HORIZON
NUCLEAR POWER

WYLFA NEWYDD

ENERGY WORKING FOR BRITAIN

Wylfa Newydd Project

6.4.94 ES Volume D - WNDA Development App D13-12 - Marine hydrodynamic modelling report - Disposal Site

PINS Reference Number: EN010007

Application Reference Number: 6.4.94

June 2018

Revision 1.0

Regulation Number: 5(2)(a)

Planning Act 2008
Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

Horizon Internal DCRM Number: WN0902-JAC-PAC-APP-00173

[This page is intentionally blank]

Wylfa Newydd Project

Marine Modelling of the Disposal Site

60PO8077/AQE/REP/007 | 1.1

15 January 2018

Document history and status

Revision	Date	Description	By	Review	Approved
1.0	14/7/17	For issue to client	Phil Shepperd	Matt Robson	Rob Bromley
1.1	15/1/18	Minor updates to text made following NRW review - for issue to client	Colin Trigg	Rachel Wilson	Rob Bromley

Distribution of copies

Revision	Issue approved	Date issued	Issued to	Comments

Marine Modelling of the Disposal Site

Project No:	60PO8077
Document Title:	Marine Modelling of the Disposal Site
Document No.:	60PO8077/AQE/REP/007
Revision:	1.1
Date:	15 January 2018
Client Name:	Horizon Nuclear Power
Client No:	
Project Manager:	Rob Bromley
Author:	Phil Shepperd
File Name:	

Jacobs U.K. Limited

Kenneth Dibben House
Enterprise Road, Southampton Science Park
Chilworth, Southampton SO16 7NS
United Kingdom
T +44 (0)23 8011 1250
F +44 (0)23 8011 1251
www.jacobs.com

Contents

Executive Summary

Horizon Nuclear Power (Horizon) has proposed to develop a new Nuclear Power Station on the north coast of Anglesey. To support the consenting of the new station, Horizon has developed a hydrodynamic model to help understand the potential effects related to construction and operation of the station.

The model has also been adapted specifically for the consideration of the fate of sediment arising from dredge activity during the construction phase, intended for release at the Disposal Site licensed marine disposal site.

The model has been locally validated against Acoustic Doppler Current Profiler (ADCP) data, and has been shown to be accurately predicting current speed and direction both on a depth-averaged basis and at locations through the water column, demonstrating robust representation of the vertical velocity profile.

The adapted model has been applied to consider the fate of dredge material from the Wylfa Newydd Project. Model outputs show that the material rapidly disperses to levels in line with background suspended sediment concentrations.

The model also shows that there is a limited build-up of sediment on the seabed, in terms of both thickness and lateral extents, with an area of 0.5km^2 being covered by 5cm of sediment by the end of the disposal programme. While this settled sediment is predicted to remain in place in the short term, saltation is likely to lead to dispersal into the wider marine environment in the longer term.

A sensitivity test has shown that the inclusion of waves increases dispersion and reduces suspended sediment concentrations; the exclusion of waves is therefore carried forward as a conservative (worst-case) approach.

Disposal of rock on the seabed has been shown to have limited effect on surrounding flow velocities. Hence, this is not considered to be significant in the context of bed processes at that Disposal Site.

1. Introduction

Horizon Nuclear Power (Horizon) has proposed to develop a new Nuclear Power Station on the north coast of Anglesey. To support the consenting of the new station, Horizon undertook extensive marine surveys to underpin the development of a 3-dimensional coastal numerical hydrodynamic model for effluent dispersion and coastal processes assessments.

The model has now been adapted to assess the fate of sediment arising from dredge activity during the construction phase, intended for release at the Disposal Site (IS043) licenced marine disposal site herein referred to as the ‘Disposal Site’.

This report describes the model development, validation and application undertaken to that end.

2. Model Development

The Horizon model was constructed using, and operates in, the Delft3D modelling suite from Deltares.[1] Delft3D represents state-of-the-art coastal modelling software and offers a range of hydrodynamic (2D and 3D), wave, sediment transport and water quality modelling tools.

Construction of the model made use of the Domain Decomposition approach, allowing grids of successively higher resolution to be dynamically nested. This approach allows for flexibility in the resolution of the model with greater resolution in areas of most interest whilst keeping the computational efficiency of structured grids.

Following construction, an extensive programme of model calibration was undertaken against a comprehensive bespoke survey dataset, primarily focused on the seas around Wylfa Head. Construction, calibration and validation of the Horizon model is described in detail in Horizon (2016). The model has also been subject to an extensive third-party review (ABPmer 2016).

It is noted that in addition to the extensive calibration/validation against data collected around Wylfa Head, calibration was also undertaken against tide gauge data at Holyhead and British Oceanographic Data Centre current meter data within the outer 2D domain. The agreement, in terms of predicted levels and phasing, was shown to be robust.

The calibrated and validated model was subject to a detailed third-party review – conducted by ABP Marine Environmental Research – during 2016 (ABPmer 2016). This was followed by extensive application of the model to the characterisation of the cooling water and chlorination by-product plumes under a range of tidal and meteorological conditions. This work is presently in the reporting stage.

The requirement for modelling the fate of dredge material disposed at the Disposal Site has led to a reconfiguration of the validated Horizon model as follows:

- Model outer (350m resolution) grid extents and vertical scheme (2-dimensional) unchanged.
- Model mid (70m resolution) and inner (23m resolution) grids remain in place and unchanged.
- Model boundary conditions unchanged.
- Model calibrated spatially varying bed roughness coefficients unchanged.
- Model time steps and other numerical parameters unchanged.
- The area of the outer grid around the Disposal Site upgraded by the inclusion of a 70m resolution grid, dynamically linked to the existing model in the same way as the exiting mid and inner grids. Grid dimensions were set to approximately 10.6km x 13km, this being designed so as to be more than sufficient to capture the key effects associated with disposal within the new grid. The new 70m grid was specified as 3-dimensional, with 10 vertical layers. The layers were each defined as representing 10% of the local depth in order to provide a level of detail which would remain consistent through the water column.
- Model bathymetry in the area around the Disposal Site was updated using the latest multibeam and single beam data available from UK Hydrographic Office.

The Disposal Site grid is shown in green in the context of the overall model in Figure 1. The Disposal Site grid is shown in detail in Figure 2.

[1] http://www.deltaressystems.com/hydro/product/621497/delft3d-suite/1130938

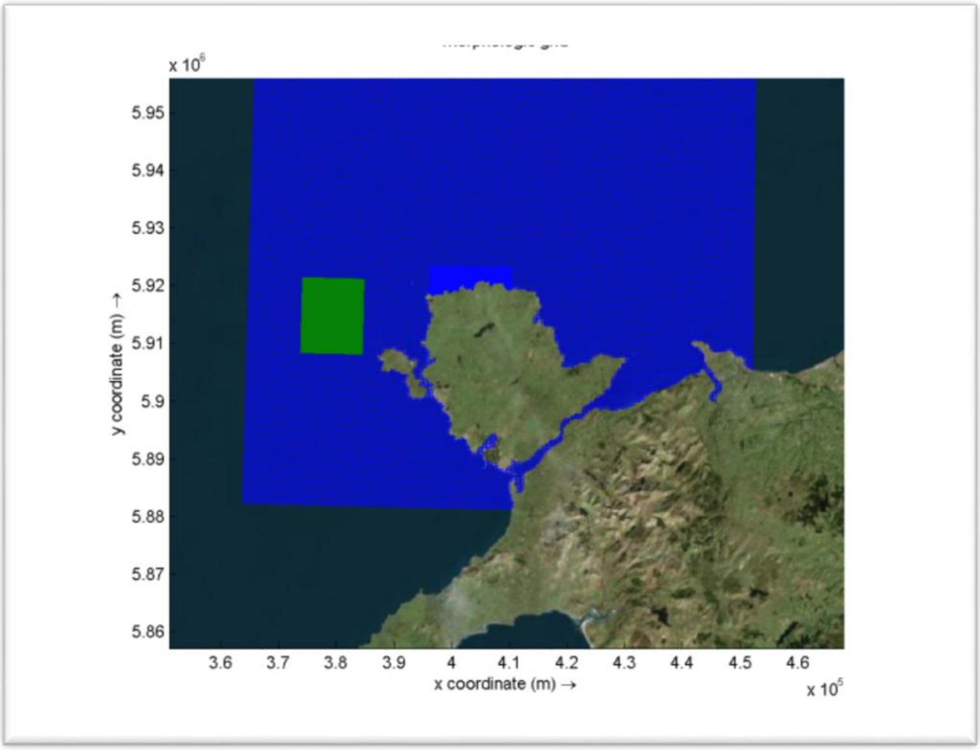


Figure 1 – The Disposal Site grid (green) in context of the hydrodynamic model mesh (blue)

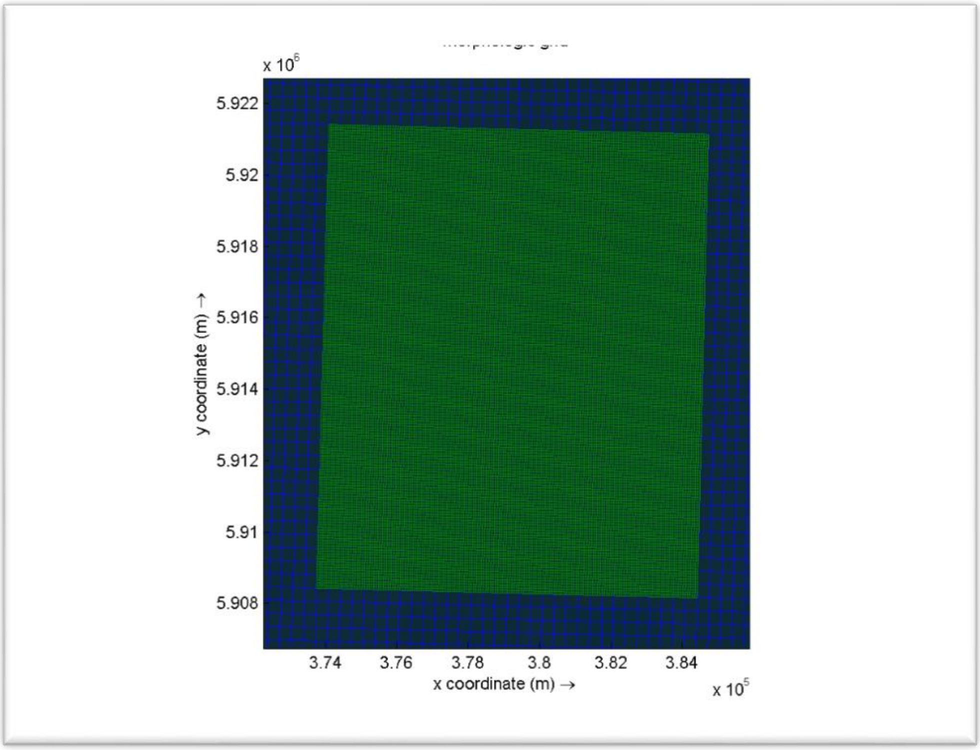


Figure 2 – The Disposal Site grid

The UKHO bathymetry data was converted to model datum and interpolated onto the model grid using a combination of gridcell averaging (where data density greatly exceeds gridcell density) and triangular interpolation (where data density does not greatly exceed gridcell density). The resultant bathymetry for the Disposal Site grid is shown in Figure 3.

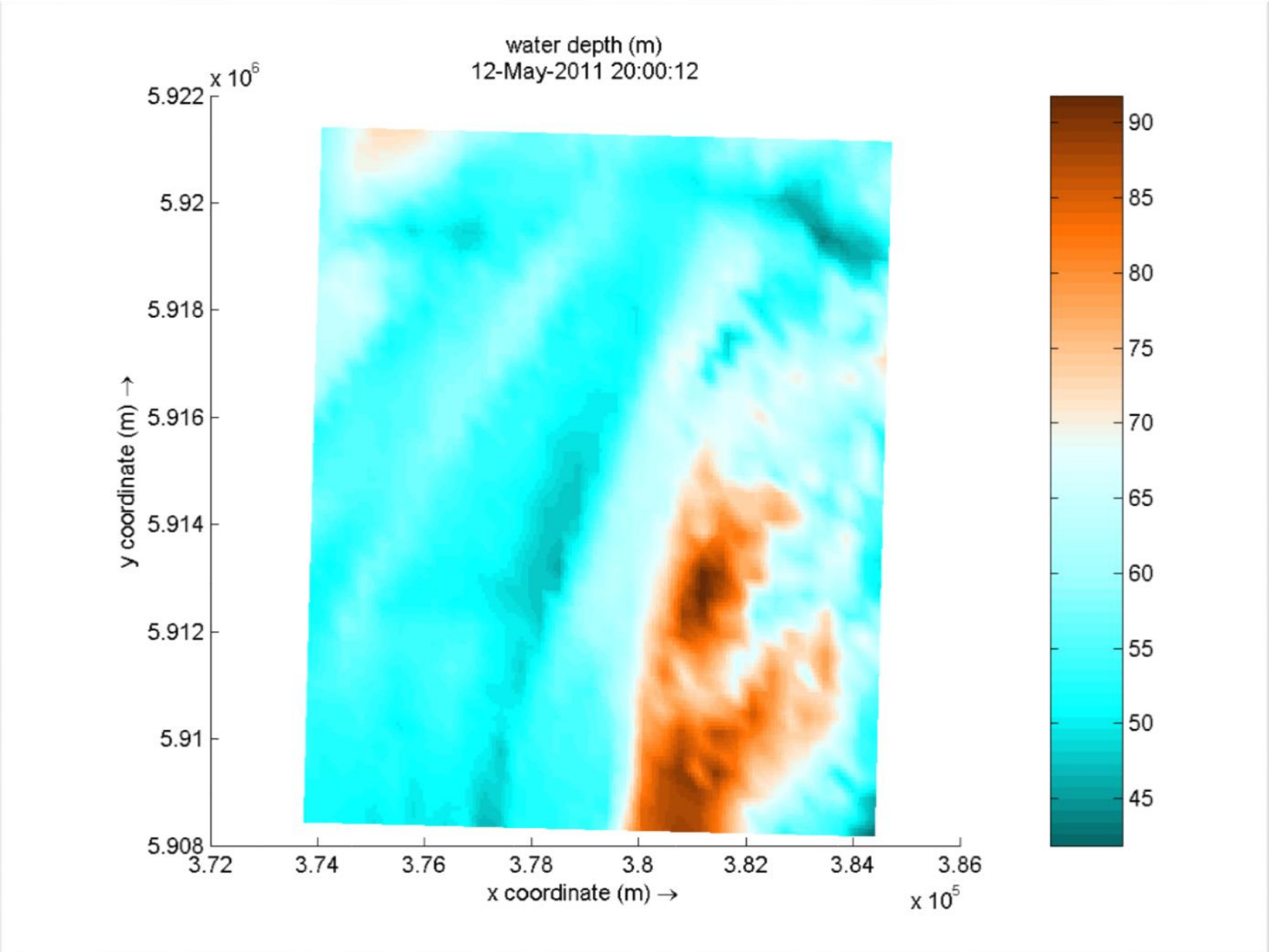


Figure 3 – The Disposal Site grid bathymetry, m below mean sea level (bMSL)

On completion of the model development phase, checks were undertaken to confirm that model stability remained robust and that simulation times were in line with expectation, before moving on to the model validation exercise. The extent of the nested domain was chosen to cover the area of interest and to allow the model to properly capture the detail of a dredge spill plume. That the grid design was suitable was confirmed in initial 2D simulations, with no apparent degradation of key plume characteristics when moving between grids because at that point its scale was appropriate to the outer grid resolution.

3. Model Validation

Validation of the reconfigured model was undertaken against ADCP current meter data provided by SEACAMS. Prior to use, the ADCP data were visually checked for quality (poor quality data tending to lead to ‘spikey’ time series plots and frequent null-returns) and found to be of good quality by these measures.

The location of the ADCP deployment is less than 400m south of the Disposal Site (see Figure 4). The ADCP was deployed at a depth of 86.6m over two full tidal cycles which covered the period 15 August – 12 September 2013. The instrument was a Teledyne 600kHz ADCP.

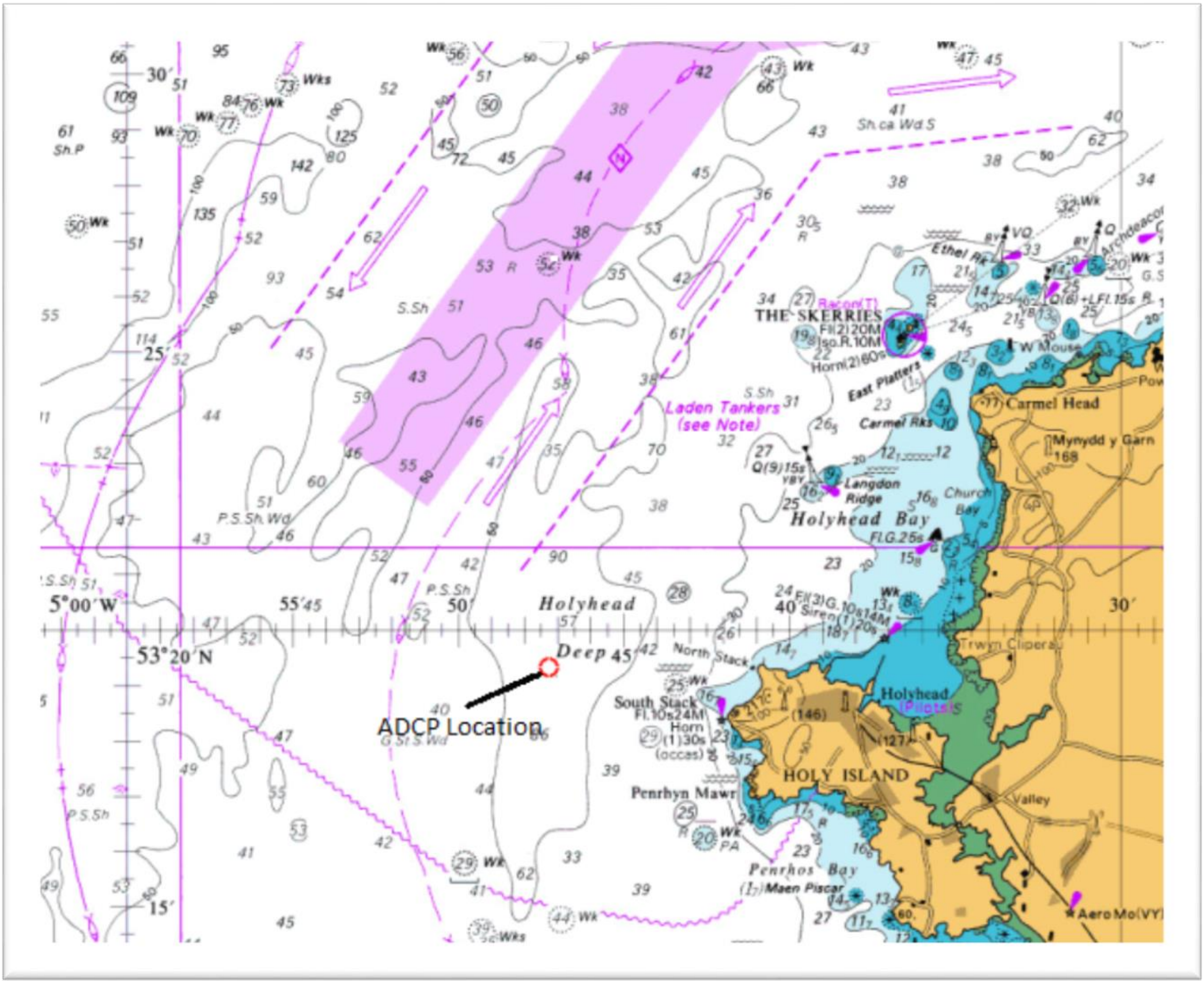


Figure 4 – SEACAMS ADCP deployment location

Validation was carried out both for depth-averaged and 3-dimensional outputs.

3.1 Depth-Averaged Validation

Depth-averaged time series output over a neap-spring cycle is plotted against corresponding depth-averaged ADCP data in Figure 5 (magnitude) and Figure 6 (direction).

