Friends of Port Mouton Bay
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Carter's Beach, looking out toward Port Mouton Island Basin. (Photo: Linda Ross)

Port Mouton Bay Summer 2008 Currents - from the perspectives of Settling, Diluting or Dispersing Fish Farm Wastes

The open-net mode of salmon farming depends on exporting waste discharges over a large, distant area – fecal particles, food particles, dissolved nutrients with their accompanying oxygen demand, and other chemicals. For this waste dispersal to actually happen, the requirements are that the waste particles remain suspended in the water column and drifting, that new, good quality water continually flow across the farm site to mix and dilute these wastes, and that the currents flow away from the farm site, preferably offshore to the open sea. To summarize these attributes of particles suspended and drifting, abundant supply of diluting waters, and transport and dispersion offshore, we will use the term, high flushing rate.

I. Background

There are concerns, based largely on the experience of the salmon farm site at Spectacle Island, Port Mouton Bay, that the proposed expansion near Port Mouton Island would also degrade the established ecosystem. There is the hypothesis that a root cause of ecosystem disruption and degradation in Port Mouton Bay is that the flushing rate is too low to adequately suspend, dilute and disperse the wastes. The preponderance of current meter data available for Port Mouton Bay is for winter, a season when wind energy tends to be strong, driving currents to be stronger, and, possibly, flushing rates increased.

There are some current meter data available for August, 2002, but these are suspect and recommended to be used only with caution (DFO, 2007).   Recognizing this data gap for summer measurements, Friends of Port Mouton Bay initiated requests to the Department of Fisheries and Oceans (DFO) and Nova Scotia Fisheries and Aquaculture (NSFA) for a collaborative project whereby a DFO current meter would be installed at Spectacle Island for two to four weeks in summer, a NSFA current meter installed off Port Mouton Island at the same time, and Friends of Port Mouton Bay (FPMB), with volunteered lobster boats and crews, would track drogues over a tide cycle (12.5 hours) near Port Mouton Island at least twice during the current meter deployment period.   A drogue consists of a 'window-blind' sail held at the desired depth by a rope from a float on the surface; as the parcel of water around the sail moves, the drogue moves with it and can be tracked from the surface float. NSFA agreed to participate. DFO Habitat Management declined on grounds that summer conditions could be predicted from existing winter observations.

The concept for the project was to combine the time coverage of the current meter data the with the spatial coverage of drogues tracked through a tidal cycle of 12.5 hours to produce pictures of the current patterns in Port Mouton Island basin. The current meter provides excellent time (readings every 10 minutes) and depth (0.5m intervals throughout the water column) coverage, but is limited spatially to the one position where the instrument is moored. Plots of drogue tracks indicate the spatial patterns of currents over the time that the tracking was continued. For example, if the current meter showed that currents had veered and waters were drifting over the farm site for a second time, and if the drogues drifted in a closed loop, as happened in March 2007 (FPMB, March 2007), these would be indicators of a low flushing rate because even if particles remained suspended, the dilution would be limited by the recirculation of 'used' water, and be evidence of retention of wastes in the vicinity of the farm site, at least during that tide cycle.

The program was adjusted for one instead of two current meters; the NSFA instrument was moored on the existing farm site at Spectacle Island from June 17 to July 3, 2008. From July 3 to July 18 it was moored at the proposed site off Port Mouton Island (Figure I-1). FPMB, using lobster boats, tracked six drogues from 1300 to 0130 on July 4-5, and from 0630 to 1900 on July 12. Three drogues were set at 3 m depth, and three at 10 m depth. If a drogue ran aground, the practice was to retrieve it, move it to the nearest place where depth was adequate, release it and label the data as constituting a new trial. After the recovery of the instrument, reports from NSFA indicated that there could be problems with the current meter data, that the instrument may not have performed properly. Therefore FPMB, concerned that insufficient summer data would be collected, doubled their efforts and their data set by tracking six 10 m drogues throughout a tide cycle on July 31 and on August 11, for a total of 50 hours of summer 2008 drogue data.

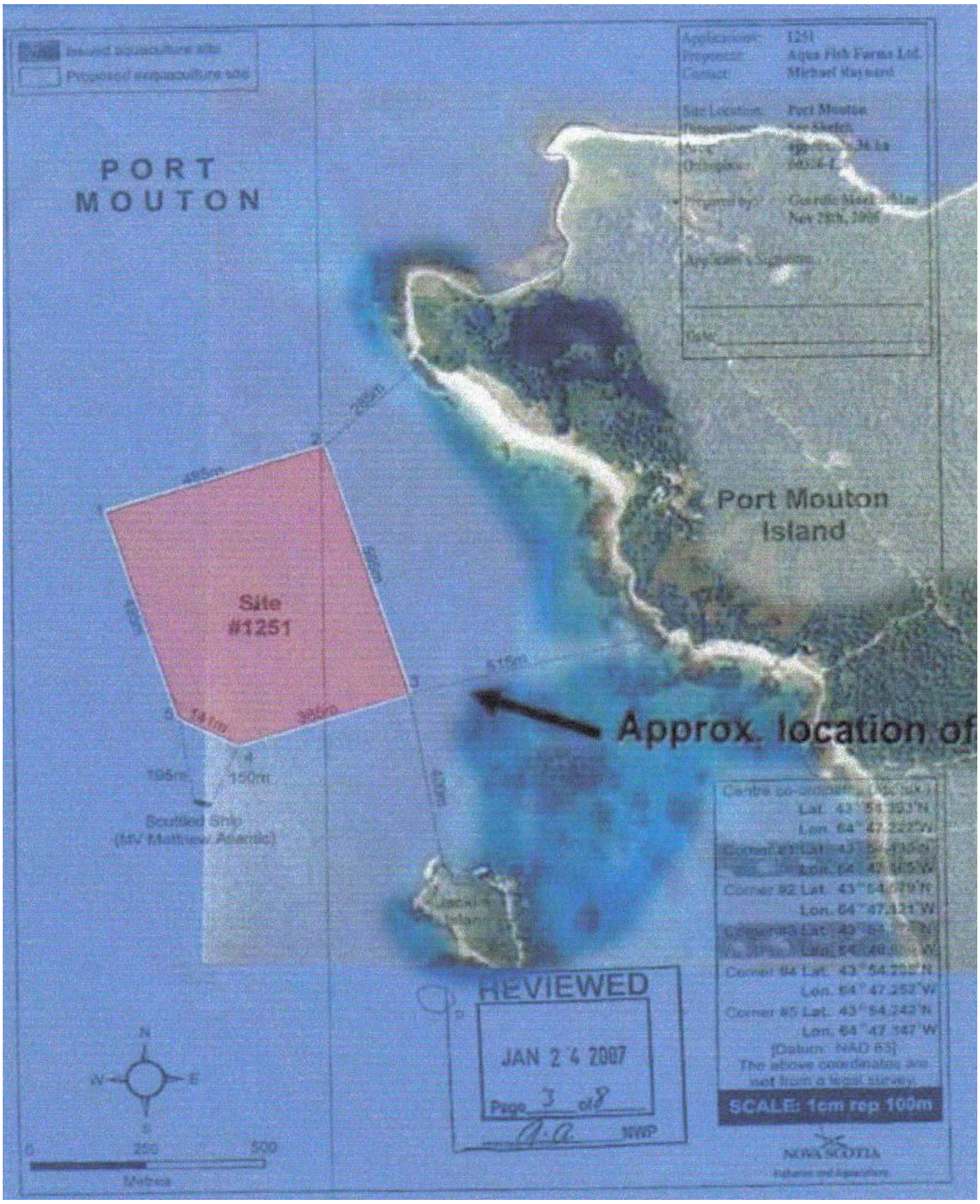
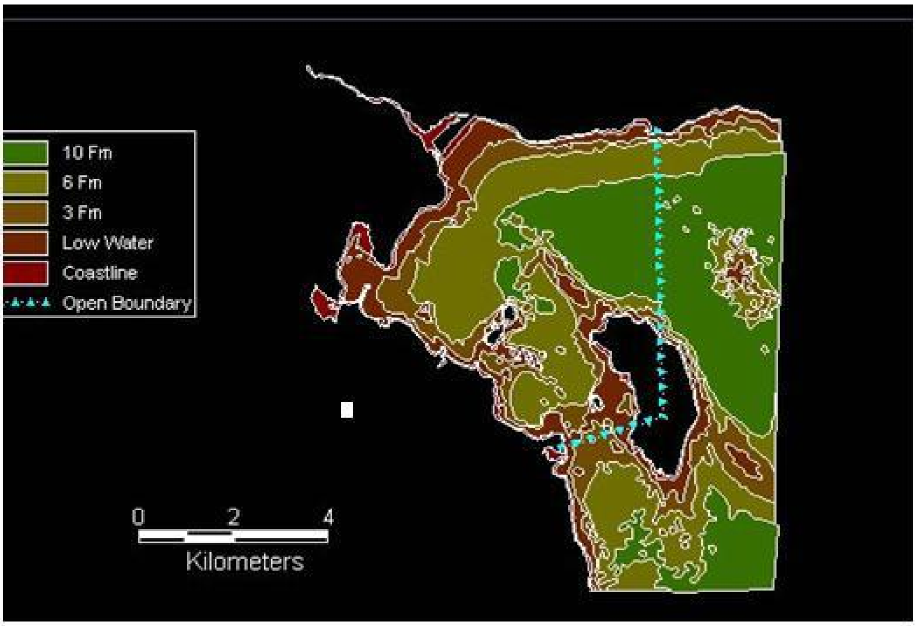


