NRA NORTH WEST 84

SANDON DOCK WASTEWATER TREATMENT WORKS

OUTFALL SURVEY OCTOBER 1992

Marine and Special Projects
report MSP-93-07

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1) INTRODUCTION

The pollution resulting from the discharge of sewage and industrial effluent to the Mersey has been a long standing problem. The scale was such that in 1982, 48 outfalls were discharging crude sewage from Liverpool, Sefton and Wirral into the lower estuary (Alexander, 1982).

To alleviate this situation a number of sites were proposed for new sewage treatment works, including a reclaimed island in the estuary between Eastham and Garston (Watson, 1974). By 1978, an outfall culvert routed through Alexandra Dock had become the favoured option with a preliminary assessment of possible problems (Hydraulics Research Station, 1978). In 1979 Hydraulics Research carried out surveys in the Canada Deep (see figure 1) on spring and neap tides which concluded that in this locality there was no significant time at which the depth averaged ambient velocity was zero (Hydraulics Research Station, 1979).

During the planning investigations, the Liverpool North Docks site became available. This waterfront site with the advantages of minimum costs for interceptor sewers and effluent outfall, and ideally located for transporting sludge for sea disposal became the focus for a new sewage treatment works. Planning permission to build a sewage treatment plant on the site was granted in 1980.

Mersey Docks and Harbour Company expressed some reservations about the scheme, particularly any increase in the amount of suspended solids taken into the dock system via their impounding station. Work by the then Rivers Division of North West Water Authority showed that a release at Sandon should have no measurable effect on the pumping station (Rivers Division, 1981).

Hydraulic calculations (Dixon, 1984) recommended a covered spillway in the short term, with an outfall approximately 300/400 metres long discharging to the 10 metre contour line for the ultimate design flow. This gave theoretical initial dilutions of 40 at mean spring low waters and over 250 at mean spring high waters.

Survey work carried out by North West Water Authority on three neap tides and one spring tide, measured current velocities through the water column from three anchored vessels on a line extending from the sealed Sandon dock entrance to the 10 metre contour. Inflatable boats tracked the movement of Rhodamine B dye, simultaneously released from the inshore and off-shore vessels at approximately high water, half-ebb and low water. Aerial photographs of the dye patches were taken from a helicopter. This work again recommended an outfall extending to the 10 metre contour line (Rivers Division, 1984).

In 1985 North West Water Authority appointed John Taylor and Sons (consulting engineers) to undertake further investigations into the proposed outfall. Part of the work entailed a hydrographic survey carried out on two spring and two neap tides. After an assessment of the data they proposed that the outfall should discharge between the 10 metre and 15 metre contour lines (John Taylor & sons, 1987).

Sandon sewage treatment works became operational over the period of April to June, 1991. By the 6th of October 1992, 6 of the intended 28 outfalls had been connected to the sewage treatment works, the flow averaged over that day being 1.2 cumecs. The ultimate design flows to be discharged are a dry weather flow of 5 cumecs and a maximum flow of 13 cumecs (John Taylor & sons, 1987).

At present the discharge is via a covered spillway over the wall of Sandon half-tide dock into the estuary. A pipe has been installed culminating in a flange so that an outfall could be attached if deemed necessary.

This report summarises a survey carried out with the following objectives:

1) to determine the impact on the receiving waters of the present arrangement of 'through the wall' discharge,

2) to determine whether an outfall to deeper water is necessary.

3) to assess the hardware and methodology of a new data logging system supplied by Norcom Technology Ltd.

2) METHODOLOGY

The survey was undertaken off Sandon Dock sewage outfall on the 6th of October 1992, a neap tide.

TABLE 1 : ENVIRONMENTAL PARAMETERS

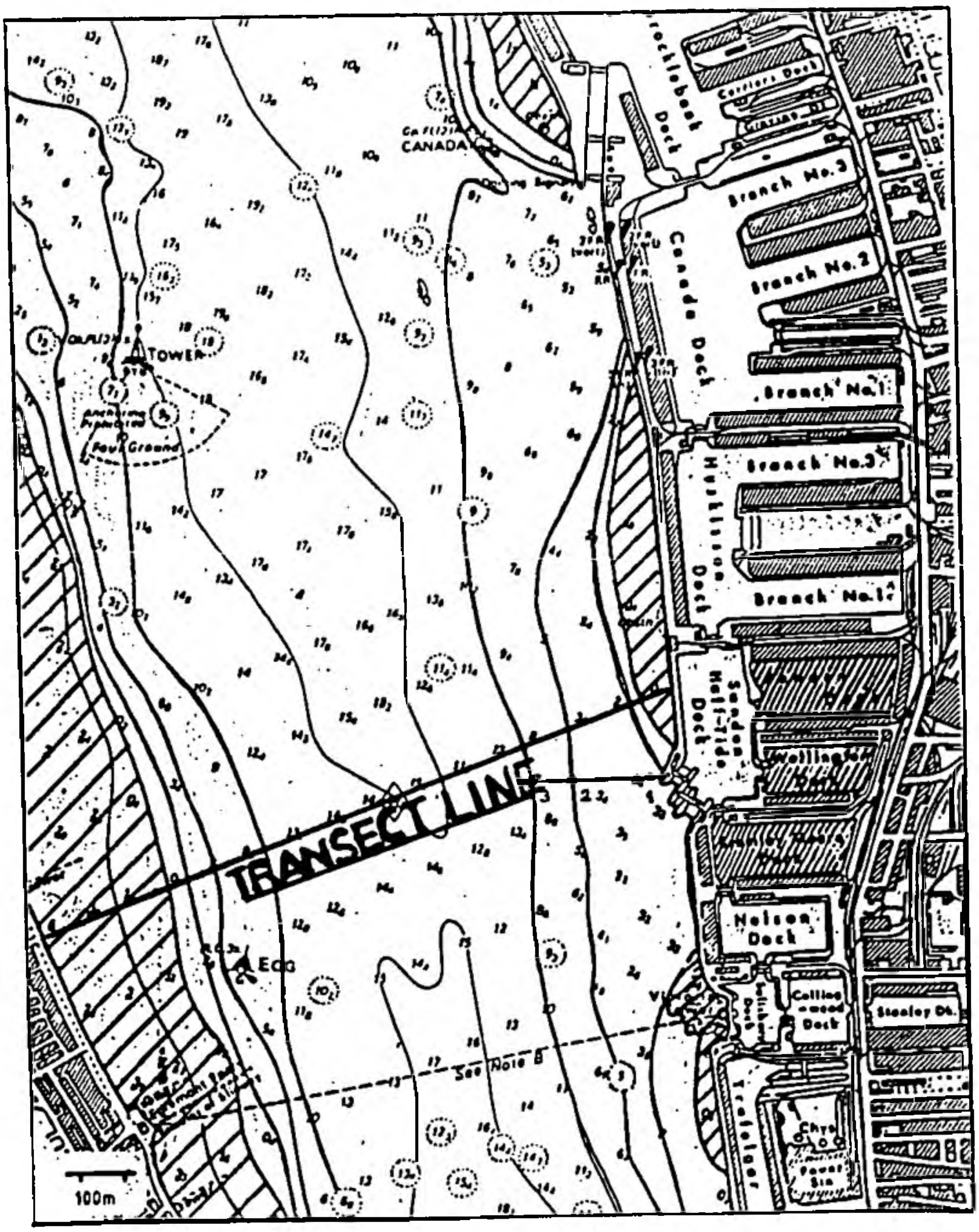
TIDE :	HIGH WATER		LOW WATER	
	TIME (BST)	HEIGHT (M)	TIME (BST)	HEIGHT (M)
	08.23	7.1	02.27	3.2
	20.42	7.6	14.59	3.3

WIND : TIME 14.00 TO 17.00
6-7 KNOTS N.N.E. (supplied by Mersey Docks
MAXIMUM GUST 17 KNOTS add Harbour Company)

Three 30 litre drums of Rhodamine B and two 1 litre bottles of B.globigii were injected into the final effluent channel, close to the settlement tanks to give the maximum distance before samples were taken before leaving the works. Samples were taken at approximately 30 second intervals, from 13.52 (BST) until 14.06, as the tracer passed. The dye emerged from the base of the spillway at 14.14 and was tracked by boat until 18.45.

The dye release was timed so as to enter the estuary approximately one hour before low water. This gives the longest period of low currents and therefore the minimum dispersion. (The initial dilution would probably be somewhat less on a Spring low water but would last for a shorter period.)

FIGURE 1 : THE LOCATION OF SANDON DOCK



A Turner Designs fluorometer, linked to a Norcom data logging system, was used to take real-time readings of Rhodamine concentration. Position data were derived from the Global Positioning System (GPS).

Samples were taken for B.globigii, total coliforms, E.coli and Rhodamine B. The results are summarised in appendix A.

Current velocity data from the 24^{th} and 25^{th} July, 1992, (similar neap tides), are also included. These data were obtained using an RDI Broadband Acoustic Doppler Current Profiler, from the transect line shown in figure 1.

3) SURVEY RESULTS

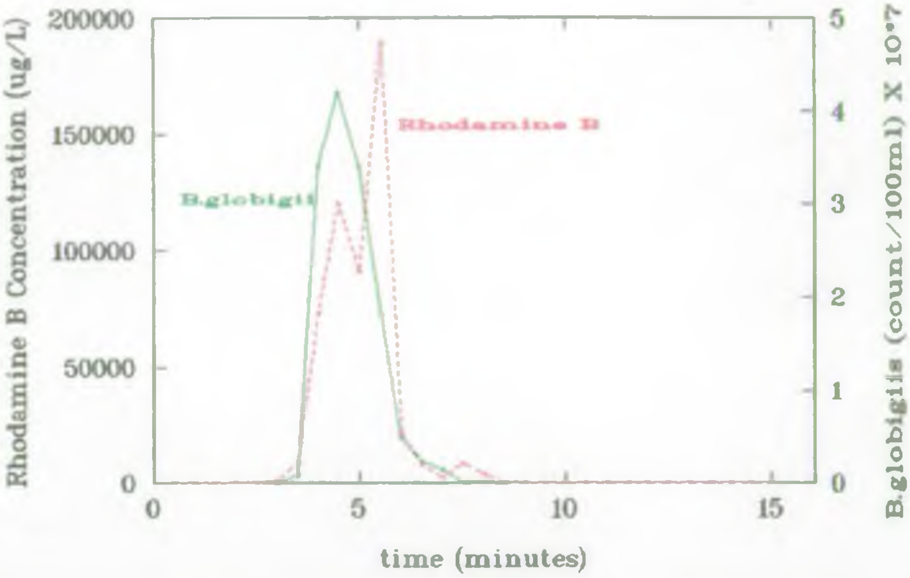
3.1 INITIAL DILUTIONS

The 'initial dilution' is that which occurs when a jet rises through the water column to the surface forming a 'boil'. It is dependent on the outfall configuration, the water depth and the ambient current. Both Rhodamine B and B.globigii were used to estimate the initial dilution.

The response of a fluorometer to Rhodamine B concentration is linear up to about 250 μg/L. It then 'saturates', such that increasing concentration gives a smaller rise in instrument reading. Beyond 500-600 μg/L, the reading actually falls. Consequently the data logging system could not be used to determine the initial dilution in the estuary. Discrete samples were taken and diluted as appropriate to enable concentrations to be determined. This was done on the following day with a similar instrument.

Figure 2 shows the concentrations of Rhodamine B and B.globigii from the samples taken within the works.

Figure 2 : Rhodamine B and B.globigii concentrations within Sandon WTW



The main concentration of tracers passed between 13.55 and 14.00. From these samples the maximum values were :

Rhodamine B concentration = 1.9×10^5 μg/L

B.globigii = 42×10^6 counts per 100ml

Figure 3 : Rhodamine B and B.globigii concentrations in Estuary

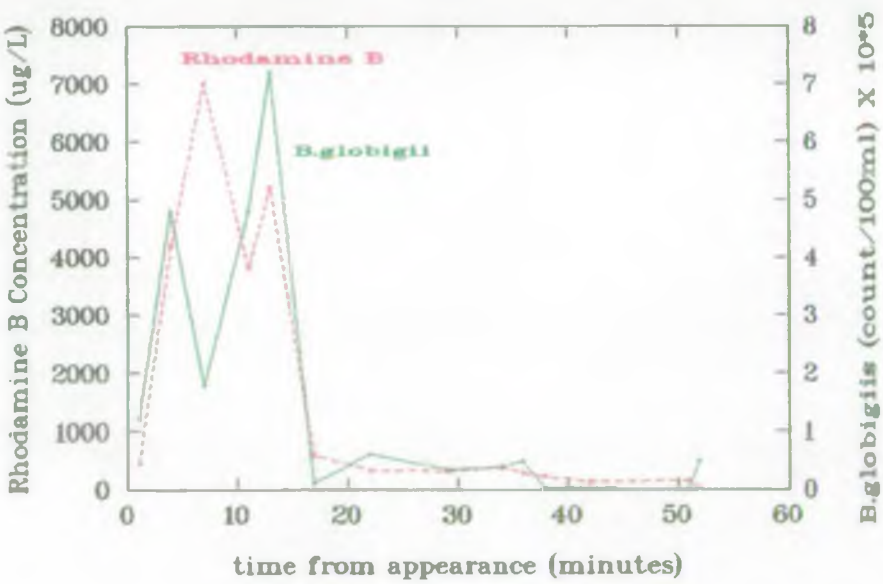


Figure 3 shows the concentrations of Rhodamine B and B.Globigii from the first 20 samples taken from the boil in the estuary.

The maximum values were:

Rhodamine B concentration = 7×10^3 μg/L
B.globigii = 7.2×10^5 counts per 100 ml

These figures give an initial dilution of:

Rhodamine B = 27:1
B.globigii = 58:1

3.2 SUBSEQUENT DILUTIONS

Figures 4 and 5 show subsequent dilution as a function of time and distance as the effluent migrated away from the outfall. The values (see Appendix B) comprise the maximum concentration found within the works divided by each subsequent peak concentration.

With respect to time, figure 4 shows how both tracers suggest that rapid dilution does not occur before 16.00, nearly two hours after first emerging. Figure 5 indicates that this occurs after a distance of approximately 1-2 km.

