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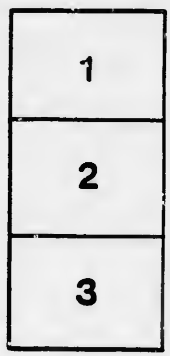

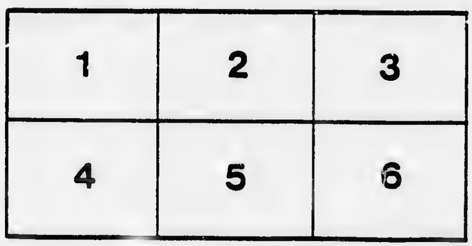

SURVEY

OF

TIDES AND CURRENTS

IN

CANADIAN WATERS

REPORT OF PROGRESS

BY

W. BELL DAWSON, C.E.

Engineer in charge of Tidal Survey.

OTTAWA

GOVERNMENT PRINTING BUREAU

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REPORT OF PROGRESS

SURVEY OF TIDES AND CURRENTS IN CANADIAN WATERS

OTTAWA, 15th December, 1894.

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

SIR,—I have the honour to submit the following report on the progress of the Survey of Tides and Currents in Canadian waters.

As the work done falls naturally into two divisions, it may be well to mention first the improvement and extension of the system of tidal stations; and then to describe the survey of the currents as commenced this season, with the results already obtained.

TIDAL OBSERVATIONS.

The range of the tides is so varied on our coasts, that the tide gauges or instruments used to record the tides, were originally designed with a special scale to suit each locality. On examining the records made by these instruments, it appeared that an important improvement could be made at some of the stations by giving them a larger scale with greater range. A uniform scale could also be adopted for the stations in the Gulf of St. Lawrence. Accordingly three new recording instruments were ordered to replace some of the present ones, and their scale was altered to make them serve for the new stations to be established this season. These instruments are of Lord Kelvin's design, of which Mr. James White of Glasgow is the maker.

At two of the stations, situated on islands, it had been necessary to make a telegraphic exchange of time once a week, to regulate the driving clock of the recording instrument. To avoid this expense, meridian instruments (named dipleidoscopes) are now employed, which when once set correctly in the meridian, give the exact time of the sun's meridian passage. One of these of a rather primitive type was already in use at Anticosti; and after considerable inquiry, three others of modern construction were obtained from a Paris maker. Two of these were defective when received; but out of the three, two efficient ones were made, which were placed at St. Paul Island and at the new station in the Strait of Belle Isle. The third one, intended for Anticosti, after being repaired, was received too late to place this season.

The tide-gauge at St. John, N. B., had given some trouble from the beginning, although not such as to interfere with the record of the tide. This gauge has a timber column three feet square, forming an open well in which the vertical tide pipes are placed. By this arrangement the pipes are surrounded by an open space which can be heated to prevent them from freezing up in winter. The column requires to be longer than the whole range from lowest to highest tide, which at St. John is over 28 feet.

The pressure of this head of water occasioned leakage, and the column required to be pumped out frequently. It was accordingly taken up in March last, and strengthened with an outside layer of 3 inch planking and extra ribbing inside. A double layer of shipping felt was placed under the new planking; and it was also thoroughly tarred and caulked, to make it watertight. A large outside ballast box had to be added at the foot of the column to keep it from floating up.

The opportunity was also taken to put in the new form of inlet pipe, specially designed to enable it to be cleaned out easily at any time. This is being put in at all the gauges as opportunity offers.

At St. Paul Island a severe gale occurred on January 13th which damaged the tide gauge. This gale was the worst on record since 1875; a lobster factory on the island twenty-five feet above high water, was completely washed away. After persevering efforts during the remainder of January, the gauge could not be put in working order. It was impossible to reach this station till the opening of navigation at the beginning of May. One of the new recording instruments was taken there at the earliest opportunity (May 12th) but it was found on setting it up that its driving clock was defective, and would not work. As the communication with the island is fortnightly, this occasioned the most unfortunate delay. The clock had to be returned to Halifax for repairs; and after much trouble which interfered also with arrangements for other work, it was not until the middle of August that the station was ultimately put in working order.

The other two recording instruments were immediately inspected; and their defects corrected after several weeks of careful examination. It was fortunate that this was done in time; as one of the instruments was intended for Belle Isle, and any defect would probably have caused the loss of a year's observations at so isolated a station.

NEW TIDE GAUGES ESTABLISHED.

It was intended to complete during this season the system of principal tide-gauges; but as the survey of the currents was also commenced this year, and the funds for both purposes were limited to the amount granted in former years for tidal observations only, it was necessary to curtail the total amount of work. It was only possible therefore to establish two additional stations for the Gulf of St. Lawrence; and the establishment of stations on the Atlantic coast had to be postponed.

The stations most required for the gulf, were in the Strait of Belle Isle and at Father Point. The tide-gauge at Belle Isle is for tidal purposes a companion to the one on St. Paul Island; as these command the two entrances by which the tides of the Gulf and River St. Lawrence enter from the Atlantic. It was also essential to have a tide-gauge in the Strait of Belle Isle this season, to furnish tidal data for the survey of the currents. The deep channel of 100 fathoms which runs into the mouth of the Lower St. Lawrence, ends in the vicinity of Father Point; and from there to Quebec the river is relatively shallow, and the tides are more liable to be affected by the winds. The range of the tide which in the Gulf is less than five feet, increases at Father Point to seventeen feet. It can thus be well observed, as all the fluctuations are so much amplified. This is also a meteorological observatory, as well as the pilot station. It is thus a most important and suitable point for a tidal station.

In the Strait of Belle Isle the tide-gauge was erected on the west side of Forteau Bay. The shelter there is fairly good, as the bay is well within the strait; and it has also the advantage of being at the narrowest part. The chief difficulty is to avoid its destruction by ice in winter. The thickness of the ice along the shores of the strait is only limited by the depth of water in which it will float. Hence if a wharf were to run out into six feet of water, it would be struck by blocks of six feet in thickness, and so on in proportion; and these blocks have often an impetus from a heavy sea to help them in their work of destruction. The fishermen's wharfs do not therefore extend into a greater depth than about three feet at low water; and the tide-gauge was placed on a timber crib filled with stone, set at the end of one of these wharfs.

The inconvenience of the shallow water is that the wave motion is so great, that it records itself on the tide diagram, and thus gives considerable trouble in obtaining the true tide curve. This difficulty was not anticipated; as according to the best information that could be obtained, a deep water wharf was to be found there. As the materials for the erection of the gauge had to be brought from Nova Scotia, it was not possible to meet this difficulty at the time. The best method of doing so will be to connect a pipe with the inlet by which the water is admitted to the guage, and lay it out along the bottom into deep water where the wave motion ceases to be felt.

At Father Point the shore between high and low water consists entirely of hard shale rock, running in ridges or reefs parallel with the shore. At the outer side, the reef falls off abruptly to low water mark, and from it a hard clay bottom slopes gradually off into deeper water. There is no shelter, as there is a clear reach of 25 miles in all directions from W.N.W. round by N. to E.; and in north-easterly directions, from which the worst gales come, the reach is from 45 to 60 miles. In winter there is also heavy ice which drifts up and down with the tide, and forms an ice-shore against the reef to a depth of 20 feet.

In these circumstances the best method to adopt was to sink a well at high water mark to the level of the lowest tides, and to excavate a trench across the reef to admit the tide to the well. The best site for the trench had been selected by the late Mr Carpmael; and he had also sunk the well to part of the depth required. The position chosen is immediately to the east of the lighthouse. The length of the trench from the well to low water is 270 feet.

The trench was excavated this season to the level throughout of low water at ordinary spring tides; and the tide was led to the well by means of piping laid along it. The excavation was done in three sections, the two inner ones being divided off by dams, and the water kept down by a steam-pump. The outer section could only be worked at the most favourable times at low water. The piping used is wooden; made of sound spruce and fir logs nearly 12 inches diameter, with a bore of 3 inches. As it is laid green, and is constantly under water it is more durable than iron, and second only to brass piping, which was considered too expensive to use. It is jointed with sail cloth saturated with white lead.

The trench is 9 to 10 feet deep for most of its [illegible] it would have been very expensive to have given it an additional depth of [illegible] ach extreme low water, chiefly on account of the amount of pumping requ[illegible]

The plan of syphoning between the levels of o[illegible] treme low water was therefore adopted. An air-tap and a special air-p[illegible] ided to allow any air which may enter the pipe to escape, and thus to keep i[illegible] tly filled with water. In the outer end of the trench, the sea surges in so heavily in rough weather that the water is much mixed with air; and to avoid any trouble from this cause, it was decided to lay an iron pipe out along the bottom for about 100 feet, extending from the end of the main pipe into water which has a depth of about 12 feet at lowest tides. The end of the main pipe is protected by a cement dam which makes the connection between the two pipes accessible; and it is always possible to renew the outer pipe if necessary.

A length of old boiler is placed vertically in the well to form an open shaft for the tide-pipes, in which heating is provided in the usual way to prevent freezing in winter. The boiler is three feet in diameter, and is lined with wood for additional warmth.

The completion of the excavation and pipe laying have been delayed by gales which have been exceptionally severe this autumn; but the tide-gauge will probably be in working order within a week or two of the present date.

At the Anticosti station the recording instrument has been replaced by one of improved scale; and an important alteration has also been made to secure better protection in rough wether. It is not infrequent in heavy gales for the waves to break entirely over the tide-house which containes the instrument.

On account of the importance of St. Paul Island as a tide station, it was thought better to make sufficient expenditure to establish it thoroughly, and to discontinue the observations at the neighbouring station on the Magdalen Islands; as it also had failed to work in January, and some expenditure would have been required there in any case. A complete outfit remains there which can be utilized for the equipment of a new station.

RECORDS, TIDE TABLES, &C.

During the year, since last December, the record of the tide has been carried forward continuously at Quebec and Anticosti, and also at St. John, N.B., with the exception of six weeks during the alterations to the gauge. The interruption at St. Paul Island reduces the record there to five months. The new gauge in the Strait of Belle Isle has been in operation since August; and it is hoped that the gauge at Father Point will shortly be in working order.

It would have been very desirable, had funds permitted to have established a tide gauge at Halifax this season to obtain the Atlantic tides for comparison. It was also ascertained that a record of the Halifax tides had been made during the years 1851 and 1852, and through the kindness of the Admiralty this record was obtained. It should be utilized to extend the basis from which the tide tables for Halifax are calculated, as they now depend on the record taken during two years only, namely, 1860 and 1861. The comparatively small outlay required for this purpose cannot be made at present, however. Since 1891 the tide tables for Halifax have been issued annually by this Department, in the form of a small booklet. Its circulation has not been large, and after correspondence with book-sellers in this country and in Britain, with a view to extending its usefulness, it was eventually decided to supply the tables for publication in two Lower Province almanacs. The tables are accompanied by tidal differences which make them available for the whole Atlantic coast of Nova Scotia.

