Cairns Shipping Development Project

Ports North

APPENDIX D.12

Draft : Environmental Impact Statement

Appendix D.12

Oil Spill Risk and Exposure Modelling Study

OIL SPILL RISK AND EXPOSURE MODELLING STUDY FOR THE CAIRNS SHIPPING DEVELOPMENT (CSD) PROJECT EIS

Prepared for:

Ports North (July 2014).

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EXECUTIVE SUMMARY

Ports North, along with the EIS project team, undertook a workshop to identify risks associated with the Cairns Shipping Development. As part of the EIS for the Project, oil spill modelling is required to assess the risk of potential oil spills from construction and operational aspects of the Project. The operational aspects of the project, which include additional supply and storage of fuel at the port, were identified as representing a greater oil spill risk compared to construction stage aspects. Therefore, modelling of potential oil spills associated with the operational activities were undertaken and described herein. Oil spills risks from construction stage aspects, while not modelled, have been considered in the EIS and are addressed as part of the Environmental Management Plans.

The Hazard Identification Assessment of the new operations associated with the expansion was undertaken and revealed oil spill risks and potential incident scenarios related to two development areas within Port Limits, being the sea channel and the proposed Fuel Transfer operations at Wharf 3, within the Trinity Inlet estuary. For these sites, hypothetical spill scenarios were developed to: (1) quantify seasonal influences on spill fates; (2) include Maximum Credible and Most Probable Spill Scenarios and (3) cover a range of locations within the Port Limits being developed, as follows:

1. Winter risk assessment of a Fuel Transfer Accident involving a maximum credible spill of IFO 180/380 at coupling point near Wharf 3 while pumping IFO between the tank and a vessel (145º 46' 49.8"E 16º 55' 37.6"S) resulting in a loss of 38 m^3 of IFO over 0.5 hour (0.5 hrs x 21 L/s = 38 m^3).
2. Summer risk assessment of a Fuel Transfer Accident involving a maximum credible spill of IFO 180/380 at coupling point near Wharf 3 while pumping IFO between the tank and a vessel (145º 46' 49.8"E 16º 55' 37.6"S) resulting in a loss of 38 m^3 of IFO over 0.5 hour (0.5 hrs x 21 L/s = 38 m^3).
3. Winter risk assessment of a Fuel Transfer Accident involving a most probable spill of IFO 180/380 at coupling point near Wharf 3 while pumping IFO between the tank and a vessel (145º 46' 49.8"E 16º 55' 37.6"S) resulting in a loss of 7.6 m^3 of IFO over 6 minutes (0.1 hrs x 21 L/s = 7.3 m^3).
4. Winter risk assessment of a collision/grounding of one IFO 180/380 supply ship (small coastal oil tanker) while in transit in channel - a polyline release within the channel from the outer channel (145º 50' 6.3"E 16º 49' 30.1"S) to the inner channel (145º 47' 6.5"E 16º 55' 1.3"S) resulting in a maximum credible loss of 700 m^3 of IFO from a collision with smaller vessel over 1 hour.
5. Summer risk assessment of a collision/grounding of one IFO 180/380 supply ship (small coastal oil tanker) while in transit in channel - a polyline release within the channel from the outer channel (145º 50' 6.3"E 16º 49' 30.1"S) to the inner channel (145º 47' 6.5"E 16º 55' 1.3"S) resulting in a maximum credible loss of 700 m^3 of IFO from a collision with smaller vessel over 1 hour.
6. Winter risk assessment of a collision/grounding of one IFO 180/380 supply ship (small coastal oil tanker) while in transit in channel - a polyline release within the channel

from the outer channel (145º 50’ 6.3”E 16º 49’ 30.1”S) to the inner channel (145º 47’ 6.5”E 16º 55’ 1.3”S) resulting in a most probable loss of 140 m^3 (being 20% of a 700 m^3) of IFO from a collision with smaller vessel over 1 hour.

The oil spill modelling was performed using a purpose built oil spill trajectory and weathering model (OILMAP) with stochastic ability, to analyse and summarize hundreds of spill simulations. Using high resolution modelled currents of the region and measured winds from coastal wind stations, OILMAP simulated the transport, spreading and weathering of the specific oil types under the influence of the changing meteorological and oceanographic conditions of the study region. For each spill scenario, the OILMAP stochastic model analysed the multitude of predictions to assess the probability of oil exposure to surrounding regions, including any shoreline exposure, as well as the minimum time and weathered state that exposure to a certain location could potentially be. The stochastic modelling approach involves simulating each of the hypothetical incidents many times (e.g. 200) using the same spill information (i.e. release location, spill volume, duration and oil type) but randomly varying the start time and in turn the prevailing wind and current conditions. This approach ensured that the predicted transport and weathering of an oil slick was subjected to a range of varying weather conditions for a given period and hence objectively quantified risk to surrounding resources. The extents of risk were defined using two thickness thresholds being 10 µm (0.01 mm) as the minimum thickness that would potentially produce an ecological impact to sensitive species and 0.5 µm (0.0005 mm) as the minimum thickness extent of visible oil as observed from an aircraft.

Collectively, 200 spill simulations were conducted for the six scenarios above, making 1,200 simulations in total for spills within the Port Limits. The results from these scenarios were reviewed and reported herein. Note that the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities and arrangements that the Port of Cairns has in place. The modelling makes no allowance for intervention following a spill to reduce volumes and/or prevent hydrocarbons from reaching sensitive areas, hence the risk profiles would be overstated.

Collectively, the findings of the oil spill risk assessment can be summarised as follows:

1. Any spill of IFO 180/380 in the tropical conditions of the Port of Cairns was quantified by the modelling undertaken herein to initially be highly evaporative, that is, will lose its light components quickly (more than 25% of total spill volume within the first 10 hours). The modelling also demonstrated that IFO 180/380 will also have slightly more than 50% residual components, so is persistent in the marine environment. These residual components will form tarballs and tarpads, once fully weathered, which will be semi solid. Over time, suspended sediment in the waters of the Port of Cairns may also adhere to the residual oil, potentially causing it to sink after about one or two weeks exposure to any suspended sediments, particular if a spill coincides with a significant rainfall and river discharge event.