3.3 DYE TRACKING

The data logging system took four readings of Rhodamine B concentration per second from the flouorometer almost continuously throughout the survey. Position fixing was gained using GPS. This system has an accuracy within 200 metres, but its precision over a one day survey has proved to be much higher than this. In the post processing stage, three GPS fixes were compared to a known position to estimate the accuracy of the system on that particular day. This resulted in the need to move the positions 45 metres to the East and 65 metres to the south. This adjustment proved to be acceptable for most

Figure 5 : Rhodamine B and B.globigii dilution in Estuary

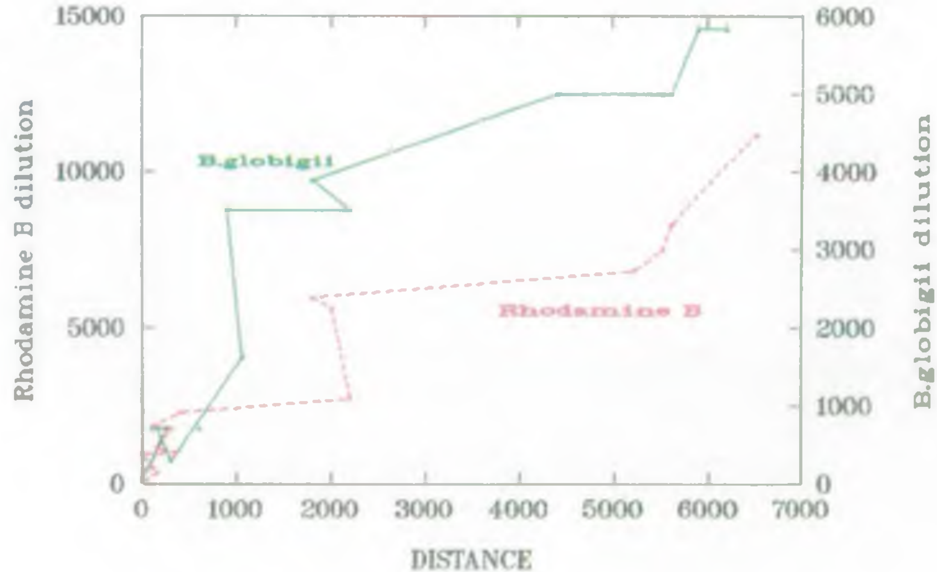
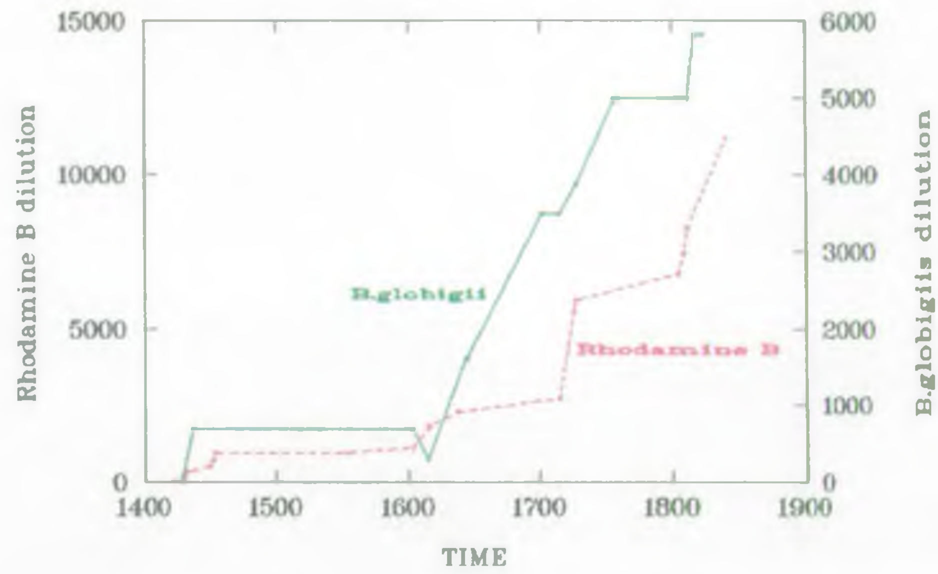


Figure 4 : Rhodamine B and B.globigii dilution in Estuary



data, although there are some obvious discrepancies, most notably chart 5 where the ships track goes over Sandon wall instead of tight up against it.

The data were edited such that in the final charts the highest value at any point is displayed, lower values being removed to avoid overwriting. The results are summarised in Appendix C, charts 1 to 6. For the reasons described earlier, the readings are only accurate below 250 μg/L.

Charts 1 to 4 are divided into 1/2 hour time steps from the emergence of the dye in the estuary at 14.14, 35 minutes before predicted low water. Chart 5 is the third hour, and chart 6 is the final hour and a half.

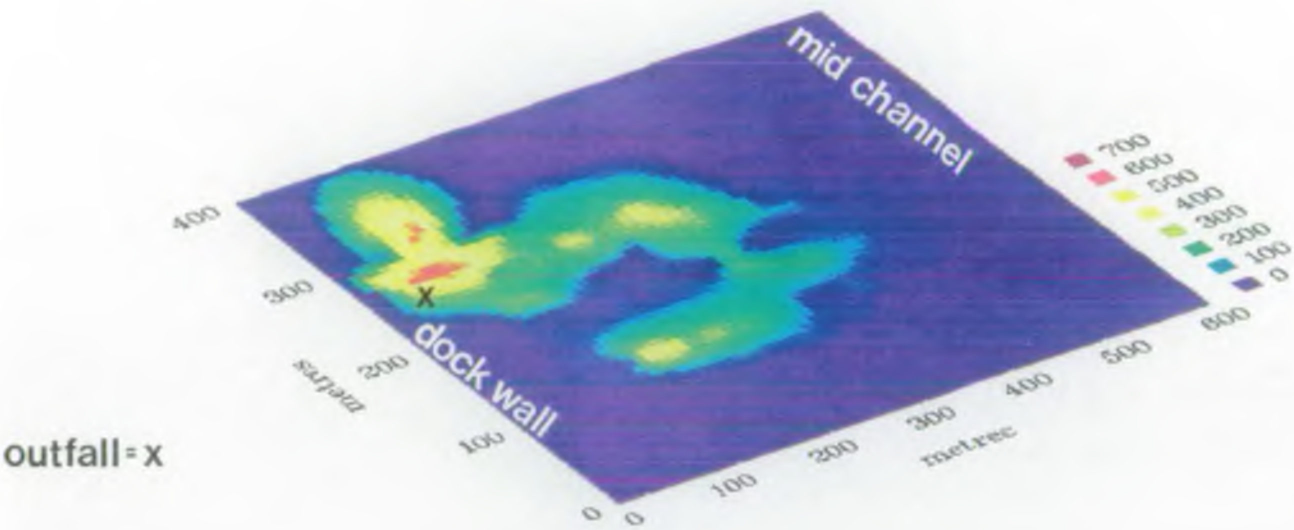
In the first half hour the most concentrated dye (over 400 μg/L) stayed relatively close to the sea wall and slowly tracked seaward for approximately 100 metres, as shown in chart 1. The delineation of the dye patch was very marked.

With the last of the ebb in the subsequent 30 minutes (chart 2), the main patch of dye, still above 400μg/L, reached approximately 250 metres seaward of the outfall, but remained within 200 metres of the sea wall. Over the first hour, sufficient data in close proximity was logged to allow reasonable contouring of the dye patch as shown in figure 6.

Between 60 and 90 minutes following discharge (chart 3), the main patch of dye was still in the area just to the north of the outfall, stretching up to 400m seaward, and 200 metres from the sea wall. A very clear demarcation line existed around the concentrated dye patch. There was some evidence that the dye was being pushed back towards the wall with the start of the flood.

Chart 4 shows the data collected between 90 and 120 minutes following discharge. With the onset of the flood tide, the area of dye increased. Peak concentrations were now approximately 250 μg/L. The area of dye extended 300m

Figure 6: Rhodamine concentrations over the first hour



to the north and 150m to the south of the outfall, but the highest concentrations were still found tight in to the sea wall.

In the third hour the dye, now with peak concentrations of around 100μg/L, extended over a kilometre south of the outfall, but still stayed within 200 metres of the sea-wall (chart 5).

In the last one and a half hours the rhodamine B patch can be seen to spread out across the estuary and reach from the old Princes lock to just beyond Tranmere, moving up the Garston channel. The survey was ended at 18.45 when the dye patch had become very dilute and hard to follow. By this time it had reached 7 km upstream of the outfall (chart 6). Over this final interval the maximum

maximum concentrations found were approximately 50 μg/L falling to 10 μg/L.

3.4 CURRENT VELOCITIES

Current velocities, measured on two days in July 1992, along a transect close to the outfall (see figure 1) are presented in Appendix D. The data are from similar tides:

6^{th} October, 1992	low water : 13.59 GMT	height : 3.3 m.
24^{th} July, 1992	low water : 11.44 GMT	height : 2.9 m.
25^{th} July, 1992	low water : 13.06 GMT	height : 2.9 m.

The cross sections show Egremont to the left and Liverpool to the right, therefore the 'view' is effectively out to sea. Positive values (reds and yellows) are the tide ebbing, while negative values (blues) are the flood tide. The black area represents the river bed.

Each transect took approximately 15 minutes to complete. The time given for each is that of the mid point of each transect.

Both days data show a similar pattern of current flows.

Two hours before low water the tide was ebbing at up to 100 cm/s over much of the channel but was noticeably slacker near to the Sandon wall.

An hour before low water the tide is still ebbing strongly over a large area in the middle of the channel. However, near to the Sandon side, the water is barely moving and there is evidence that in the region up to 150 metres from the dock wall there is a flow in the opposite direction.

Approximately 45 minutes before low water the ebb tide, although slowed considerably, is still flowing at more than 50 cm/s over a considerable area on the Liverpool side of the channel. Near the Sandon wall the counter current is now more pronounced with flows of up to 30 cm/s.

At low water this gyre has disappeared. The initial flood of denser saline water near the channel bed is evident, with the fresher water nearer the surface still ebbing.

In the hour after low water the water is still slack towards Sandon. In the second hour following low water the currents are still significantly smaller near the Sandon side of the channel.

These findings are totally in accord with previous surveys in this vicinity (Rivers division, 1984; John Taylor & Sons, 1987). Features such as the pronounced counter current during the ebb tide (which starts approximately 90 minutes after high water) and the density circulation giving rise to the tide flooding earlier at the river bed are clearly shown in the ADCP plots.

<u>4) DISCUSSION</u>

4.1 Practical Details

This was the first opportunity to evaluate the data logging system. It is felt that improvements in both the data acquisition and the means of tracer injection can be made.

The two tracers were injected over a very short period into the effluent. A controlled injection, possibly of a more dilute tracer over a longer period, e.g. 10 minutes, would have given a flatter 'plateau' of concentrations within the works and subsequently at the base of the spillway as the tracers emerged.

This could have reduced the differences between dilutions calculated for the two tracers. It is possible that the highest concentrations of B.Globigii may have been missed in the estuary, giving the higher dilution for this tracer. Rhodamine B, being a dye, was clearly visible and it was relatively easy to sample from the highest concentration. This may not have coincided with the highest concentration of B.globiggi.

In order to produce valid synoptic contours a comprehensive coverage of the area over short time intervals is required. The survey vessel tracked at approximately 3 knots to ensure that air bubbles were not entrained in the flow to the fluorometer. It is now considered that speeds of up to 6 knots could be achieved without affecting the data readings, thus enabling the area to be covered in more detail.

A further improvement to the survey design is possible. As noted earlier there was some uncertainty in the accuracy of the GPS position fixing. For this survey the availability of an accurately known point with which to correct this error reduced the importance of this. For other surveys this may not be the case. However, it can be overcome by the use of differential GPS which brings the accuracy of a fix down from 100 metres to less than 15 metres.

4.2 Results

During the first hour and a half the effluent tracked 400 metres seaward. In the next hour and a half, with the onset of the flood tide, it reached a kilometre upstream.

Over this 3 hour period it remained adjacent to the dock wall. Thereafter it moved further upstream spreading to almost the full-width of the estuary in the vicinity of Tranmere oil terminal.

The current velocity data shows that ambient flows close to the dock wall are very small for protracted periods before and after low water. Evidence of a counter current for long periods before low water was found, as observed on many previous occasions.

The discharge of approximately 1.2 cumecs into this area on the day of the survey, resulted in ponding of the effluent, with a strong demarcation line between it and the surrounding water body. The dilution of 27:1 compares unfavourably with NRA proposed minimum dilutions of 50:1 for primary treated effluent.

This situation can only deteriorate when the works becomes fully operational with a dry weather flow up to four times that presently receiving treatment.

5) CONCLUSION

The effluent from Sandon Dock Sewage Treatment Works is currently being discharged into possibly the most hydrodynamically unsuitable body of water in the local vicinity. The current regime is complex with weak flows over long periods around low water and a counter current over much of the ebb tide. The dilution of 27:1 is clearly not high enough to prevent the formation of a surface slick, and matters will deteriorate as the flow from the works increases.

An outfall discharging to the 10 metre contour line, approximately 400 metres off-shore is recommended.

APPENDIX A : SAMPLES

1) SAMPLES TAKEN WITHIN THE WORKS

sample	Time BST	Rhodamine (μg/L)	globiggi (counts/100ml)	Tcol (100/ml)	E.coli (100/ml)
1	1352	5.1	5	12840000	6880000
2	1352	4	8		
3	1353	3.5	2	13840000	7040000
4	1353	3.4	13		
5	1354	3.2	5	12960000	7280000
6	1354	900	28000		
7	1355	9000	860000	19760000	7680000
8	1355	73000	34000000		
9	1356	120000	42000000	16400000	7840000
10	1356	91000	34000000		
11	1357	190000	18000000	22640000	9120000
12	1357	21000	4800000		
13	1358	7800	2400000	16240000	4960000
14	1358	2200	1420000		
15	1359	8500	107000	8640000	7120000
16	1359	3500	140000		
17	1400	190	24000	10520000	5840000
18	1400	100	880		
19	1401	83	21000	15240000	5760000
20	1401	62	12000		
21	1402	52	300	17280000	7240000
22	1402	50	310		
23	1403	42	180	15240000	6960000
24	1403	37	600		
25	1404	36	460	19600000	9360000
26	1404	26.5	240		
27	1405	30	470	15360000	8480000
28	1405	23.5	210		
29	1406	22	4500	20480000	9520000
30	1406	22.5	150		

2) SAMPLES TAKEN WITHIN THE ESTUARY

sample	Time BST	Globigii (counts/100ml)	Rhodamine (μg/L)	TCol (100/ml)	E.Coli (100/ml)
1	1315	0		12300	8800
2	1320	0		7700	6100
3	1322	0		7500	6600
4	1326	0		936000	608000
5	1330	3		90000	72000
6	1335	2		9900	8800
7	1417	120000	440	1368000	412000
8	1420	480000	4200		
9	1423	178000	7000		
10	1427	480000	3800	576000	288000
11	1429	720000	5200		
12	1433	10800	570		
13	1438	60000	320	9600	418000
14	1445	33400	300		
15	1450	36000	380		
16	1452	48000	270		
17	1454	1660	205		

18	1458		110	78000	61000
19	1507	6	140	68000	39000
20	1508	48000	8.2	158000	114000
21	1518	60000	3.6	97000	83000
22	1527	7200	27		
23	1530	480	21		
24	1531	1580	7.8	536000	224000
25	1533	60000	160		
26	1535	48000		151000	123000
27	1541	2	0.13		
28	1549	11	0.23		
29	1553	36000	200		
30	1557	6000	17	185000	131000
31	1601	4800	15.5		
32		60000	170	108000	81000
33	1604	9600	33		
34	1608	9600	30.5		
35	1610	7200	17.5		
36	1615	144000	110	532000	272000
37	1616	300	105		
38	1619	2400	2.5	5600	4100
39	1623	12000	42	49000	39000
40	1625	1200	49		
41	1635	600	18	848000	544000
42	1637	7200	84	116000	104000
43	1643	3600	8.8		
44	1644	26000	56	105000	74000
45	1646	4800	32		
46	1652	2000	10	129000	88000
47	1656	1680	6.1		
48	1701	6000	23		
49	1702	12000	52	145000	98000
50	1712	6000	9.5		
51	1714	7200	28.5	214000	158000
52	1715	12000	70		
53	1719	7200	26		
54	1720	8400	16.5	201000	143000
55	1726	4800	34		
56	1728	10800	32		
57	1738	7200	23	141000	112000
58	1743	6000	20		
59	1747	4800	11.5		
60	1749	4800	20.5		
61	1753	7200	9.4		
62	1755	4800	10.5	168000	104000
63	1756	8400	27		
64	1759	8400	27.5	118000	76000
65	1805	8400	28		
66	1809	8400	25.5	137000	83000
67	1811	8400	23		
68	1815	4800			
69		7200			
70	1819	3600			
71	1822	7200			
72	1830	4800			
73	1839	3600	17	194000	119000
74	1843	1200	2.5	68000	43000
75	1847	6000	6.7	114000	73000