Figure I-1 Chart of the proposed site off Port Mouton Island.

The following chart, Figure I-2, shows that the area west of Port Mouton Island is a basin with only a narrow access channel at depth, northwest of Spectacle Island. Basins are often associated with infrequent flushing and accumulation of debris such as wastes on the bottom. This basin apparently retained seabed drifters released by FPMB in winter, 2007. They reappeared on the nearby shores a few months after release and shortly after a northeast wind event.

Figure I-2 Bathymetry of Port Mouton Bay, showing the basin (olive green) between Spectacle and Port Mouton Islands (black)



II. Results

In this section we compare the current meter and drogue results using the figures in the Appendix. Figure A.1 and A.2 show that the overall residual currents at the proposed site tended to flow north northeast at 3 m depth and southeast at 10 m depth. The drogue trial of July 4-5, Figures A.5 and A.6, coincided with the last eight hours of the 'early July 4' tide cycle (Figure A.1,orange, near the bottom of the chart) and the first four hours of the 'later July 4' tide cycle (Figure A.1, yellow, connected to the orange trace). When the drogues were near the site, they corresponded reasonably well with the current meter; speeds were relatively low at 3 m and 10 m. As the drogues moved north, currents became stronger, moreso at 3 m than at 10 m.

The July 12 drogue trials coincide with the last ten hours of the 'early July 12' tide cycle (Fig. A.3, red, bottom of chart) and the first two hours of the 'later July 12' tide cycle (Fig. A.3, orange, connected to the red trace), as well as Figure A.4 for 10 m on July 12 where the red and orange are at the top of the chart. The above traces can be compared with the drogue charts, Figures A.7 and A.8. The correspondence between current meter plots and drogue plots is reasonable. At 3 m depth, the strong flow of drogues northward late in the trial is reflected in the long distance orange trace in Fig. A.3, a feature not seen in drogue (Figure A.8) or current meter (Fig. A.4) at 10 m.

The final pair of drogue charts are Figures A.9 and A.10 for 10 m drogues. There were no accompanying current meter records. The drogue charts, for July 31 and August 11 were generated after the current meter had been recovered. The drogues for July 31 in Fig.A.9, were released in an approximate line from red to yellow, The yellow drogue was closest to shore and moved slowly north. The other drogues drifted south, travelling in a large arc, remaining within the basin except for a two-hour period. The exception occurred in the morning when the large vertical range of the tides grounded five of the drogues on rim at the southeastern edge of the basin. A portion of the waters being traced by these drogues likely left the basin. The tidal current reversed soon afterward and could have brought some of these waters northwestward again. For the rest of the time of observation on July 31, these drogues travelled clockwise around the basin.

On August 31, two 10 m drogues, Fig. A.10, drifted through the large radius arc, as had been seen on July 31. Other drogues made smaller circuits and recirculated within a single tide cycle.

III. Dispersal of Wastes

Would dispersal of wastes from an open-net fish farm be consistent with a resilient, sustainable human-nature interaction in Port Mouton Bay? This is a fundamental question. Is the flushing rate high enough here to support open-net technology? There are three processes that are relevant to dispersal of these wastes in Port Mouton Bay – *settling* of feed and fecal particles and flocculants, *dilution* of these waste waters, carrying dissolved nutrients and other chemicals, with a supply of uncontaminated water, and *transport* of these waste waters out to sea.

A. Settling of particulate wastes

***Summary**: There were slow currents observed for more than 40% of the time over a tide cycle at places within the Port Mouton Island basin but not at the centre of the proposed site. Currents less than 2 cm/s for more than 40% of the time were observed for two drogue trajectories on July 4-5, one drogue trajectory on July 12, and one drogue trajectory on August 11. The expectation is that wastes would accumulate in the basin, in pockets where currents are frequently slow. Therefore based on the lobster fishermen's catch survey in spring 2007 indicating far-field effects around the existing site likely attributable to distributed wastes, the suitability of this proposed site for aquaculture is brought into question because of concern for the lobster fishery there.*

In terms of settling particulates at Spectacle Island, in summer 2008 the current meter shows speeds less than 2 cm/s more than 40% of the time, rating a C, and in winter 2007-08 those speeds occurred 27% of the time, rating a B-.

