FIVE ESTUARIES OFFSHORE WIND FARM

10.14 MARINE GEOLOGY, OCEANOGRAPHY AND PHYSICAL PROCESSES SEDIMENT PLUME MODELLING RESULTS

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In preparation of this document Five Estuaries Wind Farm Ltd has made reasonable efforts to ensure that the content is accurate, up to date and complete for purpose.

Revision	Date	Status/Reason for Issue	Originator	Checked	Approved
A	Oct-24	Deadline 1	ABPmer	VE OWFL	VE OWFL

CONTENTS

TABLES

FIGURES

DEFINITION OF ACRONYMS

Term	Definition
BGS	British Geological Society
BODC	British Oceanographic Data Centre
CD	Chart Datum
Cspd	Current Speed
DHI	Danish Hydraulic Institute
ECC	Export Cable Corridor
Deg.T	Current direction in degrees north, towards
DTU	Technical University of Denmark
EIA	Environmental Impact Assessment
ES	Environmental Statement
FM	Flexible Mesh
HD	Hydrodynamic
LAT	Lowest Astronomical Tide
MDS	Maximum Design Scenario
MFE	Mass Flow Excavator
MLS	Margate Longsands
MSL	Mean Sea Level
NTSLF	National Tide and Sea Level Facility
OWF	Offshore Wind Farm
PT	Particle Tracking
SAC	Special Area of Conservation
SSC	Suspended Sediment Concentration
TSHD	Trailing Suction Hopper Dredger
UCL	University College London
UKHO	United Kingdom Hydrographic Office
UTM	Universal Transverse Mercator
VE	Five Estuaries
VORF	Vertical Offshore Reference Frames

1 INTRODUCTION

1.1 OVERVIEW

1.1.1 The Five Estuaries Environmental Statement Chapter (6.2.2 Marine Geology, Oceanography and Physical Processes – [APP-071]) presented results from spreadsheet based models describing patterns of suspended sediment concentration (SSC) and thickness of deposition representative of a range of different construction related activities. This methodological approach is considered to be robust, quantitative and appropriately detailed for the activities being assessed.

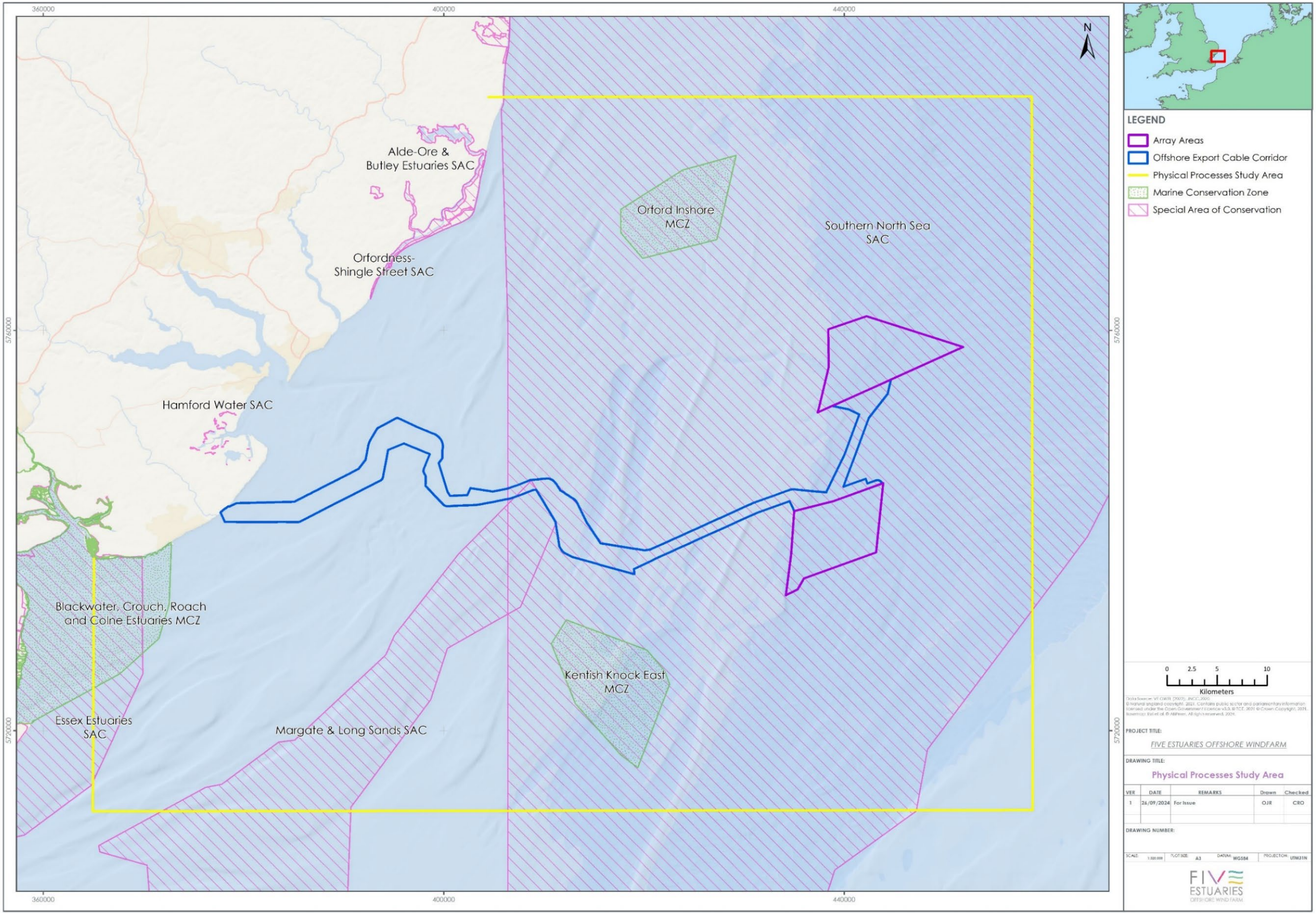
1.1.2 However, following a review of this work, Natural England provided the following Relevant Representation (Natural England, 2024):

> *"Natural England is unable to agree with the impact assessment for potential changes to Suspended Sediment Concentrations (SSCs), bed levels, and sediment type arising from construction related activities within the Array Areas, because the information provided lacks sufficient detail. Whilst it is stated that the assessment of changes to SSC and associated sediment deposition is informed by location and project-specific numerical modelling, the results presented are largely qualitative. For example, within the zone of highest SSCs increase and thickness of sediment deposition (0-50m of the construction activity), it is stated that 'sands and gravels may deposit in local thickness of tens of centimetres to several metres…', which is an order of magnitude difference"*

1.1.3 In order to address this concern, the Applicant has commissioned numerical sediment plume modelling to supplement the existing spreadsheet based analysis. The scope and methodology for the additional analysis was provided to Natural England for review, and they agreed with the approach which was proposed.

1.1.4 Overall, this additional analysis will assist with a more detailed description of the spatial pattern and magnitude of SSC change and associated levels of deposition (and sediment type) and can be used to support the assessment of impacts to sensitive species/habitats. Special Areas of Conservation (SAC) and Marine Conservation Zones (MCZ) within the study area are shown in Figure 1.1. SAC and MCZ boundaries are also superimposed on plume modelling results to determine the potential for plume overlaps with these sensitive regions.

1.1.5 This report presents information on the numerical sediment plume modelling undertaken. It details the design and validation of the models used, describes the scenarios tested, and presents the results. It is important to note that these results complement (rather than supersede) those already presented in (6.2.2 Marine Geology, Oceanography and Physical Processes – [APP-071]).



Data Source: VE OWFL (2022); JNCC, 2020.

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

Physical Processes Study Area

VER	DATE	REMARKS	Drawn	Checked
1	26/09/2024	For Issue	OJR	CRO

DRAWING NUMBER:

SCALE: 1:320 000 | PLOT SIZE: A3 | DATUM: WGS84 | PROJECTION: UTM31N

1.2 GENERAL APPROACH TO MODELLING

1.2.1 The numerical modelling for this study has been undertaken using the MIKE21FM (flexible mesh) software package from the Danish Hydraulic Institute (DHI), which has been developed specifically for application in oceanographic, coastal and estuarine environments.

1.2.2 When used by an experienced modeller, and in conjunction with suitable data inputs, these models provide reliable and realistic representations of both baseline environmental conditions and the potential effects of offshore wind farm infrastructure and other construction related activities.

1.2.3 The sediment plume modelling described in this report is undertaken using a Particle Tracking approach, whereby particles representing discrete amounts of sediment are released and subject to advection and dispersion within a tidal flow simulation of the wider study area.

1.2.4 The following sections describe first of all the tidal model design and validation, and then the plume model.

2 HYDRODYNAMIC MODEL

2.1 OVERVIEW

2.1.1 This section describes the design and inputs to a hydrodynamic model simulating tidal currents and water levels in the EIA study area for the VE OWF. This hydrodynamic model provides the basis for the sediment plume modelling described in Section 3 and has previously been described in detail within 6.5.2.2 Physical Processes Model Design and Validation – [APP-100].

2.1.2 For completeness, key details of the hydrodynamic model design and validation are repeated below in this Section 2.

2.2 TIDAL MODEL DESIGN

2.2.1 The tidal model creates a timeseries simulation of tidal water levels and depth averaged current speed and direction throughout the model domain. The tidal model is built using the MIKE21FM Hydrodynamic (HD) module, which simulates the propagation of the tidal wave and associated movements of water volume in offshore and coastal settings.

2.2.2 The tidal model is based on the ABPmer SEASTATES validated regional-scale European Shelf Tide and Surge model, used in a tide-only mode, with locally enhanced resolution in the study area. The design and performance of the regional model are described in a separate report (ABPmer, 2017).

MODEL GRID

2.2.3 The tidal model grid is based on that used by the ABPmer SEASTATES European Shelf Tide and Surge model (ABPmer, 2017). The extent of the model mesh and the distribution of mesh resolution is shown in Figure 2.1. A flexible mesh design is used (interlocking triangular 'elements' of varying shape and orientation), providing tailored spatially variable resolution within a single model mesh.

2.2.4 Resolution is uniformly high (approximately 150 m) throughout the main study area between Lowestoft and Margate, also including the VE and the surrounding windfarms. The relatively high resolution provides a sufficiently detailed description of the key bathymetric and coastal features affecting flow patterns in these areas, including the various bedforms (sand waves and mega-ripples) anchored around the Outer Thames region. The higher resolution is also relevant to the resolution of outputs from the sediment plume transport model described in Section 3.

2.2.5 The (variable) lower resolution of the mesh outside of the study area is sufficient and suitable to simulate the general progression of the tidal wave and associated movement of water volume around the European continental shelf, up to the edges of the local study area.

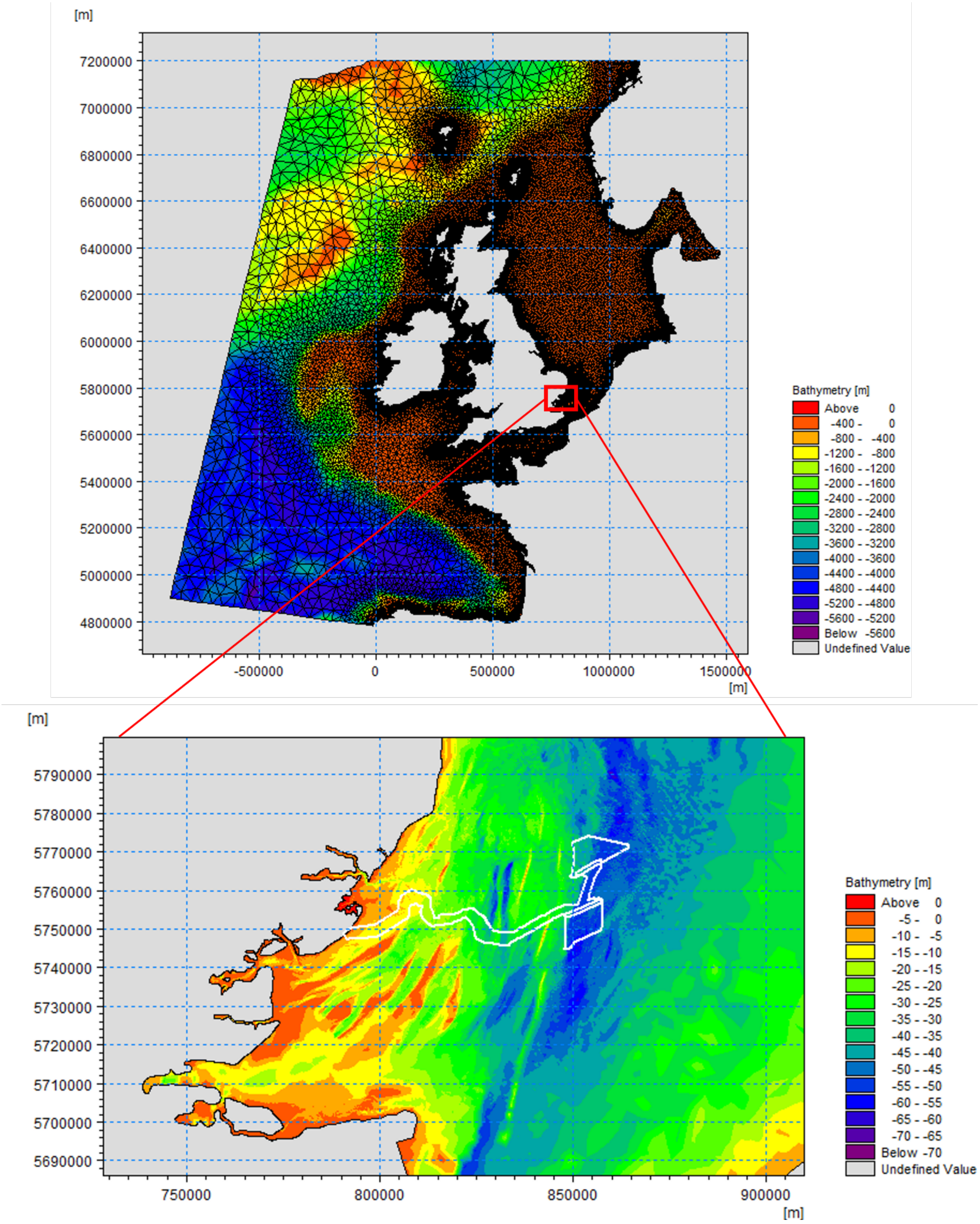


Figure 2.1 Extent of the tidal model mesh, showing regional and locally enhanced resolution. Lower plot also shows the VE windfarm extent and adjacent windfarms.

MODEL BATHYMETRY

2.2.6 Within the VE array area and cable corridor, high resolution multibeam bathymetric survey data have been collected (Fugro, 2022a, 2022b, 2022c) and are used to inform the model mesh in these areas.

2.2.7 Outside of the surveyed VE array area and cable corridor, the tidal model bathymetry is the same as used by the validated ABPmer SEASTATES European Shelf Tide and Surge model. The regional bathymetric data was largely sourced from EMODnet (https://www.emodnet-bathymetry.eu/), which is a freely available and generally reliable data source. Numerous other UKHO survey data sets were also incorporated into the ABPmer SEASTATES model mesh bathymetry. The good level of validation achieved by the ABPmer SEASTATES model with respect to water levels and currents (ABPmer, 2017) provides indirect validation of the bathymetry data source.

2.2.8 Spatially varying adjustments are made to convert the bathymetry data from the standard Lowest Astronomic Tide (LAT) and Chart Datum (CD) datums at source, to Mean Sea Level (MSL), as is required for use in the model. Adjustments are made using a combination of VORF (Vertical Offshore Reference Frames, UCL and UKHO, 2005) in UK territorial waters, and mapped statistics of the offset between LAT and MSL from the validated ABPmer SEASTATES European Shelf Tide and Surge model results.

MODEL BOUNDARY CONDITIONS

OFFSHORE TIDAL BOUNDARIES

2.2.9 The tidal model has four open water level boundaries, shown in Figure 2.2. Temporally and spatially varying tidal water levels are applied at these boundaries, representing the passage of the deep ocean tidal wave from the North Atlantic onto the European shelf (and smaller exchanges with the Baltic Sea). Tidal boundary data are obtained using the DTU10 (DTU, 2010) database of harmonic constituents. The good level of validation achieved by the model with respect to water levels and currents (ABPmer, 2017) provides indirect validation of the tidal boundary data source.

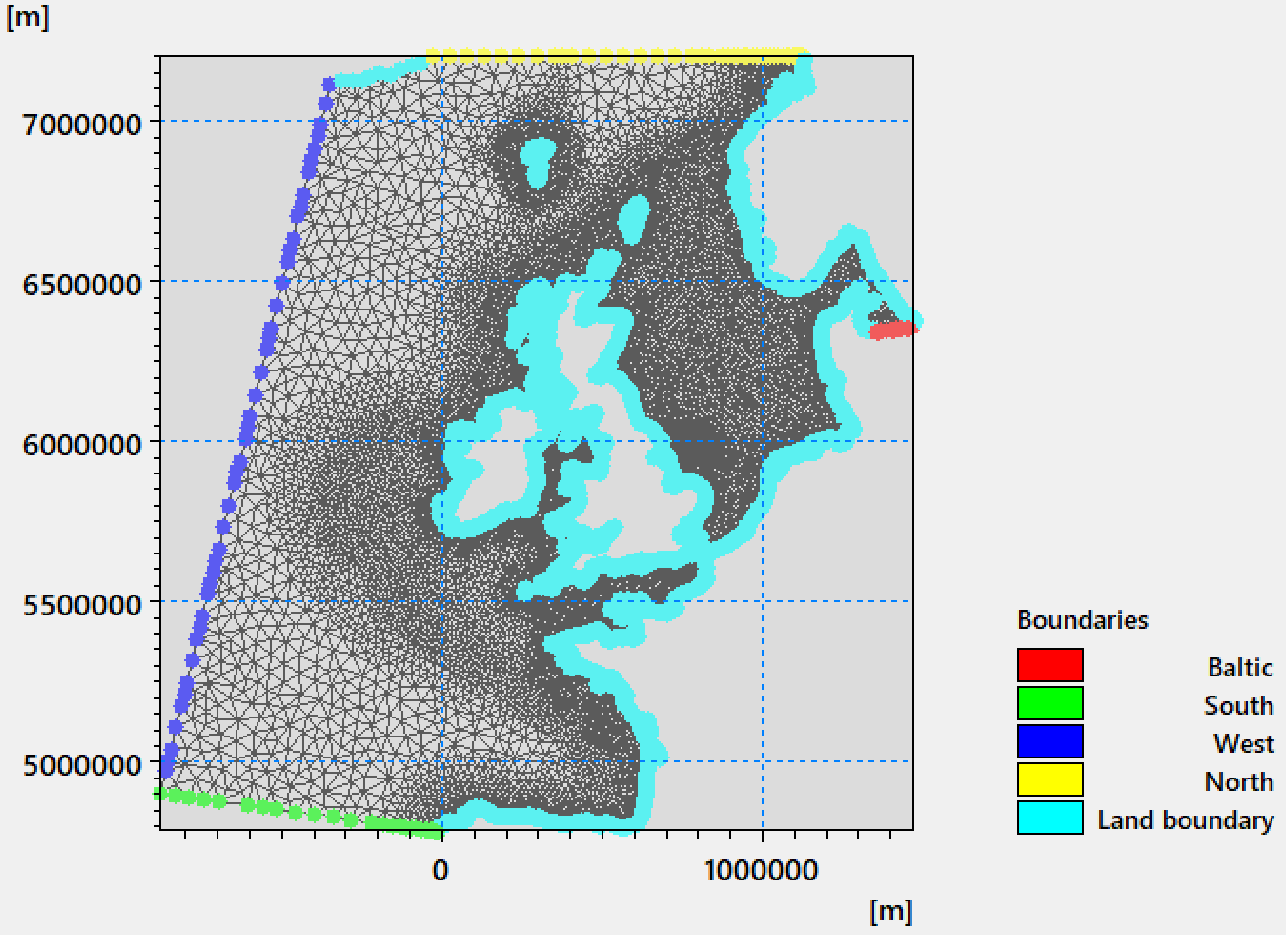


Figure 2.2: Tidal model boundaries.

METEOROLOGICAL BOUNDARIES

2.2.10 The effect of winds and air pressure (for non-tidal surge related influences) are not included in this (tide-only) model.

BED ROUGHNESS

2.2.11 Bed roughness in the model describes the friction from the seabed ‘felt’ by moving water. Changing the magnitude of bed roughness locally effects the rate at which water moves in that area and so can affect both tidal range and phasing, and (mainly the speed of) tidal currents. As such bed roughness is a key variable in the model that can be varied to optimise the model performance in comparison to coincident measured data.

2.2.12 The ABPmer SEASTATES European Shelf Tide and Surge model utilises a bespoke spatially varying map of bed roughness, created by combining information about the distribution of seabed and sediment type, and water depth. The good level of validation achieved by the model with respect to regional scale patterns of water levels and currents (ABPmer, 2017), which provides indirect validation of the bed roughness values.

2.2.13 The same validated spatially variable bed roughness distribution is applied in the present study, with no adjustments made.

2.3 TIDAL MODEL VALIDATION

2.3.1 The regional SEASTATES tide model largely controls the timing, magnitude and direction of water levels and currents entering and propagating through the local study area. The regional model has been separately validated against the tide gauge and current meter data in numerous locations around the European continental shelf, including tide gauges at Harwich, Sheerness and Dover (ABPmer, 2017)

2.3.2 The tidal model has also been validated against multiple sets/periods of measured current and water level data from spatially suitable dataset relative to the VE study area. The locations of the used instrumentation are shown in Figure 2.3.

2.3.3 Comparisons of the total measured and modelled water levels are provided in Figure 2.4 to Figure 2.6. The plots generally show that the tidal model provides a good representation of the overall magnitude, timing, and variance of water levels at the three chosen locations.

2.3.4 The time varying water level is important for the correct simulation of time varying total local water depth, which is a relevant factor in the calculation of suspended sediment. The model is shown to provide an accurate description of the absolute water level and the timing of variation in water level (especially relative to currents).

2.3.5 The main axis and direction of rotation of tidal currents, and the relative variation in peak current speed between adjacent flood/ebb tides are all important for the realistic simulation of local tidal asymmetry and net drift, which will contribute towards the rate of the transportation of sediment.

2.3.6 The direction of currents throughout the tide and the rate and direction of flow rotation are generally well represented by the model at each of the four identified current datasets (1 BODC dataset (b7625) and three Total Tide diamonds (SN013H, SN012T & SN012S), (see Figure 2.3). In addition, the model's capability is further reassured by the variation in current signature between sites SN013H and SN012T, compared to SN012S which provides a very contrasted signature. This is well replicated by the model in a bathymetrically complex location. The plots of both current speed and direction are presented in Figure 2.8 to Figure 2.10.

2.3.7 The modelled conditions (peak current speed and high and low water levels) are typically close in magnitude to either the corresponding or adjacent observed tide within a 12 or at most 24-hour period. The differences are small in absolute and relative terms and are within the range of natural variability in the same values from tide to tide.

2.3.8 Some minor differences are observed between the sites where the model simply cannot be calibrated further to simultaneously reproduce all details of all tides at all locations. Some differences may also be the result of local effects of complex bathymetry that are either not represented in the available bathymetry data, or not fully resolved by the resolution of the model.

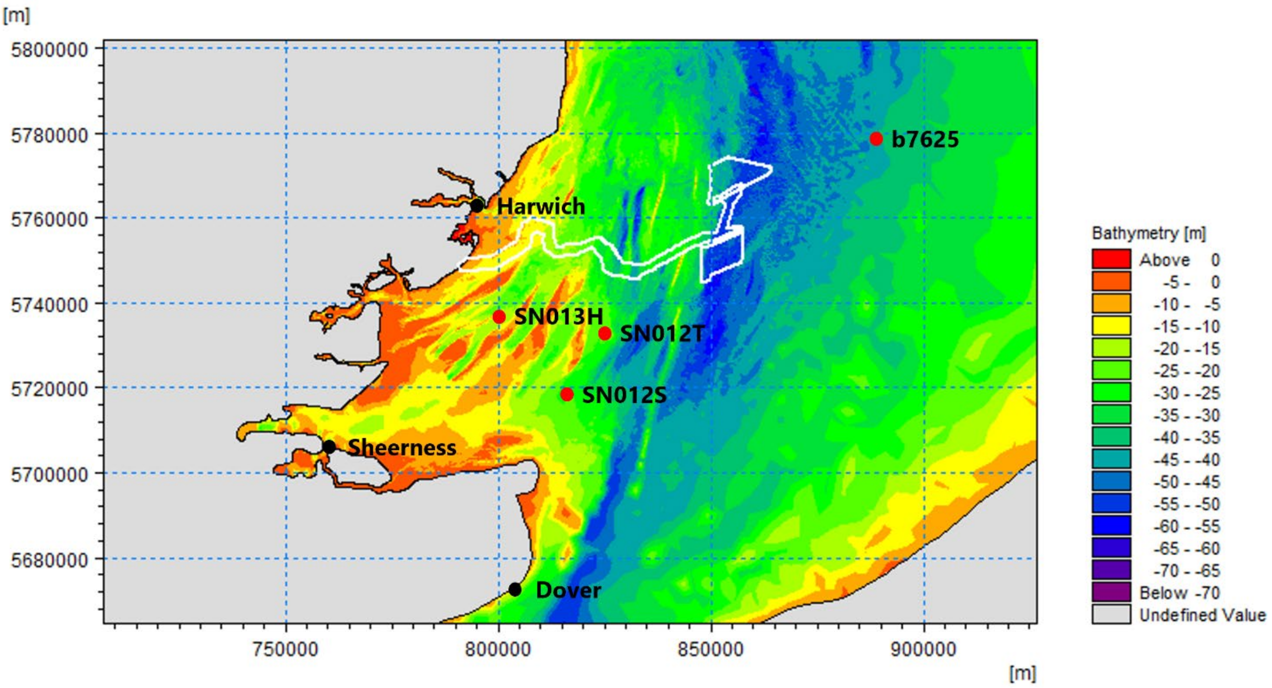


Figure 2.3: Locations of the measured data used for tidal model validation.

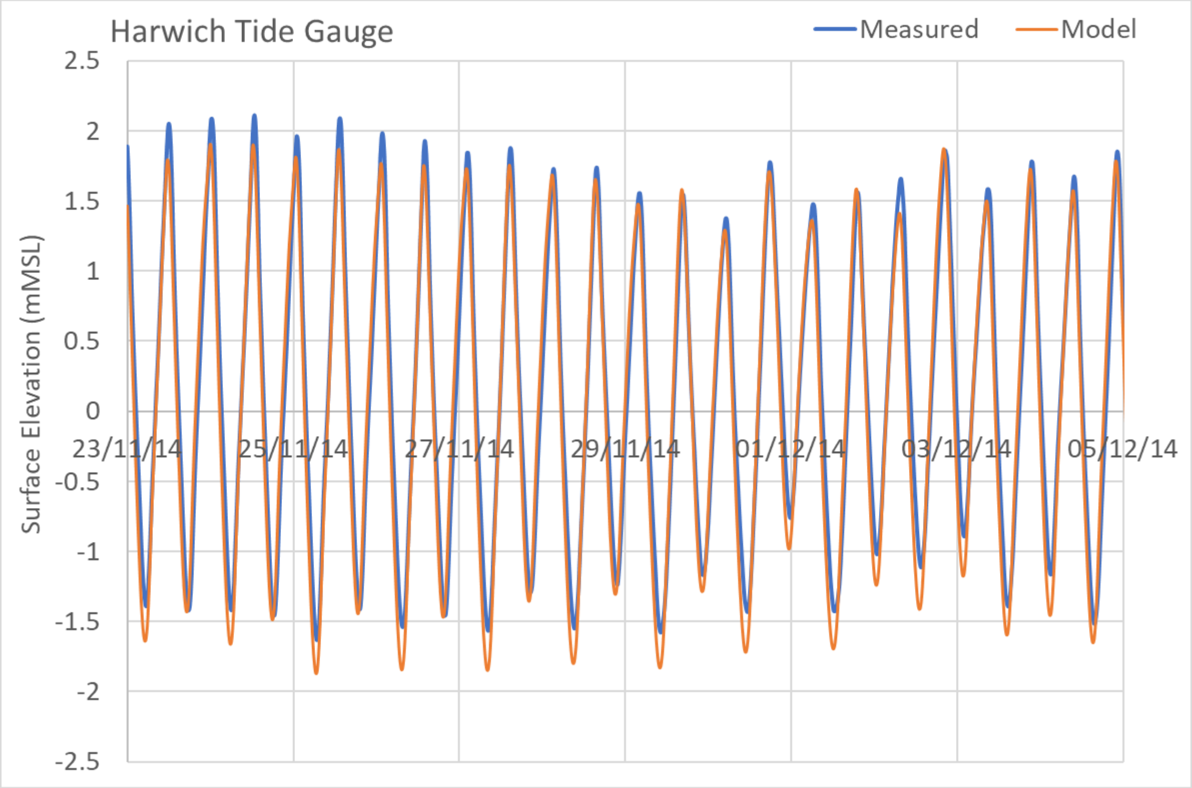


Figure 2.4: Comparison of total measured and modelled water-levels at Harwich NTSLF tide gauge.

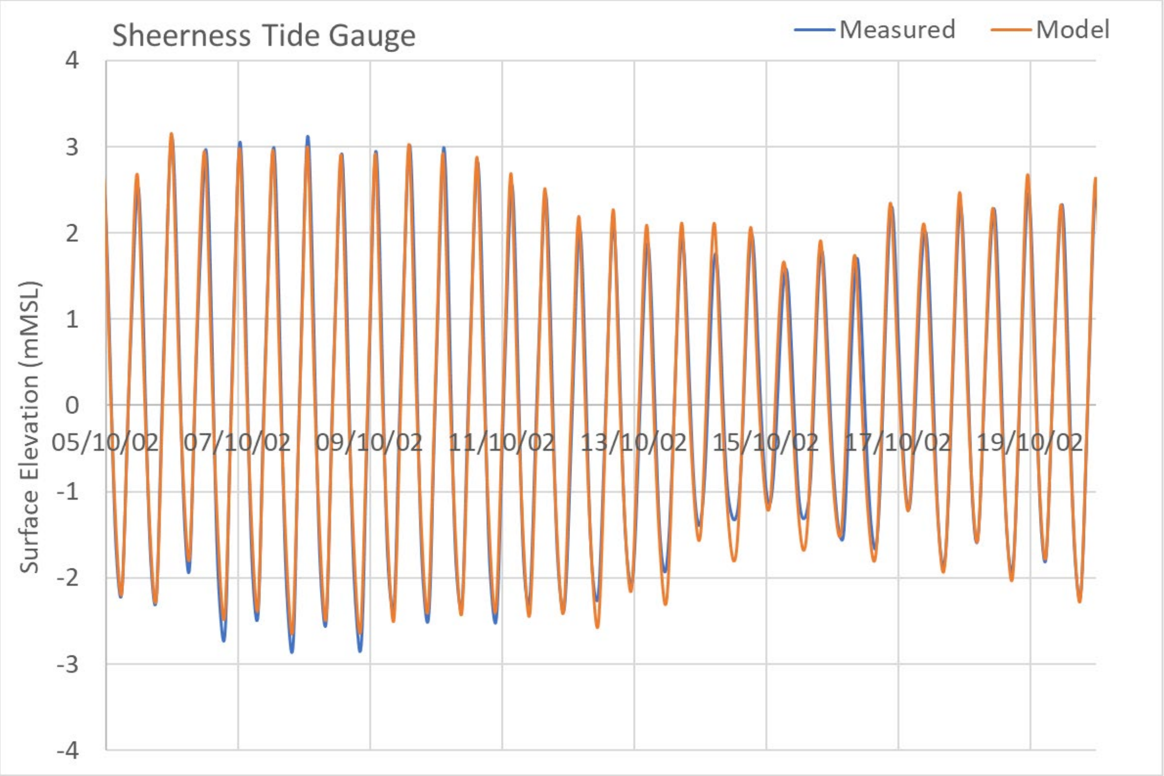


Figure 2.5: Comparison of total measured and modelled water-levels at Sheerness NTSLF tide gauge.

