Atlas of Tidal Currents for Halifax Harbour

David A. Greenberg
Fisheries and Oceans Canada
Bedford Institute of Oceanography
Dartmouth, Nova Scotia, Canada

August, 1999

Contents

List of Tables

List of Figures

1 Introduction and disclaimer

This atlas was created following a request from the Canadian Armed Forces for information on currents for navigating Halifax Harbour. It is hoped that it will serve the same purpose as the *Atlas of Tidal Currents, Bay of Fundy and Gulf of Maine* [1], namely to provide hourly snapshots of tidal currents for the purposes of navigation. Note that in Halifax Harbour the tides are not large, and compared to the Bay of Fundy and Gulf of Maine the tidal currents can be dominated and even reversed by other processes (see section 3). In addition, there are limitations of the computer model used to compute these currents (section 2).

THIS ATLAS IS PROVIDED IN THE HOPE THAT IT WILL BE HELPFUL BUT BE CAUTIONED THAT IT IS TO BE USED AT YOUR OWN RISK. UNDER NO CIRCUMSTANCES IS ANY RESPONSIBILITY ASSUMED FOR DAMAGE ARISING FROM THE USE OR THE INABILITY TO USE THIS ATLAS.

We are interested in providing the best information possible. Feedback on the accuracy or inaccuracy of the depicted currents will help establish whether this product is worthwhile and how it might be improved. Comments may be mailed to the author at the address on the cover page or e-mailed to *dgreenbe@georgs.bio.dfo.ca*.

2 The Model and its limitations

The numerical model used to generate the current diagrams was originally developed in a test exercise looking at the tsunami generated in the Halifax Harbour explosion of 1917 [7, 3, 4]. At the time this report was written, an introduction to the model was available at the internet site **http://www.maritimes.dfo.ca/science/ocean/welcome.html** by following the links **Current Research** ⇒ **Coastal Hydrodynamics Modelling** ⇒ **Coastal Embayments Circulation and Dispersion** ⇒ **Halifax Harbour**. The tidal currents have been subject to only limited verification. Where they have been compared to current meter data they agree to within the uncertainty of the observations (10 – 20%). The currents seaward of MacNab's Island have inaccuracies due to the approximations made in specifying the tide at the outer limit of the model and these should be treated as unreliable. Data vs model comparisons in this area show that the model is producing across-channel currents stronger than observed.

For those technically inclined, the model is a linear harmonic finite element model with grid resolution from 20 m to 1 km with an average node separation of 170 m. In practical terms this means that the model will not be accurate for currents that change at scales approaching the local resolution. This will be a problem near poorly resolved solid docks and areas with small bottom features and rapidly changing depths.

The model only uses one component of the tides – the M_2 Lunar component with period 12.42 hours. The relative magnitudes of the other constituents can be estimated from the amplitudes from an analysis of the Halifax Harbour tide gauge data (Table 2). The currents for the semi-diurnal components, S_2 and N_2, will have magnitudes approximately proportional to the ratio of their amplitude to the M_2 amplitude. The diurnal current components, K_1 and O_1, would scale as one half their ratio to the M_2 amplitude. These components of the currents are approximately considered by taking into account the tidal range (see section 4). Other nontidal contributions to the Harbour currents, which at times have magnitudes greater than the tides, are described in section 3 below.

Constituent	Amplitude (m)
M_2	0.628
S_2	0.138
N_2	0.138
K_1	0.100
O_1	0.048

Table 1: The amplitude of the major tidal constituents from an analysis of 1973 data from the Halifax Harbour tide gauge. The components additional to M_2 are approximately accounted for by scaling the vectors as described on section 4.

3 Nontidal Currents

There are many other processes not considered here that give rise to currents that can have magnitudes of the same order as the tidal currents shown in this atlas. Some of these are:

- **Local wind forcing.** This will depend on the force, direction and duration of the wind. It is not uncommon to see magnitudes of 5 to 15 cm $\cdot$ s^{-1}.
- **Distant meteorological forcing.** Even though the Harbour seems calm, distant weather systems can give rise to sea level changes at the mouth of the Harbour influencing the inner Harbour currents to the same degree as the local winds for periods of hours to days .
- **Resonance.** Halifax Harbour can be rung like a bell from passing weather systems or big waves at the Harbour entrance. The period of this resonant ringing is about 2.1 hours and the currents can be 5 to 10 cm $\cdot$ s^{-1} [5]. The resonance has been observed to be stronger and more frequent in winter.
- **Estuarine circulation.** The fresh water flowing out on the surface is compensated for by a deeper saltier flow into the harbour. The currents (5 – 15 cm $\cdot$ s^{-1}) are stronger at times of strong runoff, but are seen at all times of the year [6].

4 How to use this atlas

This atlas is meant to be used in conjunction with the current annual *Tide Tables* for Halifax Harbour (e.g. [2]). The general pattern can be obtained directly from one of the diagrams. Two sets of figures are given; the first set (Figures 1 – 12) covers the whole Harbour, the second set (Figures 13 – 24) covers the central part in greater detail. The strength of the current is determined by comparing the length of the current arrow with the 5 cm^{-1} current scale vector shown. The current magnitudes are derived assuming an M_2 tidal range of 1.24 m; however, *Tide Tables* indicate the tidal range can be as high as 2.1 metres, these should be further scaled for more accurate predictions.

1. Find the tidal diagram appropriate to your time relative to the tides in the *Tide Tables*. (Remember that the times in the *Tide Tables* are always local *standard* time never daylight saving.)
2. Determine the **range** (in metres) of the tide that includes the time of interest by subtracting the low from the high tide.
3. The scale factor for the currents is **range**$/1.24$.
4. In the special case where the time is exactly at high or low tide (see the second example) the range should be taken from the rising or falling tide that immediately precedes that time.

4.1 Examples

The sea level from the *Tide Tables* May 14 1999 at Halifax are shown in table 2.

- May 14 1999 9:00 ADT (the time you want to know the currents).
  - Convert to AST — 8:00 (this corresponds to about one hour after high tide).
  - The charts of interest are: Figures 2 and 14.
  - Currents will first be scaled according to their length relative to the 5 cm scale arrow on the figure.
  - The tidal range is $1.8 - 0.2 = 1.6$ so the scale factor to be applied to the currents is $1.6/1.24 = 1.3$.
- May 14 1999 20:05 ADT.
  - Convert to AST — 19:05 (this corresponds to high tide).
  - The charts of interest are: Figures 1 and 13.
  - Currents will first be scaled according to their length relative to the 5 cm scale arrow on the figure.
  - The tidal range is $2.0 - 0.2 = 1.8$ so the scale factor to be applied to the currents is $1.8/1.24 = 1.3$.

Time	Height (m)
0100	0.1
0650	1.8
1310	0.2
1905	2.0

Table 2: Extraction from *Tide Tables* — Halifax Harbour May 14 1999.

References

[1] Anonymous. Atlas of tidal currents, Bay of Fundy & Gulf of Maine. Technical report, Canadian Hydrographic Service, Fisheries and Oceans, Ottawa, 1981.

[2] Anonymous. Canadian tide and current tables, volume 1, Atlantic Coast and Bay of Fundy. Technical report, Canadian Hydrographic Service, Fisheries and Oceans Canada, 1999.

[3] David A. Greenberg, T. S. Murty, and Alan Ruffman. A Numerical Model for the Tsunami in Halifax Harbour due to the Explosion in December 1917. *Marine Geodesy*, 16:153–167, 1993.

[4] David A. Greenberg, T.S. Murty, and Alan Ruffman. Modelling the tsunami from the 1917 Halifax Harbour explosion. *Tsunami Hazzards*, 11(2):67–80, 1993.

[5] D. McGonigal, R. Loucks, and D. Ingraham. Halifax Narrows: sample current meter data 1970-71. Data Report BI-D-74-5, Bedford Institute of Oceanography, Dartmouth, N.S., 1974.

[6] Brian Petrie and Philip Yeats. Simple models of the circulation, disolved metals, suspended solids and nutrients in Halifax Harbour. *Water Poll. Res. J. Canada*, 25(3):325–349, 1990.

[7] Alan Ruffman, David A. Greenberg, and T. S. Murty. The Tsunami from the 1917 explosion in Halifax Harbour. In Alan Ruffman and Colin Howell, editors, *Ground Zero - A reassessment of the 1917 Explosion in Halifax Harbour*, page 327. Nimbus Publishing and Gorsebrook Research Institute for Atlantic Canada Studies, Halifax, Nova Scotia, 1994.

