Appendix 10A

SWAP 3D Seismic Survey Oil Spill Contingency and Response (OSCAR) Modelling

UpstreamHSE

Technical Report

Diesel Spill Modelling: SWAP 3D Seismic Survey Vessel Diesel Release

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1 Introduction

1.1 Driver and Scope of Modelling Work

This report describes the results of a number of modelling scenarios conducted to support the Shallow Water of the Absheron Peninsula (SWAP) 3D seismic survey.

This modelling study has been completed to support 2 objectives:

1. Conformance with GDP 4.6-0002 and to support emergency response, planning and preparedness for the SWAP 3D seismic survey.
2. Environmental and Social Impact Assessment for the SWAP 3D seismic survey.

The aim of this modelling study was to quantify the exposure of environmental resources in the event of an accidental spill by detailing the following:

- Fate of the spilt diesel over time and probability of impacts to surface, water column and shoreline;
- Concentration / thickness of diesel on the sea surface and in water column;
- Shortest arrival time of diesel to shore, and maximum volume of diesel on shore.

1.2 Project Description

BP signed a Production Sharing Agreement (PSA) with the State Oil Company of Azerbaijan Republic (SOCAR) in 2014, to jointly explore and develop potential prospects in the SWAP Contract Area. As part of the exploration programme BP is planning to undertake a 3D Seismic Survey.

The 3D Seismic Survey Area comprises five individual Priority Areas covering a total area of 1,520km2 and includes both offshore and onshore areas (Figure 1). The water depth of the offshore element ranges from 0 to 25m and has been subdivided into three zones for each Priority Area based on the water depth as follows:

- Transition Zone - up to 2m;
- Very Shallow Water Zone - between 2 and 5m; and
- Shallow Water Zone - > 5m (up to a maximum of 25m).

During the offshore data acquisition approximately 17 vessels will be used as source vessels (towing energy source), node vessels (deploying and collecting seabed nodes) and support vessels. The maximum fuel tank capacity is 10m3 for the vessels operating in the Shallow Water Zone (>5m depth).

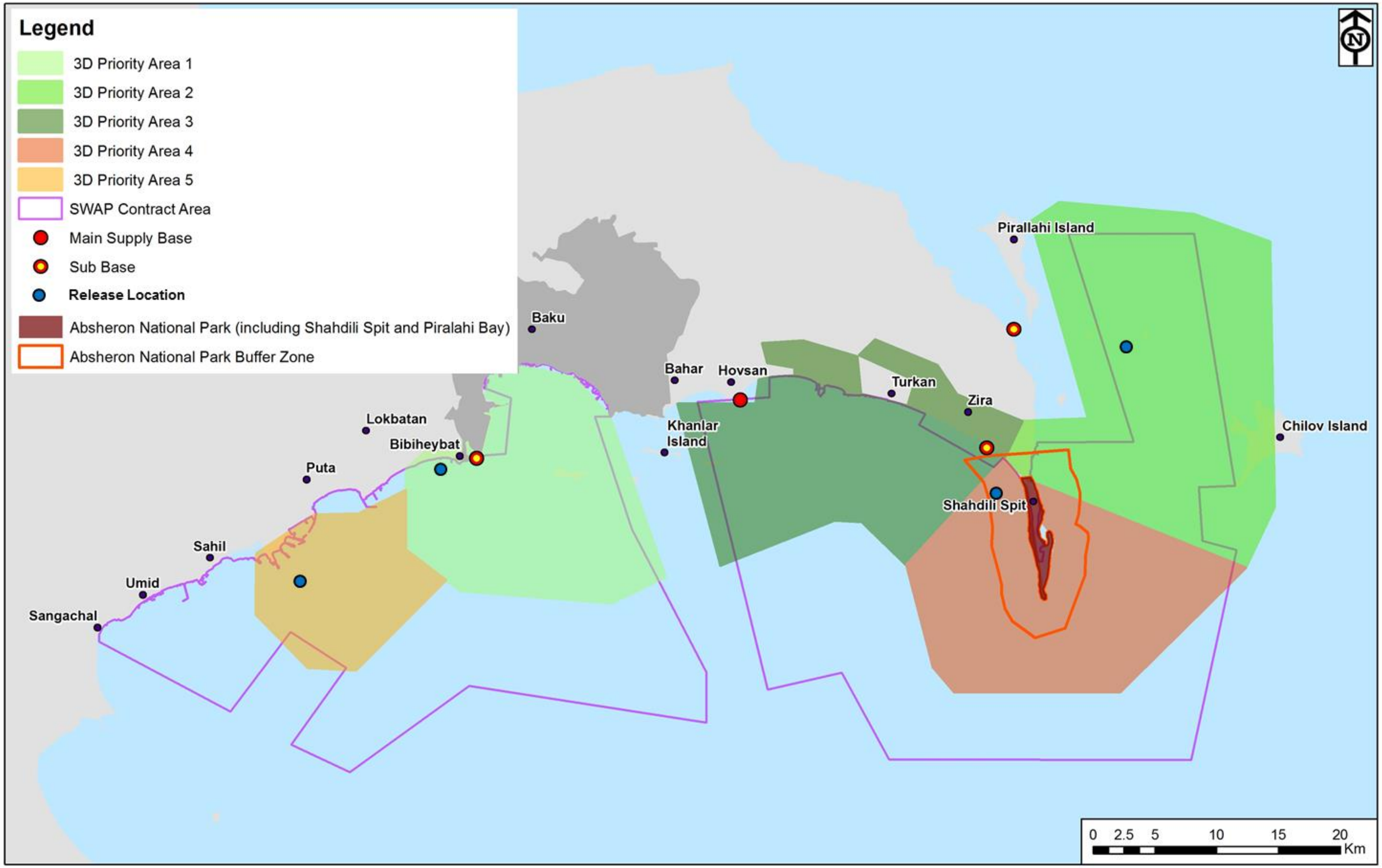
The 3D Seismic Survey is anticipated to commence in March 2016 and will last up to 9 months. The project logistics will comprise Hovsan Port which will be used as the main base camp and 3 sub-bases located along the coastline to support both on and offshore surveys (Figure 1).

1.3 Scenarios Modelled

This modelling report considers a collision with the seismic vessel working SWAP survey area resulting in a full inventory release of marine diesel. This is considered the credible worst case scenario that could potentially occur during the SWAP 3D seismic acquisition programme.

- This modelling has been carried out for four (4) scenarios that involve: A 10 m^3 instantaneous release of marine diesel (maximum survey vessel fuel tank capacity) at the sea surface.
- Four potential release locations within four of the priority survey areas (as shown in Figure 1) were selected, taking into account the proximity of most sensitive environmental receptors and resources.
- The fate of marine diesel was modelled for a period of 30 days following the release at each location.

Figure 1: SWAP 3D Survey Area and Priority Areas.



2 Oil Spill Contingency and Response (OSCAR) Modelling

2.1 How OSCAR Works

The SINTEF Oil Spill Contingency And Response model (OSCAR) is the BP Upstream Segment preferred oil spill fate and trajectory model. The use of this model is defined in BP's Group Defined Practice (GDP) 4.6-0002 – Oil Spill Preparedness & Response, Annex 2.

OSCAR is a 3-dimensional model that calculates and records the distribution (as mass and concentrations) of contaminants on the water surface, on shorelines, in the water column, and in sediments. The model allows multiple release sites, each with a specified beginning and end to the release. This allows time-variable releases at a given location, as well as throughout the study area. For subsurface releases (e.g. blowouts or pipeline leakages), the near field part of the simulation is conducted with a multi-component integral plume model that is embedded in the OSCAR model. The near field model accounts for buoyancy effects of oil and gas, as well as effects of ambient stratification and cross flow on the dilution and rise time of the plume.

The model output is recorded in three physical dimensions plus time. The model databases supply values for water depth, sediment type, ecological habitat, and shoreline type. The system has an oil physical-chemical database that supplies physical and chemical parameters required by the model.

The model computes surface spreading, slick transport, entrainment into the water column, evaporation, emulsification and shoreline interactions to determine oil drift and fate at the surface. In the water column, horizontal and vertical transport by currents, dissolution, adsorption, settling and degradation are simulated. The varying solubility, volatility, and aquatic toxicity of oil components are accounted by representing the oil in terms of a number of pseudo-components. By modelling the fate of individual pseudo-components, changes in the oil composition due to evaporation and degradation may be accounted for in the toxicity of the dissolved oil fraction.

OSCAR may compute oil weathering from crude assay data, although results that are more reliable are produced if the target oil has been through a standardized set of laboratory weathering procedures established by the SINTEF laboratories. Alternatively, the model may use oil weathering properties from oils for which data already exists, selecting the crude oil in the oil database that most closely matches the composition of the oil of concern.

2.2 Input Data to run OSCAR

OSCAR accepts as input both 2- and 3-dimensional current data from hydrodynamic models, and single point or gridded wind data from meteorological models.

The surface spreading, slick transport, entrainment into the water column, evaporation, emulsification and shoreline interactions processes that determine oil drift and fate are linked to an oil properties database. 27 key compounds within each hydrocarbon stored in the SINTEF database used within OSCAR are analysed in SINTEF laboratories. This ensures accurate representation of physical, chemical and biological behaviour of each hydrocarbon as it is released into the model.

The inputs used in this modelling study are defined in Section 3.

2.3 Outputs from OSCAR

2.3.1 Types of Output

Both single spill scenarios and stochastic scenarios with variable start times can be simulated. In the stochastic simulations, a specified number of scenarios are simulated subsequently in one run. The set of scenarios to be run may be specified either by selecting the number of scenarios to be simulated within a specified time period (single year statistics), or by specifying the number of scenarios to be run each year in a specified season (multiyear statistics). In order to provide data for computing oil drift statistics, certain oil drift parameters are accumulated for each scenario in each impacted grid cell. These results are in the end used to calculate probabilities for impact in a given cell. The impact is defined in terms of exceeding certain threshold values for oil concentration, thickness or mass. The results are presented as probabilistic maps for the different environmental compartments (sea surface, water column or shoreline).

2.3.2 Stochastic Modelling and Probabilistic Results

The following section describes some of the technical details regarding the statistical output from OSCAR.

The notion of a grid cell will be used, referring to the two-dimensional surface or shoreline grid, or the three-dimensional concentration grid. Each of these grids consists of cells, which represent the smallest area (highest spatial resolution) on which OSCAR operates when producing statistics.

OSCAR produces a set of statistics in its stochastic outputs including

- maximum or minimum;
- time-averaged;
- maximum time-averaged;
- Probability.

A map of maximum or minimum values can be produced from a stochastic simulation (for example maximum accumulated oil or minimum arrival time). This means that for all time steps and for all simulations, OSCAR has kept a record of the maximum or minimum for that particular value in each grid cell.

For example, the maximum accumulated shoreline oil map, the oil mass in every shoreline cell is checked every time step for every simulation. Whenever OSCAR detects that a shoreline cell has more oil than previously recorded, it will record this new value as the maximum. After all simulations have been performed, this maximum can then be reported for each cell.

Time-averaged statistics are used to produce an average value for a variable. For each simulation, OSCAR monitors each grid cell and records its value unless it has no impact (for example no surface oil or no total concentration). At the end of the simulation, these values are then averaged to produce the time-average. Whenever thresholds are applied pre-processing, the time-average will also exclude values below these specified thresholds.

Maximum time-averaged values can be presented as maps (such as the maximum time-averaged value total concentration). This means that for each grid cell, the value from the simulation with the largest time-average is selected and reported.

Probability maps can also be produced by the stochastic simulation. These maps indicate in the fraction or percentage of the stochastic simulations that reported the specified event (for example oil thicker than some threshold) for each cell. This can be oil on the surface, oil on the shoreline etc.

For example, the shoreline impact probability records each simulation that has some oil that hits a specific grid cell. If then three out of a total of ten simulations record oil hitting this shore cell, the probability for shoreline impact for this cell is 30%. Here there is no weighting for the frequency of oil coming ashore within each scenario.

2.4 OSCAR Outputs Used in this Report

Both stochastic and deterministic scenarios were run for the identified scenarios (refer to Section 1.2). Below is a summary of OSCAR outputs employed in this report:

- Surface diesel extent, probability, arrival time, concentration, and time-averaged thickness
- Water column diesel extent, probability, arrival time and concentration
- Shoreline diesel extent, probability, arrival time and mass.

3 OSCAR Set-Up for this Report

Metocean data from the Imperial College London ReEMS model (White and Toumi, 2013a,b*;* Nicholls *et al.,* 2014) was used for all scenarios. Data was provided in the form of 3D currents and 2D winds.

Snapshots of the surface currents from the ReEMS dataset are shown in Appendix 1 (at start of each deterministic simulation run) and Appendix 2 (regional overview for each month survey activity will be carried out).

Table 1: ReEMS current and wind data

Current and Wind	Imperial College London ReEMS
Data Coverage	01/01/2006 – 31/12/2009
Depth	32 levels, full depth[1]
Horizontal Resolution	4 km
Temporal Resolution	3 hourly
Atmospheric Forcing	ROMS WRF (3-hour)
Vertical Diffusion	Calculated
Tide	Yes
Boundary	Volga, Ural, Samur, Sulak, Terek and Kura Rivers
Current / Wind Domain	36.5N-47.7N, 46.5E-55E

3.1 Surface, Shoreline, and Water Column Diesel Thresholds

3.1.1 Surface Diesel Thickness

A minimum diesel thickness threshold of 0.04µm was used within the stochastic simulations. This value is the lower limit of the thinnest oil appearance classification – Sheen – within the Bonn Agreement (Lewis, 2007). Any diesel present on the surface thinner than 0.04µm is not included in the stochastic outputs. Surface diesel values below this BAOAC minimum threshold were not exported from OSCAR.

3.1.2 Shoreline Emulsion Mass

A minimum threshold for shoreline emulsion mass of 0.169 tonnes/km was used within the stochastic simulations for condensate releases. These values are the lower limit of the "Light Oiling" threshold used by The International Tanker Owners Pollution Federation Ltd (ITOPF, 2011). Shoreline diesel oiling values below this ITOPF minimum threshold were not exported from OSCAR.

[1] Currents are provided at 32 depths within the water column, all the way from the surface to the seabed.

The threshold of 0.169 tonnes/km for condensate releases was calculated based on:

a) the length of the hypotenuse of each surface grid (283 m)

b) a mean shoreline width of 2m,

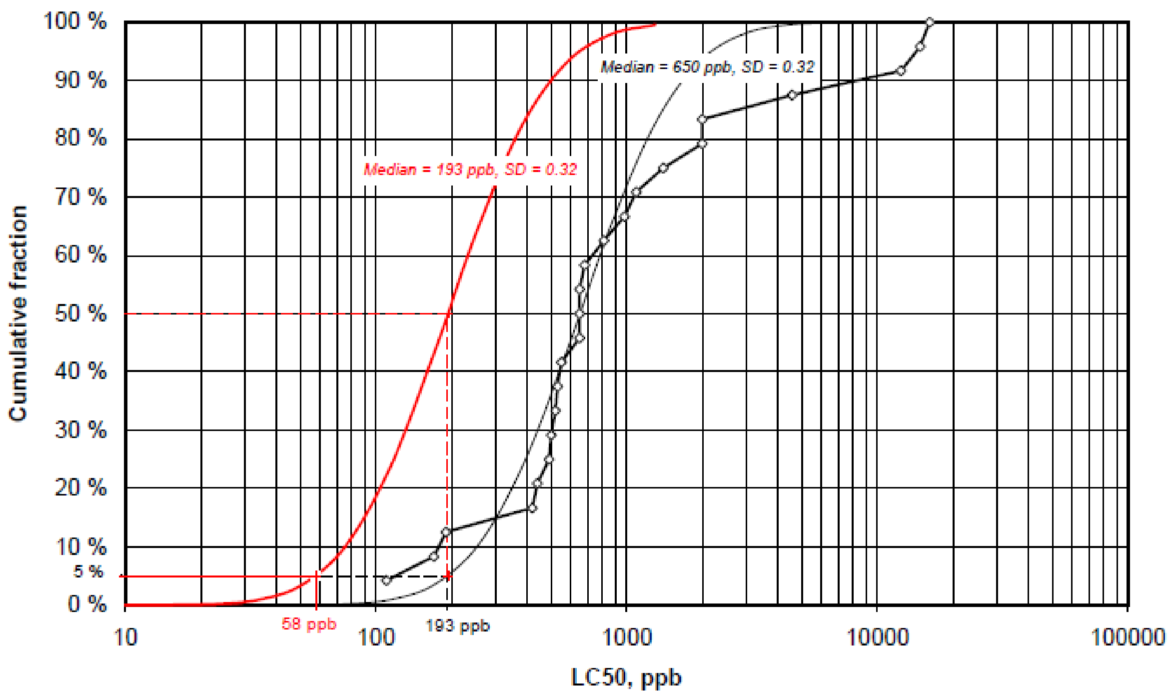
c) minimum Light Oiling threshold of 0.1litres/m^2

d) emulsion density of 846kg/m3 @STP (based on 2% water uptake)

3.1.3 Total Diesel Concentrations of Diesel in the Water Column

Total diesel concentrations in the water column pose a risk to organisms when they exceed a certain concentration. Research completed by Statoil (2006) and Det Norsk Veritas (2008) resulted in the development of species sensitivity dose-response curves to assess the impact to organisms from different water column hydrocarbon concentrations. A 5^{th} percentile LC50[2] for total hydrocarbon concentrations was found to be 58 ppb (see Figure 2). This value of 58 ppb is used within this modelling as the lower threshold for potential acute toxicological responses. Concentrations below this threshold are not exported from OSCAR. This is a conservative lethal exposure value for marine fauna as 58 ppb is below the LC50 for 95% of species as can be seen from Figure 2. At this concentration mortality is highly unlikely however toxicological effects may be both short and long-term.

Figure 2: LC50 values from toxicity studies on dispersed oil on various aquatic species.
The red line is the cumulative distribution curve of interest. This sensitive species dose-response curve shows the 5 % percentile LC50 value and SD = 0.32. From this dose-response curve, the threshold value (5 % lethal risk) is found to be 58 ppb.



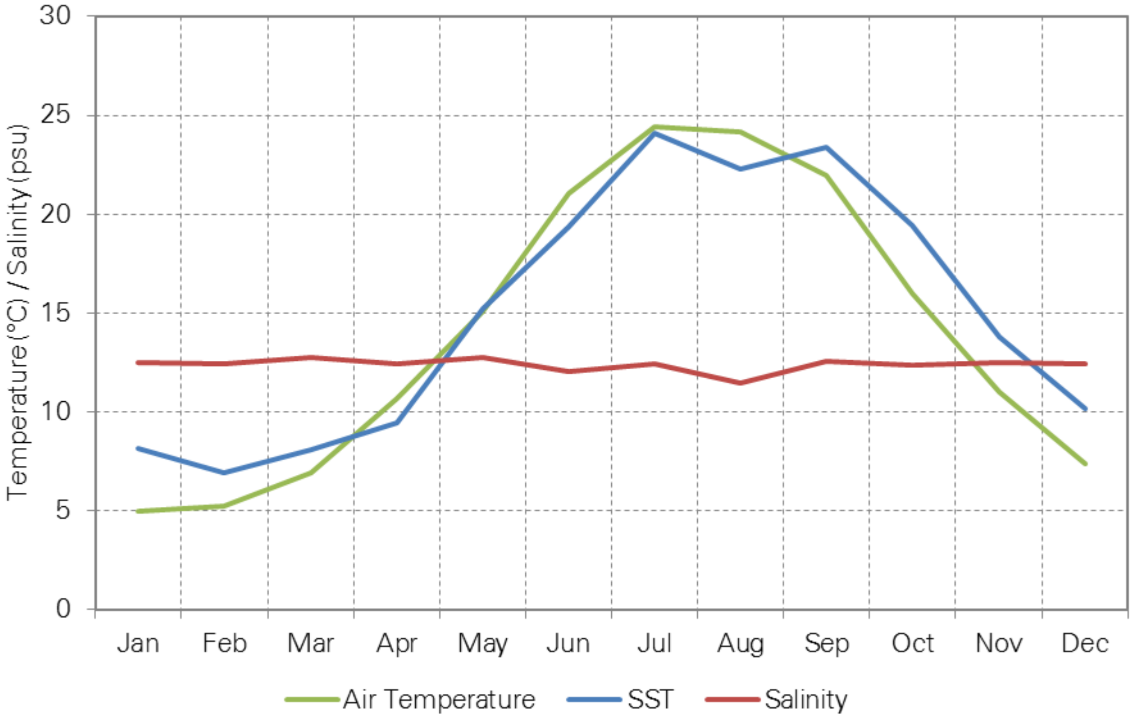
3.2 Water Column Conditions

Temperature and salinity data is used within OSCAR to calculate the trajectory and fate of released hydrocarbons. Climatological (monthly averaged) air temperature, sea surface temperature (SST) and sea

[2] LC50 refers to a concentration of diesel (dissolved and dispersed) in the water column resulting in a lethal exposure to 50% of species of organism exposed.

surface salinity (SSS) data were obtained from the National Oceanic and Atmospheric Administration (NOAA) National Virtual Ocean Data System (NVODS, 2015) covering the survey area (49.5°E - 50.5°E, 40.0°N - 40.5°N) (see Figure 3).

Figure 3: Air Temperature, SST and SSS monthly averages for the SWAP 3D Survey Area.



3.3 OSCAR Set-Up

The modelling domain used for the SWAP 3D Seismic Survey diesel releases covers an area from 49.11°E, 39.10°N – 50.50°E, 40.57°N (140km x 200km) which equals 28,000 km^2. The modelling domain with bathymetry is shown in Figure 4 and other OSCAR modelling set-up parameters and release data are outlined in Table 3 and Table 4 respectively.

OSCAR modelling domain and modelling parameters were set-up the same for all 4 scenarios:

1. Scenario 1: Priority Area 1
2. Scenario 2: Priority Area 2
3. Scenario 3: Priority Area 4
4. Scenario 4: Priority Area 5

Each of the 4 scenarios differed in the location and month(s) of the release. Details of the release locations are provided in Table 2. Air and sea surface temperatures and salinity are based on the data shown in Figure 3 and rounded to the nearest 0.5°C / psu.

Table 2: Release location, month, air and sea surface temperature and sea surface salinity for each modelled scenario.

Scenario	Release Coordinates (Long, Lat)		Month(s) of Spill	Air Temperature	Sea Surface Temperature	Sea Surface Salinity
Priority Area 1	49.787512	40.298725	Mar - Apr	9.0°C	9.0°C	12.5
Priority Area 2	50.436974	40.390684	Jun – Aug	23°C	22°C	12.0
Priority Area 4	50.327826	40.288559	Sep - Oct	19°C	21.5°C	12.5
Priority Area 5	49.665402	40.217038	Nov	11°C	14°C	12.5

Figure 4: Map showing OSCAR modelling domain used with bathymetric data.

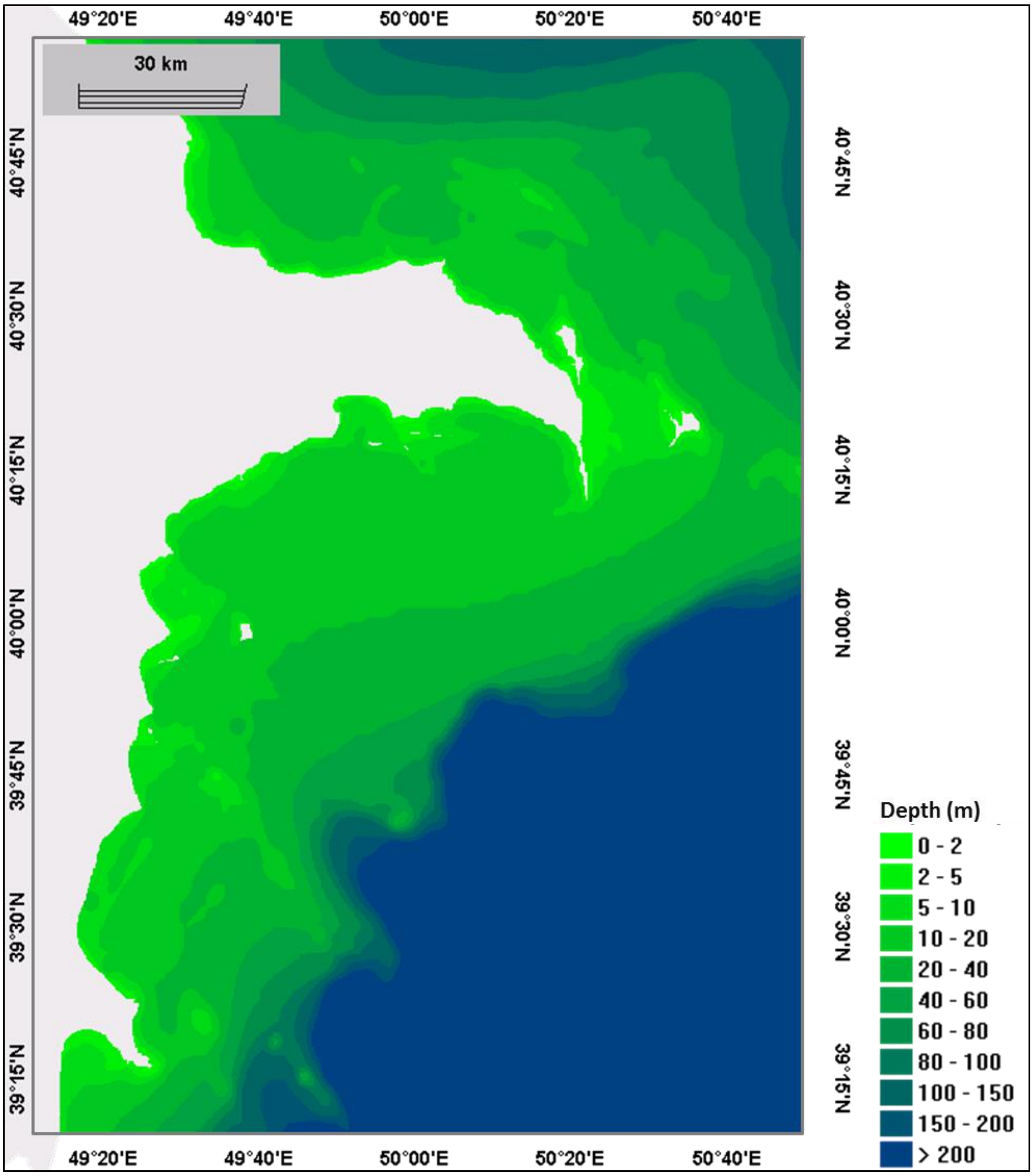


Table 3: OSCAR Set-up parameters used for the vessel diesel release.

