

Appendix K

Blacktip Oil Spill Risk Assessment
Modelling prepared by International Risk
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Blacktip Oil Spill Risk Assessment Modelling

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Abstract: This report presents the results from a modelling study undertaken on behalf of Woodside Energy Ltd to assess the fate and likely consequence of an oil spill from the proposed Blacktip facility. Tanker operations were identified as the highest risk contributor and four credible spill events were analysed: • small (8m³), medium (100m³) and large (500m³) spills of Blacktip condensate during offload to the trading tanker; and • a 500m³ heavy fuel oil spill from a ship fuel leak. The risk assessment made use of an oil spill weathering model and coupled hydrodynamic and oil spill trajectory models for the Joseph Bonaparte Gulf. Both deterministic and stochastic simulations were undertaken. The former were undertaken to demonstrate the oil trajectory and likely coastline impact for a single spill under “worst-case” ambient conditions. The latter were then undertaken to demonstrate the probability of exposure for the many different possible tide and wind combinations that could occur for both wet and dry seasons in the Joseph Bonaparte Gulf. Results show that oil would be transported predominantly onshore during the wet season and offshore during the dry season. As the tanker mooring is only 3km offshore there is a high probability of coastline contact during the wet season. This probability is reduced substantially in the dry season.			
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ABBREVIATIONS

ADCIRC	Advanced Circulation Model
ADIOS2	Automated Data Inquiry for Oil Spills
AGSO	Australian Geological Survey Office
BOM	Bureau of Meteorology
FE	Finite Element
IRCE	IRC Environment
NOAA	National Oceanic and Atmospheric Administration
NWS	North West Shelf
OPNML	Ocean Processes Numerical Modelling Laboratory
OSCP	Oil Spill Contingency Plan
WEL	Woodside Energy Limited

EXECUTIVE SUMMARY

This report presents the results from a modelling study undertaken on behalf of Woodside Energy Ltd to assess the fate and likely consequence of an oil spill from the proposed Blacktip facility. Tanker operations were identified as the highest risk contributor and four credible spill events were analysed:

- small (8m^3), medium (100m^3) and large (500m^3) spills of Blacktip condensate during offload to the trading tanker; and
- a 500m^3 heavy fuel oil spill from a ship fuel leak.

The risk assessment made use of an oil spill weathering model and coupled hydrodynamic and oil spill trajectory models for the Joseph Bonaparte Gulf. Both deterministic and stochastic simulations were undertaken. The former were undertaken to demonstrate the oil trajectory and likely coastline impact for a single spill under “worst-case” ambient conditions. The latter were then undertaken to demonstrate the probability of exposure for the many different possible tide and wind combinations that could occur for both wet and dry seasons in the Joseph Bonaparte Gulf.

Results show that oil would be transported predominantly onshore during the wet season and offshore during the dry season. As the tanker mooring is only 3km offshore there is a high probability of coastline contact during the wet season. This probability is reduced substantially in the dry season.

Blacktip condensate is expected to be highly volatile and the majority will evaporate within a few days or less should a spill occur. Adverse effects are likely to be related to the toxicity of the condensate and marine organisms in the water column coming into direct contact with a fresh spill. Toxicity of spilled condensate should reduce with time as the oil dilutes into the receiving waters and as the aromatic components volatilise. Sensitive areas such as tidal inlets and mangrove colonies should be boomed off in the event of a spill. Depending on the size of the spill, shoreline cleanup may not be necessary as beached condensate will continue to evaporate once stranded and will be washed away naturally by tide and waves. Any residual will eventually be removed by biodegradation and photo-oxidation processes.

Heavy fuel oil is much thicker than condensate and adverse effects resulting from a spill are more likely to be related to coating of wildlife dwelling on the water surface, smothering of intertidal organisms, and long-term sediment contamination. Heavy fuel oil is not expected to be as acutely toxic to water column organisms as lighter oils. Natural degradation rates for these heavy oils are very slow and, if left unattended, may persist on beaches for months to years. Recovery of oil from sea and on the shoreline is generally very effective if tackled early enough.

1 INTRODUCTION

1.1 Background

Woodside Energy Ltd (WEL) is planning to develop the Blacktip Gas Field in the Joseph Bonaparte Gulf. As part of WEL's responsibility for assessing the environmental risk of their operations, IRC Environment (IRCE) was commissioned to undertake quantitative oil spill risk assessment modelling for the project. The results from this work will form part of WEL's Environment Impact Statement and aid in the development of an effective Oil Spill Contingency Plan (OSCP) should the development go ahead.

1.2 Objective

The objective of the study is to analyse oil spill trajectories from accident events that could possibly occur during the lifetime of the Blacktip facility.

1.3 Scope

The scope of work included:

- a review of the oil properties;
- an assessment of oil weathering; and
- oil spill trajectory modelling, taking into account seasonal tide and wind conditions for the Joseph Bonaparte Gulf.

2 THE BLACKTIP PROJECT AND SPILL EVENTS

2.1 Brief Description of the Development

The Blacktip development will consist of an unmanned wellhead platform tied back to an onshore gas treatment station by a 100km subsea pipeline (Figure 2.1 and Figure 2.2). Landfall for the pipeline will be on the beach, 10km to the west of Wadeye.

Once ashore, well fluids will be separated. The gas will be exported to Gove (Nhulunbuy) for power generation at Alcan's alumina processing plant and the condensate will be stored for periodic export to an oil tanker.

2.2 Hydrocarbon Inventories

The main liquid hydrocarbon inventories associated with the Blacktip development will be:

- Blacktip condensate being produced from the reservoir, exported to the onshore gas plant for separation and storage and then offloaded to trading tanker;
- heavy fuel oil stored on the trading tanker; and
- diesel stored on support vessels and the drill rig.

Blacktip has a low oil-to-gas ratio so only a small percentage of condensate will be mixed in the reservoir fluids. Once separated from the water and gas at the onshore process plant the condensate will be stored until it is ready for offload to a trading tanker. The offloading process to the tanker and storage provides the greatest opportunity for an oil spill of any consequence to occur. As the volume of condensate produced by the project is low, only three or four tankers are expected per year.

2.3 Oil Spill Scenarios

Four credible spill events were identified for analysis:

- small (8m³), medium (100m³) and large (500m³) spills of Blacktip condensate during offload to the trading tanker; and
- a 500m³ heavy fuel oil spill from a ship fuel leak.

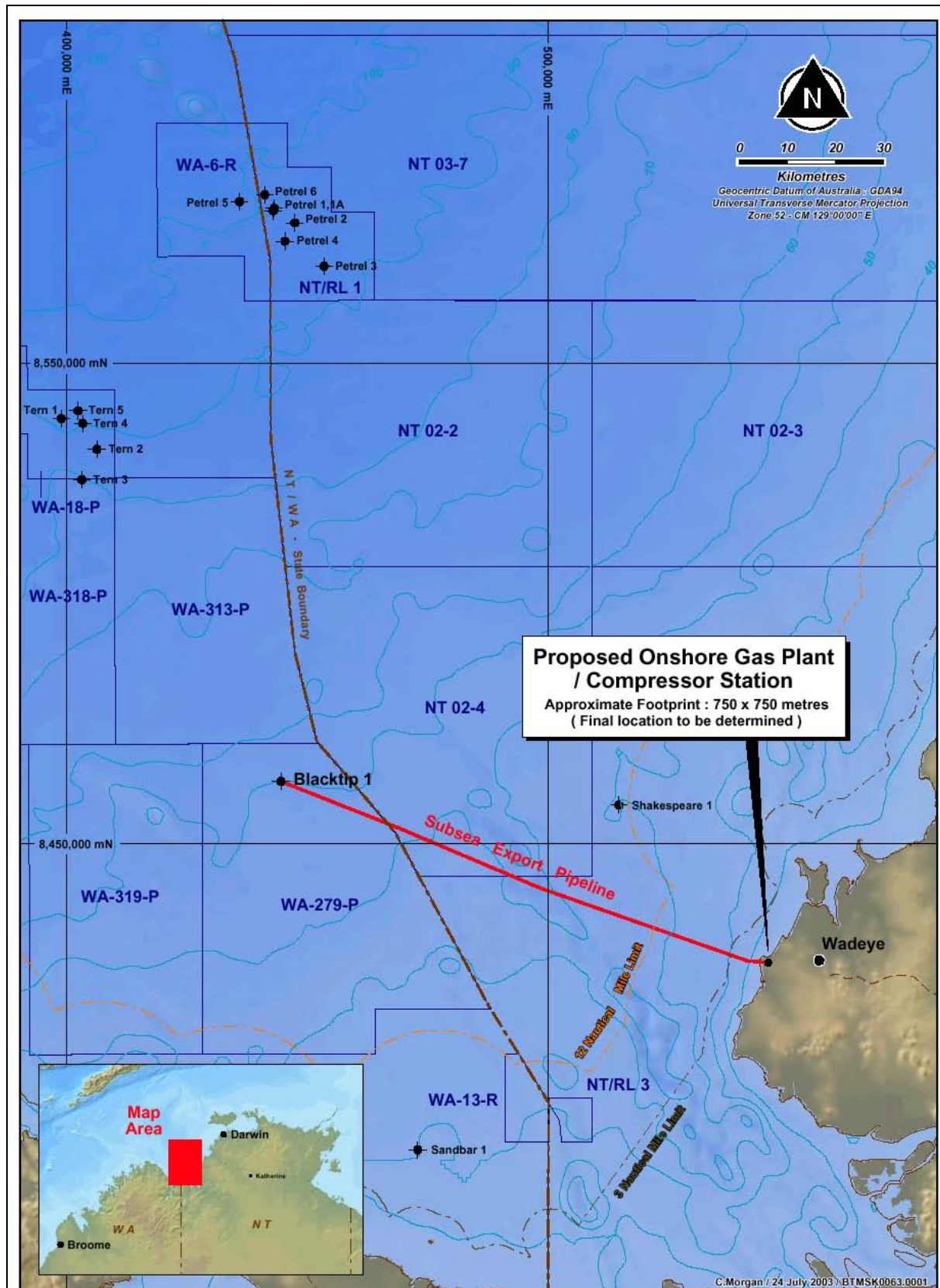
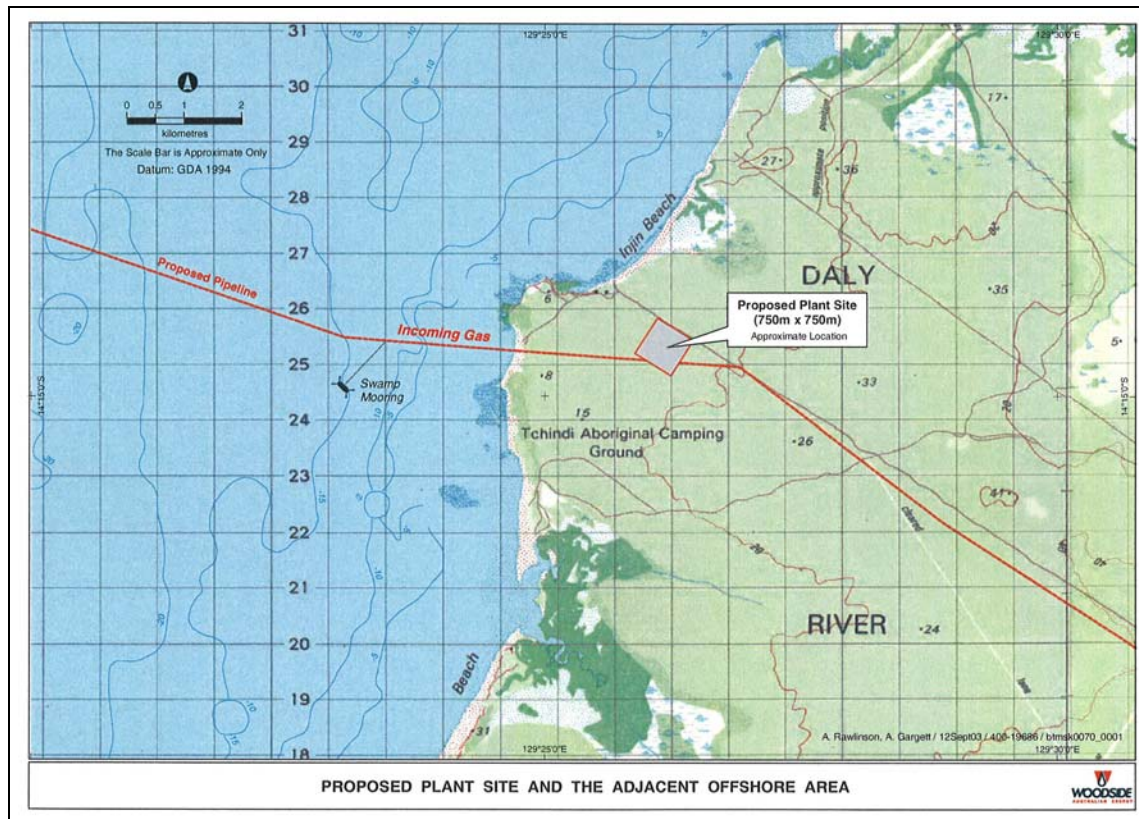
Figure 2.1 Location of the Blacktip Gas Field and associated infrastructure (from WEL)

Figure 2.2 Shoreline crossing and proposed plant site (from WEL)

3 METHODS

3.1 General

The oil spill trajectory model is made up of three modules:

- a hydrodynamic module that provides the necessary velocity fields for the oil spill trajectory model;
- an oil spill weathering module that predicts the behaviour of the oil in the receiving environment; and
- an oil spill trajectory module that simulates the fate of the oil.

These modules are described in more detail in the following subsections.

3.2 Hydrodynamic Model

3.2.1 Overview

The hydrodynamics applied in the present study were computed using the ADvanced CIRCulation model (ADCIRC). This model is a system of computer programs for solving time dependent, free surface circulation and transport problems in two and three dimensions (Westerink *et al.*, 1994). The algorithms that comprise ADCIRC utilise the finite element (FE) method in space and the model can be applied to computational domains encompassing the deep ocean, continental shelves, coastal seas and small scale estuarine systems.

3.2.2 Model Details

Figure 3.1 shows the hydrodynamic model grid for the Joseph Bonaparte Gulf. Elevations and currents were computed at 11,621 points (nodes) in the model domain. Using the significant flexibility provided by the FE method, grid resolution was increased considerably towards the coast and in particular towards the landfall for the Blacktip pipeline (Figure 3.2). The fine grid spacing is necessary to resolve the complex nearshore geometry of the coastline.

Node resolution varies from approximately 50km offshore to 50m inshore. Model bathymetry is shown in Figure 3.3. This was interpolated from the Australian Geological Survey Office (AGSO) database and, closer inshore, digitised from Admiralty Charts for the area. The model was forced from the open boundary by tidal elevations calculated from the M2, S2, N2, O1 and K1 tidal constituents. Amplitudes and phases for these were derived from the FES-95.2 global ocean model (Le Provost *et al.*, 1998).

The model was validated against tidal stations around the coastline. Example vector fields in the vicinity of the pipeline shore crossing on a spring tide at mid ebb and flood are shown in Figure 3.4 (a) and (b), respectively. Generally, tides ebb in a northerly direction and flood

towards the south. Further inshore circulation is influenced by the coastal topography with a clockwise gyre forming in the bay on the ebb tide and an anticlockwise gyre forming on the flood tide.