APPENDIX B : FURTHER DILUTIONS IN THE ESTUARY

sample	time from discharge (minutes)	approximate distance (M)	Rhodamine dilution	B.globigii dilution
9	9	0	27	-
11	15	0	37	58
12	19	150	333	-
13	24	250	-	700
15	36	100	500	-
16	38		704	-
17	40	0	927	-
21	64	600		700
25	79	100	-	700
29	99	350	900	-
32	109	150	1118	700
36	121	300	1727	292
37	122	120	1810	-
42	143	400	2262	-
44	150	1050	-	1615
49	168	900	3500	-
52	181	2200	2714	3500
55	192	2000	5588	-
56	194	1800	5938	3889
63	222	4400	-	5000
64	225	4700	-	5000
65	231	5200	6786	5000
66	235	5500	7451	5000
67	237	5600	8261	5000
69	243		-	5833
71	248		-	5833
73	265	6500	11176	-

APPENDIX C : CHARTS 1-6

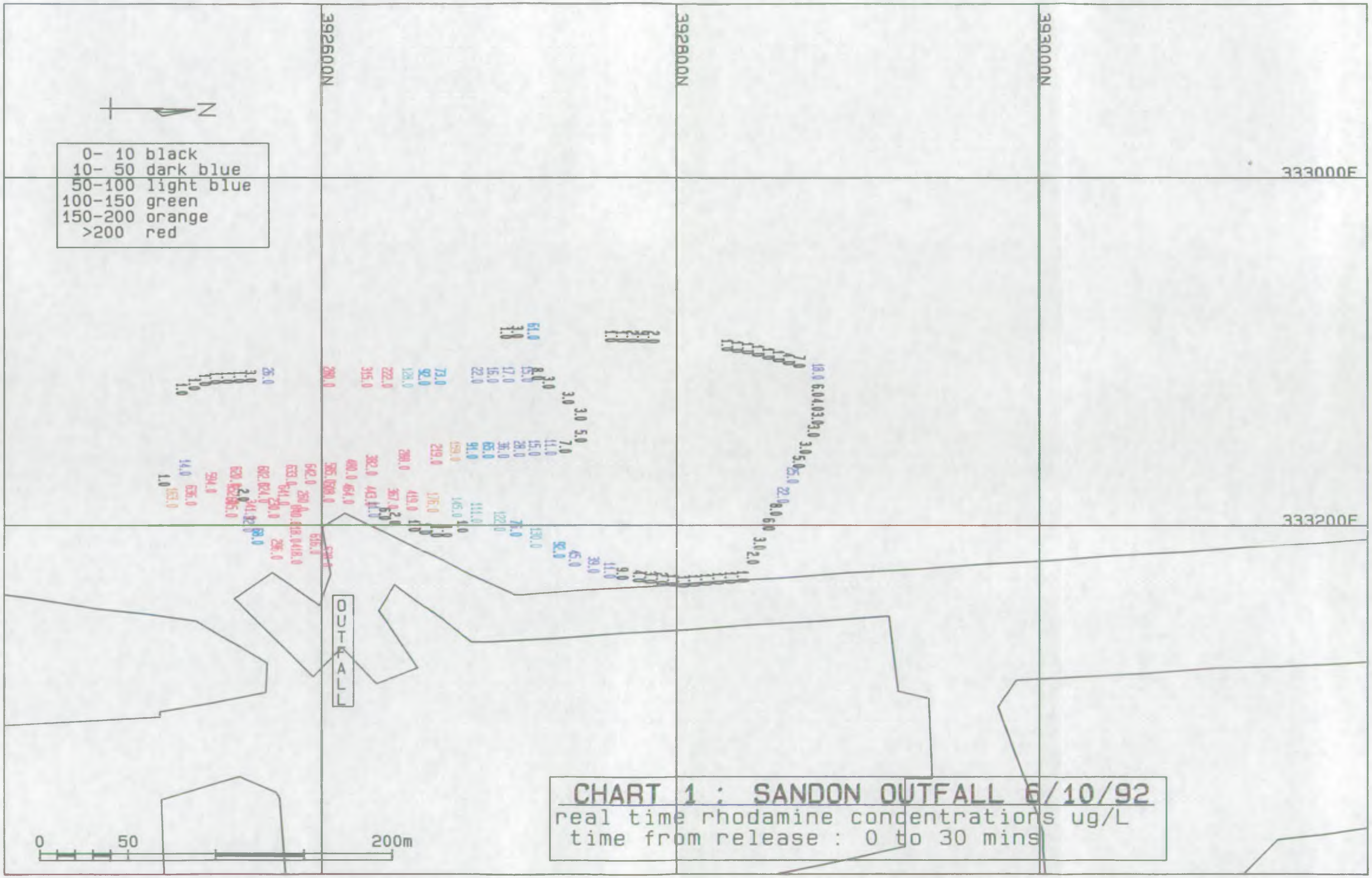


CHART 1 : SANDON OUTFALL 6/10/92
real time rhodamine concentrations ug/L
time from release : 0 to 30 mins

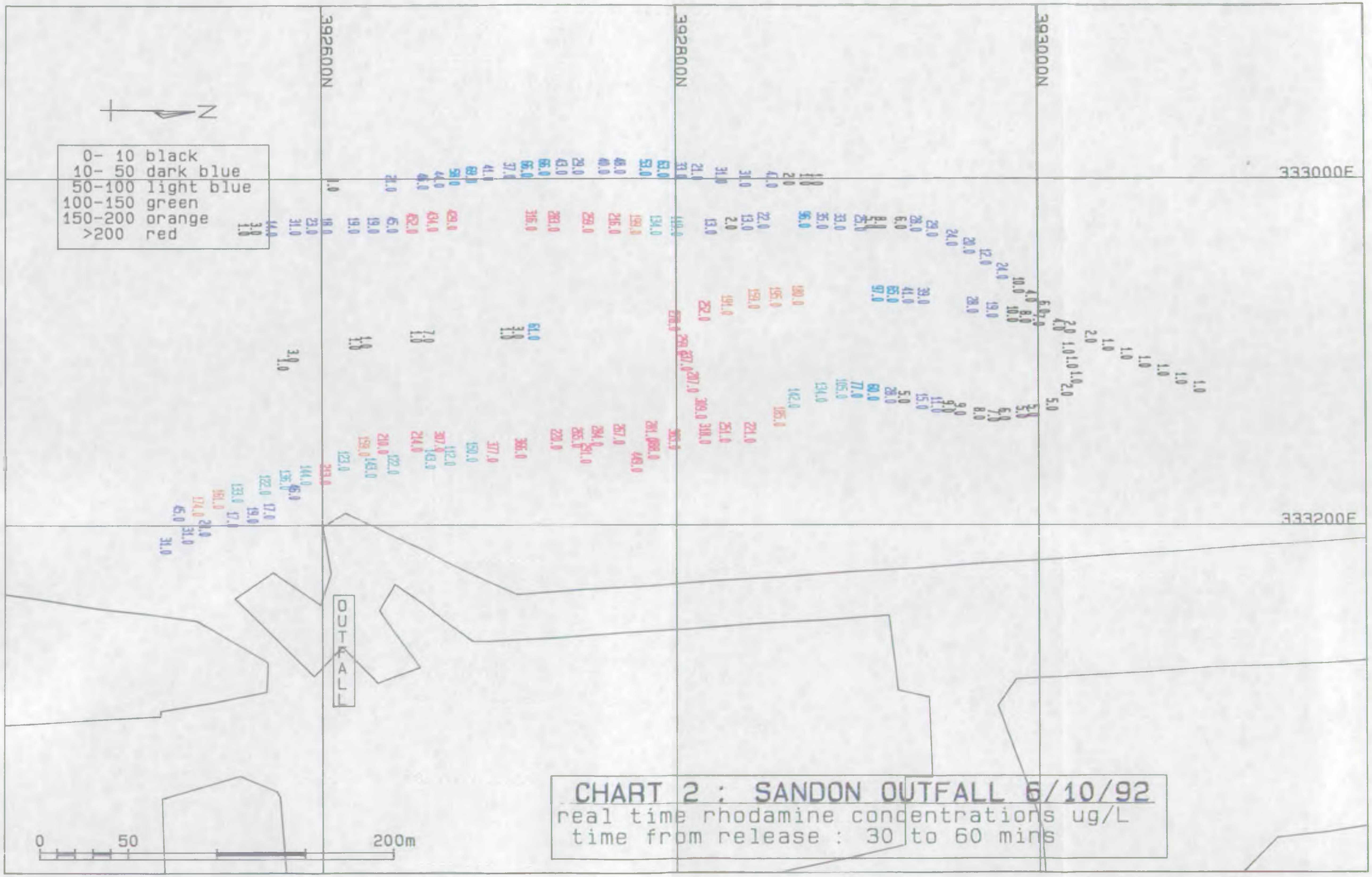
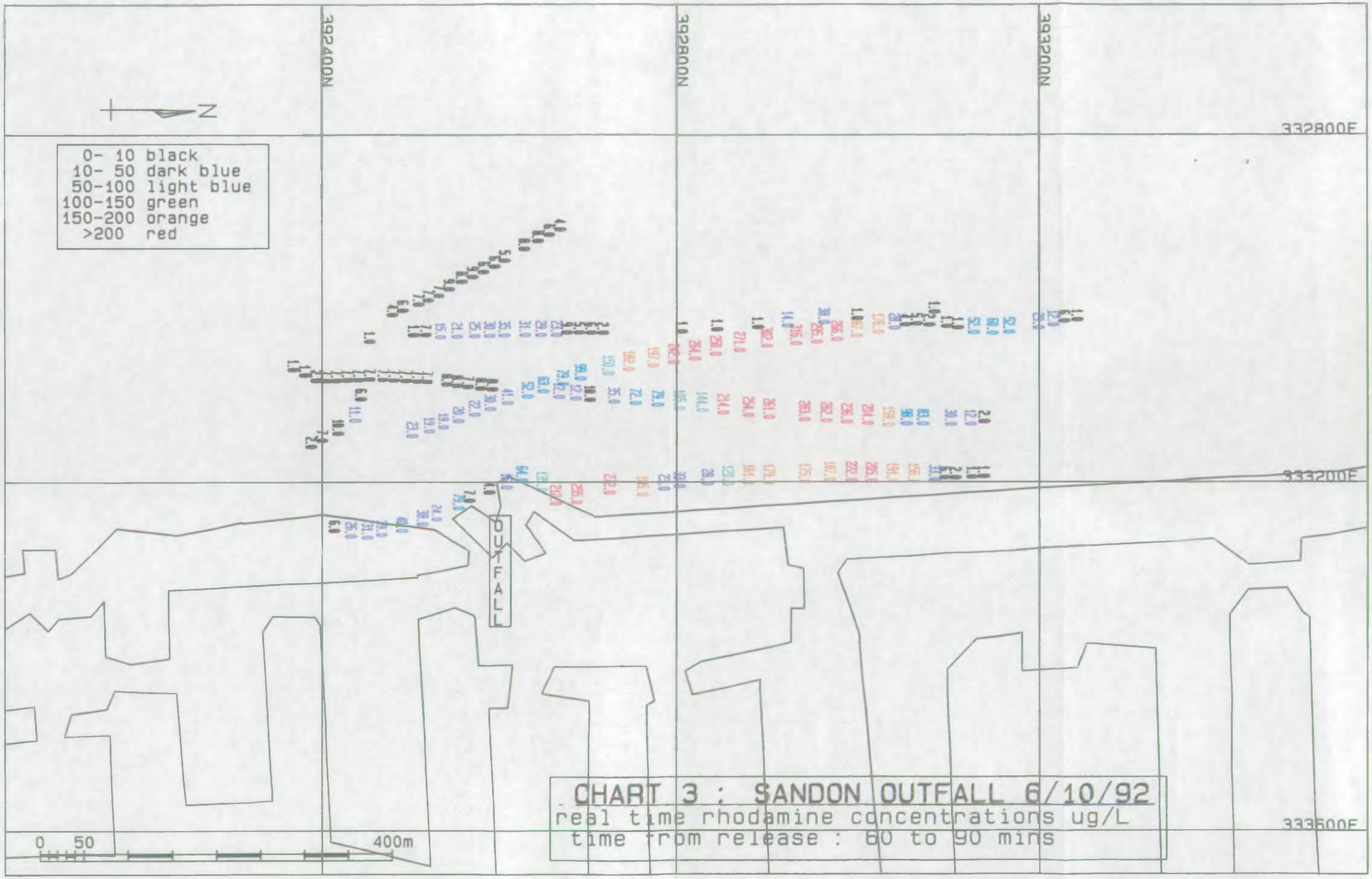
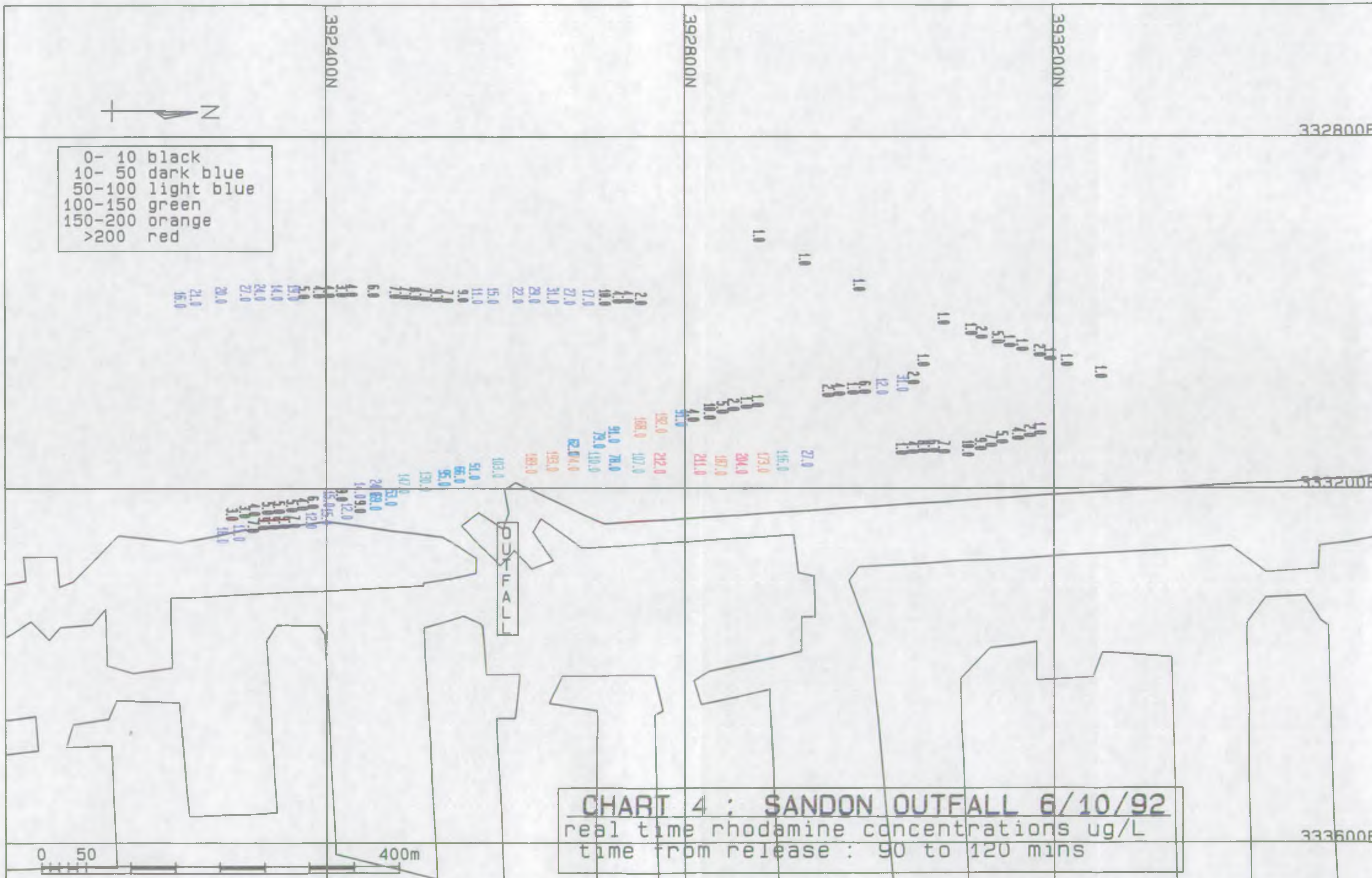
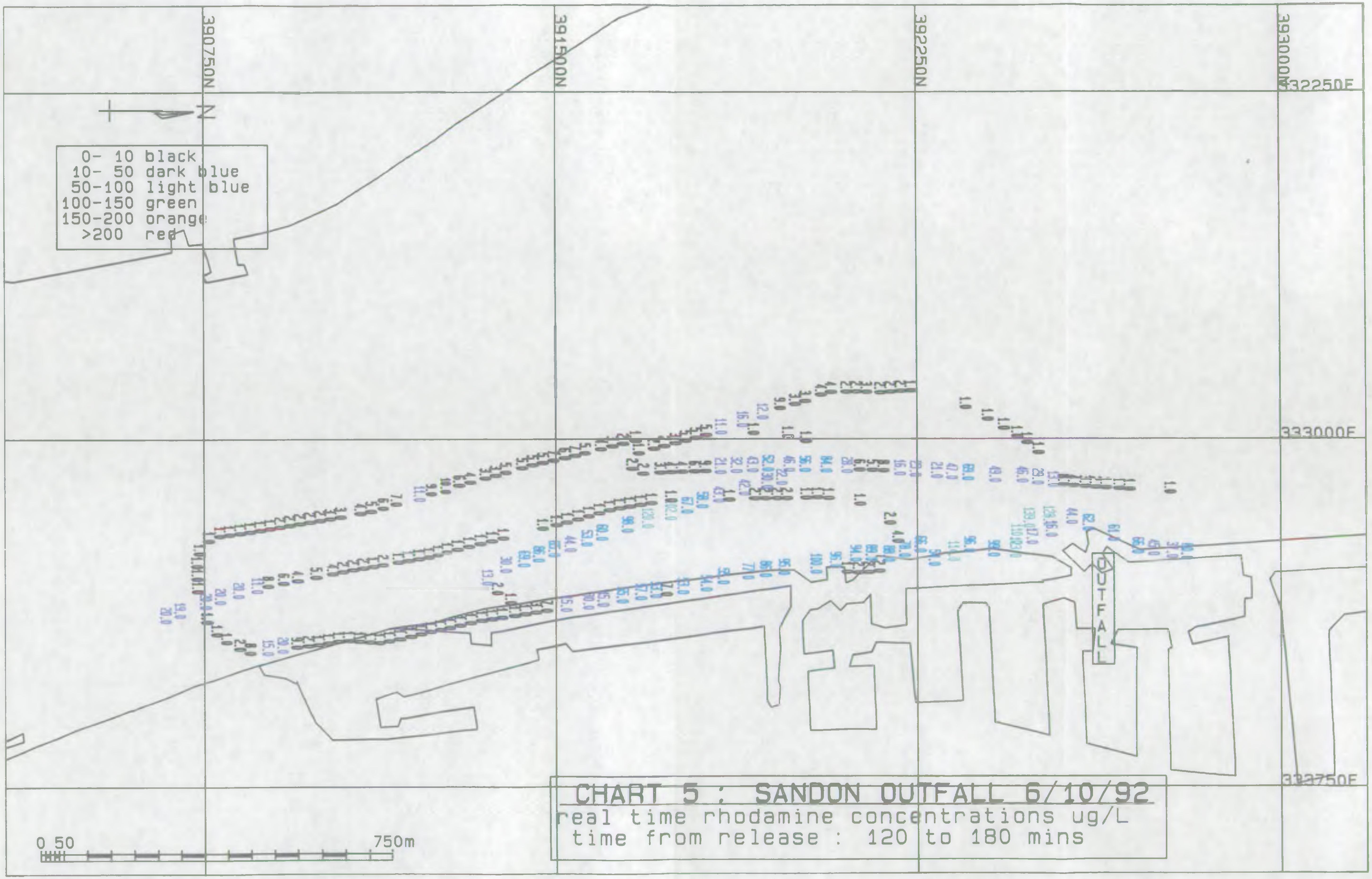