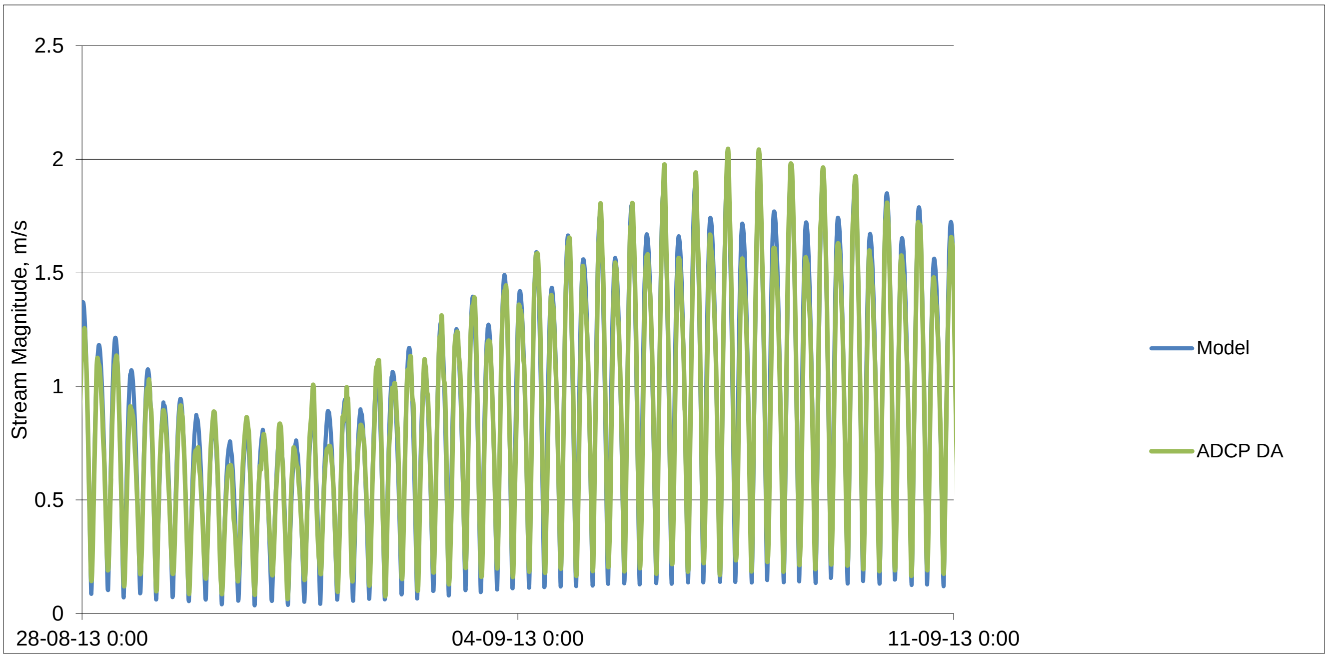


Figure 5 – Depth-averaged magnitude validation

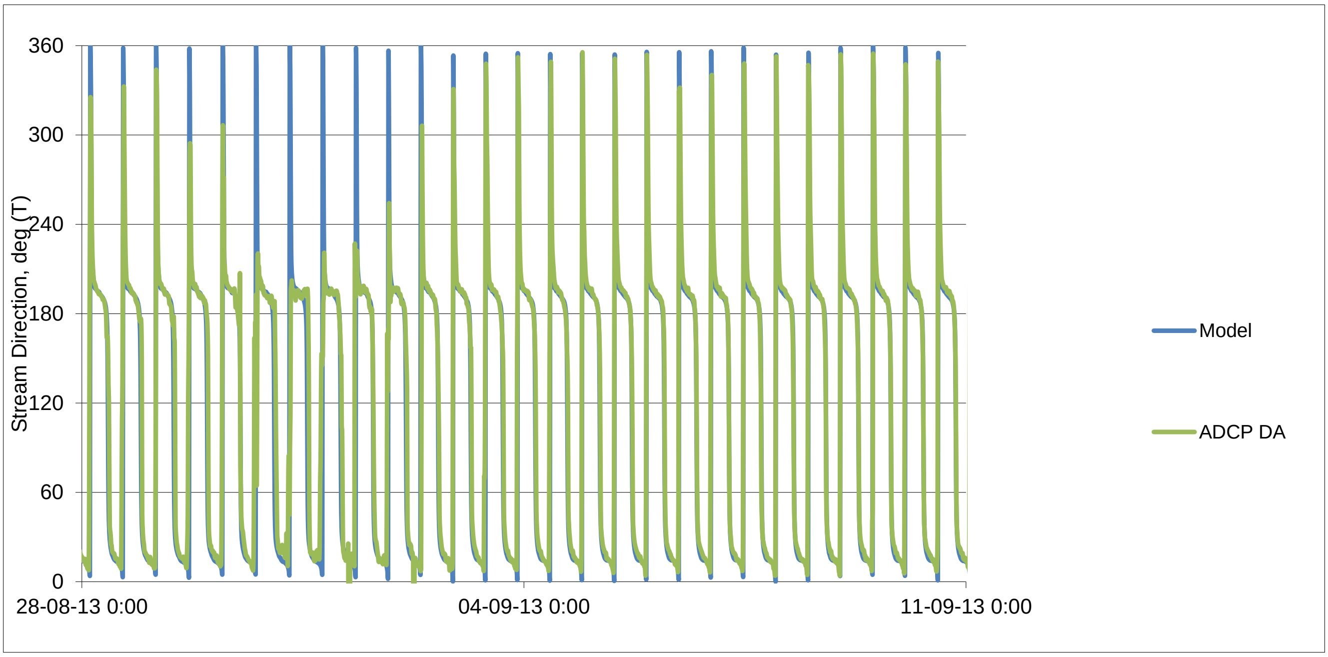


Figure 6 – Depth-averaged direction validation

3.2 3-Dimensional Validation

Output from approximately 6m above the bed over a neap-spring cycle is plotted against corresponding depth-averaged near bed ADCP data in Figure 7 (magnitude) and Figure 8 (direction).

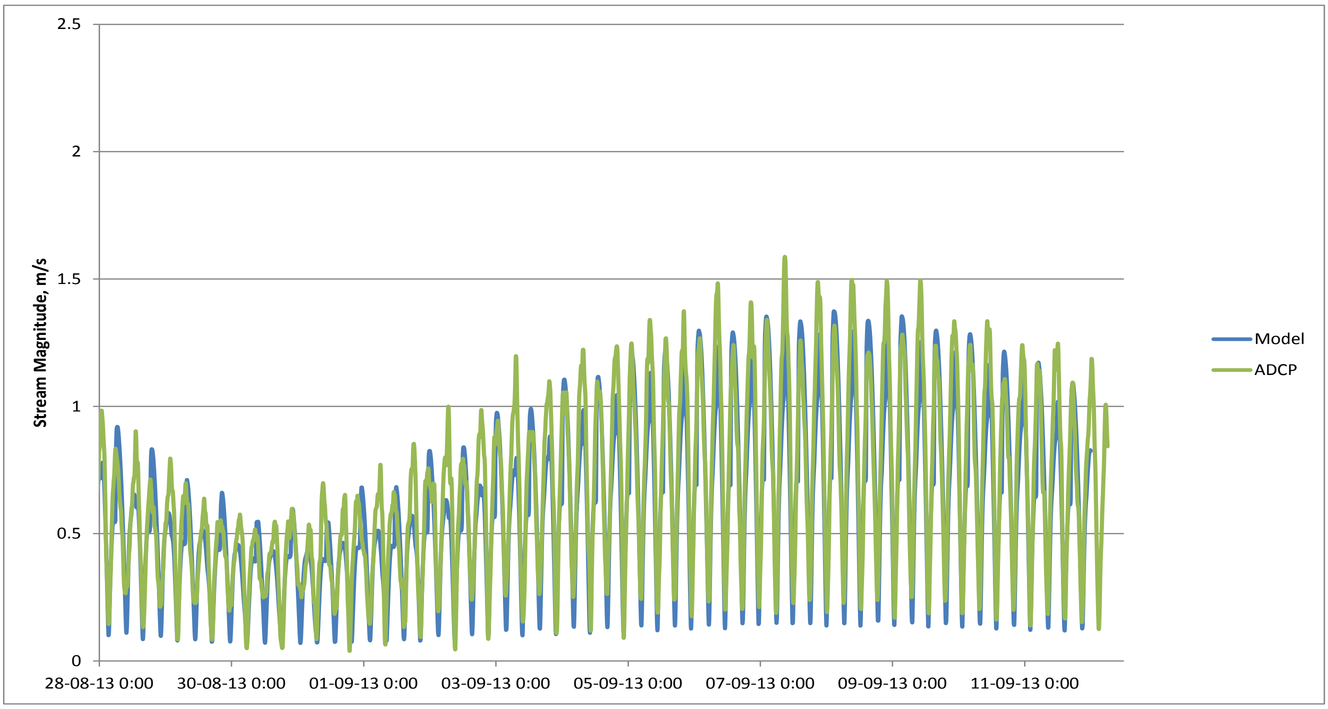


Figure 7 – Near bed magnitude validation

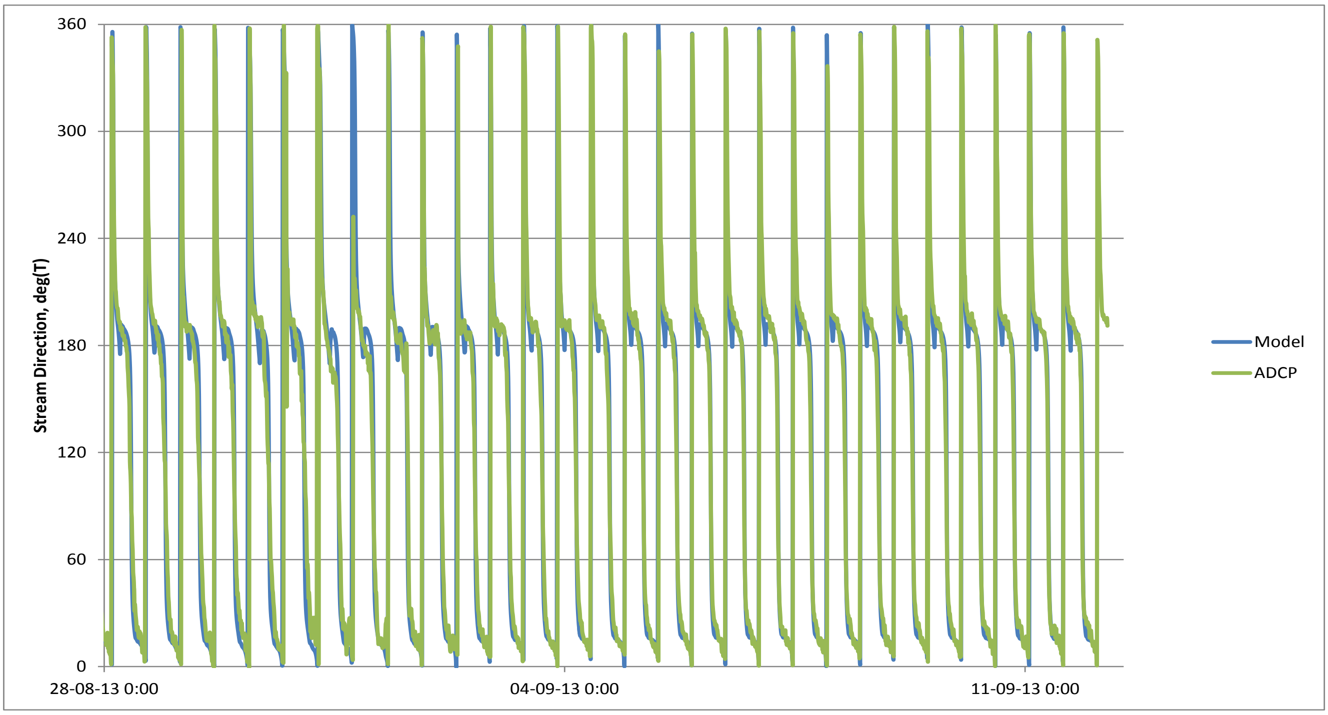


Figure 8 – Near bed direction validation

Output from mid depth, approximately 40m above the bed, is plotted against corresponding depth-averaged mid-depth ADCP data in Figure 9 (magnitude) and Figure 10 (direction).

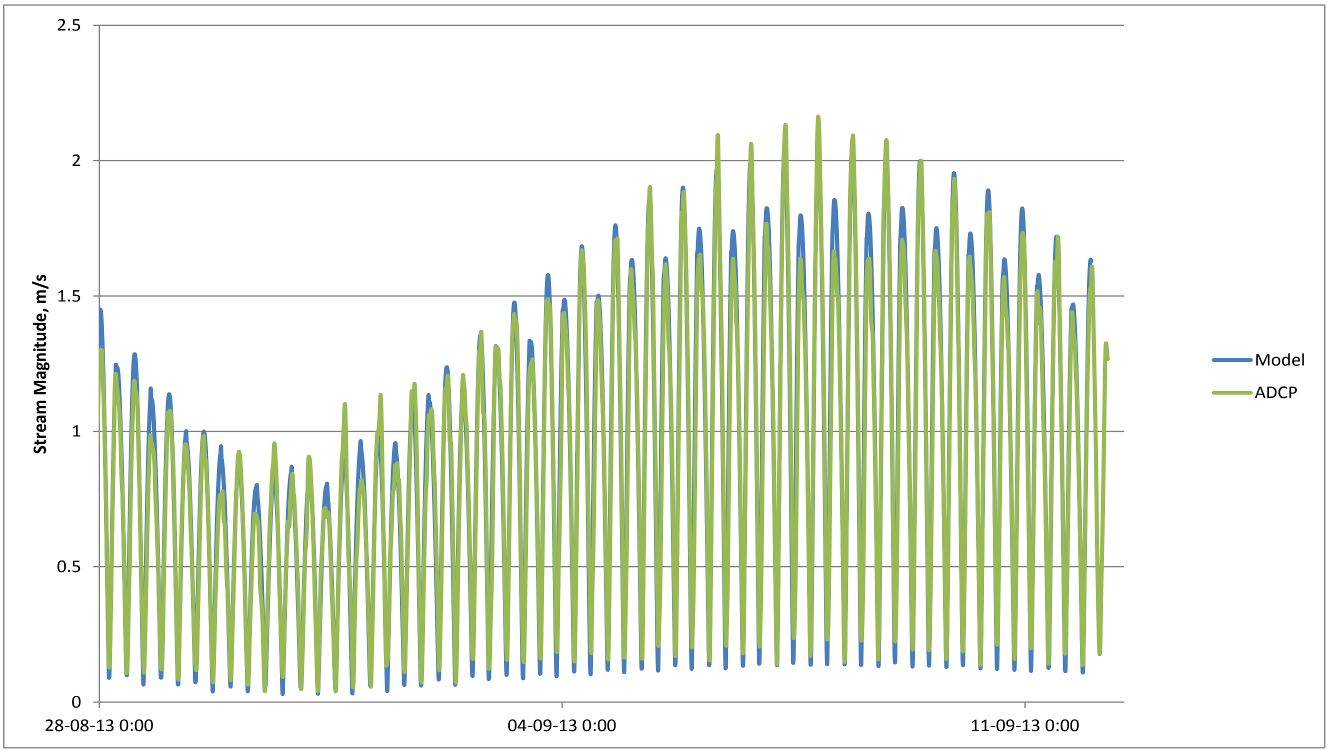


Figure 9 – Mid depth magnitude validation

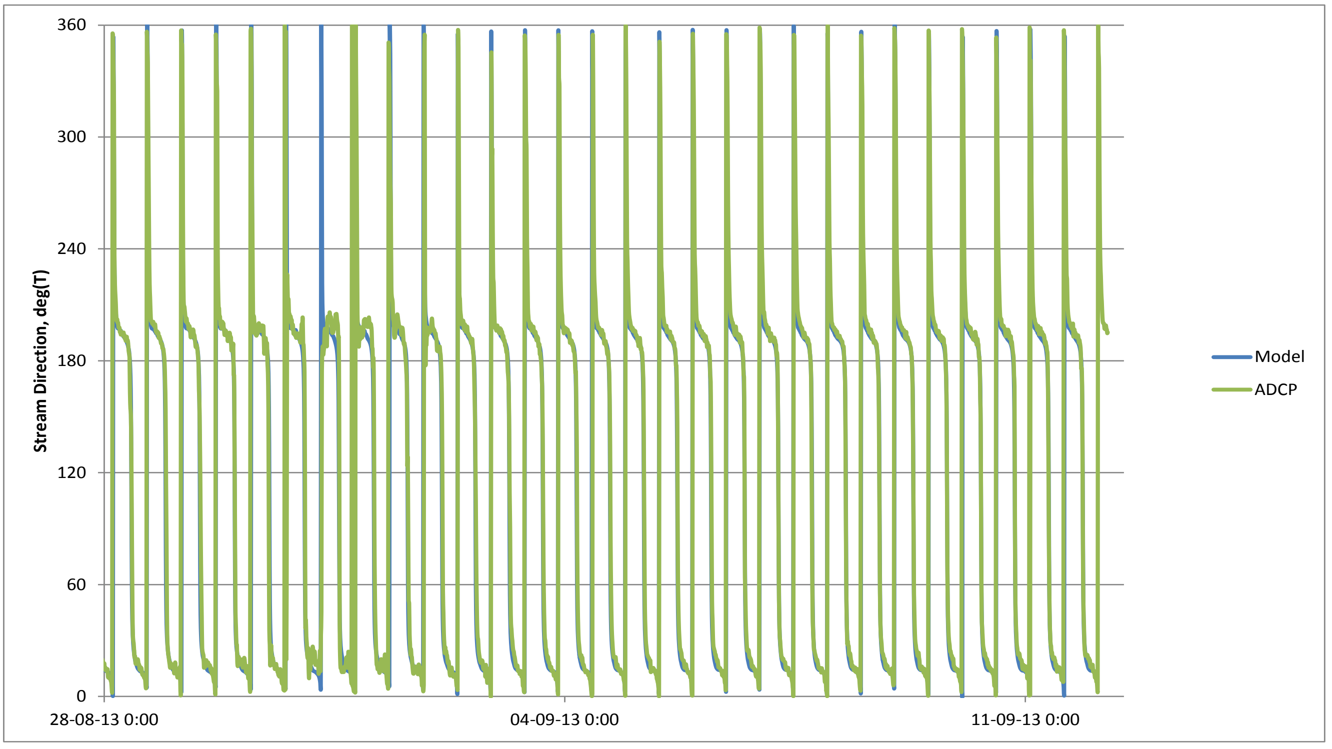


Figure 10 – Mid depth direction validation

Output from near surface, approximately 70m above the bed, is plotted against corresponding depth-averaged near surface ADCP data in Figure 11 (magnitude) and Figure 12 (direction).

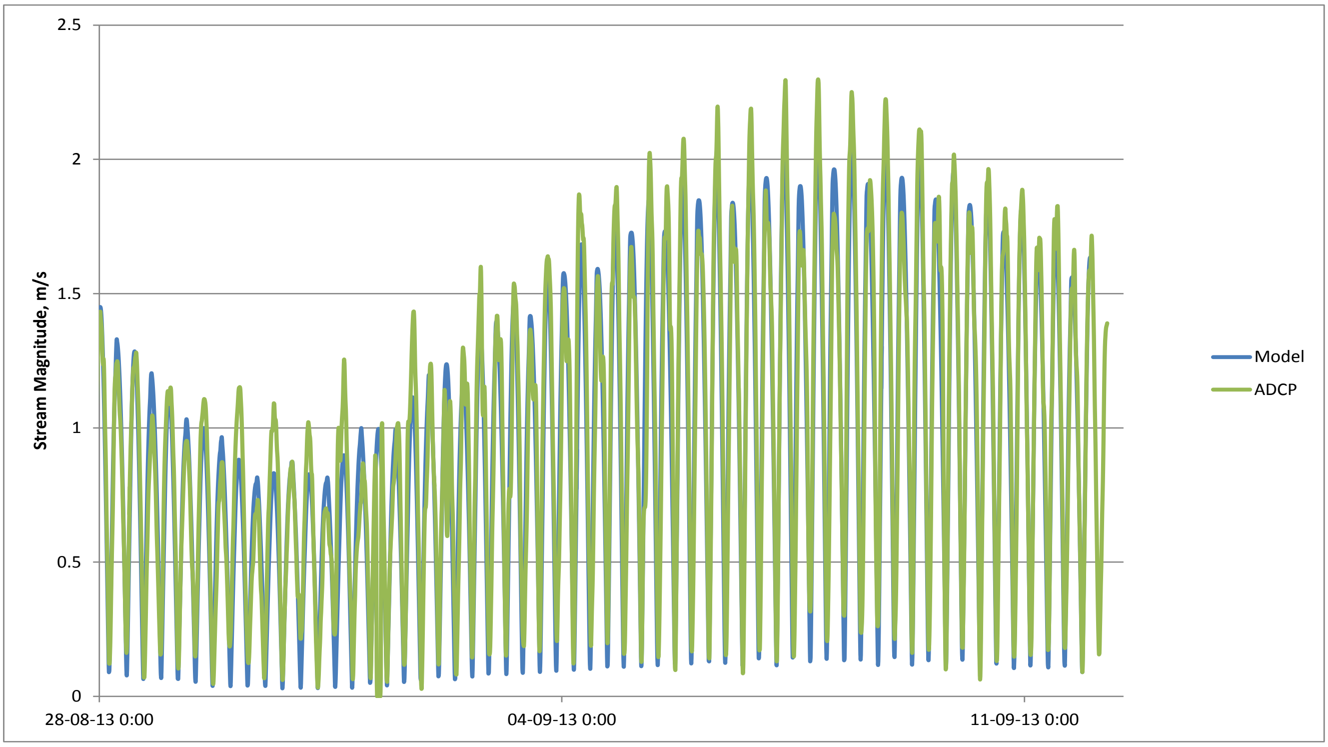


Figure 11 – Near surface magnitude validation

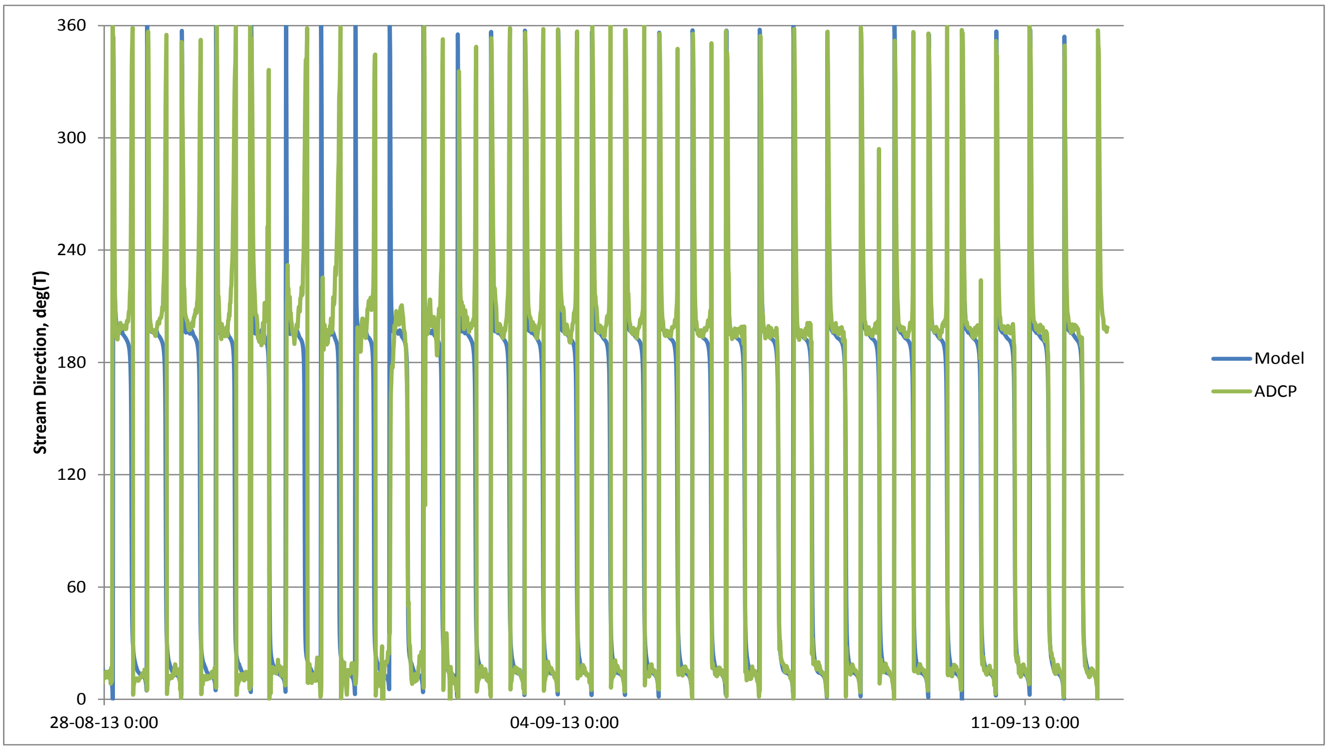


Figure 12 – Near surface direction validation

3.3 Validation Summary

It is clear from the validation plots that the model is hindcasting current velocities at this location with a high degree of confidence, both on a depth-averaged basis and in 3-dimensions. Further, the phasing of the tidal flows is robustly predicted by the model.