Figure 3.1 Hydrodynamic model grid

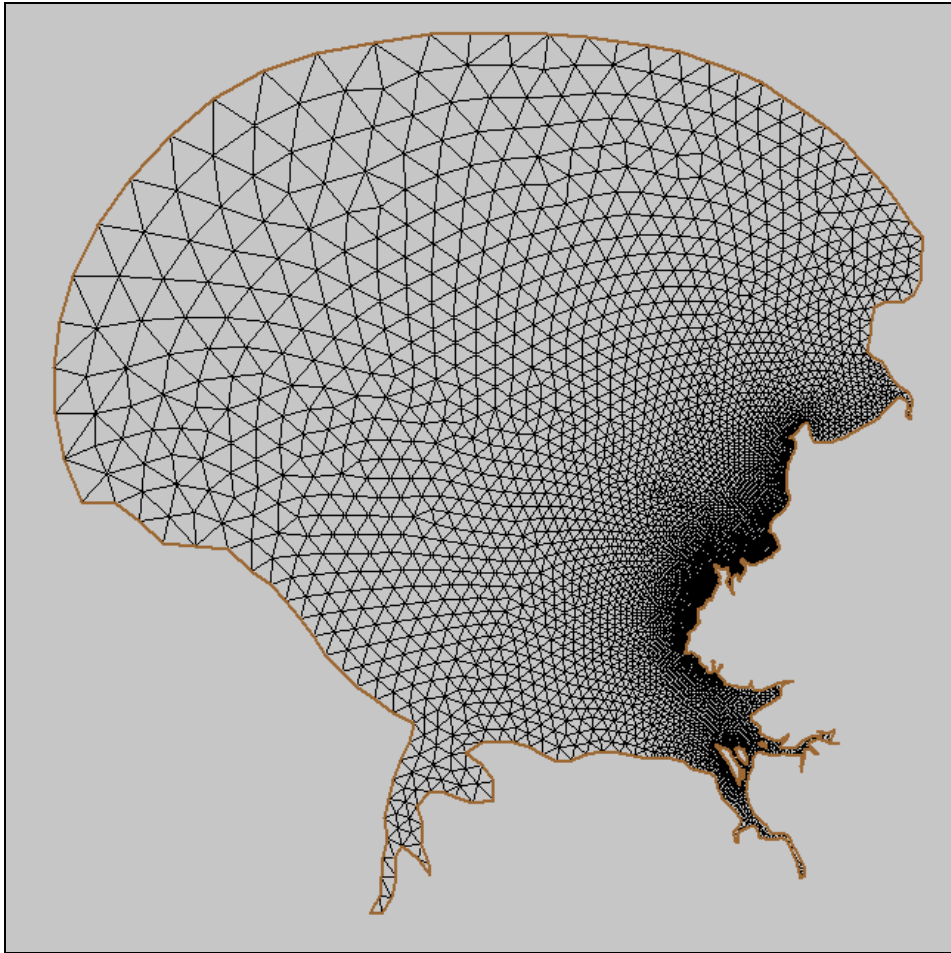


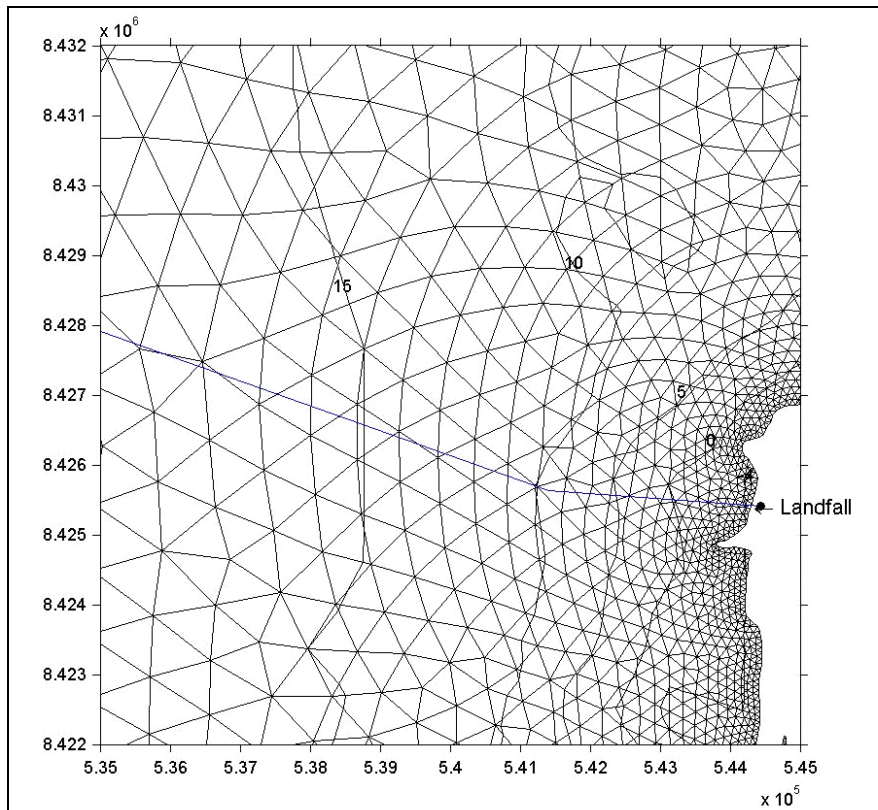
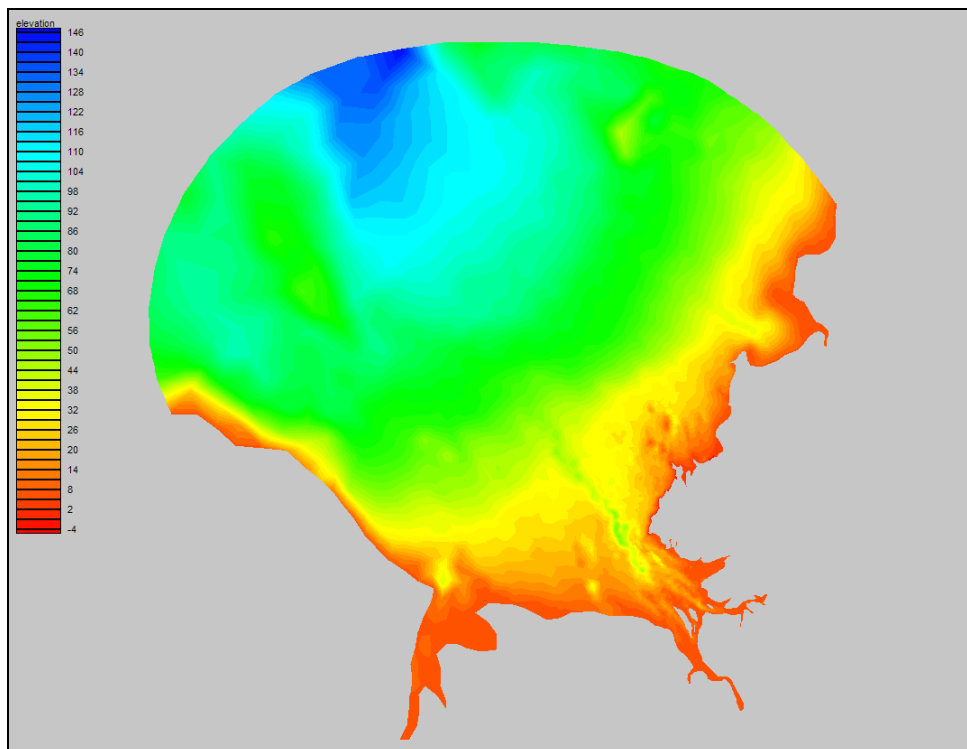
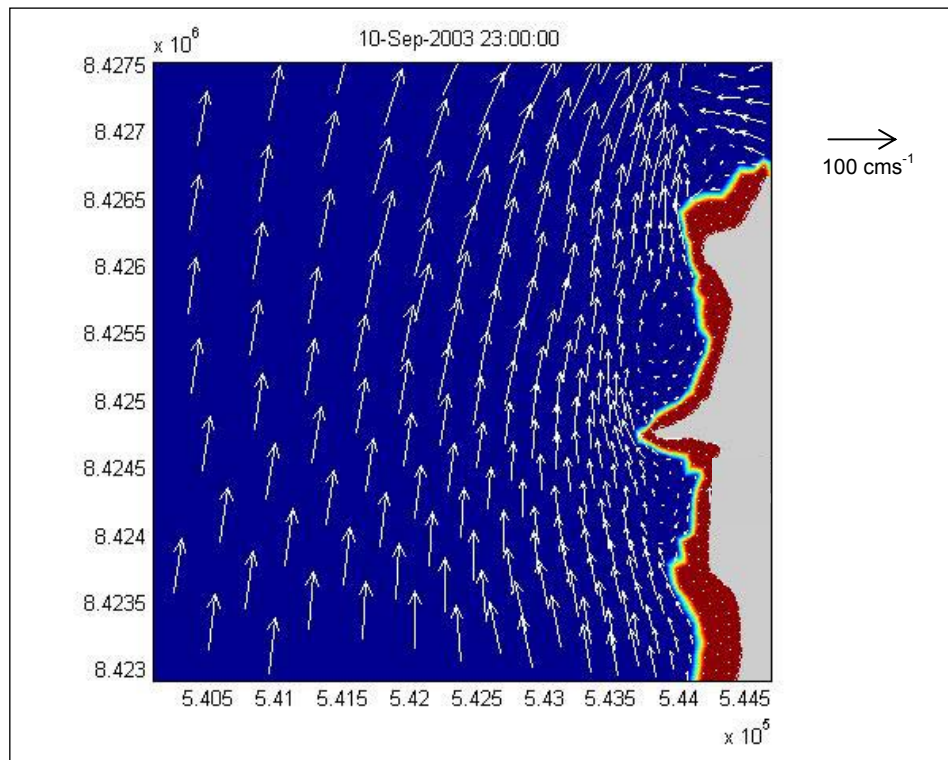
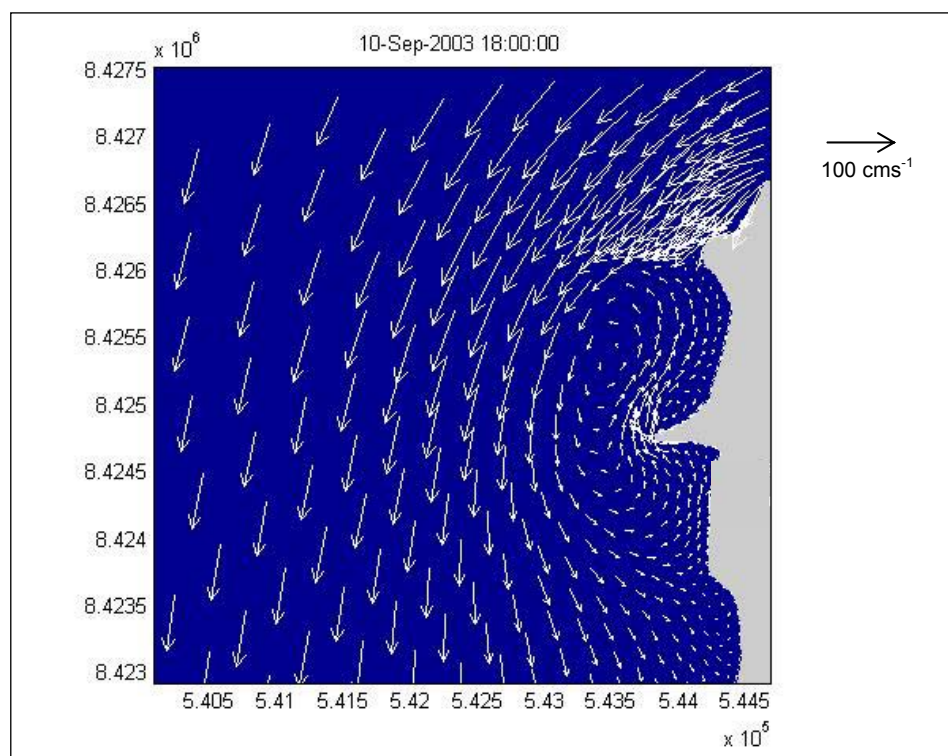
Figure 3.2 Details of the hydrodynamic model grid in the vicinity of the landfall**Figure 3.3 Model bathymetry in metres**

Figure 3.4 Predicted spring tide vector fields in the vicinity of the landfall for the Blacktip pipeline

(a) Ebb Tide



(b) Flood Tide



3.2.3 Wind Data

Wind forcing for the model was based on historic wind data from the Port Keats meteorological station operated by the Australian Bureau of Meteorology. The anemometer for this station is positioned 28m above Australian Height Datum, readings are three hourly and cover the period from 2000 – 2003. Winds were corrected to 10m above sea level using a logarithmic wind profile given by:

$$\frac{U_{10}}{U_z} = \frac{\ln(\frac{10}{z_0})}{\ln(\frac{Z}{z_0})}$$

where U_{10} = wind speed at 10m, U_z = wind speed at height Z and z_0 is the roughness length, set at 0.002.

Monthly wind roses are shown in Figure 3.5. Two distinct seasons are evident:

- the “summer” wet season between September and February when winds are predominantly from the northwest; and
- the “winter” dry season between April and July when winds are predominantly from the southeast.

The months between the seasons, March and August, are termed the transitional periods when either summer or winter conditions can prevail resulting in more variable wind directions.

3.3 Oil Spill Trajectory Module

3.3.1 General

The oil spill module is based on the classic random walk particle tracking method (Sherwin, 1992) and assumes that the oil can be idealised as a large number of particles that move independently under the action of tide and wind. The oil spill trajectory model is integrally linked with the FE model and uses a highly accurate fourth order Runge-Kutta method to track particles (Blanton, 1995).

Water properties and atmospheric conditions were input to the model to predict the behaviour and fate of the oil. Industry standard algorithms were used to predict spreading (Fay; 1969), evaporation (Fingas, 1999), emulsification (Eley, *et al.*, 1988) and entrainment (Delvigne and Sweeney, 1988) of hydrocarbons. The model was run in both deterministic and stochastic (statistical) modes.

3.3.2 Deterministic Simulations

In deterministic mode, a single simulation was undertaken to determine the fate and likely consequence of an oil spill under worst-case conditions. For Blacktip worst-case conditions

are considered to be a neap tide coinciding with a 5ms^{-1} onshore wind. Results are presented as plots showing:

- hourly concentration of oil at sea; and
- beached masses of oil.

3.3.3 Stochastic Simulations

To take into consideration the frequency of occurrence of a range of different tide and wind conditions, the model was also run in stochastic mode. In this mode, multiple simulations (100) were undertaken using randomly selected start dates for wind and current data for the defined season. Each simulation was run for 5 days and results presented as contour plots showing the probability of surface exposure to oil after 24 hours and five days, respectively.

3.4 Oil Spill Weathering Module

The National Oceanic and Atmospheric Administration's (NOAA's) Automated Data Inquiry for Oil Spills (ADIOS2) model was used to simulate detailed evaporation, dispersion and emulsification of the spill. Input data for ADIOS2 includes:

- oil properties (API, viscosity, distillation curves);
- spill details (volume and duration of the spill); and
- environmental data (wind and sea surface temperature).