2. A significant outcome of the 1,200 simulations undertaken for this study was that any spill within the Port of Cairns will come ashore and more than 50% of any spill volume will be trapped on shorelines. This will include intertidal regions that might be exposed at the time of any surface oil being in that area at the time of exposure.

3. In the estuary of the Port of Cairns (the proposed fuel transfer berth at Wharf 3), the fate of any spill of IFO 180/380 is significantly tidally driven, moving in and out with the tidal currents during the flood and ebb tidal phases. A comparison of the fates of spill during summer and winter demonstrates there is little seasonal difference in terms of the fate of the oil.

4. For any spill at Wharf 3 within the Port of Cairns estuary, wind may have a small influence on the fate of a spill during an ebb tide coinciding with a moderate to strong wind from the south, pushing any surface oil into the nearshore coastal region. In any event, an onshore wind (southeast or northeast) coinciding with a spill Wharf 3 is likely to expose fumes from the high initial evaporation of IFO 180/380 into populated areas on land (Cairns City and adjoining areas along the foreshore and estuary).

5. In the coastal region, in particular, the sea channel, the fate of any spill of IFO 180/380 is significantly wind driven. The predominant wind direction over the Port of Cairns waters is significantly from the southeast. For this wind direction, migration northwestward is possible. The distance that thick oil (> 10 Microns) can migrate northwards is significantly further for a Maximum Credible spill volume in comparison to a Most Probable spill volume.

6. Shorelines north of Cairns are populated, and shoreline impacts occurred in less than 10 hours of release in some simulations of a spill anywhere along the sea channel. Fresh (<10 hours old) shoreline trapped IFO 180/380 will evaporate even when onshore, creating a hydrocarbon vapour plume that may blow onshore with the wind that brought the oil ashore. The modelling indicated that the vapours may persist for up to 10 days for a Maximum Credible Spill Volume. Further, any surface oil reaching beaches with breaking wave action along the shore were predicted to potentially emulsify, incorporate suspended sediment and sink after a period of days if not recovered and collected before that time.

7. A comparison of the seasonal influences (that is, summer and winter conditions) on spill fate within the region revealed little variance in spill outcomes between summer and winter conditions, other than winds tend to be more variable and overall weaker in summer than winter. For that reason, a very small amount of thick oil (> 10 microns) with small probability (< 5% risk) may move offshore and into the Great Barrier Reef matrix.

8. From the 1,200 simulations undertaken for this study, only 4 simulated spills were predicted to reach the mid shelf reefs of the Great Barrier Reef at thicknesses above 10 microns, indicating a very low to insignificant risk to the offshore reefs from spills within the Port Limits of Cairns.

9. The threshold specified by the Australian Maritime Safety Authority (AMSA 2013 guidelines) for the extent of visible oil at 0.5 microns reflects typical visual pollution, but not ecological risk. 0.5 microns is a very thin film of oil which is visible due to the refractive behaviour of sunlight shining on a thin film on water. Under ideal viewing conditions (calm water and good visibility), films as thin as 0.04 microns (typically silvery sheens) can be visible and may be visible outside of the extents shown herein.

1 INTRODUCTION

The Cairns Shipping Development (CSD) Project involves the widening and deepening of the existing channel to allow the passage of larger cruise ships into the Port of Cairns (Figure 1). Upgrade to port infrastructure, such as inclusion of additional fuel storage facilities, is also required to accommodate the cruise ships. As part of the EIS for the CSD Project, Ports North (which manages the Port of Cairns) commissioned an oil spill risk assessment in accordance with Section 5.10.11 of the Federal EIS guidelines for the project. The oil spill risk assessment was undertaken in parts and included a Hazard Identification Assessment and an Oil Spill Modelling study to quantify and assist with managing oil spill risks associated with the proposed project.

This report describes the outcomes of the Hazard Identification Assessment process and details the new and/or changed oil spill risks within the Port Limits that are associated with the CSD project. The report also describes the oil spill modelling component in detail which simulated credible spill scenarios using the planned bathymetric modifications and its influence on the water flows within the Port.

Please note that the OILMAP system, the methods and analysis presented herein use modelling algorithms which have been anonymously peered reviewed and published in international journals and this work meets and exceeds the ASTM Standard F2067-07 “Standard Practice for Development and Use of Oil Spill Models”.

Note that the modelling does not take into consideration any of the spill prevention, mitigation and response capabilities and arrangements that the Port of Cairns has in place. The modelling makes no allowance for intervention following a spill to reduce volumes and/or prevent hydrocarbons from reaching sensitive areas.

