SURVEY

OF

TIDES AND CURRENTS

IN

CANADIAN WATERS

REPORT OF PROGRESS

BY

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OTTAWA
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OTTAWA, 13th April, 1896.

WM. 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. My last report, dated 31st October, 1895, described the progress made in the extension of the system of Tidal stations, and in the preparation and publication of Tide Tables; but with reference to the Survey of the Currents it was only possible at so early a date, immediately at the close of the season, to give an outline of the work as undertaken. On this account the results were compiled as soon afterwards as possible in a summary form, and issued as a "Notice to Mariners." (No. 65 of 1895; dated December 20th.) This notice was distributed as widely as possible; and a sufficient number of copies were also supplied to eight leading Transatlantic and Gulf-port steamship companies, to enable them to place copies in the hands of all their Captains.

A new departure was made this year in supplying tide tables for Halifax and Quebec, based upon the work of this Survey, to the leading Almanacs for publication. As this is the first time that tables derived from direct observation of the tides have been made available for any Canadian ports, a "Notice to Mariners" (No. 1 of 1896; dated January 8th) was issued; explaining the nature of these tide tables, and mentioning the Almanacs in which they are to be found. This notice was sent to thirty-eight publishers and agents for Almanacs in this country, Great Britain, Europe, and the United States; and was also supplied to all the Pilots in the Montreal and Quebec corporations; and to twenty-one steamship companies or their agencies, on the St. Lawrence route or at Halifax.

In the present Report, I will endeavour to give in a complete form, but as concisely as possible, the results obtained during the season of 1895. These will be more readily understood if a general description is first given of the nature of the currents in the Gulf of St. Lawrence, based upon the investigations of both seasons, 1894 and 1895, since this work was begun.

CHARACTERISTICS AND MOVEMENT OF THE WATER IN THE GULF.

The currents have now been examined at the two entrances to the Gulf, namely the Strait of Belle Isle, and Cabot Strait between Cape Breton and Newfoundland; and also at its third angle, in the passages lying between the Gaspé coast and the Mingan shore, which connect the St. Lawrence River with the Gulf. The endeavour has also been made to trace any general set or drift which may lie across the area of the Gulf from one to another of the above entrances.

The current in the Strait of Belle Isle has proved to be fundamentally tidal in its character, and when undisturbed by heavy winds it turns regularly with the tide, and runs out and in through the Strait with velocities which are nearly equal. The

strength of the current in the two directions, and its relation to the tide as observed simultaneously at Forteau Bay, are shown in Plate I. The behaviour of the current in two different months (July and September) is there given for periods during which the weather was moderate and the conditions may be considered as normal. The times of high and low water only were observed in July; but in September, after the tide gauge at Forteau Bay was erected, a continuous record of the tide was obtained. At other times, during heavy winds, especially when easterly or westerly in direction, (that is in the direction of the Strait itself which the winds usually follow) the current which runs with the wind becomes stronger than the current against it; and eventually the current may come to be continuous in the same direction as the wind. The behaviour of the current under the various conditions of wind and weather are fully described in the last report on this Survey. (See Annual Report, Department of Marine and Fisheries, for 1895, Appendix No. 3; pages 74 to 87). In that report it is also explained that all the evidence met with during two seasons, is entirely against the theory of a constant current inward at Belle Isle and outward through Cabot Strait into the Atlantic. On the contrary it is now clear that no great inflow of water into the Gulf can take place through the Strait of Belle Isle.

A confirmation of the tidal character of the current in the Strait of Belle Isle, appears in an old report by Mr. M. H. Warren, addressed to the Colonial Secretary of Newfoundland, and dated as far back as February, 1854. Mr. Warren states that he had been more than twenty times through the Straits in sailing vessels, and thrice in a steam sloop; and as Superintendent of Fisheries for the Newfoundland Government, he had spent the months of July and August of the previous season cruising in the Straits, and had anchored several times in every harbour and also rowed in a boat from harbour to harbour. He was accordingly requested to report on the navigation of the Strait, and in the course of his report he says:—"The tides in the Straits of Belle Isle are generally regular, flowing east and west; on the rising tide setting to the westward, on the falling tide to the eastward alternately every six hours. When the wind prevails east or west several days, it influences the tides; sometimes with a prevalence of east or west winds, on the change of tide there is merely slack water. In the event of a calm, there is scarcely any danger of the tide hauling a vessel on-shore on the Labrador coast, the tides generally setting off the Points. On the coast of Newfoundland from Cape Bauld to Cape Norman, the tides are not regular but set into Sacred and Pistolet Bays, which are very dangerous."

In the passage between the Gaspé coast and Anticosti, which forms the entrance to the St. Lawrence, there is a current which runs almost constantly from the north-west, or in an outward direction with reference to the River. This current may follow the line of the Gaspé coast, or it may at times lie further out, in the middle of the passage between Gaspé and Anticosti. There is in either case a flow of water from the St. Lawrence into the Gulf area, which is fairly constant; and this water was found to be fresher or lower in density than ordinary sea water.

Again in Cabot Strait, there is a current flowing outward from the Gulf, which occupies a width of some 10 or 15 miles on the side next Cape North. This current appears to be very constant; and it also proved to be lower in density and warmer than the water in the greater portion of that Strait.

It appeared probable that a connection might be found to exist between these two currents; for although they are 200 miles apart, they both flow towards the south-east or in an outward direction in relation to the River and Gulf of St. Lawrence; they both proved to be unusually fresh or low in their density; and there was good reason to believe that they were both of a constant character. It was therefore proposed during the season of 1895 to ascertain whether any connection could be traced between them; and also to examine the current in the Gaspé region as thoroughly as possible in the time.

For this purpose the S. S. "Lansdowne" was again set apart for three months, from June 26th to September 27th, which was as long as it could be spared from its ordinary duties. During this time it was necessary to call twice for coal, and also to spend several days in obtaining fresh water. In the month of August the weather was

unusually broken and stormy, which also occasioned some loss of time. There was also considerable inconvenience for want of suitable anchorage appliances, as provision had to be made for anchoring in all depths up to 250 fathoms; and on account of the low state of the funds available, it was towards the end of the season before appliances of a satisfactory character could be obtained. To counterbalance these inconveniences, arrangements were made to continue the observations of the velocity and direction of the currents throughout the night; as the velocity measurements were made by means of current meters registering electrically on board ship. From the experience of the previous season, these meters and their electrical connections were so far improved as to secure a continuous record from them at sea. These observations were made from the vessel while at anchor; as all uncertainity from lee-way and other causes was thus avoided. As the wind usually held the vessel at an angle to the direction of the current, it was necessary to measure the velocity of the surface current well below the keel; as otherwise the side of the vessel itself might interfere with the accuracy of the results. The draught of the "Lansdowne" is 13 feet 6 inches; and the surface velocity was therefore measured at the standard depth of 18 feet, which has been adopted from the first in this survey. It has also been found that there is seldom any appreciable difference in the velocity between the surface of the water and a depth of 5 fathoms. At the depth of 18 feet, the meter could usually be seen distinctly enough to indicate the direction of the current by its position in the water. When this was not the case, and at night, the direction was obtained by means of a canvas bucket, floating awash, and attached by a line from the stern.

The under-currents were also measured by means of an electrical current meter, which it was found practicable to lower to a depth of 40 fathoms. Their direction was ascertained by means of a deep fan, consisting of two sheets of galvanized iron passing through each other at right angles, and presenting to the current in any position an area of 3¼ square feet. This fan was attached to a length of sounding wire, and used with a patent sounding machine; and its depth at any moment could thus be read on the dial of this machine. The sinking weight attached to the fan could be varied to give a reasonable inclination to the supporting wire, according to the speed that the current might have; and by reading off this inclination at various depths with a clinometer, very fair ratios for the velocity could be obtained; as the resistance of the wire itself was so small. This was found specially useful for rapid approximate results at times when the surface and under-currents were veering and changing quickly in relation to each other. This deep fan was also employed to ascertain whether the deep water from 100 fathoms downwards had any motion; as the electrical appliances available would not reach these depths.

Meteorological observations were also taken throughout the season, for comparison of the barometer and wind velocities with the results of the observations of the currents themselves.

Temperature and density of the water in tracing currents. The two characteristics of the water chiefly to be relied upon in tracing currents are its temperature and its density. The colour of the water also, has been found to be appreciably different in different parts of the Gulf of St. Lawrence, but this is not an indication of a very definite character, though it may sometimes be helpful.

An examination of the region at the entrance of the St. Lawrence between the Gaspé coast and Labrador, and around the west end of Anticosti, was made at the beginning of the season, to ascertain which of these characteristics of the water could be relied upon for the purpose of tracing its movements with the best hope of success. The temperatures of the water in this region when compared with the numerous observations already obtained in other parts of the Gulf area, soon made it evident that this could not be relied upon as any definite indication of the direction of the movement of the water. The surface temperature in the summer season usually ranges from about 50° to 65° Fahrenheit; and in proceeding downwards this temperature gradually falls, until at a depth of 40 or 50 fathoms it is only 30° to 34° or practically at the freezing point. Where the greater depths are met with, the water below this again is found to be appreciably warmer. There are considerable areas, however, in which the depth is less than 50 fathoms, and where the conditions are accordingly restricted.

It appears, therefore, that in general, the temperature of the surface water merely rises with the progress of the season; and it is also natural that the water should become warmer to a greater depth as the season advances. Even this has its limitations however; as at a depth of 50 fathoms no appreciable rise in temperature has been found between the month of June and the end of September.

In the Gaspé region, as well as in Cabot Strait, the coldest water forms a layer between the depths of 30 and 50 fathoms. Also in the vicinity of the Strait of Belle Isle, the same low temperatures are found at these depths; although there the temperature towards the surface is relatively lower, as a rule, than in the other regions. As these conditions, therefore, occur at all three angles of the Gulf, and have also been found at a few intermediate points where observations have been obtained, it appears not at all impossible that this cold layer may extend very generally over the Gulf area; and it cannot therefore be taken as an indication of direction of movement of the water.

On the other hand, the density of the water, which is a measure of its degree of saltness, or the amount of fresh water with which it is mixed, is of special value in the Gulf of St. Lawrence. From a limited number of determinations made in the eastern portion of Cabot Strait, and also along the west coast of Newfoundland and in the Strait of Belle Isle, the density of the surface water in that region appears usually to range from 1·0233 to 1·0245. This is much the same as in the open Atlantic; as the density of the surface water off the coast of Nova Scotia was found to range from 1·0235 to 1·0245. The deep water, however, as found from samples taken at depths of 100 and 150 fathoms, both in the vicinity of Gaspé and in Cabot Strait, ranges in density from 1·0255 to 1·0263. Again on the western side of Cabot Strait, the out-flowing water which occupies a width of about 10 miles on the side next Cape North, has a density at the surface of 1·0220 to 1·0235; and in the western portion of the Gulf, off the New Brunswick coast, areas were found in which the density was below 1·0220. Also between the Gaspé coast and Anticosti, the out-flowing water ranges in density towards the surface, from 1·0210 to 1·0225. This distinct difference in density, especially towards the surface, affords therefore an indication which is much more definite than difference of temperature, for the purpose of tracing any general set or current across the width of the Gulf.

The deep water of the Gulf. There is reason to believe that the water in the deep channel which traverses the Gulf has no direct relation to the currents at the surface, or any appreciable influence upon them. These currents were found as a rule to diminish in velocity with the depth as far down as 40 fathoms, which was as far as actual measurements of the velocity were obtained; and indications below this depth made it improbable that any appreciable movement of the water would be found to extend to 60 fathoms. Several indications obtained with the deep fan, at 100 and 150 fathoms, when the weather was most favourable for the purpose, also show that this deep water is entirely quiescent. These indications were obtained in the Gaspé region as well as in Cabot Strait.

The deep channel referred, to runs in from the Atlantic between the Grand Banks on the east, and Banquereau and Misaine Bank on the west, with a width of some 40 miles, and a continuous depth of nearly 250 fathoms. After passing through Cabot Strait, it maintains its width and depth entirely across the Gulf; passing north of Magdalen Islands and between the Gaspé coast and Anticosti. It then penetrates the Lower St. Lawrence nearly to the mouth of the Saguenay, where the depth has only diminished to 150 fathoms at a distance of 420 miles from Cabot Strait. A branch of this deep channel also extends from the Magdalen Islands for a certain distance towards the Strait of Belle Isle.

Beneath the cold layer which occurs at a depth of about 50 fathoms, the temperature in this deep channel is again higher; and from 100 to 200 fathoms it is found to range very constantly from 37° to 41°. This result was obtained in 1894 in Cabot Strait; and the same temperatures have since been found at these depths between the Gaspé coast and Anticosti, which is 220 miles further from the Atlantic than Cabot Strait, along this deep channel.

The density of this deep water as found from samples taken at depths of 100 and 150 fathoms, both in Cabot Strait and in the vicinity of Gaspé, ranges from 1·0255 to

1·0263. This range of density is very interesting in affording an explanation for the otherwise anomalous fact that the colder water at 50 fathoms is found to float upon it.

The following tables give summaries of the temperatures and densities as found in this deep channel. In obtaining these temperatures, the registering thermometers of the Miller-Casella pattern are not suitable, as they will only register the temperature of the coldest layer irrespective of its depth. For this reason the temperature below 50 fathoms were taken with Negretti & Zambra's deep-sea reversing thermometer, which gives the actual temperature at the depth to which it is lowered. This thermometer has to be used with some care, as in rough weather the release which is mechanical, is apt to take place prematurely. Also, if there is much current, the steamer should be free and not anchored; as there is then so much stray line that great depths cannot be correctly measured. In these observations two thermometers were used which were kept in perfect working order. The thermometers were checked against each other by duplicate readings at the same depth, and were also compared directly with a standard thermometer. Any readings which there was reason to suspect of inaccuracy are omitted from the results given. The temperatures are Fahrenheit.

TEMPERATURES AND DENSITIES IN THE DEEP CHANNEL, GULF OF ST. LAWRENCE.

From observations extending over a distance of 200 miles, from Cape Breton to the Gaspé region.

Locality and Date.	Surface.	50 Fathoms.	100 Fathoms.	150 Fathoms.	200 Fathoms.
	°	°	°	°	°
Between St. Paul Island and Cape Ray; at three points 12 miles apart. 16th Aug., 1894.	58	31½	37½	40½	39½
	60	33	38½	40½	.....
	59	.....	40	40½	.....
At 13 miles W. by N. from Cape Ray. 22nd Aug., 1894	58	.....	39	.....	40
At 14 miles W. by N. from Cape Ray. 28th Aug., 1894	.....	32½	40	40½	39½
At the centre of Cabot Strait. 30th Aug., 1894	63	34	40	40	39½
On a line along the middle of Cabot Strait, at three points 7 miles apart. 27th Sept., 1894.	53	32½	37	38	40
	52	32½	.....	40½	39½
	52	32½	39	40½	39½
Between Fame Point and Ellis Bay, Anticosti; at three points 6 miles apart. 29th June, 1895.	53	32	36½	38½	.....
	46	31½	36½	38	.....
	48	32	37	39½	.....
At 29 miles E. by S. from Cape Gaspé. 23rd Sept., 1895	52	32½	37½	39½	.....
At 40 miles E.S.E. from Cape Gaspé. 23rd Sept., 1895	53	33½	38½	40	.....
At 12 miles E.S.E. from St. Paul Island. 24th Sept., 1895	55	35½	39	40½	.....
At 30 miles E.S.E. from Cape Egmont. 25th Sept., 1895	54	37	39½	40½	.....
Mean Temperatures	54·4	33·0	38·4	39·8	39·6

Locality and Date.	Surface.	50 Fathoms.	100 Fathoms.	150 Fathoms.
At 24 miles N.E. ½ N. from Fame Point. 12th Sept., 1895	1·0222	.....	1·0258	1·0262
At 11 " N.E. by N. " " 13th " 1895	1·0220	1·0248	1·0260	1·0261
At 29 " E. by S. from Cape Gaspé. 23rd " 1895	1·0234	1·0248	1·0255	1·0259
At 40 " E.S.E. " " 23rd " 1895	1·0238	1·0251	1·0257	1·0258
At 12 " E.S.E. from St. Paul Island. 24th " 1895	1·0221	1·0250	1·0257	1·0263
At 30 " E.S.E. from Cape Egmont. 25th " 1895	1·0229	1·0251	1·0256	1·0260
Mean Densities	.....	1·0250	1·0257	1·0261

The densities here given, were first determined at sea with the usual precautions to insure correct results, which will be described further on. The samples were then bottled, and the densities re-determined in Ottawa by means of new hydrometers of greater accuracy. In cases where the difference between the two determinations amounted to 0·0002 the mean value is given. The densities are all reduced to 60° Fahrenheit, and give the true specific gravity of the water. It may be mentioned for comparison that the typical density of ocean water is 1·0260.

The density of the deep water corresponds with the density at similar depths, in the open Atlantic off the coast of Nova Scotia, as reported by the "Challenger" expedition. This suggests the possibility that this deep water may be in reality a tongue of ocean water which penetrates the Gulf in its greater depths. It would, no doubt, be very interesting to trace the connection of this deep water with the ocean, as the channel in which it lies runs out into the Atlantic Basin with uninterrupted depth. But this investigation does not promise any result of immediate practical importance.

The chief advantage to be derived from these results is to enable the field of investigation in tracing the currents in the Gulf, to be limited to the layer of 50 or 60 fathoms from the surface; as the surface water of less density even at the lowest temperature it can have without freezing, does not penetrate beyond this limit. The rate at which the current decreases in velocity with the depth, as shown by a large number of actual measurements as far down as 40 fathoms, and the indications obtained at the greater depths already referred to, also make it improbable that there is any appreciable motion below 50 or 60 fathoms. Also, with regard to the disturbance caused by the waves, it is improbable that this would extend to more than half that depth. In the English Channel and the Mediterranean, the effect of the waves in the roughest weather does not appear to extend below 20 or 25 fathoms, judging by the disturbance of fine sand at the bottom. The height of the waves in the open Gulf during the two seasons in ordinarily rough weather, seldom exceeded 12 or 14 feet. During the exceptionally heavy gale of August 24th, 1895, while lying in Cabot Strait, the anemometer on board recorded an average of 71 miles per hour for 13 hours, including the night; and the waves had attained a height of 16 to 18 feet before dark. This was partly due to the shortness of the waves themselves; as the direction of the wind was backing rapidly at the time from east towards north.

It is very possible that some relations may subsist between the depth at which the coldest water is found, the density of the water itself, and the depth to which the disturbance of the wind and waves may extend; but for the purposes in view in tracing the currents, the limitation of the necessary investigations to the layer of water at the surface, of some 50 fathoms in thickness is the chief practical advantage which results.

GENERAL CURRENT ACROSS THE GULF AREA.

These general explanations have been given to make clear the nature of the problem and its limitations. Before making the actual endeavour to trace the water across the Gulf, from the entrance of the St. Lawrence to Cape Breton, it was necessary to begin by ascertaining the movements of the outflowing current in the vicinity of Gaspé, and its other characteristics. This occupied the month of July.

