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Introduction

The Grand Manan Channel is a body of water lying between the
Island of Grand Manan and the Maine Coast. The bottom of this
channel is almost level and its sides precipitous, giving it a
nearly rectangular cross section. Currents, associated with the
extreme tides of the Bay of Fundy, carrying water over the shoals
to the south and through the irregular features in the Northern
Approaches, produce a body of virtually homogeneous water in the
channel (Hachey, 1931, Watson, 1936, McLellan, 1951). Much has
been written concerning the water movements in the channel although
the factual data presented have been few.

This survey was designed to add to the recorded data, using a
new instrument which has some distinct advantages in the study of
such an area.

Dawson (1908) reported hourly directions and magnitudes of
currents for a station (Lat. 44°45'05"N, Long 66°55'55"W) in the
centre of the channel, which was occupied from August 29th to
September 1st, 1904. Measurements were made with a current metre
placed at a depth of six metres and registering electrically.
The current values were adjusted to correspond with the average
tidal range of 21 feet (5.9 metres) at Saint John. The current
vector rotated clockwise, showing a maximum velocity along the
axis of the channel of 2.15 knots (110 centimetres per second)
during ebb, and 2.65 knots (136 centimetres per second) during
flood.

Mavor (1922) interpreted Dawson's data for this, and other stations to show a residual clockwise circulation around Grand Manan Island. However, in a later paper (Mavor 1923), where temperature and salinity observations were considered, he concluded "that it is unlikely that great general movement of the water could occur where the resistence to the tide is such as to cause great mixing".

Bigelow (1924) referred to this clockwise circulation but it is probable that his information was drawn from the reports of Dawson and Mavor.

Watson (1936), from a study of a distribution of temperature, salinity and density in two sections across the channel, inferred that "the residual current is directed northward but is small".

Current Survey 1950

From October 3rd to 5th, 1950, H.M.C.S. "New Liskeard" was made available for a current survey of the Grand Manan Channel. The ship was equipped with a Geomagnetic Electrokinetograph (von Arx, 1950) which permitted under-way measurement of surface currents.

Three lines were laid down, one across each end of the channel and one in its northern approaches (Figure 1). Steaming at eleven knots back and forth over the base course, jogs were made, following the sailing plan A2 (von Arx, 1950), at intervals of approximately twenty minutes. This procedure gave data for some five current vectors on each crossing of the line. Six or more crossings of each line were made during the thirteen hour periods. Details of the three lines are given in Table 1.

- Table I -

Lines of Current Observations in the Grand Manan Channel.

    A. Grand Manan Channel - Southern End

        From: 44 38.8'N, 67 9.2'W

        To: 44 46.4'N, 66 55.9'W

        Number of crossings 7

        Number of current vectors 34

        Time Oct. 3, 1950 - 11.05 to 23.42 A.S.T.

    B. Grand Manan Channel - Northern End

        From: 44 48.8'N, 65 55.2'W

        To: 44 49.1'N, 66 45.2'W

        Number of crossings 9

        Number of current vectors 37

        Time Oct. 4, 1950 - 1.15 to 13.57 A.S.T.

    C. Grand Manan Channel - Northern Approaches

        From: 44 49.7'N, 66 46.0'W

        To: 44 59.1'N, 66 50.3'W

        Number of crossings 6

        Number of current vectors 32

        Time Oct. 4, 1950 - 14.46 to Oct. 5 2.25 A.S.T.

    At the time of this survey the tidal range for the port of Saint John was 14 feet (Tide Tables for the Atlantic Coast, 1950) being neap tides. The mean tidal range for this port is 21 feet (Dawson, 1908).

The Geomagnetic Electrokinetograph

The Geomagnetic Electrokinetograph ("G.E.K" or "jog-log")
is an under-way current meter developed by von Arx (1950) of the
Woods Hole Oceanographic Institution. It consists of a two-wire
cable towed at some distance behind the ship, each wire terminated
by a non-polarizing electrode, one of which is at some distance
behind the other. This cable, together with the water extending
between the electrodes constitutes an electric circuit. In it,
electromotive forces arise when it has a component of velocity per-
pendicular to its length, so that it cuts across the vertical com-
ponent of the earth's magnetic field. This electromotive force, E,
is given by $E = V H_z L \cdot 10^{-8}$ volts where V is the velocity component
in centimetres per second at right angles to the trailing cable, H_z
the vertical intensity of the earth's magnetic field in oersteds and
L the length of conductor in centimetres. A recording potentiometer
registers the potential difference at the inboard cable terminals.
This is equal to the electromotive force induced in the extra length
of cable to the more distant electrode. Though an equal electro-
motive force is induced in the water, which is itself a moving con-
ductor, this is essentially short circuited by stationary water
layers below and the conducting bottom of the channel. The two
electrodes are thus at virtually the same potential

In the ideal case, with a shallow current running over a very
deep stationary layer, the velocity component of the water trans-
verse to the cable is exactly given by $V = \dfrac{E}{H_z L} 10^8$ and, for a
given H_z, L may be chosen so that the potentiometer reading
corresponds with the velocity in knots.

