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Regulation 5(2) [a]
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Supplementary Environmental Information

Validation of 3D Flow & Sediment Models used for Assessment of Impacts of AMEP on Fine Sediment Transport

Supplementary Report EX 8.5

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CONTENTS

FIGURES

INTRODUCTION

This note provides supplementary information on the validation of the 3D hydrodynamic and mud transport models used to assess the impacts on fine sediments of the proposed Able Marine Energy Park (AMEP) located at South Killingholme on the south bank of the Humber Estuary, and reported in (HR Wallingford, 2011).

1 FLOW MODEL

1.1.1 The 3D flow model domain extends from South Ferriby to Spurn Head (HR Wallingford, 2011). The model was driven by tidal levels from the JBA baseline flow model, provided for a spring-neap cycle (plus lead-in period), for the period 13 May and 2 June 2010. The 3D flow model was used to provide predicted flows for baseline and with-scheme hydrodynamics in a suitable format for 3D sediment modelling using DELWAQ-3D.

1.1.2 The JBA flow model was used for the assessment of estuary-wide impacts on hydrodynamics (JBA, 2011) and was validated against flow and tide level data from two ADCP devices (deployed for the same period in 2010) as well as Totaltide data on currents as well as water levels at tide gauges for various locations within the Humber Estuary. The validation of JBA's model is detailed in (JBA, 2011)

1.1.3 Figure 1 shows the locations where model results are presented and compared. Figures 2 and 3 show modelled depth averaged flow speeds and water levels from the TELEMAC-3D model compared against those from the JBA model. These show very good agreement between the models. Figure 4 shows comparison of model predicted depth averaged flow speeds and water levels against observations. The TELEMAC-3D model is shown to be validated and appropriate for driving the fine sediment modelling.

2 MUD MODEL

2.1.1 The DELWAQ-3D model set-up and parameterisation is described in HR Wallingford (2011). Boundary concentrations of 300 mg/l and 1000 mg/l were set at Spurn Head and South Ferriby respectively (for flows into the model domain). A sensitivity test was carried out whereby these concentrations were doubled and it was found this did not significantly affect the concentrations within the model domain (concentrations within the model are more affected by the cyclical processes of deposition during slack water and resuspension of bed sediments during a rising or falling tide).

2.1.2 It should be noted that turbidity meters had been deployed for the specific spring-neap cycle for which the modelling was undertaken, but that this deployment had been unsuccessful in collecting any data (IECS, 2010). Therefore IECS returned to the site and collected water samples in September 2010, for a much larger spring tide and a smaller neap tide than those modelled in the period 13 May and 2 June 2010. Additional data relating to measurements of suspended sediment concentrations was also sought for the project area. Measurements published in (ABPmer, 2009) included data from Grimsby for very similar tides to those modelled in the spring-neap cycle. Additionally Delwaq-3D has been run for a larger spring tide in order to specifically compare with the IECS September 2010 spring tide measurements.

2.1.3 The available suspended sediment data were used to validate the mud model. The data that were used, and the tide range for which those data were collected, are tabulated below.

Table 1 – Suspended sediment data and comparison of tide range for which measurements were taken against modelled tide for which comparisons were made

	Grimsby (ABP, 2009)	HST water samples (IECS, 2010)	Model runs (spring-neap cycle) (HRW, 2011)	Large spring tide model run
Spring range	5.7	7.4	5.8	7.6
Neap range	3.6	3.3	3.9	n/a

2.1.4 Figures 5 and 6 show the model validation plots as presented in HR Wallingford, 2011. The figures show excellent validation of modelled suspended sediment concentrations against observations at Grimsby where the modelled and measured tides were similar.

2.1.5 The figures also show good comparison of model predicted near-surface suspended sediment concentrations when compared to the IECS September neap tide measurements. Peak modelled surface suspended sediment concentrations are 50- 78% higher than observations, which matches very well with the difference that would be expected (~65%) between a 3.9m modelled neap tide and a 3.3m observed neap tide[1]

2.1.6 The IECS spring tide observations were collected for a very large spring tide with a 7.4m tide range (see Table 1). In HR Wallingford (2011) these were plotted against modelled suspended sediment concentrations for a 5.8m spring tide from the modelled spring-neap cycle. This difference in tidal range explains the large difference between model predictions and observations shown in Figure 6. In fact, by using the same empirical relationship described in footnote 1 below, one would expect the modelled peak suspended sediment concentrations to be about 50% of those for which observations were made (in fact peak modelled concentrations are ~40% of observed).

2.1.7 Subsequent to the modelling assessment reported in (HR Wallingford, 2011), HR Wallingford was supplied boundary condition data from JBA to run a very large spring tide condition (7.6m tide range).

2.1.8 The model predicted suspended sediment concentrations for this large tidal range are compared against the IECS spring tide surface observations in Figure 7 (using the same model parameterisation as for the spring neap cycle). Although the model predicted concentrations were shown to compare well for the spring neap cycle, with the same parameterisation the model underpredicts (by about 40%) against the available IECS surface observations for this large spring tide. It should be noted also that the IECS water samples were taken from the Humber Sea Terminal (HST) facilities from the location shown in Figure 9. This will also potentially lead to uncertainties arising from local effects such as vessel operations and turbulence local to the structures during the large spring tide.