CHART 2 : SANDON OUTFALL 6/10/92
real time rhodamine concentrations ug/L
time from release : 30 to 60 mins



392400N
392800N
393200N
N
0- 10 black
10- 50 dark blue
50-100 light blue
100-150 green
150-200 orange
>200 red
332800E
333200E
333600E
OUTFALL
0 50
400m
CHART 3 : SANDON OUTFALL 6/10/92
real time rhodamine concentrations ug/L
time from release : 60 to 90 mins


392400N
392800N
393200N
N
332800E
333200E
333600E
0- 10 black
10- 50 dark blue
50-100 light blue
100-150 green
150-200 orange
>200 red
OUTFALL
0 50
400m
CHART 4 : SANDON OUTFALL 6/10/92
real time rhodamine concentrations ug/L
time from release : 90 to 120 mins



0- 10 black
10- 50 dark blue
50-100 light blue
100-150 green
150-200 orange
>200 red
390750N
391500N
392250N
393000N
332250E
333000E
333750E
OUTFALL
0 50
750m
CHART 5 : SANDON OUTFALL 6/10/92
real time rhodamine concentrations ug/L
time from release : 120 to 180 mins

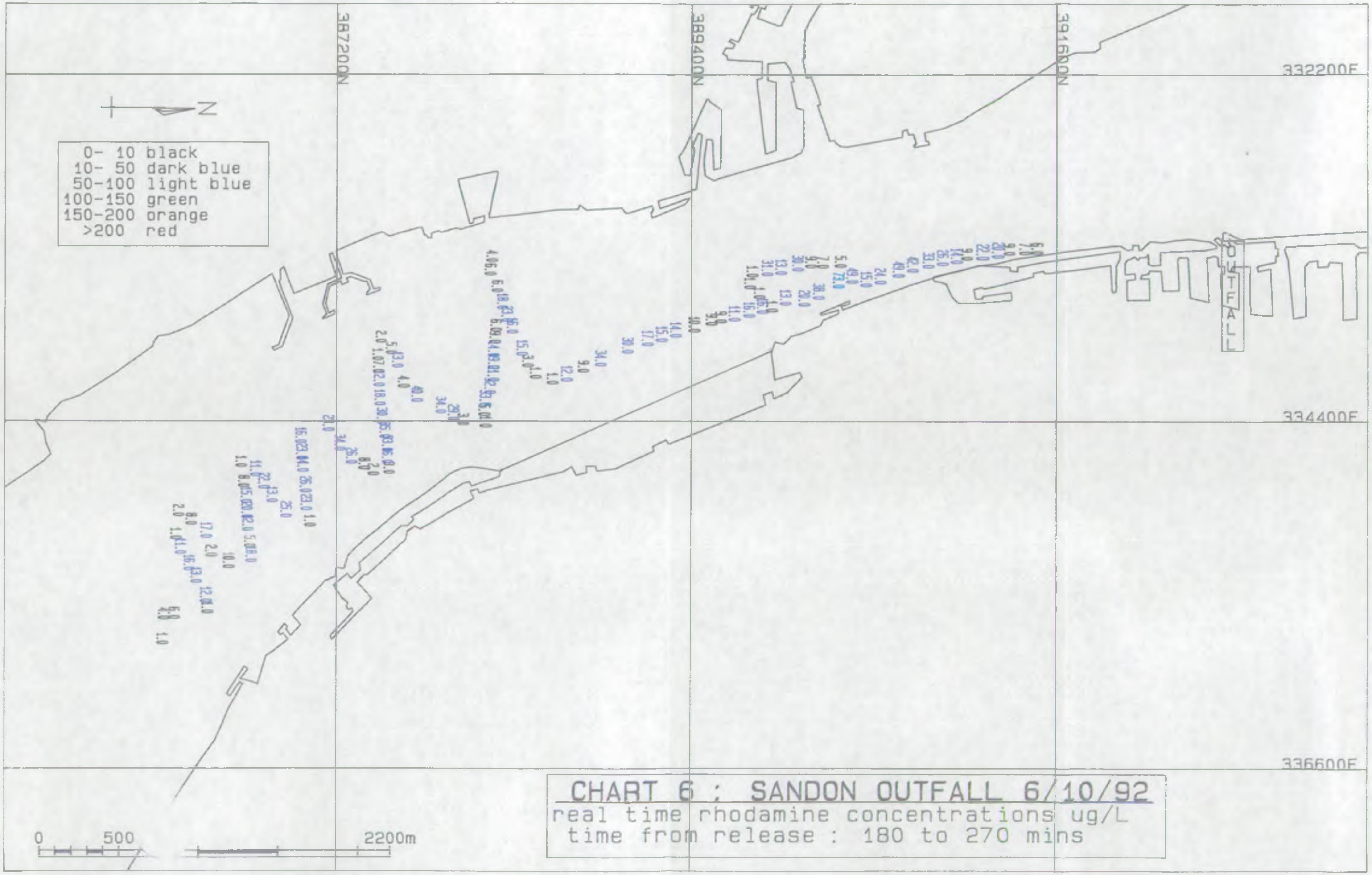
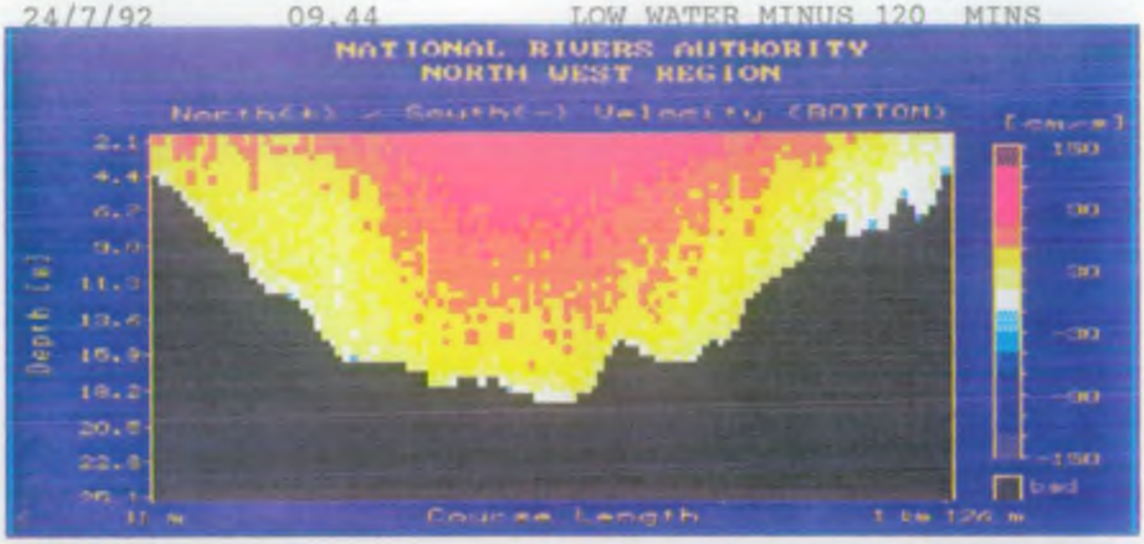


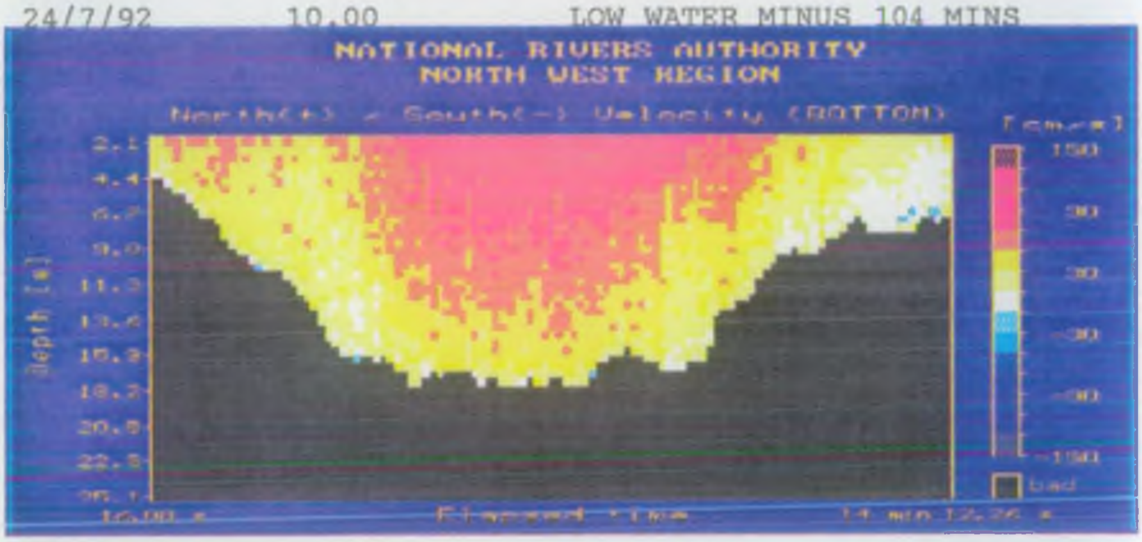
CHART 6 : SANDON OUTFALL 6/10/92
real time rhodamine concentrations ug/L
time from release : 180 to 270 mins

