

Mostyn Deep Sediment Transport Studies

**Report EX 4630
September 2002**

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Contract - Consultancy

This report describes work commissioned by Shoreline Management Partnership, whose representative was Dr Barber. The work was carried out under the HR Wallingford job number DDR3319 by Mr RL Soulsby, Dr CT Mead and Ms JA Magill and was managed by Mr TJ Chesher in the Ports, Estuaries and Industry Department.

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Summary

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As part of a series of studies relating to the disposal of maintenance dredged material the Port of Mostyn is considering the potential for nearshore disposal at the entrance to the Dee Estuary in the vicinity of Mostyn Deep.

Studies were undertaken to estimate the capacity of the tidal currents in this region for transporting sediment, and to compare the potential transport rate with measured transport rates derived from field data of currents and suspended sediment concentrations.

Additional studies were also undertaken to assess the dispersion of the sediment away from discrete locations within the proposed disposal area, and the fate of the dispersed material in the longer term.

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1. INTRODUCTION

1.1 Background

As part of a series of studies relating to the disposal of maintenance dredged material the Port of Mostyn is considering the potential for nearshore disposal at the entrance to the Dee Estuary in the vicinity of Mostyn Deep. Typical volumes for disposal may be of the order of 200,000m³ per annum, disposed at a rate of approximately 50,000m³ per week.

Studies were undertaken to estimate the capacity of the tidal currents in this region for transporting sediment, and to compare the potential transport rate with measured transport rates derived from field data of currents and suspended sediment concentrations. The aim of this exercise was to establish the magnitude of the sediment transport using two discrete methods.

As well as an analysis of the sediment transport capacity of the flow in the vicinity of Mostyn Deep, studies were also required to assess the dispersion of the sediment from the disposal area, and the fate of the dispersed material in the longer term. The sediment dispersion simulations were carried out using established tidal flow fields used in the previous dredging studies (Reference 1).

1.2 Scope of work

The studies described in this report were aimed at providing the following information:

1. Analysis of recently collected field data and assessment of the sediment transporting capacity at two specific locations within the proposed disposal area;
2. Analysis of the dispersion from the disposal area and sediment transport pathways away from the proposed disposal area.

1.3 Report outline

The remainder of this report is structured as follows. Chapter 2 describes the analysis of the sediment transport capacity at two specific locations close to Mostyn Deep to the north of the existing port. Chapter 3 summarises the numerical modelling studies of the dispersion of deposited material. In Chapter 4 conclusions arising from the study are presented.

2. SEDIMENT TRANSPORT PROCESSES AT MOSTYN DEEP

2.1 Introduction

Calculations of sediment transport rates have been made using data collected by Exploration Associates at two sites in Mostyn Deep. These are referred to as ADCP1 (315226 mE, 384895 mN), and ADCP2 (313923 mE, 385442 mN). ADCP1 is near the Mostyn buoy, and ADCP2 is in deeper water near the NE Mostyn buoy. Measurements were made of the water depth, current speed and direction, turbidity, wave conditions and ancillary parameters. The sediment transport rate represents the mass of sediment transported per second by the current (possibly aided by wave action) across a 1m width of seabed transverse to the flow direction.

Two types of calculations were required:

- the predicted sediment transport capacity obtained using standard formulae with inputs of the measured current speeds, water depths and sediment grain size;
- the measured sediment transport rates obtained using the above data plus the observed turbidities (and hence suspended sediment concentrations).

2.2 Data review

At each of sites ADCP1 and ADCP2 the following measurements were made over the period 24 April to 13 June 2002 (49 days):

- current speed and direction at 1m intervals above bed (lowest = 2.21m) every 15 minutes by an Acoustic Doppler Current Profiler (ADCP) mounted in a frame on the seabed;
- turbidity at 0.5s digitisation rate for a 3 minute record every 30 minutes by a turbidity meter mounted at a height of 0.8m in the ADCP frame;
- water depth logged by the turbidity meter to same recording schedule;
- temperature and salinity;
- wave statistics at a site near to ADCP1, including hourly values of significant wave height (H_s), zero-crossing period (T_z), and direction.

In addition, stations were worked at ADCP1 and ADCP2 on 14 May and 30 May 2002 taking profiles of current speed and direction with a Direct Reading Current Meter (DRCM) at 1m depths below water surface, together with turbidity, salinity and temperature. Water samples were also taken and analysed for suspended sediment concentration.

The following were supplied to HR Wallingford by the client:

- reports "Oceanographic Survey Mostyn Deep" Volumes 1, 2 and 3 by Exploration Associates, containing a description of the methods used and graphical presentations of the data;
- electronic files containing Excel spreadsheets of the data;
- for the long-term turbidity records a CD-ROM with the 0.5-second data was supplied. These were averaged over the 3-minute records by HR to provide half-hourly turbidities.

Attention was primarily focused on the day 30 May 2002, when the more reliable of the DRCM surveys was made. The tidal range at Liverpool on 30 May 2002 was predicted in the tide tables as 7.3m, compared with a Mean Spring Range of 8.4m. The chosen tide was thus somewhat less than Mean Springs.

A comparison between the current speeds from the ADCP1 at a height of 7.21m and DRCM1 at 6m below surface (with a mean water depth of 13.2m) showed good agreement. This consistency check gave confidence both in the current speed measurements and in the conversion of DRCM depths to heights

above bed. Comparison of full velocity profiles at times of peak flood and ebb current confirmed consistency.

The turbidity data was supplied in both NTU (Nephelometric Turbidity Units), and in sediment concentration units (mg/l). Conversion from NTU to mg/l had been undertaken by Exploration Associates on the basis of the total sediment concentration in the water samples. Examination of the variation of turbidity with time showed two features:

- (a) a periodic variation with a semi-diurnal period, in phase with the temperature and salinity variations, and relatively constant with height above the bed;
- (b) a periodic variation with a quarter-diurnal period, peaking at about the times of peak flood and ebb current speed, with large values near the bed and a relatively strong decrease with height above the bed.

Feature (a) is characteristic of advection of suspended fine mud and silt up and down the estuary. In rivers this is called “washload”, and is recognised as not influencing the local erosion and deposition of sediment because it stays in suspension for long times. It is usually subtracted from the total concentration for subsequent analysis of the sediment transport rate.

Feature (b) is characteristic of local suspension of sand, which responds quickly to the changing tidal current. This does affect the local erosion and deposition. The concentration near the bed is much larger than the washload.

The present dredging study is primarily concerned with sand. Consequently, the turbidity was re-calibrated against the water samples to apply only to the sand fraction. This was accomplished by passing a line with zero mean through the largest concentrations in the samples, which were taken to apply to the suspended sand (Figure 2). The same calibration was found to apply to both sites (which had the same model of turbidity meter), namely:

$$\text{Concentration (mg/l)} = 1.2 \times \text{NTU} \quad (2.1)$$

For the turbidity data from the seabed frames a constant washload of 20 mg/l at ADCP1, and 40mg/l at ADCP2, was subtracted to give the sand concentration in mg/l. A more elaborate time-varying method was applied to the DRCM turbidities, in which the concentration 2m below surface was deemed to be washload, and subtracted from all levels. In all cases, any negative numbers resulting from the subtractions were set to zero.

The wave data were examined, and occurrences with $H_s \geq 0.5\text{m}$ were highlighted. These occurred eight times during the 49-day measurement period, with durations of 1 to 5 hours. The effect of the waves is discussed in Section 2.4.

On the basis of particle size distributions from grab samples within the estuary, the bed was taken to be represented by

$$\begin{aligned} d_{10} &= 90 \mu\text{m} \\ d_{50} &= 200 \mu\text{m} \\ d_{90} &= 350 \mu\text{m} \end{aligned}$$

The temperature and salinity were taken as constant values of 12.5°C and 31 PSU.

2.3 Sediment transport capacity

Several methods are available for predicting the sediment transport rate at a point for a given sediment grain size, water depth and current speed. In all of them, the sediment transport rate increases rapidly with

the current speed, and finer grains are transported more readily than coarser grains. The methods all assume that the current speed is constant in the streamwise direction, and that there is an ample supply of the specified sediment size at the calculation point; they then predict the sediment transport capacity.

Three of the most widely used methods have been applied in this study to give some measure of the error-bounds on the predictions. These are:

- The Ackers and White (1973) formula, with the revised (1990) coefficients (A&W);
- Van Rijn (1984) full theory (VR);
- Engelund and Hansen (1972) formula, with Engelund (1966) alluvial friction (E&H).

The formulae and full references are given in “Dynamics of Marine Sands” (Soulsby, 1997), Section 10.2. All the methods were derived for use in rivers (uni-directional flow), but they are commonly used also in tidal (reversing) flows in the absence of waves. Waves are omitted in the present calculations, for reasons justified later. The three methods were applied to the currents data from the ADCP at the two sites ADCP1 and ADCP2.

The depth averaged current speed (\bar{U}) was calculated from the profiles by integration using the trapezium rule (see Soulsby, 1997, Eq. 29). These values, together with water depth and sediment grain sizes, were used as inputs to the software package SandCalc which provides an easy way of calculating the Ackers and White, Van Rijn, and Engelund and Hansen methods. Computations were made at half hourly intervals, centred on the peak ebb and flood current speeds, for a single tide.

Figures 3 and 4 show, for ADCP1 and ADCP2 respectively:

- The variation in water depth;
- Current speeds at heights of 2.21, 4.21 and 8.21m, and the depth-averaged current speed (\bar{U});
- Sediment transport rate by the three methods.

The numbers on the abscissa are at 15-minute intervals after midnight.

Values are tabulated in Tables 1 and 2, in which are also shown the transports integrated over the ebb tide, the flood tide, and the whole tide. At ADCP1 the peak flood current is slightly larger than the peak ebb current, resulting in a flood-directed net transport of between 158 and 765 kg/m/tide, depending on the method. At the deeper site ADCP2 the ebb currents are similar to ADCP1, but the flood currents are much stronger, resulting in a flood directed net transport of between 1787 and 7926 kg/m/tide, (about 10 times larger than at ADCP1). At both sites there are large peaks in the flood sediment transport at the time of peak current that have a decisive effect on the net transports.

2.4 Sensitivity analysis on predictions of sediment transport rates

The predictions of sediment transport rates are sensitive to two factors: (a) the choice of prediction method, (b) variations or inaccuracies in the input parameters.

The calculations with SandCalc (Tables 1 and 2) used three methods: Ackers & White (revised), Van Rijn (full method), and Engelund & Hansen, referred to as A&W, VR and E&H respectively. The calculations showed a variation between methods (taking VR as the baseline) of about a factor of 2 for current speeds larger than about 0.6m/s. Thus at a given time the largest prediction was about twice the baseline, and the smallest about half the baseline. This is a typical level of accuracy for sediment transport calculations. In some cases A&W was the largest, and in others E&H was the largest, with VR usually in between.

The sensitivity to variations in inputs is exemplified in the table below. The baseline inputs were taken as those for site ADCP1 at the time of the maximum flood current (11:15 on 30/05/02), and are listed in the

table. The VR method was taken as being representative of the other methods. Each input parameter was varied in turn, keeping the other inputs constant. The calculated sediment transport rates are found to be very weakly dependent on the water temperature and salinity, and only slightly dependent on the water depth and the degree of sediment sorting (d90/d10). In all these cases the percent change in the transport rate is much less than the percent change in the input parameter. The transport is relatively strongly dependent on the median grain-size (d50) and the sediment mineral density (although an increase of 10% in density over that of quartz would be unusual). The transport is most strongly dependent on the current speed, increasing by 61% for a 10% increase in current speed. The effect of smaller changes in the parameters can be estimated *pro rata*, although larger changes should be calculated specifically.

Sensitivity analysis on sediment transport predictions

The sensitivity of the prediction formulae for sediment transport to changes in inputs is tested. The Baseline case is the inputs for site ADCP1 at the peak flood current 30/05/02 at 11:15, time no. 46

Temp =	12.5 deg C	Salinity =	31 PSU
Depth =	13.7 m	Current =	1.05 m/s
Sed. density =	2650 kg/m ³	d50 =	200 microns
d10 =	90 microns	d90 =	350 microns

Van Rijn (Full method) used to calculate total sediment transport rate q_t
 Baseline is $q_t = 0.000203 \text{ m}^2/\text{s} = 0.538 \text{ kg/m/s}$

Input parameter	Change in parameter	% change in q_t
Water depth	+10%	-2
Current speed	+10%	+61
d50 grainsize	+10%	-12
d90/d10	+10%	+4
Sed. density	+10%	-20**
Temperature	+5 deg C	-0.3
Salinity	+4 PSU	0
Bed level (same vol flux)	raise 1m	+51
Waves*	Hs=1m Tz=5.5s	+13

* % change calculated using Soulsby/van Rijn formula with/without waves
 S/VR formula gives $q_t = 0.000391 \text{ m}^2/\text{s}$ for Baseline

** based on mass transport rate (kg/m/s)

A test was made of the ability of the current to disperse a layer of sediment 1m thick dumped on the seabed. The effect is to both reduce the water depth (weak effect on transport), and to increase the current speed (strong effect on transport). The modified current speed was calculated using 2D continuity such that the volume flux of water per metre width of bed remained constant. (In practice the increase would not be so great, since the flow will also expand sideways around the dumped material.) The transport rate increased by 51%, demonstrating that the flow has a greatly increased capacity to transport sediment away if the disposed material starts to accumulate.

A test was also made of the effect of waves on sediment transport in Mostyn Deep. During the period of wave measurements in Mostyn Deep, 24/4/02 to 13/6/02, the significant wave height H_s exceeded 0.5m on eight occasions, lasting for durations of 1 to 5 hours. The maximum H_s encountered was 0.915m (twice), and the corresponding zero-crossing wave periods were about 5.5s. In all the cases the water level was above Mean Sea Level, demonstrating that shoals exclude waves from the Dee Estuary for water levels below MSL. The highest waves occurred near to High Water, when current speeds are close to slack

water, and consequently when sediment transport is zero or small. The waves were much smaller at times of peak flood or ebb current. Nevertheless, to test the effect of waves on the sediment transport waves of height $H_s = 1\text{m}$ and $T_z = 5.5\text{s}$ were added to the Baseline conditions described above. In this case the predictions of sediment transport rate were made using the Soulsby/Van Rijn (SVR) method (Soulsby, 1997, Eq 136), since the methods used above do not cater for waves. The baseline inputs using SVR gave a transport rate 93% larger than the VR method, despite the statement by Van Rijn (1984) that the VR formula (which the SVR formula reduces to in the absence of waves) is matched to his Full method generally to within 20%. Addition of the stated waves increased the sediment transport (using SVR) by 13%. Thus the effect of waves on the sediment transport in Mostyn Deep is weak, especially since the conservative case of large waves at time of peak current was taken. The effect at the deeper ADCP2 site would be even weaker.

Thus we can conclude:

- The predicted sediment transport rates have an uncertainty of about a factor of 2 due to differences in prediction methods;
- The predicted sediment transport rates are strongly sensitive to the current speed, and moderately sensitive to the median grainsize. They are relatively insensitive to the water temperature, salinity and depth, and the sediment sorting;
- If the dumped sediment starts to accumulate on the bed, the current speed increases for reasons of continuity, and this in turn raises the sediment transport rate locally thereby increasing the dispersion of sediment;
- The effect of waves on sediment transport in Mostyn Deep is unimportant.

2.5 Sediment flux calculations

The measured sediment transport rates were calculated from the suspended sand concentrations in mg/l, at a height of 0.8m, calibrated as described in Section 2.2, together with the ADCP current profiles. The variation with height of the concentration was assessed from the DRCM turbidity profiles on 30 May 2002. The height above bed of the DRCM was calculated from the recorded depth beneath surface and the simultaneous water depth from the closely adjacent bottom-mounted turbidity meter. After removal of the washload (see Section 2.2), the concentration profile was found to decrease approximately linearly from the bed to a height of between 7.5m and 10.5m, depending on the time in the tide. An example is shown in Figure 5. This differs from conventional sediment transport theory, in which an inverse power-law decay of concentration with height is assumed (see Soulsby, 1997, Section 8.4). Guided by the data and pragmatism, the concentration profile $C(z)$ for this study is taken to follow the general form:

$$C(z) = C_{80} \left(\frac{9.21 - z}{9.21 - 0.80} \right) \quad \text{For } 0 \leq z \leq 9.21\text{m} \quad (2.2a)$$

$$= 0 \quad \text{For } z > 9.21\text{m} \quad (2.2b)$$

where z is height above bottom, C_{80} is the sand concentration at 0.8m from the bottom-mounted turbidity meter, and the height 9.21m is one of the ADCP levels. The concentration at each of the ADCP current levels was computed using Eq.(2.2). The current speed at $z = 0.8\text{m}$ was calculated from the speed measured at $z = 2.21\text{m}$ assuming that the speed varies as $z^{1/7}$ (see Soulsby, 1997, Eq.28a). This gives pairs of speed and concentration at heights of 0.8, 2.21, 3.21, 4.21, ... 9.21m, which were multiplied to give sediment flux at each height. The flux was integrated through the depth between $z = 0$ and 9.21m, taking a constant flux beneath 0.8m, to give the suspended sediment transport rate, q_s . The contribution q_b from bedload transport was estimated by calculating the friction velocity u_* from the measured current at 2.21m using Eq(35) of Soulsby (1997), and using it in the Nielsen bedload formula (Soulsby, 1997, Eq.124). The total sediment transport rate q_t was calculated from:

$$q_t = q_s + q_b \quad (2.3)$$

The results for sites ADCP1 and ADCP2 are tabulated in Table 3 and 4 for the same tide on 30 May 2002 as used in the sediment transport capacity predictions (Section 2.3). Figures 6 and 7 show in the upper panel the variation through the tide of water depth, current speed at height of 4.21m (approximately equal to \bar{U}), and sand concentration at 0.8m. The lower panel shows the sediment transport rate as suspended transport (q_s), bedload transport (q_b) and total transport (q_t). The numbers on the abscissa refer to the same 15-minute intervals as in Figure 3 and 4.