An attempt was made from the records already obtained, to determine direct tidal differences with long established stations. The tide at Quebec is nearly simultaneous in absolute time with the tide at Dover; and the tide at St. John, N.B., with Brest, which is the best established station in France. Also the tide at Halifax, although earlier than at any of the European ports, is nearly simultaneous with Sandy Hook, at the entrance to New York harbour, which is the best station established by the United States Coast Survey. If such tidal differences could be determined or the law of their variation ascertained, it might save the labour and expense of special calculations for some of our ports. Possibly when a longer record is obtained, this may be done with a better hope of success.

At present the record at Quebec and St. John, N.B., is nearly sufficient for the calculation of preliminary tide tables for these ports. At places where the range of the tide is so great, these tables should show the rise and fall of the tide, as well as the times of high and low water. At Quebec, the rise and fall can be referred to the original low water datum of the Admiralty charts; as the reference bench-mark still exists which was cut on the building of the Department of Marine, at the time the Admiralty surveys were made. At St. John, N.B., there is no bench-mark or other level from which to ascertain with certainty the low water datum adopted in the Admiralty surveys, or in the more recent surveys of the harbour made by the Department of Public Works. It is specially important at St. John, to have a correct low water datum, not only in the interests of navigation, and for such purposes as the construction of slips for repair of vessels, but also because properties are often defined by the low water line. In the absence of any permanent mark to record the results which were before obtained, the only course to take was to commence the work again. A bench-mark was accordingly established on the footing course of the new Custom-house building; and for further security its level was also connected with the foundation course of the Post Office. To this bench-mark the rise and fall of the tide is now referred; and a satisfactory low water datum will thus in time be obtained.

SURVEY OF THE CURRENTS.

The intention of the Department in making this Survey, is to obtain information in the first place regarding the currents to be found along the main routes taken by steamships and sailing vessels through the Gulf of St. Lawrence and off the Atlantic coast. It is not proposed therefore to follow inshore currents in detail. For these purposes, there is very little in the way of existing information that is of value. The information which fishermen and others living along the shores could furnish, although valuable to smaller vessels in entering local harbours, is of little service for the main purpose in view; as the currents in the open waters in the offing are usually very different from those with which they are acquainted. The larger sailing vessels and steamships themselves are not in a position to obtain such information with sufficient definiteness; as the effect of any current is complicated with lee-way and other circumstances which cannot be eliminated without special observations which they have not the time to make. The vessels which have most opportunity to obtain information of value, are men-of-war, when they cruise regularly on certain courses, and can afford time for special observations; and steamers employed in repairing cables, while grappling, and placing anchored buoys in open waters; as they have thus a fixed point to work from, in determining the direction of the current.

Information even of a cursory character may be of value in cases where a current is constantly in the same direction, without much fluctuation; but as a rule the currents themselves are affected by the tides and winds and therefore require continuous observation at definite positions to ascertain their nature. The winds and barometer are already observed continuously by the Meteorological Service in connection with this Department; and the tidal stations now established, serve to furnish the tidal data required for the survey of the currents, as well as the record of the tides themselves.

It was considered most important at the outset to ascertain the nature of the currents at the two main entrances to the Gulf of St. Lawrence; namely, in the Strait of Belle Isle, and Cabot Strait between Cape Breton and Newfoundland. The most satisfactory plan would have been to place a surveying vessel in each of these straits; to obtain simultaneous observations over a longer period of time. This could not be arranged for want of means; and the best that could be done was to set apart the s. "Lansdowne" for three months in which it could be spared with least inconvenience from its other duties. It was accordingly decided to divide this time between the two places; taking the months of July and September for the Strait of Belle Isle, in order to obtain as different conditions as possible; and taking August for Cabot Strait, in the hope of obtaining more settled weather for so exposed a position. On the first trip to Belle Isle, materials were taken for the erection of a tide gauge in that strait.

The party consisted of myself, Mr. H. M. McKay, B. A. Sc., and Captain Douglas, R. N. R. Mr. McKay acted as assistant in the survey of the currents, with the help of Mr. R. McKeen for the night work. He also took the meteorological observations. Captain Douglas had charge of the erection of the tide guage at Belle Isle; and at other times during the season he superintended the alterations at St. Paul Island and Anticosti and the construction of the tide gauge at Father Point. Dr. W. E. Deeks accompanied us in July to obtain information for the Department on the reproduction and propagation of fish. The Captain and officers of the vessel also gave their hearty co-operation in facilitating the work.

The general itinerary was as follows:—

June 29.—Left St. John, N.B., calling at Halifax for materials for Belle Isle and at Sydney for coal.

July 6.—Arrived at Forteau Bay, in the Strait of Belle Isle.

July 7 to August 9.—Surveys in the Strait of Belle Isle and vicinity; and erection of tide gauge at Forteau Bay.

August 10 to 12.—Returned to Cabot Strait.

August 13 to 31.—Surveys in Cabot Strait; including also a call at Sydney for coal and supplies.

September 1 to 4.—Second trip to Belle Isle.

September 5 to 25.—Surveys in the Strait of Belle Isle.

September 26 to 29.—Returned from Belle Isle to Pictou; including a call at St. Paul Island, and some work in Cabot Strait.

On the longer trips as much information as possible was obtained. The patent log was first carefully checked against measured runs on the chart, to make sure of its accuracy. It was then used to ascertain the direction of the current by making runs between accurately determined starting and ending points. The actual course steered was determined from the average of readings taken every 10 or 15 minutes on the binnacle compass, which was one of Sir William Thomson's design. The leeway of the vessel was either eliminated or allowed for.

On arrival at the locality where the definite surveys were to be made, several stations were chosen on the chart as the most advantageous positions for the work, and one or other was taken up according to wind and weather and the shelter to be obtained. The days that were too rough to work at any fixed station, were utilized for temperature work; which was therefore done with little loss of time available for other purposes.

The data regarding the ss. "Lansdowne" used in the survey are as follows :—

Registered tonnage..	
Gross tonnage..	463 tons.
Length of keel..	680 "
Breadth of beam..	180 feet.
Ordinary draught..	32 "
Horse power..	13 ft. 6 in.
Maximum speed..	80
....	10 knots.
Area on longitudinal section :—	
Above water..	2,980 sq. feet.
Under water..	2,160 "

The last items are of importance in connection with the leeway made under given conditions.

METHODS AND APPLIANCES.

In a survey of this character it is desirable to avoid complication with the shore currents, which usually extend a mile or two out. The distance from land is therefore seldom less than 3 to 5 miles, and often 10 to 20 miles or more; and the best method to adopt is to anchor the vessel, and use it as a fixed point from which to determine the velocity and direction of the current. The most favourable opportunities must be taken while at anchor to determine the position of the vessel itself, either by sights to the shore or astronomically; and these determinations must be repeated as frequently as possible to make sure that no change in position is occurring from dragging of the anchor. The current itself can then be best measured by means of current meters, supplemented by the use of drift buoys and other methods as occasion offers.

The depths in which it was necessary to anchor ranged from 30 to 40 fathoms in the Strait of Belle Isle, and up to 260 fathoms in Cabot Strait. For these greater depths, wire rope hawser was used; and as the friction of the water itself is usually counted upon to give a considerable grip to such a length of rope, a comparatively small anchor will hold. On this account also, there is little give in rough weather at the inner end next the vessel; and it is necessary to provide against the sudden strains due to its motion. The anchor rope was therefore led over a large bow pulley with which the "Lansdowne" is provided; and an accumulator or compressor was introduced between this pulley and the point of attachment to the vessel, which was carried back nearly amidships. This compressor acted in the same way as an ordinary spring balance, and served to take up the motion of the vessel. It was nearly the same in design as the appliance used on the United States surveying steamer "Blake" and described and figured in the report on the "Gulf Stream Investigations" by Lieut. Pillsbury, Appendix No. 10 to report for 1890, United States Coast Survey. It consisted of a series of 60 rubber discs of 5 inches diameter; making a total length of 12 feet; the greatest compression in use reduced its length to 8 feet 8 inches.

The chief difficulty in providing suitable anchorage appliances was the want of funds; as the amount voted for the survey, was little over half of the estimated expense. The endeavour was therefore made to tide over this first season with the lightest and cheapest appliances. The wire hawser for deep anchorage was handled with the ordinary steam winch already on the vessel; and considerable trouble and anxiety also resulted from the dragging of the anchors used, much of which might have been avoided with better and heavier appliances. As the currents themselves seldom exceeded two miles an hour, it took very little to hold the vessel in calm weather. But in heavy winds it was difficult to avoid dragging, which even took place against the current, when the wind and tide were in opposite directions, and the vessel lay broadside to the wind.

These difficulties were also increased by the character of the bottom. In the Strait of Belle Isle the bottom appears to be of the smoothest rock, according to all indications; so much so that it appears plausible to suppose that it has been polished in course of time by the icebergs in the strait. In Cabot Strait the bottom is marked "mud" on the chart; and heavy fine-prong grapnels with wide palms were accordingly tried as mud anchors. But although there is undoubtedly mud in places, the bottom itself is mostly hard. All indications regarding the character of the bottom were carefully noted; and any marine forms brought up on the anchors were also preserved.

The current meters with which the velocity and direction of currents can best be determined, are now usually constructed to register electrically, which is a great advantage, especially for tidal currents which are continually varying in velocity. Such a meter can be used to obtain a continuous record, both day and night if desired, without removing it from the water. These meters are made on two different principles; one kind measures the current by means of a set of small buckets revolving horizontally, on the same principle as an anemometer; and the other consists of a fan similar to a screw propellor or wind-mill, which revolves in a vertical plane. The meter has in either case a tail which keeps its head to the current; and its position in the water thus indicates the direction of the flow. For marine purposes, the horizontal meter appeared to be the most suitable for general use; as it is less affected by the vertical motion of the waves and the rolling of the vessel. The meter on the fan principle is more apt to "head up" and "head down" as the vessel rolls, and so to give an exaggerated record. In this survey, one meter of each of these descriptions was employed.

As a vessel at anchor always lies between wind and tide, and these are seldom in the same direction, it is usually rolling. In the present instance the time in which the "Lansdowne" made a complete double roll in moderate working weather, was from six to seven seconds. In this interval the meter was raised and lowered some two to three feet through the water. When the height of the waves exceeded five to six feet, the rolling was much greater, and the meters could not be depended upon to register correctly. A simple device was eventually adopted to avoid this difficulty; the meter was suspended over the side by a rope which was carried over a large pulley on a davit arm and attached at the opposite side of the deck. A weight was attached to the horizontal part of this rope which depressed it and allowed sufficient give and take over the pulley to compensate for the rolling of the vessel. The electric wires were led independently to the meter.