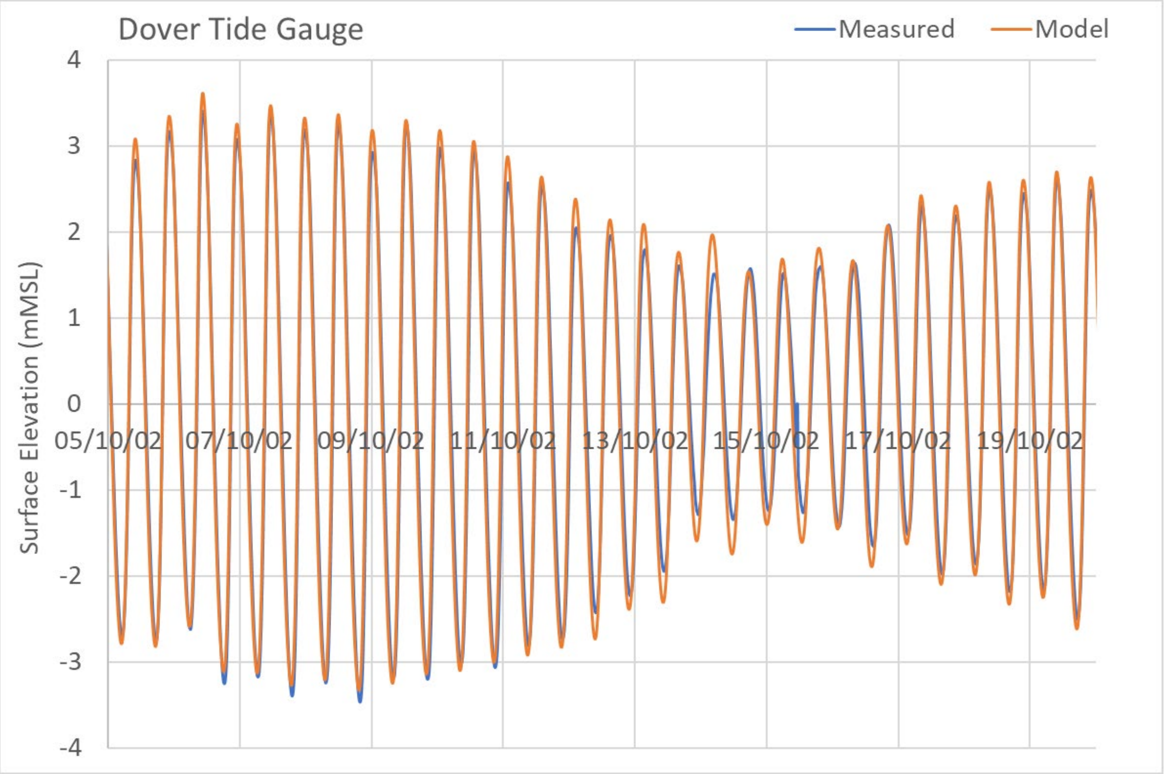


Figure 2.6: Comparison of total measured and modelled water-levels at Dover NTSLF tide gauge.

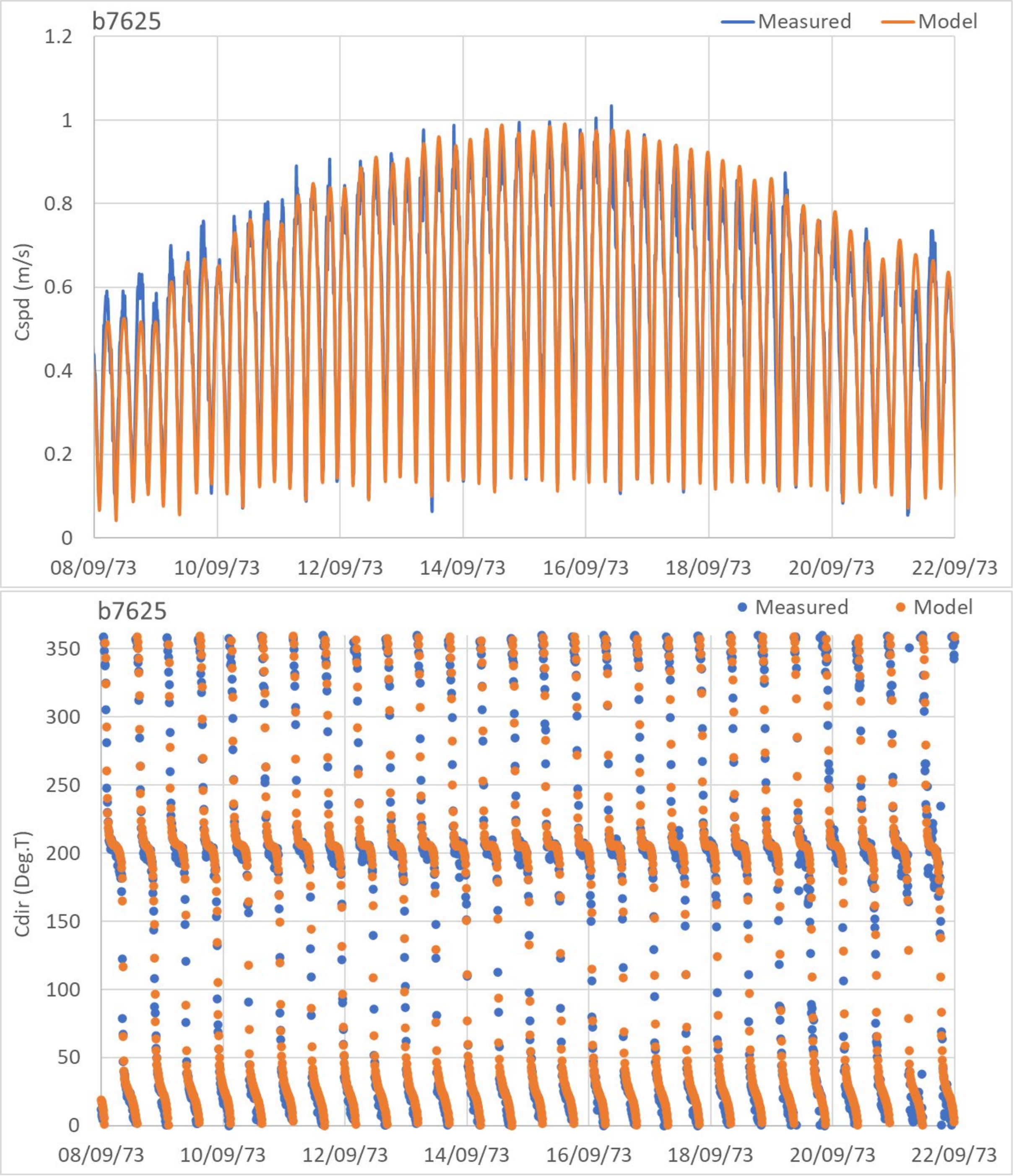


Figure 2.7: Comparison of measured (total) and modelled (tide-only) hydrodynamic parameters at b7625, southern North Sea.

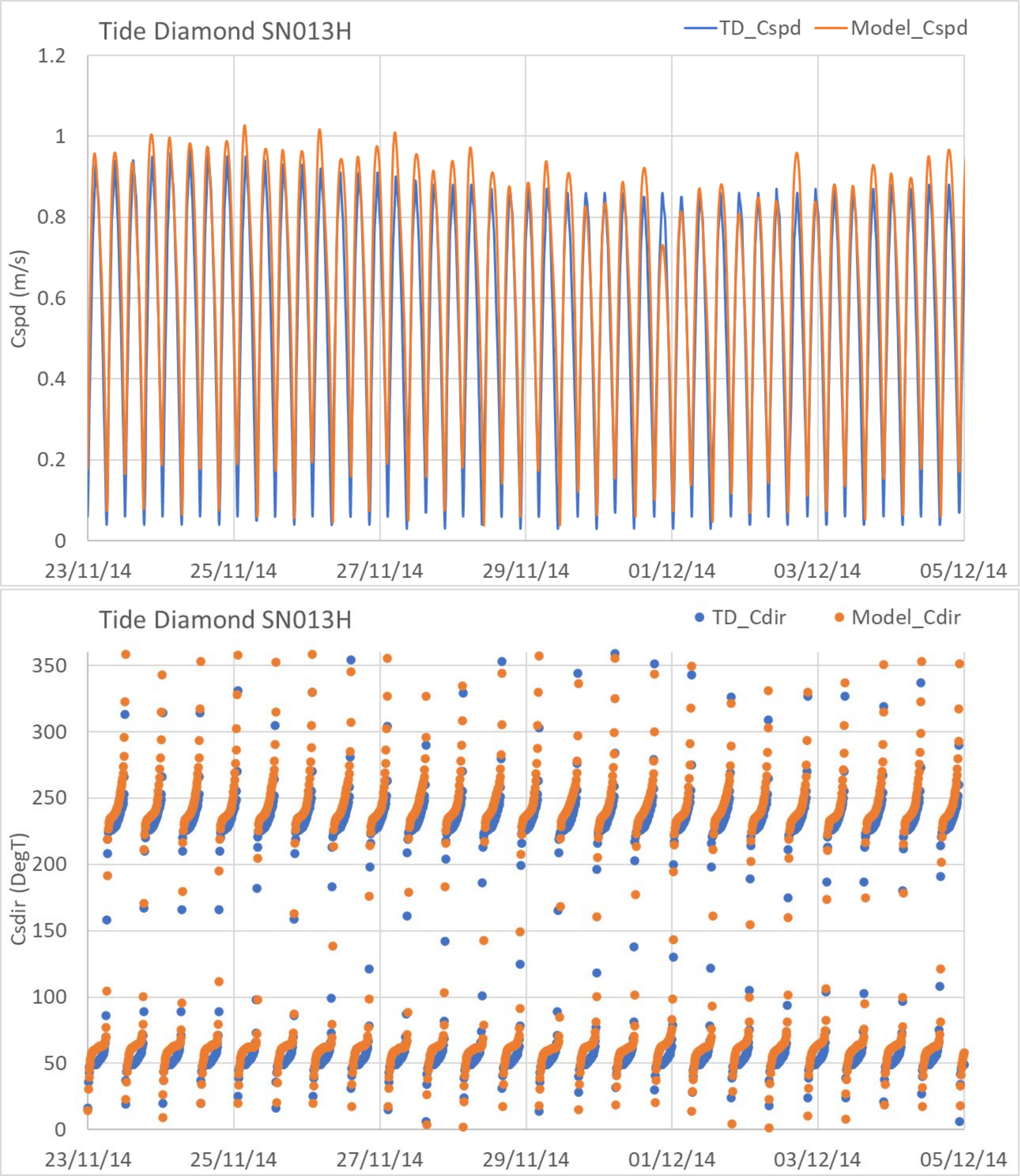


Figure 2.8: Comparison of tide diamond and modelled hydrodynamic parameters at SN013H, Outer Thames.

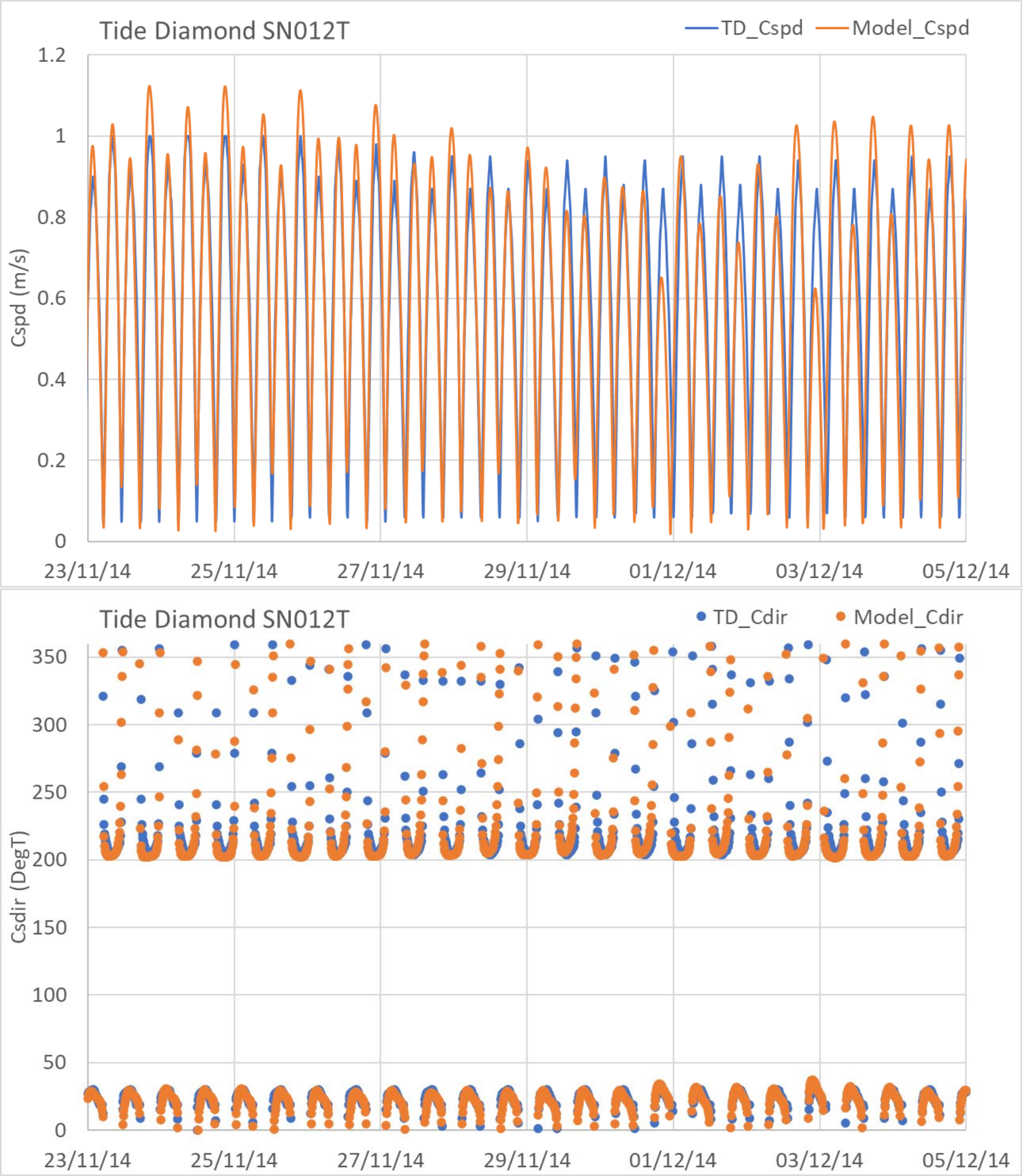


Figure 2.9: Comparison of tide diamond and modelled hydrodynamic parameters at SN012T, Outer Thames.

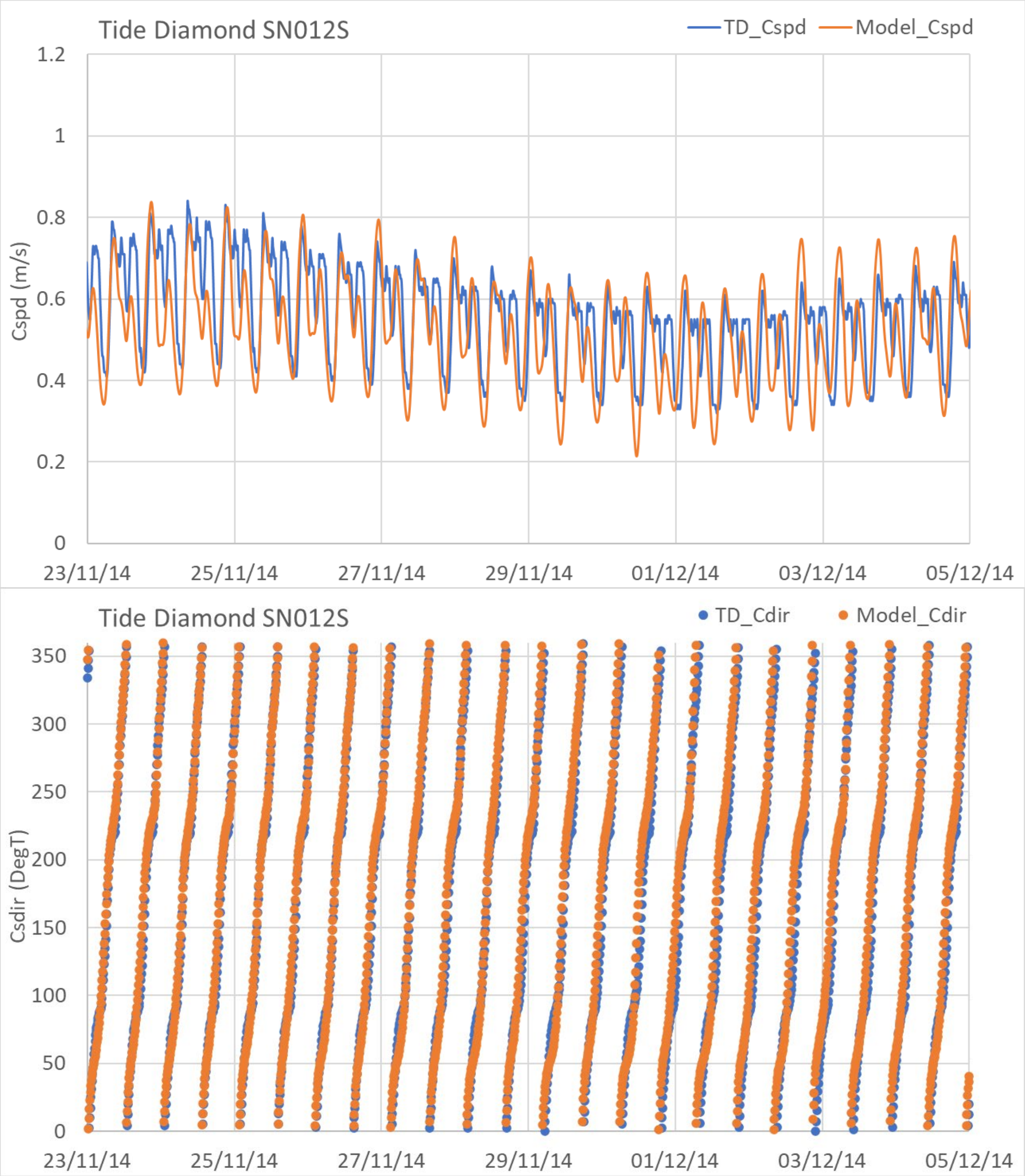


Figure 2.10: Comparison of tide diamond and modelled hydrodynamic parameters at SN012S, Outer Thames.

3 SEDIMENT PLUME MODEL

3.1 OVERVIEW

3.1.1 The sediment plume model provides a timeseries simulation of SSC and settled sediment thickness in response to sediment release, advection and dispersion within the model domain. The sediment plume model is built using the MIKE21FM Particle Tracking (PT) module which simulates the horizontal and vertical advection and dispersion of sediment, represented as numerous discrete particles, within a temporally and spatially varying flow field.

3.2 SEDIMENT PLUME MODEL DESIGN

MODEL GRID, BATHYMETRY AND HYDRODYNAMIC INPUTS

3.2.1 The sediment plume model utilises the same model grid and the flow field timeseries generated by the validated MIKE21HD model described in Section 2. The model is therefore able to consider a range of tidal conditions over a range of representative (e.g. spring and neap) tidal conditions. A relatively high level of spatial resolution (~150 m) is used in the area of the proposed sediment releases, including the export cable corridor.

SEDIMENT TYPES, SETTLING, DISPERSION AND EROSION RATES

3.2.2 Five different sediment grain size fractions are considered in the plume dispersion modelling, although only certain grades may be relevant to specific scenarios. The sediment grain size fractions considered and their associated settling rates (from Soulsby, 1997) are summarised in Table 3.1.

Table 3.1: Sediment grain size fractions used.

Sediment Fraction Name	Representative Grain Size	Representative Settling Velocity
Gravel	~8,000 µm	0.5 m/s
Coarse sand	~1,000 µm	0.1 m/s
Medium sand	~250 µm	0.03 m/s
Fine sand	~150 µm	0.01 m/s

3.2.3 A higher than default horizontal dispersion rate of 1.0 m^2/s is applied to all sediment grain size fractions. Smaller values (0.1 and 0.01 m^2/s) were also considered but resulted in very narrow plumes with a very limited footprint of effect that did not appear to measurably disperse over the model simulation period. The value used is within the (relatively wide) range of generally reported values based on observations of this parameter. As a result, the rate of increase in plume width with time is (slightly) increased, which provides a more conservative indication of area of effect. The corresponding SSC values are (slightly) reduced but are still realistically elevated in comparison to typical baseline values. A vertical dispersion rate of 0.01 m^2/s is applied to all sediment grain size fractions.

3.2.4 Once deposited to the seabed, sediment in the model is made unable to be eroded and will remain *in situ*. In practice, sediment in a plume that has been deposited to a similar area of seabed will immediately re-join the natural sedimentary environment and will be naturally eroded at the same time and rate as all other naturally present sediment in that location. By restricting re-erosion, the area and thickness of initial deposition from the sediment plume can be observed in more detail.

3.3 SEDIMENT PLUME MODEL VALIDATION

3.3.1 Predictive location specific plume models are not normally validated, as location specific observations of the activities being simulated are rarely available. However, this type of modelling approach, in conjunction with validated hydrodynamic inputs, is generally accepted to provide a realistic description of sediment plumes in the marine environment.

3.3.2 The following additional points also support confidence in the modelling process and results:

- Section 2.3 validates the accuracy and representativeness of the water level, current speed and direction data that control the rate and direction of sediment plume advection in the particle tracking model.
- The representative rate of dispersion is controlled by the model settings but can be variable in practice depending on other environmental conditions (e.g. wave conditions).
- The inputs and settings used in the model and the definitions of the sediment disturbance activities are considered to be conservatively realistic. The modelling process and analysis of the results are undertaken by an experienced coastal processes modeller.

4 SEDIMENT DISTURBANCE MAXIMUM DESIGN SCENARIOS

4.1 SEDIMENT PLUME MODEL RUNS

4.1.1 The Maximum Design Scenarios (MDS) are determined using the information contained in the project design envelope, as set out in 6.1.1 Offshore Project Description – [APP-069]. For each activity, the rate and duration of sediment disturbance and the total volume of sediment is calculated for the realistic worst-case occurrence of the activity. The effect of all other options in the design envelope are therefore expected to be equal to or less than the results presented in this report.

4.1.2 The following MDS sediment releases have been considered:

- Four activity types:
  - Pre-lay cable trenching using a Mass Flow Excavator (MFE) tool at the seabed;
  - Sandwave clearance using a MFE tool at the seabed;
  - Dredge spoil disposal at the water surface related to seabed preparation for cables or foundations (including sandwave clearance);
  - Drill arisings release at the water surface during drilling for monopile foundations;
- At locations in the array area, along the length of and in the middle of the export cable corridor, and near to the landfall, as applicable;
- Occurring (separately) on and around representative spring and neap tidal periods.

4.1.3 The following cumulative sediment releases have also been considered for representative spring and neap tidal periods:

- Sandwave clearance using an MFE tool at the seabed within the proposed North Falls (north and south) and East Anglia TWO wind farm array areas;
- Dredge spoil disposal at the water surface related to seabed preparation for cables or foundations (including sandwave clearance) within the proposed North Falls (north and south) and East Anglia TWO wind farm array areas;
- Drill arisings release at the water surface during drilling for monopile foundations within the proposed North Falls (north and south) and East Anglia TWO wind farm array areas;
- Aggregate extraction (overflow from spillways and material rejected by screening) release at the water surface within licensed aggregate extraction regions in the Physical Processes Study Area.

4.1.4 The subsequent plume settlement and dispersion is simulated over a further period following the end of the sediment disturbance to characterise the persistence and rate of dispersion of the plume. Where fines are present, a three-day period is sufficient for the purposes of the EIA assessment. Sands and gravels, will have redeposited to the seabed within a much shorter timescale (up to approximately 1 hour, depending on water depth).

4.1.5 Table 4.1 provides a summary of the sediment plume scenarios, the location of each release, the mass of sediment and the type of sediment at each site.

Table 4.1: Modelled sediment plume scenarios.

Scenario No.	Mean Tidal Condition	Activity	Release Location (UTM30)	Rate and Duration of Disturbance	Grain Size Fractions (% of Total)
VE array area					
1	Neap	Pre-lay trenching (MFE)	Central North array area X 853087 Y 5771482	1000 kg/s for 24 hours 50 min, 400m/hr, @3m above bed. Rate assumes 100% release of material from the trench	Gravel (10%) Coarse sand (20%) Medium sand (30%) Fine sand (30%) Silt (10%)
2	Spring				
3	Neap		Central South array area X 850533 Y 5753363		
4	Spring				
5	Neap	Sandwave clearance (MFE)	Central North array area X 854946 Y 5769995	1000 kg/s for 12 hours 20 min, static, @3m above bed	Gravel (10%) Coarse sand (20%) Medium sand (30%) Fine sand (30%) Silt (10%)
6	Spring				
7	Neap		Central South array area X 852771 Y 5751699		
8	Spring				
9	Neap	Drilling a monopile	Central North array area X 854946 Y 5769995	294 kg/s for 34 hours, static, @ water surface	Gravel (10%) Coarse sand (20%) Medium sand (30%) Fine sand (30%) Silt (10%)
10	Spring				
11	Neap		Central South array area X 852771 Y 5751699		
12	Spring				
13	Neap Peak Flood		Central North array area X 854946	1,749,000 kg sudden release,	Gravel (10%) Coarse sand (20%)
14	Spring Peak Flood				

Scenario No.	Mean Tidal Condition	Activity	Release Location (UTM30)	Rate and Duration of Disturbance	Grain Size Fractions (% of Total)
		Dredge spoil disposal	Y 5769995	static, @ water surface	Medium sand (30%) Fine sand (30%) Silt (10%)
15	Neap Peak Flood		Central South array area X 852771 Y 5751699		
16	Spring Peak Flood				
VE Export Cable Corridor					
17	Neap	Pre-lay trenching (MFE)	ECC (along whole length)	1000 kg/s for 182 hours 40 min, 400m/hr, @ 3m above bed. Rate assumes 100% release of material from the trench	Variable (see Figure 4.1)
18	Spring				
19	Neap	Sandwave clearance (MFE)	ECC overlap with MLS SAC X 821559 Y 5753293	1000 kg/s for 12 hours 20 min, static, @3m above bed	Gravel (0%) Coarse sand (15%) Medium sand (45%) Fine sand (35%) Silt (5%)
20	Spring				
21	Neap	Dredge spoil disposal	ECC overlap with MLS SAC X 821559 Y 5753293	1,749,000 kg sudden release, static, @ water surface	Gravel (0%) Coarse sand (15%) Medium sand (45%) Fine sand (35%) Silt (5%)
22	Spring				

Scenario No.	**Mean Tidal Condition**	**Activity**	**Release Location (UTM30)**	**Rate and Duration of Disturbance**	**Grain Size Fractions (% of Total)**
VE Nearshore Region					
23	Neap	Sandwave clearance (MFE)	~2.5 km from landfall X 793886 Y 5749060	1000 kg/s for 12 hours 20 min, static, @3m above bed	Gravel (20%) Coarse sand (10%) Medium sand (0%) Fine sand (10%) Silt (60%)
24	Spring				
25	Neap	Dredge spoil disposal	~2.5 km from landfall X 793886 Y 5749060	1,749,000 kg sudden release, static, @ water surface	Gravel (20%) Coarse sand (10%) Medium sand (0%) Fine sand (10%) Silt (60%)
26	Spring				
Cumulative Releases					
27	Neap	Aggregate extraction	Closest point within each licensed aggregate extraction area to the VE array area	740 kg/s for 4 hours 30 minutes, static, @ water surface	Medium sand (30%) Fine sand (30%) Silt (40%)
28	Spring				
29	Neap	Drilling a monopile	Closest point within North Falls and East Anglia TWO OWF array areas to the VE array area	294 kg/s for 34 hours, static, @ water surface	Gravel (20%) Coarse sand (20%) Medium sand (40%) Fine sand (15%) Silt (5%)
30	Spring				

Scenario No.	Mean Tidal Condition	Activity	Release Location (UTM30)	Rate and Duration of Disturbance	Grain Size Fractions (% of Total)
31	Neap	Sandwave clearance (MFE)	Closest point within North Falls and East Anglia TWO OWF array areas to the VE array area	1000 kg/s for 12 hours 20 min, static, @3m above bed	Gravel (20%) Coarse sand (20%) Medium sand (40%) Fine sand (15%) Silt (5%)
32	Spring				
33	Neap	Dredge spoil disposal	Closest point within North Falls and East Anglia TWO OWF array areas to the VE array area	1,749,000 kg sudden release, static, @ water surface	Gravel (20%) Coarse sand (20%) Medium sand (40%) Fine sand (15%) Silt (5%)
34	Spring				

4.2 RELEASE LOCATION ASSUMPTIONS

4.2.1 The pre-lay trenching MFE in Scenarios 1, 2, 3 and 4 is represented as a moving source within the VE north and south array areas, over a 24hr 50min period (i.e. two full tidal cycles), moving initially from south to north (with the current axis) for one tide (including one ebb and one flood) and then from west to east (across the current axis) for one tide, at a constant (maximum) rate of 400 m/hr (covering ~10 km during the simulation period).

4.2.2 The location of the static releases in Scenarios 5 to 16 (local sandwave clearance, drilling and dredge spoil disposal) is approximately central in the north and south VE array areas.

4.2.3 The pre-lay trenching MFE in Scenarios 17 and 18 is represented as a moving source over a 182hr 40min period (i.e. ~14 full tidal cycles), moving from the landfall to the edge of the array area, at a constant (maximum) rate of 400 m/hr (covering ~73 km during the simulation period).

4.2.4 The location of the static releases in Scenarios 19 to 22 (local sandwave clearance and dredge spoil disposal) is within the small part of the ECC that overlaps with the northeastern point of the Margate and Long Sands (MLS) Special Area of Conservation (SAC). It should be noted that as highlighted within 9.31 Schedule of Mitigation – Routemap [APP-264] any sediment removed from within the MLS SAC will be deposited back within the SAC or within the same sediment cell.

4.2.5 The location of the static releases in Scenarios 23 to 26 (local sandwave clearance and dredge spoil disposal) is in the shallow nearshore area, approximately 2.5km offshore of the landfall for the VE export cable corridor.

4.2.6 The locations of the static release in Scenarios 27 and 28 (aggregate extraction) were chosen as the closest point in each licensed aggregate extraction site to the VE array area in order to capture the worst-case scenario for cumulative impacts.

4.2.7 The locations of the static release in Scenarios 29 to 34 (local sandwave clearance, drilling and dredge spoil disposal) were chosen as the closest point in the proposed North Falls (north and south) and East Anglia TWO OWF array areas to the VE array area in order to capture the worst-case scenario for cumulative impacts.

4.3 PRE-LAY TRENCHING (MFE) ASSUMPTIONS

4.3.1 The mass of sediment placed into suspension by pre-lay cable trenching with an MFE tool was estimated as follows:

4.3.2 100% of material from a V-shaped trench (2.94 m wide and 3.5 m deep) is dispersed into the water column, resulting in 5.14 m^3 of sediment released per one meter trenched. Assuming 100% of the material is fluidised and displaced is highly conservative. In reality, this figure is expected to be less than 50%.

4.3.3 This is converted to a mass of sediment released by applying a dry bulk density of 1,750 kg/m^3 for uniform sand (5.14 m^3 x 1,750 kg/m^3 = 9,000 kg).

4.3.4 The rate of trenching is assumed to be 400 m/hr. This allows a sediment release rate of 1,000 kg/s to be calculated ((9,000 kg x 400)/(60 x 60) = 1,000 kg/s). This estimate is highly conservative in comparison to the working rate of the device (1000 m^3/hr, which corresponds to approximately 440 kg/s.

4.4 SANDWAVE CLEARANCE (MFE) ASSUMPTIONS

4.4.1 The rate of sediment disturbance (1000 kg/s) by an active MFE tool was conservatively estimated based on the MDS trench cross section dimensions, the speed of progress of the tool, and the bulk density of the local sediment type at each of the three locations. This estimate is conservative in comparison to the working rate of the device (1000 m^3/hr, which corresponds to approximately 440 kg/s).

4.4.2 All of the disturbed sediment is initially released at 3 m above the local seabed level. In practice, an MFE will also displace some proportion of sediment from the trench to the adjacent seabed through liquefaction and nearbed gravity flow (rather than necessarily putting sediment into suspension higher into the water column). This scenario therefore provides a conservative representation of the nearfield effect of the MFE process.