Sedimentation rate depends on current speed as well as density, shape and size of the particles. There is a criterion from the Decision Support System (DSS) for siting aquaculture facilities (Hargrave, 2002), relating to fish farm wastes, stating that currents of speed less than 2 cm/s for more than 40% of the time represent conditions of unacceptable settling and accumulation of wastes.

Speeds from the current meter and from the drogue trajectory charts were sorted in histograms and the results corresponding to the DSS criterion are listed in Table III.1. As an example, Figure III-1 is the histogram for the current meter during two tide cycles on July 4-5 at 10 m depth. It indicates that for 21% of the time during that tide cycle the speed was below 2 cm/s. (The entire record for twenty-five tide cycles yielded 20%.) This rates a B- in DSS scoring which does reduce the score but is not a pre-emptory disqualifier.

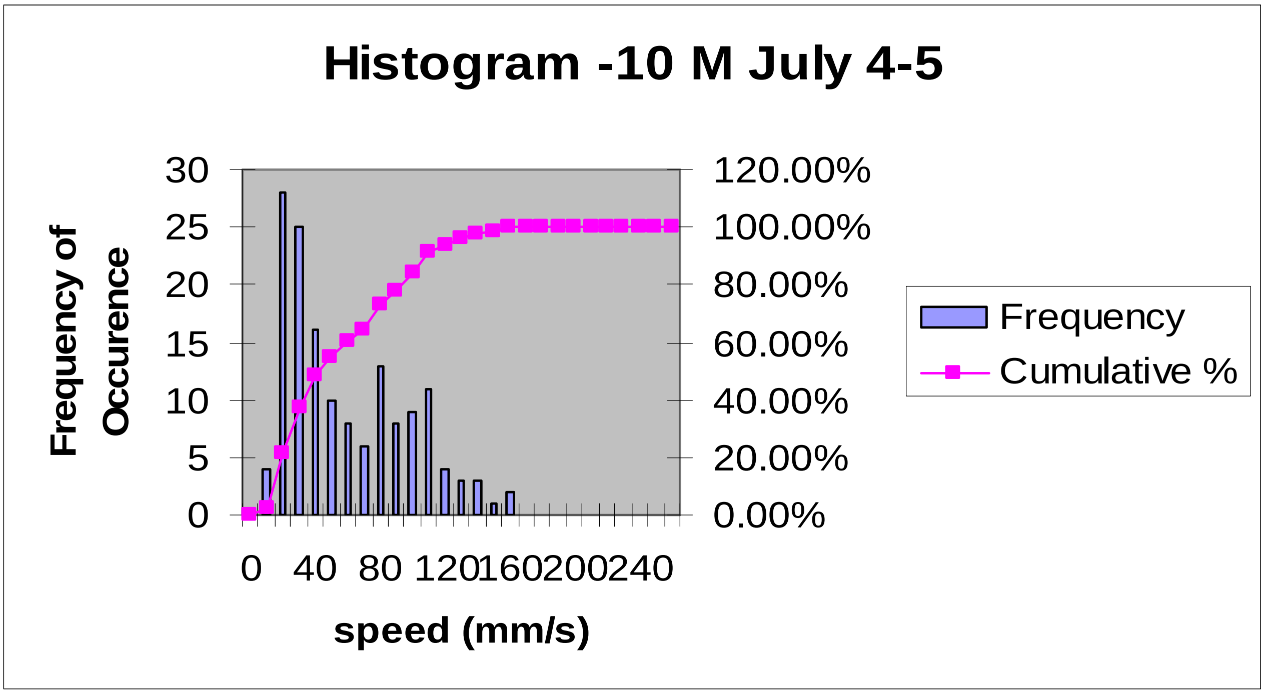


Figure III-1 Histogram of current meter data

Table III.1 The percentage of time for speed (v) less than 2 cm/s and the corresponding DSS score, where C evaluates the site as unsuitable.

Date	Current Meter or Drogue, Depth (m)	% of tide cycle v< 2 cm/s	DSS Score
July 4-5 Large tide	c/m 14 m	15	B+
	10	21	B-
	5	8	A
	3	10	B+
	Drogues		
	R3 3 m	7	A
	R4 3	0	A
	R5 3	0	A
	P1 10 m	47	C
	W1 10	33	B-
	W3 10	60	C
July 12 Neap tide	c/m 14	15	B+
	10	32	B-
	5	12	B+
	3	21	B-
	Drogues		
	R3 3 m	26	B-
	R4 3	26	B-
	R5 3	37	B-
	P1 10 m	56	C
	W2 10	21	B-
	W3 10	39	B-
July 31 Large tide	No current meter deployed		
	Drogues		
	R3 10 m	40[1]	B-
	R4 10	16	B+
	R5 10	10	B+
	GR1 10	11	B+
	O4 10	7	A
	G1 10	5	A
Aug 11 Neap tide	No current meter deployed		
	Drogues		
	R3 10 m	26	B-
	R4 10	50	C
	R5 10	0	A
	GR1 10	37	B-
	O4 10	35	B-
	W3 10	0	A
Spectacle Is			
June 25/08 & July 2/08	c/m 7 m	41, 42	C

[1] grounding may have interfered

Date	Current Meter or Drogue, Depth (m)	% of tide cycle v< 2 cm/s	DSS Score
Dec 18/07 – Jan 18/08	c/m 10 m	27	B-

At Spectacle Island, average 10 m speeds are 3.1 cm/s in summer and 4.3 cm/s in winter. In terms of settling particulates, in summer the current meter shows speeds less than 2 cm/s more than 40% of the time, rating a C, and in winter those speeds occurred 27% of the time, rating a B-. The one month winter 2007-8 period of mooring was particularly energetic and included 15 days with winds in the range of 30-57 km/h.

The results in Table II.1 are derived from histograms for current meter signals (two tide cycles on days when drogues were deployed) and drogues (one tide cycle on days when drogues were deployed). The current meter measurements at the centre of the proposed expansion site at selected depths showed slow speeds for as much as 32% of the time. Though reducing the score, this frequency of occurrence of current speed less than 2 cm/s would not by itself disqualify the site according to the DSS criterion.

Some of the drogues at 10 m depth traced trajectories exhibiting slow speeds for more than 40% and as much as 60% of the time. These results suggest that there are sheltered areas in the basin where drift speeds are low and settling of particulates would occur.