It will make the matter more intelligible however, to give first the results of the density observations and other information obtained with regard to the general movement of the water in the open Gulf; and afterwards to describe the nature of the Gaspé current more fully, from all the information obtained in both July and September. The actual movements of this current are complicated; for although in general terms it is constant in the one direction, it is liable to displacement in position; and consequently at any given point, the current is so far from being constant that it may even be reversed in its direction, while the main body of the current may have taken a different course.

For our present purpose it will be sufficient to state that in general a constant current flowing towards the south-east with a breadth of some 10 to 12 miles, will be found in some part of the width of 40 miles which lies between the Gaspé coast and Anticosti. The water in this current is unusually low in its density, especially towards the surface;

and its velocity varies from about one to two and a half knots per hour. Again in Cabot Strait, there is a current which occupies some 10 to 15 miles of its width on the side next Cape North, also running towards the south-east with about the same velocity, and having a density nearly as low as the Gaspé current itself. The best continuous observations of the velocity and direction of these two currents, obtained during moderate weather when the conditions may be considered as normal, are shown in Plate II, where they are compared with each other and with the tides.

It will be seen from this comparison that the current in the offing of Cape North varies somewhat in its velocity, and also veers slightly in its direction; but no relation between these changes and the tide itself could be made out. The fluctuation in the velocity of the Gaspé current appears to be more regular in its relation to the tide; which will be referred to again.

The density of the water in these currents is shown in the sections given in Plate VIII. These sections, and the density in relation to the depth as there shown, may be taken as typical. The actual densities near shore however, are in both cases the lowest that were found. The undulations in the lines of equal density in the section off Cape North, are due to the disturbance caused by St. Paul Island; as the section runs past it at three miles to the south-eastward, or on the lee side with regard to the current. The density of this current is also shown in the sections given as Table C. and D. at the end of this Report.

Tracing the water across the Gulf of St. Lawrence by its density. In tracing this water of low density across the width of some 200 miles which lies between these currents, it was necessary to decide at what depth the densities for comparative purposes should be taken. If the density of the surface water was taken, there was the advantage of obtaining samples in all weather, however rough; while on the other hand the results would be more affected by disturbance from the surface drift caused by the wind. A comparison of the densities at a depth of 20 fathoms would be very suitable, as this would be about the middle of the layer of water in which the greater part of the movement occurs. The density contours at this depth would however be much interupted by the banks in the Gulf area, notably the Orphan Bank, Bradelle Bank, and extensive shallows around the Magdalen Islands. A depth of 10-fathoms was found to be the best to select; as the 10-fathom line is close to shore around the Gaspé coast, Anticosti, Prince Edward Island and Cape Breton; and all the banks are cleared at this depth except around the Magdalen Islands, where the 10 fathom line lies from five to ten miles off shore. Hence at 10 fathoms the density contours are practically uninterrupted throughout the Gulf, and at this depth the disturbing influence of winds of short duration should be less felt. It appeared therefore on the whole to be the best depth for the purpose in view.

It was necessary to make the determinations of the density at the time, as it was a question of tracing the water, and ascertaining the limits of areas of less density, without any previous clue as to where the limits would probably be found. The samples of water below the surface were obtained by Negretti and Zambra's type of deep-sea water-bottle, which consists of a vertical tube with spring valves at the two ends to inclose the water at any desired depth. The valves are released by a weight sliding on the line; and the line itself must therefore be clear of all tags or knots, and it was found convenient to mark off the depths on the line with red paint. Before releasing the valves, the bottle while still open at the ends was raised and lowered a few feet through the water to rinse out any water of a different density which it might have carried down with it from an upper layer. The samples obtained ranged in temperature from 32° to 70° Fahrenheit, and they were therefore put in glass stoppered bottles and allowed to come as nearly as possible to the ordinary temperature of 60° before their densities were taken, in order to reduce the amount of the correction necessary for difference in temperature. The densities were determined by means of hydrometers of open range, specially designed for the purpose. The bottling of the samples had also the advantage of enabling the hydrometer readings to be taken while the steamer was at anchor; and although these anchorages were in the open, the rolling of the vessel did not interfere with accurate reading, as the vibration of the machinery would have done.

In correcting for temperature, the coefficient of expansion was that given in the Report of the "Challenger" Expedition for standard sea-water of specific gravity 1·0260. Although the rate of expansion is not the same for water of the various densities met with, the use of a constant coefficient gives results which are sufficiently close, as the actual correction required for a few degrees above or below 60° is always small; and on the other hand the differences in density are themselves so large as to be quite evident from the first few places of decimals. This method amounts to neglecting the secondary correction which results from the variation in the coefficient of expansion expressed as a function of the density. An exception was made in favour of the densities of the deep water already given; as for these a coefficient of expansion was determined by direct experiment to correspond with the actual range of density which these samples were found to have.

The general plan adopted was to take the density of the water along a series of sections, and at various depths between the surface and 50 fathoms; or as far down as the depth at which the coldest water had been found. Density sections of this character were first carried across from the Gaspé coast to Anticosti, and from Anticosti to the Mingan shore, to serve as a basis of comparison. The points at which the densities were taken along these section lines, were from three to seven miles apart, according as the density was found to vary more or less rapidly. A series of section lines were then laid out on the chart, to cover a belt of about 80 miles in width, extending entirely across the Gulf from the passage between Gaspé and Anticosti to Cabot Strait. These lines lay as nearly as possible from south-west to north-east, or across the direction which the water might be supposed to take; and the sections were extended as far as was found necessary to define the areas occupied by the water of the various densities which had been met with in the Gaspé region itself. The density work was done in the day time; and current observations and measurements were obtained for comparison at the night anchorages in the open Gulf. This work occupied the month of August.

These section lines were run from the Gaspé coast to Anticosti; from the mouth of the Bay des Chaleurs to the Orphan Bank, and across to the east end of Anticosti; thence to the Magdalen Islands, and on lines running north-east and south-west from these islands; across Cabot Strait, and on parallel lines extending north-eastward from Cape Breton Island. Also in returning towards Gaspé, additional section lines were run from the west coast of Cape Breton to the Magdalen Islands and Prince Edward Island, to ascertain more definitely from what direction the water comes which flows past Cape North to the south-eastward. Several of the section lines in the vicinity of the Magdalen Islands and Anticosti were also run a second time to ascertain to what extent the results already found might be liable to disturbance, or whether they might be considered as permanent.

On account of the stormy character of the month of August, the determination of the deeper densities in some parts of the open Gulf were incomplete; and it was found that a better general chart of the Gulf could be obtained from the surface densities only; as shown in Plate III. Also the area to the westward of the Magdalen Islands could not be completed on account of the time lost during gales; but this omission does not affect the general result. In the region lying between Gaspé, Anticosti, and the Magdalen Islands, section lines were run at the commencement of the work, and a second time after an interval of five weeks. During this time very little difference was found in the general position of the density contours. In some cases, the lines given on the chart show their mean position, between their first and last determinations. It will be seen from this chart that the water of less density lies on the south-western side of the Gulf; and that the area it occupies is approximately limited by a line from South-west Point, Anticosti, to St. Paul Island, C. B. It is therefore in the direction of this line that any slow movement or set of a general character across the Gulf area must take place. It will be seen also that the water between Gaspé and Anticosti ranges in its surface density from 1·0210 to 1·0225, and that water of this density extends continuously across the Gulf to Cabot Strait on the south-western side of the line indicated; although the out-flowing water at Cape North has increased somewhat in density from the above as it there ranges from 1·0220 to 1·0235 at the surface. This can be safely

attributed to a gradual mixing with the salter water of the Gulf, in this distance. The Magdalen Islands lie across the path of this water as an obstruction in its course, and consequently the density contours are much disturbed by these islands. The way in which these contours are bent, seems also to accord with a flow of water of lower density against their north-western side.

On comparing the charts given in Plates VI and VII, which show the density contours at a depth of 10 fathoms in the region lying between the Magdalen Islands and the west coast of Cape Breton, it will be seen that the water in that region is unusually liable to disturbance from the wind. This appears to result from the interruption occasioned by the Magdalen Islands themselves; which makes it necessary for the water to find its way round the north or south ends of these islands on its way towards Cape North. The density sections in that region were taken in the early part of August, and the same lines were again run at the end of that mouth, as shown by the dates given. The actual direction and mileage of the wind, dating from a few days previous to the time of the observations in each case, is shown on the charts. In order to make the comparison clearer, the mileage of the wind is given for the same length of time; namely 16 days in each case.

Although there were three gales included in the latter period, it is noteworthy that the leading features indicated by the density contours remain the same. The density is least along the west coast of Cape Breton, and increases towards the Magdalen Islands; and in both cases the contours themselves lie east and west with the same general direction. The relative proportion of the water which may pass north or south of the Magdalen Islands on its way towards Cape North is not however clearly indicated by these charts alone; as the disturbance from the wind was so great as to make it difficult to say which of the features presented should be considered as the nearest to normal. For example, water of the same density may extend continuously from the Bird Rocks to St. Paul Island, while at another time this is intercepted by water of much higher density intervening. We may therefore leave the reply to this inquiry until we have examined the further evidence supplied by the direct observations of the set of the current throughout the regions under consideration.

The best measure of the actual amount of disturbance occasioned by the wind, was obtained from density sections between the Magdalen Islands and Cape Breton Island, which were run twice at different times along the same lines; and meanwhile, from August 12th to 15th there were 1650 miles of wind in 84 hours; thus averaging 20 miles an hour, and in direction chiefly from the S.S.W. and S. (magnetic). This amount of wind displaced the density contours to the northward about 19 miles at the surface, 15 miles at 10 fathoms, and 9 miles at 20 fathoms. The influence of this wind probably extended to the bottom; as the average depth there is little over 30 fathoms. It must not be assumed however that this displacement is entirely due to the local effect of the wind; as it may have resulted in part from a change in the direction of the set over wider areas. This instance serves also to show how well adapted these density methods are to such problems in the tracing of currents and their disturbance. Further examples of this will be given from the Gaspé region as illustrated by the density charts in Plates IV and V, when the Gaspé current itself is described.

Direct observations of the currents in the open Gulf.—We may first mention the results obtained at the night anchorages or stations occupied while the density work itself was in progress. These opportunities so far as obtained, furnish results based upon careful measurements of both velocity and direction, and serve to illustrate the nature of the currents in the open Gulf. The directions are those from which the current runs; as this gives the direction of the current in the same way that the direction of the wind is always defined. The directions are magnetic in all cases; and the velocities of the current were measured at the standard depth of 18 feet. The time is given on the 24 hour system. The observations obtained were as follows:—

Near the north end of the Orphan Bank, at a station 39 miles S.E. from Bonaventure Island. From 16.00 o'clock on Aug. 6th through the night to 6.30 on Aug. 7th. Weather very calm. Current ran from directions between N.W. and N. for 8 hours; then changed and ran from the S.E. and during the 6 hours following it veered

round through S. and S.W. to W. The velocity throughout varied only from 0·50 to 0·79 of a knot per hour.

Near the north end of the Orphan Bank, at a station 30 miles E.S.E. from Bonaventure Island; on the night of Sept. 5th to 6th. Current ran from directions between N.N.W. and E.N.E. during 5 hours; then from directions between E. and S.E. during 4 hours; and again from westerly directions during 2 hours. The velocity throughout ranged from 0·64 to 1·45 knots per hour.

Off the east end of Anticosti, at a station 11 miles S.E. from Heath Point; on the night of Aug. 7th to 8th. Current during 4 hours ran from directions between W.S.W. and W. with an average velocity of 0·85 knot per hour.

At a station 29 miles E. by S. from Bird Rocks, on the night of Aug. 27th to 28th. Current from directions between E.S.E. and S. during 9 hours, with an average velocity of 0·78 knot per hour.

In the following records at the north-east and south-west ends of the Magdalen Islands, the currents appear to be more distinctly tidal in their character:—

At a station 7 miles off the south coast of Amherst Island, on the evening of Aug. 12th. Current during 2 hours from the S.E. and averaging about one knot.

At a station 6 miles off the south coast of Amherst Island, on the night of Aug. 29th to 30th. Current from the S.S.E. for 3 hours, and then from the N.W. for 5 hours. The current was stronger from the first direction than from the N.W.

At a station 4 miles E.N.E. from East Point, Coffin Island, on the night of Sept. 3rd to 4th. Current from directions between S.W. and S. for 9 hours, with a velocity ranging from 0·70 to 1·30; and then from directions between W. and N.W. for 2 hours with an average velocity of 0·70 knot per hour.

The nature of the current on the eastern side of Cabot Strait, is shown by the following observations, some of which were made in 1894:—

At a station 13 miles W. by N. from Cape Ray, on Aug. 22nd, 1894. Current during 5 hours from directions ranging from E. to S.S.E. with a velocity of a little over one knot.

Again at the same station continuous observations were obtained for 42 hours from Aug. 27th to 29th, 1894. During 37 hours out of this time, the current ran from a south-easterly direction, veering only from E.S.E. to S.S.E.; with an occasional variation as far as E.N.E. and S. for about an hour at a time. The velocity throughout the time varied from 0·62 to 1·28 knots per hour, with an average of about one knot.

At a station 12 miles W. by N. from Cape Ray, on August 23rd, 1895. Current during 2 hours ran about one knot per hour from the N.N.W.

The following table shows the constant character of the current on the western side of Cabot Strait, as observed at different dates in 1894 and 1895. The observations nearer to Cape North are given first; and then those eastward of St. Paul Island. Some of the determinations are obtained from the track of the vessel as plotted on the chart, while steering on definite courses to and from Cape North; and the remainder are from observations at anchorages.

OUTWARD CURRENT ON THE WEST SIDE OF CABOT STRAIT.

DIRECTION and Velocity of the Current off Cape North, and near St. Paul Island; from the best observations obtained in 1894 and 1895; to illustrate the constant character of the current. The velocity is measured at the standard depth of 18 feet, when obtained at anchor. The other observations, (marked "On course run" in the time column,) are deduced from definite courses run between points fixed by sextant angles.

LOCALITY.	Date.	Length of Time. (When at anchor.)	Range of Direction. (Magnetic.)	Range of Velocity. Knots per hour.
Between Cape North and St. Paul Island.				
At 10 miles S.E. by E. from Cape North..	24 Aug., 1894.	46 hours.....	N.W. to N.....	1·43 to 2·11.
At 8 miles S.E. by S. from Cape North...	10 " 1895.	12 " ...	N.N.W. to N.E.	0·56 to 1·32.
Between Cape North and St. Paul Island..	16 " 1895.	On course run.	From N.W.....	....
Off St. Paul Island	24 " 1895.	" ..	" "	1·00 knot.
Between Cape North and St. Paul Island..	24 " 1895.	" ..	" "	1·60 knots.
Within 5 miles of Cape North.....	27 " 1895.	" ..	" N.E. by N.	2·00 "
From 5 to 13 miles from Cape North.....	27 " 1895.	" ..	" " ..	0·75 knot.
East of St. Paul Island.				
At 10 miles N.E. from St. Paul Island....	13 Aug., 1894.	10 hours.....	N.N.W. to N.E.	0·60 to 1·41.
At 10 miles N.E. " "	14 " 1894.	8 "	" " ..	0·66 to 1·05.
At 9 miles N.E. by E. " "	15 " 1894.	32 "	N.W. to N.E....	0·74 to 1·44.
At 10 miles N.E. " "	31 " 1894.	4 "	N. to N.N.E....	0·62 to 0·96.
East of St. Paul Island	27 Sept., 1894.	On course run.	From N.N.W....	1·60 knots.

The following description of the current between the Magdalen Islands and Cape North is given by Captain Gwinn of Grandance, C.B., formerly a resident of Aspee Bay and engaged in fishing and seal hunting. He states that off Cape North the current runs continuously from a north-westerly direction, except that sometimes it may be checked or reversed for a few days by heavy south-easterly winds. The current is no stronger in the spring than at other times. From the Magdalen Islands towards Cape North, the current has a more tidal character, but it makes to the south-eastward. When sealing in the spring, vessels caught in the ice will drift south-eastward past Cape North, and sometimes as far as St. Pierre Island.

To complete all the information which has so far been obtained regarding the currents in the western portion of the Gulf of St. Lawrence, we may here give a condensed summary of the reports received in reply to the circulars sent to several of the leading steamship companies. The only replies received from transatlantic steamers were from three vessels of the Allan and Dominion Lines, with reference to eight trips on the Belle Isle route; and containing the following reports of the current in the Gaspé region:—

Between Fame Point and East Point of Anticosti; on eight trips the current was found to run *twice* from the N.W. and W. with a velocity of one-quarter to one-half knot per hour; and *six times* there was no current appreciable.

The greater number of the replies were from the steamers of the Black Diamond line, running constantly on the route from Montreal to Sydney C.B., and St. Johns, Newfoundland. The period over which the reports extend, is from June 17th to October 16th, 1895; and in the following summary they are classified according to the various regions traversed. It is to be noted with reference to the region from Cape Chatte to Cape Gaspé, that these steamships on the return trip usually keep close to the shore to take advantage of the inshore tide, and to avoid the more constant outward current in the offing. The 30-fathom line is about one mile from the shore all along this part of the coast.

Off the Gaspé coast from Cape Chatte to Cape Gaspé ; on 22 trips reported, the current was found to run *sixteen times* in the outward direction from the N.W. with a velocity of one to three knots ; *four times* from the S.E. or E.S.E. with a velocity less than one and a half knots ; and *twice* the current ran off or on shore, or in unusual directions.

Between Gaspé and the Magdalen Islands ; on 14 trips reported, the current was found to run *nine times* in the outward direction from the N.W. or N. with velocities which average one knot ; and *five times* from the S.E. or E. with velocities from one-half to one knot.

Between the Magdalen Islands and Cape North ; on 13 trips reported, the current was found to run *eight times* in the outward direction, from the N.W. the W. or the S.W. with a velocity of one-half to one knot ; and *twice* from the S.E. or the S. with a velocity of half a knot. Also *three times* there was no current appreciable. It is also noted by Captain Gould, that in the vicinity of Cape North during easterly winds, the current appears to divide ; and to the westward of that cape a current is found which runs from the N.N.E. as if it were a branch from the main current past the cape.

Conclusions as to the character of the general current across the Gulf area. In reviewing the information as above detailed, the practically constant character of the currents in the Gaspé region and the vicinity of Cape North is fully endorsed ; when their liability to displacement by the wind is taken into account. The general connection between the currents is also clear from the density charts ; which show the water of lower density to be continuous from one region to the other, on the south-western side of the Gulf, and to be limited approximately by a line from South-west Point, Anticosti, to St. Paul Island. It is therefore along the south-western side of the Gulf that the water must find its way from the Gaspé region to Cape Breton. The current measurements, and the steamship reports of the direction of the current, also accord with a general movement of the water from the north-west towards the south-east ; as this is the more usual direction, and the one in which the velocity is the greatest. The contrary directions, and the currents which are found at times to run across this prevailing direction, are to be attributed to the influence of the tides and the wind.