Of particular note is the correct representation of the vertical velocity profile, with flow speeds reducing at depth in good agreement with the measured data. This characteristic is strongly dependent on the correct parameterisation of bed roughness, which by implication is also correctly defined in the model. The conclusion drawn from the above exercise is that the model is capable of reproducing the hydrodynamics of the area and is an appropriate tool for robust assessment of the fate of disposed dredge material.

The high predicted and measured velocities underline the dispersive nature of this site, such features lending themselves well to the disposal of sands and fine sediments into deep water.

4. Model Input Data

The Delft3D sediment transport module supports both bedload and suspended load transport of non-cohesive sediments and suspended load of cohesive sediments. For schematisation the model distinguishes 'mud' (cohesive suspended load transport),'sand' (non-cohesive bedload and suspended load transport) and 'bedload (non-cohesive bedload only or total load transport) fractions. The only difference between 'bedload' and 'sand' fractions lies in the fact that the suspended load advection-diffusion equation is not solved for the 'bedload fraction.

Details of model applications and input data are described below.

4.1 Sediment Input Data Assumptions

Based on the capital dredge requirements for the excavation and disposal of sediment, the following has been assumed for modelling of the plume dispersion:

- Total volume of sediment to be disposed: 242,000m^3.
- Disposal schedule: 2 x 3,500m^3 disposals per day. Each barge with an approximate capacity of 3,500m^3.
- Duration of dredge disposal activity: 35 days.
- That each sediment disposal event would take place approximately within the middle of the Disposal Site.
- That sediment fractions are partitioned as per Table 1.

The disposal activity was therefore defined in the model as two (No.2) releases per day, at 0600 and 1800, for 35 days. The 'full programme' model simulations therefore started at 0000 on 1 April 2011 with six hours of hydrodynamic 'spin-up' before the first release at 0600. The final release was set to 5 May, with the simulations continuing for a further seven days before completing on 12 May 2011. The simulation period allows the model to sample a range of tidal conditions representative of those expected during the construction work.

In order to define the release parameters in the model, it was necessary to convert from volume of sediment to weight. Using a standard sediment grain density of 2,650kg m^{-3} and a typical porosity factor of 0.6, an overall sediment density of 1600kg m^{-3} in the dredger hopper was calculated.

Allowing for a hopper dump duration of 10 minutes: (1,600kg m^{-3} x 3,500m^3) / 600 seconds = **9333kg s^{-1}**.

The partitioning of the sediment is detailed in Table 1.

Table 1 – Sediment partitioning

	Coarse Sand	Medium Sand	Fine Sand	Fines
Diameter, mm	1	0.3	0.1	0.063
% of total	56	12	9.6	22.4

Settling velocity and sedimentation/erosion characteristics for the sand fractions are calculated through an advanced set of equations within the model numerical scheme. For the fines fraction, the model code includes the effects of flocculation on settling velocity and on subsequent deposition and erosion characteristics. A full description of the sediment model's underlying equations is given in Deltares (2011).

Simulations were also undertaken of Horizon's sediment disposal in combination with the Port of Holyhead's assumed dredge disposal activities. The port's licensed activity is for an annual disposal of 99,000 tonnes (assumed to be <0.063mm diameter and thus represent fines). As a worst case it is therefore assumed that the Port would dispose to their licenced quantity (99,000 tonnes) and that this would occur within the same timeframe as the proposed Horizon sediment disposals. Assuming that each Port disposal would be 2,500 m^3 It has been assumed that 21 disposals would be required. As such, the simulations of the Port disposals commence at 0600 on 1 April 2011 and would then take place every four hours until 21 releases have taken place.

Disposal from the Port of Holyhead takes place close to the eastern margin of the Disposal Site; conversely the Horizon sediment disposal has been modelled based on each disposal event taking place approximately within the middle of the Disposal Site. Although distance between the disposal events from the two dredging operations would likely be much greater than 1km, this separation distance has been assumed for the modelling.

4.2 Model Application Scenarios for Sediment Disposal

The model scenarios are shown in Table 2. Simulation CPU times were nine days for the full disposal scenarios, running one at a time on an i7 8-core 8Gb HP workstation.

Table 2 – Model application scenarios for sediment disposal

Scenario ID	Description	Comments
Holy-TQ-Base	Full 35 day disposal time frame + 7 days, no disposal.	Baseline hydrodynamics.
Holy-TQ-Disposal-Once	Single 3,500m^3disposal + 11 days.	Disposal at High Water -4 on an intermediate tide moving away from neaps.
Holy-TQ-Disposal-WAVE	Single 3,500m^3disposal + 11 days. Waves ('High Typical') included.	Sensitivity run to test the effects of waves on sediment settling and bed processes. 'High Typical' is as per the Cooling Water Wave simulations, with H_s = 1.48m from 249.2° as measured approx. 1,500m north of Wylfa Head.
Holy-TQ-Disposal	Full 35-day disposal time frame + 7 days, 2 x 3,500m^3 disposals per day for 35 days.	Full disposal programme.
Holy-TQ-and-Port	Full 35-day disposal time frame + 7 days, 2 x 3,500m^3 disposals per day for 35 days. Plus 6 x 2,500m^3 disposals of fines-only per day for 3.5 days associated with maintenance dredging at Holyhead Port.	Fines release from Horizon dredge operations = 1,568m^3 per day. Fines release from Port dredge operations = 15,000m^3 per day.

Scenario ID	Description	Comments
Holy-TQ-No-Disposal-Mod	No disposal, + 11 days, local bathymetry reduced by 1m and bed roughness increased from Chezy 65 to Chezy 30 in a client-defined area to consider hydrodynamic effects of non-mobile rock disposal in a defined area.	Chezy 65 the calibrated value. Chezy 30 reflecting changes in roughness length associated with rock disposal.

4.3 Model Application Scenarios for Rock Disposal

A separate model simulation was used to understand and quantify the potential effects of the rock disposal on the existing coastal processes i.e. once the rocky material was deposited on the seabed what the potential changes would be on tidal regime and sediment transport regime.

As initially considered by Horizon and following advice by NRW (30 May 2017), careful consideration has been given to the potential changes on hydrodynamics and sediment transport resulting from the placement of rock.

Based on the capital dredge requirements for the disposal of excavated rock, and also consideration of the potential ecological effects from rock disposal, the following key assumptions have been made:

- All rock material would be micro-sited within the Disposal Site in an area (375,000m^2) approximately 200m from the eastern margin of the Disposal Site (see Figure 13).
- Disposal of rock material would potentially raise the seabed by 1m across the micro-sited disposal area.

At this location the model bathymetry indicates that depths range from 60 to 70m below MSL.

Following the above, modelling was carried out to assess the potential for changes to hydrodynamics and therefore any changes to sediment processes that the disposed rock would have on the seabed following the immediate completion of the disposal activities. This was achieved by reducing model depth locally by 1m, and locally increasing bed roughness to simulate the increased roughness length of the disposal area due to the presence of the rock.

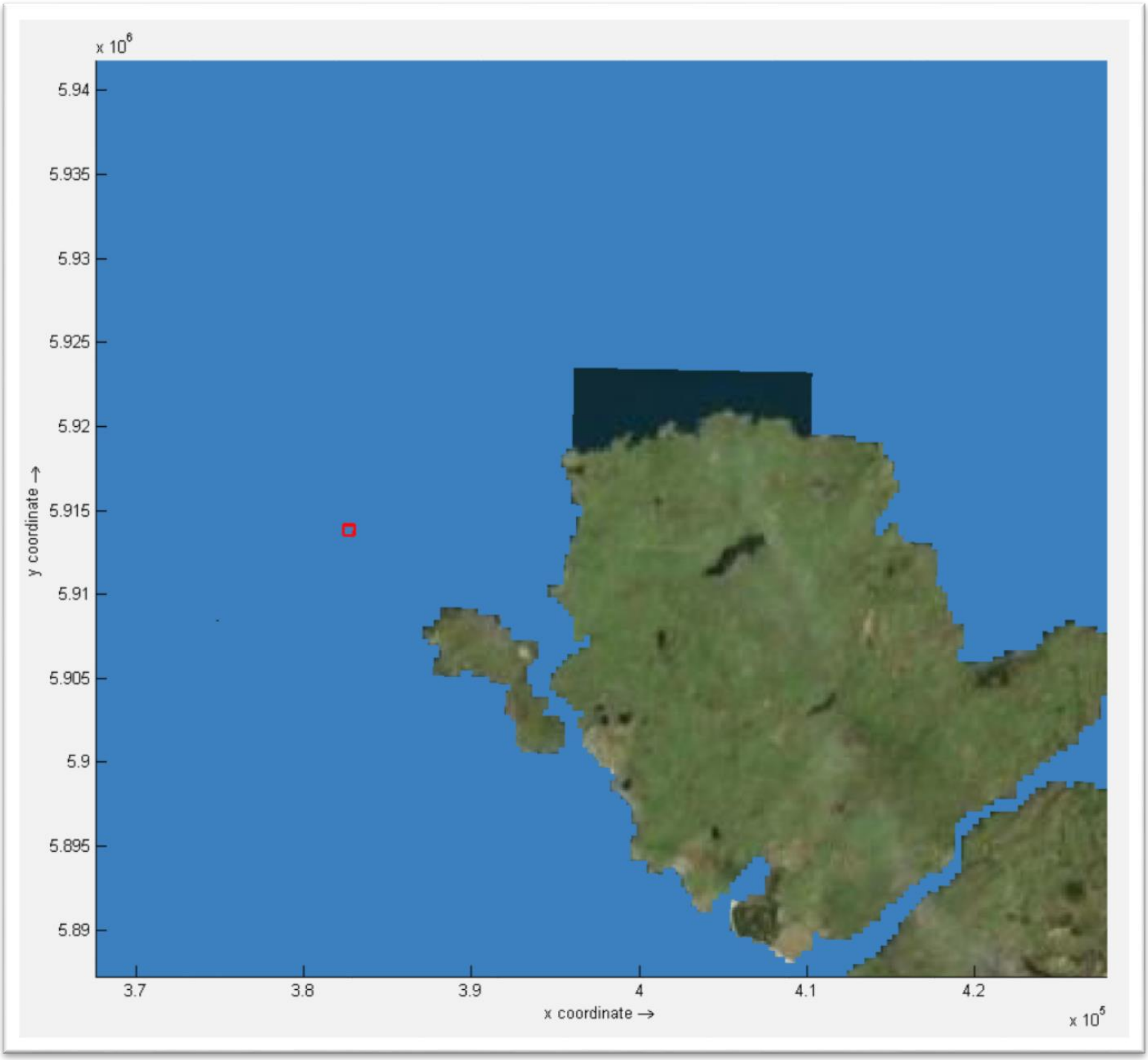


Figure 13 – Rock disposal area (red rectangle marked). The marked rectangle represents the area in which bathymetry and roughness were modified.

5. Modelling Results

5.1 Sediment disposal

Outputs from the sediment plume dispersion simulations are presented in this section. In all cases, no background suspended or bed sediment was included in the simulations, so in all cases the simulation output is effectively in addition to the background concentrations.

Data recorded from a water quality survey within and adjacent to the Disposal Site, during autumn 2017, indicated a typical background suspended sediment concentration of 5.5 x 10^{-3}kg m^{-3} (Jacobs, 2017, Application Reference Number: 6.4.83), with reported values ranging from <3 x 10^{-3}kg m^{-3} to 14.7 x 10^{-3}kg m^{-3}. This is reflected in the choice of scale on the suspended sediment plots throughout this report, extending from 1 x 10^{-3}kg m^{-3} to 10 x 10^{-3}kg m^{-3}.

5.1.1 Single Dredge Release

Fine sand fraction

Output from the Holy-TQ-Disposal-Once simulation is shown, for the fine sand fraction at one, two and three hours after disposal in Figure 14 to Figure 16.

Concentrations are shown for the fine sand fraction, with other sand fractions not being visible on the selected scale at two hours. Output is presented for the surface layer, where the highest concentrations were predicted to occur, with concentrations in lower layers not being visible on the selected scale at two hours.

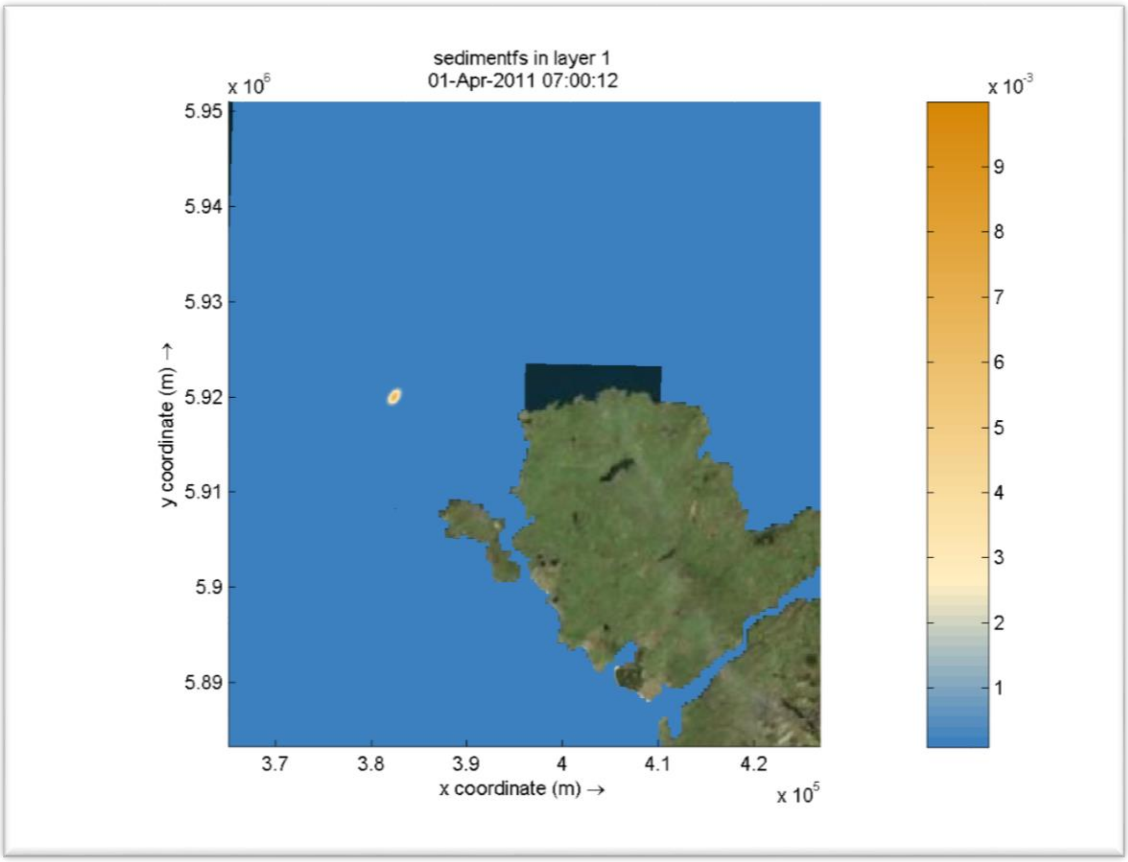


Figure 14 – Suspended sediment concentrations, kg m^{-3}, single disposal +1h, fine sand

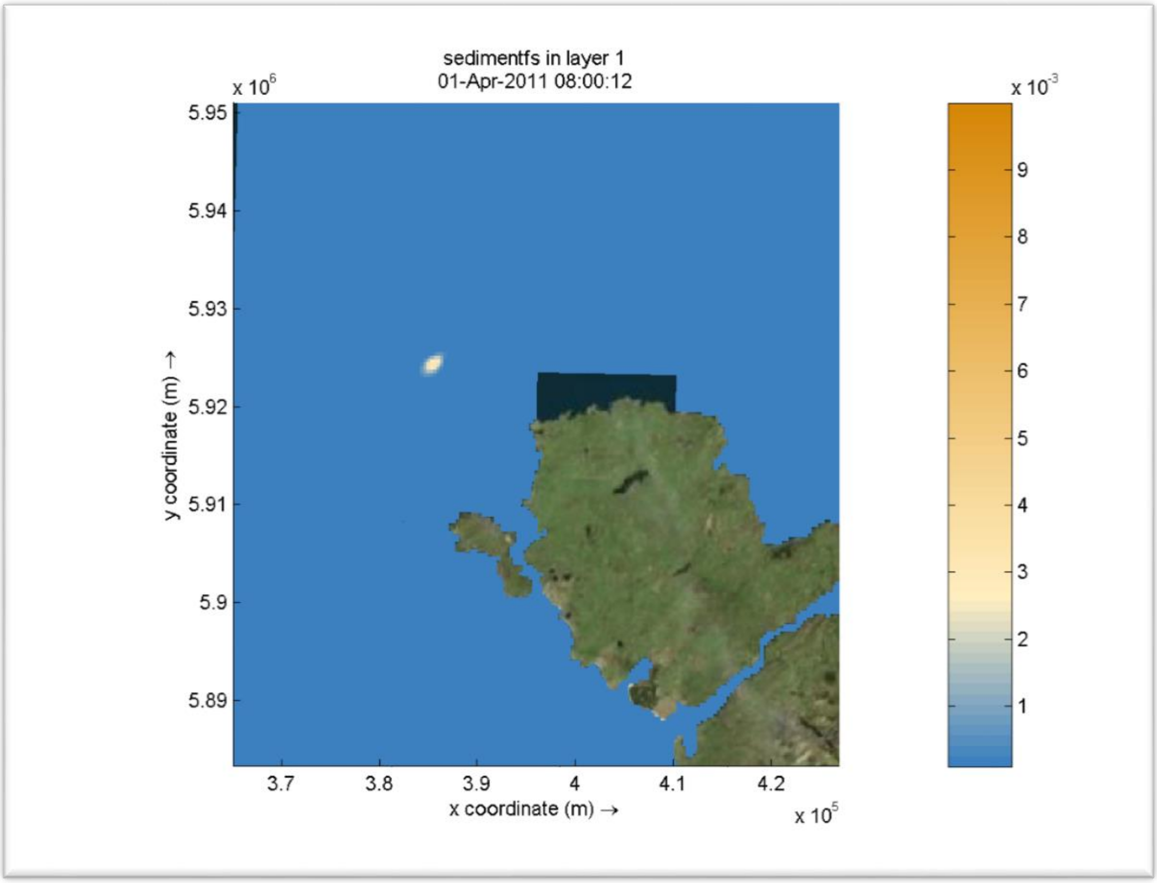


Figure 15 – Suspended sediment concentrations, kg m^{-3}, single disposal +2h, fine sand

From Figure 14, a small area (approximately 1,500m x 500m) is visible on the chosen scale, with only a small area (approximately 500m x 150m) predicted to have concentrations of disposed fines equal to or above typical background suspended sediment concentrations. As stated above, below the surface layer of the model (approximately 7m thick) concentrations are further reduced.