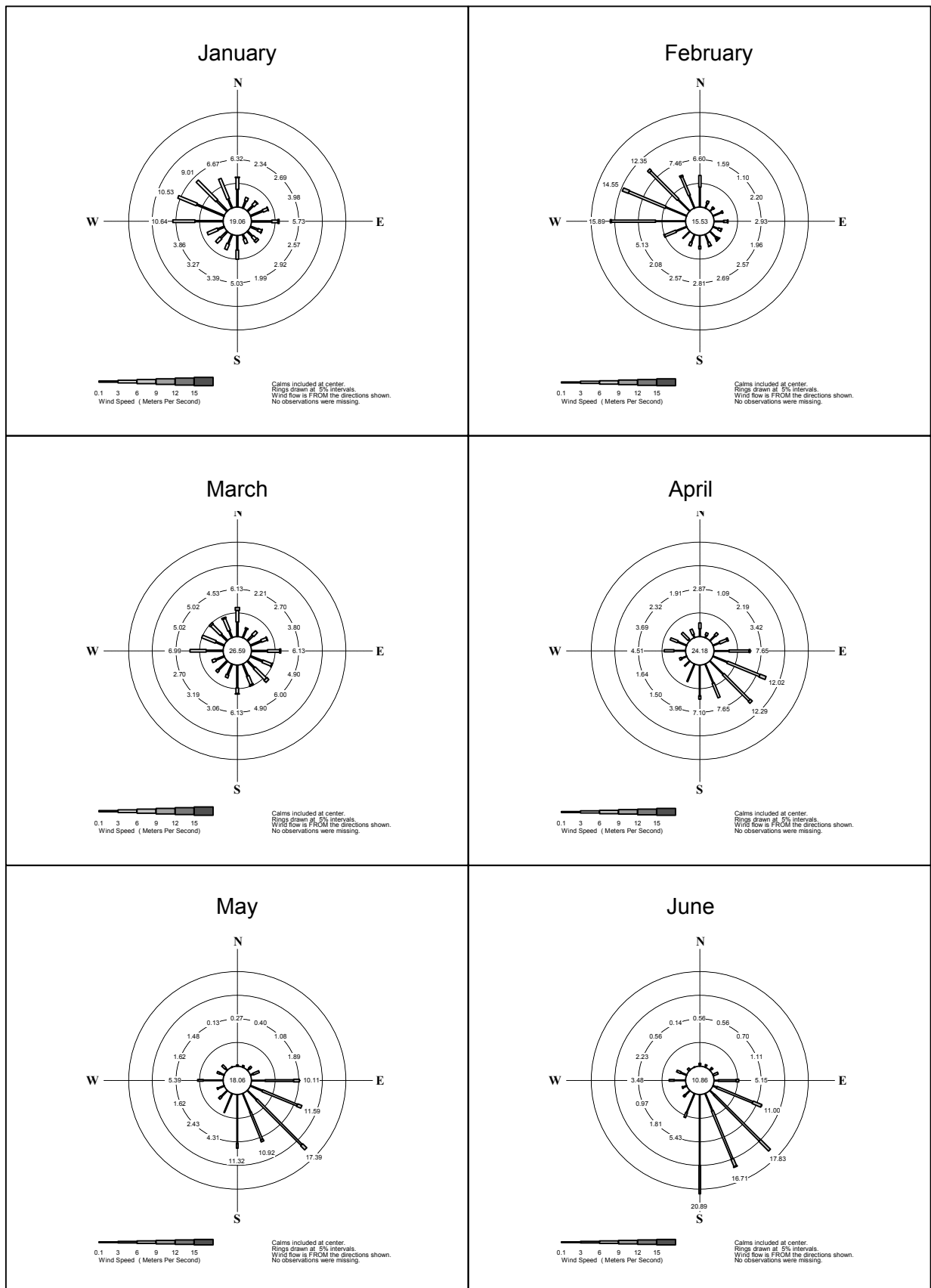
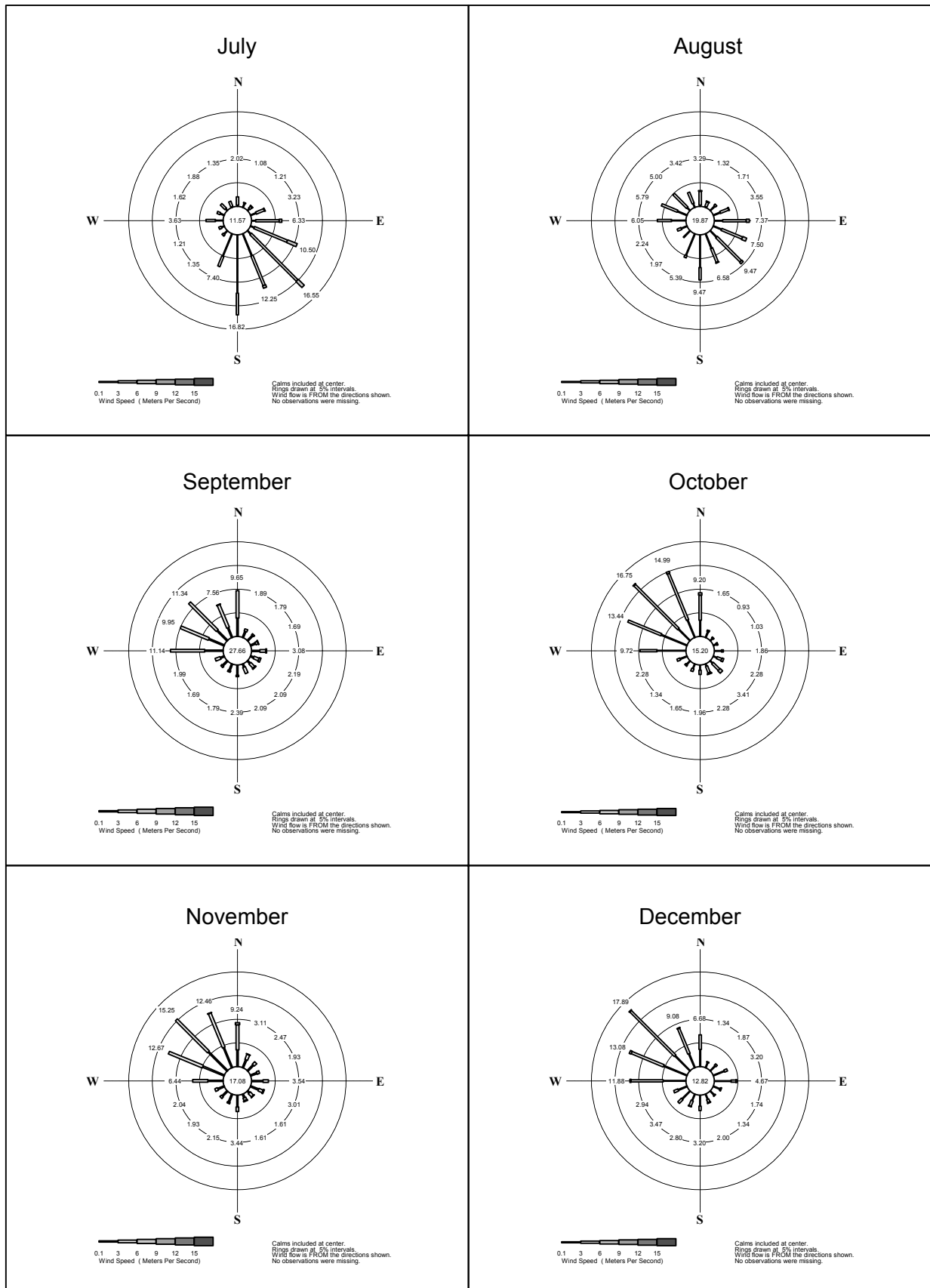
Figure 3.5 Monthly wind roses for Port Keats (BOM (2000 -2003))

Figure 3.1 (cont.)



4 CONDENSATE CHARACTERISTICS AND PREDICTED WEATHERING BEHAVIOUR

4.1 General

The two types of oil modelled in the oil spill events were:

- Blacktip condensate; and
- Heavy Fuel Oil

4.2 Blacktip Condensate

The properties of Blacktip condensate are detailed in WEL (2003). Key characteristics relevant to the behaviour of oil spilt to sea are summarised in Table 4.1. Essentially it is light oil with a relatively narrow boiling range, meaning that most of the oil will evaporate or naturally disperse within a few days of being spilt. It is much lighter than seawater and if spilt to sea would spread rapidly to form a thin sheen. As wind and sea states increase wave action would physically disperse the oil into the water column, forming small droplets that are carried and kept in suspension by the currents.

Table 4.1 Condensate properties used in the model (based on NWS condensate)

Parameter	Blacktip Condensate
Specific Gravity	0.794
API (°)	49
Pour Point (°C)	<-30
Viscosity @ 20°C (cSt)	2.46
Distillation Cuts	
Temp (°C)	Vol %
95	5
108	10
123.5	20
135.5	30
149	40
164.5	50
185.5	60
207	70
238.5	80
274	90

Figure 4.1 to Figure 4.4 presents the predicted weathering results from the ADIOS2 model. Evaporation ranges from 85% for 8m³ and 80% for 500m³. Dispersion is minimal for wind speeds below 4ms⁻¹, however, for the larger 10ms⁻¹ wind, dispersion increases accounts for 20% of the smaller volume and about 10% of the larger volume.

Figure 4.1 Predicted weathering of Blacktip condensate for a continuous release of 8m^3 over a duration of 1 hour for a 4ms^{-1} wind

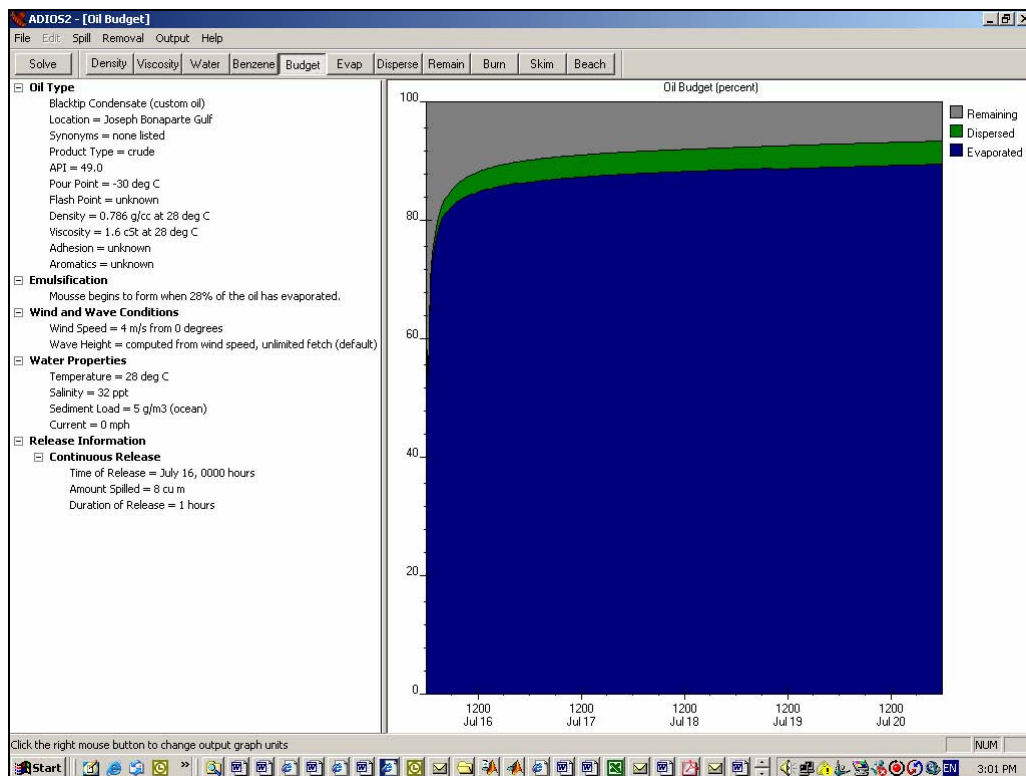


Figure 4.2 Predicted weathering of Blacktip condensate for a continuous release of 8m^3 over a duration of 1 hour for a 10ms^{-1} wind

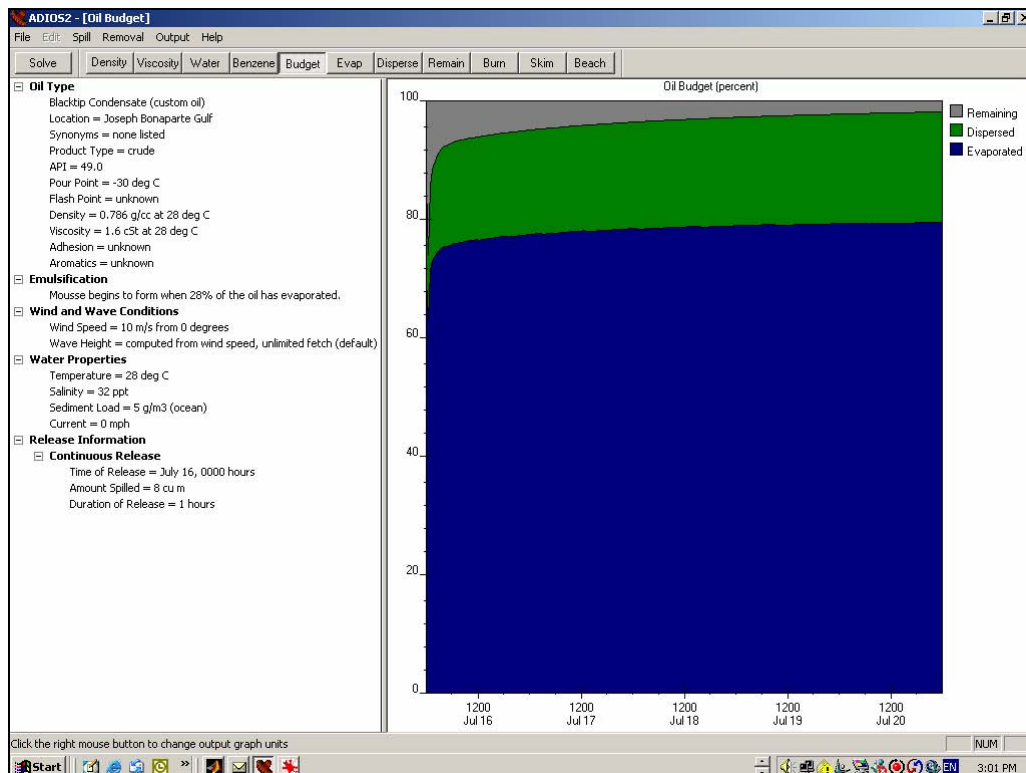


Figure 4.3 Predicted weathering of Blacktip condensate for a continuous release of 500m³ over a duration of 3 hours for a 4ms⁻¹ wind