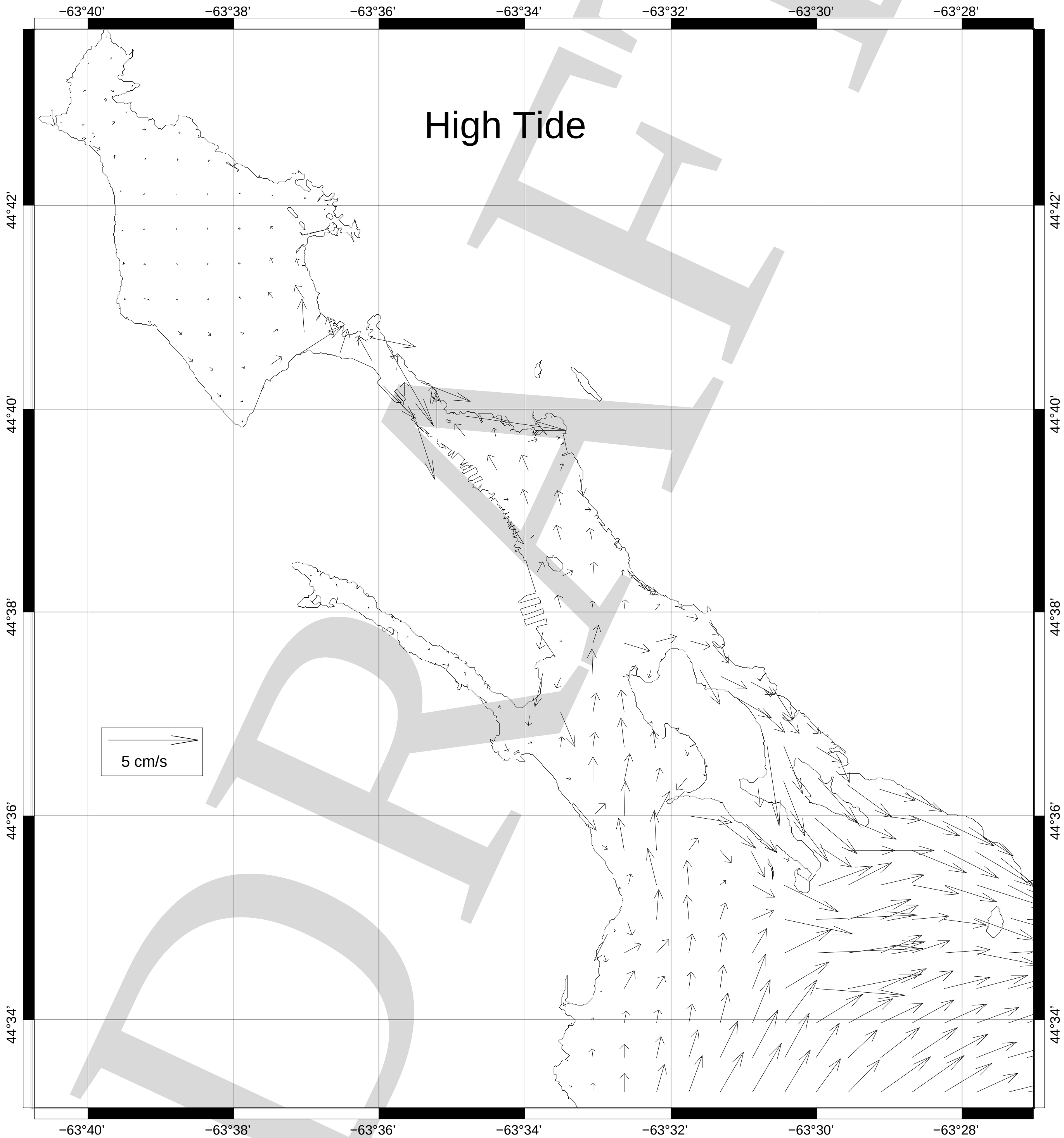

Figure 1: Full Harbour, high tide

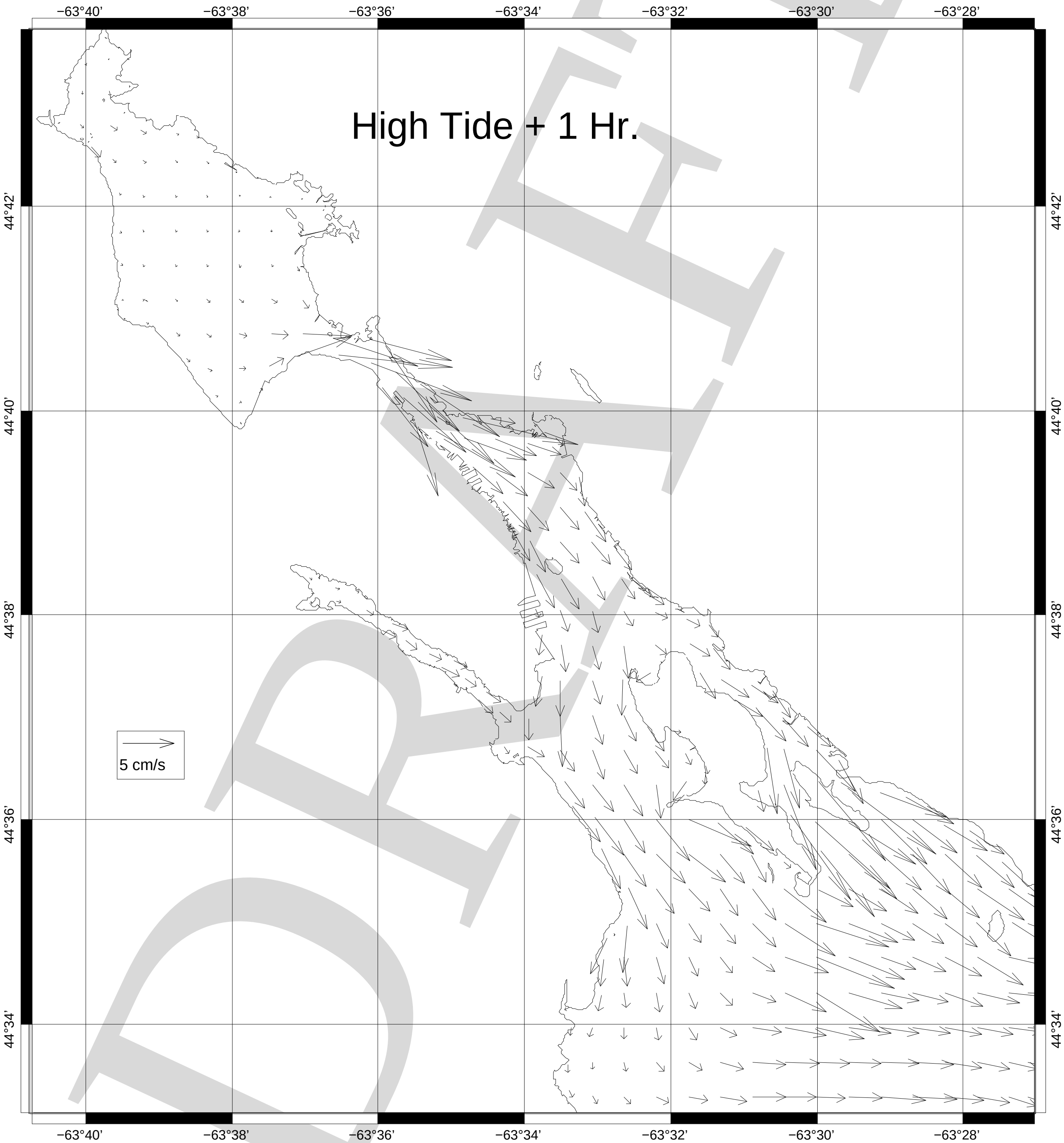

Figure 2: Full Harbour, one hour after high tide

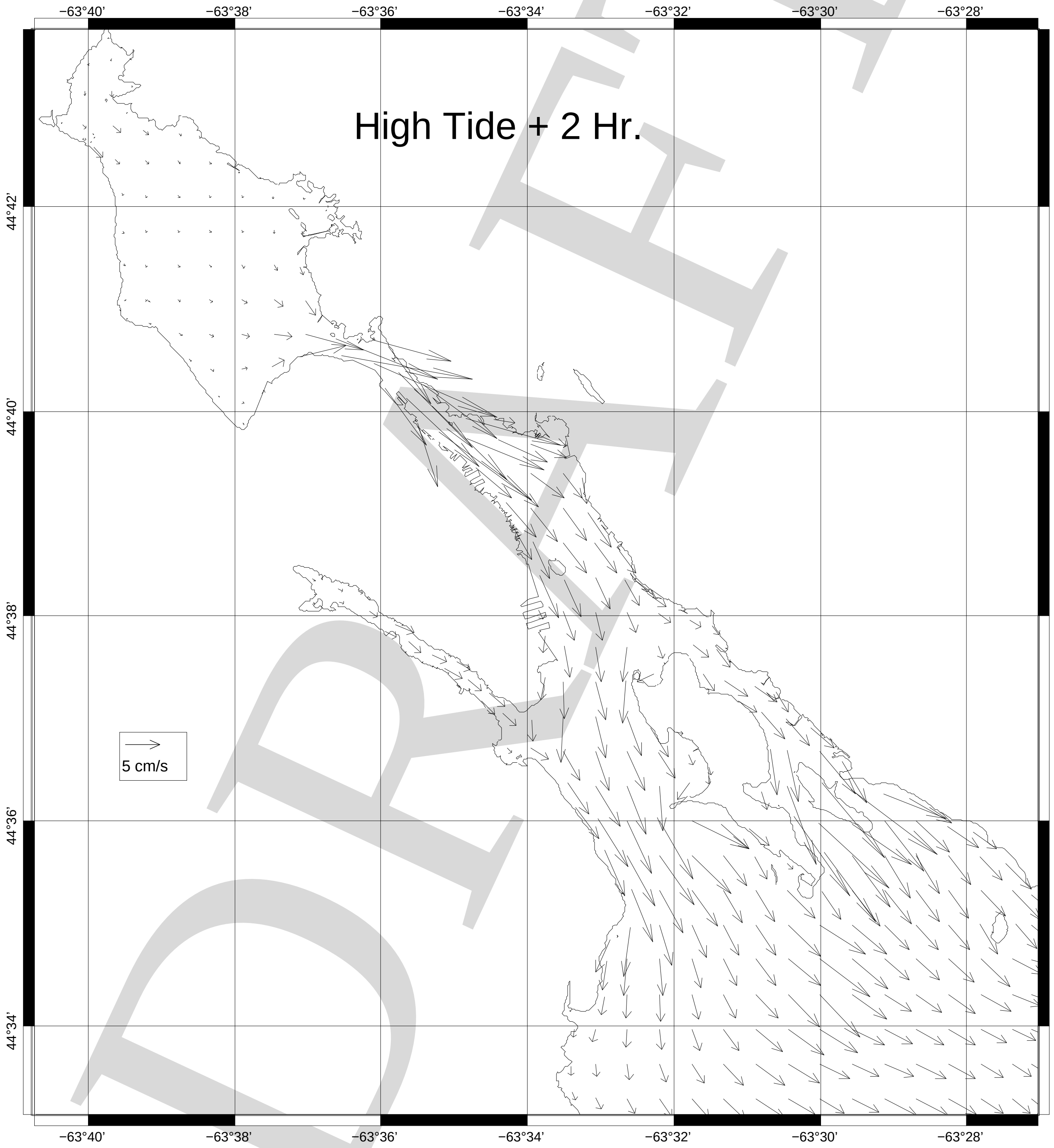

Figure 3: Full Harbour, two hours after high tide

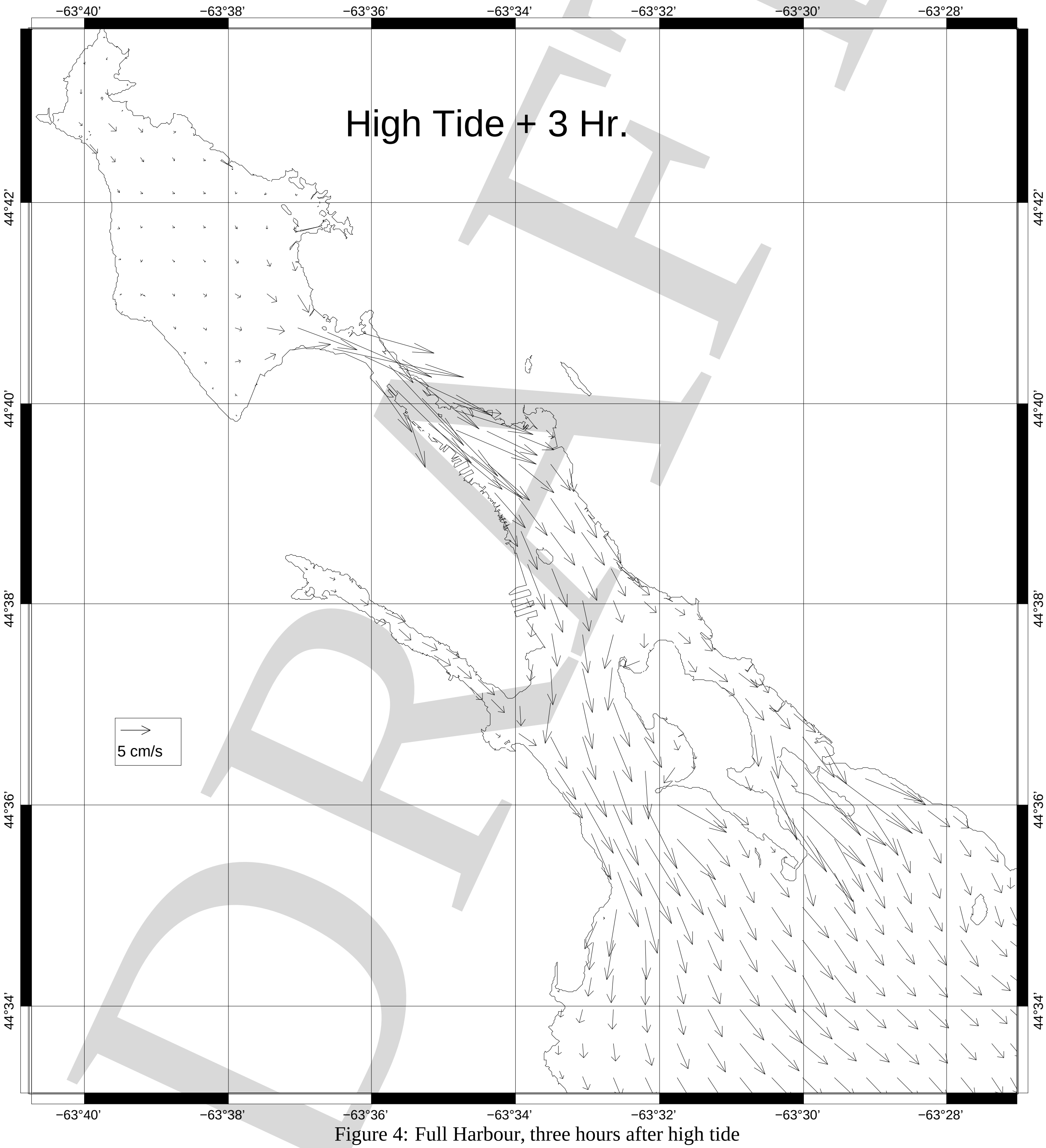