[1] Depth averaged saturated concentration may be assumed to scale approximately with the cube of tide range, the difference in tide range is 18% and the cube of the difference 65%.

2.2 INFILL AND MAINTENANCE DREDGING REQUIREMENTS

2.2.1 The model is shown to be well validated against available observations on suspended sediment concentrations for the simulated spring neap cycle. A further verification check was undertaken in HR Wallingford (2011) comparing the model predicted sedimentation rates for baseline conditions against reported annual maintenance dredging quantities available for two locations (the model predictions were scaled up to annual values, assuming the maintained depth is, in practice, maintained).

2.2.2 At these locations the predicted infill was 2-3 times higher than the reported values. This difference was used as the basis for providing a range of upper and lower estimates in HR Wallingford (2011).

2.2.3 It was emphasised in the modelling study (HR Wallingford, 2011) that the predicted siltation rates provide a likely range of potential future maintenance dredging requirements. In reality the actual siltation rates and maintenance requirements would be influenced by many factors: meteorological; operational (including vessel activity) and other; and so these ranges remained estimates with considerable uncertainty and potential for variation from year to year and also within any year.

2.2.4 HR Wallingford (2012) has subsequently expanded this comparison of model predicted sedimentation against reported (observed) maintenance dredging quantities, by considering more available data. With the exception of the reported dredging for South Killingholme Oil Jetty (for which the 2010 and 2011 quantities are much lower than predicted), the berths for which data are reported show model predicted baseline sedimentation rates are 2-9 times greater than reported for 2010 and 2011 (see Table 2).

Table 2 Predicted siltation estimates compared to reported quantities

	Lower Estimate	Upper Estimate	2007	2010	2011
Humber Sea Terminal	215,000	537,000	192,000		
South Killingholme Oil Jetty	56,000	139,000		5,158	1,034
Immingham Gas Terminal	34,000	85,000		16,030	17,958
Humber International Terminal	305,000	763,000		142,450	120,142
Immingham Bulk Terminal	539,000	1,348,000	492,000	152,109	205,365
Immingham Outer Harbour	778,000	1,946,000		974,059	1,027,424

2.2.5 As stated in HR Wallingford (2011), reasons for this difference will include (amongst others) deficiencies in a simple linear scaling up of the spring-neap cycle simulated to provide an annual estimate of siltation, the absence of extreme (storm) tide conditions and wave effects, the motion of ships into and out of the berths and berth occupancy, assumptions on material types and densities, frequency (and precise locations) of maintenance dredging, and natural variability in suspended sediment concentrations in the Humber Estuary.

2.2.6 From these few additional data sets, one can see that the reported maintenance dredging quantities are all closer to the lower estimates predicted by the modelling for baseline conditions. The figures for Immingham Outer Harbour are within the range predicted by the modelling. Arguably the model would be expected to give a closer prediction of siltation in the IOH basin, in contrast to the riverside berths, as processes not included in the model leading to remobilisation of material would not necessarily lead to that material being transported out of the basin. In contrast, it is noted that the numerical modelling undertaken for IOH led to an under-prediction of the maintenance requirements and a consequent need to increase the licensed disposal quantities for maintenance dredging (ABPHES, 2008).

3 SUMMARY

3.1.1 In summary:

- The underpinning TELEMAC-3D flow model was validated and shown to be appropriate for use in driving the sediment modelling using DELWAQ-3D. The same model parameterisation was used for the with-scheme runs informing the range of impacts.

- The DELWAQ-3D sediment model was validated against limited observations of suspended sediment concentrations.

- The model results for baseline conditions were converted to annual estimates of sedimentation and compared against reported maintenance dredging quantities. In general the lower range of the model predictions is found to compare with the reported quantities of maintenance dredging.

3.1.2 Notwithstanding the above, there remains considerable uncertainty in sediment modelling (compared with e.g. hydraulic modelling). This uncertainty has been openly communicated in the Environmental Statement Chapter 8, and a precautionary approach has been adopted in the assessment towards predictions of impacts on fine sediment transport and siltation rates.