As these meters have been used almost exclusively for river work, it may be allowable to mention briefly some special points in connection with the use of electric registration for marine purposes. The principle of the registration is simply that the electric circuit is made and broken with each revolution of the meter; and the revolutions are registered by a counter actuated by an electromagnet. The meter contains an "air-chamber" in which the contact can take place; but it was found very difficult to prevent the water from working its way into it. This was overcome by filling the air-chamber with oil, which is sufficiently non conducting to prevent short circuiting, and excludes the water, and should serve also to equalize the pressure at considerable depths. On account of the higher conductivity of sea-water as compared with fresh water, it appears to be essential that there should be no exposed binding posts or other contact with the water on the down circuit. The greatest difficulty was experienced at first from this cause; and it was found necessary to have the down wire completely insulated and all connections inbedded in rubber cement throughout. These alterations made the horizontal meter work successfully, but the meter with the vertical fan had so large an air-chamber and so many binding posts that none of these means were successful; and the attempt to make it work electrically had to be abandoned, and a mechanical counter was attached to it in an extemporized way which served the purpose.

For battery power it is usual to employ dry cells; but for continuous work in tidal currents these are not suitable, as the power decreases too rapidly. This was met by using more cells than were required, and reducing the current by a resistance coil which could be varied from one to ten ohms, to balance the varying tension of the battery. This, however, required constant supervision and manipulation. It is impracticable to use the gravity battery at sea, as the motion would mix the two liquids; but a form of the ordinary zinc-carbon battery was found entirely satisfactory; as the current it gives is very steady and constant.

In a survey of currents, the primary object is to determine the velocity and direction of the surface current with reference to its effect upon vessels. It is therefore necessary to take the draught of the vessel into account, as the motion of the water may not be the same at different depths. The correct depth theoretically would be half the draught of an average vessel. It was found necessary however to lower the meter clear of the keel of the steamer used in the survey; as it usually lay more or less across the current, and the direction of its side might thus influence the direction or velocity of the current. The total depth of water was seldom less than thirty fathoms; and there was little appreciable difference in the strength of the current down to five fathoms from the surface. The draught of the "Lansdowne" was 13 ft. 6 in., and it was therefore decided to adopt a uniform depth of 18 feet (or three fathoms) for the observations of the surface current. At this depth, the meter itself could almost always be seen distinctly, and the direction of the current was shown by its position in the water. This was often at right angles to the position of the steamer, especially when the current was slack about the time of turn, and the steamer was heading to the wind. The direction was also obtained by means of an open triangle of wood weighted along one edge to keep it vertical, and with gauze stretched upon it to give it a hold in the water. This was used as an attached float, and was specially useful to show the direction of the current at night when the meter could not be seen.

The meter which revolved horizontally with the electrical connection for continuous record, was used throughout for the determination of the surface current. It was furnished by Messrs. W. & L. E. Gurley, of Troy, N.Y. The meter with the vertical fan was of German manufacture; and was used for the determination of the undercurrents. The method found most satisfactory was to obtain the speed of the undercurrent as a percentage of the surface velocity, as this could be done without depending on any ratio between the two meters themselves. The meter was allowed to run for half an hour at the standard depth of 18 feet; then lowered to any desired depth for one hour; and then again for half an hour at 18 feet. The readings were taken after each of these runs; and in this way a mean value for the surface velocity was obtained, with which the speed of the undercurrent could be directly compared. The direction of the undercurrent was obtained from the inclination of the line supporting the meter; or by means of a deep fan, as described further on.

The most important advantage in the use of meters was the opportunity to work in all weathers so long as it was not too rough to hold on at anchor. Some of the best results of the season were obtained on wet days, or in dense fog.

A method much used for currents in rivers, is to place a small buoy or float in the water and follow its course by means of sights or bearings to points on shore. In this survey the shores were usually too distant to make this possible except in the clearest weather. The best adaptation of the method was to start the buoy from the steamer while it lay at anchor, and to determine its path by bearings and distances relatively to the steamer itself. In determining undercurrents, two similar floating buoys were used; and from one of them a fan was suspended which presented a large surface to the water, and could be lowered to any required depth. The two buoys were started together; and the difference in motion gave a measure of the amount and direction of the undercurrent. The buoys for this purpose were cylindrical in shape, made of galvanized iron, about the size of two lengths of ordinary stovepipe, and weighted to stand vertical in the water. The object of this form was to avoid undue vertical motion from the waves. Each buoy carried an upright staff with two horizontal discs set exactly five feet apart, which enabled the distance of the buoy to be determined at any moment and

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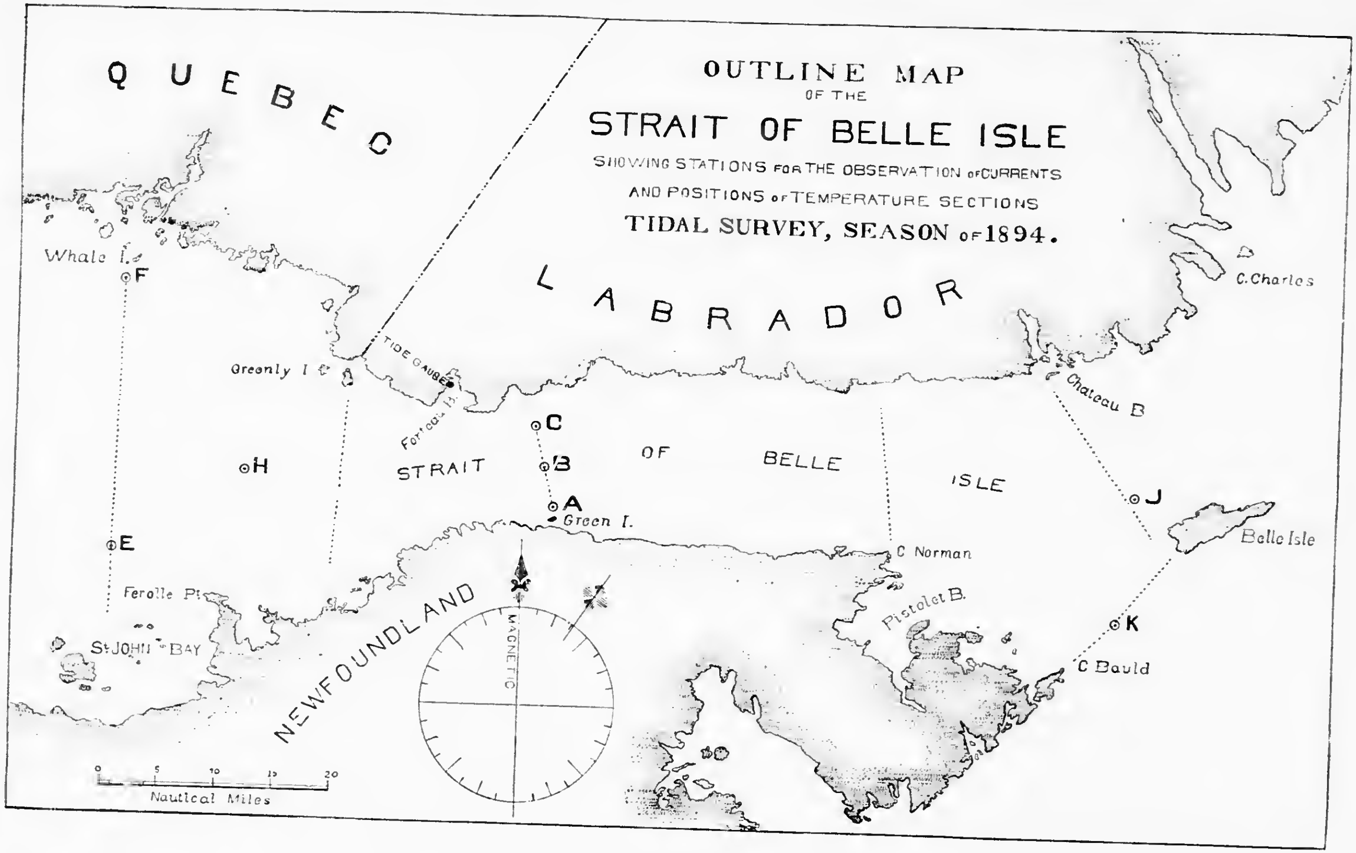
OUTLINE MAP
OF THE
STRAIT OF BELLE ISLE
SHOWING STATIONS FOR THE OBSERVATION OF CURRENTS
AND POSITIONS OF TEMPERATURE SECTIONS
TIDAL SURVEY, SEASON OF 1894.
QUEBEC
LABRADOR
STRAIT OF BELLE ISLE
NEWFOUNDLAND
C. Charles
Belle Isle
Chateau B
J
K
C Bauld
C Norman
Pistolet B.
Green I.
A
B
C
MAGNETIC
TIDE GAUGE
Forteau B.
Greenly I
H
Whale I.
F
E
Ferolle Pt
St. JOHN BAY
0 5 10 15 20
Nautical Miles

from any point of observation by means of a Rochon micrometer telescope. The deep fan consisted of two sheets of galvanized iron passing through each other at right angles, and supported by a light wood frame; the whole being just heavy enough to sink. It was suspended from its buoy by deep sea sounding wire to diminish the resistance of the intermediate water through which it passed. The depths at which it was mostly used were from 30 to 40 fathoms.

These drift buoys and the deep fan were used considerably in the Strait of Belle Isle. The practical difficulty in their use was that a boat was required to place and follow them; and it was usually too rough to use instruments in a boat, except on foggy days when good sights could not be obtained. Some good determinations were made however by this means. The deep fan was also used from the steamer, and the inclination of the line gave a good determination of the relation of surface and undercurrents, especially about the time of the turn of the tide.

During the season, the icebergs in the Strait of Belle Isle were fairly numerous; and every endeavour was made to take advantage of them as "current floats", especially to obtain simultaneous comparisons in different parts of the strait. A large proportion of this work was lost however; as a distant berg might drift further away instead of nearer, or fog might come on to obscure it. The berg might prove to be aground; or it might touch bottom from time to time, and thus be retarded and give a false indication. Also when many bergs were in sight at once, their movements changed their apparent forms, and their identity was lost unless they were very closely observed. These points are mentioned to show the discretion that is needed in estimating the value of reports as to the nature of currents, which are based on the movements of icebergs viewed from a single standpoint and without instrumental measurements.

To obtain complete information from an iceberg, some means had to be found to obtain its actual height in feet. The apparent height was then measured with a sextant or a micrometer telescope, and simultaneous bearings taken, at equal intervals of time; and in this way the path of the berg could be laid down on a plan or chart: and the direction and speed of its motion found. Without the actual height, the observations gave relative results only, with regard to the direction of the current, which were sometimes useful. Any unusual change in velocity, especially when occurring in shallower water as shown on the chart, was taken to mean that it touched bottom or was aground for a time; and these suspected parts of its journey were left out of the comparisons made. The effect of the wind on the movement of an iceberg is scarcely appreciable; as so large a proportion of its bulk is below water. This was not therefore taken into account.

The temperatures of the water were taken with registering thermometers of the Miller-Casella pattern to depths of 40 or 50 fathoms. In greater depths the reversing thermometers of Messrs. Negretti & Zambra were used for reasons that will be explained.

Densities were taken by means of hydrometers with a special range for the purpose. These were chiefly intended to detect any admixture of fresh water in regions where the water was brackish or in the neighbourhood of icebergs.

Meteorological observations were taken continuously while the survey was in progress.