Model Set-up Parameters			
Release Diameter		N/A	m
Release Location	See Table 2		
Number of Particles	Liquid / Solid Particles	10,000	
	Dissolved Particle	10,000	
	Gas Particles	1000	
Habitat Grid Spatial Resolution	Resolution in the x-direction (longitude)	200	m
	Resolution in the y-direction (latitude)	200	m
Shoreline Type / Width	Sandy Beach	2	m
Concentration Grid Resolution	Resolution in the x-direction (longitude)	200	m
	Resolution in the y-direction (latitude)	200	m
	Resolution in the z-direction (depth)	10	m
Surface Grid Spatial Resolution	Resolution in the x-direction (longitude)	200	m
	Resolution in the y-direction (latitude)	200	m
Concentration Grid Depth	Min:	0	m
	Max:	50	m
Lower Concentration Limit		58	ppb
Surface Film Thickness	Initial Thickness	1	mm
	Thick Limit	0.1	mm
	Terminal Thickness	0.04	µm
Computational / Output Time-step	Time-step	3	hours
	Output Interval	20	minutes
Release Period		1	hr
Simulation Period		30	days
Air Temperature	See Table 2		

Table 4: OSCAR release data for SWAP 3D vessel diesel inventory release

Scenario: Seismic Vessel Diesel Release					**Well/inventory loss parameters**			
Loss from well / FPSO / rig / Other (please specify)			Vessel		Instantaneous loss?	Partial – 1 hour		
Worst case volume			10 m^3		Will the well self-kill? If yes then when?	N/A		
Flow rate			N/A					
Justification for predicted worst case volume			SWAP 3D Spill Scenario Workshop					
Location								
Spill source point		Latitude	See Table 2	Longitude	See Table 2			
Installation / Facility name		Seismic Vessel						
Hydrocarbon properties								
Hydrocarbon name		Marine Diesel						
Assay available		Yes	Was an analogue used for spill modelling?			Yes		
	Name	ITOPF category	Specific gravity	API	Viscosity (cp @°C)	Asphaltene (%)	Wax (%)	Pour point (°C)
Hydrocarbon	Marine Diesel (IKU)		0.843	36.4	3.9 (Ref Temp)	N/A	N/A	-36
Analogue								
Fuel loss	Marine Diesel							
Metocean Parameters								
Air temperature	See Table 2	Sea temperature	See Table 2					
Wind data	Data period:	2006 – 2009 (4 years)						
Wind data reference	Imperial College London ReEMS							
Current data	Data period:	2006 – 2009 (4 years)						
Current data reference	Imperial College London ReEMS							
Modelled release parameters								
Surface or subsurface	Surface	Depth	0 m					
Release duration	1 hour	Instantaneous Release?	Partial – 1 hour					
Total simulation time	30 days	Total release	10 m^3					
Oil spill modelling software								
Name of software	MEMW (OSCAR)	Version	6.5.1					

4 Stochastic Modelling Results

This section presents the results from the vessel release stochastic (statistical) modelling. Each output in the sections below presents different information from the stochastic simulations. A brief explanation is provided below:

Surface Diesel Oiling

- Probability of Surface Diesel Oiling
    - Shows the probability (>5%) of surface diesel exceeding 0.04µm thickness, which is the lower limit of visible oil on the sea surface – a "sheen" – as defined by the Bonn Agreement Oil Appearance Code (BAOAC) system (Lewis, 2007).
- Minimum Arrival Time of Surface Diesel
    - Minimum arrival time of surface diesel thicker than 0.04µm (BAOAC "Sheen"). No probability threshold is applied due to limited functionality in OSCAR. Results therefore include probabilities <1%, which explains the significantly larger extent than shown in the Surface Diesel Oiling Probability maps where probabilities <5% are not included.
- Maximum Surface Diesel Thickness
    - Shows the maximum thickness of diesel that is predicted to occur on the sea surface during a release from the diesel release. Thicknesses are presented as groups accounting to the Bonn Agreement Oil Appearance Code (BAOAC). No probability threshold is applied due to limited functionality in OSCAR. Results therefore include probabilities <1%, which explains the significantly larger extent than shown in the Surface Diesel Oiling Probability maps where probabilities <5% are not included.
- Surface Diesel Oiling Exposure Time
    - Shows the maximum amount of time where diesel >0.04µm thick (BAOAC "Sheen") is present on the sea surface from the vessel release. No probability threshold is applied due to limited functionality in OSCAR. Results therefore include probabilities <1%, which explains the significantly larger extent than shown in the Surface Diesel Oiling Probability maps where probabilities <5% are not included.

Water Column Dispersion

- Probability of Dissolved Diesel in the Water Column
    - Shows the probability (>5%) that there will be total diesel (dissolved and dispersed) in the water column at concentrations >58 ppb from the release.
- Minimum Arrival Time of Dissolved Diesel
    - Shows the quickest time from the start of the release when total water column diesel concentrations (dissolved and dispersed) >58ppb reach a certain location. No probability threshold is applied due to limited functionality in OSCAR. Results therefore include probabilities <1%, which explains the significantly larger extent than shown in the Water Column Diesel Oiling Probability maps where probabilities <5% are not included.
- Dissolved Diesel Exposure Time
    - Shows the maximum amount of time where water column diesel (dissolved and dispersed) concentrations >58ppb exists in the water column. No probability threshold is applied due to limited functionality in OSCAR. Results therefore include probabilities <1%, which explains the significantly larger extent than shown in the Water Column Diesel Oiling Probability maps where probabilities <5% are not included.

- Probability of Shoreline Diesel Oiling
    - Shows probability (>1%) of shoreline diesel oiling occurring at >0.169 tonnes/km – the ITOPF "Light Oiling" threshold (ITOPF, 2011). A probability of 1% is used for shoreline diesel oiling (cf. 5% for surface and water column) to align with the approach used elsewhere within BP.
- Minimum Arrival Time of Diesel to Shoreline
    - Shows the quickest time from the start of the release when diesel oiling >0.169 tonnes/km (Minimum ITOPF "Light Oiling" Threshold) occurs along the shoreline. No probability threshold is applied due to limited functionality in OSCAR. Results therefore include probabilities <1%, which explains the somewhat larger extent than shown in the Shoreline Oiling Probability maps where probabilities <1% are not included.

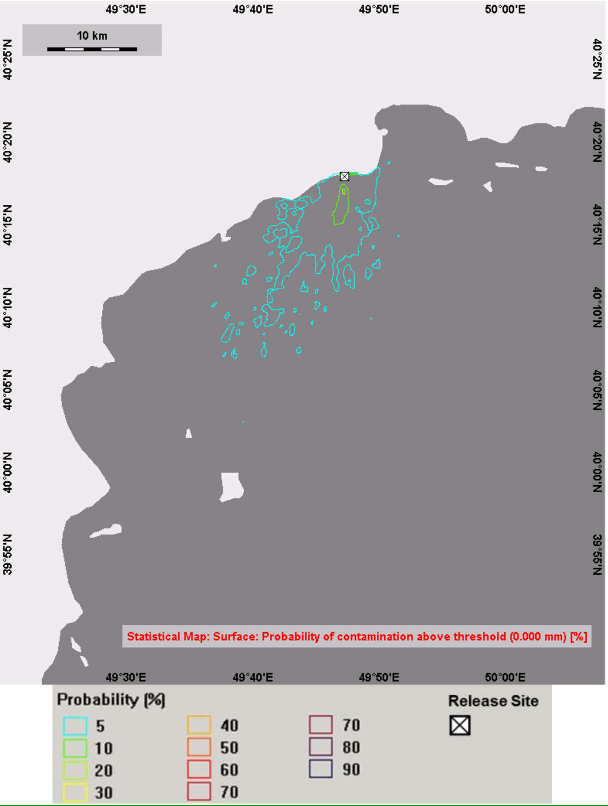
Note: The following figures are numbered according to which Priority Area (PA) they represent and which stochastic simulation output is shown, e.g. the surface probability map (output 1) for Priority Area 1 is numbered PA1.1.

4.1 Priority Area 1

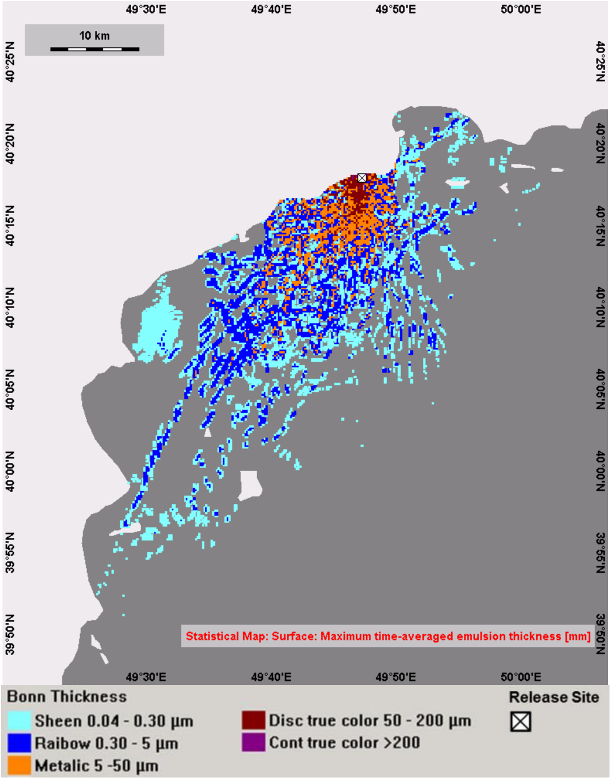
Priority Area 1 (March – April)

Stochastic Simulations - Surface Statistics

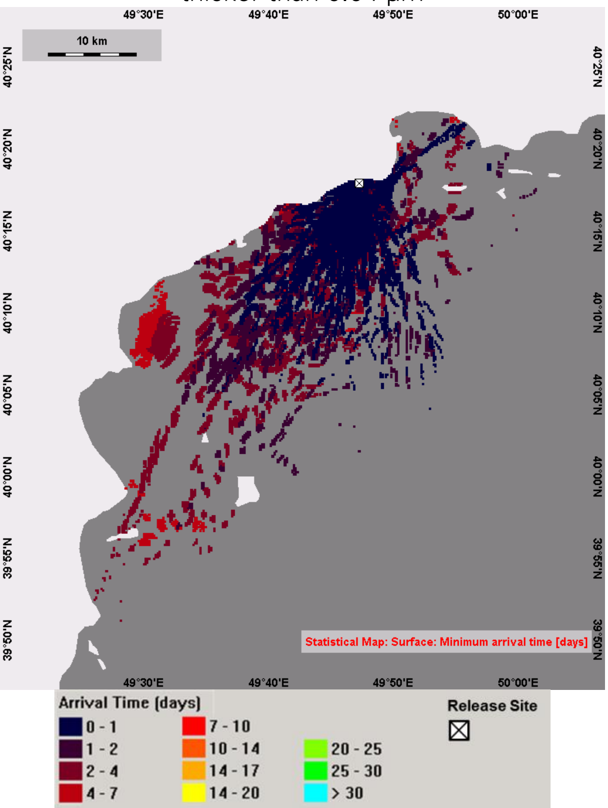
PA1.1 Surface Diesel Oiling Probability (>5%) over 0.04 µm thickness (minimum visible BAOAC thickness)



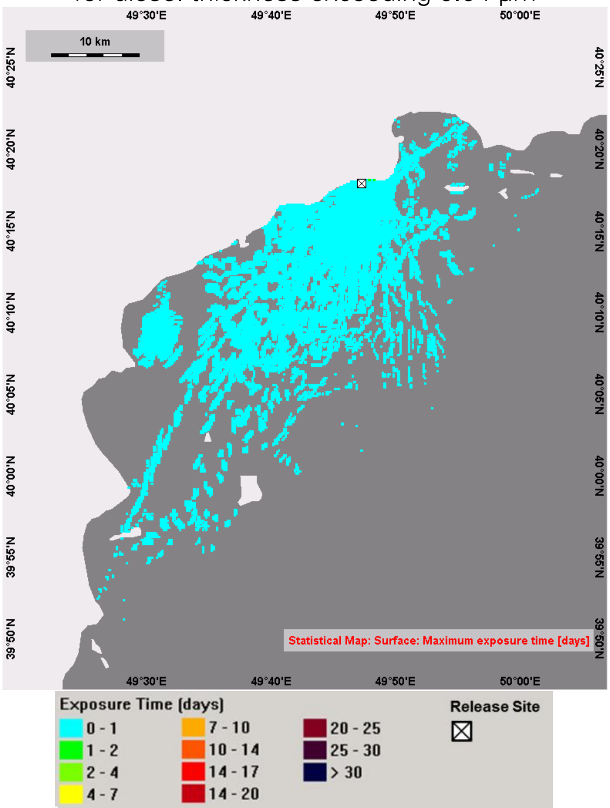
PA1.2 Surface diesel oiling average thickness (>0.04 µm) by BAOAC category



PA1.3 Minimum arrival time of surface diesel thicker than 0.04 µm



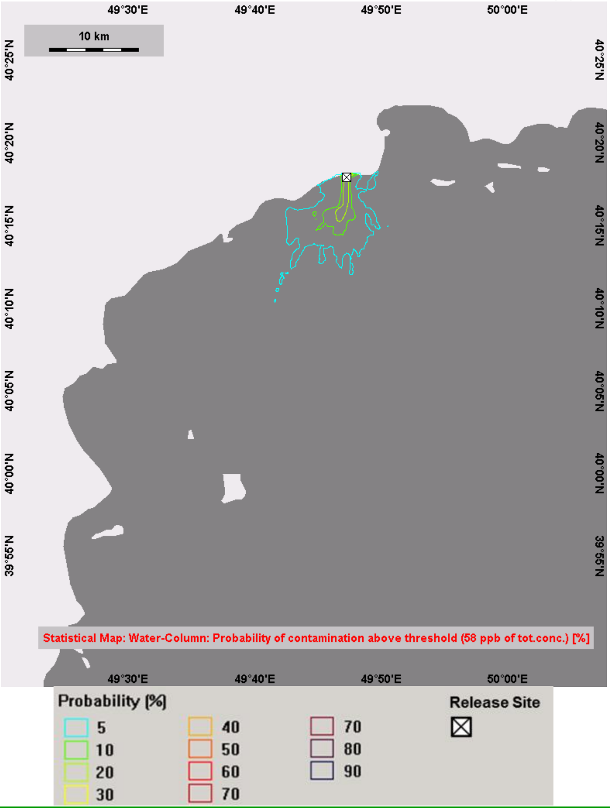
PA1.4 Maximum surface diesel exposure in days for diesel thickness exceeding 0.04 µm



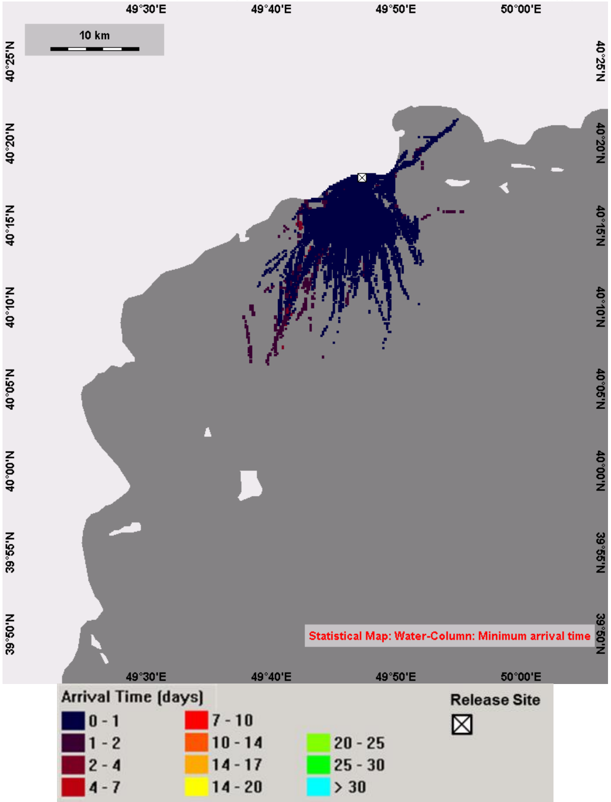
Priority Area 1 (March – April)

Stochastic Simulations – Water Column Statistics

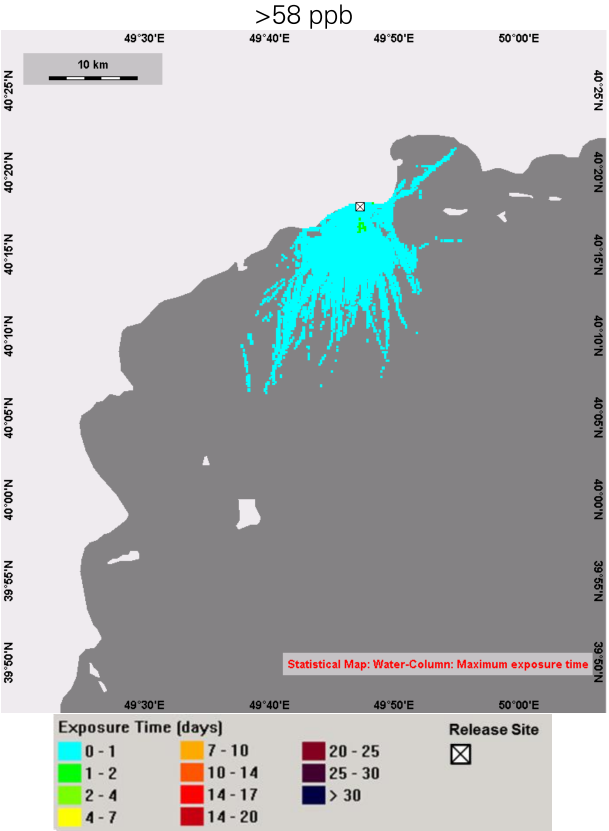
PA1.5 Probability (>5%) of water column diesel concentrations (dispersed and dissolved) >58 ppb



PA1.6 Minimum arrival time of water column diesel concentrations (dispersed and dissolved) >58 ppb



PA1.7 Maximum water column exposure in days for diesel concentrations (dispersed and dissolved) >58 ppb

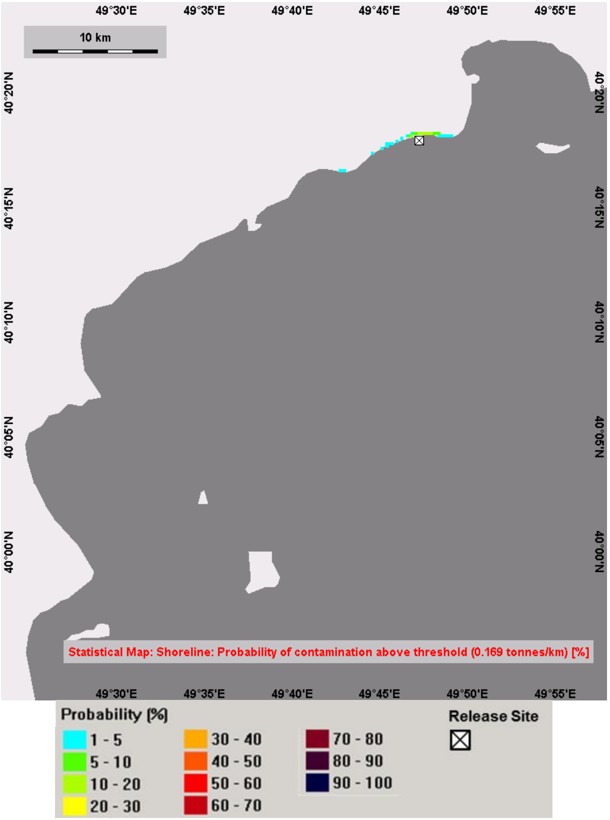


Priority Area 1 (March – April)

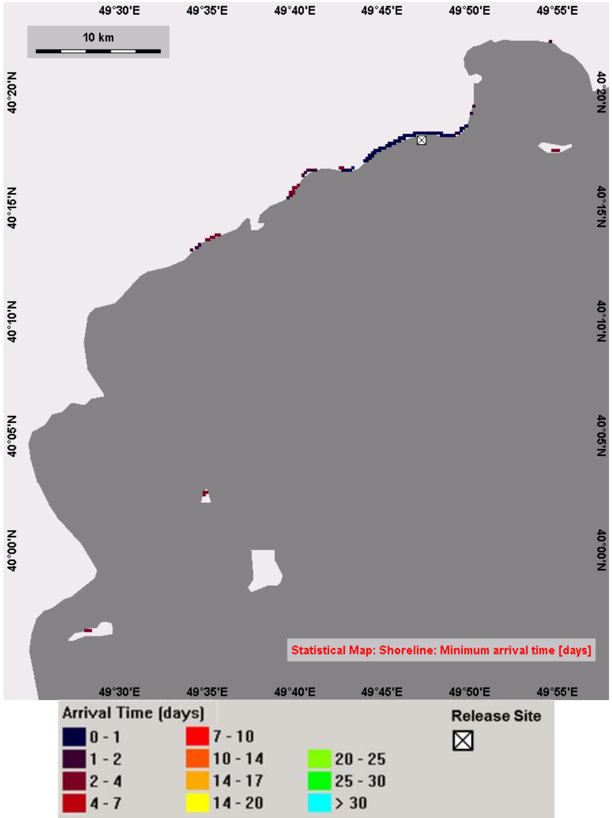
Stochastic Simulations – Shoreline Statistics

(Note: Displayed at larger scale than surface and water column maps in order to show detail of shoreline impacts)

PA1.8 Shoreline Diesel Oiling Probability (>1%) where shoreline diesel mass exceeds 0.169 tonnes/km



PA1.9 Minimum arrival time of diesel on the shoreline exceeding 0.169 tonnes/km

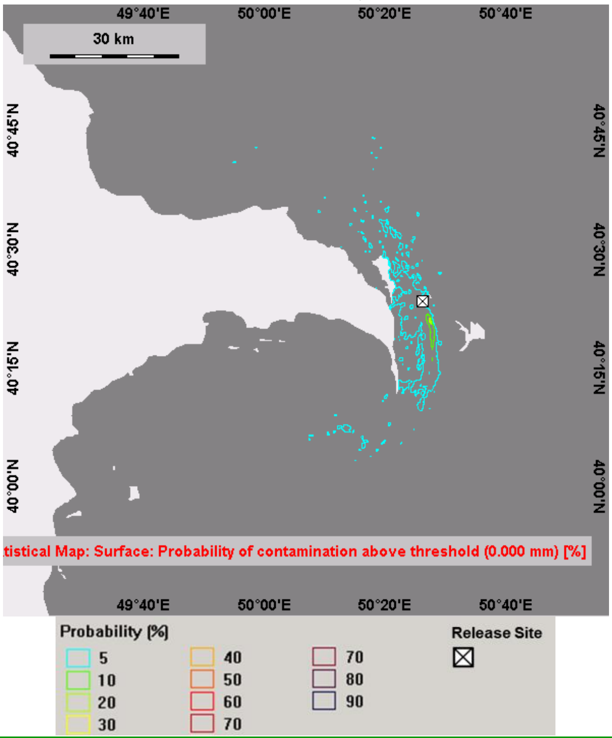


4.2 Priority Area 2

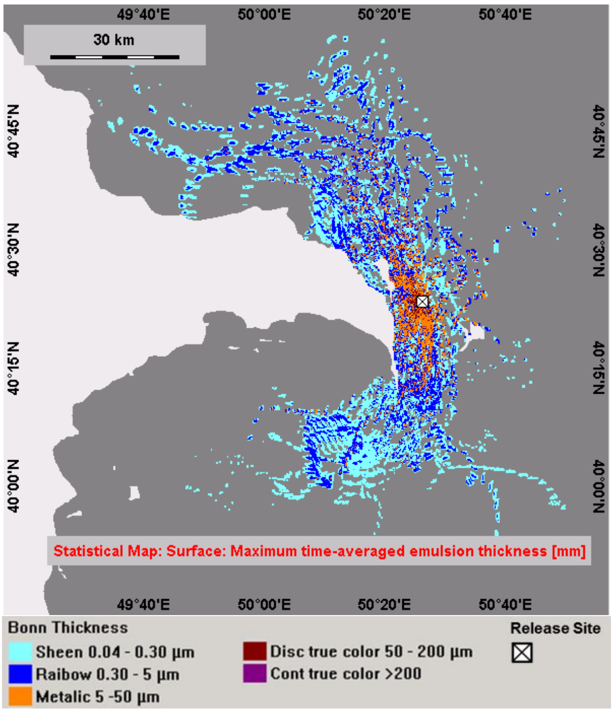
Priority Area 2 (September – October)

Stochastic Simulations - Surface Statistics

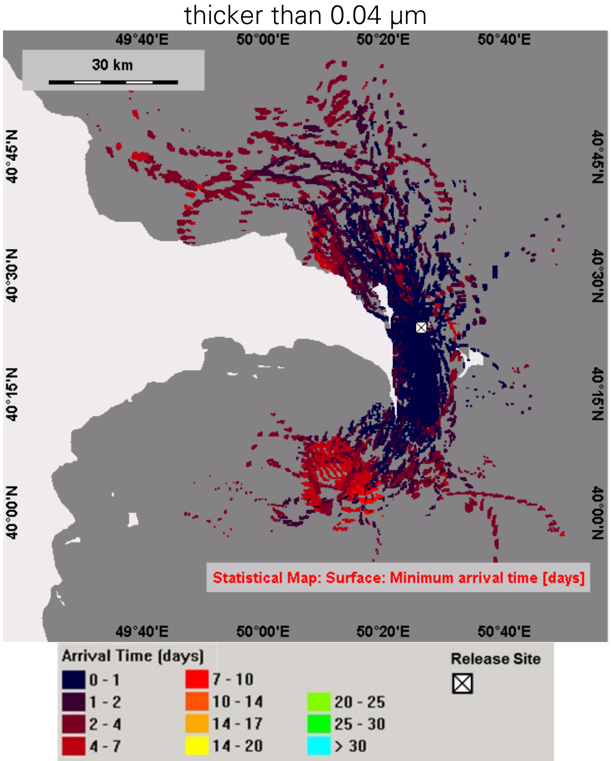
PA2.1 Surface Diesel Oiling Probability (>5%) over 0.04 µm thickness (minimum visible BAOAC thickness)