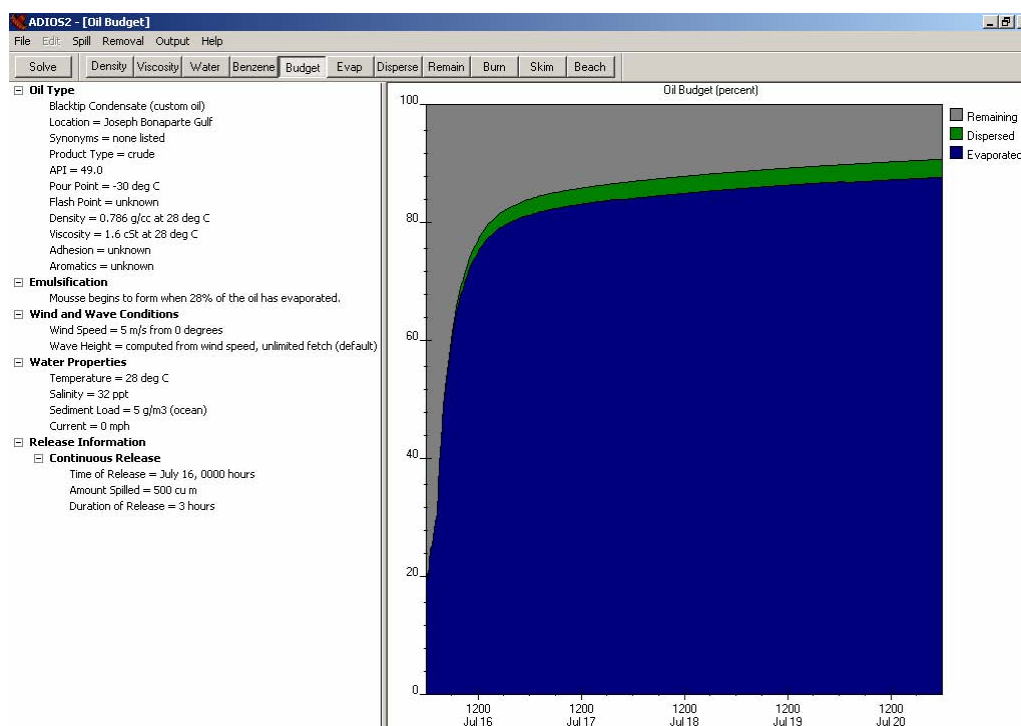
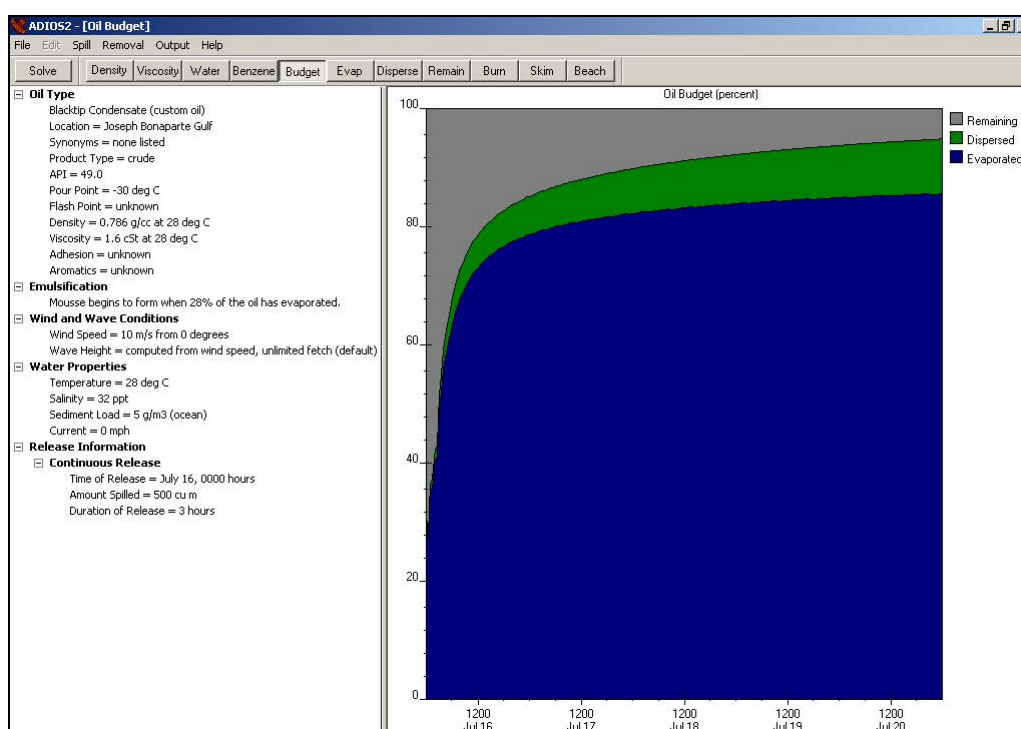


Figure 4.4 Predicted weathering of Blacktip condensate for a continuous release of 500m³ over a duration of 3 hours for a 10ms⁻¹ wind



4.3 Heavy Fuel Oil

Heavy fuel oil is a dense, viscous oil produced by blending heavy residual oils with a lighter oil (often No. 2 fuel oil) to meet specifications for viscosity and pour point. It is much denser than condensate with an API of 17.5° and is persistent (Table 4.2). Distillation cuts indicate that only 25% of the oil is volatile or semi-volatile suggesting that it does not readily evaporate.

Figure 4.5 and Figure 4.6 show the predicted weathering behaviour from the ADIOS2 model for light (4ms^{-1}) and moderate (10ms^{-1}) wind speeds, respectively. For light winds only 24% of the oil is predicted to evaporate after 24 hours with less than 1% being dispersed into the water column. For stronger winds, 25% evaporates and 7% disperses.

These oils can occasionally form an emulsion, but usually only slowly and after a period of days.

Table 4.2 Properties of heavy fuel oil used in the model

Parameter	Heavy Oil
API (°)	17.5
Viscosity (cSt)	750@15°C
Distillation Cuts	
Temp	
(°C)	Vol %
160	19
180	20
200	21
220	22
240	23
260	24
280	25

Figure 4.5 Predicted weathering of heavy fuel oil for a continuous release of 500m³ over 3 hours for a 4ms⁻¹ wind

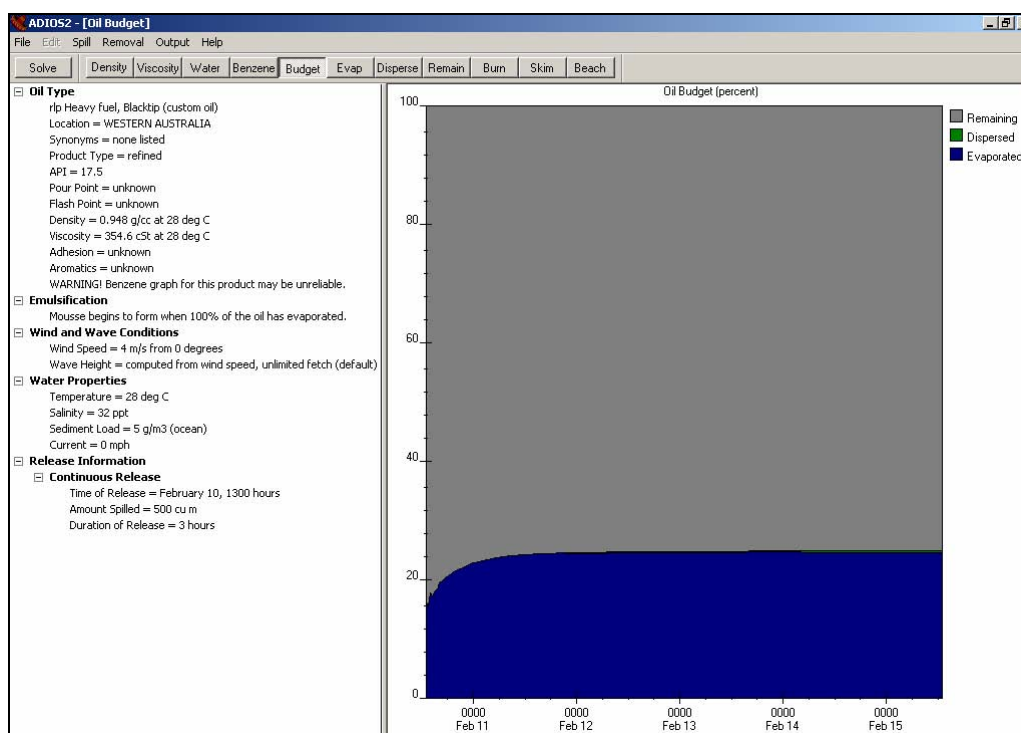
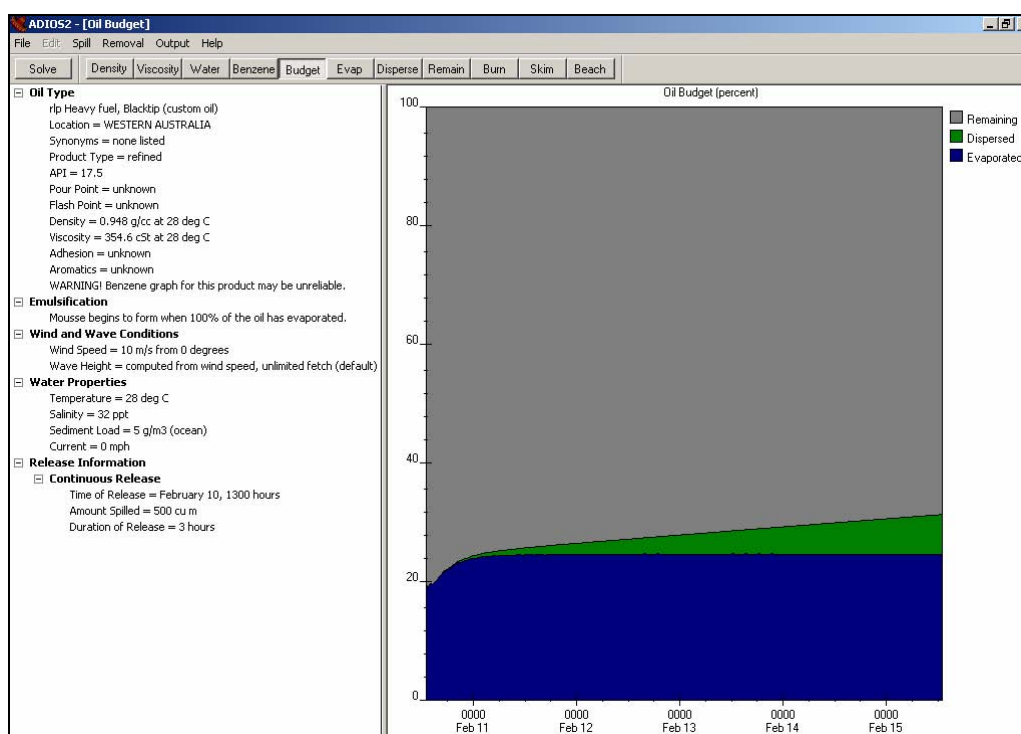


Figure 4.6 Predicted weathering of heavy fuel oil for a continuous release of 500m³ over 3 hours for a 10ms⁻¹ wind



5 MODELLING RESULTS

5.1 General

The four oil spill events simulated are summarised in Table 5.1. Both deterministic and stochastic simulations were undertaken. The former were undertaken to demonstrate the oil trajectory and likely coastline impact for a single spill under “worst-case” ambient conditions. The latter were then undertaken to demonstrate the probability of exposure for the many different possible tide and wind combinations that could occur for both wet and dry seasons.

Table 5.1 Summary of oil spill scenarios

Event	Description	Discharge Volume (m ³)	Spill Duration (hrs)	Oil type	Stochastic Simulation	Deterministic Simulation
1	Small Loadout line leak	8	0.5	Blacktip Condensate	Wet Dry	Neap Tide Wind: 5ms ⁻¹ NW
2	Medium Loadout line leak	100	3		Wet Dry	
3	Large Loadout line leak	500	3		Wet Dry	
4	Ship fuel leak	500	3	Heavy Fuel	Wet Dry	

¹Due to the similarity with the loadout line leak scenario, results for the dry season are not presented.

5.2 Event 1: Small Loadout Line Leak

Scenario: 8m³ condensate spill from the Swamp Mooring

Figure 5.1 presents the predicted surface oil concentrations for an 8m³ condensate spill at the Swamp Mooring. With all the safeguards in place, this is the maximum likely spill volume that would result either due to human error or in the event of an offtake hose rupture.

The spill duration was set at 30 minutes and timed to coincide with ebb currents on a neap tide. A 500m slick was formed which was transported approximately 2km towards the northeast. On the turn of tide, the slick returned southwards and was entrained into the pipeline shore crossing bay where it came into contact with the shoreline. By the time oil impacted the beach concentrations had reduced to below 0.005kgm⁻². This is equivalent to about 7mLm⁻², which is unlikely to cause either a toxic or physical impact.

The model predicted that 86% of the slick would have evaporated by the time it reached the beach and that 800kg of oil would become stranded (Figure 5.2). Note that the model does not allow outwashing of the condensate so the masses shown in Figure 5.2 are cumulative with no further weathering applied. In reality, oil would continue to evaporate once on the beach. Any residual would be removed by biodegradation and photo-oxidation. Blacktip condensate is therefore unlikely to persist in the environment.

The above is just one example of the many possible combinations of wind and tide conditions that a spill could experience. The stochastic simulations aim to attach statistical probabilities to oil exposure for such an event. Probabilities of surface exposure for the variety of wind and tide conditions during the wet and dry seasons are shown in Figure 5.3 and Figure 5.4, respectively. The oil concentration limit was set at 0.005kgm^{-2} , below which no adverse environmental effects are assumed.

The probabilities after five days are similar to those after one day, which suggests that most of the condensate evaporates within 24 hours. For the wet season, the model predicts that about 40km of shoreline is at risk and that there is a 5 to 10% probability of impact. For the dry season it is unlikely that there will be any shoreline impact at all.

5.3 Event 2: Medium Loadout Line Leak

Scenario: 100m^3 condensate spill from the Swamp Mooring

Figure 5.5 presents the predicted surface oil concentrations for a 100m^3 condensate spill at the Swamp Mooring. This volume of condensate equates to a total loss of inventory from the pipeline extending from the beach to the swamp mooring.

The spill duration was set at three hours and timed to coincide with ebb currents on a neap tide. After the three hours release duration, a 4km slick had formed extending towards the northeast. On the turn of tide, the slick returned southwards and the trailing edge was entrained into the pipeline shore crossing bay where it came into contact with the shoreline. The leading edge continued southwards where it was progressively washed ashore. By the time oil impacted the beach concentrations had reduced to below 0.05kgm^{-2} .

The model predicted that 83% of the slick would have evaporated by the time it reached the beach and that a total of 12,000kg of oil would become stranded (Figure 5.6). As described previously, once on the beach, the oil would continue to evaporate and any residual would be removed by biodegradation and photo-oxidation.

Figure 5.7 and Figure 5.8 show the probabilities of surface exposure for the variety of wind and tide conditions during the wet and dry seasons, respectively. Again, the oil concentration limit was set at 0.005kgm^{-2} .

For the wet season, after 24 hours, the probability of shoreline impact is 25% and the length of coastline with a greater than 5% probability of being contacted is 25km. After five days the probability of shoreline impact is slightly greater and the length of coastline at risk about the same.

For the dry season, the contours are skewed towards the northeast, reflecting the prevailing wind direction. After 24 hours, the probability of shoreline impact is 5 to 10% and the length of coastline with a greater than 5% probability of being contacted is 15km towards the south and less than 10km towards the north. After five days the probability of shoreline impact and the length of coastline at risk are similar.

5.4 Event 3: Large Loadout Line Leak

Scenario: 500m³ condensate spill from the Swamp Mooring

Figure 5.9 presents the predicted surface oil concentrations for a 500m³ condensate spill at the Swamp Mooring. This volume of condensate equates to a total loss of inventory from the whole pipeline extending from the onshore treatment plant to the swamp mooring.

As before, the spill duration was set at three hours and timed to coincide with ebb currents on a neap tide. The distribution of the oil is similar to that described previously although oil concentrations are higher and the mass washed ashore increased to 75,000Kg (Figure 5.10).

Figure 5.11 and Figure 5.12 show the probabilities of surface exposure for the variety of wind and tide conditions during the wet and dry seasons, respectively.

For the wet season, after 24 hours, the probability of shoreline impact is 25% and the length of coastline with a greater than 5% probability of being contacted is 40km. After five days the probability of shoreline impact and the length of coastline at risk increased to 50% and 50km, respectively.

For the dry season, the contours are once again skewed towards the northeast, reflecting the prevailing wind direction. After 24 hours, the probability of shoreline impact is 5 to 10% and the length of coastline with a greater than 5% probability of being contacted is 20km towards the south and less than 10km towards the north. After five days the probability of shoreline impact and the length of coastline at risk are 10 to 25% and 40 km, respectively.

5.5 Event 4: Ship Fuel Leak

Scenario: 500m³ spill of heavy fuel from the Swamp Mooring

In this simulation the maximum heavy fuel inventory of 500m³ was spilt over a three hour duration under the same conditions used in the previous three scenarios. The predicted plume distribution is the same (Figure 5.13), however, as evaporation rates are much reduced, concentrations in the slick and masses washed ashore are greater (Figure 5.14). A total of 400,000kg of oil were predicted to be washed onto the shoreline. This is likely to be persistent and if left unattended is likely to cause a significant localised environmental impact.