From Figure 15 and Figure 16 the disposal plume is seen to rapidly disperse to concentrations below typical background concentrations within three hours of release.

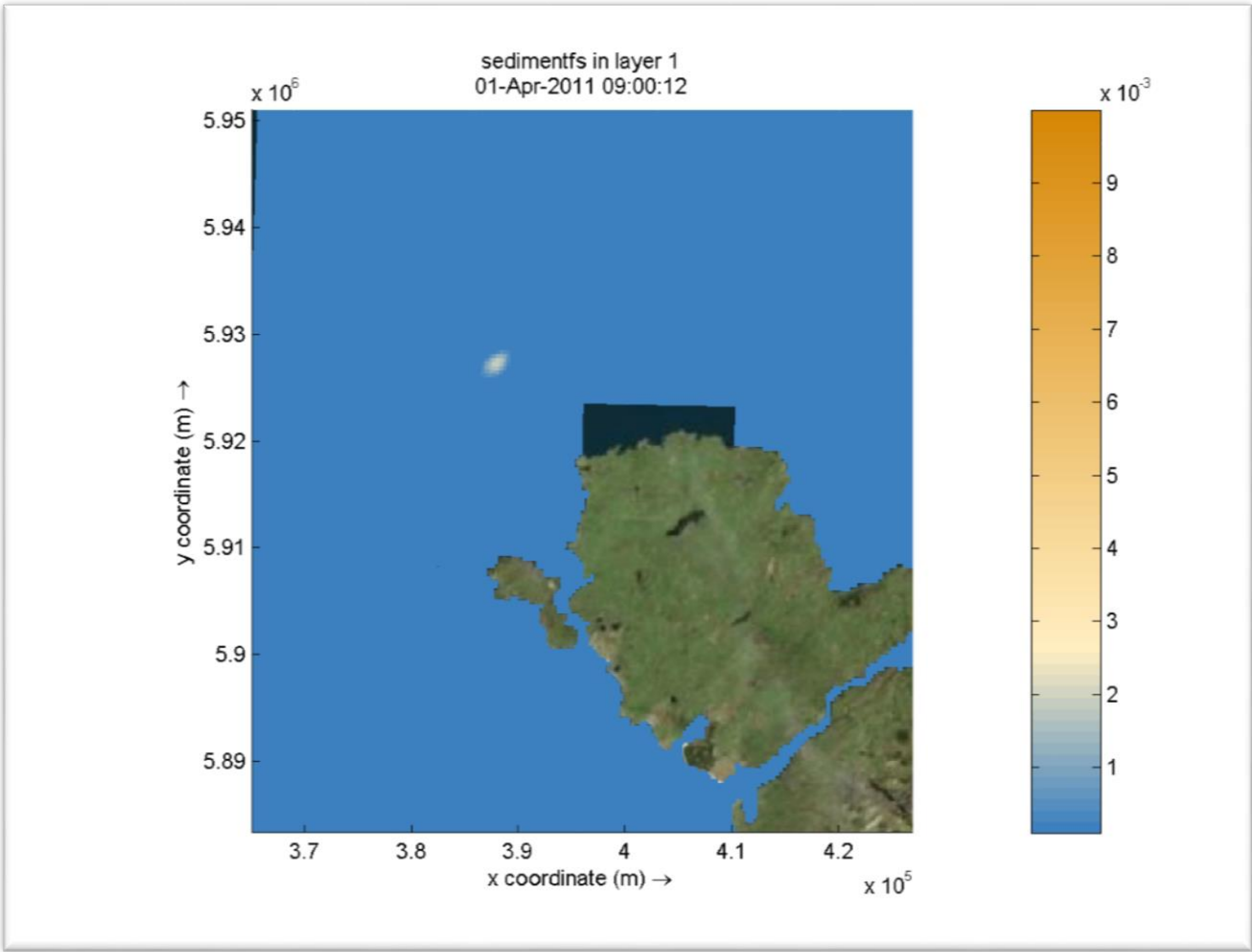


Figure 16 – Suspended sediment concentrations, kg m^{-3}, single disposal +3h, fine sand

Fines fraction

Output from the Holy-TQ-Disposal-Once simulation is shown for the fines fraction at one, two and three hours after disposal in Figure 17 to Figure 19. Output is presented for the surface layer only (10% of total water column), where the highest concentrations were predicted to occur.

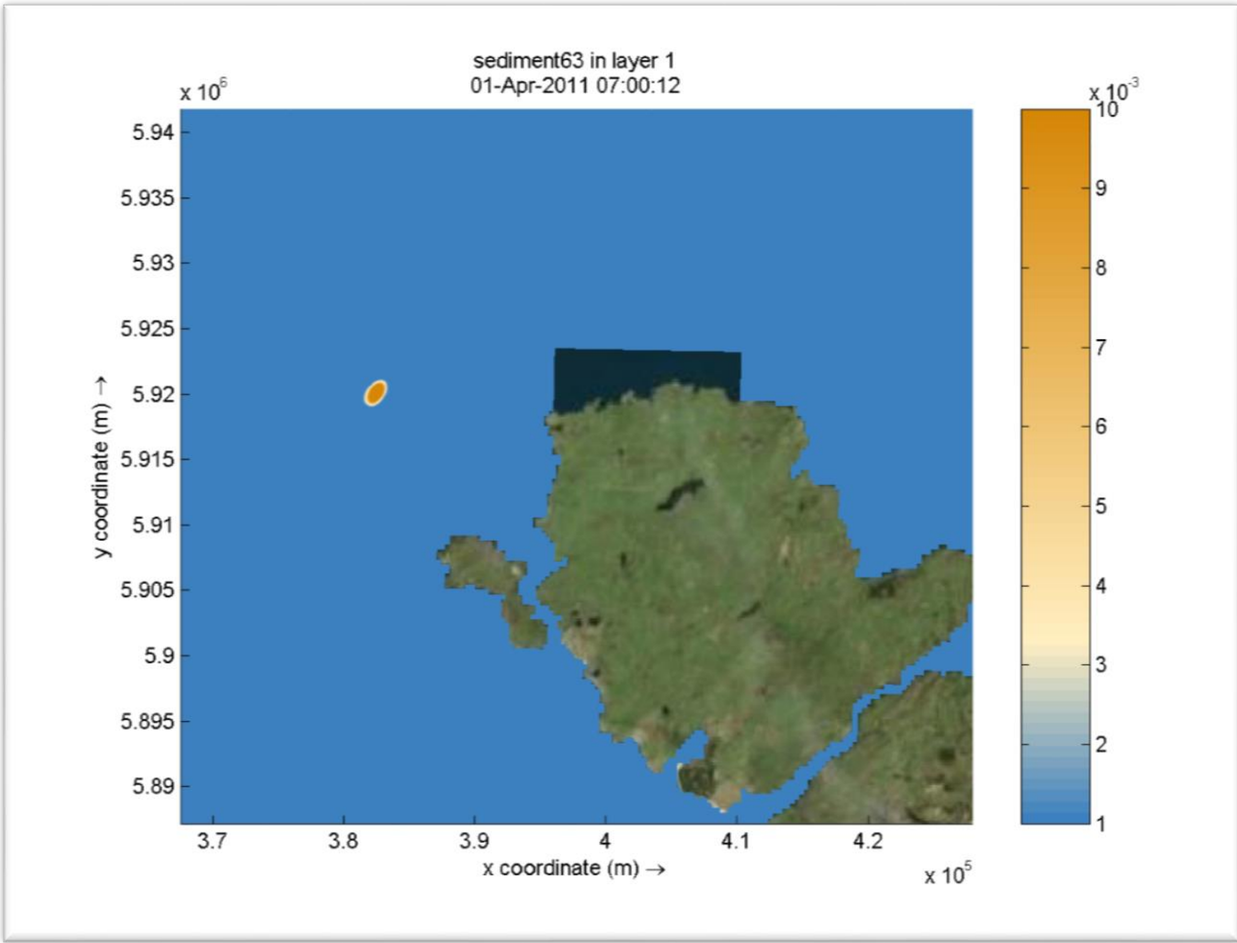


Figure 17 – Suspended sediment concentrations, kg m^{-3}, single disposal +1h, fines

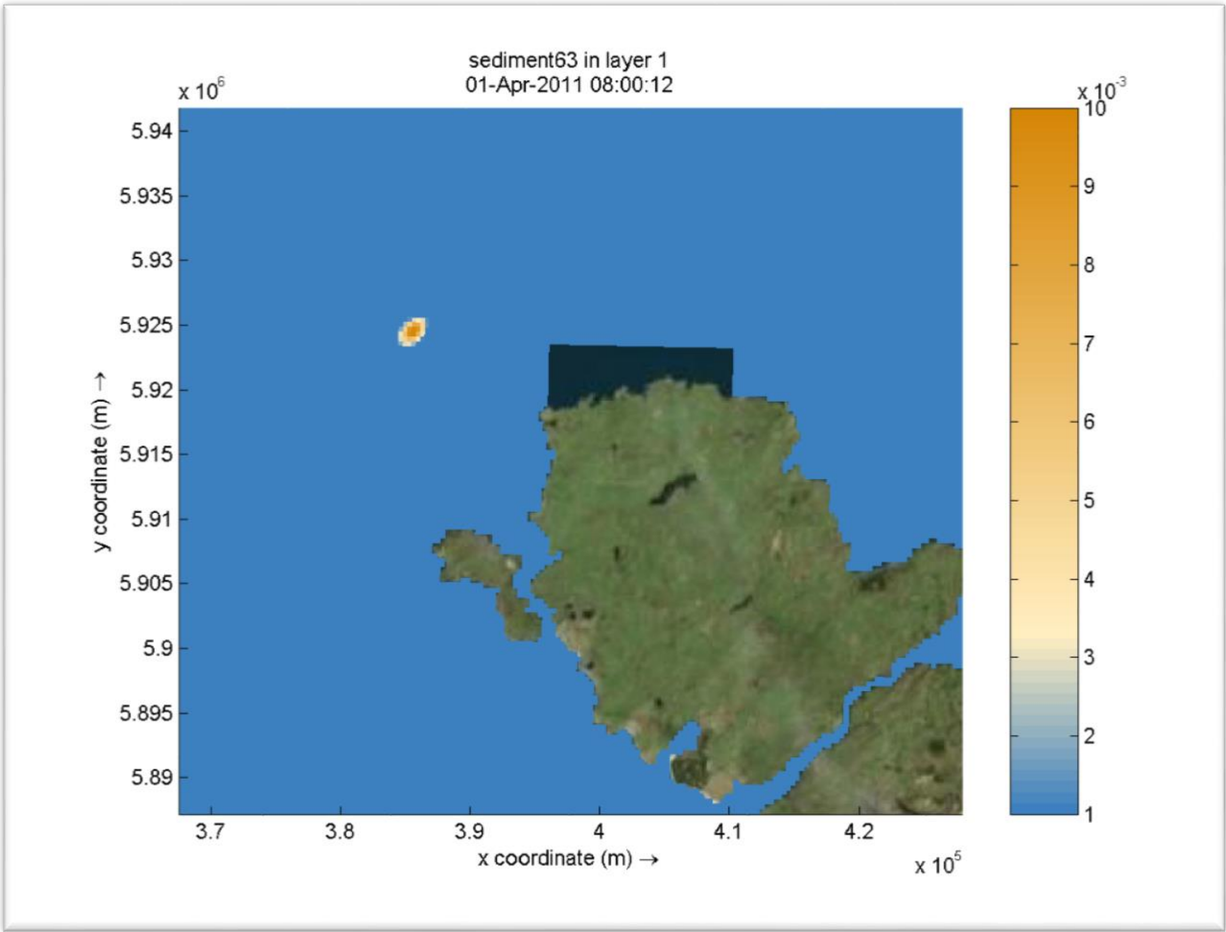


Figure 18 – Suspended sediment concentrations, kg m^{-3}, single disposal +2h, fines

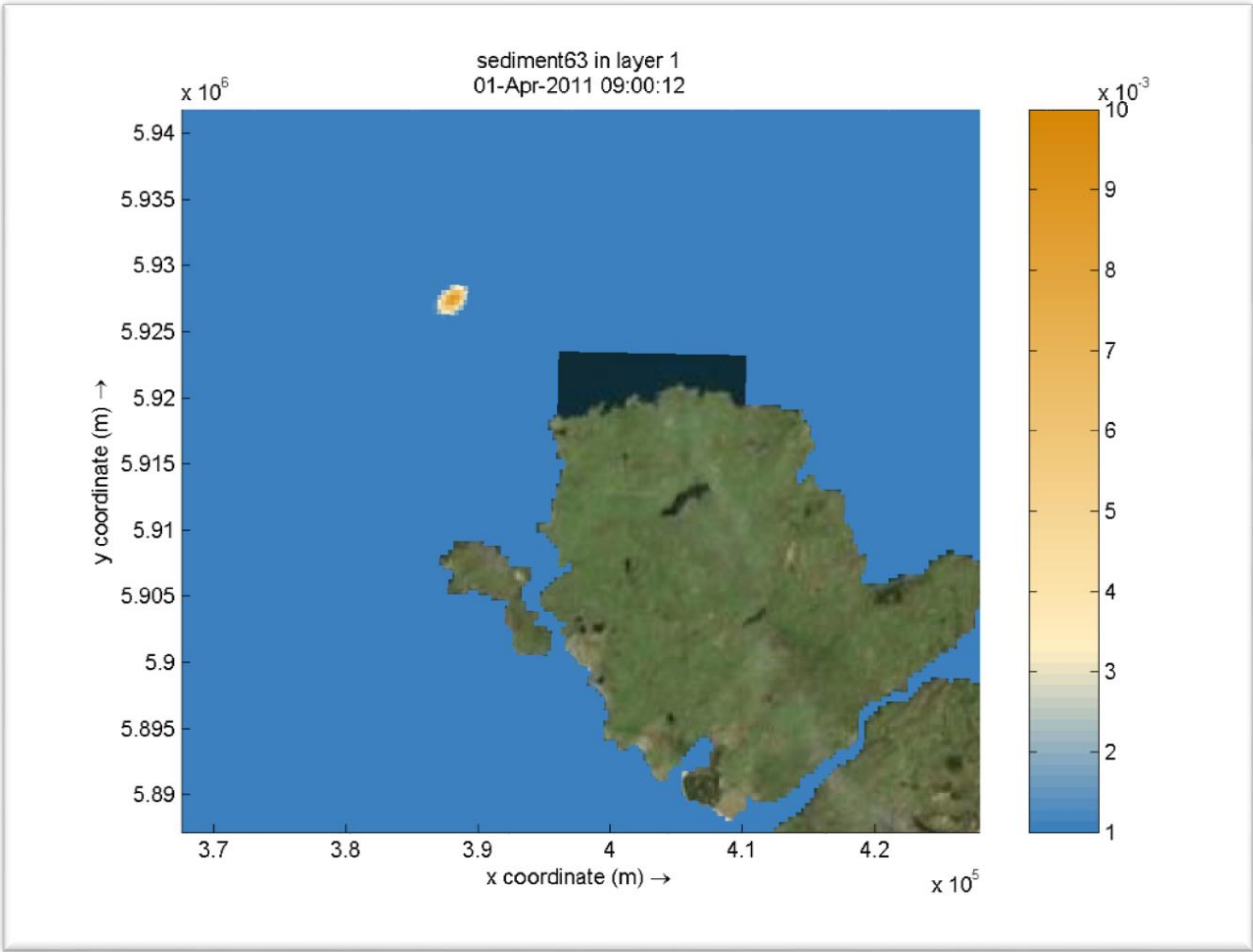


Figure 19 – Suspended sediment concentrations, kg m^{-3}, single disposal +3h, fines

From the above plots, it is apparent that suspended fines associated with a single disposal event rapidly disperse to concentrations in line with background suspended sediment concentrations after approximately three hours.

No accumulation (as a function of deposition and resuspension) of sand or fines on the bed as a result of this single disposal was reported by the model.

5.1.2 Single Release with Waves

Output from the Holy-TQ-Disposal-WAVES simulation is shown, for one and two hours after disposal in Figure 20 to Figure 21 respectively. These plots are directly comparable to Figure 14 and Figure 15 above.

Concentrations are shown for the fine sand fraction only, with all other sand fractions not being visible on the selected scale at two hours. Output is presented for the surface layer (10% of total depth), where the highest concentrations were predicted to occur, with concentrations in lower layers not being visible on the selected scale at two hours.

It is clear that the addition of waves has resulted in more rapid dispersion of the dredge material. It is therefore concluded that the ‘no waves’ simulations are more conservative in their predictions and that inclusion of waves, leading to complex statistical considerations (reflecting the joint probability of wave, dredge disposal and tidal conditions) and hence multiple simulations, is not required.

In relatively shallow water waves will influence the bed shear stress and hence potential for deposition and resuspension. However, the proposed disposal site is deep (range from 60 – 70m) and for realistic wave conditions the influence of waves on bed shear stress can be ignored. Wave conditions that might influence bed shear at the depths recorded at the Disposal Site would be far beyond the working limits for dredge disposal operations.

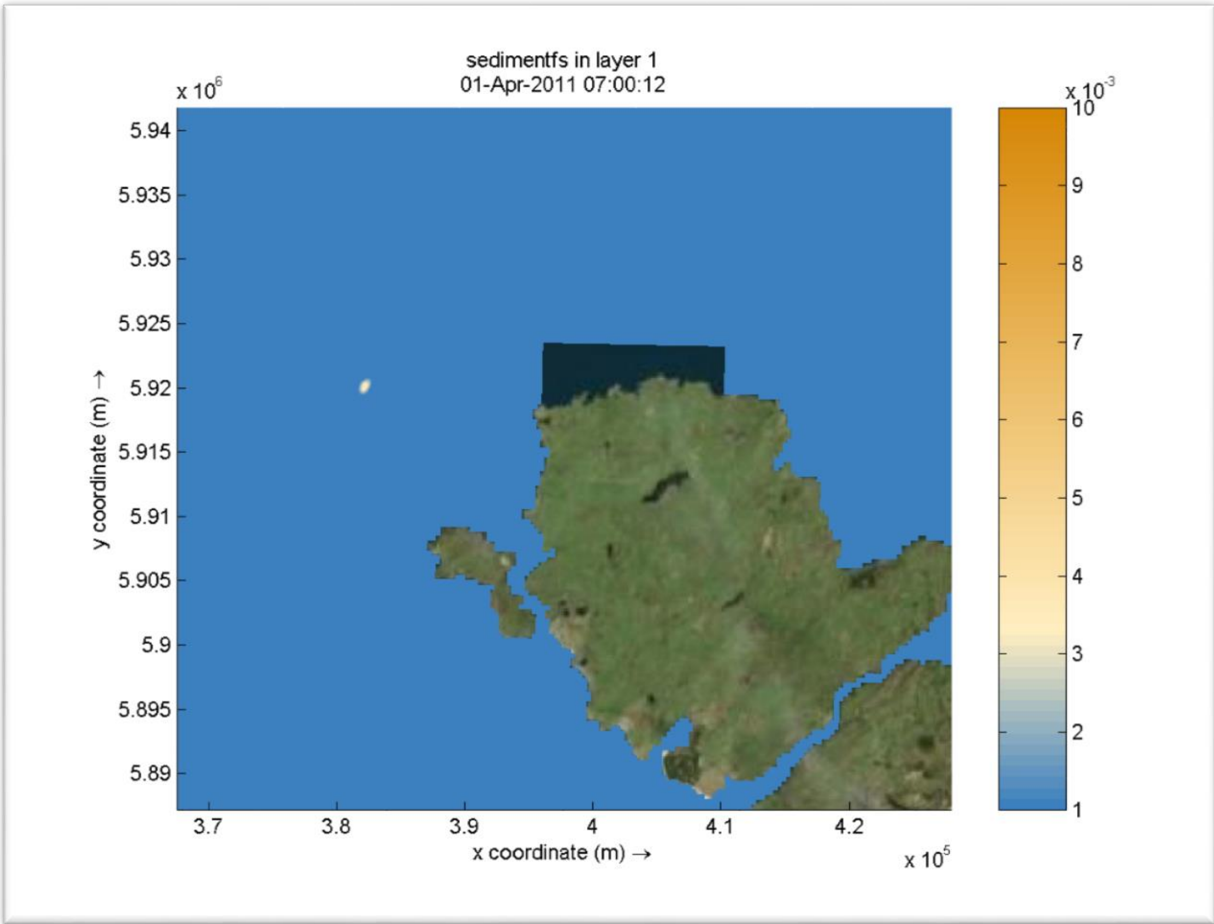


Figure 20 – Suspended sediment concentrations, kg m^{-3}, single disposal with waves +1h

From Figure 20, the sediment has rapidly dispersed to concentrations in line with background suspended sediment concentrations one hour after release.