B. Dilution of nutrients, other chemicals, and suspended particulates

Summary: *Based on both current meter data (Dec 2007 –Jan 2008, and July 3-17, 2008) and drogue data (March 2007, July 4-5, 2008 and July 12, 2008), effective dilution is expected to be reduced around the proposed farm site because recirculation occurs and would act to raise concentrations.*

Dilution of wastes in waters on the farm site depends on the distance from shore, rate of discharge of wastes, mixed layer depth, the rate of supply of diluting water, and background concentrations in diluting water. Dilution is counteracted if the waters recirculate because repeating the exposure to the farm source of wastes raises the concentrations. Oxygen demand provides an example. If recirculation through the farm site occurs, the oxygen depletion is re-inforced by the additional injection of oxygen demand.

The series of diagrams in the Appendix illustrate recirculation around the proposed farm site and retention of waters within the Port Mouton Island basin. Figures A.1 to A.4 are progressive vector plots of the current meter record for various depths at Port Mouton Island, July, 2008. Whenever the trajectory crosses on itself, making a loop, or re-enters the approximately 500 m x 600 m lease area, the inference is that a parcel of water has made a repeat passage over the farm site, picking up new injections of waste particles. Some small loops indicate recirculation within an hour, some within a tide cycle of 12.5 hours, and some large loops have time scales of two tide cycles or more. These ~25 hour loops tend to have a space scale of approximately 2000 metres, the scale of the basin.

The repeat crossings of paths in the current meter record represent probable recirculation over the proposed farm site, with new wastes being incorporated, raising their concentrations in the water. Loops in the drogue trajectories on the farm site represent actual recirculation.

Figures A.6, A.7 and A.8 show cases where recirculation of drogues over the proposed site has occurred. On July 4, Fig. A.6, one 10 m drogue recirculated over and one stalled approximately within the farm site. On July 12, all drogues, at 3 m and at 10 m, Figs A.7 and A.8, passed over the farm site, or close to it, more than once. On July 31,

Fig. A.9, and August 11, Fig. A.10, no drogues recirculated over the farm site.

A power spectrum analysis of the 10 m signal from the current meter showed a prominent peak at 12 hours period and a larger peak at 25 hours period. One could speculate that there are two modes in Figure A.10 - one mode in which drogues travel around a 'short track' within the basin, almost back to their starting point in one tide cycle, and a second mode in which drogues travel just halfway around the basin in one tide cycle. The main point is that the 10 m drogues, released from a variety of locations and tide stages, were found for the most part to remain within the basin. Transport to the open sea was not a predominant pattern. Another feature is that several of these 10 m drogues reached the western limits of the basin behind Spectacle Island. Surface drifters discussed in FPMB (2008) travelled from the Port Mouton Island site west to shorelines west of Spectacle Island.

Other drogue trials (of longer duration) could be undertaken – releasing drogues along a basin diameter line to see if the whole line 'wheels' around with a period of two tide cycles, and releasing drogues hourly from the farm site.

C. Transport away for wide-spread dispersal – or not

***Summary**: That the 3 m drogues, with dissolved nutrients, would escape from the basin by passing over the rim of submerged ledges was anticipated. It is the 10 metre drogues which are more constrained by the bathymetry; they circulated and were retained within the basin in most cases rather than drifting out to sea. The results imply that transport out to sea of sediment wastes in lower layers cannot be relied upon; it is possible that dissolved wastes in upper layers can be transported outside the basin.*

We note that the current meter data alone might lead an interpreter to suggest incorrectly that the southeastward currents at 10 m depth, for example, continued southeastward and flowed right out of the basin. The spatial coverage provided by the drogues shows that recirculation within the basin was the predominant mode experienced in summer 2008 with the current meter recording the currents on the eastern side.

The drogues are most valuable for revealing the transport away to the open sea – or not. The chart, Figure A.5, for July 4-5, 2008 during one 12.5 hour tide cycle, shows all three 3-metre drogues, which were released south of the current meter mooring (the aqua triangle), drifting toward the north and north east, and leaving the basin. The corresponding current meter record was in approximate agreement with these speeds and directions. No recirculation was indicated by these drogues; they dispersed.

In contrast, Figure A.6 the chart for 10 m drogues, for the same time period, shows the three deep drogues moving more slowly and remaining within the basin.

On July 12, Fig. A.7, the 3m drogues showed recirculation near the proposed site, then gathered speed and two of the three escaped from the basin. The 10 m drogues of July 12, Fig. A.8, remained within the basin, relatively near their line of release shown in black.

On July 31 and August 11, the 10 m drogue patterns were distinct from those of July 4 and 12 – large arcs were travelled instead of small, slow excursions. In most cases observed, the 10 m patterns, large or small scale, were contained within the basin.

IV. Conclusions:

The area west of Port Mouton Island is a basin with only a narrow access channel at depth, northwest of Spectacle Island. Basins are often associated with infrequent flushing and accumulation of debris such as wastes on the bottom. In this case the upper layers are transported in and out over the approximately 5 m deep rim; the lower layers are constrained.

Earlier drogue trials in March, 2007 (FPMB, 2007) at three metres depth produced trajectories that remained within the basin and approximated closed loops, suggesting a low flushing rate because of dilution being counteracted and transport out to sea not occurring. Winter current meter (10 m depth) data from mid-December, 2006 to mid-January 2007 also indicate recirculation at the farm-site (FPMB, 2007).

The summer 2008 combined current meter and drogue project provides a more complete evaluation of probable deposition of wastes, dilution, and transport in Port Mouton Island Basin. The correspondence between current meter data and drogue data is reasonable.

Our interpretation is that particles settle in the low speed areas existing in the basin, that dilution in the lower layers of the basin water column is impeded by recirculation, and that transport out to sea from the lower layers is not reliable – flow direction circles or reverses. The implications are that deposition can be expected to occur in pockets where current speeds are low enough, that waste waters in the lower layers of the water column will remain in the basin for considerable times, and that concentrations of sediment wastes could build-up in the basin until a northeast wind storm event occurs which will, in our experience, transport wastes toward shorelines of the National Park.

The currents and circulation found in Port Mouton Island basin indicate a low flushing rate unsuitable for salmon aquaculture – this combination of low flushing rate and massive discharges of wastes poses significant risk to the existing, productive ecosystem.

Acknowledgements:

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Ronald H Loucks, Ph.D.

Ruth E. Smith

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Appendix: Charts of Current Meter Progressive Vectors and Drogue Trajectories.