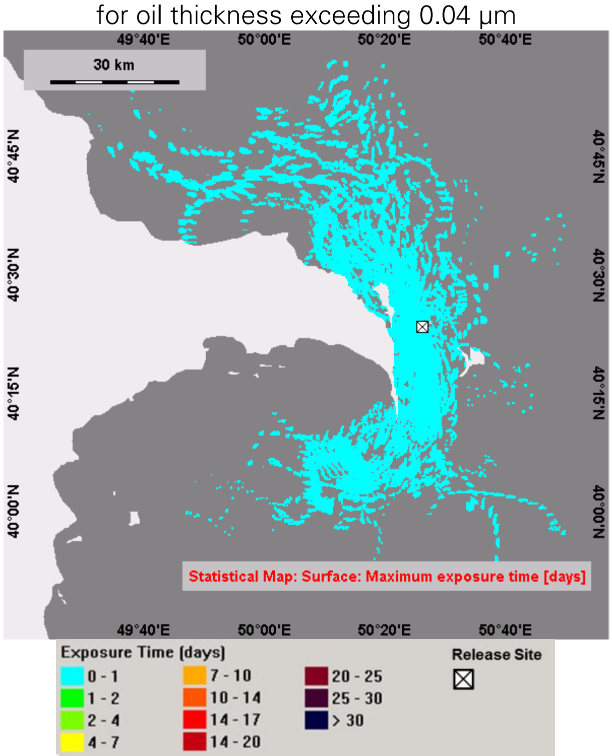
PA2.2 Surface diesel oiling average thickness (>0.04 µm) by BAOAC category



PA2.3 Minimum arrival time of surface diesel thicker than 0.04 µm



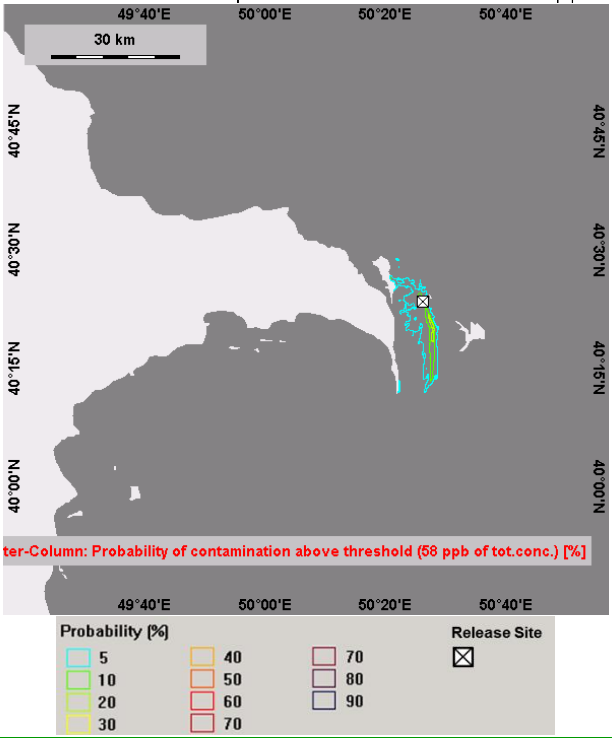
PA2.4 Maximum surface diesel exposure in days for oil thickness exceeding 0.04 µm



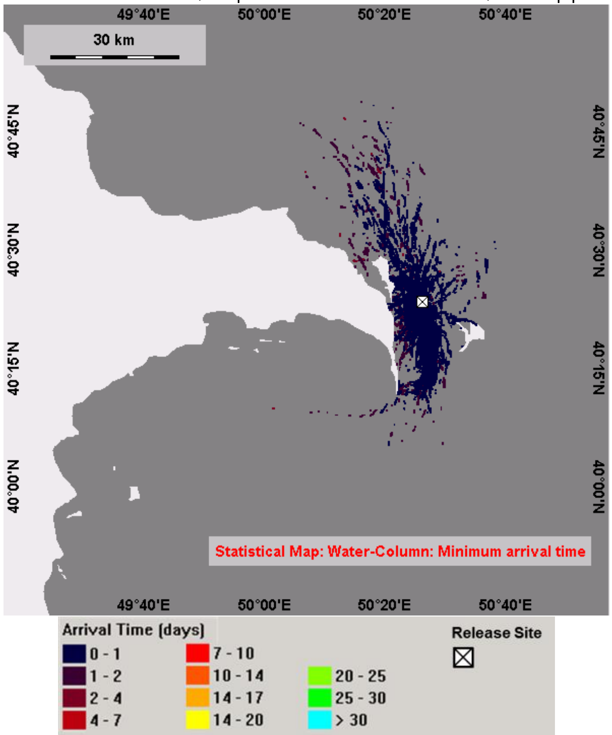
Priority Area 2 (September – October)

Stochastic Simulations – Water Column Statistics

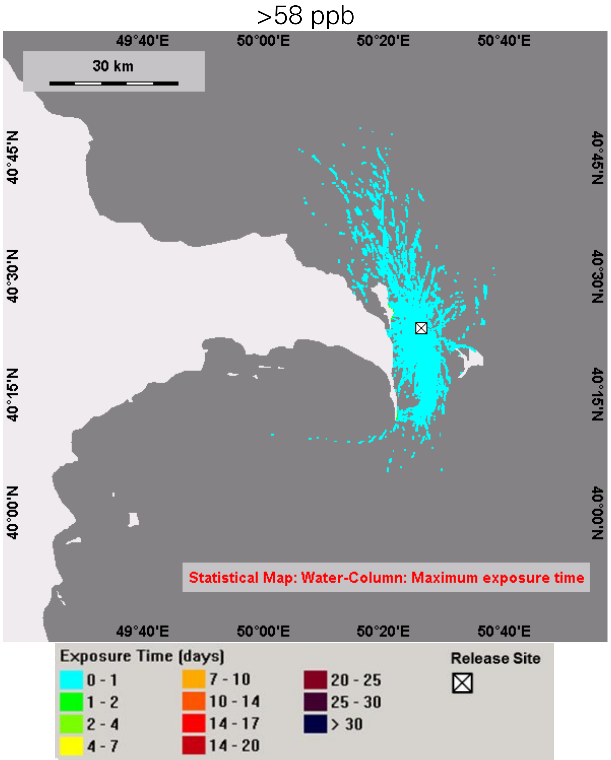
PA2.5 Probability (>5%) of water column diesel concentrations (dispersed and dissolved) >58 ppb



PA2.6 Minimum arrival time of water column diesel concentrations (dispersed and dissolved) >58 ppb



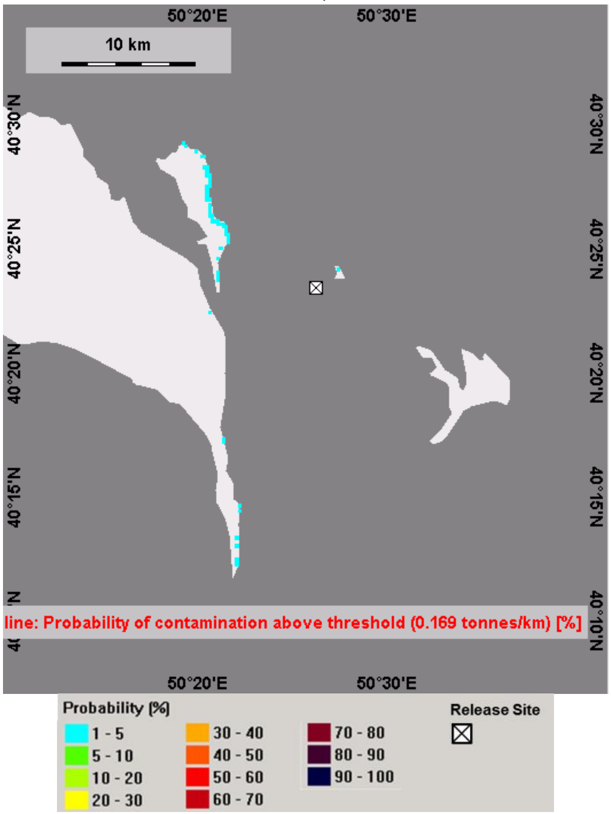
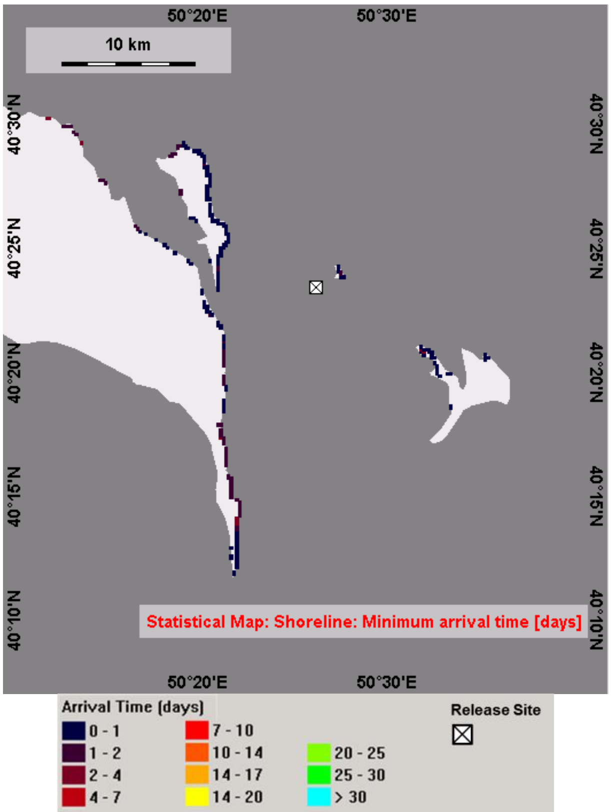
PA2.7 Maximum water column exposure in days for diesel concentrations (dispersed and dissolved) >58 ppb



Priority Area 2 (September – October)

Stochastic Simulations – Shoreline Statistics

(Note: Displayed at larger scale than surface and water column maps in order to show detail of shoreline impacts)

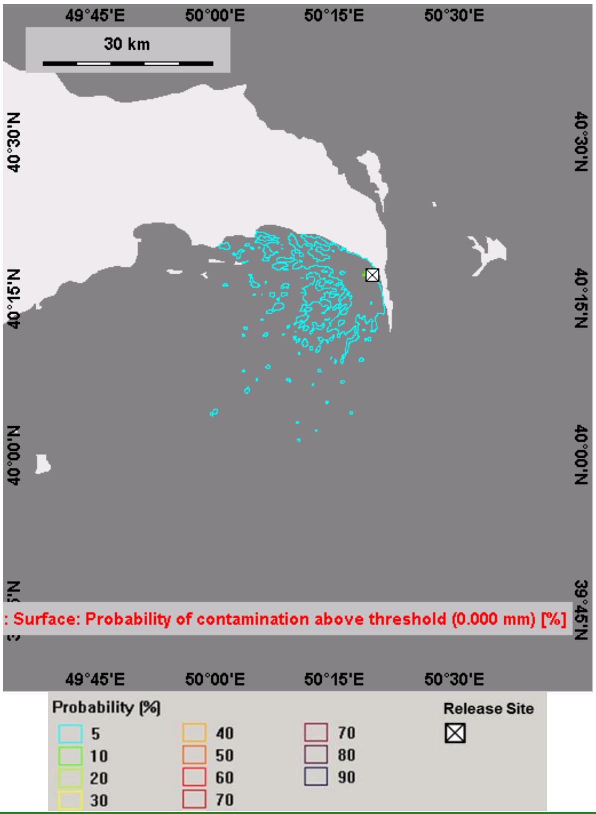
PA2.8 Shoreline Diesel Oiling Probability (>1%) where shoreline diesel mass exceeds 0.169 tonnes/km	PA2.9 Minimum arrival time of diesel on the shoreline exceeding 0.169 tonnes/km
	

4.3 Priority Area 4

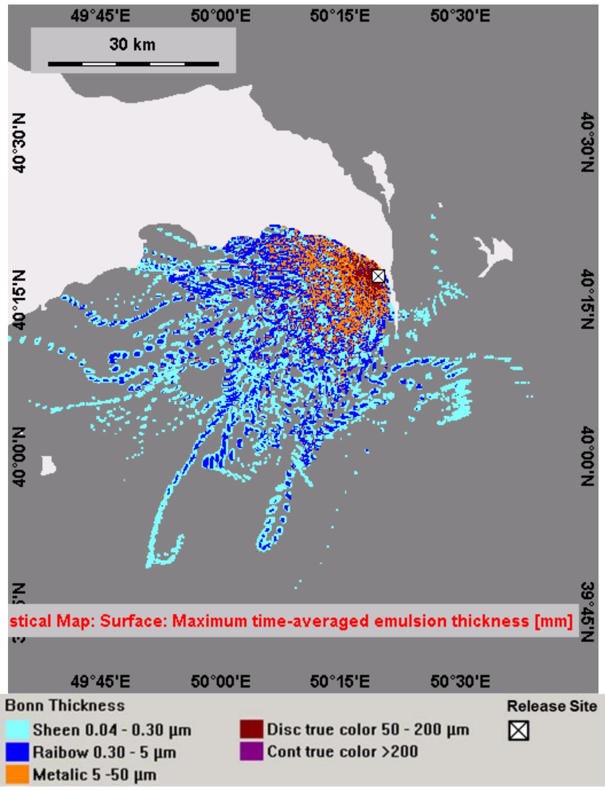
Priority Area 4 (June – July)

Stochastic Simulations - Surface Statistics

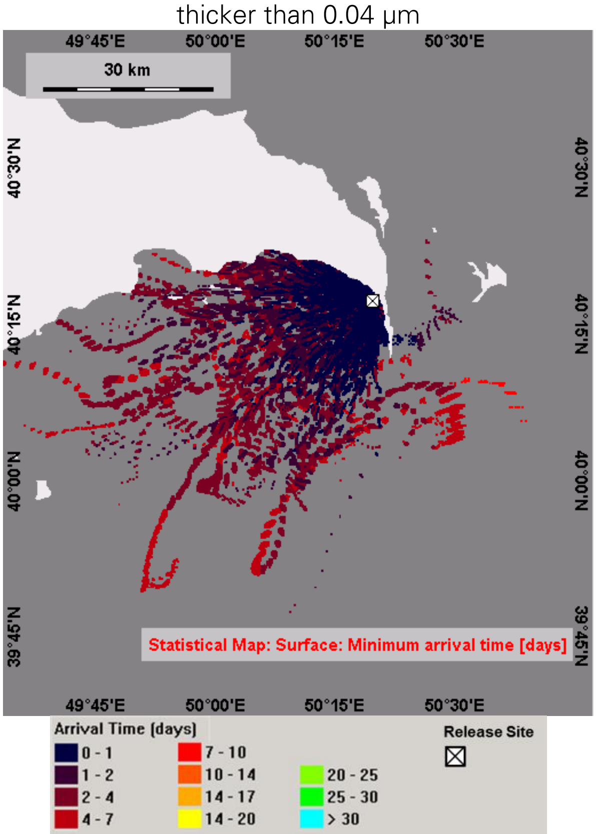
PA4.1 Surface Diesel Oiling Probability (>5%) over 0.04 µm thickness (minimum visible BAOAC thickness)



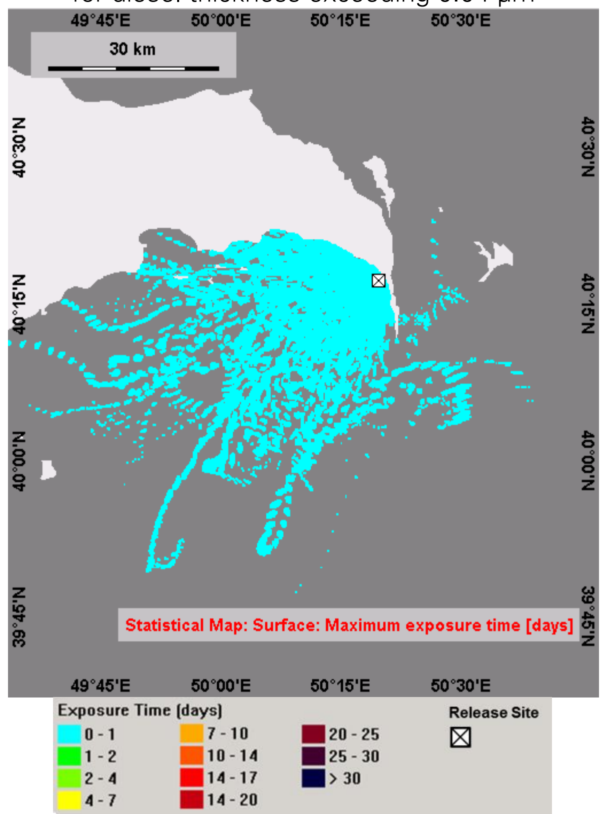
PA4.2 Surface diesel oiling average thickness (>0.04 µm) by BAOAC category



PA4.3 Minimum arrival time of surface diesel thicker than 0.04 µm



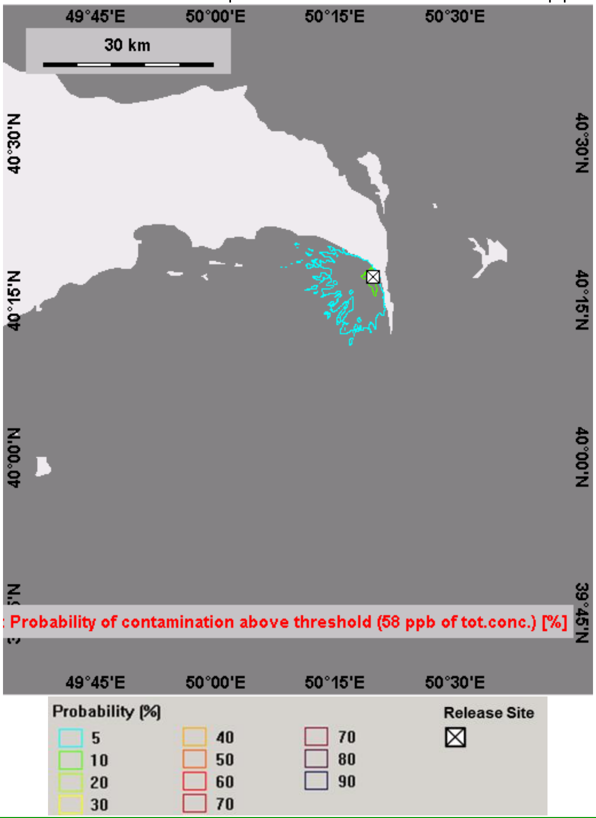
PA4.4 Maximum surface diesel exposure in days for diesel thickness exceeding 0.04 µm



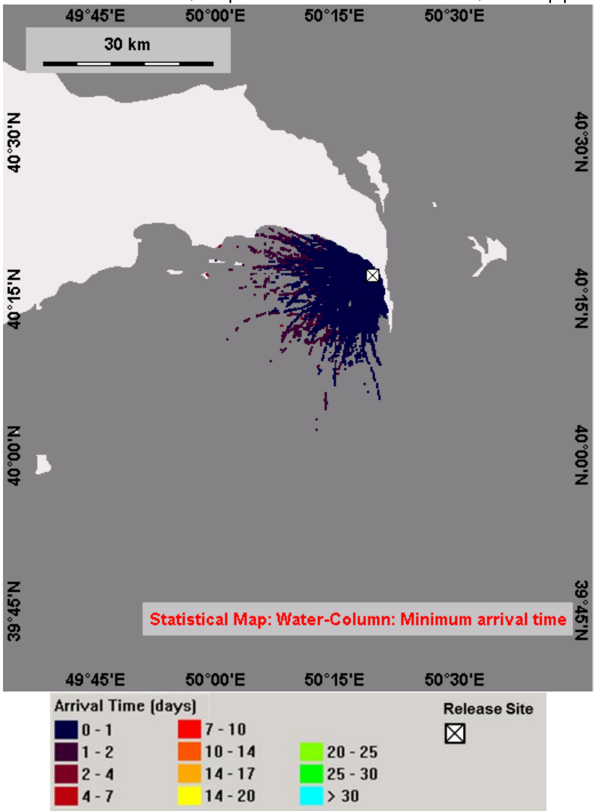
Priority Area 4 (June – July)

Stochastic Simulations – Water Column Statistics

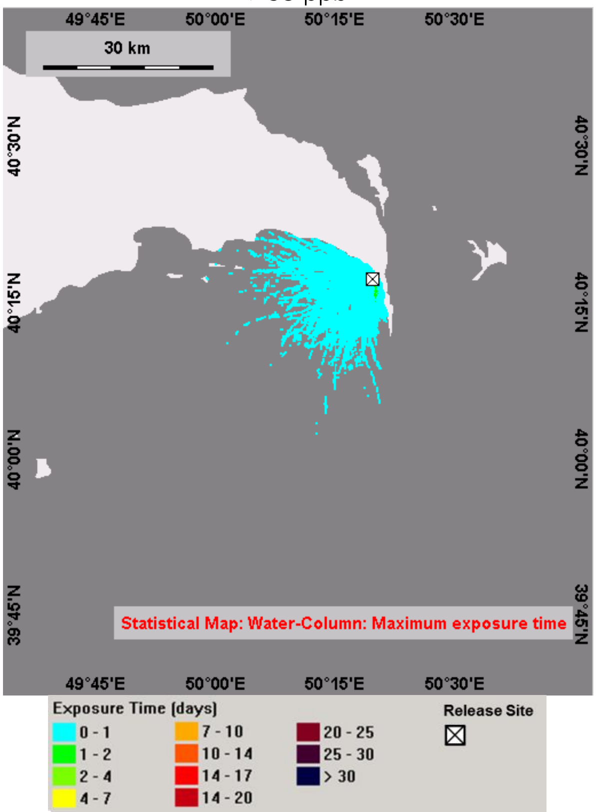
PA4.5 Probability (>5%) of water column diesel concentrations (dispersed and dissolved) >58 ppb



PA4.6 Minimum arrival time of water column diesel concentrations (dispersed and dissolved) >58 ppb



PA4.7 Maximum water column exposure in days for diesel concentrations (dispersed and dissolved) >58 ppb

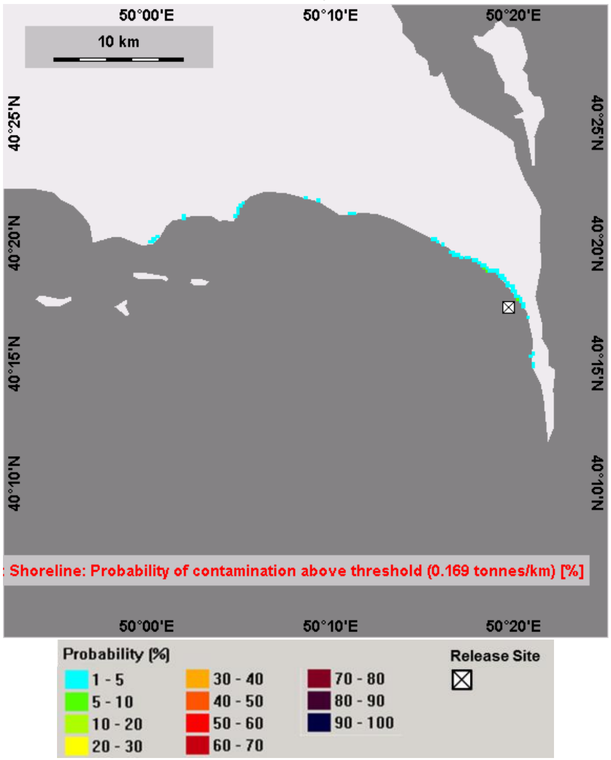


Priority Area 4 (June – July)

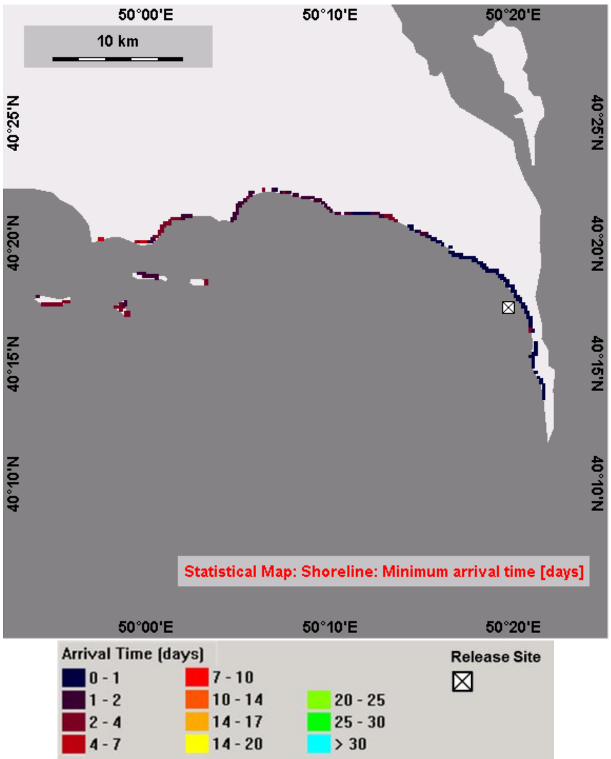
Stochastic Simulations – Shoreline Statistics

(Note: Displayed at larger scale than surface and water column maps in order to show detail of shoreline impacts)