Bedload transport was in most cases less than 10% of the total transport, as is commonly found for fine/medium sands.

At site ADCP1 the peak concentration on the ebb is much larger than on the flood, despite the current speeds being rather similar. The peak concentration occurs about 2 hours later than peak current on the ebb, and slightly earlier than peak current on the flood. This may indicate that high concentrations of sediment are advected to site ADCP1 from the shoals lying south-east during the ebb tide. The total transport follows a similar pattern to the concentration with larger transport during the ebb tide. The transport during the ebb tide is 3152kg/m, and during the flood tide is 1734kg/m. There is thus a net residual transport of 1418kg/m/tide in the ebb direction.

At site ADCP2 the behaviour is reversed, with larger concentrations occurring during the flood tide. This is in line with expectations, because the peak flood current is appreciably stronger than the ebb. The timing of the peaks of concentration are displaced from the peaks of current speed, and the flood exhibits a double peak, which is not easily explained. The transport during the ebb tide is 3249kg/m and during the flood is 6501kg/m, giving a net residual transport of 3252kg/m/tide in the flood direction.

Comparing sites ADCP1 and ADCP2, the currents during the ebb are similar at the two sites, and so are the integrated sediment transports. The flood current at ADCP1 is similar to the ebb, but concentrations are larger on the ebb, leading to net ebb transport. At ADCP2 the flood current and concentration are both larger than the ebb leading to a net flood transport which is nearly twice the magnitude of the net ebb transport at ADCP1.

The predicted and measured sediment transport are plotted together in Figure 8. It can be seen that the predicted values are generally of a similar magnitude to the measured values. This level of agreement is typical of sediment transport studies, since it is not an exact science. The main features of the predictions and measurements are:

- At ADCP1 measured ebb transports are larger than predictions, and measured flood transports are smaller than predictions;
- This leads to a measured net ebb-directed transport in contrast to the predicted net flood-directed transport at ADCP1;
- A better measure of agreement between measured and predicted transports is found at ADCP2, both yielding a flood-residual transport. The measured net transport lies within the range of predicted net transports from the three methods;
- At both ADCP1 and ADCP2 the peak flood current speed happened to occur between the half-hourly turbidity measurements. Thus the large peak predicted transports on the flood are not seen in the measurements.

The discrepancy between the measured and predicted transports at ADCP1 is not as significant as it appears. The flood and ebb tides are rather closely balanced here, and the TELEMAC flow model shows that ADCP1 lies close to a boundary between flood-directed and ebb-directed peak currents. While the predicted transports rely on an assumption that the currents and depths are uniform everywhere, the actual concentrations will include advected sediment from adjacent areas. This may tip the balance either way at

this site. Conversely, ADCP2 lies firmly within a zone of flood-dominated currents, and hence measured and predicted transports are in better agreement.

2.6 Long-term sediment flux calculations

The calculations in Section 2.5 applied only to a single tide taken from the full 49-day set of measurements taken. To examine the representativeness of this tide a simplified analysis has been made of the whole data-set.

The detailed integrations performed for the single tide in an Excel spreadsheet would be excessively laborious to apply to the whole time-series. However, a simplified but reasonably accurate method of calculating the half-hourly sediment transport rates has been devised. If the shape of both the velocity and the concentration profiles can be scaled by a constant length scale, it can be deduced mathematically that the suspended sediment transport q_s can be written as:

$$q_s = AC_{80} \cdot U_{421} \quad (2.4)$$

where C_{80} is the measured concentration at 0.8m, U_{421} is the measured current speed at 4.21m, and A is a constant of integration. The assumptions hold for this particular study because the linear decay of the concentration profile given by Eq(2.2a) is based on a single length-scale (9.21m); this would not always be the case in other studies.

The value of constant A can be determined from the full computations made for the single tide on 30 May 2002. Figure 9 shows that the assumptions hold to within about 10% in most cases, yielding large values of the coefficient of determination R^2 , and giving values of $A = 0.0042$ for ADCP1 and $A = 0.0041$ for ADCP2. A similar simplification of the bedload transport leads to:

$$q_b = BU_{421}^{1.5} - D \quad (2.5)$$

where coefficients B and D can be obtained by calibration against the single tide. This yields $B = 0.056$ and $D = 0.024$ for ADCP1, and $B = 0.054$ and $D = 0.023$ for ADCP2.

The measured values of U_{421} , C_{80} and water depth were entered into a spreadsheet for the whole 49-day measurement period, at half-hourly intervals. Equations 2.4 and 2.5 were applied and summed to give half-hourly values of q_t . The ADCP current directions were used to assign a positive value to q_t for flood-directed currents, and a negative value for ebb currents. These are plotted in the middle panel of Figures 10 and 11. A 25-hour integration period was chosen as being close to the 24-hour 50 minute period of two tides (flood – ebb – flood – ebb). The net sediment transport over each 25-hour period was calculated by summation of the q_t values (bottom panel of Figures 10 and 11). The 25-hour tidal range was calculated as maximum depth minus minimum depth during the 25 hours (top panel of Figures 10 and 11), to illustrate the spring-neap cycle through the deployment.

It is important to note that some of the turbidity data was contaminated with rogue points or off-scale values. It would be a major task to identify these and replace them, and this has not been done. The results should thus be treated with caution, especially in the first 8 days or so when these data problems were especially frequent.

The variation of the 25-hour tidal range is very similar at ADCP1 and ADCP2, as would be expected. The largest spring tides occur 2 to 5 days after deployment. The largest half-hourly sediment transports (q_t) occur then (although these days have the least reliable turbidity measurements), on both ADCP1 and ADCP2. Large transports also occur during the later two periods of spring tides, and these values are more reliable. Little transport takes place during neap tides.

The 25-hour net sediment transport at ADCP1 is predominantly negative (ebb-directed), although there are also many occurrences of flood-directed 25-hour residuals. This again is consistent with the position of ADCP1 near the boundary between flood and ebb dominant currents. Values are generally larger during spring tides. In most cases (ignoring the first 8 days) the net transport lies between 5000kg/m/25hr in the ebb direction, and 2000kg/m/25hr in the flood direction. An attempt to correlate 25 hour residuals with 25 hour ranges showed no clear pattern.

Results at ADCP2 show a similar spring-neap dependence to ADCP1, but with a much stronger flood dominance, visible in both the middle and lower panels of Figure 11. The jagged appearance of the transport plots is due to a greater number of contaminations of the turbidity data at ADCP2. The 25-hour net sediment transports are almost exclusively flood-directed. Values generally lie between 2000 and 15000kg/m/25hr (ignoring the first 8 days).

3. SEDIMENT DISPERSION MODELLING

3.1 Introduction

Mathematical modelling was undertaken, based on currents simulated by the tidal flow model established for the previous studies (Reference 1). The mesh of this model is illustrated in Figure 12. The modelling was largely carried out using HR Wallingford's SANDTRACK model, which is a recent development of the SEDPLUME-RW model. SEDPLUME-RW is a long-established Lagrangian model, which simulates the dispersal of cohesive sediments released into the water column during dredging-related activity, and SANDTRACK is an enhancement of that model to represent the behaviour of non-cohesive sediments. Details of the SANDTRACK model are given in Section 3.2. In Section 3.3, the input data and results of the model simulations are described.

The cycle of spring tide currents was used as input to the sediment dispersal modelling, and the peak flood and ebb tidal currents simulated by the flow model are illustrated in Figure 13. During the course of the modelling, it was established that the forms of the sand transport pathways simulated were critically dependent on imbalances between maximum flood and ebb tide current speeds. Approximate indications of these imbalances are given in Figures 14 and 15, which illustrate, for the simulated spring tide and neap tide respectively, the zones in which the maximum flood tide current speed exceeds the maximum ebb tide speed, and the zones in which this situation is reversed.

3.2 SANDTRACK Model details

The SANDTRACK model simulates the paths taken by a large number of identified ("tagged") sand grains in coastal areas in response to waves and currents. A number of practical applications require such a Lagrangian approach, as distinct from the more traditional Eulerian calculations of the transport rates of bulk quantities of identical, non-tagged, grains. These include dispersal of dredged material, and the fate of contaminated particles.

The particle-tracking algorithm determining the movement of tagged grains takes account of the following processes:

- burial and re-emergence;
- initiation of motion and entrainment by combined waves and currents;
- bedload transport;
- suspended transport;
- turbulent diffusion.

A novel method of simulating these processes has been devised, by formulating functions to parameterise each of them, and then specifying a grain speed as the product of the functions. The resulting speed that the grain travels at, U_{gr} , is related to the speed of the current, U_c , near the bed, and the orbital velocity of wave action, if significant. The particle-tracking algorithm is implemented within HR Wallingford's SEDPLUME-RW model, originally devised to track the dispersal of muddy sediments. This in turn is driven by currents computed by the TELEMAC model. A schematic illustration of the dependence of U_{gr} on U_c for both SANDTRACK and the original version of SEDPLUME-RW is shown in Figure 16 (without taking account of burial processes). It can be seen that for current speeds only a little exceeding the threshold of motion, SANDTRACK gives much smaller values of U_{gr} than SEDPLUME, as would be expected for sand grains. However, at larger currents (or when waves are present), the grains in SANDTRACK move more nearly at the speed of the mean current, and are more similar to the speeds in SEDPLUME.

Applications of SANDTRACK include:

- a validation exercise simulating dispersal of radioactive sand tracer measured in the 1960s in Morecambe Bay;
- 30-year simulation of grain dispersal on the north coast of Scotland.

3.3 Model simulations

The sand dispersal modelling used as input data the spring tide currents for a repeating, semi-diurnal cycle generated by the existing tidal flow model. These current data were used repeatedly throughout each model simulation; that is, the simulation length was assumed to consist of a continuous sequence of identical spring tides. This is an approximation to reality, because the tidal range varies continually between spring and neap tides. A model sensitivity test indicated that 200 μ m sand grains at the sea bed at ADCP Position 1 would be immobile under neap tide conditions, so that inclusion of neap tide currents in the modelling was unnecessary. The modelling approach adopted neglects flows associated with tides of intermediate range, and also those associated with tides of larger ranges than the simulated spring tide. It is, however, considered that the assumptions made affect only the timescales of the modelling: the results presented are for a period of 700 tidal cycles which are assumed to represent the dispersion of the placed dredged material over a period of order one year. Given the uncertainties involved in sediment transport modelling, and the relatively long durations of the simulations undertaken, this is not considered to be a serious limitation of the approach adopted.

The effects of waves were omitted from the modelling, as the previous modelling study (Reference 1) established that wave effects in the study area are small in comparison to the effects of tidal currents on sand transport.

For each model simulation, one barge load (1,400m³) of dredged material was assumed to be placed on the sea bed at the disposal site under investigation, represented by 1000 tagged sand grains. This placement was assumed to be instantaneous, without any loss of material into the water column during placement, and without effect on the calculated tidal currents. A model test designed to assess the sensitivity of the results to extended release times indicated that, for release durations of up to one tidal cycle, the simulated long-term sediment distribution was generally insensitive to the release duration.

A median sand grain diameter of 200 μ m was assumed for both the placed material and the existing sea bed throughout the study area. Tests on the sensitivity of the model results to the assumed sand grain diameter indicated that, for mobile grains, the qualitative features of the simulated sand distributions were generally insensitive to the grain diameter. This is consistent with the model representing sand grains that are mainly moving close to or on the seabed.

In the following sub-sections, the model results derived for various disposal sites are described. In all cases, sand deposits densities are presented on a square mesh of 100m elements. The durations of most of the simulations were one year although, when interpreting the results, one should bear in mind the uncertainties in the timescales discussed above.

3.3.1 ADCP Position 1 disposal site

A simulation was carried out to assess the dispersal of dredged material placed on the sea bed at ADCP Position 1. The distribution of sand deposits densities after one year is shown in Figure 17.

On commencement of the simulation, all of the material placed at the disposal site moved to the SE. As the simulation progressed, some of the material continued to the SE until it reached a location some 2km from the release point, whilst the remainder moved NE, then NW, to form the zone of deposits largely in the NE quadrant near the release point. Detailed analyses of the model results indicates that the particles in this zone moved in roughly elliptical paths, with major axes coincident with the dividing line between flood-dominated (maximum flood tide speeds exceed maximum ebb tide speeds) and ebb-dominated flow (Figure 14). The SE extent of the sand deposits distribution is also coincident with this dividing line.

A sensitivity test was carried out to determine whether the features of the sand deposits distribution were sensitive to the prevailing current speed magnitudes. This test was the same as that described above for disposal at ADCP Position 1, except that the spring tide current speeds computed by the tidal flow model were increased by 10%. Such a procedure does not necessarily represent the effects of an increase in tidal

range, as it neglects any differences in flow pattern between tides of different range, but it does enable an approximate assessment of the sensitivity to current speed magnitudes to be made. The results of the sensitivity test are shown in Figure 18.

The increased current speeds resulted in some spreading of the deposits within the overall distribution, although the main features of the distribution were unchanged (compare Figures 17 and 18). Increased spreading approximately parallel to the major axis of the deposits distribution took the form of individual model particles moving away from the main patch to the NW and SE (in the case of increased movement to the SE, this applied to only one model particle, which left the output grid of the SANDTRACK model, so is not included in Figure 18). The similarity of the bulk features of the two deposits distributions is believed to result from the fact that the velocity scaling applied in the sensitivity test did not alter the location of the dividing line between flood-dominated and ebb-dominated flow. Figures 14 and 15 highlight the difference in the peak velocity direction between spring and neap tides, and indicates that as the tide modulate between spring and neap tide conditions, the location of this dividing line between flood-dominated and ebb-dominated flow will also vary. It is considered that the effect of this modulation would be to enhance the spreading of the deposits within the overall distribution.

3.3.2 ADCP Position 2 disposal site

A simulation was carried out to assess the dispersal of dredged material deposited on the sea bed at ADCP Position 2. The distribution of sand deposits densities after one year is shown in Figure 19.

Unlike the material deposited at ADCP Position 1, the material originating at ADCP Position 2 was dispersed entirely to the SE of the disposal site at the end of the one-year simulation. Most of the material lay between some 1.5km and 3km from the release point, with some material having moved further, to a location approximately 5km from the release point (Figure 19). The principal difference between the behaviour of the material released at ADCP Positions 1 and 2 is believed to be associated with the different locations of these potential disposal sites in terms of flood- and ebb-dominant tidal currents (Figure 14). The material which originated at ADCP Position 2 remained largely within a zone of flood-dominance, whereas the material which originated at ADCP Position 1 encountered zones of both flood- and ebb-dominated flow.

3.3.3 Intermediate disposal site

In view of the markedly different dispersal patterns of material placed at ADCP Positions 1 and 2, a further simulation was undertaken, based on a disposal site mid-way between the two ADCP locations. The distribution of sand deposits densities after one year is shown in Figure 20.

The material originating at the intermediate disposal site moved in a similar way to the material originating at ADCP Position 2, although with a trajectory directed more towards the east. At the end of the simulation, the material was between some 3km and 5km from the point of release (Figure 20). Again, this behaviour is consistent with the material remaining largely within a zone of flood-dominated flow.

3.3.4 Dispersion of material as suspended load

As described in Section 3.1, SANDTRACK is derived from the HR Wallingford SEDPLUME model which simulates the dispersal of cohesive sediments released into the water column during dredging-related activity. For the sediment sizes in question in this study, most of the sediment is confined to the lower part of the water column, moving near or on the seabed. A relatively small proportion of the sediment will, however, be entrained higher into the water column (especially when the currents are highest, or if vertical accelerations occur). By way of a sensitivity test, the SEDPLUME model was run for the same grain size sediment (200 μ m) and for the same spring tidal condition for a period of 10 weeks. The resulting distribution of sand deposits densities is presented in Figure 21. This simulation indicates that material that is carried in suspension will be dispersed over a greater area and in a shorter period, when compared to the material which moves close to the bed. It is re-iterated that most of the sediment in this assessment will move close to the bed.