Figure 4: Full Harbour, three hours after high tide

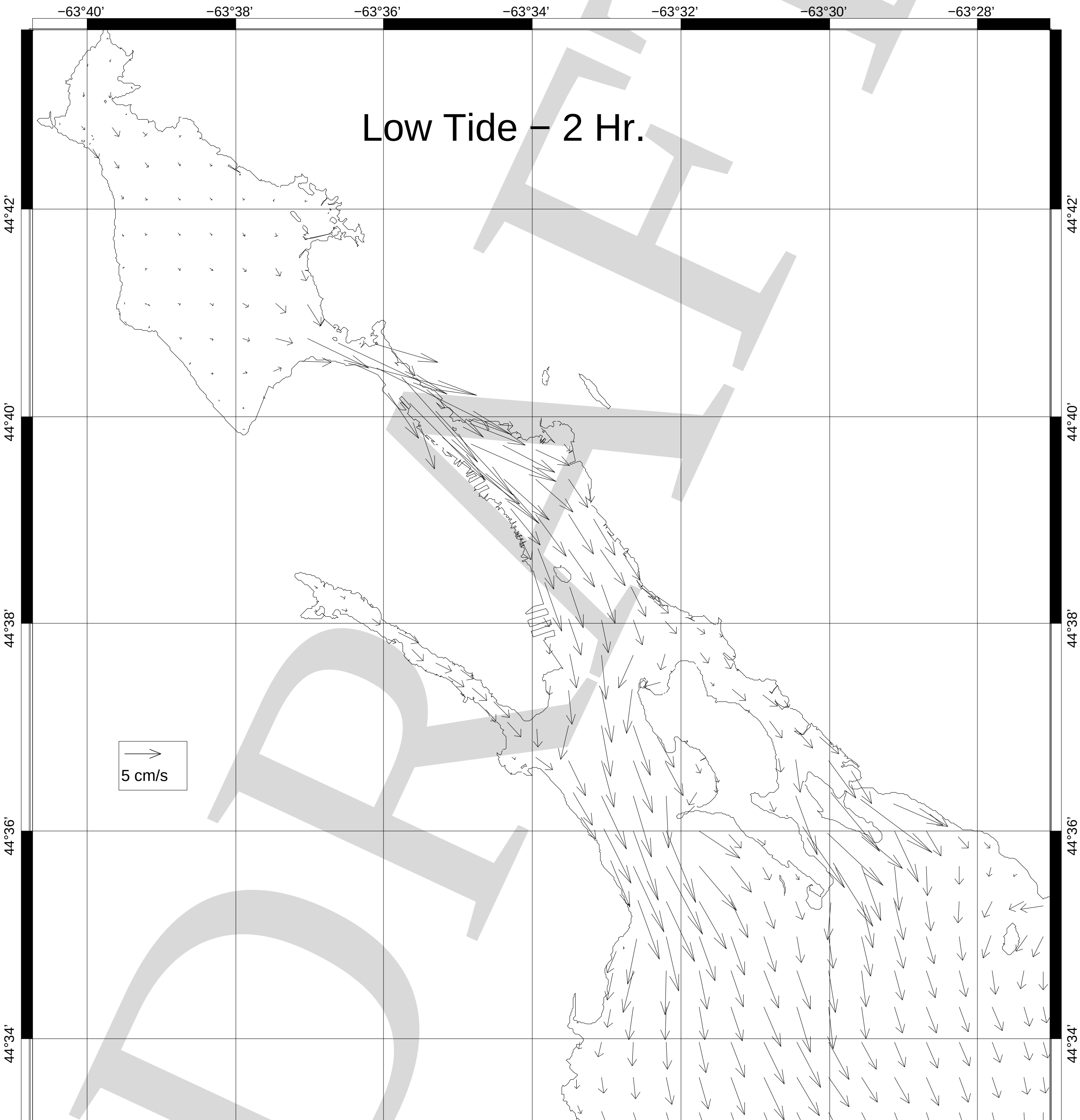

Figure 5: Full Harbour, two hours before low tide

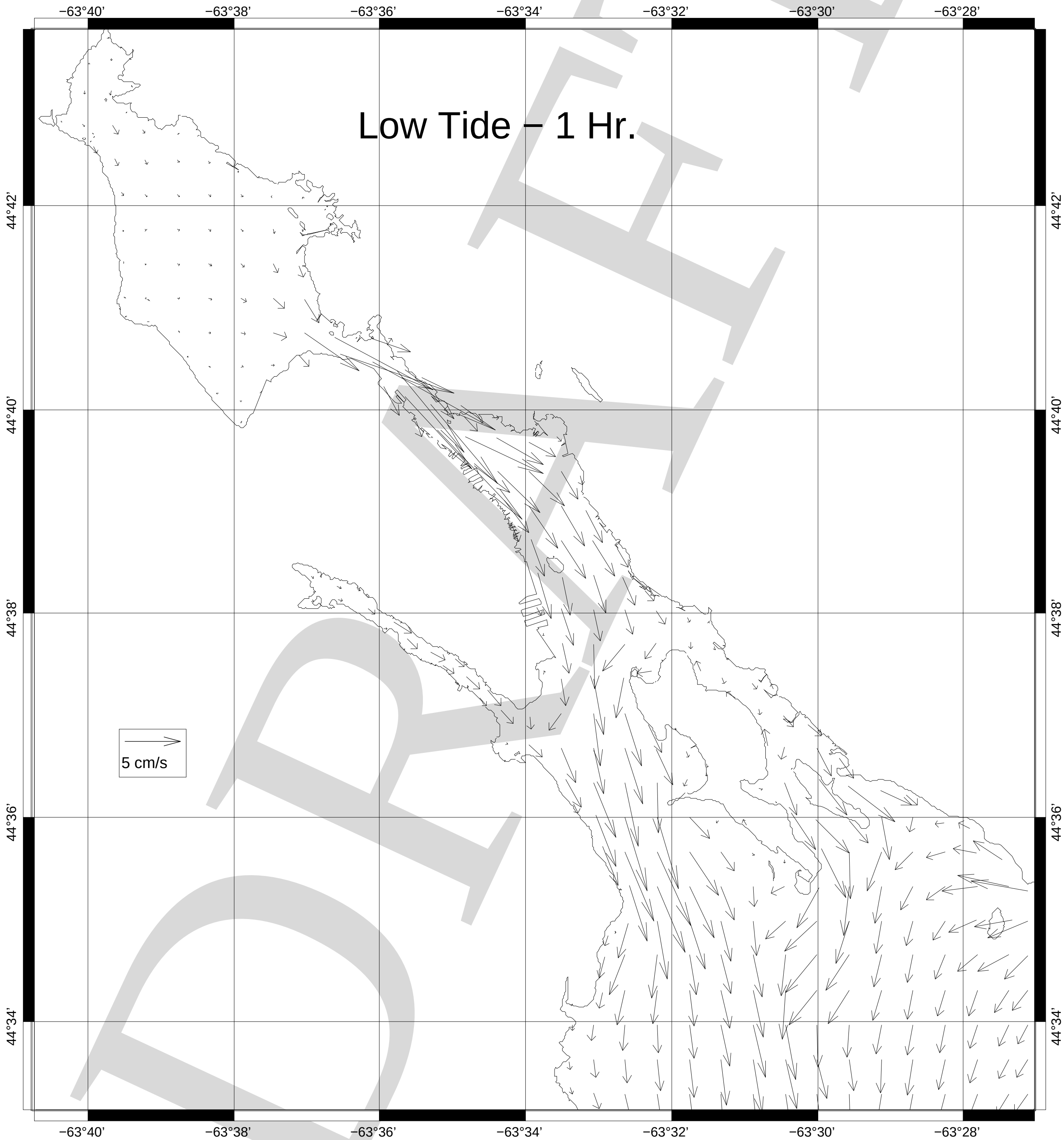

Figure 6: Full Harbour, one hour before low tide

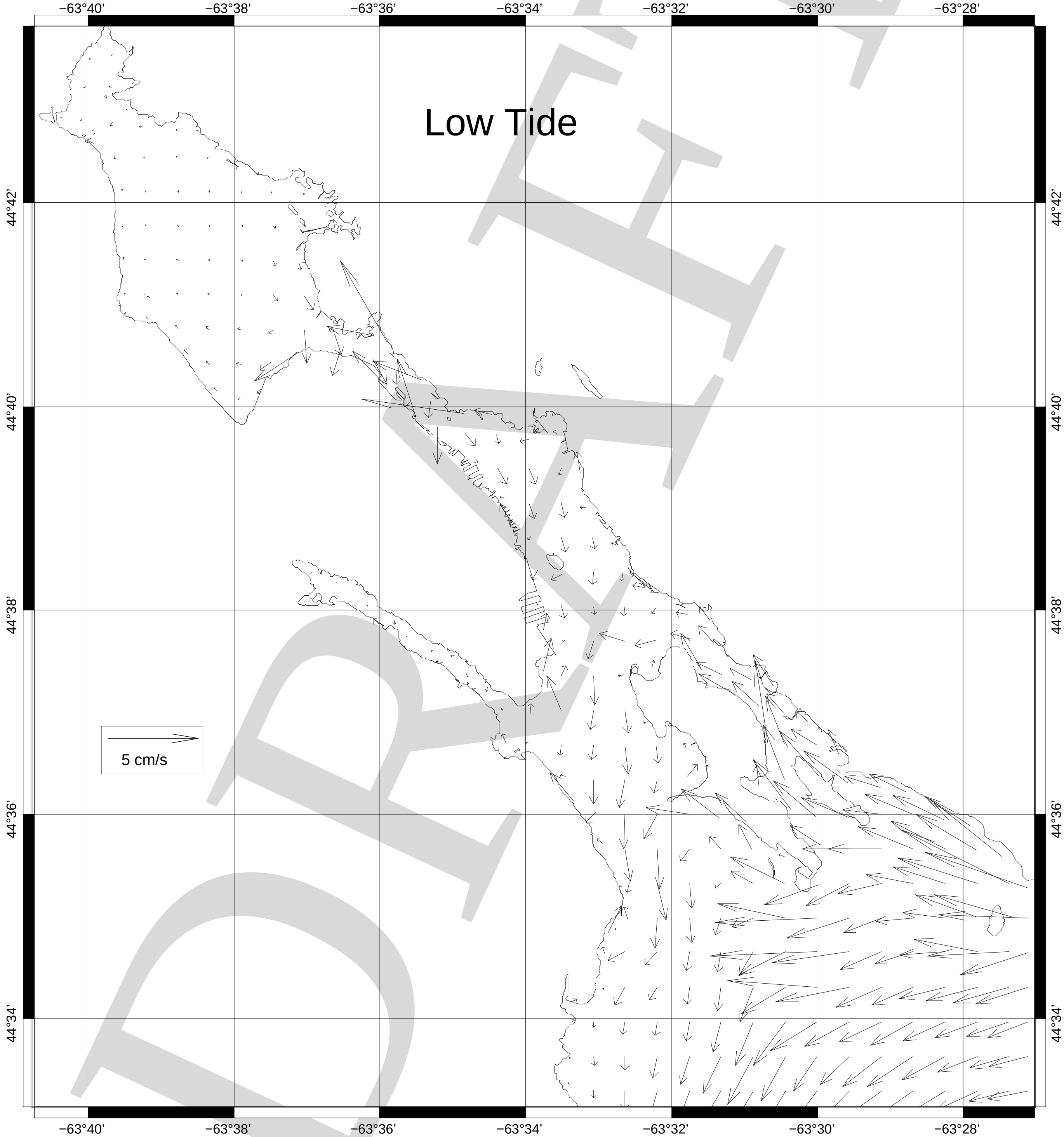

Figure 7: Full Harbour, low tide