4.5 DRILLING ASSUMPTIONS

4.5.1 The mass of sediment placed into suspension by drilling was estimated as follows:

- 13,672 m^3 of spoil is produced per foundation drilled, assuming a drill diameter of 16 m and drill depth of 68 m.
- This is converted to a mass of sediment released by applying a soil (rock) density of 2,650 kg/m^3.
- The rate of drilling is assumed to be 34 hours per foundation (122,400 seconds), therefore the rate of sediment release is calculated as 296 kg/s.

4.6 DREDGE SPOIL RELEASE ASSUMPTIONS

4.6.1 The mass of sediment placed into suspension by a spoil release scenario is estimated as follows:

- A representative large hopper sediment volume of 11,000 m³ is released suddenly (within a single 10 minute timestep in the model).
- The total mass of sediment released is estimated as 11,000 m³ sediment x 0.6 solidity ratio x 2,650 kg/m³ solid density = 17,490,000 kg.
- The majority (90%) of the sediment volume is realistically assumed to descend directly to the bed in the ‘active phase’ of the plume as a single mass of sediment, which does not contribute to the more diffuse SSC effects considered by the plume model.
- The remaining 10% of sediment (10% of 17,490,000 kg =1,749,000 kg) is assumed to be dispersed into the water column at the point of release, allowing sediment grains to remain in suspension for longer, forming the ‘passive phase’ of the plume.
- It is assumed that the sediment is sufficiently mixed by the dredging process that the proportion of sediment fractions in the active and passive phases are the same as the original seabed sediment.

4.6.2 The proportion of sediment assumed to be in the passive and active phases is a conservatively representative value that may vary in practice. The chosen value (up to 10% in the passive phase) is consistent with studies on this topic by Becker *et al*. (2015).

4.7 AGGREGATE EXTRACTION ASSUMPTIONS

4.7.1 During aggregate dredging operations material is resuspended into the water column via three main processes: Disturbance of seabed by the drag head, overflow from the spillways and rejected material after screening. The first of these processes is not considered in the plume modelling as the most significant releases of fine sediment into the water column are as a result of overflow and screening.

4.7.2 The amount of material released into the water column during the aggregate extraction process is estimated based on work by HR Wallingford (1999). A typical screened aggregate load is assumed to take ~4.5 hours to extract. In the process 12000000 kg of material is assumed to overflow from spillways and as material rejected by the screening process. ~This gives a modelled sediment release rate of 740kg/s (12000000 kg / (4.5 hrs x 60 x 60)).

4.8 SEDIMENT TYPE ASSUMPTIONS

4.8.1 The assumed sediment type within the VE array area and ECC is informed by acoustic variations in low frequency side scan sonar data, collected and analysed by Fugro during the geophysical survey (Fugro, 2022a, 2022b).

4.8.2 The seabed within the VE array area is primarily made up of coarse-grained sediments – sands and gravelly sands – accounting for approximately 75% of the footprint of the array areas. Remaining areas are characterised by muddy sand, found in the west of the northern array area and in localised northeast to southwest trending bands in the southern array area. The proportion of each grain size fraction (gravel, coarse sand, medium sand, fine sand and silt) was therefore chosen as 10%, 20%, 30%, 30% and 10%, respectively for plume releases originated from the VE array area, capturing the predominantly sandy nature of the sediment with smaller contributions from gravel and silt fractions. A 10% silt content is conservatively assumed in sediment disturbed within the array area, although a much lower proportion (<1%) is likely in most regions.

4.8.3 The distribution of seabed sediment along the ECC is highly complex, with widespread coverage of coarse grains (sands and gravels) and finer grained (muddy) sediments. As such the sediment type along the ECC for the mobile pre-trenching release scenario is spatially varied to best capture the average sediment composition along the release route (Figure 4.1).

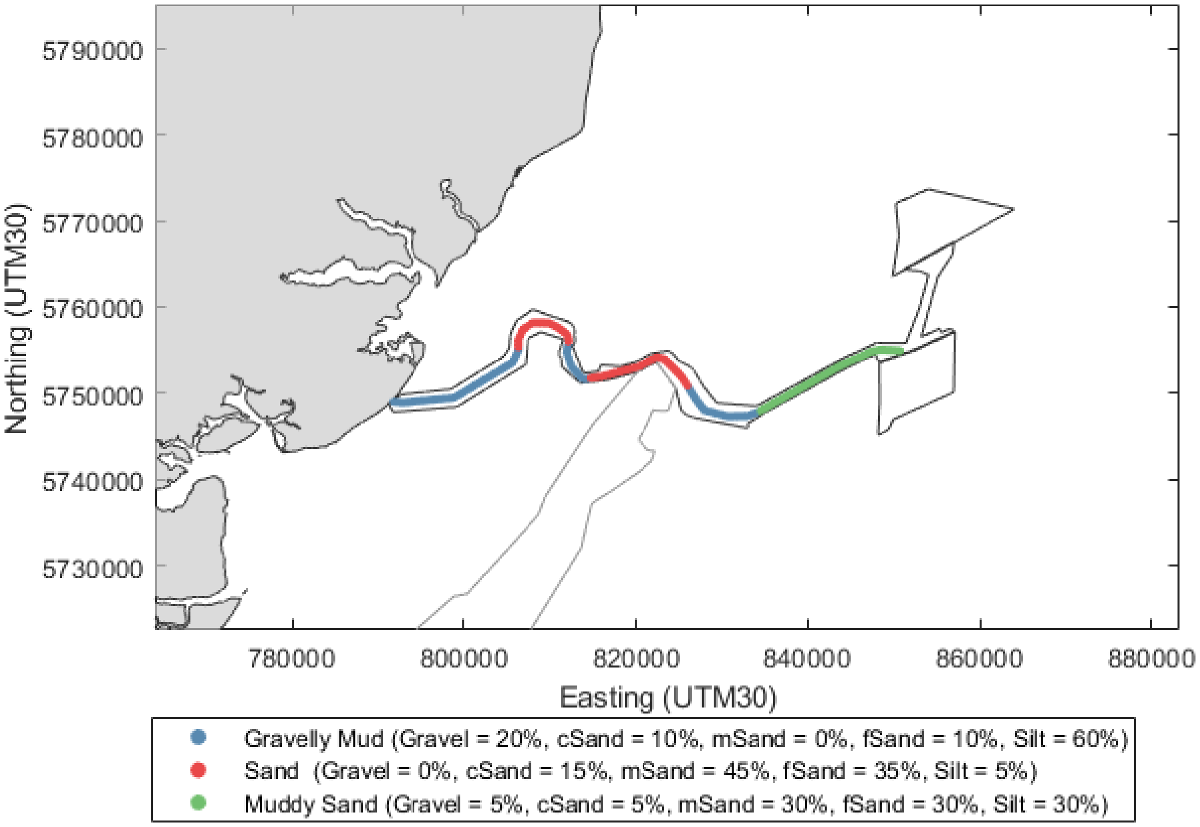


Figure 4.1: Assumed sediment type along the export cable corridor.

4.8.4 BGS grab samples for locations closest to the North Falls and East Anglia TWO wind farms are used to define the sediment composition representative of releases from these areas.

4.8.5 The proportion of sediment mass in each grain size fraction is accounted for in the number and mass of the individual particles released at each timestep within the models.

5 SEDIMENT PLUME MODEL RESULTS

5.1 OVERVIEW

5.1.1 This section presents the plume modelling results with respect to the likely nature of sediment plumes (footprint, concentration, duration) and resulting sediment deposition (footprint and thickness) as a result of the MDS sediment disturbance during the construction of VE OWF.

The following results are provided as Figure 7.1 to Figure 7.34 in Section 7:

- Results for each model scenario in Table 4.1.
- Maps of SSC at the end of the sediment disturbance, and one and three days later.
- Maps of maximum instantaneous SSC at any time throughout the model simulation period.
- Timeseries of SSC at a central location in the area of sediment disturbance.

The following results are provided as Figure 8.1 to Figure 8.5 in Section 8:

- Results for each model scenario in Table 4.1.
- Maps of settled sediment thickness at the end of the model simulation period.

5.1.2 Results for SSC describe an increase in SSC relative to the ambient naturally occurring condition.

5.1.3 Figure 1.1 shows the SACs and MCZs within the study area. To help identify the potential extent of plume interaction with these areas, SAC and MCZ boundaries have been overlaid on the plume modelling results. (It is noted here that the Southern North Sea SAC has not been included on the result maps: this is because this SAC is designated for harbour porpoise, rather than seabed habitat features.)

5.2 SEDIMENT PLUME SSC RESULTS

PLUMES FROM PRE-LAY TRENCHING, SANDWAVE CLEARANCE AND DRILLING (I.E. EXTENDED RELEASE PERIODS OVER MULTIPLE FLOOD/EBB CYCLES)

5.2.1 Maps of the increase in SSC as a result of pre-lay cable trenching using an MFE (moving nearbed source) are provided by Scenarios 1 to 4 for the array area, and Scenarios 17 and 18 for the export cable corridor, for neap and spring tidal conditions, respectively, in Section 7.

5.2.2 Maps of the increase in SSC as a result of local sandwave clearance using an MFE (static nearbed source) are provided by Scenarios 5 to 8 for the array area, Scenarios 19 and 20 for the middle of the export cable corridor, and Scenarios 23 and 24 for the nearshore end of the export cable corridor, for neap and spring tidal conditions, respectively, in Section 7.

5.2.3 Maps of the increase in SSC as a result of continuous drilling at one location (static surface source) are provided by Scenarios 9 to 12 for the array area, for neap and spring tidal conditions, respectively, in Section 7.

5.2.4 The following summary provides a general description and characterisation of the more detailed results shown in the Scenario images listed above. See the individual figures for site and scenario specific details of SSC and plume dimensions.

5.2.5 The plume feature resulting from continuous sediment disturbance activities is characterised as a long, relatively thin plume extending downstream from the point of active disturbance. Where the source is moving in the pre-lay trenching scenarios, the path of active disturbance in the simulation period is visible in the results images as a line of higher maximum instantaneous SSC, with elevated SSC regions extending from this aligned with the tidal axis.

5.2.6 The combined SSC from all sediment types is expected to be very high within 5 meters of the release location during active sediment disturbance (millions of mg/l within 5 m of the activity, i.e. more sediment than water in the local plume). This level of detail is not resolved directly by the sediment plume model, which indicates a more dispersed initial concentration of 1,000 to 10,000 mg/l. This initial elevated SSC effect is highly localised and will persist only while the disturbance continues in that specific area. As the sediment plume settles and disperses both vertically and horizontally over time and distance downstream, the SSC is anticipated to decrease to less than 1000 mg/l within tens of meters.

5.2.7 Gravels and sands will settle relatively quickly to the seabed (Table 1). At a representative higher current speed of 1 m/s during spring tides, these sediment types will settle from the maximum anticipated height of initial suspension (3 m above the bed) to the seabed within the following approximate distances from the release point: 5 m for gravels, 30 m for coarse sand, 90 m for medium sand, and 250-300 m for finer sands. This distance will be proportionally reduced during periods of lower current speed, such as times outside peak flow and generally around neap tides.

5.2.8 During spring tidal conditions, the disturbed sediment is carried away from the working area at a faster rate, dispersing the sediment mass over a larger area and water volume, and so the resulting SSC in the plume is relatively lower than on a comparable neap tide.

5.2.9 During slack water (on both neap and spring tides), water is not moving sediment away from the area of disturbance, resulting in suspended sediment accumulating in a local area of relatively higher SSC. This local area of higher SSC is subsequently advected by the tide and may take longer to reduce to background levels than other parts of the plume generated during non-slack water conditions.

5.2.10 The extended release scenarios (pre-lay trenching, sandwave clearance (MFE) and drilling) all exhibit the same general plume characteristics discussed here, but the SSC and size of the plume scales with the sediment release rate used to characterise each disturbance mechanism.

5.2.11 For all release scenarios discussed in this section (Scenarios 1-12, 17-20, 23-24), SSC is less than 5 mg/l everywhere three days after the disturbance has ended.

5.2.12 Sediment released within the MLS SAC along the export cable corridor (Scenarios 19-20) forms a spatially constrained plume with limited width/footprint this means that only a small proportion of the MLS SAC is affected by the increase in SSC for the limited duration it takes for the plume to be advected past by the tide. The path followed by the tidal ellipse is also not the same on every tide, therefore it is unlikely that the same area of seabed will be affected by elevated SSC within the localised plume for more than one or two consecutive tides. Following the end of the active release within the MLS SAC, SSC reduces rapidly to concentration of <5 mg/l within ~1 hour. One day after the release has ended, the plume has been fully dispersed and no elevated SSC is predicted.

5.2.13 Sediment released along the export corridor that aligns with the Kentish Knock East MCZ will create elevated SSC within the MCZ. However, the plume is spatially constrained with limited width/footprint. This means only a small proportion of the Knock East MCZ is likely to be affected by the increase in SSC for a limited duration, depending on the particular timing of tidal current speed and direction at the time of the activity. Also, as the MCZ is approximately 6 km from the closest point along the export cable corridor, the plume SSC will be already greatly reduced due to re-settlement of sediment, by the time it is advected into the MCZ. Following the end of the active release near the Knock East MCZ, SSC reduces rapidly to a concentration of <5 mg/l within ~1 hour. One day after the release has ended, the plume has been fully dispersed and no elevated SSC is predicted.

PLUMES FROM SPOIL DISPOSAL

5.2.14 Maps of the increase in SSC as a result of spoil disposal at the water surface from a TSHD are provided by Scenarios 13 to 16 for the array area, Scenarios 21 and 22 for the central export cable corridor, and Scenarios 25 and 26 for nearshore areas close to the landfall, for neap and spring tidal conditions, respectively, in Section 7.

5.2.15 The following summary provides a general description and characterisation of the more detailed results for each location shown in the figures listed above. See the individual figures for site and scenario specific details of SSC and plume dimensions.

5.2.16 The passive phase plume feature resulting from a spoil disposal event is characterised as an isolated circular plume, initially with higher concentration in the centre, decreasing with radial distance outwards.

5.2.17 Gravels and sands will settle relatively quickly towards the seabed (Table 1). From the maximum expected height of initial suspension (approximately 40 meters above the bed within the VE array area), these sediments are likely to resettle on the seabed, ceasing to increase SSC, within a 1 to 60 minutes. At a representative higher current speed of 1 m/s during spring tides, these sediments will settle to the bed within approximately 70 meters for gravel, 350 meters for coarse sand, 1,150 meters for medium sand, and 3,500 meters for finer sands from the release point. This distance will be proportionally shorter during periods of lower current speed, such as outside peak flow times and generally around neap tides. Fine sand and silt sized sediments persist in suspension for longer than relatively coarser sediment grain sizes (i.e. medium sand, coarse sand and gravels) and so control the majority of the effect on SSC beyond these durations/distances.

5.2.18 The proportion of silt in the seabed sediment being disturbed is greater in the nearshore area (60%) than in the cable corridor (5%) or array area (10%), and the water depth is also shallower, leading to proportionally higher SSC in the plume in the nearshore area from otherwise similar activities causing sediment plumes.

5.2.19 The level of SSC associated with all sediment fractions is realistically expected to be locally very high at the location of the spoil release (millions of mg/l within 5 m of the activity, i.e. more sediment than water in the local plume. This level of detail is not resolved directly by the sediment plume model, which indicates a more dispersed initial concentration of 1,000 to 10,000 mg/l.

5.2.20 Due to ongoing dispersion and the settlement of non-silt sediment to the seabed during the first half tidal cycle, the level of SSC associated with the remaining silt in the advected plume will reduce with time to less than 10 mg/l in central parts of the plume after one day, and to less than 2 mg/l after 3 days.

5.2.21 Spoil disposal within the MLS SAC along the ECC (Scenarios 21 and 22) forms a plume with limited width/footprint this means that only a small proportion of the MLS SAC is affected by the elevated increase in SSC for the limited duration it takes for the plume to be advected past by the tide. The limited width of the spoil disposal plume also means that only locations closely aligned to the disposal location along the tidal axis are likely to be measurably affected. In reality, it is highly unlikely that any spoil will be disposed of within the MLS SAC and as noted above in paragraph 4.2.4 any sediment removed from within the M&LS SAC will be deposited back within the SAC or within the same sediment cell.

5.3 SEABED SEDIMENT DEPOSITION RESULTS

BED LEVEL CHANGES ASSOCIATED WITH PLUMES FROM MFE

5.3.1 Estimates of the footprint and thickness of sediment deposition from MFE trenching are provided based on:

- The results of the sediment plume model; and
- Near-field spreadsheet model estimates (for all sediment types).

5.3.2 The sediment plume model results provide the more reliable description of settlement thickness in the far-field, i.e. for sediments that are subject to advection and dispersion over timescales greater than 1 hour and distances greater than 500-1000 m.

5.3.3 The near-field spreadsheet model provides a more generalised but demonstrably realistic range of potential deposition area/thickness combination estimates in the nearfield, i.e. for sediment of any type that is deposited more rapidly to the seabed in timescales less than 1 hour and distances less than 500-1000 m. Such estimates can provide a more reliable description of details in the nearfield that are not resolved spatially or temporally by the sediment plume model.

FAR-FIELD PLUME MODEL ESTIMATES

5.3.4 Maps of settlement thickness as a result of pre-lay cable trenching using an MFE are provided by Scenarios 1 to 4 for the array area, and Scenarios 17 and 18 for the export cable corridor, for neap and spring tidal conditions, respectively, in Section 8.

5.3.5 Maps of settlement thickness as a result of localised sandwave clearance using an MFE are provided by Scenarios 5 to 8 for the array area, Scenarios 19 and 20 for the middle of the export cable corridor, and Scenarios 23 and 24 for the nearshore end of the export cable corridor, for neap and spring tidal conditions, respectively, in Section 8.

5.3.6 The following summary provides a general description and characterisation of the more detailed results for each location shown in the figures listed above. See the individual figures for site and scenario specific details of settlement thickness and extent.

5.3.7 The results show the thickness of sediment following initial deposition. The same sediment may be subsequently re-eroded and resettled elsewhere as part of the ongoing natural sediment transport regime.

5.3.8 The predicted thickness of settlement is limited. The coarser sand and gravel fractions at each site settle to the seabed within a limited time of release (from seconds up to 5 minutes, i.e. within the 10 minute timestep of the sediment plume model) and so tend to be deposited within a relatively small footprint (from metres up to 200 m), resulting in a relatively greater local average thickness of 50 to 500 mm in the VE array area and 50 to 800 mm within the export cable corridor. The predicted thickness of settlement for only the finer sediments dispersed more widely in the passive phase plume at these locations is very limited, in the order of <2 mm in all sites, over a dispersed area of effect.

5.3.9 Sediment accumulation of this magnitude would not cause a measurable change in bed level or sediment type in practice, particularly considering the mobile nature of the seabed under baseline conditions. Fine sediments that do settle are also likely to experience further erosion and dispersion during subsequent tides.

5.3.10 A small area of deposited sediment is predicted in the northern corner of the MLS SAC where the ECC corridor overlaps the SAC. A maximum thickness of ~400 mm is predicted here when highly conservative assumptions representing sediment release from MFE are applied in the model (release rate = 1000 kg/s). This estimate is conservative in comparison to the working rate of the device (1000 m^3/hr, which corresponds to approximately 440 kg/s). Also the predicted region of deposition is very small, with the highest deposition (>300mm) predicted for an area of ~0.026 km^2.

NEAR-FIELD SPREADSHEET MODEL ESTIMATES

5.3.11 Coarser sediments (gravels and sands) will settle form the maximum height of disturbance (3 m above the bed) relatively rapidly towards the seabed and so the distance of advection and dispersion is realistically limited to distances within 5 m (gravel) to ~250-300 m (finer sands) downstream from the trench during representative stronger tidal current conditions (1 m/s). Distances will be proportionally less at times of lower current speed. The plume model does not resolve spatial details less than the resolution of the model mesh (<~100 m) and tidal current speed varies widely over flood and ebb, and spring and neap cycles. The following method provides a range of realistic estimates of deposition thickness within the nearfield.

5.3.12 The volume of sediment displaced from the trench is finite and proportional to the trench cross section (up to 6 m^2) and so it is possible to estimate the maximum average sediment thickness for a range of realistic downstream dispersion distances. Results are presented in Table 5.1. This calculation assumes that 100% of the material in the trench is fluidized and displaced, with the downstream dispersion occurring perpendicular to the trench axis. The VE ECC, however, follows a slightly shallower angle (approximately 45 degrees) oblique to the tidal axis along most of its length. Consequently, the predicted distances may be reduced, leading to a corresponding increase in thickness. Where the current direction is more oblique to the trench, the perpendicular distance from the trench to the edge of the deposit might be reduced, with a proportional increase in average thickness. In all cases, a larger footprint or extent of effect for any reason will result in a proportionally smaller average thickness of deposition, and *vice versa*.

Table 5.1: Maximum average sediment deposit thickness for a range of realistic downstream dispersion distances

Downstream Dispersion Distance (m)	Maximum Average Thickness of Sediment Accumulation (mm) for Varying Trench Cross Sections		
	4 m²	5 m²	6 m²
5	800	1,000	1,200
10	400	5,00	600
25	160	2,00	240
50	80	100	120
100	40	50	60
150	27	33	40
200	20	25	30
250	16	20	24
300	13	17	20

BED LEVEL CHANGES ASSOCIATED WITH PLUMES FROM SPOIL DISPOSAL

5.3.13 Estimates of the footprint and thickness of sediment deposition from dredge spoil disposal are provided based on:

- Sediment plume model predictions for the passive phase of the plume only.
- Near-field spreadsheet model estimates for the passive phase of the plume only (for all sediment types); and
- Near-field spreadsheet model estimates for the active phase of the plume only (for all sediment types).

5.3.14 The sediment plume model results provide the more reliable description of settlement thickness in the far field, i.e. for sediments that are subject to advection and dispersion over timescales greater than 1 hour and distances greater than 500-1000 m.

5.3.15 The near-field spreadsheet plume model provides a more generalised but demonstrably realistic range of potential deposition area/thickness combination estimates in the nearfield, i.e. for sediment of any type that is deposited more rapidly to the seabed in timescales less than 1 hour and distances less than 500-1000 m. Such estimates provide a more reliable description of details in the nearfield that are not resolved spatially or temporally by the sediment plume model.

5.3.16 The results from the plume model relate only to the sediment in the passive phase of the plume (i.e. 10% of the total sediment volume/mass being deposited). Results for the passive and active phases of the plume should be considered together in order to describe the full effect of the dredge spoil release.

PASSIVE PHASE – FAR-FIELD PLUME MODEL ESTIMATES

5.3.17 Maps of settlement thickness resulting from the passive phase of the plume (~10% of the sediment volume) during dredge spoil disposal are provided by Scenarios 13 to 16 for the array area, and Scenarios 21 and 22 for the export cable corridor, for neap and spring tidal conditions, respectively, in Section 8. The settlement thickness resulting from the active phase of the plume (~90% of the sediment volume) is considered separately in another section below.

5.3.18 The following summary provides a general description and characterisation of the more detailed results for each location and activity shown in the figures. See the individual figures for site and scenario specific details of settlement thickness and extent.

5.3.19 The results show the thickness of sediment following initial deposition. The same sediment is expected to immediately re-join the natural sedimentary environment and will be subsequently re-eroded and resettled elsewhere as part of the ongoing natural sediment transport regime.

5.3.20 The predicted thickness of settlement accounting for all sediment types in the passive phase plume is limited. The coarser sand and gravel fractions at each site settle to the seabed within a limited time of release (from minutes to 1 hour) and so tend to be deposited within a relatively small footprint. In the VE array area the deposit is highly constrained, remaining within 7km of the release location. The maximum deposited thickness is 10 to 40 mm. In the export cable corridor, the deposit is within 3km of the release location, with a maximum thickness of 25mm. Nearshore the deposit remains within 5km of the release location, a maximum deposited thickness of 50mm is predicted. The predicted average thickness of settlement for the finer sediments dispersed more widely in the passive phase plume at these locations is very limited, in the order of <2 mm in all sites, over a dispersed area of effect.

5.3.21 During spring tides, due to higher current speeds the deposits are dispersed more between the surface and the seabed, forming larger deposits with lower average local thickness.

5.3.22 Sediment accumulation of this magnitude would not cause a measurable change in bed level or sediment type in practice, particularly considering the mobile nature of the seabed under baseline conditions. Fine sediments that do settle are also likely to experience further erosion and dispersion during subsequent tides.

5.3.23 A small area of deposited sediment is predicted in the northern corner of the MLS SAC, with a thickness of ~25mm.

PASSIVE PHASE – NEAR-FIELD SPREADSHEET MODEL ESTIMATES

5.3.24 Coarser sediments (gravels and sands) in the passive plume will settle from the water surface (up to 40 m above the seabed in the VE array area) relatively rapidly towards the seabed and so the distance of advection and dispersion is realistically limited to distances within 70 m (gravel) to ~3,500 m (finer sands) downstream from the disposal site during representative stronger tidal current conditions (1 m/s on spring tides). Distances will be proportionally less at times of lower current speed (and during neap tides). The plume model does not resolve spatial details less than the resolution of the model mesh (~100 m) and tidal current speed varies widely over flood and ebb, and spring and neap cycles. The following method provides a range of realistic estimates for sediment thickness in the near field.

5.3.25 The total volume of sediment in the passive phase of the plume is limited (10% of 11,000 m^3 = 1,100 m^3) and so it is possible to estimate the maximum average sediment thickness for a range of realistic dispersion footprint dimensions. Results are presented in Table 5.2. These estimates conservatively assume that all sediment in the passive phase is deposited to the seabed, however, the silt fraction (comprising up to 60% of the sediment mass in the passive phase, depending on the location, see Table 4.1) will remain in suspension for longer (as described by the plume model results above) and will not contribute to these estimates.

Table 5.2: Maximum average sediment deposit thickness as a result of the passive plume for a range of realistic downstream dispersion distances.

Downstream Dispersion Distance (m)	**Maximum Average Thickness of Sediment Accumulation (mm) for Varying Dispersion Widths.**		
	50 m	100 m	200 m
100	220	110	55
250	88	44	22
500	44	22	11
750	29	15	7
1,000	22	11	6
2,000	11	6	3
3,000	7	4	2
4,000	6	3	1
5,000	4	2	1

ACTIVE PHASE – NEAR-FIELD SPREADSHEET MODEL ESTIMATES

5.3.26 The active phase of the plume will descend rapidly and directly to the seabed, where it will spread laterally, initially with the force of impact and then under gravity. The final shape or dimensions of the deposit therefore cannot be predicted in detail. The volume of sediment in the active phase of the plume is also limited (90% of 11,000 m^3 = 9,900 m^3) and so it is also possible to estimate the maximum average sediment thickness for a range of realistic dispersion footprint areas. Results are presented in Table 5.3.

Table 5.3 Maximum average sediment deposit thickness for a range of realistic active phase deposit dimensions and areas

Deposit Length Scale (m)	Deposit Footprint Area (m^2)*	Maximum Average Thickness of Sediment Accumulation (mm)
50	2,500	3,960
100	10,000	990
150	22,500	440
200	40,000	248
222	49,500	200
315	99,000	100
445	198,000	50
*Deposit footprint area = Deposit length scale^2		

5.4 TIDAL EXCURSION DISTANCE AND PLUME ADVECTION

5.4.1 The local extent of the sediment plume at any given time describes the instantaneous local magnitude and extent of elevated SSC. The plume is being almost continuously moved (advected) by the ambient currents. This section considers the distances and directions that the plume might be displaced from the source before it is dissipated to near background concentrations, and therefore the overall spatial extent that any local plume effects might be (temporarily) experienced.

5.4.2 The sediment plume is mainly advected from the source of the sediment disturbance by the ambient tidal currents. The relative motion (local speed and direction) of the plume at any given time in the tidal cycle will vary depending not only on the relative time in the flood ebb cycle, but also the spatially varying flow characteristics along the path of advection.

5.4.3 In open water, plume advection typically describes an elliptical path, which may or may not be closed, i.e. returning to approximately the same position at the end of the tidal cycle. In areas of more complex flow, the path may be more complex, e.g. following coastline or bathymetric features, and the path may not be necessarily closed. The distance that the plume is advected from the disturbance source (both along the tidal axis and laterally across it) describes the area over which any effects on SSC are likely to occur. Conversely, areas beyond the tidal excursion distance and footprint are unlikely to experience any effect on SSC from the plume.

5.4.4 The displacement of the plume features by tidal currents provides a proxy measure of the tidal excursion distance from each of the release locations for representative neap and spring range conditions. The path of the plume (including changes in flow speed and direction elsewhere in the model domain) provides a 'Lagrangian' estimate. In areas of more complex flow (e.g. near to headlands and estuaries), this can provide a more realistic measure than the alternative 'Eularian' estimate (based on the net displacement of water past a particular location).

5.4.5 The tidal excursion distance is the approximate distance over which a package of water (or a section of plume with elevated SSC) is advected during one flood or ebb tide.

5.4.6 The values below were determined based on the observed advection of the plume features in the sediment plume model results, over multiple flood and ebb cycles, during representative mean neap and mean spring tidal range conditions. There can be variation in the peak current speed between consecutive flood and ebb tides, therefore, a small range of tidal excursion distances are presented for tidal ranges representative of mean neap and mean spring conditions.

5.4.7 The tidal excursion distance varies in proportion to the peak current speed during particular flood or ebb cycles. As such, the distance may also be smaller than the mean neap conditions (on smaller than mean neap tidal ranges) and occasionally larger than the mean spring condition (on larger than mean spring tidal ranges).

5.4.8 In the north VE array area:

- On neap tides, the tidal excursion distance is between ~7-8 km, depending on the peak flow speed during that half tidal cycle.
- On spring tides, the tidal excursion distance is between ~16-17 km, depending on the peak flow speed during that half tidal cycle.

5.4.9 In the south VE array area:

- On neap tides, the tidal excursion distance is between ~6-7 km, depending on the peak flow speed during that half tidal cycle.
- On spring tides, the tidal excursion distance is between ~16-17 km, depending on the peak flow speed during that half tidal cycle.

5.4.10 In the middle part of the VE export cable corridor:

- On neap tides, the tidal excursion distance is between ~5-6 km, depending on the peak flow speed during that half tidal cycle.
- On spring tides, the tidal excursion distance is between ~15-16 km, depending on the peak flow speed during that half tidal cycle.

5.4.11 In the nearshore area close to the landfall of the VE export cable corridor:

- On neap tides, the tidal excursion distance is ~4 to 5 km.
- On spring tides, the tidal excursion distance is ~8 to 9 km.

5.5 POTENTIAL CUMULATIVE INTERACTION

SUSPENDED SEDIMENT CONCENTRATION

5.5.1 Maps of the increase in SSC as a result of aggregate extraction within the active licensed areas are provided by Scenarios 27 and 28, for neap and spring tidal conditions, respectively, in Section 7.

5.5.2 Maps of the increase in SSC as a result of drilling are provided by Scenarios 29 and 30 for the North Falls and East Anglia TWO array areas, for neap and spring tidal conditions, respectively, in Section 7.

5.5.3 Maps of the increase in SSC as a result of sandwave clearance using an MFE are provided by Scenarios 31 and 32 for the North Falls and East Anglia TWO array areas, for neap and spring tidal conditions, respectively, in Section 7.

5.5.4 Maps of the increase in SSC as a result of spoil disposal are provided by Scenarios 33 and 34 for the North Falls and East Anglia TWO array areas, for neap and spring tidal conditions, respectively, in Section 7.

5.5.5 Meaningful sediment plume interaction generally only has the potential to occur if the activities generating the sediment plumes are located within one spring tidal excursion ellipse from one another and occur at the same time.

5.5.6 The North Falls array areas are located to the west of the VE Offshore array areas with respect to the tidal axis, which means that overlap and interaction between plumes created by activities at North Falls array and activities in the VE Array Area are very unlikely – as supported by the modelled VE array and North Falls array plume footprints.

5.5.7 Overlap and interaction between plumes created in the North Falls array areas and the VE export cable corridor are possible, but the limited footprint and transient nature of the plumes created from disturbance activities in these individual locations suggest any cumulative impacts will be of low magnitude and short duration. The potential area of cumulative influence may overlap the Kentish Knock East MCZ; however, any cumulative change in SSC will be of low magnitude and short duration. No cumulative increase in SSC will occur at the MLS SAC.

5.5.8 Overlap and interaction between plumes created in the south of East Anglia TWO array area and the north of the VE array area are possible, however the limited footprint and transient nature of the plumes created from disturbance activities in these individual locations suggest any cumulative impacts will be small and short-lived.