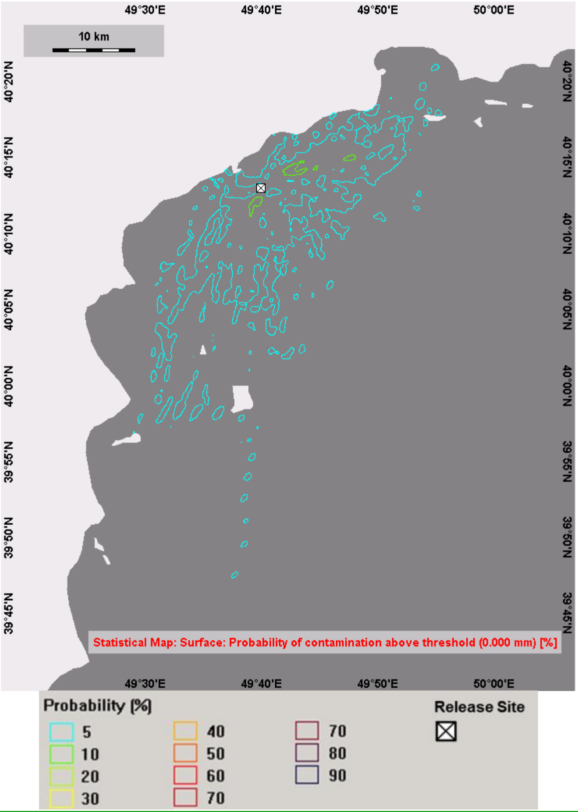
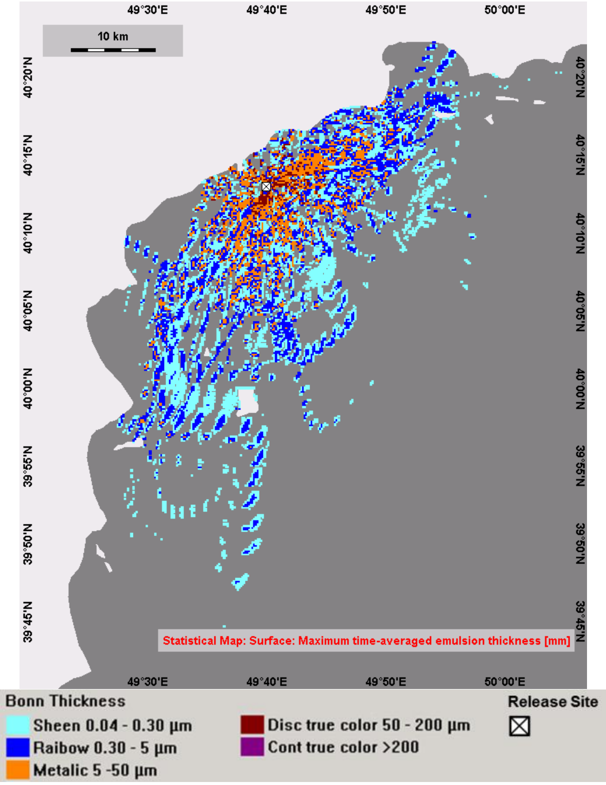
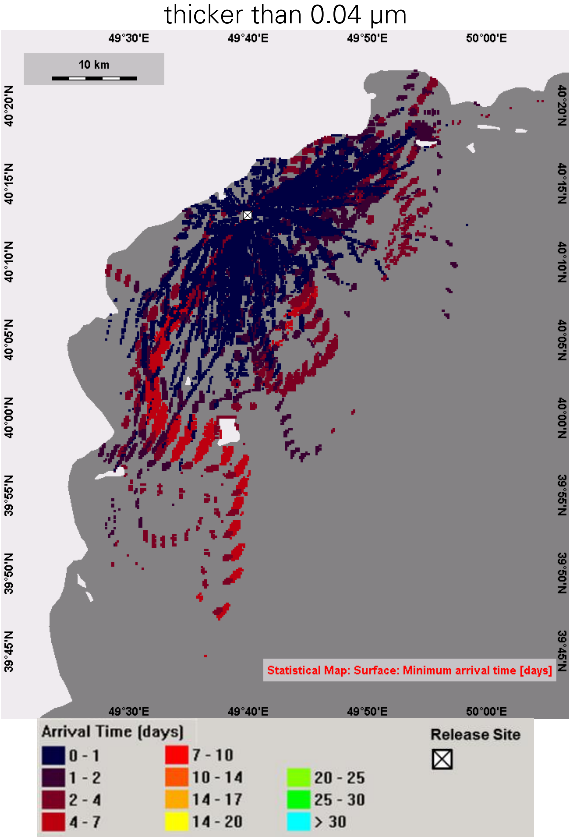
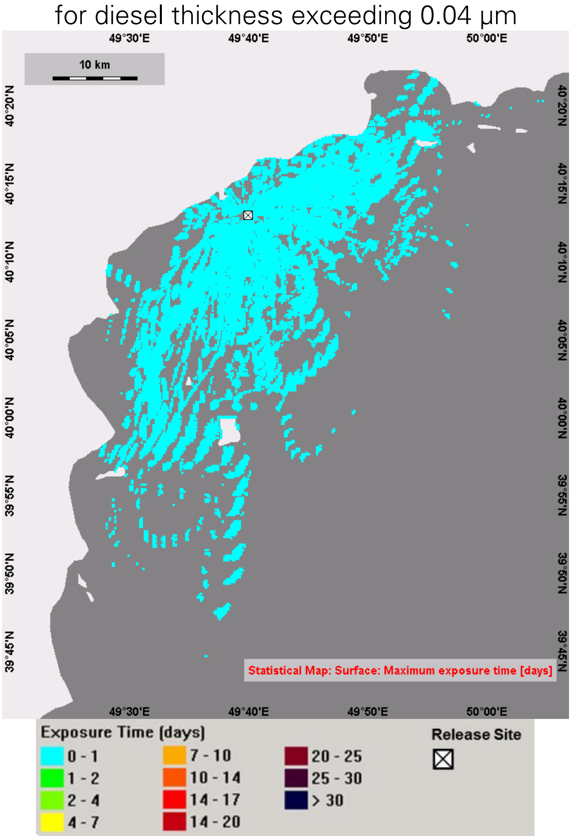
PA4.8 Shoreline Diesel Oiling Probability (>1%) where shoreline diesel mass exceeds 0.169 tonnes/km



PA4.9 Minimum arrival time of diesel on the shoreline exceeding 0.169 tonnes/km



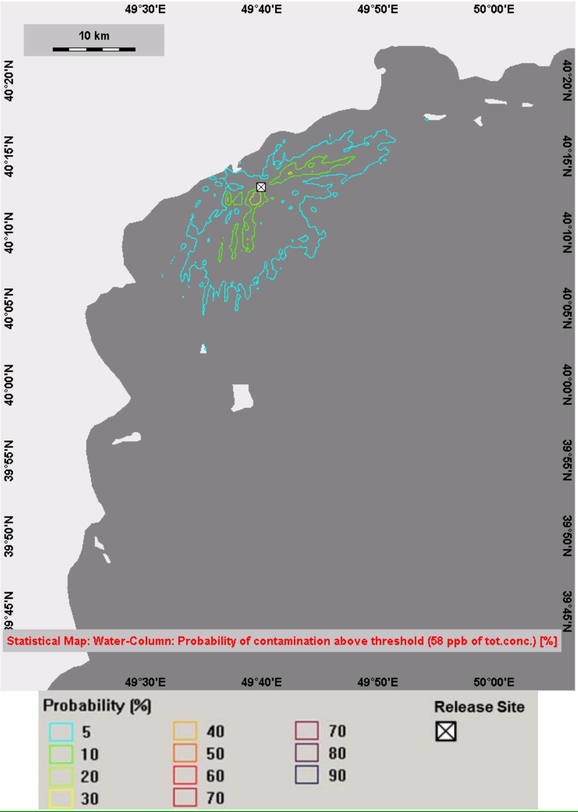
4.4 Priority Area 5

Priority Area 5 (November)	
Stochastic Simulations - Surface Statistics	
PA5.1 Surface Diesel Oiling Probability (>5%) over 0.04 µm thickness (minimum visible BAOAC thickness) 	PA5.2 Surface diesel oiling average thickness (>0.04 µm) by BAOAC category 
PA5.3 Minimum arrival time of surface diesel thicker than 0.04 µm 	PA5.4 Maximum surface diesel exposure in days for diesel thickness exceeding 0.04 µm 

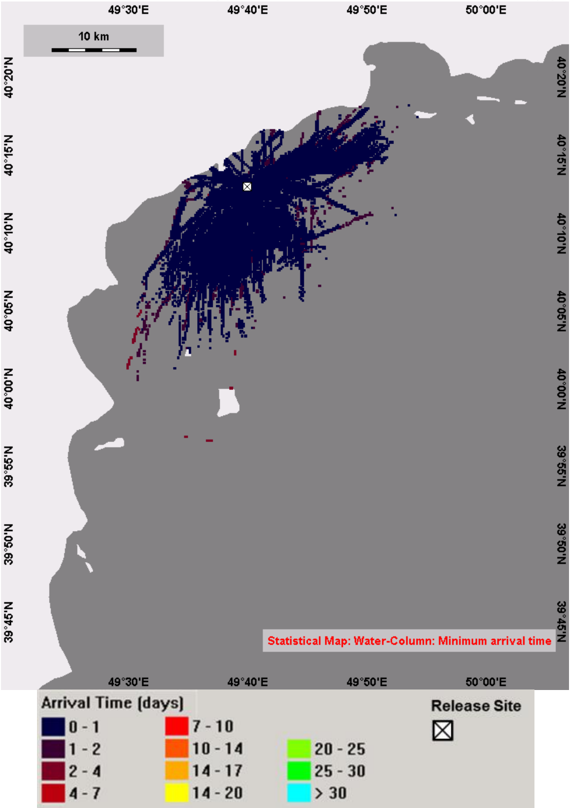
Priority Area 5 (November)

Stochastic Simulations – Water Column Statistics

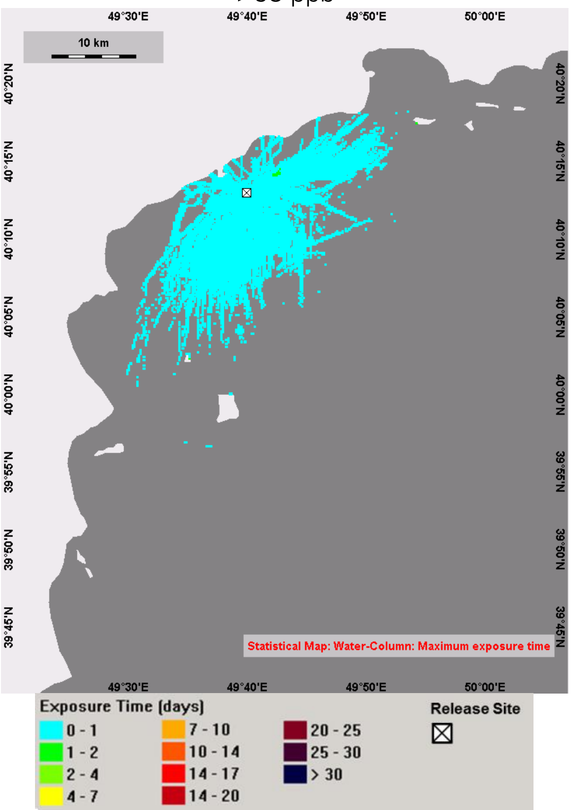
PA5.5 Probability (>5%) of water column diesel concentrations (dispersed and dissolved) >58 ppb



PA5.6 Minimum arrival time of water column diesel concentrations (dispersed and dissolved) >58 ppb



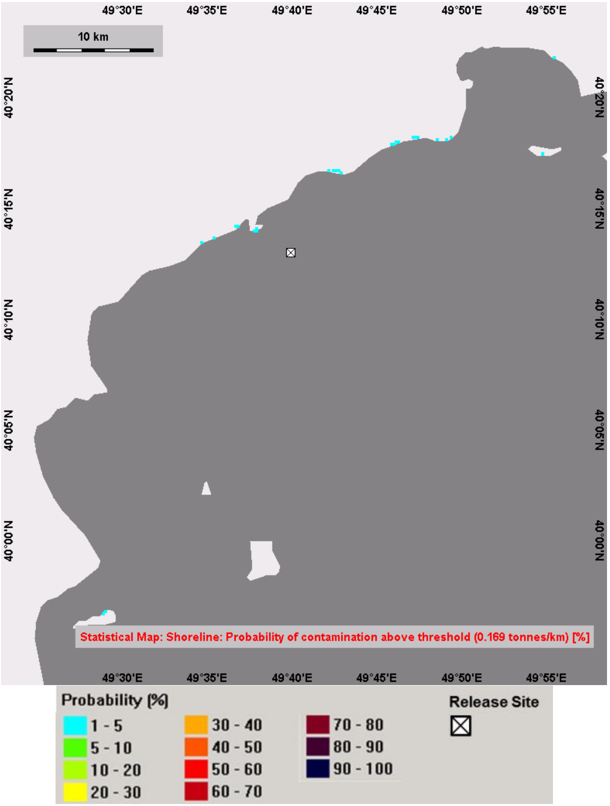
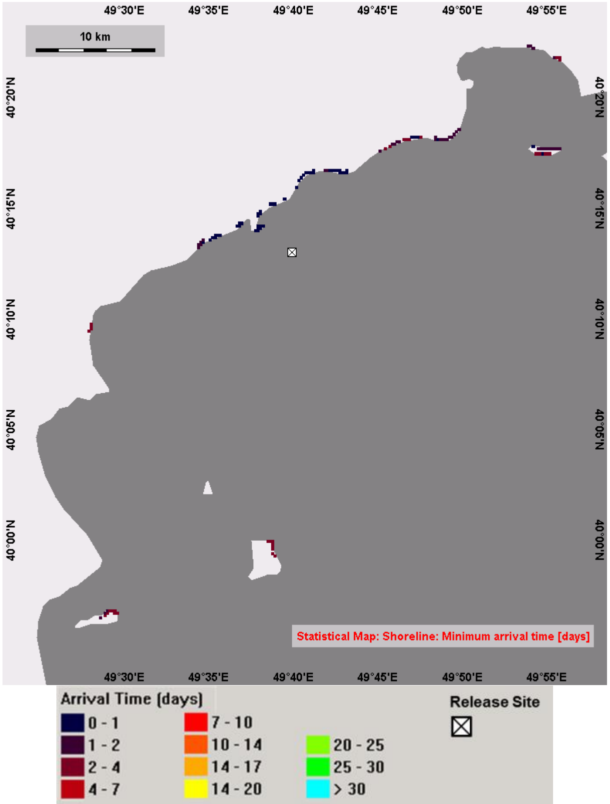
PA5.7 Maximum water column exposure in days for diesel concentrations (dispersed and dissolved) >58 ppb



Priority Area 5 (November)

Stochastic Simulations – Shoreline Statistics

(Note: Displayed at larger scale than surface and water column maps in order to show detail of shoreline impacts)

PA5.8 Shoreline Diesel Oiling Probability (>1%) where shoreline diesel mass exceeds 0.169 tonnes/km	PA5.9 Minimum arrival time of diesel on the shoreline exceeding 0.169 tonnes/km
	

4.5 Tabulated Stochastic Results

The table below synthesises key outputs from the stochastic modelling. The surface area[3] and shoreline lengths[4] with greater than 5% probability of impact are provided, along with shortest arrival time to shore and maximum mass of diesel ashore. Scenario numbers are provided for shortest arrival time to shore and maximum mass ashore. Deterministic modelling (Section 0) was carried out for the scenarios with maximum mass of diesel ashore.

Table 5: Stochastic Simulation Summaries for the four Priority Areas.

Scenario	Surface Area with ≥5% Probability of Impact[3] (km^2)	Shoreline Length with ≥1% Probability[4] of Impact[5] (km)	Shortest Arrival Time to Shore (hh:mm)	Maximum Mass of Diesel Ashore (tonnes)
Priority Area 1	5.68	9.05	00h:40m (Scenario #2)	8.47 (Scenario #96)
Priority Area 2	7.06	17.82	03h:20m (Scenario #78)	8.06 (Scenario #200)
Priority Area 4	1.37	19.52	01h:20m (Scenario 68)	8.22 (Scenario #26)
Priority Area 5	5.08	7.35	02h:20m (Scenario #50)	6.91 (Scenario # 74)

[3] Surface Area calculated as number of surface grid cells with probability ≥5% multiplied by area of each grid cell (0.04 km^2)

[4] Probability threshold of 1% used for shoreline impacts, compared to 5% for surface and water column, to align with BP standard practice

[5] Shoreline Length calculated as number of shoreline grid cells with probability ≥5% multiplied by the hypotenuse of each grid cell (282.84 m)

5 Deterministic Modelling Results

5.1 Worst Case Shoreline Diesel Oiling

From the stochastic simulations the worst-case scenarios in terms of shoreline impacts (greatest mass ashore) were identified (see Table 5). These worst case scenarios correspond to release times as follows (YYYY:MM:DD HH:MM)[6]:

- Priority Area 1: 2007:04:04 08:00
- Priority Area 2: 2009:06:25 07:00
- Priority Area 4: 2006:09:26 05:00
- Priority Area 5: 2008:11:14 04:00

This worst case shoreline diesel oiling scenarios above were re-run (using the same settings as the stochastic simulations) as single deterministic simulations so the evolution of this spill and the fate of the diesel could be analysed.

The following pages show the evolution of the Worst Case Shoreline Diesel Oiling scenarios over time (1 – 30 days) and also maximum surface thickness and water column concentrations at any time, and mass balance over the first 30 days of the release.

Table 6 below summarises the shoreline and surface impacts from each worst case scenario (note: for minimum arrival time to shore and maximum mass of oil onshore, refer to Table 5).

Table 6: Shoreline and Surface Impacts during Worst Case (deterministic) Shoreline Diesel Oiling Scenarios.

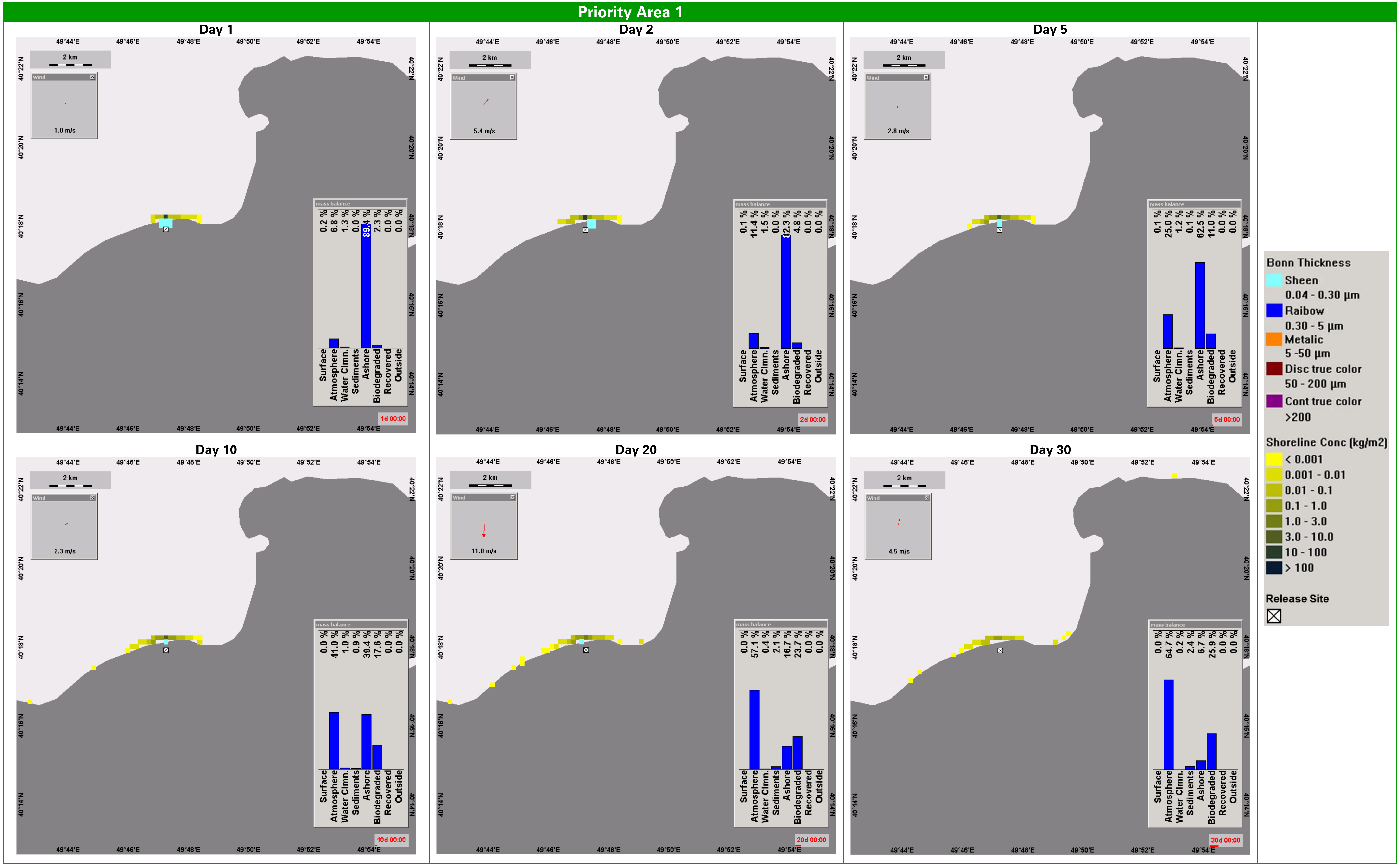
Scenario	Maximum Extent (and Time[7]) of Shoreline Diesel Oiling[8] (km / dd:hh)	Extent of Shoreline Diesel Oiling[8] after 30 days (km)	Mass of Diesel Onshore after 30 days (te)	Maximum Area of Surface Diesel >0.04µm (km^2)
Priority Area 1	1.70 / 03d:18h	1.14	0.59	3.73
Priority Area 2	1.99 / 12d:06h	1.42	0.64	3.00
Priority Area 4	1.70 / 05d:12h	0.57	0.58	1.56
Priority Area 5	1.99 / 01d:18h	1.70	0.79	1.56

[6] Note that the stochastic simulations covered the full period of current and wind data, from 01/01/2006 – 31/12/2009 (see Table 1 on page 7) for the months specified at each release location (see Table 2 on page 9), therefore the deterministic scenarios were selected based on the worst-case shoreline oiling impacts that occurred during the entire modelled period. The worst case conditions are therefore considered to be representative of potential worst case conditions during the actual SWAP 3D survey period.

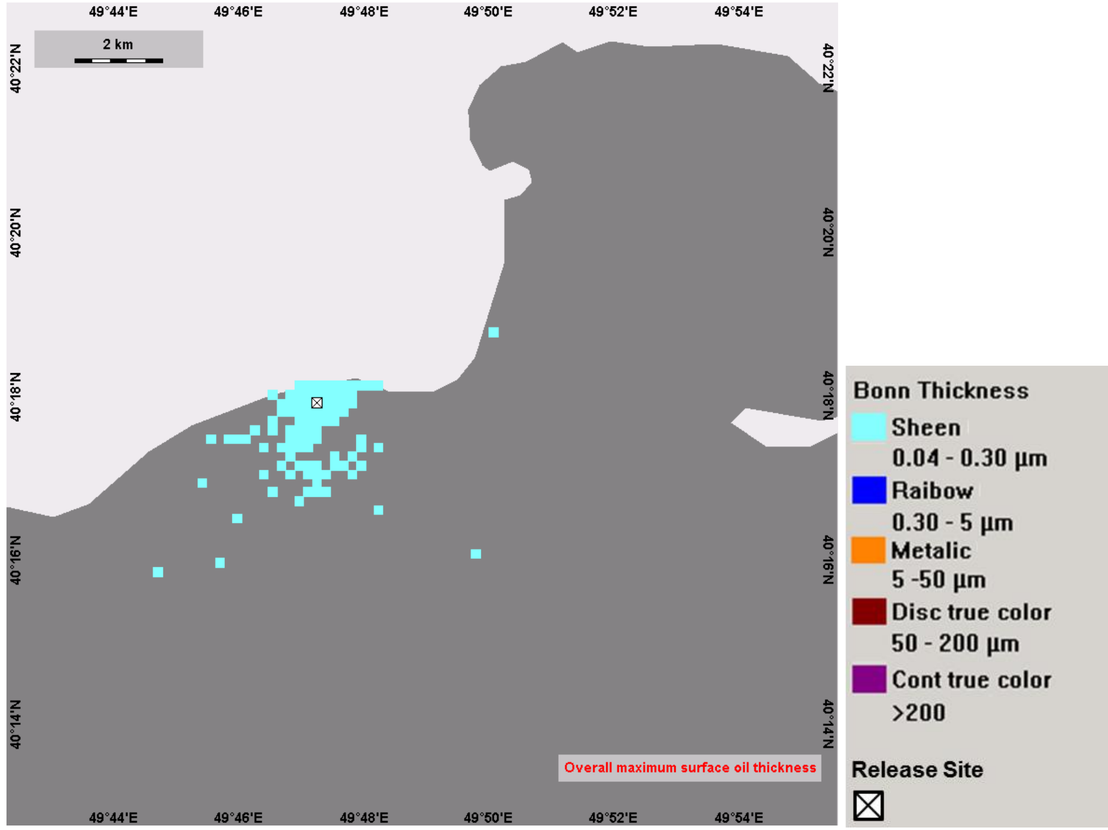
[7] Note: Where multiple time-steps result in the same extent (length) of shoreline being oiled, the first time-step at which that result occurs is taken. As total mass ashore declines during the course of the scenarios, this therefore represents the time at which the greatest mass of oil is spread over the greatest length of shoreline (although the total mass is still less than the maximum mass, which generally coincides with first arrival time to shore (see Table 5).

[8] Oiled Shoreline Length determined from MEMW.xls output file.