STRAIT OF BELLE ISLE.

To appreciate the importance of this strait as a highway for ocean traffic, an approximate measure of its amount can be obtained from the traffic on the Lower St. Lawrence. The record kept at Father Point shows that during the present season there passed in each direction on the average 98 steamships per month, with an aggregate tonnage of 156,650 tons (registered), representing an actual carrying capacity of fully 50 per cent more than this. The traffic per month through the Strait of Belle Isle is nearly equal to this, as nearly all these steamships pass also through the strait during the months it is open; and the figures do not include any sailing vessels, which pass almost always south of Newfoundland.

The strait itself has a width of 10 to 12 miles for 35 miles of its length; and is entirely free from any rock or shoal throughout. It lies east and west (magnetic.) The north shore is bold and the water off it is deep; the south shore is low, but dips off rapidly into about 30 fathoms. Foggy weather is not infrequent, even in the summer time; and it may be of service to note some points regarding its character, based on observations during July and September. The fog never lifts, but always clings closely to the water. This appears to be due to the low temperature of the water itself. The invariable way in which it clears, is by drifting off before winds from good directions. The best clearing wind is from the north (magnetic) and the statement in the Sailing Directions that all winds with northing in them are clearing winds, may be taken to represent the probabilities in the case. As the northern side of the strait is thus the first to clear, vessels will obtain any advantage there is to be had by keeping to that side.

There is a wide-spread impression that the current in the Strait of Belle Isle runs constantly inwards; and on some physical maps, and also on the weather charts issued by the meteorological department, this is definitely represented. A branch from the Arctic current which runs southward along the outer coast of Labrador, is shown to run in at Belle Isle and to find its way out again through Cabot Strait to the Atlantic. On the other hand the fishermen along the coast seem to believe that the current is usually in the same direction as the prevailing wind at the time. The remark on the Admiralty chart is as follows:—"The movements of the water in Belle Isle Strait are made up of a general westerly set affected by tidal streams and winds. The resulting set may be in either direction." This remark gives little countenance to the theory of a constant inward flow; and it is in itself sufficiently non-committal to cover almost any conditions.

The idea of a constant inward flow appears to be based on the drift of icebergs; and as they are most usually seen drifting inwards it has been inferred that this is the constant direction of the current. The converse of this is however much nearer the truth; and it may be stated in general, that when icebergs are numerous at the outer end of the strait around Belle Isle, and are also found within the strait, this indicates that the direction of the current has been predominantly inwards from the eastward during the few days previous; while the absence of icebergs indicates a current predominantly outwards from the westward. This refers to the presence or absence in the strait of floating bergs, and not to the presence of bergs which may be aground near either shore. It is also to be noted that only a very small percentage of the bergs off the outer end of the strait ever enter it. Captain Vaughan, who resided four years on Belle Isle, states in a pamphlet on the subject that for ten icebergs which enter the strait there are fifty that pass the mouth and go southward. In doing so they follow the general drift of the Arctic current which passes Belle Isle; and the larger bergs also ground at the entrance to the strait. A section of the strait on a line north from Cape Norman shows no depth exceeding 50 fathoms. The largest berg which was seen this season at the outer end of the strait was aground in 59 fathoms of water off Chateau Bay. Its dimensions above water were as follows:—Length, 790 feet; width, 290 feet; height, 105 feet. This may therefore be taken as beyond the limiting size of bergs which can enter the strait.

It may be stated in general terms that the current in the Strait of Belle Isle was found to be fundamentally a tidal one. The best comparisons of the current with the tides showed a complete correspondence between the two, especially during the prevalence of moderate westerly winds. On some occasions there were several days during which the current ran east and west for an equal length of time in each direction and turned regularly in correspondence with the rise and fall of the tide. This may therefore be considered as the normal condition of the current. With a heavy and long continued wind the current would first run for a longer time with it and a shorter time against it; and eventually would run continuously in the same direction as the wind, with a fluctuation in velocity corresponding to the tide. This continuous current might be in either direction according to the direction of the wind.

The direct effect of the wind in raising the waves appears also to be unusually great in this strait. The best example observed is briefly as follows:—September 14, morning,

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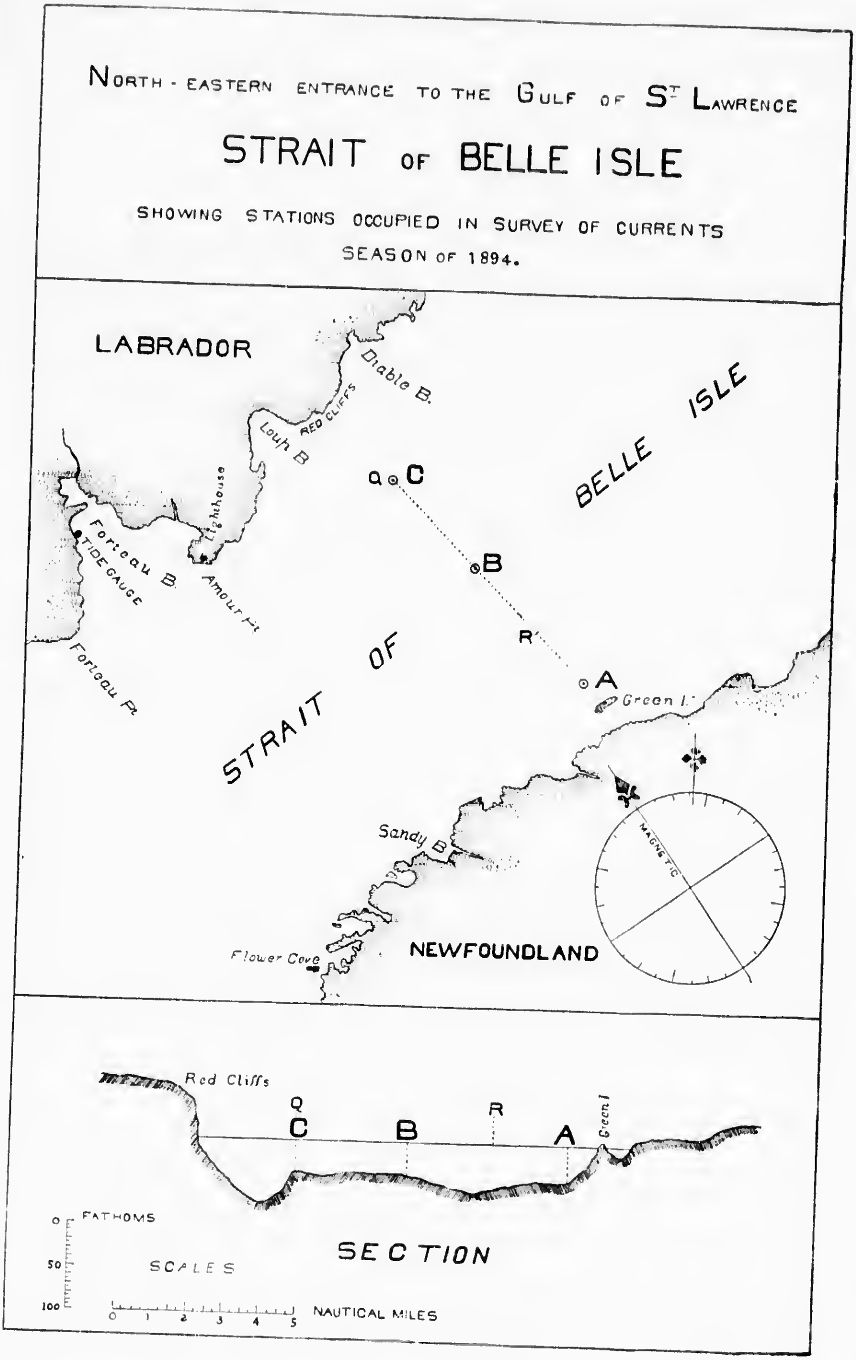
North-Eastern entrance to the Gulf of St Lawrence
STRAIT of BELLE ISLE
SHOWING STATIONS OCCUPIED IN SURVEY OF CURRENTS
SEASON OF 1894.
LABRADOR
Diable B.
RED CLIFFS
Louh B
Lighthouse
Forteau B.
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Forteau Pt
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Flower Cove
NEWFOUNDLAND
Red Cliffs
Green I
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SECTION
0 1 2 3 4 5
NAUTICAL MILES

calm, clear and smooth; barometer, 30·34 and nearly steady. During forenoon, wind sprang up from the south-west and increased by 2 p.m., to 35 miles per hour. At 4 p.m. waves were 6 to 7 feet high and 90 feet crest to crest. The total mileage of wind which produced these waves was 182 miles or an average of 30 miles an hour during six hours. Depth of water 40 fathoms. The disturbance due to waves of this height would probably not extend to more than a fourth part of this depth.

In this strait also, where the range of the tide is only about four feet, and the current seldom exceeds two knots per hour, the effect of the wind upon the current is all the more marked in proportion.

It must not be too hastily assumed however that the wind alone is the cause of the movement of the water in the same direction; as it appears probable that the tendency of the current to flow in the same direction as the wind, is due to the combined influence of the wind itself, and to difference in barometric pressure over wide areas. When the pressure is exceptionally high or low over a large area like the Gulf of St. Lawrence, the effect should be all the more noticeable, as the corresponding flow has to take place through comparatively narrow entrances or straits. It is also to be expected that the direct effect of the wind itself would be to produce primarly a surface drift; while difference of pressure would cause a more even flow throughout the whole depth. Hence to distinguish between the effect of the wind and barometer, it would be necessary to investigate fully the relation between the surface velocity and the undercurrent throughout the whole range of varying conditions.

CURRENTS IN THE STRAIT AS OBSERVED.

The current in the Strait of Belle Isle was examined in both July and September at its narrowest part near Amour Point. To avoid the tide rips which occur off this point, a section was chosen a little to the eastward, on a line from Green Island at the south side, to the red cliffs on the north shore which lie immediately east of Loup Bay. The width of the strait is there 11½ miles; and three stations were chosen on the section, station A at one mile off Green Island; station B in the centre; and station C three miles from Red Cliff. The position of these stations and the section of the strait are shown on the plan herewith. The usual depth is 30 to 40 fathoms; but the water is much deeper near the north shore. The bottom appears to be bare rock running in ridges parallel with the direction of the strait. The steamer was anchored at these stations for one or two days at a time; and was moved from one to another to ascertain any difference in the current at the two sides of the strait while the same conditions of wind and weather prevailed. The tides were observed simultaneously at Forteau Bay, within 12 miles of these stations. In July the times of high and low water only were noted; but in September after the tide gauge was erected there, a continuous record day and night was obtained for both tides and currents; although the latter was much interrupted by bad weather. In September only two stations were taken up; one (station Q) being coincident with C; and the other (station R) intermediate between A and B.

Comparisons of the current on the north and south sides of the strait were made by the best means available, to detect any difference between them. The best simultaneous observation of the currents on the two sides was obtained on 15th September, at station R, three miles off Green Island, while an iceberg was drifting up and down with the tide four miles from the north shore. At that time the current was running east and west in fair harmony with the tides; and complete data were obtained from the iceberg, as its height was measured immediately afterwards. The results were as follows:—

(Morning: current inward from the East.)