In shallow water and/or with deep currents the electro-
motive force induced in the moving water is not completely offset,
and the recorded potential is somewhat less. To compensate for
this, the potentiometer reading is multiplied by a correction
factor "k", which must be calculated from theoretical considerations,
measured by simultaneous determination of current by a different
method, or estimated from empirical data. Von Arx (1950) has
published the results of a large number of experimental determin-
ations to assist in selecting "k". In any case, the relative com-
parison of currents, and the calculation of directions may be done
without a knowledge of the "k" value.

In very shoal water (less than 10 metres deep) von Arx found
"k" to range from 1.5 to 15. In water 10-100 metres deep, on the
continental shelf "k" values averaged less than 2, while beyond 150
metres the "k" factor averaged 1.05. In this investigation a "k"
factor of 2.0 was used. This was arbitrarily chosen to give current
values comparable to those reported by Dawson (Dawson 1908).

Mutually perpendicular current vectors are obtained by inter-
rupting the ship's course with a rectangular jog and return at
approximately twenty minute intervals.

Composition of these two vectors provide the total current
and the direction. The latter is, of course, independent of the
value of the "k" factor.

Observations in the Grand Manan Area

The reduction of the electrokinetograph data was carried out
according to the procedure described by von Arx. The zero point,

which is the reading corresponding to zero velocity, was taken as the mean value of the reading before and after reversing the electrodes by a change in course of one hundred and eighty degrees. A separate zero was thus found for each jog. Random variations up to some 0.2 knots (10 centimetres per second) were found to occur in this value. A zero point based on a running mean of the individual zeros was also used to compute current components. No large differences were found with the two methods and only the data based on individual zeros are used here.

The instrument readings were corrected for the local value of the vertical component of the earth's magnetic field, $H_z = 0.540$.

Results of this current survey are presented in three diagrams, Figures 2, 3, and 4, one for each line of observation (Figure 1). In each diagram the mean course of the ship is shown. On lines parallel to this, showing the successive crossings of the channel section, the current vectors are represented to scale. The origin of each vector shows the position along the mean course at which the observation was made. The time (A.S.T.) is given for each observation. Times of High and Low Water for the port of Saint John are also given in the Figures.

(a) Southern End, Figure 2.

On the flooding tide the currents were small, and predominantly eastward until three hours before the time of High Water (Saint John), when they increased to approximately one knot directed towards the northeast. Thereafter they became less regular, as evidenced at 1534 hours when a velocity of 0.16 knots (8.3 centimetres per second) toward the northeast was observed between 1.08 knots (55.6 centimetres per second) and 0.88 knots (45.2 centimetres per second)

vectors. The 1622 hour observation, at the extreme west of the
section showed a southward component which appeared before the time
of high water. At this end of the section an eastward component
persisted after high water.

South of Little River the trend of the Maine Coast changes
abruptly, and this, coupled with the resistance offered by the shoals
to the southwest of Grand Manan, probably tends to direct the flood-
ing tide eastward.

· Currents on the ebbing tide were noticeably stronger than on
the flood, setting in to the south immediately at the time of High
Water, at approximately 0.8 knots (41 centimetres per second) and
thereafter increasing to 1.5 knots (77 centimetres per second).
After half-ebb the currents veered to the southwest, reaching a
velocity of 1.8 knots (92.5 centimetres per second) in the centre
of the section. The southward flow persisted after the time of Low
Water, while a strong eastward component developed on the western
half of the section.

The largest currents were observed near the centre of the
section throughout.

(b) Northern End, Figure 3.

On the flooding tide, at the western end of the section,
there was considerable variation in current strength and direction.
Here, the flood, which was observed at the beginning and end of the
series, began with northeast currents, changing to east and south-
east currents at half flood. Towards High Water westward flow was
observed at the extreme west of the section, indicating that flooding
of Cobscook Bay had become an influence.