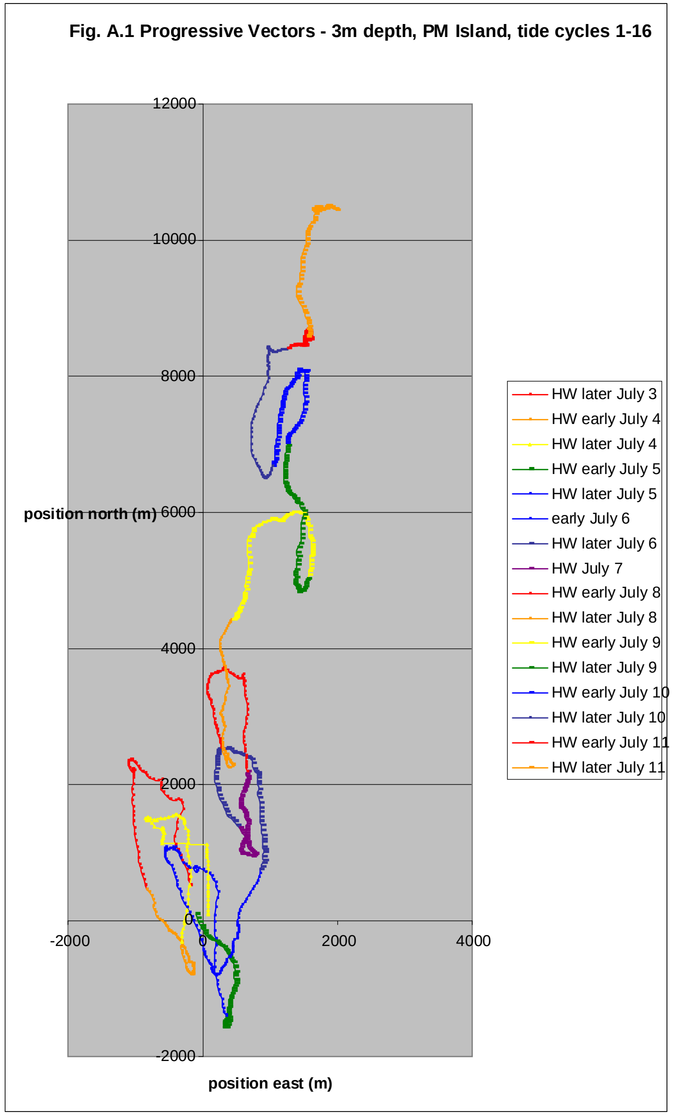

Fig. A.1 Progressive Vectors - 3m depth, PM Island, tide cycles 1-16
12000
10000
8000
position north (m) 6000
4000
2000
0
-2000
-2000
0
2000
4000
position east (m)
HW later July 3
HW early July 4
HW later July 4
HW early July 5
HW later July 5
early July 6
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HW later July 11

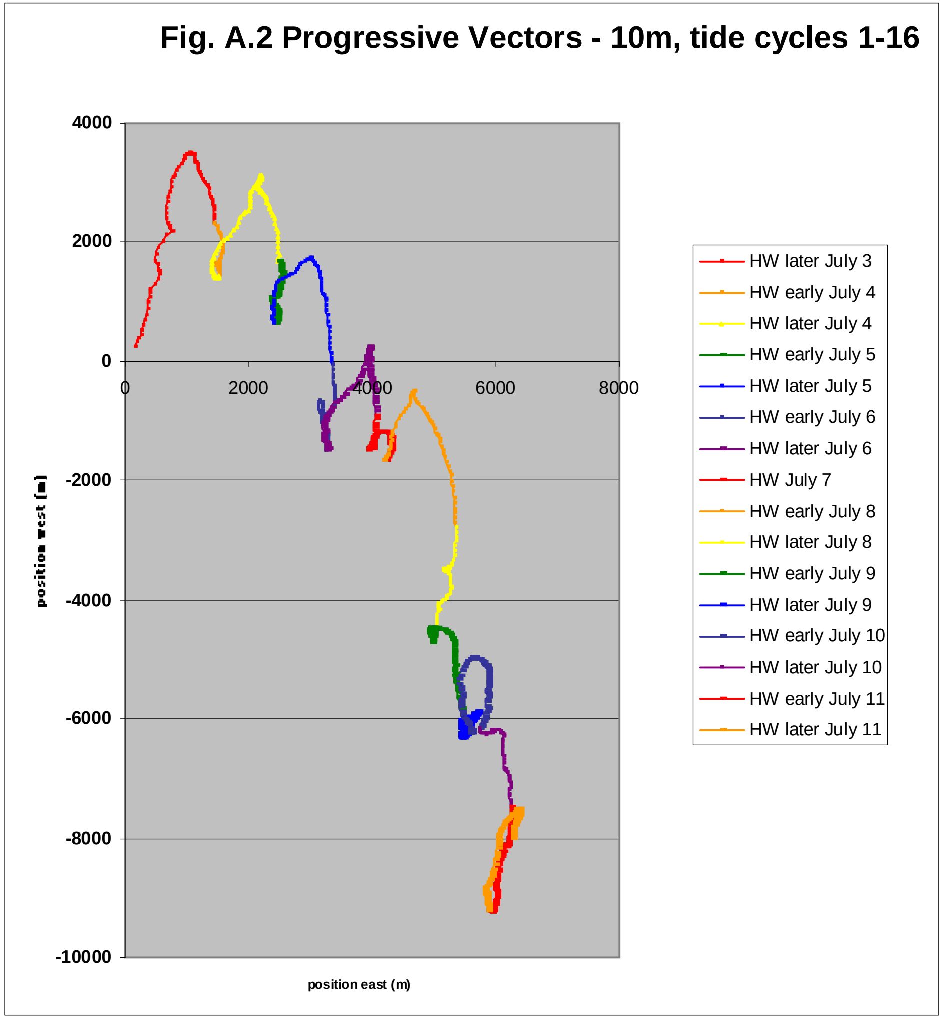

Fig. A.2 Progressive Vectors - 10m, tide cycles 1-16
4000
2000
0
-2000
-4000
-6000
-8000
-10000
0
2000
4000
6000
8000
position east (m)
HW later July 3
HW early July 4
HW later July 4
HW early July 5
HW later July 5
HW early July 6
HW later July 6
HW July 7
HW early July 8
HW later July 8
HW early July 9
HW later July 9
HW early July 10
HW later July 10
HW early July 11
HW later July 11

