APPENDIX B

Drill Cuttings Modelling Report

Global Wells Organization

Newfoundland Orphan Basin Exploration Drilling Program: Drilling mud and cuttings dispersion modelling

Contents

1 Executive summary

This report presents the results of modelling the theoretical dispersion of drilling muds and cuttings released while conducting an exploration drilling program on offshore exploration licences (ELs) in the Orphan Basin, ranging from approximately 270 and 470 km northeast of St. John's, Newfoundland and Labrador, in the Northwest Atlantic Ocean. The modelling was conducted using the SINTEF Marine Environmental Modelling Workbench (MEMW) software, which includes the numeric Dose-related Risk and Effects Assessment Model (DREAM) for chemical releases and Particle Tracking model for drilling discharges (ParTrack).

The main purpose of the modelling was to generate results leading to the development and validation of statements on environmental impact assessment for inclusion in the Environmental Assessment for the Project. Although the precise location of wellsites for the drilling program are not currently known, the drilling mud and cuttings dispersion modelling employed the same representative wellsites for the West Orphan Basin (WOB) and East Orphan Basin (EOB) exploration wells used in oil spill modelling and acoustic assessment.

The provisional 4-string well designs were used as the basis for the modelling work. It was assumed that synthetic based mud (SBM) would be used once the riser is installed. The modelling accounted for likely discharges for the entire well drilled over a 30 day period, including water based mud (WBM) discharges at seafloor for initial hole sections (pre-riser installation), bulk WBM discharges, and treated SBM associated cuttings from the MODU, post-riser installation. A total of 6 separate drilling and batch releases will occur while drilling each exploration well. An Excel mass balance model was developed to calculate the total volume and tonnage of drill cuttings, water based mud and SBM discharged to sea. Of the well designs currently being considered, the design with the largest overall casing/hole volume was used in the modelling, to ensure the worst case volume discharge of cuttings was considered in assessing the environmental impact of the drilling discharges. Similarly, to make sure the worst case scenario was used in modelling the discharge of mud and cuttings from the sections drilled with NAFs, it was assumed that a SBM would be used in conjunction with cuttings dryers to achieve an acceptable oil retention of 6.9% oil on cuttings by wet weight of base fluid on cuttings, before discharging the residue to sea.

Two location scenarios were considered representing the West Orphan Basin (WOB - 1,360 m water depth) and East Orphan Basin (EOB - 2,785 m water depth)

The 3-D current hindcast dataset used in DREAM modelling to drive drill cutting dispersion and pollutant transport was comprised of daily HYCOM current speeds with Bedford Institute Tides linearly superimposed interpolated onto a three hourly time step for the period 1st January 2006 and 31st December 2010. In addition, a 2-D wind field dataset covering the same time period was generated from the National Centre for Atmospheric Research (NCAR) / National Centre for Environmental Protection (NCEP) Climate Forecast System Reanalysis (CFSR). The World Ocean Atlas was used to extract average monthly temperature and salinity vs. depth profiles over the release locations for use in the dispersion modelling.

Currents assist the dispersion of drilling discharges in the water column by advection and mixing. Thus the thickness of drill cuttings deposited on the seabed is very much dependent on the metocean conditions that occur at the time of modelling. Periods of low (benign) current conditions can increase sediment thicknesses and the impact on benthic communities due to smothering, whereas during periods of high (energetic) currents, dispersion and dilution of drilling discharges will reduce sediment thicknesses and burial impacts.

Thus the 5-year hindcast HYCOM current dataset was analysed to find the most benign and energetic surface metocean conditions at each well location averaged over a 45 day period to cover the well duration and the associated start dates for these time periods were identified and used in the model simulations. For both wellsite locations, two scenarios were modelled: one assuming the lowest (45 day period moving-average) ambient surface currents and one assuming the highest ambient surface current conditions over the 5 year period (2006 to 2010).

At both sites, although around 50% by weight of the mud and cuttings released was transported outside the boundaries of the modelling domain, any drill solids deposited on the sea-floor were at insignificant thicknesses of less than 0.001mm (1 micron).

At the WOB wellsite the predicted deposition footprint was predominantly towards the south, whereas at the EOB well location it was directed towards the south southeast (SSE) .

The deposition footprint was evaluated at three thickness “thresholds”.

Site 1 - WOB wellsite

- A drill solid deposition thickness > 1 micron (0.001 mm) represents an approximate minimum thickness threshold for detecting the presence of drill solids by sediment chemical analysis to identify elevated levels of barium and other metals. Under low ambient surface current conditions, the predicted area for total drill solids deposit thicknesses > 1 micron was 3,470 hectares and extended 11.9 km from the wellsite at its furthest extent. Under high ambient surface current conditions the drill solids became more dispersed in the water column, hence the 1 micron thickness boundary area was reduced to 2,149 hectares and extended 7.5 km away from the wellsite.

- Similarly, the predicted areal coverages for cuttings thicknesses > 1 mm (“visible” thickness threshold) were 8.1 and 5.7 hectares for the lowest and highest ambient current scenarios and extended up to 577 m and 635 m away from the wellsite respectively.

- At deposition thicknesses ≥ 6.5 mm, which is considered to be the predicted no effect threshold (PNET) for non-toxic sedimentation, benthic communities comprised of sedentary or slow moving species, may be smothered and the sediment quality will be altered in terms of nutrient enrichment and oxygen depletion. The modelling results predict that these sediment thicknesses could extend approximately 128 m from the discharge point, or cover an area of approximately 0.69 hectares under the lowest ambient surface current conditions. In contrast, under the highest ambient surface current conditions the impacted area increases to 0.85 hectares but the maximum predicted distance from the wellsite location for the threshold thickness is reduced to 85 m.

- The closest distance to the wellsite that SBM cuttings were predicted to settle was 422 m under low ambient surface current conditions and 625 m under the highest ambient surface currents, whilst the largest WBM cuttings deposition thickness in any of the model grid cells was 1.782 m within 2 m of the seabed discharge location. In contrast the maximum SBM cuttings deposition thickness in any of the model grid cells was 2.1 mm

Site 2 - EOB wellsite

- Under low ambient surface current conditions, the predicted area for total drill solids deposit thicknesses > 1 micron was 3,642 hectares and extended 8.01 km from the wellsite at its furthest extent. Under high ambient surface current conditions the drill solids coverage for deposition thicknesses > 1 micron increased to 5,464 hectares and extended 9.17 km away from the wellsite.

- The predicted areal coverages for cuttings thicknesses > 1 mm ("visible" thickness threshold) were 3.5 and 3.2 hectares for the lowest and highest ambient current scenarios and extended up to 147 m and 145 m away from the wellsite respectively. These are significantly smaller areal coverages and distances than those predicted for the WOB well location and is attributable to the higher average seabed and surface current velocities at the EOB well location as well as the increased water depth which all combine to increase the dispersion of discharged drill solids, thereby reducing drill solids deposition thicknesses in the 100 micron to 1 mm thickness size range

- At PNET deposition thicknesses ≥ 6.5 mm, the modelling results predict that these sediment thicknesses could extend approximately 55 m from the discharge point, or cover an area of approximately 0.64 hectares under the lowest ambient surface current conditions. Under the highest ambient surface current conditions the impacted area was slightly less at 0.61 hectares with the maximum predicted distance from the wellsite location for the threshold thickness increased to 57 m.

- The closest distance to the wellsite that SBM cuttings were predicted to settle is 599 m under low ambient surface current conditions and 1,094 m under the highest ambient surface currents, whilst the largest WBM cuttings deposition thickness in any of the model grid cells was 1.240 m within 2 metres of the seabed discharge location. In contrast the maximum SBM cuttings deposition thickness in any of the model grid cells was 0.5 mm.

- These results show that the SBM cuttings discharged at the sea surface from the EOB wellsite location are transported over a greater distance before settling compared to those discharged from the WOB wellsite, which is located in shallower water, thus resulting in a thinner layer of SBM cuttings spread over a larger area.

2 Introduction

BP Canada Energy Group ULC (BP) proposes to conduct exploration drilling activities within the areas of its existing offshore exploration licences (ELs) in the Orphan Basin, ranging from approximately 270 and 470 km northeast of St. John's, Newfoundland and Labrador, in the Northwest Atlantic Ocean. The Newfoundland Orphan Basin Exploration Drilling Program (the Project) may involve drilling up to 20 exploration wells over the term of the ELs (2017 to 2026) with an initial well proposed to be drilled in 2020 pending regulatory approval. Water depths in the ELs range from 970 m to nearly 3,000 m.

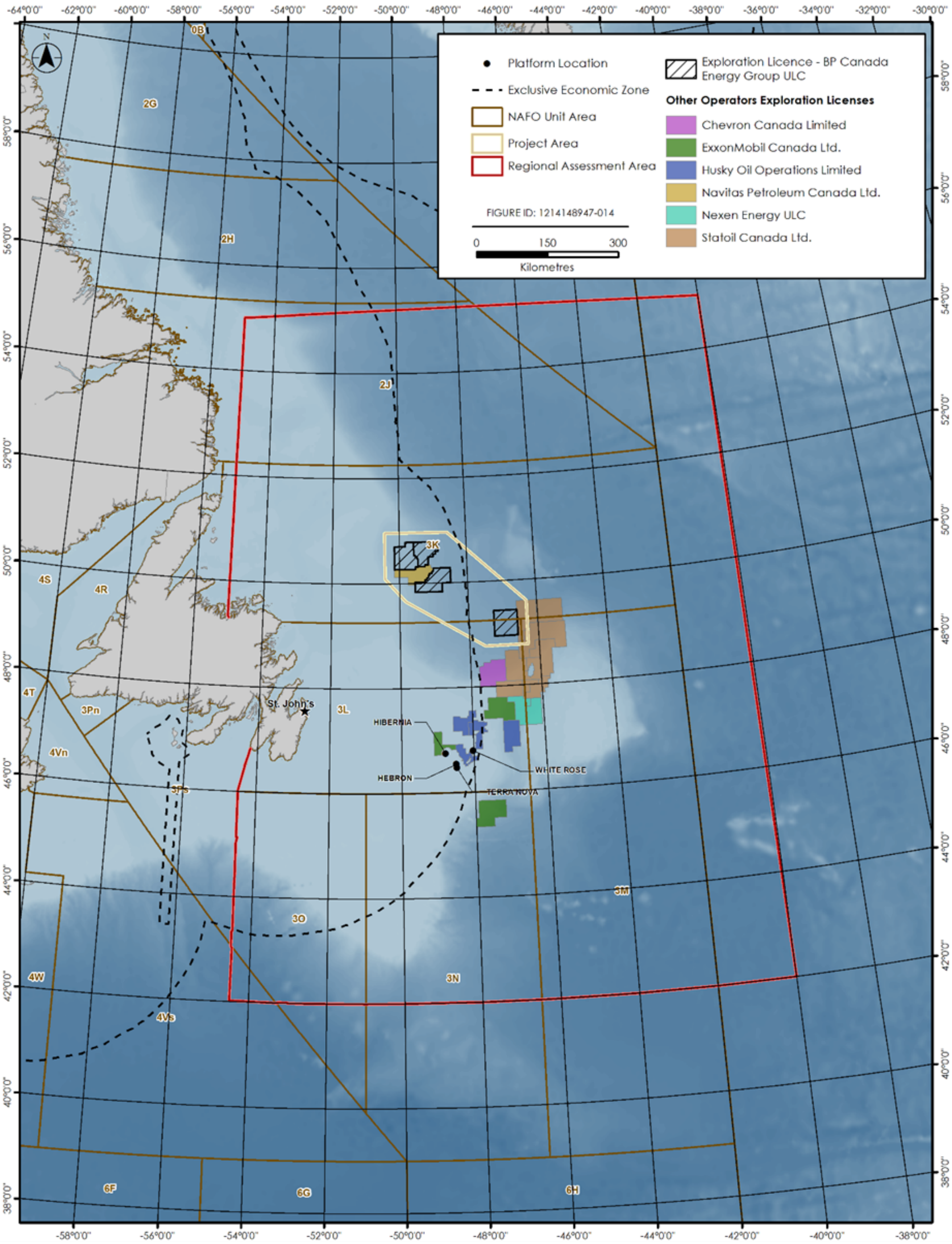


Figure 2.1 BP Canada Energy Group offshore exploration licenses in the Orphan Basin

2.1 Scope of Work

The main purpose of the modelling was to generate results leading to the development and validation of statements on the potential environmental impact of mud and cuttings suspensions and sediment deposition resulting from the operational release of drilling discharges during offshore drilling for inclusion in the Environmental Assessment for the Project. The Environmental Impact Statement guidelines [(1)] issued by the Canadian Environmental Assessment Agency states that:

"In its EIS, the proponent will describe:

- *the nature, composition and fate (e.g. areal extent) of drilling wastes (e.g. muds, cuttings) at various water depths and at various stages of drilling, including during riserless drilling and drilling with the marine riser in place, using dispersion modelling;."*

Dispersion modelling of the release of drilling muds and cuttings from the Project was conducted using the SINTEF Marine Environmental Modelling Workbench (MEMW) software, which includes the numeric Dose-related Risk and Effects Assessment Model (DREAM) for chemical releases and Particle Tracking model for drilling discharges (ParTrack).

3 Drilling Program

Specific drill sites have not yet been finalized but will be located within the ELs delineated in Figure 2.1.

BP has not yet selected the MODU that will be used to drill the wells for the Newfoundland Orphan Basin Exploration Drilling Program. In consideration of the water depths in the ELs (up to approximately 3,000 m), it is expected that either a semi-submersible rig or a drillship will be used.

Prior to drilling, the proposed wellsite location will be surveyed using a remotely operated vehicle (ROV) to inspect the seabed for potential hazards and sensitive habitat (e.g., habitat-forming corals).

The well design has not been finalised. However, it is anticipated that that the first two sections of the well (conductor hole and surface hole) will be drilled riserless with a water-based mud (WBM) or seawater, with mud and cuttings returned to the seabed where they will accumulate in the vicinity of the wellhead. The discharge of WBM cuttings at the seabed, while drilling the first two hole sections is accepted as industry standard practice and is consistent with the Offshore Waste Treatment Guidelines (OWTG) (NEB et al. 2010 [(2)]). Once a riser system has been installed, the deeper (lower) hole sections of the well will be drilled using a recirculating drilling fluid system. The marine riser run between the Blowout Preventer (BOP) and the drilling vessel will provide a conduit for the return of drilling fluid and cuttings back to the drilling vessel. WBM and/or synthetic-based mud (SBM) will be used for these hole sections.

On the drilling vessel the drilled cuttings and drilling fluid will be separated and cleaned using solids control equipment. The mud returns carrying the drilled cuttings will initially pass through a shale shaker where the majority of mud will be separated from the cuttings. Where SBM is used; cuttings from the shale shaker will be passed through a cuttings dryer, which will remove SBM from cuttings. Residual synthetic base fluid on cuttings discharged to the marine environment will not exceed 6.9 g/100 g oil on wet solids (48-hour mass weighted average) in accordance with the OWTG [(2)]. Monitoring of the residual base fluid on cuttings levels will be carried out during hole sections involving use of SBM. After recovery of drill fluids and confirmation of treatment success, the drill cuttings will be discharged from the drilling vessel at the well site. Spent and excess WBM may be discharged from the drilling vessel without treatment as per the OWTG [(2)]. No whole SBM will be discharged to the sea; spent SBM that cannot be reused during drilling will be brought to shore for disposal.

4 DREAM (Dose related Risk and Effect Assessment Model)

4.1 Model Background

The numerical model DREAM (Dose related Risk and Effect Assessment Model) has been developed at SINTEF with support from StatoilHydro, ENI, Total, ExxonMobil, Petrobras, ConocoPhillips, Shell, and BP. The model is a decision support tool for management of operational discharges to the marine environment. DREAM is integrated with the oil spill model OSCAR within a graphical user interface called the Marine Environmental Modelling Workbench (MEMW). The system has been in continuous development for the past 15 years with a drilling discharge capability added to the system. DREAM is a 3-dimensional, time-dependent, multiple-chemical transport, exposure, dose, and effects assessment model. DREAM can account simultaneously for up to 200 chemical components, with different release profiles for 50 or more different sources (Reed et.al.[3, 4]). Each chemical component in the effluent mixture is described by a set of physical, chemical, and toxicological parameters. Because petroleum hydrocarbons constitute a significant fraction of many industrial releases, DREAM incorporates a complete surface slick model, in addition to the processes governing pollutant behaviour and fates in the water column.

4.2 General model description

DREAM is a software tool designed to support rational management of environmental risks associated with operational discharges of complex mixtures. The model has been evolved over a number of years (Reed et al.[3,4]; Johnsen et al.[5] ; Rye et al.[6,7]). Governing physical-chemical processes are accounted for separately for each chemical in the mixture, including:

- vertical and horizontal dilution and transport,
- dissolution from droplet form,
- volatilization from the dissolved or surface phase,
- particulate adsorption/desorption and settling,
- bio-degradation,
- sedimentation to the sea floor.

The algorithms used in the computations, and verification tests of the resulting code, are presented in Reed et al.[2]. The model has also been verified against field measurements (Neff et al.[8]; Durrell et al.[9]).

Chemical concentrations in the water column are computed from the time- and space-variable distribution of pseudo-Lagrangian particles. These particles are of two types, those representing dissolved substances, and those representing droplets composed of less soluble chemical components or solid particulate matter in the release. These latter particles are pseudo-Lagrangian in that they do not necessarily move strictly with the currents, but may rise or settle according to their physical characteristics.

Each mathematical particle represents conceptually a Gaussian cloud (or “puff”) of dissolved chemicals, droplets, or sinking particles). Concentration fields are built up in the model from the superposition of all of these clouds of contaminants. Each cloud consists of an ellipsoid with a particle at its centre, and semi-axes a function of the time-history of the particle. (Ellipsoids encountering boundaries are truncated, with mass being conserved through reflection from the boundary, sorption to the boundary, or some combination of the two.) Particles representing dissolved substances carry with them the following attributes:

- x, y, and z spatial coordinates,
- mass of each chemical constituent represented by the particle,
- distance to and identity of the nearest neighbour particle,
- time since release,
- spatial standard deviations in x, y, and z.

Particles representing non-dissolved substances, such as oil droplets, drill muds or cuttings, carry two additional attributes:

- mean droplet diameter,
- droplet density.

Concentrations are computed within one of three user-specified three-dimensional grid systems. The first is a translating, expanding grid that follows the evolution of a release, thus providing higher resolution during the early stages and lower resolution as time progresses. The second is a fixed grid, with resolution defined by the user. The third is a grid with fixed horizontal resolution, but time-variable vertical resolution. This latter grid is useful, for example, in resolving surface releases of oil, in which the near-surface vertical evolution may be of particular interest.

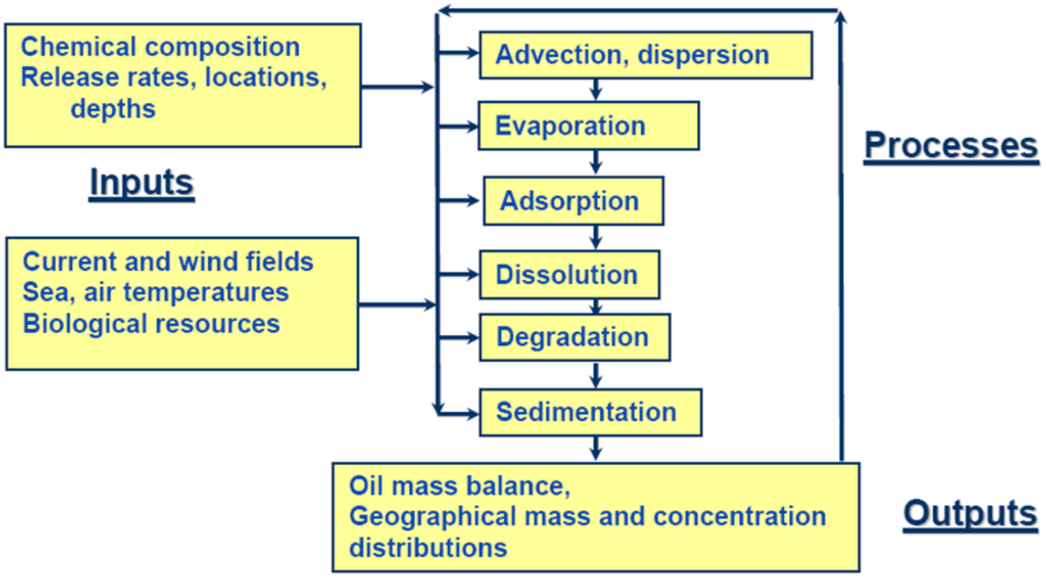
As mentioned earlier, the position of each particle locates the centre of a moving, spreading ellipsoidal cloud, with axes a function of the time-history of the particle. The theoretical distribution of mass within the ellipsoid is assumed Gaussian. Each such ellipsoid will typically contribute mass to many cells in the concentration field, and neighbouring ellipsoids will typically overlap spatially. Thus a given cell in the concentration field will in general contain a concentration resulting from the presence of multiple nearby particle clouds. This hybrid numerical – analytic scheme removes much of the dependence of the computed concentration field on both the number of particles and the resolution of the physical 3-dimensional grid.