4. CONCLUSIONS

The conclusions regarding the sediment transport capacity and sediment dispersion assessment for this site are summarised as follows:

1. The recently collected field data provided valuable information for use in assessing the predicted sediment transport capacity (using conventional formulae), and the measured sediment rates. It was found that the predicted rates of transport are generally of a similar magnitude to the measured values. This information confirms that the hydrodynamic conditions at the two locations considered are responsible for transporting significant amounts of sediment.
2. Transport rates are high during both flood and ebb conditions, and the direction and magnitude of net sediment transport appears to vary strongly with location. This aspect is highlighted by the sensitivity in the dominant current field.
3. Sensitivity tests on the predicted sediment transport rates indicated that the rate of transport is sensitive to currents speed, and hence to changes in the seabed level, on the basis that accretion on the bed would locally raise the current. Therefore, if the dumped sediment starts to accumulate on the bed, the current speed increases for reasons of continuity, and this in turn raises the sediment transport rate locally thereby increasing the dispersion of sediment.
4. Dispersion of the disposed material was assessed using a sophisticated particle tracking model, with complex bed processes including burial. Simulations over long timescales were performed in order to investigate the long-term dispersion patterns.
5. The dispersion modelling indicated that the dispersal of the material was relatively slow, when compared to that of finer material that is carried higher in the water column. After a period of order one year the disposed material has generally dispersed over an area of typically up to 5km from the disposal site.
6. Some of the disposed material will be carried higher into suspension and will be dispersed more readily, so that over time there will be a general “leakage” out of the area, but it is estimated that this rate of leakage is low.
7. Despite the findings described above, it is not considered likely or feasible that sediment will accumulate on the seabed for the reasons given in item 3 above, namely that significant accumulation would have the effect of locally increasing the transporting capacity, thereby removing the accumulation.
8. The dispersion of the material appears to be dependent on the disposal location, with the three locations simulated giving markedly different dispersion patterns.
9. The dispersion process was simulated for single spring tides only, and although a sensitivity test to current speed indicated that the results were not particularly sensitive to this parameter, it is likely that different tidal conditions will give different dispersion rates. Neap tides will not disperse much material, whereas tides with a larger range than the spring tide simulated would more readily disperse the material.
10. The model results indicate that, over periods of order one year, material from the disposal area will become distributed to the NW and/or SE. There is no evidence of any likely movement of sediment to the east of the Dee Estuary.

5. REFERENCES

Port of Mostyn Proposed Navigation Improvements. Numerical modelling study of approach channel sedimentation. HR Wallingford report EX4054, July 1999.

Tables

Table 1 Predicted sediment transport rates at ADCP1, 30/5/02

ADCP1		30/05/02 Temp = 12.5 degC		Salinity = 31 ppt		d10=90mu	d50=200mu	d90=350mu
Depth	Ubar *	A&W	VR(full)	E&H	No.	A&W	VR(full)	E&H
m	m/s	m^2/s	m^2/s	m^2/s		kg/m/s	kg/m/s	kg/m/s
16.7	0.04				6			
16.7	0.15				7			
16.7	0.32				8			
16.5	0.46	3.66E-10	7.33E-07	3.52E-06	9	0.0000	0.0019	0.0093
16.4	0.62				10			
16.2	0.71	1.12E-05	2.21E-05	3.98E-05	11	0.0297	0.0586	0.1055
16.0	0.74				12			
15.7	0.81	3.69E-05	4.82E-05	6.63E-05	13	0.0978	0.1277	0.1757
15.4	0.93				14			
15.0	0.84	5.08E-05	5.99E-05	7.63E-05	15	0.1346	0.1587	0.2022
14.6	0.87				16			
14.3	0.94	1.22E-04	1.12E-04	1.14E-04	17	0.3233	0.2968	0.3021
13.9	0.88				18			
13.5	0.74	1.83E-05	3.00E-05	4.83E-05	19	0.0485	0.0795	0.1280
13.1	0.79				20			
12.8	0.72	1.46E-05	2.59E-05	4.38E-05	21	0.0387	0.0686	0.1161
12.4	0.69				22			
12.1	0.65	5.46E-06	1.41E-05	2.89E-05	23	0.0145	0.0374	0.0766
11.8	0.61				24			
11.5	0.47	1.15E-08	1.27E-06	5.07E-06	25	0.0000	0.0034	0.0134
11.2	0.45				26			
11.0	0.40	0	7.84E-08	9.47E-07	27	0.0000	0.0002	0.0025
10.8	0.33				28			
10.6	0.28				29			
10.5	0.23				30			
10.3	0.19				31			
10.2	0.09				32			
10.2	0.04				33			
10.2	0.07				34			
10.2	0.18				35			
10.3	0.29				36			
10.4	0.39				37			
10.5	0.49	6.48E-08	1.96E-06	7.02E-06	38	0.0002	0.0052	0.0186
10.7	0.56				39			
11.1	0.63	4.10E-06	1.20E-05	2.57E-05	40	0.0109	0.0318	0.0681
11.4	0.69				41			
11.8	0.79	3.45E-05	4.53E-05	6.30E-05	42	0.0914	0.1200	0.1670
12.3	0.80				43			
12.8	0.87	7.17E-05	7.57E-05	8.82E-05	44	0.1900	0.2006	0.2337
13.2	0.93				45			
13.7	1.05	2.70E-04	2.03E-04	1.69E-04	46	0.7155	0.5380	0.4479
14.3	0.87				47			
14.8	0.78	2.77E-05	3.96E-05	5.82E-05	48	0.0734	0.1049	0.1542
15.2	0.73				49			
15.5	0.71	1.15E-05	2.24E-05	4.03E-05	50	0.0305	0.0594	0.1068
15.8	0.64				51			
16.0	0.51	8.72E-08	2.17E-06	7.72E-06	52	0.0002	0.0058	0.0205
16.2	0.37				53			
16.3	0.28				54			
16.4	0.16				55			
16.4	0.03				56			
FLOOD residual		Sed. transport over ebb tide (kg/m/ebb)				1237	1499	2032
		Sed. transport over flood tide (kg/m/flood)				2002	1918	2190
		Net sed. transport over tide (kg/m/tide)				765	419	158
Calculated by R.L. Soulsby, 21/8/02, using SandCalc V2.0 for Ackers & White, Van Rijn (full), Engelund & Hansen. Results file stored in Mostyn Deep/adp1q305.txt Additional calculations in Excel spreadsheet Mostyn Deep/ADCP_speeds&transps, sheet ADCP1_ACTUAL300502								

Table 2 Predicted sediment transport rates at ADCP2, 30/5/02

ADCP2		30/05/02 Temp = 12.5 degC		Salinity = 31 ppt		d10=90mu	d50=200mu	d90=350mu
Depth	Ubar *	A&W	VR(full)	E&H	No.	A&W	VR(full)	E&H
m	m/s	m^2/s	m^2/s	m^2/s		kg/m/s	kg/m/s	kg/m/s
24.3	0.08				6			
24.3	0.22				7			
24.1	0.40	0	0	3.48E-07	8	0.0000	0.0000	0.0009
24.0	0.58				9			
23.8	0.70	7.73E-06	1.79E-05	3.49E-05	10	0.0205	0.0474	0.0925
23.6	0.79				11			
23.3	0.84	4.14E-05	5.33E-05	7.17E-05	12	0.1097	0.1412	0.1900
23.0	0.92				13			
22.6	0.95	1.10E-04	1.06E-04	1.12E-04	14	0.2915	0.2809	0.2968
22.2	0.94				15			
21.9	0.91	8.03E-05	8.47E-05	9.64E-05	16	0.2128	0.2245	0.2555
21.5	0.91				17			
21.1	0.86	5.25E-05	6.25E-05	7.92E-05	18	0.1391	0.1656	0.2099
20.7	0.82				19			
20.4	1.02	1.90E-04	1.60E-04	1.45E-04	20	0.5035	0.4240	0.3843
20.0	0.81				21			
19.7	0.80	2.98E-05	4.22E-05	6.14E-05	22	0.0790	0.1118	0.1627
19.4	0.81				23			
19.1	0.73	1.34E-05	2.48E-05	4.33E-05	24	0.0355	0.0657	0.1147
18.8	0.67				25			
18.6	0.54	2.60E-07	3.21E-06	1.05E-05	26	0.0007	0.0085	0.0278
18.4	0.45				27			
18.2	0.38				28			
18.1	0.34				29			
17.9	0.21				30			
17.8	0.11				31			
17.8	0.08				32			
17.8	0.12				33			
17.8	0.17				34			
17.9	0.24				35			
18.0	0.32				36			
18.1	0.41	0	2.93E-08	8.03E-07	37	0.0000	0.0001	0.0021
18.3	0.50				38			
18.7	0.57	6.88E-07	4.86E-06	1.44E-05	39	0.0018	0.0129	0.0382
19.0	0.69				40			
19.4	0.81	3.35E-05	4.55E-05	6.44E-05	41	0.0888	0.1206	0.1707
19.9	0.99				42			
20.4	1.08	2.83E-04	2.16E-04	1.77E-04	43	0.7500	0.5724	0.4691
20.8	1.29				44			
21.3	1.39	1.41E-03	8.05E-04	4.18E-04	45	3.7471	2.1333	1.1077
21.9	1.23				46			
22.4	1.12	3.50E-04	2.57E-04	2.00E-04	47	0.9275	0.6811	0.5300
22.8	1.12				48			
23.1	0.91	7.85E-05	8.36E-05	9.58E-05	49	0.2080	0.2215	0.2539
23.4	0.94				50			
23.6	0.80	2.73E-05	4.01E-05	5.98E-05	51	0.0723	0.1063	0.1585
23.8	0.60				52			
23.9	0.44	0	2.24E-07	1.55E-06	53	0.0000	0.0006	0.0041
24.0	0.34				54			
24.0	0.17				55			
24.0	0.06				56			
FLOOD residual		Sed. transport over ebb tide (kg/m/ebb)				2506	2645	3123
		Sed. transport over flood tide (kg/m/flood)				10432	6926	4910
		Net sed. transport over tide (kg/m/tide)				7926	4281	1787

Calculated by R.L. Soulsby, 21/8/02, using SandCalc V2.0 for Ackers & White, Van Rijn (full), Engelund & Hansen.
 Results file stored in Mostyn Deep/adp2q305.txt
 Additional calculations in Excel spreadsheet Mostyn Deep/ADCP_speeds&transps, sheet ADCP2_ACTUAL300502

Table 3 Measured sediment transport rates at ADCP1, 30/5/02

Mostyn ADCP1 30/05/02 Sediment transport rates calculated from measured currents & turbidity									
Time	Depth	U(4.21)	Turbidity	Concn.	sand conc	Half-hour	qs	qb	qt
	m	m/s	NTU	mg/l	mg/l	no.	kg/m/s	kg/m/s	kg/m/s
01:35:10	17.9	0.163	19.1	22.9	2.9	7	0.0031	0.0000	0.0031
02:05:10	17.6	0.475	19.8	23.7	3.7	9	0.0094	0.0000	0.0094
02:35:10	17.0	0.69	20.7	24.9	4.9	11	0.0187	0.0087	0.0274
03:05:10	16.3	0.809	23.8	28.6	8.6	13	0.0276	0.0147	0.0423
03:35:10	15.5	0.802	19.4	23.3	3.3	15	0.0177	0.0138	0.0315
04:05:10	14.7	0.925	24.7	29.7	9.7	17	0.0883	0.0267	0.1150
04:35:10	13.8	0.695	94.3	113.2	93.2	19	0.2725	0.0066	0.2791
05:05:10	13.1	0.716	60.5	72.6	52.6	21	0.2431	0.0075	0.2505
05:35:10	12.5	0.655	187.8	225.4	205.4	23	0.5369	0.0024	0.5393
06:05:10	12.0	0.489	125.5	150.6	130.6	25	0.2645	0.0000	0.2645
06:35:10	11.4	0.491	91.5	109.8	89.8	27	0.1607	0.0000	0.1607
07:05:10	11.1	0.337	35.1	42.1	22.1	29	0.0283	0.0000	0.0283
07:35:10	10.9	0.226	19.3	23.1	3.1	31	0.0025	0.0000	0.0025
08:05:10	10.9	0.051	14.0	16.8	0.0	33	0.0067	0.0000	0.0067
08:35:10	11.2	0.241	36.5	43.9	23.9	35	0.0378	0.0000	0.0378
09:05:10	11.6	0.496	48.7	58.5	38.5	37	0.0871	0.0000	0.0871
09:35:09	12.4	0.59	48.7	58.5	38.5	39	0.1137	0.0035	0.1173
10:05:10	13.3	0.682	55.0	66.0	46.0	41	0.1635	0.0085	0.1720
10:35:10	14.4	0.753	73.6	88.3	68.3	43	0.2258	0.0101	0.2358
11:05:10	15.3	0.913	50.5	60.6	40.6	45	0.1594	0.0263	0.1857
11:35:10	16.2	0.805	42.6	51.1	31.1	47	0.0931	0.0110	0.1041
12:05:10	17.0	0.704	18.1	21.7	1.7	49	0.0044	0.0062	0.0105
12:35:10	17.4	0.641	16.1	19.3	0.0	51	0.0000	0.0036	0.0036
13:05:10	17.7	0.357	14.1	16.9	0.0	53	0.0000	0.0000	0.0000
13:35:10	17.8	0.174	13.2	15.8	0.0	55	0.0000	0.0000	0.0000
EBB residual			Sed. transport over ebb tide (kg/m/ebb)				3007	145	3152
			Sed. transport over flood tide (kg/m/flood)				1609	125	1734
			Net sed. transport over tide (kg/m/tide)				-1398	-20	-1418
Calculated by R.L. Soulsby, 5/9/02 in Excel spreadsheet Mostyn Deep/Transport1_from_meas., sheet Summary Sand conc = re-calibrated suspended sed conc - 20 mg/l washload Concentrations based on measured values at z = 0.8m and assumed linear decrease with height to zero at 9.21m qs = suspended sediment transport rate from measured currents and concentrations qb = bedload sediment transport rate, using Nielsen formula with current at 2.21m qt = total sediment transport rate = qs + qb									

Table 4 Measured sediment transport rates at ADCP2, 30/5/02

Mostyn ADCP2 30/05/02 Sediment transport rates calculated from measured currents & turbidity										
Time	Depth	U(4.21)	Turbidity	Concn.	sand conc	Half-hour	qs	qb	qt	
	m	m/s	NTU	mg/l	mg/l	no.	kg/m/s	kg/m/s	kg/m/s	
01:18:15	24.6	0.168	42.8	51.3	11.3	6	0.0104	0.0000	0.0104	
01:48:15	24.3	0.441	40.5	48.6	8.6	8	0.0168	0.0000	0.0168	
02:18:15	23.9	0.63	37.1	44.6	4.6	10	0.0169	0.0048	0.0217	
02:48:15	23.1	0.741	41.3	49.5	9.5	12	0.0399	0.0117	0.0516	
03:18:15	22.4	0.852	48.8	58.6	18.6	14	0.0723	0.0178	0.0901	
03:48:15	21.5	0.837	49.3	59.1	19.1	16	0.0868	0.0170	0.1038	
04:18:15	20.8	0.783	66.3	79.6	39.6	18	0.1516	0.0152	0.1668	
04:48:15	20.0	0.929	68.7	82.4	42.4	20	0.1854	0.0302	0.2156	
05:18:15	19.2	0.733	82.7	99.3	59.3	22	0.2942	0.0084	0.3025	
05:48:15	18.7	0.707	221.4	265.7	225.7	24	0.6210	0.0074	0.6284	
06:18:15	18.2	0.452	94.9	113.8	73.8	26	0.1364	0.0000	0.1364	
06:48:15	17.9	0.368	53.7	64.5	24.5	28	0.0379	0.0000	0.0379	
07:18:15	17.6	0.137	66.1	79.3	39.3	30	0.0229	0.0000	0.0229	
07:48:15	17.5	0.028	63.3	76.0	36.0	32	0.0132	0.0000	0.0132	
08:18:15	17.6	0.152	72.3	86.7	46.7	34	0.1692	0.0000	0.1692	
08:48:15	17.9	0.424	321.2	385.4	345.4	36	0.6073	0.0000	0.6073	
09:18:15	18.5	0.601	155.1	186.1	146.1	38	0.3860	0.0026	0.3885	
09:48:15	19.3	0.716	140.9	169.1	129.1	40	0.4124	0.0057	0.4180	
10:18:15	20.3	0.944	117.1	140.5	100.5	42	0.5917	0.0226	0.6143	
10:48:14	21.2	1.038	276.9	332.3	292.3	44	1.1437	0.0280	1.1718	
11:18:15	22.3	1.234	50.7	60.9	20.9	46	0.0928	0.0554	0.1483	
11:48:15	23.1	1.027	33.7	40.4	0.4	48	0.0016	0.0334	0.0350	
12:18:15	23.8	0.906	27.0	32.4	0.0	50	0.0025	0.0273	0.0298	
12:48:15	24.1	0.513	38.0	45.6	5.6	52	0.0117	0.0005	0.0122	
13:18:15	24.3	0.222	37.2	44.7	4.7	54	0.0041	0.0000	0.0041	
FLOOD residual							Sed. transport over ebb tide (kg/m/ebb)	3046	203	3249
							Sed. transport over flood tide (kg/m/flood)	6185	316	6501
							Net sed. transport over tide (kg/m/tide)	3139	113	3252
Calculated by R.L. Soulsby, 5/9/02 in Excel spreadsheet Mostyn Deep/Transport2_from_meas., sheet Summary Sand conc = re-calibrated suspended sed conc - 40 mg/l washload Concentrations based on measured values at z = 0.8m and assumed linear decrease with height to zero at 9.21m qs = suspended sediment transport rate from measured currents and concentrations qb = bedload sediment transport rate, using Nielsen formula with current at 2.21m qt = total sediment transport rate = qs + qb										