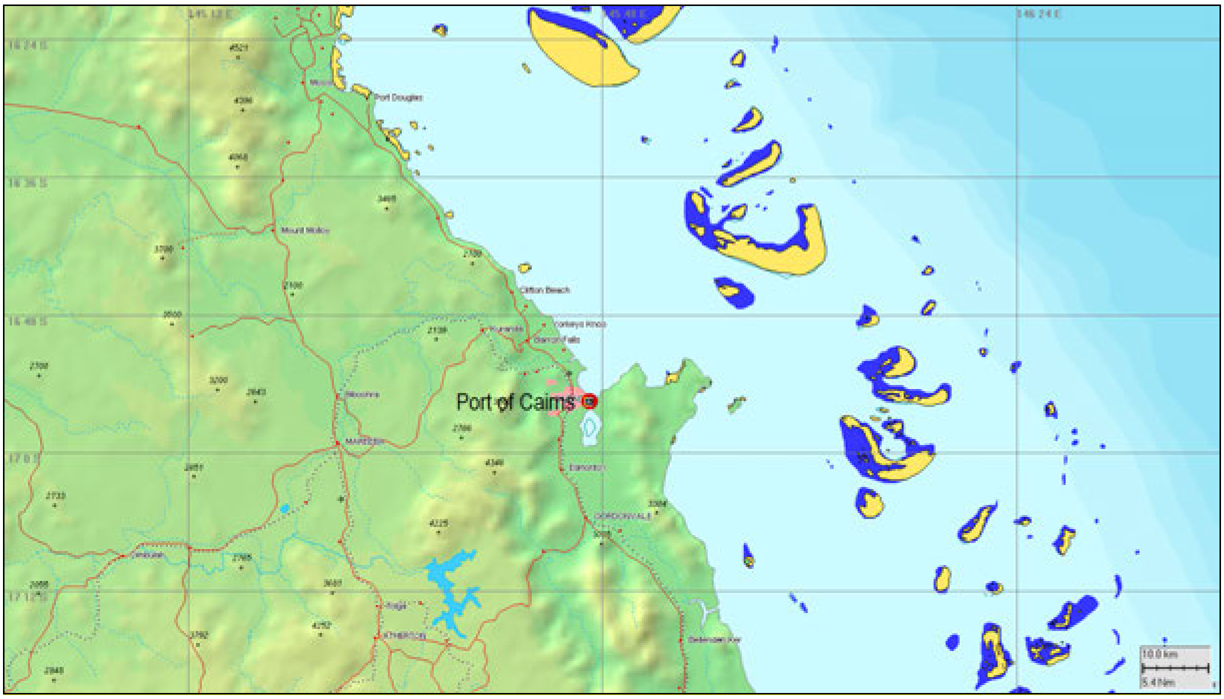

Figure 1: Map showing Port of Cairns and surrounding features.

2 HAZARD IDENTIFICATION ASSESSMENT

Ports North, along with the EIS project team, undertook a workshop to identify risks associated with the Cairns Shipping Development. As part of the EIS for the Project, oil spill modelling is required to assess the risk of potential oil spills from construction and operational aspects of the Project. The operational aspects of the project, which include additional supply and storage of fuel at the port, were identified as representing a greater oil spill risk compared to construction stage aspects. Therefore, modelling of potential oil spills associated with the operational activities were undertaken and described herein. Oil spills risks from construction stage aspects, while not modelled, have been considered in the EIS and are addressed as part of the Environmental Management Plans.

Existing oil spill hazards at the port related to current operations such as the mooring of cruise ships, fuel bunkering and cargo shipments will not be assessed. As cruise ship activity already occurs in the existing port, the Project will not result in any changes to these activities. As a note one of the main cargo shipments into Cairns is fuel, with fuel vessels up to 30,000 DWT currently accessing the Port.

Cruise ships operating in Australian water use IFO (intermediate fuel oil) 180/380. As such, the fuel to be stored at the Port of Cairns, and to be used for refuelling of cruise ships, is IFO 180/380. IFO is a blend of HFO (heavy fuel oil) and marine gas oil.

IFO would likely be continued to be supplied to the Port of Cairns via a small coastal oil tanker with an approximate size of 30,000 DWT (typical size of a coastal oil tanker). IFO is not currently available to cruise ships at the Port of Cairns. The existing fuel farm is the preferred location for new fuel storage infrastructure. IFO supply to wharves 1-5 will be provided via a dedicated pipeline with a pump station in the storage area. A minor building near wharf 3 will allow the connection of the onshore services with the vessel fuel services. This will be the coupling point for IFO supply vessels (oil tankers).

As the IFO storage area will be bunded, spills from the storage tank are considered to represent a relatively low risk. However, the supply pipeline and the coupling point at Wharf 3 represent a higher risk where a Fuel Transfer Accident could occur.

On advice from port operational personnel, fuel transfer operations will be observed at all times. Hence a realistic maximum credible spill scenario would be 0.5 hours of pumping before the system can be shut down in the case of an incident occurring. Therefore, fuel loss for a Fuel Transfer Accident is assumed to be 38 m^3 (0.5 hours of pumping at 21 L/s before the system can be shut down).

Another risk area involves the movement of the IFO supply vessel (the small coastal oil tanker) along the channel area, where collision and grounding risks are increased. Given the shallow and wide spread soft muddy benthos of the Cairns Harbour, the collision risk is higher than the grounding risk. For the channel, where only one large ship can be in the channel at one time, a collision here would involve a smaller vessel potentially entering the channel midway along.

Consequently, the maximum credible spill of IFO is a collision with a smaller vessel, that is, a slight collision, but potentially resulting in the complete loss of one wing fuel tank. The typical size of a coastal oil tanker that would likely supply the Port of Cairns would be approximately 30,000 DWT. Correspondingly, the Queensland Coastal Contingency Action Plan 2011 (QCCAP 2011) identifies that the maximum spill volumes associated with a slight collision and grounding risks associated with the tank sizes of 30,000 DWT oil tankers to be 700 m^3.

The AMSA 2013 guidelines suggest that stochastic spill modelling be used to quantify the risk of related impacts associated with the risk scenarios developed through the Hazard Identification Assessment workshop. From the two sites selected above, a range of spill scenarios were developed to: (1) quantify seasonal influences on spill fates; (2) include Maximum Credible Spill Scenarios and (3) cover a range of locations within the port limits. In summary, the two identified hazard changes resulted in the following scenarios modelled:

1. A Fuel Transfer Accident involving an IFO spill at the coupling point near Wharf 3 in the port (145º 46' 49.8"E 16º 55' 37.6"S) while transferring IFO between the storage tank and a vessel. A Maximum Credible spill volume would be the loss of 38 m^3 of fuel (0.5 hrs of pumping at 21 L/s) while a Most Probable spill volume would be the loss of 7.6 m^3 of fuel (0.1 hrs of pumping at 21 L/s). The assessment also involved simulations covering either summer or winter conditions or both.
2. Collision of IFO supply vessel (oil tanker) with smaller vessel in channel – line release between outer channel (145º 50' 6.3"E 16º 49' 30.1"S) and inner channel (145º 47' 6.5"E 16º 55' 1.3"S). This spill may result in the loss of up to 1 tank containing up to 700 m^3 of fuel. A Maximum Credible spill volume would be the loss of the entire tank (700 m^3 of fuel) while a Most Probably spill volume would be the loss of 20% of one tank (140 m^3 of fuel). The assessment involved simulations covering either summer or winter conditions or both.

The stochastic oil spill modelling selected for the risk assessment was OILMAP, which is designed to simulate the transport, spreading and weathering of specific oil types under the influence of changing meteorological and oceanographic forces. It is also the Oil Spill Trajectory Model (OSTM) for the National Plan. The findings from this assessment will assist Ports North to assess the potential risks and to develop appropriate oil spill contingency plans.