The model is driven by winds and currents either produced by other numerical models, or measured as time series in the region of interest. Global datasets of bathymetry and coastlines are supplied with the system, and can be augmented by the user via standard GIS and/or ASCII formats.

Processes governing the behaviour of pollutants in DREAM are presented in Figure 4.1.

DREAM employs surface oil spill model algorithms to simulate the behaviour and fates of surface slicks. Such slicks can occur in the model as the result of rising oil drop released at the air-water interface. In the water column, horizontal and vertical advection and dispersion of entrained and dissolved hydrocarbons are simulated by random walk procedures.

Figure 4.1 General Schematic of the DREAM Model



Vertical turbulence is a function of wind speed (wave height) and depth; horizontal turbulence is a function of the age of a pollutant 'cloud'. Pollutants near the sea surface may evaporate to the atmosphere. Partitioning between particulate-adsorbed and dissolved states is calculated based on linear equilibrium theory. The contaminant fraction that is adsorbed to suspended particulate matter settles with ambient particles. Contaminants at the bottom are mixed into the underlying sediments, and may dissolve back into the water. Degradation in water and sediments is represented as a first order decay process, with the possibility of producing intermediate metabolites. Results of model simulations are stored at discrete time-steps in data files for subsequent viewing and analysis.

For spilled oil, processes such as advection, spreading, entrainment and vertical mixing in the water column are not directly dependent on oil composition, although all tend to be linked through macro-characteristics such as viscosity and density. Other processes, such as evaporation, dissolution, and degradation are directly dependent on oil composition.

DREAM focuses primarily on underwater releases, such that surface phenomena are of secondary interest. Oil droplets contained in produced water, for example, may rise to the surface and form a surface slick, such that related processes must also be represented in the model. DREAM uses the same algorithms for these processes as used in the oil spill contingency and response model OSCAR. These algorithms are described in detail in Reed et al.[(4)]. The DeepBlow model (Johansen[(5)]), developed in response to the interest in petroleum exploration in deep waters, has been generalized and serves as the 3-dimensional dynamic near field module for DREAM as well as for the oil spill model OSCAR. DeepBlow is a Lagrangian element model, the plume being represented by sequence elements. Each element, which can be thought of as a conical cylindrical section of a bent cone, is characterized by its mass, location, width (radius), length (thickness), average velocity, pollutant concentrations, temperature and salinity. These parameters will change as the element moves along the trajectory, i.e. the element increases in mass due to shear-induced and forced entrainment, while rising or sinking according to buoyancy and becoming sheared over by the cross flow. This modified version, called Plume-3D, functions as a near-field module for produced water and drilling discharges, as well as other releases of complex mixtures in an aquatic environment. This module is activated automatically whenever a release is specified to originate under water. Depending on depth and other input parameters, the module automatically computes the near-field plume, and the release of dissolved, solid, and droplet-related pollutants from the plume and into the far field.

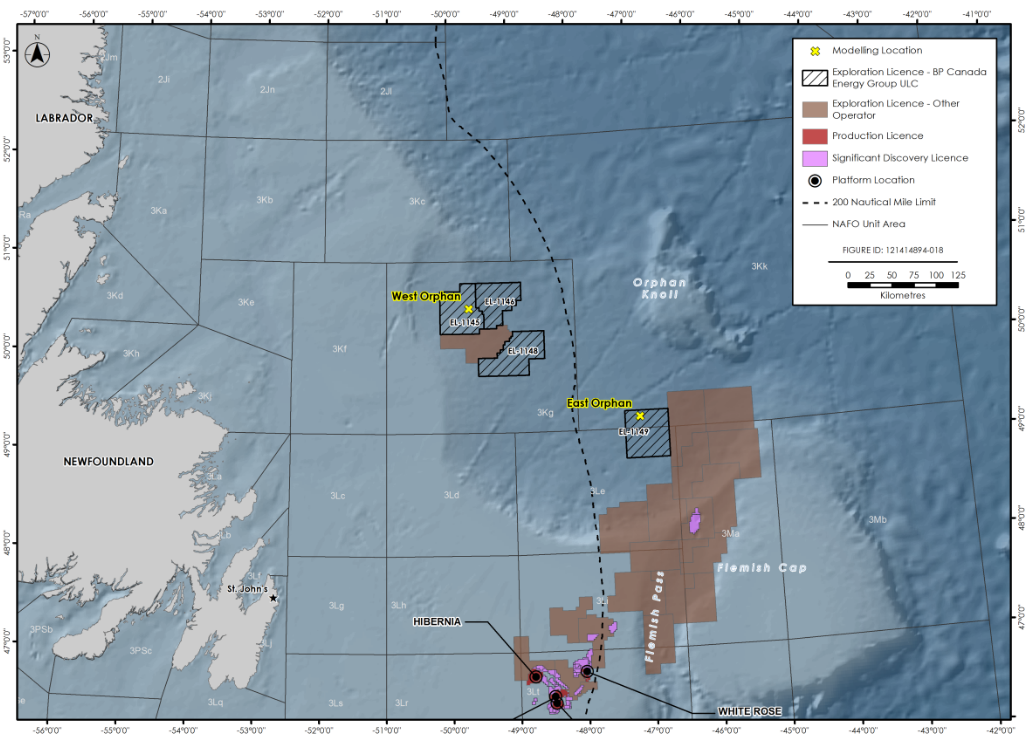
5 Model Setup and Input Data

Although the precise location of wellsites for the drilling program are not currently known, the drilling mud and cuttings dispersion modelling employed the same representative wellsites for the West Orphan Basin (WOB) and East Orphan Basin (EOB) exploration wells used in oil spill modelling and acoustic assessment (Figure 5.1). Table 5.1 shows the well location coordinates for these two representative wellsite scenarios.

Table 5.1 Drilling mud and cuttings dispersion modelling locations

Location	EL	Water Depth (m)	UTM Easting	UTM Northing
Site 1 (West Orphan Basin)	EL 1145	1360	168454.17	5,608,064
Site 2 (East Orphan Basin)	EL 1149	2785	352,231	5,471,024

Figure 5.1 Potential locations of Orphan Basin exploration wells selected for cuttings dispersion modelling



5.1 Drilling data

The provisional well designs presented in Tables 5.2 and 5.3 were used as the basis for the modelling work. It was assumed that SBM would be used once the riser is installed.

The modelling accounted for likely discharges for the entire well drilled over a 30 day period, including WBM discharges at seafloor for initial hole sections (pre-riser installation), bulk WBM discharges, and treated SBM associated cuttings from the MODU, post-riser installation. A total of 6 separate drilling and batch releases will occur while drilling each exploration well.

Table 5.2 Provisional well casing plan for WOB Exploration well

Newfoundland West Orphan Offshore Exploration Well - DEPTHS AND CASING POINTS								
TYPICAL 4-STRING WELL					Interval Length (m)	Casing Depth (m bml)	Section Measured Depth (m brt)	Total Metres Drilled by Hole Size (m)
Water Depth (m)							1,360	
Interval	Casing Size (ins)	Casing ID (ins)	Bit Diameter (ins)	Overguage Hole Diameter (ins)				
42"- Sea Water & Gel Sweeps & PAD Mud	36 " @	34.00	42.00	47.00	80	80	1,440	80
26" Sea Water & Gel Sweeps & PAD Mud	20" @	18.38	26.00	29.10	810	890	2,250	810
17 1/2" SBM	13 - 5/8" @	12.25	17.50	18.80	1,550	2,440	3,800	1,550
12 1/4" SBM	9-5/8"@	8.50	12.25	13.15	1,200	3,640	5,000	1,200

TYPICAL 4-STRING WELL					Interval Length (ft)	Casing Depth (ft bml)	Section Measured Depth (ft brt)	Total footage drilled by Hole Size (ft)
Water Depth (ft)							4,462	
Interval	Casing Size (ins)	Casing ID (ins)	Bit Diameter (ins)	Overguage Hole Diameter (ins)				
42"- Sea Water & Gel Sweeps & PAD Mud	36 " @	34.00	42.00	47.00	262	262	4,724	262
26" Sea Water & Gel Sweeps & PAD Mud	20" @	18.375	26.00	29.10	2,657	2,920	7,382	2,657
17 1/2" SBM	13 - 5/8" @	12.25	17.50	18.80	5,085	8,005	12,467	5,085
12 1/4" SBM	9-5/8"@	8.5	12.25	13.15	3,937	11,942	16,404	3,937

Table 5.3 Provisional well casing plan for EOB Exploration well

Newfoundland East Orphan Offshore Exploration Well - DEPTHS AND CASING POINTS								
TYPICAL 4-STRING WELL					Interval Length (m)	Casing Depth (m bml)	Section Measured Depth (m brt)	Total Metres Drilled by Hole Size (m)
Water Depth (m)							2,785	
Interval	Casing Size (ins)	Casing ID (ins)	Bit Diameter (ins)	Overguage Hole Diameter (ins)				
42"- Sea Water & Gel Sweeps & PAD Mud	36 " @	34.00	42.00	47.00	80	80	2,865	-
26" Sea Water & Gel Sweeps & PAD Mud	20" @	18.38	26.00	29.10	835	915	3,700	-
17 1/2" SBM	13 - 5/8" @	12.25	17.50	18.80	1,000	1,915	4,700	-
12 1/4" SBM	9-5/8"@	8.50	12.25	13.15	1,800	3,715	6,500	-
TYPICAL 4-STRING WELL					Interval Length (ft)	Casing Depth (ft bml)	Section Measured Depth (ft brt)	Total footage drilled by Hole Size (ft)
Water Depth (ft)							9,137	
Interval	Casing Size (ins)	Casing ID (ins)	Bit Diameter (ins)	Overguage Hole Diameter (ins)				
42"- Sea Water & Gel Sweeps & PAD Mud	36 " @	34.00	42.00	47.00	262	262	9,399	-
26" Sea Water & Gel Sweeps & PAD Mud	20" @	18.375	26.00	29.10	2,739	3,002	12,139	-
17 1/2" SBM	13 - 5/8" @	12.25	17.50	18.80	3,281	6,283	15,420	-
12 1/4" SBM	9-5/8"@	8.5	12.25	13.15	5,905	12,188	21,325	-

An Excel mass balance model was developed to calculate the total volume and tonnage of drill cuttings, water based mud and SBM discharged to sea using the well and casing design information and mud dilution factor data inputs presented in Tables 5.4 and 5.5. Typical generic mud formulations for each hole section were then used to calculate the tonnage of each chemical component discharged to sea as shown in Annex A, Tables A1 – A6.

The average rate of penetration for each hole section and the time interval between drilling discharges was calculated using time estimates of drilling and completion activities for the wells as shown in Tables 5.6 and 5.7. Estimates of the amounts and types of drilling discharges expected are shown in Tables 5.8 and 5.9 and Figures 5.2 and 5.3.

Modelling was conducted for all 8 drilling operational releases. Of the well designs currently being considered, the design with the largest overall casing/hole volume was used in the modelling, to ensure the worst case volume discharge of cuttings was considered in assessing the environmental impact of the drilling discharges. Similarly, to make sure the worst case scenario was used in modelling the discharge of mud and cuttings from the sections drilled with NAFs, it was assumed that a SBM would be used in conjunction with cuttings dryers to achieve an acceptable oil retention of 6.9% oil on cuttings by wet weight of base fluid on cuttings, before discharging the residue to sea.

The particle size distribution of particulates (barite, drill cuttings, bentonite etc.) in the drilling discharges used in the modelling are presented in Figure 5.4.

Table 5.4 Drilling fluid assumptions for WOB exploration well

ASSUMPTIONS

1. Hole Washout, Cuttings SG and Release Point Information

Interval	Percent Overgauge	% Volume Washout	Cuttings SG	Discharge Depth (m)		Discharge Temperature at Release Point (deg C)	Diameter of outlet opening (m)	Orientation of outlet opening
				Above sea-floor	Below sea surface			
42"- Sea Water & Gel Sweeps & PAD Mud	12%	25%	2.2	1.0	-	18.0	-	Vertical, up
26" Sea Water & Gel Sweeps & PAD Mud	12%	25%	2.2	1.0	-	18.0	-	Vertical, up
17 1/2" SBM	7%	15%	2.6	-	15	18.0	0.50	Vertical , down
12 1/4" SBM	7%	15%	2.6	-	15	18.0	0.50	Vertical , down

2. Hole Displacement Excess (Riserless Sections)

Interval	Pill Volume (bbls)	Frequency (Every x ft)	Safety Margin (%)
42" - Hi Vis Sweeps	100	45	20%
26" - Hi Vis Sweeps	100	45	20%

PAD Mud Displacement Criteria

Interval	Surface Volume (bbls)	# x OH Vol	# x CSG Vol	# of PAD Displacements
42" - PAD Mud	700	2	1	2
26" - PAD Mud	700	2	1	2

3. Fluid Densities and NAF Composition

Average Fluid Densities			NAF Composition				
Interval	Max Mud SG	Max Mud Weight ppg	O/W ratio		Solids	Oil	Water
42" - Hi Vis Sweeps	1.03	8.60	n/a	n/a	n/a	n/a	n/a
42" - PAD Mud	1.08	9.00	n/a	n/a	n/a	n/a	n/a
26" - Hi Vis Sweeps	1.14	9.50	n/a	n/a	n/a	n/a	n/a
26" - PAD Mud	1.38	11.50	n/a	n/a	n/a	n/a	n/a
17 1/2" SBM	1.26	10.50	75	25	6.8%	69.9%	23.3%
12 1/4" SBM	1.53	12.80	75	25	5.3%	71.0%	23.7%
Base oil	0.79	6.58					

4. Mud Dilution Factors

Interval	bbl/ft	bbl/m
17 1/2" SBM	0.1930	0.63
12 1/4" SBM	0.0950	0.31

Table 5.5 Drilling fluid assumptions for EOB exploration well

ASSUMPTIONS

1. Hole Washout, Cuttings SG and Release Point Information

Interval	Percent Overgauge	% Volume Washout	Cuttings SG	Discharge Depth (m)		Discharge Temperature at Release Point (deg C)	Diameter of outlet opening (m)	Orientation of outlet opening
				Above sea-floor	Below sea surface			
42"- Sea Water & Gel Sweeps & PAD Mud	12%	25%	2.2	1.0	-	18.0	-	Vertical, up
26" Sea Water & Gel Sweeps & PAD Mud	12%	25%	2.2	1.0	-	18.0	-	Vertical, up
17 1/2" SBM	7%	15%	2.6	-	15	18.0	0.50	Vertical , down
12 1/4" SBM	7%	15%	2.6	-	15	18.0	0.50	Vertical , down

2. Hole Displacement Excess (Riserless Sections)

Interval	Pill Volume (bbls)	Frequency (Every x ft)	Safety Margin (%)
26" x 42" - Hi Vis Sweeps	100	45	20%
26" - Hi Vis Sweeps	100	45	20%

PAD Mud Displacement Criteria

Interval	Surface Volume (bbls)	# x OH Vol	# x CSG Vol	# of PAD Displacements
26" x 42" - PAD Mud	700	2	1	2
26" - PAD Mud	700	2	1	2

3. Fluid Densities and NAF Composition

Average Fluid Densities			NAF Composition				
Interval	Max Mud SG	Max Mud Weight ppg	O/W ratio		Solids	Oil	Water
26" x 42" - Hi Vis Sweeps	1.03	8.60	n/a	n/a	n/a	n/a	n/a
26" x 42" - PAD Mud	1.08	9.00	n/a	n/a	n/a	n/a	n/a
26" - Hi Vis Sweeps	1.14	9.50	n/a	n/a	n/a	n/a	n/a
26" - PAD Mud	1.26	10.50	n/a	n/a	n/a	n/a	n/a
17 1/2" SBM	1.20	10.00	75	25	6.8%	69.9%	23.3%
12 1/4" SBM	1.32	11.00	75	25	5.3%	71.0%	23.7%
Base oil	0.79	6.58					

4. Mud Dilution Factors

Interval	bbl/ft	bbl/m
17 1/2" SBM	0.1930	0.63
12 1/4" SBM	0.0950	0.31

Table 5.6 Activity time estimates associated with drilling and completion operations for WOB exploration well

D&C Sequence #	Operation	Total Days	Cumulative Days	Cumulative Days Post Spud	Average ROP (m/hr)	Start of Discharge (time since end of last discharge)	
						(hrs)	(days
1	Rig Move	6.0	6.0				
2	Run BHA and Drill 42" Section	1.5	7.5	1.5	2.2	0.0	0.0
3	Run and Cement 36" Conductor	2.0	9.5	3.5			
4	Run BHA and Drill 26" Section	3.5	13.0	7.0	9.6	24.0	1.0
5	Run and Cement 20" Casing	2.0	15.0	9.0			
6	Run BHA and Drill 17.5" Section	4.0	19.0	13.0	16.1	24.0	1.0
7	Run and Cement 13-5/8" Casing	2.0	21.0	15.0			
8	Run BHA and Drill 12.25" Section	4.0	25.0	19.0	12.5	48.0	2.0
9	Logging	2.5	27.5	21.5			
10	Plug and Abandon	4.0	31.5	25.5			

Table 5.7 Activity time estimates associated with drilling and completion operations for EOB exploration well

D&C Sequence #	Operation	Total Days	Cumulative Days	Cumulative Days Post Spud	Average ROP (m/hr)	Start of Discharge (time since end of last discharge)	
						(hrs)	(days
1	Rig Move	6.0	6.0				
2	Run BHA and Drill 42" Section	1.5	7.5	1.5	2.2	0.0	0.0
3	Run and Cement 36" Conductor	2.0	9.5	3.5			
4	Run BHA and Drill 26" Section	3.5	13.0	7.0	9.9	24.0	1.0
5	Run and Cement 20" Casing	2.0	15.0	9.0			
6	Run BHA and Drill 17.5" Section	4.0	19.0	13.0	10.4	24.0	1.0
7	Run and Cement 13-5/8" Casing	2.0	21.0	15.0			
8	Run BHA and Drill 12.25" Section	4.0	25.0	19.0	18.8	48.0	2.0
9	Logging	2.5	27.5	21.5			
10	Plug and Abandon	4.0	31.5	25.5			

Table 5.8 Quantitative estimate of the amounts and types of drilling discharges expected from drilling the WOB exploration well

DISCHARGES BY HOLE SECTION PER WELL	Discharges While Drilling					Batch Discharge of WBM Mud at End of Sections			
Hole Section / Mud Type	Total Footage Drilled	Cuttings Discharge (tonnes)	Mud Discharge (tonnes)	Chemicals* discharged (tonnes)	Oil Discharge (tonnes)	Emptying of Sand traps		Whole mud displacement	
						Mud Discharge (tonnes)	Chemicals discharged (tonnes)	Mud Discharge (tonnes)	Chemicals *discharged (tonnes)
42"- Sea Water & Gel Sweeps & PAD Mud	262	197	115	2	0	n/a	n/a	506	44
26" Sea Water & Gel Sweeps & PAD Mud	2,657	765	1,283	19	0	n/a	n/a	2,107	754
17 1/2" SBM	5,085	708	196	163	86	n/a	n/a	n/a	n/a
12 1/4" SBM	3,937	268	91	79	33	n/a	n/a	n/a	n/a
Total	**11,942**	**1,938**	**1,685**	**263**	**119**	**0**	**0**	**2,613**	**798**

* Chemicals includes commercial solids (barite bentonite etc.) added to the mud system

TOTAL DISCHARGES PER WELL

Waste Category	Discharges by Volume		Discharges by Weight
Total Cuttings discharged to sea while drilling	5,156 bbls	820 m^3	**1,938 tonnes**
Total WBM discharged to sea while drilling	7,786 bbls	1,238 m^3	**1,397 tonnes**
Total Batch discharge of WBM to sea	9,616 bbls	1,529 m^3	**2,613 tonnes**
Total SBM discharged to sea while drilling	1,356 bbls	216 m^3	**288 tonnes**
Total Drilling Chemicals Discharged to Sea			**1,061 tonnes**
Note:			
Discharges of Synthetic Base Oil included within the SBM discharge amount to:	952 bbls	151 m^3	**119 tonnes**