APPENDIX D : CURRENT MEASUREMENTS

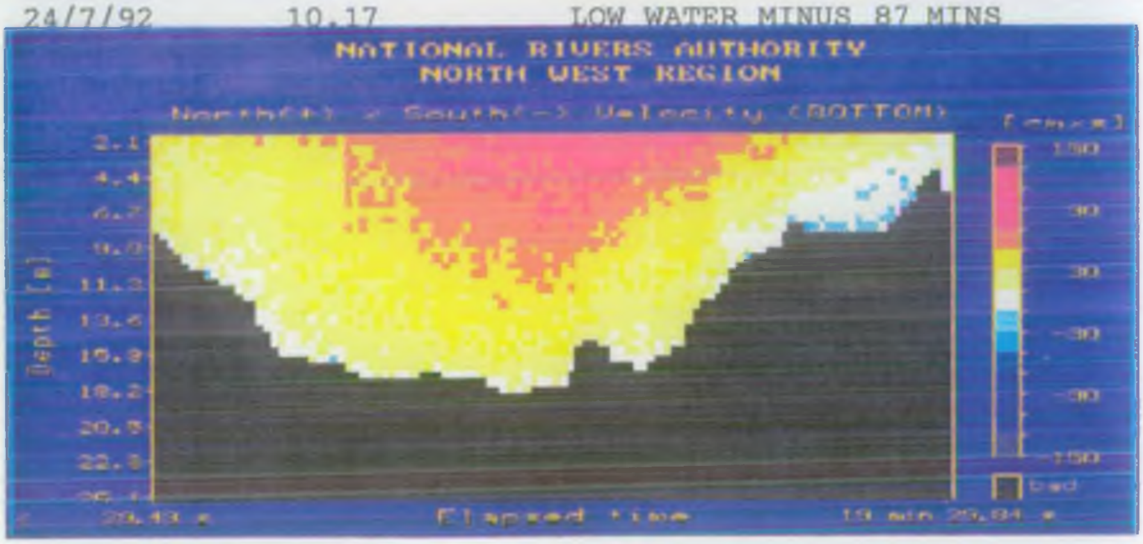
24/7/92 09.44 LOW WATER MINUS 120 MINS



24/7/92 10.00 LOW WATER MINUS 104 MINS



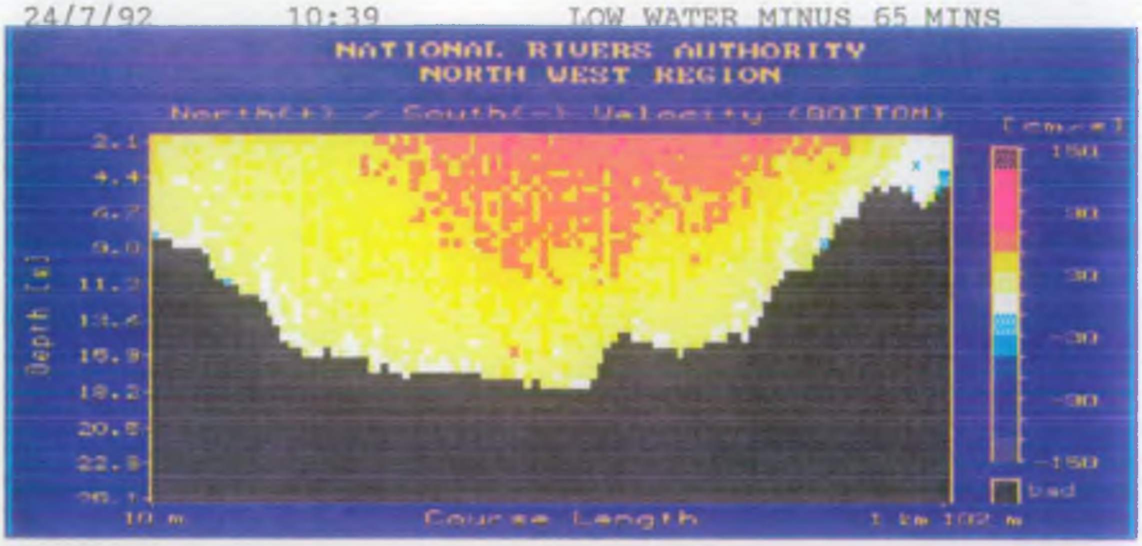
24/7/92 10.17 LOW WATER MINUS 87 MINS



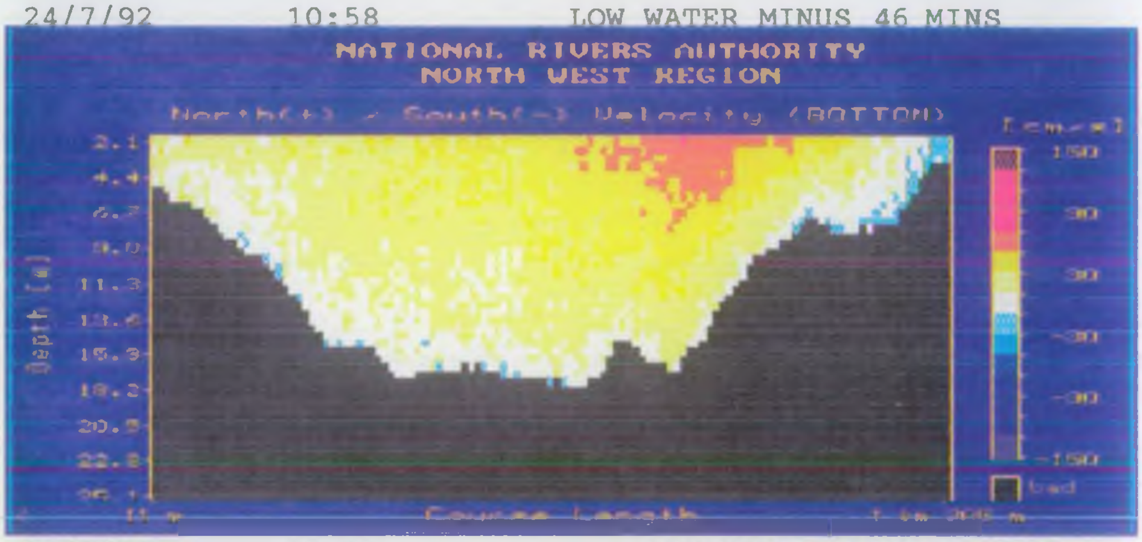
0 250 500 750 1000

DISTANCE ACROSS TRANSECT (METRES)

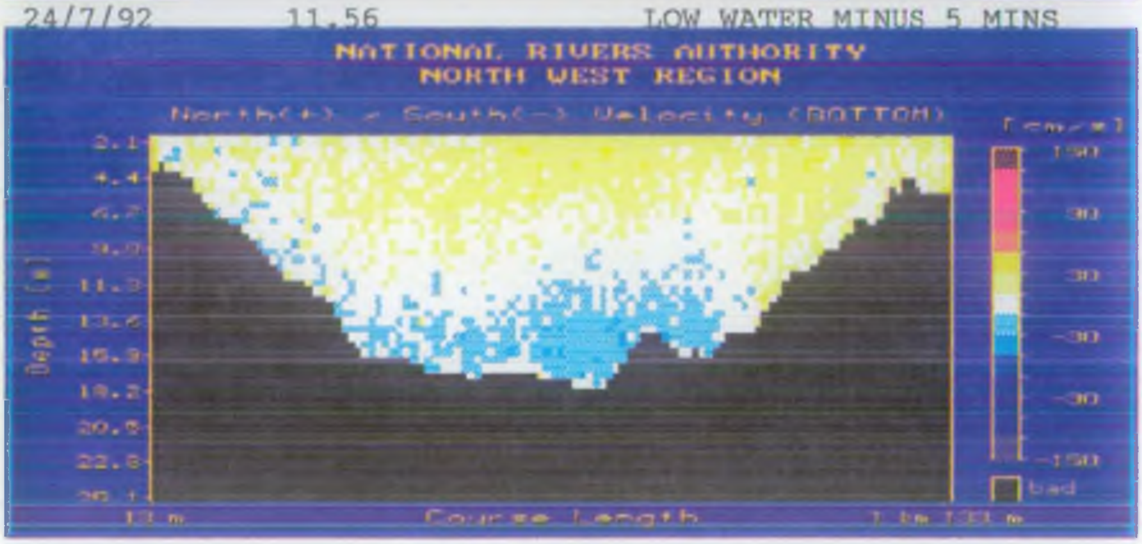
24/7/92 10:39 LOW WATER MINUS 65 MINS



24/7/92 10:58 LOW WATER MINUS 46 MINS

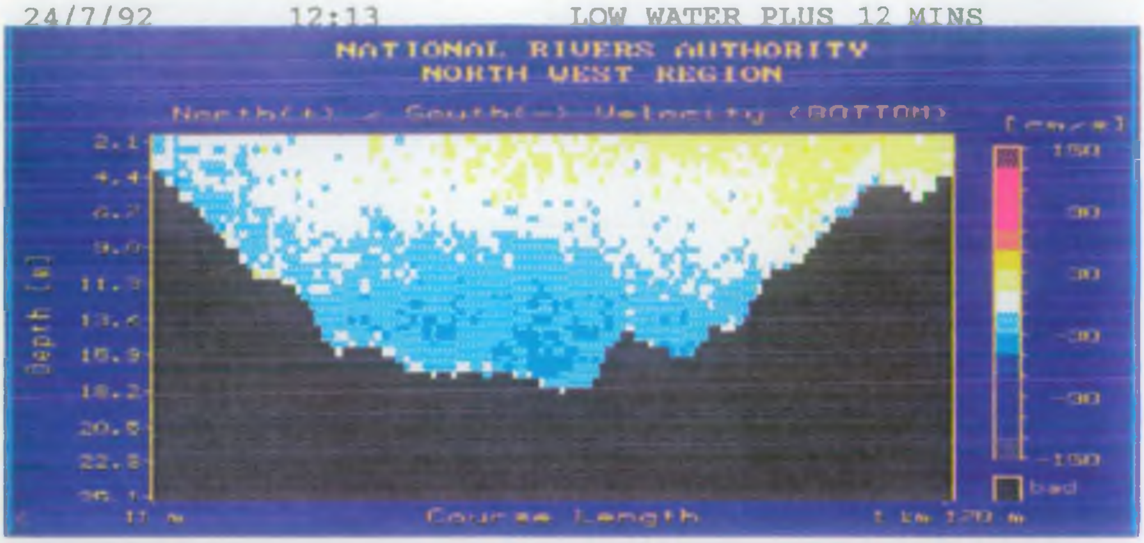


24/7/92 11.56 LOW WATER MINUS 5 MINS

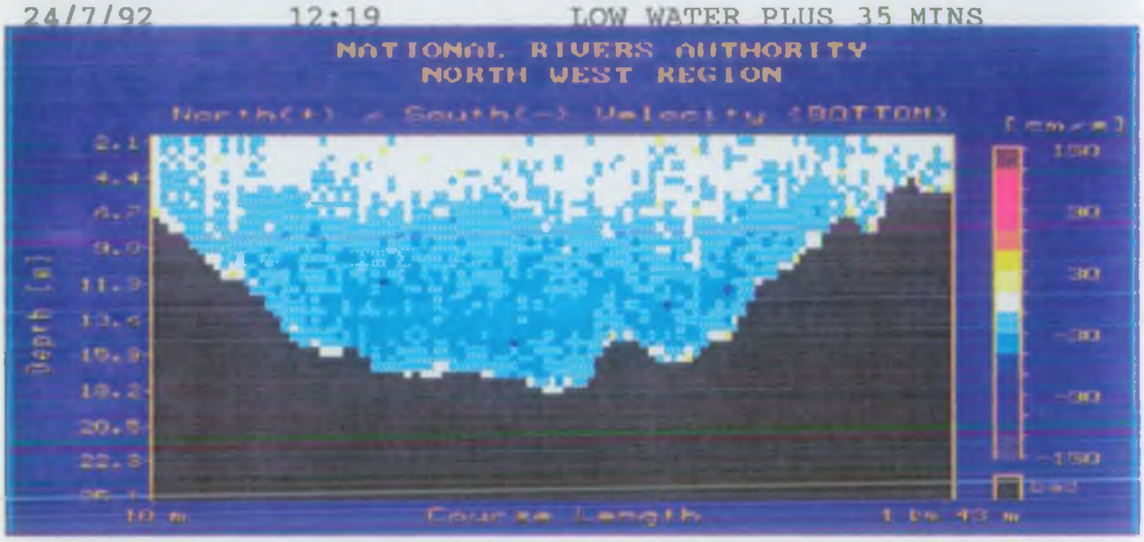


DISTANCE ACROSS TRANSECT (METRES)