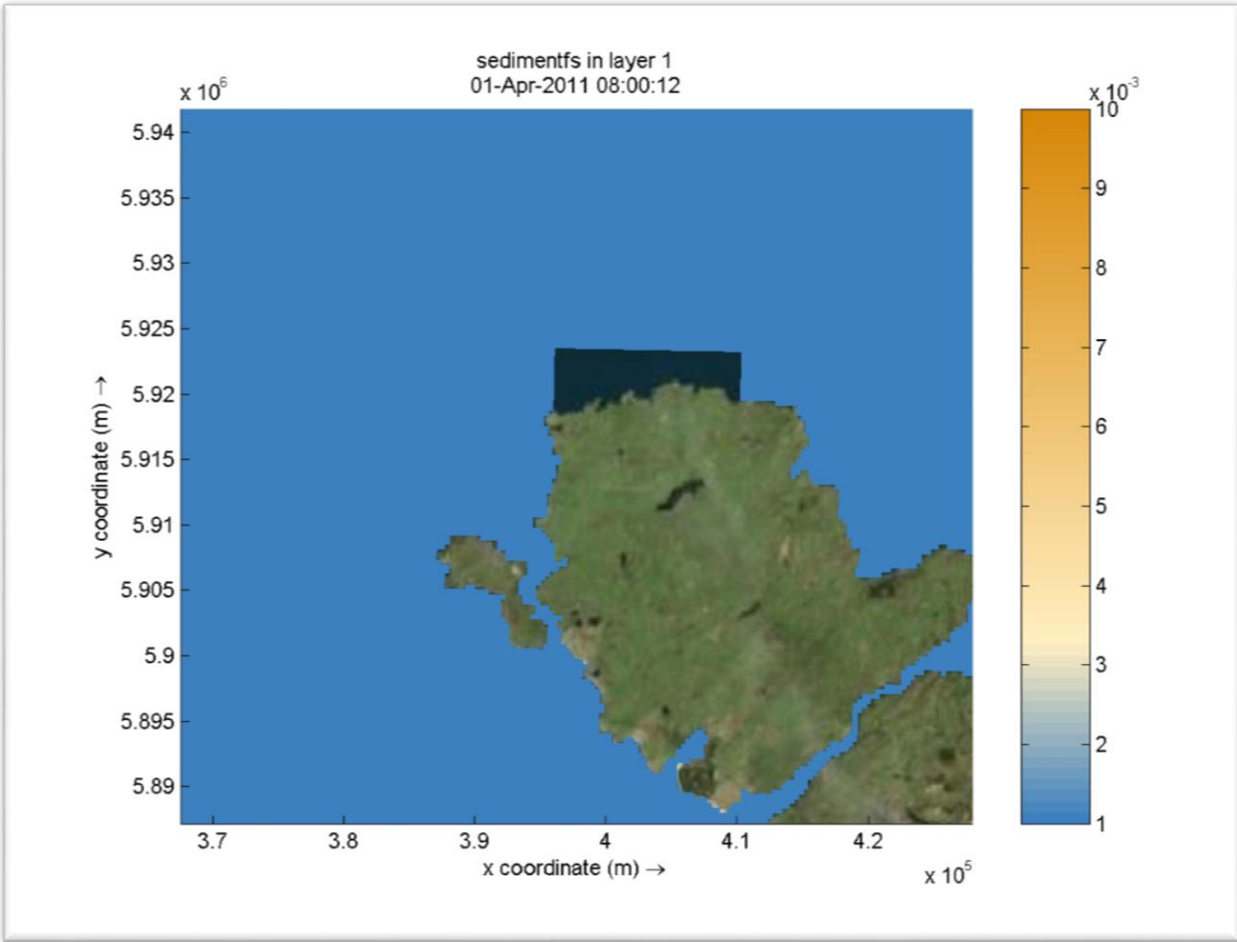


Figure 21 – Suspended sediment concentrations, kg m^{-3}, single disposal with waves +2h

From Figure 21, the sediment has rapidly dispersed to concentrations above background not visible on the selected scale within two hours of release.

No accumulation of sediment on the bed as a result of this single disposal was reported by the model.

5.1.3 Full Disposal Programme

Fine sand

Output from the Holy-TQ-Disposal simulation is shown, for fine sand one hour after the final disposal after 35 days, in Figure 22.

Concentrations are shown for the fine sand fraction, with all other sand fractions not being visible on the selected scale at two hours. Output is presented for the surface layer (10% of the water column), where the highest concentrations were predicted to occur, with above background concentrations in lower layers not being visible on the selected scale at two hours.

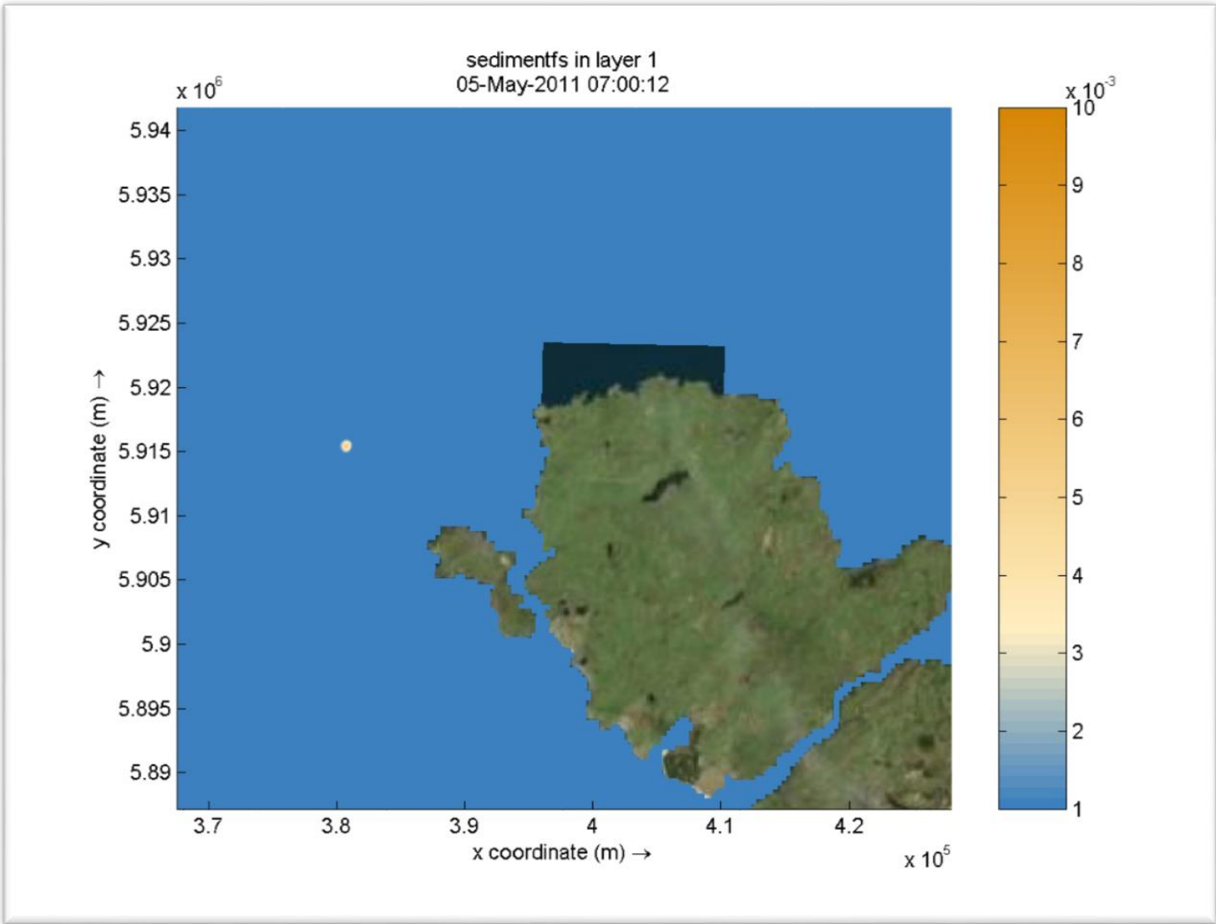


Figure 22 – Suspended sediment concentrations, kg m^{-3}, full programme final disposal +1h, fine sand

From the above figure, it is clear that there is no significant build-up of suspended sediment in the water column over the disposal programme. This is in accordance with the highly dispersive nature of the site.

Fines

Output from the Holy-TQ-Disposal simulation, for the fines fraction one hour after the final disposal after 35 days, is shown in Figure 23. Output is presented for the surface layer (10% of the water column), where the highest concentrations were predicted to occur.

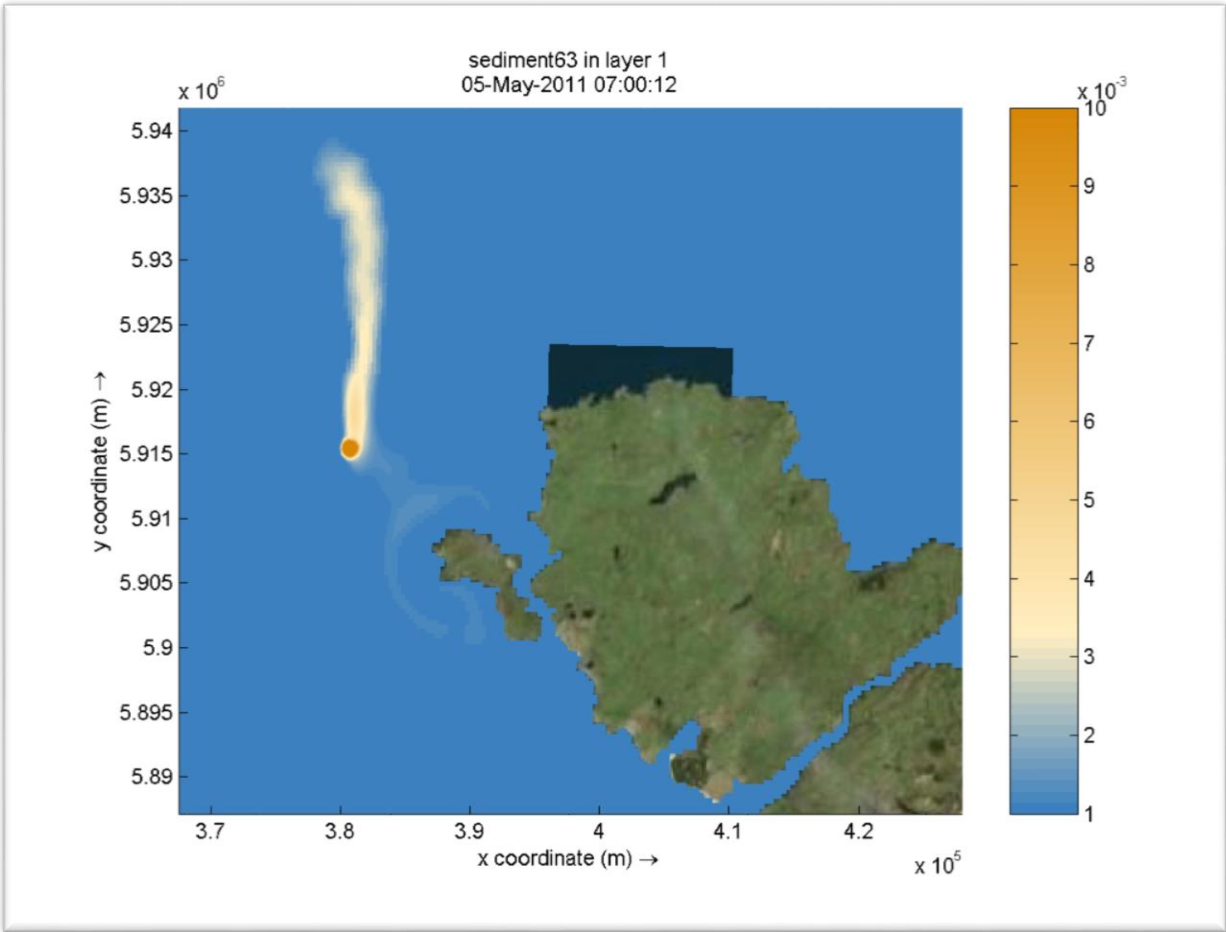


Figure 23 – Suspended sediment concentrations, kg m^{-3}, full programme final disposal +1h, fines

From the above plot, the footprint of the final release is apparent, as is a low level build-up of fines in the water column as a result of the overall disposal activity. This build-up is to levels which are lower than the typical background suspended sediment concentration.

A further output is presented in Figure 24, showing fines concentrations 48 hours after the final release. Suspended concentrations associated with the releases are shown to be well below background levels.

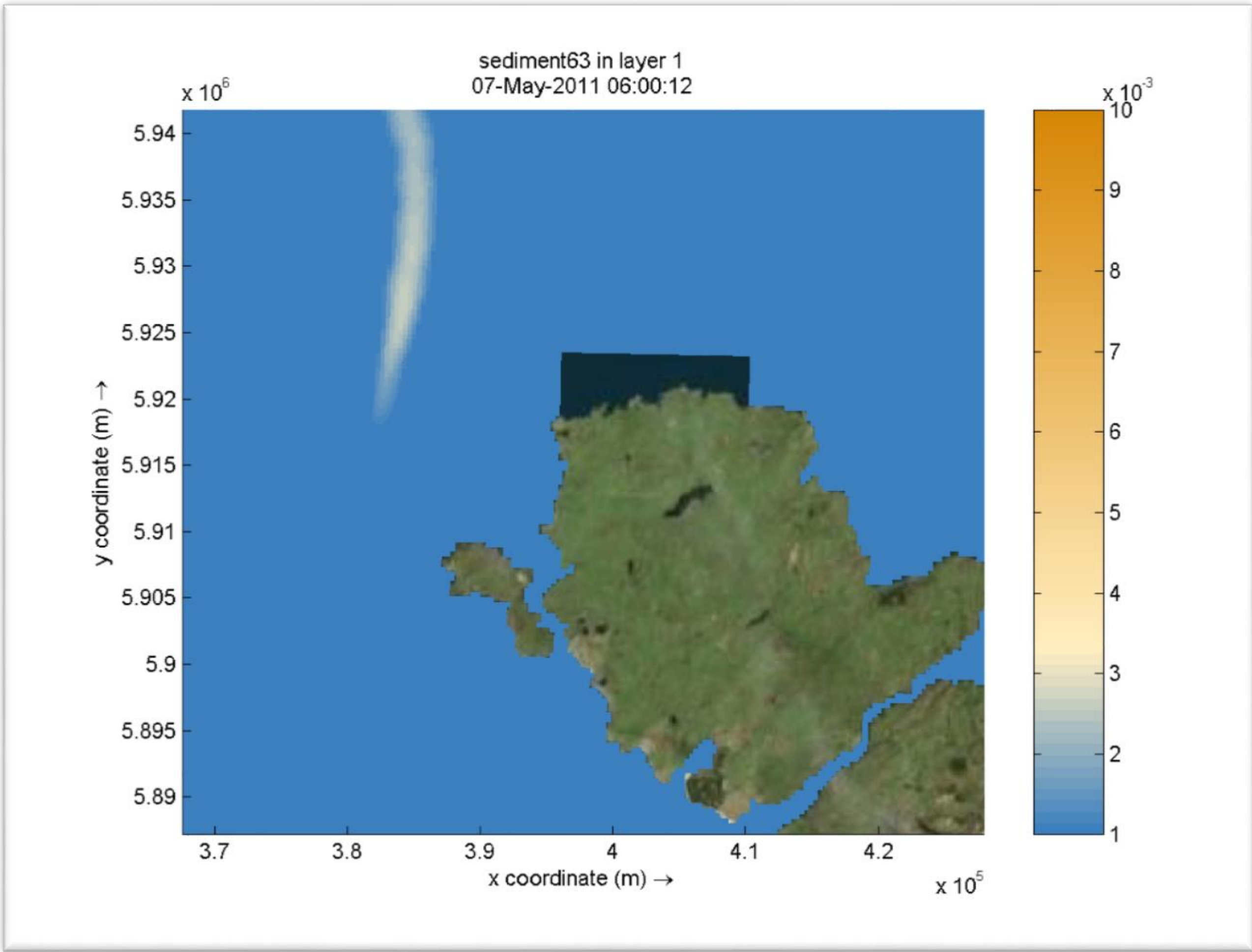


Figure 24 – Suspended sediment concentrations, kg m^{-3}, full programme final disposal +48h, fines

Total Suspended Sediment

Output from the Holy-TQ-Disposal simulation, for the coarse sand, medium sand, fine sand and fines fractions in summation, one hour after the final disposal after 35 days, is shown in Figure 25. Output is presented for the surface layer (10% of the water column), where the highest concentrations were predicted to occur. This plot is visually almost indistinguishable from the fines plot presented above (Figure 23), demonstrating the validity of presenting the fractions separately in this report.

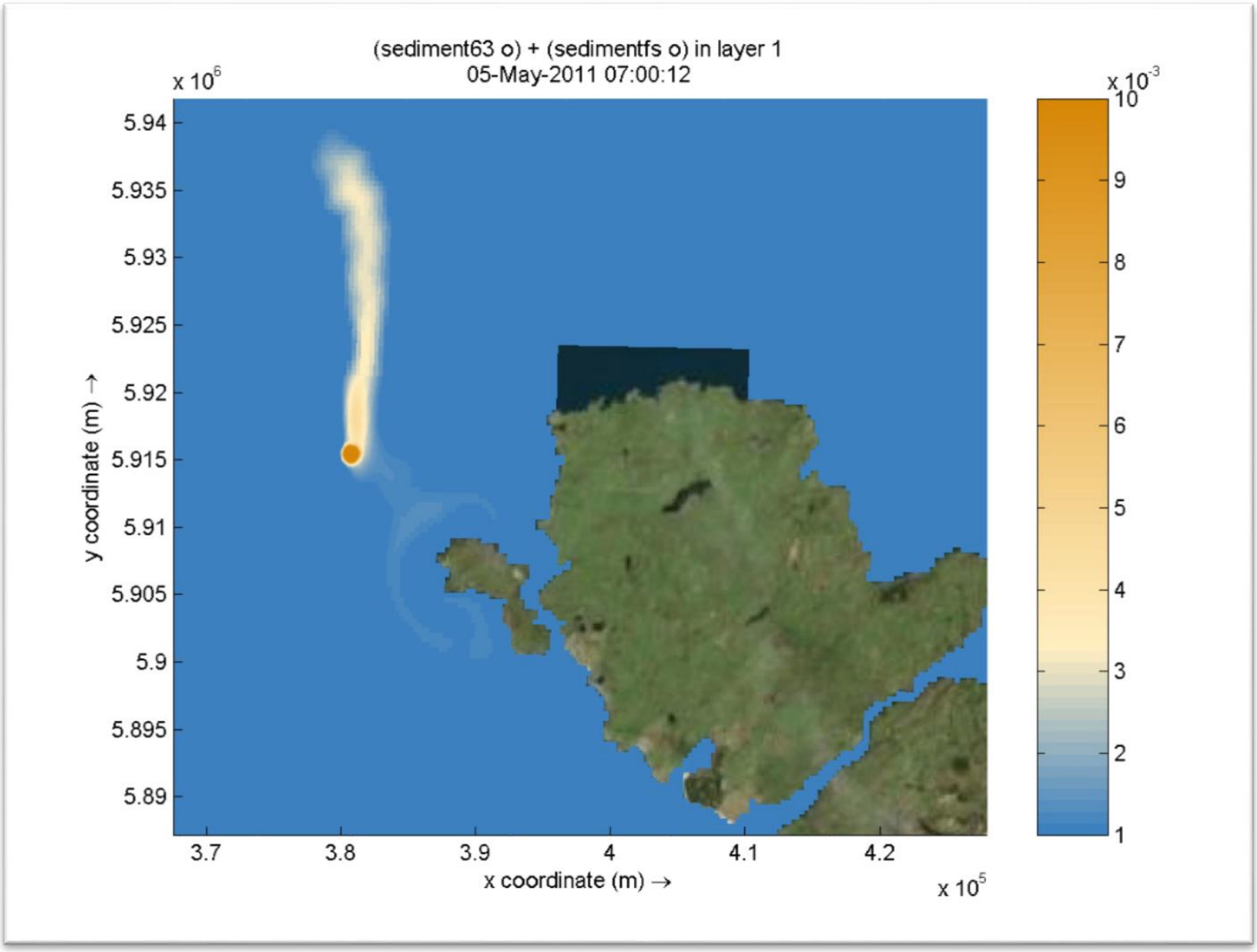


Figure 25 – Suspended sediment concentrations, kg m^{-3}, full programme final disposal +1h, all fractions

Bed Deposition

Sediment thickness on the bed at the end of the disposal programme is shown in Figure 26. The extent of the Disposal Site disposal area is shown on this figure, demonstrating no build-up of sediment on the bed outside of the disposal area. The x and y coordinates presented in model outputs are in metres $x10^5$ (x coordinate) and $x10^6$ (y coordinate).

This figure is 'zoomed in' for ease of reference in Figure 27. Note that the scale extends from 1cm to 50cm.