In the region between Gaspé and the Magdalen Islands, the effect of the tide from the Bay des Chaleurs was felt as far as 30 miles out from Miscou Island at the mouth of the Bay ; and this may therefore occasion an apparent cross current in that vicinity at times ; and thus account for some of the irregularities there met with.

In the region lying around the Magdalen Islands and extending to Cape North, the effects of the disturbance of the wind have already been referred to. The tide also at both ends of these islands, flows in the two directions, and only the difference in flow can be taken to represent the movement towards the south-east. In reply to the inquiry as to what direction the water comes from which flows to the south-eastward around Cape North, it seems fair however to conclude from the evidence furnished by the density observations, that the greater proportion finds its way eastward between the Magdalen Islands and Prince Edward Island ; while a certain amount may also pass north of the Magdalen Islands, on the line from Bird Rocks to St. Paul Island. That some water passes round both ends of the Magdalen Islands on its way to Cape North is also confirmed by the steamship reports in that region, as the currents from the north-west and south-west correspond with these two routes respectively. It is probable also that some of the water may come from Northumberland Strait, as the water there is also low in its density.

It can hardly be doubted that the low density of the water in the Gaspé current is to be attributed to the outflow of the St. Lawrence River ; and we are thus able to trace the influence of this water as far as Cape Breton, where it finally mingles with the water of the ocean. The volume discharged by the St. Lawrence has been measured immediately above Lake St. Peter at different seasons ; and with the addition of the Richelieu, St. Maurice, Saguenay, and other tributaries along its estuary, the total volume of fresh water discharge would probably amount in all to 340,000 cubic feet per second. This volume of fresh water will mingle with sea water for which we may assume a density of 1·0245 ; as this may be taken to represent either the mean density

of Atlantic coast water to a moderate depth, or the density of the deeper water in the Gulf itself. Under these conditions, the fresh water of the St. Lawrence would be sufficient to furnish a stream of water of density 1·0237 which would be 12 miles wide and 84 feet deep, and moving with a velocity of one knot per hour. This would represent the average density of the Gaspé current, and would probably be an approximation to its average velocity and its volume; and such a comparison may therefore serve to illustrate the way in which the conditions may be accounted for, if the data themselves were more closely known.

A further explanation is required to show why this current is usually on the side next the Gaspé coast, and why the water of less density should keep to the south-western side of the Gulf, and finally flow out of the Gulf on the western side of Cabot Strait, instead of spreading over the surface of the Gulf generally. When a belt of water of low density lies along a coast, it is out of equilibrium and tends to spread more widely over the surface unless restrained by some cause from doing so. The direction of the Lower St. Lawrence itself, as the prevailing winds are westerly, would tend to keep the out-flowing water of less density to the south-eastern side. This reason does not hold in the open Gulf however; as the direction of the prevailing winds in summer is south-westerly, which is across the direction that the water takes, and must tend to make it extend further out into the Gulf than it would otherwise do. It may be noted however that the positions in which this water is found are in accord with the influence of the rotation of the earth. In passing down the Lower St. Lawrence it makes towards the north; and the moving water is therefore impelled to the right, or against the south-eastern shore; while after rounding the Gaspé peninsula, the southing in its course towards the ocean would make it tend from the same cause to keep towards the south-western coast of the Gulf. It is not impossible that this influence may have some appreciable effect; as the mean latitude in the regions under consideration is 48° north.

It may not be possible to do more at present than to suggest an explanation, by indicating as above such causes as are known to operate. When the conditions themselves throughout the course of the year are better known, more complete and satisfactory explanations may be found to account for them.

There is one point however, which it is important to notice in order to understand the relation of the Gulf area to the St. Lawrence River and the Ocean respectively. The volume of fresh water from the St. Lawrence as already explained, may be sufficient to dilute the sea water to the low density found in the Gaspé current or in the corresponding current flowing outward through Cabot Strait; but it is evident that the total volume of water which actually leaves the Gulf is vastly greater than the volume of fresh water which it receives from the St. Lawrence River. The volume so leaving the Gulf must therefore be replaced by water which enters it from the ocean. The investigations already made show that there is a balance of flow in favour of the inward direction at the Strait of Belle Isle; and there are also indications that the motion on the eastern side of Cabot Strait is usually inwards. It is probably from these directions that the loss to the Gulf area is supplied; and this also accords with the density of the water along the west coast of Newfoundland, which appears to be practically the same as in the neighbouring Atlantic. As already explained, the evidence is against the view that there is any return current in the underlying water of the deep channel in the Gulf.

In these circumstances it may be stated with confidence as a practical conclusion, that such currents as may be met with in the open Gulf are never likely to have a velocity which is as great as that already found in the Gaspé current and off Cape North.

CURRENTS IN THE GASPÉ REGION.

It may be stated in general, that a current is usually found in the offing of the Gaspé coast, flowing from the north-west to the south-east, all the way along from Cape Chatte to Cape Rosier. This current may therefore be termed appropriately the Gaspé Current. It occupies a width of some 10 or 12 miles; but between it and the coast the inshore current is tidal, and runs in both directions. The existence and direction of

this current must be attributed to the influence of the St. Lawrence River, and to the direction of the prevailing winds on the Lower St. Lawrence.

As this current is liable to displacement in position, and may then follow a course further out from the Gaspé coast, a broader description must be given, before it can be termed constant. From the observations made during the season of 1895, compared with the Admiralty Charts and Sailing Directions, and such other information as has been obtained, the most correct statement that can be made is, that a constant current flowing from the north-west to the south-east with a breadth of some 10 or 12 miles, will be found in some part of the width of 40 miles which lies between the Gaspé coast and Anticosti.

When the possibility of the displacement of this current from one position to another is taken into account, much that would otherwise be anomalous is explained. A steamship which keeps to any one fixed course in passing through this region, may find a current of a very different character at different times; and also at any given point, such variable conditions may be found as to make it appear that nothing definite can be said regarding the nature of the current. For example, the following statement in the Sailing Directions can be readily explained when the displacement of the current is recognized: "The rate of this current has been noted, off different parts of the coast between capes Chatte and Gaspé, in the months of June, July, August, and September, and in different years, and scarcely ever found the same. It varied between 1 and 2 knots in westerly winds. It was weaker, often nearly insensible in easterly winds; and in one instance, off Mount Louis River in a calm which was followed by a strong breeze from the eastward, it could not be perceived." (*St. Lawrence Pilot*, 1894; Vol. I., page 20.)

The constant outward direction of the current from the north-west, as well as the liability of the current to displacement, can also be inferred from the different Admiralty Charts, when compared with each other and with the Sailing Directions. On the Admiralty Chart entitled: "Entrance to the River St. Lawrence," No. 1621, a current is shown to run constantly along the Gaspé coast from a north-westerly direction at about three miles off shore. In the Sailing Directions it is stated that this may be felt as far out as 9 to 12 miles from land. Another line of constant current is also shown as lying along a line from the vicinity of Cape Magdalen to South-West Point, which thus traverses the middle of the passage between the Gaspé coast and Anticosti. It is this central line of current which is alone represented on the general chart of the Gulf of St. Lawrence, No. 2516. It is explained however in the Sailing Directions that the current does not follow both these lines at the same time; and the change from one position to the other is attributed to the influence of south-west winds.

The first of these lines represents fairly the usual direction of the current along the Gaspé coast. The other line is properly to be regarded as an alternative route which the current may take. When the current is found in the position shown by the line along the middle of the passage, it may even be accompanied by a reversal of the direction of the current along the Gaspé coast. There are also fluctuations in the velocity of the current which are probably to be attributed to the influence of the tides.

In endeavouring to ascertain the behaviour of a current of this character at different times and under varying conditions of wind and weather, it was necessary to resort to a variety of methods. For the conditions themselves, the meteorological data were obtained from South-west Point, Anticosti, which is a fully equipped observatory. There is also much better opportunity to ascertain the direction of the wind correctly on the Anticosti side, as it is comparatively flat, whereas the Gaspé side is mountainous within a short distance of the coast. The self-recording tide gauge erected at South-west Point furnished complete tidal data for the region in question.

Some good determinations of the nature of the current under normal conditions were obtained at anchorages selected for the purpose, and accompanied by density sections and observations of the velocity and depth of the under-current. When the current was found to vary, or change to some unusual direction, it was necessary at once to take steps to trace it; or to run extended density sections to ascertain what new positions the water of less density had assumed. This method of density sections

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proved very useful when rapid determinations of changed conditions were required. This was also supplemented by tracking, or running courses directly towards or from the shore. The comparison between the course run, as shown by the compass and log, and the course made, as shown by a series of points fixed by sextant angles, often served to indicate what was going on at the time, and where the current lay. Such investigation would be much facilitated by having another vessel to take continuous observations at a selected point for comparison. A vessel for this purpose could be towed to its position and placed correctly by the surveying steamer; but it would then require for its safety either to be able to ride at anchor in all weathers, or to have sufficiently powerful appliances to raise anchor from 250 fathoms, when heavy weather came on.

The region selected as the best for the investigation of the behaviour of the Gaspé current, was that lying between the Gaspé coast and the Island of Anticosti. This region is limited by the shore lines extending from Fame Point to Cape Rosier on the Gaspé side, and from West Point to South-west Point on the Anticosti side. These shore lines are parallel to each other at a distance of 40 miles apart; and the currents are therefore likely to be more regular and less disturbed than in either of the more open areas lying immediately to the north-west and south-east. This region also deserved the more careful study as it is there that vessels make and leave the Gaspé coast on the routes leading into the St. Lawrence. The currents in the Mingan Channel between Anticosti and the Mingan shore were also examined, and information was thus obtained regarding both passages by which the St. Lawrence River communicates with the Gulf.

The Mingan Channel. The examination of the Mingan Channel was made chiefly to ascertain whether any return current of a constant character could be found there, which might serve to replace the outflow of water in the Gaspé current itself. With this view, two stations were occupied in this channel from July 16th to 20th; and the period of the neap tides was chosen, when the influence of the tide would be less marked. The weather although foggy and wet, was quiet and fairly normal. From observations on board, the wind did not exceed 16 miles per hour; and the barometer ranged from 29·61 to 29·87. The stations occupied were in the narrowest part of the channel, where its width is only 18 miles. The stations were at four miles N.E. of North Point, Anticosti; and six miles S.S.W. from Niapisca Island, one of the Mingan Islands. This position was chosen for the second of these stations, to avoid any cross currents produced by the tide running between the Mingan Islands. Continuous current measurements were obtained at these stations; and the undercurrent was carefully observed nearly to the bottom, as the depth did not exceed 53 fathoms at either station. Temperatures and density sections across the channel were also taken as nearly as possible at the same time for comparison.

The current proved to be tidal in its character, and ran through the channel from the north-west and south-east alternately; but often veered considerably from these directions. In order to ascertain whether there was any difference in favour of one direction rather than the other, the current measurements were so reduced as to give the total mileage of water passing in each direction through the channel; (by projecting the actual direction and velocity during each half-hour on the axis of the channel, and summing up the velocity components thus obtained). At the station off North Point, current measurements were obtained during a continuous period of 49 hours; and at the other station during 29 hours. This latter period however, includes three periods of tidal flow from the north-west and only two from the south-east; and to make the comparison a fair one, it must be reduced to 23 hours. The total mileage of flow in the two directions at both stations will then be as follows, for the surface current:—

Inwards from the south-east.....	48·75 nautical miles.
Outwards from the north-west.....	39·36 nautical miles.

Also, the total time during which the current ran from any south-easterly direction was 41 hours; and from any north-westerly direction it was 31 hours. There would thus be 24 per cent of excess in favour of the inward direction from the south-east, as shown by the ratio of the mileages; although on the other hand the rate of motion from the south-

easterly direction was less on the average than from the north-west. The actual difference in favour of the inward direction as given by the above reduction of the observations, is only 0·13 of a knot per hour.

A careful study of the under-currents in this channel shows that they have a complicated character. Their velocities and directions were obtained on seven different occasions, and at a series of depths to within about 15 fathoms of the bottom in water of 53 and 47 fathoms, at the two stations. On three of these occasions the under-current was found to be as strong or even much stronger than at the surface; but on the four other occasions it decreased in its velocity with the depth in the usual way. These variations also occurred with either direction of the surface current. If the surface velocity is taken as 100, the average velocity of the under-current between ten fathoms and the bottom varied from 38 to 182 per cent; and the general average of all the determinations showed it to be 95 per cent of the surface velocity. As the variation is so great it cannot safely be said in which direction the under-current would in general be the strongest, relatively to the surface current.

It is clear from the above observations that there is no constant inward current north of Anticosti, at all comparable with the Gaspé current. The difference of the flow in the two directions is however in favour of a very slight inward flow from the south-east. The temperatures taken at slack water after the flow in each direction, showed the usual decrease with the depth from 52° at the surface to 32° or 34° at 40 fathoms. There was no change in the temperature to accord with the direction of the current. The greater surface density towards the Mingan side is an illustration of the difference found on the windward and leeward sides of a channel. At 20 fathoms the density is practically constant all the way across. These temperature and density conditions tend therefore to confirm the view that any longitudinal flow through the channel must be very slight.

The tidal character of the current in the Mingan Channel is confirmed by Mr. A. Malhouin, Light-keeper at West Point, Anticosti. He states that the current runs from the south-east with the rising tide and from the north-west with the falling tide. The current on the south shore of Anticosti in that vicinity, is much weaker than in the Mingan Channel, and is under the influence of the wind, and runs accordingly from either the north-west or south-east. If the current from the south shore is from the north-west it appears to divide at West Point when the tide is falling in the Mingan Channel; but when the tide is rising, the currents meet not further east than English Bay, or about 8 miles from West Point. In the spring, the ice on the south shore drifts with the wind and current in an outward direction, from the north-west, except when the wind is easterly, which is not frequent. The ice is not over six feet thick except when packed or in shoves.

It is also stated by Mr. H. Pope, light-keeper and meteorological observer at South-west Point, that the wind is almost always N.W. or S.E.; that is to say, it follows the general direction of the channel between Gaspé and Anticosti. It appears that from May till the early part of August the winds are usually from the S.E. and from the middle of August through the autumn and winter, they are chiefly from the N.W.

The Gaspé current proper. The general results obtained with regard to the currents in the Mingan Channel and in the vicinity of West Point, also accord with the Sailing Directions where it is broadly stated that no constant outward current is felt to the northward of a line joining Point de Monts and Anticosti. Hence the various positions taken by the constant current which we have now to consider more fully, are limited to the northward; and the region already indicated, between the Gaspé coast and Anticosti, proves to be the best that could be selected for the investigation of its varying behaviour. On the Gaspé side the even character of the coast line of the Lower St. Lawrence, continues from Fame Point to Cape Rosier; and the bottom dips off abruptly all along; as the 30 fathom line lies only one mile off shore, and the 100 fathom line on an average three miles off. The current therefore does not extend to the bottom; but the depth in which it is necessary to anchor in making the observations is very considerable; and at all the greater depths the bottom is soft mud and poor holding ground. Patent stockless anchors were used, giving a double grip; and also heavy four-prong grapnels with specially large palms.

In the early part of July the current was found to flow with regularity in that offing. The weather at that time was very moderate, and the conditions generally appeared to be normal. From June 26th to July 6th the wind did not exceed 17 miles an hour, and its direction was variable; the barometer ranged in its daily mean from 30·27 to 29·75 which is higher than the average for the months of June and July, 1895. The observations taken on a cross-line running N.E. from Fame Point, from July 2nd to 6th may therefore be considered as typical of the normal condition of the current. Also, as the moon was full on the 6th, the velocity so far as it may be affected by the tide, should be about the average.

The current was observed at two stations 3¼ miles N.N.E. from Fame Point and 5½ miles N.E. ½ N. from that point during a period of 64 hours, from July 2nd to 5th. The depth at these stations ranged from 140 to 205 fathoms. The observations were continuous, day and night, throughout that period, with the exception of four hours, when the anchor dragged, and a new position had to be taken at the other station. These stations were in the strongest part of the current; and the velocity was measured at the standard depth of 18 feet. The result is shown on Plate II, where the tide at South-west Point is given for comparison. During the whole period of 64 hours, the current ran continuously from the north-west, and only veered in direction from N. to N.W. by W. The greatest velocity observed was 2·81 knots per hour on July 5th; as the current appeared on the whole to increase in velocity towards the spring tides, although this increase is less evident in the tide curve itself on account of the diurnal inequality. The fluctuation in the velocity of the current corresponds distinctly with the tide; as in general it decreases during the rise of the tide, and increases during the fall of the tide. This is to be expected, as the tide enters the estuary of the St. Lawrence against the direction of the current.

At a depth of 10 fathoms, the current was sometimes stronger than at the surface; but usually the velocity decreased regularly with the depth. At 20 fathoms it was only 50 per cent of the surface velocity; and at 30 fathoms 20 per cent. This rate of decrease would give the current a total thickness of 40 fathoms.

In order to ascertain the width and thickness of the current further out, another station was occupied on July 5th and 6th at 12 miles N.E.½N. from Fame Point. The current there ran constantly from the N.W. during 23 hours, with a velocity which ranged from 0·33 to 1·48 knots per hour; and a thickness which extended at times to 40 fathoms, but usually averaged 30 fathoms.

Further out still, at 24 miles from Fame Point, or midway between the Gaspé coast and Anticosti, the current was found to run slowly from quite another direction; and this point was therefore beyond the limit of the constant current.

It would appear from the above that the constant outward current had at that time a width of approximately 14 miles; and a thickness of 40 fathoms near the Gaspé coast, which decreased towards the outer edge. Its surface velocity where the current was strongest, ranged from 1·10 to 2·81 knots per hour. Its temperature ranged from 53° at the surface, to 33° at 30 fathoms, and 32° at 50 fathoms. Its average density, as shown by the section of July 13th, for a width of 14 miles and between the surface and 10 fathoms was 1·02195; and to a depth of 40 fathoms was 1·02368.

The character of the current was also observed immediately afterwards, on another cross-line sixteen miles further to the eastward, in the offing of Griffin Cove. The weather however was not so settled; as from July 7th to 13th the wind during five days was from the S.S.W. rising as high as 19 miles per hour on the daily average; and this was interrupted on the 10th and 11th by a return wind from the N.N.W. averaging 31 miles per hour for 27 hours. This corresponds with the nearest approach of a storm centre which passed over Halifax on the 10th. The barometer fell to 29·64 on the 9th and had risen again a little above 30·00 on the 12th and 13th. The current was observed at a station 5 miles E.½N. from Griffin Cove during a period of 48 hours, from July 8th to 10th. Throughout that time it ran continuously from the N.N.W., veering only from N.W. to N. and with a velocity ranging from 0·79 to 2·15 knots per hour. The current here also, in the same way as at Fame Point, had a tendency to be strongest at low water and weakest at high water; although the variation was usually much less

than the total range above mentioned. It is to be noted in this case that the observations were taken at the spring tides, as the moon was full on the 6th. The velocity of the under-current was measured at four different times, at which the surface velocity itself varied only from 1·23 to 1·83 knots per hour. The mean of the four determinations gives the following percentage ratios for the undercurrent at different depths :—

Surface, actual	...	1·23 to 1·83 knots per hour.		
At 10 fathoms.....		77 per cent of surface velocity.		
At 20 "		38	"	" "
At 30 "		29	"	" "

This rate of decrease indicates a depth of about 45 fathoms as the total thickness of the current. At another station 9½ miles E. from Griffin Cove, where an anchorage was made for 3 hours on the morning of the 11th, or immediately after the heavy N.W. wind of the 10th, the current was found to average a little over three knots per hour. The vessel was dragging anchor at the time with the current ; but the distance it dragged was measured and allowed for, in the velocity as stated.

