14.50
Surface.....	Surface current veers from West through north to East.	0·3 ENE	0·3 E	0·2 ESE	0·4 SE	0·3 SE	0·5 S *b* E	0·6 SSE
3 fathoms..		Slack.	0·3 ESE	0·2 SE	0·4 SE	0·3 SE	0·7 S	0·7 S
5 do ..		NE'ly	0·2 E	....	0·2 WSW	None.	0·7 SSW	0·7 SSE
10 do ..		NE'ly	None.	....	0·3 WSW	0·2 W	0·5 SW	0·4 SSW
20 do ..		0·4 W	0·4 W	0·5 W'ly	0·6 WSW	0·6 W	0·5 W *b* S	0·4 SW
30 do ..		0·3 W	0·3 W	0·4 W'ly	....	0·4 W	0·4 WSW	0·3 SW

Depth.	Friday—*Continued.*		Saturday, 22nd Aug., 1896.						
	17.00	18.50	9.00	10.00	11.40	12.35	14.25	15.00	15.20
Surface...	0·6 SSE	0·5 S *b* E	— SE *b* S	— S *b* E	0·8 S	0·8 S	0·9 SSW	— S	— S
3 fathoms	0·6 S *b* E	0·5 S *b* E	0·5 SE	— S *b* E	0·8 S	0·8 S *b* W	1·0 SSW	— S	— S
5 do ..	0·7 S	....	0·6 SE	0·7 S *b* W	— S *b* W	0·7 SSW	0·8 SW	0·9 SW	0·9 SW
10 do ..	0·4 SW	0·5 SW	0·9 SSW	0·9 SSW	0·9 SW	....	0·6 SW	....	0·4 SW
20 do ..	0·3 WSW	0·4 SW	0·5 SW	0·4 SSW	0·4 SW	....	0·4 SSW	....	0·4 SW
30 do ..	None.	None.	0·4 SW	0·4 SW	0·4 SW	....	None.	....	....

STATION E.—OFF SHECATICA BAY. DEPTH, 98 FATHOMS.

Depth.	Monday, 24th Aug., 1896.			Wednesday, 26th Aug., 1896.				
	12.00	13.25	—	10.45	11.45	13.30	14.40	16.00
Surface ..	0·3 ENE	0·4 NE	Rough weath'r; continuing on Tuesday.	0·3 NE	0·3 ENE	0·3 ESE	0·5 ESE	0·6 ESE
3 fathoms..	0·2 E'ly	0·3 E		0·3 NNE	0·3 ENE	0·3 ESE	0·5 ESE	0·6 ESE
5 do ..	None.	....		0·3 NNE	0·3 NE	0·3 ENE	0·4 E	....
10 do ..	0·3 E'ly	0·4 ENE		0·3 WNW	0·3 WSW	None.	0·3 E	....
20 do ..	None.	0·5 E		None.	0·2 NW	None.	None.	....
30 do ..	None.	0·4 ESE		0·3 W'ly	0·2 NW	....	None.	None.
50 do ..	....	0·4 ESE		None.	....	....	....	....

Depth.	Wednesday—*Con.*		Thursday, 27th Aug., 1896.						
	16.40	18.40	9.00	9.50	10.30	10.50	11.50	13.15	13.55
Surface	0·6 ESE	0·6 SSE	Slack.	Slack.	Slack.	None.	0·2 S *b* E	None.	None.
3 fathoms..	0·6 SE	0·5 SSE	None.	None.	....	None.	None.	0·3 NW	....
5 do ..	0·5 ESE	0·6 SSE	0·3 SW	0·5 W	....	0·2 W	0·4 NW	None.	....
10 do ..	0·4 ESE	None.	0·3 W	0·3 WSW	....	0·4 W	0·5 NW	None.	....
20 do ..	None.	None.	None.	0·3 NW	....	None.	None.	0·2 W'ly	....
30 do ..	0·3 SE	....	None.	0·2 W	None.	....	....	....	None.
50 do ..	0·2 E'ly	....	....	....	None.	....	....	....	None.
80 do ..	0·2 E'ly	....	....	....	....	....	....	....	....

TABLE II.—Under-currents—*Concluded.*

STATION F.—OFF RICH POINT. DEPTH, 40 FATHOMS.