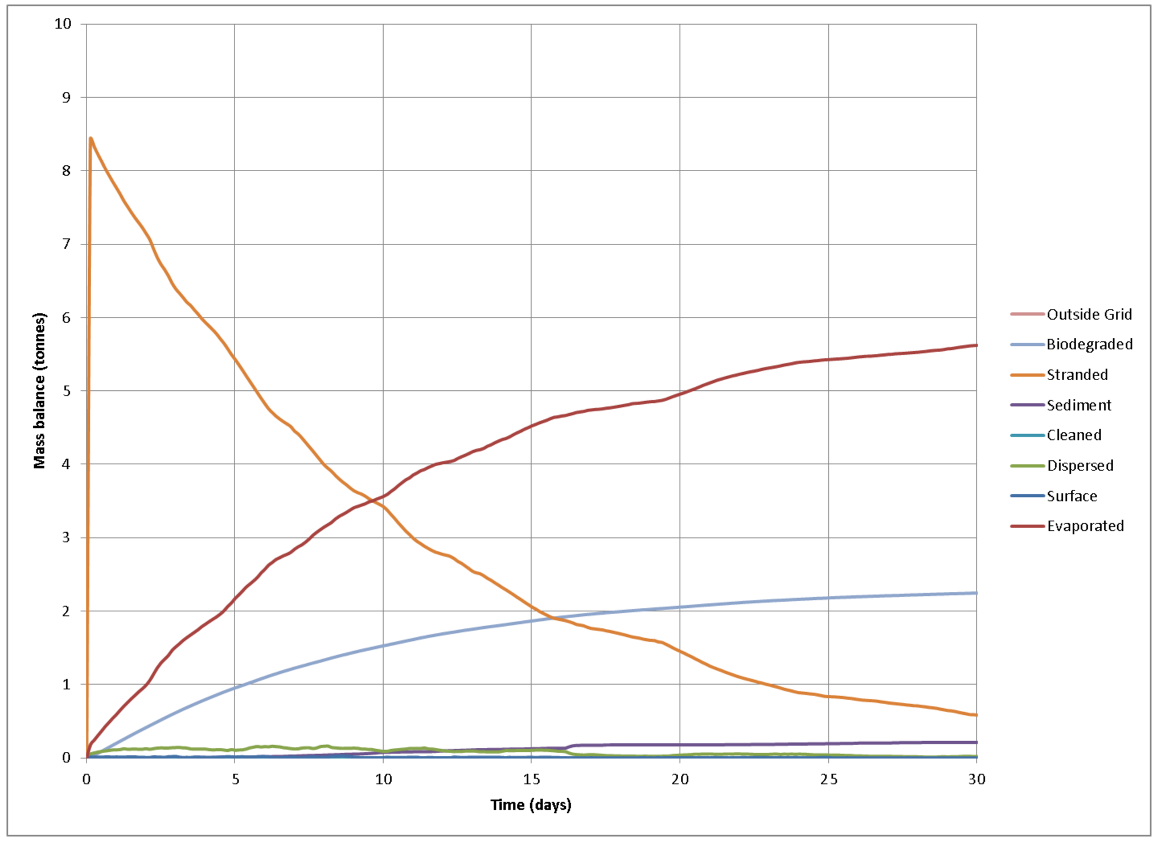
5.2 Priority Area 1



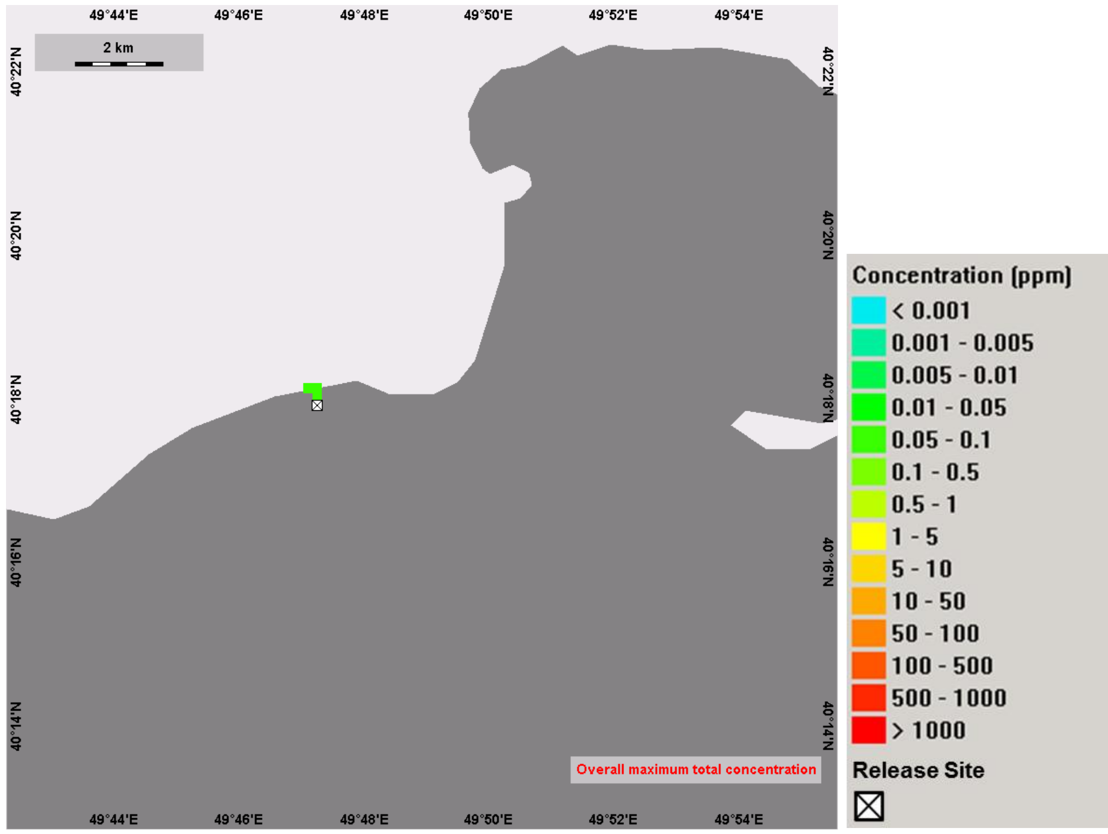
Maximum surface diesel thickness (>0.04µm) in any cell at any time-step within the modelling domain during the Worst Case Shoreline Diesel Oiling scenario



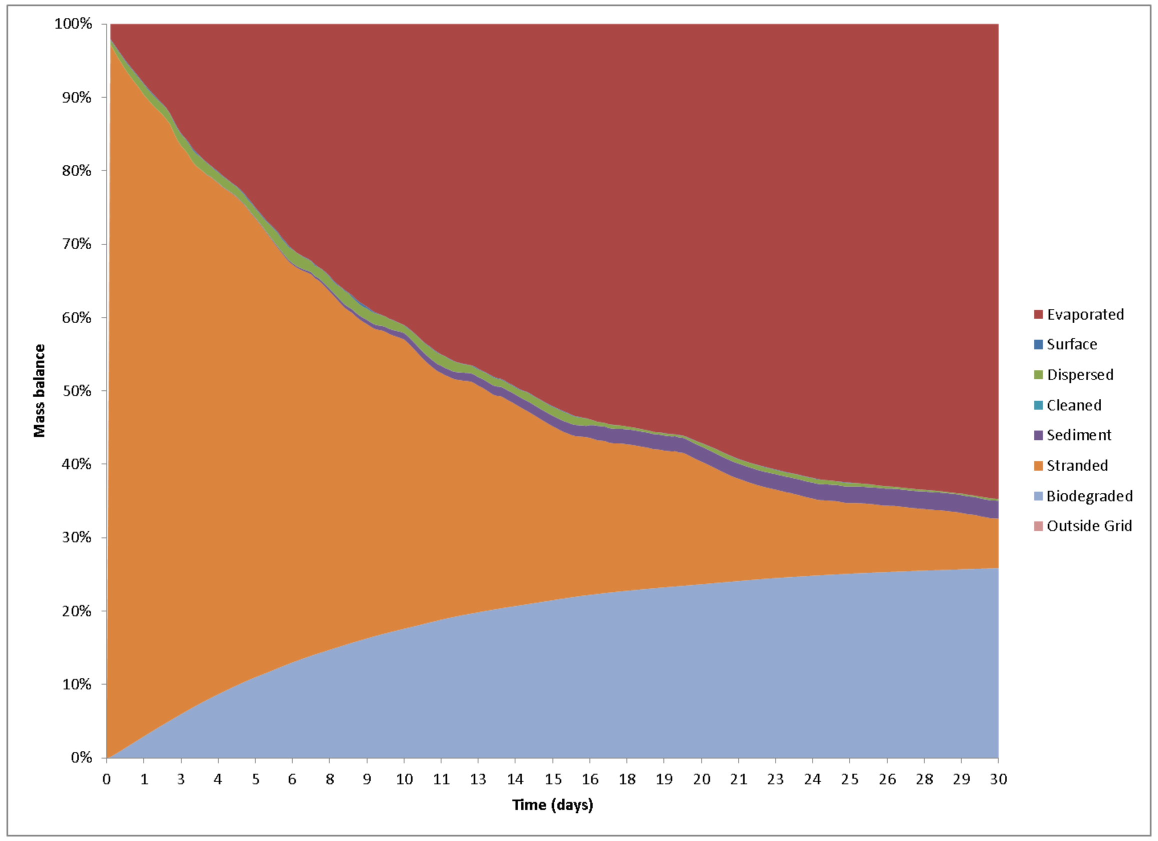
Fate of diesel (mass) following release (to 30 days) for the Worst Case Shoreline Diesel Oiling scenario



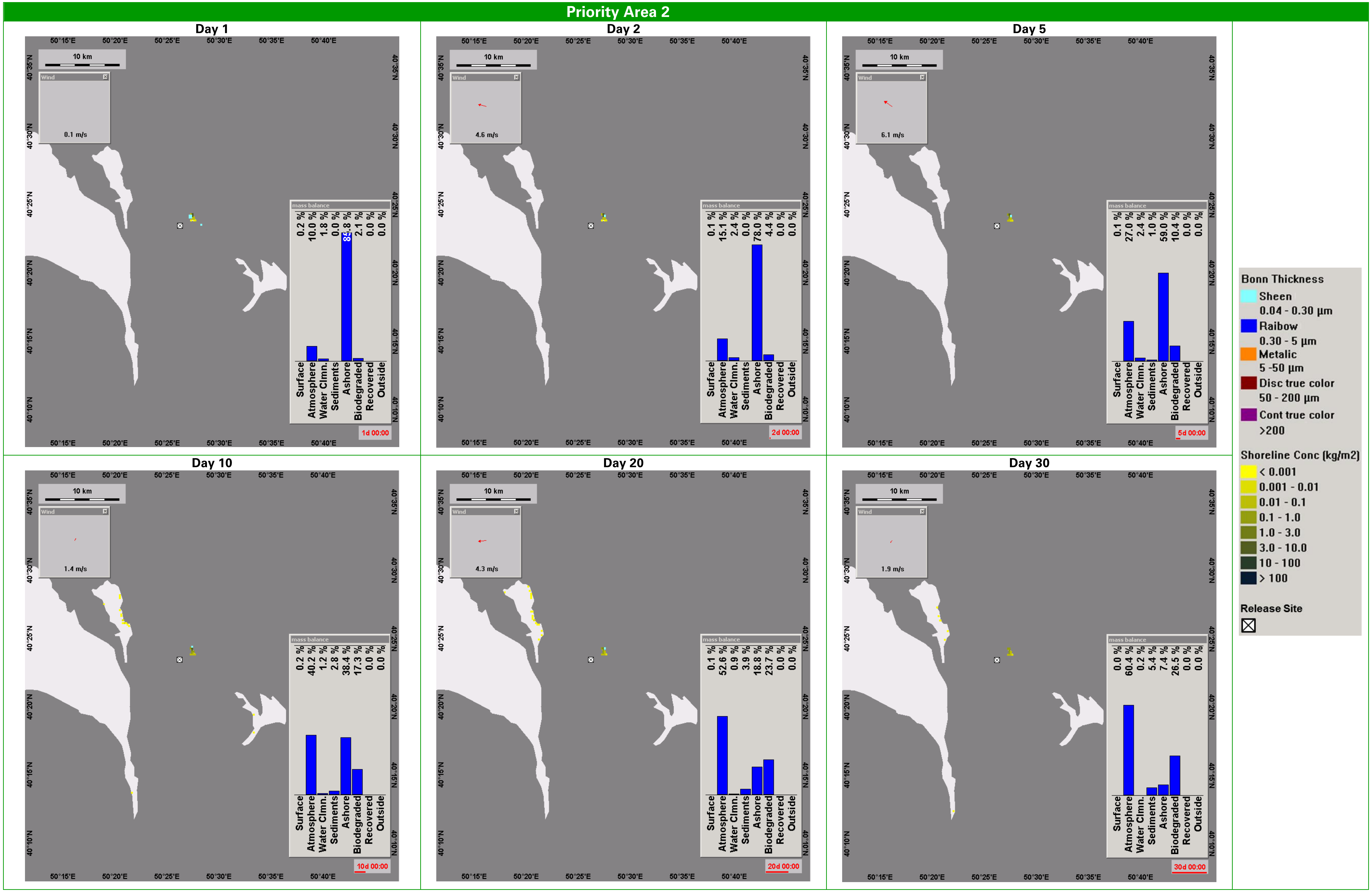
Maximum total diesel concentrations in the water column (> 58ppb) in any cell at any time-step within the modelling domain during the Worst Case Shoreline Diesel Oiling scenario



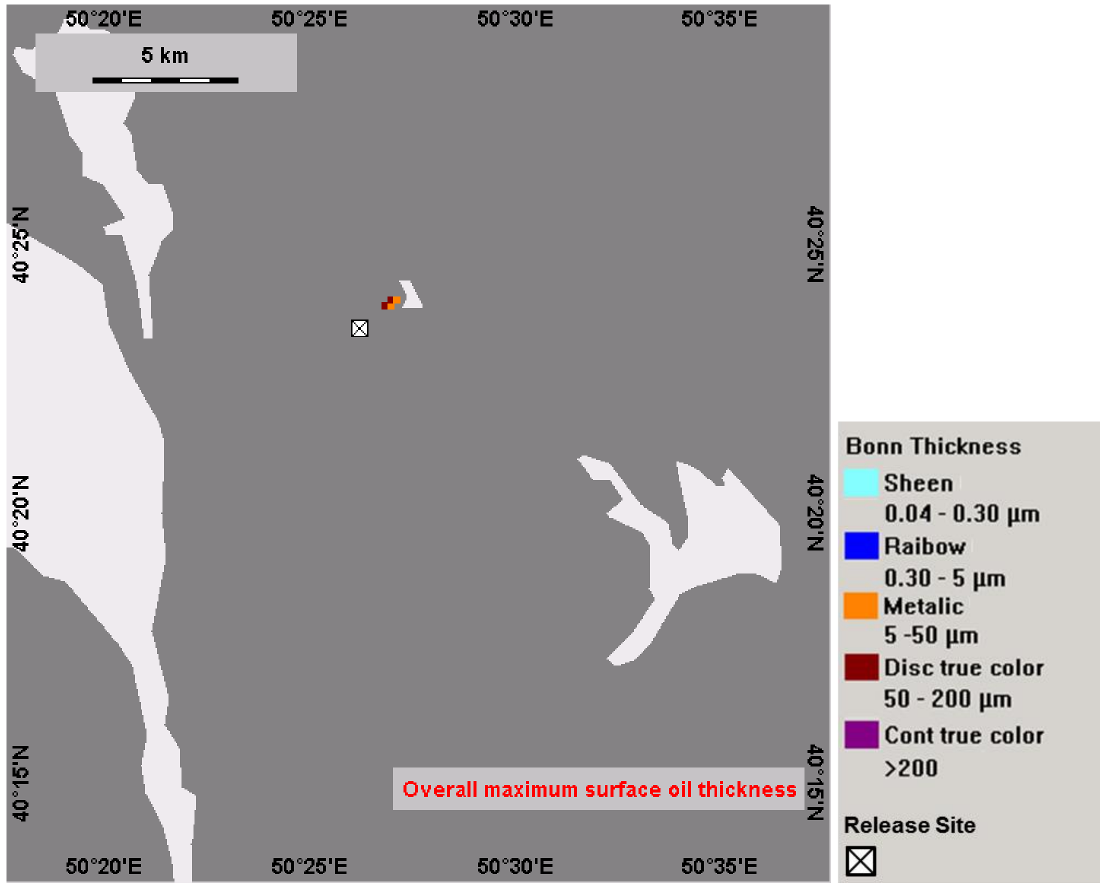
Fate of diesel (%) following release (to 30 days) for the Worst Case Shoreline Diesel Oiling scenario



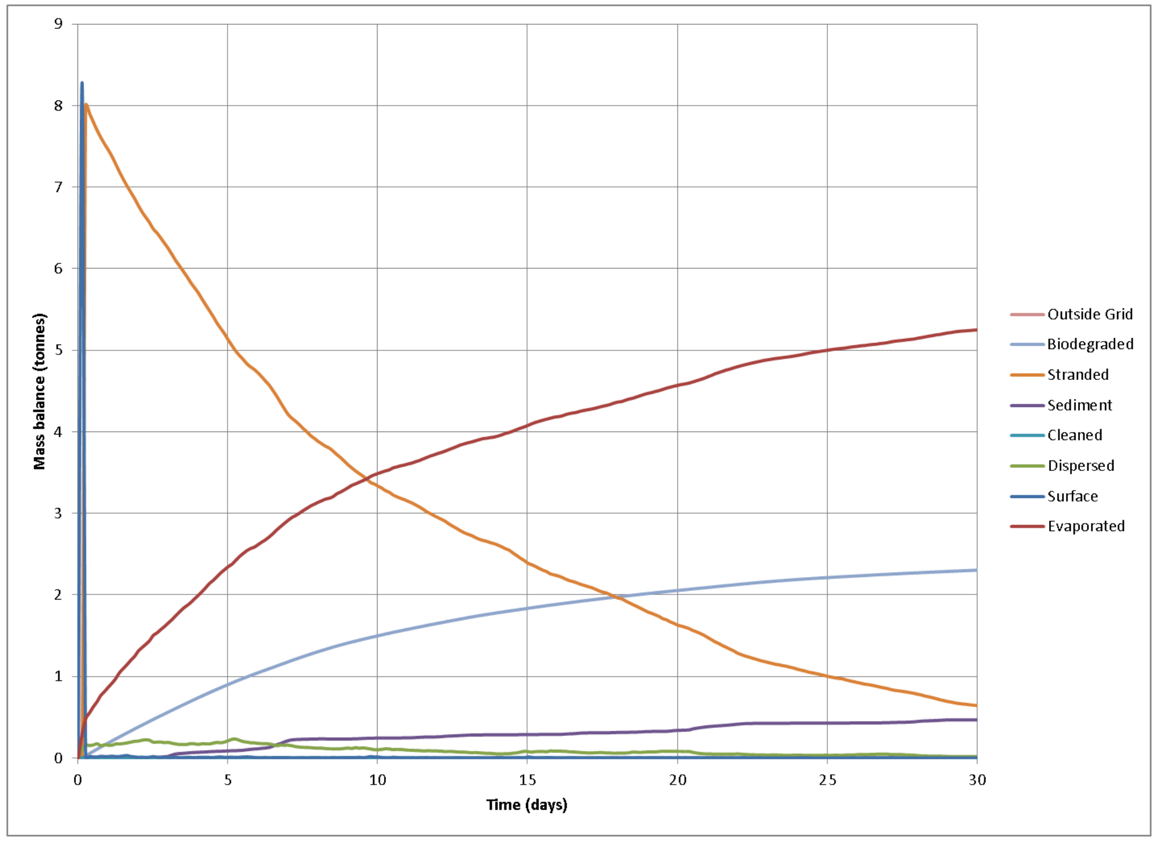
5.3 Priority Area 2



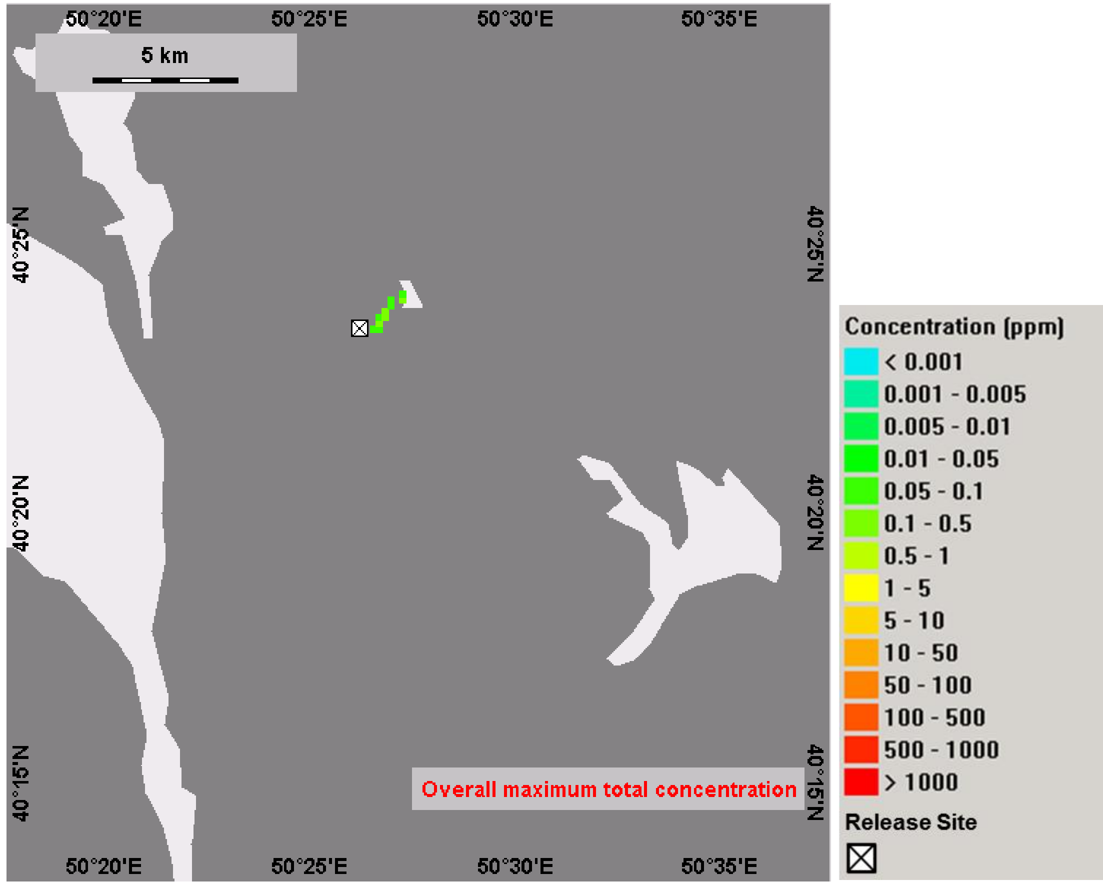
Maximum surface diesel thickness (>0.04µm) in any cell at any time-step within the modelling domain during the Worst Case Shoreline Diesel Oiling scenario



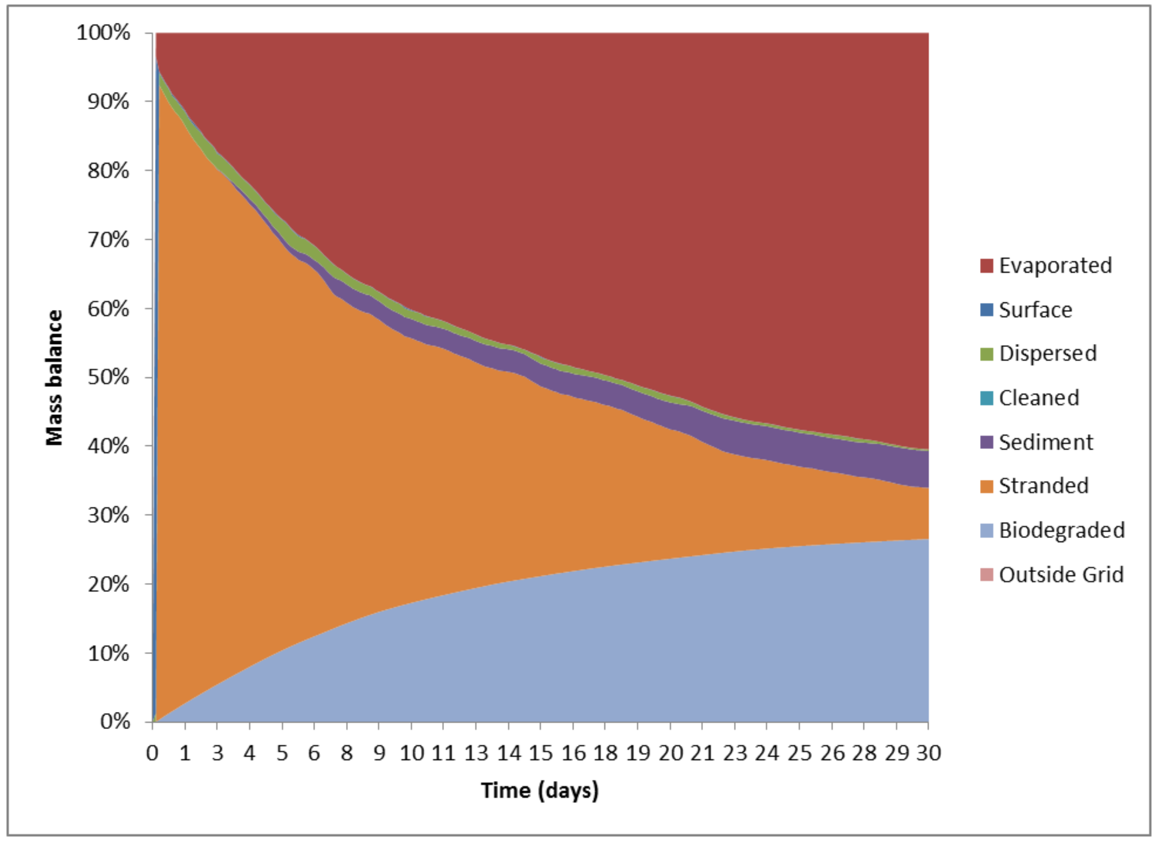
Fate of diesel (mass) following release (to 30 days) for the Worst Case Shoreline Diesel Oiling scenario