Figures

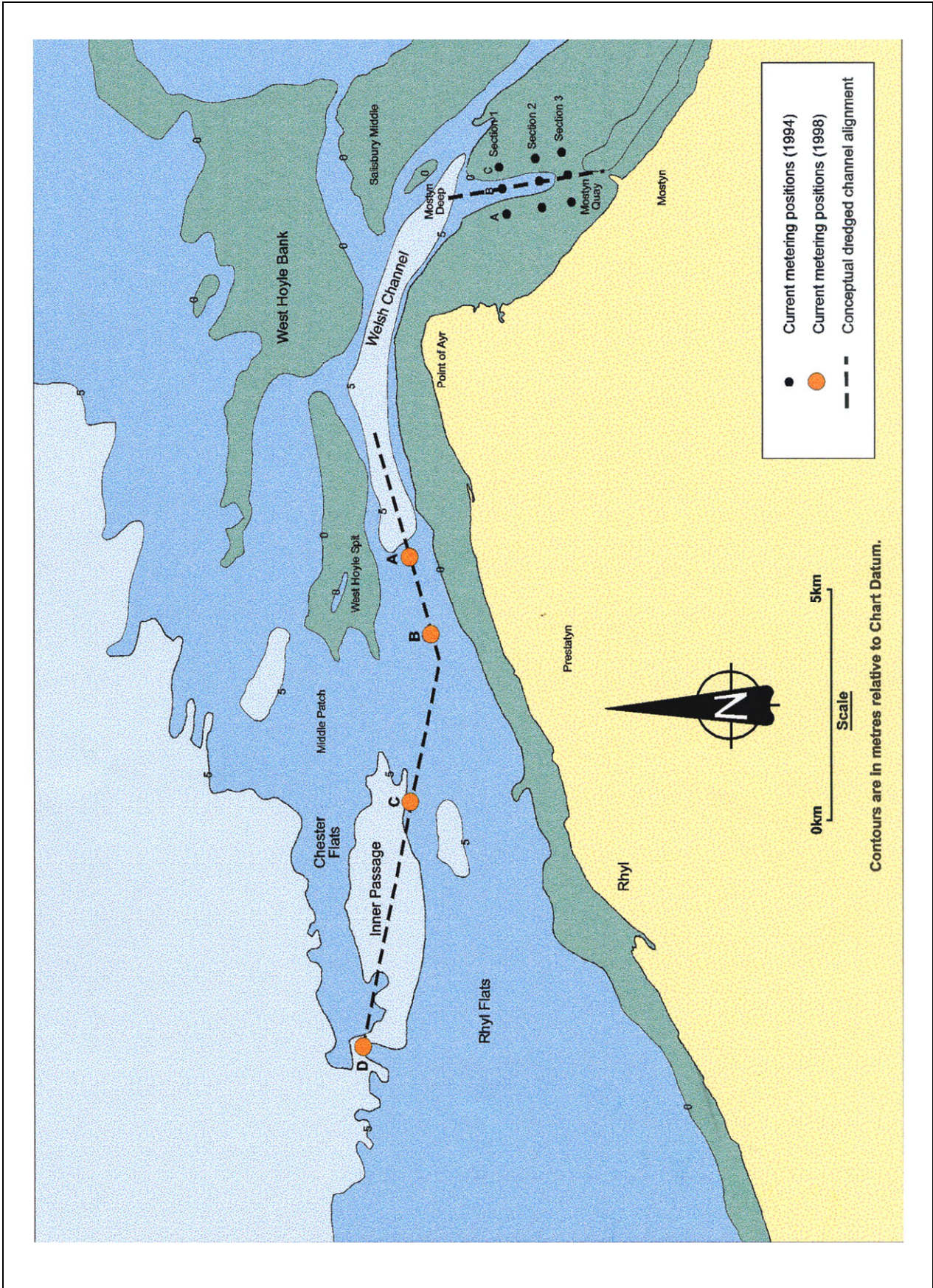


Figure 1 Location map

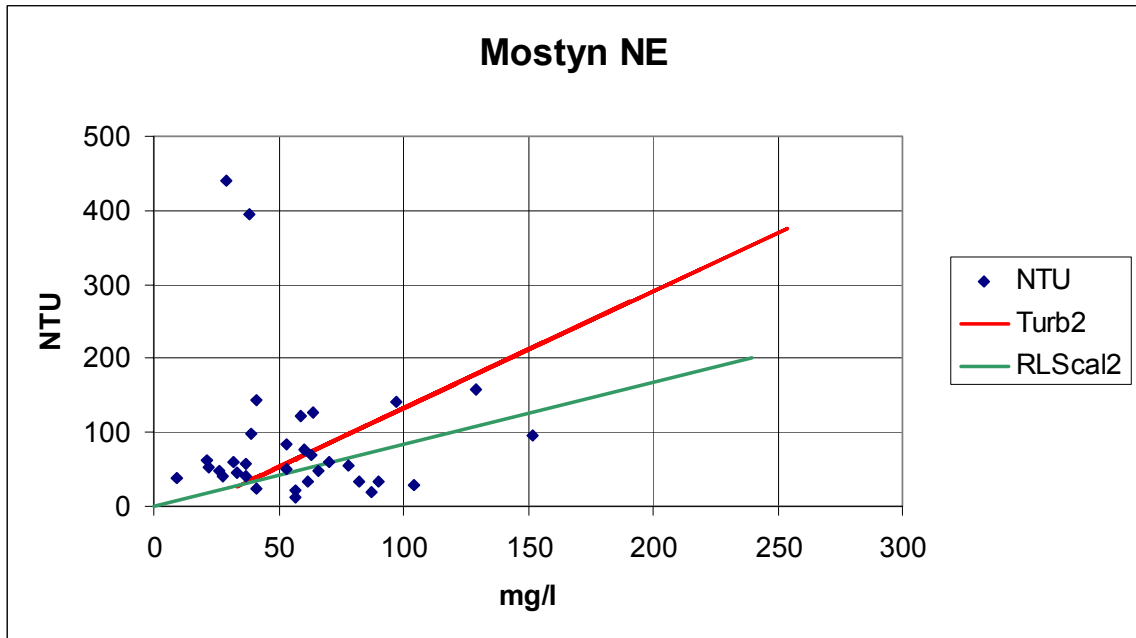
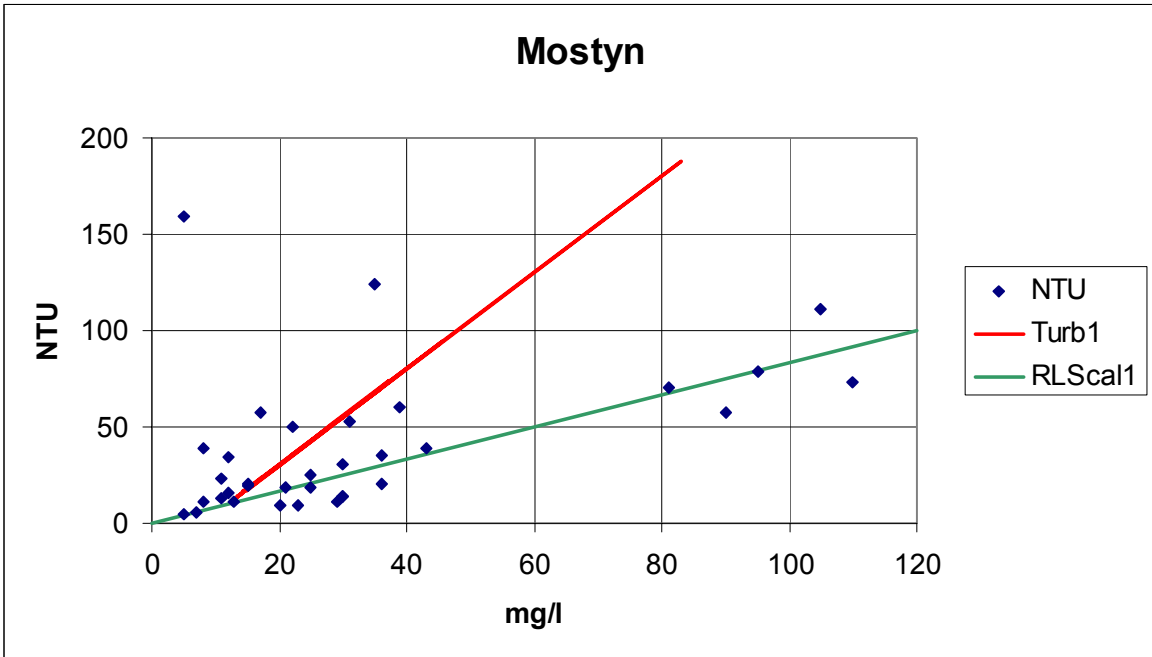


Figure 2 Re-calibrations of turbidity: NTU to mg/l. Red = original calibration, green = re-calibration