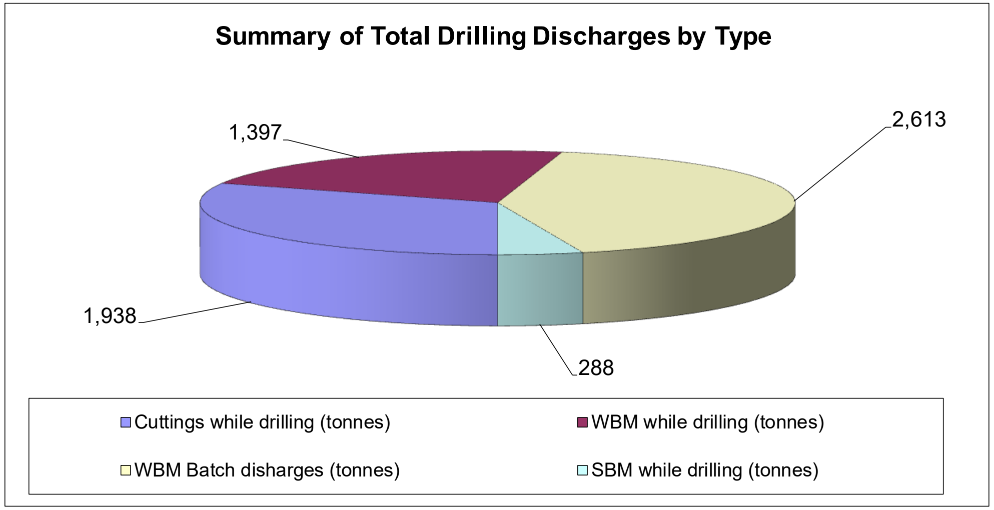


Table 5.9 Quantitative estimate of the amounts and types of drilling discharges expected from drilling the EOB exploration well

DISCHARGES BY HOLE SECTION PER WELL	Discharges While Drilling					Batch Discharge of WBM Mud at End of Sections			
						Emptying of Sand traps		Whole mud displacement	
Hole Section / Mud Type	Total Footage Drilled	Cuttings Discharge (tonnes)	Mud Discharge (tonnes)	Chemicals* discharged (tonnes)	Oil Discharge (tonnes)	Mud Discharge (tonnes)	Chemicals discharged (tonnes)	Mud Discharge (tonnes)	Chemicals *discharged (tonnes)
42"- Sea Water & Gel Sweeps & PAD Mud	262	197	115	2	0	n/a	n/a	506	44
26" Sea Water & Gel Sweeps & PAD Mud	2,739	788	1,322	20	0	n/a	n/a	1,978	524
17 1/2" SBM	3,281	457	121	98	55	n/a	n/a	n/a	n/a
12 1/4" SBM	5,905	402	118	99	50	n/a	n/a	n/a	n/a
Total	12,188	1,844	1,675	219	105	0	0	2,484	568

* Chemicals includes commercial solids (barite bentonite etc.) added to the mud system

TOTAL DISCHARGES PER WELL

Waste Category	Discharges by Volume		Discharges by Weight
Total Cuttings discharged to sea while drilling	4,935 bbls	785 m^3	**1,844 tonnes**
Total WBM discharged to sea while drilling	8,005 bbls	1,273 m^3	**1,437 tonnes**
Total Batch discharge of WBM to sea	9,886 bbls	1,572 m^3	**2,484 tonnes**
Total SBM discharged to sea while drilling	1,194 bbls	190 m^3	**238 tonnes**
Total Drilling Chemicals Discharged to Sea			**787 tonnes**
Note:			
Discharges of Synthetic Base Oil included within the SBM discharge amount to:	841 bbls	134 m^3	**105 tonnes**

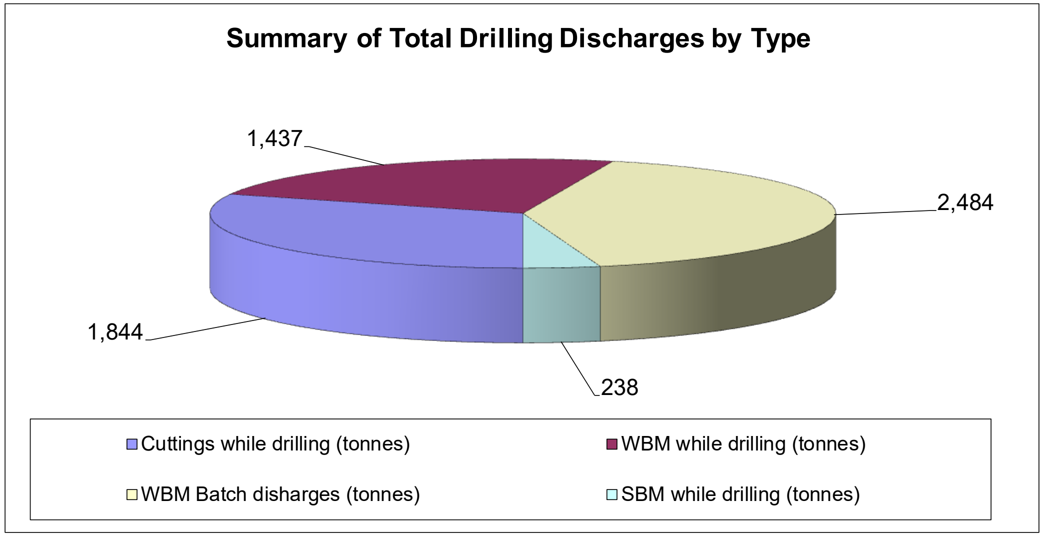


Figure 5.2 Average discharge rates to water of mud and cuttings components over the duration of WOB exploration well

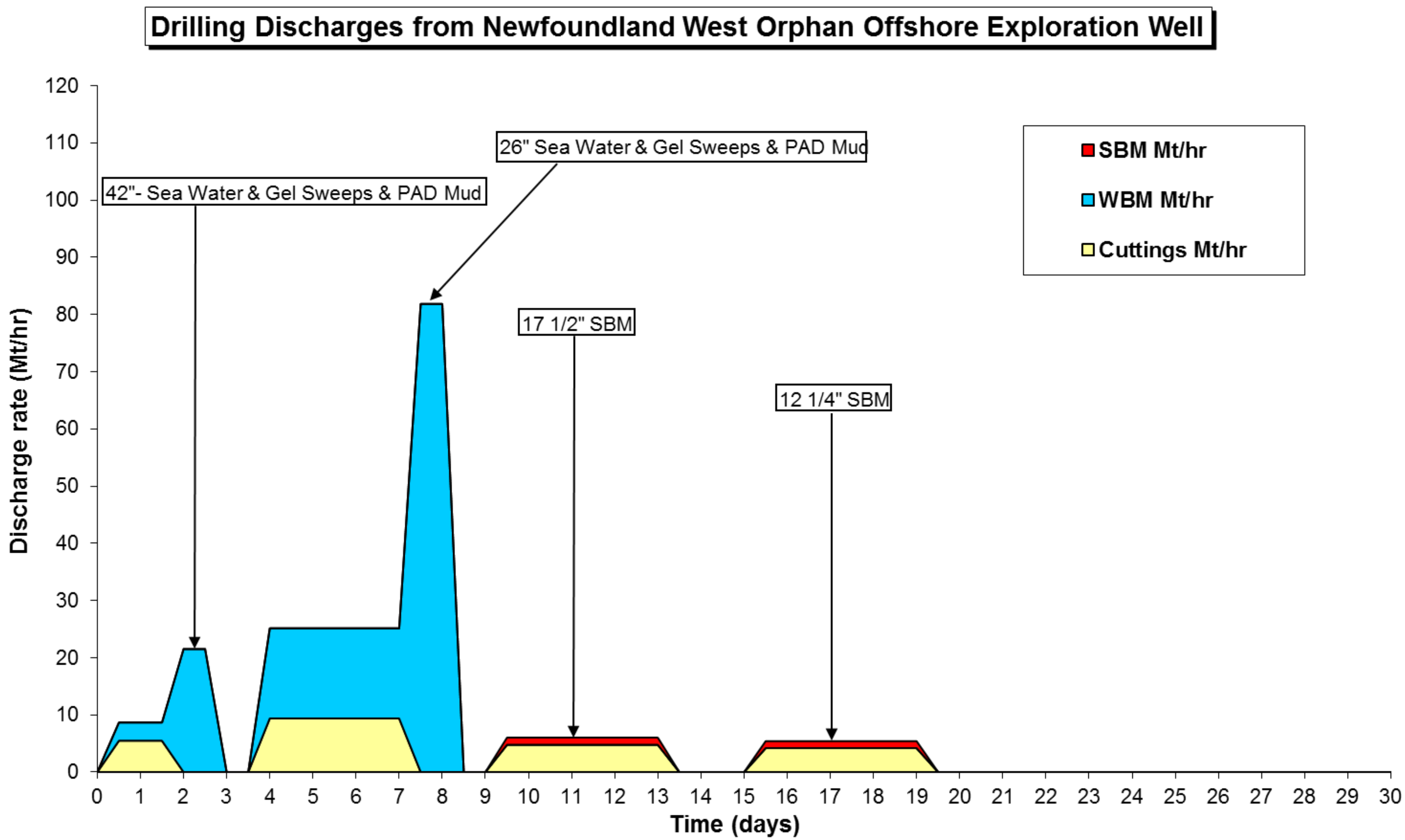


Figure 5.3 Average discharge rates to water of mud and cuttings components over the duration of EOB exploration well

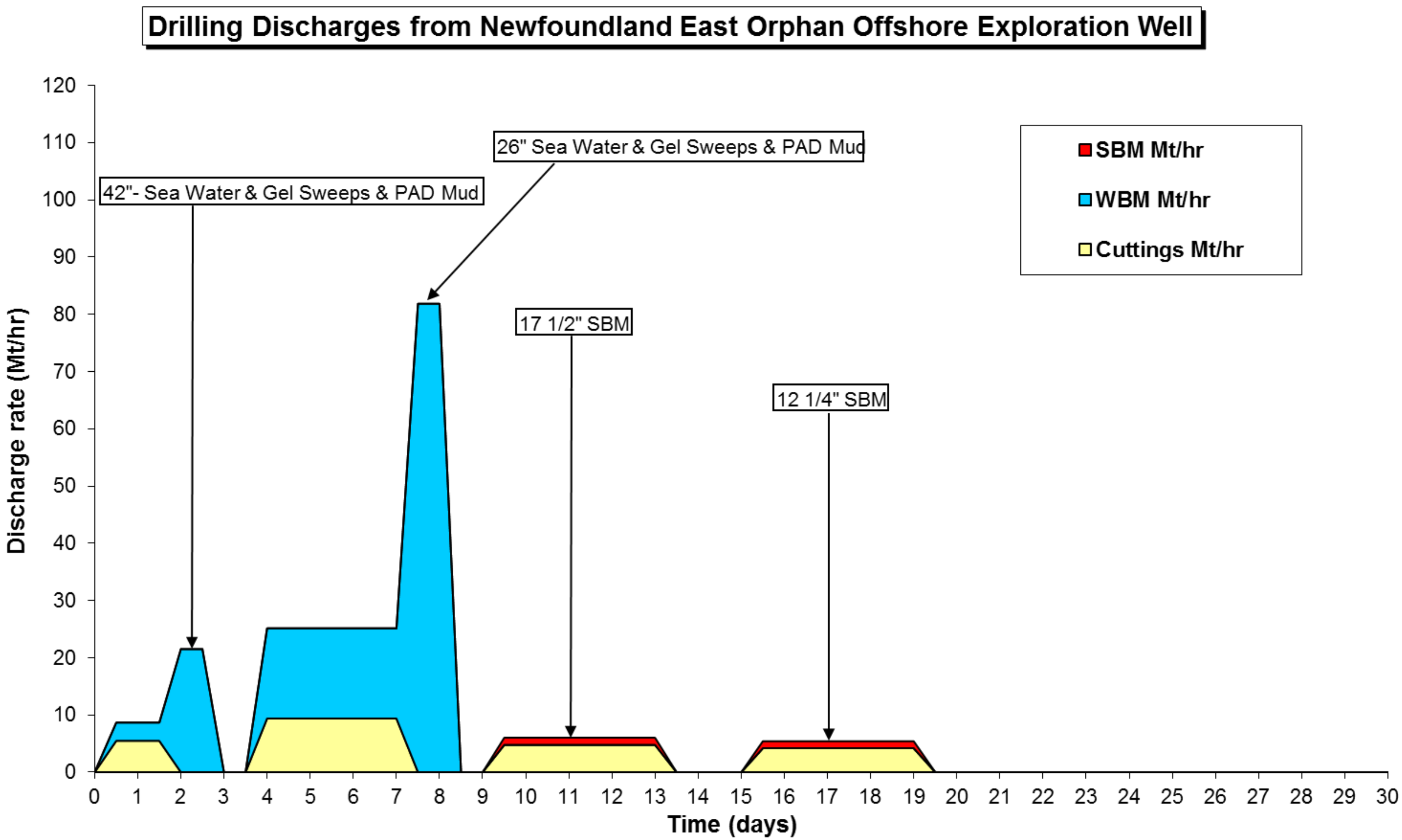
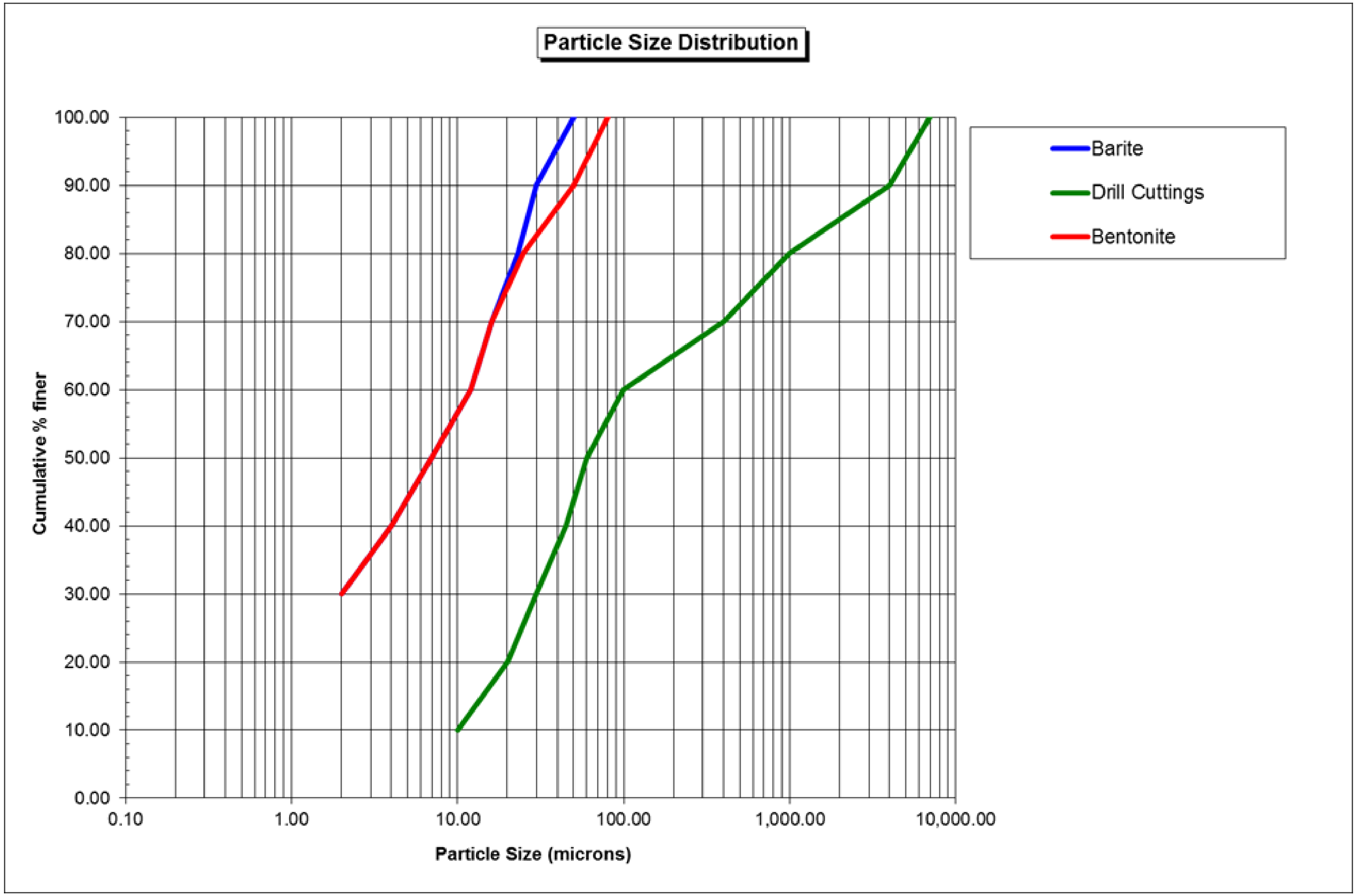


Figure 5.4 Size distributions of particulates used in the drilling discharge modelling



5.2 Environmental Data

5.2.1 Hydrodynamic and Wind Data

Currents, winds and other meteorological and oceanographic factors are critical parameters which can influence drill cutting dispersion and pollutant transport. Meteorological and oceanographic data is available from a number of sources and can be formatted to work in the DREAM model.

5.2.2 Currents

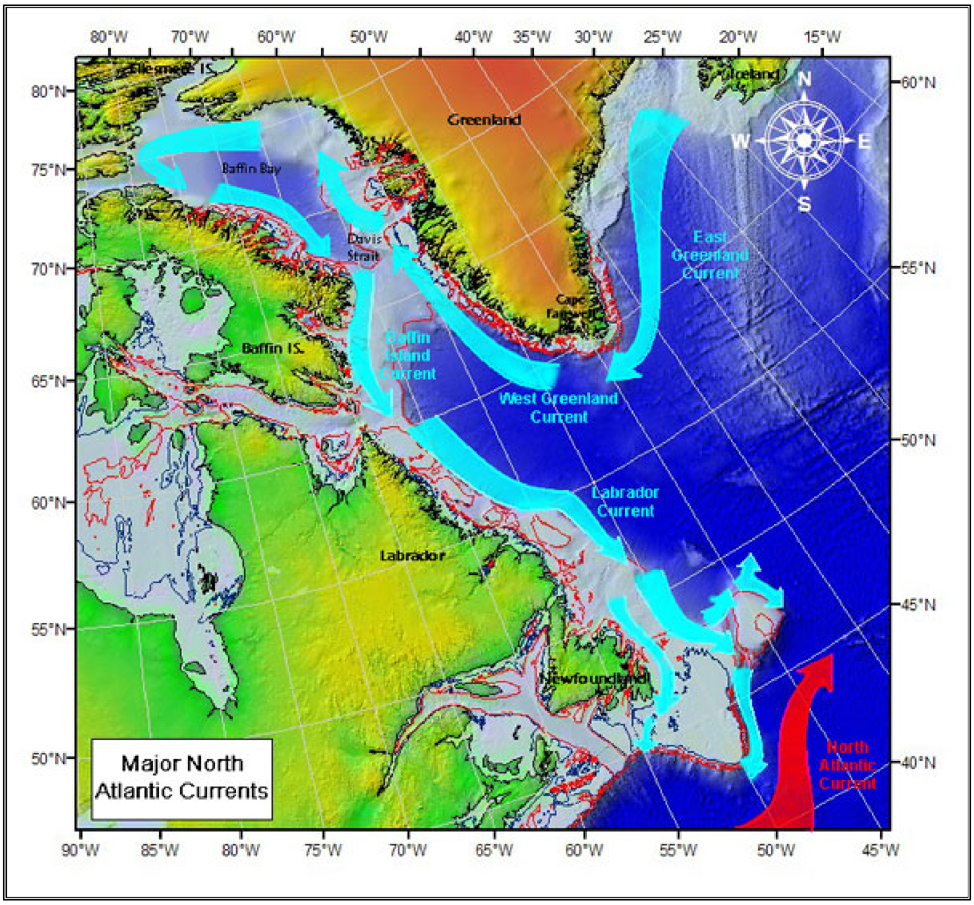


Figure 5.5 Regional Circulation Scheme near the Newfoundland Orphan Basin

The Labrador Current (Figure 5.5) is the dominant current in the Newfoundland Orphan Basin. The Labrador Current is composed of the West Greenland, Baffin Island Currents and Irminger Current. The Labrador Current originates from the Hudson Strait at 60°N and flows southward over the Labrador and Newfoundland Shelf and Slope to the tail end of the Grand Banks at 43°N (Lazier and Wright 1993[10]). The Labrador Current becomes two branches on the southern Labrador Shelf: an inshore branch with approximately 15% of the transport and a main offshore branch, with approximately 85% of the transport (Lazier and Wright 1993[10]). The main branch of the offshore Labrador Current typically flows along the Continental Slope between 300 and 1,500 m (Lazier and Wright 1993[10]). The inshore branch is a weaker flow, not well defined, except in specific regions where bathometry effects are dominate such as in the Avalon Channel (Narayanan et al. 1996[11]). The mean surface water velocities of the offshore branch typically range from 25 to 50 cm/s, and those of the inshore branch are weaker and range from 5 to 20 cm/s (Fissel and Lemon 1991[12]; Lazier and Wright 1993[10]; Colbourne 2000[13]). The currents on the Newfoundland Slope are highly variable due to the influences of strong atmospheric forcing, large inflows of sea ice, and interactions with the Gulf Stream and North Atlantic Current (Han and Li 2004[14]). This results in the Labrador Current having seasonal and interannual variations in velocity and transport. Typically, the upper waters of the Labrador Current are stronger in fall and winter and weaker in spring (Lazier and Wright 1993[10]; Han and Tang 1999[15]; Han and Li 2004[14]). Lazier and Wright (1993[10]) found seasonal variations in the upper 400 m level circulation and no significant variations deeper than the 1,000 m level.