Figure 5.15 and Figure 5.16 show the predicted probability of exposure to condensate for the wet and dry seasons respectively. Results are similar to the large condensate spill with a 25% probability of oil impacting shoreline within one day during the wet season and a 5 to

10% probability in the dry season. Probability envelopes generally extend over a wider area reflecting the persistence of fuel oil in the environment.

Figure 5.1 Predicted surface oil concentration for an 8m³ spill of Blacktip condensate over 0.5 hrs during a neap tide and an onshore 5ms⁻¹ wind (wet season).

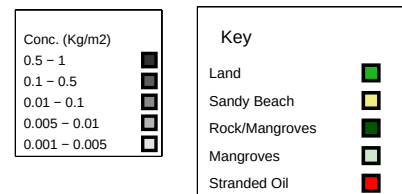
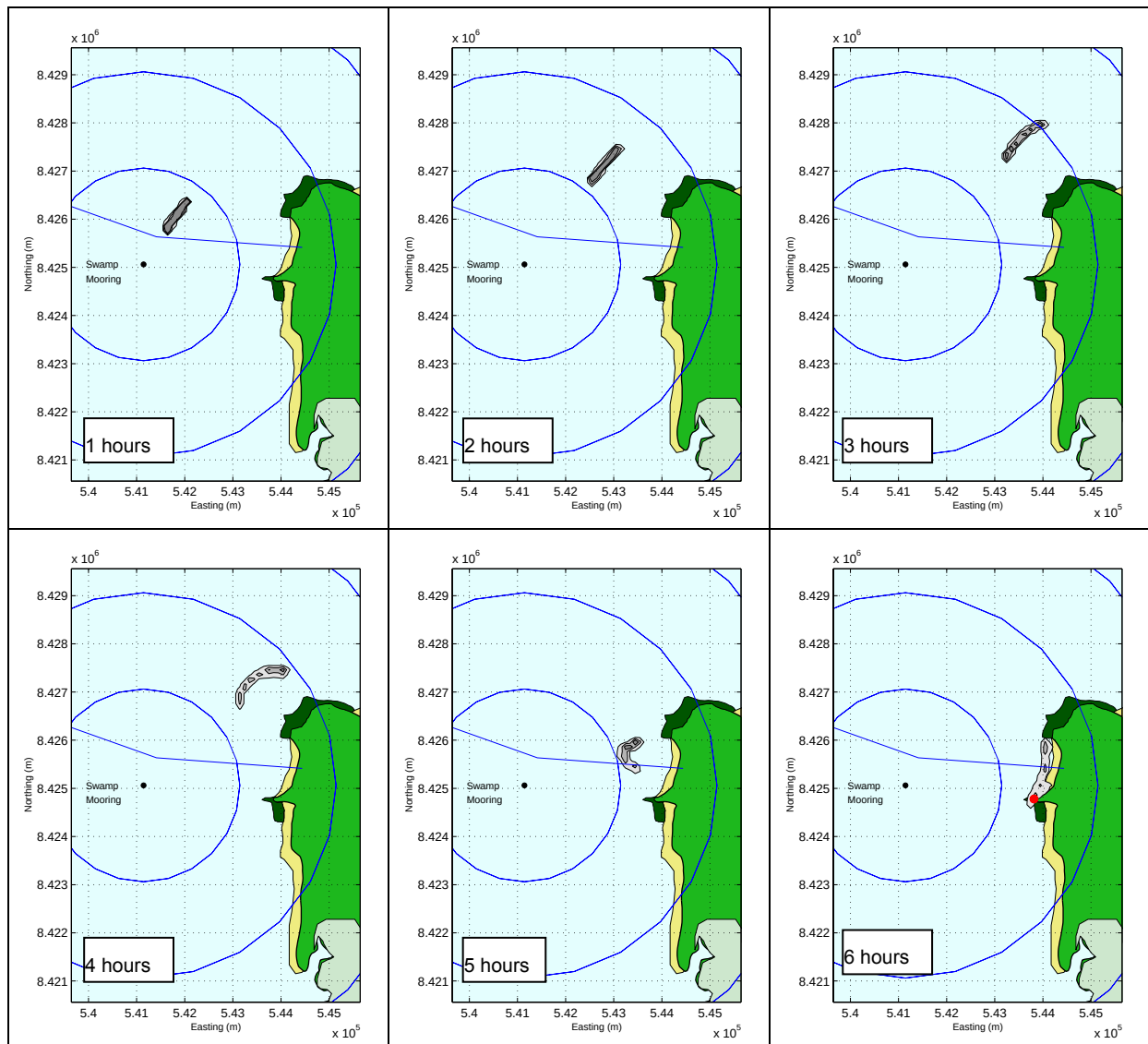
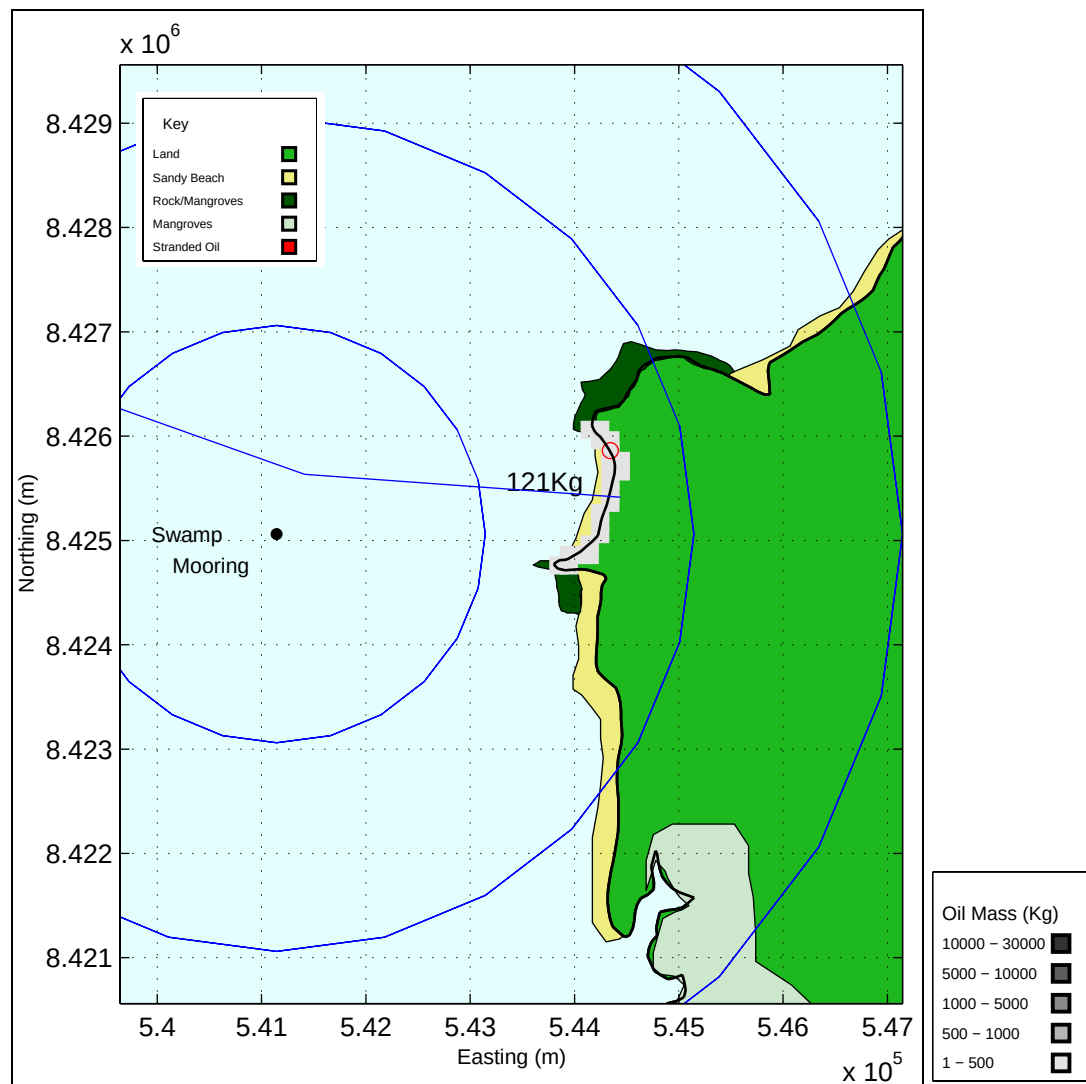


Figure 5.2 Predicted mass of beached oil for a 8m³ spill of Blacktip condensate over 0.5 hrs during a neap tide in the wet season.



Notes for Figure 5.1 and Figure 5.2:

- (1) Figure 5.1, shows the trajectory and predicted condensate concentration for an 8m³ spill under worst-case conditions. The resulting mass of oil washed up on the beach is presented in the figure above. Note that the model does not allow outwashing of the condensate so this is the cumulative mass of oil that arrives on the beach with no further weathering processes applied. The red circle indicates the largest mass of oil washed up, which in this case is 121kg.
- (2) Blacktip condensate is highly volatile and approximately 86% was evaporated whilst at sea. Once ashore this process would continue. The light condensate would penetrate porous sediments. It would not tend to stick to rock or sandy substrates and would be washed away by waves and tidal flushing. Any residual resistant to evaporation would be removed by biodegradation and photooxidation within a relatively short time frame.
- (3) Shoreline cleanup would not be required and the likely environmental consequence would be a minor short-lived local impact.
- (4) The proposed pipeline and range rings about the Swamp Mooring are shown in blue.
- (5) Range rings are drawn at 2 km intervals.

Figure 5.3 Probability of surface exposure resulting from a 8m³ condensate spill over 0.5 hours for the wet season

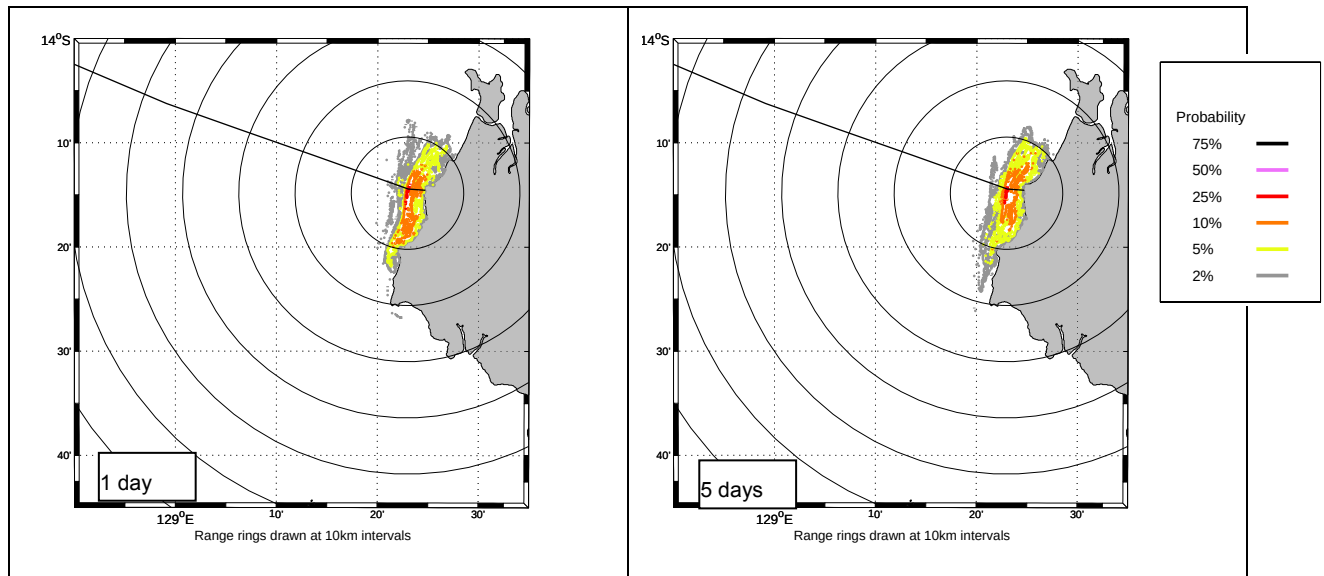
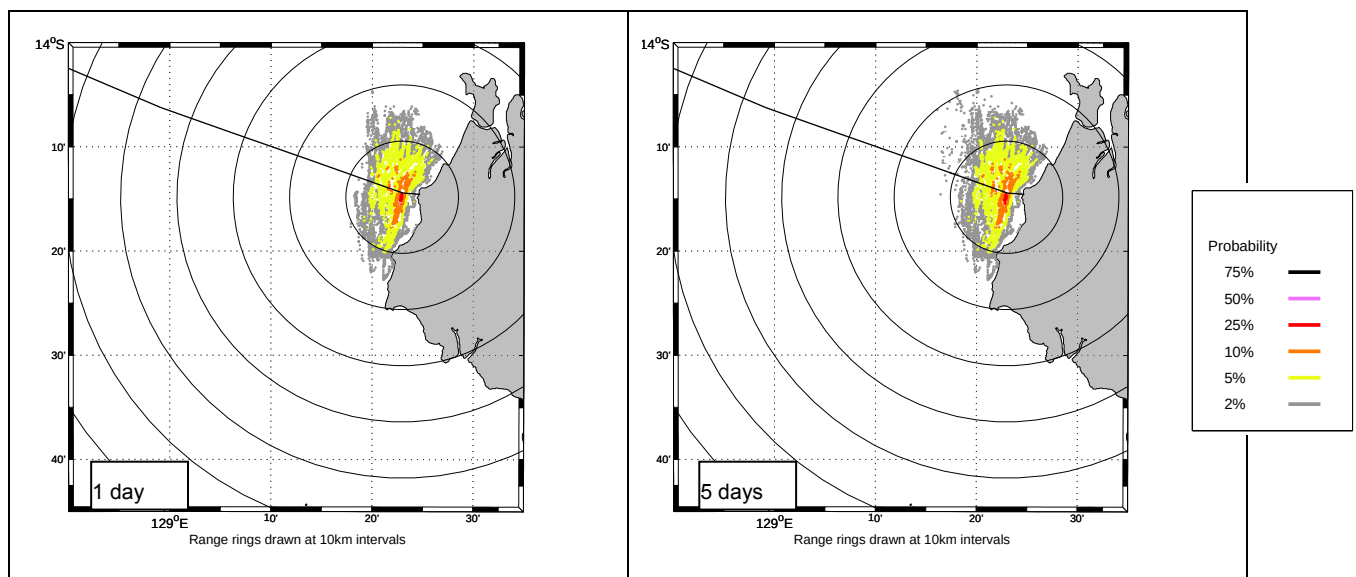


Figure 5.4 Probability of surface exposure resulting from a 8m³ condensate spill over 0.5 hours for the dry season



Notes:

- (1) The probability contours were calculated from 100 oil spill simulations using randomly selected wind and circulation data for the defined months of the specified seasons.
- (2) Significant oil concentrations assumed to be 0.005kg/m² (<10mL/m²).
- (3) Range rings are drawn at 10 km intervals.

Figure 5.5 Predicted surface oil concentration for a 100m³ spill of Blacktip condensate during a neap tide and an onshore 5ms⁻¹ wind (wet season).