Turn of current at Station R at 11·15.

Turn as shown by iceberg at 12·15.

(Afternoon: current outward from the West.)

Turn of current at Station R at 16·45.

Turn as shown by iceberg at 16·15.

(Evening: current inward from the East.)

The current on the north side of the strait thus ran inwards from the east for a longer time than on the south side; and outwards from the west for a shorter time. Also, on the north side, the current from the east as shown by the path of the iceberg, was stronger than the current from the west, while on the south side the currents were practically equal in the two directions. Also, during a period of persistent current from the east (8th September), observations at station C, at the north side, compared with the speed of icebergs near the south shore, showed that the current was practically equal at the two sides of the strait.

From these observations, and also from a comparison of the current as measured successively at the different stations, it appears that there is on the whole a tendency on the south side to greater tidal regularity, and on the north side to greater persistency of flow in one direction or the other. This is probably due to the greater depth on the north side, and consequently the greater momentum of the water there, as compared with the frictional resistance.

With this explanation regarding the amount of difference in the current on the two sides of the strait, we may proceed to a closer comparison of the relation between the tides and currents, based upon observations during such times as the current ran in harmony with the tides, and turned in regular correspondence with them. Also, the best instances that were observed of a persistent or predominant current for several days, from the east or west respectively, and the conditions under which this took place.

The tide itself, as recorded at Forteau Bay, has a range which does not exceed four feet. The difference between the spring and neap tides is not usually noticeable; while on the other hand, when the moon's declination is great, the diurnal inequality in the tides is quite distinct. The currents in the strait show the same characteristics; there is no distinct difference in the velocity at spring and neap tides, as the currents are much more disturbed by the winds than any such difference would amount to. But the diurnal inequality in the current is well marked when this inequality occurs in the tide itself. The greatest velocity of the current in either direction under ordinary conditions does not exceed two knots per hour.

The dates during which the currents followed the tides with the greatest regularity, and the conditions of weather then prevailing, are given below. The directions of the wind are magnetic, as these correspond best with the direction of the strait itself. The magnetic variation is 35° W.

Monday, July 9 to Friday, July 13. Wind moderate; from the west or variable in direction. During the four days there were 60 hours westerly wind, averaging 9 miles per hour.

Thursday, July 26 to Saturday July 28.—During two days previous (July 24 to 26) there were 36 hours of westerly winds averaging 1[illegible] miles per hour; and 12 hours of easterly and variable winds averaging 14 miles per hour. From July 26 to 29, winds from N. W. to S. W. for 54 hours, averaging 15 miles per hour.

Monday, September 17 to Friday, September 21.—Including the two days previous, or in all from September 15 to 21, there were 72 hours of westerly winds, averaging 15 miles per hour; and 72 hours of easterly winds averaging 8 miles per hour.

The following summaries show the velocity of the current in the two directions, which in these periods is nearly equal; and also the relation between the times of high and low water at Forteau Bay, and the turn of the current in the strait, as observed at stations on the line ABC.

Velocity of the Current.

July 9 to 11 at Station A.
July 12 and 13 at Station B.
Current from east, maximum: 1·16 to 1·98 knots per hour.
Current from west, maximum: 1·30 knots per hour.

July 26 to 28 at Station B.
Current from east, maximum: 1·80 to 1·[illegible] knots per hour.
Current from west, maximum: 1·08 to [illegible] do

September 17 to 21 at Station C.
Current from east, maximum : 1·02 to 2·04 knots per hour.
Current from west, maximum : 0·92 to 1·81 do

The inequalities of the current in the last instance correspond with the diurnal inequality in the tides themselves.

Comparison of Currents with Tides.

During the periods of the greatest regularity as above. (The time is standard time for 60th meridian. In July, the time of H. W. and L. W. is from observation only. In September it is taken from the self-registering tide-gauge.)

Date.	Tide.	Direction and Turn of Current.
	H. M.	H. M.
July 9	H.W. at 14·15	Current ran from the E. for 1.45 after H.W.
do 10	L.W. at 8·30	do W. do 2.30 do L.W.
do 10	H.W. at 17·00	do E. do 0.00 (at H.W.)
do 11	L.W. at 10·05	do W. do 2.35 after L.W.
do 11	H.W. at 17·35	do E. do 1.55 do H.W.
do 12	L.W. at 11·20	do W. do 2.55 do L.W.
do 12	H.W. at 19·20	do E. do 0.40 do H.W.
do 13	L.W. at 12·15	do W. do 2.15 do L.W.
July 26	H.W. at 15·30	do E. do 2.30 do H.W.
do 27	L.W. at 10·50	do W. do 0.40 do L.W.
do 27	H.W. at 16·45	do E. do 2.30 do H.W.
do 28	H.W. at 5·15	do E. do 0.15 do H.W.
do 28	L.W. at 11·45	do W. do 1.15 do L.W.
do 28	H.W. at 17·35	do E. do 2.55 do H.W.
do 29	H.W. at 7·00	do E. do 0.00 (at H.W.)
Sept. 17	H.W. at 11·00	do E. do 1.30 after H.W.
do 17	L.W. at 16·50	do W. do 2.30 do L.W.
do 17	H.W. at 23·00	do E. do 1.30 do H.W.
do 18	L.W. at 5·45	do W. do 1.15 do L.W.
do 18	H.W. at 12·00	do E. do 2.30 do H.W.
do 19	H.W. at 12·50	do E. do 1.40 do H.W.
do 19	L.W. at 18·45	do W. do 1.30 do L.W.
do 19	H.W. at 23·55	do E. do 2.35 do H.W.
do 20	L.W. at 6·55	do W. do 1.05 do L.W.
do 20	H.W. at 13·15	do E. do 2.15 do H.W.
do 20	L.W. at 19·55	do W. do 2.05 do L.W.
do 21	H.W. at 1·15	do E. do 2.15 do H.W.
do 21	L.W. at 7·30	do W. do 1.00 do L.W.

Further Comparison of Currents with Tides during the same periods of greatest regularity. Direct comparisons with time of moon's transit; in Standard time for the 60th meridian.

Date. 1894.	Tide after Moon's Transit.		Turn of Current after Moon's Transit.	
	H. W.	L. W.	From E. to W.	From W. to E.
July 9	8.47		10.32	
do 10		14.40		17.10
do 10	10.47		10.47	
do 11		15.29		18.04
do 11	10.36		12.31	
do 12		15.58		18.53
do 12	11.35		12.15	
do 13		16.06		18.21
July 26	9.19		11.49	
do 27		16.14		16.54
do 27	9.42		12.12	
do 28	9.43		9.58	
do 28		16.13		17.28
do 28	9.34		12.29	
do 29	10.27		10.27	
Sept. 17	9.40		11.10	
do 17		15.30		18.00
do 17	9.18		10.48	
do 18		16.03		17.18
do 18	9.55		12.25	
do 19	9.56		11.36	
do 19		15.51		17.21
do 19	8.36		11.11	
do 20		15.36		16.41
do 20	9.29		11.44	
do 20		16.09		18.14
do 21	9.00		11.15	
do 21		15.15		16.15
Means	9.47	15.45	11.27	17.33
Mean interval after High Water			1.40	
do do Low Water				1.48

At other times the current was often much more persistent in one direction or the other. The most marked example of a persistent current running out of the Strait from the westward was as follows:—

Monday, July 16th to Thursday, July 19th. During these three days the current as observed at station C ran in from the east for only 5 hours and out from the west for 19 hours each day. The maximum velocity of the current from the east was 1·38 knots per hour; and from the west 2·44 knots per hour. The long run from the west was stronger at the beginning and end of the time, with an interval of weaker flow between the two. The times of high water corresponded with this minimum in the current from the west, and with the maximum current from the east. This condition of the current may therefore be considered as consisting of two components; a steady flow from the west, together with the usual tidal current in the two directions. As the moon's declination was at its maximum at the time, the diurnal inequality would largely account for the difference between the actual current from the east at the one tide, and the minimum of the current from the west at the other.

The best example of a persistent current running in through the strait from the eastward occurred from Wednesday, September 5th to Saturday, September 8th. All the indications concurred in showing that the current ran continuously in the one direction during these days; although the observations were much interrupted by bad weather. There were also about a dozen icebergs seen in the strait during this time; and their motion agreed with the regular observations, in showing that the current ran continuously inward from the east. The current as observed at station C varied from a minimum of 0·54 knots per hour to a maximum of 3·15, in the one direction. The tides themselves were anomalous; as the low water for five successive tides scarcely fell below mean sea level, and the whole rise was less than two feet, or about half the usual amount.

In stating the conditions of wind and barometer during these periods of predominant flow, it may be well to recall that a difference of barometric pressure should tend to produce flow from the higher towards the lower pressure, just as in the case of the wind.

At the time of the predominant flow from the westward, (July 16th, to 19th), the wind ranged from N. W. to S W. For three days previously, from July 13th to 16th the average for 72 hours was 16 miles per hour; and from July 16th to 18th, the, average for 60 hours was 14 miles per hour from the same direction. This was succeeded by easterly winds and broken weather. Also, from the morning of the 14th the difference of barometric pressure gave a barometric gradient which was inwards at Cabot Strait and outwards at the Strait of Belle Isle. This continued till the evening of the 17th when the pressure equalized itself; and by the morning of the 19th a low pressure area developed over the gulf which gave inward gradients at both straits and thus reversed the conditions for Belle Isle. The effects of both wind and barometer are thus in general accord with the direction of the current from the westward. It will also be noted that the total mileage of westerly wind in the case of this predominant current, is nearly double of its greatest amount during the periods when the current ran in harmony with the tides.

During the continuous flow from the east (Sept. 5 to 8) the conditions of wind and barometer were disturbed and complicated, as a storm centre was passing over the northern part of Newfoundland at the time. The low pressure area of this storm centre was over the gulf during the 5th and was nearest to the strait on the morning of the 6th, on its way eastward to the Atlantic. From the morning of the 5th till the evening of the 8th there were 60 hours of N. N. W. wind averaging 25 miles per hour, and rising at times to 45 miles. During the remainder of the time the winds were light and variable. The relation of wind and barometer to the current at this time is not clear; beyond the general fact of the occurrence of a severe disturbance at the time of this continuous current.

The features of the current in their relation to the winds and the tides might be illustrated by diagrams were there time to prepare these for this report.

Under-currents.—The under-currents in the Strait of Belle Isle were carefully observed at a depth of 25 to 30 fathoms by the methods already described, and also by obtaining the speed of icebergs, which served as "deep floats" for comparison with the surface velocity. The undercurrent would have had much greater importance if the current through the strait had proved to be a continuous one, for which an actual gauging of volume was required.

During the times that the current ran in fair correspondence with the tides, when the conditions may be considered as normal, the undercurrent was usually stronger than the surface current when the flow was from the east, and it was always weaker than the surface current when the flow was from the west. From the best ratios obtained while the current ran steadily, and omitting observations near the turn of the tide, the following percentages have been obtained:—

Current from the east. Undercurrent 5 per cent stronger than the surface current.