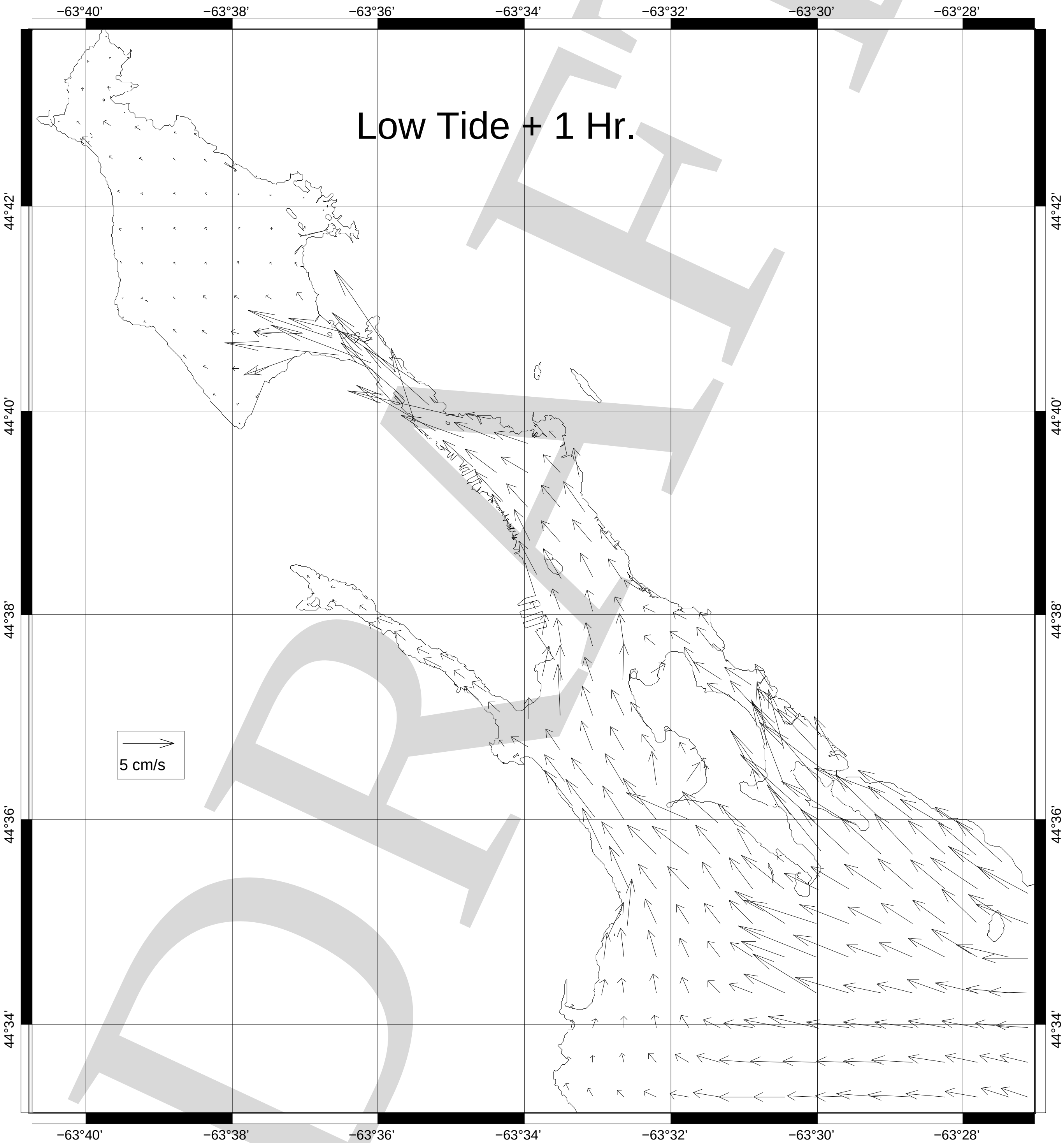

Figure 8: Full Harbour, one hour after low tide

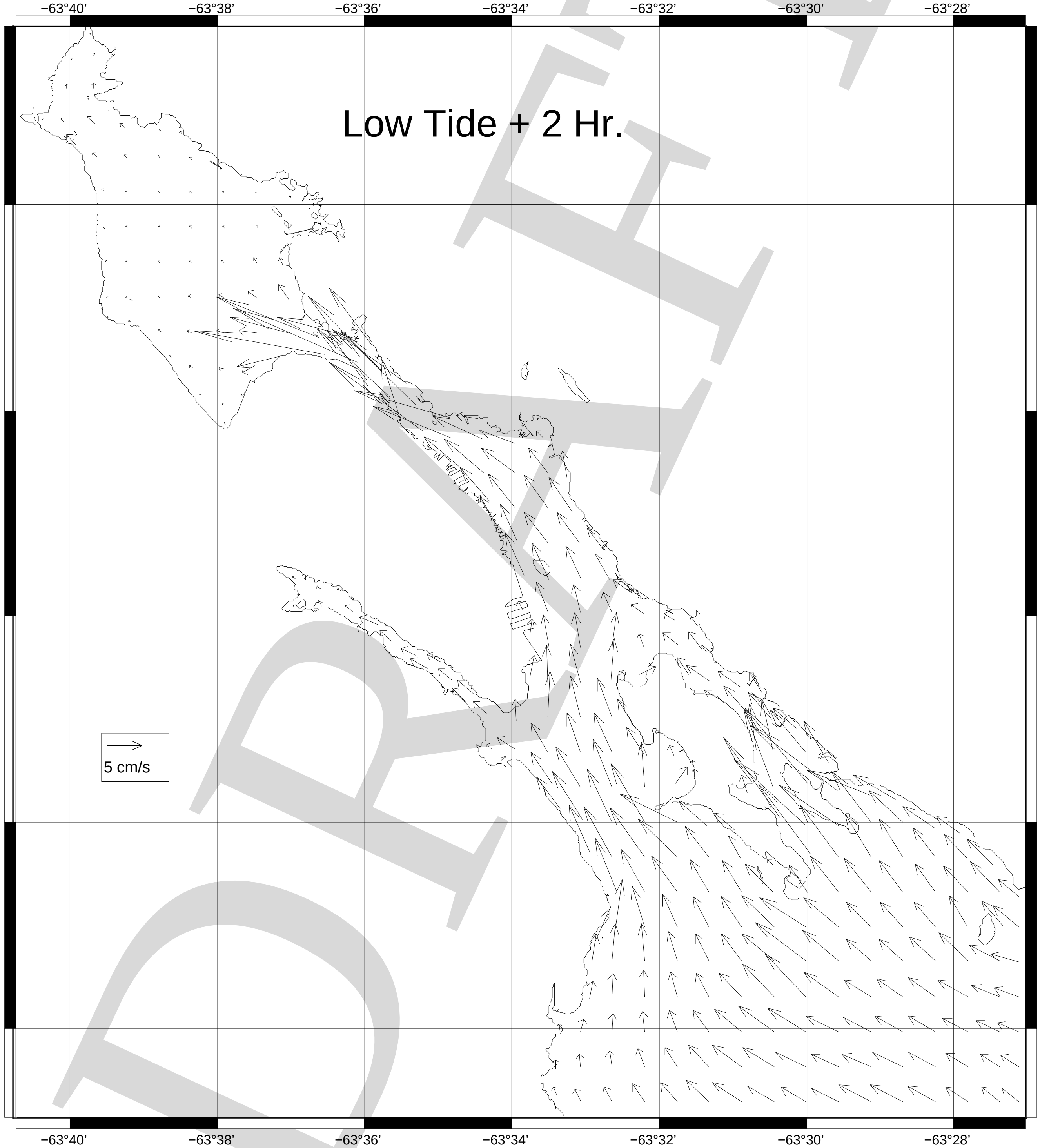

Figure 9: Full Harbour, two hours after low tide

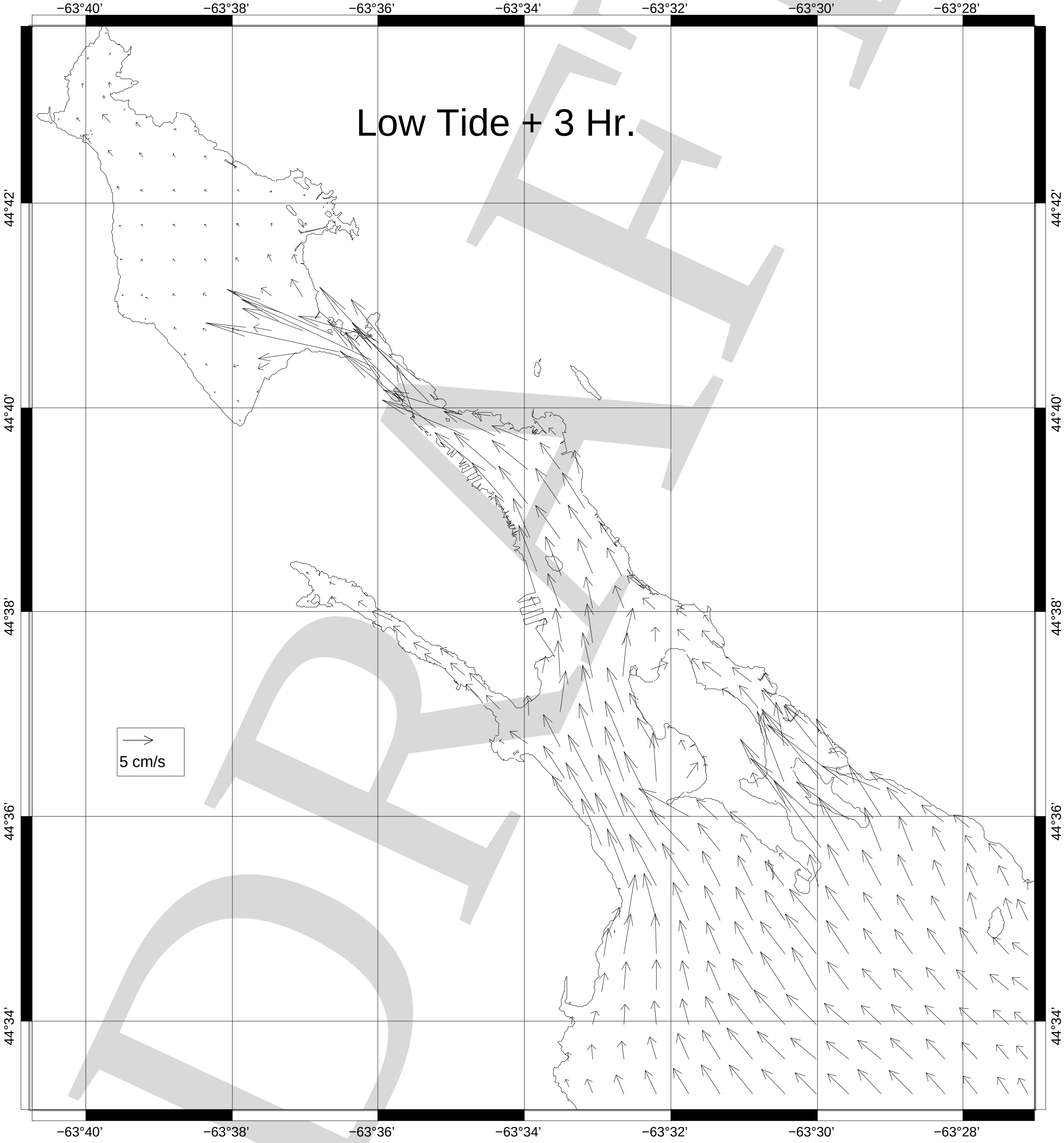

Figure 10: Full Harbour, three hours after low tide

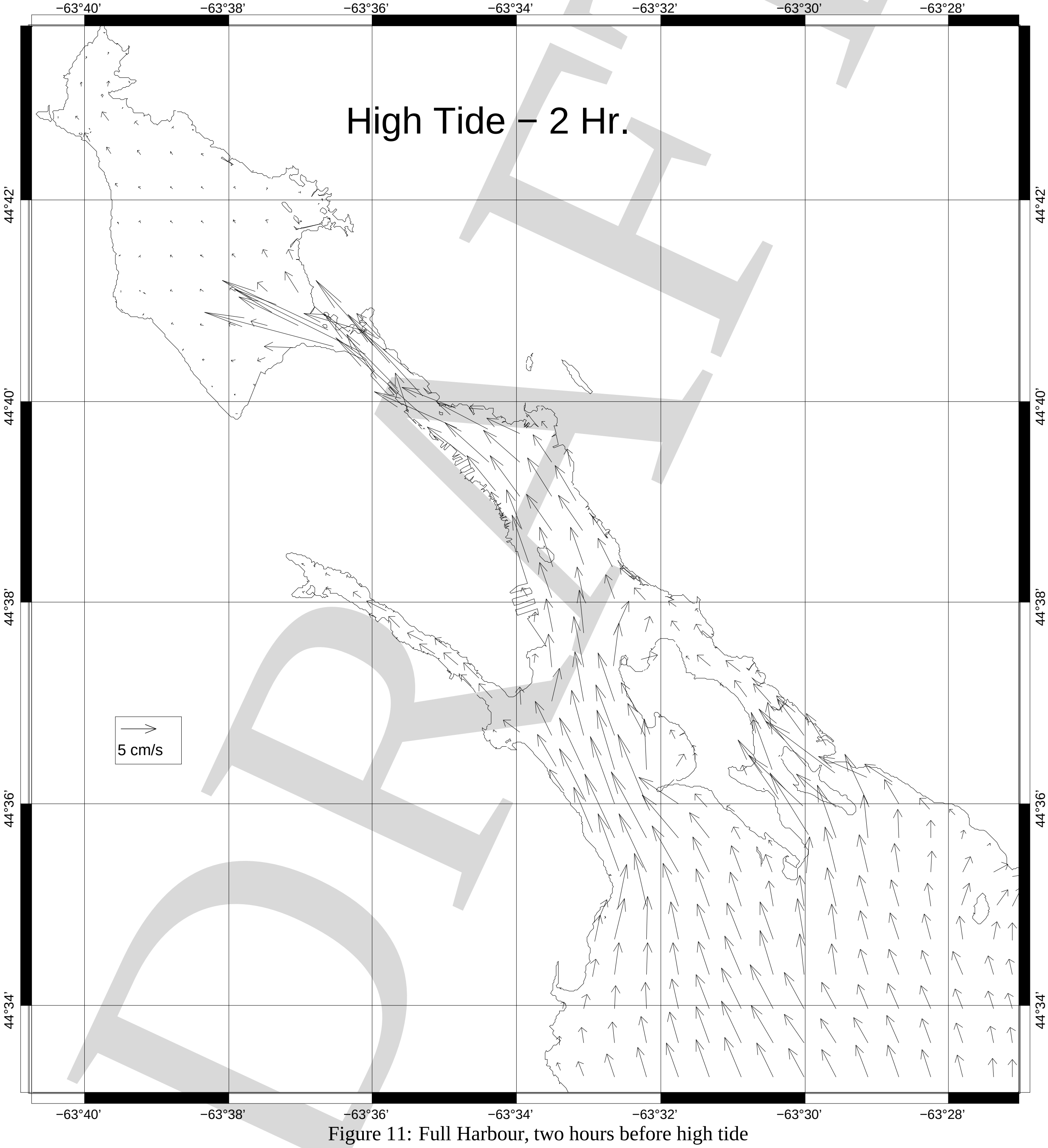