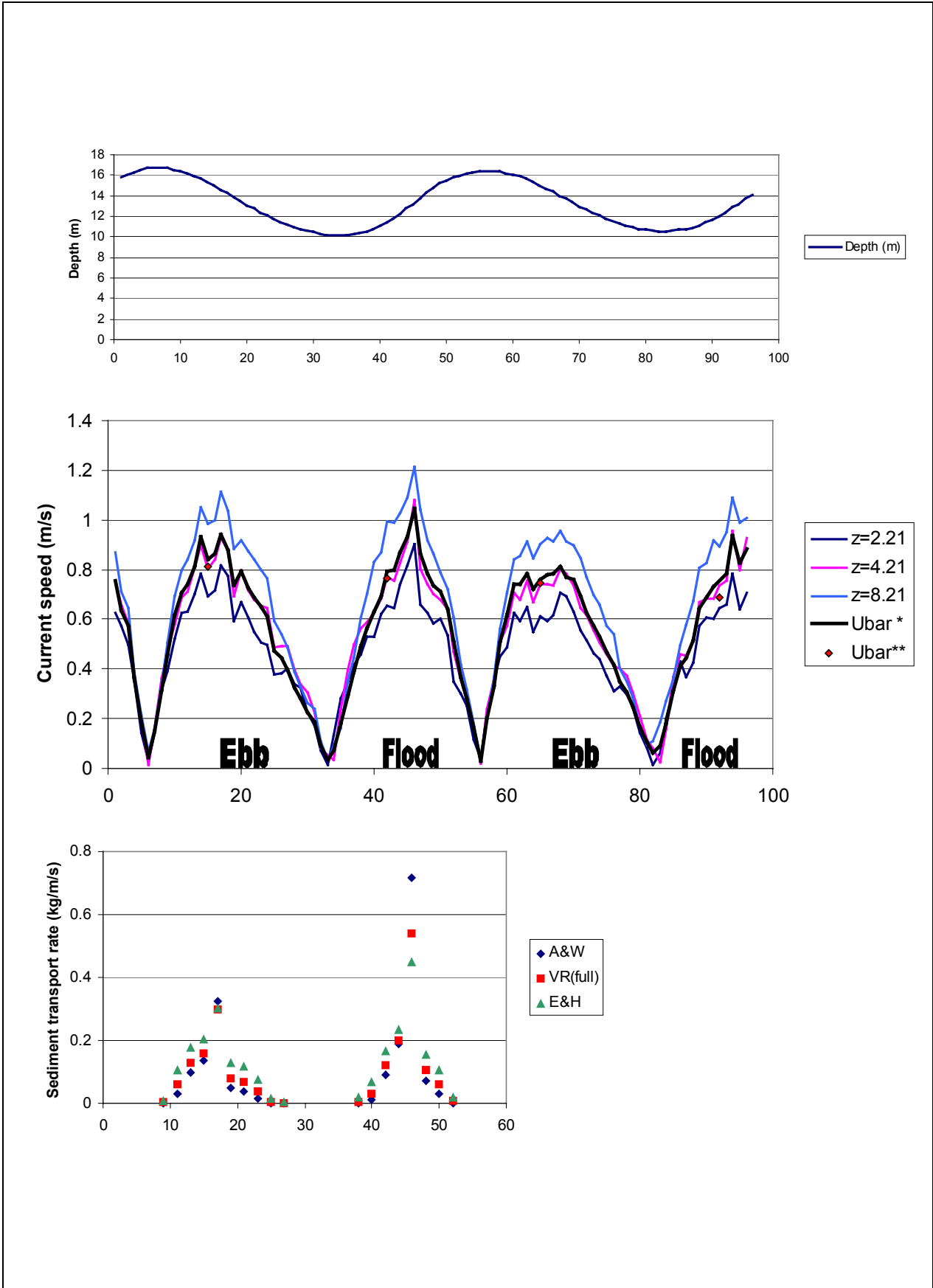


Figure 3 Predicted sediment transport rates at ADCP1, 30/5/02

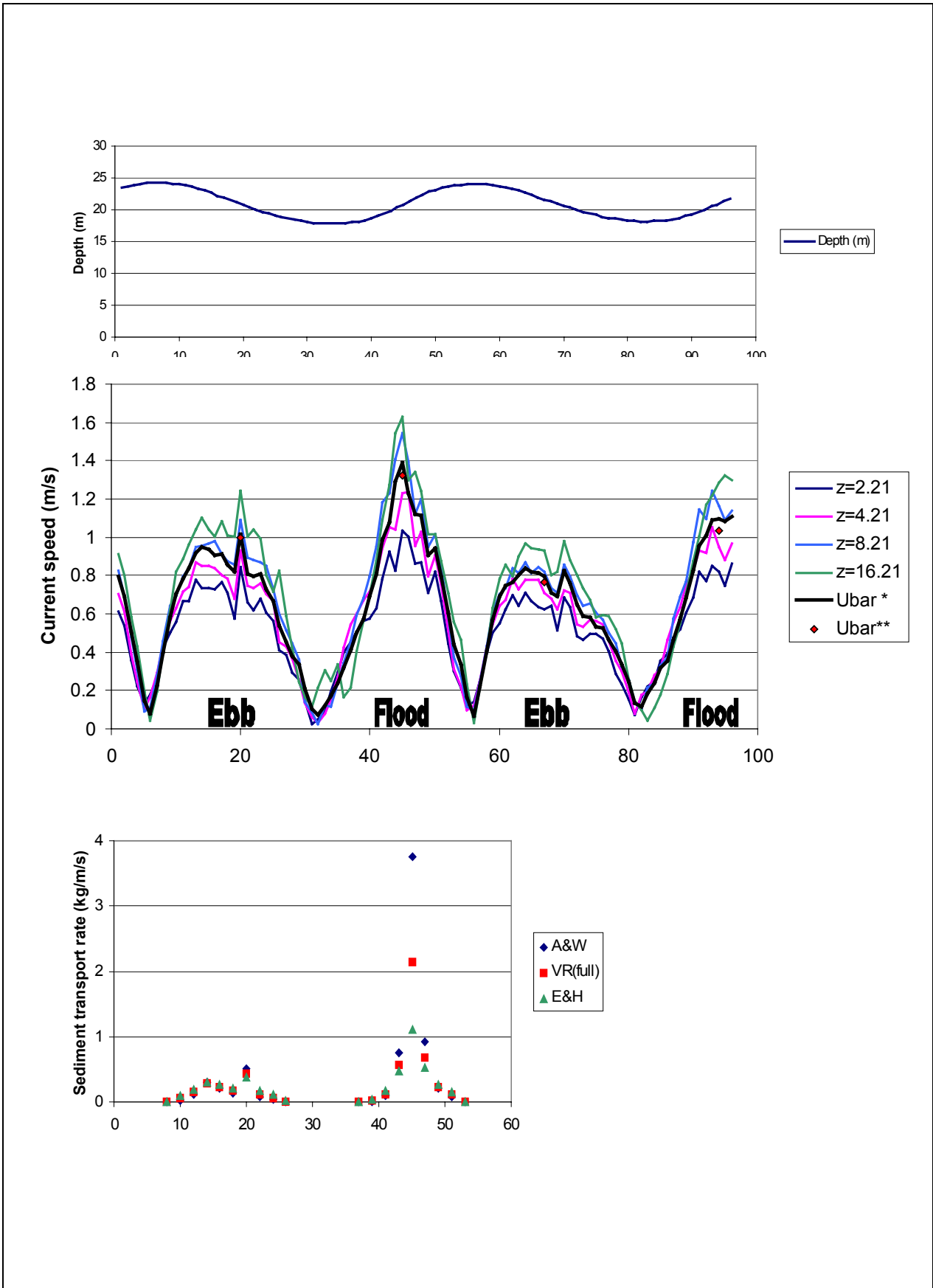


Figure 4 Predicted sediment transport rates at ADCP2, 30/5/02

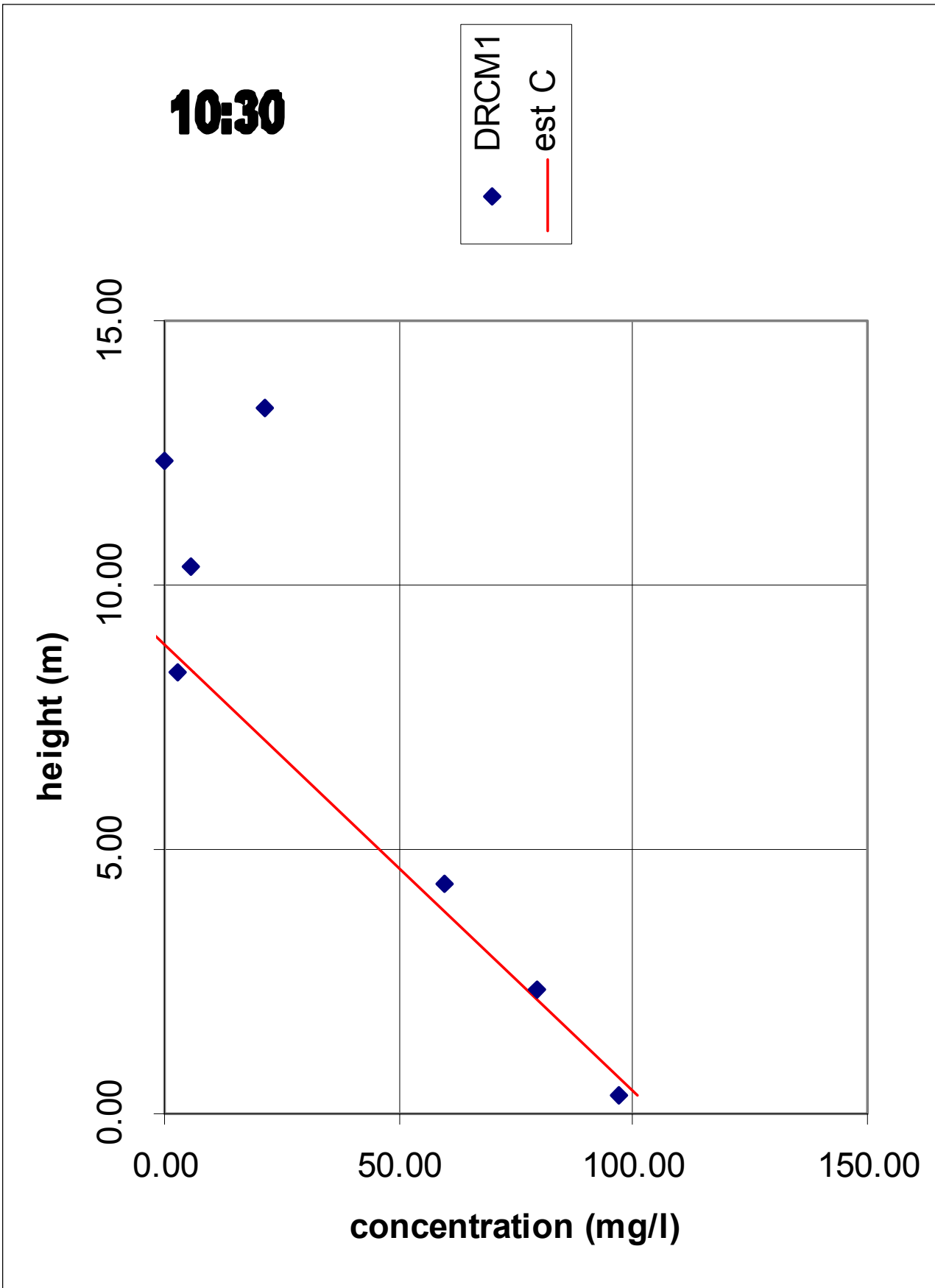


Figure 5 Example of concentration profile from DRCM, 30/5/02

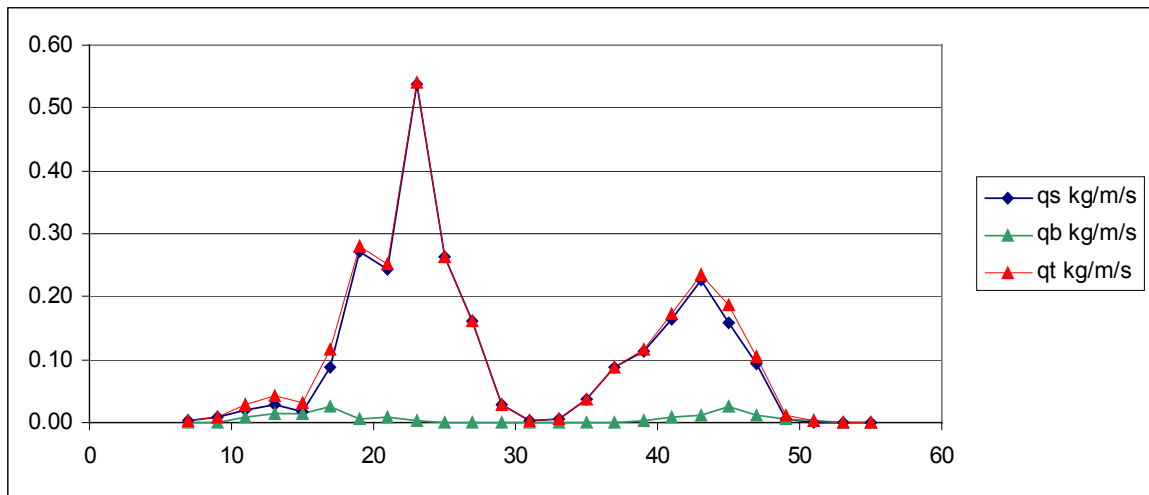
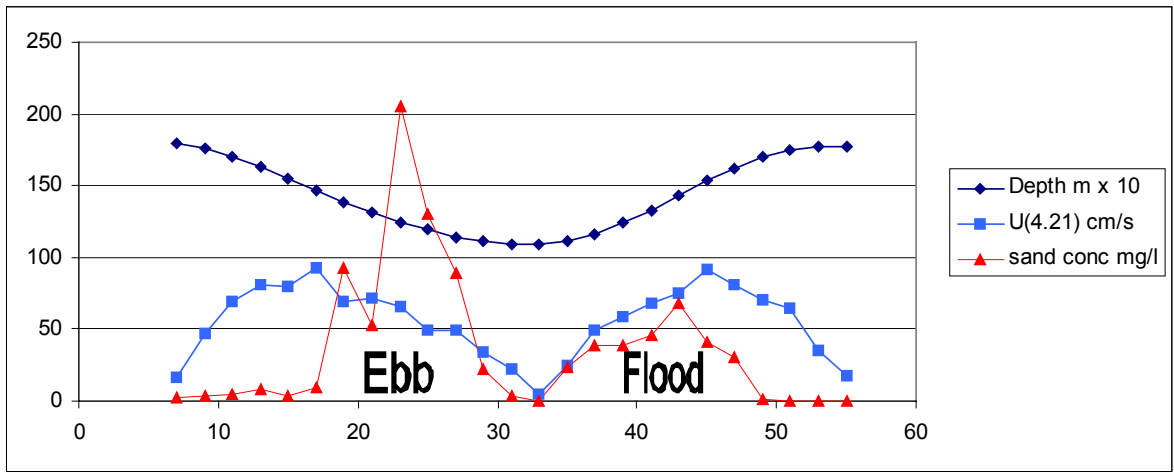


Figure 6 Measured sediment transport rates at ADCP1, 30/5/02

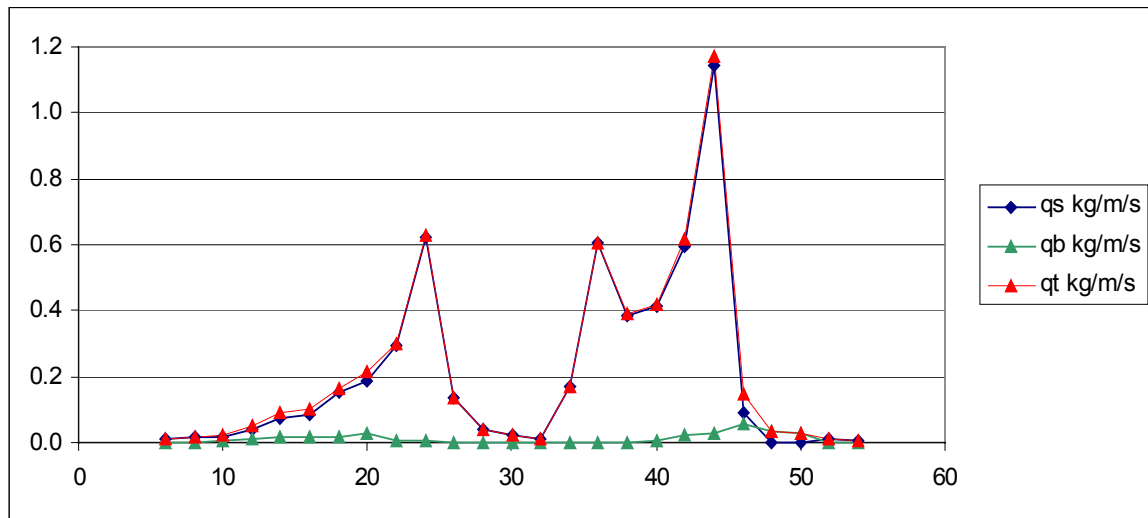
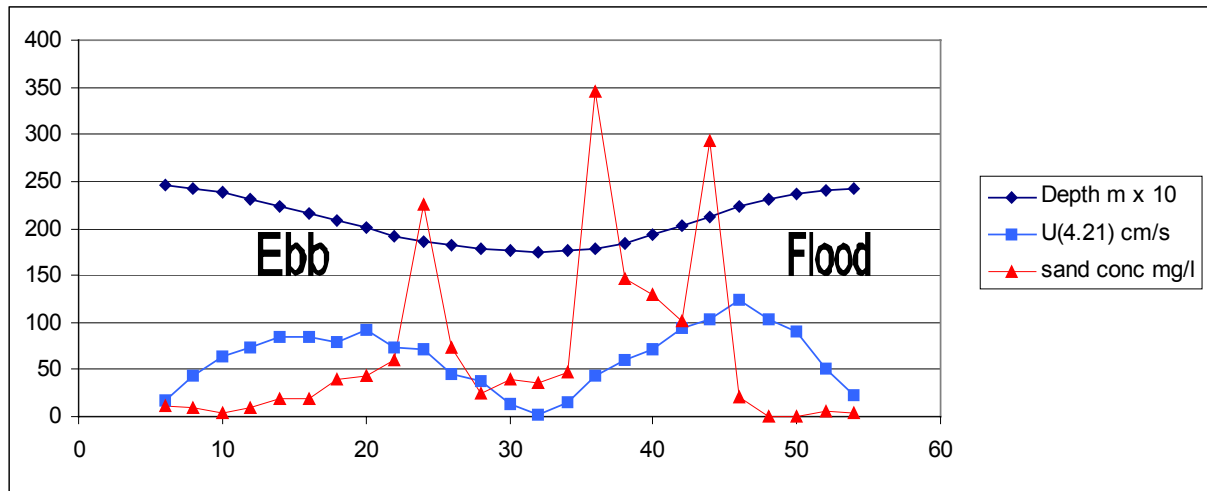


Figure 7 Measured sediment transport rates at ADCP2, 30/5/02

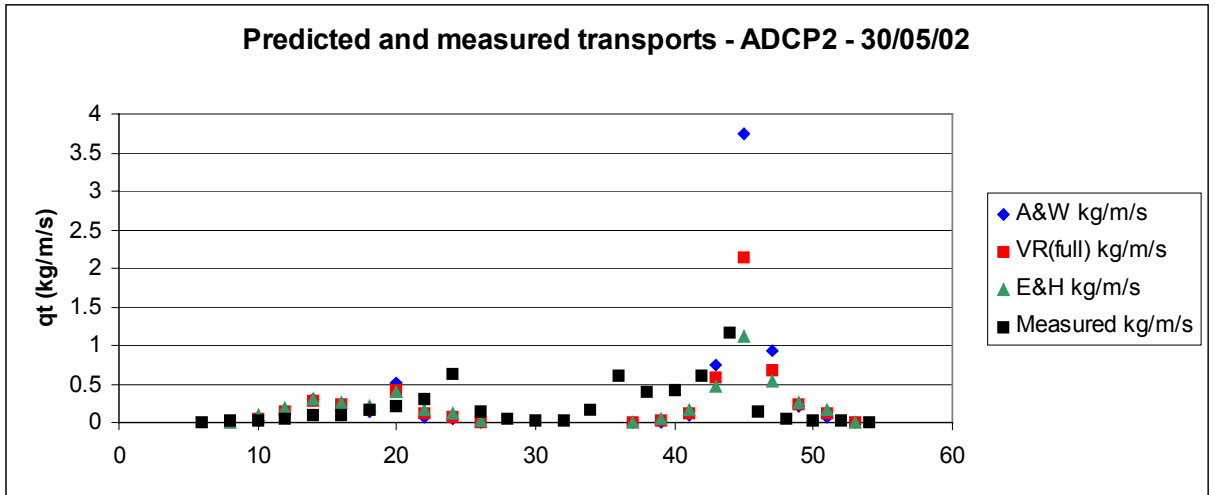
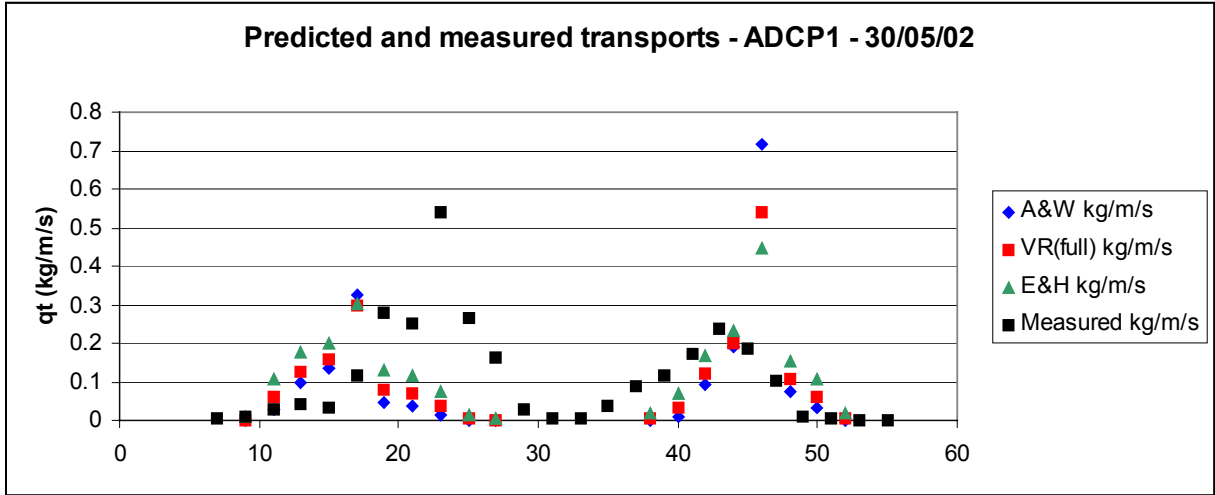
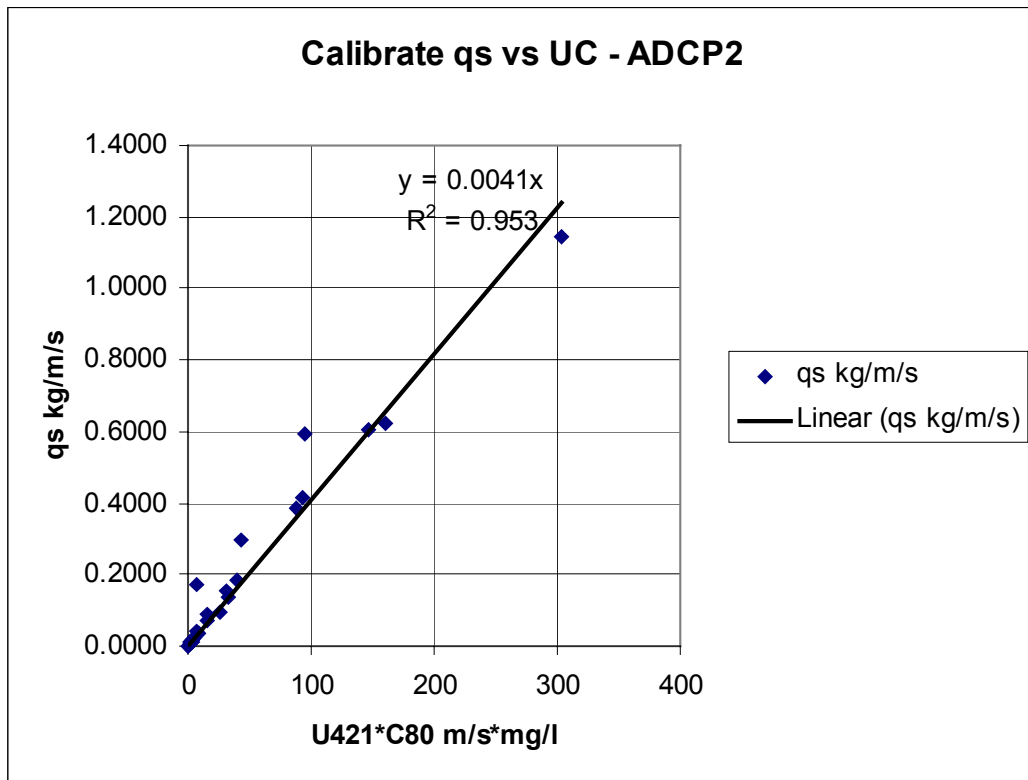
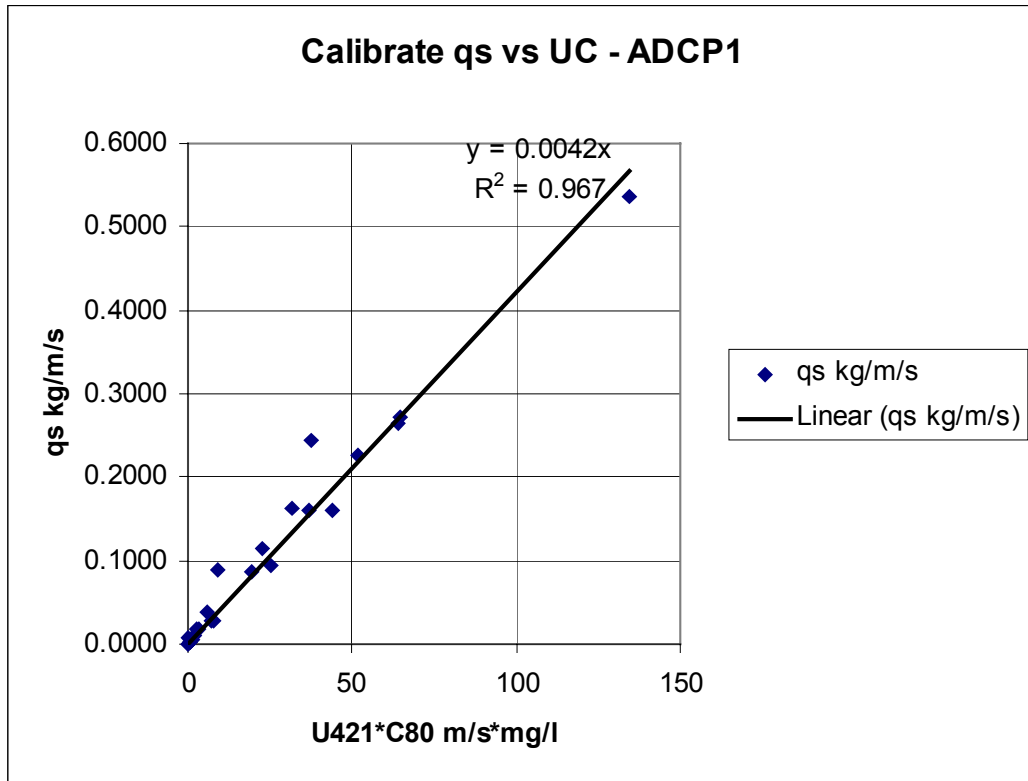