5.5.9 The plume generated in the south of the East Anglia TWO array area is beyond a tidal excursion ellipse distance from the VE ECC, meaning that overlap and interaction between plumes created by activities at the East Anglia TWO array and activities in the VE ECC is very unlikely.

5.5.10 The majority of the aggregate dredging sites are located to the east of the VE array areas with respect to the tidal axis, which means that overlap and interaction between plumes created by aggregate dredging at these sites and activities in the Offshore array areas are very unlikely – as supported by the modelled VE array and aggregate extraction plume footprints. The plume from the aggregate extraction site 524 has the potential to overall and interact with plumes created in the southern VE array area, however the limited footprint and transient nature of the plumes created from disturbance activities in these individual locations suggest any cumulative impacts will be small and short-lived.

5.5.11 Some overlap of aggregate extraction and VE ECC plumes might occur in the central section of the export cable corridor only, however the limited footprint and transient nature of the plumes created from disturbance activities in these individual locations suggest any cumulative impacts will be small and short-lived.

SEABED SEDIMENT DEPOSITION

5.5.12 Maps of settlement thickness as a result of aggregate extraction within the active licensed areas are provided by Scenarios 27 and 28, for neap and spring tidal conditions, respectively, in Section 8.

5.5.13 Maps of settlement thickness as a result of drilling are provided by Scenarios 29 and 30 for the North Falls and East Anglia TWO array areas, for neap and spring tidal conditions, respectively, in Section 8

5.5.14 Maps of settlement thickness as a result of sandwave clearance using an MFE are provided by Scenarios 31 and 32 for the North Falls and East Anglia TWO array areas, for neap and spring tidal conditions, respectively, in Section 8

5.5.15 Maps of settlement thickness as a result of spoil disposal are provided by Scenarios 33 and 34 for the North Falls and East Anglia TWO array areas, for neap and spring tidal conditions, respectively, in Section 8.

5.5.16 There are no overlapping areas of deposition between the North Falls array release and the VE array releases. However, there is potential for overlap between deposits from the East Anglia TWO array and the north VE array. The spatial extent of the area where bed deposition from both events occurs is minimal, with the magnitude of bed deposition from each release location being less than 5mm. Consequently, the cumulative deposition is expected to be very small, likely less than 10mm.

5.5.17 Bed deposition arising from aggregate extraction at site 524 is the only scenario that results in cumulative deposition with the VE array area releases. However, the magnitude of deposition in the area of overlap is small, less than 10mm. There are no other overlapping areas of deposition between the aggregate extraction releases and the VE array releases.

5.5.18 There is some potential for overlap between the VE export cable corridor pre-lay trenching deposition and the aggregate extraction deposition footprints arising from extraction areas 509, and 510. These areas of cumulative deposition are highly constrained due to the small deposition footprint from the aggregate extraction releases. Additionally, no cumulative deposition is predicted within the MLS SAC. The magnitude of bed deposition from the individual events within these areas of cumulative deposition is typically less than 50mm. Consequently, the cumulative deposition is expected to be small, likely less than 100mm.

6 CONCLUSION

6.1.1 To address the Relevant Representation provided by Natural England (10.1.1. Response to Natural England's Relevant Representations)). Numerical sediment plume modelling has been carried out to supplement the initial spreadsheet-based analysis presented in the Environmental Statement Chapter (6.2.2 Marine Geology, Oceanography and Physical Processes – [APP-071]).

6.1.2 The results of this sediment plume modelling study complement (rather than supersede) those already presented in (6.2.2 Marine Geology, Oceanography and Physical Processes – [APP-071]), addressing the concerns raised by Natural England in their Relevant Representation (10.1.1. Response to Natural England's Relevant Representations). The numerical modelling approach delivers a more detailed analysis of SSC and sediment deposition patterns compared to the original spreadsheet-based methods.

6.1.3 For continuous disturbances such as pre-lay trenching, the plumes are characterized as long and thin, aligned with tidal currents, and do not affect the same area of the seabed for more than one or two consecutive tides due to the variability of tidal ellipses. Instantaneous spoil release events create an isolated circular plume, initially with higher concentration in the centre, decreasing with radial distance outwards.

6.1.4 The coarser sand and gravel fractions at each site settle to the seabed within a limited time of release (from seconds up to 5 minutes) and so tend to be deposited within a relatively small footprint (from metres up to 200 m), resulting in a relatively greater local average thickness of 50 to 500 mm in the VE array area and 50 to 800 mm within the export cable corridor. The predicted deposition for the finer sediments is dispersed, resulting in relatively small average thicknesses, in the order of <2 mm over the affected area.

6.1.5 Cumulative impacts from other activities, such as aggregate extraction and other wind farm construction projects, are also shown to be limited. Meaningful plume interaction can only occur if activities are located within the same spring tidal excursion ellipse and occur simultaneously. Given the limited footprint and transient nature of the individual plumes, any cumulative effects are expected to be small and short-lived.

6.1.6 The findings confirm that the changes in SSC and deposition in within designated areas of seabed, including SACs and MCZs, are limited. Notably, the predicted changes in SSC and sediment deposition are largely confined to the vicinity of construction activities, with minimal overlap into designated conservation areas.

6.1.7 This report strengthens the ES by providing quantitative evidence that the project's potential environmental impacts have been thoroughly assessed, reinforcing the conclusion that the Project will not lead to large, persistent changes to SSC and bed sediment thickness.

7 REFERENCES

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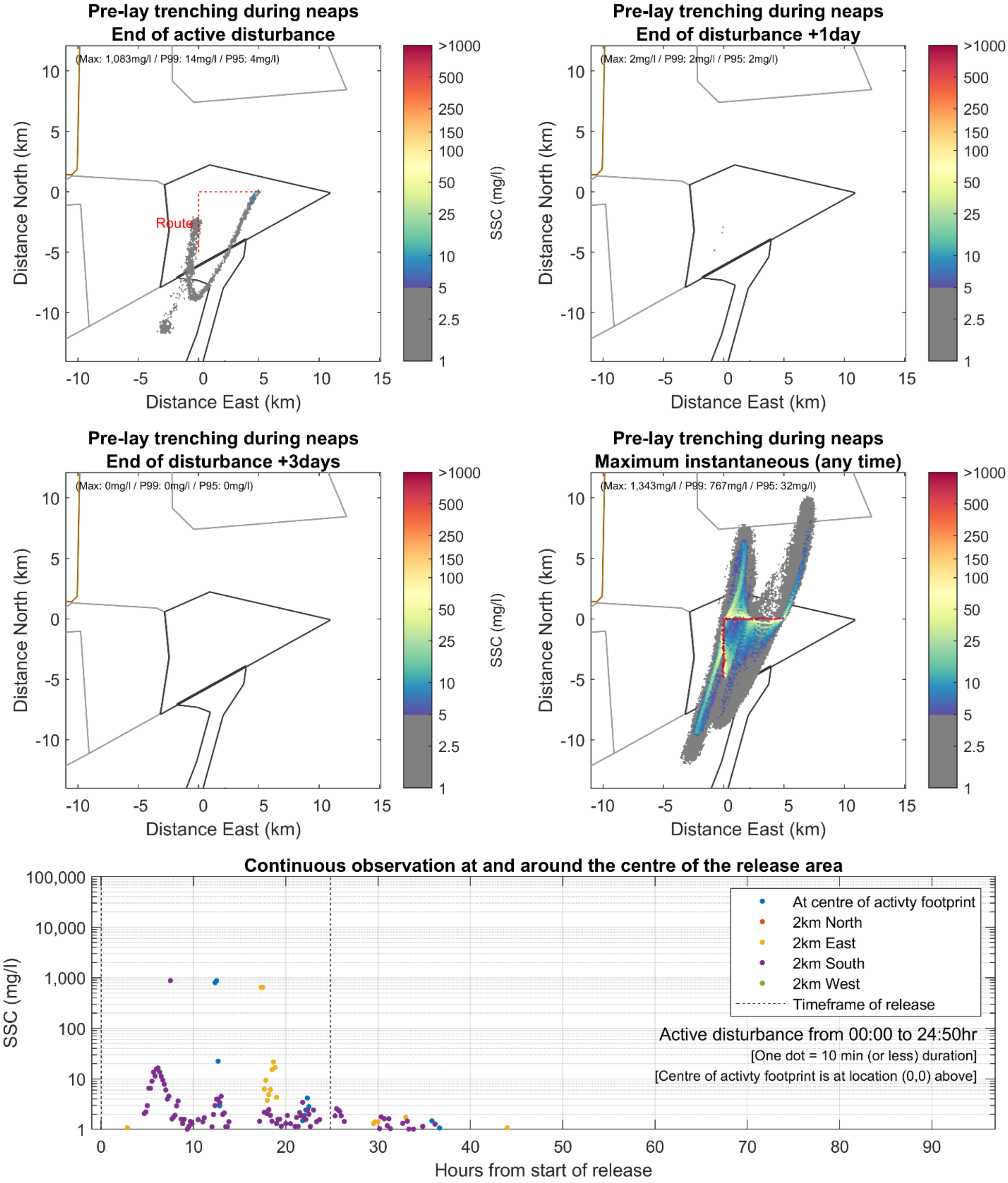
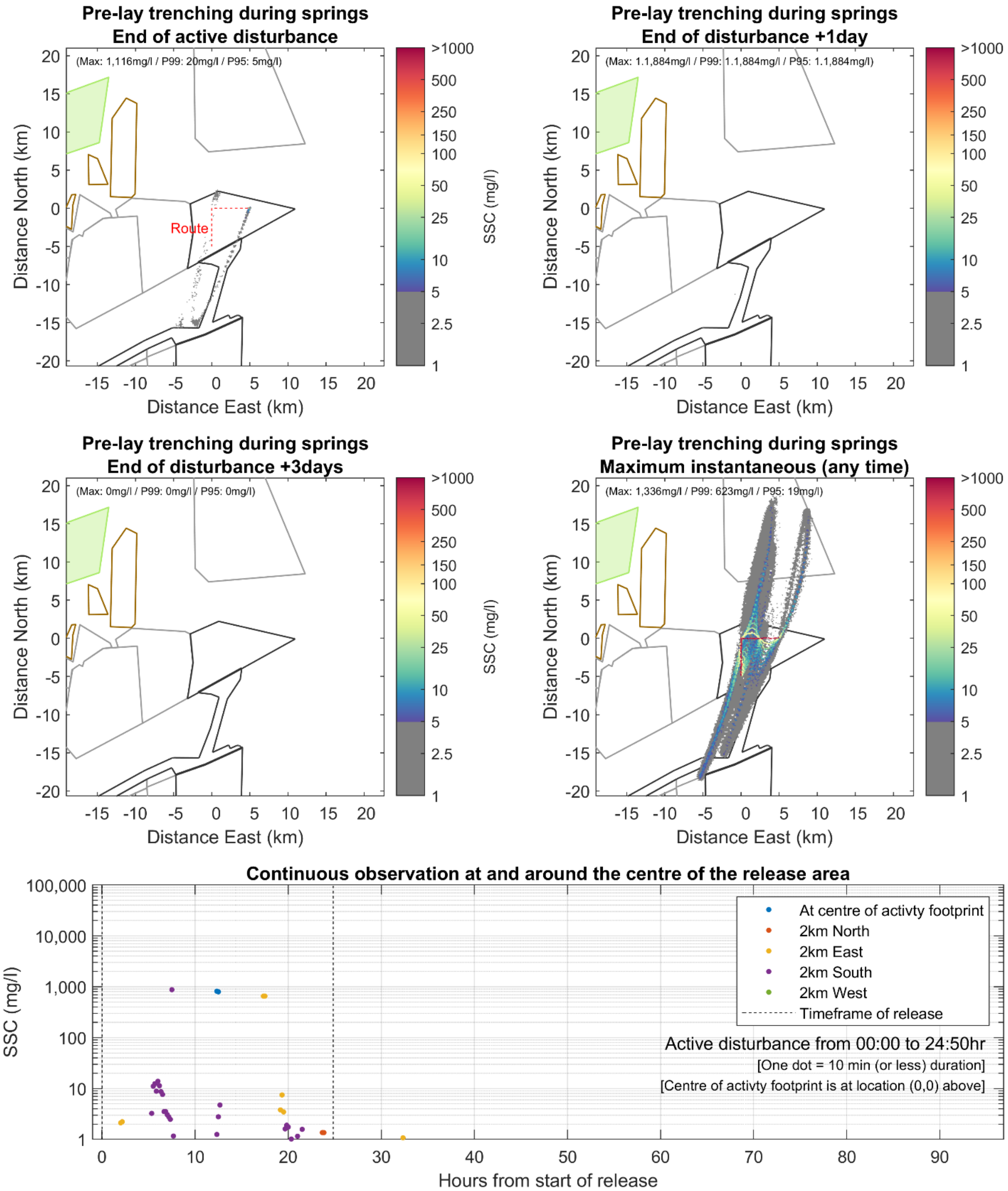
8 APPENDIX A – FAR FIELD PLUME MODEL RESULTS – SUSPENDED SEDIMENT CONCENTRATION FIGURES



The red dashed line indicates the modelled MFE trenching release route. The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. Licensed aggregated extraction sites are outlined in brown.

Figure 7.1: Increase in suspended sediment concentration as a result of Scenario 1: pre-lay trenching using an MFE in the northern VE array area. Mean neap tide.



Pre-lay trenching during springs
End of active disturbance

Pre-lay trenching during springs
End of disturbance +1day

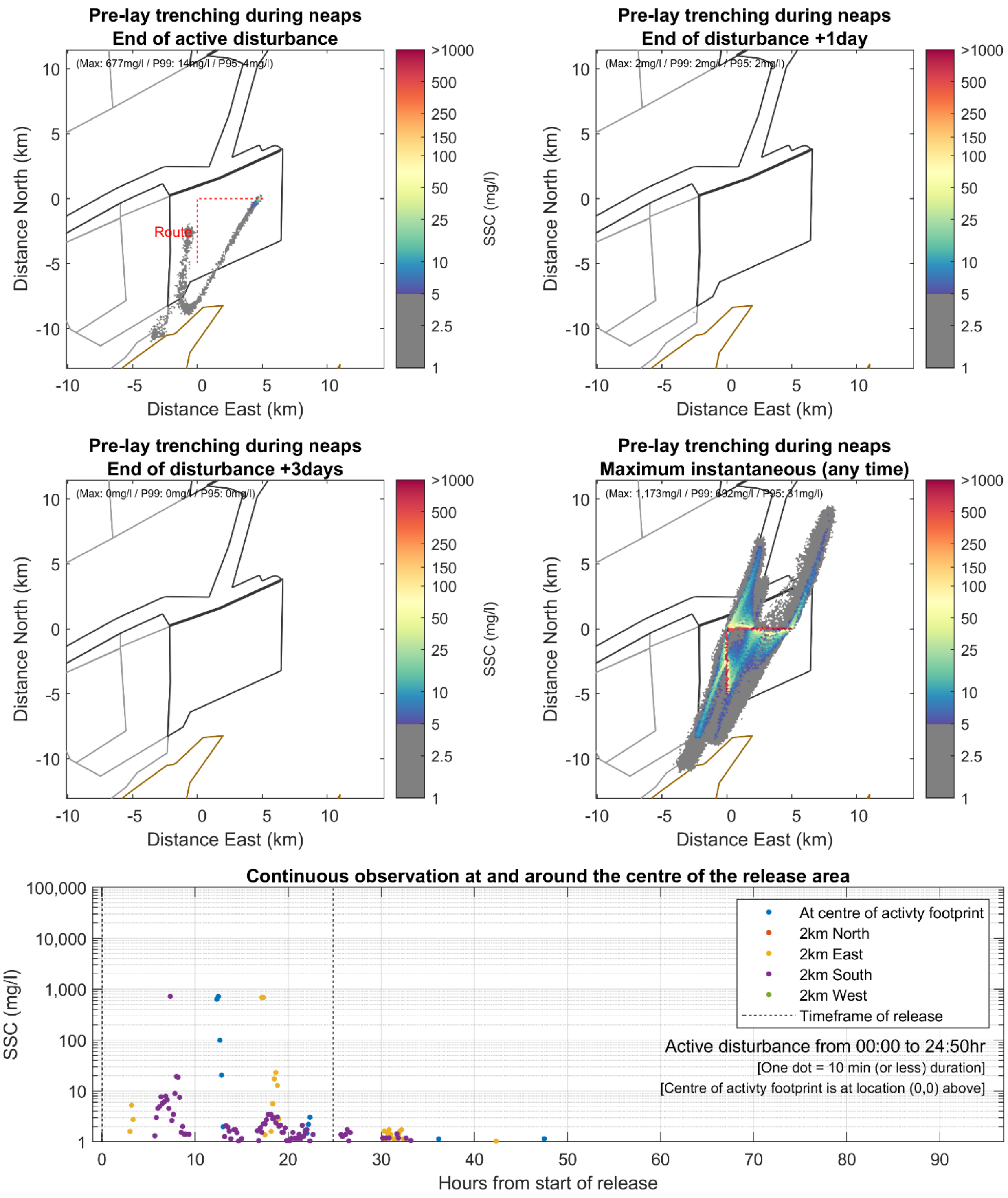
Pre-lay trenching during springs
End of disturbance +3days

Pre-lay trenching during springs
Maximum instantaneous (any time)

Continuous observation at and around the centre of the release area

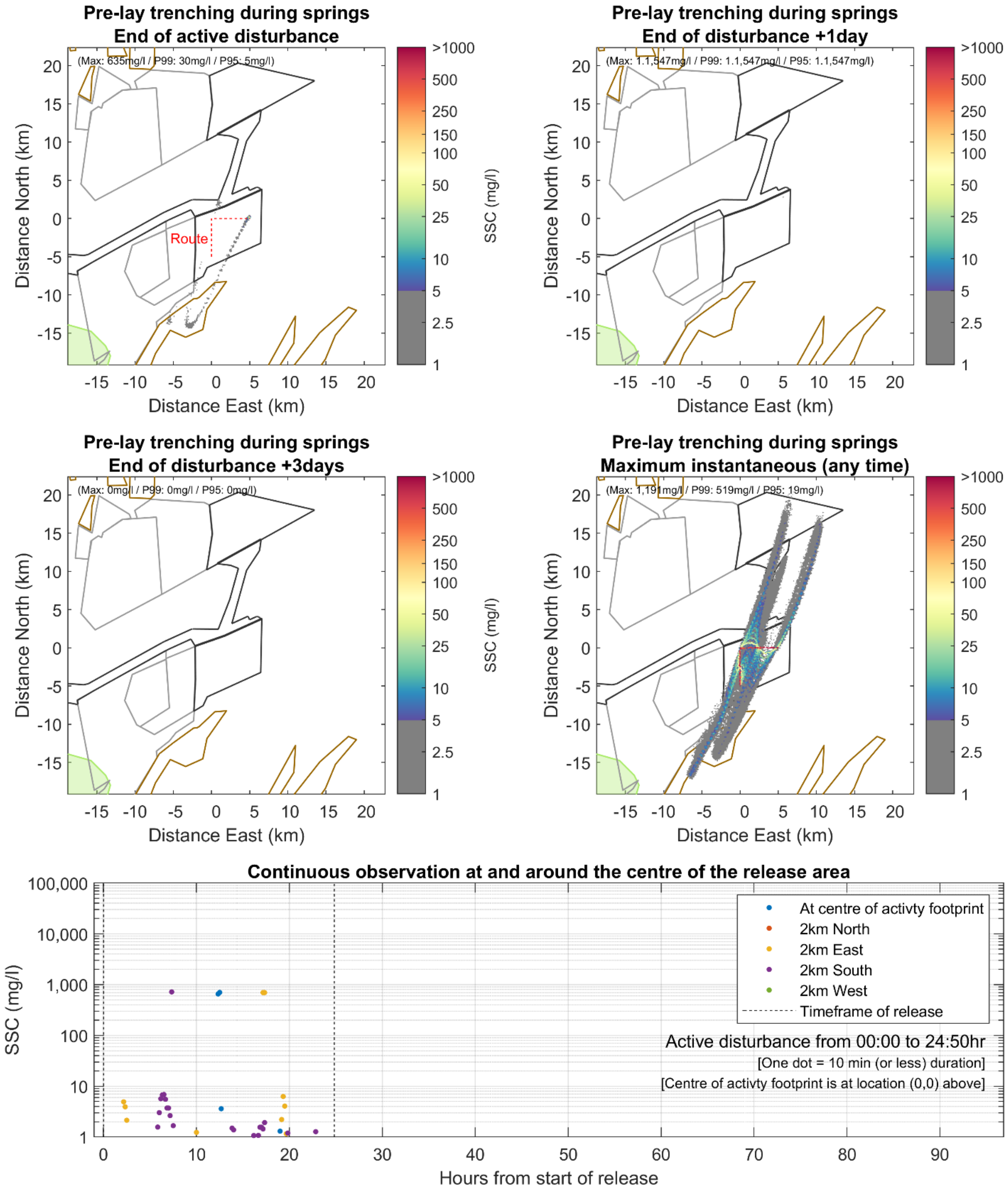
The red dashed line indicates the modelled MFE trenching release route. The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.2: Increase in suspended sediment concentration as a result of Scenario 2: pre-lay trenching using an MFE in the northern VE array area. Mean spring tide.



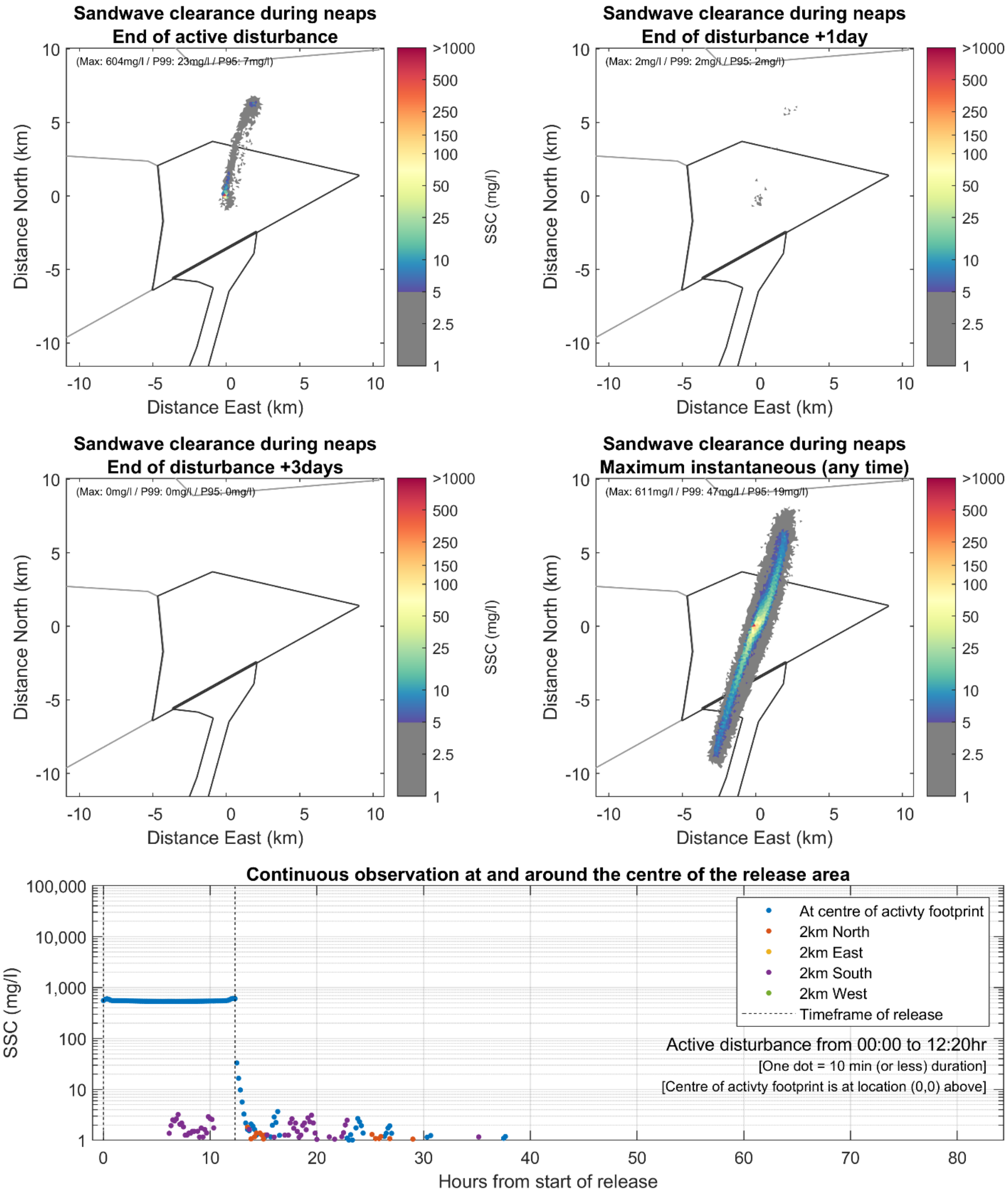
The red dashed line indicates the modelled MFE trenching release route. The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. Licensed aggregated extraction sites are outlined in brown.

Figure 7.3: Increase in suspended sediment concentration as a result of Scenario 3: pre-lay trenching using an MFE in the VE array area. Mean neap tide.



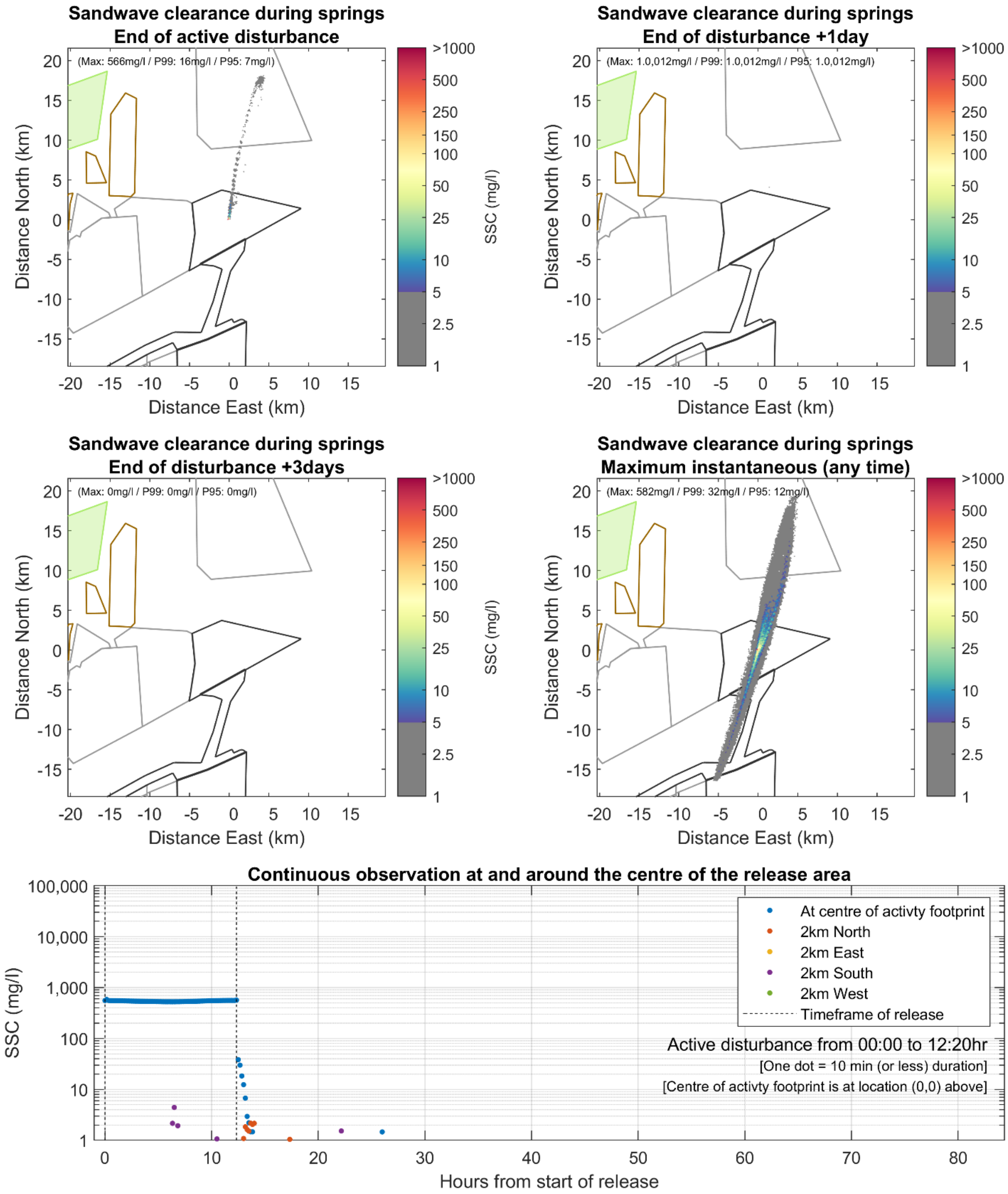
The red dashed line indicates the modelled MFE trenching release route. The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.4: Increase in suspended sediment concentration as a result of Scenario 4: pre-lay trenching using an MFE in the southern VE array area. Mean spring tide.



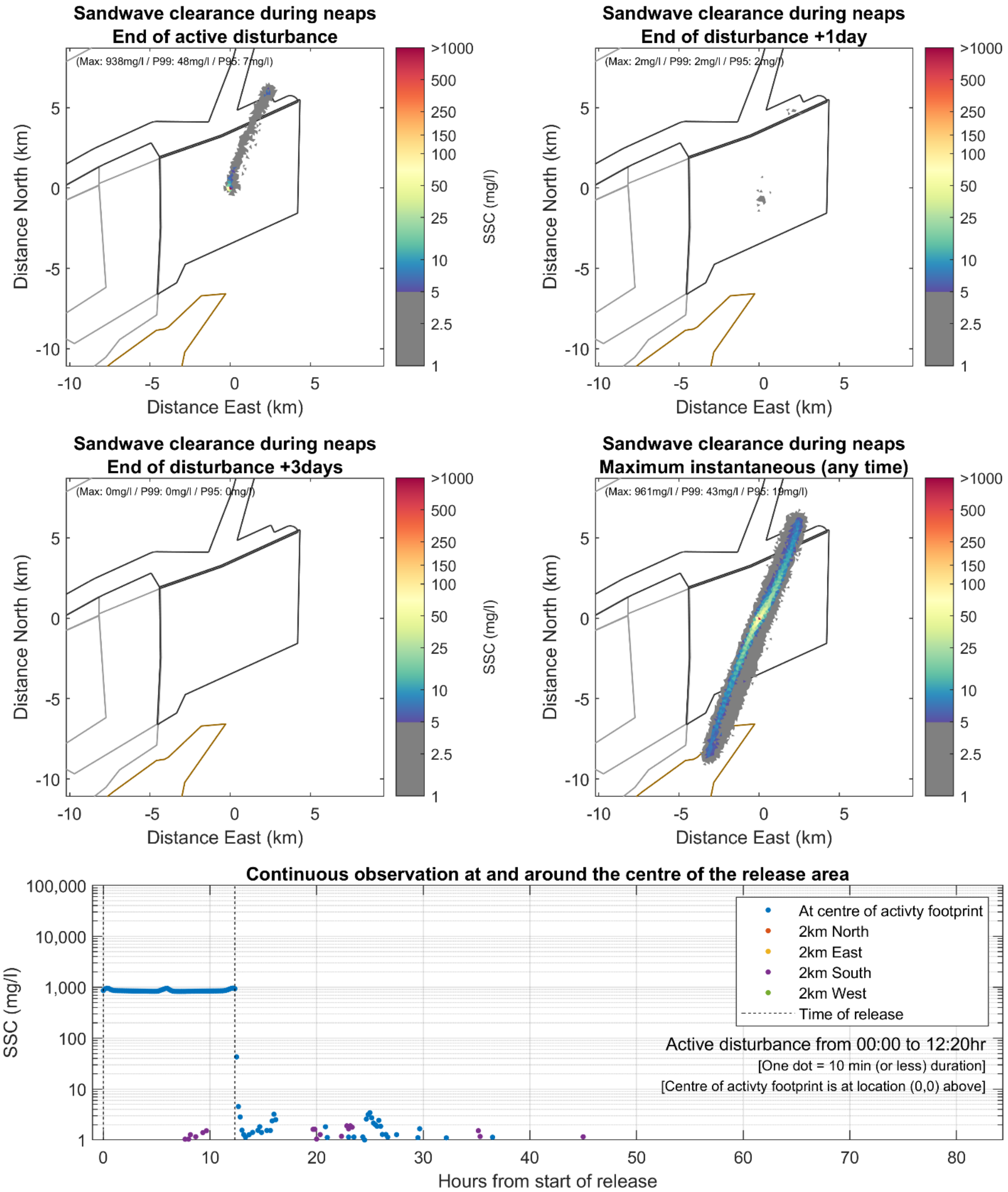
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey.