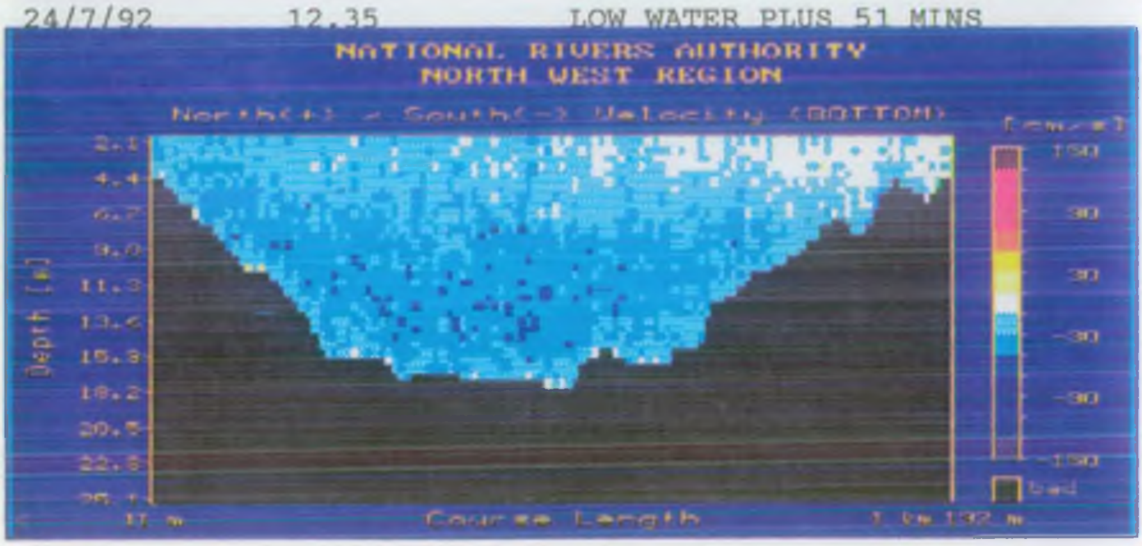
24/7/92 12:13 LOW WATER PLUS 12 MINS



24/7/92 12:19 LOW WATER PLUS 35 MINS



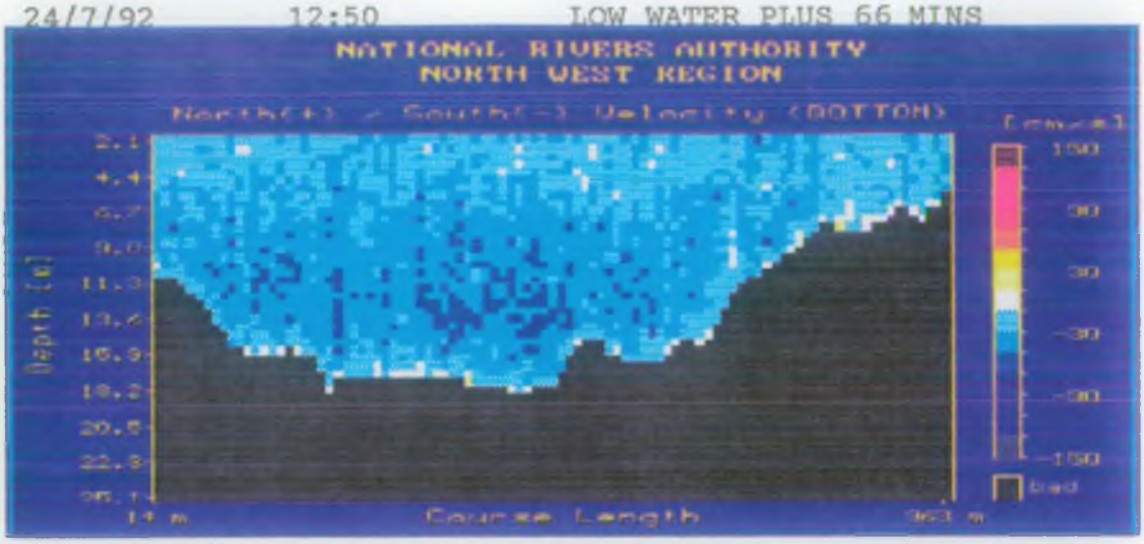
24/7/92 12.35 LOW WATER PLUS 51 MINS



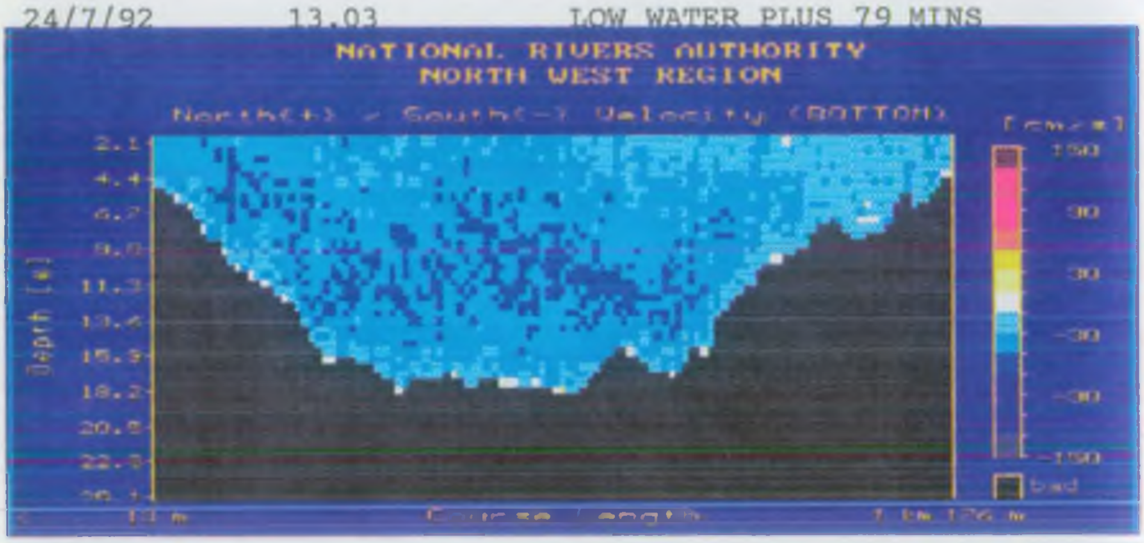
0 250 500 750 1000

DISTANCE ACROSS TRANSECT (METRES)

24/7/92 12:50 LOW WATER PLUS 66 MINS



24/7/92 13.03 LOW WATER PLUS 79 MINS

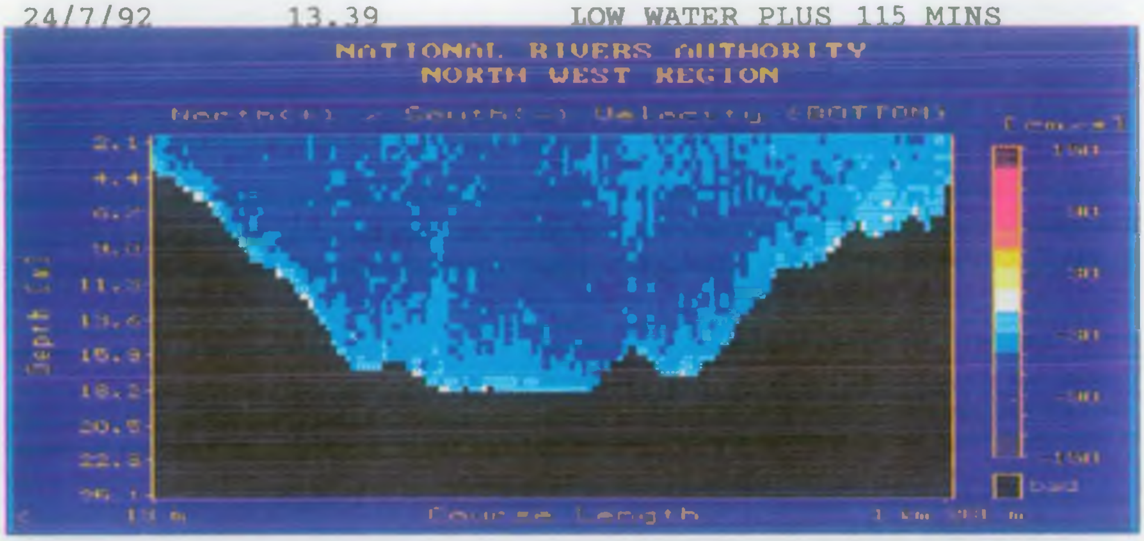


24/7/92 13.22 LOW WATER PLUS 98 MINS

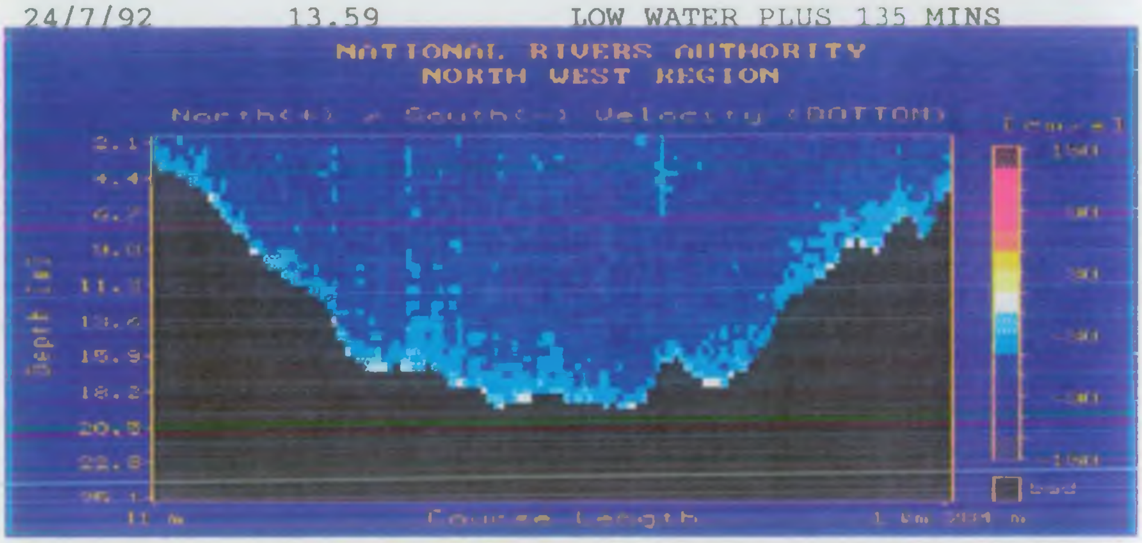
0 250 500 750 1000

DISTANCE ACROSS TRANSECT (METRES)

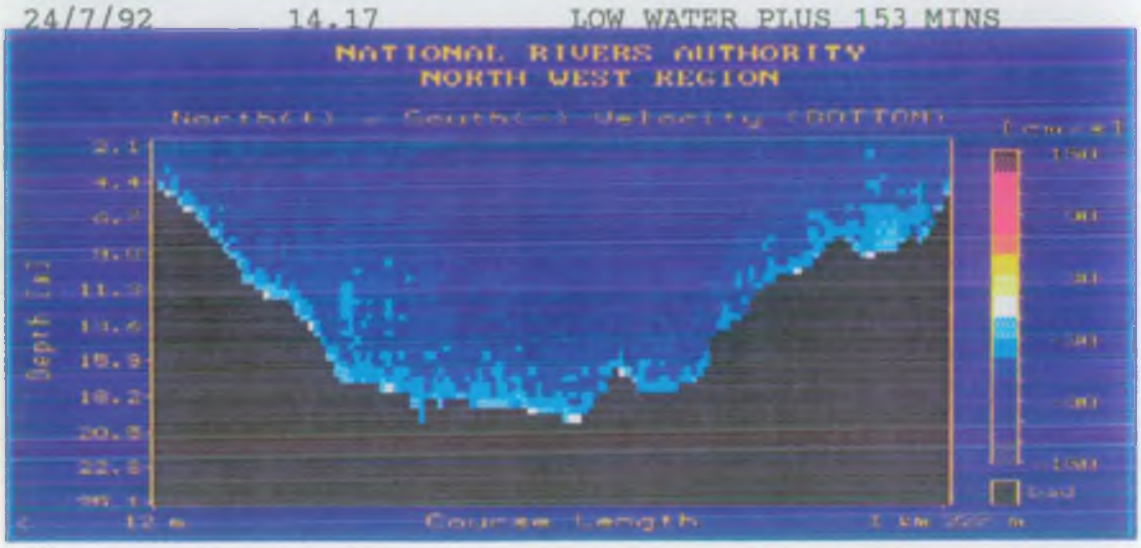
24/7/92 13.39 LOW WATER PLUS 115 MINS



24/7/92 13.59 LOW WATER PLUS 135 MINS

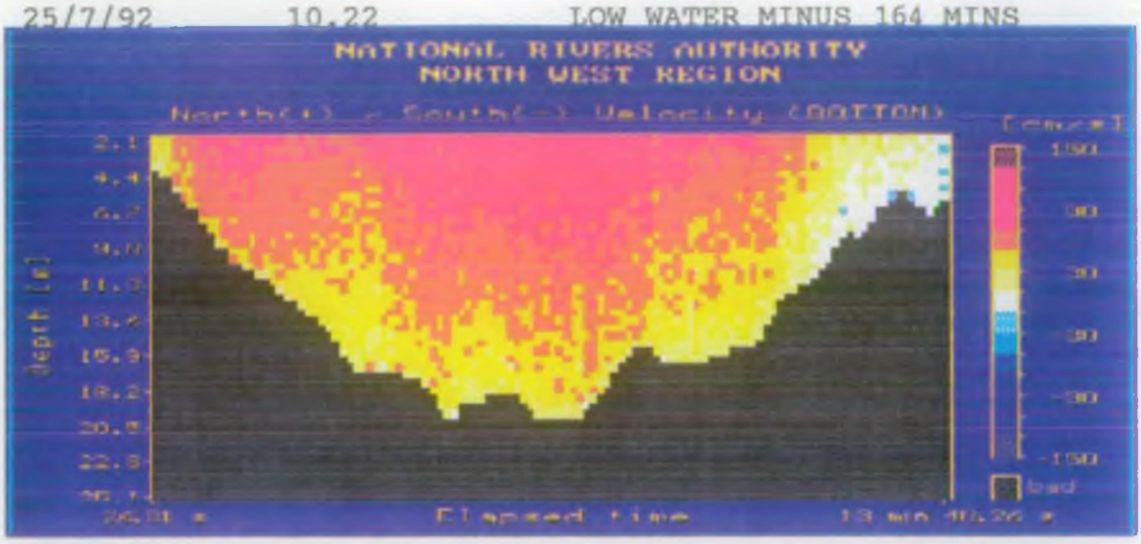


24/7/92 14.17 LOW WATER PLUS 153 MINS

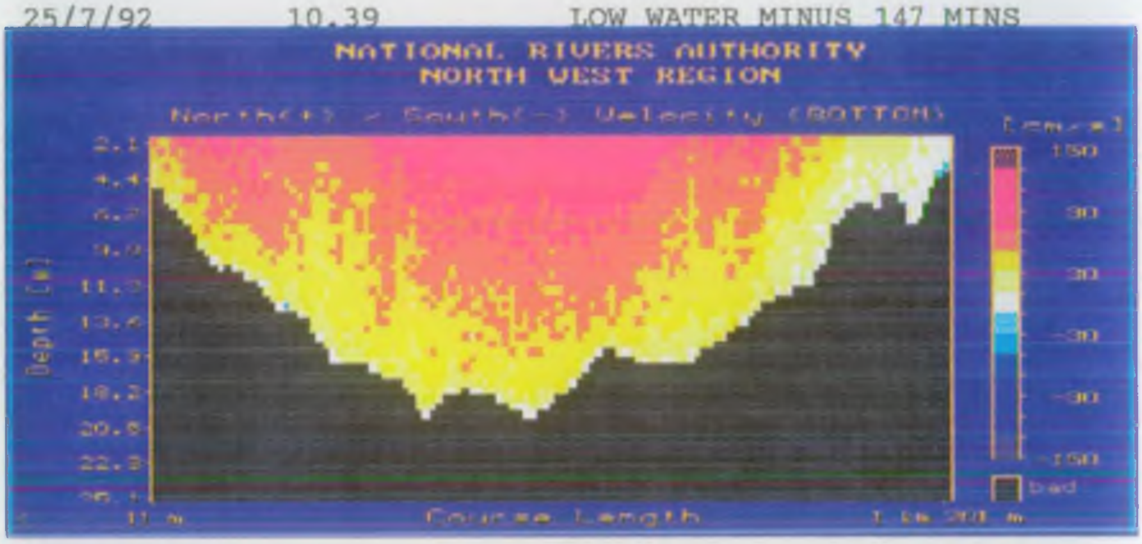


DISTANCE ACROSS TRANSECT (METRES)