The currents in the eastern end of the section were northwest-ward in the first hour after Low Water, followed by weaker northward currents. Unfortunately several observations were missed in this part of the series.

On the ebb tide there was a well defined pattern of south-ward flow and a distinct westward component in all but one vector, with velocities increasing to 1.5 knots (77 centimetres per second) at half-ebb. It is obvious that the retreat of waters from the Bay of Fundy proper was channelled through this passage to a marked degree.

(c) Northern Approaches, Figure 4.

Currents in this section were of considerably less velocity than in the other sections and there was a large velocity component along the base course direction. In the northern half of this section southward flow was observed throughout the tidal cycle with a com-ponent across the section, into the channel, at all times. A maximum velocity of 1.3 knots (67 centimetres per second) was observed at Low Water.

In the Southern half of the section, for a period of five hours, approximately from the half-ebb to the half-flood, the predominant currents were strong, approaching a maximum of 2 knots (103 centi-metres per second). Their direction was southward with always an appreciable component across the section into the channel. For an equal period centred on the High Water, eastward currents out of the channel region prevailed.

Non-Tidal Currents

Dominant flow to the southward through the channel is indicated

in all three sections. The average of the velocity components normal to the section was found for each section during a whole tidal period. From this the net flow in cubic metres per tidal cycle was calculated. At the time of this survey the moon was near its maximum declination resulting in a marked inequality in successive tides which would account for a resultant flow up to some ten percent of the mean tidal flow. Adjustment was made of offset this inequality.

Table 2 shows the results of these calculations which indicate a southward flow through the three sections of 12×10^9, 7.5×10^9, and 6.2×10^9 cubic metres per tidal cycle of 12.4 hours, with a mean value of 8.6×10^9 cubic metres per tidal cycle.

This pattern may be much altered by the tidal range and meteorological factors. The southward flow is in disagreement with various interpretations of Dawson's data which were taken over a 67 hour period when the tidal range was 19 feet (Dawson 1908). The use of data from Dawson's single station to give a general picture of persistent dominant flow through the channel is probably not justified. A further and more extensive study of the area will be necessary before a complete description of the water movements in the channel can be made.

Summary

Current measurements at a series of stations across the north and south ends of the Grand Manan Channel and across its Northern Approaches have been made through complete tidal cycles. These observations were obtained with the geomagnetic electrokinetograph which provided current directions and magnitudes of better than relative significance.

At the time of this survey a system of strong southerly currents was observed on the ebb while flood currents were smaller and less systematic.

The record of shore lines and the submarine topography have marked influences upon the flow patterns in the channel and approaches.

The residual flow across each section was found to be through the channel to the south. Approximate calculations of the magnitude have been made for each section and found to be of the same order of magnitude, 8.6×10^9 cubic metres per tidal cycle.

Acknowledgments

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Table 2.

Residual Flow through the Lines of Observation in the

Grand Manan Channel.

	South Section A	North Section B	Approaches C
Mean Residual Current (knots)	.31	.24	.10
(centimetres per second)	16.	12.	5.1
Length of section (nautical miles)	11.5	7.5	13.
(Kilometres)	21.3	13.9	24.1
Mean depth (fathoms)	43	53	62
(metres)	79	97	113
Residual flow (cubic metres per tidal cycle)	12×10^9	7.5×10^9	6.2×10^9
Residual flow (cubic metres per tidal cycle)	Mean Value	$(8.6 \pm 3.4) \times 10^9$	