Figure 7.5: Increase in suspended sediment concentration as a result of Scenario 5: sand wave clearance using an MFE in the northern VE array area. Mean neap tide.



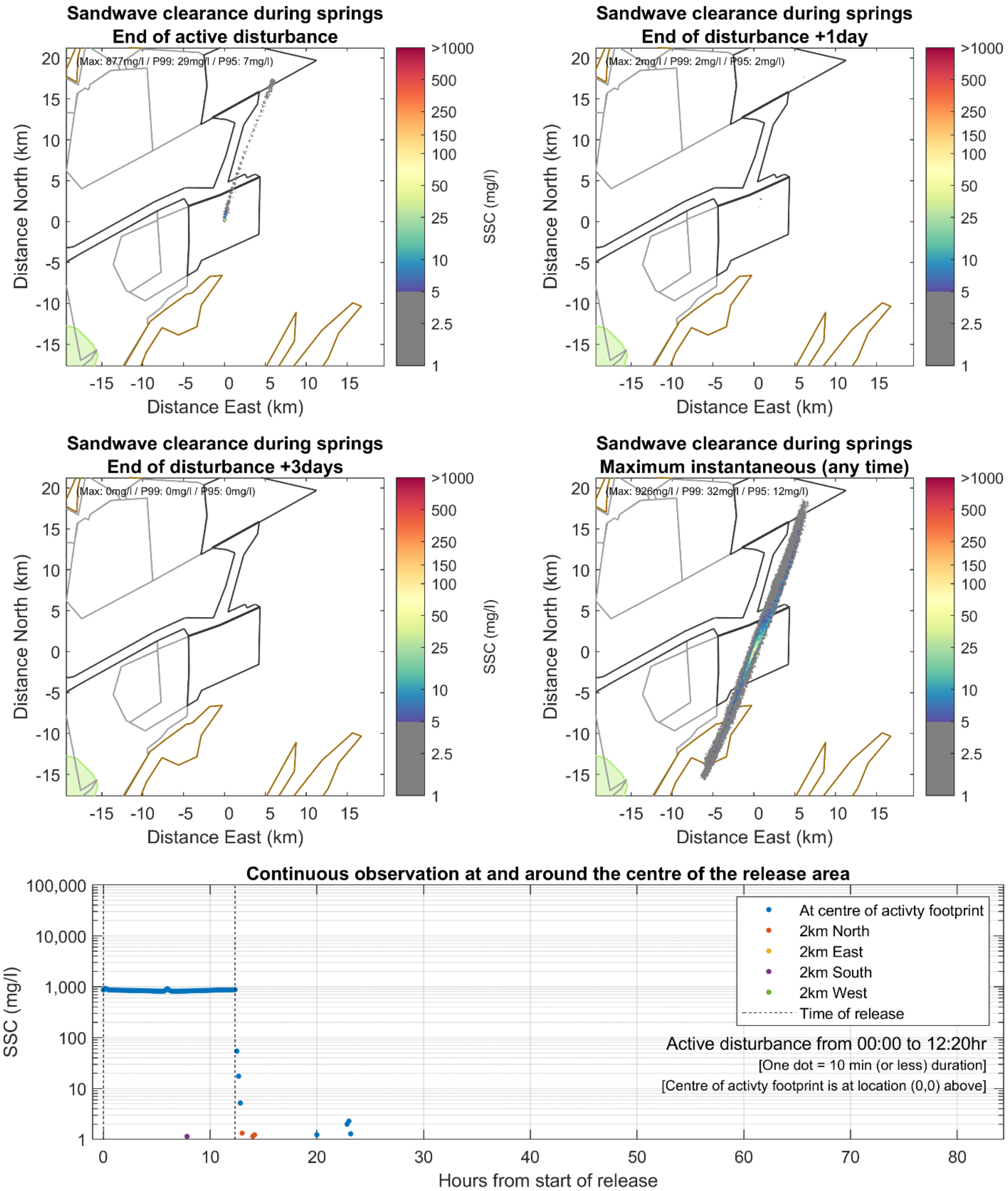
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.6: Increase in suspended sediment concentration as a result of Scenario 6: sand wave clearance using an MFE in the northern VE array area. Mean spring tide.



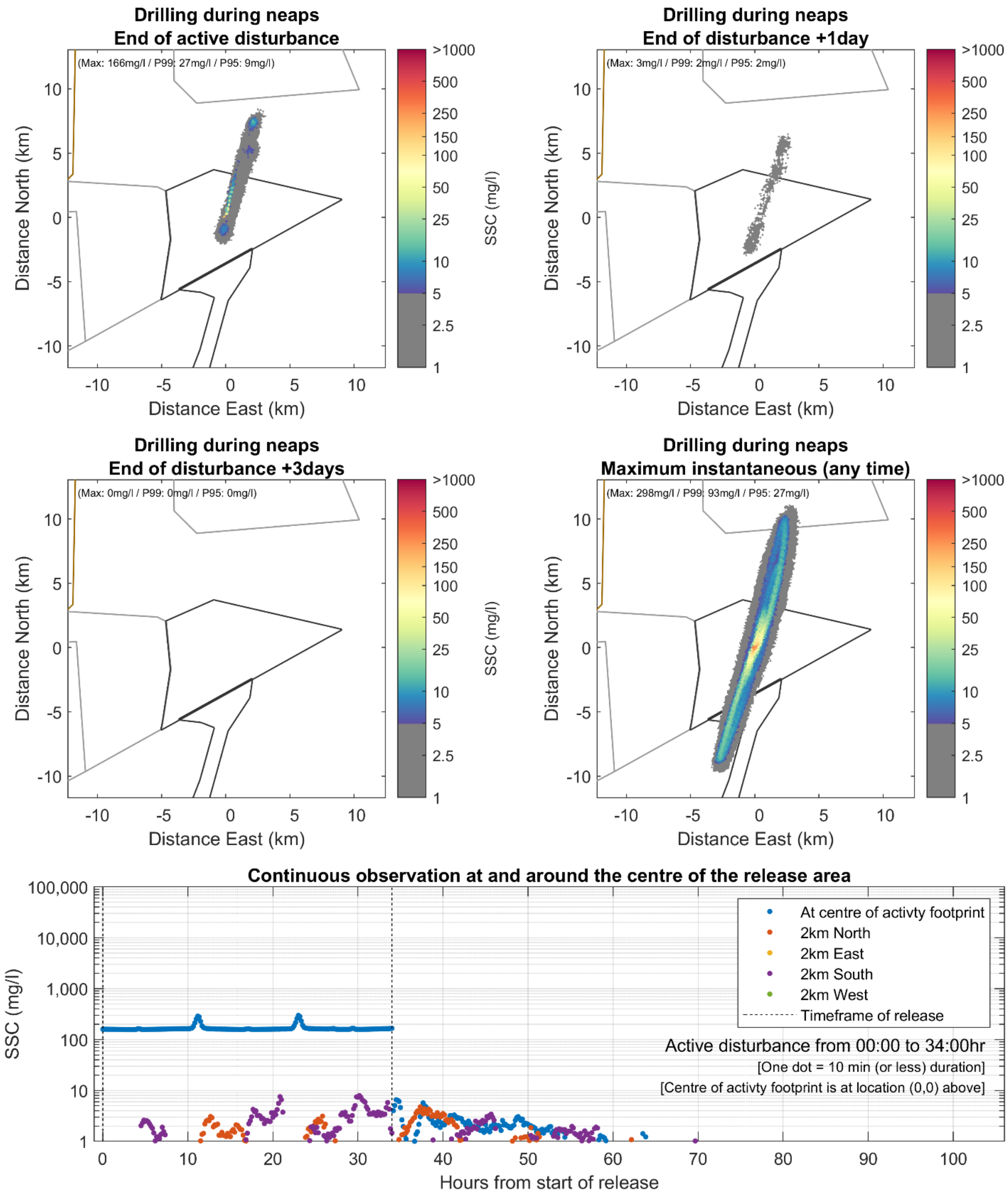
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. Licensed aggregated extraction sites are outlined in brown.

Figure 7.7: Increase in suspended sediment concentration as a result of Scenario 7: sand wave clearance using an MFE in the southern VE array area. Mean neap tide.



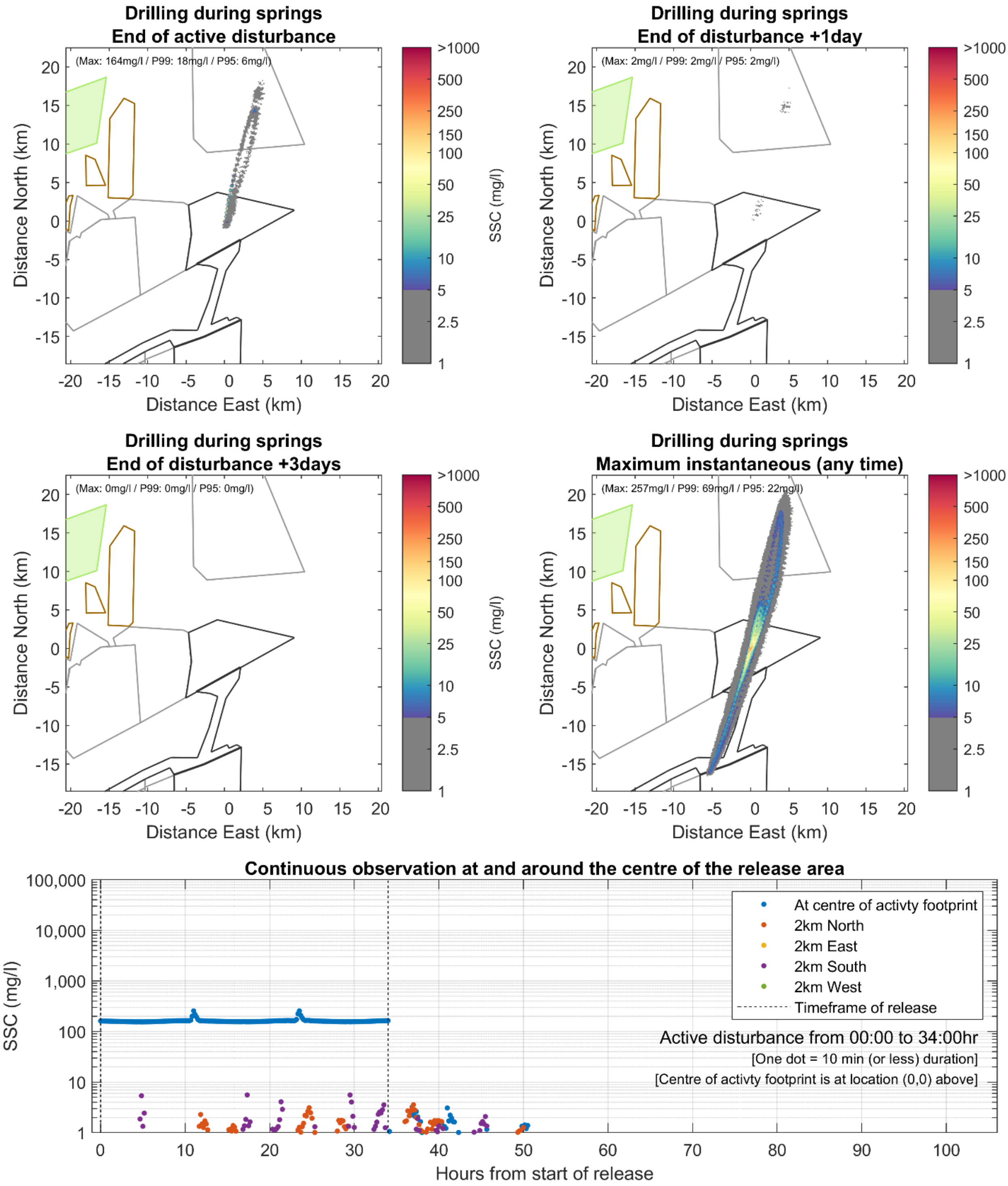
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.8: Increase in suspended sediment concentration as a result of Scenario 8: sand wave clearance using an MFE in the southern VE array area. Mean spring tide.



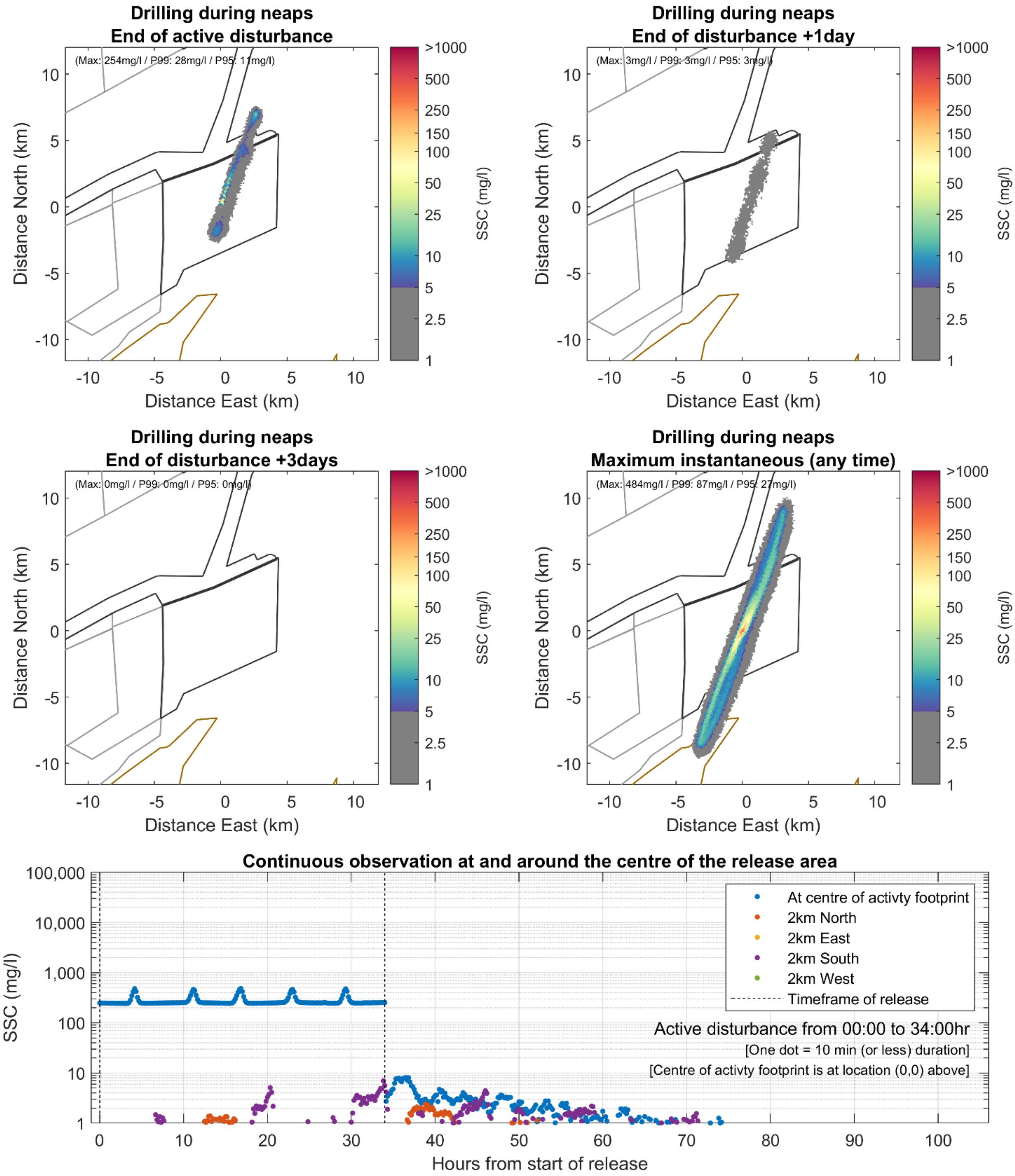
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. Licensed aggregated extraction sites are outlined in brown.

Figure 7.9: Increase in suspended sediment concentration as a result of Scenario 9: drilling a large monopile in the northern VE array area. Mean neap tide.



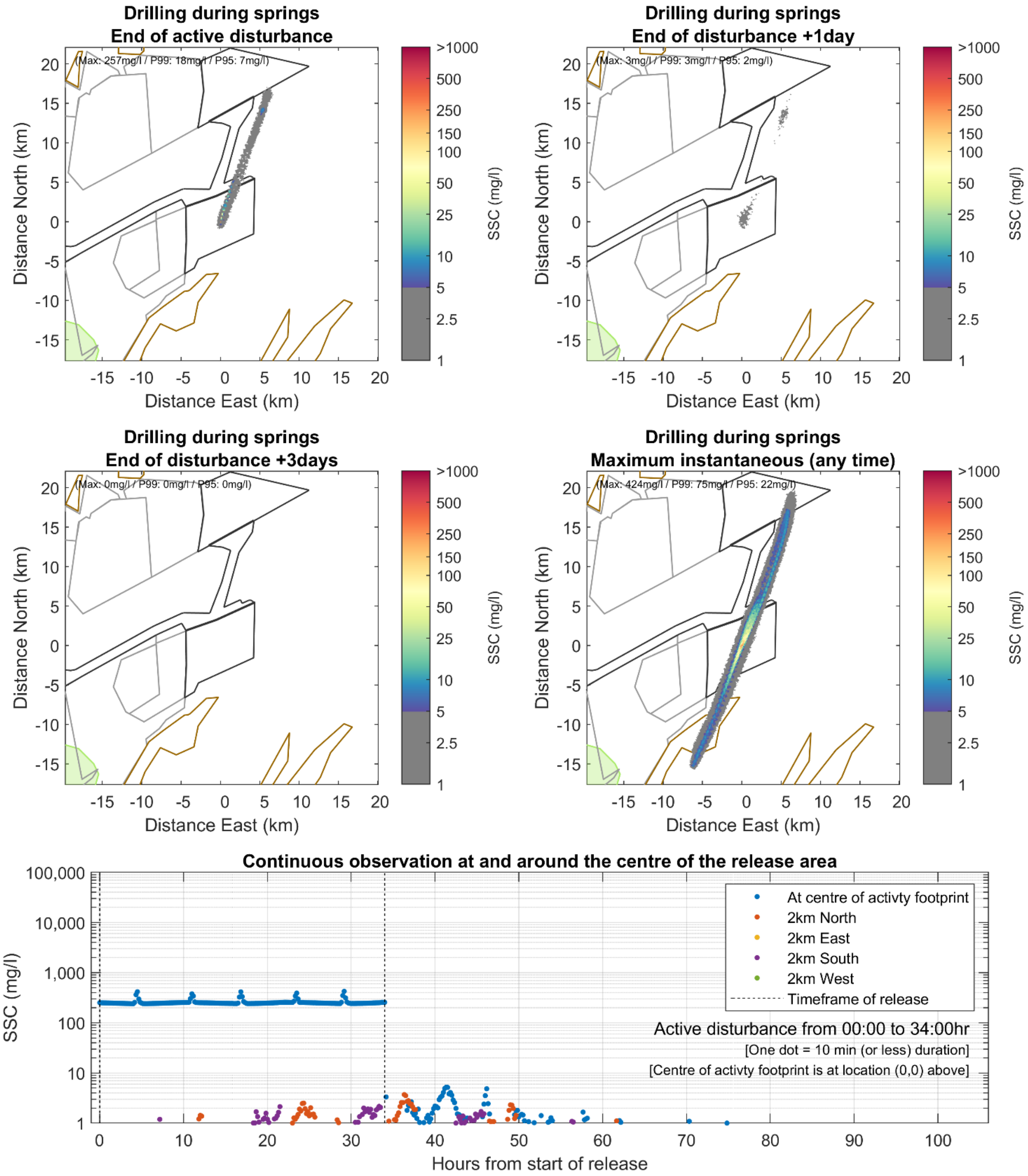
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.10: Increase in suspended sediment concentration as a result of Scenario 10: drilling a large monopile in the northern VE array area. Mean spring tide.



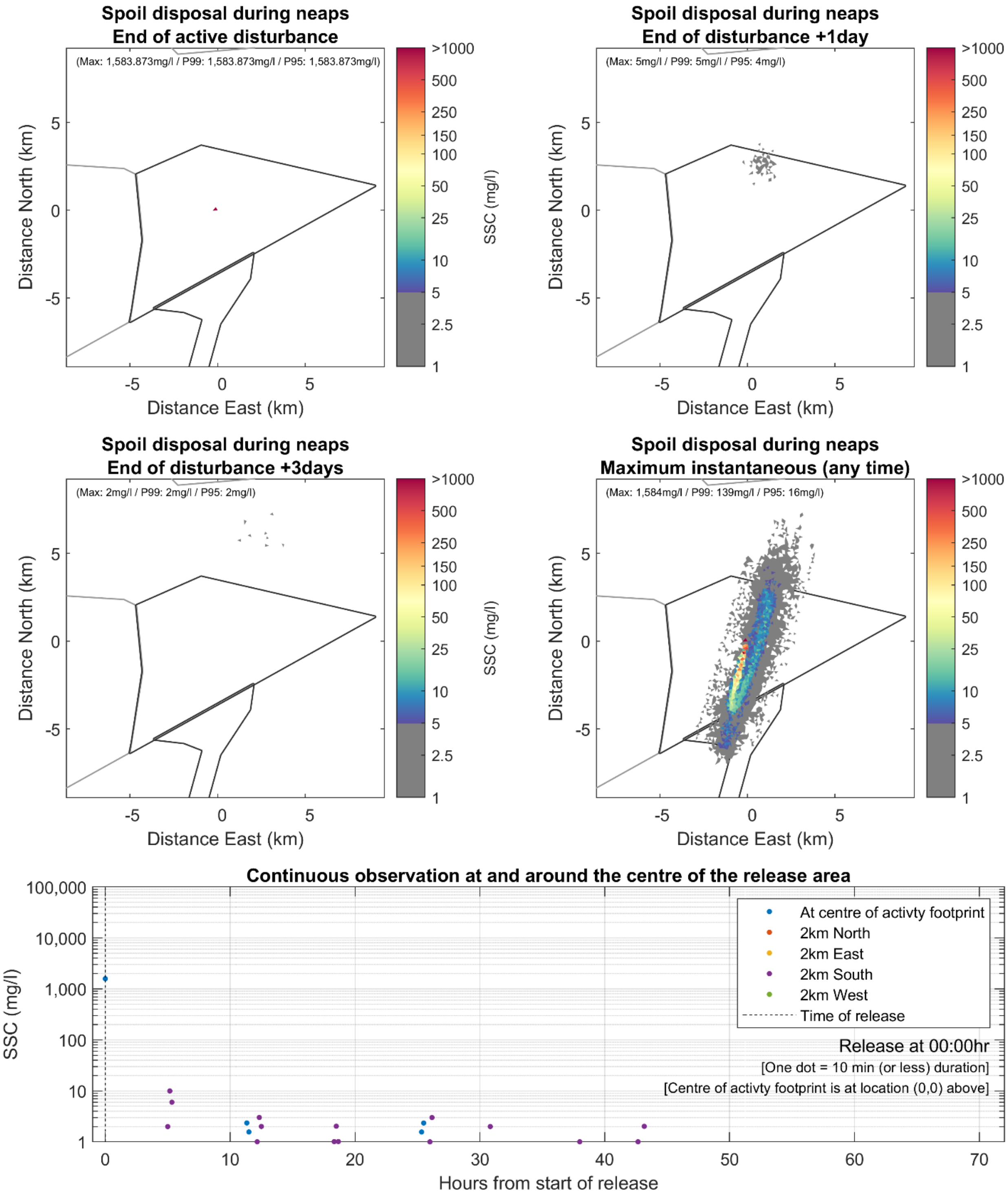
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. Licensed aggregated extraction sites are outlined in brown.

Figure 7.11: Increase in suspended sediment concentration as a result of Scenario 11: drilling a large monopile in the southern VE array area. Mean neap tide.



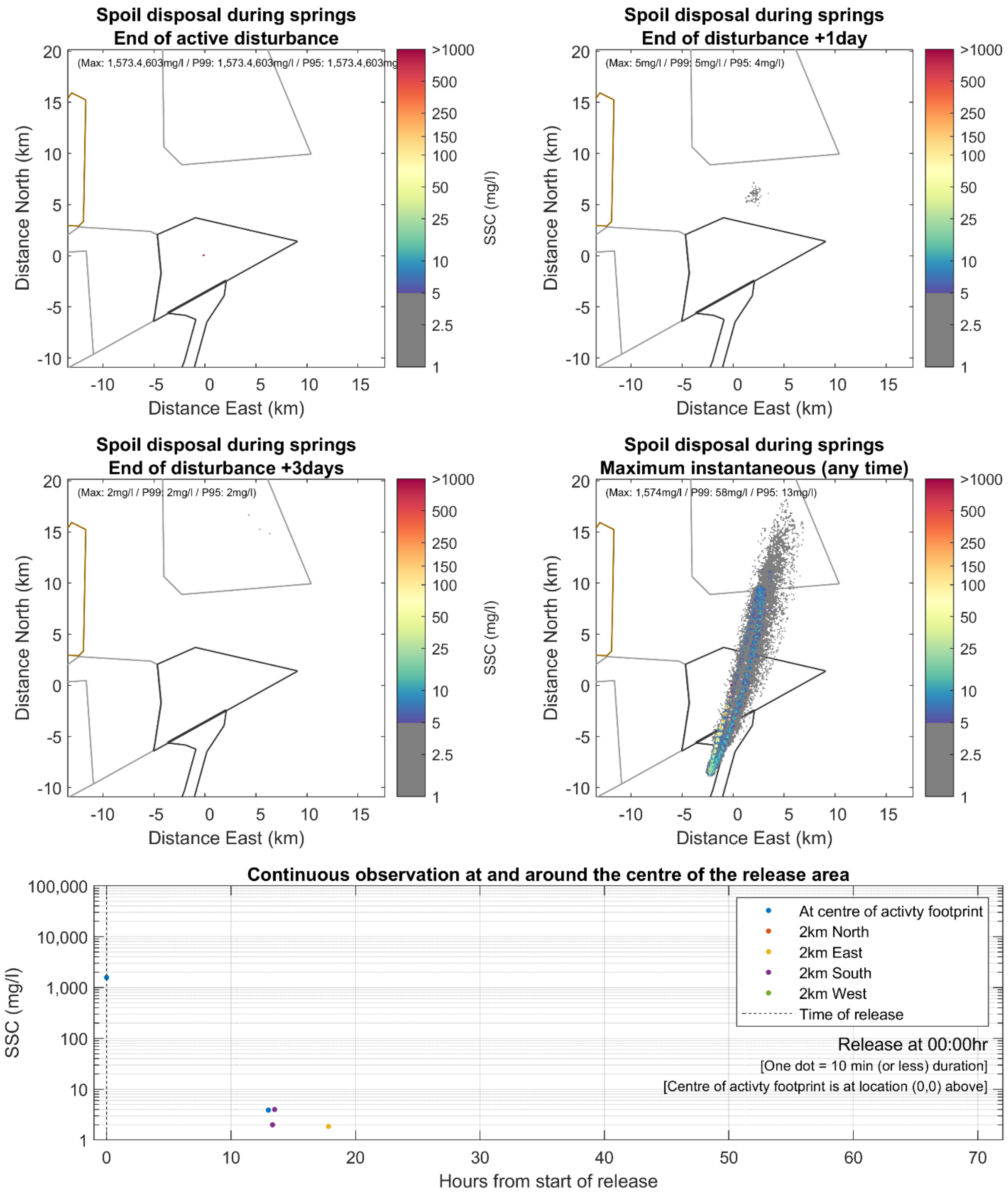
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey.MCZs shown in light green Licensed aggregated extraction sites are outlined in brown.

Figure 7.12: Increase in suspended sediment concentration as a result of Scenario 12: drilling a large monopile in the southern VE array area. Mean spring tide.



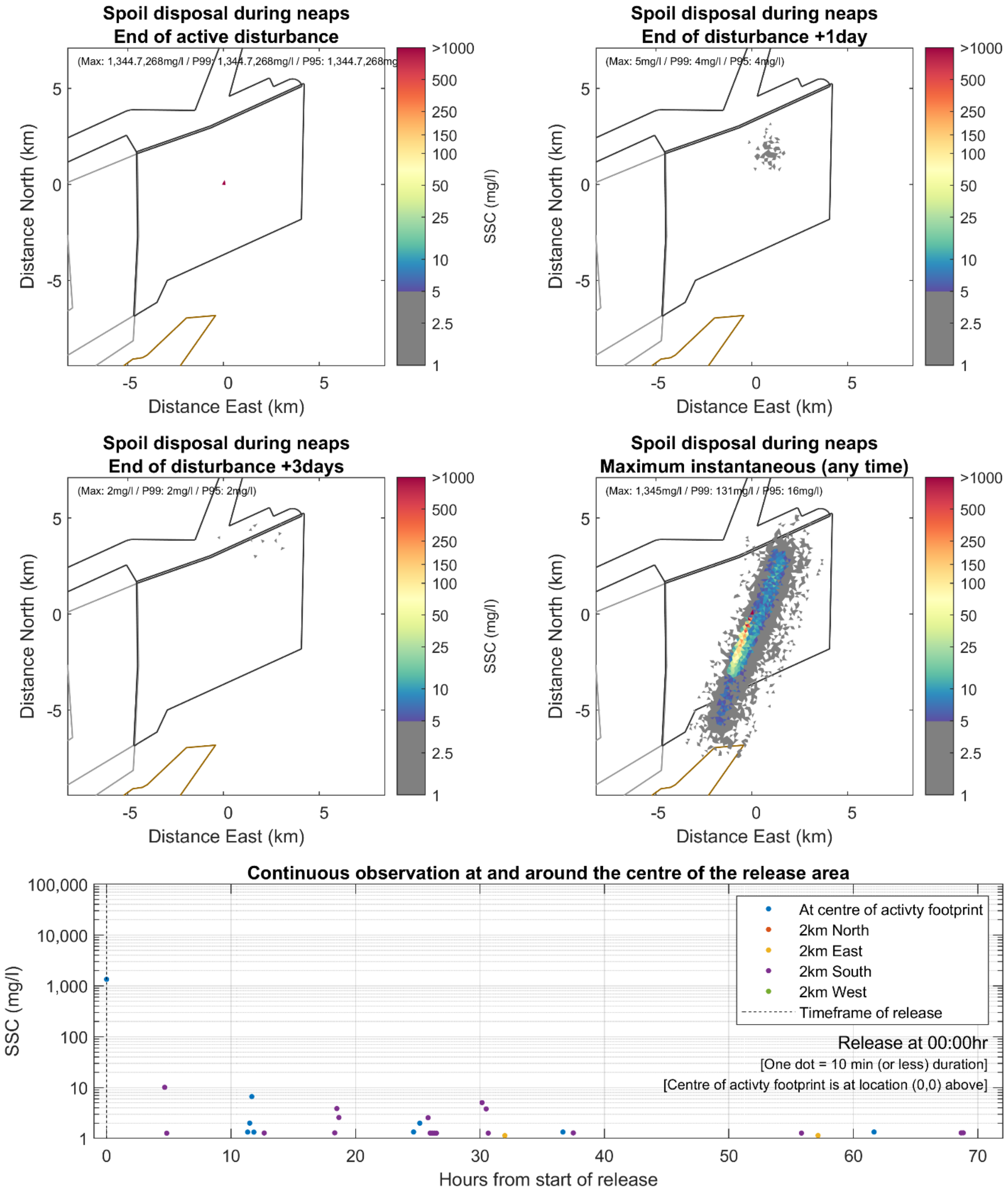
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey.

Figure 7.13: Increase in suspended sediment concentration as a result of Scenario 13: dredge spoil disposal in the northern VE array area. Mean neap tide.