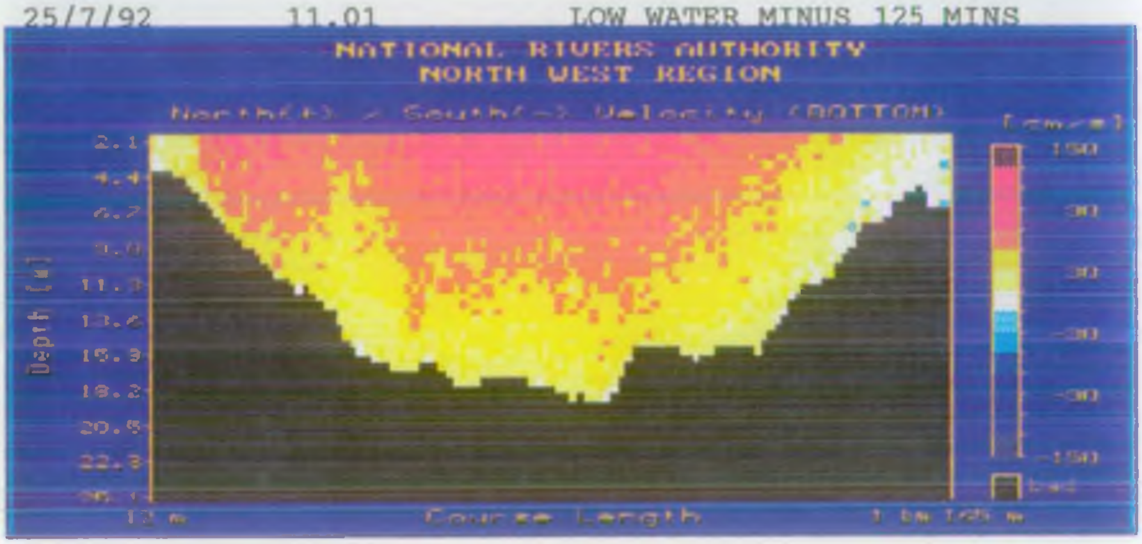
25/7/92 10.22 LOW WATER MINUS 164 MINS



25/7/92 10.39 LOW WATER MINUS 147 MINS



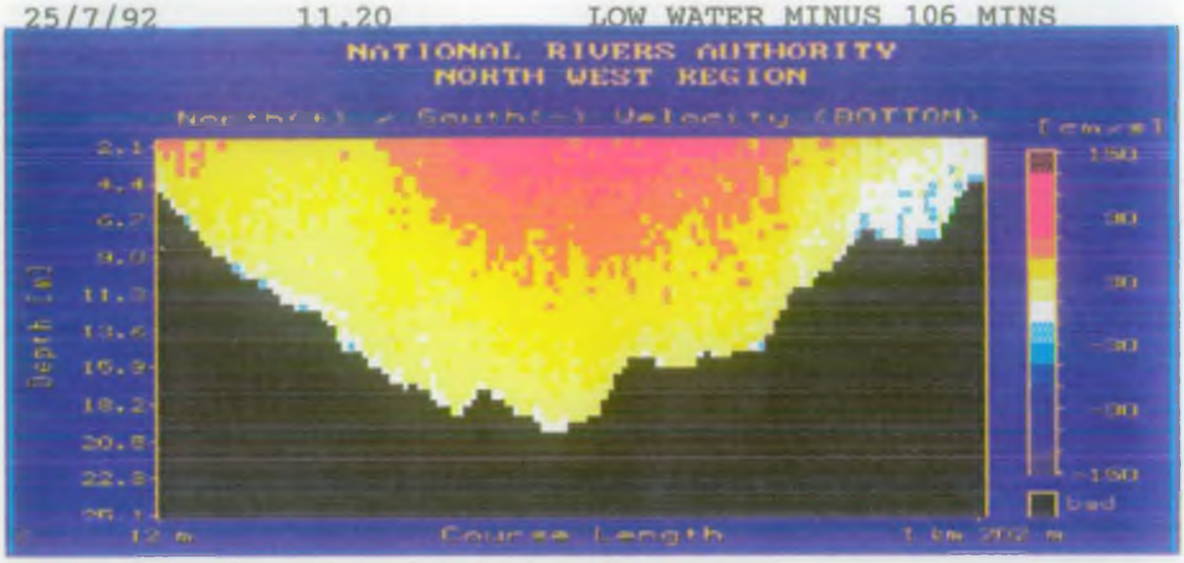
25/7/92 11.01 LOW WATER MINUS 125 MINS



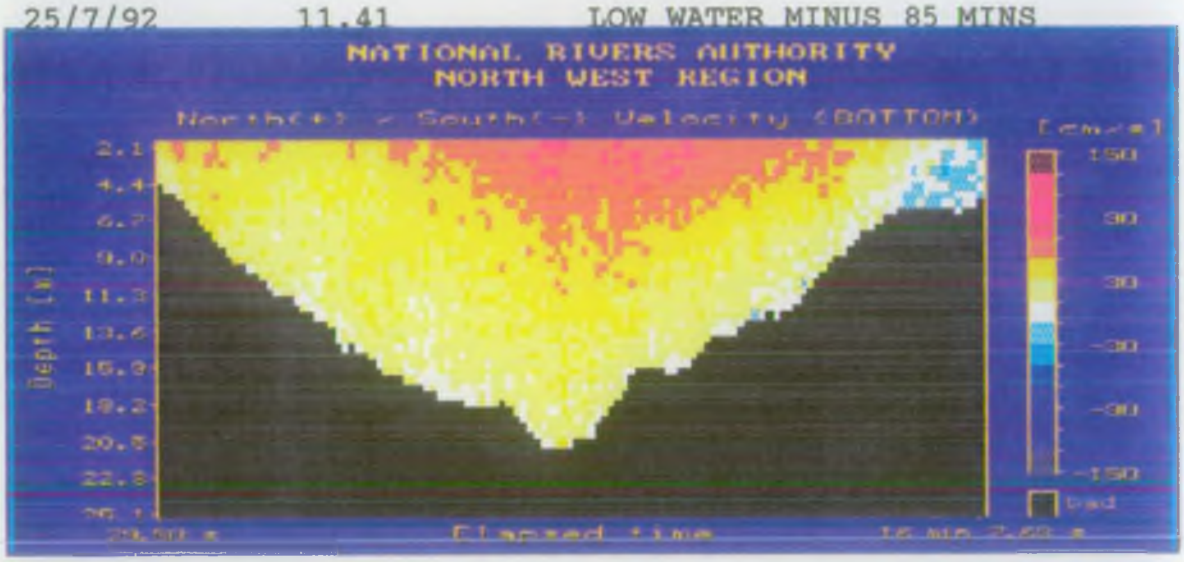
0 250 500 750 1000

DISTANCE ACROSS TRANSECT (METRES)

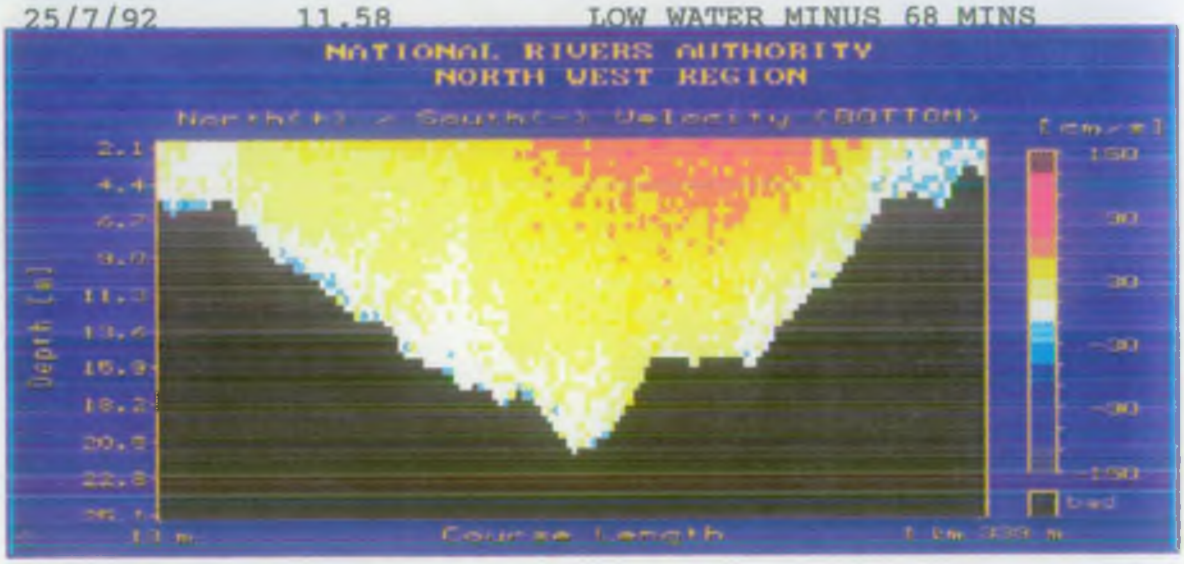
25/7/92 11.20 LOW WATER MINUS 106 MINS

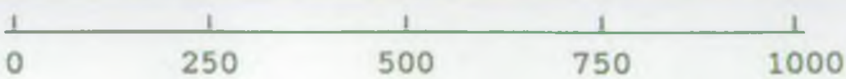


25/7/92 11.41 LOW WATER MINUS 85 MINS



25/7/92 11.58 LOW WATER MINUS 68 MINS

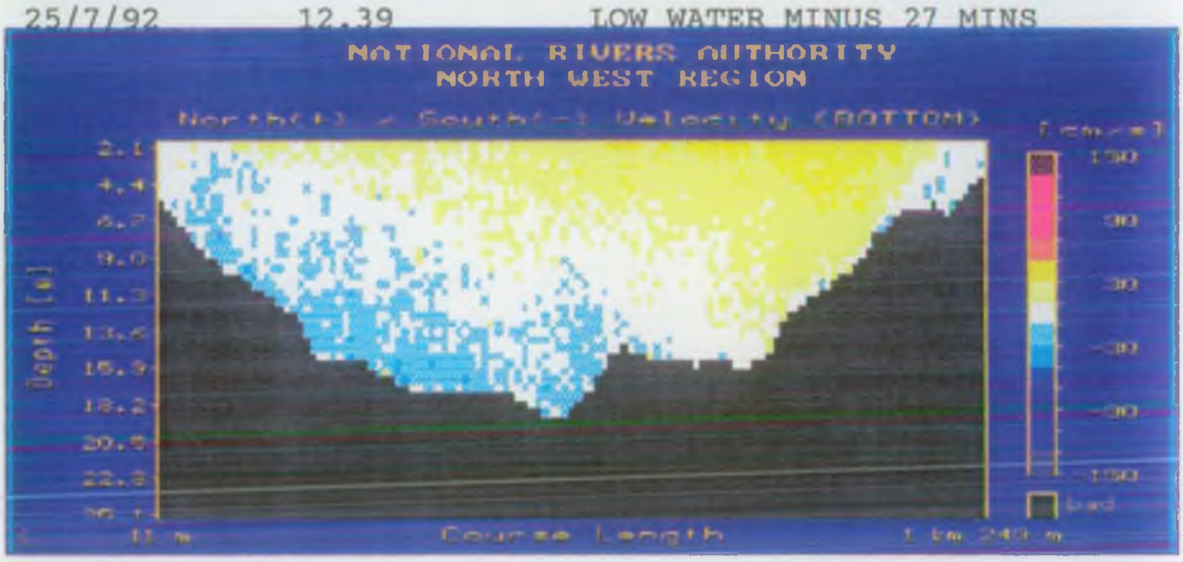




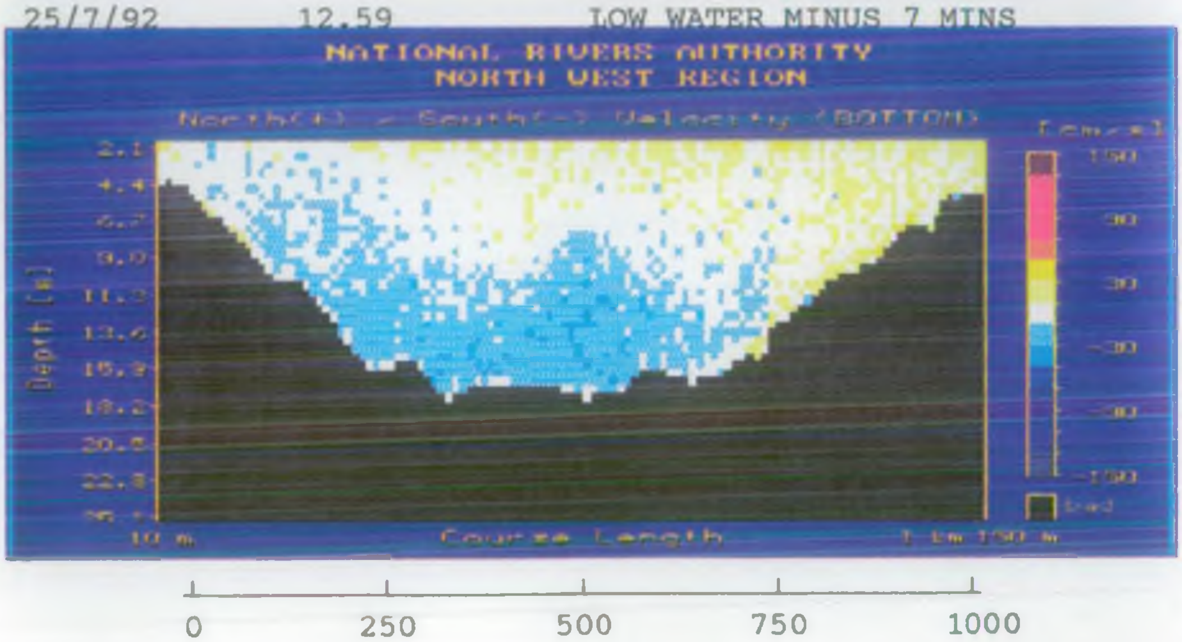
DISTANCE ACROSS TRANSECT (METRES)

25/7/92 12.20 LOW WATER MINUS 46 MINS

25/7/92 12.39 LOW WATER MINUS 27 MINS

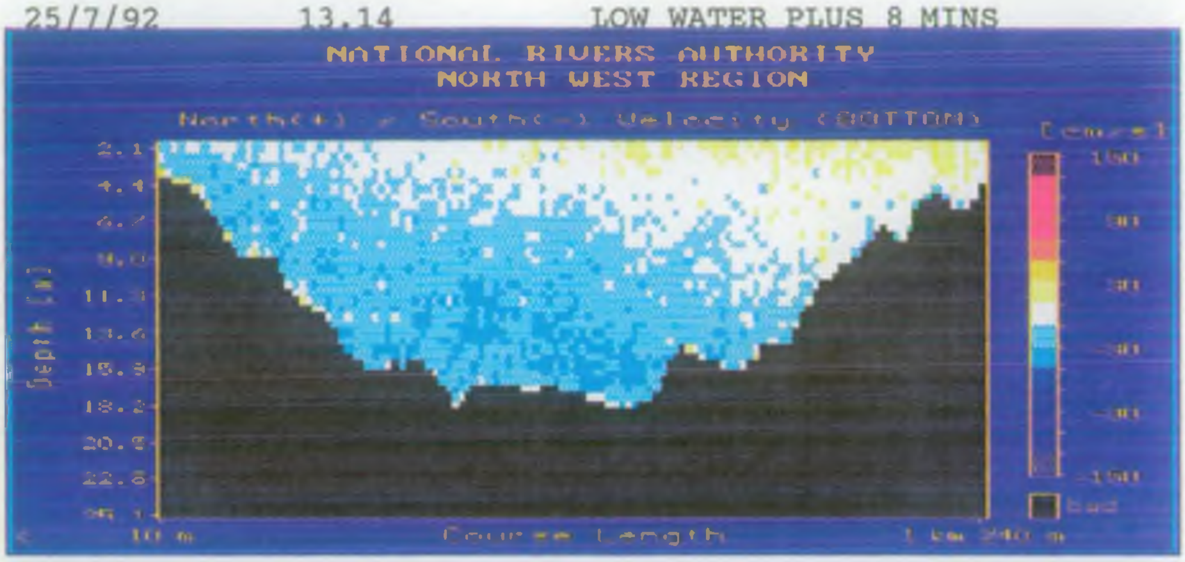


25/7/92 12.59 LOW WATER MINUS 7 MINS

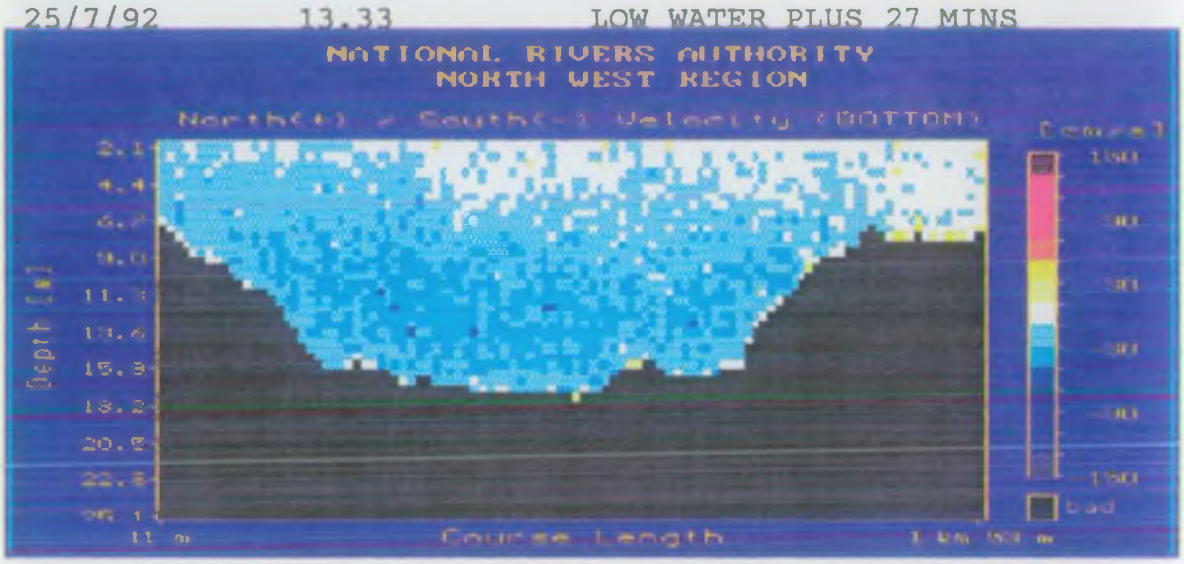


DISTANCE ACROSS TRANSECT (METRES)