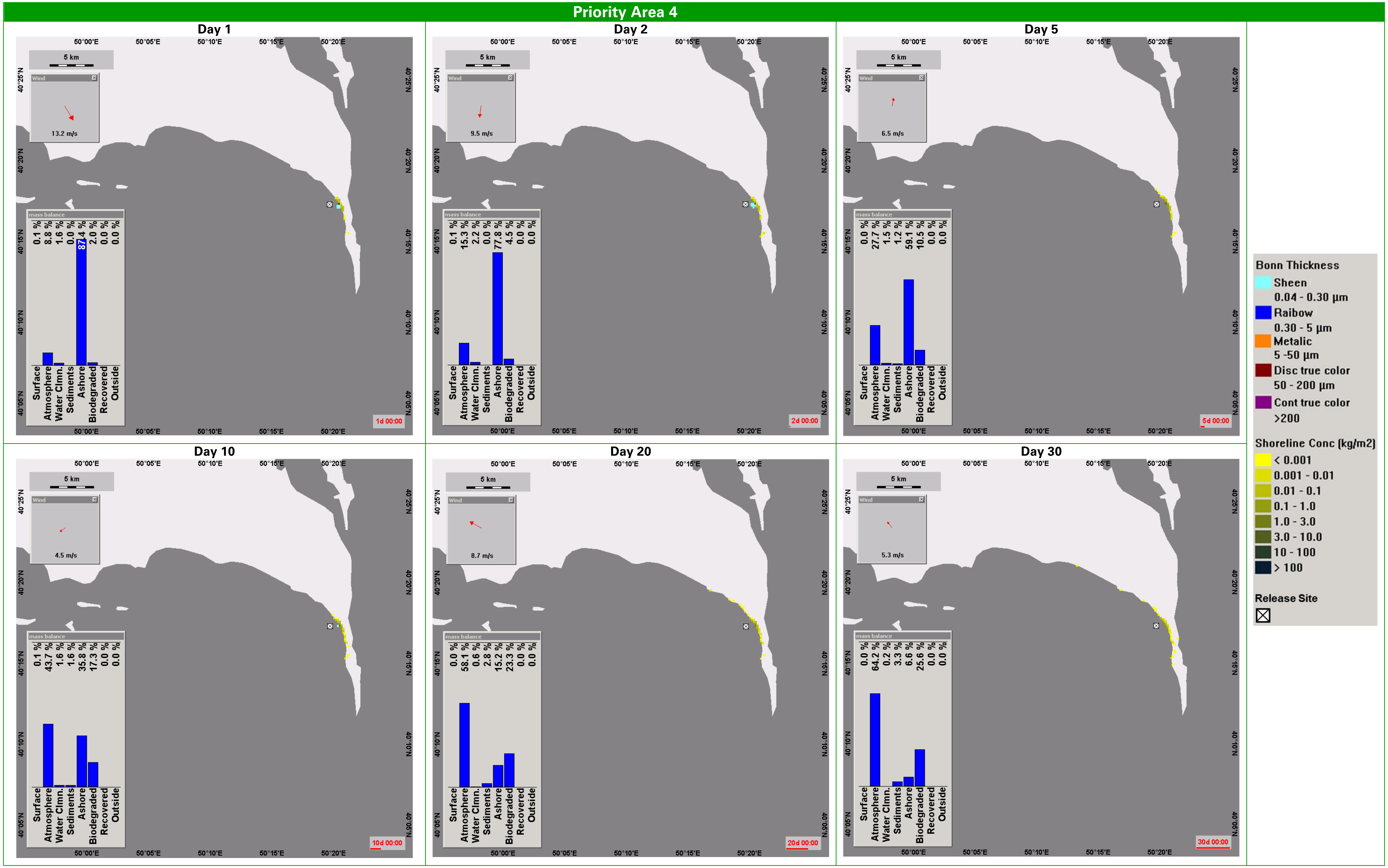
Maximum total diesel concentrations in the water column (> 58ppb) in any cell at any time-step within the modelling domain during the Worst Case Shoreline Diesel Oiling scenario



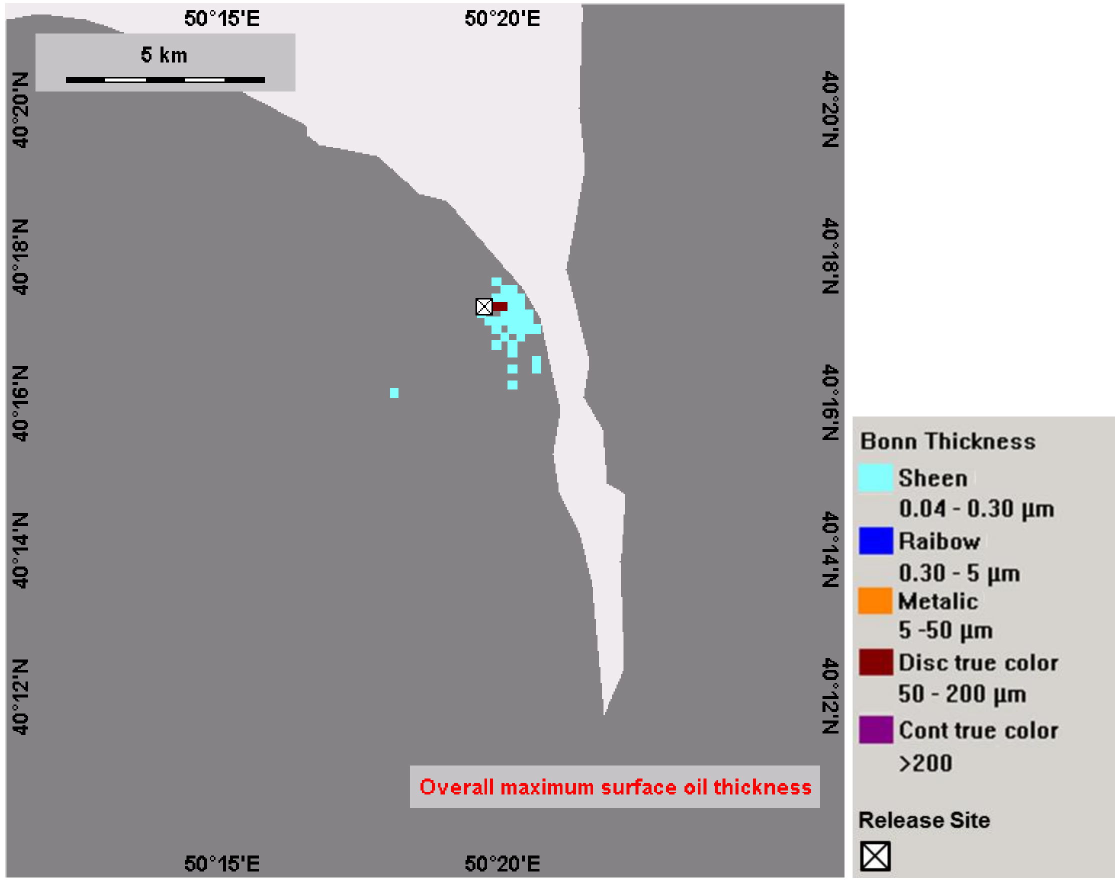
Fate of diesel (%) following release (to 30 days) for the Worst Case Shoreline Diesel Oiling scenario



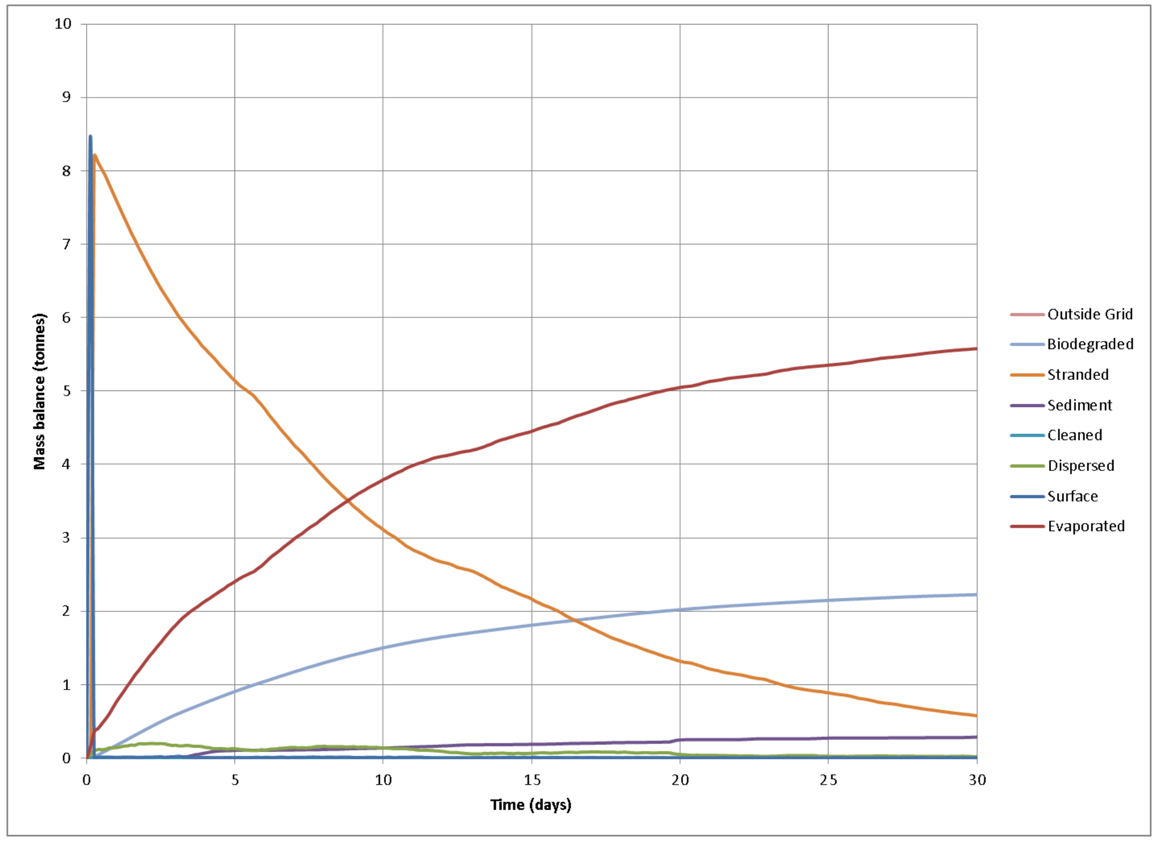
5.4 Priority Area 4



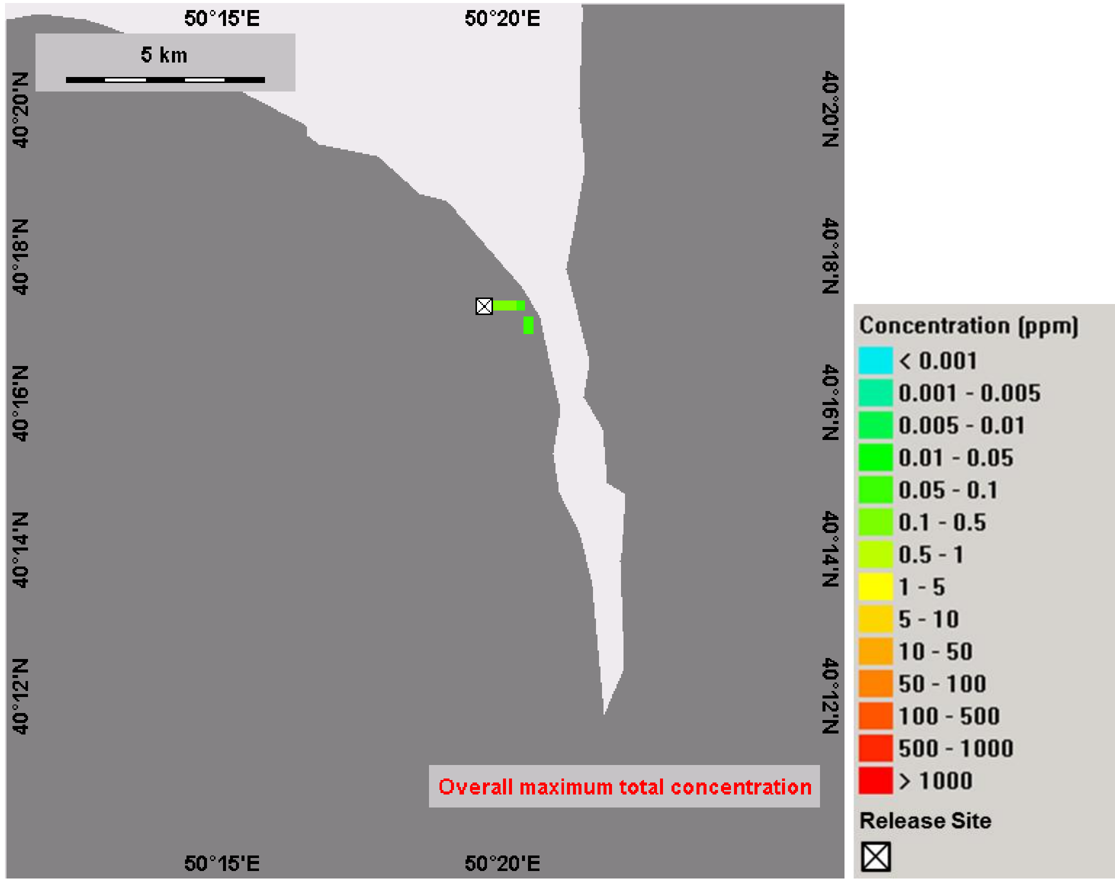
Maximum surface diesel thickness (>0.04µm) in any cell at any time-step within the modelling domain during the Worst Case Shoreline Diesel Oiling scenario



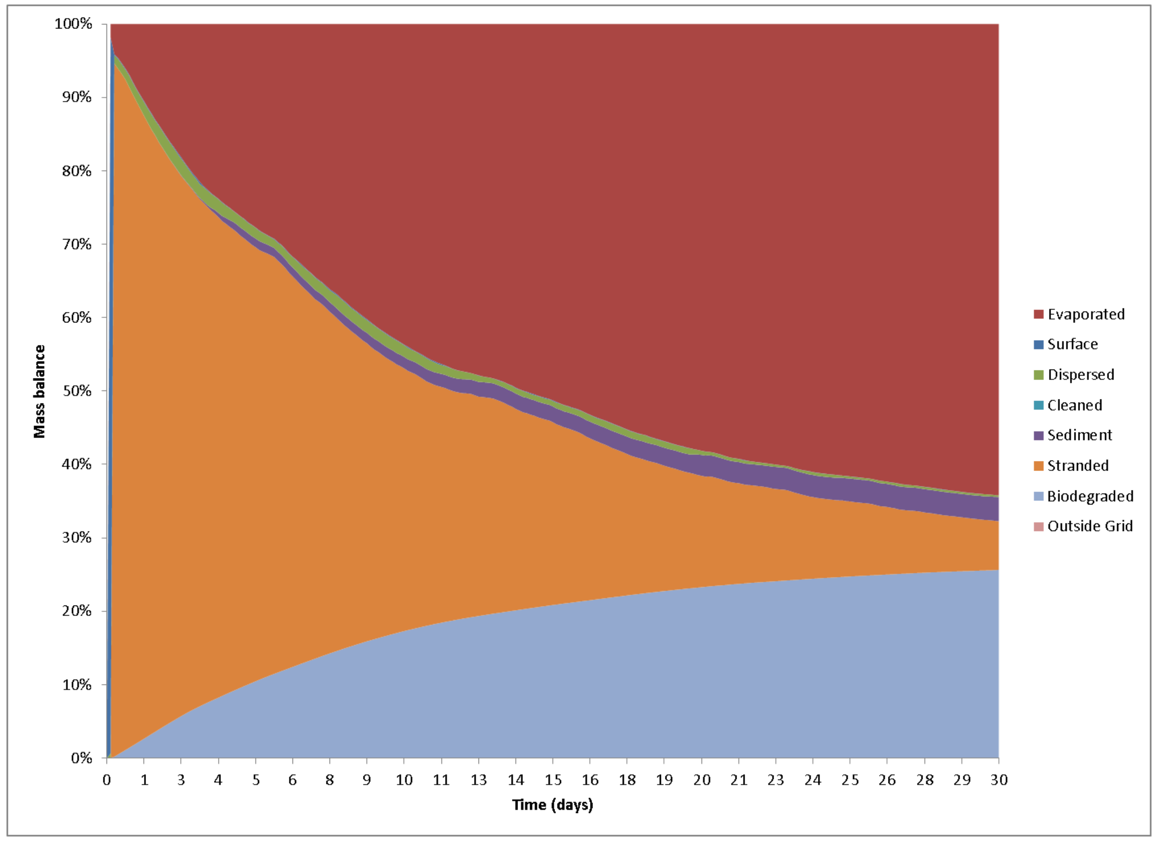
Fate of diesel (mass) following release (to 30 days) for the Worst Case Shoreline Diesel Oiling scenario



Maximum total diesel concentrations in the water column (> 58ppb) in any cell at any time-step within the modelling domain during the Worst Case Shoreline Diesel Oiling scenario

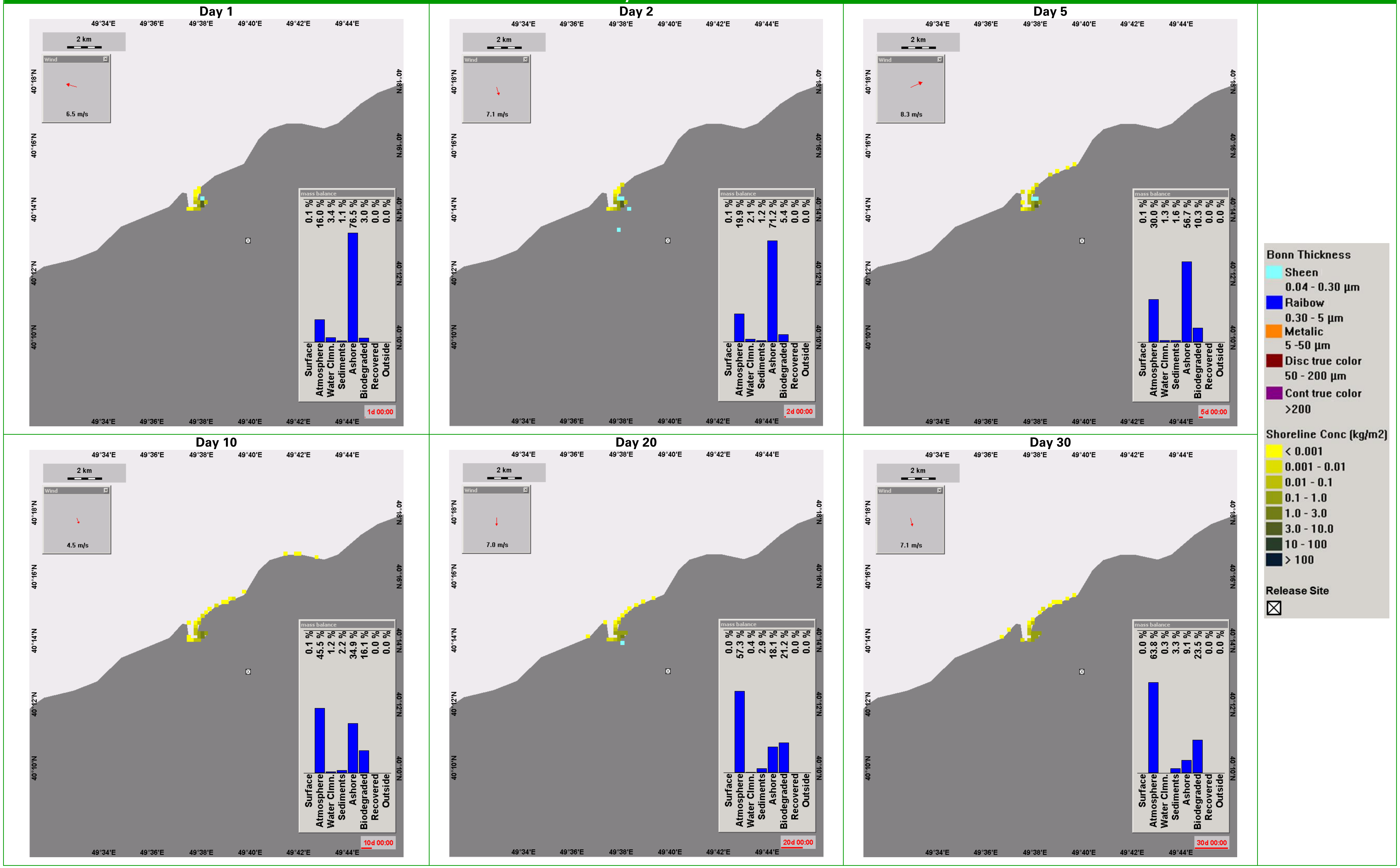


Fate of diesel (%) following release (to 30 days) for the Worst Case Shoreline Diesel Oiling scenario

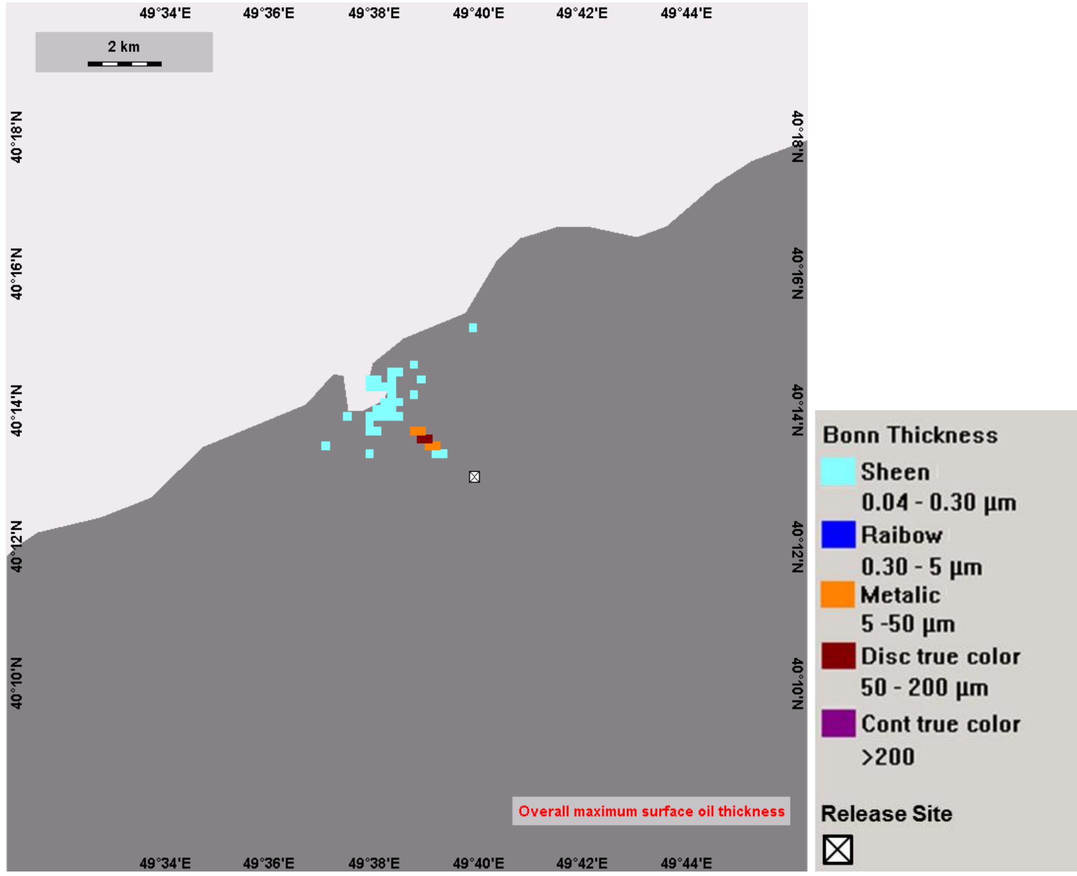


5.5 Priority Area 5

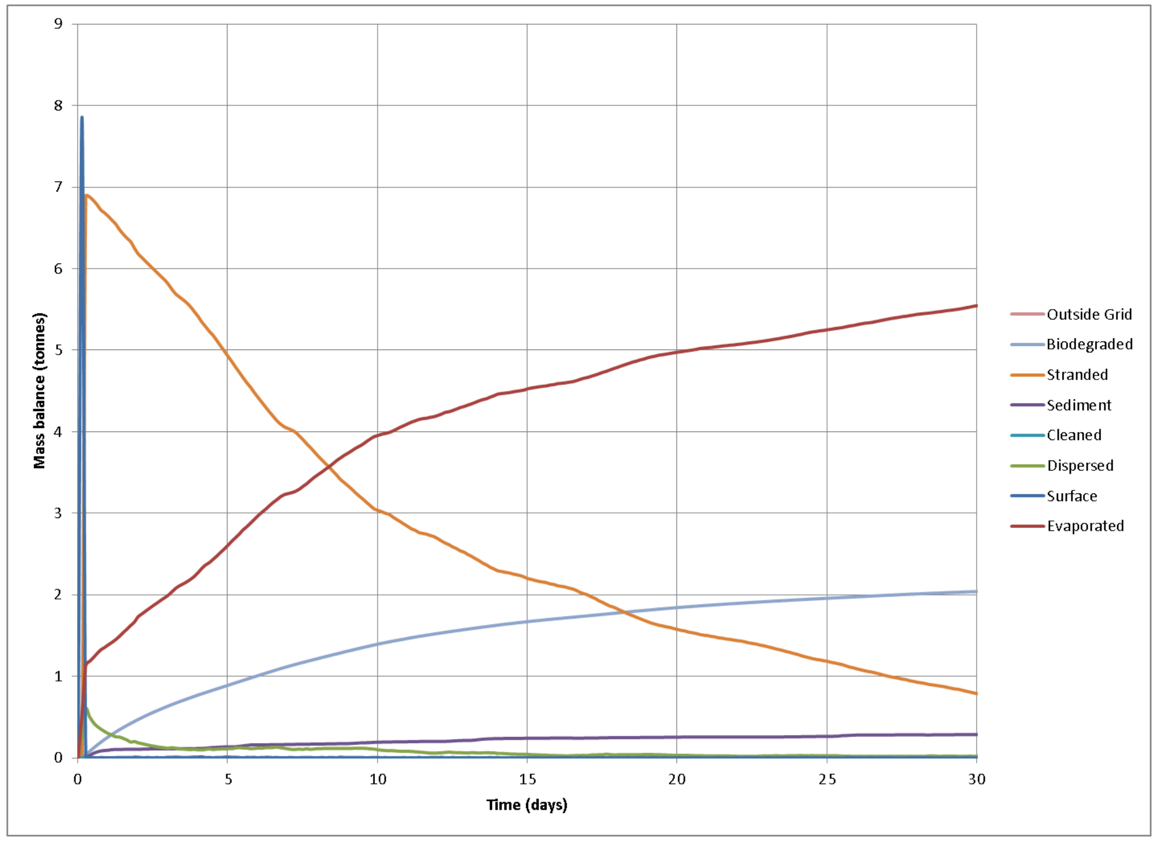
Priority Area 5



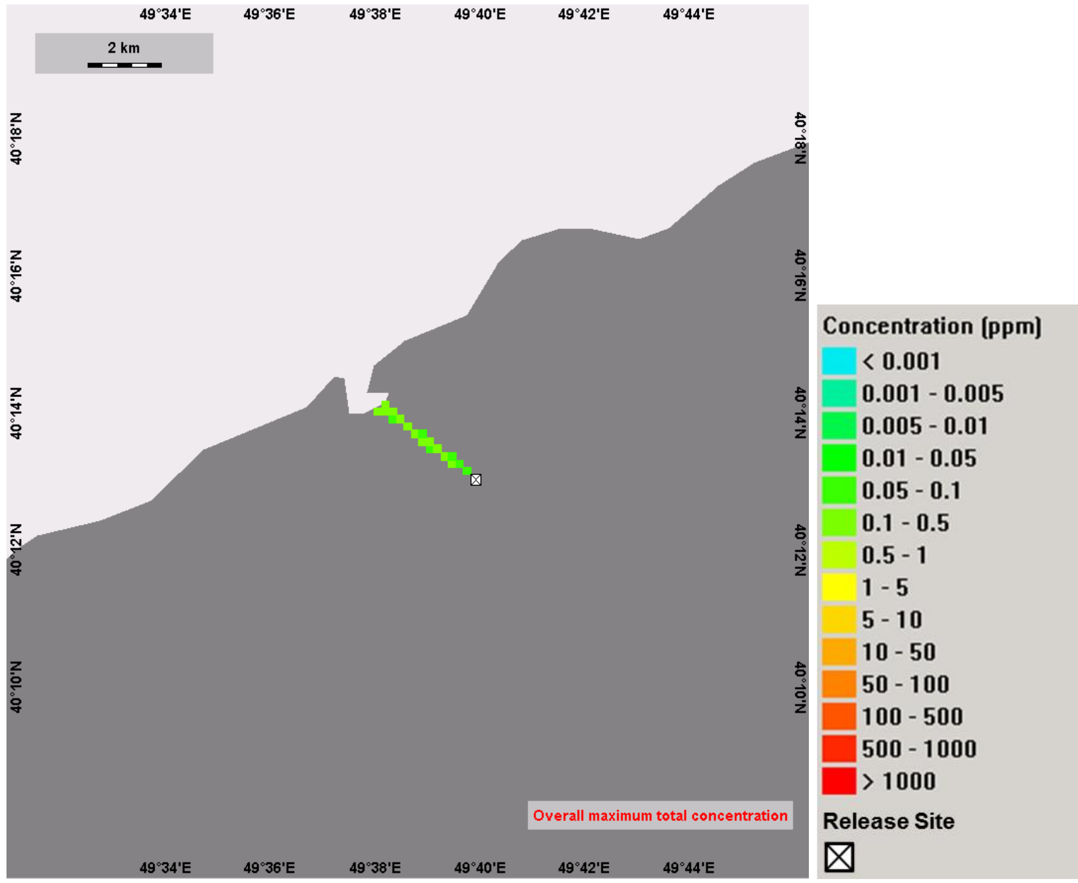
Maximum surface diesel thickness (>0.04μm) in any cell at any time-step within the modelling domain during the Worst Case Shoreline Diesel Oiling scenario