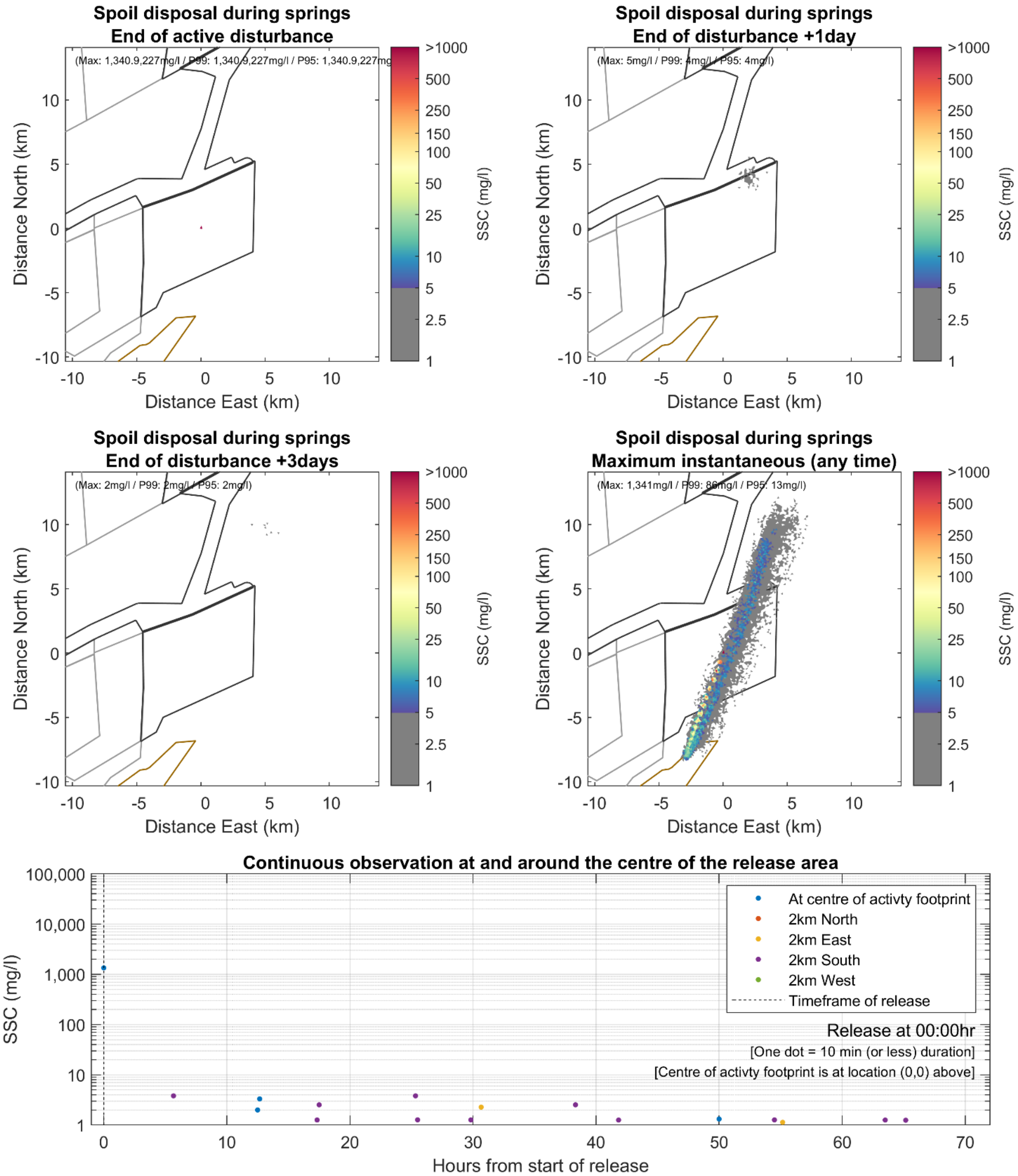
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. Licensed aggregated extraction sites are outlined in brown.

Figure 7.14: Increase in suspended sediment concentration as a result of Scenario 14: dredge spoil disposal in the northern VE array area. Mean spring tide.



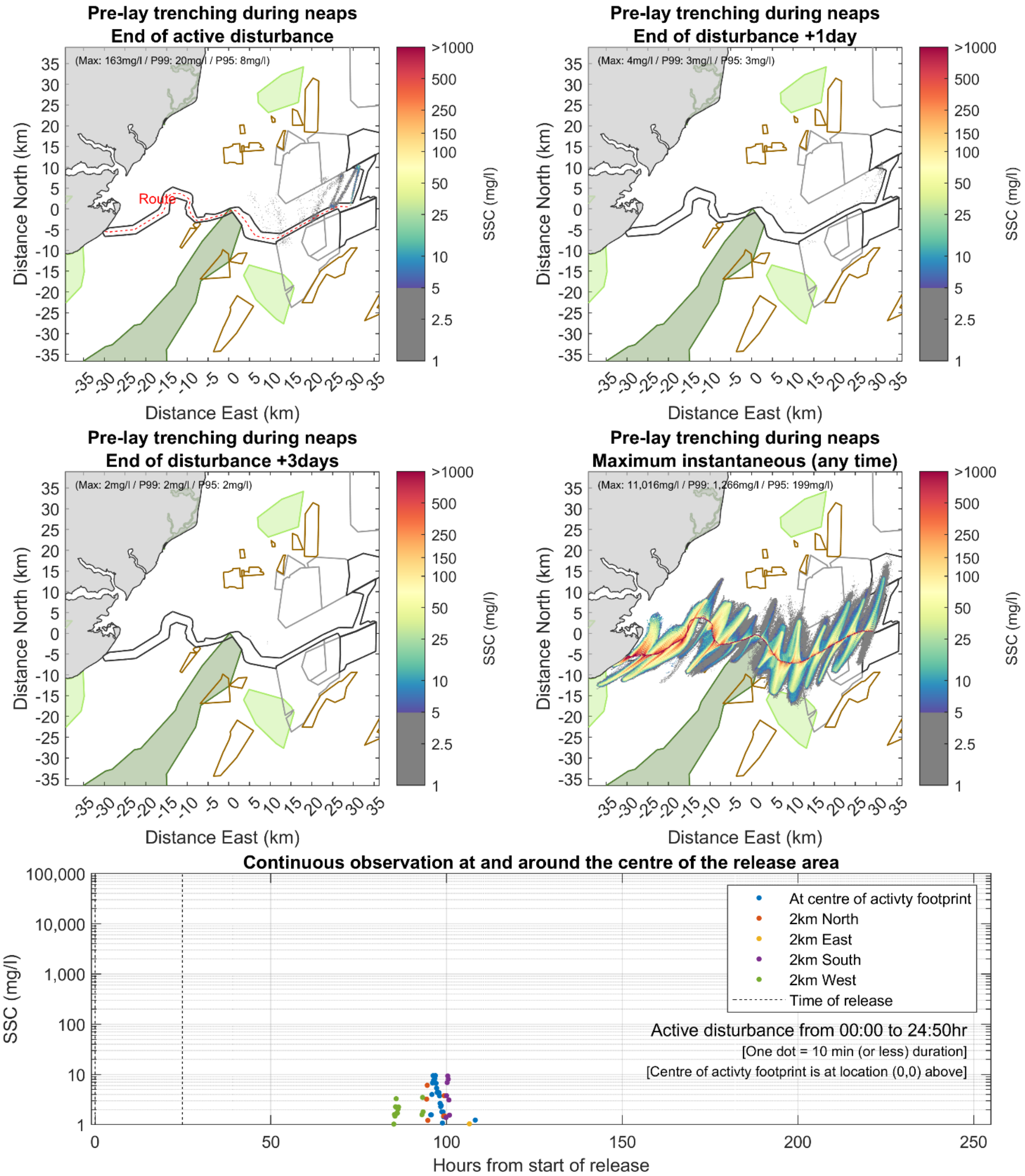
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. Licensed aggregated extraction sites are outlined in brown.

Figure 7.15: Increase in suspended sediment concentration as a result of Scenario 15: dredge spoil disposal in the southern VE array area. Mean neap tide.



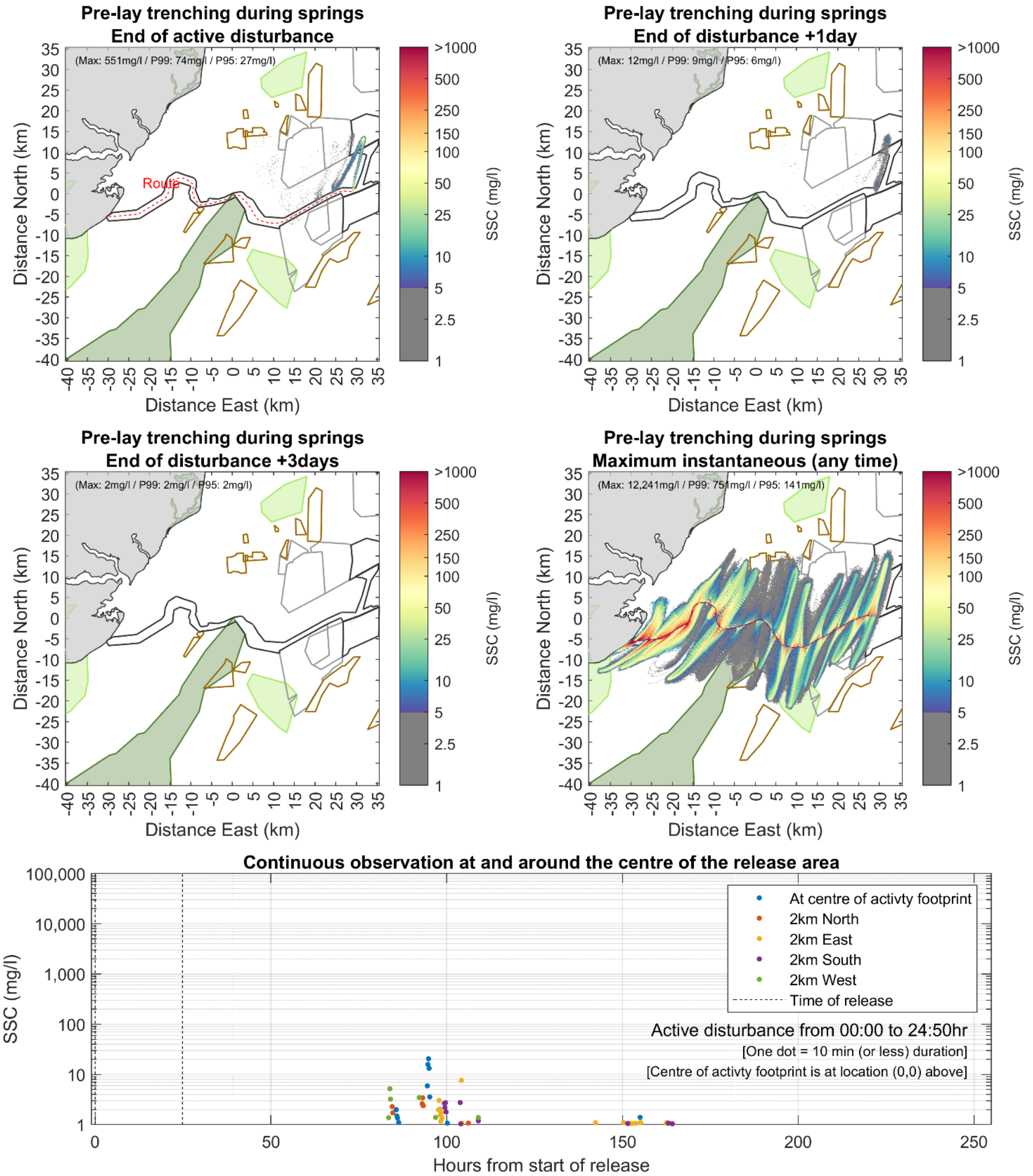
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. The MLS SAC perimeter is outlined in green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.16: Increase in suspended sediment concentration as a result of Scenario 16: dredge spoil disposal in the southern VE array area. Mean spring tide.



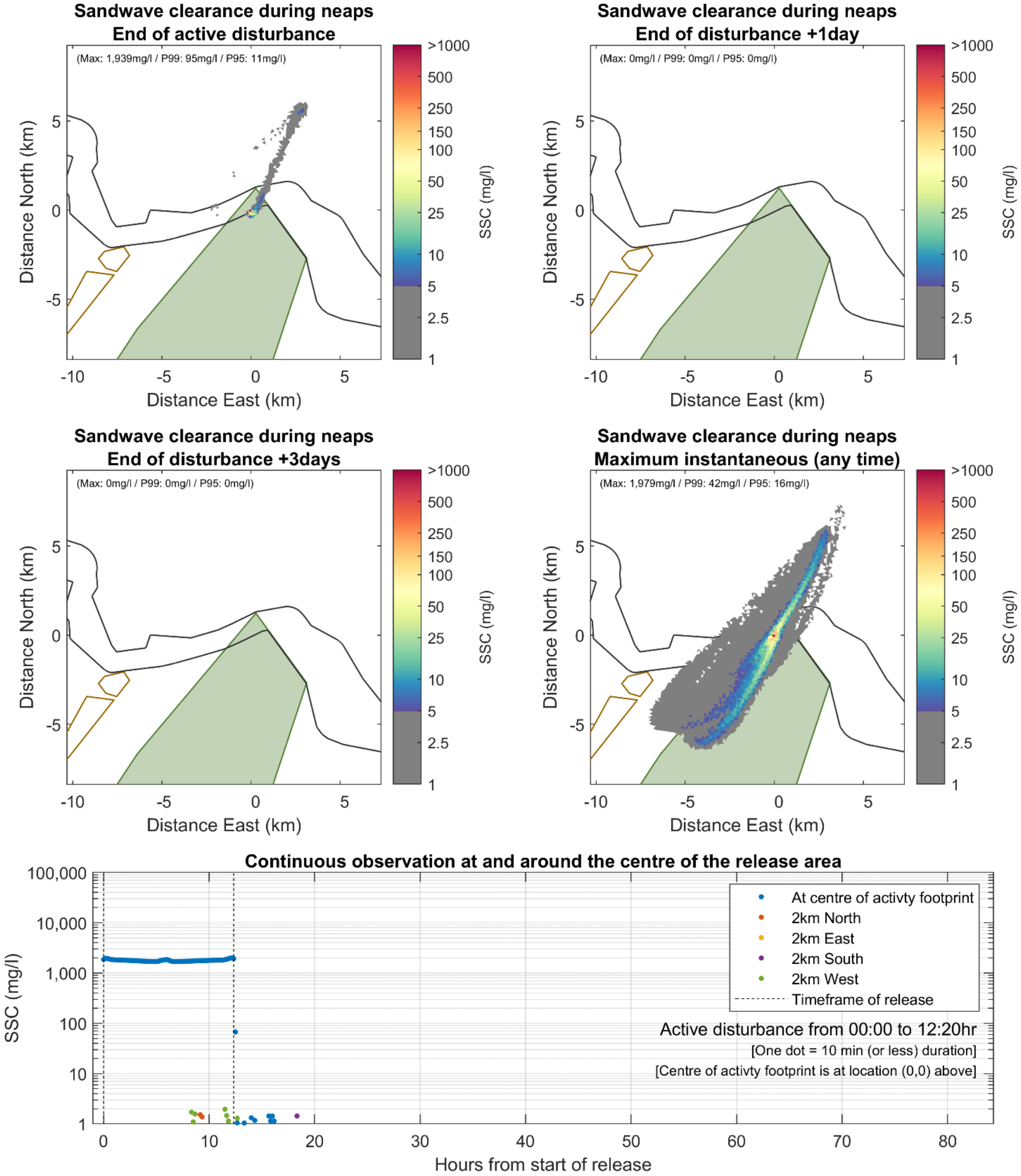
The red dashed line indicates the modelled MFE trenching release route. The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.17: Increase in suspended sediment concentration as a result of Scenario 17: pre-lay trenching using an MFE along the length of the VE export cable corridor. Mean neap tide.



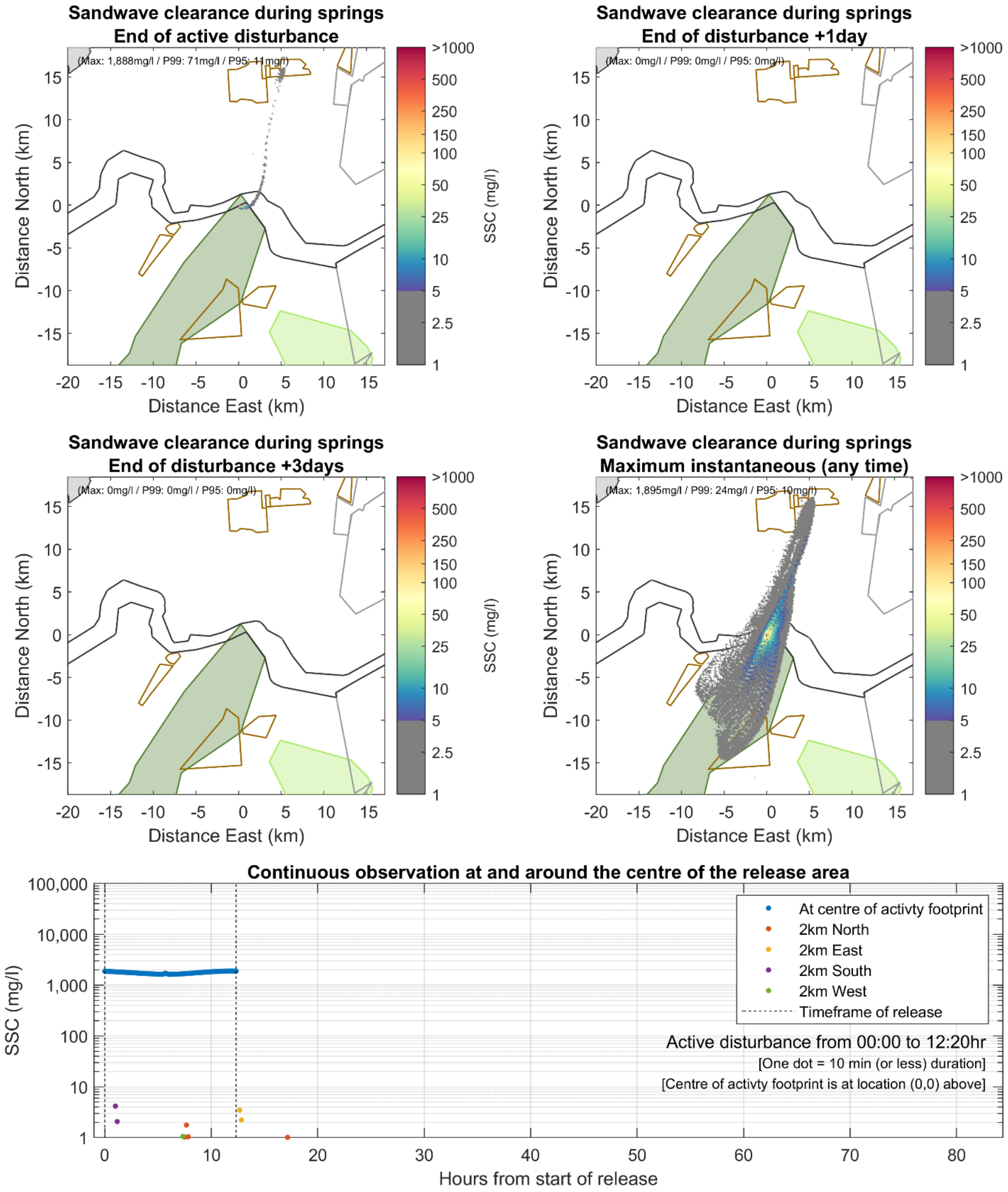
The red dashed line indicates the modelled MFE trenching release route. The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.18: Increase in suspended sediment concentration as a result of Scenario 18: pre-lay trenching using an MFE along the length of the VE export cable corridor. Mean spring tide.



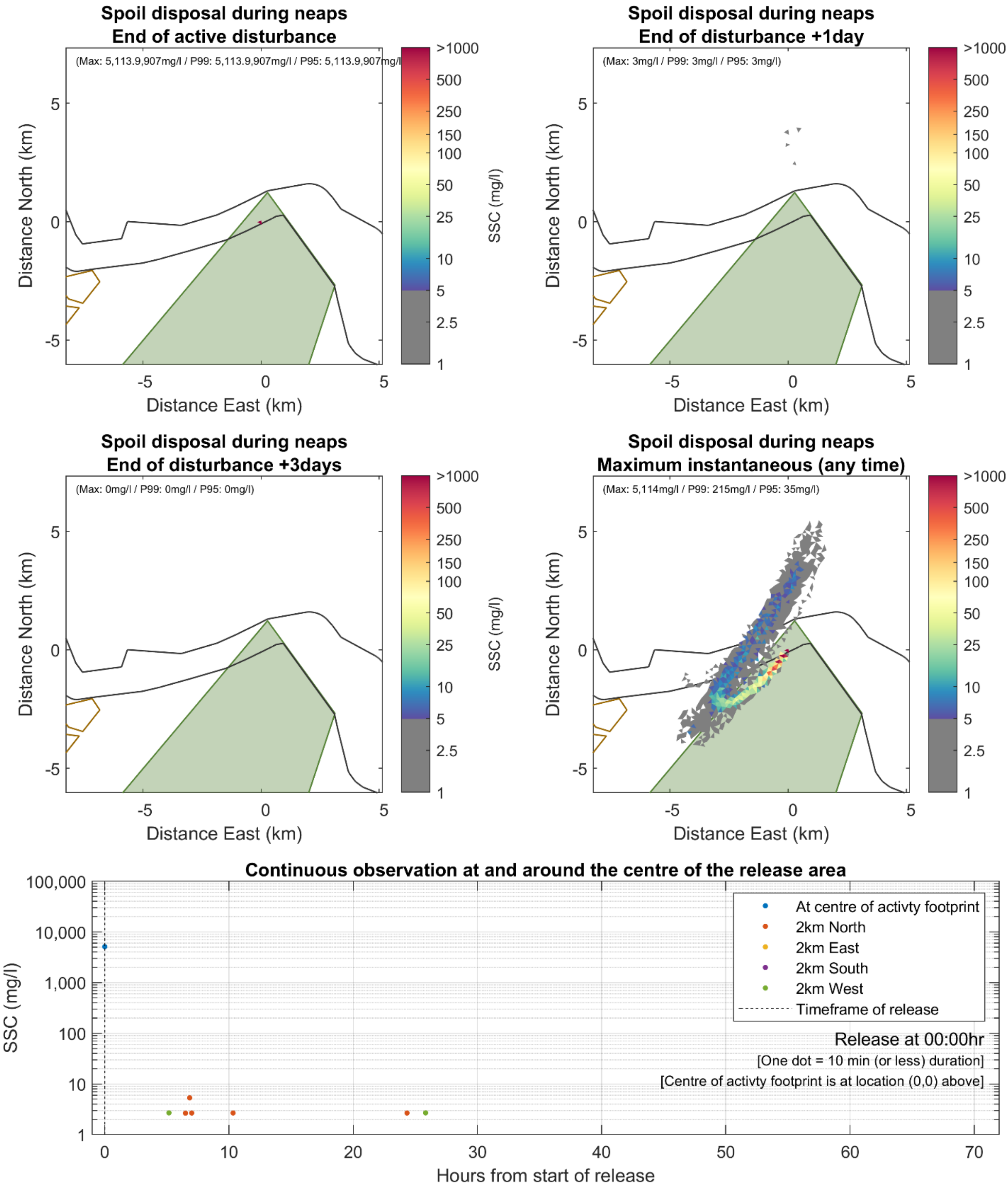
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. Margate & Long Sands SAC is shown in dark green (Southern North Sea SAC is not included). Licensed aggregated extraction sites are outlined in brown.

Figure 7.19: Increase in suspended sediment concentration as a result of Scenario 19: sand wave clearance using an MFE at a central location in the VE export cable corridor. Mean neap tide.



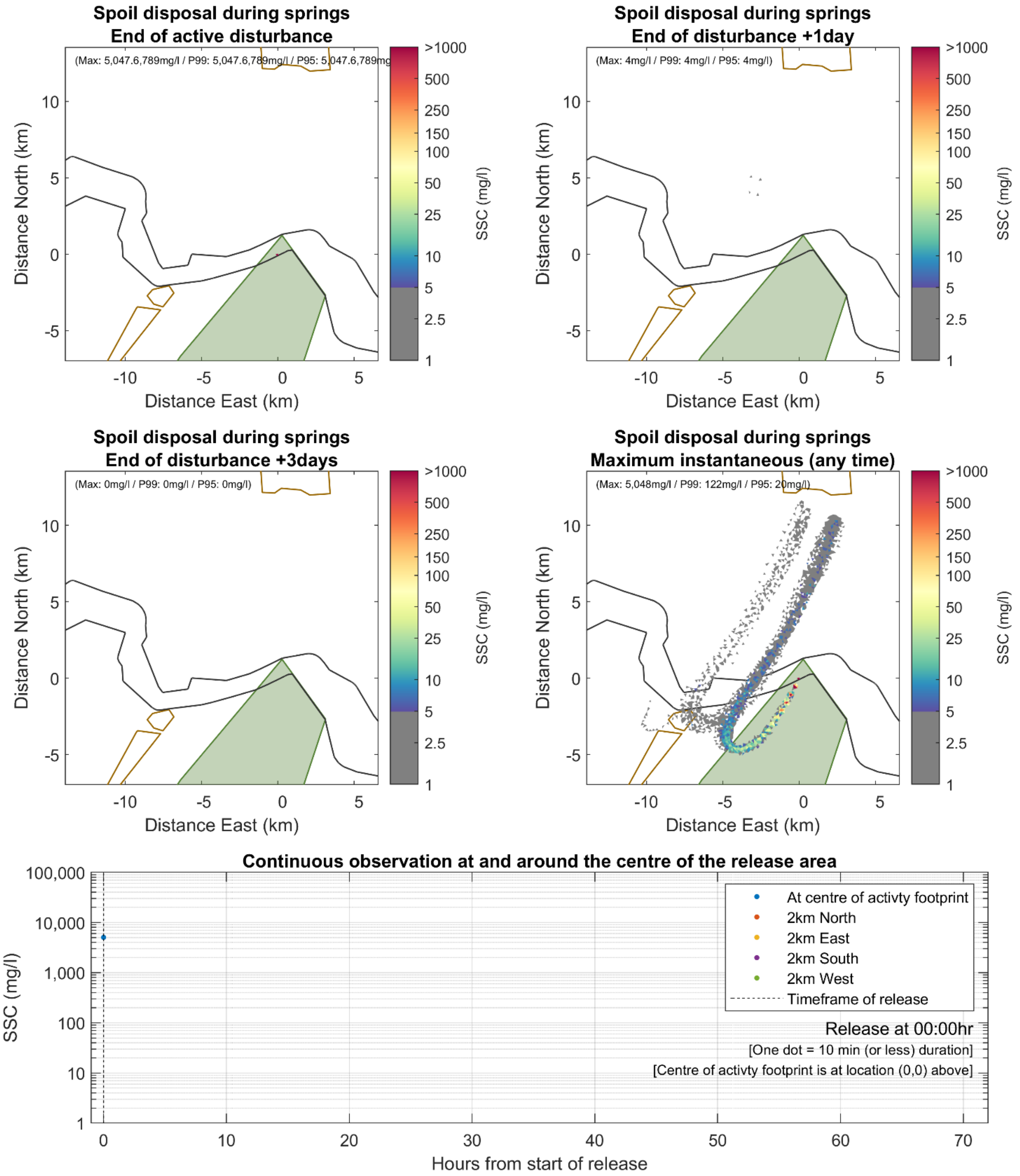
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. Margate and Long Sands SAC is shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.20: Increase in suspended sediment concentration as a result of Scenario 20: sand wave clearance using an MFE at a central location in the VE export cable corridor. Mean spring tide.



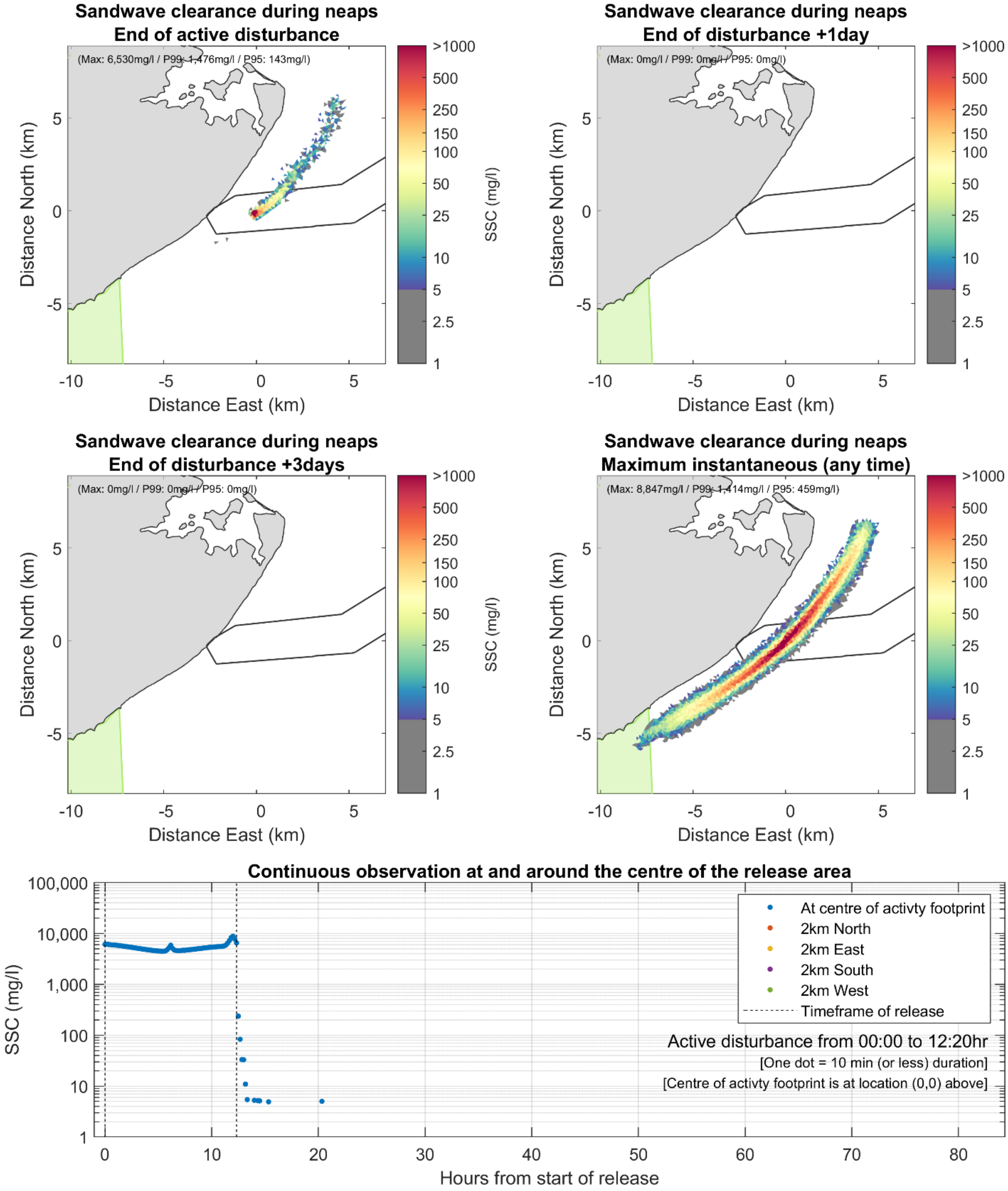
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. Margate & Land Sands SACs is shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.21: Increase in suspended sediment concentration as a result of Scenario 21: dredge spoil disposal at a central location in the VE export cable corridor. Mean neap tide.



The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. Margate & Long Sands SAC is shown in dark green (Southern North Sea SAC is not included). Licensed aggregated extraction sites are outlined in brown.

Figure 7.22: Increase in suspended sediment concentration as a result of Scenario 22: dredge spoil disposal at a central location in the VE export cable corridor. Mean spring tide.