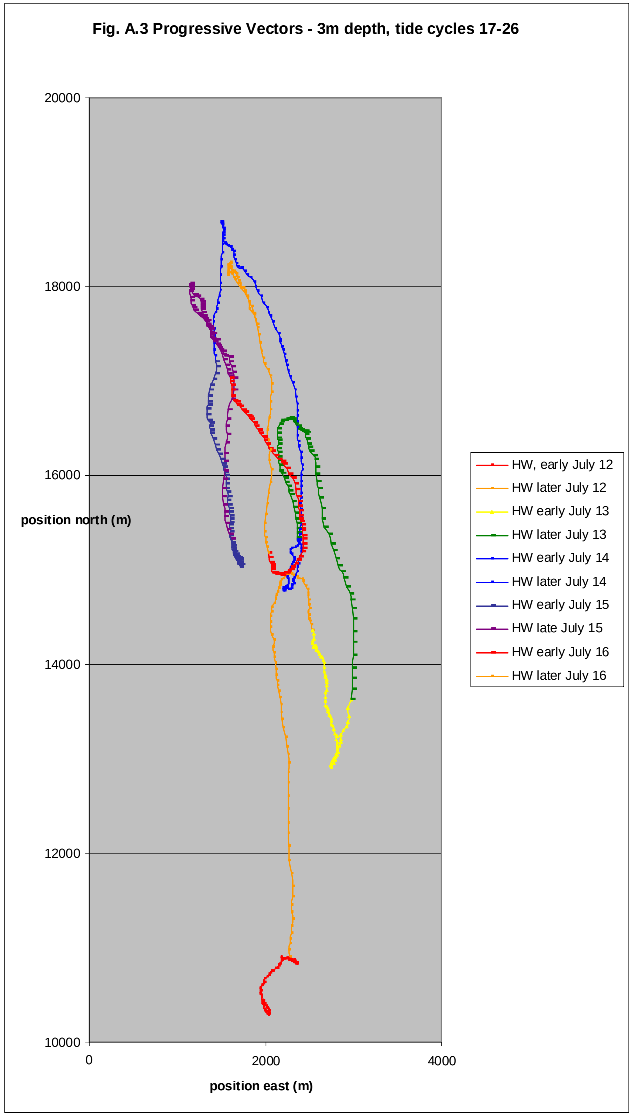

Fig. A.3 Progressive Vectors - 3m depth, tide cycles 17-26
20000
18000
16000
14000
12000
10000
0
2000
4000
position north (m)
position east (m)
HW, early July 12
HW later July 12
HW early July 13
HW later July 13
HW early July 14
HW later July 14
HW early July 15
HW late July 15
HW early July 16
HW later July 16

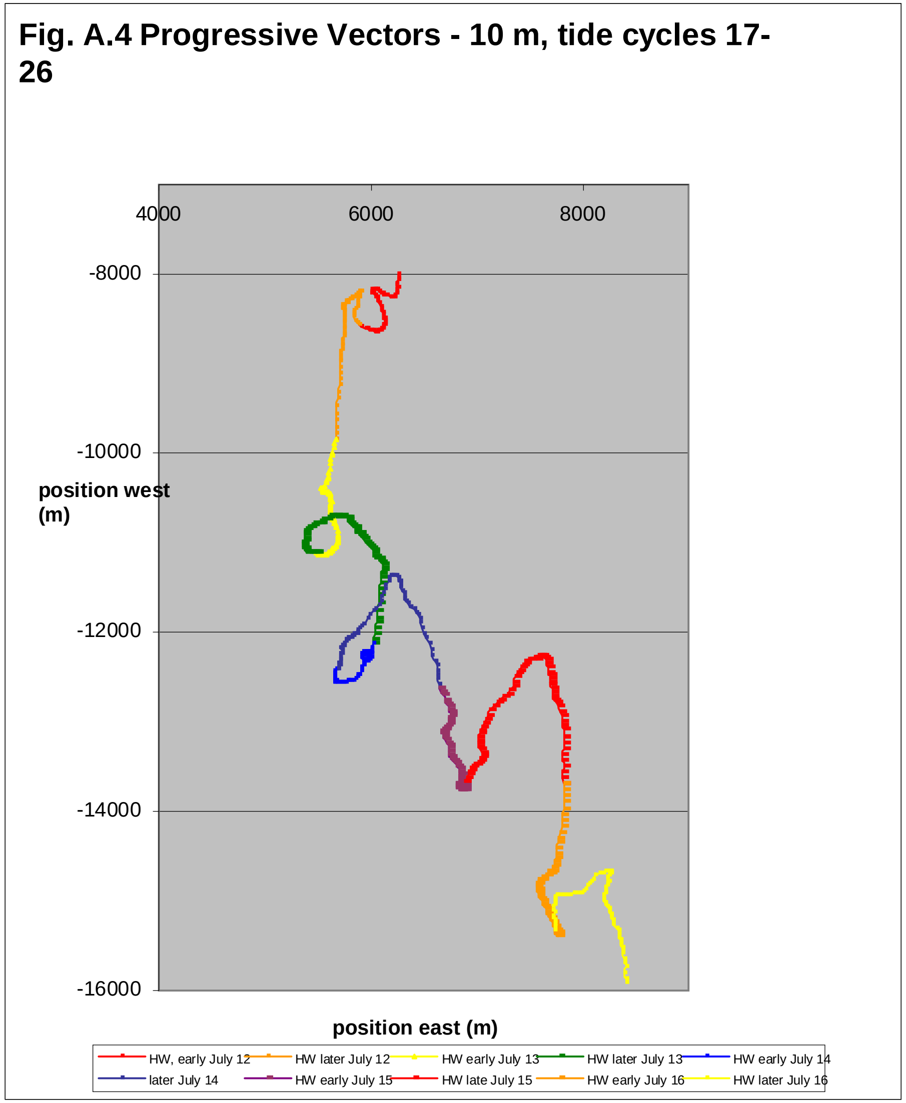

Fig. A.4 Progressive Vectors - 10 m, tide cycles 17-26
4000
6000
8000
-8000
-10000
-12000
-14000
-16000
position west (m)
position east (m)
HW, early July 12
HW later July 12
HW early July 13
HW later July 13
HW early July 14
later July 14
HW early July 15
HW late July 15
HW early July 16
HW later July 16