Figure 11: Full Harbour, two hours before high tide

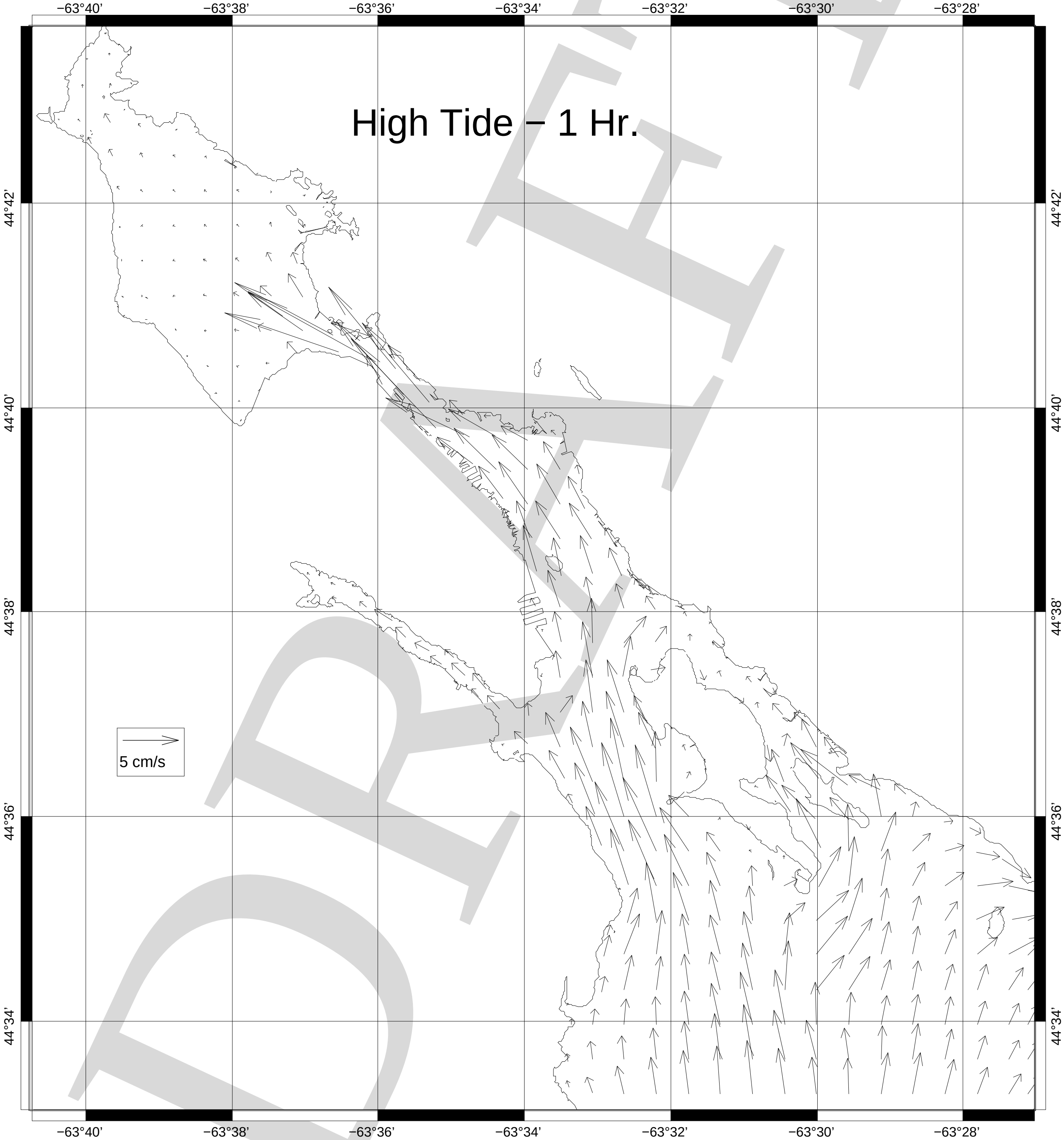

Figure 12: Full Harbour, one hour before high tide

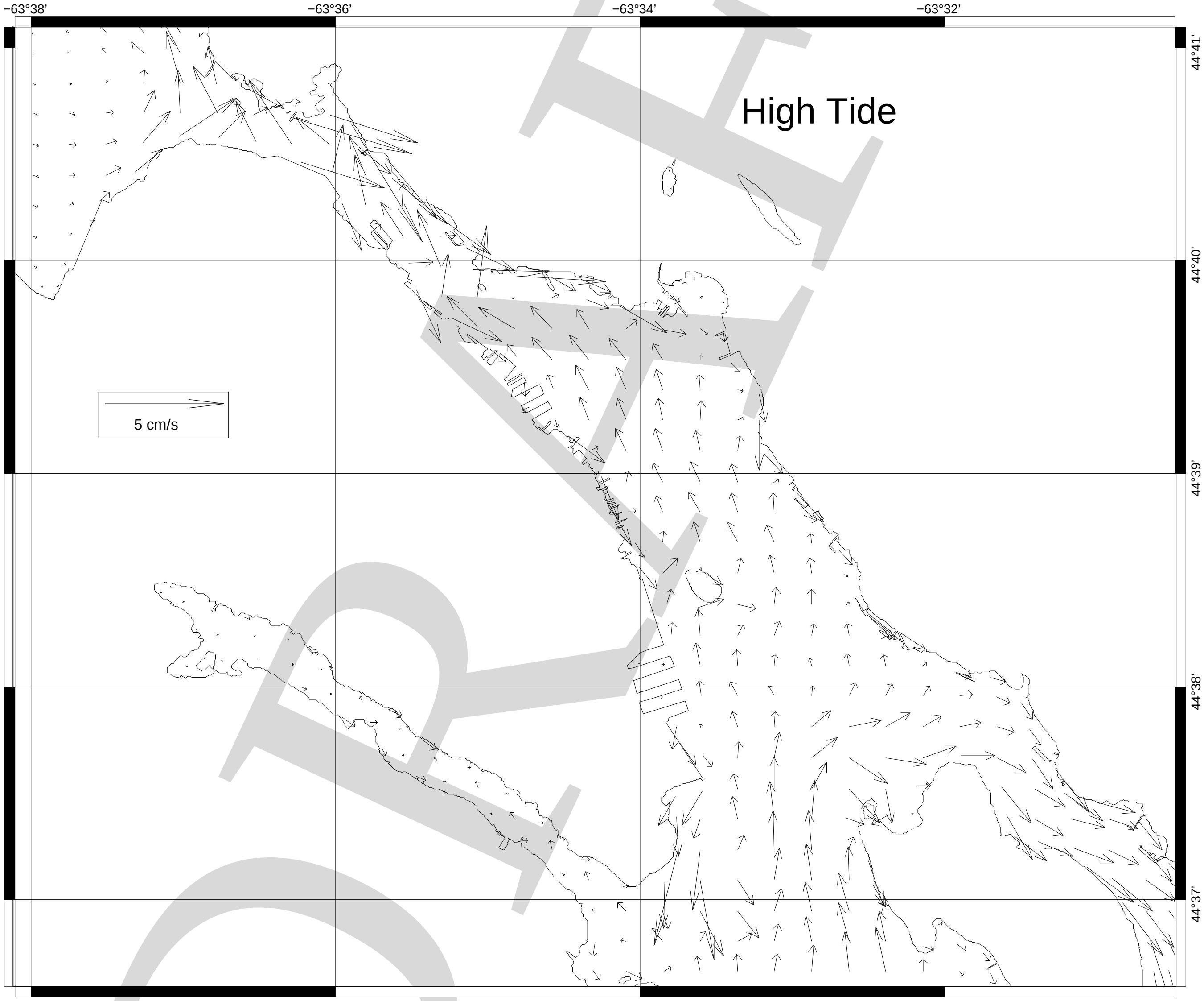

Figure 13: Inner Harbour, high tide

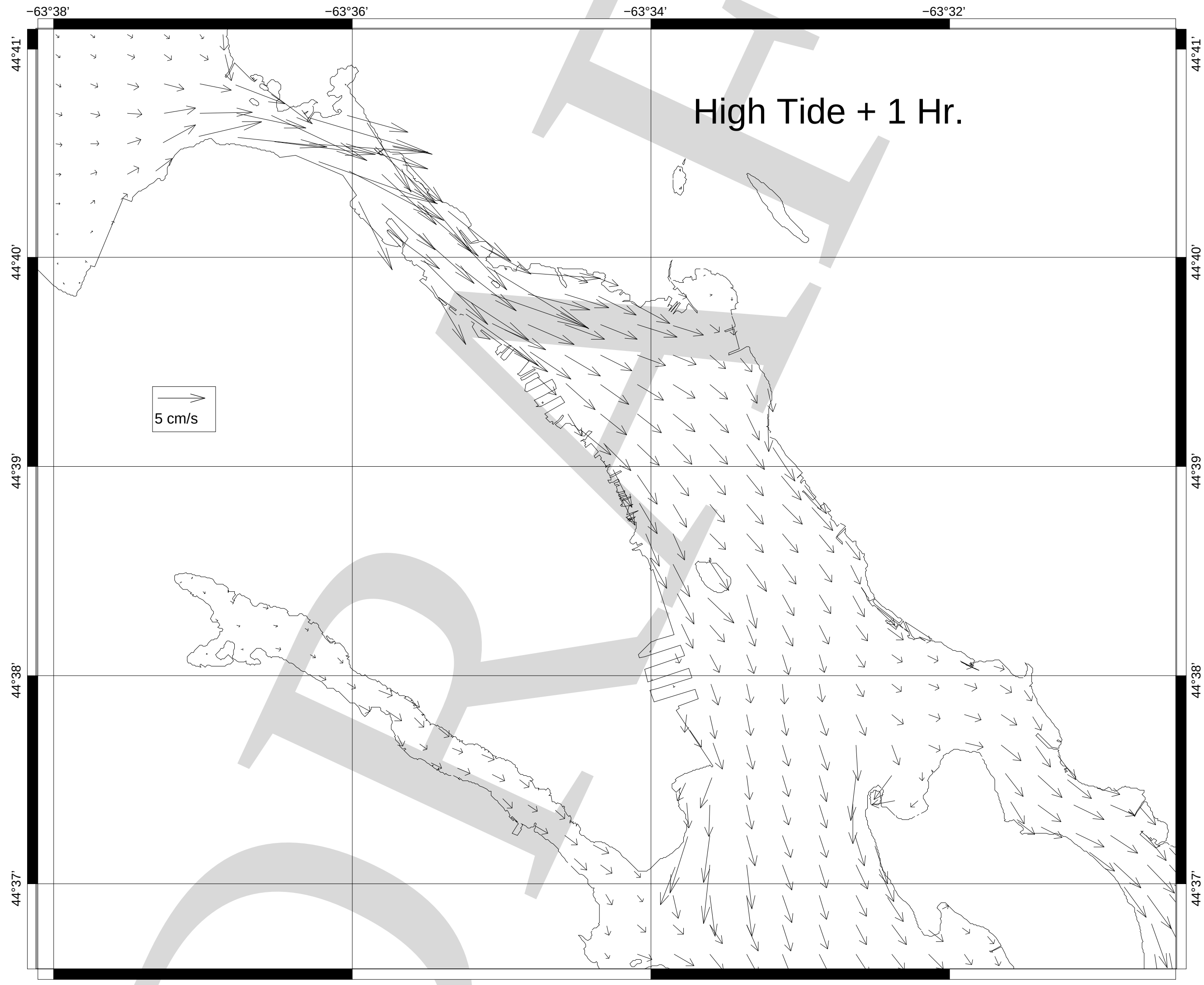

Figure 14: Inner Harbour, one hour after high tide