Sandwave clearance during neaps
End of active disturbance

Sandwave clearance during neaps
End of disturbance +1day

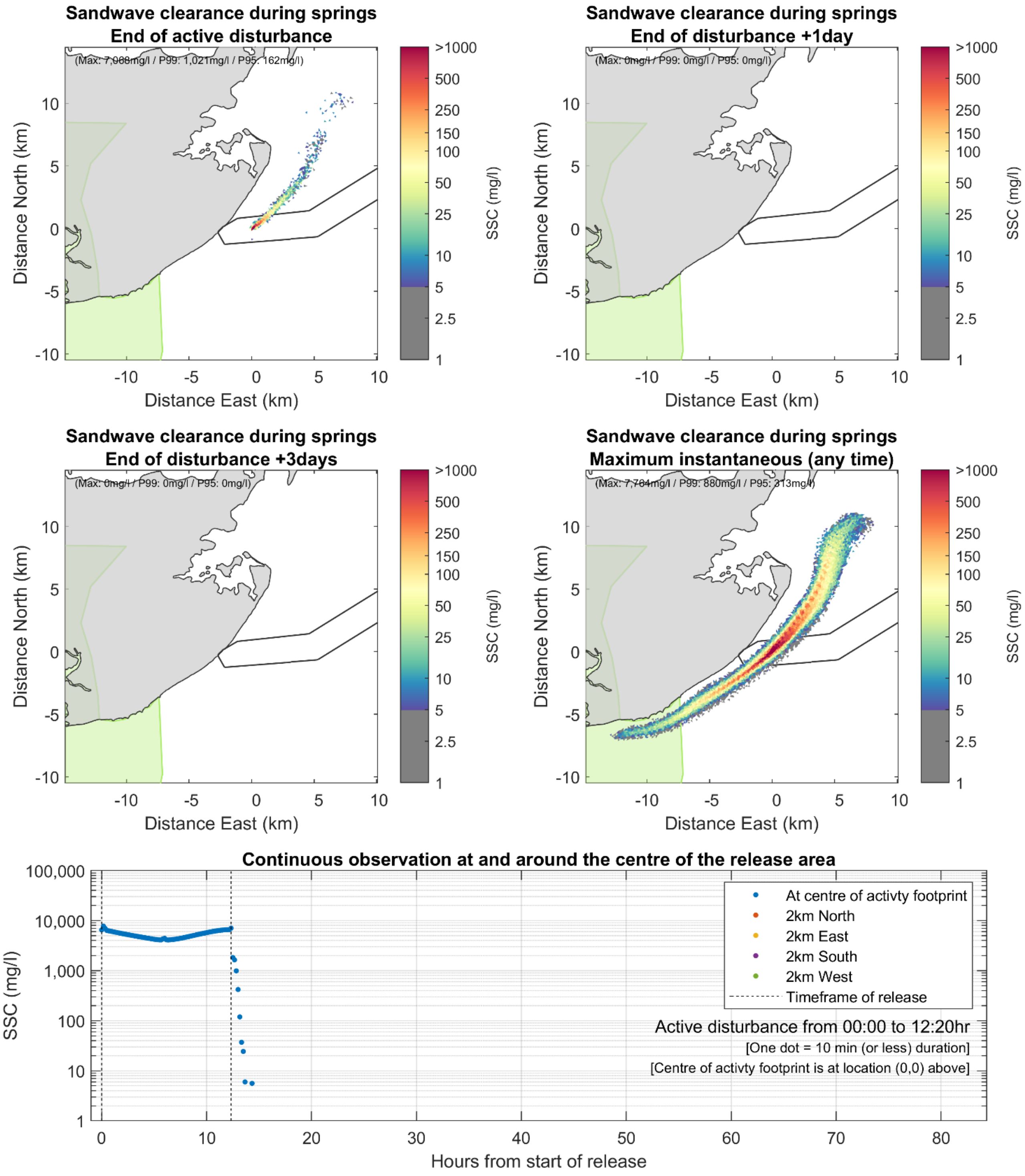
Sandwave clearance during neaps
End of disturbance +3days

Sandwave clearance during neaps
Maximum instantaneous (any time)

Continuous observation at and around the centre of the release area

The Five Estuaries array area and export cable corridor is outlined in black.

Figure 7.23: Increase in suspended sediment concentration as a result of Scenario 23: sand wave clearance using an MFE at a nearshore location in the VE export cable corridor. Mean neap tide.



Sandwave clearance during springs
End of active disturbance

Sandwave clearance during springs
End of disturbance +1day

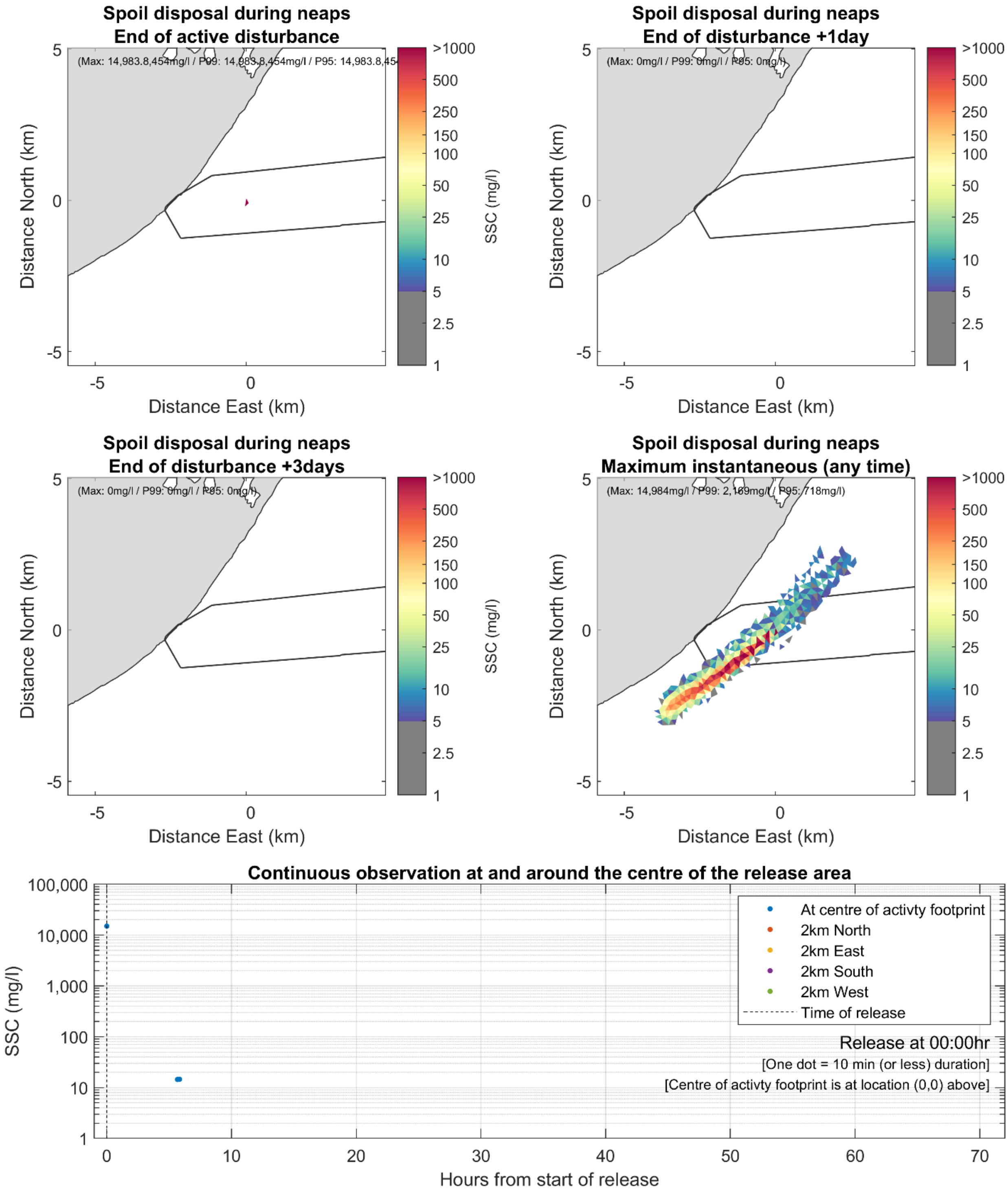
Sandwave clearance during springs
End of disturbance +3days

Sandwave clearance during springs
Maximum instantaneous (any time)

Continuous observation at and around the centre of the release area

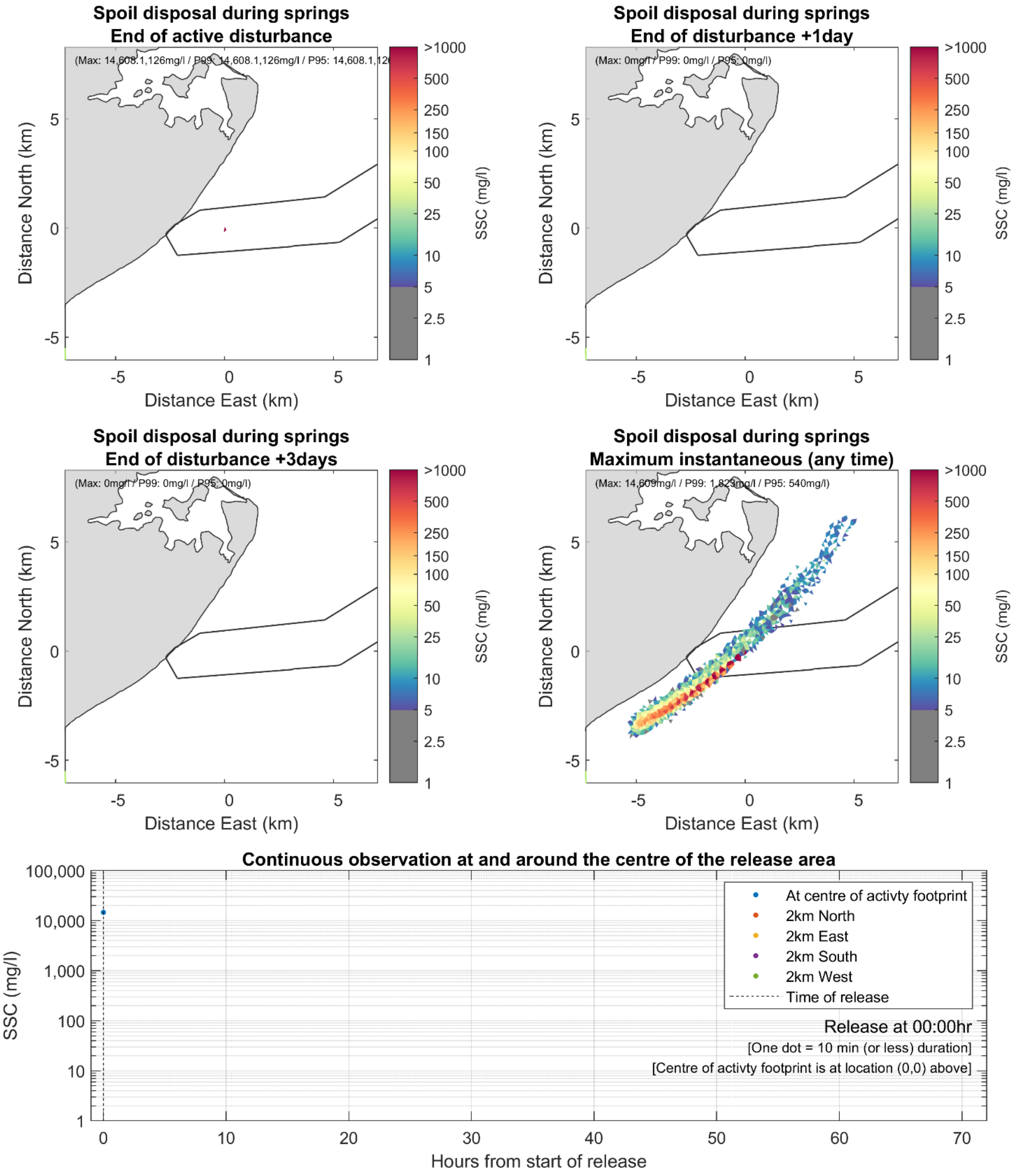
The Five Estuaries array area and export cable corridor is outlined in black.

Figure 7.24: Increase in suspended sediment concentration as a result of Scenario 24: sand wave clearance using an MFE at a nearshore location in the VE export cable corridor. Mean spring tide.



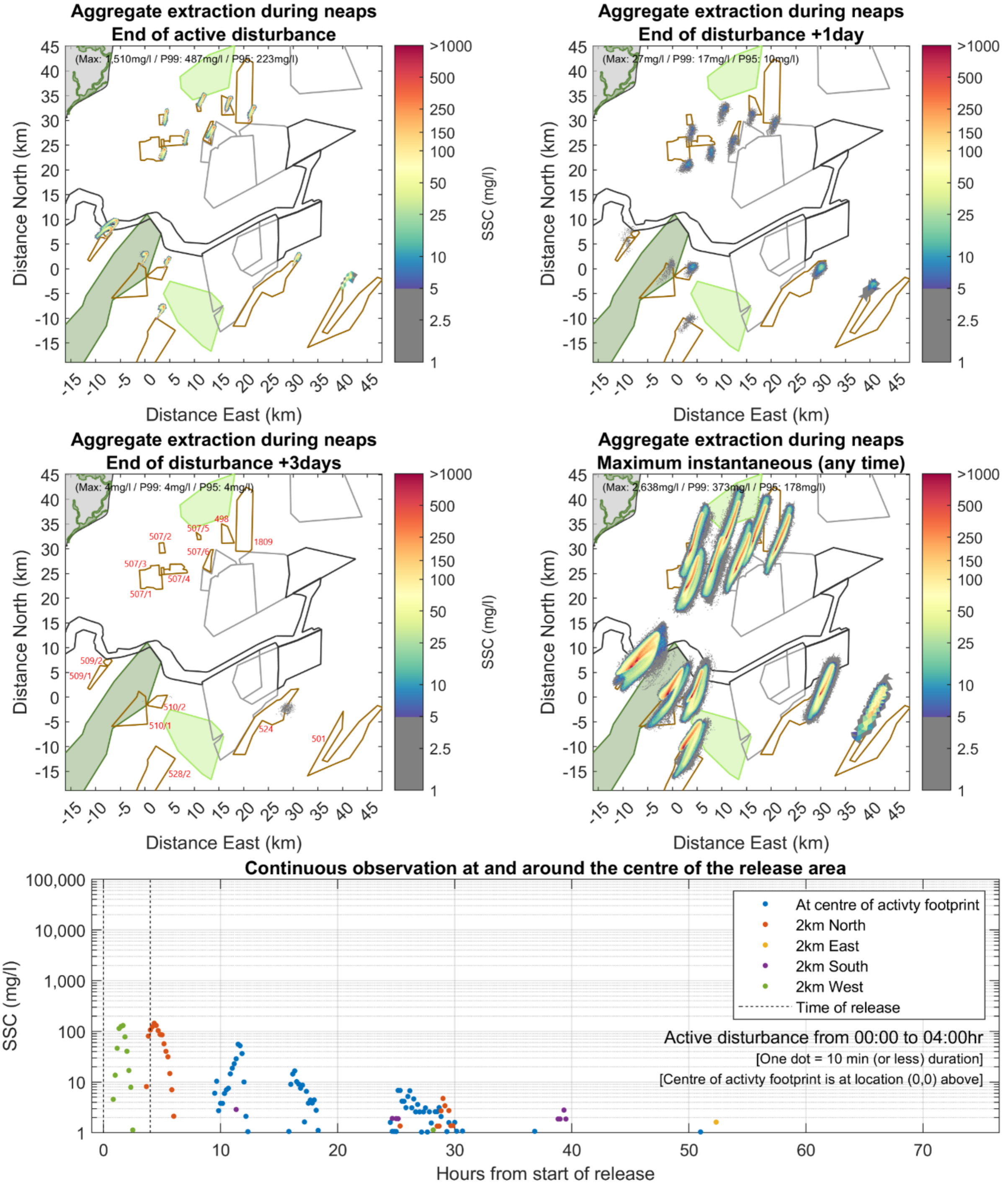
The Five Estuaries array area and export cable corridor is outlined in black.

Figure 7.25: Increase in suspended sediment concentration as a result of Scenario 25: dredge spoil disposal at a nearshore location in the VE export cable corridor. Mean neap tide.



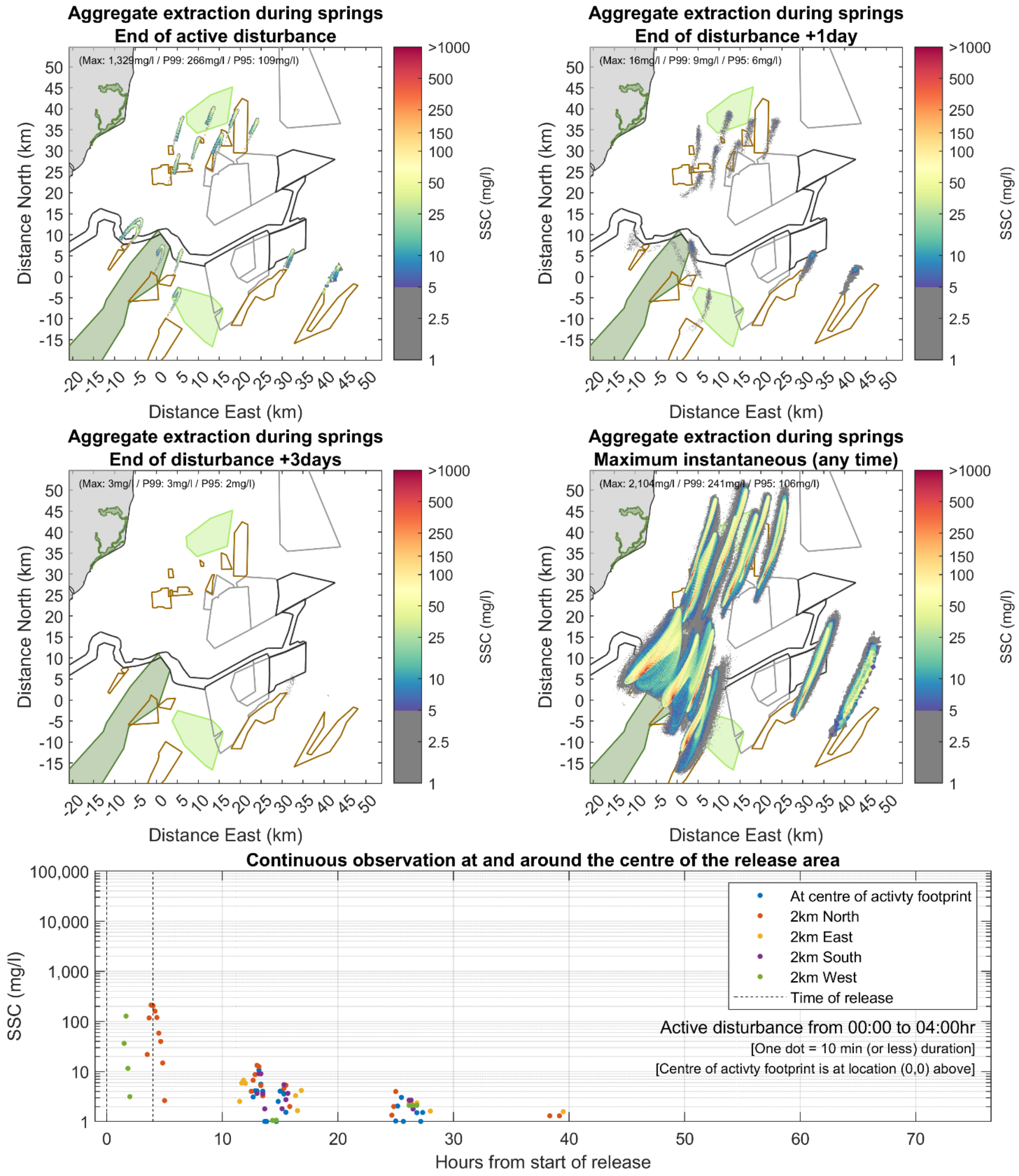
The Five Estuaries array area and export cable corridor is outlined in black.

Figure 7.26: Increase in suspended sediment concentration as a result of Scenario 26: dredge spoil disposal at a nearshore location in the VE export cable corridor. Mean spring tide.



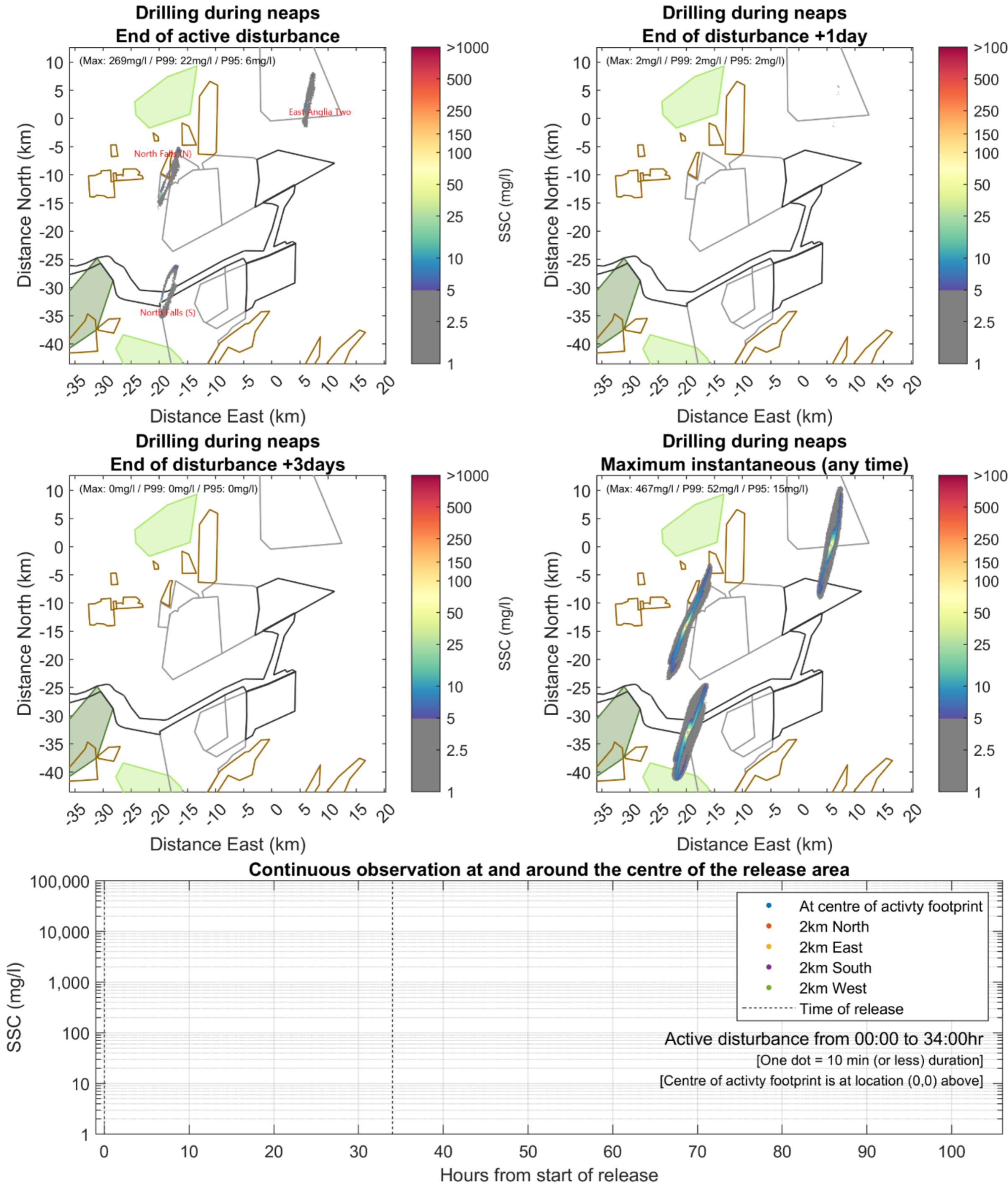
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.27: Increase in suspended sediment concentration as a result of Scenario 27: aggregate extraction at active licensed sites in the VE study area. Mean neap tide.



The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.28: Increase in suspended sediment concentration as a result of Scenario 28: aggregate extraction at active licensed sites in the VE study area. Mean spring tide.


Drilling during neaps
End of active disturbance
(Max: 269mg/l / P99: 22mg/l / P95: 6mg/l)

Drilling during neaps
End of disturbance +1day
(Max: 2mg/l / P99: 2mg/l / P95: 2mg/l)

Drilling during neaps
End of disturbance +3days
(Max: 0mg/l / P99: 0mg/l / P95: 0mg/l)

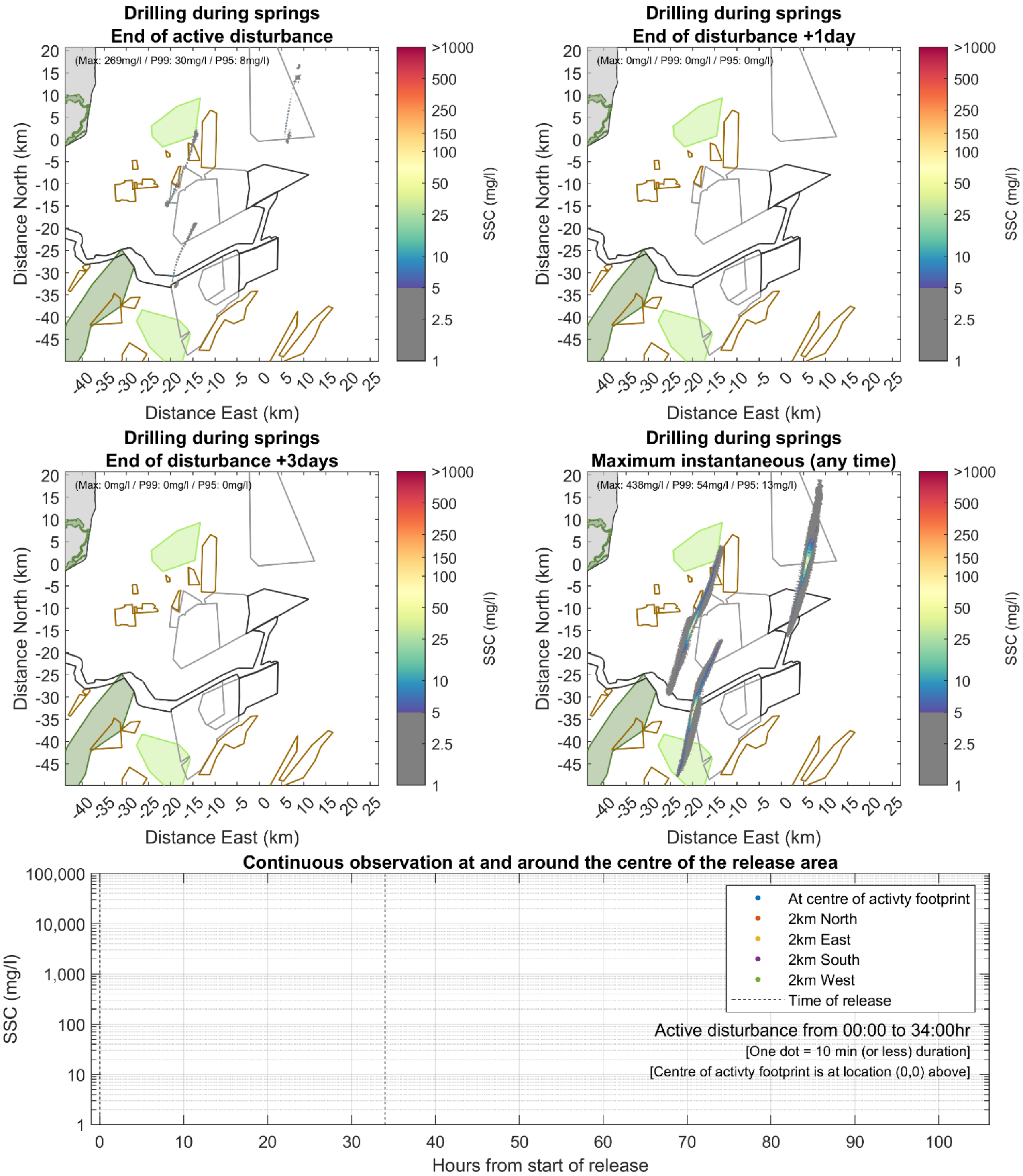
Drilling during neaps
Maximum instantaneous (any time)
(Max: 467mg/l / P99: 52mg/l / P95: 15mg/l)

Continuous observation at and around the centre of the release area

Active disturbance from 00:00 to 34:00hr
[One dot = 10 min (or less) duration]
[Centre of activty footprint is at location (0,0) above]

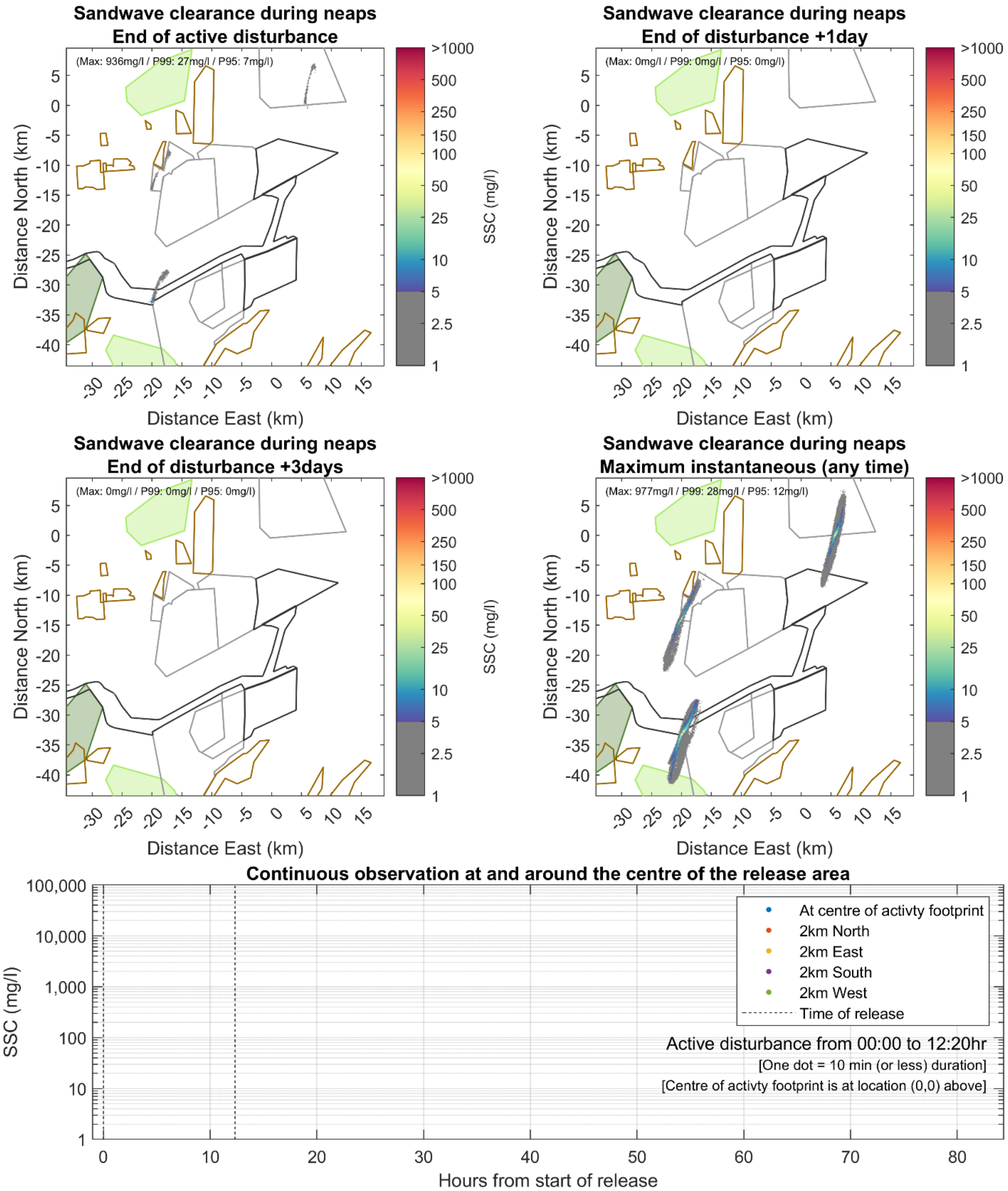
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.29: Increase in suspended sediment concentration as a result of Scenario 29: drilling a large monopile in the North Falls and East Anglia TWO array areas. Mean neap tide.