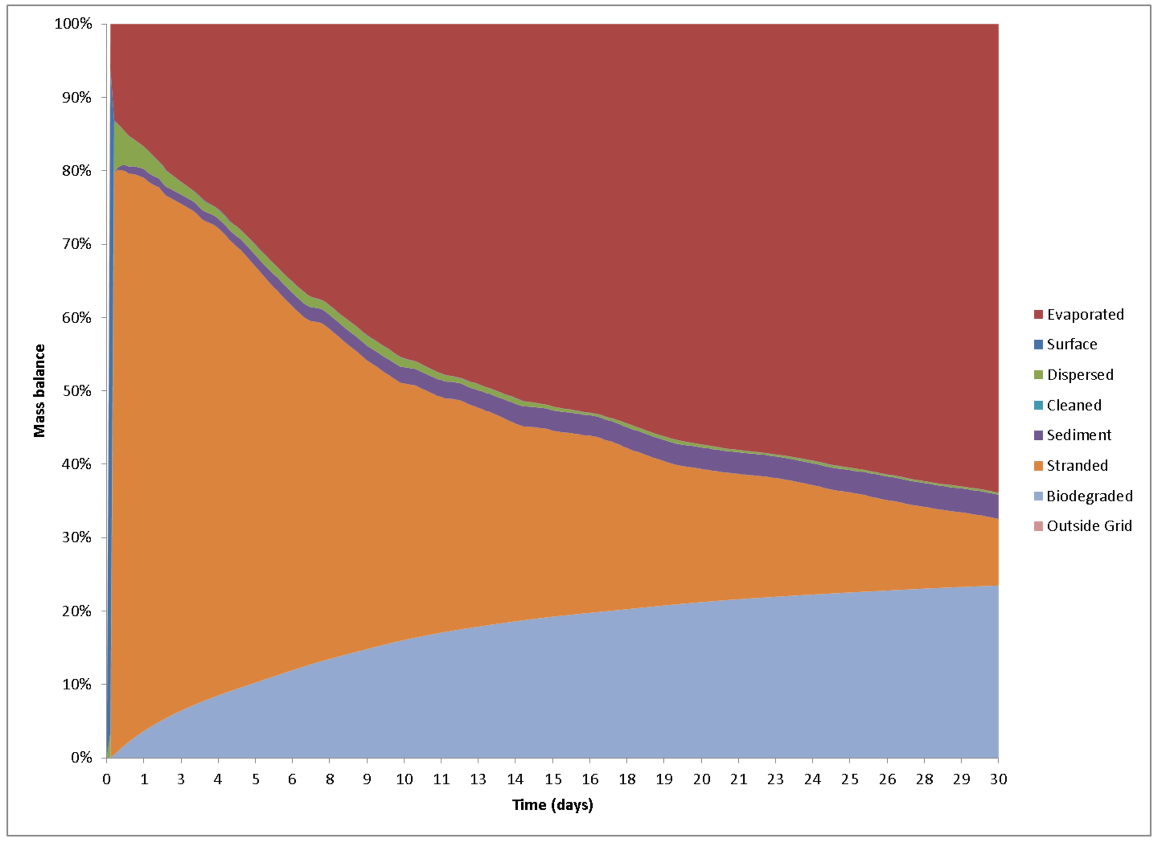
Fate of diesel (mass) following release (to 30 days) for the Worst Case Shoreline Diesel Oiling scenario



Maximum total diesel concentrations in the water column (> 58ppb) in any cell at any time-step within the modelling domain during the Worst Case Shoreline Diesel Oiling scenario



Fate of diesel (%) following release (to 30 days) for the Worst Case Shoreline Diesel Oiling scenario



6 Summary

Stochastic and deterministic modelling has been completed for four Priority Areas (PA1, PA2, PA4 and PA5) for the Shallow Water of the Absheron Peninsula (SWAP) 3D seismic survey programme.

Detailed maps and results are presented in the earlier sections, and summarised below.

6.1 Stochastic Modelling

6.1.1 Surface

Stochastic modelling results showed that total sea surface areas at risk of diesel oiling exceeding 0.04 µm (P>5%) were in the range 1.37 km^2 (PA4) to 7.06 km^2 (PA2). The small size of areas at risk reflects the small initial release volume (10 m^3).

6.1.2 Shoreline

Due to the close proximity of all release locations to shore, minimum arrival times of diesel to shore were from 40 minutes (PA1) to 3 hours 20 minutes (PA2). Shoreline impacts resulted in maximum mass of diesel ashore in the range of 6.91 te (PA5) to 8.47 te (PA1), and maximum extent (length) of shoreline diesel oiling (P>1%) ranging from 7.35 km (PA5) to 19.52 km (PA4).

6.2 Deterministic Modelling

6.2.1 Surface

Maximum areas of sea surface diesel oiling exceeding 0.04 µm varied from 1.56 km^2 (PA4, PA5) to 3.73 km^2 (PA1).

6.2.2 Shoreline

Results showed maximum impacted shoreline extents (length) from 1.70 km (PA1, PA4) to 1.99 km (PA2, PA5) and end-of-scenario (30 days) shoreline diesel oiling ranging from 0.57 km (PA4) to 1.70 km (PA5).

In all worst-case shoreline scenarios modelled, the mass of oil ashore decreased significantly during the modelled period (30 days) due to re-suspension and evaporation. The mass of diesel remaining onshore at the end of the scenarios ranged from 0.58 te (PA4) to 0.79 te (PA5).

6.2.3 Mass Balance

In all deterministic scenarios, evaporation accounted for the fate of ~40% of the spilled diesel. Biodegradation accounted for a further ~20-30%. The remaining ~10-15% was modelled to be stranded, primarily onshore (~10%) or in sediments (~5%). No significant differences between release months (i.e. seasons) were observed, most likely due to the small release volumes involved and proximity to shore.

7 References

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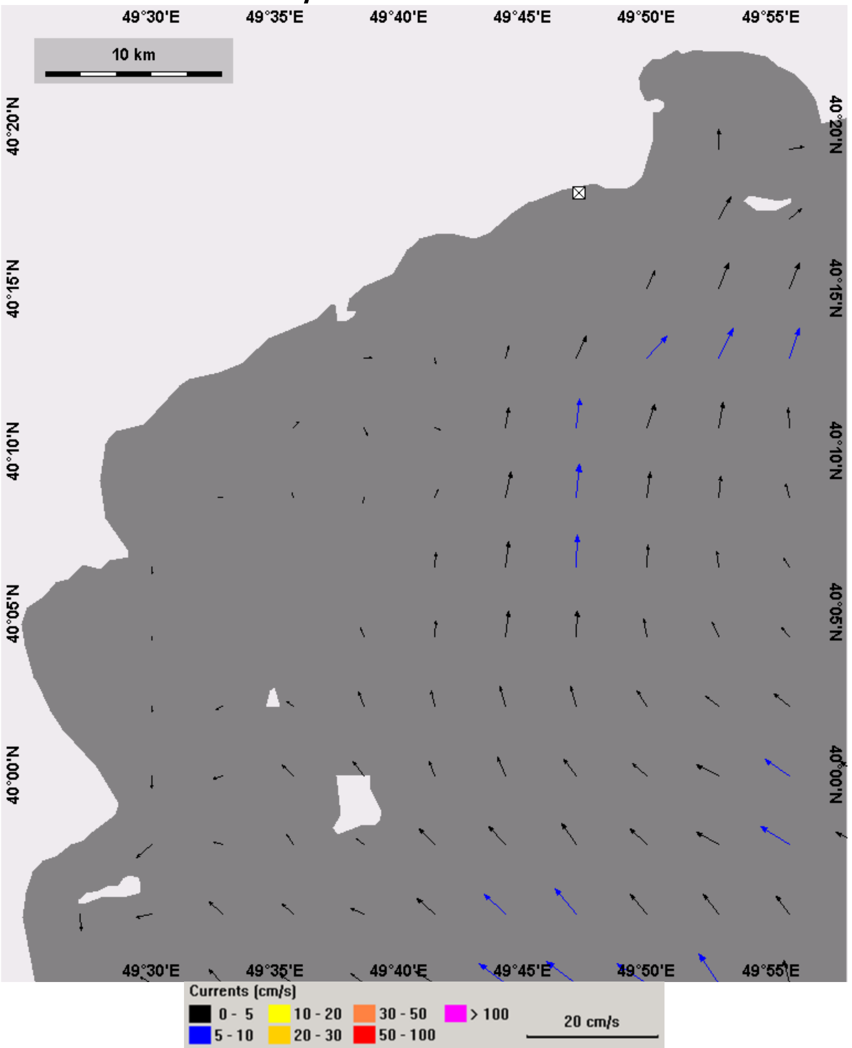
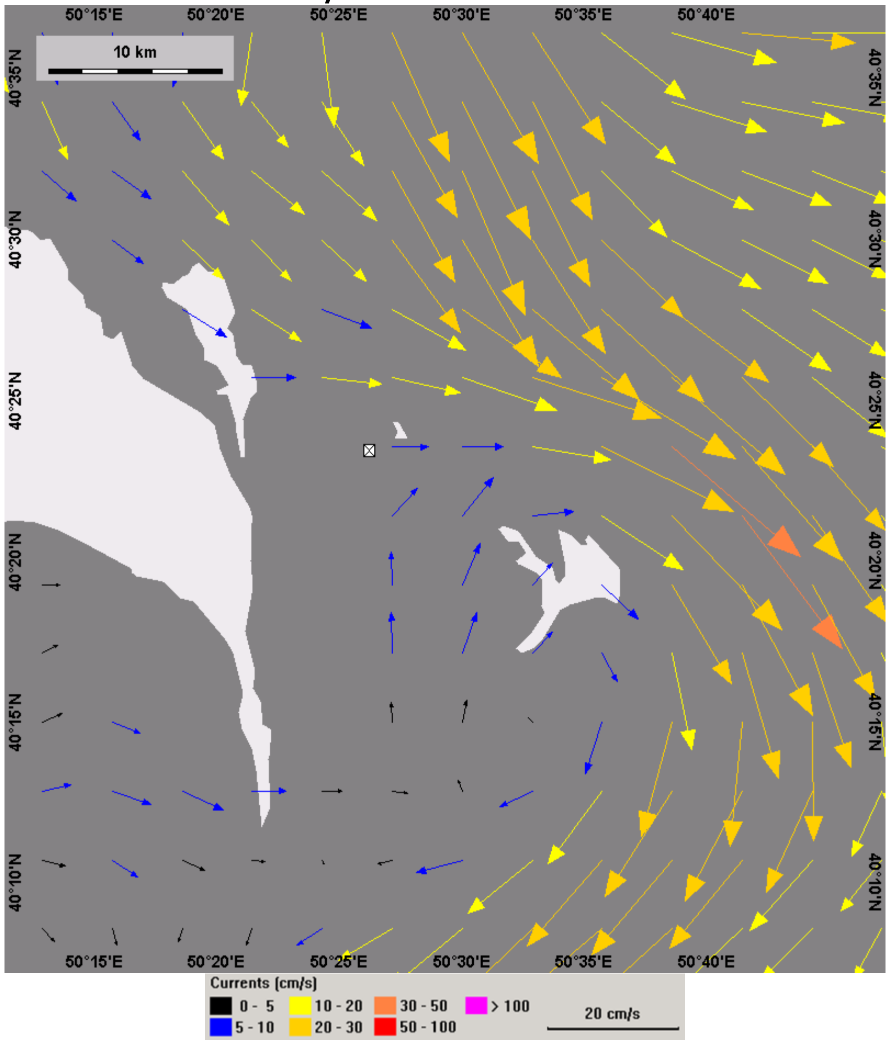
Appendix 1 Deterministic Scenarios Surface Currents

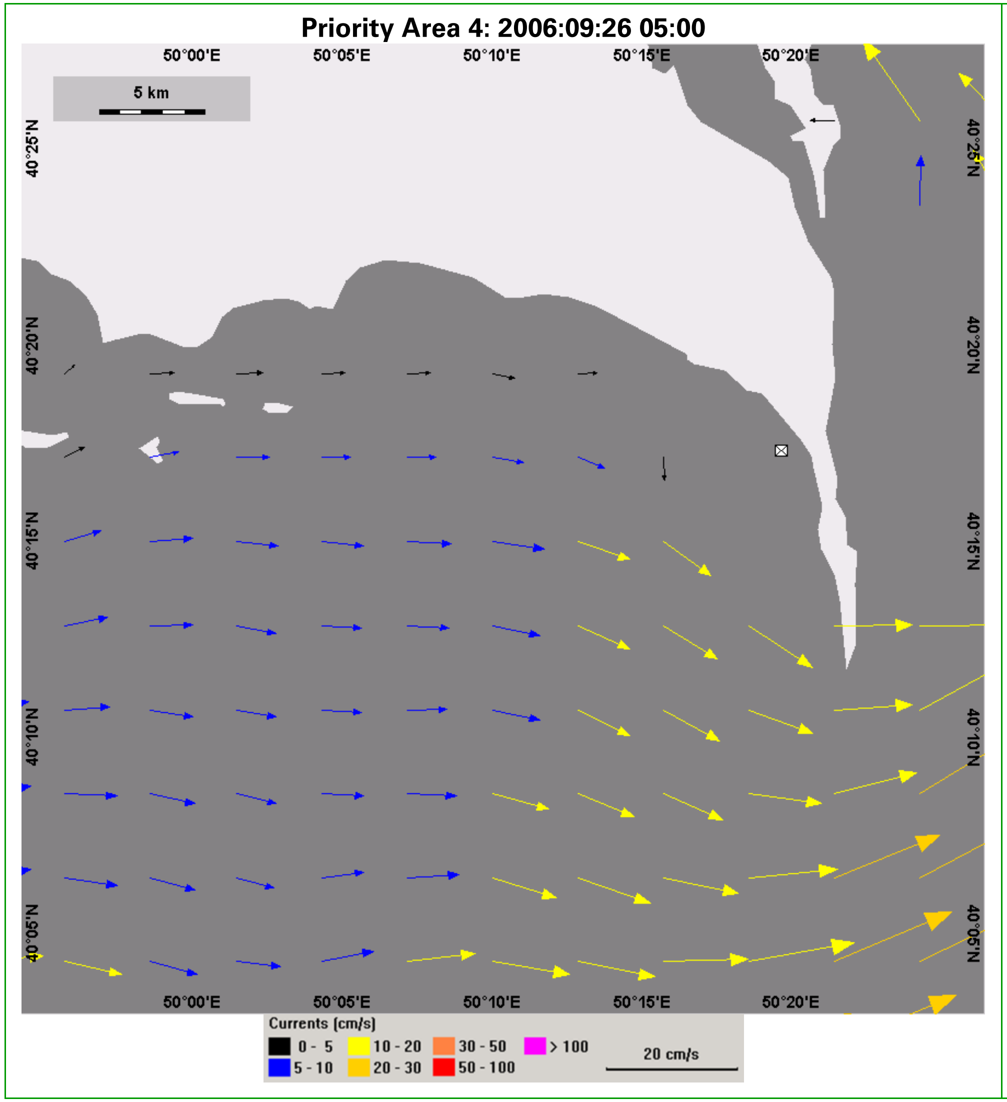
The following figures show the surface currents within the vicinity of the release location at the beginning of each deterministic scenario (i.e. time 00:00 in each model run).

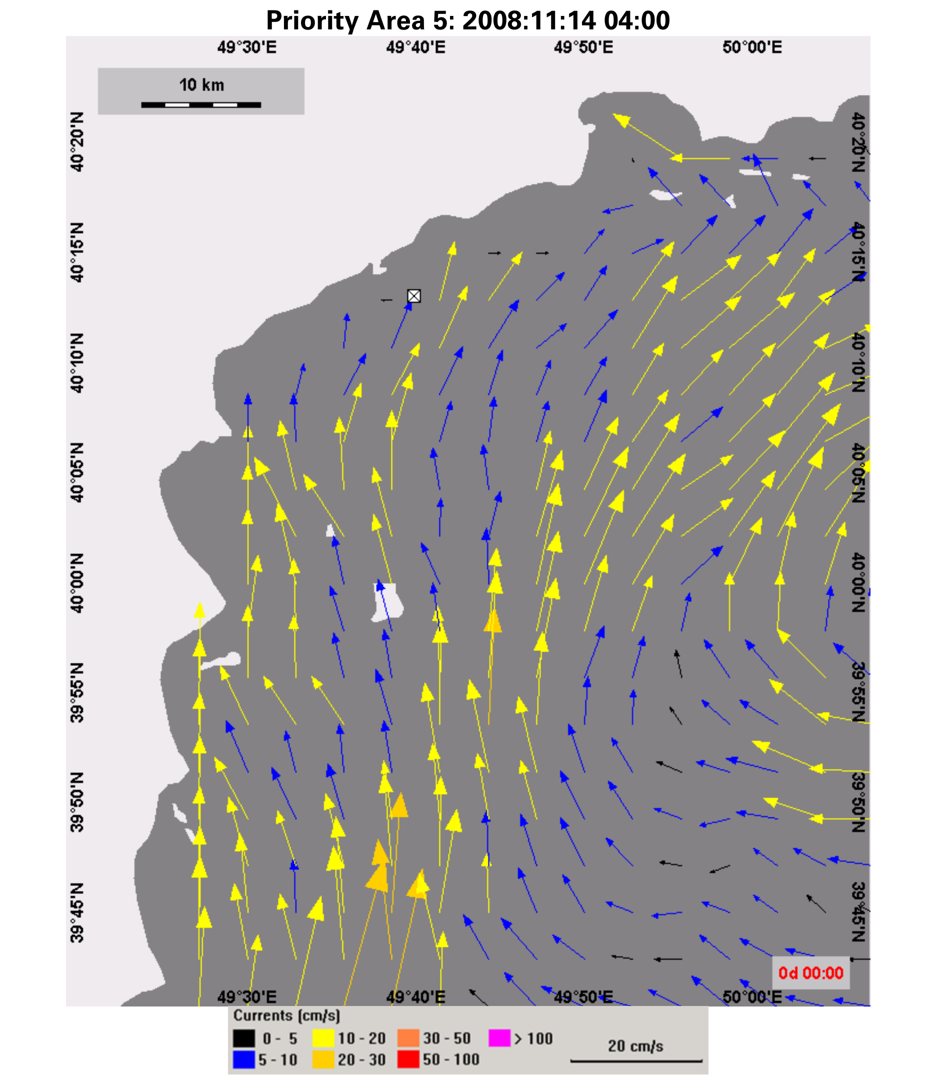
Priority Area 1: 2007:04:04 08:00



Priority Area 2: 2009:06:25 07:00



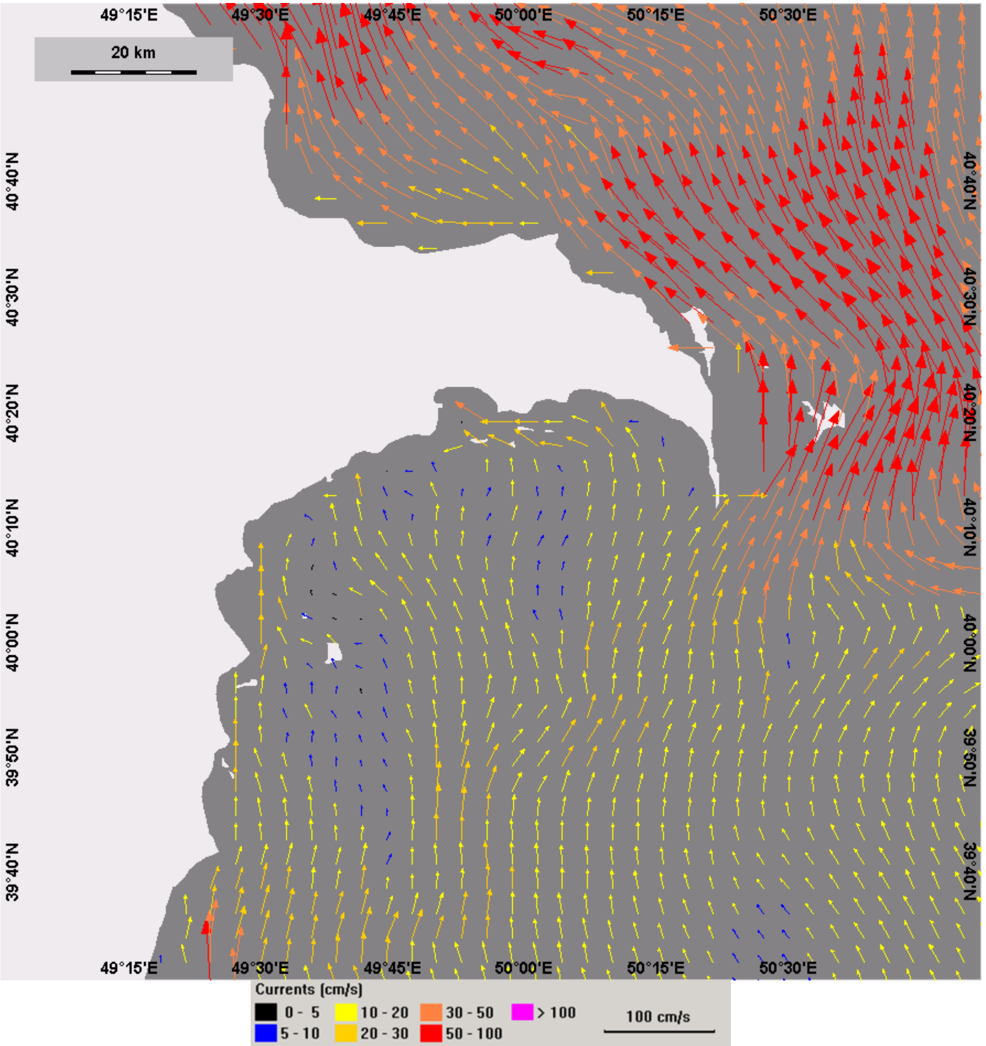

Priority Area 4: 2006:09:26 05:00
5 km
50°00'E
50°05'E
50°10'E
50°15'E
50°20'E
40°25'N
40°20'N
40°15'N
40°10'N
40°05'N
Currents (cm/s)
0 - 5
10 - 20
30 - 50
> 100
5 - 10
20 - 30
50 - 100
20 cm/s


Priority Area 5: 2008:11:14 04:00
10 km
49°30'E
49°40'E
49°50'E
50°00'E
40°20'N
40°15'N
40°10'N
40°05'N
40°00'N
39°55'N
39°50'N
39°45'N
0d 00:00
Currents (cm/s)
0 - 5
10 - 20
30 - 50
> 100
5 - 10
20 - 30
50 - 100
20 cm/s