Further out, at a station 11½ miles E. ½ N. from Griffin Cove, continuous observations during 25 hours on July 11th and 12th, showed that the current was there more distinctly influenced by the tide. During the two complete tides included in this period, the current veered with remarkable regularity in correspondence with them. During the rise of the tide, it veered from N.N.W. to E.N.E., and during the fall of the tide it backed again from E.N.E. to N.N.W. It thus ran from these extreme directions at the time of high and low water. It is to be noted that the direction of the current at high water was directly on shore ; but on account of the importance of the on-shore and off-shore directions of the current, these will be classed together, further on. The velocity of the current ranged from 0·65 to 1·27 knots per hour ; but without any regular fluctuation to correspond with the tide.

While the current ran from the E.N.E. or towards the shore, with a velocity at the surface of 1.15 knots per hour, it was found that the direction of the under-current was the same to a depth of 25 fathoms, and its speed was there about half as great as at the surface. From 25 fathoms to a great depth, it ran from the E.S.E., but was much weaker. Again on two occasions when the current was from the N. and N.W. and at its weakest, its total thickness was 20 and 25 fathoms, and its direction the same as at the surface.

At a station still further out, 23 miles E.N.E. from Griffin Cove, or somewhat beyond the middle of the passage from the Gaspé side, the current as observed during 22 hours on July 12th and 13th was found to run from the two opposite directions alternately. This showed a greater preponderance of tidal influence ; but the change in direction did not correspond in time with the tide. It may be said in general that during the fall of the tide the current usually ran from directions between W.N.W. and N.N.W. and during the rise of the tide, from directions between S.S.E. and S. On the whole, during the period of 22 hours the current veered between W. and N.N.W. for 14 hours, and between S.S.E. and S. for 8 hours ; and the total time during which the tide was falling was 12 hours 10 minutes, and rising during 9 hours 50 minutes. This will serve best to show the general relation in the case. The velocity was much the same in each direction ; and ranged from 0.35 to 0.64 of a knot per hour. There is therefore no difference of flow in favour of the constant direction of the Gaspé current, as far out as this station.

It thus appears that in the offing of Griffin Cove at that time, the current for a width of about 12 miles ran either constantly outwards from the N.W. or had a large preponderance of flow from that direction. It had a thickness of some 45 fathoms near the Gaspé coast, and only 25 fathoms at 11 miles off shore. It was thus on the whole narrower and deeper than at Fame Point, but had an average surface velocity which was very much the same. The influence of the tide was increasingly marked towards the outer edge of the current ; until midway between Gaspé and Anticosti, it became entirely tidal in its character, and without any preponderance of flow in one direction rather than the other.

The density section shown on Plate VIII was made at this time, when the current was running as above described ; and the direction of the section is along the line of the above stations.

Reversal of the Gaspé current. On the next opportunity of making a series of observations of the Gaspé current, towards the end of July, the current was found to lie midway between the Gaspé coast and Anticosti ; and between it and the Gaspé coast the current ran in the reverse direction, or from the south-east.

The weather, dating from a few days before the observations began, or for a period of 15 days from July 21st to August 4th inclusive, was on the whole quiet, although showery and sometimes foggy. There was sometimes considerable swell running up from the south-east ; on some of the calmest days. The actual conditions were as follows : The barometer fell gradually from the mean height of 29·94 on the 21st to 29·54 on the 29th and rose again to 29·90 by the 4th of August. Its average height during the 15 days was 29·78 ; while the average for the two months of July and August, 1895, was 29·76. During the fall of the barometer as above, the wind was almost constantly from the S.S.W. and the velocity did not exceed 15 miles per hour on the average for any one day. While the barometer rose, the wind continued southerly, except when interrupted occasionally by moderate N.W. winds. The strongest wind during the whole period was on the 31st when it averaged 19 miles per hour for 24 hours. The total mileage of S.S.W. winds during the 15 days, was 3498 miles ; and from other directions, chiefly N.N.W., it was 731 miles. The height of the barometer given is the daily average in each case ; and both the wind and barometer are from the continuous observations taken at South-west Point, as already explained. These southerly winds are usual during July and the early part of August ; but at this time they were very continuous, and they were also accompanied by strong westerly winds on the Lower St. Lawrence. The wind was thus blowing in upon the waterway in this region from both ends, which may help to account for the behaviour of the current ; although the weather in the region itself was quiet and not marked by anything unusual ; and there were no storms in the Gulf region or along the Atlantic coast. It will be excusable to describe fully the behaviour of the current at this time ; as there is at present no published information regarding the reversal of the current as then observed.

The current on July 25th at a station midway between the Gaspé coast and Anticosti, was found to be running constantly from a north-westerly direction. This station was 24 miles N.E. from Fame Point and 18 miles from Ellis Bay. It was so chosen in order to be on the line marked "Constant current" from the W.N.W. which was shown on the large scale chart No. 1621, entitled "Entrance to the St. Lawrence." At another station however, also on this line, and 20 miles further to the E.S.E. (situated 15 miles N.N.W. from South-west Point) which had been occupied immediately before during 26 hours, the current was found to veer and back irregularly through all points of the compass. Accordingly on the following day, July 26th, a density section was run across the whole width of the passage from Ellis Bay to Fame Point, to ascertain for comparison with the current, the position occupied by the water of least density. This section is shown in Table A. ; and it was found that the water of least density occupied a width of 17 miles in the middle of the passage, lying between 10 miles and 27 miles from the Gaspé coast. The mean density of this water, between the surface and 10 fathoms, was 1·0217 ; while beyond it on each side, it was 1·0220 or more. The water of least density thus occupied the same position in the passage as the current from the north-west.

The same station in the middle of the passage was again occupied on the afternoon of the 26th, as nearly as it could be found by dead reckoning during a thunderstorm, to ascertain whether this direction of the current would prove to be continuous. The record obtained altogether, was from the afternoon of the 25th throughout the following night, during 13 hours ; and again from the afternoon of the 26th during 21 hours. The current throughout that time ran from directions between N.N.W. and W. with the exception of five hours in all, at different times, when it veered to the south of west as far as S.S.W. while the current was at its weakest. The velocity ranged from 0·49 to 1·30 knots per hour ; and the greatest velocity was from directions between N.N.W.

and W.N.W. From the best indications obtained, the thickness of the current ranged from 30 fathoms to 50 fathoms or over, while running from the more usual directions.

From courses carefully run on the afternoon of the 27th from the above station to Cape Gaspé, it was found that between 12 and 4 miles from shore in the offing of Fame Point, the current was running from the south-east, or contrary to its usual direction. There was no appreciable current in either direction off Fox River and Griffin Cove; and it was only from Cape Rosier to Cape Gaspé and within two miles of the shore, that a current from the northward was found.

These indications were followed up from July 30th to August 2nd at two stations 4 miles and 9½ miles from Fame Point, on a line running N.E. by N., and where the total depth ranged from 150 to 205 fathoms. (The station 4 miles from Fame Point was nearly in the same position as those of July 2nd to 5th, when the current ran steadily from the north-west.) On this occasion it ran continuously from the south-east at both stations; and the conditions were so nearly alike that they may be described together. On July 30th during 23 hours, and on August 1st and 2nd during 27 hours the current ran constantly from directions between E.S.E. and S. The velocity during these periods ranged from 0·51 to 1·40 knots per hour at one station, and 0·48 to 1·38 at the other.

Although the current ran constantly from the one direction, its strength varied regularly with the tide, and was greatest about the time of high water, and least about low water; which is the converse of its former behaviour, and corresponds with the contrary direction of the current itself. The direction of the under-current was taken at five different times at each of these stations, or ten times in all, and while the surface current was both strongest and weakest. There was no current from the usual north-westerly direction as far down as 50 fathoms; but the under-current ran from the same direction as the surface current or within two points of it. When weakest the strength of the under-current fell off rapidly below 20 fathoms; and at the most the thickness of the current did not probably exceed 40 fathoms.

This current from the south-east was found to extend to two miles from the shore; and within that distance it was replaced by the usual inshore tide in the two directions as found at an anchorage one mile off shore on the night of the 31st, when it was too rough to hold in the open.

On returning to the middle of the passage on the afternoon of August 2nd, where an anchorage was again made at 24 miles N.E. from Fame Point, it was found that the current was then running from north-easterly directions. During 9 hours the current ran from directions between N. by W. and N.E. by E. with a velocity which averaged 1·34 knots per hour. The direction of the current was thus directly across the passage at this time, and also at right angles to the line of "Constant current" there shown on the chart. This direction probably corresponds with the direction of the bend of the current, between its north-westerly and south-easterly direction; and the north-westerly current itself may have moved nearer to the Anticosti side since the 26th.

The variation in the density of the water during this period helps to indicate the nature of the circulation which was going on. At the middle of the passage on July 26th, where the flow was from the north-west, the water of least density as already mentioned, occupied a width of 17 miles. This belt had a mean density between the surface and 10 fathoms of 1·0217; while the water flowing from the south-east between this belt and Fame Point, had a mean density to the same depth of 1·0221. A few days later on July 31st and August 1st, the density of the water flowing from the south-east between 4 and 10 miles from Fame Point, and between the surface and 10 fathoms, was only 1·0208; and on August 2nd at the middle of the passage, the water then flowing from the north-east had a mean density to 10 fathoms of 1·0215. The water of least density which occupied the middle of the passage, must therefore have circled round and run back in the south-easterly current in the offing of the Gaspé coast; as this water continued to decrease in density during the time. This circling movement of the water is further confirmed by a density section across the passage further to the eastward, which was run on August 3rd from Salt Lake Bay, Anticosti, to Cape Gaspé. On this whole width, as shown in Table B, the mean density between

the surface and 10 fathoms was 1·0230 or more; except in the immediate vicinity of Cape Gaspé, where the usual northerly current was found, and the mean density fell to 1·0226. This section therefore serves to limit the course taken by the water of least density, as it shows that it circled back to form the return current from the south-east, without going so far east as to cross this line. It is thus clear that at this time there was no water with the usual low density flowing from the mouth of the St. Lawrence into the Gulf area. A comparison of the density charts, Plates III, IV, and V, makes this plain; for in Plate III there is a belt of water 25 miles in width, extending from West Point, Anticosti, past Cape Gaspé, which has a surface density below 1·0225; and a belt in the same position with nearly the same width in Plate V, has a density at 10 fathoms which is below 1·0235. On the other hand, in Plate IV, which shows the densities at 10 fathoms at the dates referred to, the contours of 1·0235 and 1·0240 run from West Point, Anticosti, and pass close to Cape Gaspé; while the next contour 1·0230, is doubled back in the offing of the Gaspé coast, in correspondence with the reversal of the current as already described. There is thus too little width between Cape Gaspé and these contours for any appreciable quantity of water of low density to pass out into the Gulf area. Hence the circulation at this period, including the reversal of the current in the offing of the Gaspé coast, must be regarded as an exceptional occurrence.

Period of disturbance of the Gaspé current. When the next opportunity occurred to examine the Gaspé current, in the early part of September, the winds were stronger, from southerly and north-westerly directions alternately, and the current ran mostly from westerly directions; although it was much disturbed and even ran as a cross-current at the middle of the passage.

On the 31st of August there was strong S. wind, followed on the 1st and 2nd of September by heavy wind from the N.N.W. This was accompanied on the Lower St. Lawrence by heavy W. wind, with a mileage during the three days of 1950 miles, as recorded at Father Point. It is to be noted that winds which have directions between W. (magnetic) at Father Point, and S. at Anticosti, are off-shore along the Gaspé coast, and tend to carry the current away from the coast. There were strong southerly winds on the 4th and 5th, and again on the 7th and 8th; which were also accompanied by moderate westerly and south-westerly winds on the Lower St. Lawrence. This was followed on the 10th by strong N. wind, which then averaged 25 miles per hour for 24 hours. On the following days the wind fell off. On the 8th and 9th a storm centre was passing in the offing of the Nova Scotia coast.

The barometer as recorded at South-west Point during the period of the observation of the currents, was as follows: From September 6th to 13th the barometer fell gradually from the mean height of 30·23 on the 7th to 29·58 on the 13th, and afterwards rose rapidly to 30·13 on the 15th. The average height for the month of September 1895, was 29·84.

At the station 4½ miles N.E. by N. from Fame Point, (in practically the same position as the stations of July 3rd and 30th), the current on September 9th and 10th was found to be slack and variable. During a period of 16 hours, it ran first for 3 hours from the S.E. and S., then for 10 hours from directions between N.N.W. and W.N.W. veering once as far as W.S.W., and again for 3 hours from southerly directions. Its velocity throughout was considerably below one knot per hour. While the current was slack, during a change from S.S.E. to N.N.E., the under-current also fell off to nothing as far down as 50 fathoms; which shows that there was no deep under-current in any constant direction. Although the prevailing current was from the usual north-westerly direction, it would appear that the inshore tide occupied a greater width than usual at this time, and that its influence extended as far out as to this station; as on the morning of the 9th the tide within three miles of the shore from Cape Rosier to Fame Point, was found to have a velocity of 1·40 knots per hour from N. by W.

It was therefore advisable to ascertain the direction of the current in the middle of the passage. As the heavy weather of the 10th had made it necessary to take shelter under Cape Rosier, a course was carefully run N.E. by N. from there on the morning of the 11th, on which a series of points were accurately fixed as far out as 12

miles from shore. It was thus found that within six miles of the shore the current ran from N. by W. with a velocity of 2·20 knots; and from 6 to 12 miles from shore, it ran from N.N.W. with a velocity of 1·55 knots per hour. On anchoring at the station 24 miles N.E. ½ N. from Fame Point in the middle of the passage, the current was found to be running from the south-west, or across the direction of the passage. During a period of 24 hours on the 11th and 12th, it ran steadily from directions between W.S.W. and S.S.W. with a velocity which varied from 0·86 to 1·70 knots per hour. The least of these velocities occurred at high water, and the greatest at low water; which would indicate that although the current was there running across the passage, it may have formed a bend in a line of current which if traced would be found to make outwards and not inwards.

On account of this transverse direction of the current, the under-current was carefully examined, at three different times. It was found to run from the same direction as the surface current, or within one or two points of it. The strength and thickness of the under-current were greater than usual. Between 30 and 40 fathoms in depth, it was still on the average 61 per cent of the surface velocity; and the current also extended to a greater depth than 50 fathoms. The current in this transverse direction was thus remarkable for its strength and thickness.

In order to ascertain where this current came from, another anchorage was made 13 miles to the south-west against its direction, at a station 11 miles N.E. by N. from Fame Point. The current there, on September 12th and 13th, during a period of 20 hours, was found to veer continuously from the S.S.E. through south, west, and north, to N.E. and back to north. The velocity varied from 0·41 to 1·55 knots per hour. These changes in direction and velocity were without relation to the times of high and low water; but on closer examination they are found to be less anomalous than would appear at first sight. The greatest speed of the current was from south-westerly directions; and it was weak when running from directions between N.N.W. and N.E. The strength and thickness of the under-current during south-westerly directions were not obtained however, as these occurred during the night; but while the current ran from directions east of north, it was found to have a thickness of less than 5 fathoms; and below this, the under-current continued to run from the W. to a depth of over 50 fathoms. It thus appears that the body of the movement was from S.W. and W. while the veering of the surface current was superficial and weak. This station therefore lay at the outer edge of the veering current found nearer shore; and below this there was the same deep under-current as found at the middle of the passage, flowing from the south-west and west.

On the Anticosti side, at a station 5½ miles off Ellis Bay, during the night of the 13th, where the total depth was only 45 fathoms, the current was found to run pretty steadily from the north-west at the surface; while the under-current from 15 to 30 fathoms, ran from the south and south-east. These directions were parallel to the shore; and the reverse directions of the surface and under-currents were probably due to the transverse direction of the deep under-current in the middle of the passage, which would tend to make it bear against this shore.

It is clear from these descriptions, that the direction of the current must have been very disturbed and circuitous during the above period. Under such conditions the difficulty is specially felt of arriving at definite conclusions and tracing the general course of the current by means of observations taken on a single vessel; especially when the vessel itself is so heavy and difficult to hold at anchor. The density methods however give valuable help in supplementing the current measurements themselves; which are necessarily interrupted in the above circumstances. The density contours shown on Plate V are based on sections run immediately before and after these observations, on the 7th and 14th of September. The irregular character of these contours corresponds with the disturbed condition of the current at the time, and with the transverse direction of the current in the middle of the passage. It is clear however, that the water in this transverse current finds its way outwards past Cape Gaspé eventually, as already inferred from the nature of its tidal behaviour. Also, from all the indications obtained, there can be no doubt that the current off Cape Gaspé ran continuously from the northward throughout these days.

The density sections referred to are given in Tables E and F; and from these it will be seen that between Fame Point and Ellis Bay the water of least density occupied the middle of the passage for a width of 20 miles. This width is greater than usual, as the current was there running in the direction of the section itself. In Table F, the water of least density is seen to lie immediately off Cape Gaspé, which corresponds with the position of the out-flowing water in that vicinity.

During the following week, from September 16th to 21st, the current was examined in the offing of Griffin Cove and the vicinity of Gaspé. The weather was broken and rough, and although continuous observations could not be made for long at a time, a good deal of information was obtained from careful tracking while it was too rough to hold at anchor. From September 13th to 21st the meoterological conditions were as follows: The low barometer of the 13th when the mean height was only 29.58 rose rapidly to 30.13 on the 15th, fell again to 29.50 on the 18th, and rose a little above 30.00 by the 20th. The winds were northerly on the 13th and 14th while the barometer was rising; and these gave place to south-westerly winds while it fell. When at its lowest there were heavy winds from the N.N.W. amounting to a total mileage of 1179 miles from that direction alone during the 17th, 18th, and 19th; and averaging as high as 29 miles per hour for 24 hours on the 18th. On the 20th and 21st the winds became moderate and variable.

Although repeated endeavours were made to hold at anchor, the only observations of this kind were obtained at a station 5 miles E.N.E. from Griffin Cove, during 7 hours on the 17th, and again during 17 hours from noon on the 20th throughout the following night. The current on the first occasion was found to veer from E.S.E. through E. to N.N.E. and back to E.; and again on the second occasion it veered from N.N.E. through N. and W. as far as S. As the shore line here lies N. by W. some of these directions are directly on-shore and off-shore; and the current when running thus was often near its greatest strength. The current was at times quite slack, but was usually between half a knot and one knot, and did not exceed 1·36 knots per hour. No definite relation to the turn of the tide could be found for either the direction or the variation in velocity; but a careful analysis of the directions showed that during the rise of the tide the current ran from directions on the south side of a line lying W. by N. and E. by S. and during the fall of the tide from directions on the north side of that line. This is in general accord with the direction of the rising and falling tide; and the only exceptions occurred when the current was weak and vaccilaiting.