The Labrador Current flows southward until it reached the southern part of Orphan Basin, where it is diverted eastward by the bathymetry. Upon reaching the entrance to Flemish Pass, the current divides into two branches. One branch continues to flow eastward north of Flemish Cap and the other branch flows southward through Flemish Pass.

East of the Tail of the Grand Banks, the Gulf Stream loses its characteristics and divides into branches. One of these branches flows northward (Figure 5.5) on the eastern side of Flemish Cap to the Orphan Basin region. Greenan et al. (2010[16]) found that the waters in the Orphan Knoll region of Orphan Basin were warmer in 2009 than in 2008 from an incursion of a filament from a meander of the North Atlantic Current.

5.2.3 Wind

The Project Area experiences predominately southwest to west flow throughout the year. There is a strong annual cycle in the wind direction. West to northwest winds which are prevalent during the winter months begin to shift counter-clockwise during March and April, resulting in a predominant southwest wind by the summer months. As autumn approaches, the tropical-to-polar temperature gradient strengthens, and the winds shift slightly, becoming predominately westerly again by late fall and into winter. Low pressure systems crossing the area are more intense during the winter months. As a result, mean wind speeds tend to peak during this season.

In addition to mid-latitude low pressure systems crossing the Grand Banks, tropical cyclones often move northward out of the influence of the warm waters of the Gulf Stream, passing near the Island of Newfoundland. Once the cyclones move over colder waters they lose their source of latent heat energy and often begin to transform into a fast-moving and rapidly developing extratropical cyclone producing large waves and sometimes hurricane force winds.

Low pressure systems crossing the area are more intense during the winter months, with mean wind speeds tending to peak during this season.

5.2.4 Metocean input data for the DREAM Model

The 3-D current dataset used in DREAM modelling to drive drill cutting dispersion and pollutant transport was comprised of 3 hourly HYCOM current speeds with Bedford Institute Tides linearly superimposed. The HYCOM currents are from the Navy Research Laboratory experiment 19.1 (HYCOM GLBu0.08) for the period 1st January 2006 to 31st December 2010. The spatial resolution is 1/12.5 degrees and the results were extracted onto a domain that spans: longitude 30 to 70 degrees West and latitude 35 to 65 degrees North. The HYCOM currents were provided on forty depth levels, from the surface to 5,000m. HYCOM uses Gebco 30 minute bathymetry, Climate Forecast System Reanalysis (CFSR) atmospheric forcing and assimilates data from a variety of sources. The tidal currents have been derived from the constituents in the Bedford Institute WebTide module and the profile through depth was reconstructed by assuming a 1/7 power law.

The NOAA/NSIDC climate data record of passive microwave sea ice concentration (version 3) have also been used to drive the OSCAR model. This data set provides a Climate Data Record (CDR) of sea ice concentration from passive microwave data. It provides a consistent, daily and monthly time series of sea ice concentrations from 09 July 1987 through the most recent processing for both the north and south polar regions. All data are on a 25 km x 25 km grid.

Snapshot maps showing examples of the wind, current and ice fields generated from the National Centre for Atmospheric Research (NCAR) / National Centre for Environmental Protection (NCEP) Climate Forecast System Reanalysis (CFSR), HYCOM and National Snow and Ice Data Centre (NSIDC) datasets respectively are presented in Figures 5.6 – 5.9. The World Ocean Atlas was used to extract average monthly temperature and salinity vs. depth profiles over the release locations for use in the dispersion modelling.

Table 5.6 Metocean Data Parameter Inputs

	Input Data	Temporal Resolution	Reference
Bathymetry	GEBCO-1 minute	n/a	http://www.gebco.net/
Current velocity	HYCOM	3 hrly	https://hycom.org/
Temperature	World Ocean Atlas	Monthly	https://www.nodc.noaa.gov/OC5/woa13/
Salinity	World Ocean Atlas	Monthly	https://www.nodc.noaa.gov/OC5/woa13/
Tides	Bedford Institute Tides	3 hrly	http://www.bio.gc.ca/
Winds	NCAR /NCEP (CFSR)	3 hrly	http://rda.ucar.edu/pub/cfsr.html
Atmospheric forcing	NCAR/NCEP (CFSR)	3 hrly	http://rda.ucar.edu/pub/cfsr.html
Sea ice	National Snow and Ice Data Centre	daily	http://nsidc.org/
Wave heights	Calculated in OSCAR	n/a	n/a
Wind induced current	Calculated in OSCAR	n/a	n/a

Figure 5.6 Snapshot map showing an example of the 2-dimensional wind field generated from the NCAR / NCEP (CFSR) dataset

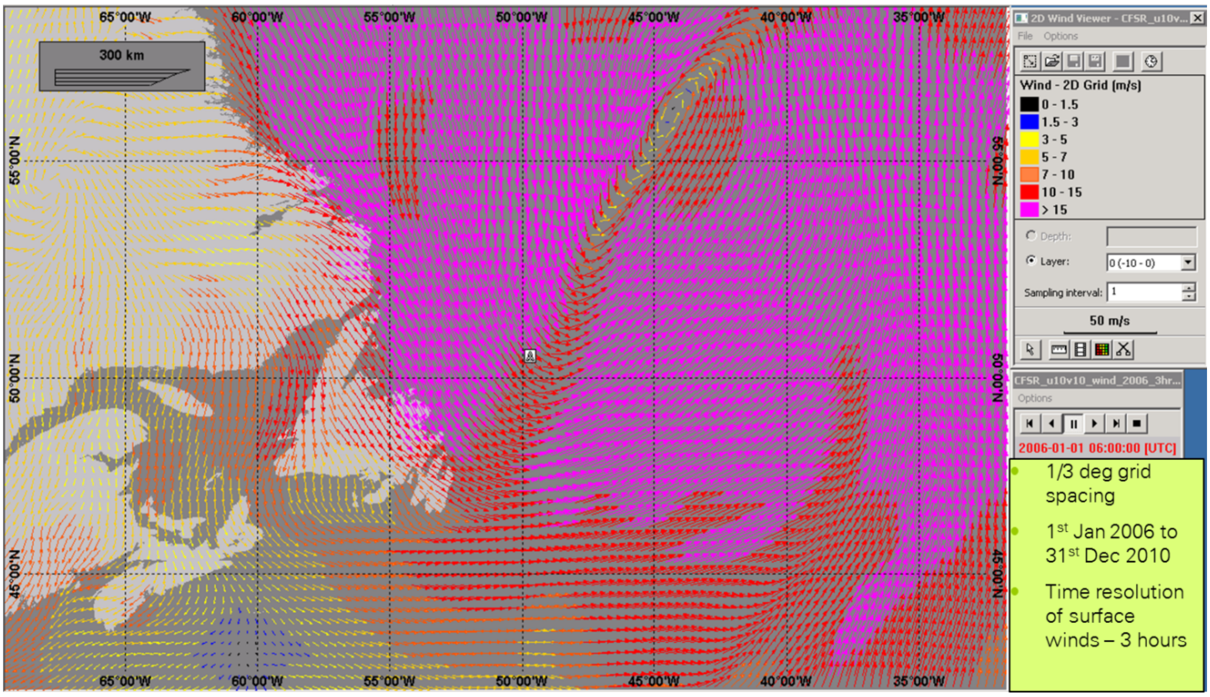


Figure 5.7 Snapshot map showing an example of the surface current field from 3-dimensional HYCOM generated dataset

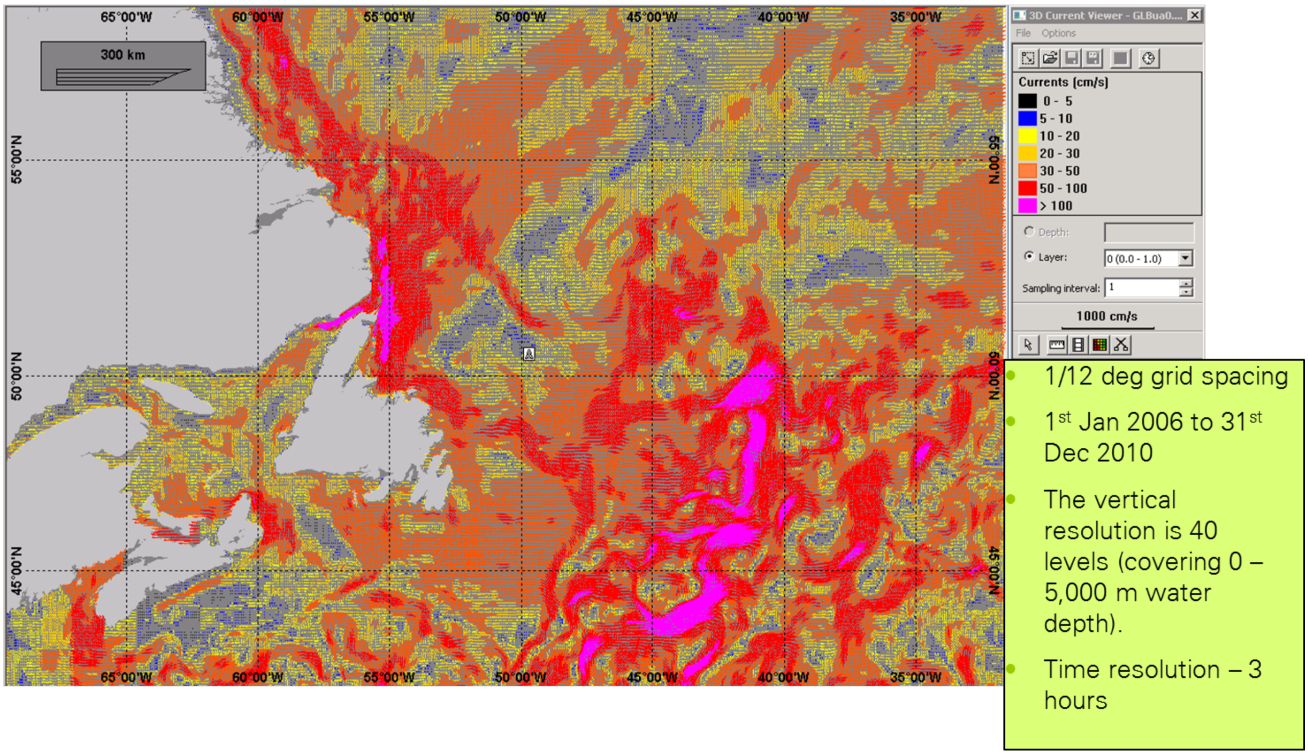


Figure 5.8 Snapshot map showing an example of the current field for the water depth range 950 - 1,125 m extracted from the 3-dimensional HYCOM generated dataset

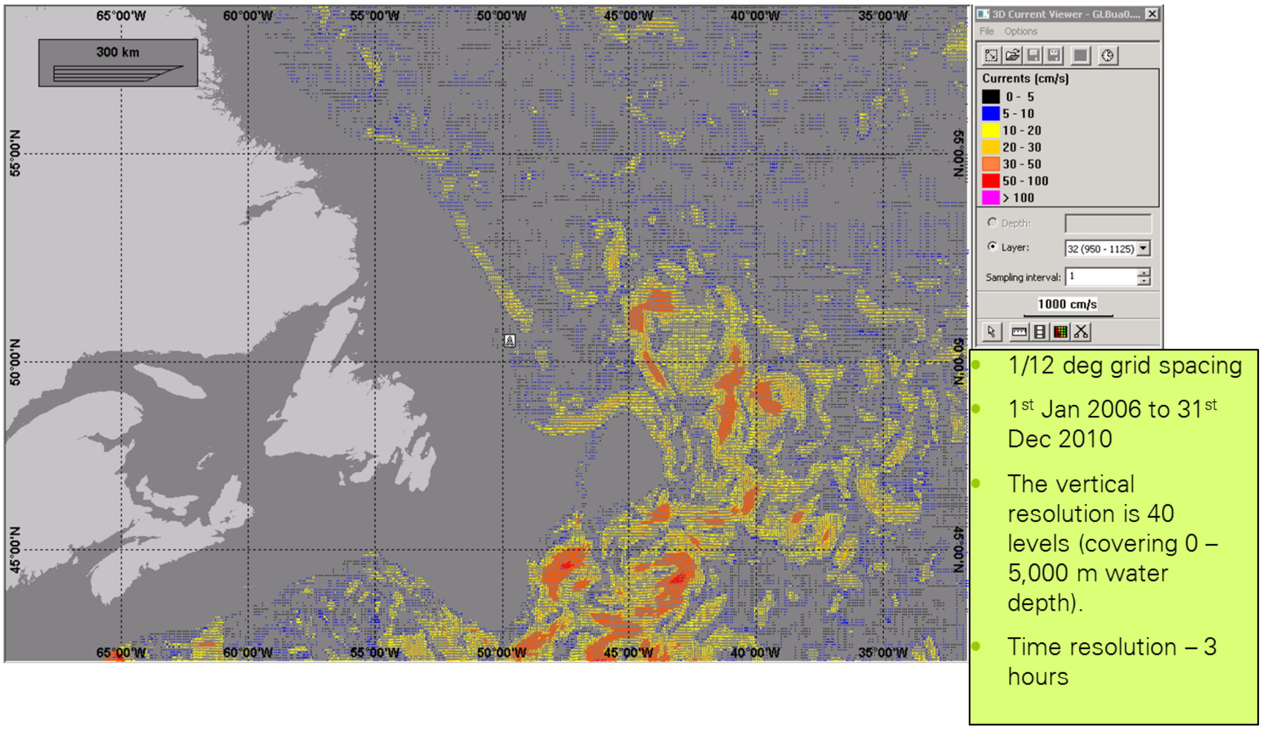
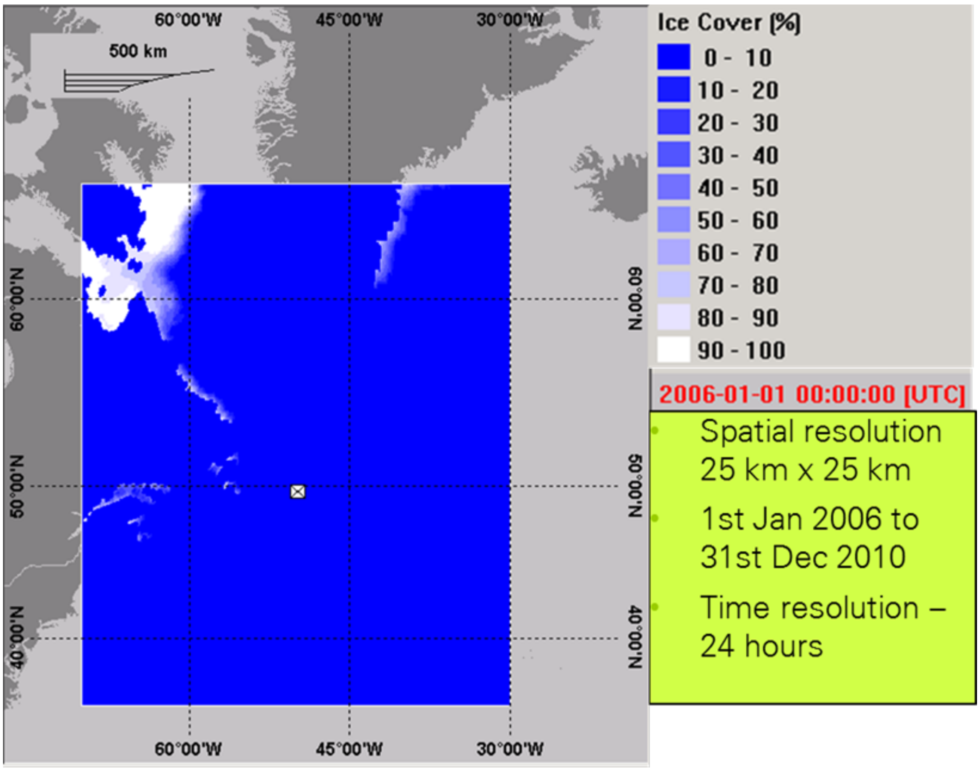


Figure 5.9 Snapshot map showing an example of the sea ice data extracted from the National Snow & Ice Data Center (NSIDC)



5.2.5 Predicted currents at the WOB and EOB wellsite locations

Currents assist the dispersion of drilling discharges in the water column by advection and mixing. Thus the thickness of drill cuttings deposited on the seabed is very much dependent on the metocean conditions that occur at the time of modelling. Periods of low (benign) current conditions can increase sediment thicknesses and the impact on benthic communities due to smothering, whereas during periods of high (energetic) currents, dispersion and dilution of drilling discharges will reduce sediment thicknesses and burial impacts.

Thus the 5-year hindcast HYCOM current dataset was analysed to find the most benign and energetic surface metocean conditions at each well location averaged over a 45 day period to cover the well duration and the associated start dates for these time periods were identified and used in the model simulations.

Figures 5.10 and 5.11 shows the time-series of 45 day period moving-average of daily-mean current velocities at 0 m BSL and - 50 m BSL at the WOB and EOB locations respectively. It should be noted that the highest and lowest current periods were derived from the averaged 45 day period moving-average daily-mean currents between 0 m and -100 m BSL.

For both wellsite locations, two scenarios were modelled: one assuming the lowest (45 day period moving-average) ambient surface currents and one assuming the highest ambient surface current conditions over the 5 year period (2006 to 2010).

These start dates and the associated current conditions used within the modelling are detailed in Tables 5.7 and 5.8

Figure 5.10 Time series of daily-mean current velocity 45 day period moving-average at 0 m BSL, -25 m, -50 m and -100 m BSL water depths for the WOB wellsite location between 1st Jan 2006 to 31st Dec 2010

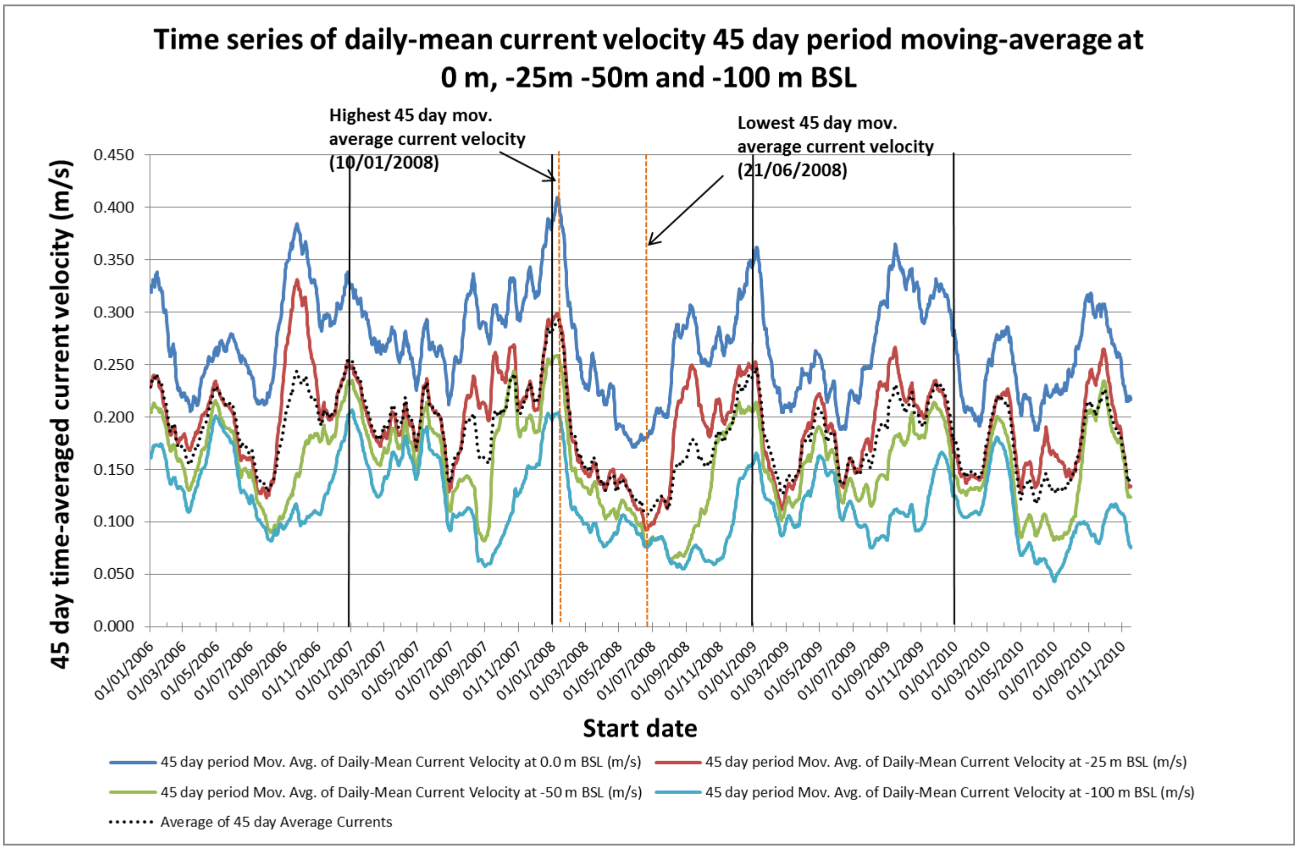


Table 5.7 Start date and current conditions for the periods of minimum (least dispersion) and maximum (most dispersion) mean daily currents averaged over a 45 day period at the WOB wellsite location between 1st Jan 2006 to 31st Dec 2010.