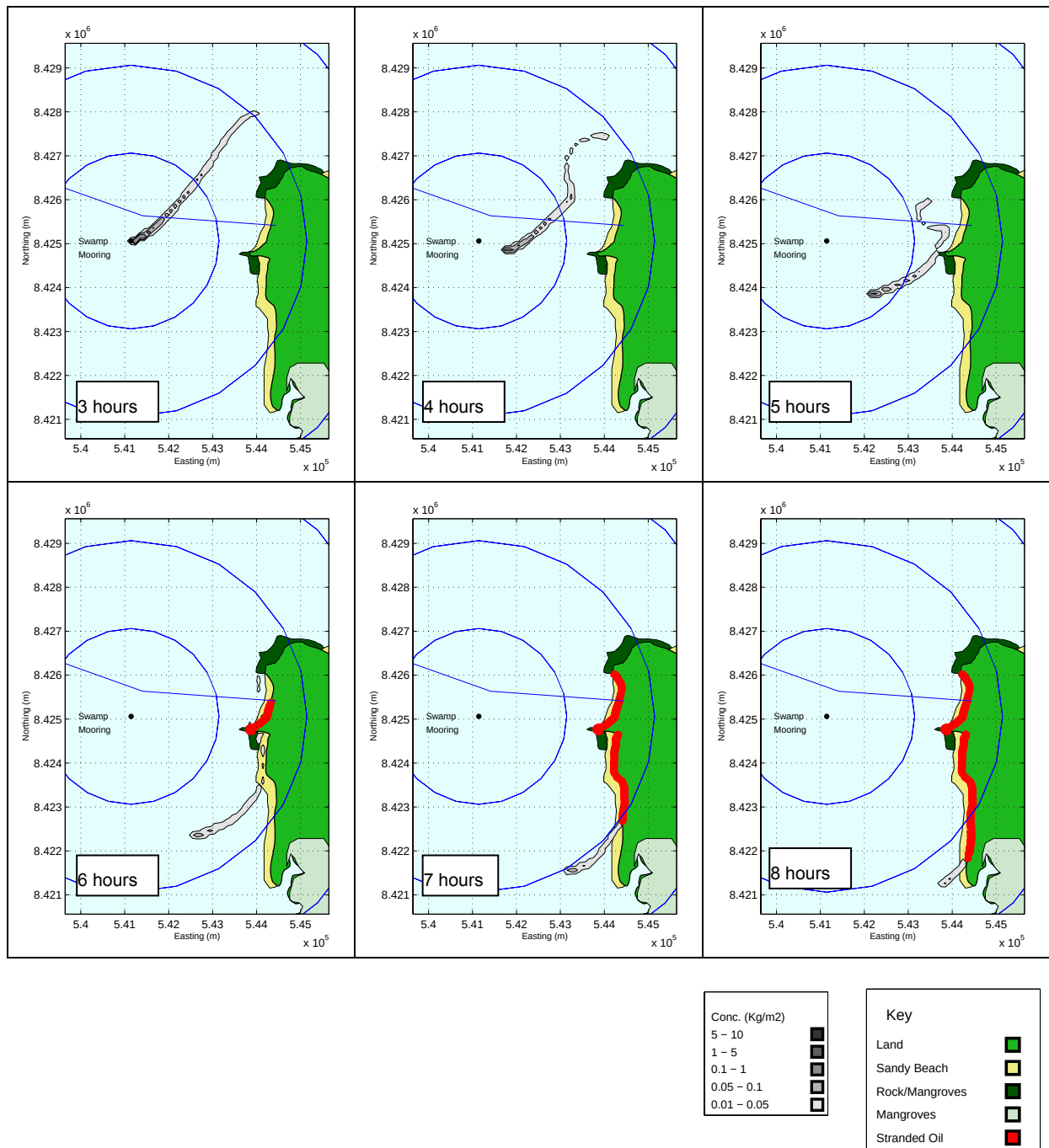
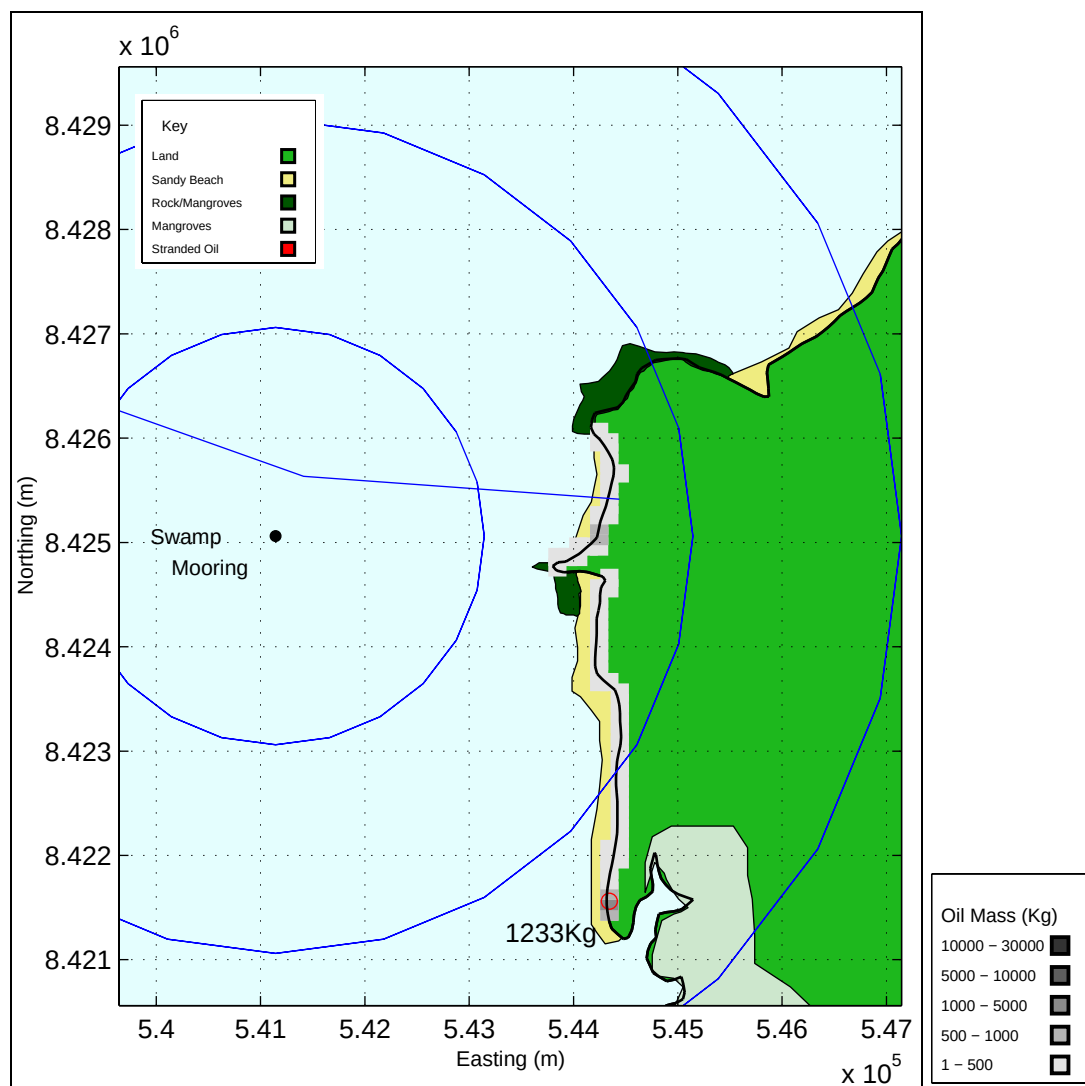


Figure 5.6 Predicted mass of beached oil for a 100m³ spill of Blacktip condensate during a neap tide in the wet season.



Notes for Figure 5.5 and Figure 5.6:

- (1) Figure 5.5 shows the trajectory and predicted condensate concentration for a 100m³ spill under worst-case conditions. The resulting mass of oil washed up on the beach is presented in the above figure. Note that the model does not allow outwashing of the condensate so this is the cumulative mass of oil that arrives on the beach with no further weathering processes applied. The red circle indicates the largest mass of oil washed up, which in this case is 1,233kg.
- (2) Blacktip condensate is highly volatile and approximately 83% was evaporated whilst at sea. Once ashore this process would continue. The light condensate would penetrate porous sediments. It would not tend to stick to rock or sandy substrates and would be washed away by waves and tidal flushing. Any residual resistant to evaporation would be removed by biodegradation and photoxidation within a relatively short time frame.
- (3) Shoreline cleanup would not be required and the likely environmental consequence would be a minor short-lived local impact.
- (4) The proposed pipeline and range rings about the Swamp Mooring are shown in blue.
- (5) Range rings are drawn at 2 km intervals.

Figure 5.7 Probability of surface exposure resulting from a 100m³ condensate spill over 3 hours for the wet season

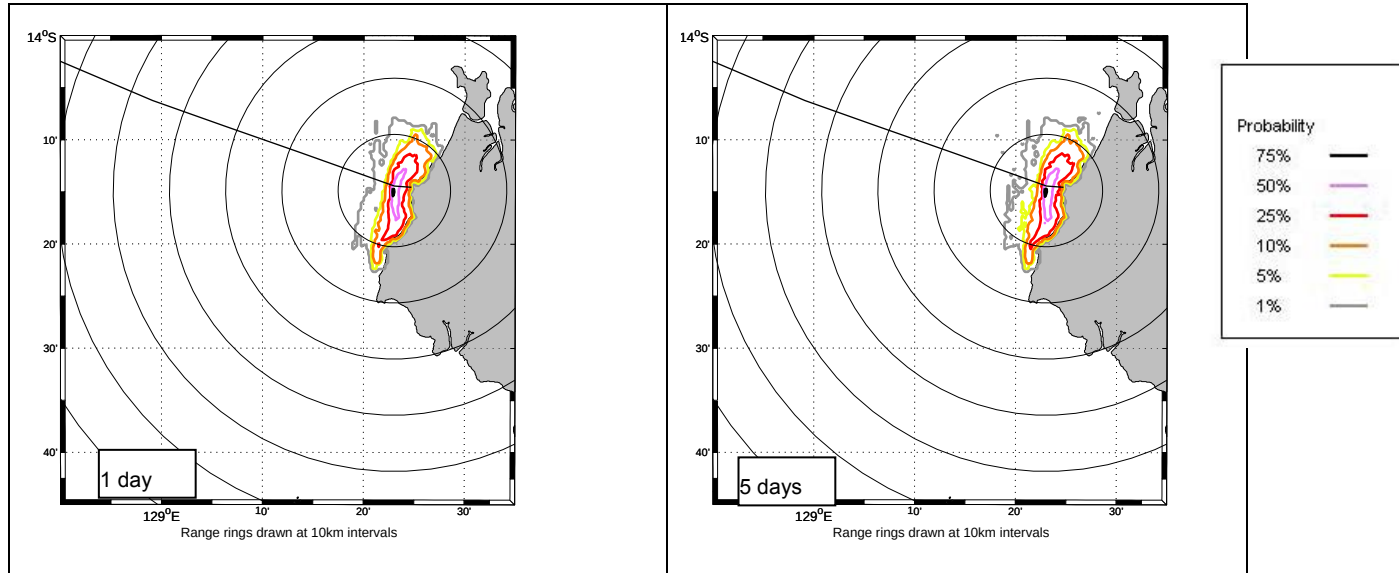
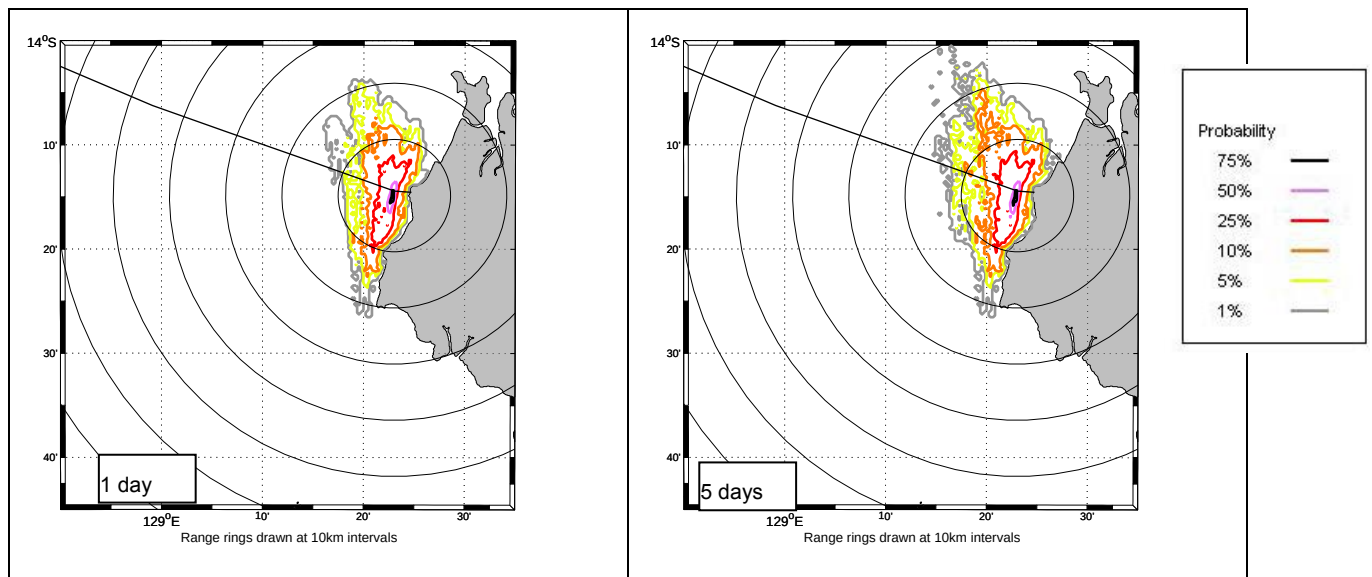


Figure 5.8 Probability of surface exposure resulting from a 100m³ condensate spill over 3 hours for the dry season



Notes:

- (1) The probability contours were calculated from 100 oil spill simulations using randomly selected wind and circulation data for the defined months of the specified seasons.
- (2) Significant oil concentrations assumed to be 0.005kg/m² (<10mL/m²).
- (3) Range rings are drawn at 10 km intervals.

Figure 5.9 Predicted surface oil concentration for a 500m³ spill of Blacktip condensate during a neap tide and an onshore 5ms-1 wind (wet season).