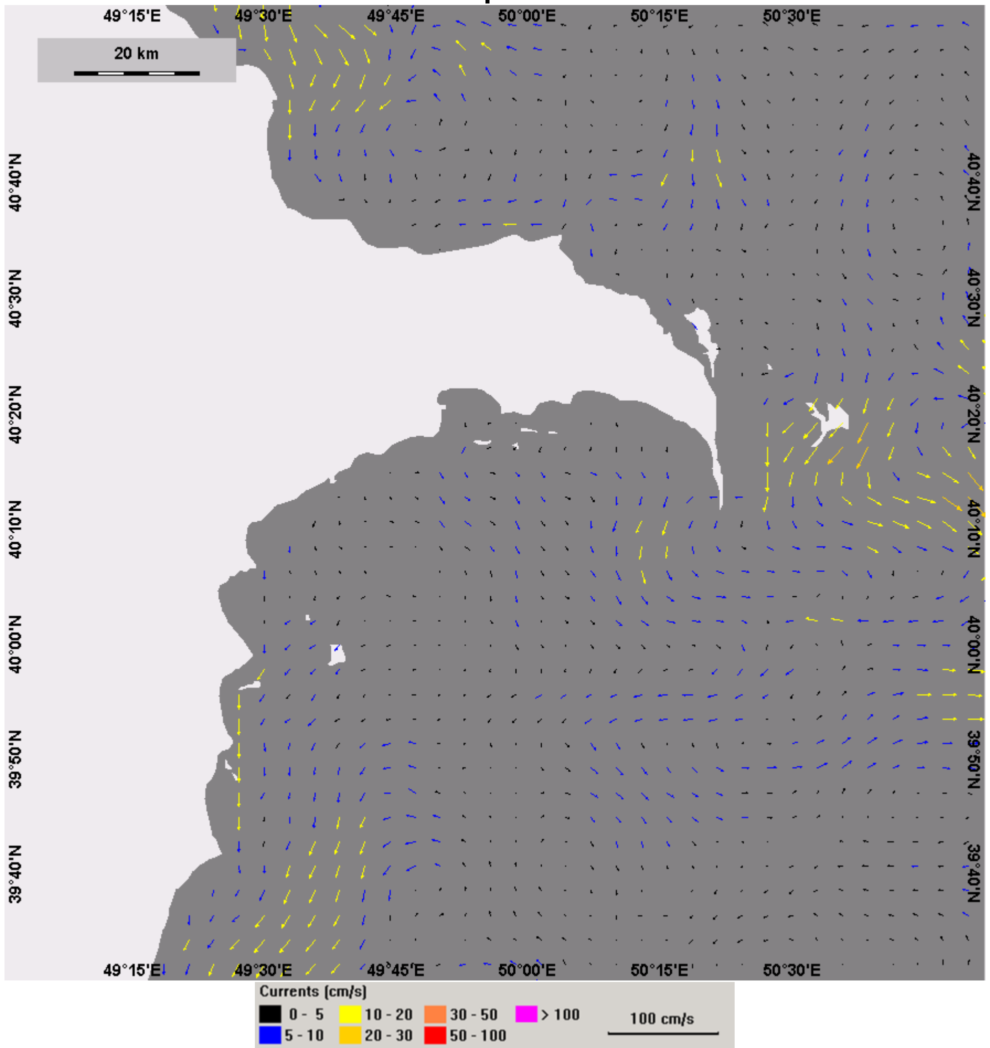
Appendix 2 Regional Overview Surface Currents

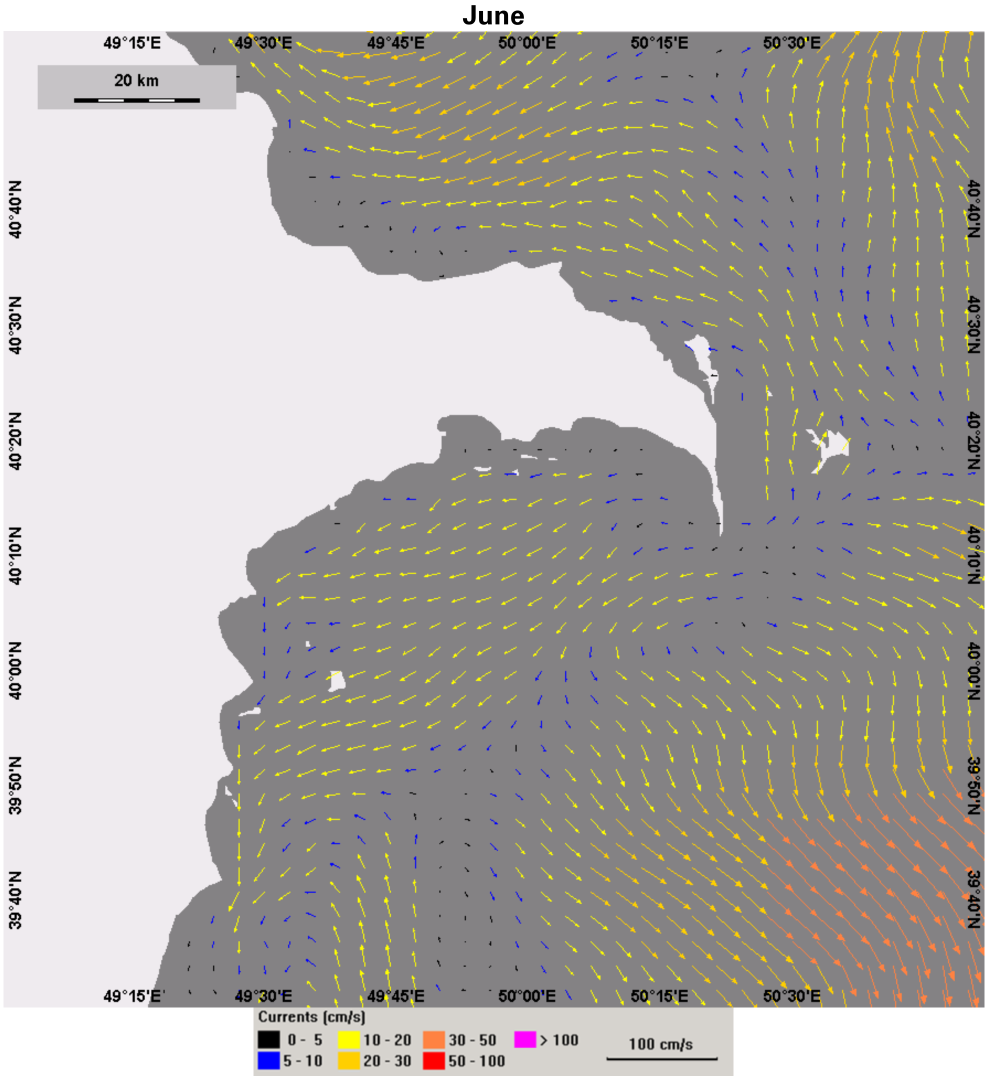
The following figures show the surface currents in the broader SWAP region at the beginning of each month seismic activity will be undertaken (i.e. Mar-Apr, Jun-Jul, Sep-Oct and Nov). Data is taken from the year 2007 within the Imperial College London ReEMS dataset.

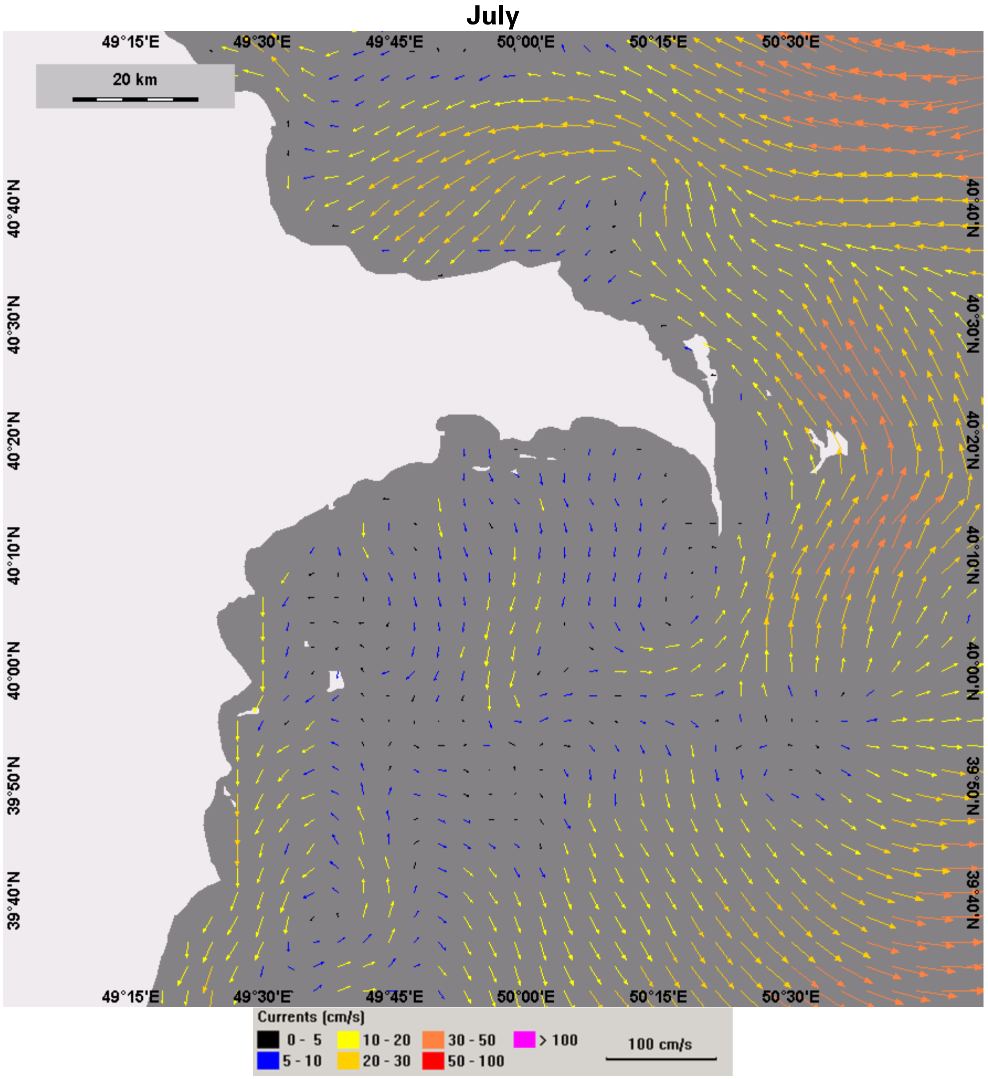
March



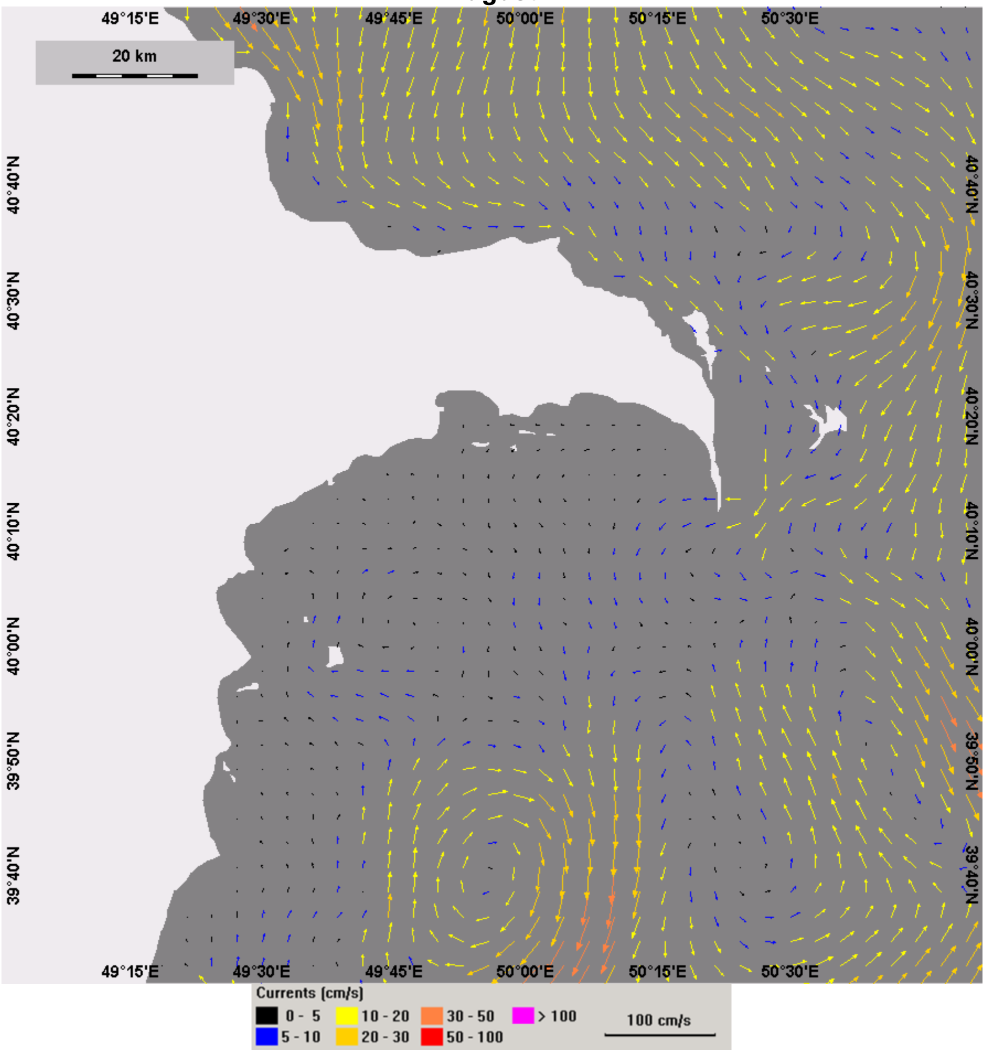
April



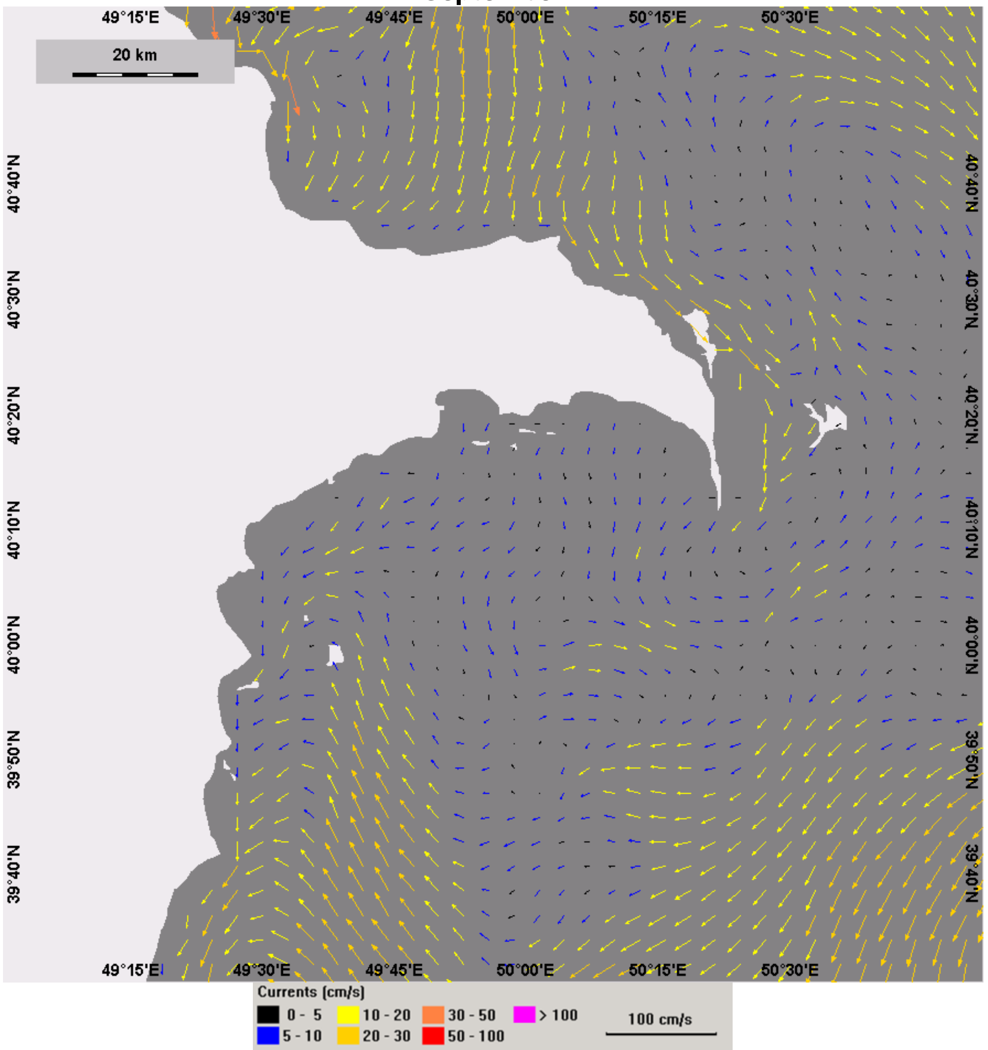

June
20 km
49°15'E
49°30'E
49°45'E
50°00'E
50°15'E
50°30'E
40°40'N
40°30'N
40°20'N
40°10'N
40°00'N
39°50'N
39°40'N
Currents (cm/s)
0 - 5
5 - 10
10 - 20
20 - 30
30 - 50
50 - 100
> 100
100 cm/s

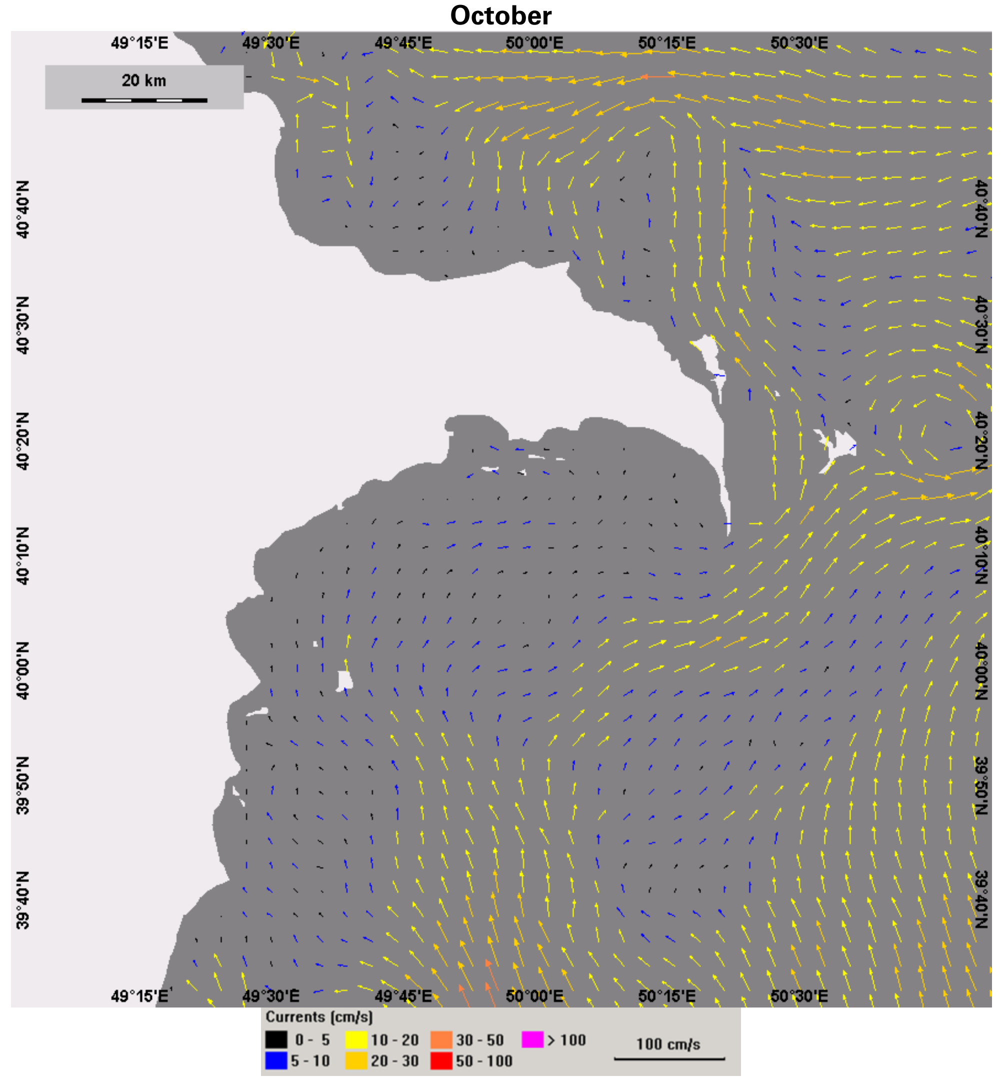

July
20 km
49°15'E
49°30'E
49°45'E
50°00'E
50°15'E
50°30'E
40°40'N
40°30'N
40°20'N
40°10'N
40°00'N
39°50'N
39°40'N
Currents (cm/s)
0 - 5
5 - 10
10 - 20
20 - 30
30 - 50
50 - 100
> 100
100 cm/s

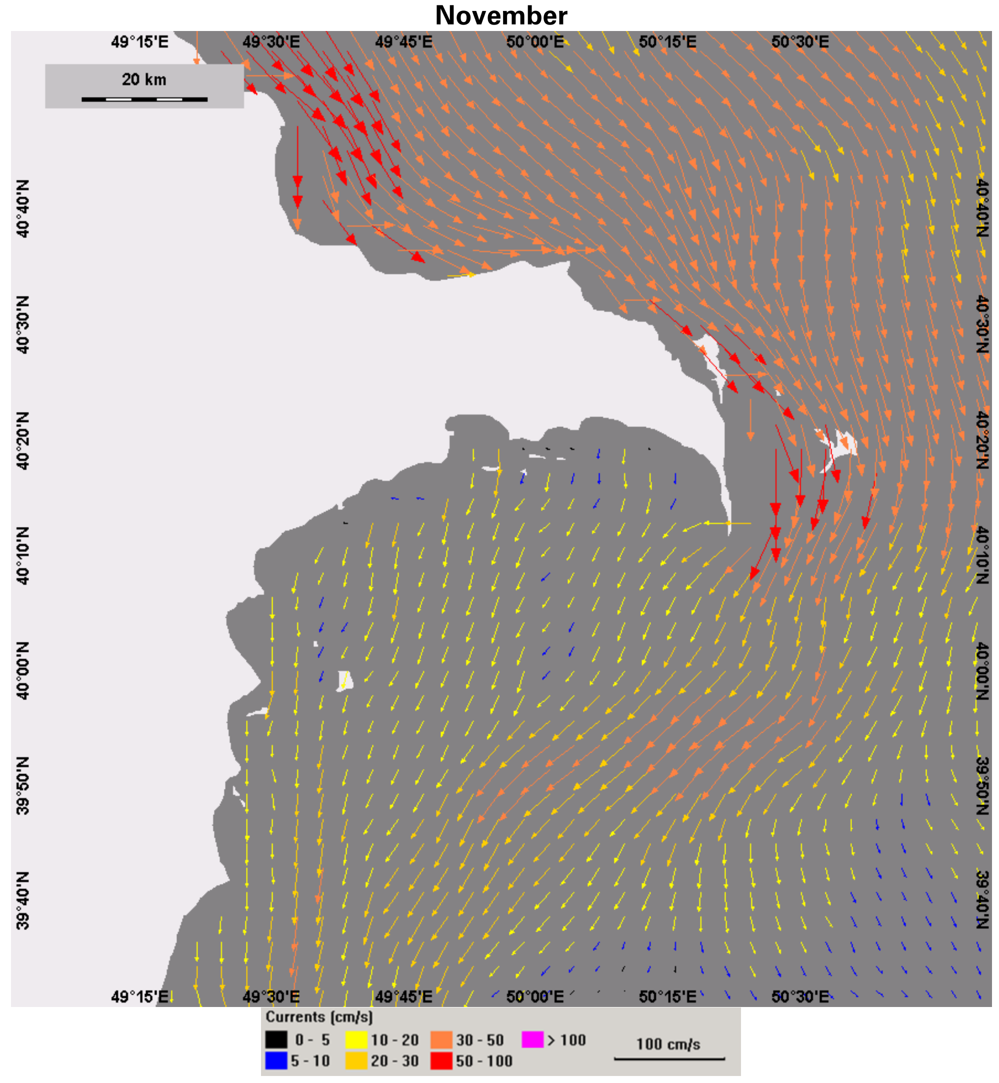
August



September




October
20 km
49°15'E
49°30'E
49°45'E
50°00'E
50°15'E
50°30'E
40°40'N
40°30'N
40°20'N
40°10'N
40°00'N
39°50'N
39°40'N
Currents [cm/s]
0 - 5
5 - 10
10 - 20
20 - 30
30 - 50
50 - 100
> 100
100 cm/s


November
20 km
49°15'E
49°30'E
49°45'E
50°00'E
50°15'E
50°30'E
40°40'N
40°30'N
40°20'N
40°10'N
40°00'N
39°50'N
39°40'N
Currents [cm/s]
0 - 5
5 - 10
10 - 20
20 - 30
30 - 50
50 - 100
> 100
100 cm/s

Appendix 3 OSCAR Output Shapefiles

All Shapefiles are provided in WGS 1984 coordinate system.

Stochastic Simulation Outputs

Gridded stochastic simulation outputs are provided below as zipped Shapefiles. Each zip file contains Shapefiles for surface, water column and shoreline results, with multiple attributes contained within each Shapefile. The following table explains the attribute naming convention for the attributes contained within each Shapefile:

Surface		Water Column		Shoreline	
Attribute ID	***Parameter***	***Attribute ID***	***Parameter***	***Attribute ID***	***Parameter***
Stoc_Out	Probability	Stoc_Out	Probability	Stoc_Out	Probability
Stoc_Out_1	Arrival Time	Stoc_Out_1	Arrival Time	Stoc_Out_1	Arrival Time
Stoc_Out_2	Thickness	Stoc_Out_3	Exposure		
Stoc_Out_3	Exposure				

Priority_Area_1_Stoch.zip Priority_Area_2_Stoch.zip Priority_Area_4_Stoch.zip Priority_Area_5_Stoch.zip

Deterministic Simulation Outputs

Gridded deterministic simulation outputs are provided below as zipped Shapefiles. Each zip file contains the following Shapefiles:

- **Prority_Area_X_Determ_Thickness** – the maximum surface thickness for grid cells where thickness exceeds 0.04µm.
- **Prority_Area_X_Determ_Concentration** – the maximum total diesel concentrations for grid cells where the concentration exceeds 58 ppb.
- **Prority_Area_X_Determ_Shoreline_Oiling_Max** – the maximum extent (length) of shoreline oiling during the modelled period (30 days) – see Table 6 on page 26.
- **Prority_Area_X_Determ_Shoreline_Oiling_30days** – the extent of shoreline oiling at end of scenario (30 days).

Priority_Area_1_Determ.zip Priority_Area_2_Determ.zip Priority_Area_4_Determ.zip Priority_Area_5_Determ.zip

Metadata Standards

The attached zip file contains the metadata standards for the stochastic and deterministic Shapefiles.

AGT_Metadata_Standards_OSCAR_Modelling.zip