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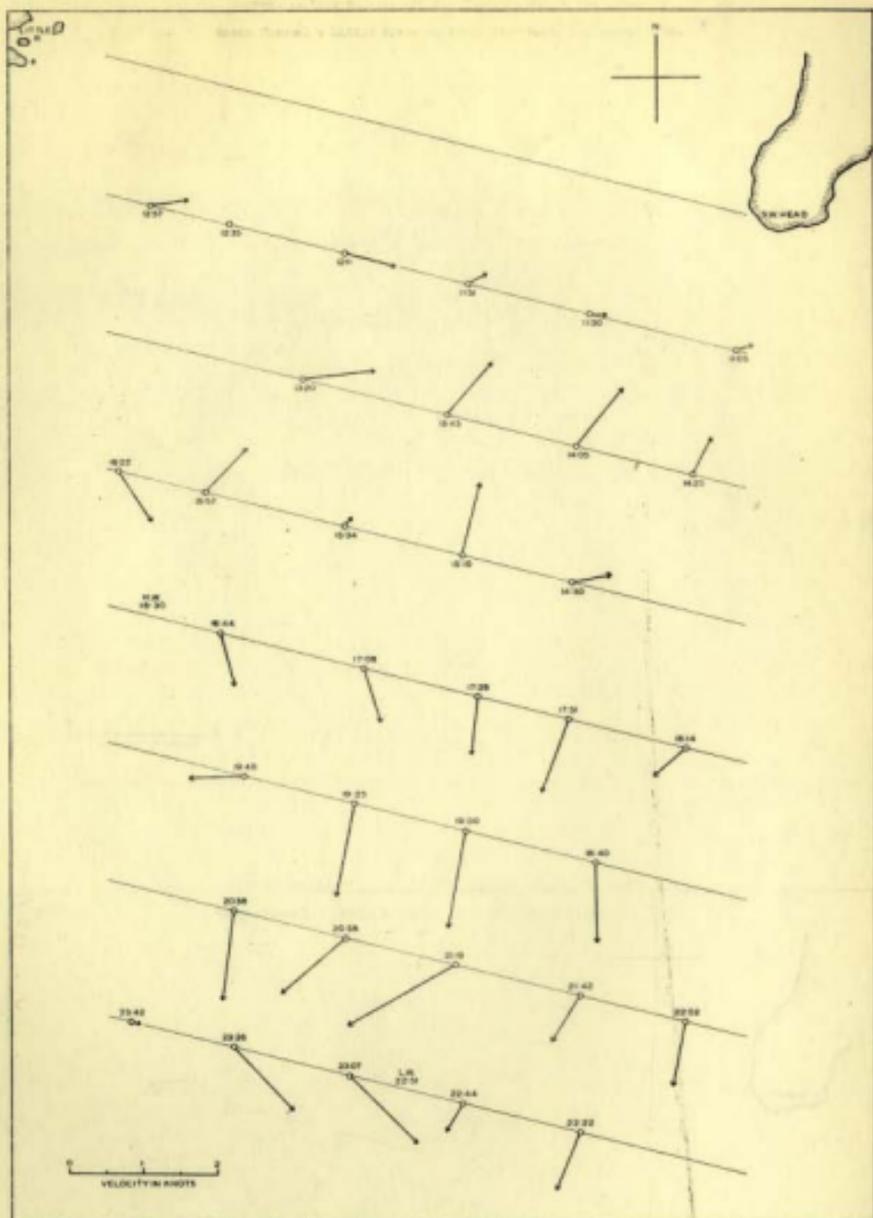J. Biol. Bd. Can. 2, 2, 141-208, 1936.

Figure 1.

The Grand Manan Channel area showing bottom topography and
lines of current observations.

Figure 2.

Current vectors observed in the Southern end of the Grand

Manan Channel : Little River to South West Head, 3 October, 1950.
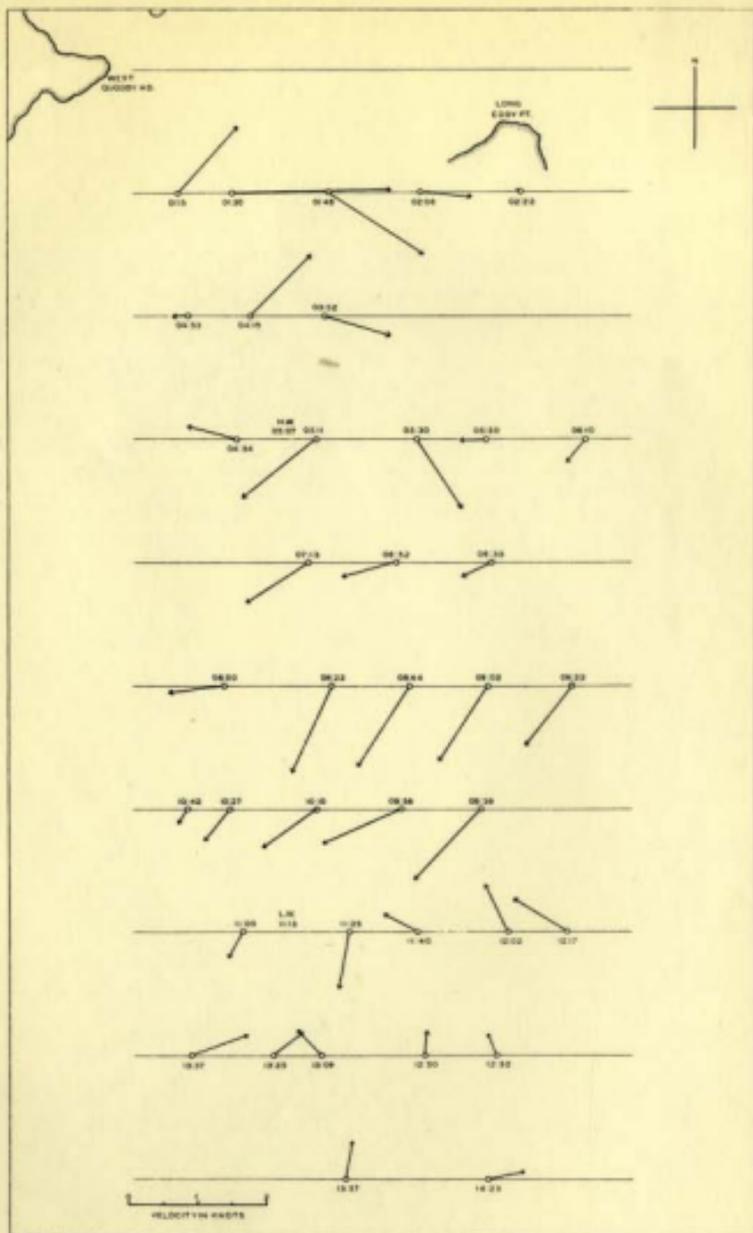
Figure 3.