Current from the west. Undercurrent 70 per cent of the velocity of the surface current.

During the period of predominant current from the westward (July 16-19) the undercurrent ran with much greater regularity in the two directions than the surface current. This indicates that the surface current itself was of the nature of a "wind drift," and that the time was not sufficiently prolonged for the wind to influence the current to the bottom.

During the period of persistent flow from the eastward (Sept. 5 to 8) the under-current was decidedly stronger than the surface current, amounting on the average to nearly 20 per cent more. This result was obtained chiefly from the motion of icebergs.

TEMPERATURES.—The temperature of the water was taken to ascertain its relation to the direction of the current through the strait; as the water at the Atlantic end of the strait is colder than the water at the western end towards the Gulf of St. Lawrence. It was therefore to be expected that the current running in from the east would be the colder of the two; and the temperature of the water might thus furnish an indication to vessels of the probable direction of the current. The temperature sections as tabulated below, were taken across the strait from surface to bottom, from Belle Isle itself to nearly as far west as Rich Point. The columns represent a series of points at equal intervals across the width of the strait from north to south. The temperatures are Fahrenheit.

Temperature Sections, at outer end of Strait of Belle Isle. On a line running S.E. (magnetic) from Chateau Bay to Belle Isle, August 7th, 1894. Current at the time from N.N.E. (magnetic) velocity at Station J, 1·00 knot per hour. Icebergs numerous at the time.

CHATEAU BAY TO BELLE ISLE.

Surface	37°	—°	39°	39°	43°	41°
10 fathoms	35	38	38	38	41	35
20 do	31	33	32	33	32	32
25 do	—	—	—	31	31	—
30 do	—	31	31	—	—	30
35 do	—	—	—	30	—	—
40 do	—	30	30	—	—	—
Total depth	25 F.	55 F.	90 F.	41 F.	30 F.	40 F.

Section on a line running S.W. (magnetic) from Belle Isle to Cape Bauld, August 9th, 1894. Current at the time N.N.W. (magnetic) velocity at station K, 1·15 knots per hour. Icebergs numerous near Belle Isle.

BELLE ISLE TO CAPE BAULD.

Surface	37°	42°	40	42°	52°
10 fathoms	35	35	35	42	51
20 do	31	32	32	35	44
30 do	30	30	31	32	36
40 do	—	30	30	31	33
Total depth	41 F.	43 F.	60 F.	54 F.	50 F.

Temperature section across Strait of Belle Isle, on a line running magnetic south from Wreck Bay to Cape Norman, August 6th, 1894. Current at the time probably running in from the eastward.

WRECK BAY TO CAPE NORMAN.

Surface	37°	41°	41°	49°	53°
10 fathoms	37	41	41	42	52
20 do	32	30	31	42	44
25 do	30	—	31	—	—
30 do	—	30	—	35	—
Total depth	35 F.	38 F.	42 F.	38 F.	22 F.

Temperature section at the west end of the Strait of Belle Isle, on a line running magnetic south from Blanc Sablon Bay to Ste. Geneviève Bay, August 3rd and 4th, 1894. Current from the west.

BLANC SABLON TO STE. GENEVIEVE BAY.

Surface	52°	54°	53°	53°	54°
10 fathoms	41	49	53	53	53
20 do	39	43	47	52	53
30 do	38	39	42	49	52
40 do	38		39	46	
Total depth	48 F.	38 F.	56 F.	52 F.	38 F.

Same section as above; repeated September 13th. Current at the time probably from the eastward.

Surface	40°	41°	44°	47°	49°
10 fathoms	39	40	43	46	48
20 do	38	38	37	44	46
30 do	37	36	36	37	

Temperatures west of the Strait of Belle Isle. Section on a line running magnetic south from Whale Island (Esquimaux Islands) to St. John Bay, between stations E and F, August 1st, 1894. Surface current from the west.

WHALE ISLAND TO ST. JOHN BAY.

Surface	53°	50°	51°	52°
10 fathoms	51	49	43	51
20 do	41	41	36	38
30 do	39	38	33	34
40 do	....	....	32	33
50 do	36	32		
85 do	35	30		
Total depth	110 F.	100 F.	55 F.	40 F.

Same section as above; repeated September 25th. Current slight; direction not ascertained.

Surface	51°	45°	47°	49°
10 fathoms	50	44	45	46
20 do	41	35	38	40
30 do	37	33	34	35
40 do	33	33	33	33
50 do		32	32	

Temperatures at Station G, 19 miles N.W. of Rich Point and 24 miles west of above section. August 2nd, 1894. Surface current from the west.

Surface	52°	10 fathoms	33°
5 fathoms	51	20 do	32
7 do	44	28 do	31
8 do	40	Total depth = 33 F.	

The following temperatures at the middle of the strait at station B, may be given for comparison with these temperature sections. They give a good average, being at the centre of the strait ; and they were taken as nearly as possible at the same dates as given above. The lower temperatures in September are probably due to the continuous current from the eastward, shortly before that date, and also to the presence of icebergs.

Station B.	July 28.	Sept. 12.
Surface	53°	39°
10 fathoms	52	39
20 do	40	37
30 do	37	37

These temperature sections show that the water at the eastern end of the Strait is distinctly colder than at its western end towards the gulf. It is therefore to be expected that the current from the east should be the colder of the two. It will be seen from the following examples that the difference is appreciable although very slight. These examples are selected from the numerous observations taken in the central part of the strait (Stations A, B, C), and show the greatest differences observed during periods when the current was running regularly with the tides. The temperatures were taken at slack water after the flow from the east or the west respectively.

Station A, July 11	After current from the E.	After current from the W.
Surface	46°	48°
10 fathoms	45	45
20 do	37	41
30 do	33	36
Station B, July 25 and 26.	**After current from the E.**	**After current from the W.**
Surface	46°	51°
10 fathoms	45	51
20 do	40	45
30 do	35	37

The difference is naturally more marked during the periods of predominant flow in one direction, already mentioned. After the period of predominant flow from the west, the temperatures were higher for the average of the whole depth than at any other time:—

Station A July 21	Surface	50°	20 fathoms	44°
	10 Fath	47	30 do	41

The lowest temperature was found on September 8th, after three days of continuous flow from the east. The surface temperature at Station C was then 37°.

These observations show that there is little appreciable difference in the temperature of the currents in the two directions so long as the current maintains its tidal character. The difference between the temperatures to the west of the Strait, at the dates given in August and September deserves, however, a few words of explanation, as it appears probable in the circumstances that the difference is as great as would ever occur in the summer season.

From July 24 to 31 there were in all 124 hours of westerly wind averaging 20 miles per hour, and only 48 hours of easterly wind averaging 19 miles per hour; or in all 2,530 miles westerly wind, and 890 miles easterly wind. The westerly winds also continued during August 1 and 2. The stations E, F, and G, were occupied between July 31 and Aug. 3 immediately after these prolonged westerly winds; and the current was found to be from the west at all three stations, with a velocity of somewhat over one knot per hour at E and F, and three-quarters of a knot at G, as observed in the early part of the afternoon on three successive days. It was also found that the thickness of the layer of water which was in motion from the west corresponded closely with the surface layer of higher temperature, which ranged from 5 to 10 fathoms in thickness at these stations.

These conditions explain the higher temperature of the water at the time; and it is also probable after so much westerly wind, that the current at E and F had as high a velocity as it is ever likely to attain from a westerly direction. The clear width here between the mouth of St. John Bay and Esquimaux Islands is 32 miles.

The low temperatures of Sept. 13 on the section at Blanc Sablon must be attributed to the current which ran predominantly from the east for some time previous to that date. We thus have an example of the cold water occupying the whole Strait to its western end.

It is thus clear that during periods of predominant flow in one direction, the difference in temperature is well marked; and it might perhaps be possible to ascertain from extended observations the amount of the difference to be expected under such conditions, above or below the normal temperature for the season. But at best, the temperature could only be taken to indicate the predominant direction of the current during the few days previous, and could not be relied upon to show its actual direction at the time.

The temperature of the water has a more important relation to the presence of ice in the Strait. When the predominant direction of the current is inward from the east for a few successive tides, it will undoubtedly carry icebergs into the strait if there are any at its outer end at the time. The current from the east is thus not only cold in itself, but also brings in ice with it which further chills the water in the strait. The cold water, the current from the east, and the presence of icebergs within the strait are thus concomitants of each other.

It is not to be inferred however that warm water in the Strait is an indication that ice will not be met with; because the water in the Strait itself may be relatively warm, notwithstanding that icebergs are numerous at its mouth around Belle Isle, and possibly as far in as the vicinity of Cape Norman. It is possible for this ice to be moving southward with the general Arctic current on both sides of Belle Isle, past the mouth of the strait, without affecting either the direction of the current or the temperature of the strait to any great distance inwards.

The following statement with regard to the current in the Strait of Belle Isle at other seasons of the year, is based on information furnished by Mr. T. M. Wyatt, who has been light-keeper at Amour Point for 15 years; and by Mr. Charles Davis, a resident of Fortean Bay. In the spring of the year, the prevailing winds are easterly, and the current also runs in continuously from the eastward, and only slacks with the tide without turning. The duration of this easterly current varies from year to year, but usually continues for one or two months in the interval between the beginning of April and the end of June. A strong west or north-west wind however, will make the current run from the westward. In summer, the currents are less strong and not so persistent, and are more under the influence of the tides. In the autumn, the winds are often easterly in the latter part of September and October; but perhaps more often westerly; and in either case, the current is influenced by their direction. Later in the autumn, north-west winds occur with colder weather. These winds continue to be prevalent during the winter months, and give the current a set from the westward.

This statement must be qualified by the usual uncertainties attributable to the weather; and it is also to be noted that the currents are more persistent on the north shore where these observations were made. The residents on the south shore would convey the impression that the currents were much more regular in their tidal character but their statements appear to be based upon the currents in the shallow water inshore, which may be different from those in the open strait.

Mr. Davis has records and notes kept at Forteau Bay, and extending back to the time of his grandfather in 1835; which he hopes to be able to prepare for publication.

Summary.

In the following summary, the general characteristics of the current in the Strait of Belle Isle are given as correctly as they can be deduced from its behaviour during the time the observations were made. The velocities given were measured at the standard depth of 18 feet.

1. The current is fundamentally tidal in its nature; and under normal conditions, it runs east and west with velocities which are nearly equal. It attains at times a velocity of two knots per hour in each direction.

2. The conditions are normal in moderate weather, and during the prevalence of moderate westerly winds.

3. During heavy winds, especially when easterly or westerly in direction, 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.

4. The greatest velocities of the current which were observed during heavy winds (in the months of July and September) were as follows: from the east 3·15 knots; and from the west 2·50 knots per hour.

5. The presence of ice in the strait, and the temperature of the water, have also a relation to the predominant direction of the current; but they do not afford a reliable indication of its actual direction at the time.