3 SCOPE OF WORK

The modelling scope of work included:

1. Incorporate the high resolution currents developed by BMT WBM that included the new outer harbour development influence on flow fields for the summer and winter months, when currents were typically at their strongest. The high resolution grid will be incorporated with regional currents (for example, HYCOM with tides) from the APASA COASTMAP Environmental Data Server (EDS) as used by SAR agencies for the Great Barrier Reef and Coral Sea for the period 2007 to 2014. These broader scale datasets are modelled from observations of ocean state from ongoing Global

Satellite Ocean Altimetry and Temperature measurements over 25 years. They are also the same used for notable spill events (Montara, AMSA, SEWPAC Studies and MSQ for Pacific Adventurer and Sheng Neng Grounding on the Great Barrier Reef);

2. Use ambient wind data, current data and detailed oil characteristics as input into the OILMAP Stochastic Model to undertake 200 spill simulations for each season (summer and winter)to predict the range of potential movement and weathering of spilt oil originating from the two hypothetical spill scenarios;
3. For each spill scenario, analyse the multitude of predictions to assess the probability of oil exposure to surrounding regions, including any shoreline exposure, as well as the minimum time and weathered state that exposure to a certain location could potentially be; and
4. Report on the single trajectories, (identified from the stochastic results) which resulted in the maximum volume of oil to reach the shore where possible.

4 REGIONAL CURRENTS

The Port of Cairns is adjacent to the City of Cairns and lies north of Cape Grafton. Offshore of Cape Grafton is the Great Barrier Reef; the closest offshore reef is known as Green Island. The flows inshore of this reef are tidal and wind driven.

The tides flood into the Port of Cairns from the Coral Sea in a southwest movement typically and ebb to the northeast in a semi diurnal cycle (12 hours) with a diurnal inequality. The tides also demonstrate a Spring/Neap cycle, resulting in greater tidal height ranges and stronger tidal currents during the springs.

Wind forcing on surface flows is typically from the Southeast direction which pushes inshore waters northward. These can contribute significantly to the net drifts in the region, more so than the tidal flows which oscillate backwards and forwards with the semi diurnal cycle.

It is important to note, that while there is considerable influence on shelf waters in general from the offshore deepwater East Australian Current, none of this exists within the sheltered Port of Cairns, due to the blocking influences of Cape Grafton.

5 REGIONAL WINDS

To account for the wind influence on any oil spill, high resolution wind data was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha, et al., 2010). CFSR wind model is a fully coupled, data-assimilative hindcast model representing the interaction between the earth's oceans, land

and atmosphere and incorporates wind measurements where available. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals.

The CFSR wind data for the years 2009–2013 (inclusive) was extracted across the entire model domain for input into the oil spill model. Figure 2 shows a snapshot of the winds during the winter months.

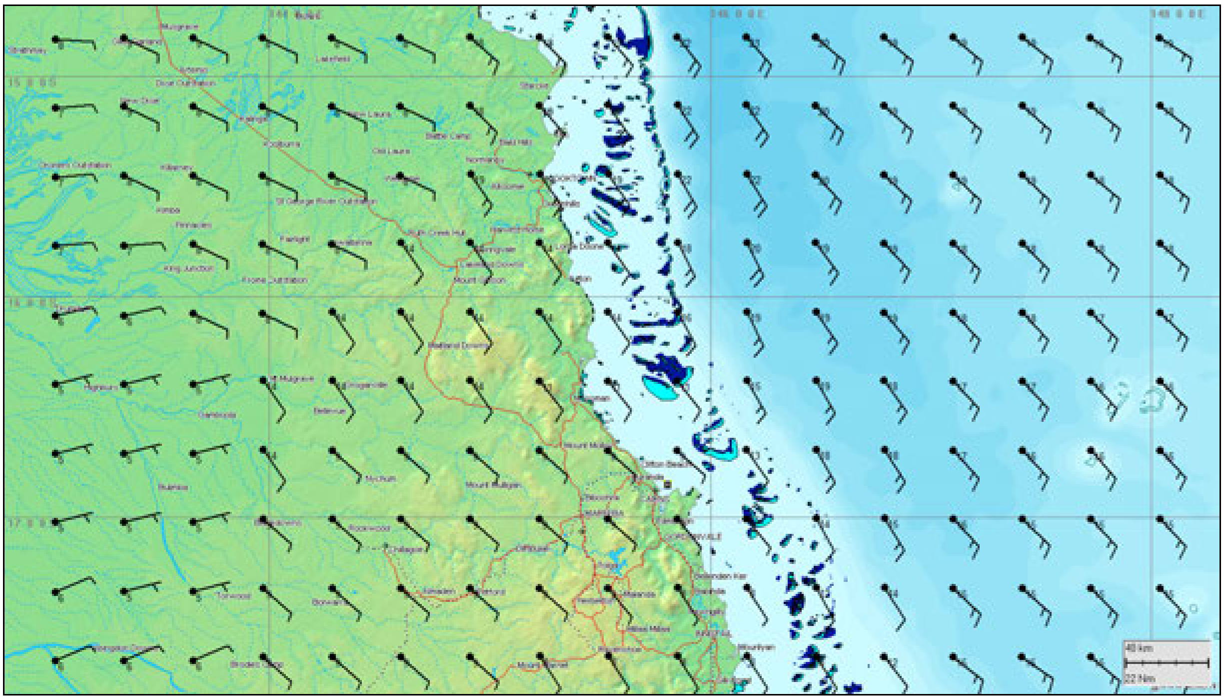

Figure 2: Map showing wind barbs (speed and direction) for moderate southeast winds over the Cairns Region and the Northern Great Barrier Reef.

Figure 3 shows the monthly wind rose distributions for Cairns. Note that the atmospheric convention for defining wind direction, that is, the direction the wind blows **from**, is used to reference wind direction throughout this report. Each branch of the rose represents wind coming from that direction, with north to the top of the diagram. Twelve directions are used. The branches are divided into segments of different length and thickness which is proportional to the frequency of winds from that direction and colour coded to indicate the relative wind seeds that have occurred from that direction.