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FIGURES

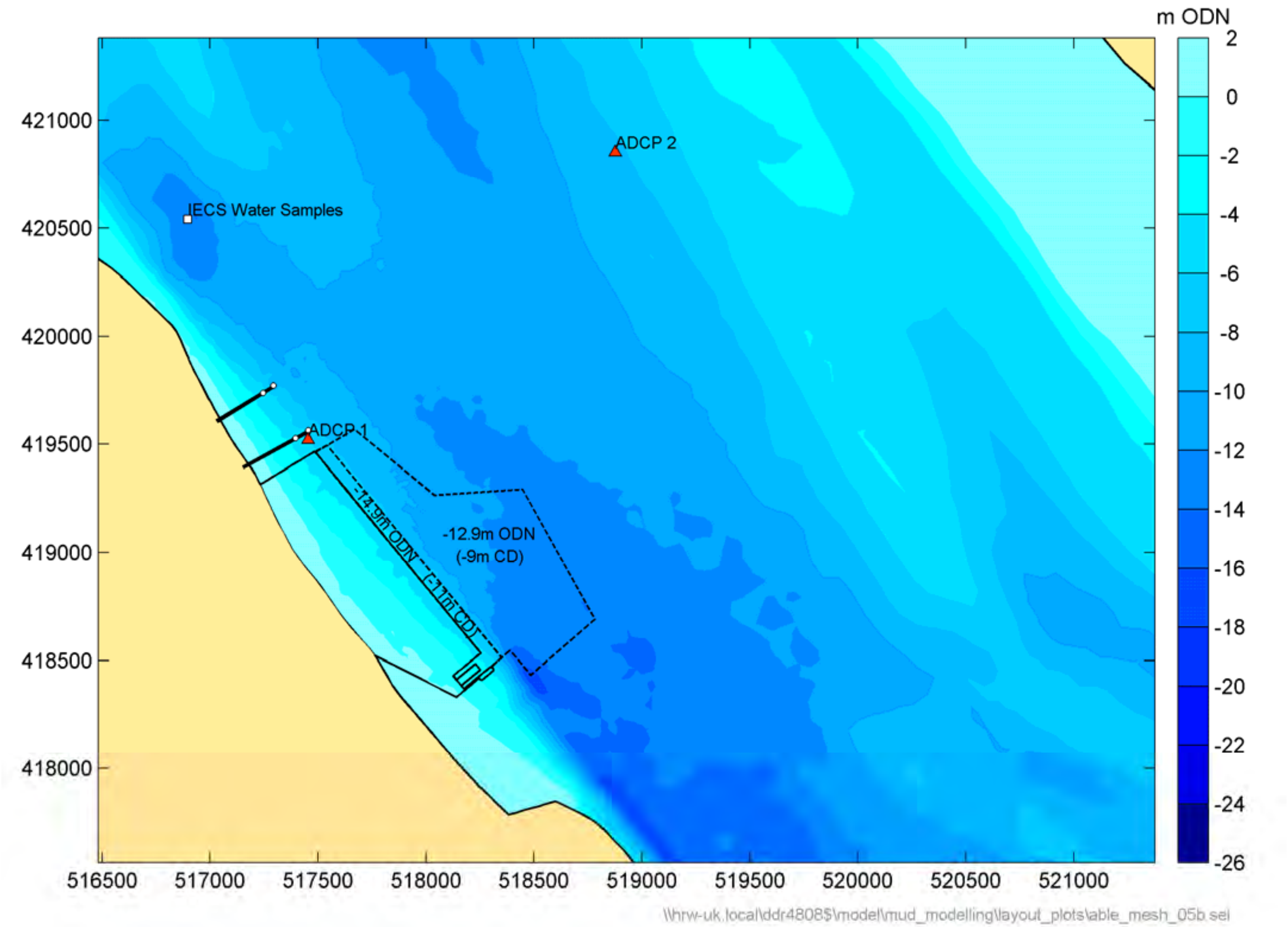

Figure 1 Deployment locations of bed mounted ADCP instruments and the IECS water sample location (on the Humber Sea Terminal jetty).