The under-current, however, did not follow the surface current in these extreme variations, but maintained directions which were fairly parallel to the shore. From this station the extreme bearings to the coast line in the two directions were N.E.¼ N. and S.S.W., and the direction of the under-current kept within the limits of these bearings and their opposites, and did not therefore have directions which tended on and off shore. While the surface current ran from north-westerly or south-easterly directions, the under-current had the same direction within one or two points; but when the surface current tended on shore, the under-current changed gradually in direction with the depth, and from about 30 fathoms downward it was practically parallel with the shore line. Hence the body of the movement was along shore, and the cross-currents were relatively superficial.

From information obtained on the courses run, the prevalent direction of the current during these days was from the N.N.W. in the offing of Griffin Cove, and from the N. off Cape Gaspé itself. The velocity ranged usually from 1·00 to 1·80 knots per hour; but on September 19th immediately after the heavy north-westerly wind of the 18th, the current had a velocity off Cape Gaspé of 2·60 knots per hour, which was one of the highest speeds observed. The general direction of the current as thus determined, and its greater strength near Cape Gaspé, accords with the density contours as shown in Plate V.

On-shore and off-shore directions of the current. On account of the importance of these directions, it may be well to group together all the instances which were met with during the course of the observations. The most noteworthy instance off the Gaspé coast, occurred on September 17th at a station 5 miles E.N.E. from Griffin Cove. The

current there during five hours set directly on-shore; as it ran from directions between E.S.E. and N.E. with a velocity which ranged from 1·04 to 1·35 knots per hour. The under-current however from 30 fathoms downwards ran more nearly parallel with the coast. Also, at the same station on September 20th the current while veering in direction set off-shore during two hours; but it was then slack, having a velocity of little over half a knot per hour.

At a station 4½ miles N.E. by N. from Fame Point, on the night of September 9th, the current while veering in direction set off-shore for one hour, but with a velocity of little over half a knot. Also at a station further from shore, 11 miles from Fame Point, on September 13th the current while slack ran during two hours from directions which set on-shore. As the current between this and the shore was irregular in its direction at the time, it is probable that this on-shore direction would not continue far without changing to some other course.

A similar instance occurred on July 11th at a station 11½ miles E.½ N. from Griffin Cove. The current while veering in direction near the time of high water, set on-shore during three hours; and it had the same direction again during two hours at the next high water on the following night; the velocities varying from 0·66 to 1·25 knots per hour. At this time however the current nearer the shore was running steadily along the coast without veering with the tide.

These off-shore and on-shore directions are thus more likely to occur at points some distance out; because there as already explained, the current veers more widely in direction under the influence of the tide. But between this and the shore, the usual constant current along the Gaspé coast will generally be found; and the on-shore directions of the current will thus be intercepted.

On the Anticosti side of the passage, where the direction of the current veers as a rule through a wide range, the off and on shore directions are more common. Three stations were occupied off the south coast of Anticosti, and one of them twice; and almost always some such directions of the current were found to occur.

A station 6 miles S.W. from Ellis Bay was occupied on July 22nd and 23rd for 42 hours; and the current at four different times set on-shore for periods of six hours, three hours, one hour, and one hour; and also off-shore for one hour. These periods came irregularly with the veering of the direction of the current, and did not appear to have any relation to the tide. The under-current however from 20 fathoms downwards was more nearly parallel to the coast. The velocity of the current was nearly as great as in other directions; but it did not exceed one knot per hour. This station was again occupied for 12 hours on the night of September 13th when the current ran more steadily along the shore. It veered to an on-shore direction during one hour however; but with a speed of little over half a knot.

A station 15 miles to the north-westward of South-west Point, and 6½ miles from the coast of Anticosti, was occupied during 26 hours on July 24th and 25th. This was chosen because it was on the line marked "Constant current" on the chart, as already explained; but the current was found to be weak and variable in direction. It veered from north to east and back to north; then through west to south, and on through east to north; and again from north through east to south. Some of these directions were necessarily off and on shore; and on the whole during the 26 hours, the current set off-shore at three different times, for periods of four hours, three hours, and two hours; but only once on-shore, during three and a half hours. The current however was weak, and seldom exceeded half a knot per hour.

At a station 6 miles S.S.E. from South Point, Anticosti, the current on the night of September 4th was found to run steadily for 10 hours, from directions between E.S.E. and S.S.E. some of which set obliquely on shore.

The above instances will serve to illustrate the character of the current on the Anticosti side; although comparatively little time was spent there, because of the greater importance of the Gaspé side in this region with relation to the leading steamship routes.

Return flow.—As the usual volume of the out-flowing water of the Gaspé current is vastly greater than the volume of the St. Lawrence River, there must be some return flow to compensate for it. The Gaspé current, whether it flows near the coast or in the

middle of the passage, has usually a width of about 12 miles and a mean depth of 30 fathoms, with an average velocity between the surface and that depth of one knot per hour. Such a current would therefore have a volume sixty-four times greater than the St. Lawrence River. In the Mingan Channel, north of Anticosti, the current is tidal in both directions; and there was found to be only a very slight difference of flow in favour of the inward direction. Also, the deep water at 100 and 150 fathoms in the passage between Gaspé and Anticosti, was found to be without movement. In these circumstances it would appear probable that the return flow must take place in some part of the width of this passage, and either at the surface or as an under-current of moderate depth.

The indications, so far as obtained, point to the Anticosti side of the passage as the locality where this return flow probably takes place. Two night anchorages were made off the south coast of Anticosti near its eastern end. On August 7th at 11 miles S.E. from Heath Point, the current ran steadily from the W.S.W. for four hours; which was as long as it was then possible to hold at anchor. Also, on September 4th at six miles S.S.E. from South Point, it ran steadily for 10 hours from directions between E.S.E. and S.S.E. These inward directions correspond with the higher density of the water in that locality, as shown on Plates IV. and V.; which also indicates that the water must make westward around the east end of Anticosti.

It is not possible to trace the course of this return flow without more extended information; and it is also probable that it may change in position, when the outward current itself takes different routes. The necessity for some return flow also makes the reversal of the current on the Gaspé side less anomalous.

Information from fishermen.—The following description of the currents in the Gaspé region is given by two Gaspé fishermen who have lived for many years at Cape Gaspé, and have noticed the set of the currents while fishing off the Gaspé coast and around Anticosti. They have also excellent opportunity during the winter to judge of the current from the movement of the ice off Cape Gaspé itself; as their point of view on the cape is nearly 600 feet above the water. They state that the inshore tide which runs up and down, is seldom more than one mile or one and a half miles wide, off the cape. Outside of this, the ice runs constantly down all winter, and no open water is visible. This continues as long as the wind is north or north-west, which is its prevailing direction in winter; but when the wind changes to south or south-west, the ice leaves the shore, and makes open water as far out as can be seen. There is no change in the speed of the ice towards spring; but the fresh water ice which then begins to appear is quite different from the winter ice and can be readily recognized. The current however is stronger in the spring of the year than in the autumn.

Off the south coast of Anticosti, between South-west Point and South Point, they have found the current to set obliquely on-shore from the southward; and in the Mingan Channe, north of Anticosti, they believe the current to make inwards from the south-east more than outwards. They therefore consider that the current circles round, running outwards on the Gaspé side and inwards on the Anticosti side; and that it is assisted in turning by the inward set in the Mingan Channel. This circling movement appears to be confirmed by the case of a boat used for duck shooting, which went adrift off Cape Gaspé in January, and passed the Cape a second time in the early part of March.

SUMMARY OF THE BEHAVIOUR OF THE GASPÉ CURRENT.

The descriptions above given, from the extended observations made will serve to show the general behaviour of the current between the Gaspé coast and Anticosti at different times; and also the special features which it may occasionally present, or assume locally. The region extending from Fame Point to Cape Gaspé was studied with the most care, as it is there that vessels make and leave the Gaspé coast on all the trans-atlantic and Gulf routes which lead into the St. Lawrence.

In the following summary, which is based upon these investigations of July and September, 1895, the characteristics of the current are given as correctly as possible, by

making a distinction between the nature of its behaviour at different times. The statements with regard to the influence of the wind and barometer, as the cause of its varying behaviour, are given at present as suggestions to direct attention to the probable reasons in the case.

(1.) *The usual current.*—While the ordinary weather for the season of the year prevails, the current in the offing of the Gaspé coast runs constantly outwards from the N.W. and N.N.W. (magnetic). It usually occupies a belt of about 12 miles in width lying from 2 to 14 miles off shore, in the vicinity of Fame Point. This belt appears to become narrower and the current stronger towards Cape Rosier; and between it and the shore there is a tidal current in both directions, as shown on the Admiralty Chart No. 1621, entitled "Entrance to the St. Lawrence." In passing Cape Gaspé it keeps closer to the shore, cutting off the in-shore tide, and its direction there varies from N.N.W. to N.N.E. This current past Cape Gaspé was found to be constant during very varying conditions of the current elsewhere. The velocity of the current usually ranges from one to two knots; the highest observed being 2·81 knots per hour. From determinations off Griffin Cove, the mean density of the current, for a width of 14 miles and between the surface and 10 fathoms, is 1·0220; and between the surface and 40 fathoms its mean density is 1·0237.

(2.) *Displacement of the current.*—The main current from the north-west, consisting of water of the least density, was found at times to lie in the middle of the passage between the Gaspé coast and Anticosti; and to have approximately the position shown by the line along the middle of the passage marked "Constant current" on Admiralty charts Nos. 2516 and 1621. When the current is in this position, the area between it and the Gaspé coast may be occupied by weak and fluctuating currents, or even by a reverse current running inwards from the south-east. This position of the current in the middle of the passage may therefore be regarded as a displacement of the current, or an alternative route which it may take.

(3) *Reversal of the Current.*—When the current takes this route along the middle of the passage, there may be a reverse current running inwards from the south-east along the Gaspé coast. Such a current as observed in the offing of Fame Point, may occupy a belt lying between two miles and twelve miles from shore, and may run constantly from the south-east for as much as six days, with a velocity which ranges from 0·50 to 1·40 knots per hour. This reverse current may thus occupy the site of the usual outward current along the Gaspé coast; and it appears to be caused by the current in the middle of the passage circling round and turning back. While this takes place, the current past Cape Gaspé still runs from the north, and its direction will probably be a little east of north. This appears to be a branch which leaves the main current at the bend, where it turns back to form the current from the south-east.

(4.) *Off and on-shore directions of the current.*—It is possible for the current while veering in direction, to set directly off or on-shore for a few hours at a time. The instances of this which were met with, have been given above as examples.

(5.) *Tidal influence.*—(*a.*) When the current runs constantly in one direction, whatever position it may take, and whether it runs with its usual outward direction or is reversed, it is always subject to a fluctuation in velocity which corresponds with the tide. When the current has its usual direction from the north-west, or outwards from the St. Lawrence towards the Gulf, it is strongest at low water and weakest at high water; but when the current runs inwards the reverse is the case.

(*b.*) At times and places that the current veers in direction, especially when the velocity is not great, it has been found to make outwards during the fall of the tide; that is, to run from some direction on the north-west side of a line lying south-west and north-east; and to make inwards during the rise of the tide, from some direction on the opposite side of such a line.

(6.) *Return flow.*—It is evident that there must be some return flow to compensate for the out-flowing water of the Gaspé current; as its volume is more than sixty times as great as the average dischage of the St. Lawrence River. The current in the Mingan channel is a tidal one, in both directions, with only a very slight difference of flow in favour of the inward direction. Also, the deep water in the channel between Gaspé

and Anticosti was found to be without movement. It would therefore appear probable that the return flow must consist of an inward movement of the water in some part of the width of the main channel, and perhaps usually on the Anticosti side; and that this movement occurs either at the surface, or as an under-current at a moderate depth.

(7.)—*Influence of the wind.*—It appears probable that the chief reason that the current keeps along the Gaspé coast is because the prevailing winds on the Lower St. Lawrence are towards the south-east side. When the winds are also north-westerly in the Gaspé region they assist in keeping the current along that shore, and tend to increase its speed. On the other hand the current appears to be kept away from the coast, and to be most disturbed when the winds are from the southward of west (magnetic) on the Lower St. Lawrence, and at the same time south or south-east in the Gaspé region. The winds then blow in upon both ends of the waterway which forms the entrance to the St. Lawrence, and they have an off-shore direction along that part of the coast which the Gaspé current usually follows. The winds can only have the above directions in these regions when a low pressure area or storm centre is travelling along a course which lies to the northward of the St. Lawrence valley. The low pressure area itself on this course, when nearest to the Gaspé region, would also assist in checking and disturbing the usual current; as the difference in barometric pressure tends to make the water flow towards the lowest pressure, just as in the case of the wind.

This northern course for an area of low pressure is less frequent, as the usual path of storms lies to the south of the St. Lawrence valley, or along the Atlantic sea-board. The conditions above indicated are therefore unusual; and if the displacement and the reversal of the Gaspé current are dependent upon them, it is clearly correct to consider these conditions of the current itself as exceptional.

It may therefore be said in general, that vessels may expect to find the usual outward current from the north-west along the Gaspé coast, unless they have reason to infer from the weather they meet with, that a low pressure area or storm-centre is passing to the northward; accompanied by winds which are southward of west (magnetic) along the Lower St. Lawrence; and strong southerly winds with a falling or low barometer at the entrance to the St. Lawrence south of Anticosti. The condition of the current will then be disturbed; and it may lie in the middle of the passage between the Gaspé coast and Anticosti; while a current which is irregular, or possibly inwards from the south-east, may be found in the offing of the Gaspé coast. Vessels making inwards, especially if the weather is foggy, must not count too definitely however on the absence of the outward current as an assistance in rounding the Gaspé coast; as under these disturbed conditions, there are times when the current may be setting more or less on-shore.

I have, sir, the honour to remain,

Your obedient servant,

W. BELL DAWSON,

In charge of Tidal Survey.

TABLE A.—Density Section from the Gaspé Coast to Anticosti Island. On a line running N.E. ½ N. (magnetic) from Fame Point to Ellis Bay, Anticosti. Date, 26th July, 1895.

(Gaspé side.) (Anticosti side.)

Mileage from Fame Point.	0 M. (Shore.)	3 M.	6 M.	9 M.	12 M.	15 M.	18 M.	21 M.	25 M.	32 M.	39 M.	42 M. (Shore.)
Surface	.....	1·0214	1·0208	1·0213	1·0207	1·0208	1·0208	1·0209	1·0205	1·0218	1·0225	.....
10 fathoms	.....	1·0227	1·0232	1·0231	1·0228	1·0223	1·0220	1·0230	1·0229	1·0233	1·0242	.....
20 "	.....	1·0241	1·0243	1·0244	1·0235	1·0233	1·0235	1·0237	1·0239	1·0242	.....	.....
30 "	.....	1·0247	.....	1·0248	.....	1·0245	.....	.....	.....	.....	.....	.....
50 "	.....	1·0253	1·0251	.....	1·0250	.....	1·0244	.....	1·0247	1·0251	.....	.....

TABLE B.—Density Section from the Gaspé Coast to Anticosti Island. On a line running E. by N. ½ N. (magnetic) from Cape Gaspé to Salt Lake Bay, Anticosti. Date, 3rd August, 1895.

Gaspé side.) (Anticosti side.)

Mileage from Cape Gaspé.	0 M. (Shore.)	3 M.	6 M.	10 M.	14 M.	19 M.	24 M.	28 M.	33 M.	39 M.	45 M.	47 M. (Shore.)
Surface	.....	1·0218	1·0217	1·0217	1·0220	1·0218	1·0223	1·0224	1·0228	1·0226	1·0230	.....
10 fathoms	.....	1·0235	1·0243	1·0243	1·0240	1·0243	1·0243	1·0244	1·0242	1·0245	1·0246	.....
20 "	.....	1·0244	1·0250	1·0248	1·0249	1·0248	1·0249	1·0248	1·0246	1·0248	1·0249	.....
50 "	.....	.....	.....	1·0253	1·0253	1·0253	.....	1·0253	.....	.....	.....	.....

The above densities are all reduced to the temperature of 60° Fahrenheit. The mileage is in nautical miles measured from the shore.

TABLE C.—Density Section between Cape North, C.B., and Cape Ray, Newfoundland. On a line running E. ½ N. (magnetic) from Cape North to Port Basque, Newfoundland. Date, 24th August, 1895.

(Cape Breton side.) (Newfoundland side.

Mileage from Cape North.	0 M. (Shore.)	3 M.	6 M.	9 M.	12 M.	16½ M.	24 M.	31 M.	38 M.	45 M.	52 M.	57 M.	60 M. (Shore.

The above densities are all reduced to the temperature of 60° Fahrenheit. The mileage is in nautical miles measured from the shore.

TABLE C.—Density Section between Cape North, C.B., and Cape Ray, Newfoundland. On a line running E. ½ N. (magnetic) from Cape North to Port Basque, Newfoundland. Date, 24th August, 1895.

(Cape Breton side.) (Newfoundland side.

Mileage from Cape North.	0 M. (Shore.)	3 M.	6 M.	9 M.	12 M.	16½ M.	24 M.	31 M.	38 M.	45 M.	52 M.	57 M.	60 M. (Shore.
Surface		1·0218	1·0224	1·0225	1·0229	1·0230	1·0237	1·0236	1·0238	1·0240	1·0241	1·0245	
10 fathoms		1·0219	1·0234	1·0225	1·0233	1·0231	1·0237	1·0238	1·0239	1·0242	1·0247	1·0249	
20 "		1·0236	1·0235	1·0243	1·0245	1·0248							
30 "						1·0250		1·0250	1·0249	1·0252			
50 "			1·0249		1·0255		1·0248	1·0252		1·0252	1·0253		

TABLE D.—Density Section running due North from Cape North, C.B. On a line running N.E. by N. ½ N. (magnetic) for 53 miles from Cape North. Date, 27th August, 1895.

Mileage from Cape North.	0 M. (Shore.)	1 M.	3 M.	5 M.	9 M.	13 M.	19½ M.	26 M.	33 M.	40 M.	46½ M.	53 M.	—
Surface		1·0224	1·0225	1·0227	1·0224	1·0233	1·0237	1·0235	1·0236	1·0240	1·0236	1·0238	
10 fathoms		1·0229	1·0231	1·0227	1·0226	1·0235	1·0240	1·0235	1·0238	1·0240	1·0240	1·0238	
20 "			1·0240	1·0241	1·0246	1·0247		1·0249		1·0245		1 0245	
50 "			1·0247		1·0253		1·0255		1·0252		1·0251		

The above densities are all reduced to the temperature of 60° Fahrenheit. The mileage is in nautical miles measured from the shore.

TABLE E.—Density Section from Cape Gaspé to Anticosti Island. On a line running E. by N. ½ N. (magnetic) from Cape Gaspé to Salt Lake Bay, Anticosti. Date, 7th September, 1895.