Figure 8 Comparison of predicted and measured sediment transport rates



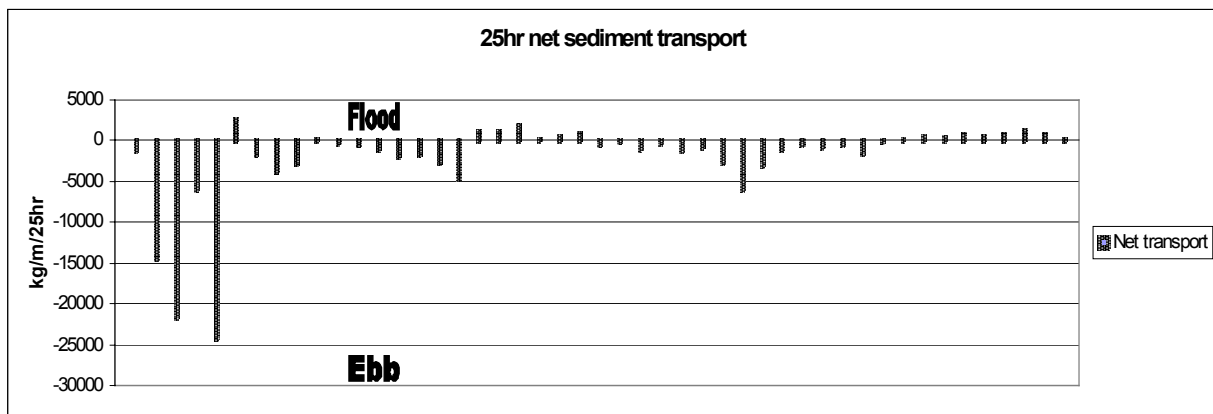
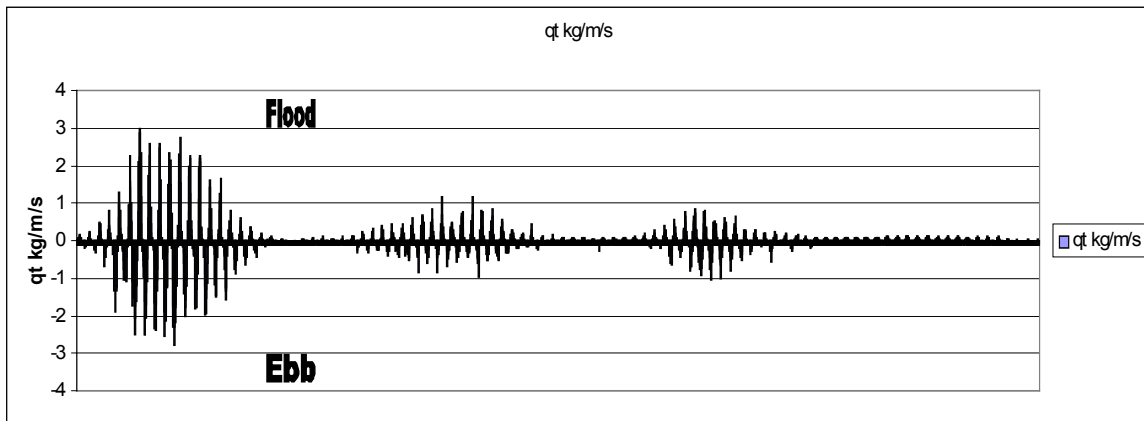
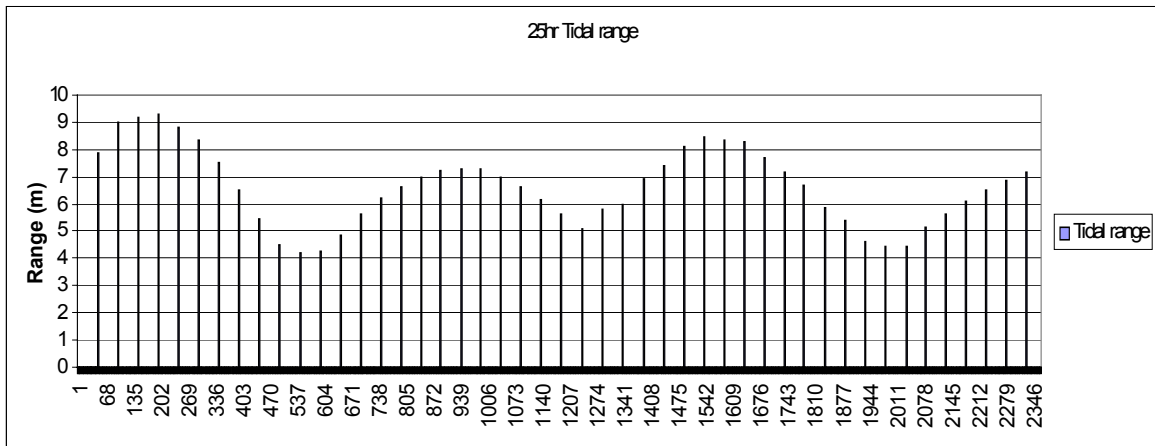


Figure 10 Long-term sediment transport at ADCP1

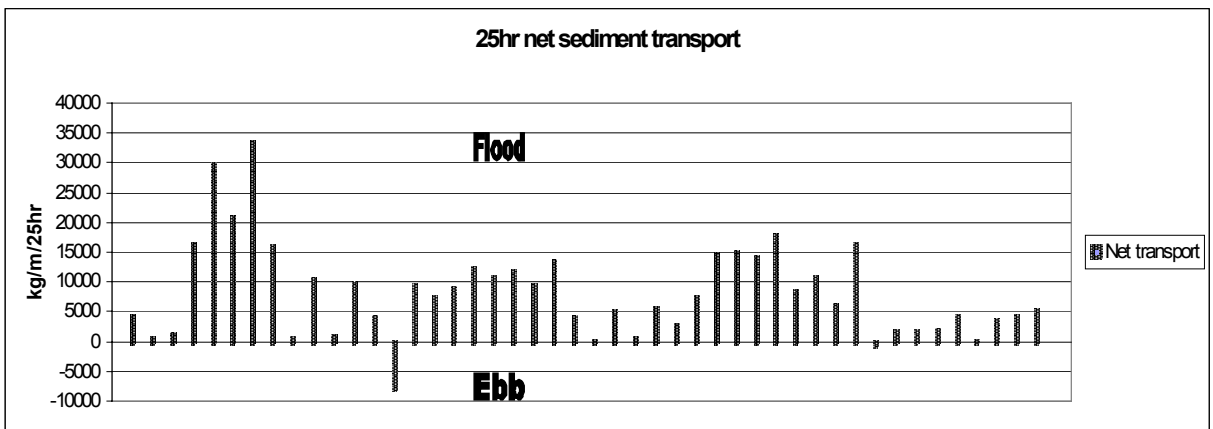
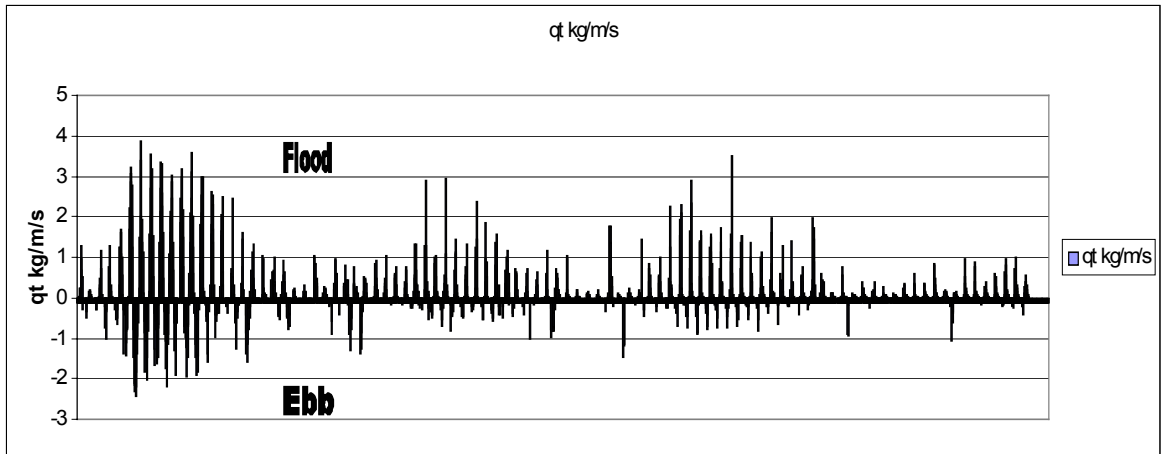
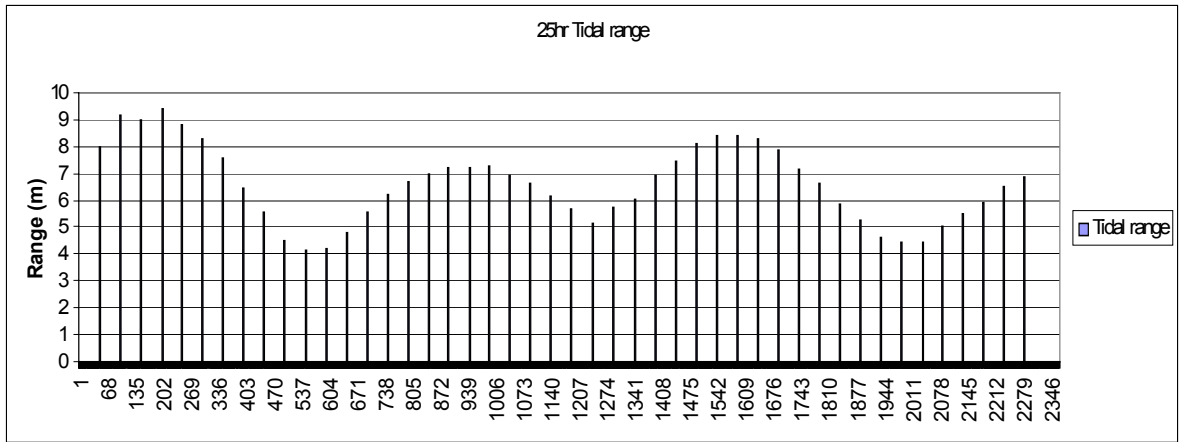