Figure 3 shows that winds are typically from the southeast direction. Further, winds are typically stronger during winter than summer.

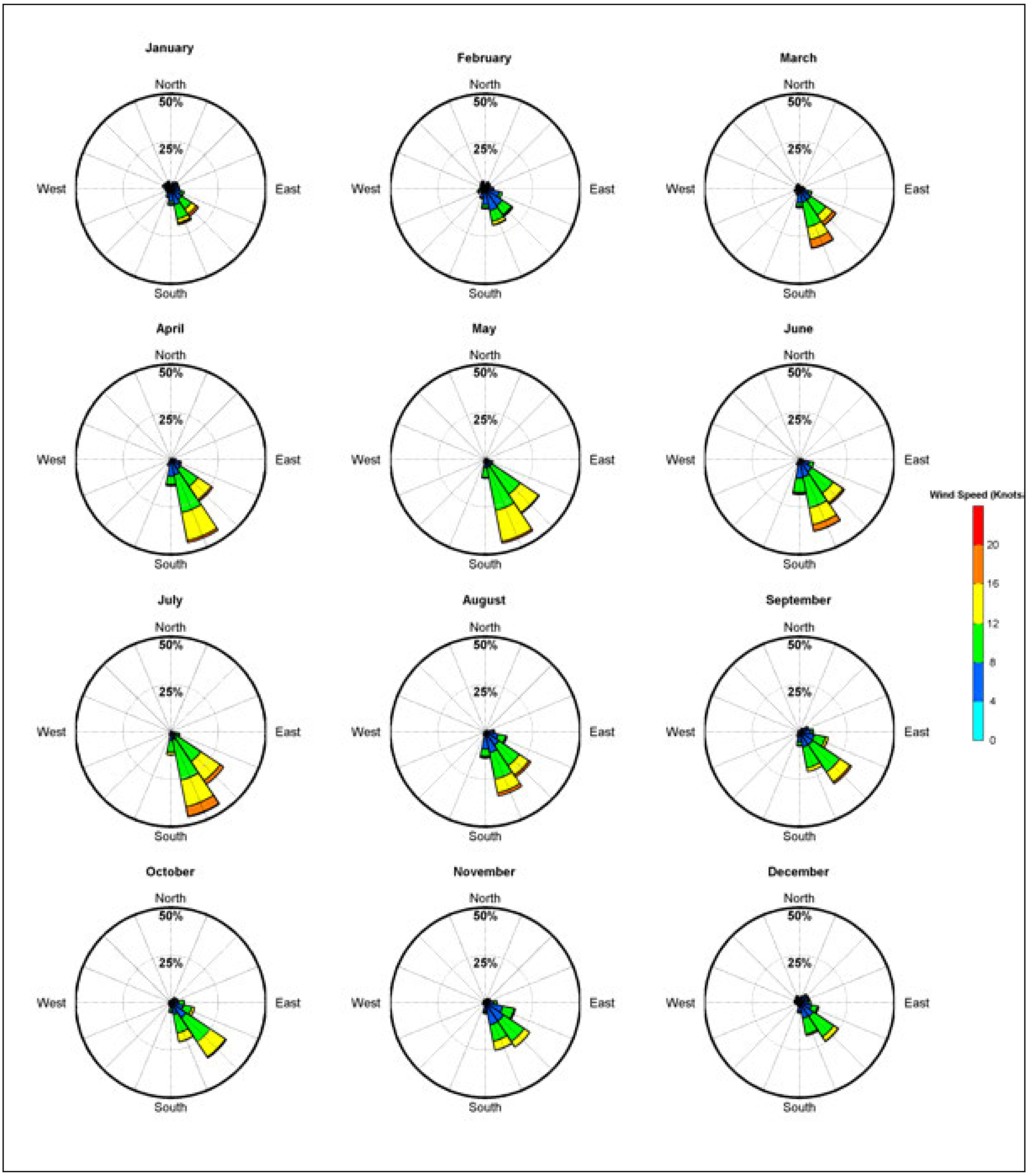

Figure 3: Monthly wind rose distribution for the winds just offshore of the Port of Cairns during 2009 to 2013, inclusive.

6 WATER TEMPERATURE

Average coastal sea surface water temperature for Cairns according to the National Oceanographic Data Centre – World Ocean Atlas was found to vary seasonally from a minimum of 24 ºC in winter to a maximum of 29 ºC in summer.

7 OIL SPILL MODEL - OILMAP

The spill modelling was carried out using a purpose-developed trajectory and fates model, OILMAP. The OILMAP physical fates model calculates the transport, spreading, entrainment and evaporation of spilled oil over time, based on the prevailing metocean conditions and the physical properties of the oil type.

The model uses the specific properties of each oil type to predict weathering under different conditions. These specific properties include the density, viscosity, surface tension and the slope of the distillation curve. These properties are used to determine the oil's spreading, evaporation, entrainment and shoreline interactions. If oil reaches the shorelines (as defined in the OILMAP GIS), details are recorded on the quantity, travel time to contact the shore, and habitat resources at the stranding location. It also incorporates a geographic information system (GIS) for defining the location and nature of natural resources, which is often helpful in analysing and interpreting model predictions. Predictions of the OILMAP model have been validated worldwide (Spaulding *et. al.* 1992, 1994) including in Australia (King *et. al.* 1999).

7.1 Stochastic Modelling

OILMAP may be used to simulate the fate of a single oil spill at a specified time and therefore under a given set of time-varying wind and current conditions. This is generally the approach for an exercise or known spill event.

As spills can occur during any set of wind and current conditions, OILMAP's stochastic module is required to quantify the risks for a given period (e.g. season), as has been done in this study. The stochastic modelling approach involves running multiple single simulations (e.g. 100) using the same spill information (i.e. release location, spill volume, duration and oil type) but varying the start time and in turn the prevailing wind and current conditions. This approach ensures that the predicted transport and weathering of an oil slick is subjected to a range of varying weather conditions for a given period.