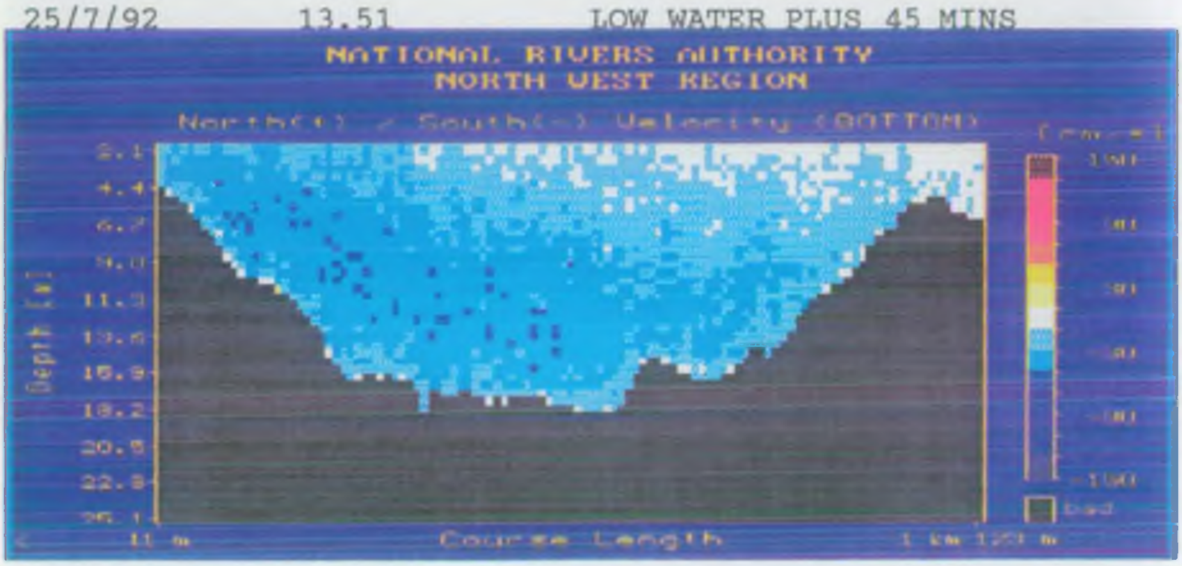
25/7/92 13.14 LOW WATER PLUS 8 MINS



25/7/92 13.33 LOW WATER PLUS 27 MINS

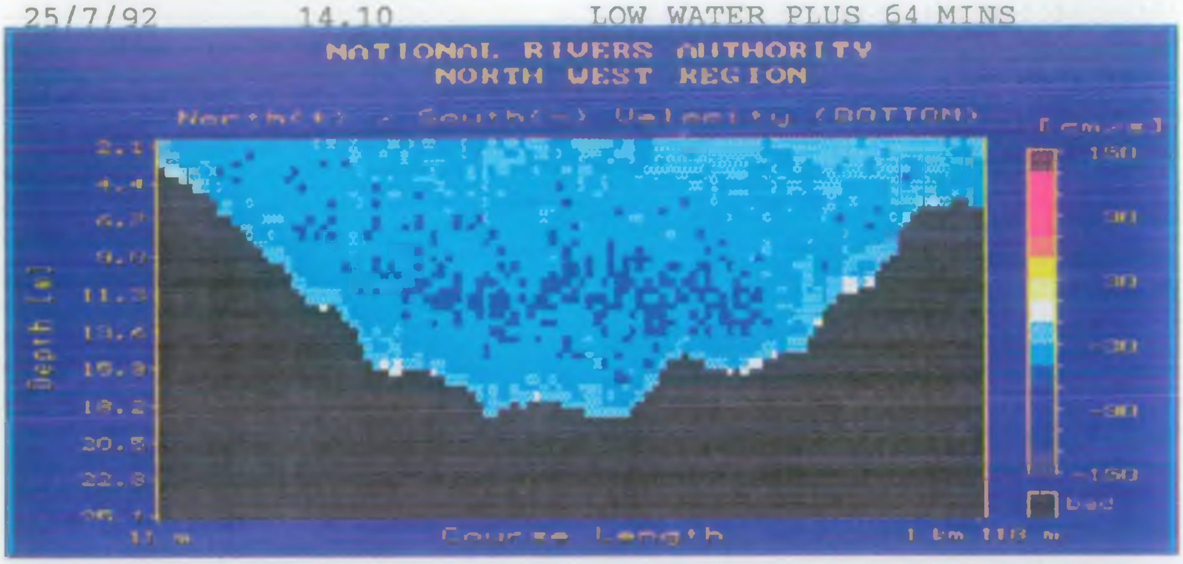


25/7/92 13.51 LOW WATER PLUS 45 MINS

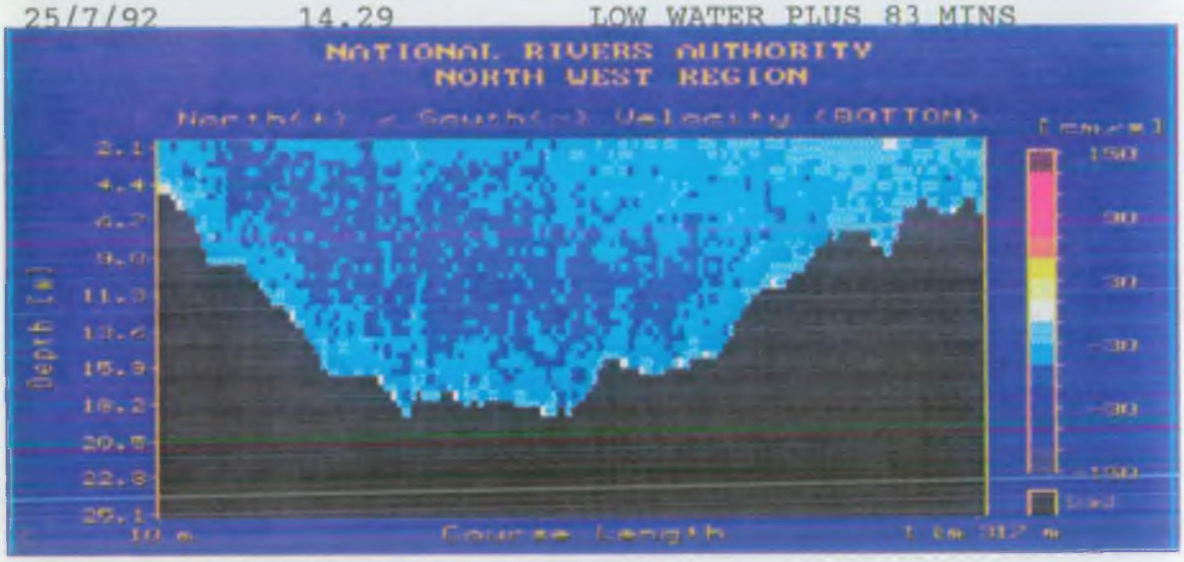


DISTANCE ACROSS TRANSECT (METRES)

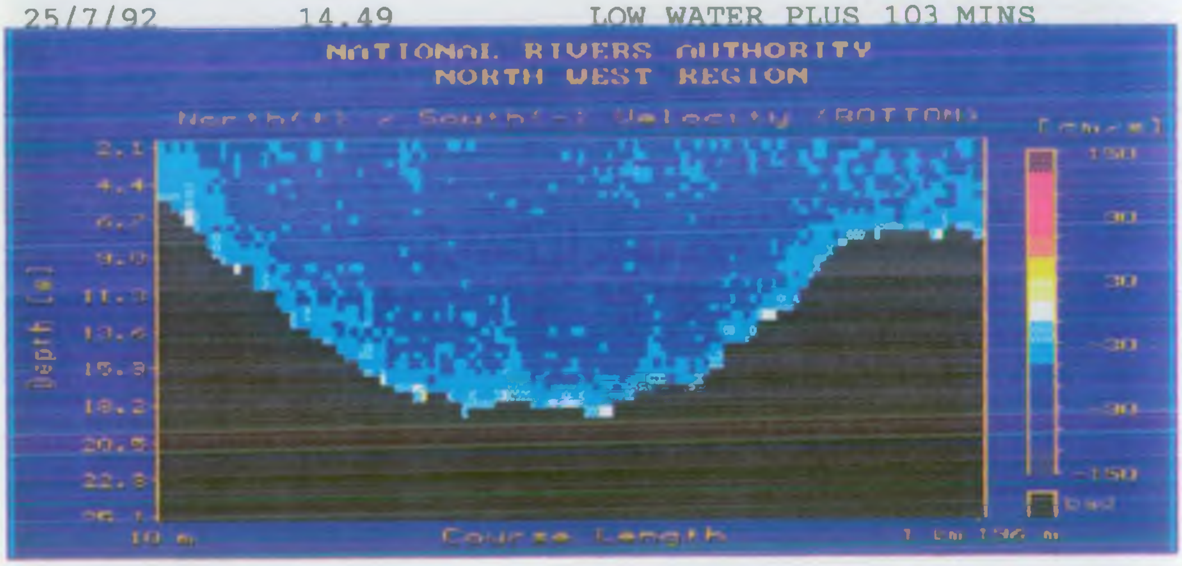
25/7/92 14.10 LOW WATER PLUS 64 MINS



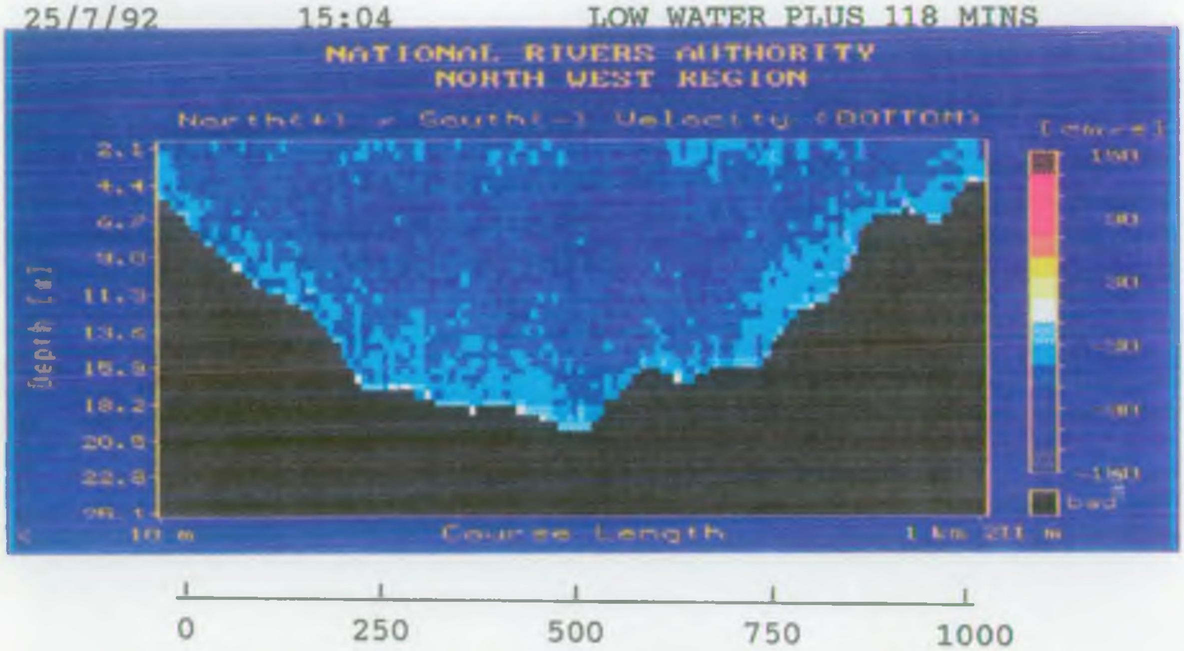
25/7/92 14.29 LOW WATER PLUS 83 MINS



25/7/92 14.49 LOW WATER PLUS 103 MINS



25/7/92 15:04 LOW WATER PLUS 118 MINS



DISTANCE ACROSS TRANSECT (METRES)

REFERENCES

1) Hydraulics Research Station; 'Mersey Estuary, Preliminary Assessment of New Sewage Outfalls'; Report no. EX 849, December 1978.

2) Hydraulics Research Station; 'A Proposed Sewage Outfall to the River Mersey'; Report no. EX 890, September 1979.

3) Alexander B.; 'Future Improvements to the Mersey Estuary'; Royal Society of Health 5, 1982.

4) Watson J.D. & D.M., 'Merseyside Sewerage and Sewage Disposal'; Steering Committee on Pollution of the Mersey Estuary, March 1974.

5) Rivers Division; 'Mersey Estuary, Study of Proposed Liverpool Bank Outfall'; North West Water, May 1981.

6) Dixon A., 'North Liverpool Docks S.T.W. Effluent Outfall Hydraulics Calculations'; North West Water, February 1984.

7) Rivers Division, 'Liverpool North Works ETW Outfall Studies'; North West Water, August 1984.

8) John Taylor & sons (consulting engineers); 'Mersey Estuary Scheme, Sandon Dock Sewage Treatment Works, Stage II Outfall Report on Investigations'; commissioned by North West Water, March 1987.