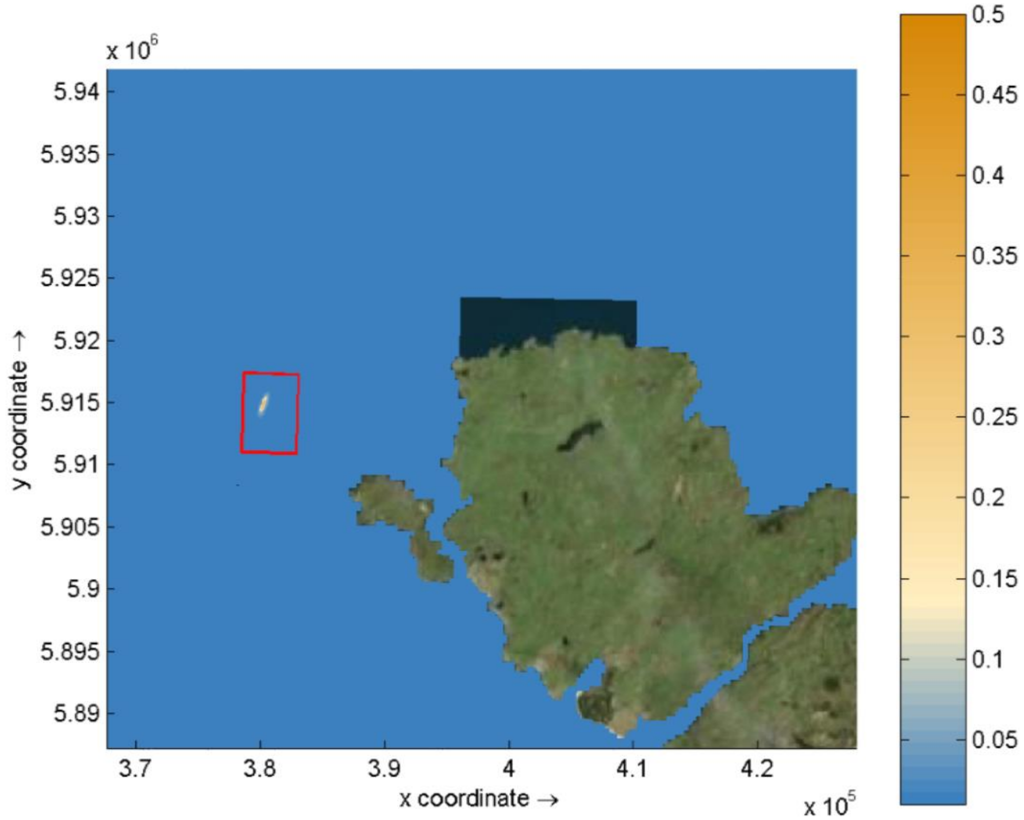


Figure 26 – Disposed sediment thickness on the bed, in metres, on completion of full disposal programme.

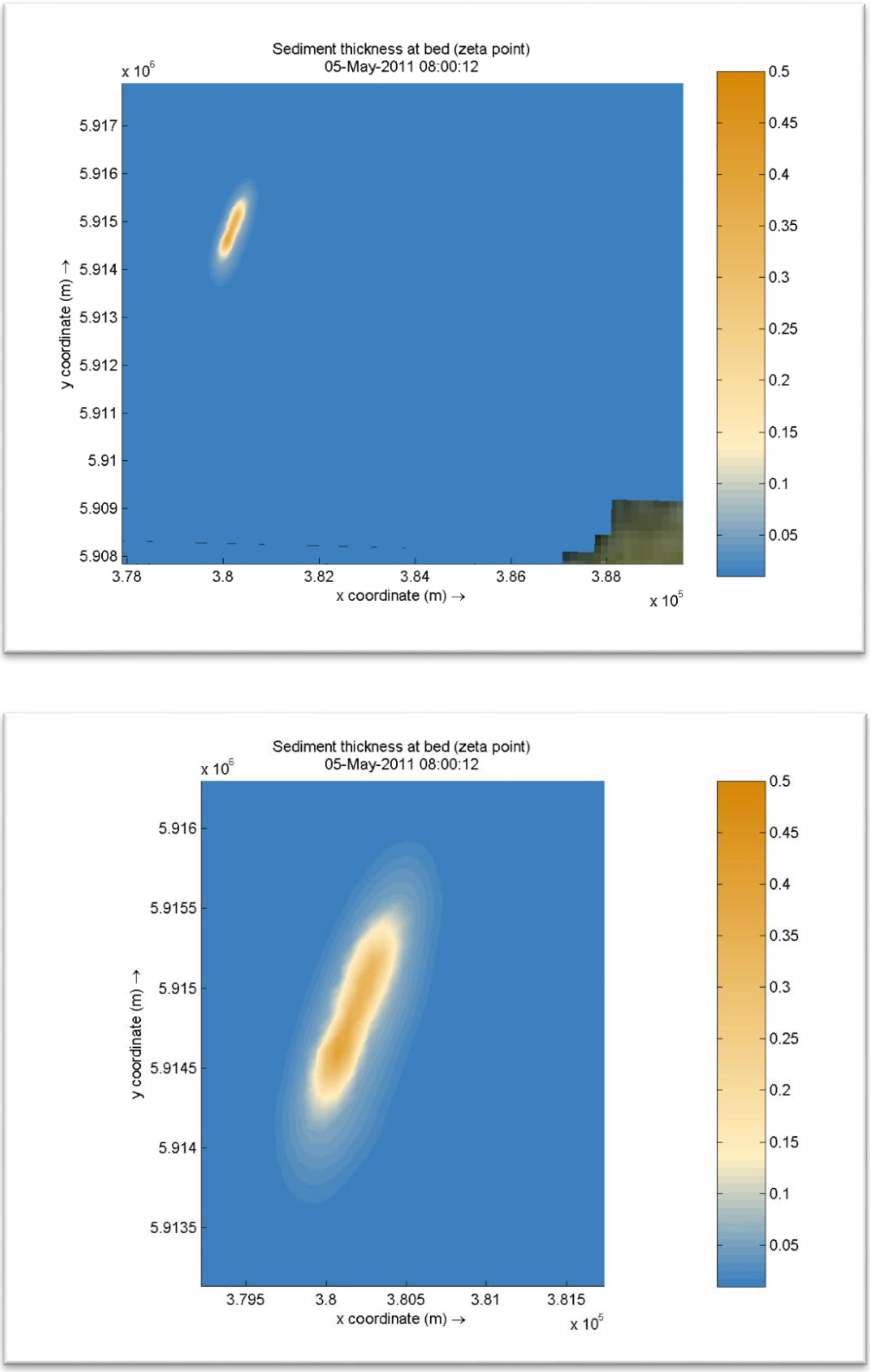


Figure 27 – Disposed sediment thickness on the bed, in metres, on completion of full disposal programme: zoom

The extents of the sediment deposited on the seabed are shown in Table 3.

Table 3 – Deposited sediment extents

Threshold	Major Axis Length	Minor Axis Length	Area
0.01m	2,800m	900m	1.8km^2
0.05m	1,600m	430m	0.5km^2
0.3m	690m	110m	0.07km^2

The development of sediment depth on the seabed, taken from the thickest point, is shown in Figure 28. The maximum sediment depth achieved is 0.43m, reported by the model in a single computational cell of area 70m x 70m.

It can be seen that at that point, a 5cm depth of sediment is reached after the fourth disposal event, although the height is rapidly reduced and is only sustained above 5cm after the fifth event.

While the graph indicates reworking of the sediment, with the depth not increasing for sustained periods, ultimately this reworking stops as the deposited sediment is sorted by the tidal action so that only the coarser sediments remain. The water level is also shown for reference.

Although the graph suggests that the depth of sediment on the seabed is maintained on completion of the disposal programme, this is a reflection of short-term tidal processes, rather than longer-term processes. In the longer term, bedload saltation (rolling, sliding, hopping) of the sediment particles would be expected to lead to their gradual dispersal to the wider environment at velocities much lower than those of the tidal flows.

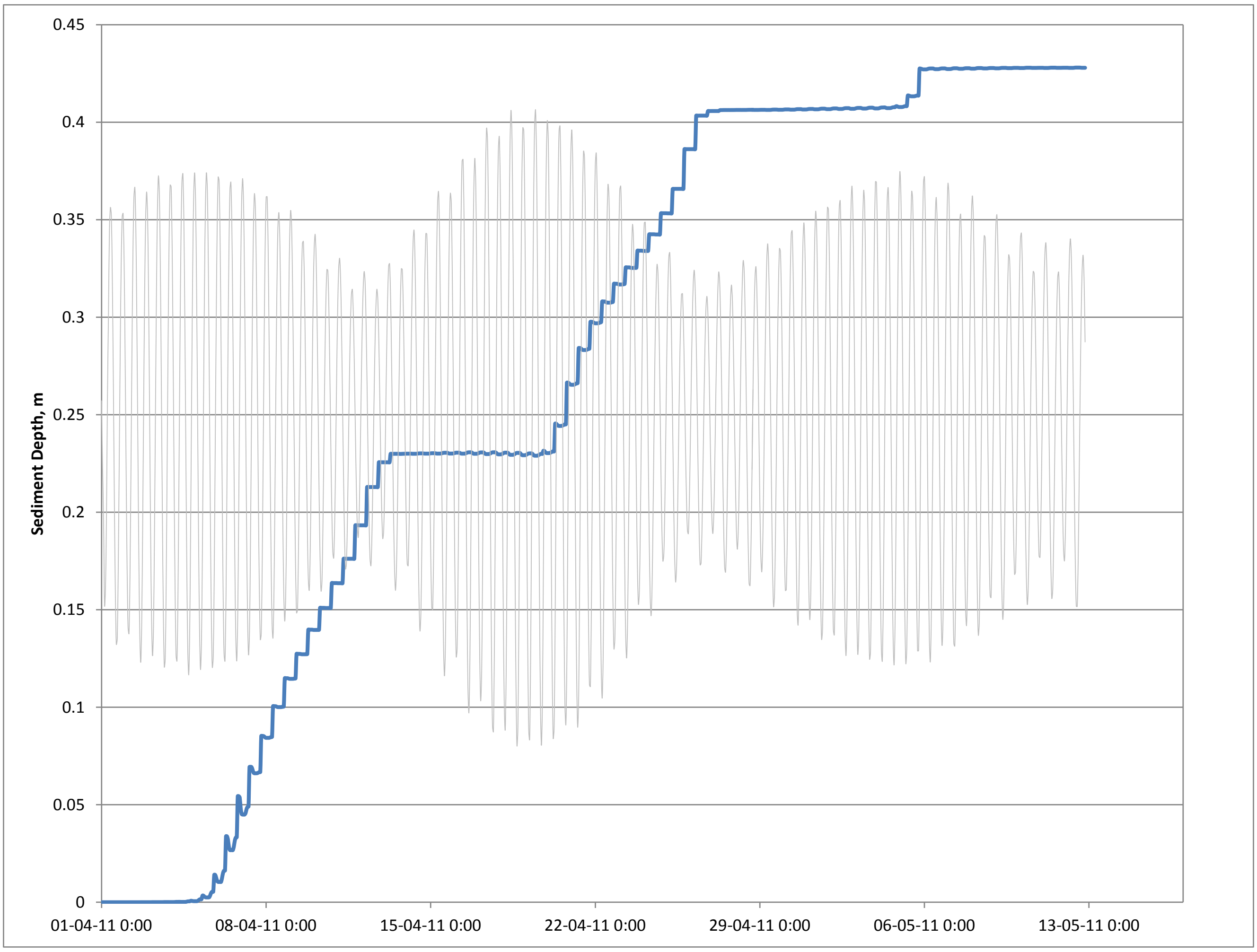
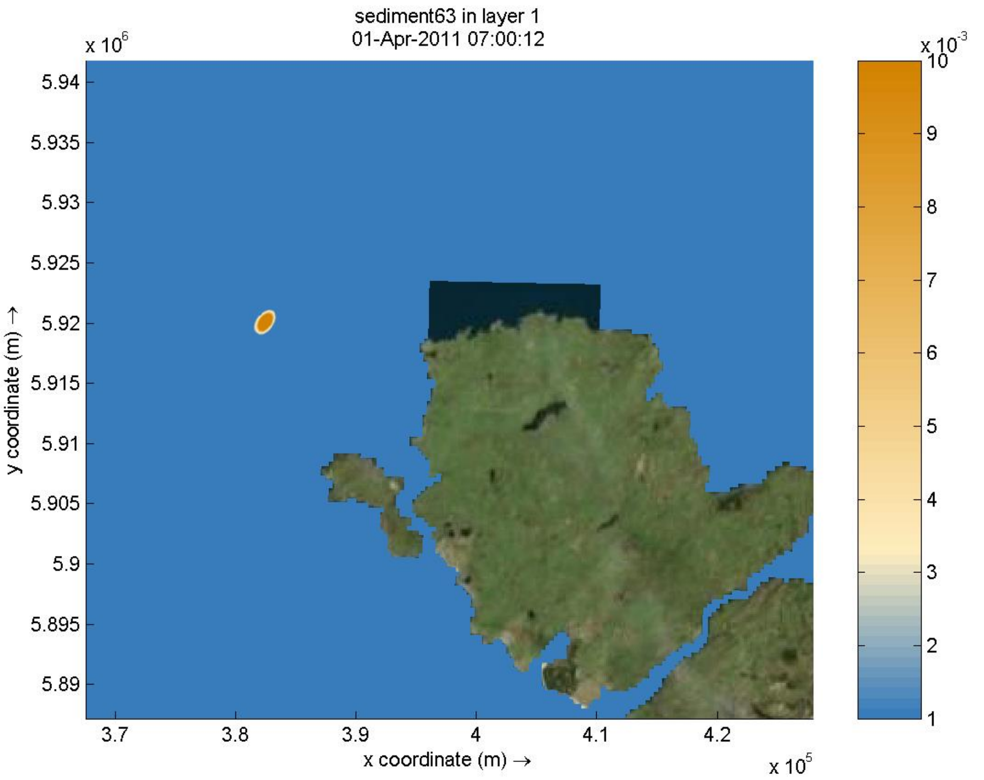


Figure 28 – Development of sediment on the bed, thickest point, m.

5.1.4 Full Disposal Programme + Holyhead Port Operations

Output from the Holy-TQ-and-Port simulation is shown, for one hour and two hours after the first, simultaneous disposals in Figure 29 and Figure 30 respectively. For comparison, the equivalent output from the Holy-TQ-Disposal simulation is also shown in each figure. Separation distance between disposal operations was set to 1km, considered to be a reasonable minimum value for vessel operations.

Concentrations are shown for the fines fraction, since the Holyhead Port disposal is understood to consist only of fines. Output is presented for the surface layer (10% of the water column), where the highest concentrations were predicted to occur.



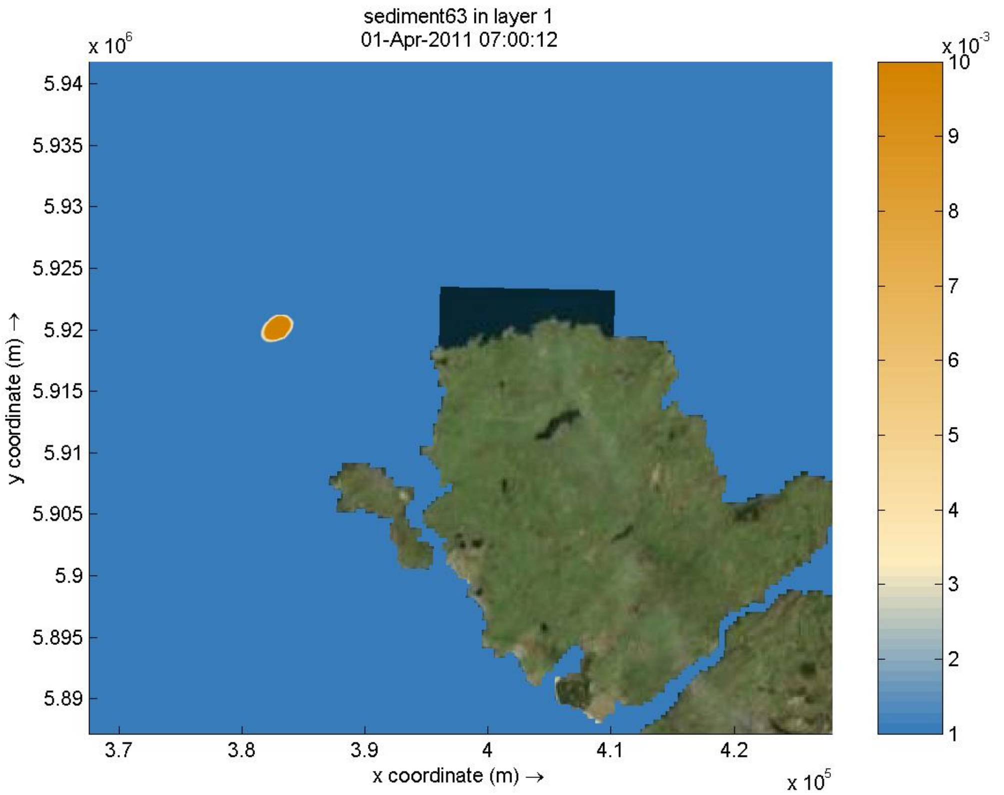


Figure 29 – Suspended sediment concentrations, kg m^{-3}, fines, Horizon only (top) Horizon & Port (bottom),first disposal +1h

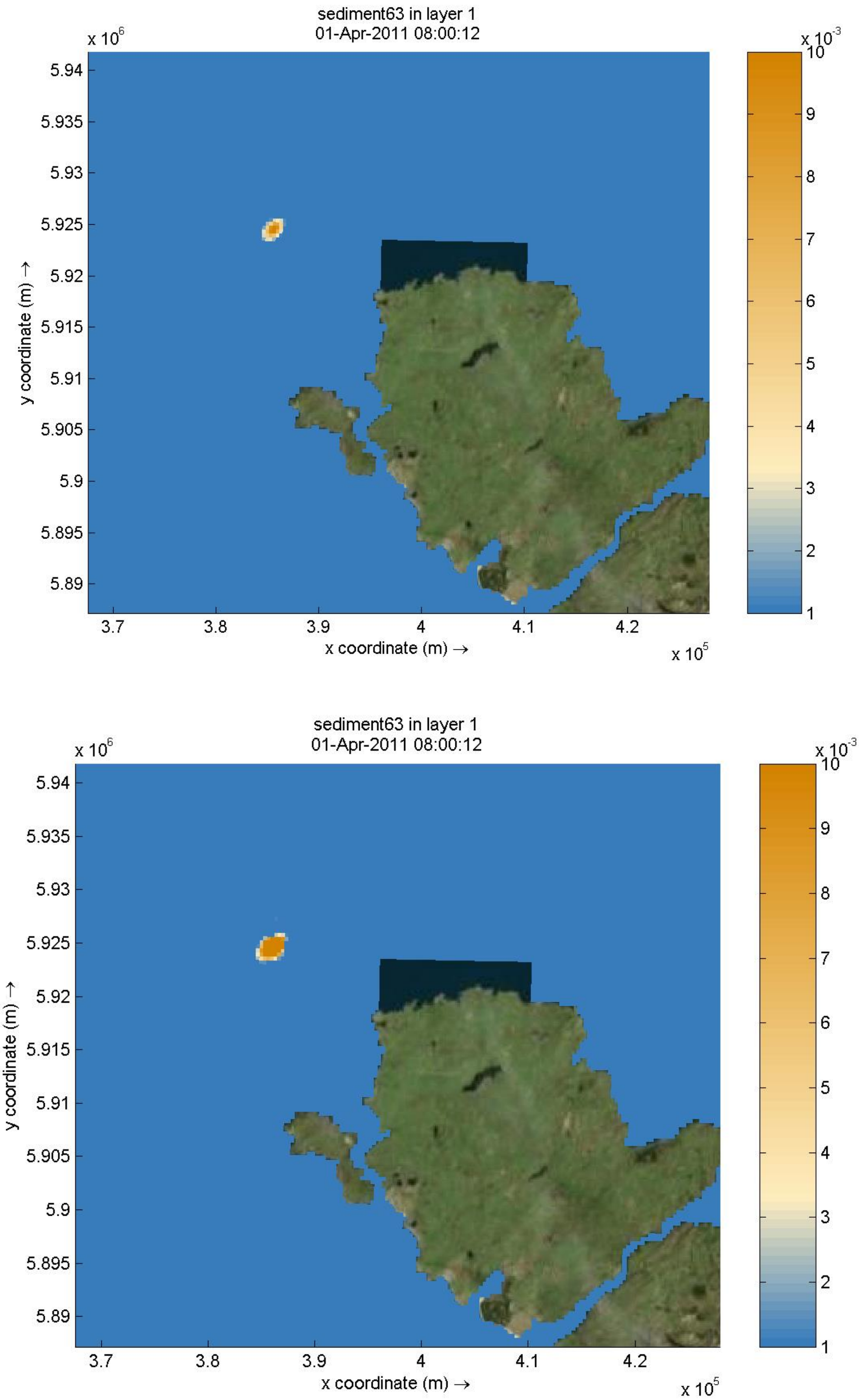


Figure 30 – Suspended sediment concentrations, kg m-3, fines, Horizon only (top) Horizon & Port (bottom), first disposal +2h

Output from the Holy-TQ-and-Port simulation is shown, for one hour after the final port disposal, in Figure 31. For comparison, the equivalent output from the Holy-TQ-Disposal simulation is also shown.