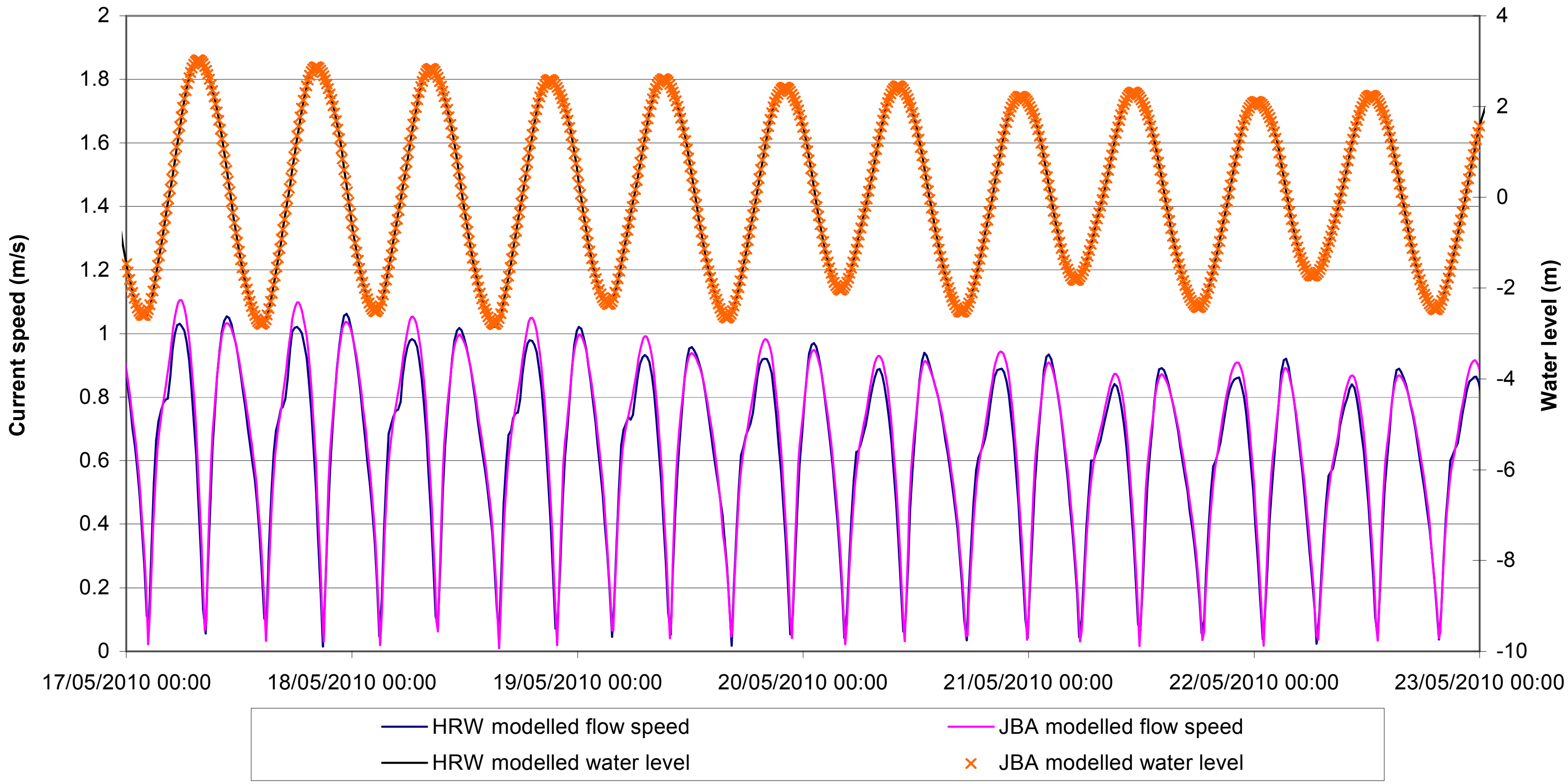

Figure 2 Comparison of HR Wallingford and JBA modelled depth averaged flows and water levels (Station 1)

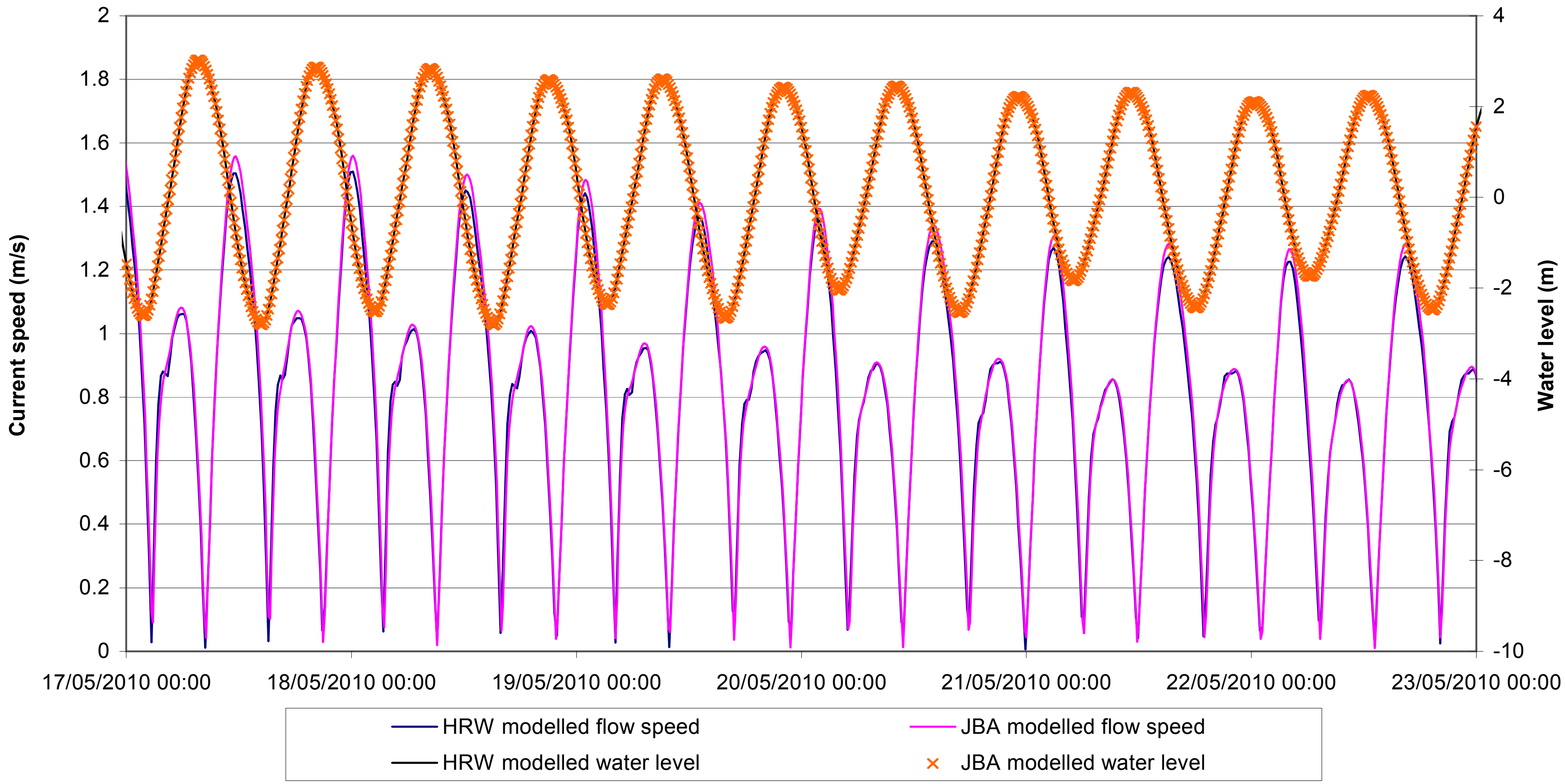

Figure 3 Comparison of HR Wallingford and JBA modelled depth averaged flows and water levels (Station 2)