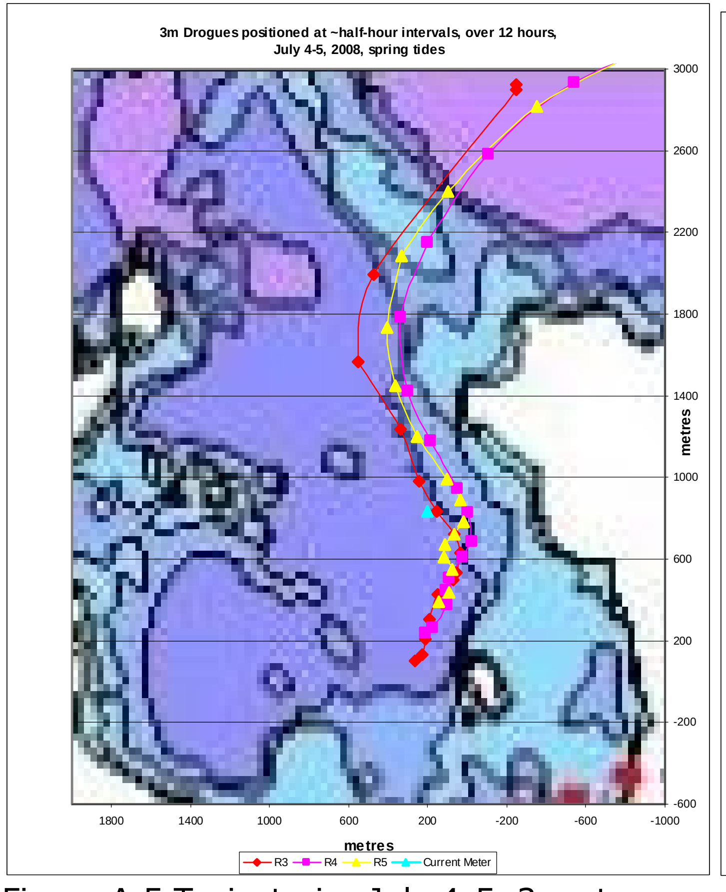

Figure A.5 Trajectories July 4-5, 3 metres

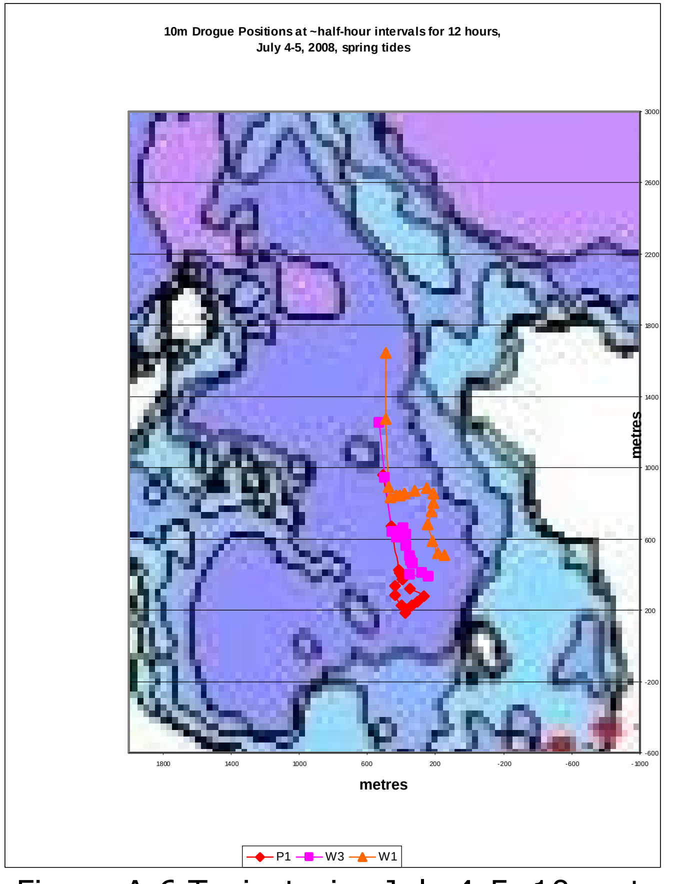

Figure A.6 Trajectories July 4-5, 10 metres

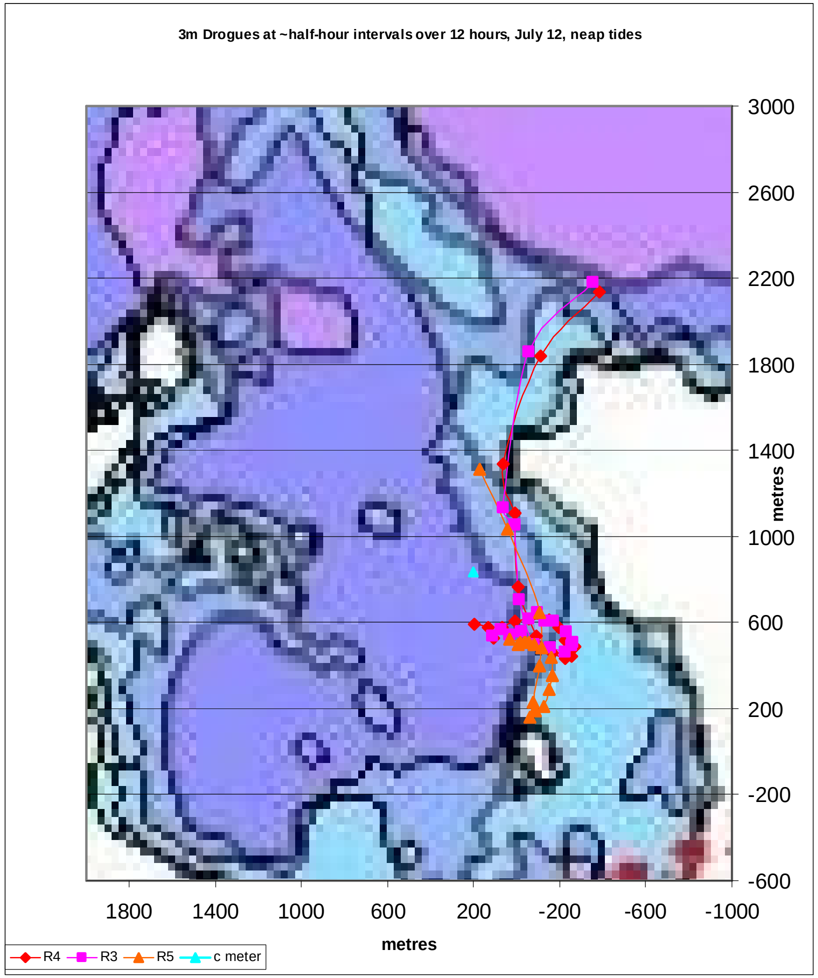

Figure A.7 Trajectories July 12, 3 metres