Start Date	Metocean Conditions	45 day time-averaged daily mean current velocity at: 0 m BSL (surface) (m/s)	45 day time-averaged daily mean current velocity -100 m BSL (m/s)	46 day time-averaged daily mean current velocity -1,300 m BSL (m/s)
21/06/2008	Lowest Current Velocities	0.180	0.076	0.058
10/01/2008	Highest Current Velocities	0.410	0.203	0.036

Figure 5.11 Time series of daily-mean current velocity 45 day period moving-average at 0 m BSL, -25 m, -50 m and -100 m BSL water depths for the WOB wellsite location between 1st Jan 2006 to 31st Dec 2010.

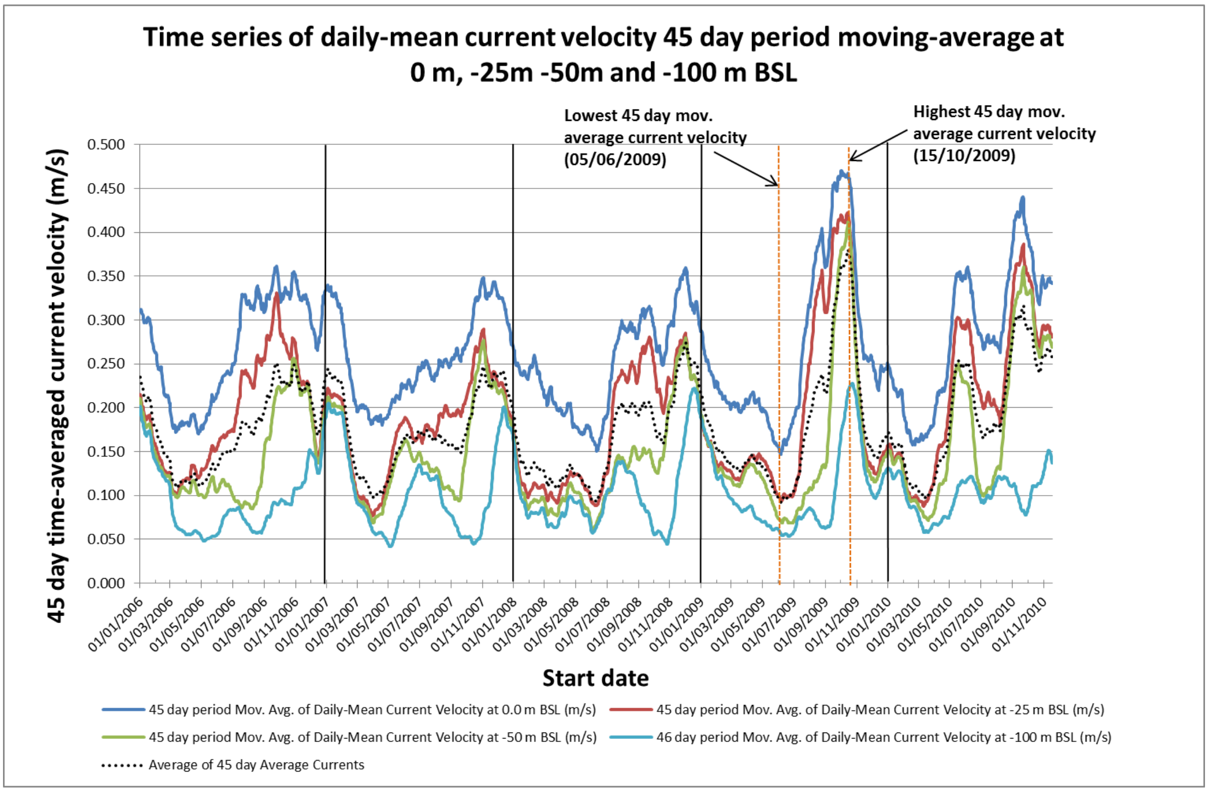


Table 5.8 Start date and current conditions for the periods of minimum (least dispersion) and maximum (most dispersion) mean daily currents averaged over a 45 day period at the EOB wellsite location between 1st Jan 2006 to 31st Dec 2010.

Start Date	Metocean Conditions	45 day time-averaged daily mean current velocity at: 0 m BSL (surface) (m/s)	45 day time-averaged daily mean current velocity -100 m BSL (m/s)	45 day time-averaged daily mean current velocity -2,700 m BSL (m/s)
05/06/2009	Lowest Current Velocities	0.147	0.057	0.093
15/10/2009	Highest Current Velocities	0.468	0.219	0.102

5.2.6 Habitat and Depths

The MEMW system refers to several internal depth data sources for building depth grids. (Sea Topo 8.0, IBCAO, beta version).

6 Results and Discussion

For each location, the results presented in this section represent a summary of drill solids material that settles on the seabed and associated thicknesses by distance from the well site origin together with plan-view maps of the cuttings deposition footprints.

DREAM tracks the trajectory and deposition of each solid component in the discharge and can display the output for each separately or as the combined total of all components

Cuttings from drilling the upper two well sections with WBM will all be released close to the seafloor. Therefore, there is little time for the cuttings to be transported large distances by the ambient currents. Conversely SBM cuttings, treated and released near the sea surface (15 m assumed, see Tables 5.3 and 5.4) will travel much greater distances before reaching the seabed.

In the results sections for each site, the predicted maximum distance from the wellsite and areal coverage of total drill solids (WBM and SBM), WBM and SBM cuttings deposited on the seafloor as a function of cuttings thickness are presented in a Tables. Statistics out to 3 km from the well site are reported from simulations that used a finer 5 m x 5 m horizontal grid cell resolution. Simulations that used a courser 50 m x 50 m were used to report statistics outside of 3 km.

6.1 Site 1 - West Orphan Basin wellsite scenarios

Figures 6.1 and 6.2 shows the predicted post-drilling seabed deposition footprint of drilling discharge particulate matter for the WOB well location scenario under low and high ambient surface current conditions

The predicted deposition footprint is predominantly towards the south. Although the mass balance outputs indicated that approximately 50% by weight of the mud and cuttings released was transported outside the boundaries of the modelling domain (13 km x 16 km), the quantity of material involved is extremely small compared with the water volume in which the material is dispersing. Thus, the resulting effect on oceanic suspended particulate matter concentrations is likely to be indistinguishable. Moreover, Figures 6.1 and 6.2 show that although some particles maybe deposited outside of the modelling domain, the resulting cuttings deposition thicknesses are insignificant (< 0.001 mm or <1 micron). The area within the 1 micron deposition thickness contour boundary (shown in yellow) defines the area where drill solids components might be detected through sediment chemical analysis to identify elevated levels of barium and other metals. Under low ambient surface current conditions, this area covers circa 3,470 hectares and extends 11.9 km from the wellsite at its furthest extent. Under high ambient surface current conditions the drill solids became more dispersed in the water column, hence the 1 micron thickness boundary was reduced to 2,149 hectares and extended 7.5 km away from the wellsite (see Figures 6.3 and 6.4).

Figure 6.1 Seabed deposition footprint of total drill solids at the WOB wellsite under the lowest ambient surface current conditions

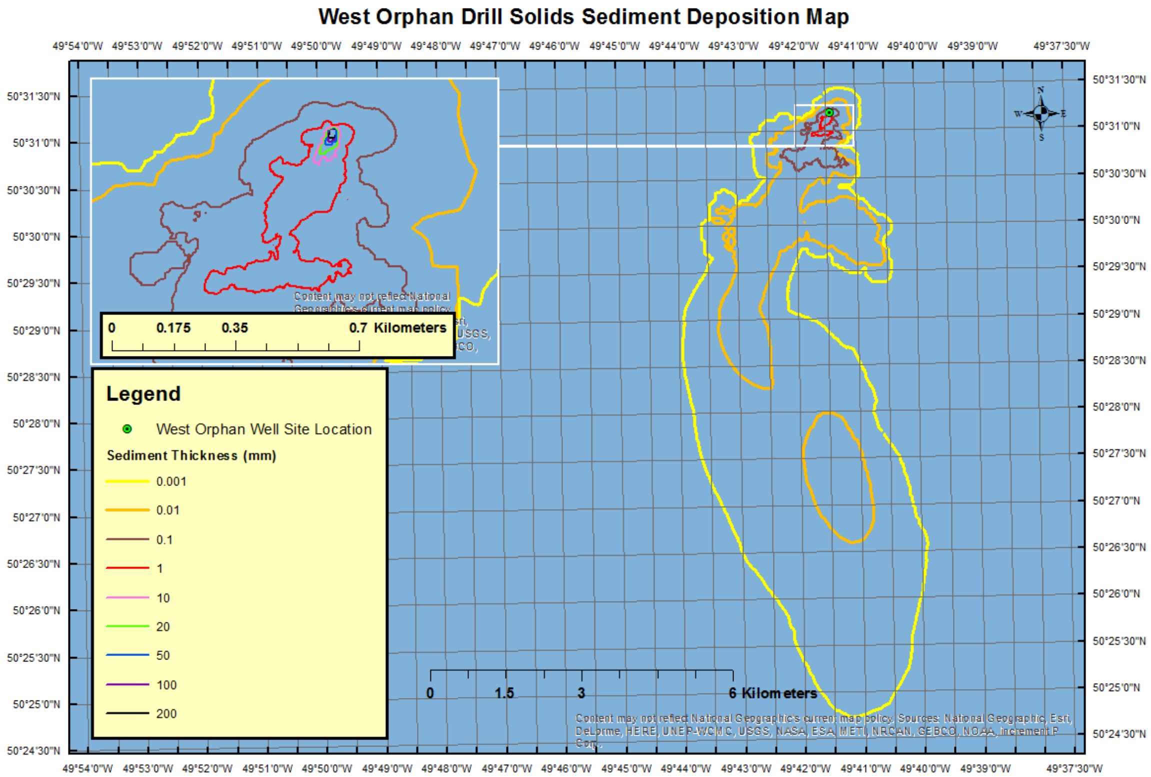


Figure 6.2 Seabed deposition footprint of total drill solids at the WOB wellsite under the highest ambient surface current conditions

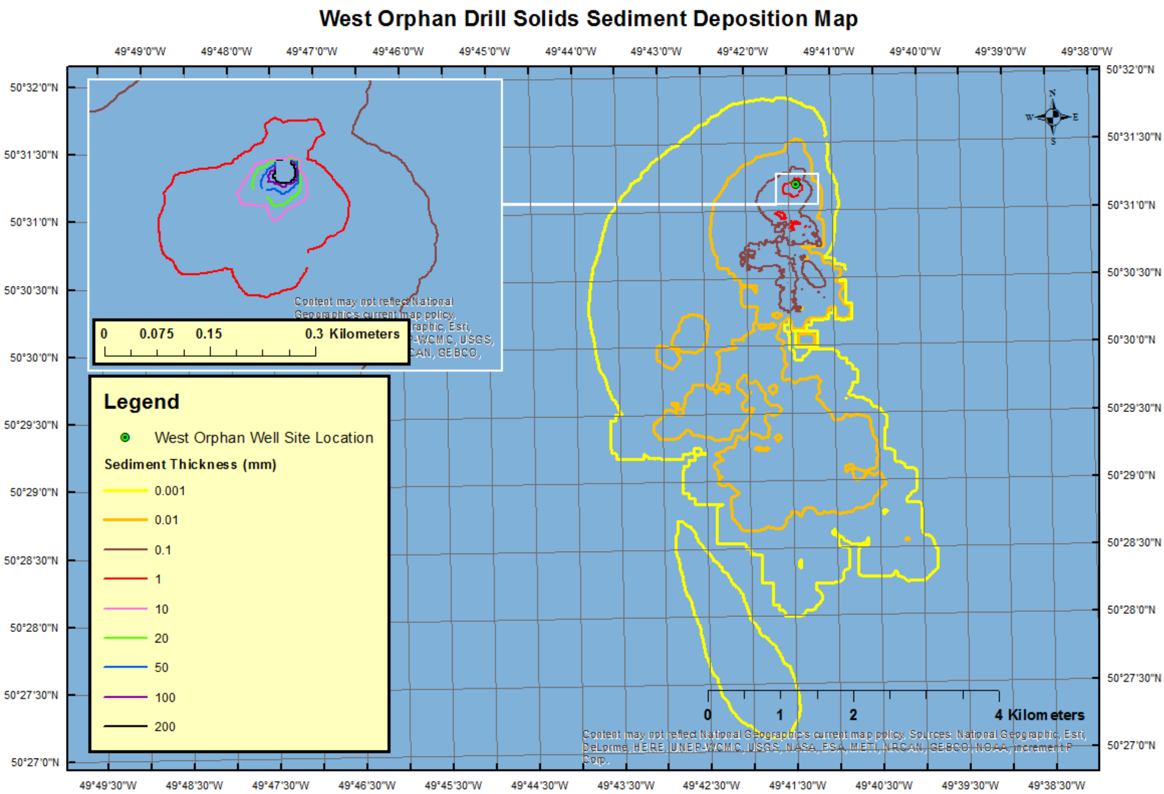


Table 6.1 WOB wellsite - Predicted areal extent of sedimentation from drilling discharges

Drill cuttings deposition thickness (mm)	Low Ambient Surface Currents			High Ambient Surface Currents		
	Cumulative Area Exceeding			Cumulative Area Exceeding		
	Hectares	Sq km	m^2	Hectares	Sq km	m^2
0.001	3,470	34.70	34,701,135	2,149	21.49	21,493,225
0.01	954	9.54	9,542,731	745	7.45	7,451,983
0.1	73	0.73	731,151	93	0.93	925,109
0.2	45	0.45	449,485	45	0.45	447,099
0.5	17	0.17	166,209	16	0.16	157,316
1	8.1	0.081	80,992	5.7	0.057	57,362
2	2.5	0.025	25,166	2.3	0.023	22,720
5	0.88	0.0088	8,842	0.98	0.0098	9,781
10	0.44	0.0044	4,447	0.56	0.0056	5,604
20	0.26	0.0026	2,616	0.29	0.0029	2,853
50	0.12	0.0012	1,151	0.12	0.0012	1,223
100	0.07	0.0007	706	0.06	0.0006	611
200	0.03	0.0003	340	0.05	0.0005	509
500	0.02	0.0002	157	0.02	0.0002	204

Table 6.2 WOB wellsite - Predicted drill cuttings deposition thickness versus maximum distance from wellsite

Drill cuttings deposition thickness (mm)	Low Ambient Surface Currents	High Ambient Surface Currents
	Maximum Extent from Discharge Point (m)	Maximum Extent from Discharge Point (m)
0.001	11,910	7,537
0.01	8,457	5,075
0.1	1,260	1,750
1	577	625
2.5	250	130
5	162	94
10	99	67
20	70	40
50	43	22
100	32	12
500	12	2

Figure 6.3

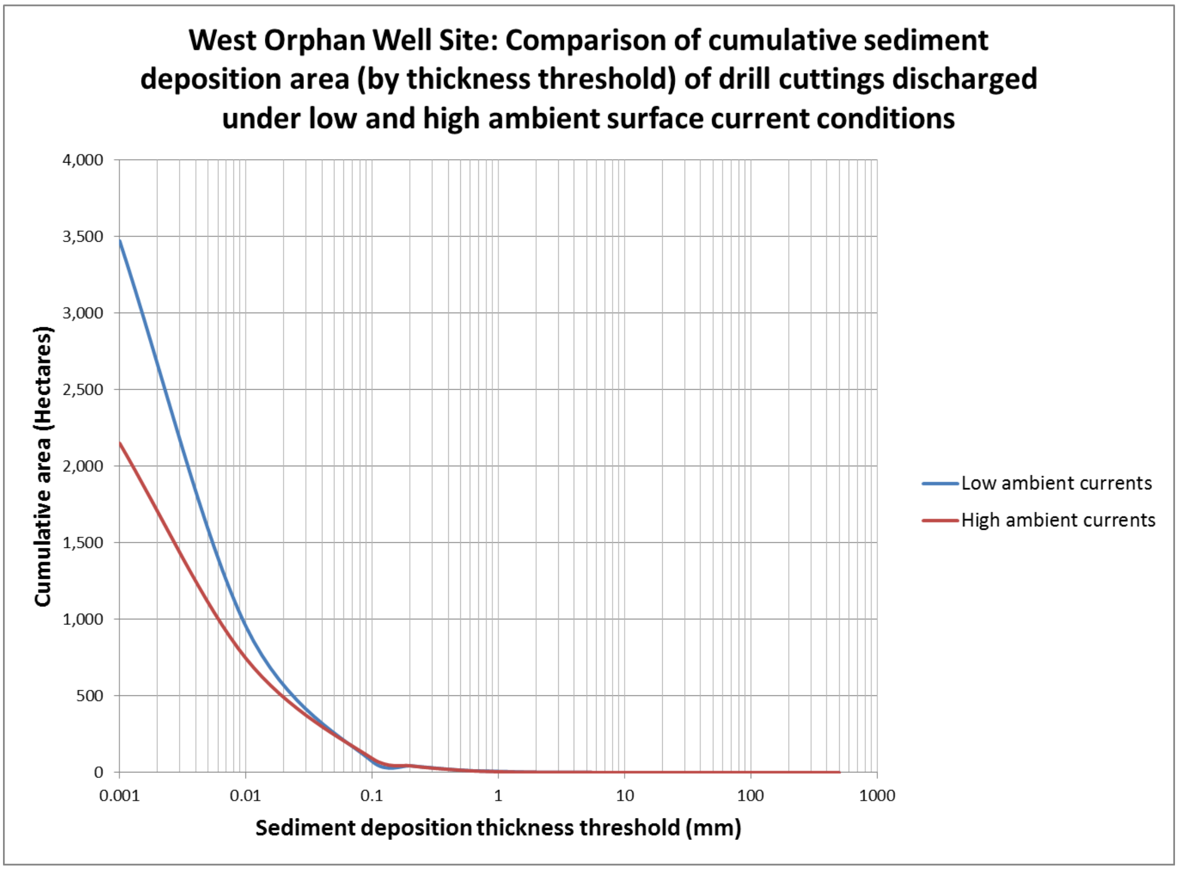
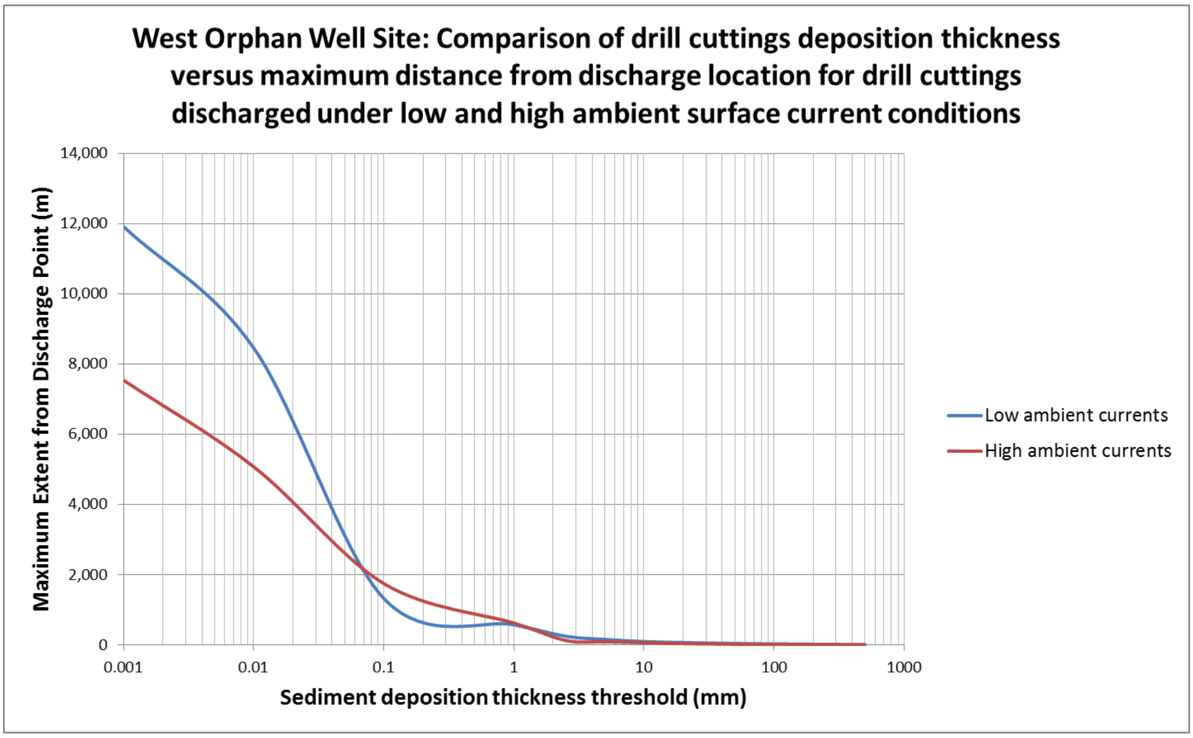


Figure 6.4



The predicted near-field deposition areas are shown in Figures 6.5 and 6.6 for the lowest and highest ambient surface current conditions respectively. Deposition thicknesses >1 mm ("red" area) define the areas where any drilling discharge solids deposited on the seafloor might be visible. The predicted areal coverages for cuttings thicknesses > 1 mm were 8.1 and 5.7 hectares for the lowest and highest ambient current scenarios and extended up to 577 m and 635 m away from the wellsite respectively.