During each simulation, the model records the areas exposed to oil, as well as the time elapsed prior to contact or exposure. Once the stochastic modelling is complete, the model output and statistical descriptors for each of the individual simulations are combined to determine:

- Probability that a region (or grid cell) may be exposed to oil slicks;
- Minimum time before exposure and
- Probability of shoreline exposure.

The model output estimators (probability and time) are calculated independently for each location in the grid and the stochastic model output <u>does not</u> represent the extent of any one spill event (which would be significantly smaller) but rather provides a summary of the individual simulations for a given period/season. For this assessment, 200 simulations were performed for each scenario and combined into a single stochastic output for each scenario and season. This equated to 800 individual simulations for the entire assessment.

7.2 Oil Thickness Threshold

The OILMAP model is able to track oil on the water surface to thicknesses that are lower than biologically significant, or that can be physically cleaned up. Therefore the threshold for oil on the sea surface was set to a minimum thickness of 0.5 µm (0.0005 mm) based on the AMSA 2013 guideline being the extent of visible oil as observed from an aircraft. A minimum thickness for ecological impact of 10 µm (0.01 mm) based on the AMSA 2013 guideline is also helpful for response planning. Oil at these threshold thicknesses are described as a rainbow sheen in appearance (for the lower threshold) to a metallic sheen appearance (for the higher threshold), according to the Bonn Agreement Oil Appearance Code (BAOAC) 2006 (see Table 1). Figure 4 demonstrates the difference in appearance between a silvery sheen, rainbow sheen and metallic sheen on the water's surface.

Table 1: The Bonn Agreement Oil Appearance Code.

Code	Description Appearance	Layer Thickness Interval (µm)	Litres per km^2
1	Sheen (silvery/grey)	0.04 – 0.30	40 – 300
2	Rainbow	0.30 – 5.0	300 – 5,000
3	Metallic	5.0 – 50	5,000 – 50,000
4	Discontinuous True Oil Colour	50 – 200	50,000 – 200,000
5	Continuous True Oil Colour	200 – >200	200,000 – >200,000

Figure 4: A photograph showing the difference between metallic appearance in the centre and the silvery and rainbow sheen oil around the edges. The thickness of the metallic is between 5 µm - 50 µm; rainbow sheen is between 0.3 µm – 5.0 µm; and silvery sheen is between 0.04 µm – 0.3 µm. The thickness of the (source: Bonn Agreement Aerial Surveillance Handbook, 2004 – Part 3, Annex A).

7.3 Model Settings and Assumptions

Oil spill modelling was undertaken to examine the possible outcomes associated with two potential spill locations and differing factors such as spill volume, tidal and seasonal influences. These were modeled using stochastic analysis of 200 different weather outcomes for each scenario as follows:

1. Winter risk assessment of a Fuel Transfer Accident involving a maximum credible spill of IFO 180/380 at coupling point near Wharf 3 while pumping IFO between the tank and a vessel (145º 46’ 49.8”E 16º 55’ 37.6”S) resulting in a loss of 38 m^3 of IFO over 0.5 hour (0.5 hrs x 21 L/s = 38 m^3).
2. Summer risk assessment of a Fuel Transfer Accident involving a maximum credible spill of IFO 180/380 at coupling point near Wharf 3 while pumping IFO between the tank and a vessel (145º 46’ 49.8”E 16º 55’ 37.6”S) resulting in a loss of 38 m^3 of IFO over 0.5 hour (0.5 hrs x 21 L/s = 38 m^3).
3. Winter risk assessment of a Fuel Transfer Accident involving a most probable spill of IFO 180/380 at coupling point near Wharf 3 while pumping IFO between the tank and a vessel (145º 46’ 49.8”E 16º 55’ 37.6”S) resulting in a loss of 7.6 m^3 of IFO over 6 minutes (0.1 hrs x 21 L/s = 7.3 m^3).
4. Winter risk assessment of a collision/grounding of one IFO 180/380 supply ship (small coastal oil tanker) while in transit in channel - a polyline release within the channel from the outer channel (145º 50’ 6.3”E 16º 49’ 30.1”S) to the inner channel (145º 47’ 6.5”E 16º 55’ 1.3”S) resulting in a maximum credible loss of 700 m^3 of IFO from a collision with smaller vessel over 1 hour.
5. Summer risk assessment of a collision/grounding of one IFO 180/380 supply ship (small coastal oil tanker) while in transit in channel - a polyline release within the channel from the outer channel (145º 50’ 6.3”E 16º 49’ 30.1”S) to the inner channel (145º 47’ 6.5”E 16º 55’ 1.3”S) resulting in a maximum credible loss of 700 m^3 of IFO from a collision with smaller vessel over 1 hour.
6. Winter risk assessment of a collision/grounding of one IFO 180/380 supply ship (small coastal oil tanker) while in transit in channel - a polyline release within the channel from the outer channel (145º 50’ 6.3”E 16º 49’ 30.1”S) to the inner channel (145º 47’ 6.5”E 16º 55’ 1.3”S) resulting in a most probable loss of 140 m^3 (being 20% of a 700 m^3) of IFO from a collision with smaller vessel over 1 hour.

Each scenario was tracked to a threshold thickness as suggested by the AMSA 2013 guidelines, being 0.5 micron which is the extent of visible oil from an aircraft and 10 microns, which is the lowest thickness for which an ecological impact has been observed (smothering for example to sensitive species).

8 MODELLING RESULTS

8.1 Maximum Credible Spill during Fuel Transfer

Stochastic spill modeling was used for the winter season and summer season quantitative risk assessment for a Fuel Transfer Accident. The incident involved a spill of IFO 180/380 at coupling point near Wharf 3 while pumping IFO between a vessel and the onshore storage tank resulting in a maximum credible loss of 38 m^3 of IFO over 0.5 hour (0.5 hrs x 21 L/s = 38 m^3).

A representative worst-case single spill simulation was selected from the 400 simulations carried out for each both seasons. The basis of selection was typically to demonstrate how the largest volume ashore occurred from the many simulations (200 for each season) during an incoming (flood) tide.