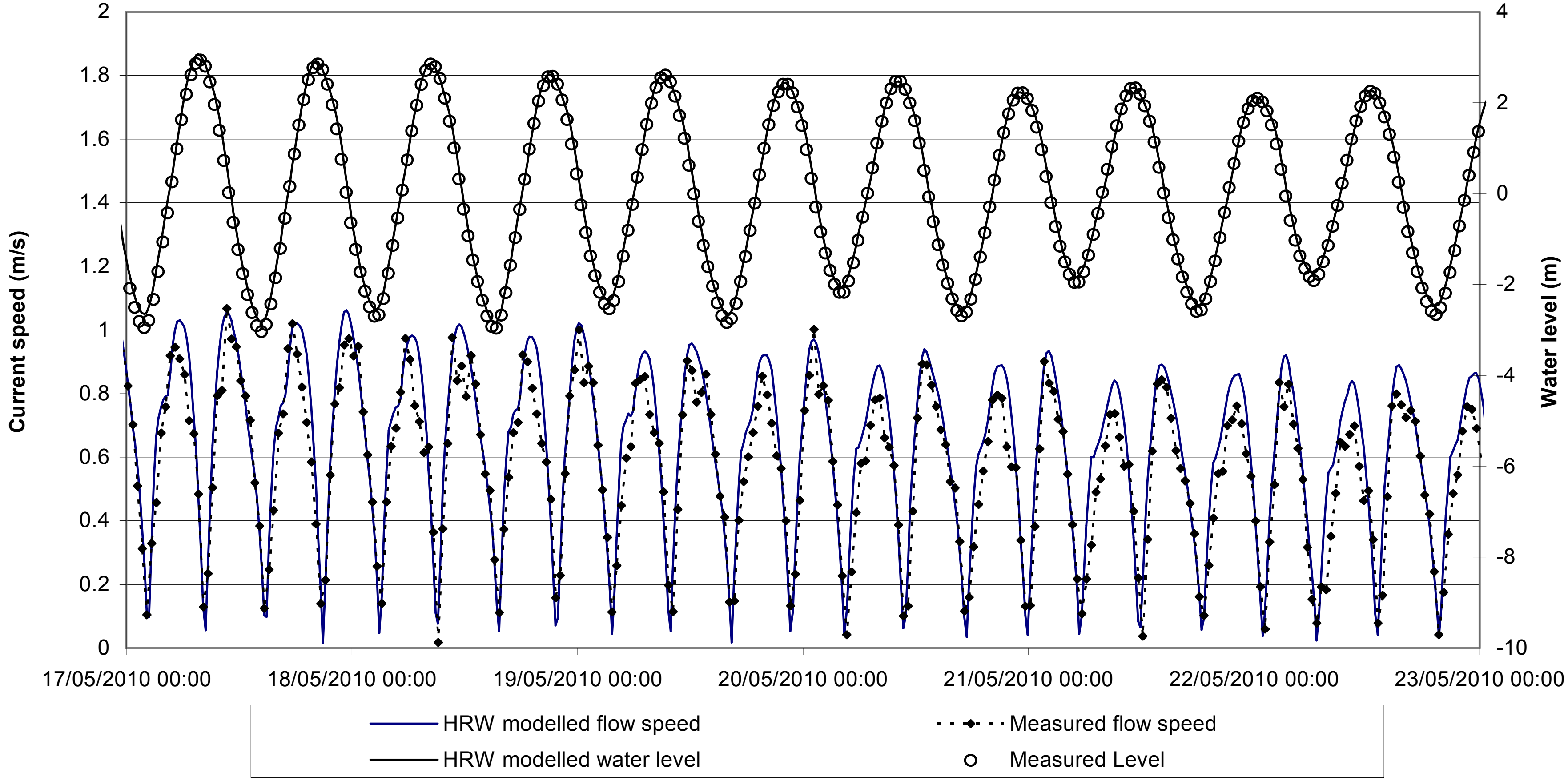

Figure 4 Comparison of HR Wallingford modelled flows speeds and water levels against observations