Depth.	Thursday.	Friday, 28th Aug., 1896.							
	18.40	8.50	9.50	11.25	13.40	14.40	15.00	16.25	17.30
Surface.....	0·4 E *b* N	Slack.	0·4 ESE	0·4 SSE	None.	None.	0·5 NW	0·5 NW	0·5 N *b* W
3 fathoms..	0·4 E *b* S	0·5 E *b* S	0·4 SE	0·4 SSE	0·4 WNW	0·4 W	Undercur-	0·5 NW	0·5 NNW
5 do ..	0·4 E	Uncert.	0·4 SE	0·3 S	0·4 NW	0·4 NW	rent comes	0·6 NW	0·6 NNW
10 do .	None.	None.	None.	Slack.	0·4 NNW	None.	up to sur-	0·3 ESE	0·3 ESE
20 do ..	None.	None.	....	None.	None.	None.	face.	0·3 ESE	0·4 ESE
30 do ..	None.	None.	....	None.	None.	None.		None.	None.

STATION G.—OFF COW HEAD, NEWFOUNDLAND. DEPTH, 42 FATHOMS.

Depth.	3rd Sept.	Tuesday, 8th Sept.					Wednesday, 9th Sept.		
	14.45	11.15	13.15	15.15	17.00	18.40	8.30	10.10	11.25
Surface...	0·3 NNW	0·5 NE	0·5 N *b* E	0·6 N *b* E	0·5 N	0·4 NNE	0·7 ENE	0·7 ENE	0·6 E *b* N
3 fathoms	....	0·4 NE	0·5 N *b* W	0·6 NNW	0·5 NNW	0·4 N	0·7 ENE	0·7 ENE	0·6 E *b* N
5 do	0·5 NNW	0·4 NE	0·6 N *b* W	0·4 NW	0·6 NNW	0·3 NNE	0·6 ENE	0·6 E *b* N	0·4 E *b* N
10 do	0·6 NNW	0·4 NE	0·5 N *b* E	0·4 N *b* E	0·5 N	0·3 N	0·5 ENE	0·5 E *b* N	0·4 E *b* N
20 do	None.	0·4 NE	0·4 NNE	0·3 N *b* E	None.	0·3 N	0·3 ENE	0·3 E *b* N	0·3 ENE
30 do	None.	0·3 NE	....	0·3 N *b* E	None.	0·3 N	0·5 ENE	0·4 E *b* N	0·2 ENE

Depth.	Wednesday—*Continued.*				Thursday, 10th Sept.			
	13.10	15.05	16.10	17.25	8.55	10.25	12.45	14.50
Surface....	0·6 E *b* N	0·4 E *b* N	0·3 ENE	— E *b* N	0·7 ENE	0·7 ENE	0·8 ENE	0·7 ENE
3 fathoms..	....	0·4 ENE	0·3 ENE	....	0·7 ENE	0·7 ENE	0·9 ENE	0·7 ENE
.5 do ..	0·5 E *b* N	0·3 —	....	0·5 E	0·6 ENE	0·7 ENE	0·8 ENE	0·7 NE *b* N
10 do ..	0·4 E *b* N	0·3 ENE	0·4 ENE	0·5 E	0·7 ENE	0·7 ENE	0·6 ENE	0·5 NE *b* N
20 do ..	0·3 E *b* N	0·3 ENE	0·3 ENE	0·3 E	0·5 ENE	0·5 ENE	0·4 ENE	None.
30 do ..	None.	None.	None.	0·3 E	0·5 ENE	0·5 ENE	0·4 ENE	None.

Depth.	Thursday—*Concluded.*		Monday, 14th Sept., 1896.					Remarks.
	16.00	18.40	13.10	13.50	14.20	16.55	17.50	
Surface ...	0·6 NE *b* E	0·6 NE	None.	None.	0·1 ENE	0·1 N	0·1 N *b* W	Very little current except at 10 and 20 fathoms.
3 fathoms.	0·6 NE	0·5 NNE	Slack.	None.	Slack.	0·1 NW	0·1 N *b* W	
5 do .	0·5 NE *b* N	0·4 NNE	Slack.	None.	....	....	....	
10 do .	0·6 NE *b* E	0·5 N *b* E	Slack.	0·5 NNE	0·5 NNE	0.4 NW	0·5 NNW	
20 do .	None.	0·2 ENE	Slack.	0·3 NNE	....	0·4 NNE	None.	
30 do .	None.	None.	Slack.	None.	....	None.	None.	