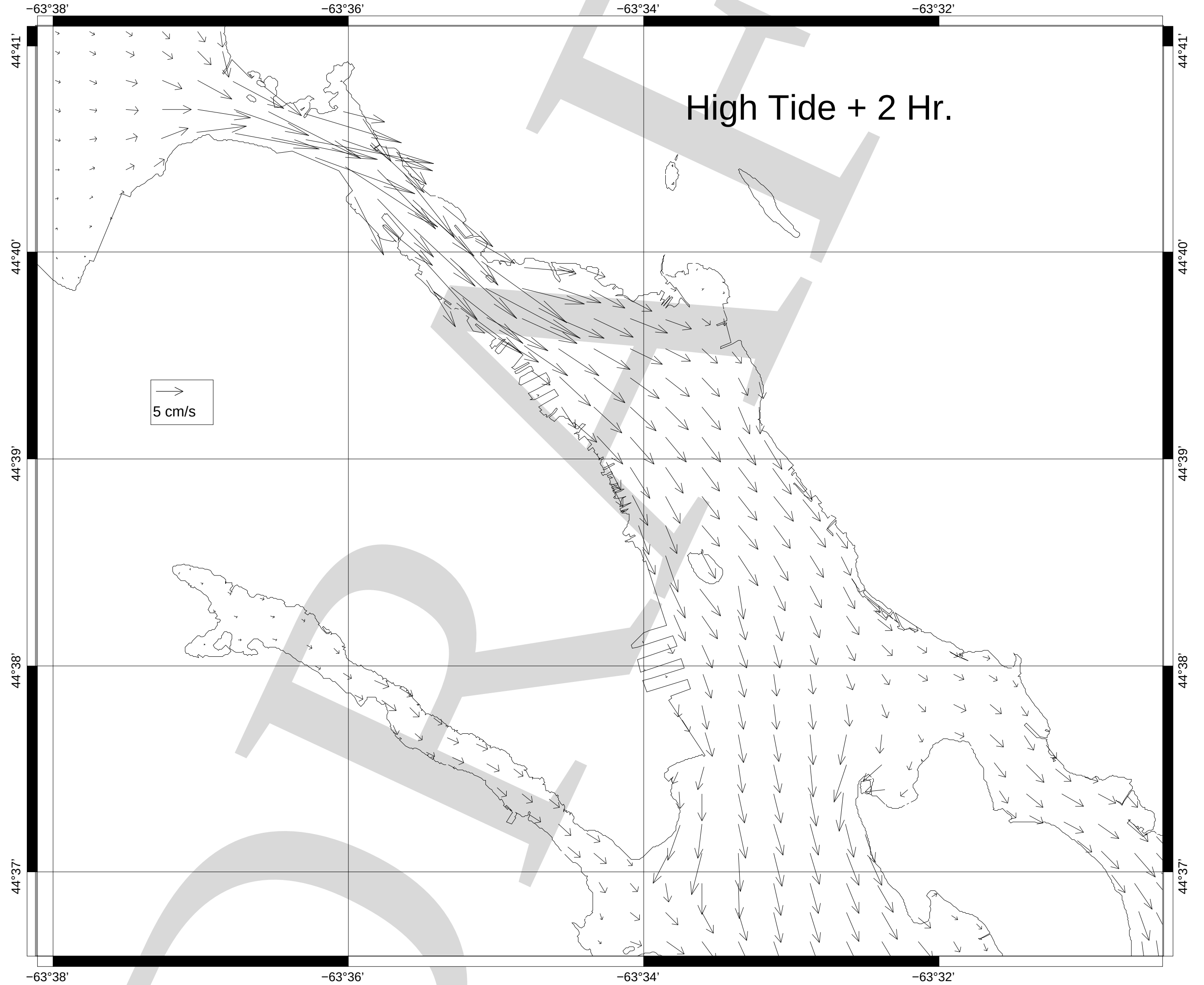

Figure 15: Inner Harbour, two hours after high tide

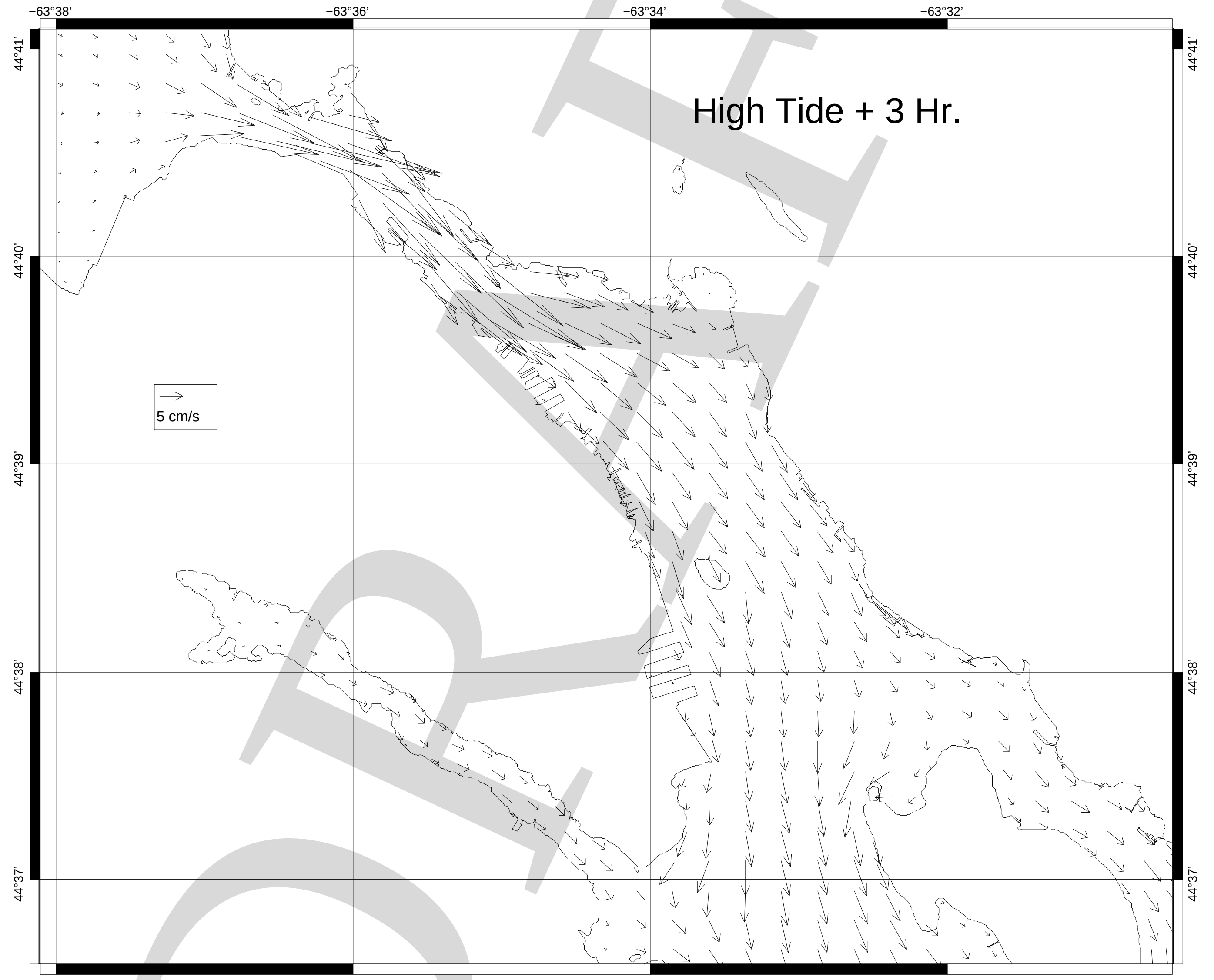

Figure 16: Inner Harbour, three hours after high tide

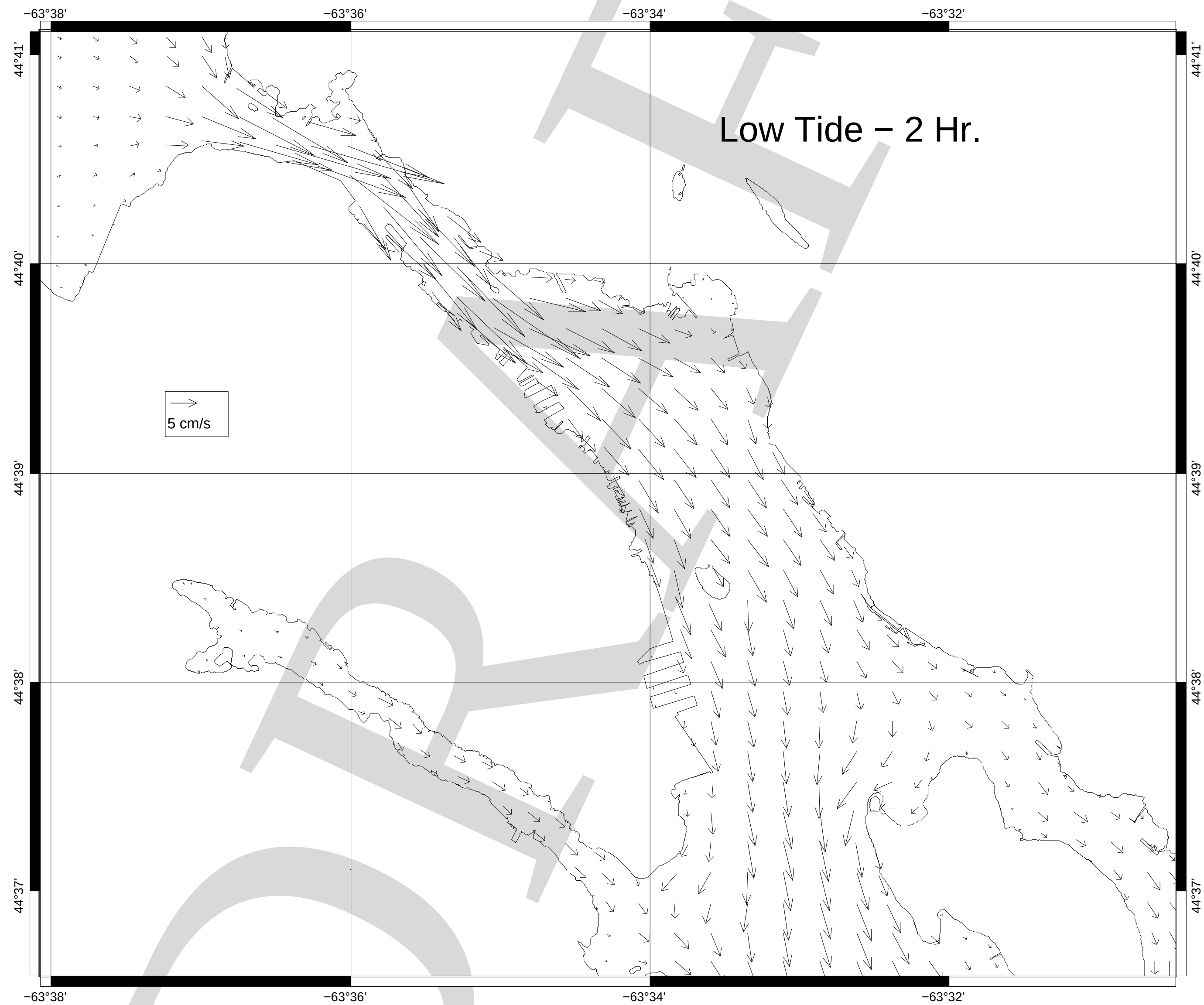

Figure 17: Inner Harbour, two hours before low tide