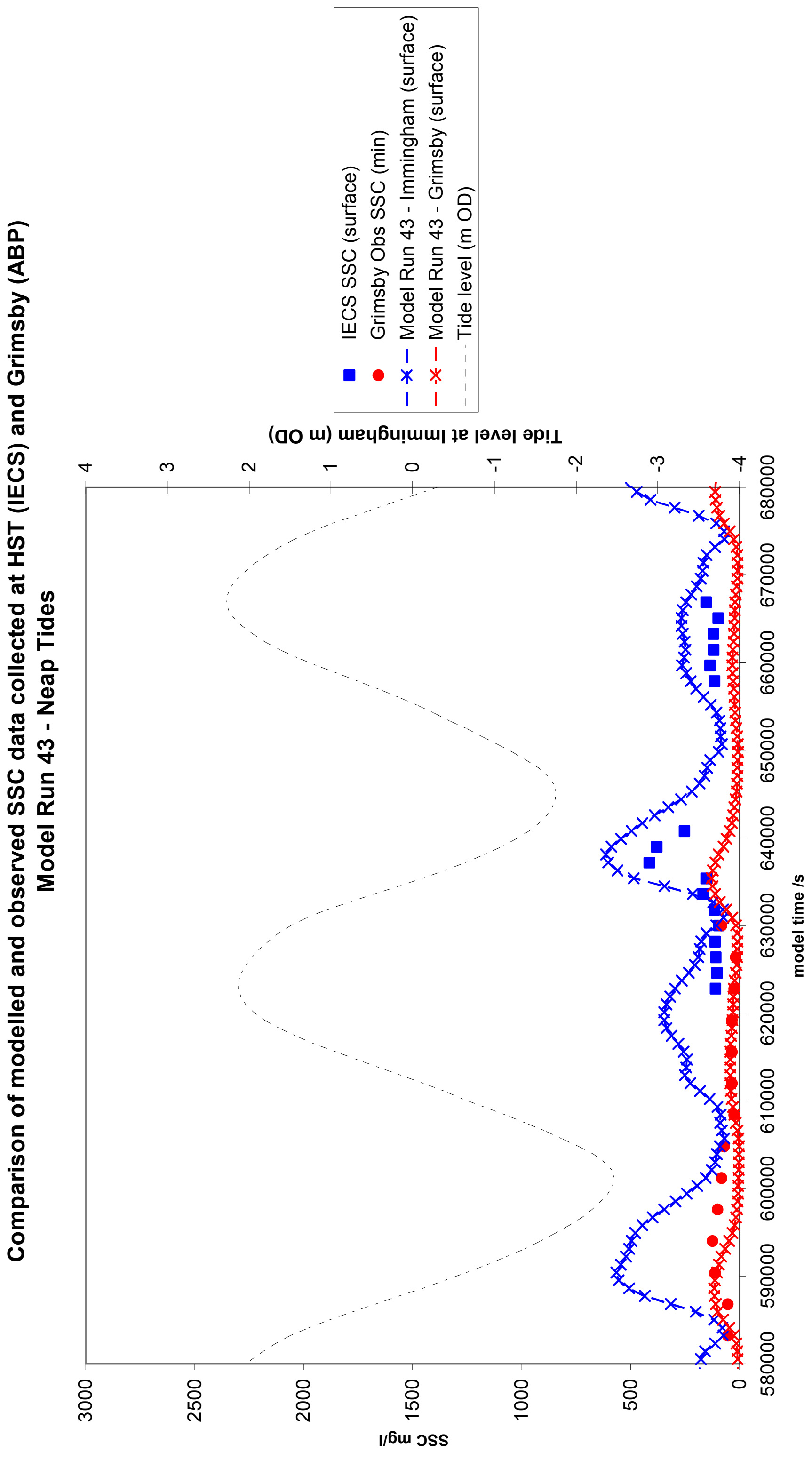

Figure 5 Comparison of modelled suspended sediment concentrations against observations made at Grimsby (ABP, 2009) and Humber Sea Terminal (IECS, 2011b)