Figure 6.5 Predicted nearfield seabed deposition footprint of total drill solids at the WOB wellsite under the lowest ambient surface current conditions (for cuttings thickness > 0.1 mm)

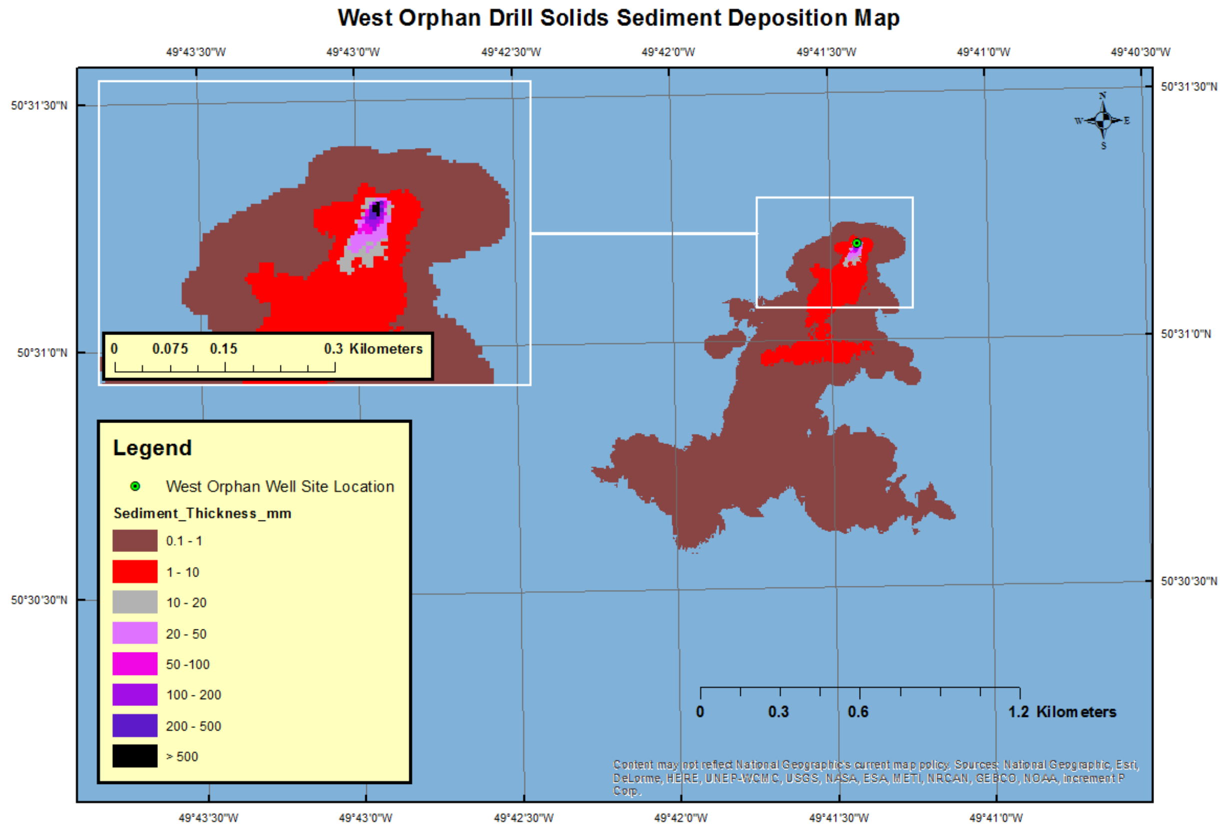
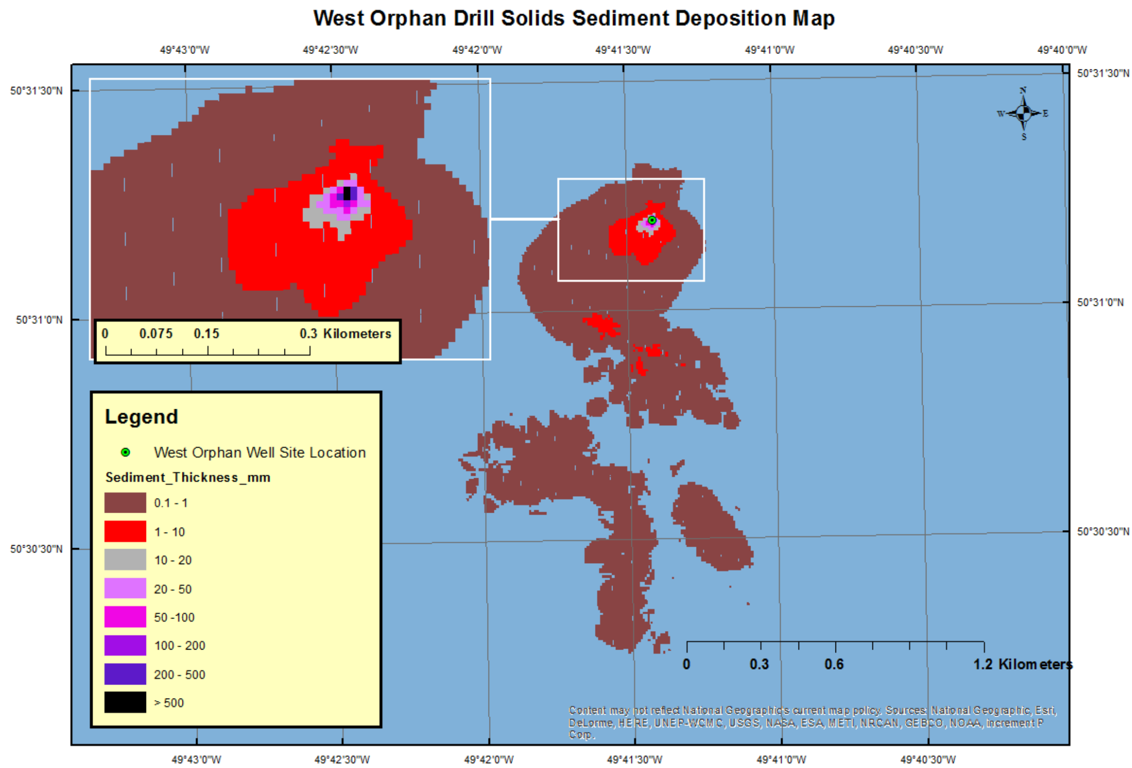


Figure 6.6 Predicted nearfield seabed deposition footprint of total drill solids at the WOB wellsite under the highest ambient surface current conditions (for cuttings thickness > 0.1 mm)



The sedimentation data can also be used to predict potential environmental effects on the benthic environment. Previous studies indicate that sedimentation and burial effects from drill muds and cuttings on benthic invertebrates have mainly been localized to the vicinity of a drill cuttings pile area (Neff et al 2000[17]; Holdway 2002[18]; Schaanning et al 2008[19]; Trannum et al 2010[20]; Larsson et al 2013[21]; Cordes et al 2016[22]; Tait et al 2016[23]). At deposition thicknesses of 6.5 mm or more which is considered to be the predicted no effect threshold (PNET) for non-toxic sedimentation, (Neff et al 2004[24]; Smit et al 2006[25]; 2008[26]), benthic communities comprised of sedentary or slow moving species, may be smothered and the sediment quality will be altered in terms of nutrient enrichment and oxygen depletion.

The modelling results predict that these sediment thicknesses could extend approximately 128 m from the discharge point, or cover an area of approximately 0.69 hectares under the lowest ambient surface current conditions. In contrast, under the highest ambient surface current conditions the impacted area increases to 0.85 hectares but the maximum predicted distance from the wellsite location for the threshold thickness is reduced to 85 m.

Figures 6.7 and 6.8 show the contribution to sediment footprint and thickness for each of the solid components released in the drilling discharges (drill cuttings from each hole section, bentonite and barite). As expected, the predicted deposition footprint of discharges from the two 'top hole' WBM riserless sections discharged directly onto the seabed is localised around the wellhead location, whereas material from subsequent SBM hole sections discharged at the sea surface were spread over a much larger area.

Figure 6.7 Contribution to seabed deposition footprint and thickness from solid components (drill cuttings, bentonite and barite) released in the drilling discharges at the WOB well site under the lowest ambient surface current conditions

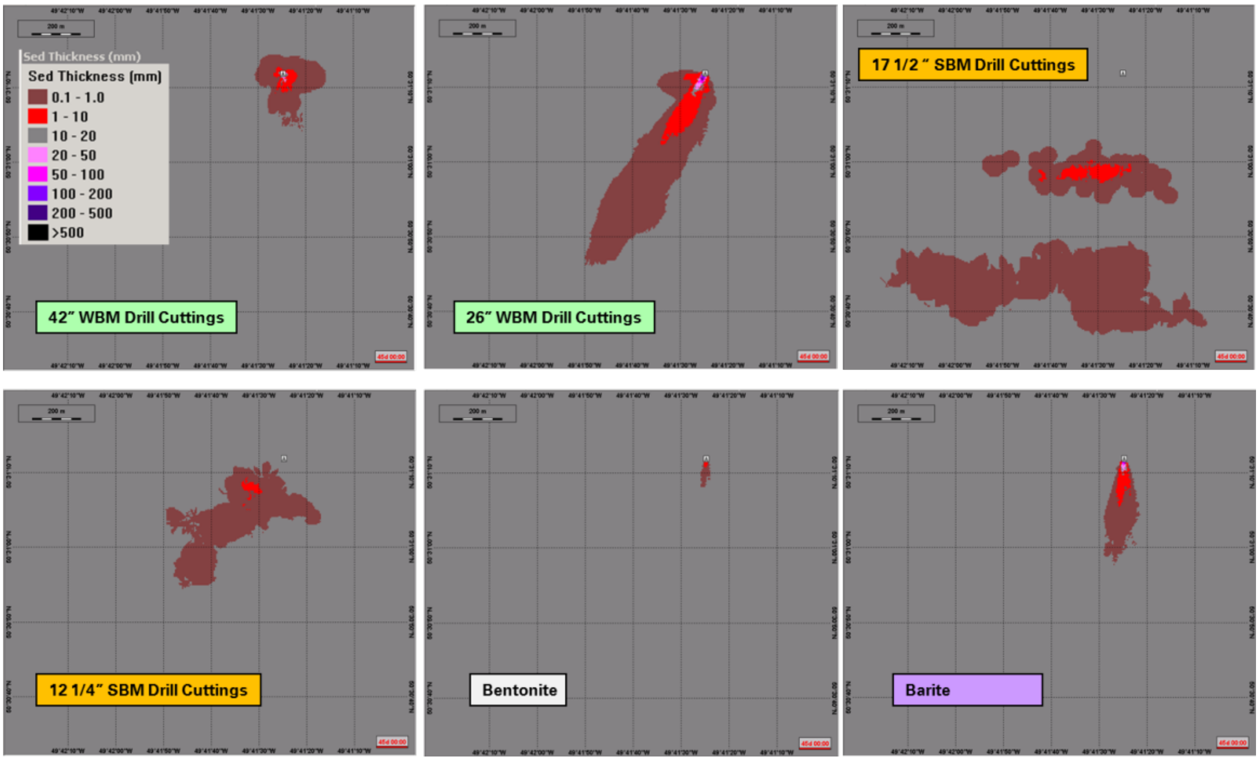


Figure 6.8 Contribution to seabed deposition footprint and thickness from solid components (drill cuttings, bentonite and barite) released in the drilling discharges at the WOB well site under the highest ambient surface current conditions

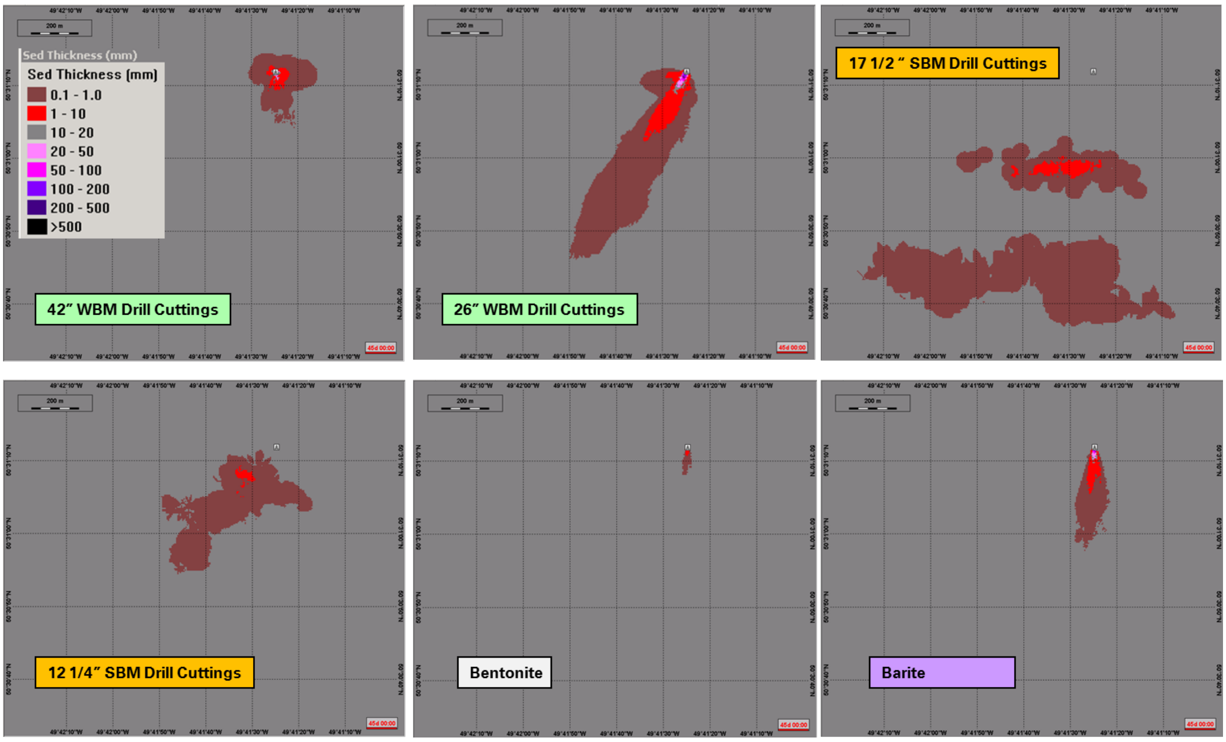


Table 6.4 shows that the closest distance to the wellsite that SBM cuttings are predicted to settle is 422 m under low ambient surface current conditions and 625 m under the highest ambient surface currents, whilst the largest WBM cuttings deposition thickness in any of the model grid cells is 1.782 m within 2 m of the seabed discharge location. In contrast the maximum SBM cuttings deposition thickness in any of the model grid cells is 2.1 mm

Table 6.3 WOB wellsite - Predicted areal extent of WBM and SBM cuttings sedimentation from drilling discharges

Drill cuttings deposition thickness (mm)	WBM		SBM	
	Low Ambient Surface Currents	High Ambient Surface Currents	Low Ambient Surface Currents	High Ambient Surface Currents
	Cumulative Area Exceeding Hectares		Cumulative Area Exceeding Hectares	
0.001	2,054.1544	960.0795	735.7973	1,204.1782
0.01	402.6060	185.5082	397.9947	569.4082
0.1	22.2810	31.2260	54.2788	54.6090
0.2	12.6616	15.3336	28.7703	19.6865
0.5	5.5302	6.1945	7.1942	6.3174
1	2.9639	3.1176	2.0196	0.9782
2	1.5408	1.6811	0.0157	0.0000
5	0.6854	0.7641	0.0000	0.0000
10	0.3479	0.3973	0.0000	0.0000
20	0.1988	0.2343	0.0000	0.0000
50	0.1073	0.0917	0.0000	0.0000
100	0.0549	0.0509	0.0000	0.0000
200	0.0340	0.0509	0.0000	0.0000
500	0.0131	0.0204	0.0000	0.0000

Table 6.4 WOB wellsite - Predicted WBM and SBM cuttings deposition thickness versus maximum distance from wellsite

Drill cuttings deposition thickness (mm)	WBM		SBM	
	Low Ambient Surface Currents	High Ambient Surface Currents	Low Ambient Surface Currents	High Ambient Surface Currents
	Maximum Extent from Discharge Point (m)		Maximum Extent from Discharge Point (m)	
0.001	9,952	3,762	3,636	5,815
0.01	5,485	1,564	3,215	5,074
0.1	928	607	1,314	1,749
1	340	184	571	625
2.5	196	126	422	0
5	156	94	0	0
10	99	63	0	0
20	70	40	0	0
50	43	22	0	0
100	28	8	0	0
500	7	2	0	0
Max Thickness (mm)	1,782	679	2.1	1.4

6.2 Site 2 - East Orphan Basin wellsite scenarios

Figures 6.9 and 6.10 shows the predicted post-drilling seabed deposition footprint of drilling discharge particulate matter for the EOB well location scenario under low and high ambient surface current conditions.

The predicted deposition footprint is predominantly towards the SSE. Under low ambient surface current conditions, the total drill solids deposition area within the 1 micron yellow contour boundary covers circa 3,642 hectares and extends 8.01 km from the wellsite at its furthest extent (Tables 6.5 and 6.6). Under high ambient surface current conditions the drill solids coverage for deposition thicknesses > 1 micron increased to 5,464 hectares and extended 9.17 km away from the wellsite.