8.1.1 Worst-Case Spill during Fuel Transfer

The worst-case volume on shore from a 38 m^3 spill of IFO was 26 m^3, due to evaporation of the volatile components within IFO in the tropical conditions of Cairns Harbour. Oil stranded ashore within minutes of release due to the close proximity of the shoreline to the release location. The spill in this example occurred just prior to low tide, so was drawn into the estuary shortly after the spill commenced, loosing oil to the shorelines as it travelled. At the turn of the tide, a significant amount of oil evaporated and weathered oil became trapped along the shorelines and intertidal areas within the estuary. As the tide began to ebb (6 hours after the spill occurred), the remaining weathered oil travelled out of the estuary into the channel. After 12 hours, the incoming flood tide and predominant wind from the southeast, pushed weathered thin oil onto the Cairns foreshore.

Figure 6 to Figure 11 shows the time sequence of oil movement from the spill event. The slick was initially made up of significantly true colour (Black) and discontinuous true colour (Transparent Black) surrounded by heavy sheens (within 1 hour). Mass was lost overtime (Figure 7 and Figure 8) due to evaporation and oil stranding along shorelines and intertidal muds, and was composed of discontinuous true colour (Transparent Black) surrounded by heavy sheens (within 3 hours) which thinned out to rainbow sheens within 6 hours. By 9 hours (Figure 9), the slick had lost most of its mass to black oil stranding along shorelines and intertidal muds and evaporation. The slick was over a 1 km in length but predominantly existed as a large slick of brightly rainbow colours sheens with some heavy sheen patches. After 12 hours (Figure 10), the slick had lost almost all of its mass to black oil stranding along shorelines and intertidal muds and evaporation. The remnant slick was now only small patches of brightly coloured rainbow colours sheens that were eventually pushed by the wind onto the Cairns foreshore. Figure 11 shows the final shoreline stranding image, including the area of the water surface that had been swept by oil.

Figure 5 shows an example weathering graph detailing the time history of oil partitioning into different states from the worst case spill. The figure indicated that the spilt fuel oil would evaporate and lose mass from surface oil to stranded oil over time.

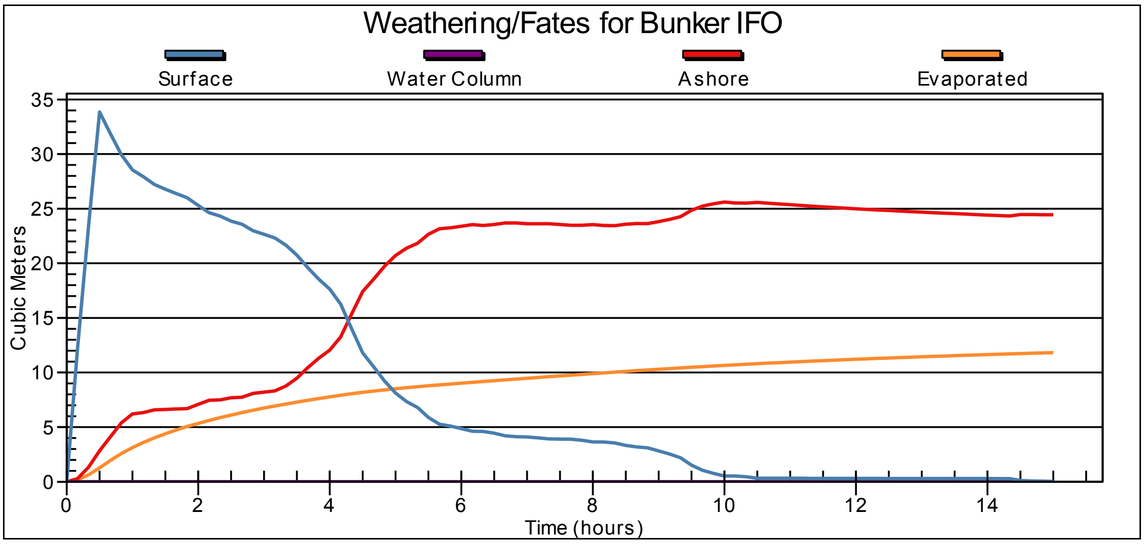

Figure 5: An oil weathering graph from an oil spill involving 38 m^3 of IFO over 0.5 hours during a fuel transfer incident.