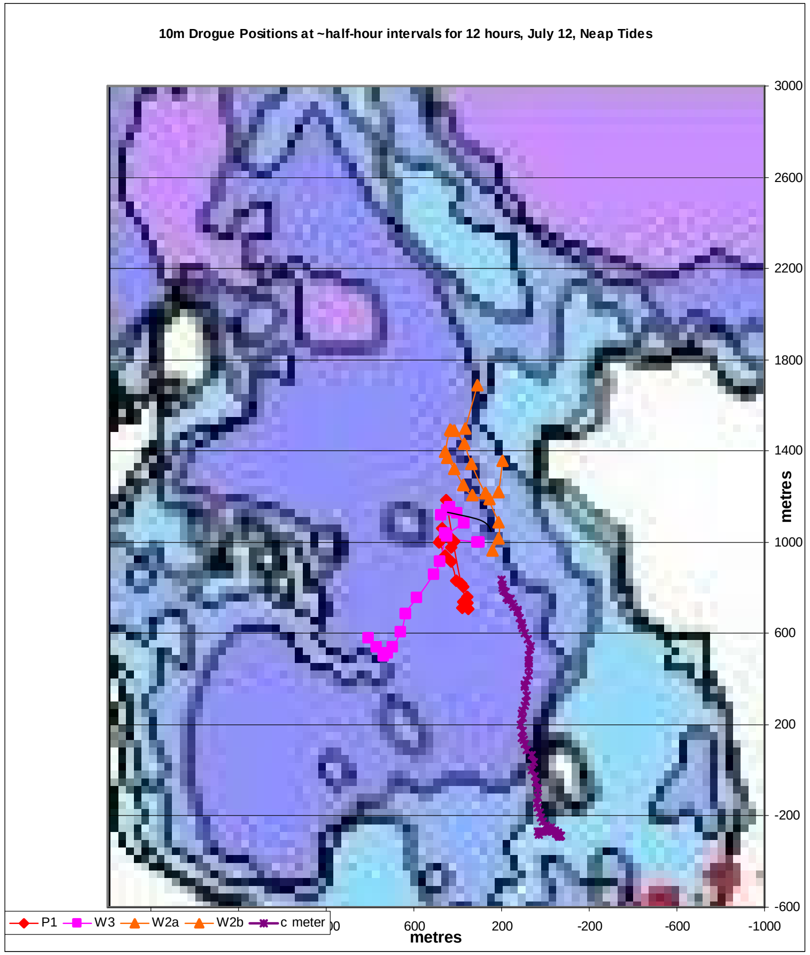

Figure A.8 Trajectories July 12, 10 metres

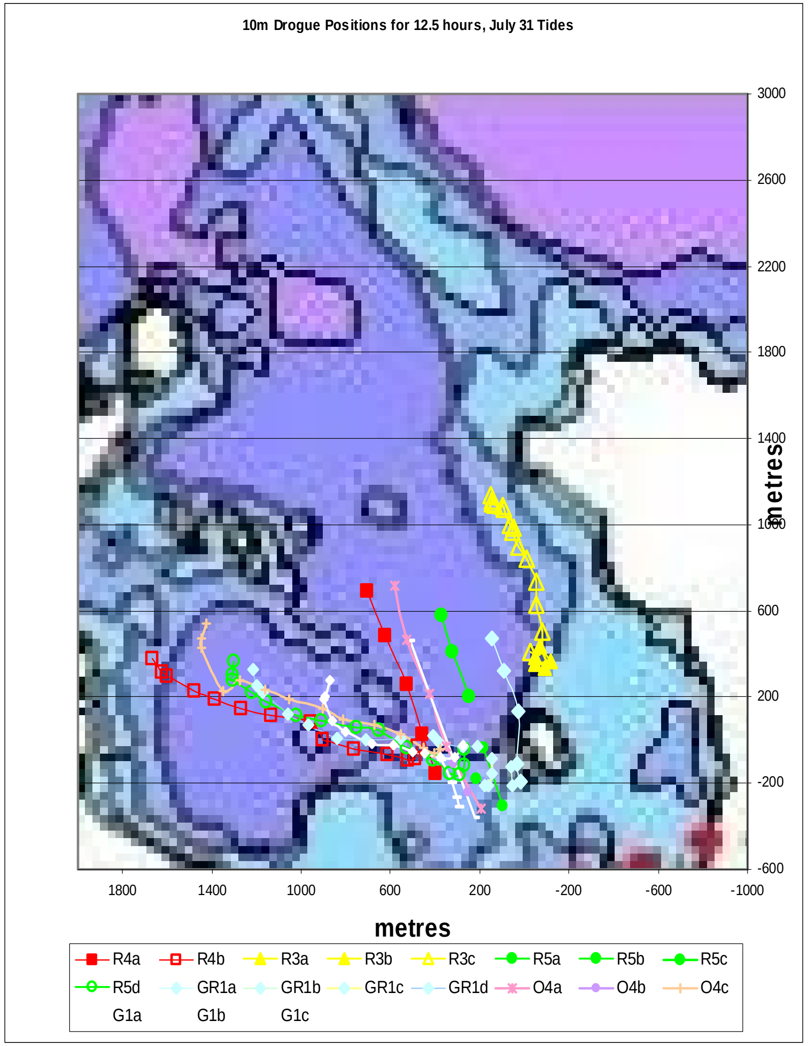

Figure A.9 Trajectories July 31, 10 metres

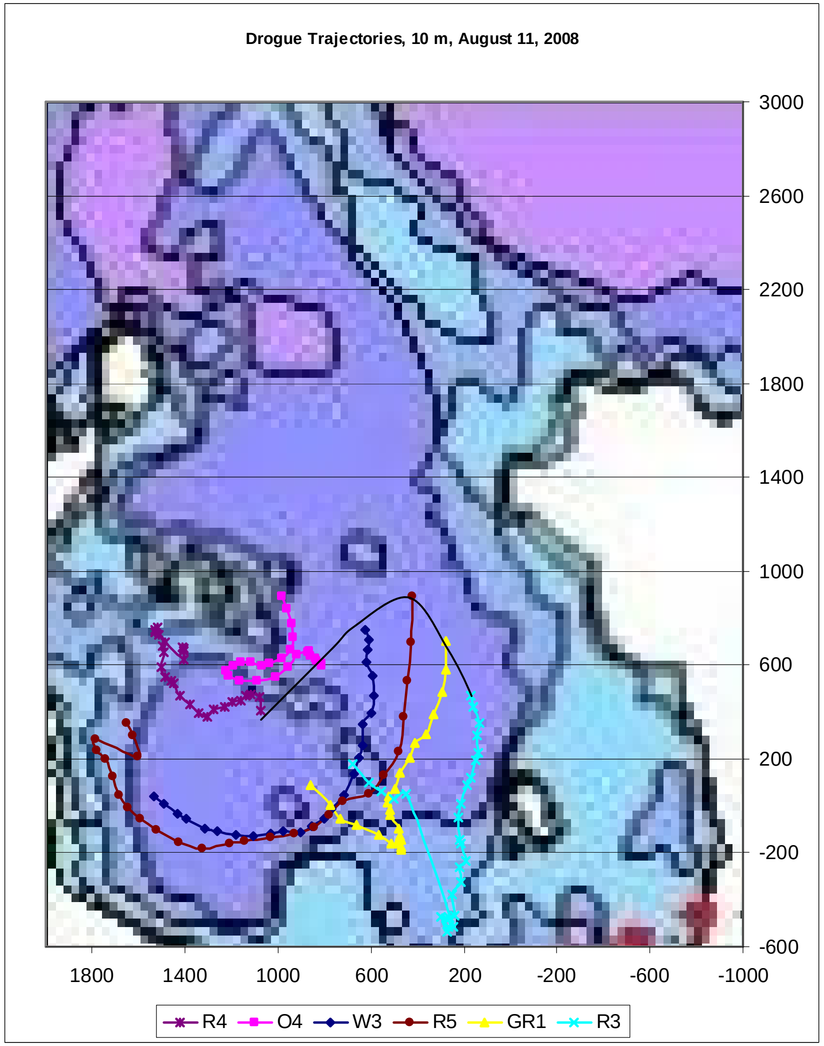

Figure A.10 Trajectories August 11, 10 metres