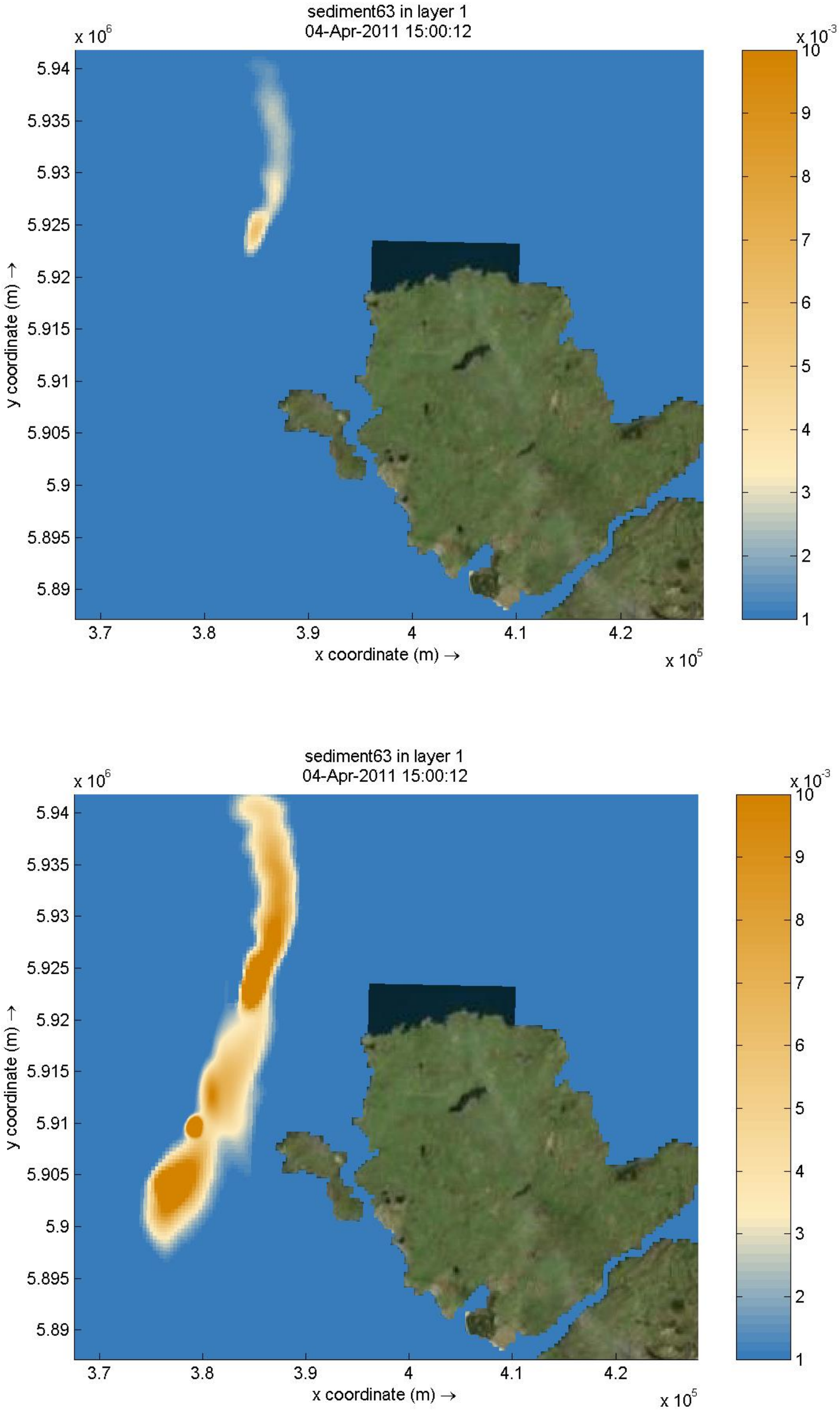


Figure 31 – Sediment concentrations, kg m^{-3}, fines, Horizon only (top) Horizon & Port (bottom), final Port disposal + 1h

As outlined above, the fines release from the Horizon dredge operations are 1,568m^3 per day, compared with the fines release from Holyhead Port operations of 15,000m^3 per day. The cumulative impact of this difference is apparent in the above plot, with the additional fines suspended in the water column as a result of the Horizon disposal not being of significance in the context of the much larger port releases. For further comparison, the port disposal only is shown below in Figure 32. This plot is visually indistinguishable from the 'Horizon & Port' plot presented above.

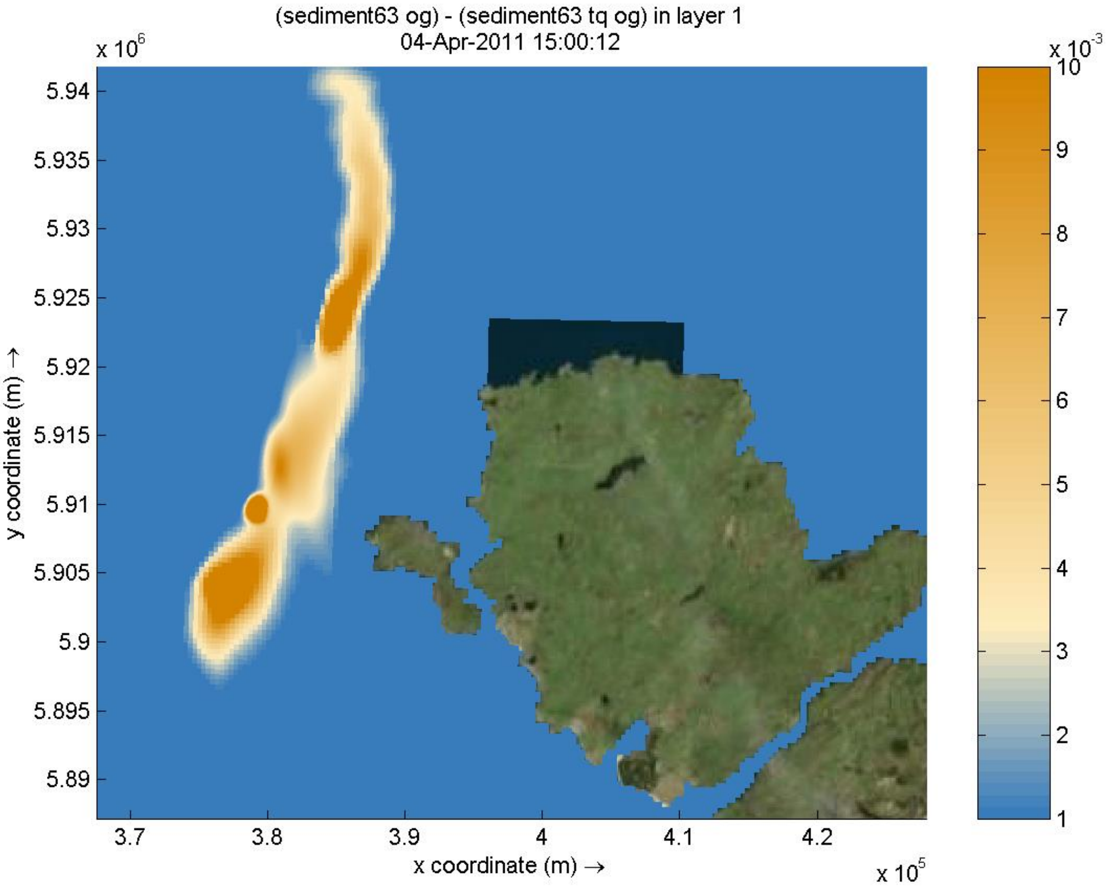


Figure 32 – Sediment concentrations, kg m^{-3}, fines, Port only

Note that while the area of increased suspended sediment concentrations associated with the port release appears large when compared with the Horizon disposal plots, they are nonetheless comparable to the typical background sediment concentrations.

5.2 Rock Disposal

Although consideration has been given to the potential effect that the addition of rocks could have on wave climate, it is considered that at the depth where rock disposal is proposed (60 – 70m bMSL), there would be no measurable effect on wave climate from the disposal, which would be 1m or less in height.

Note that the location considered for rock disposal is outside the predicted area of influence of the sediment releases considered above, and no interaction between the two would be anticipated. The rock disposal location is shown, in the context of the Disposal Site disposal area, in Figure 33.

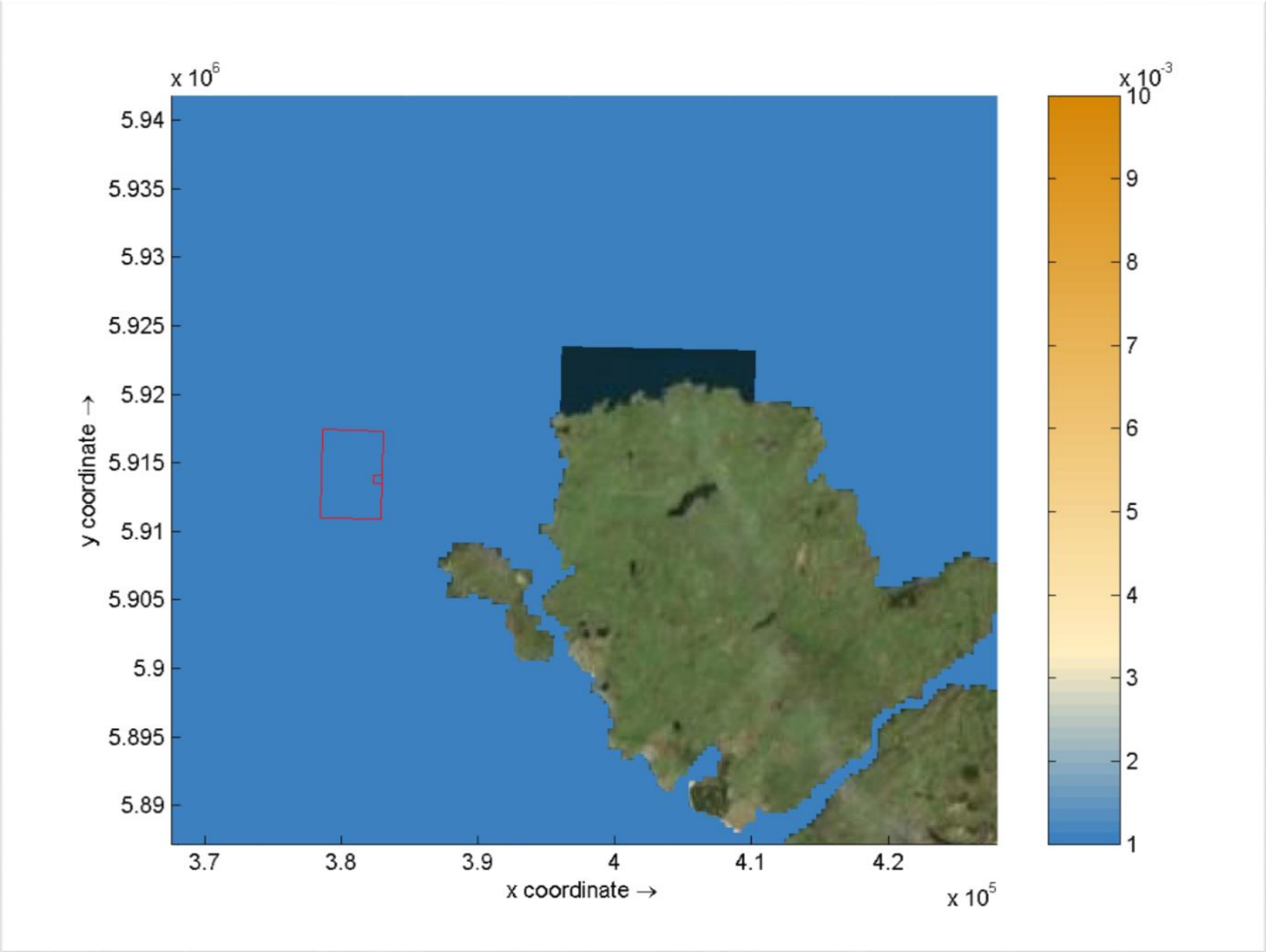


Figure 33 – Rock disposal site in the context of the Disposal Site area

5.2.1 Hydrodynamic Changes

Maps showing velocity changes around the defined rock disposal area are shown for hourly intervals over a spring tide, in Appendix A. All maps show the bottom 10% of the water column.

In all instances, velocity over the disposal area itself is reduced, as would be expected, although in themselves these are not of interest. There is evidence of a slight wake (approximately 25% reduction in speed) on the flood tide, although this is limited to the immediate lee of the disposal area, and recovers within 50m. On the ebb, a wake of approximately 15% velocity deficit is apparent over a larger area, recovering within 150m.

These small, relative changes are not considered to be significant in the context of existing bed processes in this area. The small changes observed from the modelling output represent highly localised effects that do not extend beyond 150m from the Disposal Site, and then only during a short window of the tidal cycle.

5.2.2 Sediment transport changes

Acknowledging the limited and highly localised changes to the tidal regime, in addition to the unbounded area around the disposed rock, any changes to sediment transport would be highly localised and not measurable beyond the immediate vicinity of the rock disposal site.

6. Conclusions

The Horizon hydrodynamic model has been modified to provide high resolution 3-dimensional coverage of the proposed Disposal Site.

The model has been locally validated against ADCP data, and has been shown to be accurately predicting current speed and direction both on a depth-averaged basis and at locations through the water column, demonstrating robust representation of the vertical velocity profile.

This validation is dependent on the model's bed roughness parameter being correct; the model's representation of bed shear stresses and associated parameters is therefore correct.

The model has been applied to consider the fate of dredge material from the Wylfa Newydd Project site.

Model applications show that the material rapidly disperses to levels in line with background concentrations.

The model also shows that there is a limited build-up of sediment on the seabed, both in terms of thickness and lateral extents, with an area of 0.5km^2 being covered by 5cm of sediment by the end of the disposal programme. While this sediment is predicted to remain in place in the short term, saltation is likely to lead to dispersal into the wider marine environment in the longer term.

A sensitivity test has shown that the inclusion of waves increases dispersion and reduces suspended sediment concentrations; exclusion of waves is therefore carried forward as a conservative approach.

Disposal of rock on the seabed has been shown to have a very limited effect on surrounding flow velocities; these are not considered to be significant in the context of bed processes at the Disposal Site.

7. References

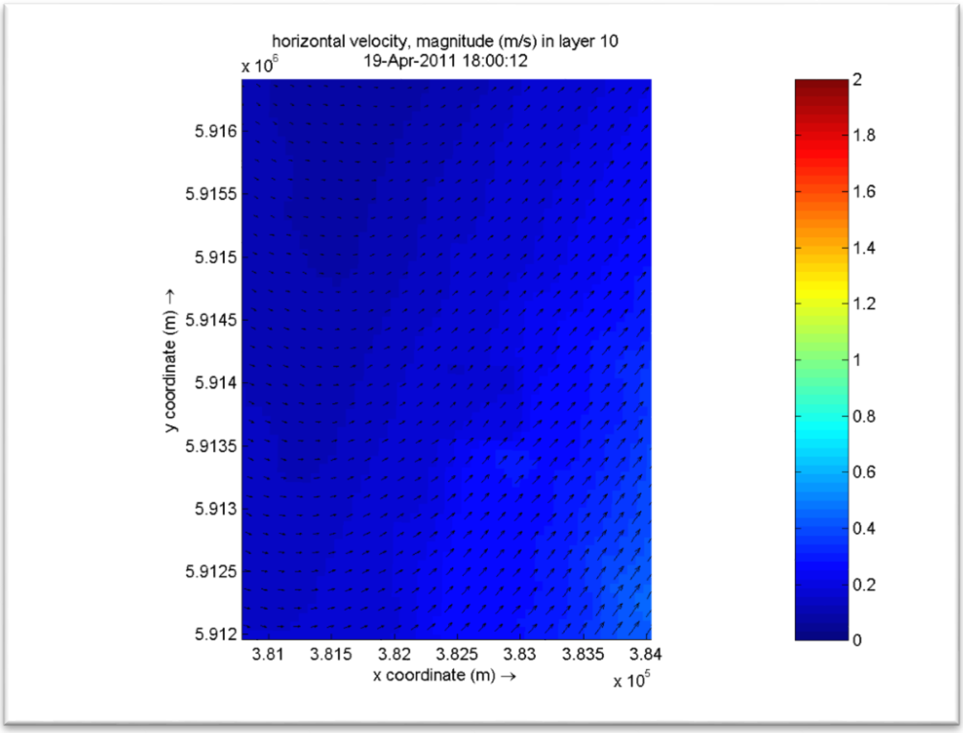
ABPmer 2016 – Audit of the Wylfa Hydrodynamic Model; ABPmer Report No. R2583P2

Jacobs (2017). Water Quality and Plankton Survey Report. Report no. 60PO8007/AQE/REP/004.

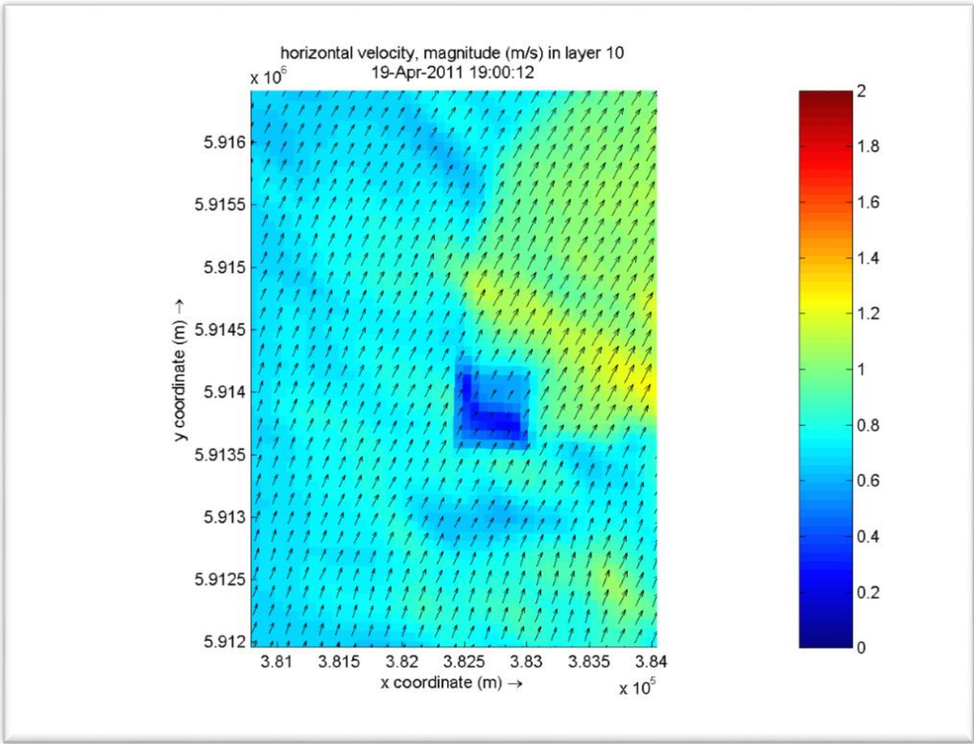
Horizon Nuclear Power 2016 - Wylfa Hydrodynamic & Water Quality Modelling; Phase 2 Model Build, Calibration & Validation; DCRM Ref Number: WYL-PD-PAC-REP-00015

.

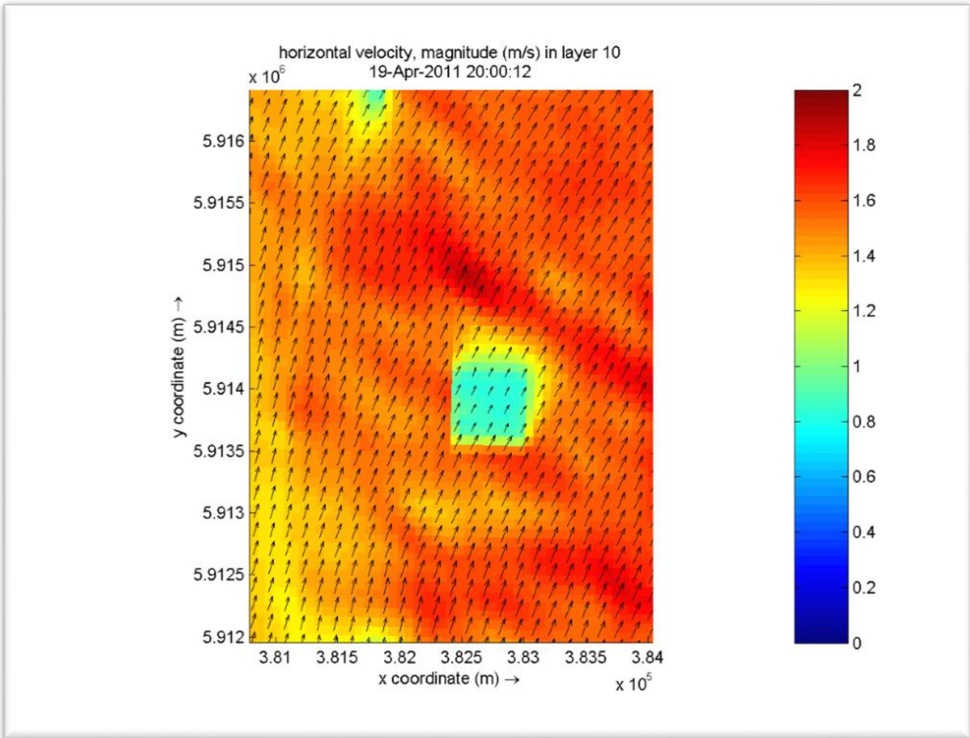
Appendix A. Hourly Near Bed Velocities, Rock Disposal Area



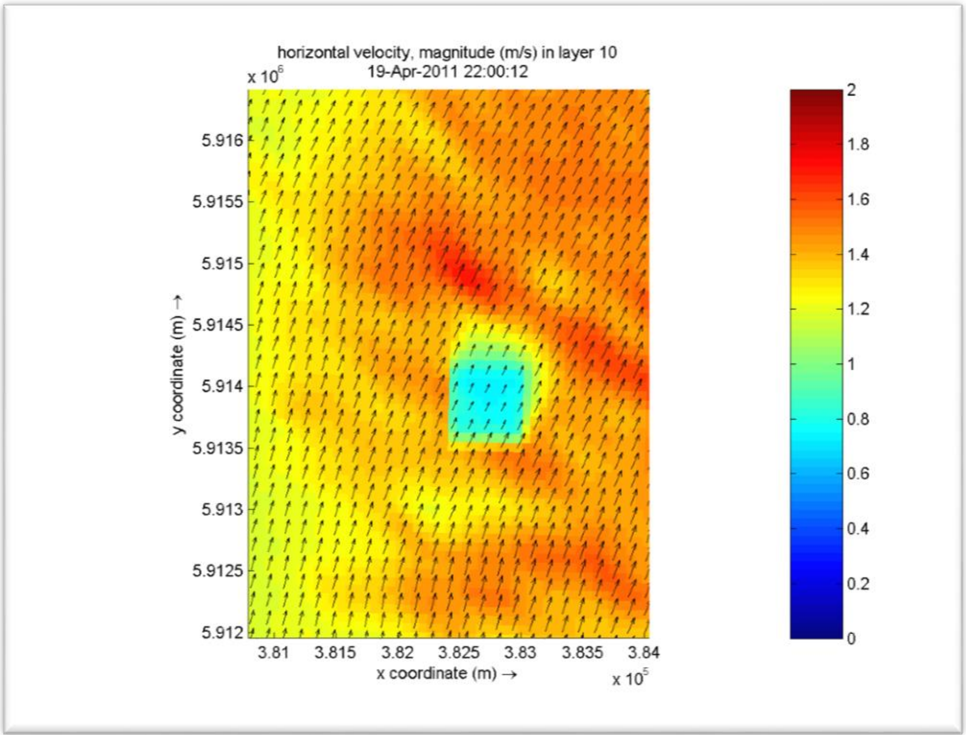
A1. Post-disposal near bed velocities. Commencement of Flood, m/s.