Figure 6.9 Seabed deposition footprint of total drill solids at the EOB wellsite under the lowest ambient surface current conditions

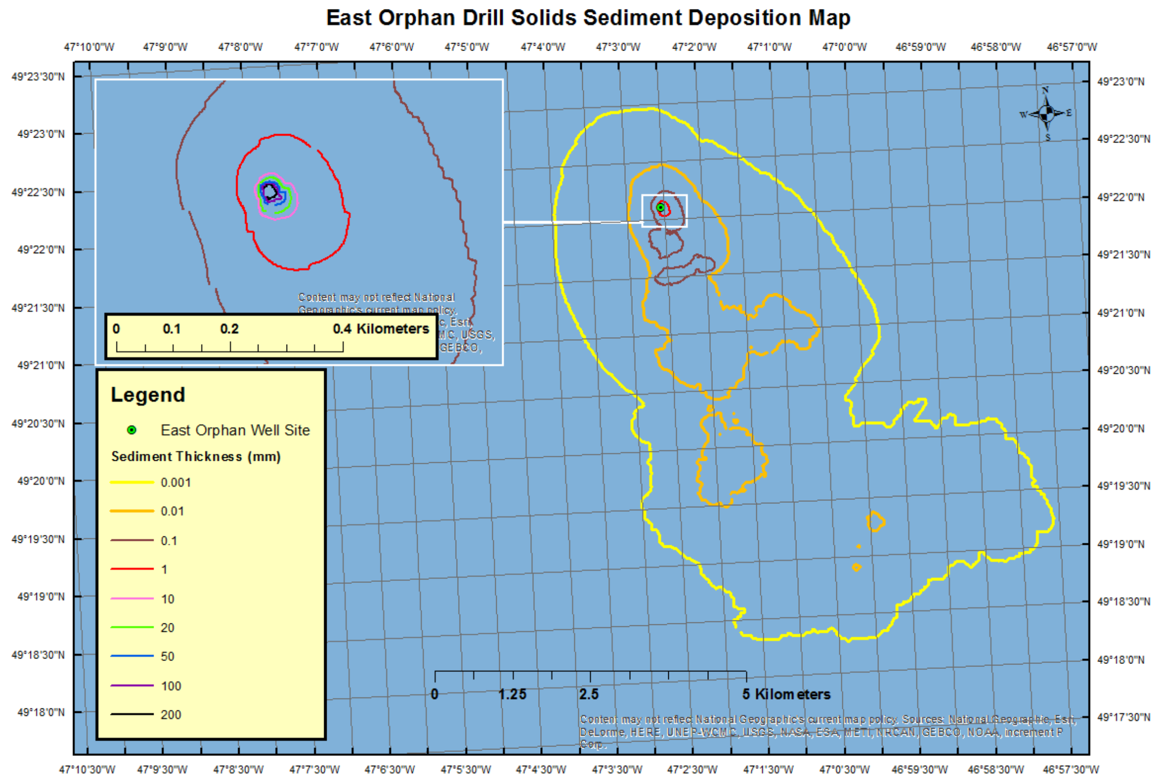


Figure 6.10 Seabed deposition footprint of total drill solids at the EOB wellsite under the highest ambient surface current conditions

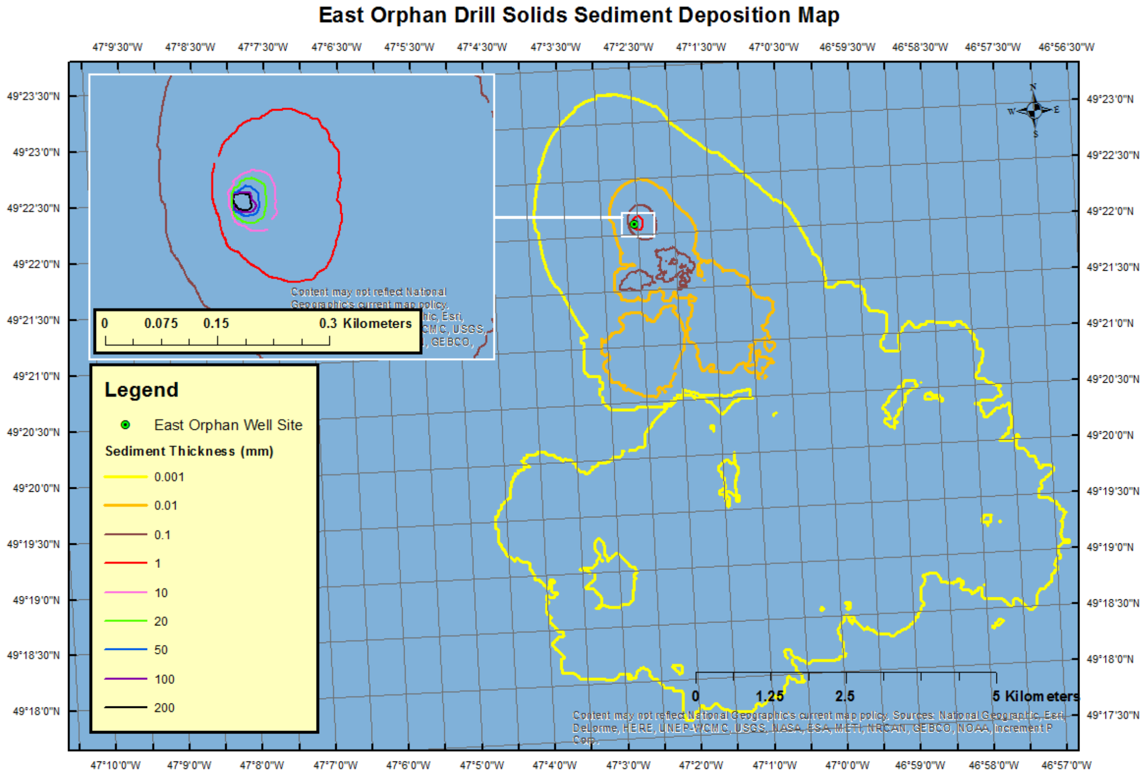


Table 6.5 EOB wellsite - Predicted areal extent of sedimentation from drilling discharges

Drill cuttings deposition thickness (mm)	Low Ambient Surface Currents			High Ambient Surface Currents		
	Cumulative Area Exceeding			Cumulative Area Exceeding		
	Hectares	Sq km	m^2	Hectares	Sq km	m^2
0.001	3,642	36.42	36,420,817	5,464	54.64	54,643,237
0.01	631	6.31	6,313,922	557	5.57	5,569,042
0.1	63	0.63	632,136	57	0.57	571,931
0.2	34	0.34	343,524	20	0.20	203,689
0.5	7	0.07	66,198	6	0.06	56,181
1	3.5	0.035	34,878	3.2	0.032	31,599
2	1.9	0.019	18,914	1.7	0.017	17,083
5	0.85	0.0085	8,542	0.76	0.0076	7,626
10	0.46	0.0046	4,576	0.41	0.0041	4,144
20	0.24	0.0024	2,440	0.22	0.0022	2,237
50	0.12	0.0012	1,220	0.11	0.0011	1,093
100	0.07	0.0007	706	0.05	0.0005	534
200	0.04	0.0004	407	0.04	0.0004	381
500	0.01	0.0001	102	0.02	0.0002	203

Table 6.6 EOB wellsite - Predicted drill cuttings deposition thickness versus maximum distance from wellsite

Drill cuttings deposition thickness (mm)	Low Ambient Surface Currents	High Ambient Surface Currents
	Maximum Extent from Discharge Point (m)	Maximum Extent from Discharge Point (m)
0.001	8,012	9,174
0.01	6,549	3,277
0.1	1,282	1,366
1	147	145
2.5	97	96
5	69	68
10	48	47
20	32	33
50	19	22
100	8	14
500	2	7

The predicted near-field deposition areas are shown in Figures 6.11 and 6.12 for the lowest and highest ambient surface current conditions respectively. Deposition thicknesses >1 mm ("red" area) define the areas where any drilling discharge solids deposited on the seafloor might be visible. The predicted areal coverages for cuttings depositional thicknesses > 1 mm were 3.5 and 3.2 hectares for the lowest and highest ambient current scenarios respectively and extended up to 147 m and 145 m away from the wellsite. These are significantly smaller areal coverages and distances than those predicted for the WOB well location and is attributable to the higher average seabed and surface current velocities at the EOB well location (compare Tables 5.7 and 5.8) as well as the increased water depth which all combine to increase the dispersion of discharged drill solids, thereby reducing drill solids deposition thicknesses in the 100 micron to 1 mm thickness size range (See Figures 6.13 and 6.14)

At deposition thicknesses of 6.5 mm or more which is considered to be the predicted no effect threshold (PNET) for non-toxic sedimentation, the modelling results predict that these sediment thicknesses could extend approximately 55 m from the discharge point, or cover an area of approximately 0.64 hectares under the lowest ambient surface current conditions. Under the highest ambient surface current conditions the impacted area was slightly less at 0.61 hectares with the maximum predicted distance from the wellsite location for the threshold thickness increased to 57 m.

Figure 6.11 Predicted nearfield seabed deposition footprint of total drill solids at the EOB wellsite under the lowest ambient surface current conditions (for cuttings thickness > 0.1 mm)

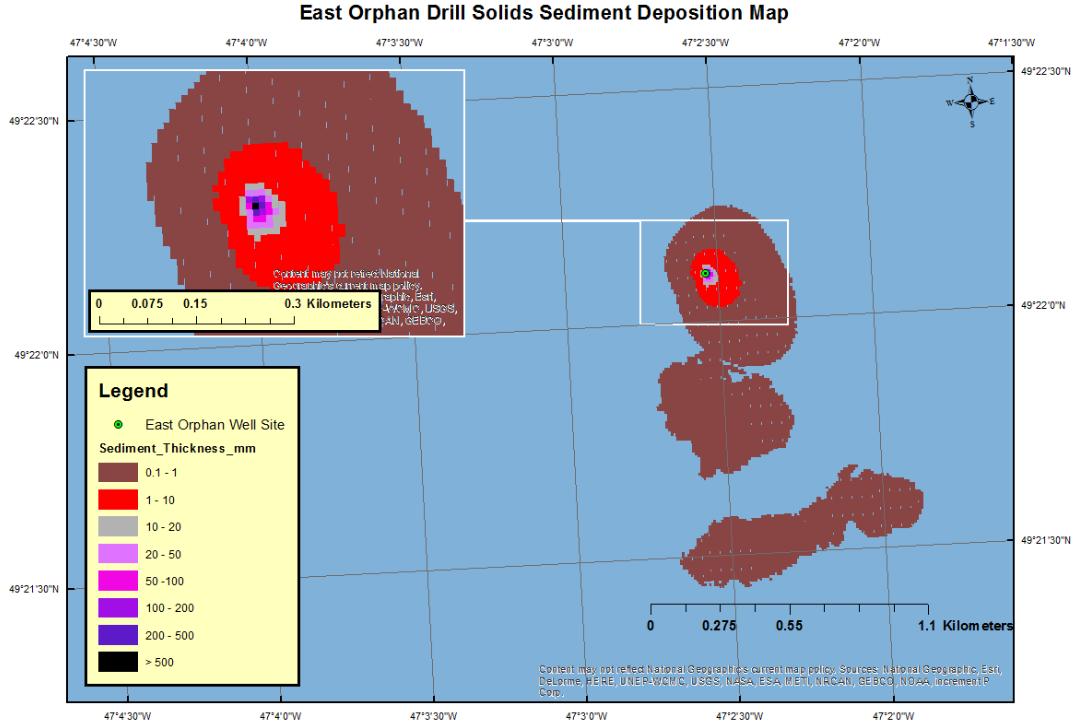


Figure 6.12 Predicted nearfield seabed deposition footprint of total drill solids at the EOB wellsite under the highest ambient surface current conditions (for cuttings thickness > 0.1 mm)

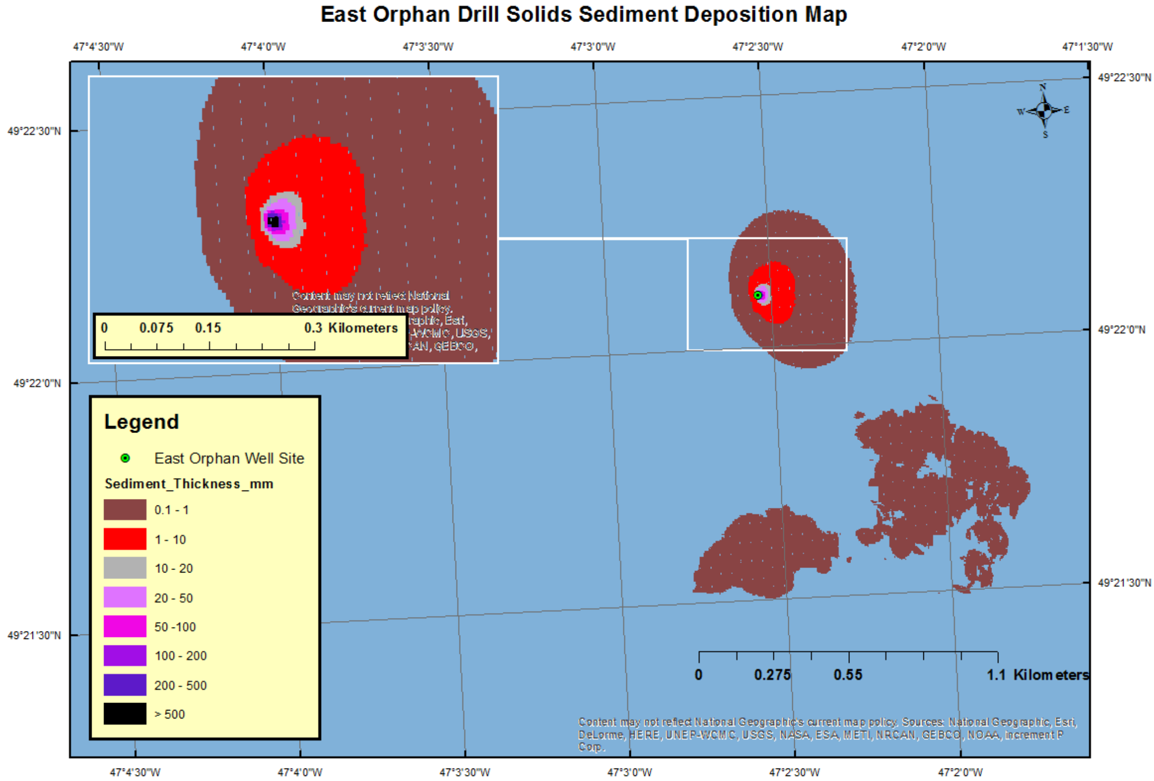


Figure 6.13

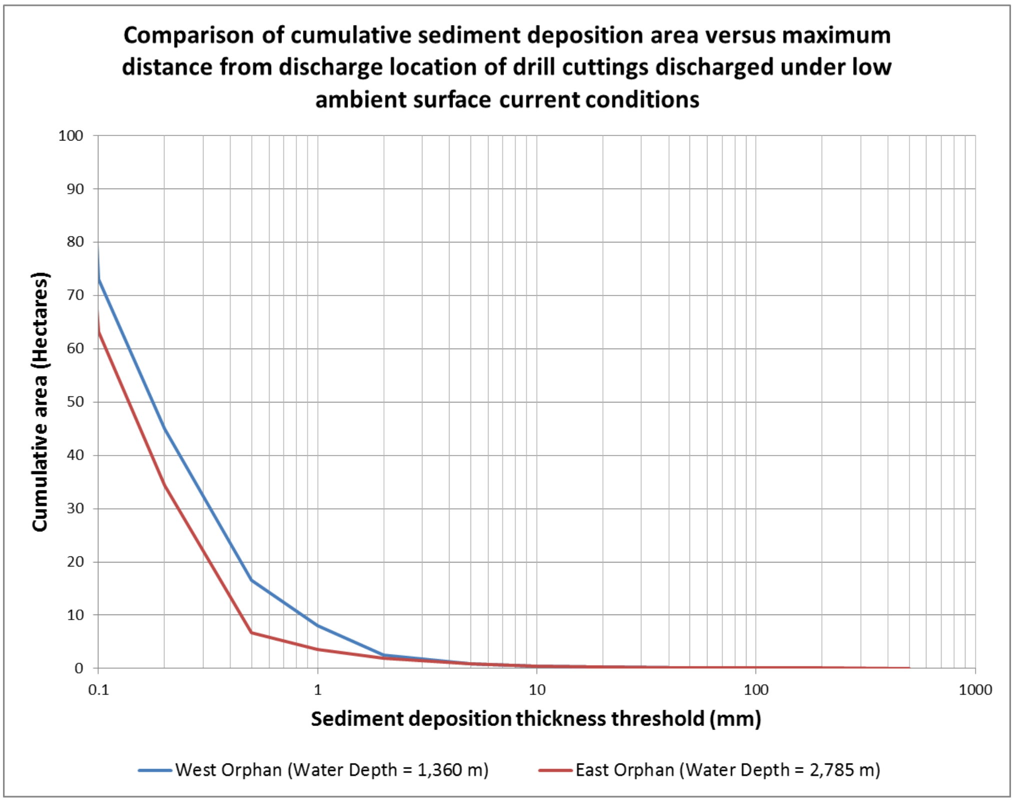
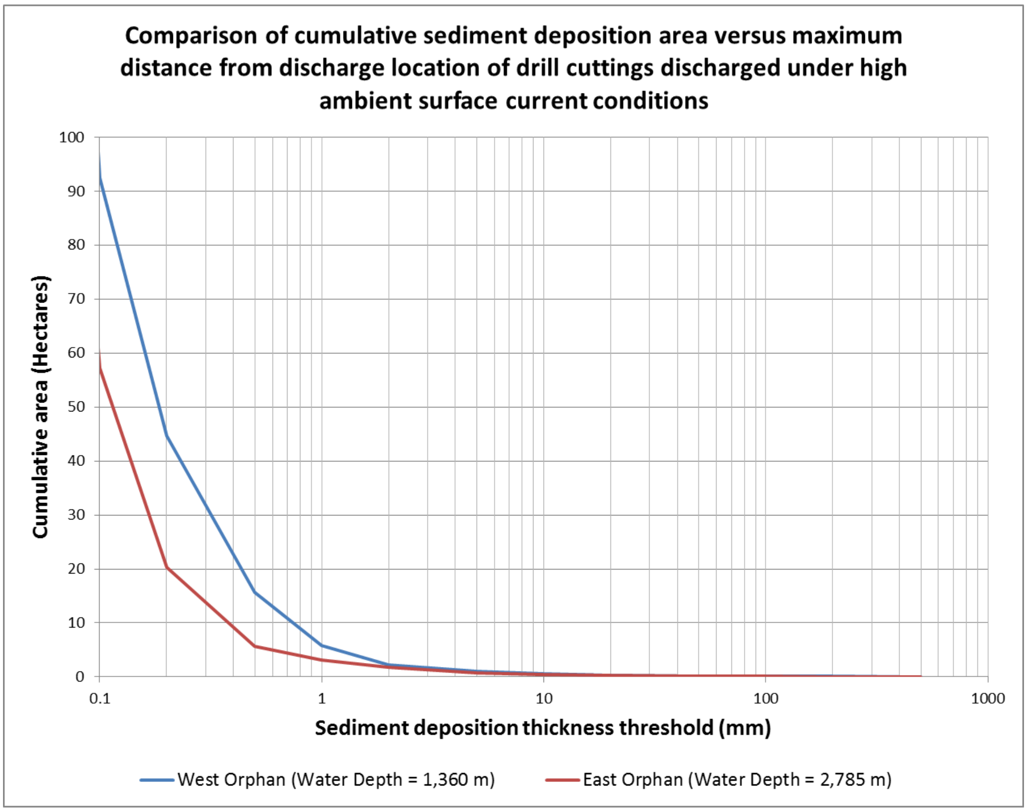


Figure 6.14



Figures 6.15 and 6.16 show the contribution to sediment footprint and thickness for each of the solid components released in the drilling discharges (drill cuttings from each hole section, bentonite and barite).