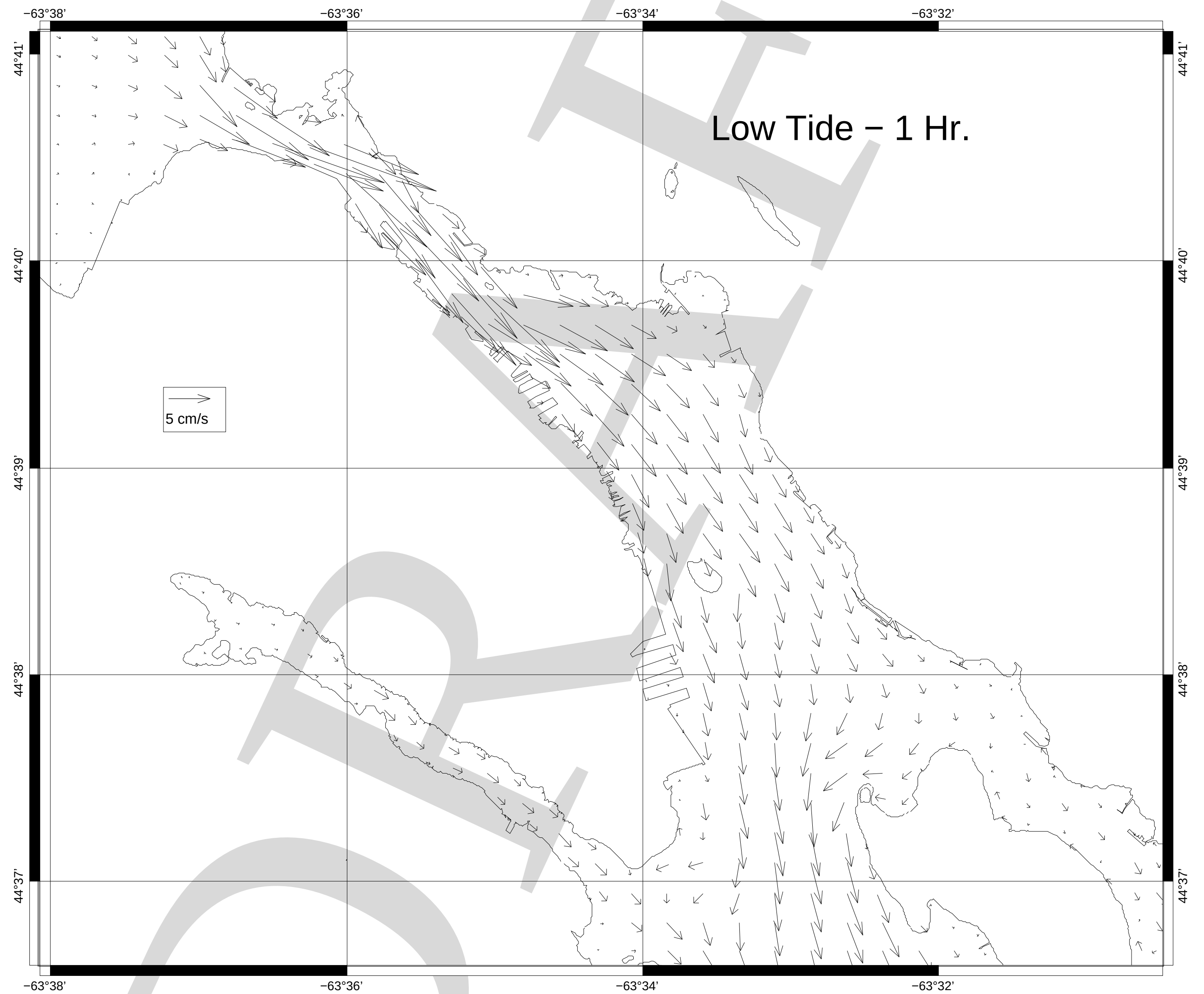

Figure 18: Inner Harbour, one hour before low tide

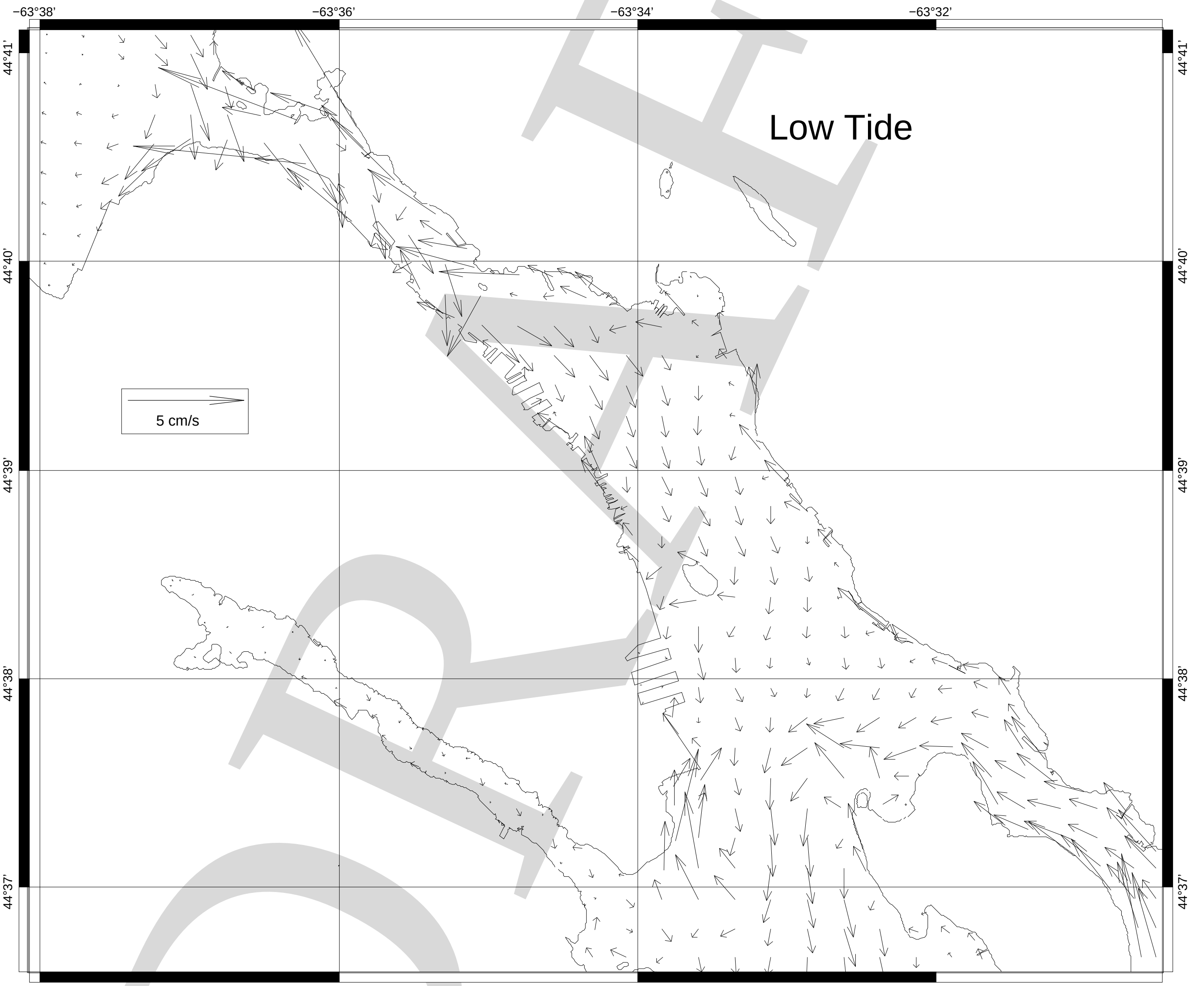

Figure 19: Inner Harbour, low tide

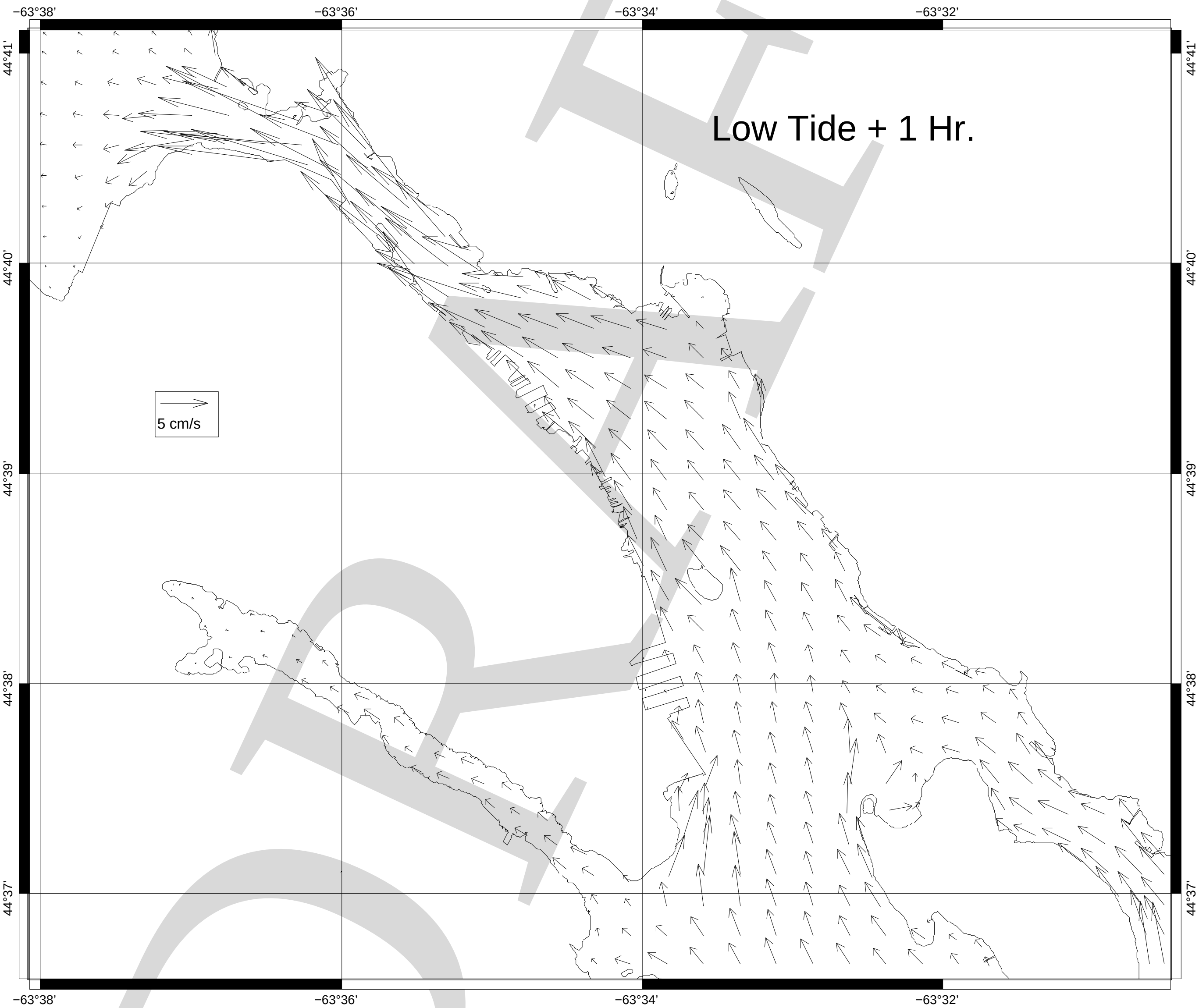

Figure 20: Inner Harbour, one hour after low tide

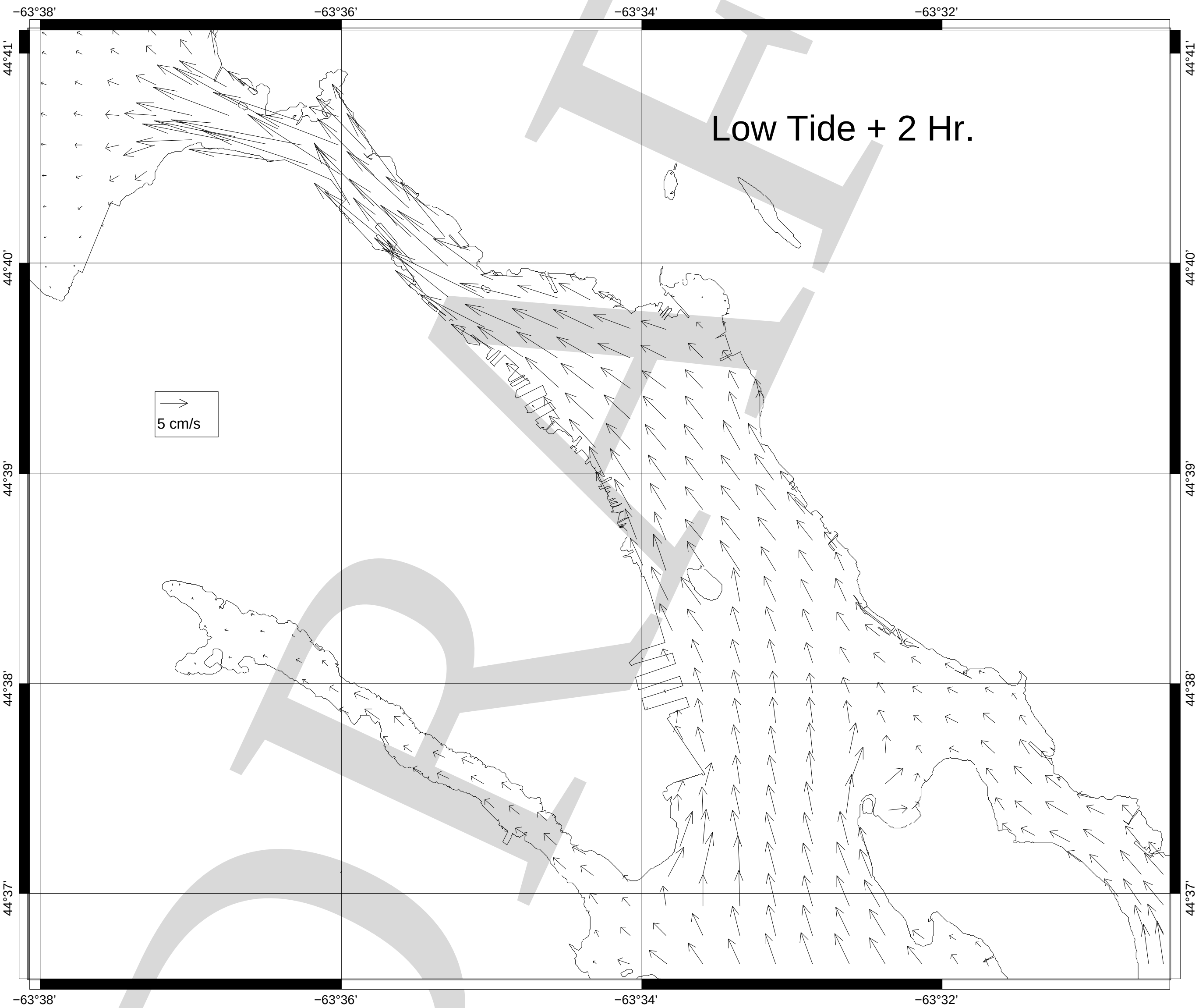