(Gaspé side.) (Anticosti side.)

Mileage from Cape Gaspé.	0 M. (Shore.)	1 M.	3 M.	7 M.	11 M.	16 M.	20 M.	25 M.	31 M.	38 M.	42 M.	44 M.	47 M. (Shore.)
Surface		1·0224	1·0223	1·0225	1·0232	1·0232	1·0230	1·0233	1·0232	1·0234	1·0239	1·0237	
10 fathoms		1·0225	1·0227	1·0233	1·0238	1·0242	1·0235	1·0240	1·0238	1·0237		1·0244	
20 "			1·0234	1·0245	1·0245	1·0245	1·0242	1·0247	1·0247	1·0244		1·0246	
30 "					1·0246		1·0248			1·0250			
50 "				1·0249		1·0250			1·0256				

TABLE F.—Density Section from the Gaspé Coast to Anticosti Island. On a line running N.E. ½ N. (magnetic) from Fame Point to Ellis Bay, Anticosti. Date, 14th September, 1895.

(Gaspé side.) (Anticosti side.)

Mileage from Fame Point.	0 M. (Shore.)	1 M.	3 M.	6 M.	9 M.	12 M.	17 M.	22 M.	26 M.	31 M.	36 M.	42 M. (Shore.)
Surface		1·0218	1·0222	1·0220	1·0217	1·0220	1·0214	1·0217	1·0220	1·0218	1·0219	
10 fathoms			1·0223	1·0223	1·0222	1·0220	1·0217	1·0221	1·0233	1·0231	1·0232	
20 "			1·0236	1·0235	1·0230	1·0231	1·0228	1·0233	1·0237	1·0242	1·0241	
30 "			1·0246		1·0242		1·0240		1·0244			
50 "				1·0248		1·0246		1·0245		1·0247		

The above densities are all reduced to the temperature of 60° Fahrenheit. The mileage is in utical miles measured from the shore.

10 fathoms.					1·0236	1·0235	1·0230	1·0231	1·0228	1·0233			
20	"				1·0246		1·0242		1·0240		1·0244		
30	"												
50	"					1·0248		1·0246		1·0245		1·0247	

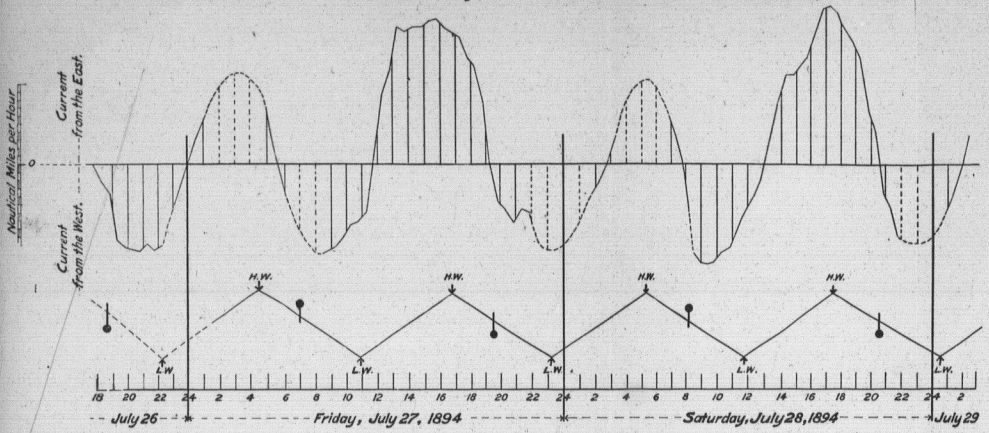
The above densities are all reduced to the temperature of 60° Fahrenheit. The mileage is in utical miles measured from the shore.

PLATE 1.

CURRENT IN THE STRAIT OF BELLE ISLE DURING MODERATE WEATHER,

COMPARED WITH THE TIDE AND THE TIME OF THE MOON'S TRANSITS,

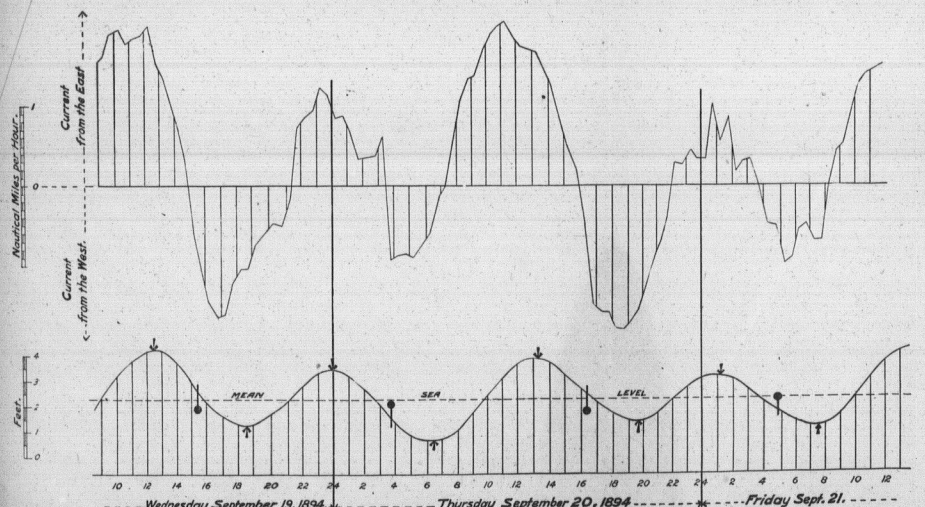
(The time throughout is standard time for the 60th meridian.)



CURRENT AS OBSERVED AT STATION "B", 6 MILES E.S.E. (MAGNETIC) FROM AMOUR POINT (DOTTED PORTIONS NOT ACTUALLY MEASURED BY CURRENT METER.)

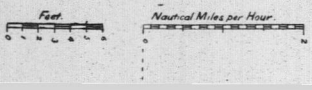
TIME OF HIGH AND LOW WATER AT FORTEAU BAY.

NOTE.
MOONS TRANSITS THUS :-
UPPER TRANSIT
LOWER TRANSIT



CURRENT AS OBSERVED AT STATION "C" 6 MILES E. FROM AMOUR POINT, AND 2½ MILES FROM NORTH SHORE.
(THE INEQUALITY IN THE CURRENT CORRESPONDS WITH THE DIURNAL INEQUALITY IN THE TIDE ITSELF)

TIDE AT FORTEAU BAY FROM SELF-RECORDING TIDE GAUGE.


Feet.
0 1 2 3 4 5 6
Nautical Miles per Hour.
0 1 2

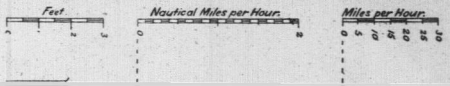
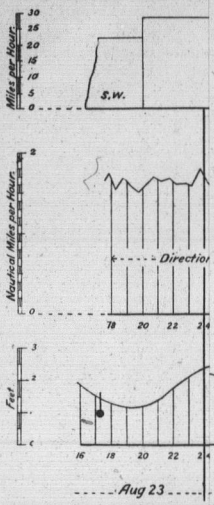

Feet.
0 1 2 3
Nautical Miles per Hour.
0 1 2
Miles per Hour.
0 5 10 15 20 25 30

PLATE II.

NORTH-WEG OF CAPE NORTH,

ISITS.



WIND AS RECORDED BY ANEMOMETER ON SURVEYING STEAMER. DIRECTIONS MAGNETIC.

CURRENT AS OBSERVED AT STATION N', 10 MILES S.E. (MAGNETIC) FROM CAPE NORTH., DIRECTIONS MAGNETIC.

TIDE FROM SELF-RECORDING TIDE GAUGE ON ST PAUL ISLAND.

CURRNDITIONS.

Current ot Point, Anticosti.

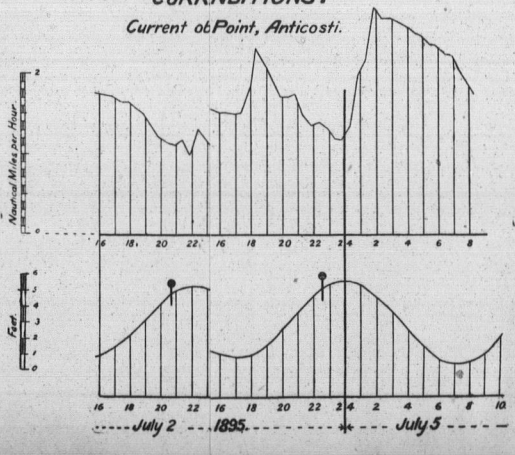
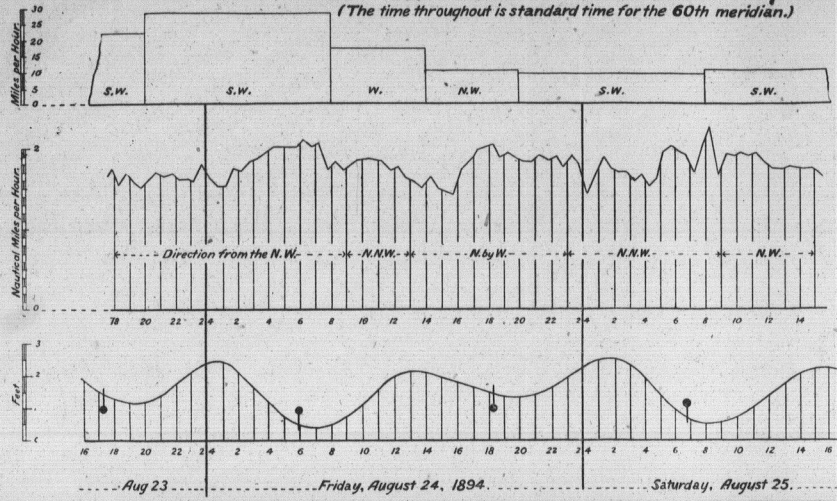


PLATE II.

NORTH-WESTERLY CURRENT IN CABOT STRAIT, IN THE OFFING OF CAPE NORTH,

IN RELATION TO THE WIND, TIDE, AND TIME OF THE MOON'S TRANSITS.

(The time throughout is standard time for the 60th meridian.)



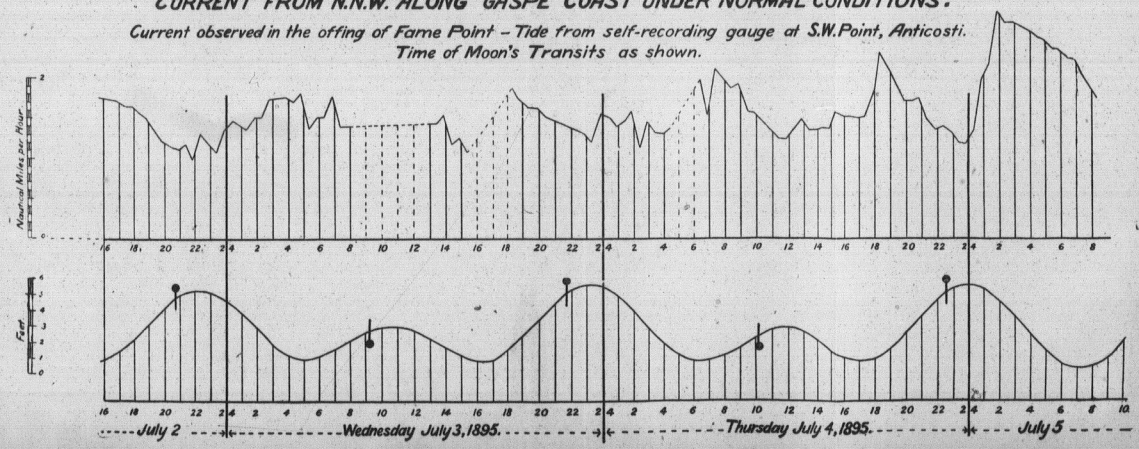
WIND AS RECORDED BY ANEMOMETER ON SURVEYING STEAMER. DIRECTIONS MAGNETIC.

CURRENT AS OBSERVED AT STATION N', 10 MILES S.E. (MAGNETIC) FROM CAPE NORTH., DIRECTIONS MAGNETIC.

TIDE FROM SELF-RECORDING TIDE GAUGE ON ST PAUL ISLAND.

CURRENT FROM N.N.W. ALONG GASPE COAST UNDER NORMAL CONDITIONS.

Current observed in the offing of Fame Point – Tide from self-recording gauge at S.W. Point, Anticosti.
Time of Moon's Transits as shown.




68°
Seven It
30
Mouth o
River St
Martin B
G A
48°
N E
BRUNS
56°

PLATE III.

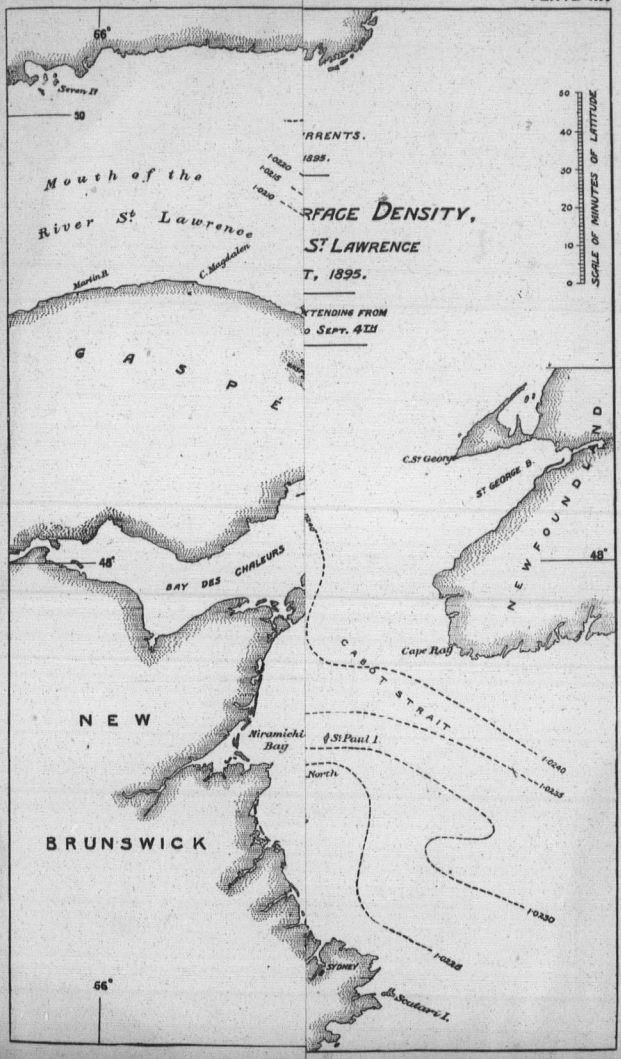
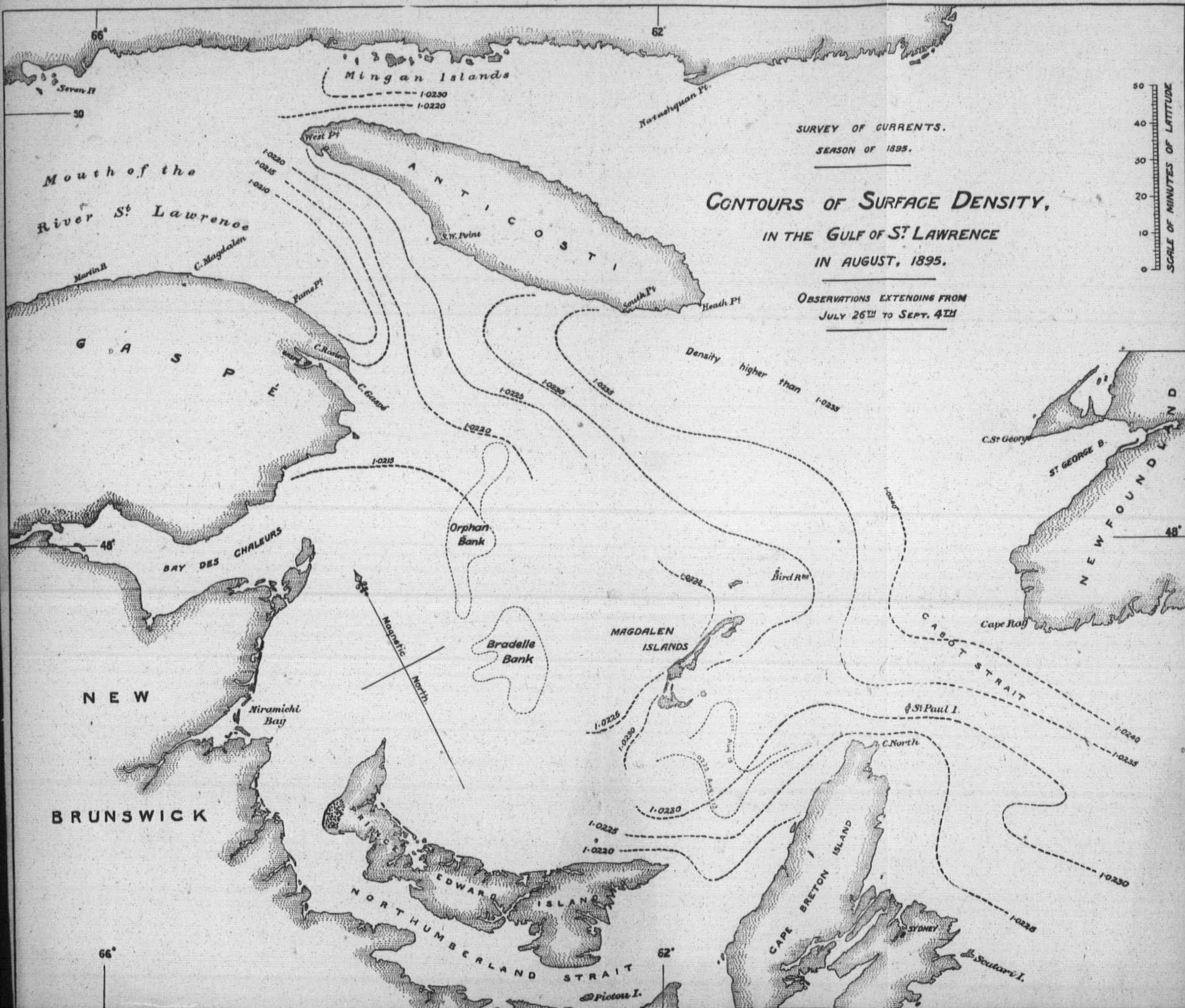

66°
Seven Is
50
RRENTS.
1895.
Mouth of the
River St Lawrence
RFACE DENSITY,
St LAWRENCE
T, 1895.
TENDING FROM
SEPT. 4TH
SCALE OF MINUTES OF LATITUDE
50
40
30
20
10
0
Martin Pt
C. Magdalen
GASPÉ
C. St George
St GEORGE B.
NEWFOUNDLAND
48°
BAY DES CHALEURS
Cape Ray
CABOT STRAIT
NEW
Miramichi Bay
St Paul I.
North
BRUNSWICK
1020
1025
1030
1035
1040
SYDNEY
St Scatari I.
66°

PLATE III.