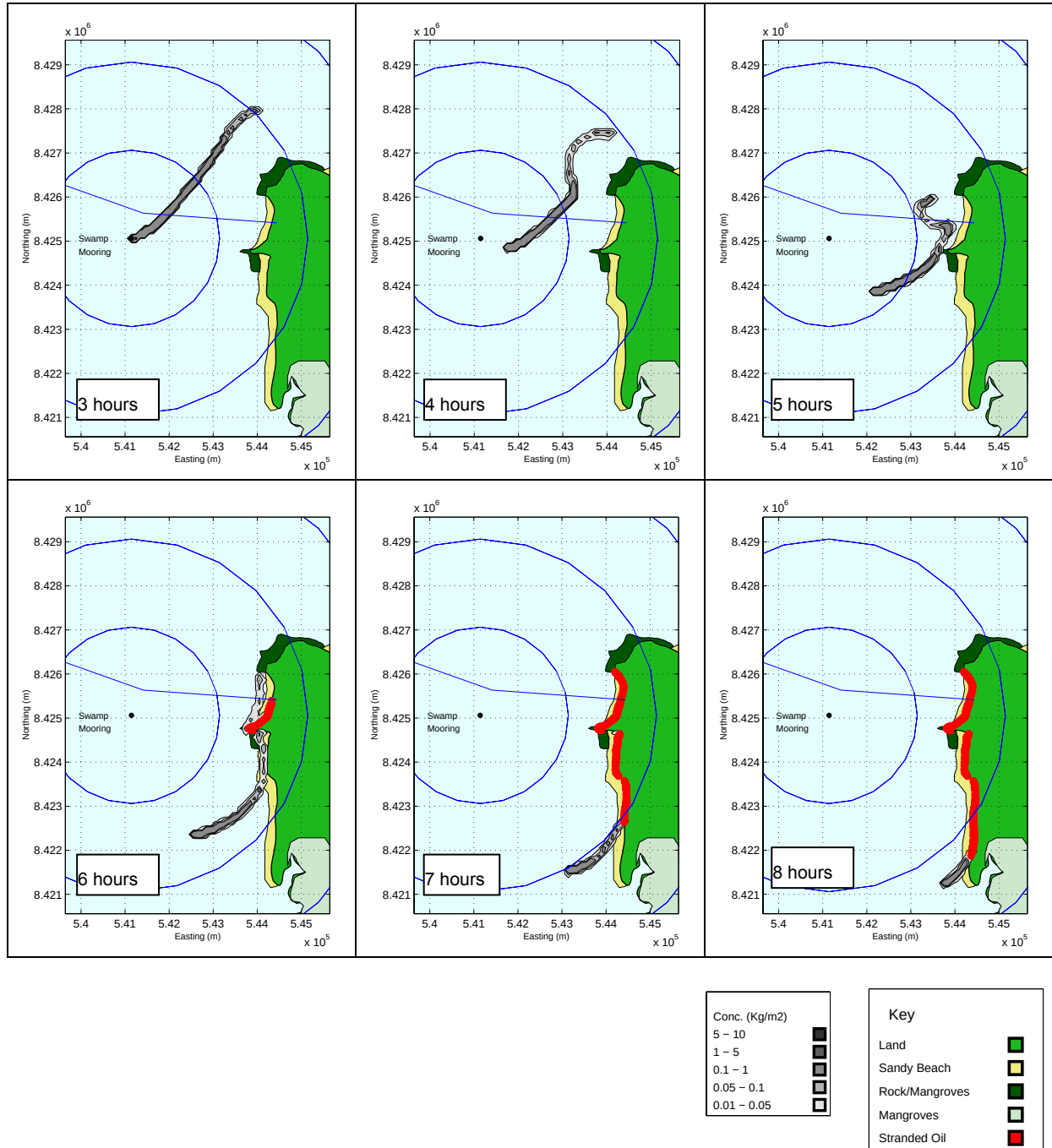
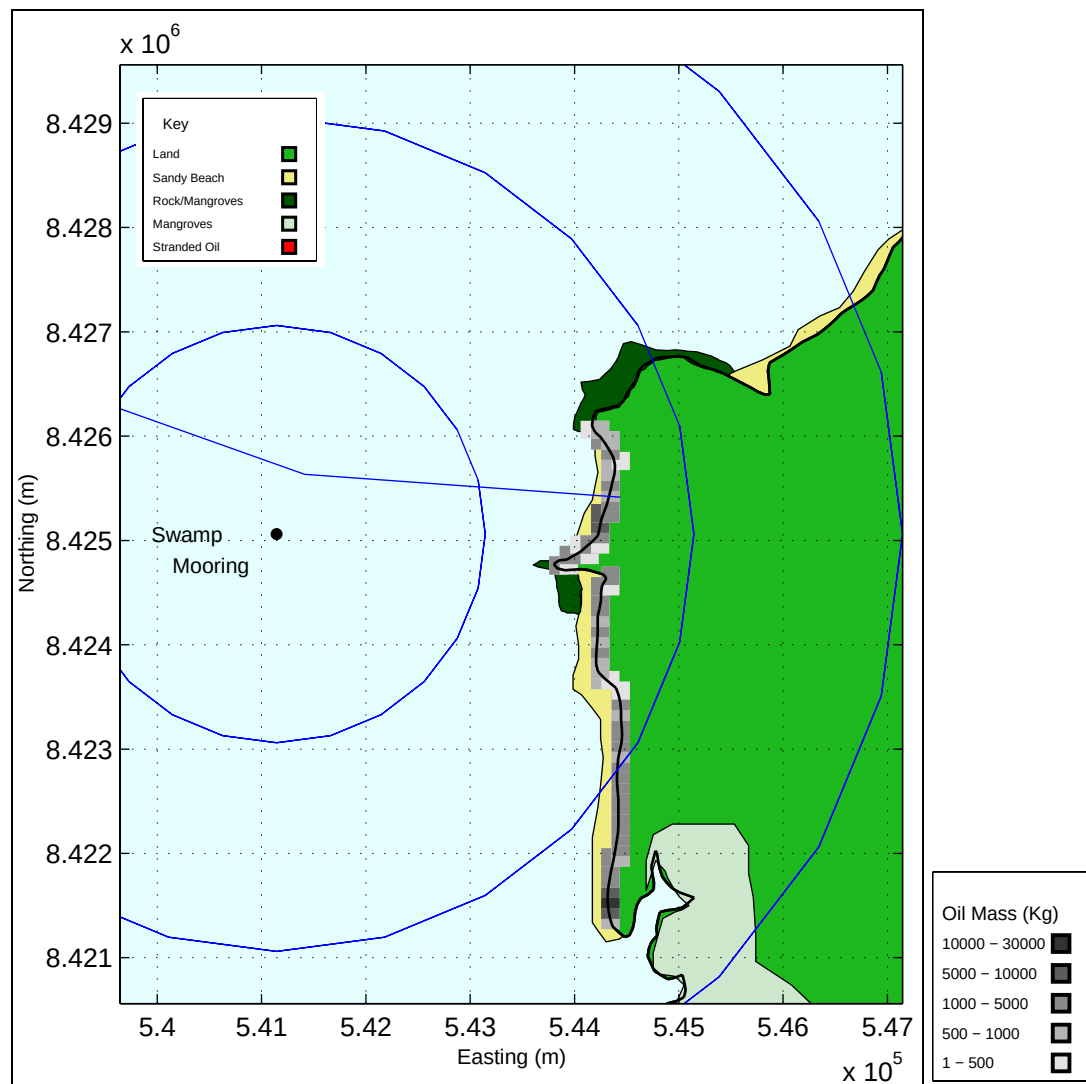


Figure 5.10 Predicted mass of beached oil for a 500m³ spill of Blacktip condensate during a neap tide in the wet season.



Notes for Figure 5.9 and Figure 5.10 :

- (1) Figure 5.9 shows the trajectory and predicted condensate concentration for a 500m³ spill under worst-case conditions. The resulting mass of oil washed up on the beach is presented in the above figure. Note that the model does not allow outwashing of the condensate so this is the cumulative mass of oil that arrives on the beach with no further weathering processes applied. The largest mass of oil washed up is just under 6,000kg.
- (2) Blacktip condensate is highly volatile and approximately 80% was evaporated whilst at sea. Once ashore this process would continue. The light condensate would penetrate porous sediments. It would not tend to stick to rock or sandy substrates and would be washed away by waves and tidal flushing. Any residual resistant to evaporation would be removed by biodegradation and photooxidation within a relatively short time frame.
- (3) Shoreline cleanup would not be required and the likely environmental consequence would be a minor short-lived local impact.
- (4) The proposed pipeline and range rings about the Swamp Mooring are shown in blue.
- (5) Range rings are drawn at 2 km intervals.

Figure 5.11 Probability of surface exposure resulting from a 500m³ condensate spill over 3 hours for the wet season

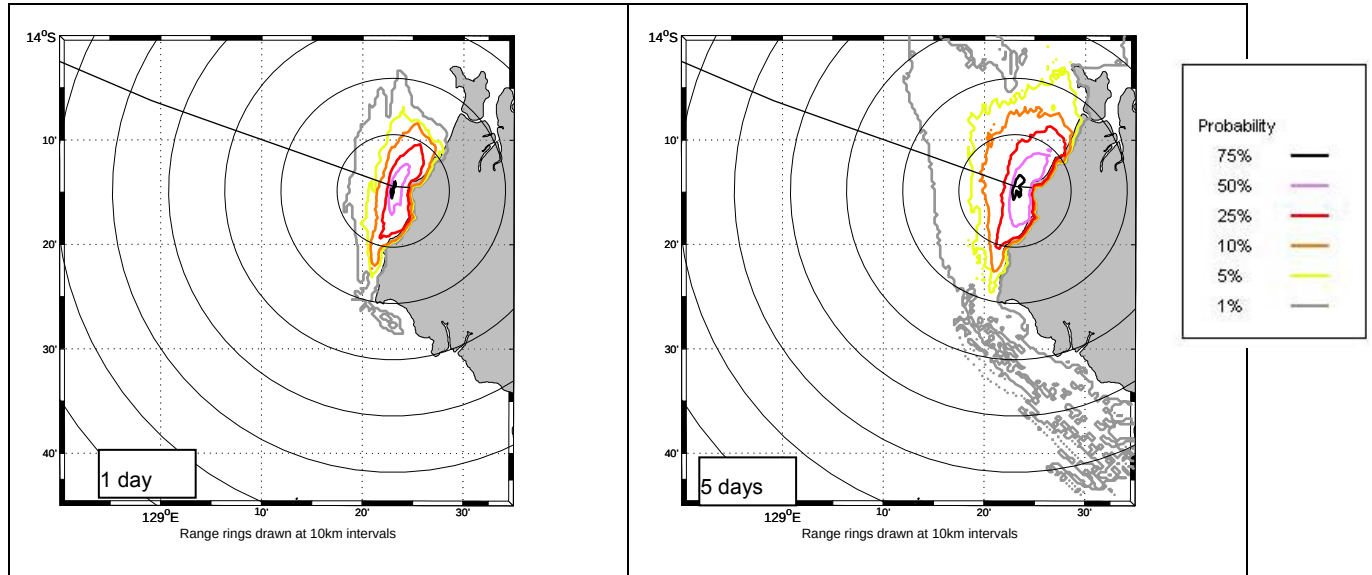
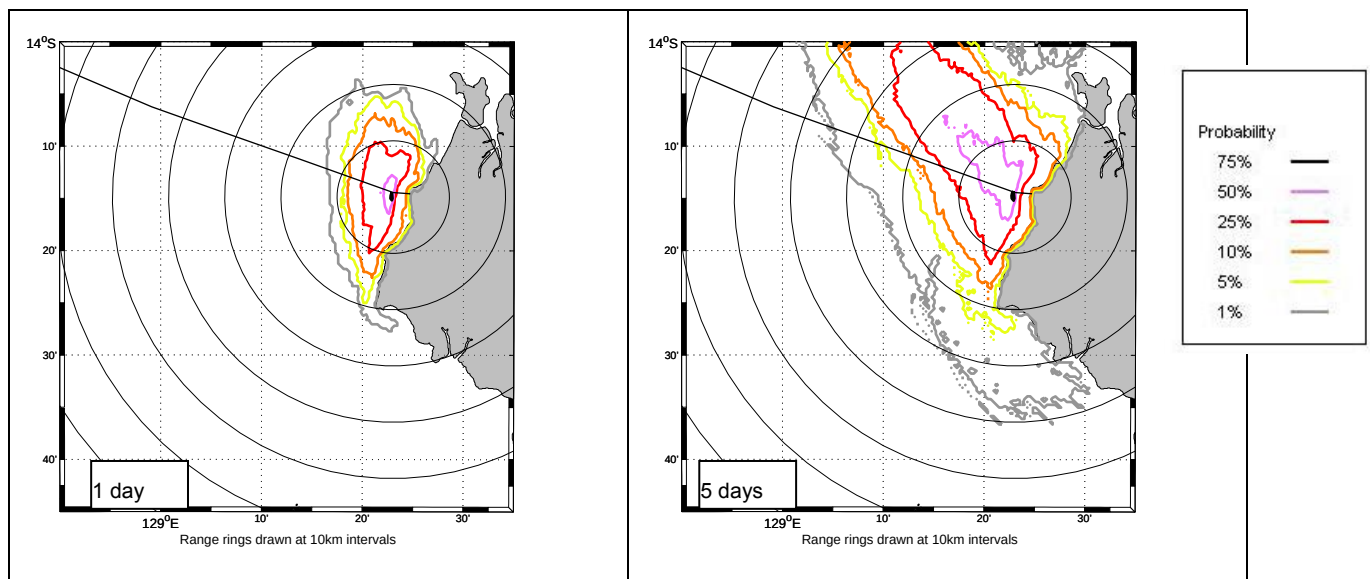


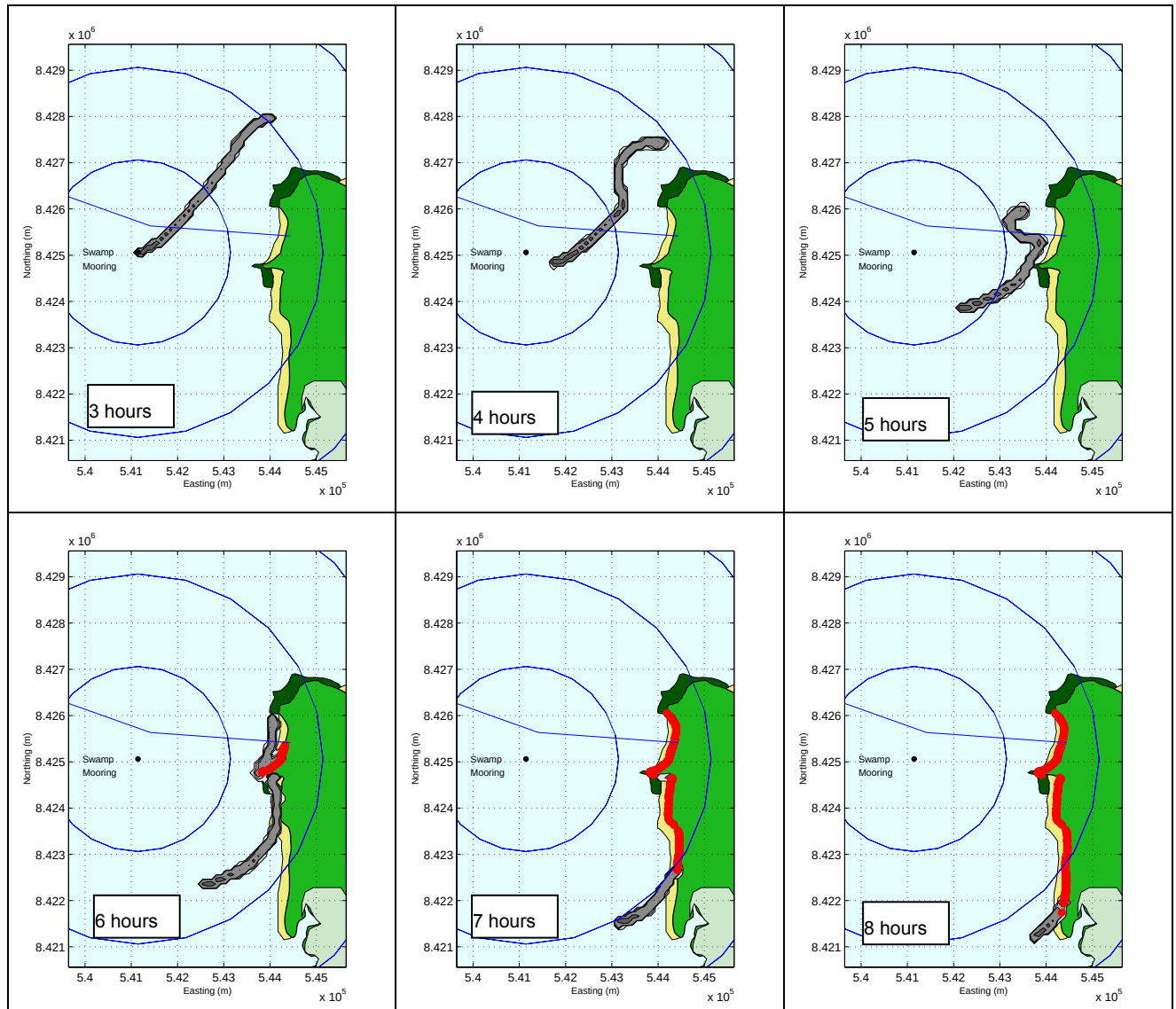
Figure 5.12 Probability of surface exposure resulting from a 500m³ condensate spill over 3 hours for the dry season



Notes:

- (1) The probability contours were calculated from 100 oil spill simulations using randomly selected wind and circulation data for the defined months of the specified seasons.
- (2) Significant oil concentrations assumed to be 0.005kg/m² (<10mL/m²).
- (3) Range rings are drawn at 10 km intervals.