Figure 21: Inner Harbour, two hours after low tide

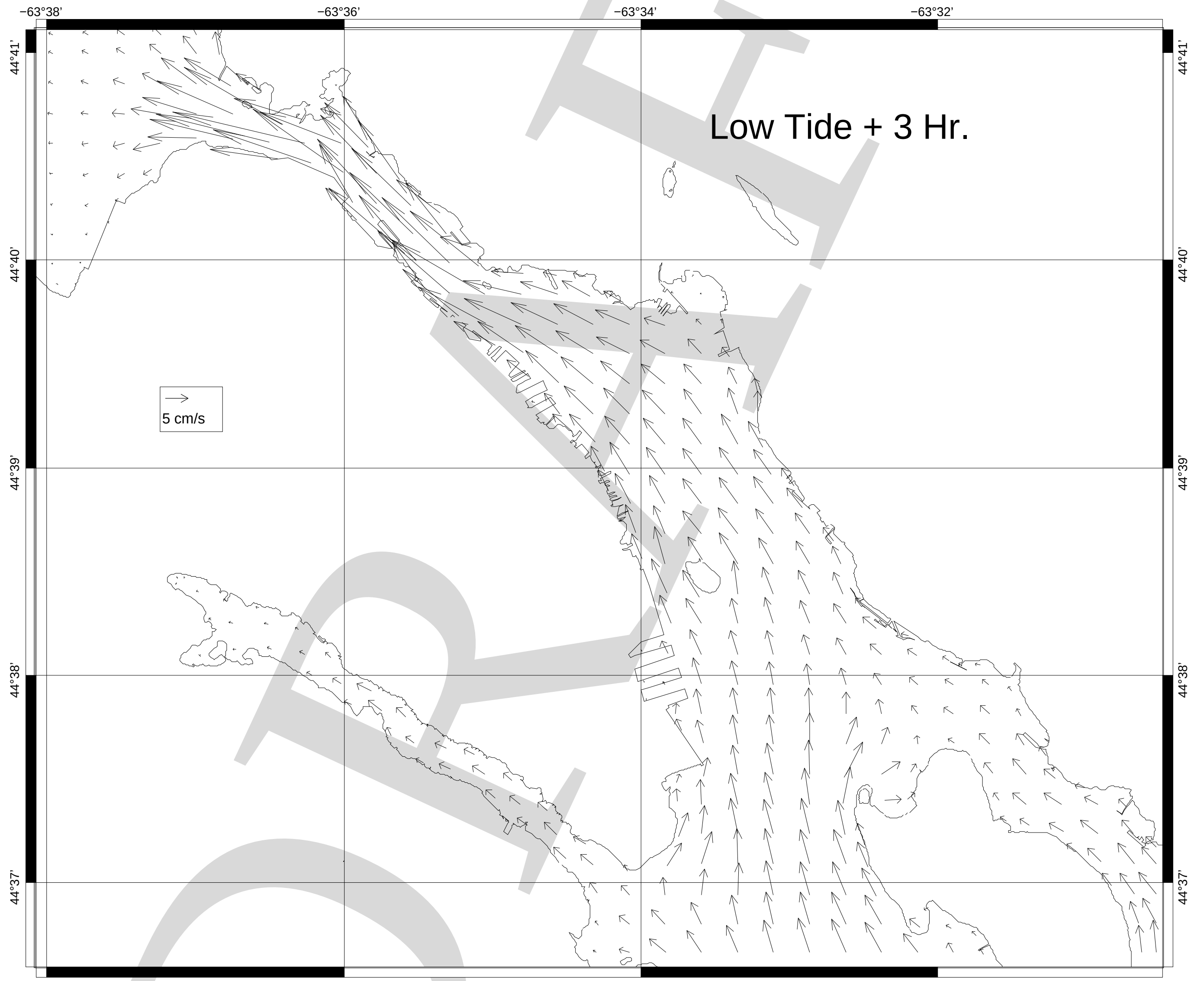

Figure 22: Inner Harbour, three hours after low tide

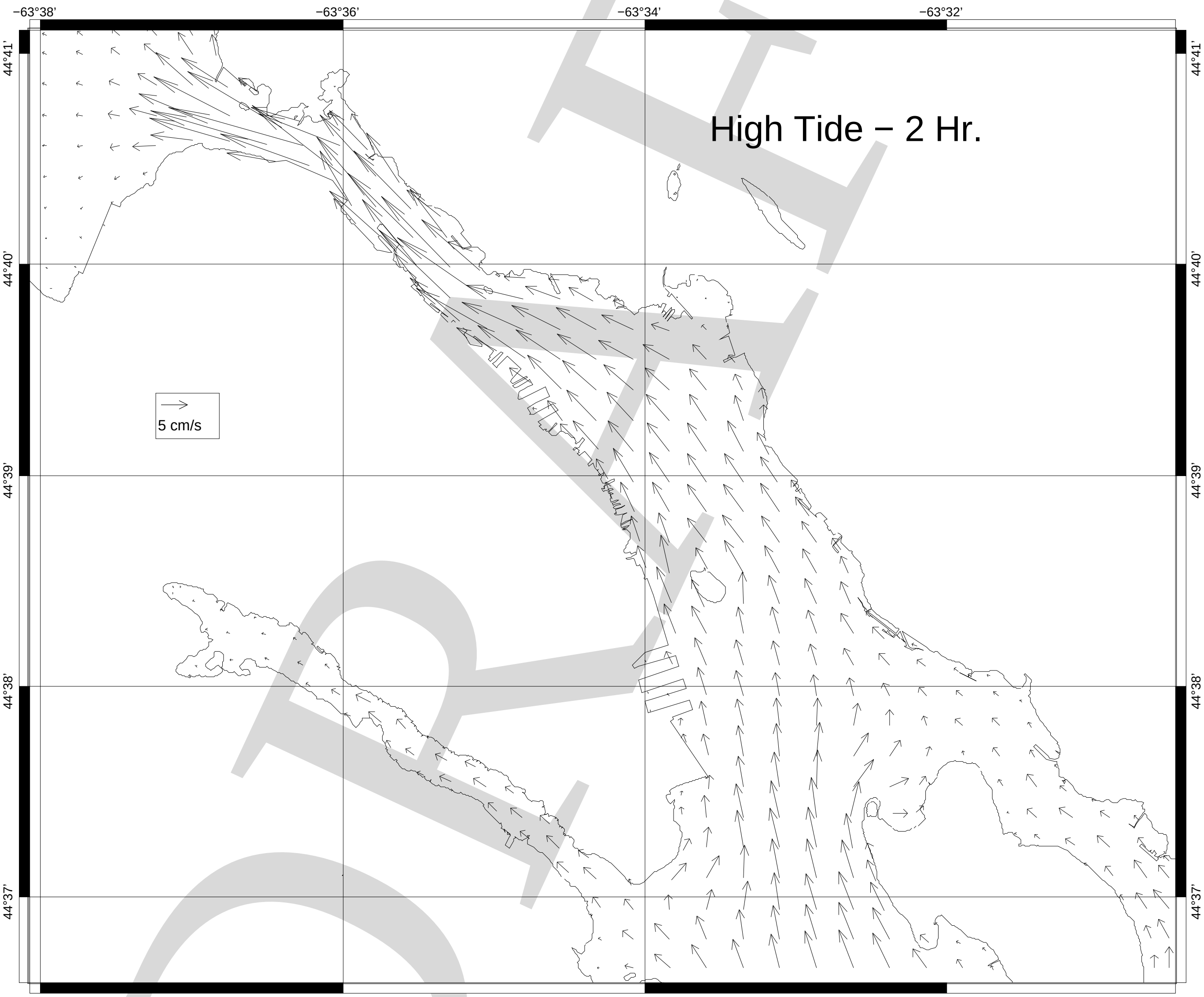

Figure 23: Inner Harbour, two hours before high tide

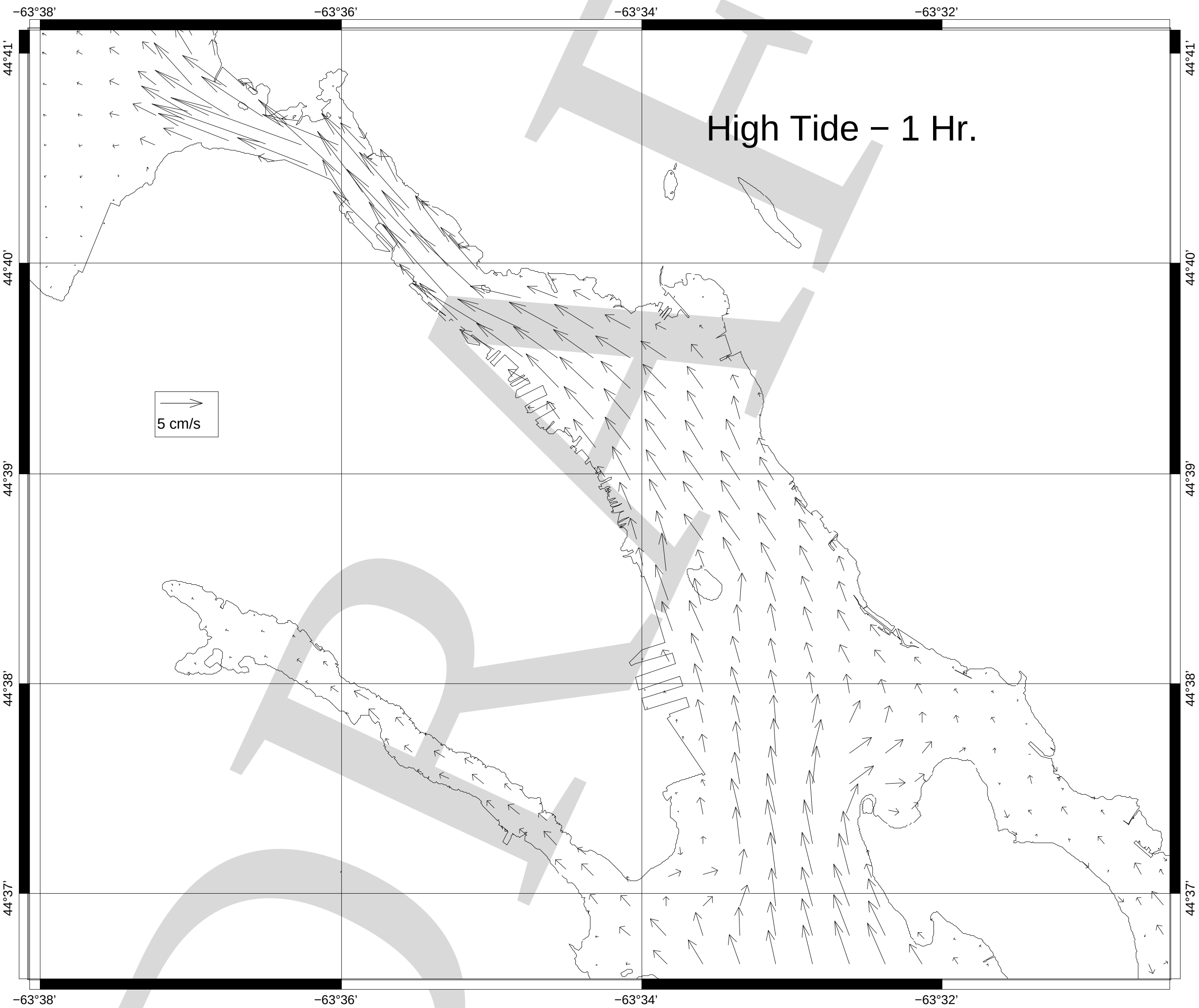

Figure 24: Inner Harbour, one hour before high tide