SURVEY OF CURRENTS.
SEASON OF 1895.
CONTOURS OF SURFACE DENSITY,
IN THE GULF OF ST. LAWRENCE
IN AUGUST, 1895.
OBSERVATIONS EXTENDING FROM
JULY 26TH TO SEPT. 4TH
SCALE OF MINUTES OF LATITUDE
Mingan Islands
Seven Is.
Natashquan Pt.
West Pt.
ANTICOSTI
S.W. Point
South Pt.
Heath Pt.
Mouth of the
River St. Lawrence
C. Magdalen
Martin R.
Fame Pt.
C. Rozier
C. Gaspé
GASPÉ
Density higher than 1·0235
Orphan Bank
Bradelle Bank
Bird Rks.
MAGDALEN
ISLANDS
Magnetic North
BAY DES CHALEURS
NEW
BRUNSWICK
Miramichi Bay
PRINCE EDWARD ISLAND
NORTHUMBERLAND STRAIT
Pictou I.
CAPE BRETON ISLAND
C. North
St. Paul I.
SYDNEY
Scatari I.
CABOT STRAIT
C. St. George
ST. GEORGE B.
NEWFOUNDLAND
Cape Ray
1·0230
1·0220
1·0215
1·0210
1·0225
1·0235
1·0240
66°
62°
50
48°

65
G
A
65°

PLATE IV.

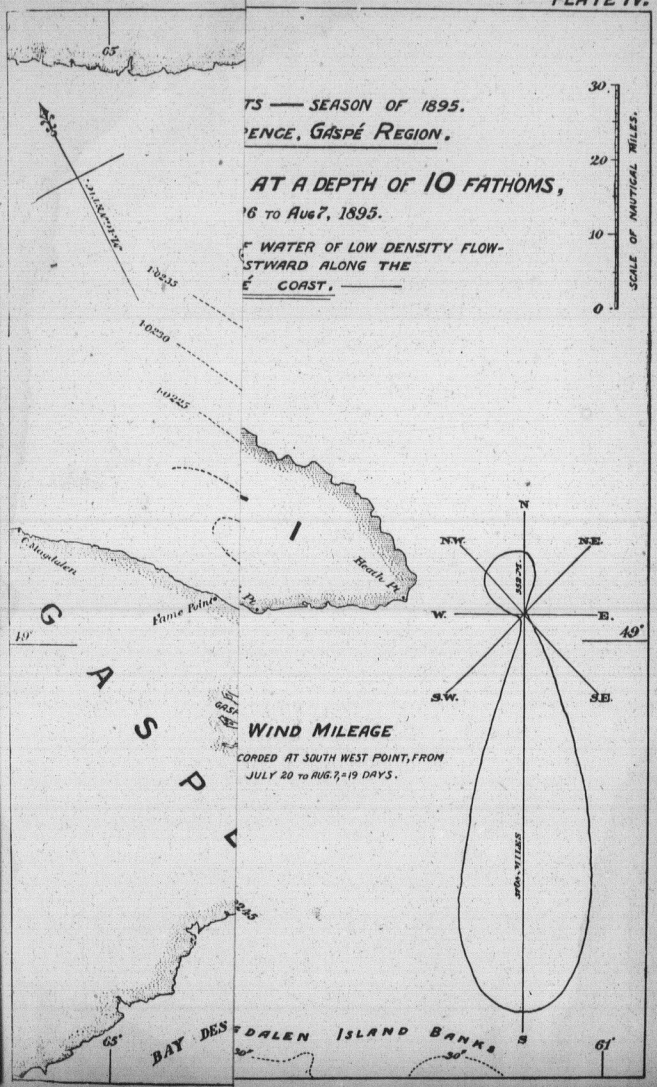
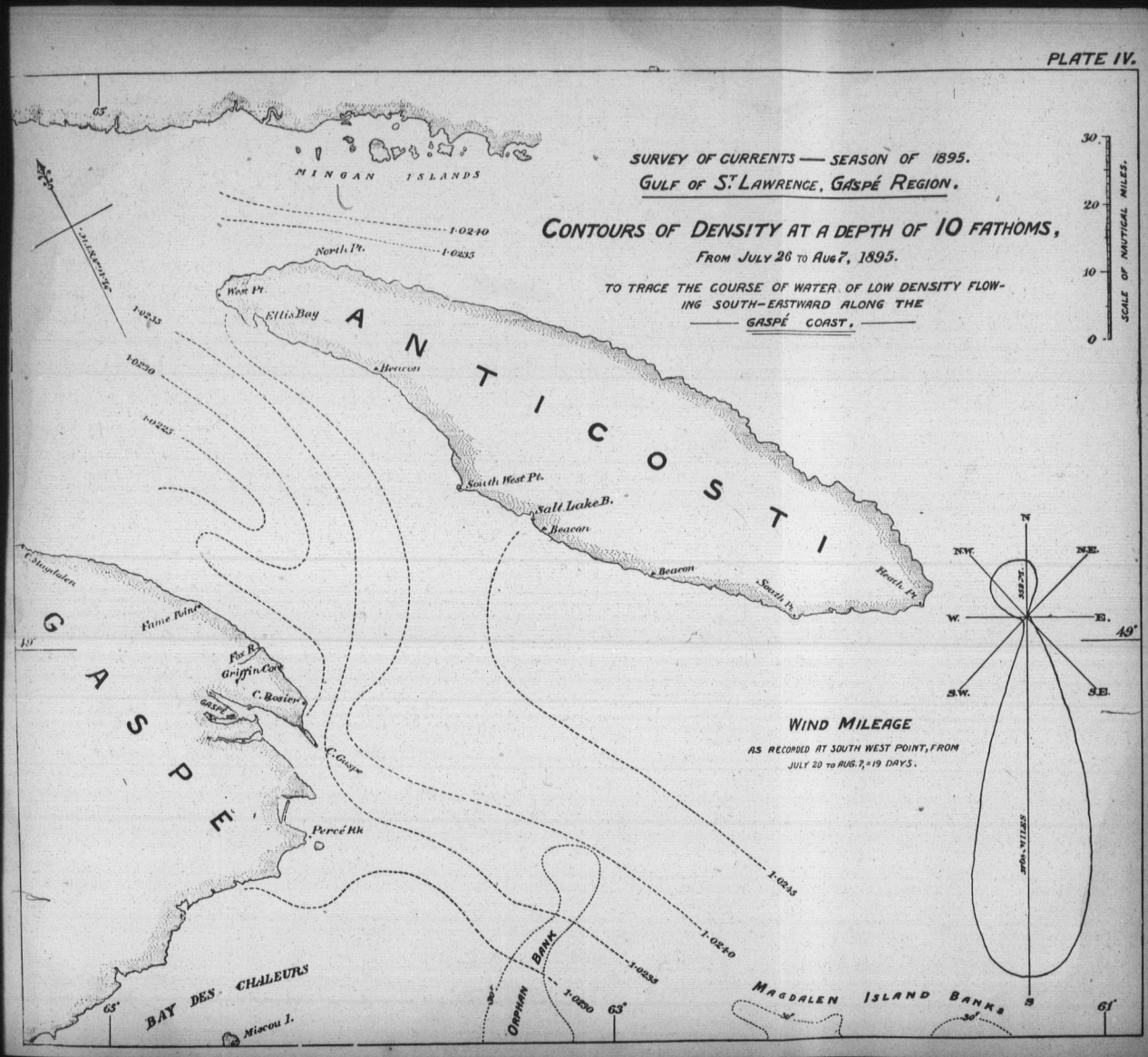

65°
TS — SEASON OF 1895.
ENCE, GASPÉ REGION.
AT A DEPTH OF 10 FATHOMS,
6 TO AUG 7, 1895.
F WATER OF LOW DENSITY FLOW-
STWARD ALONG THE
COAST.
30
20
10
0
SCALE OF NAUTICAL MILES.
10235
10230
10225
Heath Pt.
Flame Point
49°
N
NW.
NE.
W.
E.
SW.
SE.
S
WIND MILEAGE
CORDED AT SOUTH WEST POINT, FROM
JULY 20 TO AUG. 7, = 19 DAYS.
GASPÉ
BAY DES
DALEN ISLAND BANKS
61°

PLATE IV.


SURVEY OF CURRENTS — SEASON OF 1895.
GULF OF St. LAWRENCE, GASPÉ REGION.
CONTOURS OF DENSITY AT A DEPTH OF 10 FATHOMS,
FROM JULY 26 TO AUG. 7, 1895.
TO TRACE THE COURSE OF WATER OF LOW DENSITY FLOWING SOUTH-EASTWARD ALONG THE GASPÉ COAST.
SCALE OF NAUTICAL MILES.
30.
20
10
0
MINGAN ISLANDS
1·0240
1·0235
1·0230
1·0225
North Pt.
West Pt.
Ellis Bay
Beacon
ANTICOSTI
South West Pt.
Salt Lake B.
Beacon
Beacon
South Pt.
Heath Pt.
C. Magdalen
Fame Points
Fox R.
Griffin Cove
C. Rosier
GASPÉ
C. Gaspe
Percé Rk
GASPÉ
BAY DES CHALEURS
Miscou I.
ORPHAN BANK
MAGDALEN ISLAND BANKS
65°
63°
61°
49°
N
NW.
NE.
W.
E.
SW.
SE.
S
WIND MILEAGE
AS RECORDED AT SOUTH WEST POINT, FROM JULY 20 TO AUG. 7, 19 DAYS.
300 MILES

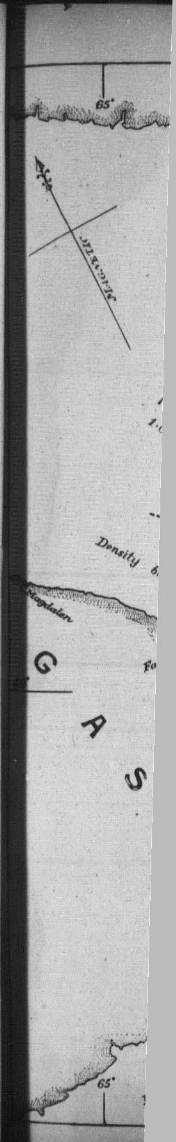

65°
Density
G
A
S
65°

PLATE V.

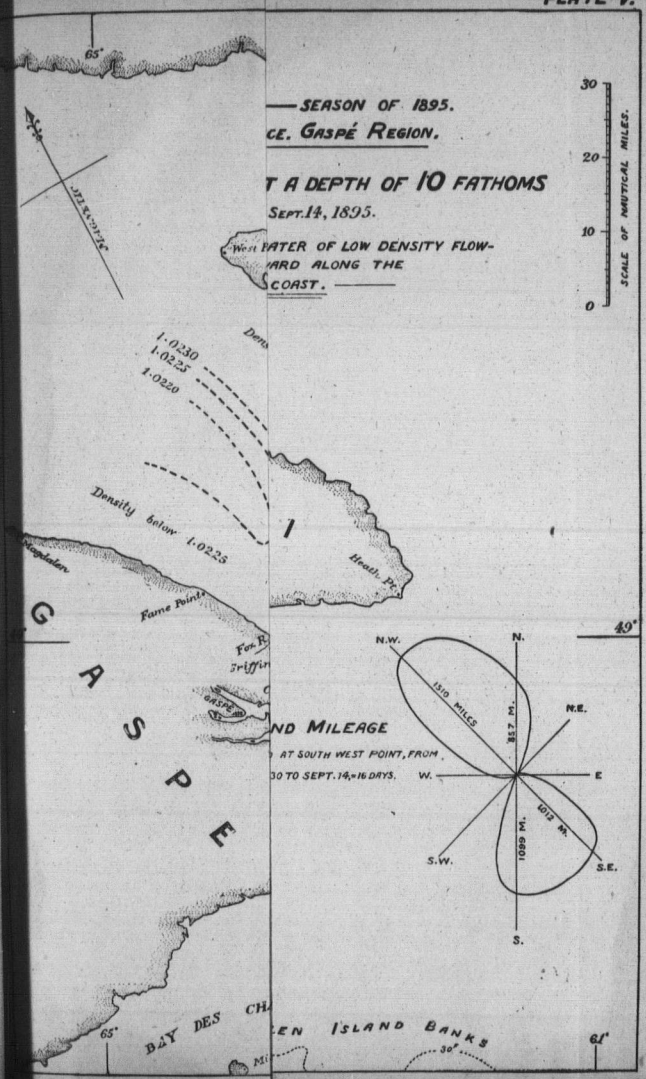
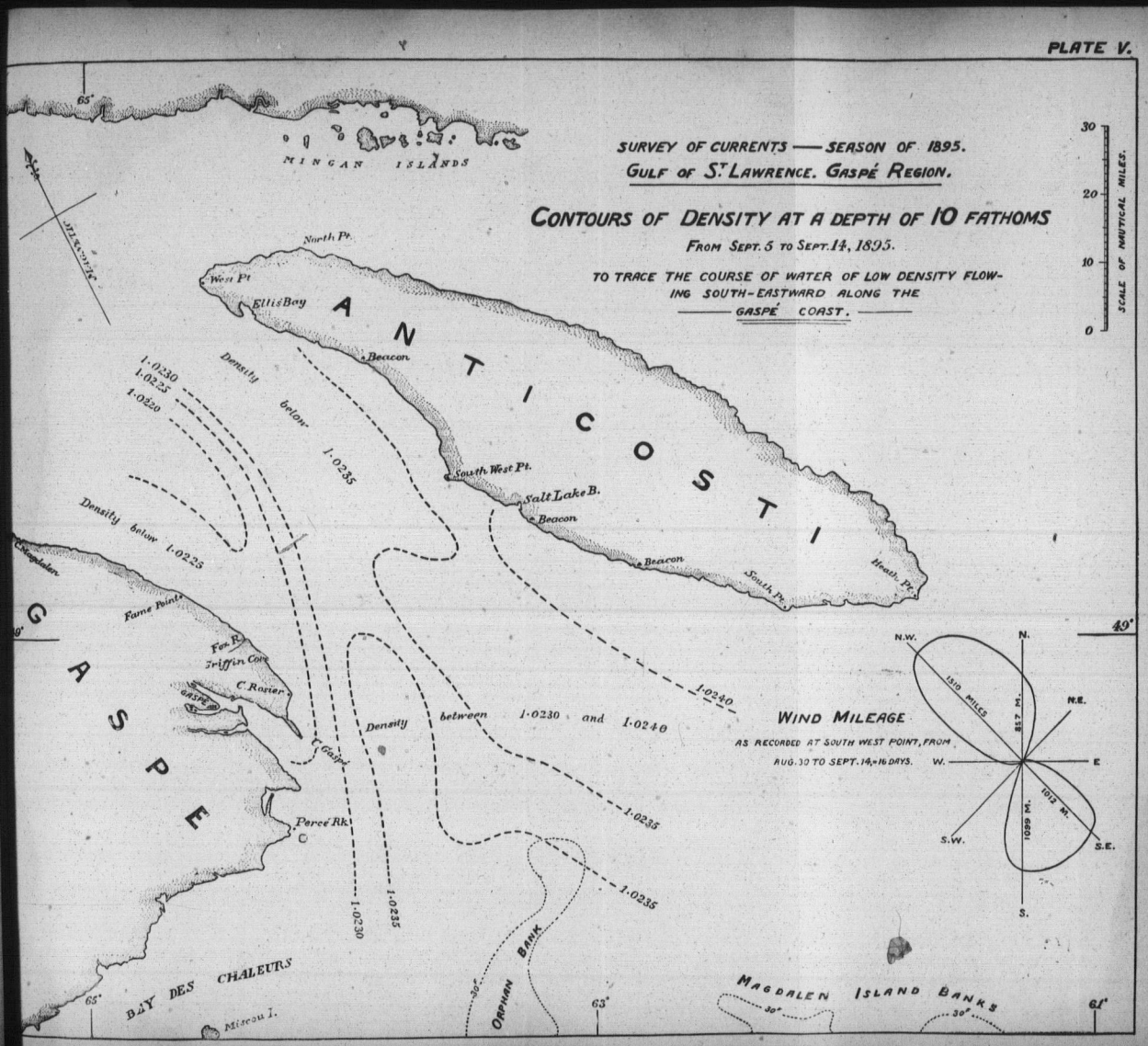
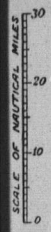

—SEASON OF 1895.
CE. GASPÉ REGION.
T A DEPTH OF 10 FATHOMS
SEPT. 14, 1895.
WATER OF LOW DENSITY FLOW-
WARD ALONG THE
COAST.
SCALE OF NAUTICAL MILES.
30
20
10
0
1.0230
1.0225
1.0220
Density below 1.0225
Heath Pt.
Fame Point
GASPÉ
49°
65°
N.W.
N.
N.E.
W.
E.
S.W.
S.E.
S.
1310 MILES
357 M.
1012 M.
1089 M.
ND MILEAGE
AT SOUTH WEST POINT, FROM
30 TO SEPT. 14, = 16 DAYS.
BAY DES CH
EN ISLAND BANKS
30'
61'

PLATE V.