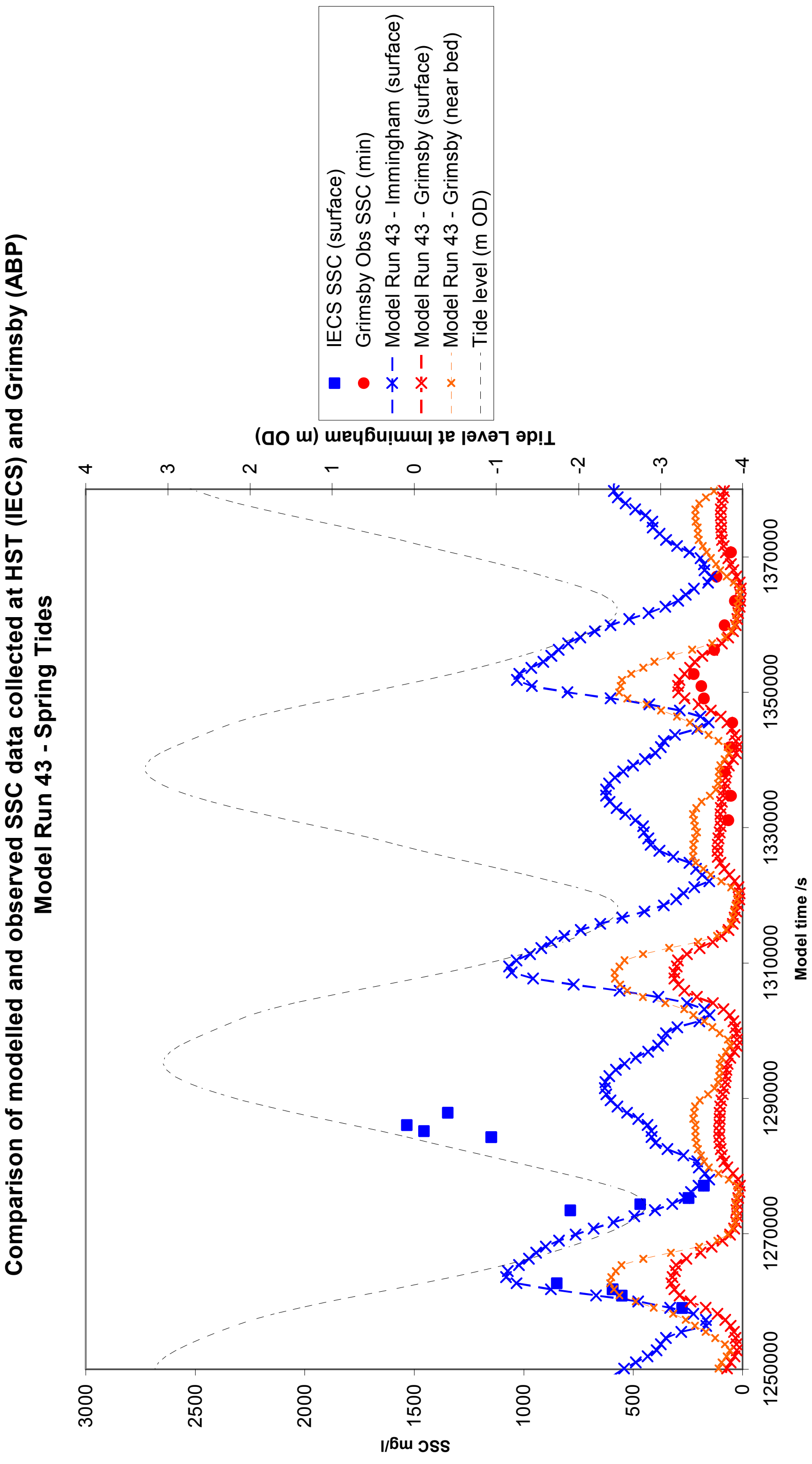

Figure 6 Comparison of modelled suspended sediment concentrations against observations made at Grimsby (ABP, 2009) and Humber Sea Terminal (IECS, 2011b)