Current vectors observed in the Northern end of the Grand
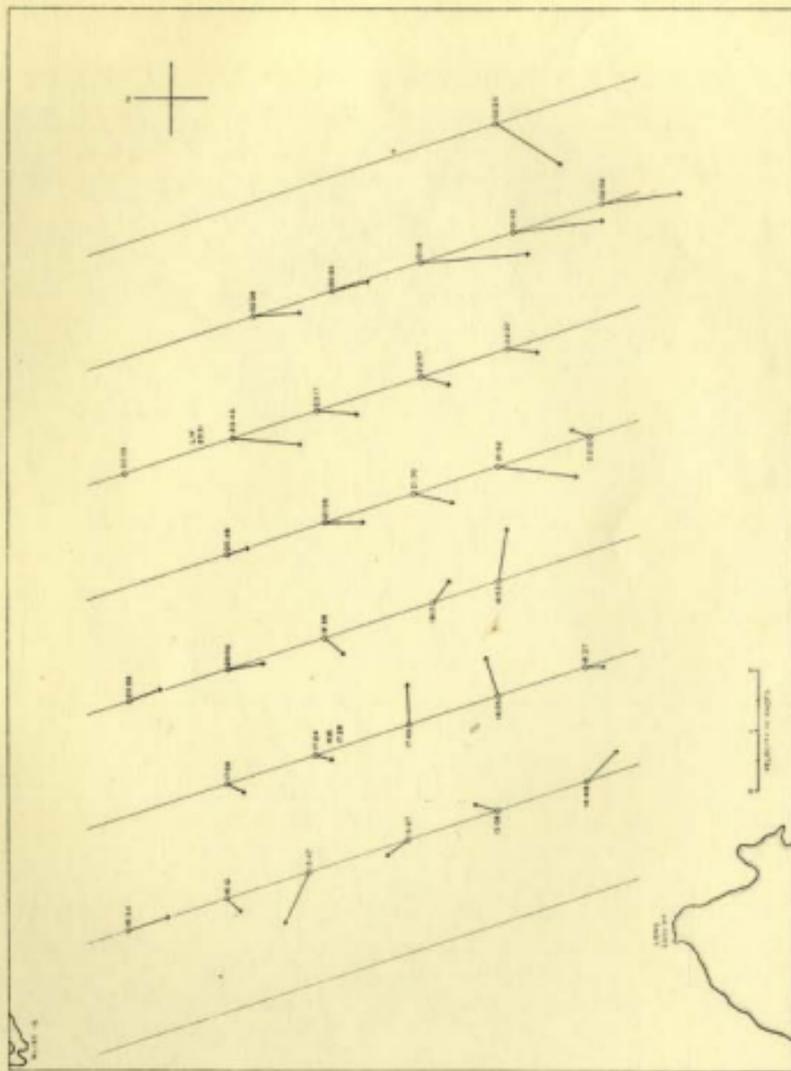Manan Channel: West Quoddy Head to Long Eddy Point, 4 October 1950.

Figure 4.

Current vectors observed in the Northern Approaches to the Grand Manan Channel: Long Eddy Point to Miss Island, 4 and 5 October 1960.