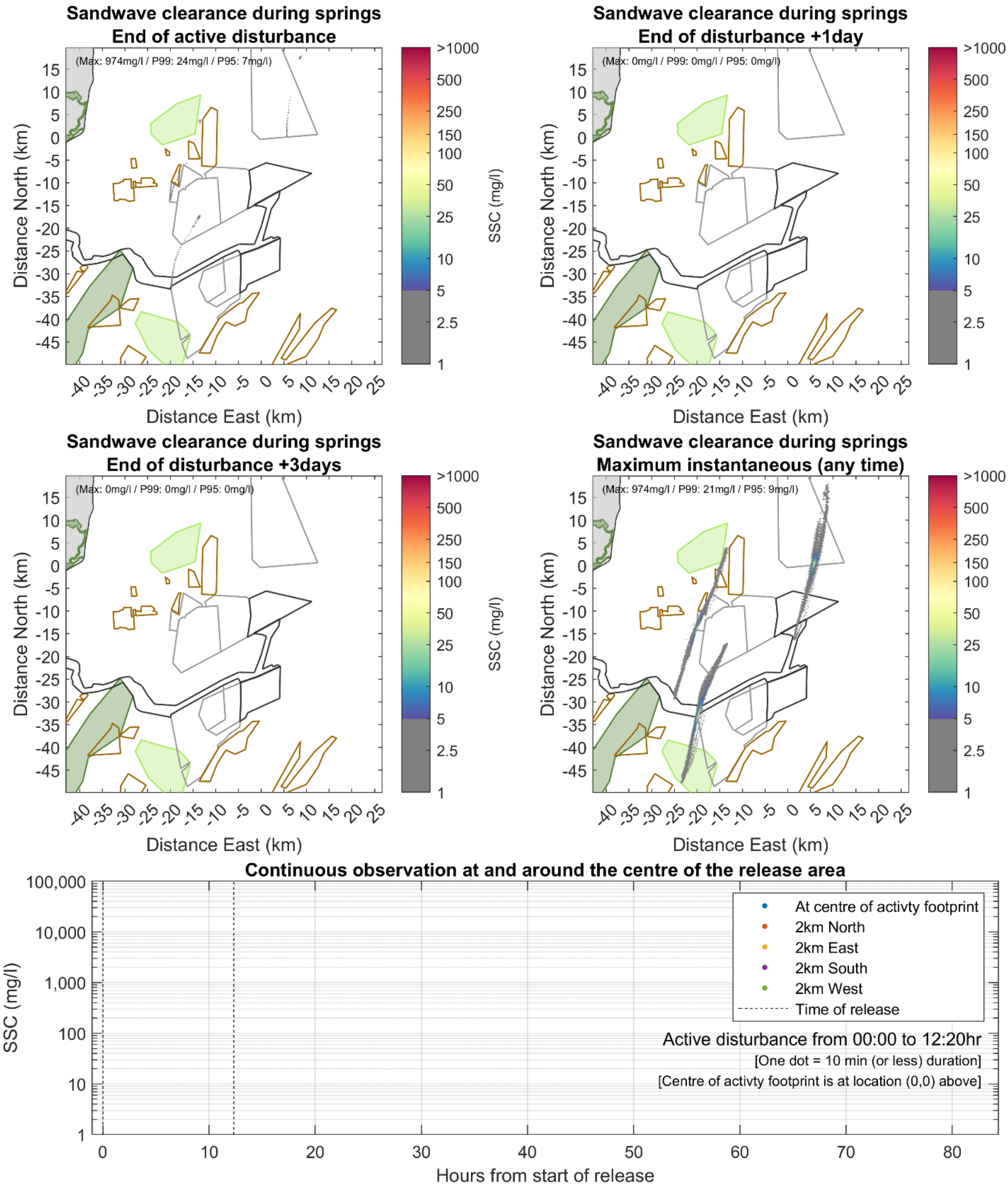
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.30: Increase in suspended sediment concentration as a result of Scenario 30: drilling a large monopile in the North Falls and East Anglia TWO array areas. Mean spring tide.



The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.31: Increase in suspended sediment concentration as a result of Scenario 31: sand wave clearance using an MFE in the North Falls and East Anglia TWO array areas. Mean neap tide.


Sandwave clearance during springs
End of active disturbance

Sandwave clearance during springs
End of disturbance +1day

Sandwave clearance during springs
End of disturbance +3days

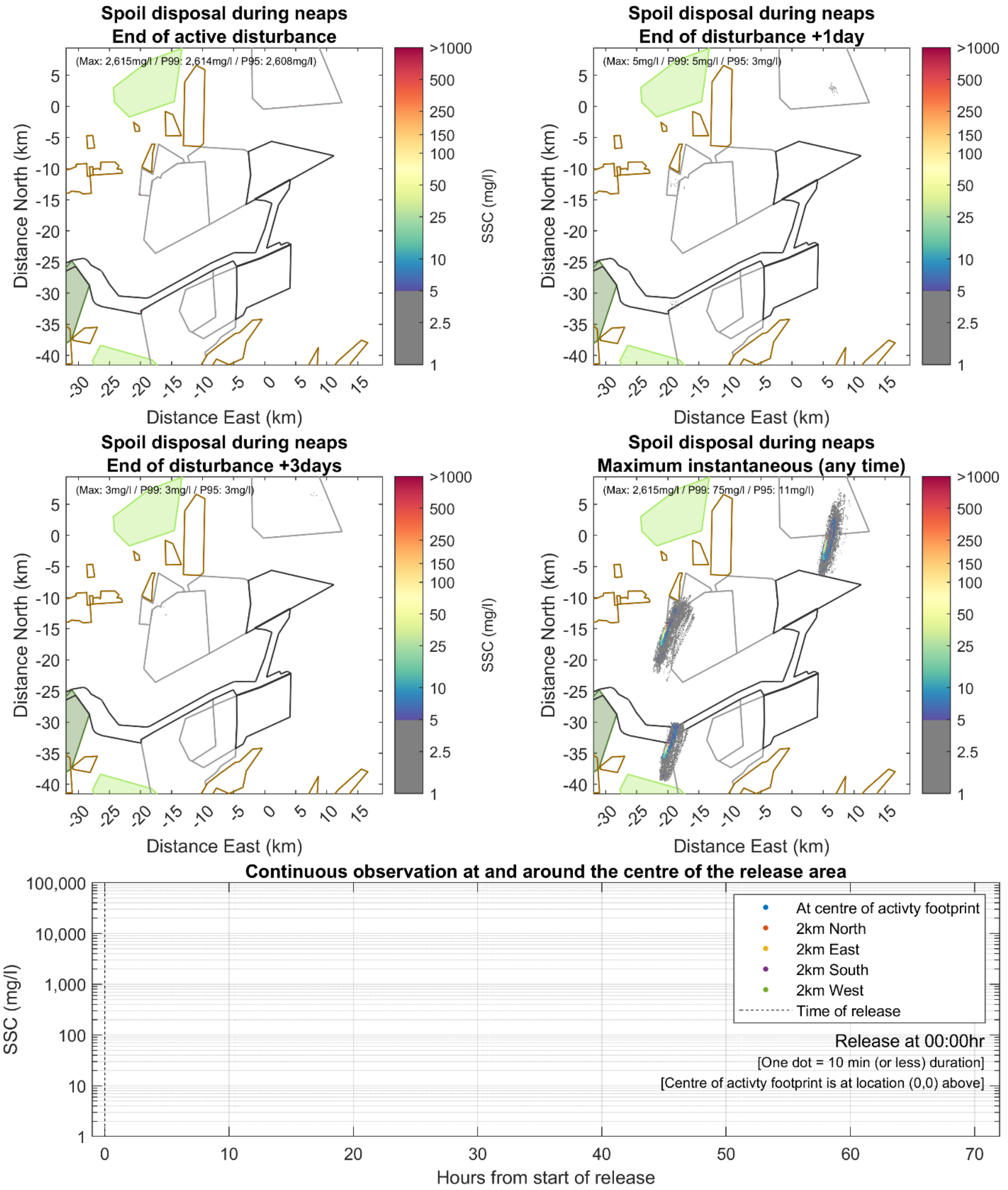
Sandwave clearance during springs
Maximum instantaneous (any time)

Continuous observation at and around the centre of the release area

Active disturbance from 00:00 to 12:20hr
[One dot = 10 min (or less) duration]
[Centre of activty footprint is at location (0,0) above]

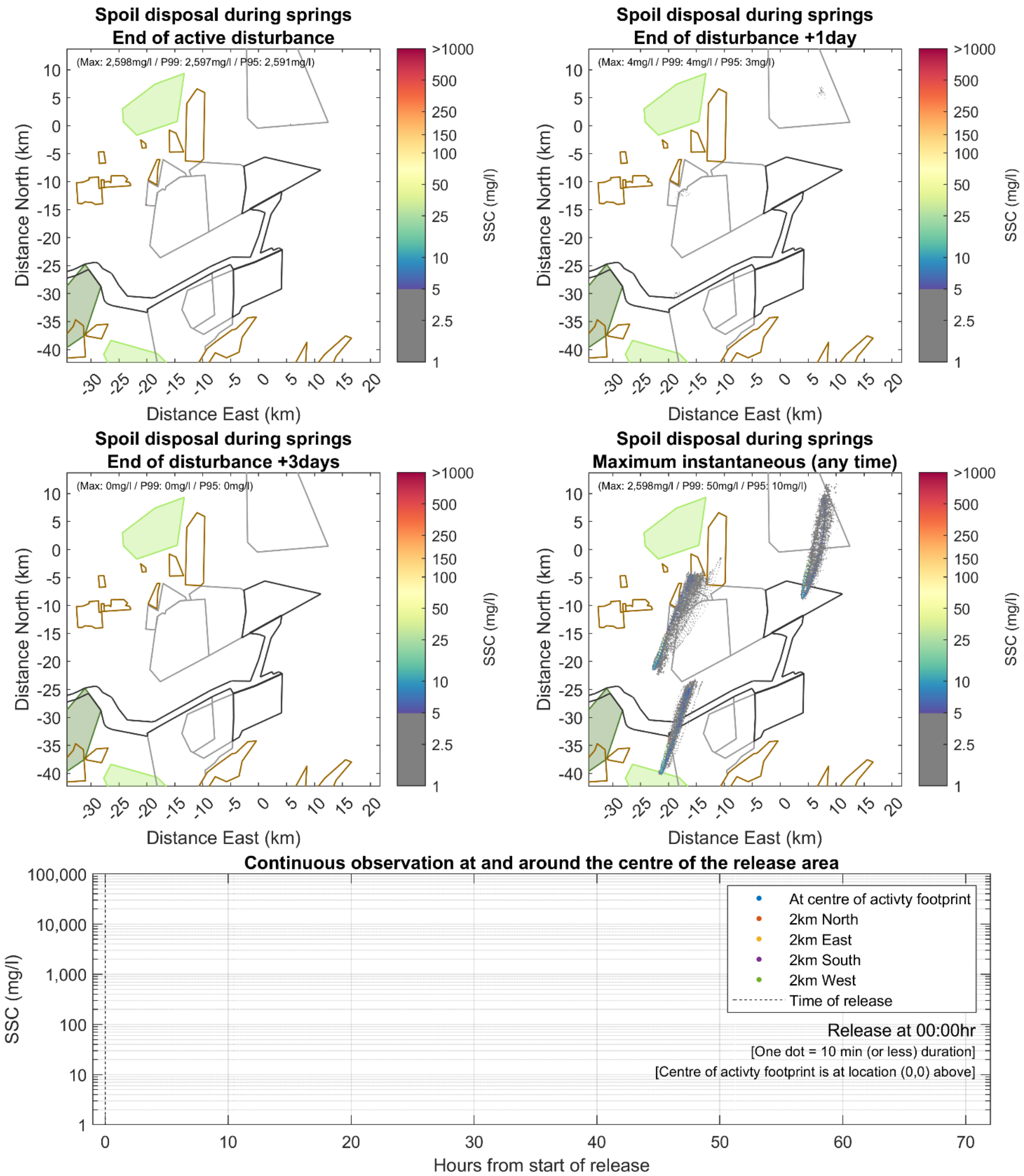
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 7.32: Increase in suspended sediment concentration as a result of Scenario 32: sand wave clearance using an MFE in the North Falls and East Anglia TWO array areas. Mean spring tide.



The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

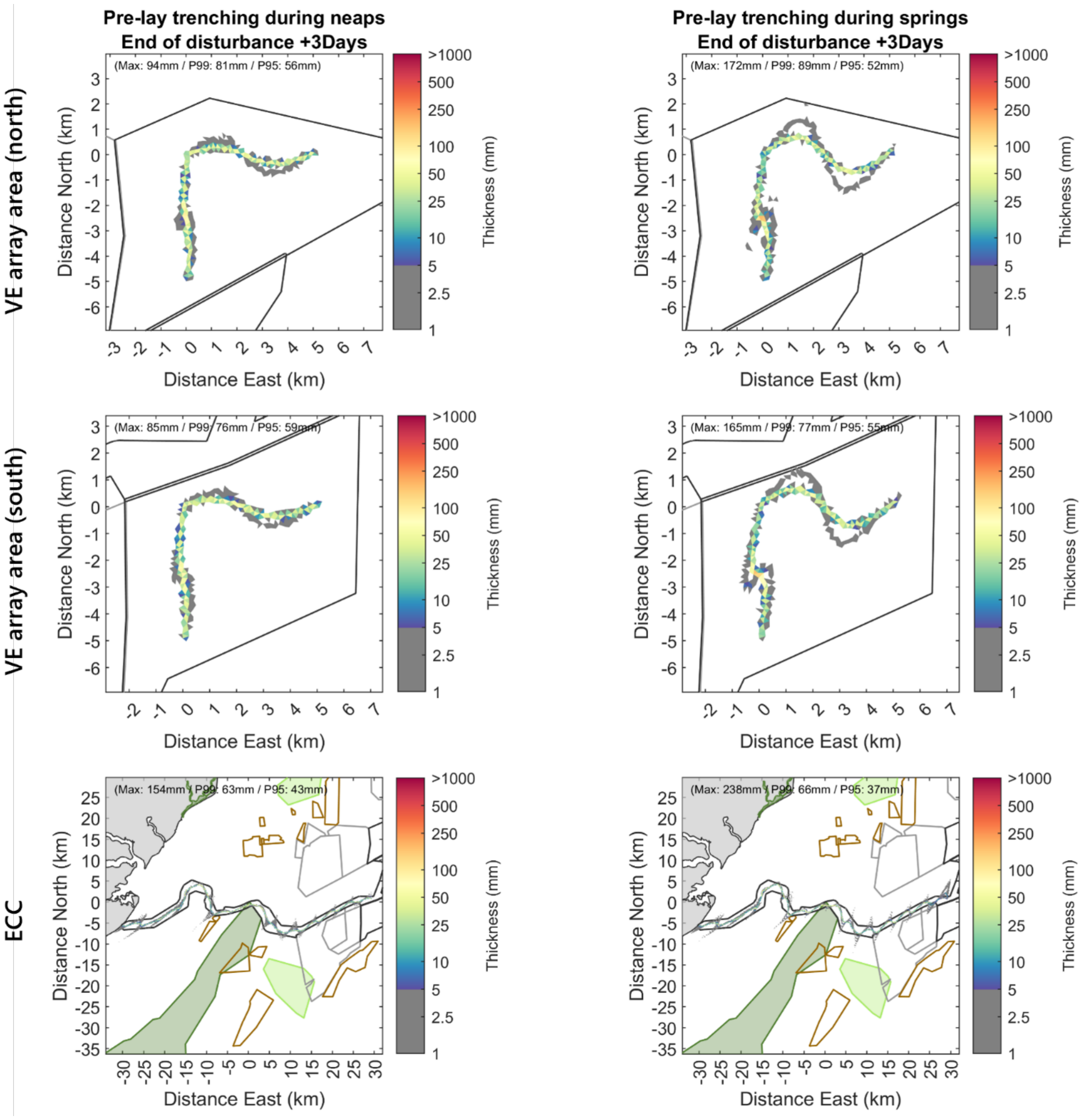
Figure 7.33: Increase in suspended sediment concentration as a result of Scenario 33: dredge spoil disposal in the North Falls and East Anglia TWO array areas. Mean neap tide.



The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

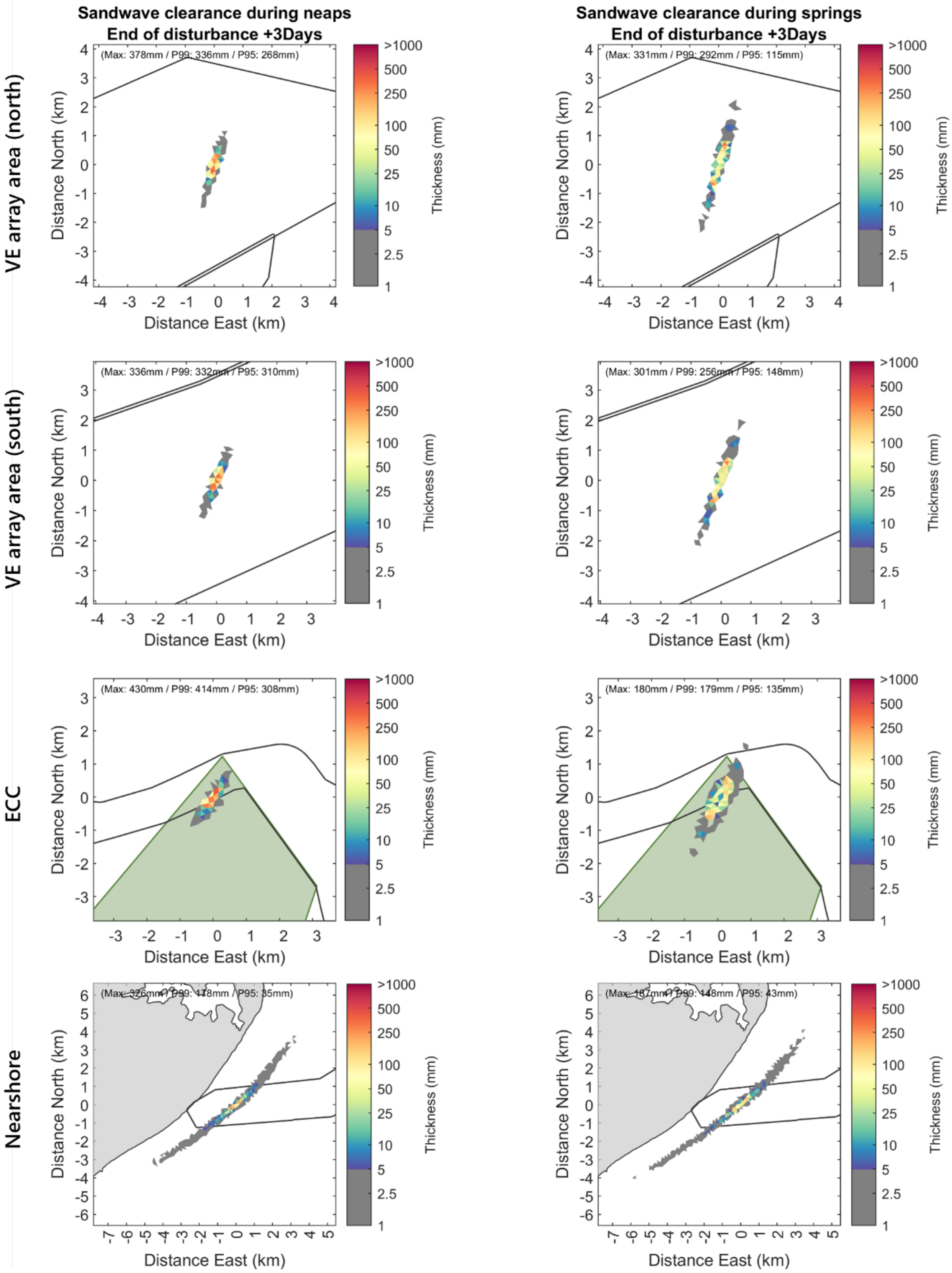
Figure 7.34: Increase in suspended sediment concentration as a result of Scenario 34: dredge spoil disposal in the North Falls and East Anglia TWO array areas. Mean spring tide.

9 APPENDIX B – FAR FIELD PLUME MODEL RESULTS – SEABED DEPOSITION THICKNESS FIGURES



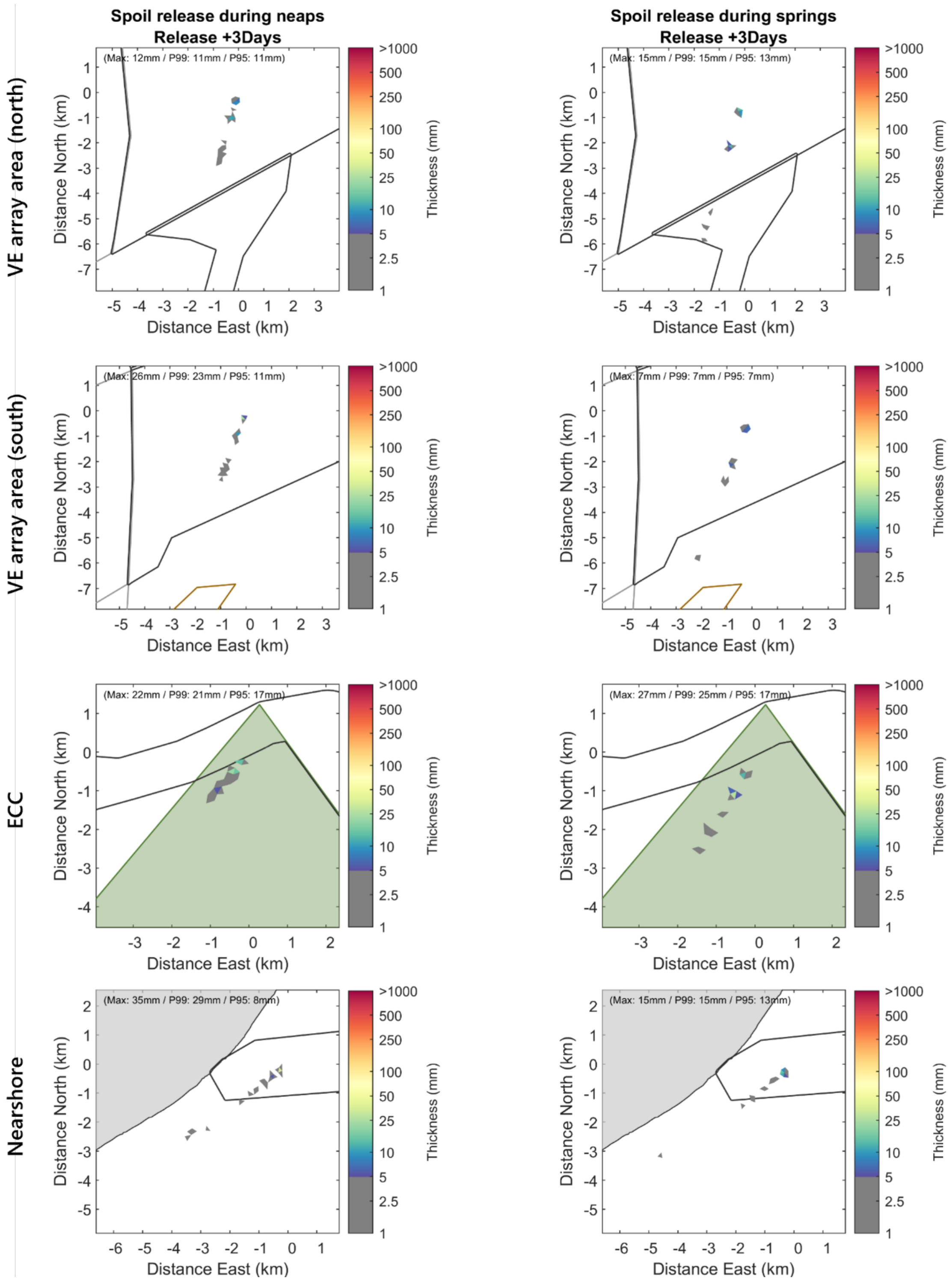
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. . SACs are shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 8.1: Sediment settlement thickness as a result of pre-lay trenching using an MFE in the VE array area and export cable corridor. Mean spring and mean neap tides.



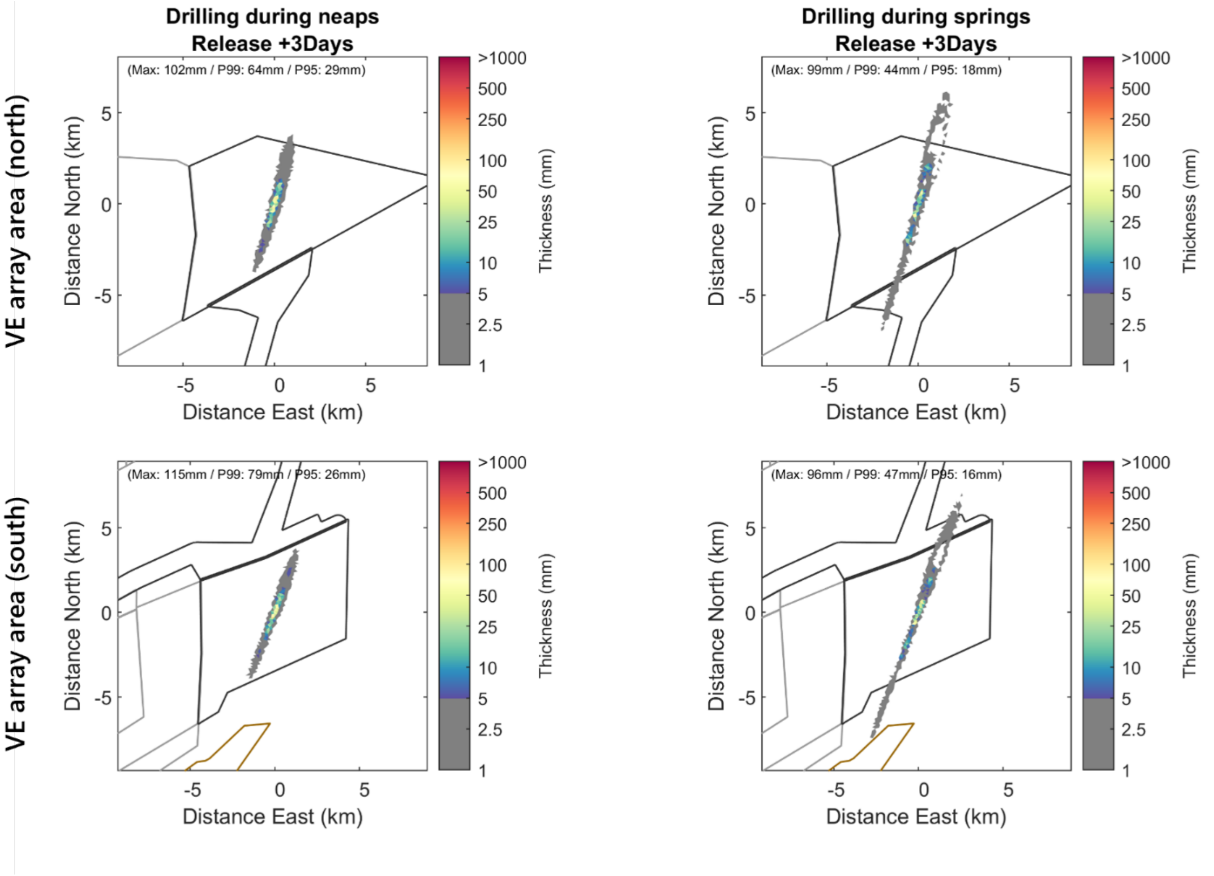
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included).

Figure 8.2: Sediment settlement thickness as a result of sand wave clearance using an MFE in the VE array area, export cable corridor and nearshore area. Mean spring and mean neap tides.



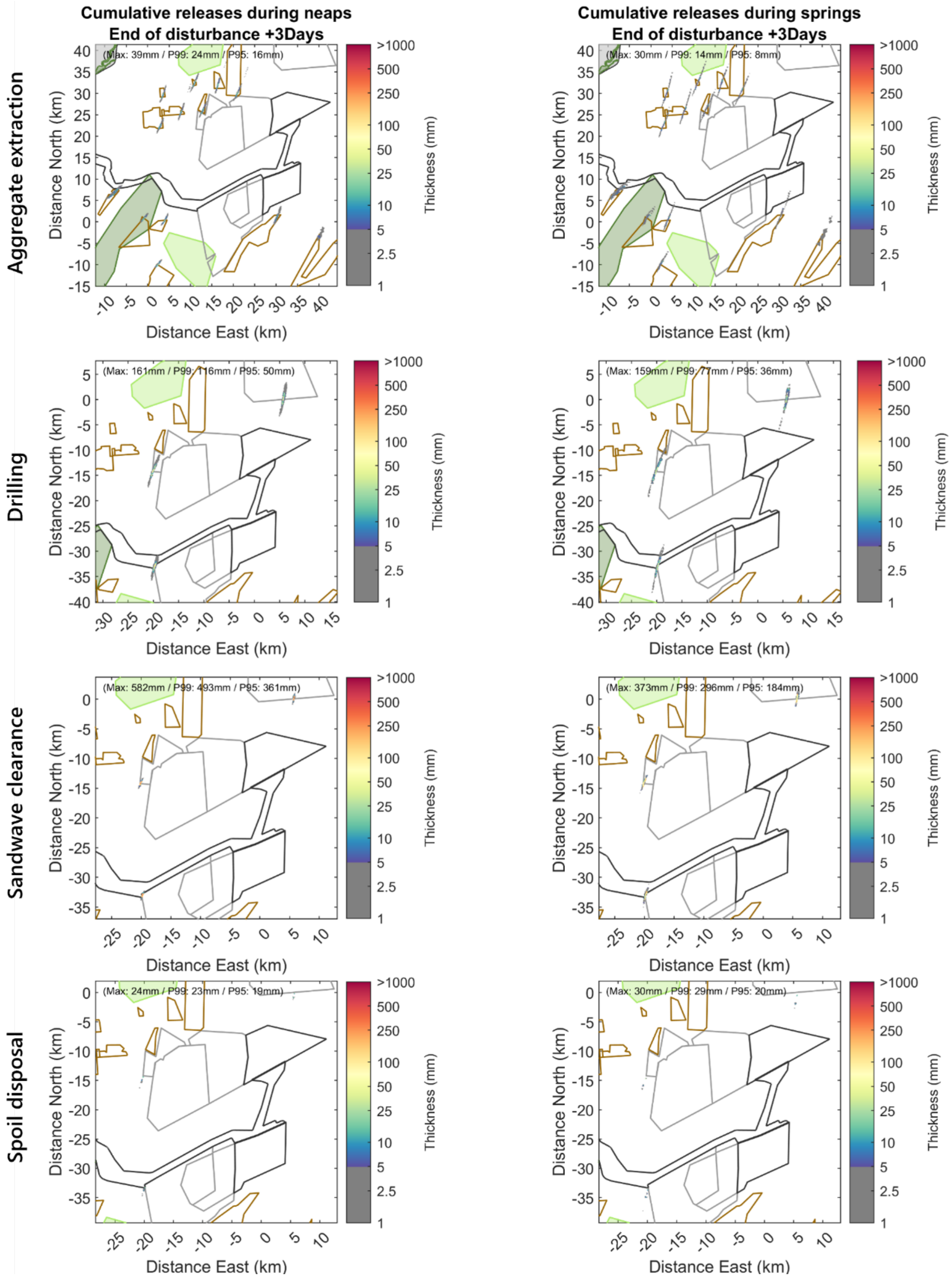
The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included). Licensed aggregated extraction sites are outlined in brown.

Figure 8.3: Sediment settlement thickness as a result of the passive phase plume from dredge spoil disposal in the VE array area, export cable corridor and nearshore area. Mean spring and mean neap tides.



The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. Licensed aggregated extraction sites are outlined in brown.

Figure 8.4: Sediment settlement thickness as a result of drilling a large monopile in the VE array area. Mean spring and mean neap tides.



The Five Estuaries array area and export cable corridor is outlined in black, other OWF array areas within the study area are outlined in grey. SACs are shown in dark green (Southern North Sea SAC is not included) and MCZs shown in light green. Licensed aggregated extraction sites are outlined in brown.

Figure 8.5: Sediment settlement thickness as a result of aggregate extraction, drilling a large monopile in the North Falls and East Anglia TWO array areas, Sandwave clearance in the North Falls and East Anglia TWO array areas and Spoil disposal in the North Falls and East Anglia TWO array areas. Mean spring and mean neap tides.

FIVE
ESTUARIES
OFFSHORE WIND FARM

PHONE	0333 880 5306
EMAIL	fiveestuaries@rwe.com
WEBSITE	www.fiveestuaries.co.uk
ADDRESS	Five Estuaries Offshore Wind Farm Ltd Windmill Hill Business Park Whitehill Way, Swindon, SN5 6PB
COMPANY NO	Registered in England and Wales company number 12292474