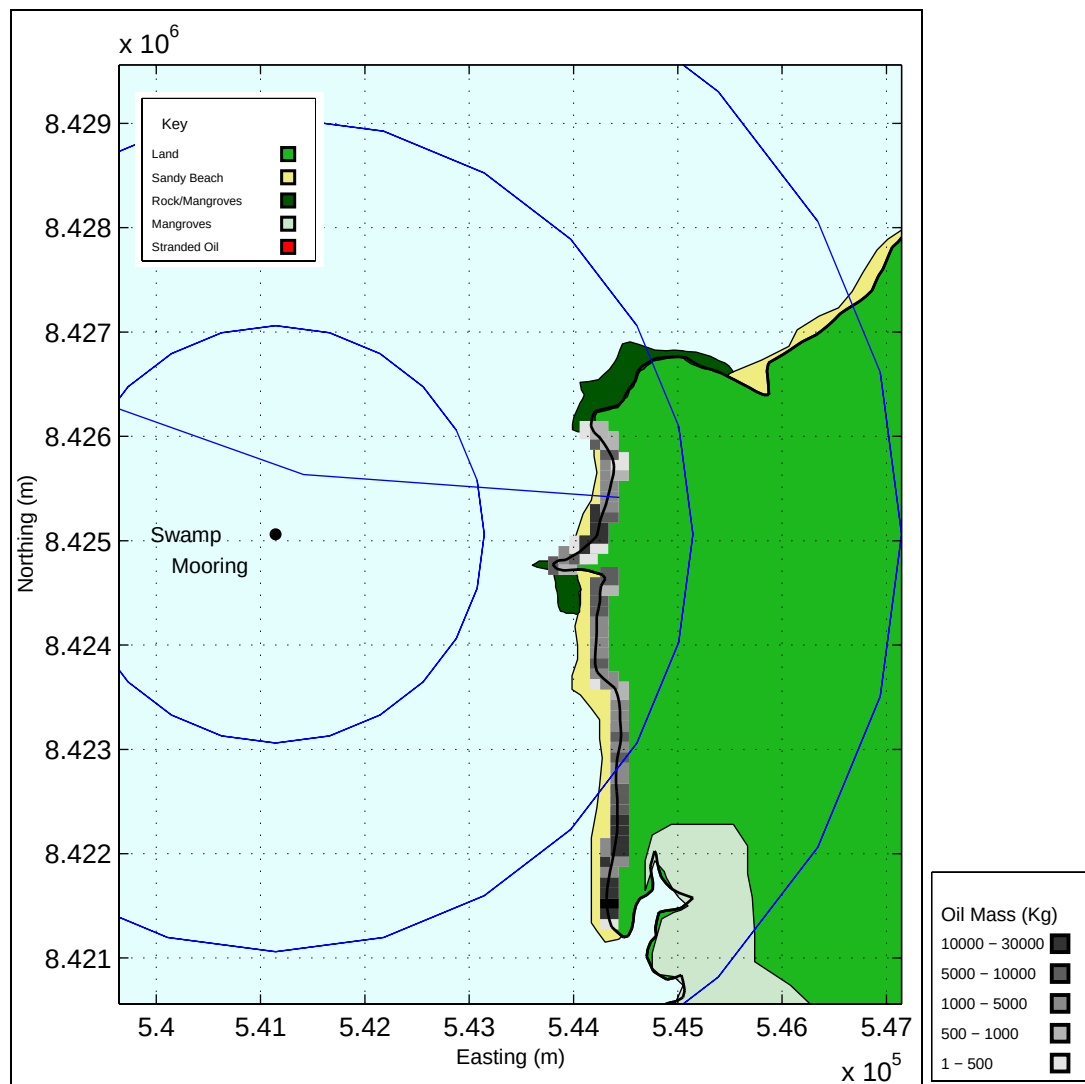
Figure 5.13 Predicted surface oil concentration for a 500m³ heavy oil fuel spill during a neap tide and an onshore 5 ms⁻¹ wind (wet season).



Conc. (Kg/m ²)	
5 - 10	
1 - 5	
0.1 - 1	
0.05 - 0.1	
0.01 - 0.05	

Key	
Land	
Sandy Beach	
Rock/Mangroves	
Mangroves	
Stranded Oil	

Figure 5.14 Predicted mass of beached oil for a 500m³ heavy oil fuel spill during a neap tide in the wet season.



Notes for Figure 5.13 and Figure 5.14:

- (1) Figure 5.13 shows the trajectory and predicted heavy fuel oil concentration for a 500m³ spill under worst-case conditions. The resulting mass of oil washed up on the beach is presented in the above figure. Note that the model does not allow outwashing of the condensate so this is the cumulative mass of oil that arrives on the beach with no further weathering processes applied. The largest mass of oil washed up is 32,000kg over 100m.
- (2) Stranded heavy fuel oil tends to remain on the surface rather than penetrate sediments. Natural degradation rates for these heavy oils are very slow and, if not cleaned up, the oil may persist on beaches for months to years.
- (3) Shoreline cleanup would be required. Adverse effects of floating heavy fuel oils are related primarily to coating of wildlife dwelling on the water surface, smothering of intertidal organisms, and long-term sediment contamination. Heavy fuel oil is not expected to be as acutely toxic to water column organisms as lighter oils. The likely environmental consequence with cleanup would be moderate with a recovery time of 5 – 10 years.
- (4) The proposed pipeline and range rings about the Swamp Mooring are shown in blue.
- (5) Range rings are drawn at 2 km intervals.

Figure 5.15 Probability of surface exposure resulting from a 500m³ heavy oil fuel spill over 3 hours for the wet season

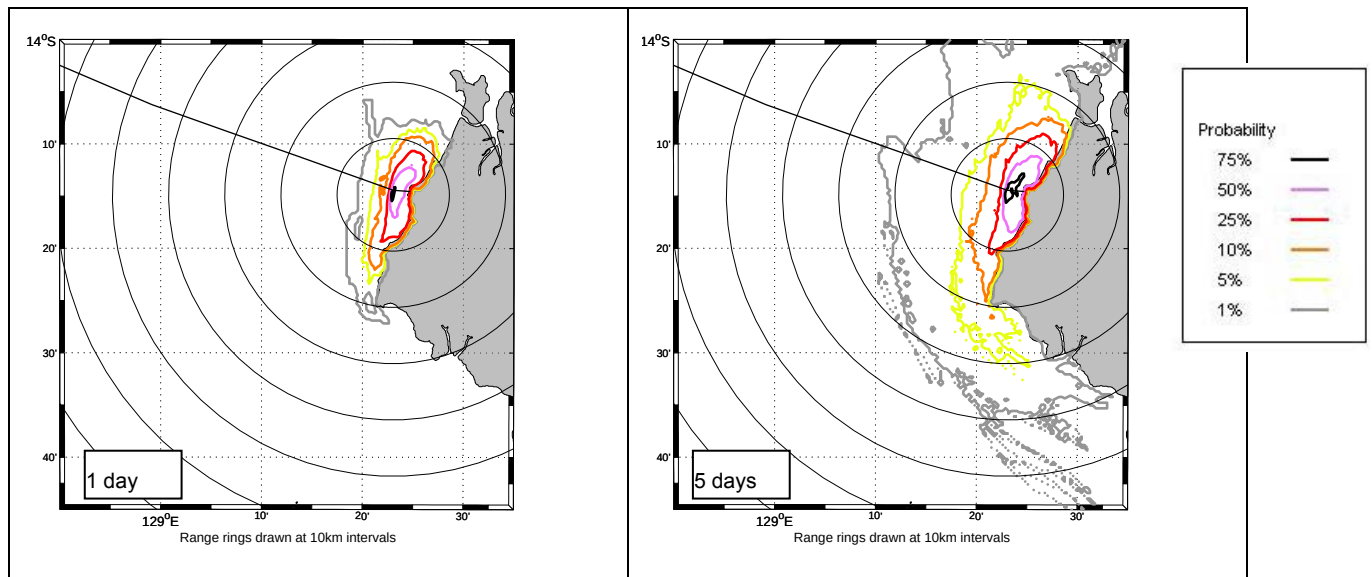
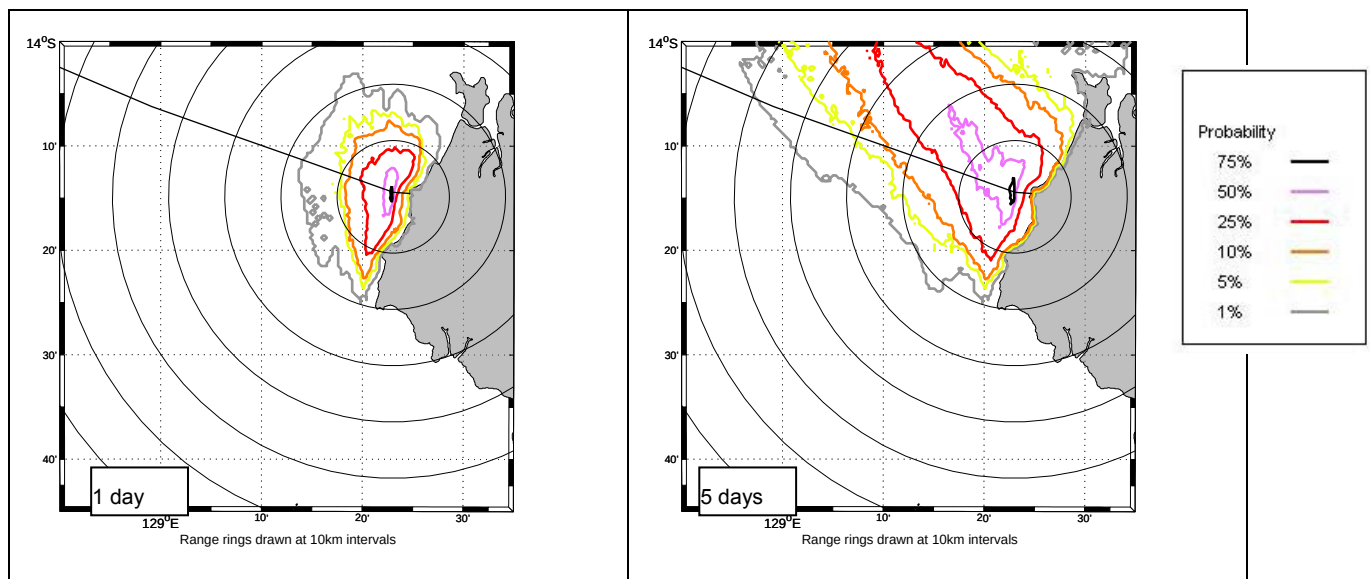


Figure 5.16 Probability of surface exposure resulting from a 500m³ heavy oil field spill over 3 hours for the dry season



Notes:

- (1) The probability contours were calculated from 100 oil spill simulations using randomly selected wind and circulation data for the defined months of the specified seasons.
- (2) Significant oil concentrations assumed to be 0.005kg/m² (<10mL/m²).
- (3) Range rings are drawn at 10 km intervals.

6 ENVIRONMENTAL IMPACT

6.1 Blacktip Condensate Spills

Small condensate spills will evaporate rapidly and are unlikely to reach environmentally sensitive areas in concentrations high enough to result in significant impact. In contrast, medium and large spills could persist at concentrations above toxic thresholds for longer durations. During the wet season there is a high probability that these will be washed ashore with minor, short term environmental damage.

Should condensate become stranded on the shoreline, it would tend to penetrate porous sediments and be washed away by waves and tidal currents. It would continue to evaporate and, over longer time scale of one to two months, any residual would be readily degraded by naturally occurring microbes. Shoreline cleanup should, therefore, not be required.

The condensate is likely to be acutely toxic and could cause mortality to floating and water column marine organisms that come into direct contact with a fresh spill. Toxicity will reduce with time as the oil weathers and specifically as the aromatic component evaporates.

6.2 Heavy Fuel Oil Spills

When spilt on water, heavy fuel oil usually spreads into thick, dark coloured slicks, which can contain large amounts of oil. The most viscous oils will often breakup into discrete patches and tarballs when spilled instead of forming slicks. Oil recovery by skimmers and vacuum pumps can be very effective early in the spill. Very little of this viscous oil is likely to disperse into the water column.

Due to its high viscosity, beached oil tends to remain on the surface rather than penetrate sediments. Light accumulations usually form at the high-tide line; heavy accumulations can pool on the beach. Shoreline cleanup can be very effective, before the oil weathers, becoming stickier and even more viscous. Natural degradation rates for these heavy oils are very slow. The oil may persist on beaches for months to years.

Adverse effects of floating heavy fuel oils are related primarily to coating of wildlife dwelling on the water surface, smothering of intertidal organisms, and long-term sediment contamination. Heavy fuel oil is not expected to be as acutely toxic to water column organisms as lighter oils.

Direct mortality rates can be high for seabirds, waterfowl, and fur-bearing marine mammals, especially where populations are concentrated in small areas, such as during bird or marine mammal migrations.

Direct mortality rates are generally less for shorebirds because they rarely enter the water. Shorebirds, which feed in intertidal habitats where oil strands and persists, are at higher risk of sublethal effects from either contaminated or reduced population of prey.

The most important factors determining the impacts of heavy fuel oil contamination on mangroves are the extent of oiling on the vegetation and the degree of sediment contamination from the spill or disturbance from the cleanup. Many plants can survive partial oiling; fewer survive when all or most of the above-ground vegetation is coated with heavy oil. Recovery of oiled mangroves depends on the initial and residual loading as well as damages resulting from cleanup efforts.

7 CONCLUSIONS

Tanker operations were considered to pose the greatest risk for an oil spill accident. For the purposes of modelling, four credible tanker operation scenarios were analysed for two different oil types:

- small (8m³), medium (100m³) and large (500m³) spills of Blacktip condensate during offloading to the trading tanker; and
- a 500m³ heavy fuel oil spill from a tanker fuel leak.

Blacktip condensate is a light oil that rapidly evaporates from the sea surface. Modelling indicates that more than 80% will be removed through evaporate within 24 hours of being spilt. Blacktip condensate is therefore non-persistent and is unlikely to result in long term environmental damage should a spill occur. In contrast heavy fuel oil is a viscous, non-volatile and persistent oil.

Oil would be transported predominantly onshore during the wet season and offshore during the dry season. As the tanker mooring is only 3km offshore there is a high probability of coastline contact during the wet season. Shoreline impact is possible in the dry season, however, the probability is substantially reduced.

Adverse effects resulting from a condensate spill are likely to be related to marine organisms in the water column coming into direct contact with a fresh spill. Toxicity of spilled condensate should reduce with time as the aromatic components volatilise and the oil becomes diluted. Shoreline cleanup may not be necessary as beached condensate will continue to evaporate once stranded and will be washed away naturally by tide and waves. Any residual will be removed by biodegradation and photo-oxidation processes over time frames of one to two months.

Adverse effects resulting from a heavy fuel spill are more likely to be related to coating of wildlife dwelling on the water surface, smothering of intertidal organisms, and long-term sediment contamination. Heavy fuel oil is not expected to be as acutely toxic to water column organisms as lighter oils.

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