SURVEY OF CURRENTS — SEASON OF 1895.
GULF OF ST LAWRENCE. GASPÉ REGION.
CONTOURS OF DENSITY AT A DEPTH OF 10 FATHOMS
FROM SEPT. 5 TO SEPT. 14, 1895.
TO TRACE THE COURSE OF WATER OF LOW DENSITY FLOWING SOUTH-EASTWARD ALONG THE GASPÉ COAST.
SCALE OF NAUTICAL MILES.
30
20
10
0
MINGAN ISLANDS
ANTICOSTI
North Pt.
West Pt.
Ellis Bay
Beacon
South West Pt.
Salt Lake B.
Beacon
Beacon
South Pt.
Heath Pt.
GASPE
Fame Point
Fox R.
Griffin Cove
C. Rosier
Gaspé
Perce Rk.
BAY DES CHALEURS
Miscou I.
ORPHAN BANK
MAGDALEN ISLAND BANKS
Density below 1·0225
Density below 1·0235
Density between 1·0230 and 1·0240
1·0230
1·0225
1·0220
1·0240
1·0235
1·0235
1·0230
WIND MILEAGE
AS RECORDED AT SOUTH WEST POINT, FROM AUG. 30 TO SEPT. 14, = 16 DAYS.
N.
N.E.
E.
S.E.
S.
S.W.
W.
N.W.
1310 MILES
857 M.
1012 M.
1609 M.
65°
63°
61°
49°

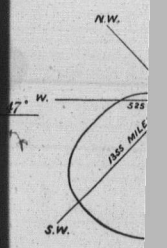


Co

WIND

AS RECORDED AT MA

AUG. 2 TO A



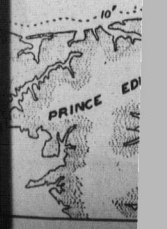


PLATE VI

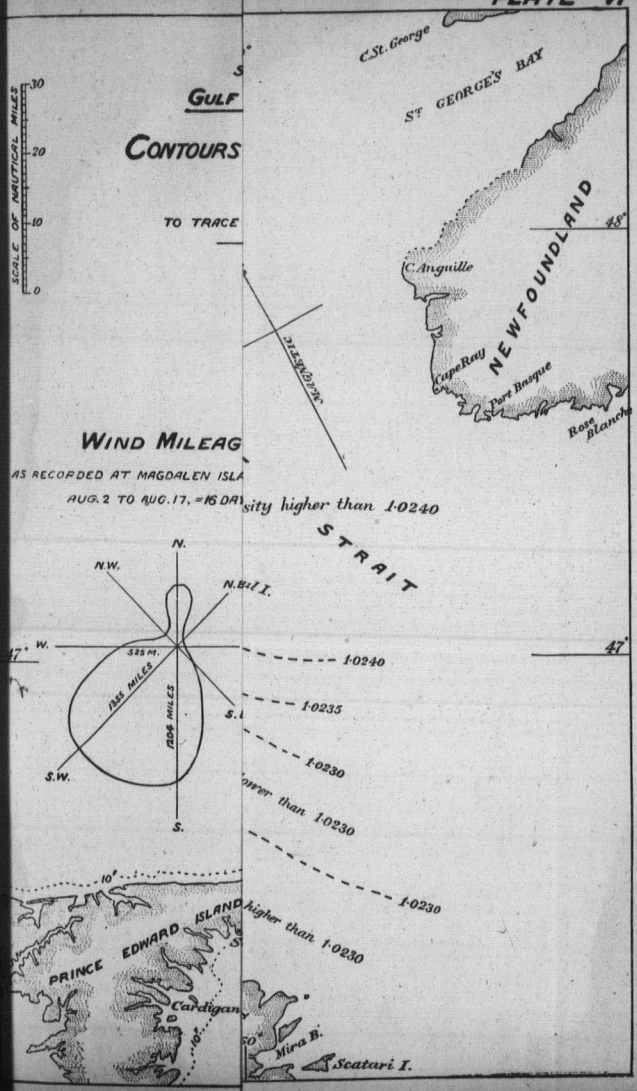

C. St. George
ST GEORGE'S BAY
NEWFOUNDLAND
48°
C. Anguille
Cape Ray
Port Basque
Rose Blanche
SCALE OF NAUTICAL MILES
30
20
10
0
GULF
CONTOURS
TO TRACE
WIND MILEAG
AS RECORDED AT MAGDALEN ISLA
AUG. 2 TO AUG. 17, =16 DA
sity higher than 1·0240
STRAIT
N.
N.W.
N.E.
I.
47° W.
47°
525 M.
385 MILES
405 MILES
S.W.
S.
1·0240
1·0235
1·0230
lower than 1·0230
1·0230
higher than 1·0230
10°
PRINCE EDWARD ISLAND
Cardigan
60°
Mira B.
Scatari I.

PLATE VI

SURVEY OF CURRENTS —— SEASON OF 1895.

GULF OF St. LAWRENCE — CAPE BRETON REGION.

CONTOURS OF DENSITY AT A DEPTH OF 10 FATHOMS

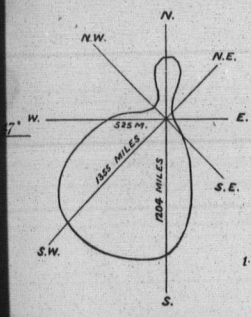
FROM AUG. 9 TO AUG. 17, 1895.

TO TRACE THE COURSE OF WATER OF LOW DENSITY FLOWING EASTWARD AROUND CAPE NORTH

SCALE OF NAUTICAL MILES 30 20 10 0

WIND MILEAGE

AS RECORDED AT MAGDALEN ISLANDS FROM AUG. 2 TO AUG. 17. = 16 DAYS



Bird Rocks

MAGDALEN ISLANDS

1·0230 1·0240 1·0245 1·0235 1·0240 1·0240 1·0235 1·0230

Density higher than 1·0240

CABOT STRAIT

St. Paul I.

C. North

1·0240 1·0235 1·0230

C. Egmont

Ingonish

Density lower than 1·0230

1·0230

Cheticamp I.

CAPE BRETON ISLAND

Gt. Bras d'Or

Density higher than 1·0230

Sydney Hr.

SYDNEY

Mira B.

Seatari I.

Port Hood

C. Mabou

East Pt.

PRINCE EDWARD ISLAND

Souris

Cardigan B.

C. St. George

ST GEORGE'S BAY

NEWFOUNDLAND

C. Anguille

Cape Ray

Port Basque

Ross Blanche

60° 48° 47° 62°

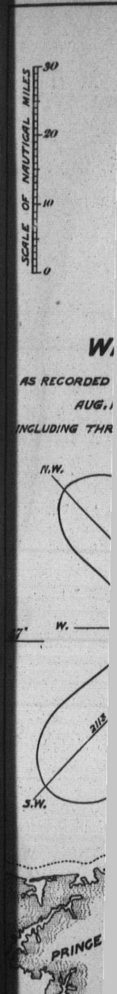

SCALE OF NAUTICAL MILES
30
20
10
0
AS RECORDED
AUG.
INCLUDING THR
N.W.
W.
47°
2113
S.W.
PRINCE

PLATE VII

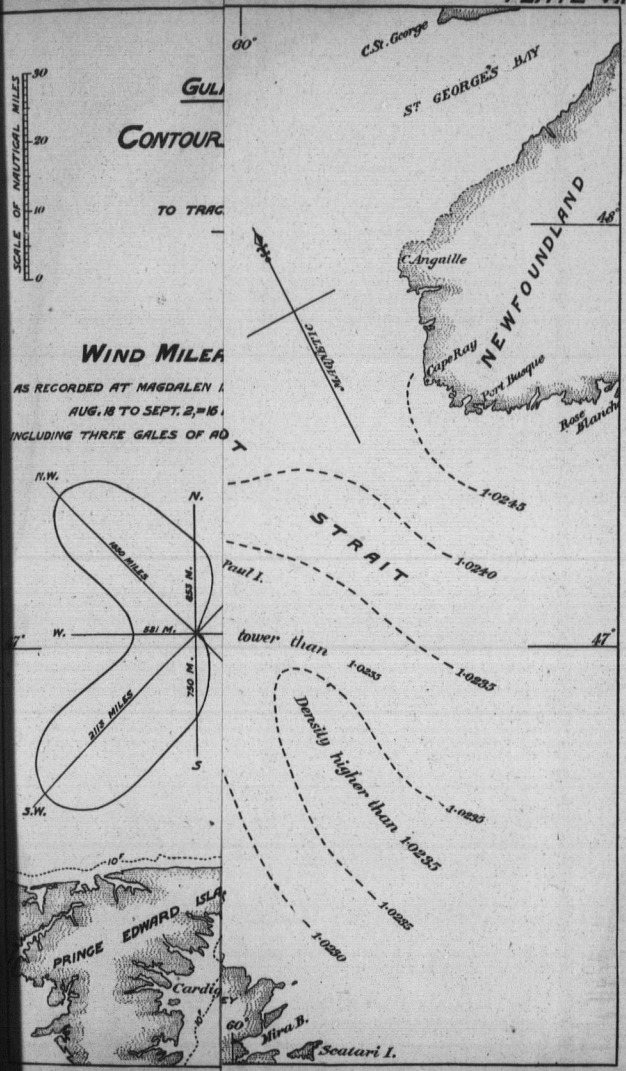

SCALE OF NAUTICAL MILES
30
20
10
0
GULF
CONTOUR
TO TRAC
WIND MILEA
AS RECORDED AT MAGDALEN I
AUG. 18 TO SEPT. 2, 18
INCLUDING THREE GALES OF AD
N.W.
N.
W.
S.
S.W.
180 MILES
655 M.
681 M.
750 M.
311½ MILES
60°
C. St. George
ST GEORGE'S BAY
48°
C. Anguille
NEWFOUNDLAND
Cape Ray
Port Basque
Rose Blanche
1·0243
1·0240
STRAIT
Paul I.
47°
lower than 1·0233
1·0233
Density higher than 1·0235
1·0235
1·0235
1·0230
PRINCE EDWARD ISLA
Cardi
Mira B.
Scatari I.

PLATE VII

SURVEY OF CURRENTS — SEASON OF 1895.

GULF OF St. LAWRENCE — CAPE BRETON REGION.

CONTOURS OF DENSITY AT A DEPTH OF 10 FATHOMS

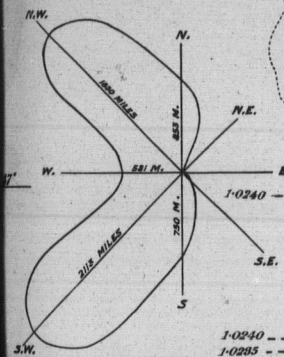
FROM AUG. 22 TO SEPT. 3, 1895.

TO TRACE THE COURSE OF WATER OF LOW DENSITY FLOWING EASTWARD AROUND CAPE NORTH

SCALE OF NAUTICAL MILES 30 20 10 0

WIND MILEAGE

AS RECORDED AT MAGDALEN ISLANDS FROM AUG. 18 TO SEPT. 2, = 16 DAYS INCLUDING THREE GALES OF AUG. 19, 22 & 25.



Bird Rocks

MAGDALEN ISLANDS

Density between 1·0230 and 1·0235

1·0240

1·0235

1·0230

Density lower than 1·0230

Density lower than 1·0235

Density higher than 1·0235

CABOT STRAIT

St. Paul I.

C. North

C. Egmont

Ingonish

Chéticamp I.

CAPE BRETON ISLAND

Gt. Bras d'Or

Sydney Hr.

SYDNEY

C. Mabou

Port Hood

Mira B.

Scatari I.

East Pt.

PRINCE EDWARD ISLAND

Souris

Cardigan B.

C. St. George

ST. GEORGE'S BAY

C. Anguille

NEWFOUNDLAND

Cape Ray

Port Basque

Rose Blanche

48°

47°

62°

60°

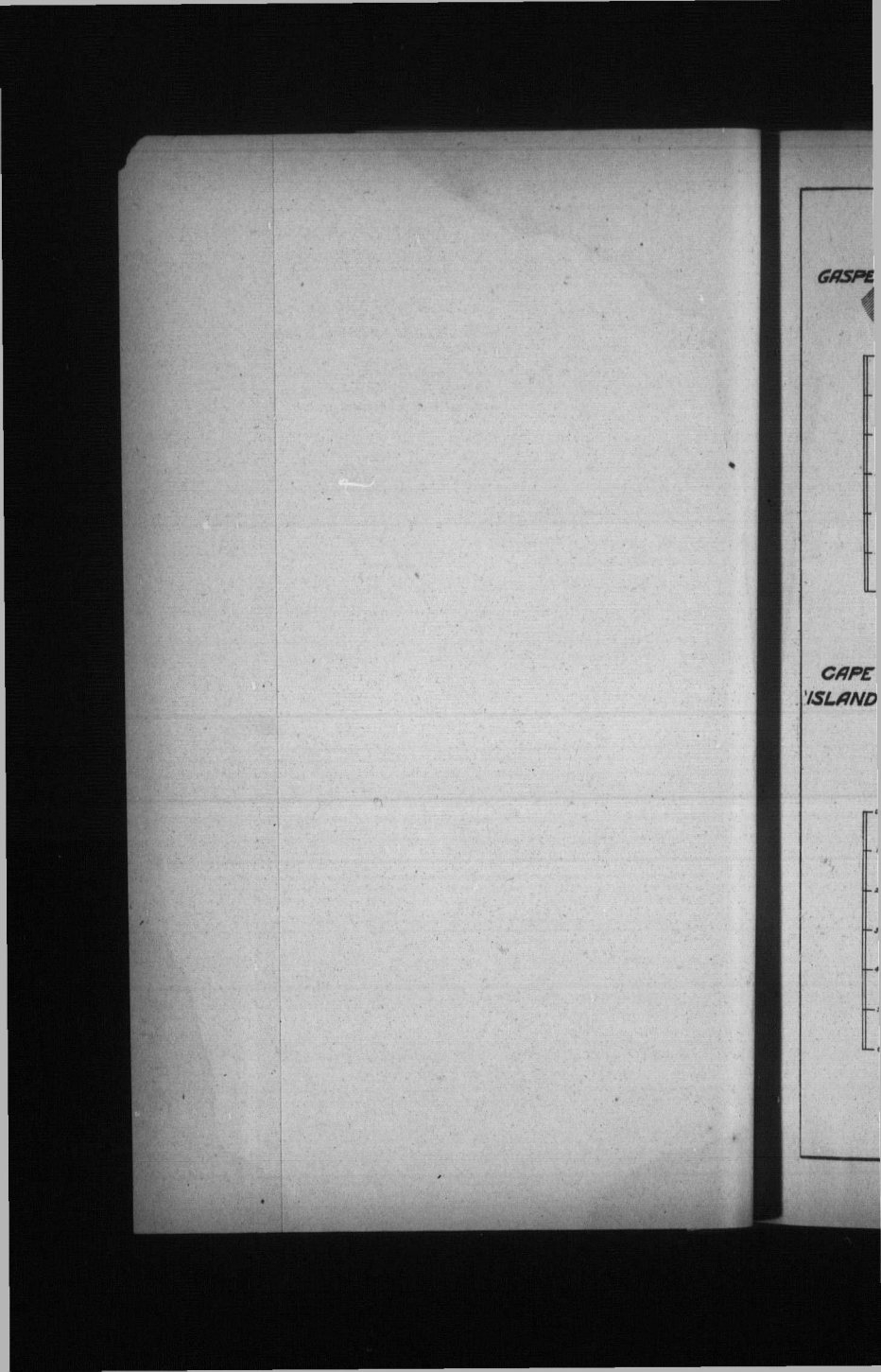
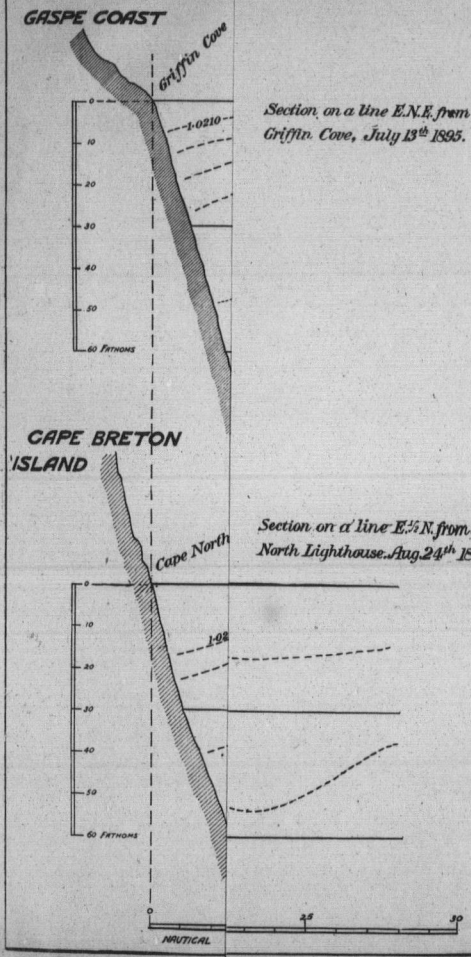

GASPE
CAPE
ISLAND

PLATE VIII.

SECTIONS FOR OFF CAPE NORTH, C.B.

CHER MODERATE.



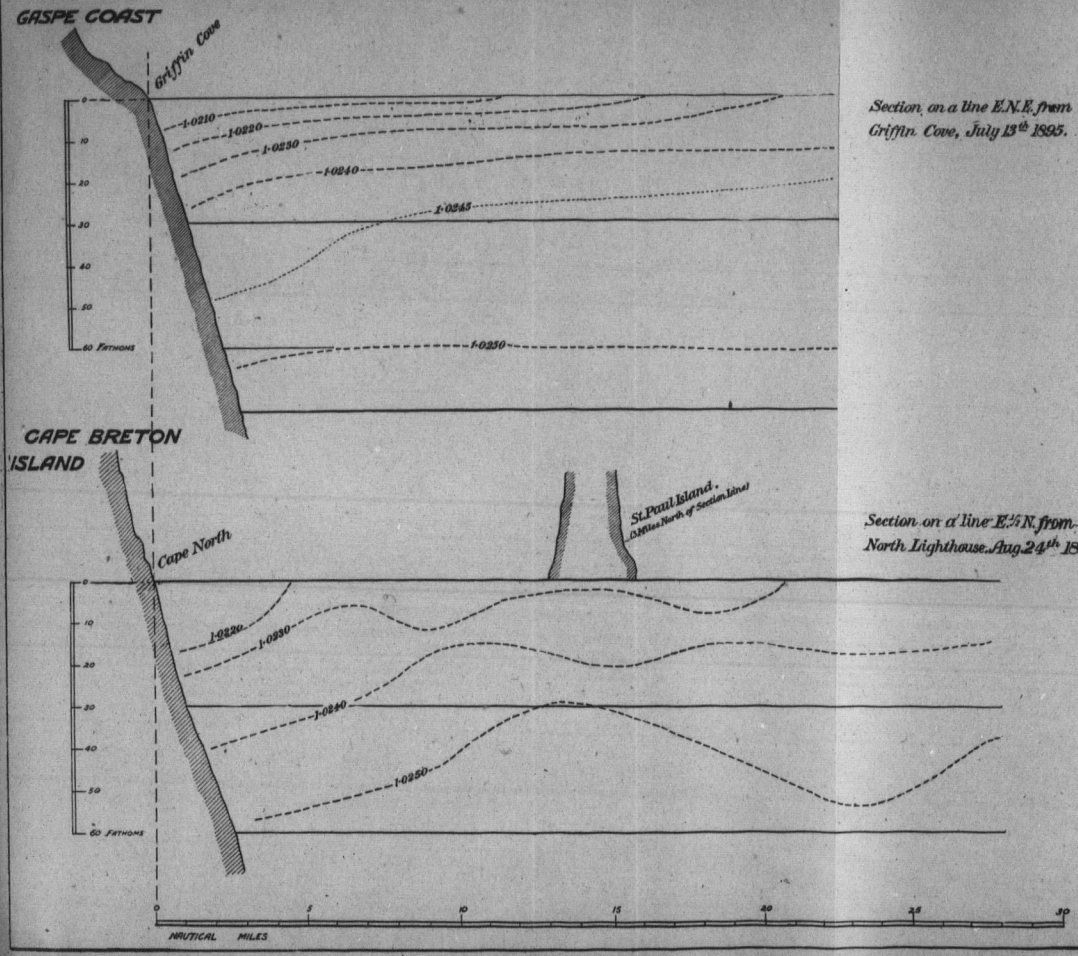
Section on a line E.N.E. from Griffin Cove, July 13th 1895.

Section on a line E.½N. from Cape North Lighthouse. Aug. 24th 1895.

PLATE VIII.

SECTIONS FOR COMPARISON OF DENSITIES OFF THE GASPÉ COAST AND OFF CAPE NORTH, C.B.

CURRENTS FROM THE USUAL NORTH WESTERLY DIRECTION, AND WEATHER MODERATE.



Section on a line E.N.E. from Griffin Cove, July 13th 1895.

Section on a line E.½N. from Cape North Lighthouse. Aug. 24th 1895.