Figure 6.15 Contribution to seabed deposition footprint and thickness from solid components (drill cuttings, bentonite and barite) released in the drilling discharges at the EOB well site under the lowest ambient surface current conditions

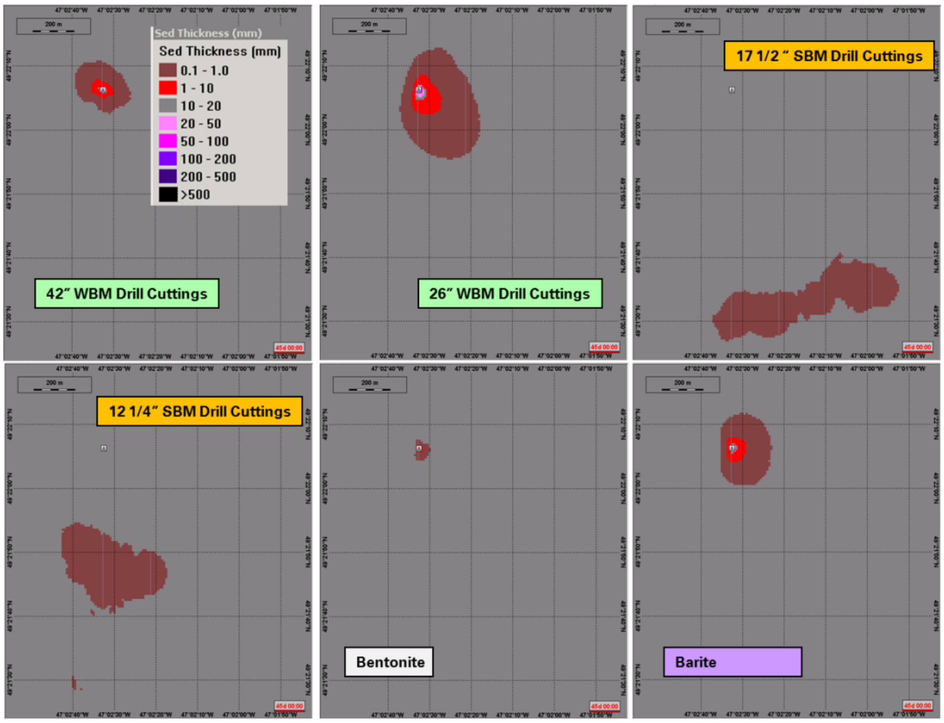
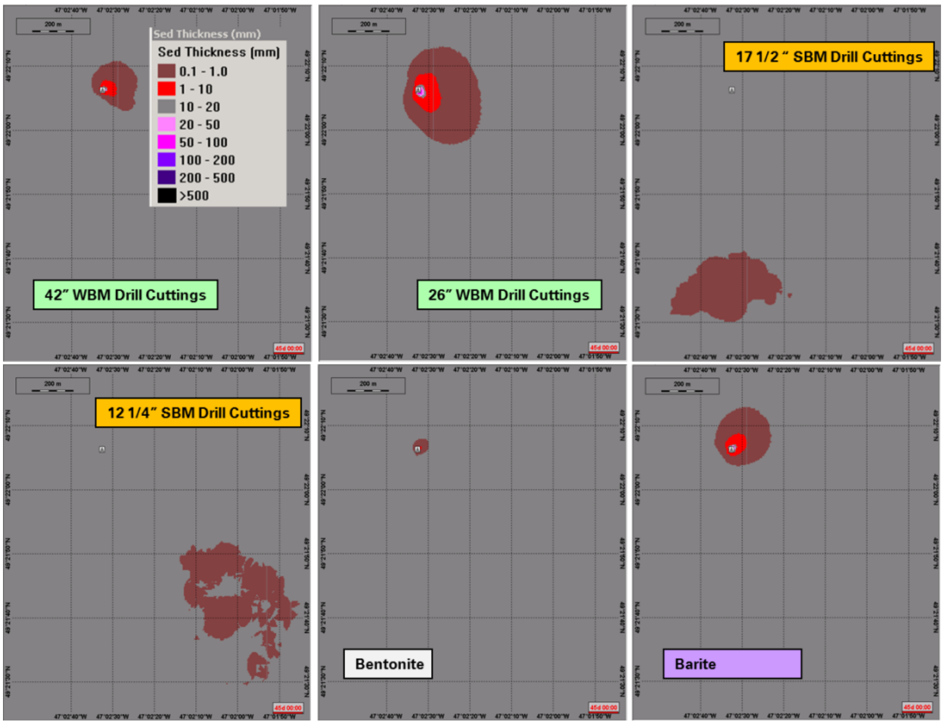


Figure 6.16 Contribution to seabed deposition footprint and thickness from solid components (drill cuttings, bentonite and barite) released in the drilling discharges at the EOB well site under the highest ambient surface current conditions



Once again as expected, the predicted deposition footprint of discharges from the two 'top hole' WBM riserless sections discharged directly onto the seabed is localised around the wellhead location, whereas material from subsequent SBM hole sections discharged at the sea surface were spread over a much larger area.

Table 6.8 shows that the closest distance to the wellsite that SBM cuttings are predicted to settle is 599 m under low ambient surface current conditions and 1,094 m under the highest ambient surface currents, whilst the largest WBM cuttings deposition thickness in any of the model grid cells is 1.240 m within 2 metres of the seabed discharge location. In contrast the maximum SBM cuttings deposition thickness in any of the model grid cells is 0.5 mm

Table 6.7 EOB wellsite - Predicted areal extent of WBM and SBM cuttings sedimentation from drilling discharges

Drill cuttings deposition thickness (mm)	WBM		SBM	
	Low Ambient Surface	High Ambient Surface	Low Ambient Surface	High Ambient Surface
	Cumulative Area Exceeding Hectares		Cumulative Area Exceeding Hectares	
0.001	1,389	1,237	2,114	3,823
0.01	155	127	402	377
0.1	19	17	33	34
0.2	11	9.5	18	8.5
0.5	5.0	4.4	0.04	0.00
1	2.7	2.4	0.00	0.00
2	1.4	1.3	0.00	0.00
5	0.62	0.58	0.00	0.00
10	0.34	0.31	0.00	0.00
20	0.19	0.16	0.00	0.00
50	0.08	0.08	0.00	0.00
100	0.05	0.05	0.00	0.00
200	0.03	0.03	0.00	0.00
500	0.01	0.02	0.00	0.00

Table 6.8 EOB wellsite - Predicted WBM and SBM cuttings deposition thickness versus maximum distance from wellsite

WBM drill cuttings deposition thickness (mm)	WBM		SBM drill cuttings deposition thickness (mm)	SBM	
	Low Ambient Surface Currents	High Ambient Surface Currents		Low Ambient Surface Currents	High Ambient Surface Currents
	Maximum Extent from Discharge Point (m)			Maximum Extent from Discharge Point (m)	
0.001	3,584	3,138	0.001	8,012	9,174
0.01	1,148	1,011	0.01	6,504	3,277
0.1	400	358	0.1	1,282	1,142
1	133	134	0.2	1,250	1,094
2.5	89	92	0.5	599	0
5	61	64	1	0	0
10	41	46	2	0	0
20	28	31	5	0	0
50	10	21	10	0	0
100	10	13	50	0	0
500	0	5	100	0	0
Max Thickness (mr	330	1,240		0.5	0.5

The results presented in Table 6.7 and 6.8 show that the SBM cuttings discharged at the sea surface from the EOB wellsite location are transported over a greater distance before settling compared to those discharged from the WOB wellsite, which is located in shallower water, thus resulting in a thinner layer of SBM cuttings spread over a larger area (see Tables 6.3 and 6.4)..

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Annex A - Breakdown of drilling discharge composition by hole section for the WOB exploration well

Table A 1 - Section 1

SECTION 1				
Drilling Fluid Formulation 42" Hole				
Bit Diameter (ins)	42.00	Section Length (m)		80
Wellbore Washout (Volume %)	25%	Drilling Rate (m/hr)		2.2
Mud Density	SG	[ppg]	Start of Discharge (time since previous discharge stopped, days)	0.00
Hi Vis Sweep	1.03	8.60		
PAD Displacement Mud	1.08	9.00		
Mud Type (WBM/OBM/SBM)	WBM			
Mud Description	Guar Gum HiVis Sweeps / PAD Displacement Mud (Riserless Drilling)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	Above sea-floor		Below sea surface	
	1		-	
Diameter of outlet opening (m)	-			
Orientation of outlet opening	Vertical, up			
Weight of Cuttings Discharged (MT)	196.99			
Hi Vis Sweep				
Volume of Mud Discharged (m^3)	111.28			
Weight of Mud Discharged (MT)	114.67			
PAD Displacement Mud				
Volume of Mud Discharged (m^3)	469.46			
Weight of Mud Discharged (MT)	506.31			
Composition	[kg/m3]	[ppb]	MT	Comments
Guar Gum Sweeps				
Polysaccharide (Viscosifier)	17.12	6.0	1.905	PLONOR
PAD Displacement Mud				
Bentonite (Viscosifier)	7.51	2.6	3.525	PLONOR
Barite (Weighting Agent)	79.88	28.0	37.503	PLONOR
Caustic Soda (pH control)	0.75	0.3	0.352	
Soda Ash (pH control)	0.75	0.3	0.352	
Non-fermenting starch (Filtration control)	2.25	0.8	1.057	
Polyanionic cellulose (Fluid Loss Control	2.25	0.8	1.057	
Xanthan Gum (Viscosifier)	0.75	0.3	0.352	
Sub Total			44.199	
Total Chemicals Discharged			46.104	

Table A 2 - Section 2

SECTION 2				
Drilling Fluid Formulation 26" Hole				
Bit Diameter (ins)	26.00	**Section Length (m)**		810
Wellbore Washout (Volume %)	25%	**Drilling Rate (m/hr)**		9.64
Mud Density	**SG**	**[ppg]**	**Start of Discharge (time since previous discharge stopped, days)**	1.00
Hi Vis Sweep	1.14	9.50		
PAD Displacement Mud	1.38	11.50		
Mud Type (WBM/OBM/SBM)	WBM			
Mud Description	Guar Gum HiVis Sweeps / PAD Displacement Mud (Riserless Drilling)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	**Above sea-floor**		**Below sea surface**	
	1		-	
Diameter of outlet opening (m)	-			
Orientation of outlet opening	Vertical, up			
Weight of Cuttings Discharged (MT)	764.60			
Hi Vis Sweep				
Volume of Mud Discharged (m^3)	1,126.67			
Weight of Mud Discharged (MT)	1,282.55			
PAD Displacement Mud				
Volume of Mud Discharged (m^3)	1,528.85			
Weight of Mud Discharged (MT)	2,106.87			
Composition	**[kg/m3]**	**[ppb]**	**MT**	**Comments**
Guar Gum Sweeps				
Polysaccharide (Viscosifier)	17.12	6.0	19.286	PLONOR
PAD Displacement Mud				
Bentonite (Viscosifier)	10.19	3.6	15.578	PLONOR
Barite (Weighting Agent)	473.60	166.0	724.064	PLONOR
Caustic Soda (pH control)	1.02	0.4	1.558	
Soda Ash (pH control)	1.02	0.4	1.558	
Non-fermenting starch (Filtration control)	3.06	1.1	4.673	
Polyanionic cellulose (Fluid Loss Control Agent)	3.06	1.1	4.673	
Xanthan Gum (Viscosifier)	1.02	0.4	1.558	
Sub Total			**753.663**	
Total Chemicals Discharged			**772.949**	

Table A 3 - Section 3

SECTION 3				
Drilling Fluid Formulation 17 1/2" Hole				
Bit Diameter (ins)	17.50	Section Length (m)		1,550
Wellbore Washout (Volume %)	15%	Drilling Rate (m/hr)		16.15
Mud Density	SG	[ppg]	Start of Discharge (time since previous discharge stopped, days)	1.00
	1.26	10.50		
Mud Type (WBM/OBM/SBM)	SBM			
Mud Description	Assume Average 75/25 o/w ratio (200,000 ppm WPS)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	Above sea-floor		Below sea surface	
	-		15	
Diameter of outlet opening (m)	0.50			
Orientation of outlet opening	Vertical , down			
Weight of Cuttings Discharged (MT)	707.83			
Volume Mud Discharged (M3)	156.05			
Weight Mud Discharged (MT)	196.35			
Composition	[kg/m3]	[ppb]	MT	Comments
Synthetic Base Oil (Base Fluid)	510.69	179.0	79.692	
Calcium Chloride (Brine Weighting Chemical)	73.12	25.6	11.411	
Lime (pH control)	7.77	2.7	1.212	
Acrylate co-polymer (Fluid loss control agent)	1.29	0.5	0.202	
Fatty acid derivative (Rheology modifier)	3.24	1.1	0.505	
Primary Emulsifier	23.30	8.2	3.636	
Organophylic Clay (Viscosifier)	5.18	1.8	0.808	
Organophylic Supreme Clay (Viscosifier)	2.59	0.9	0.404	
Polymeric Rheology Modifier	2.59	0.9	0.404	
Secondary Emulsifier (Wetting agent)	5.19	1.8	0.810	
Barite (Weighting Agent)	409.55	143.6	63.909	
Total Chemicals Discharged			162.994	

Table A 4 - Section 4

SECTION 4				
Drilling Fluid Formulation 12 1/4" Hole				
Bit Diameter (ins)	12.25	Section Length (m)		1,200
Wellbore Washout (Volume %)	15%	Drilling Rate (m/hr)		12.50
Mud Density	SG	[ppg]	Start of Discharge (time since previous discharge stopped, days)	2.00
	1.53	12.80		
Mud Type (WBM/OBM/SBM)	SBM			
Mud Description	Assume Average 75/25 o/w ratio (200,000 ppm WPS)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	Above sea-floor		Below sea surface	
	-		15	
Diameter of outlet opening (m)	0.50			
Orientation of outlet opening	Vertical , down			
Weight of Cuttings Discharged (MT)	268.11			
Volume Mud Discharged (M3)	59.47			
Weight Mud Discharged (MT)	91.21			
Composition	[kg/m3]	[ppb]	MT	Comments
Synthetic Base Oil (Base Fluid)	459.33	161.0	27.315	
Calcium Chloride (Brine Weighting Chemical)	64.48	22.6	3.834	
Lime (pH control)	7.48	2.6	0.445	
Acrylate co-polymer (Fluid loss control agent)	1.25	0.4	0.074	
Fatty acid derivative (Rheology modifier)	3.11	1.1	0.185	
Primary Emulsifier	22.43	7.9	1.334	
Organophylic Clay (Viscosifier)	4.98	1.7	0.296	
Organophylic Supreme Clay (Viscosifier)	2.49	0.9	0.148	
Polymeric Rheology Modifier	2.49	0.9	0.148	
Secondary Emulsifier (Wetting agent)	4.98	1.7	0.296	
Barite (Weighting Agent)	758.33	265.8	45.095	
Total Chemicals Discharged			79.172	

Annex B Breakdown of drilling discharge composition by hole section for the EOB exploration well

Table B 1 - Section 1

SECTION 1				
Drilling Fluid Formulation 42" Hole				
Bit Diameter (ins)	42.00	**Section Length (m)**		80
Wellbore Washout (Volume %)	25%	**Drilling Rate (m/hr)**		2.2
Mud Density	**SG**	**[ppg]**	**Start of Discharge (time since previous discharge stopped, days)**	0.00
Hi Vis Sweep	1.03	8.60		
PAD Displacement Mud	1.08	9.00		
Mud Type (WBM/OBM/SBM)	WBM			
Mud Description	Guar Gum HiVis Sweeps / PAD Displacement Mud (Riserless Drilling)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	**Above sea-floor**		**Below sea surface**	
	1		-	
Diameter of outlet opening (m)	-			
Orientation of outlet opening	Vertical, up			
Weight of Cuttings Discharged (MT)	196.99			
Hi Vis Sweep				
Volume of Mud Discharged (m^3)	111.28			
Weight of Mud Discharged (MT)	114.67			
PAD Displacement Mud				
Volume of Mud Discharged (m^3)	469.46			
Weight of Mud Discharged (MT)	506.31			
Composition	**[kg/m3]**	**[ppb]**	**MT**	**Comments**
Guar Gum Sweeps				
Polysaccharide (Viscosifier)	17.12	6.0	1.905	PLONOR
PAD Displacement Mud				
Bentonite (Viscosifier)	7.51	2.6	3.525	PLONOR
Barite (Weighting Agent)	79.88	28.0	37.503	PLONOR
Caustic Soda (pH control)	0.75	0.3	0.352	
Soda Ash (pH control)	0.75	0.3	0.352	
Non-fermenting starch (Filtration control)	2.25	0.8	1.057	
Polyanionic cellulose (Fluid Loss Control	2.25	0.8	1.057	
Xanthan Gum (Viscosifier)	0.75	0.3	0.352	
Sub Total			**44.199**	
Total Chemicals Discharged			**46.104**	

Table B 2 - Section 2

SECTION 2				
Drilling Fluid Formulation 26" Hole				
Bit Diameter (ins)	26.00	**Section Length (m)**		835
Wellbore Washout (Volume %)	25%	**Drilling Rate (m/hr)**		9.94
Mud Density	**SG**	**[ppg]**	**Start of Discharge (time since previous discharge stopped, days)**	1.00
Hi Vis Sweep	1.14	9.50		
PAD Displacement Mud	1.26	10.50		
Mud Type (WBM/OBM/SBM)	WBM			
Mud Description	Guar Gum HiVis Sweeps / PAD Displacement Mud (Riserless Drilling)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	**Above sea-floor**		**Below sea surface**	
	1		-	
Diameter of outlet opening (m)	-			
Orientation of outlet opening	Vertical, up			
Weight of Cuttings Discharged (MT)	788.20			
Hi Vis Sweep				
Volume of Mud Discharged (m^3)	1,161.44			
Weight of Mud Discharged (MT)	1,322.13			
PAD Displacement Mud				
Volume of Mud Discharged (m^3)	1,571.76			
Weight of Mud Discharged (MT)	1,977.65			
Composition	**[kg/m3]**	**[ppb]**	**MT**	**Comments**
Guar Gum Sweeps				
Polysaccharide (Viscosifier)	17.12	6.0	19.882	PLONOR
PAD Displacement Mud				
Bentonite (Viscosifier)	10.19	3.6	16.015	PLONOR
Barite (Weighting Agent)	313.83	110.0	493.267	PLONOR
Caustic Soda (pH control)	1.02	0.4	1.602	
Soda Ash (pH control)	1.02	0.4	1.602	
Non-fermenting starch (Filtration control)	3.06	1.1	4.805	
Polyanionic cellulose (Fluid Loss Control Agent)	3.06	1.1	4.805	
Xanthan Gum (Viscosifier)	1.02	0.4	1.602	
Sub Total			**523.696**	
Total Chemicals Discharged			**543.578**	

Table B 3 - Section 3

SECTION 3				
Drilling Fluid Formulation 17 1/2" Hole				
Bit Diameter (ins)	17.50	Section Length (m)		1,000
Wellbore Washout (Volume %)	15%	Drilling Rate (m/hr)		10.42
Mud Density	SG	[ppg]	Start of Discharge (time since previous discharge stopped, days)	1.00
	1.20	10.00		
Mud Type (WBM/OBM/SBM)	SBM			
Mud Description	Assume Average 75/25 o/w ratio (200,000 ppm WPS)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	Above sea-floor		Below sea surface	
	-		15	
Diameter of outlet opening (m)	0.50			
Orientation of outlet opening	Vertical , down			
Weight of Cuttings Discharged (MT)	456.67			
Volume Mud Discharged (M3)	100.68			
Weight Mud Discharged (MT)	120.64			
Composition	[kg/m3]	[ppb]	MT	Comments
Synthetic Base Oil (Base Fluid)	522.41	183.1	52.595	
Calcium Chloride (Brine Weighting Chemical)	73.12	25.6	7.362	
Lime (pH control)	7.77	2.7	0.782	
Acrylate co-polymer (Fluid loss control agent)	1.29	0.5	0.130	
Fatty acid derivative (Rheology modifier)	3.24	1.1	0.326	
Primary Emulsifier	23.30	8.2	2.346	
Organophylic Clay (Viscosifier)	5.18	1.8	0.521	
Organophylic Supreme Clay (Viscosifier)	2.59	0.9	0.261	
Polymeric Rheology Modifier	2.59	0.9	0.261	
Secondary Emulsifier (Wetting agent)	5.19	1.8	0.523	
Barite (Weighting Agent)	330.95	116.0	33.319	
Total Chemicals Discharged			98.425	

Table B 4 - Section 4

SECTION 4				
Drilling Fluid Formulation 12 1/4" Hole				
Bit Diameter (ins)	12.25	Section Length (m)		1,800
Wellbore Washout (Volume %)	15%	Drilling Rate (m/hr)		18.75
Mud Density	SG	[ppg]	Start of Discharge (time since previous discharge stopped, days)	2.00
	1.32	11.00		
Mud Type (WBM/OBM/SBM)	SBM			
Mud Description	Assume Average 75/25 o/w ratio (200,000 ppm WPS)			
Discharge temperature at release point (deg C)	18 deg C			
Discharge Depth (m)	Above sea-floor		Below sea surface	
	-		15	
Diameter of outlet opening (m)	0.50			
Orientation of outlet opening	Vertical , down			
Weight of Cuttings Discharged (MT)	402.17			
Volume Mud Discharged (M3)	89.20			
Weight Mud Discharged (MT)	117.57			
Composition	[kg/m3]	[ppb]	MT	Comments
Synthetic Base Oil (Base Fluid)	500.42	175.4	44.637	
Calcium Chloride (Brine Weighting Chemical)	70.04	24.6	6.248	
Lime (pH control)	7.48	2.6	0.667	
Acrylate co-polymer (Fluid loss control agent)	1.25	0.4	0.111	
Fatty acid derivative (Rheology modifier)	3.11	1.1	0.278	
Primary Emulsifier	22.43	7.9	2.001	
Organophylic Clay (Viscosifier)	4.98	1.7	0.445	
Organophylic Supreme Clay (Viscosifier)	2.49	0.9	0.222	
Polymeric Rheology Modifier	2.49	0.9	0.222	
Secondary Emulsifier (Wetting agent)	4.98	1.7	0.445	
Barite (Weighting Agent)	485.01	170.0	43.263	
Total Chemicals Discharged			98.538	