6. Under normal conditions, and when both surface current and under-current in the two directions are taken into account, the difference on the average is in favour of a greater inward flow from the east.

7. The actual flow throughout the year, when the influence of the wind is included, appears also on the whole to be greater in the inward direction from the east, than outward from the west.

Current in the narrow part of the gulf immediately west of the Strait of Belle Isle. Note from observations taken at stations E, F, and G.

On one occasion after prolonged and heavy westerly winds, the surface current here ran from the westward (magnetic) at the centre and on both sides. The velocity amounted to 0·79 knots per hour at the centre, and 1·19 to 1·37 knots at the sides. This in the circumstances is likely to be as great a velocity from the westward as ever occurs.

Current on the West Coast of Newfoundland.

In going and returning to Belle Isle some measurements of this current were obtained by comparing the distance run as shown by the patent log, and the actual distance measured on the chart, according to the method already described.

The two best determinations were as follows:—

Aug. 11. Rich Point to Bonne Bay. Current 0·37 knot per hour from W. S. W. (mag).

Sept. 25 and 26, Rich Point to Cape St. George. Current 0·67 knot per hour from W. S. W. (mag.)

On Sept. 4, however, the current between Bonne Bay and Rich Point appeared to have a slight set in the contrary direction: but the weather was then rough and the observation complicated with lee-way.

Lieut. Betty, navigating lieutenant of H. M. S. "Pelican" who has spent more than one season in cruising here, states that there is an almost constant current from the S.W. along the coast of Newfoundland between Cape Gregory and Rich Point; which is only intercepted by the ebb and flood tides running in and out of the larger bays on the coast.

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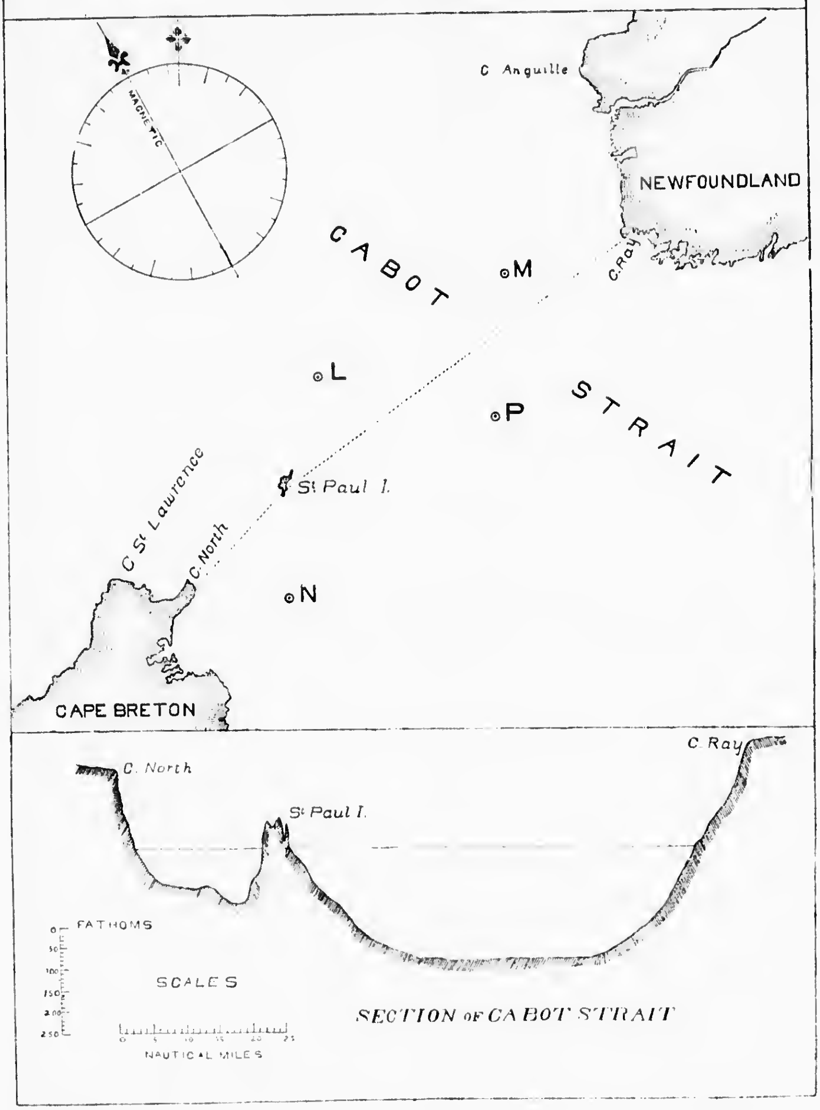
South-eastern entrance to the Gulf of St Lawrence

CABOT STRAIT

SHOWING STATIONS OCCUPIED IN SURVEY OF CURRENTS

SEASON OF 1894.



SECTION OF CABOT STRAIT

CABOT STRAIT,

or the south-eastern entrance to the Gulf of St. Lawrence between Cape Breton and Newfoundland.

This entrance to the gulf forms a portion of the deep channel or gully which runs in from the Atlantic between the St. Pierre Bank on the Newfoundland side and Banquereau and Misaine Bank on the Nova Scotia side, and thence traverses the entire width of the gulf, passes between Gaspé and Anticosti and into the mouth of the Lower St. Lawrence. This channel from the Atlantic inwards, has a width of 40 miles between the Banks on each side, and a continuous depth of over 200 fathoms. In passing through Cabot Strait, it is not contracted in width or diminished in depth except by the occurrence of St. Paul Island which lies near the western side of the deep water. This island rises abruptly from the bottom, and if left dry would probably present the appearance of one of the "Sugar-loaf" mountains of the adjacent coast. Allowing for the encroachment of this island on the western side of the channel, there is still left between it and Cape Ray a width of 32 miles in which the depth exceeds 200 fathoms; and for the greater part of this width it averages 250 fathoms.

The width of the strait lies east and west (magnetic) and the channel above described runs through it from south to north (magnetic), which makes the magnetic directions the most convenient for reference. The magnetic variation is 28° W. The currents were examined in August, between the 13th and the 31st with the interruption of the trip to North Sydney for supplies; and although the time was so short, much work was done by taking advantage of the calm weather for current measurement, and the rough days for temperature work. The record of the current was also taken continuously day and night. The stations at which the steamer was anchored, were kept to the north and south of the straight line joining Cape North and Cape Ray, to avoid the telephone and telegraph cables which lie along that line. The positions of the stations are shown on the accompanying map. The two principal stations were chosen near to the two sides of the deep channel; one of them (Station L) in 220 fathoms at 10 miles N. E. of St. Paul Island, and the other (Station M) in 230 fathoms at 13 miles W. of Cape Ray. They are thus symmetrical in position with respect to the deep channel itself; and each station was occupied twice to check any variation in the conditions.

The current, speaking generally, was found to run out of the gulf from the northward (magnetic) at Station L on the West side, and into the gulf from the south-east (magnetic) at Station M on the east side. On this account a third station P was selected where still water might be expected between these two currents; and a favourable opportunity found to ascertain whether the deep water at the bottom of the strait was in motion. The steamer was anchored at this station at the centre of the strait in 250 fathoms. The surface current was there found to be very variable in direction and at times very weak. On August 29, at a time when the surface current was almost inappreciable, the deep fan, weighted with an ordinary deep-sea lead, was lowered to a depth of 200 fathoms. This fan presented a surface of four square feet to the water, which was sufficient to indicate the slightest current, by the inclination of the line to which it was attached. This line showed an inclination of about 15° from the vertical as far down as 30 fathoms; between 30 and 50 fathoms it came within 5° of the vertical; and from 50 to 200 fathoms it remained perfectly plumb. The same indications were given again in raising it. Also on the following day, at a time when the surface current had a velocity of a little less than one knot an hour, the deep fan showed in a similar way that there was no motion below 20 fathoms. The layer of water in motion had thus a thickness of only about 20 to 40 fathoms from the surface, and below this the water was perfectly still. The relation of this thickness to the temperature at different depths will be referred to further on. This also shows that there is no constant bottom current of any appreciable velocity.

Station L, on the west side was occupied from August 13th to 15th. There was some trouble from dragging of the anchor at first; but a continuous record of the current for 32 hours was obtained. The velocity of the surface current measured at the standard depth of 18 feet, varied from 0·74 to 1·56 knots per hour, and the direction veered gradually from N. W. to N. E. and back again to N. W. The regularity of this change in direction makes it probable that it is tidal in its nature; but the observations were not continued long enough to establish any difinite relation between the two. On August 31st the station was again occupied for a few hours, and the direction and velocity were found in correspondence with the previous observations. The average direction is thus as nearly as possible from the north (magnetic) with an average velocity of very little more than one knot per hour.

While the current ran from the N. E. the undercurrent was stronger than the surface current as far down as 50 fathoms. Two measurements at 30 and 40 fathoms (made August 14th and 31st) showed the velocity at that depth to be 38 to 40 per cent stronger than at the surface.

On the other hand, while the current ran from directions west of north, two measurements of the undercurrent at 40 fathoms (made August 15th) showed the velocity to be only 50 per cent of the surface current, and its direction to be 20° more westerly.

The total thickness of the current at this station was not ascertained. This thickness might have been ascertained here and at the other stations much more definitely, if the meter which was intended for the purpose, had not failed to work electrically.

Station M, on the east side of the strait was occupied on August 22nd and again from August 27th to 29th when a continuous record of the current for 41 hours was obtained. The velocity of the surface current varied from 0·50 to 1·40 knots per hour; and the direction veered from E. to S. (mag.) the dominant direction being from the S. E. The change in direction was much less regular than at station L, and no relation can be seen between the variations in direction and velocity and the tides as recorded by the gauge on St. Paul Island.

On August 27th, at a time when the surface current had an average velocity and its usual direction from the S. E., the indication of the deep fan showed that the undercurrent extended to a depth of 50 fathoms and possibly to 100 fathoms; and that it ran from S. by E., or from a direction about 30° more southerly than the surface current. The velocity of the undercurrent at 30 and 40 fathoms ranged from 44 per cent of the surface velocity, to an equality with it; but was never greater.

On the western side of the strait, between Cape North and St. Paul Island, one station was selected at N, in 60 fathoms on the edge of the shallow water extending from Cape North. This station was occupied from August 23rd to 25th; and the current was found to run from the N. W. During the period of 48 hours immediately previous to the occupation of this station on the 23rd, the wind had ranged from N. to N. W., with an average velocity of 24 miles per hour, making a total of 1,122 miles of wind in that time. It is therefore probable that the velocity of the current as then found, was as great as it ever is. A continuous record of the current for 46 hours was obtained; and the velocity ranged from 1·39 to 2·25 knots per hour, the average being nearly 1·80 knots. In direction, the extreme variation was from N. to N.W. (mag.) the dominant direction being nearly from the N.W. There is no relation discernable between the variation in direction and the tide; but the greater velocity of the current seems to occur during the fall of the tide.

The undercurrent at 40 fathoms has only about one-third the strength of the surface current; but it appears probable that the water was in motion throughout the whole depth of 60 fathoms.