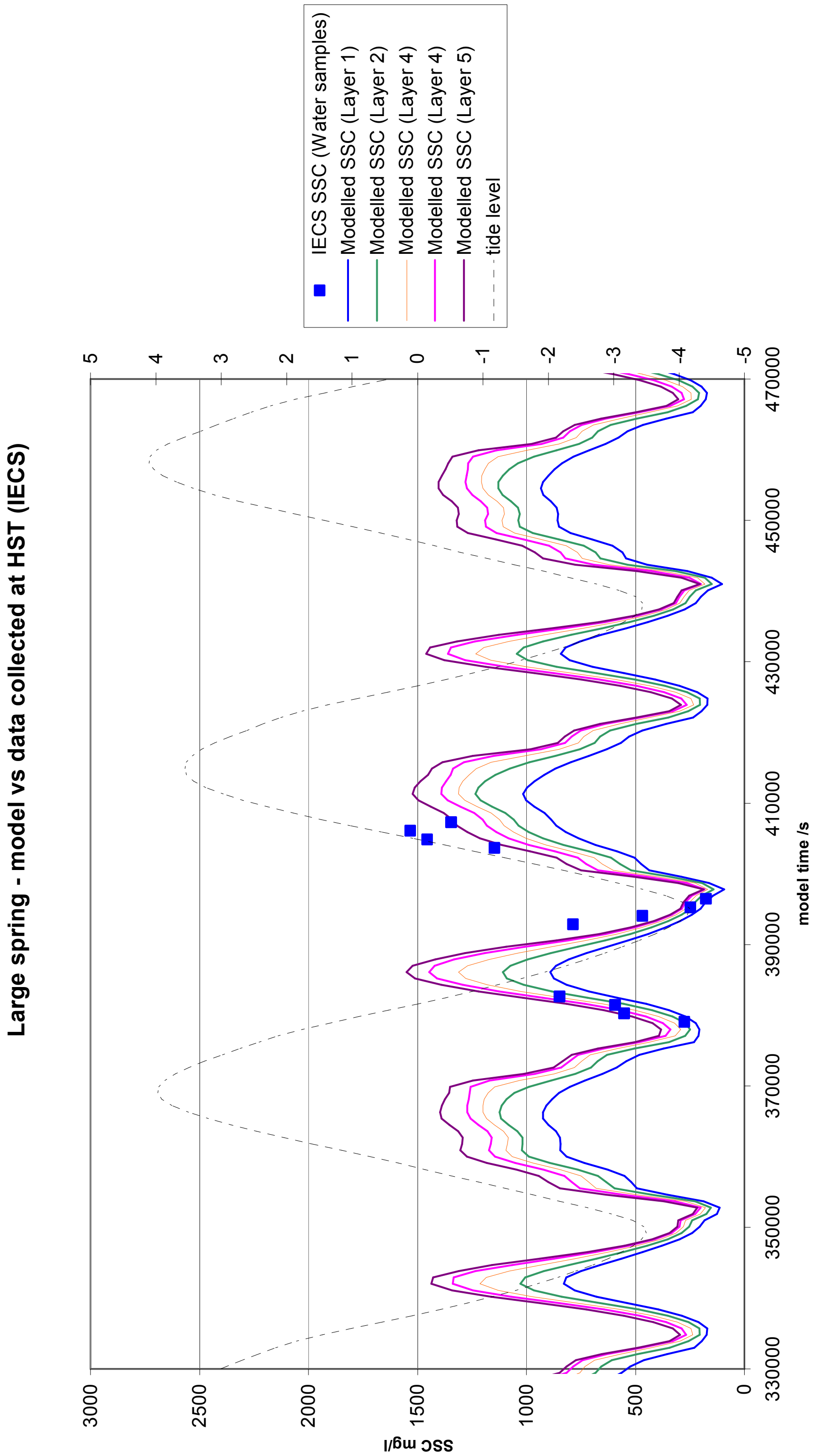

Figure 7 Comparison of modelled concentrations with the IECS surface water sample concentrations (squares) for a large spring tide.

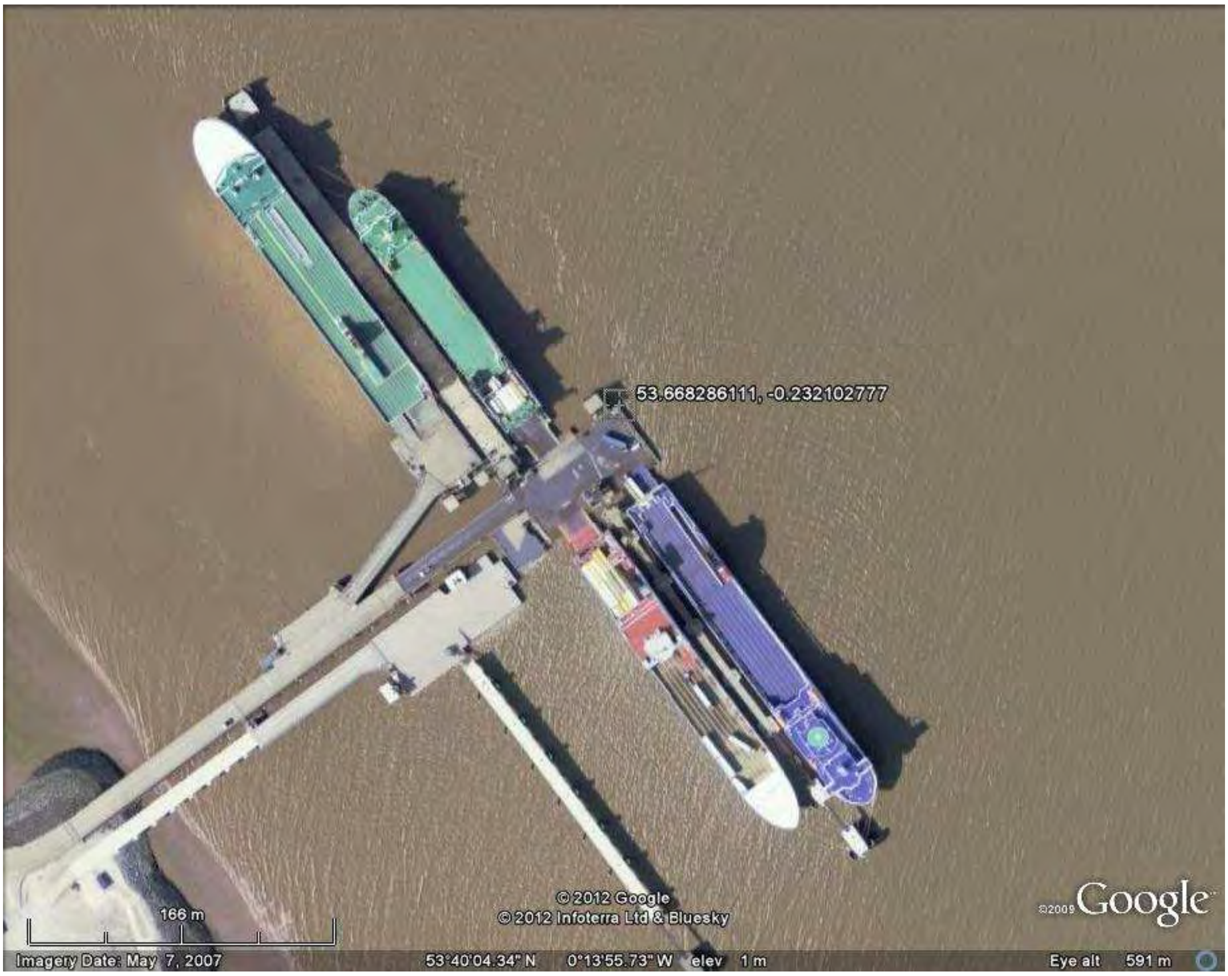

Figure 8 Aerial photo showing location of the IECS surface water sampling point