Figure 11 Long-term sediment transport at ADCP2

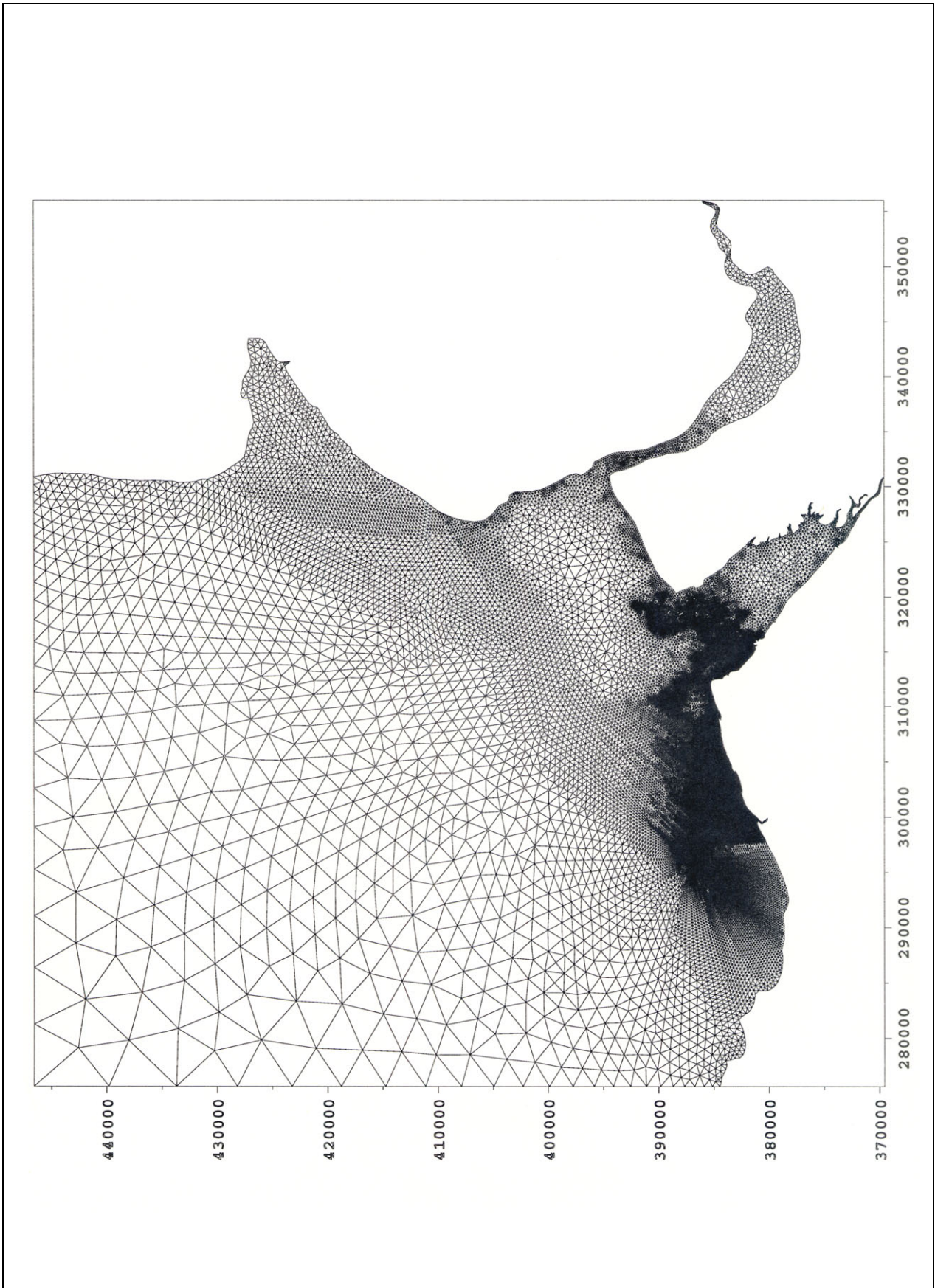


Figure 12 TELEMAC flow model mesh

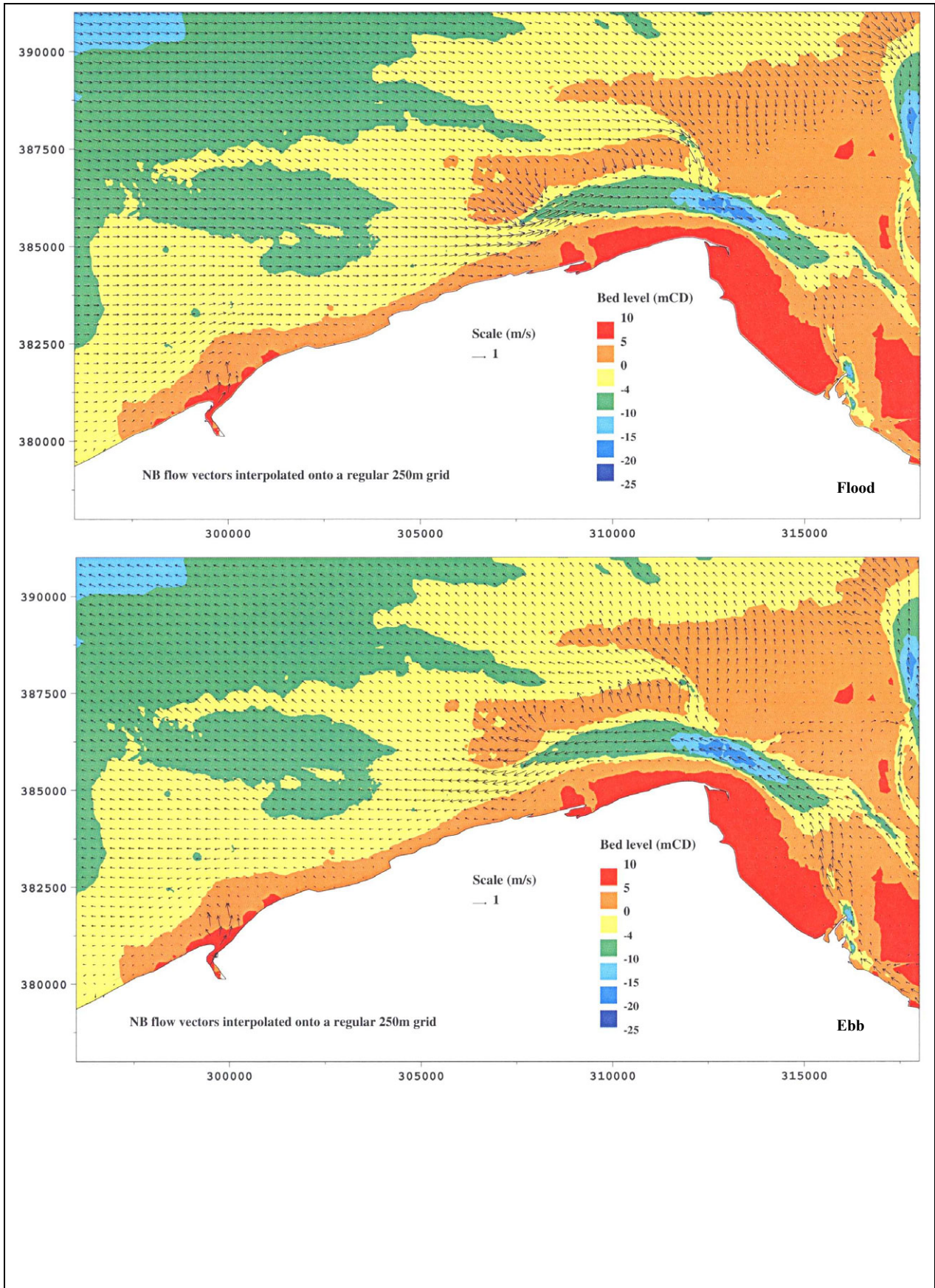


Figure 13 Spring tide peak flood and ebb currents

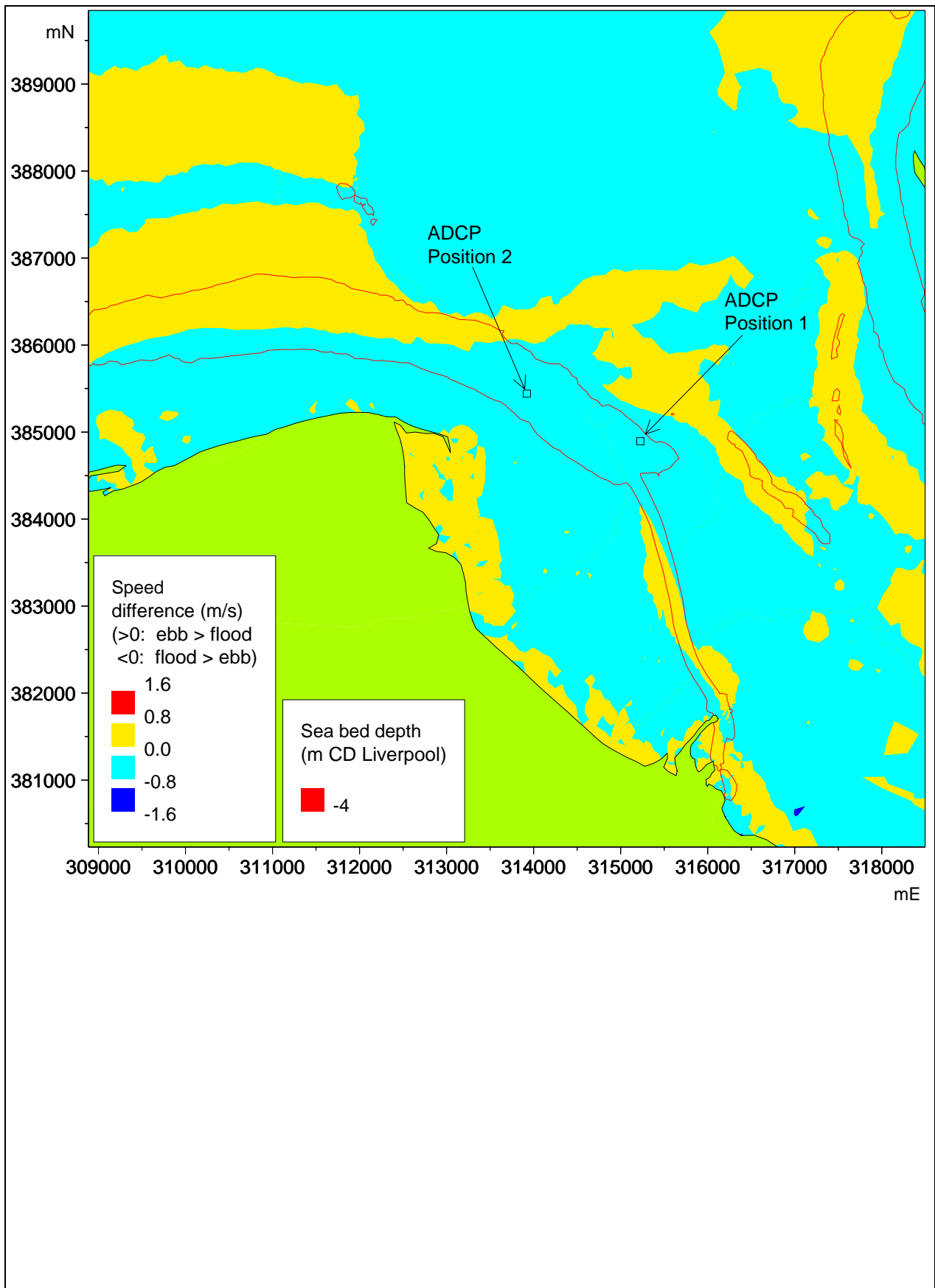


Figure 14 Difference in spring tide peak flood and ebb current speeds

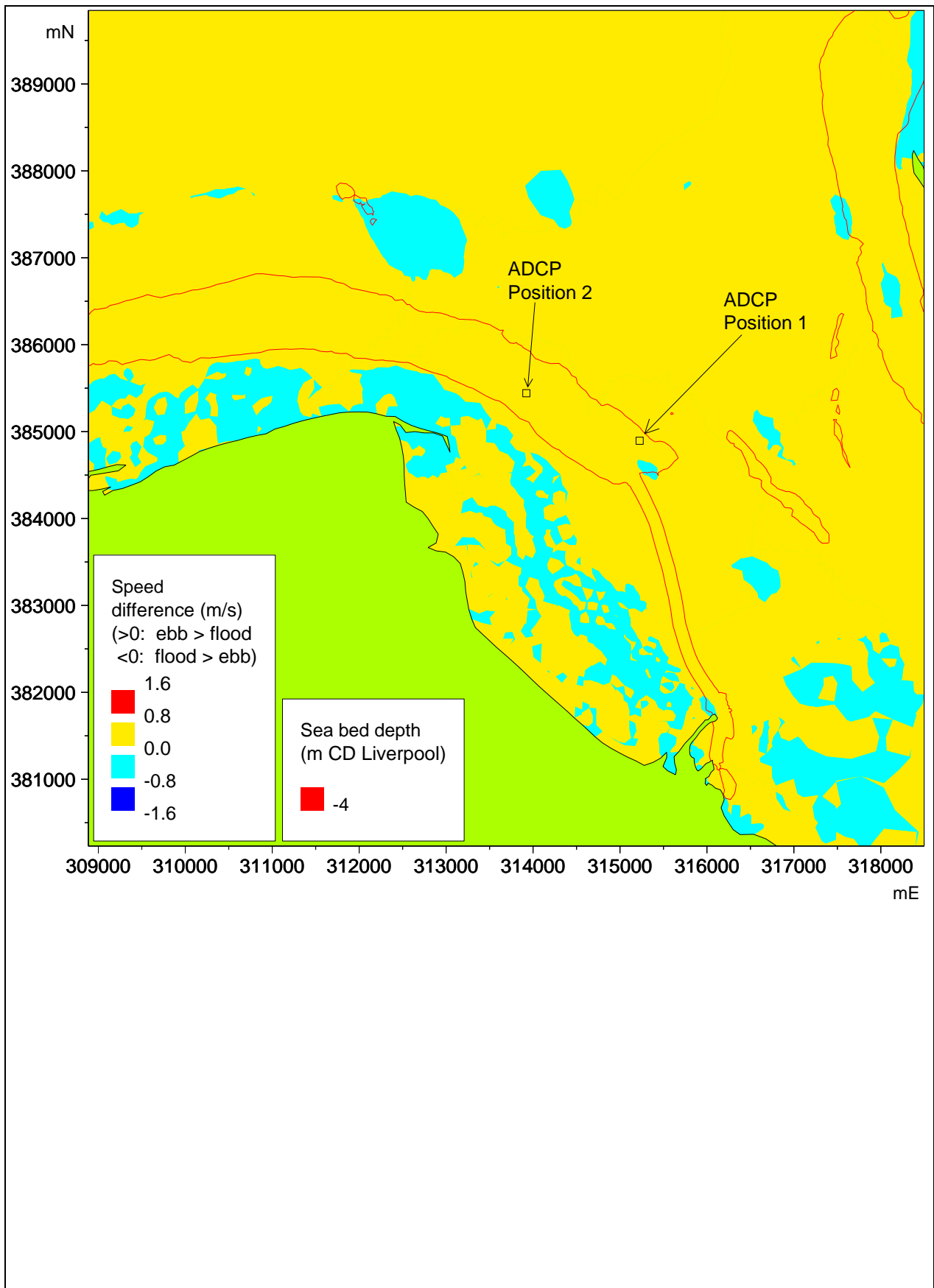


Figure 15 Difference in neap tide peak flood and ebb current speeds

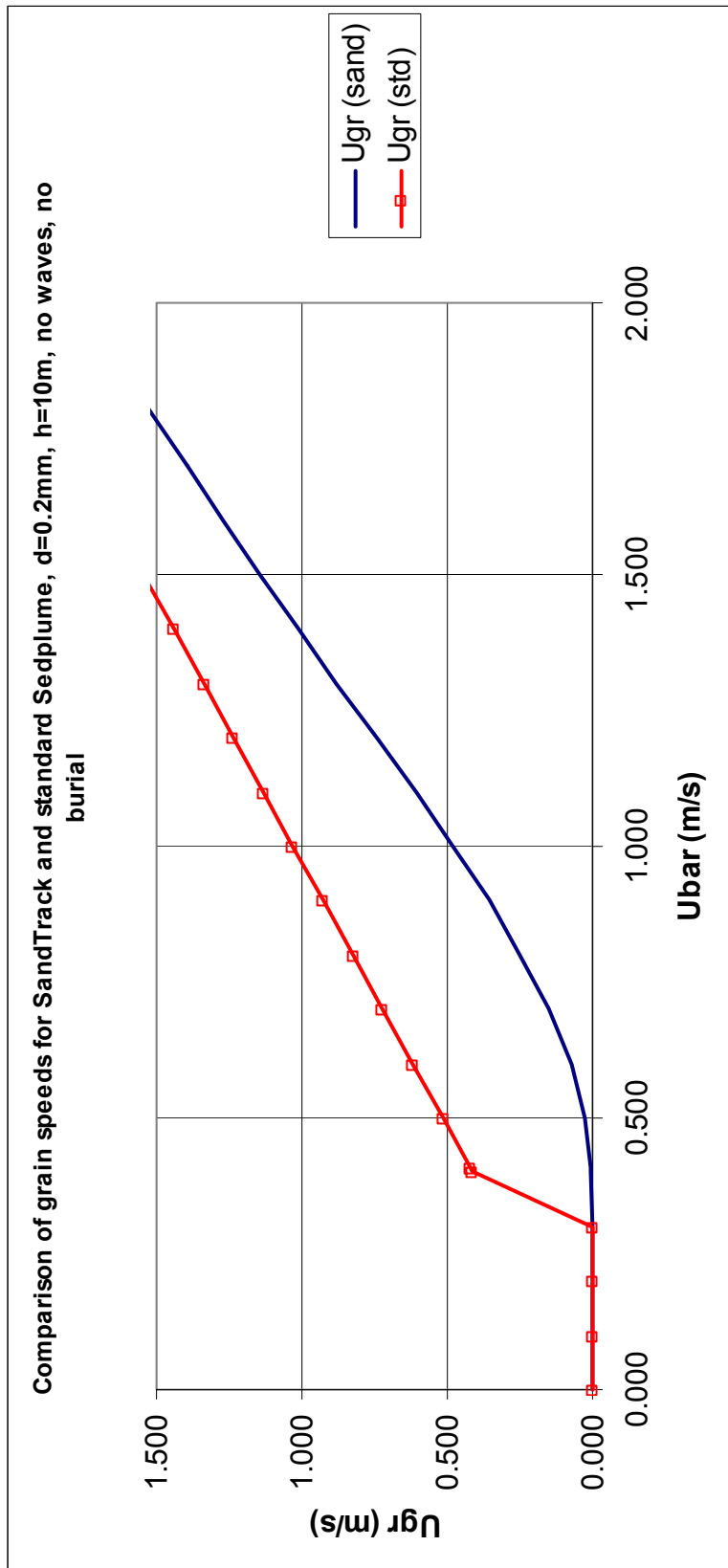


Figure 16 Comparison of grain speed for SANDTRACK and SEDPLUME