Temperatures.—The water was found to be a little warmer between Cape North and St. Paul Island than across the main opening of the Strait between that island and Cape Ray. The surface temperature there ranged from 55° to 60°; and from the surface, the temperature fell gradually with the depth till it reached 32° at about 50 fathoms. At greater depths, from 100 to 200 fathoms, the temperature was again higher and averaged about 40°. This result appeared so anomalous that the matter was carefully investigated, and every precaution taken to insure accuracy.

The temperatures, so long as they fell regularly with the depth, were taken with registering thermometers of the Miller-Casella pattern. But where there are layers of unequal temperature, such a thermometer will only register the temperature of the coldest layer, irrespective of its depth. For this reason, the temperatures below 50 fathoms were taken with Negretti and 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 very 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. It is thus necessary to use time in good weather, specially for this purpose. In the present instance, 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. In the temperature sections, the columns represent points at equal intervals apart, across the width of the strait. The temperatures are Fahrenheit.

CAPE NORTH TO ST. PAUL ISLAND.

Temperature Section, August 17th, 1894.

Surface	65	65°	58	58°
10 Fathoms	64	60	40	43
20 do	41	41	36	36
30 do	35	35	35	35
40 do	33	33	32	34
Total depth	83 F.	90 F.	120 F.	140 F.

Same section as above, repeated September 27th. Current from N. W., (the usual direction).

Surface	51	52°	52	50°
5 Fathoms	49	47	47	45
10 do	49	47	42	41
15 do	49	45	38	35
20 do	49	45	36	35
30 do	38	38	35	35
40 do	34	35	34	34

ST. PAUL ISLAND TO CAPE RAY.

Temperature section, August 16th, 1894.

Surface	59	60°	60°	59°	59	55°
10 Fathoms	42	40	44	44	41	46
20 do	34	38	37	38	36	37
30 do	32	36	35	34	33	35
40 do	31	33	33	33	33	34
50 do	31	—	33	—	—	—
100 do	$37\frac{1}{5}$	—	$38\frac{1}{5}$	40	—	—
150 do	$40\frac{1}{5}$	—	$40\frac{1}{2}$	—	—	—
200 do	$39\frac{1}{5}$	—	—	—	—	—

On account of the rapid fall of temperature from the surface to 30 fathoms, the following additional temperatures were taken, at the points mentioned.

	Off Cape North Aug. 17.	Station L. Aug. 13.	At centre of Strait Aug. 16.	Station P. Aug. 2[illegible].
	°	°	°	
Surface	65	59	60	63
5 Fathoms	64	56	54	57
8 do	—	43	—	—
10 do	64	40	44	39
12 do	—	37	—	—
15 do	60	34	36	36
20 do	41	34	37	34
30 do	35	33	35	32
40 do	33	32	33	32

Deep Temperatures from 50 to 200 fathoms, between St. Paul Island and Cape Ray. Taken with deep-sea reversing thermometers, left down for 5 to 15 minutes.

I. Temperatures on August 16th as already given.

II. At Station M, August 22nd; surface current running 1·25 knots from the S.E.

III. At Station M, August 28th; surface current running one knot from the S.S.E.

IV. At Station P, at centre of Strait, August 30th. Surface current less than one knot per hour; thermometers left down for 10 to 12 minutes.

V. On a line running North (mag.) along the centre of the Strait. Temperatures at three points seven miles apart, September 27th.

Depth.	50 Fathoms.	100 Fathoms.	150 Fathoms.	200 Fathoms.
	°	°	°	°
I	—	40	40½	—
	—	38½	40½	39½
	—	37½	40½	—
II	—	39	—	40
III	32½	40	40½	39½
IV	35	41	40	39½
V	32½	37	38	40
	32½	—	40½	39½
	32½	39	40½	39½
Mean	33·0	39·0	40·1	39·6

For comparison with this strait where warmer water occurs near the bottom, the temperatures were taken in the deep water in Bonne Bay. This bay is cut off from the sea by a line of comparatively shallow water not exceeding 30 fathoms; and the East Arm is again separated from the rest of the bay by a bar on which there is only 7 fathoms, while the depth in the Arm itself exceeds 100 fathoms. This deep water in so isolated a situation would naturally take the order of density according to depth. The temperatures down to 100 fathoms were as follows:—

	°		°
Surface	54	40 Faths.	32
10 Faths.	48	50 do	32
20 do	39	80 do	31
30 do	34	100 do	30½

The decrease is thus regular, and in conformity with the density of sea-water which unlike fresh water, increases continuously in density as the temperature falls.

Summary for Cabot Strait.

We thus find in Cabot Strait a current running out of the gulf on the western side, and into the gulf on the eastern side; while in the middle the current is weak and uncertain in direction. The temperature of the water is practically the same in both cases, except within eight miles of Cape North, where it is appreciably warmer. The depth of water in motion appears to be greater on the western side, while on the eastern side the width of the flow is greater and the under-current weaker in proportion. From a comparison of the under-current with the temperatures at various depths, it is to be inferred that the movement of the water does not extend to a greater depth than perhaps 60 or 80 fathoms at the most; and below that depth the water appears to be perfectly quiescent. The volume of water leaving the gulf on one side is thus balanced by the volume entering on the other; and as the temperatures are nearly the same, the loss or gain of heat to the gulf is much less marked than it would be if the balance of volume lay between a surface and a bottom current. The actual balance however, is on the side of loss of heat; as it is the outflowing water near the western side which has the highest temperature.

As to causes, it is not possible to speak very definitively from observations so limited in time and extent. It is more than likely that the layer of very cold water between 20 and 50 fathoms is the result of the chilling of the water during the winter; and that the warmer water at the surface is due to rise in temperature with the progress of the season. But the reason that the coldest water does not sink to the bottom is by by no means clear. If fresh water were in question, the temperature of 39° or 40° would then correspond with maximum density; but the density of sea water increases uniformly as the temperature falls. The increase however is exceedingly slight for the range from 41° to 32° which we have here to deal with; and this allows a possible explanation to be suggested. It would require the admixture of less than 1½ per cent of fresh water with sea water at 32° to give it the same density as unmixed sea water at 41°. The cold water might thus be prevented from sinking if it were chilled by fresh water ice from the river, which is not unlikely in the circumstances. The bottom water may enter direct from the unmixed water of the Atlantic; as a depth of over 200 fathoms extends uninterruptedly from this strait to the ocean.

It is clear in any case that there is no cold under-current running out along the bottom of the strait, as might be expected in accordance with the theory of continuous inflow of cold water at the Strait of Belle Isle.

The water in the greater part of this strait is as clear as average sea water, the colour having a slighty milky tinge. From St. Paul Island westward, however, a brownish tinge appears, which becomes more pronounced towards Cape North, where the water is nearly as brown as in the Ottawa river. The colour at station N. was sufficient to stain the gauze netting of the attached float used to show the direction of the current. This suggested the possibility that the presence of St. Lawrence water might here be detected; but the difference in density was too slight to be indicated by the hydrometers used. A number of bottled samples have been taken from the surface and from the cold layer at 40 fathoms, in order to determine the density with greater accuracy.

The determinations of the density were made at the laboratory of the Inland Revenue Department, with the following results, reduced to 60° Fahrenheit:—

Cape Ray to St. Paul Island.

Average of surface water, from a mixture of a number of samples (27 Aug., '94)	1·0242
At Station P. at centre of Strait, surface water (30 Aug., '94)	1·0241
do do at 40 fathoms (30 Aug., '94)	1·0253

St. Paul Island to Cape North.

Average of surface water (17 Aug., '94) .... 1·0227
At Station N, 8 miles off Cape North :—Surface water, (23 Aug., '94) .... 1·0218
Surface water (25 Aug., '94) ..... 1·0221
At 40 fathoms (25 Aug., '94) ..... 1·0249

The lesser density of the surface water between St. Paul Island and Cape North is evident; while at 40 fathoms its density is nearly equal to the average in the wider part of the Strait, where the density of 1·0242 is the average for both the outgoing and incoming water. In comparison with this, the mean density of 1·0220 at Station N., between Cape North and St. Paul Island, would indicate an admixture of 9 per cent. of fresh water. Although this result is based upon a few observations it affords an indication of importance, as it points to the presence of river water, and therefore a possible connection between the Gaspé current and the current flowing outwards at Cape North ; and thus furnishes a clue which should be followed up and further investigated.

GENERAL REMARKS.

One of the aims in this season's work, was to ascertain the nature of the currents in the two entrances to the Gulf of St. Lawrence as a basis for the examination of the currents throughout its area. From this point of view a few general remarks may now be made.

In the Strait of Belle Isle, while the current maintains its tidal character, there is only a difference in favour of inward flow from the east ; and during the summer months the actual balance of flow does not probably give more than a moderate percentage in favour of the inward direction. The influence therefore on the Gulf as a whole cannot be very great. During times however when the current runs predominantly in one direction for several days with a velocity which may attain a maximum of three knots, the effect upon the gulf must be more marked, and the distance to which its influence extends may be considerable.

A predominant current running inwards through the strait in the early spring, may not have a very marked influence so far as temperature is concerned ; because at that season the water in the north-eastern end of the gulf must be nearly as cold as the water entering through the strait. This incoming volume of water may help however to account for the increased velocity which the outward current on the west side of Cabot Strait is reported to have in the spring. Even if the water itself does not reach Cabot Strait, it may still act by displacement as the total volume of the gulf must remain nearly the same. This is much more probable than the explanation often made that this increased velocity is due to the spring floods in the tributaries of the St. Lawrence River. The influence of the St. Lawrence upon the currents in the gulf is usually much exaggerated. It may therefore be well to mention that a current of only half a knot per hour through the Strait of Belle Isle, would admit a volume of water 40 times greater than the discharge of the St. Lawrence as measured between Montreal and Lake St. Peter.

The two main currents at the two sides of Cabot Strait are the most important with reference to the interior of the gulf. It is possible that the current on the western side may have some relation to the current running outward along the Gaspé coast, and the reported direction of the current near the Magdalen Islands seems to make this the less improbable. The current along the west coast of Newfoundland might possibly prove to be a continuation of the inward current on the eastern side of Cabot Strait. Further to the north-east, in the narrower part of the gulf towards the Strait of Belle Isle, the current was also found on one occasion to be running from the westward at both sides simultaneously ; but the circumstances appear then to have been exceptional, as already pointed out.

These suggestions are made to show that the currents in Cabot Strait require to be further traced; and this should be done both within and without the strait and the facts already ascertained will be helpful as a basis in doing so. It may also prove of importance to follow the progressive change of temperature in these currents from the early spring throughout the summer; as this should give light as to the nature of these currents, and would also help in tracing their direction and influence.

There is thus an ample choice in deciding upon the best direction in which to carry forward the survey of the currents from the basis already obtained. It will also be possible to speak with greater certainty regarding these currents, when they have been more extensively followed and investigated.

I have, sir, the honour to remain,

Your obedient servant,

W. BELL DAWSON,

Engineer in charge of Tidal-Survey.