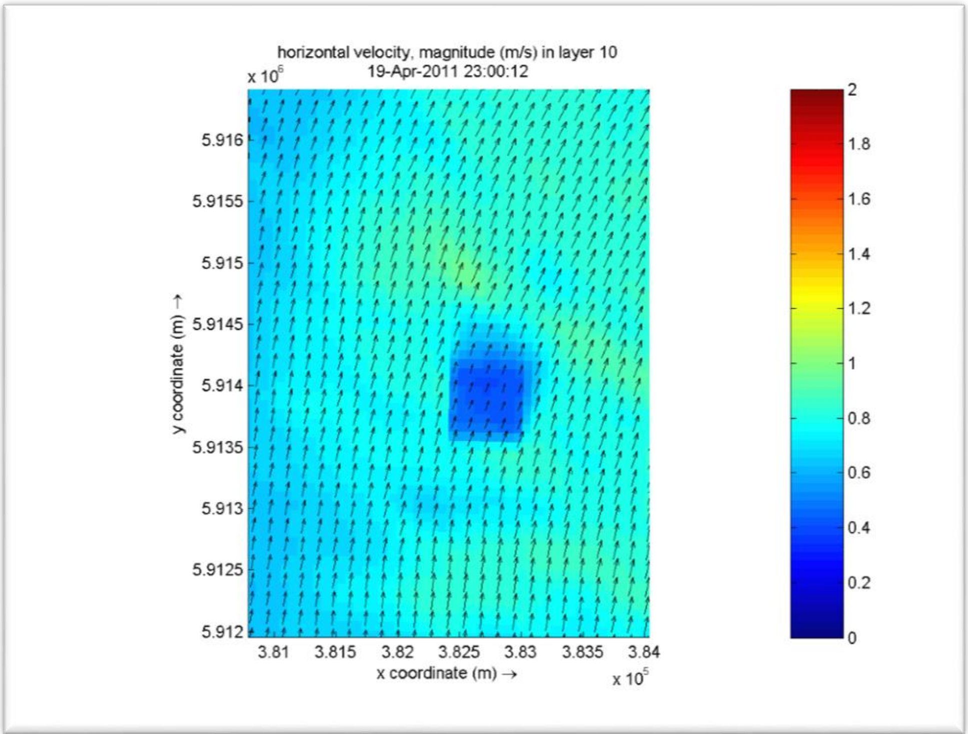
A2. Post-disposal near bed velocities. Commencement of Flood +1h, m/s.



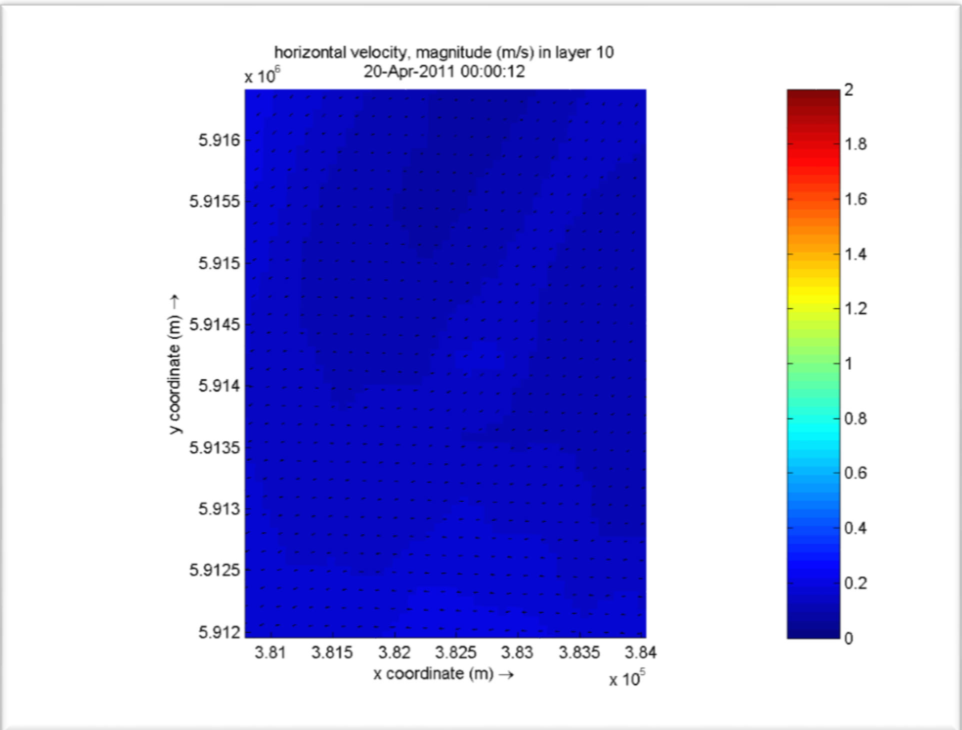
A3. Post-disposal near bed velocities and velocity changes. Commencement of Flood +3h, m/s.



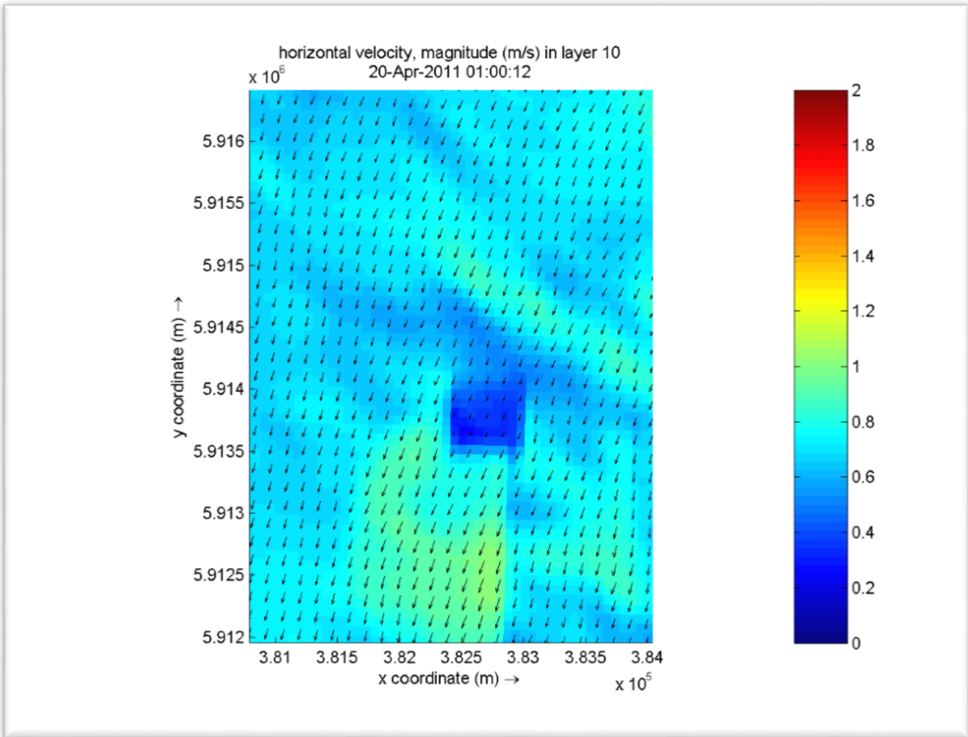
A4. Post-disposal near bed velocities. Commencement of Flood +4h, m/s.



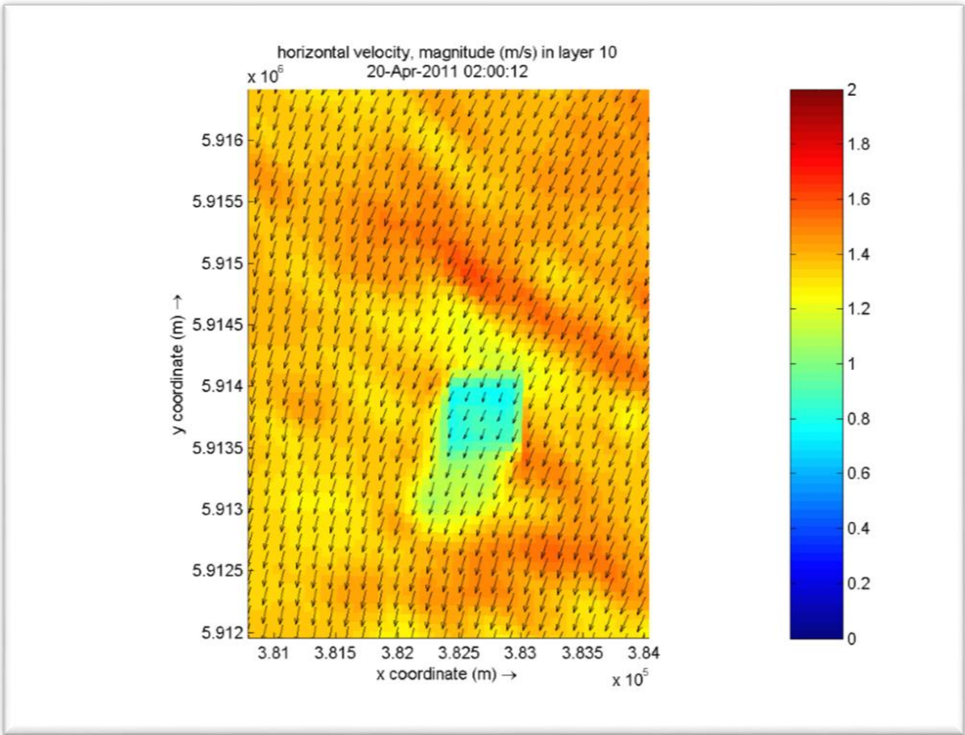
A5. Post-disposal near bed velocities. Commencement of Flood +5h, m/s.



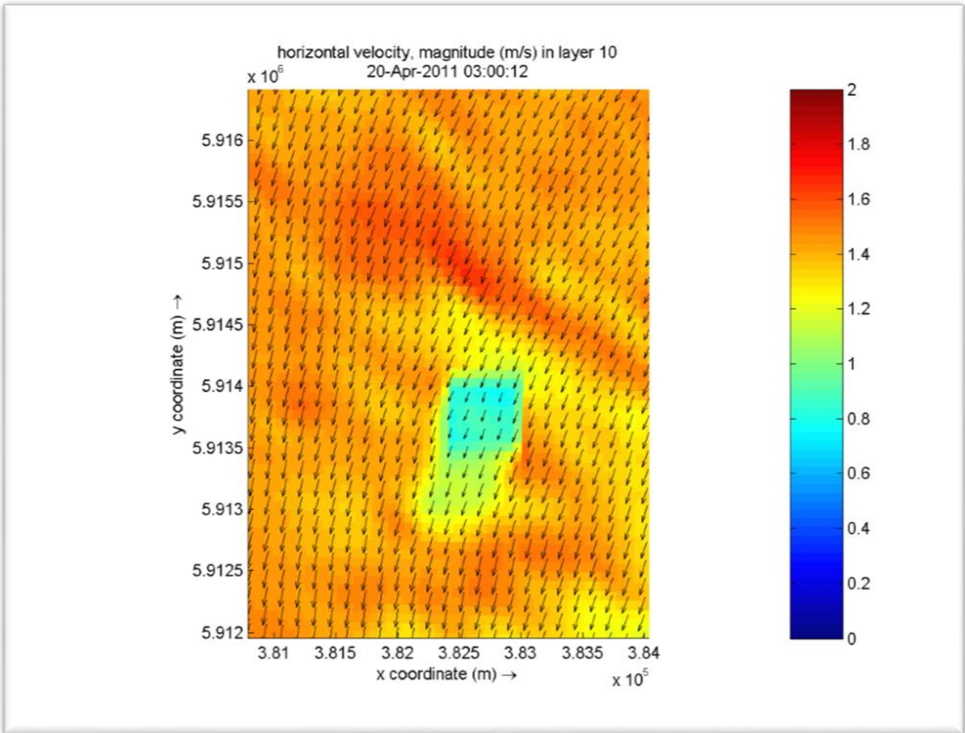
A6. Post- disposal near bed velocities. Commencement of Flood +6h, m/s



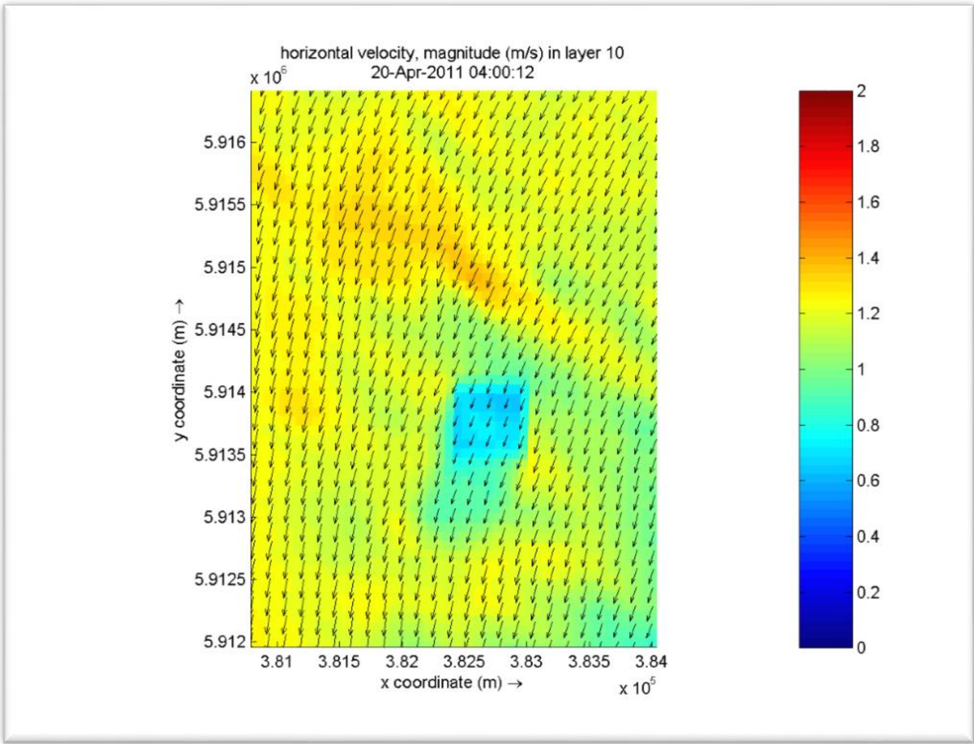
A7. Post-disposal near bed velocities. Commencement of Flood +7h, m/s.



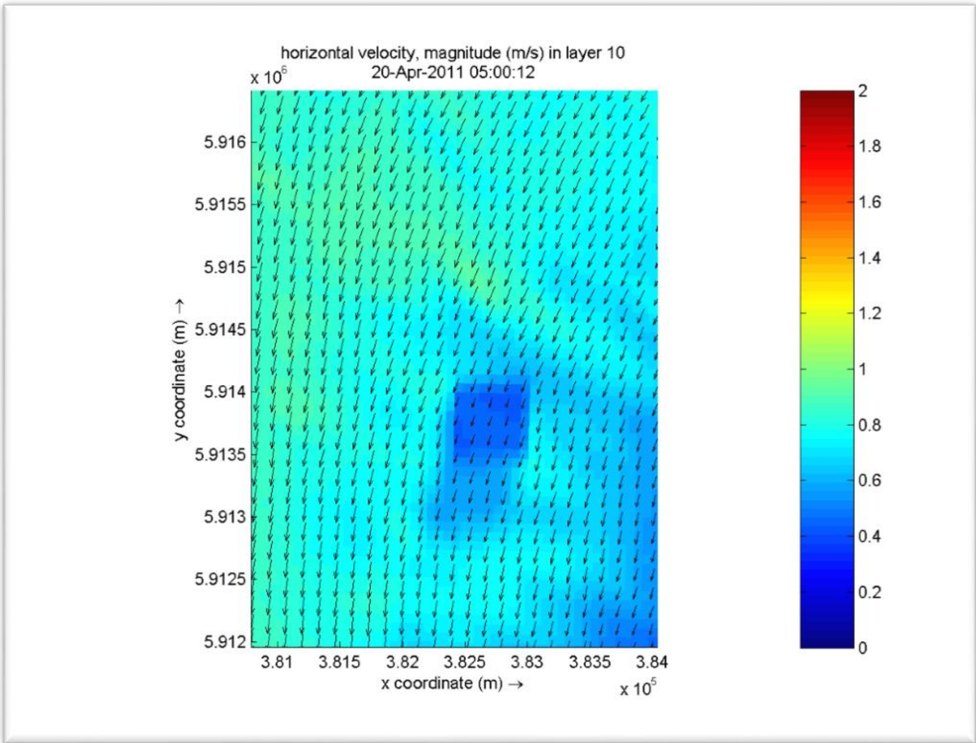
A8. Post-disposal near bed velocities. Commencement of Flood +8h, m/s.



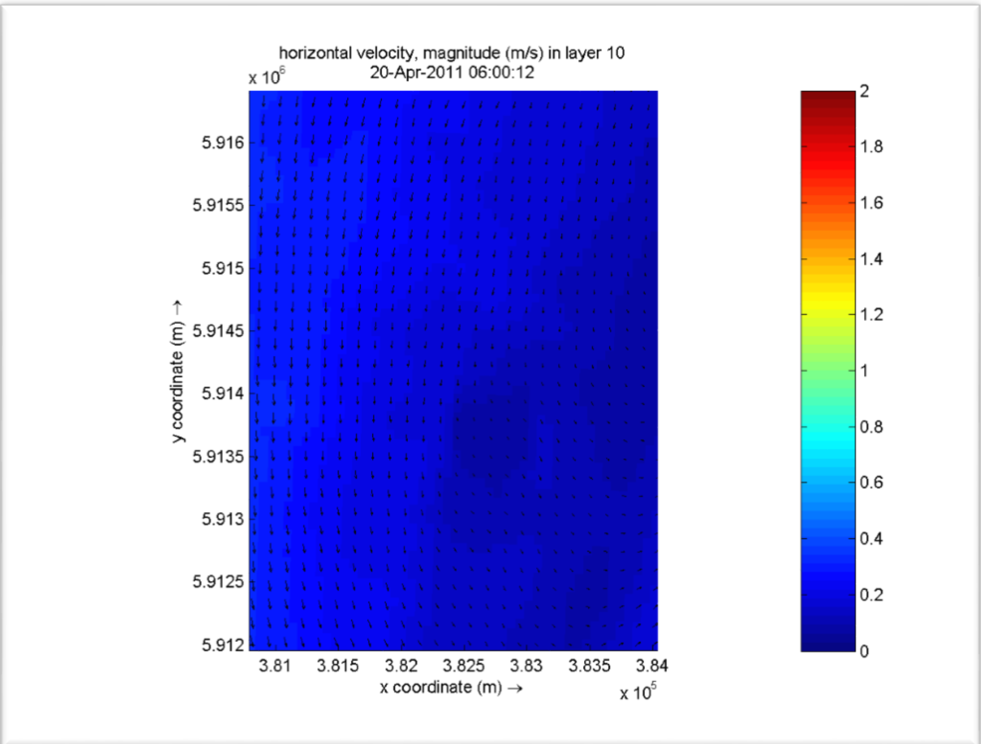
A9. Post-disposal near bed velocities. Commencement of Flood +9h, m/s.



A10. Post-disposal near bed velocities. Commencement of Flood +10h, m/s.



A11. Post-disposal near bed velocities. Commencement of Flood +11h, m/s.



A12. Post-disposal near bed velocities. Commencement of Flood +12h, m/s.