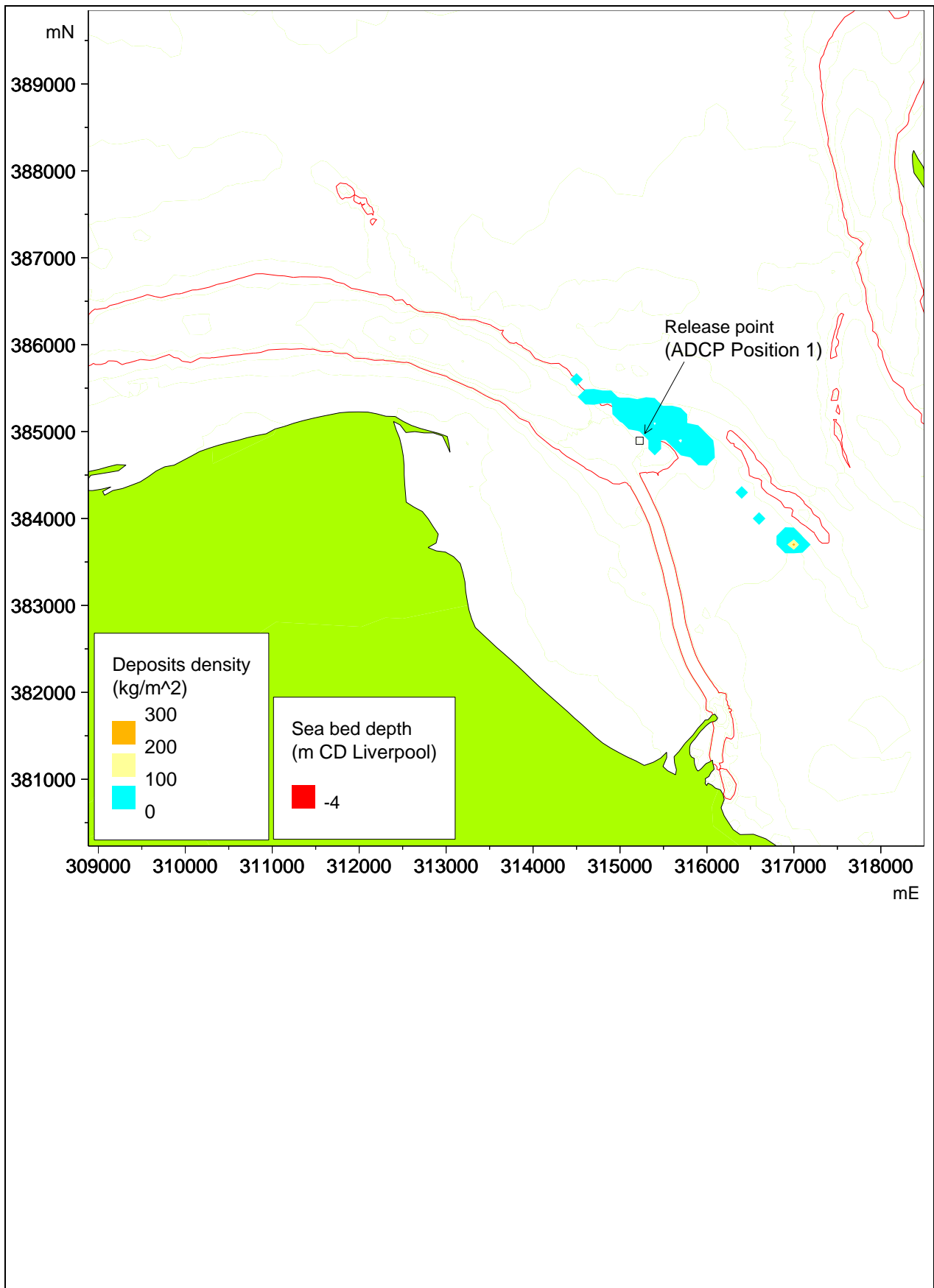


Figure 17 Dispersion from ADCP1 after a period of order one year

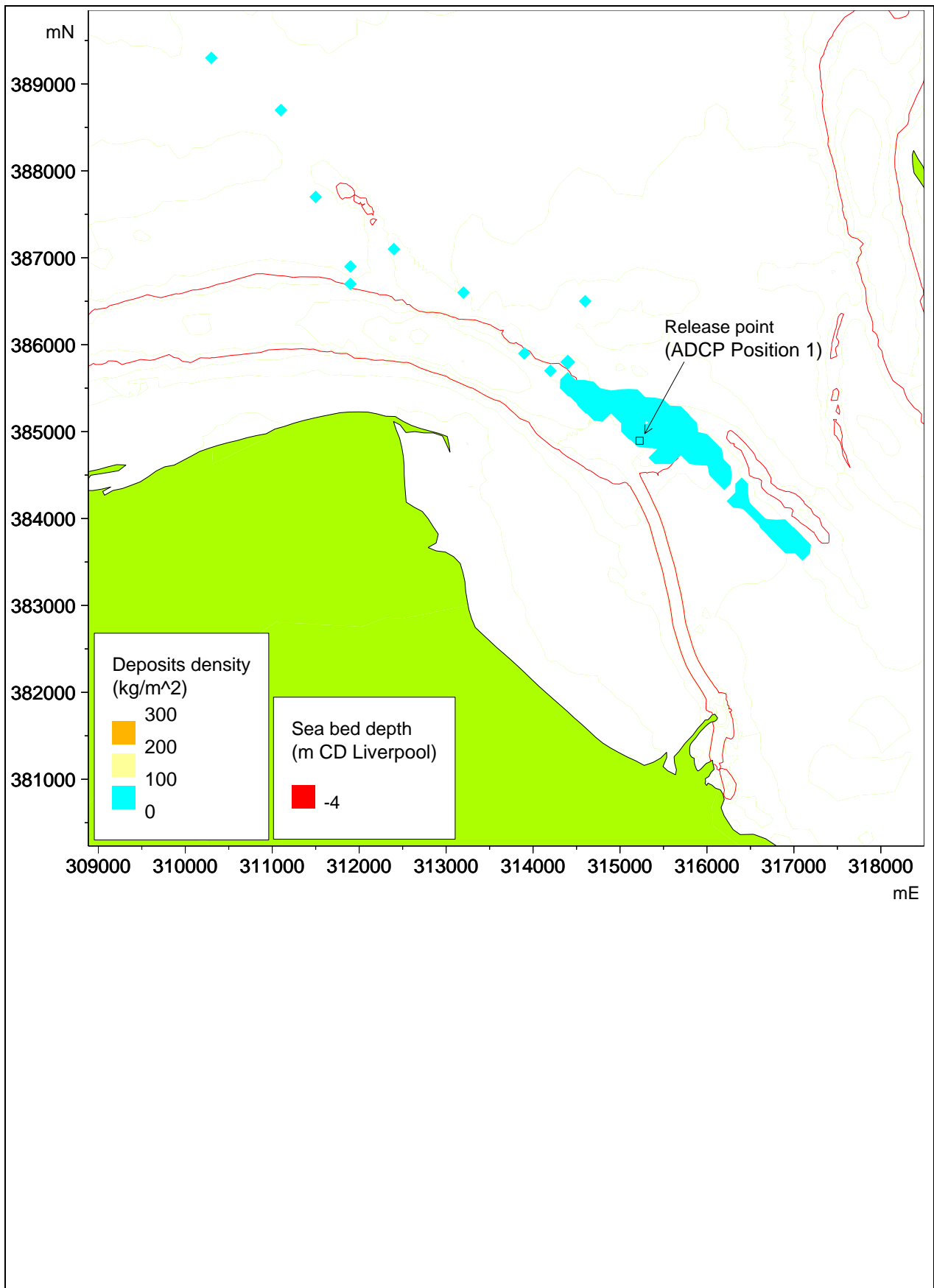


Figure 18 Sensitivity test to currents (dispersion from ADCP1, after a period of order one year)

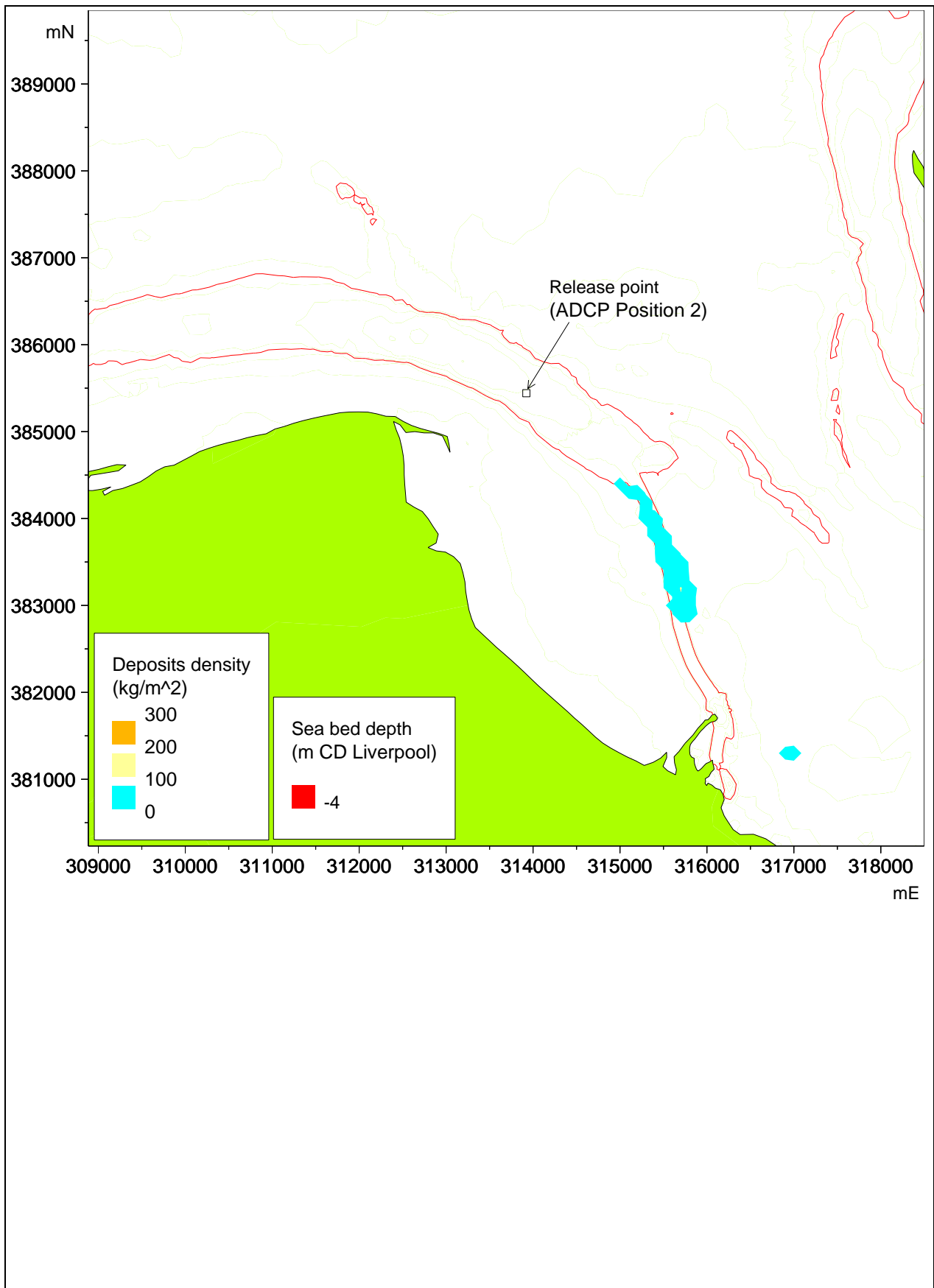


Figure 19 Dispersion from ADCP2 after a period of order one year

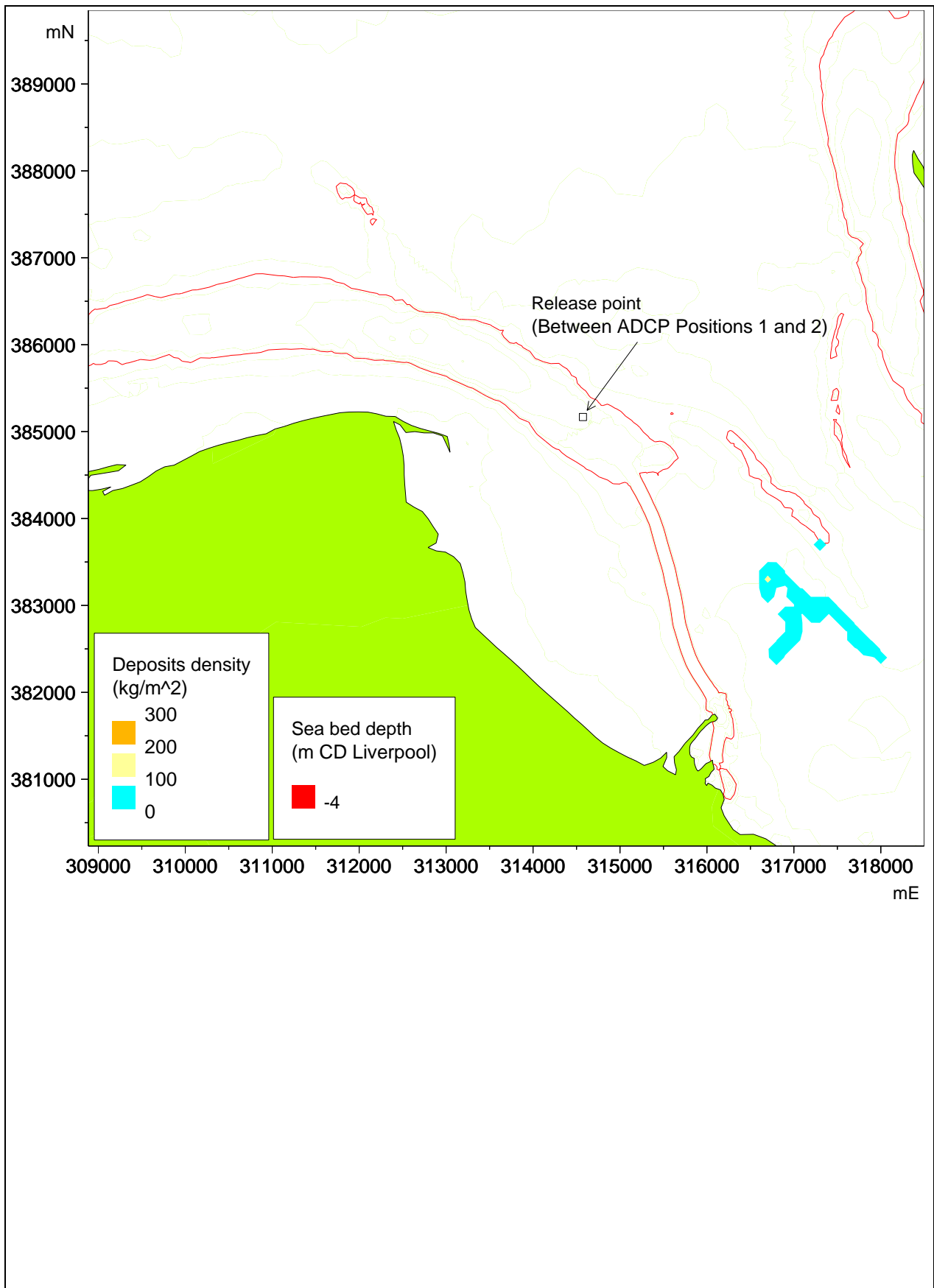


Figure 20 Dispersion from partway between ADCP1 and ADCP2 after a period of order one year

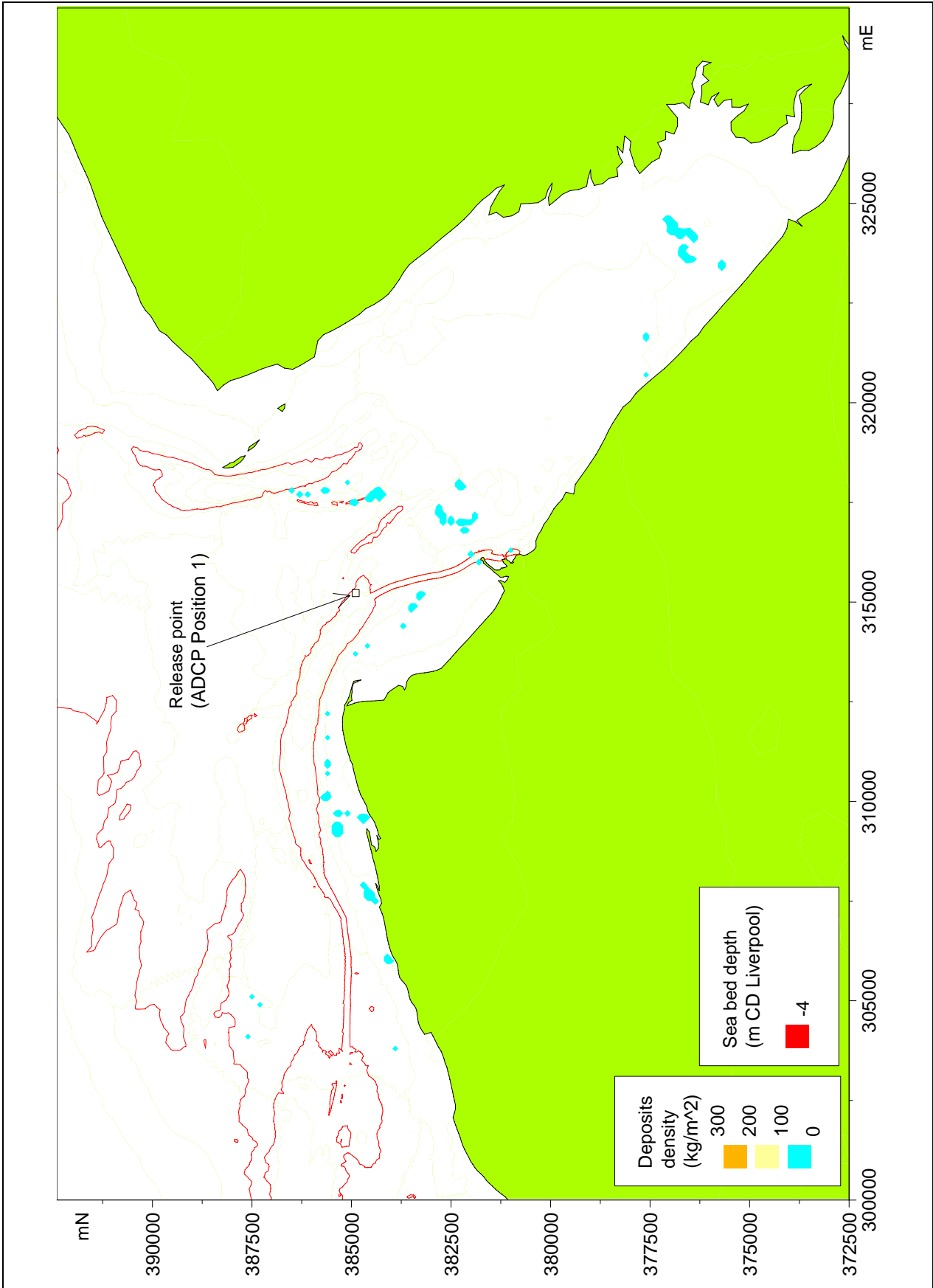


Figure 21 Suspended sediment dispersion using SEDPLUME