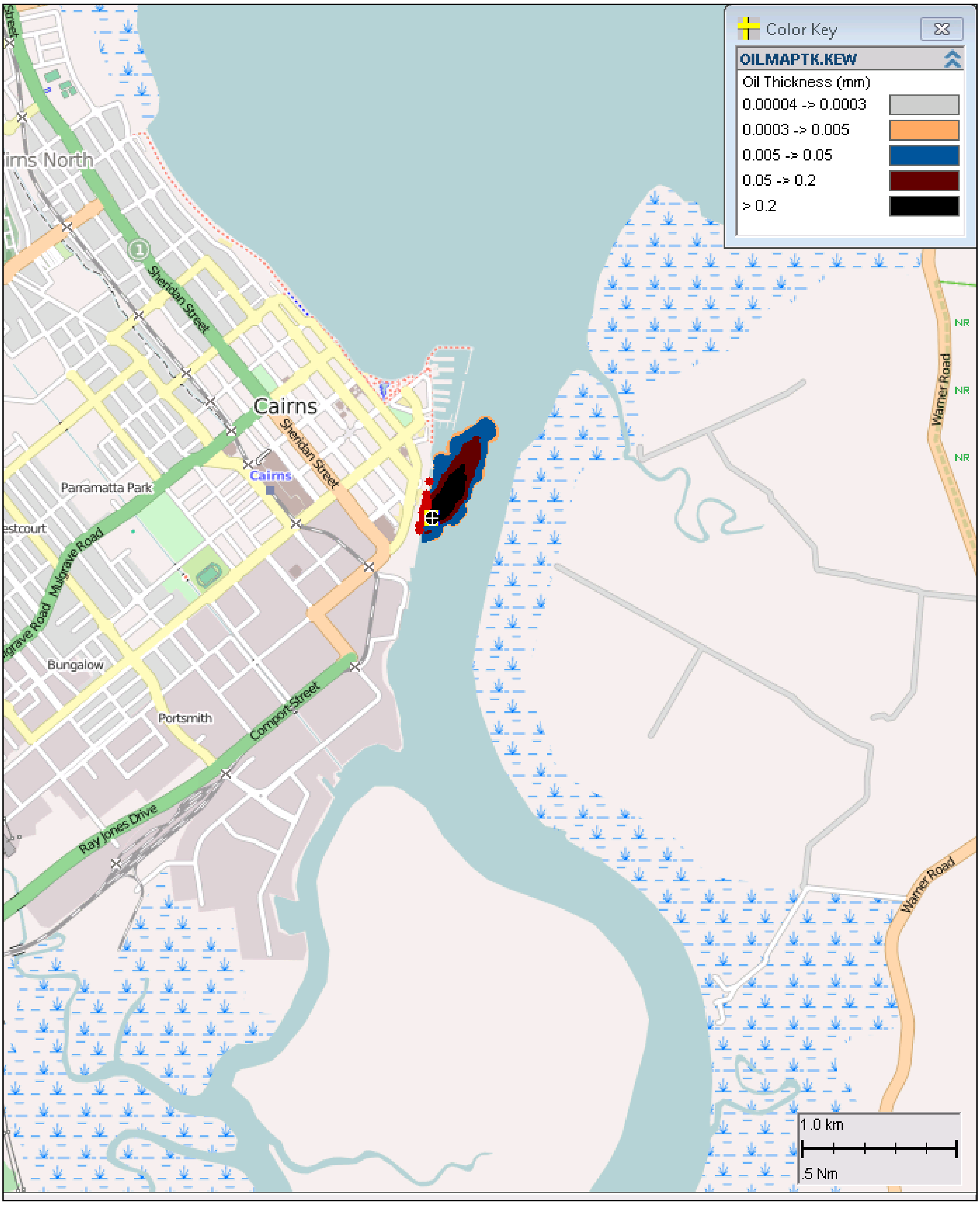

Figure 6: Snapshot of a worst case spill after 1 hour from a 38 m^3 of IFO over 0.5 hours during a fuel transfer incident. In this example the spill started just prior to low tide. The red dots along the shoreline show the position of oil stranded on shorelines.

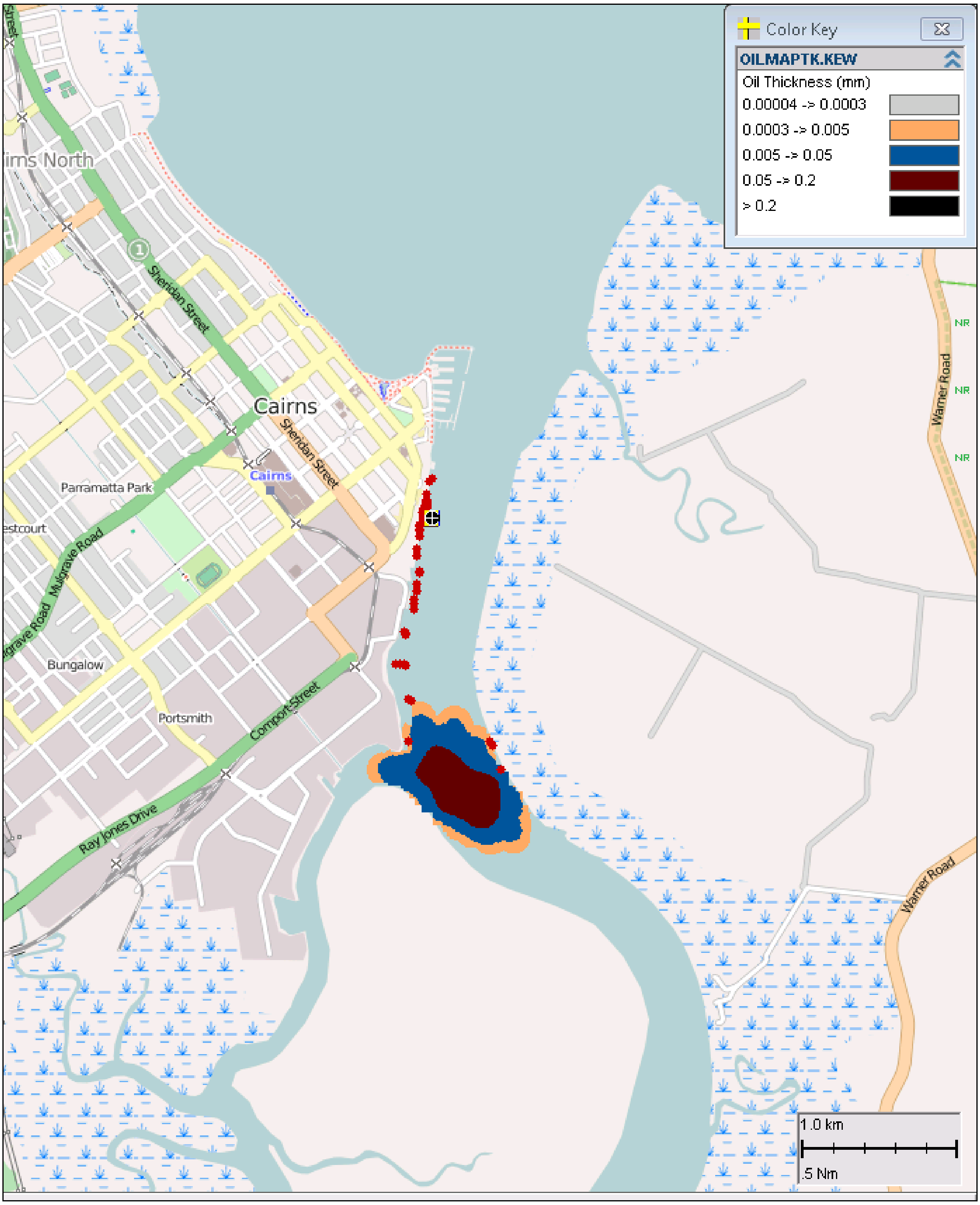

Figure 7: Figure above shows a snapshot of a worst case spill after 3 hours. In this example the spill moved into the estuary with the incoming tide. The red dots along the shoreline show the position of oil stranded on shorelines.

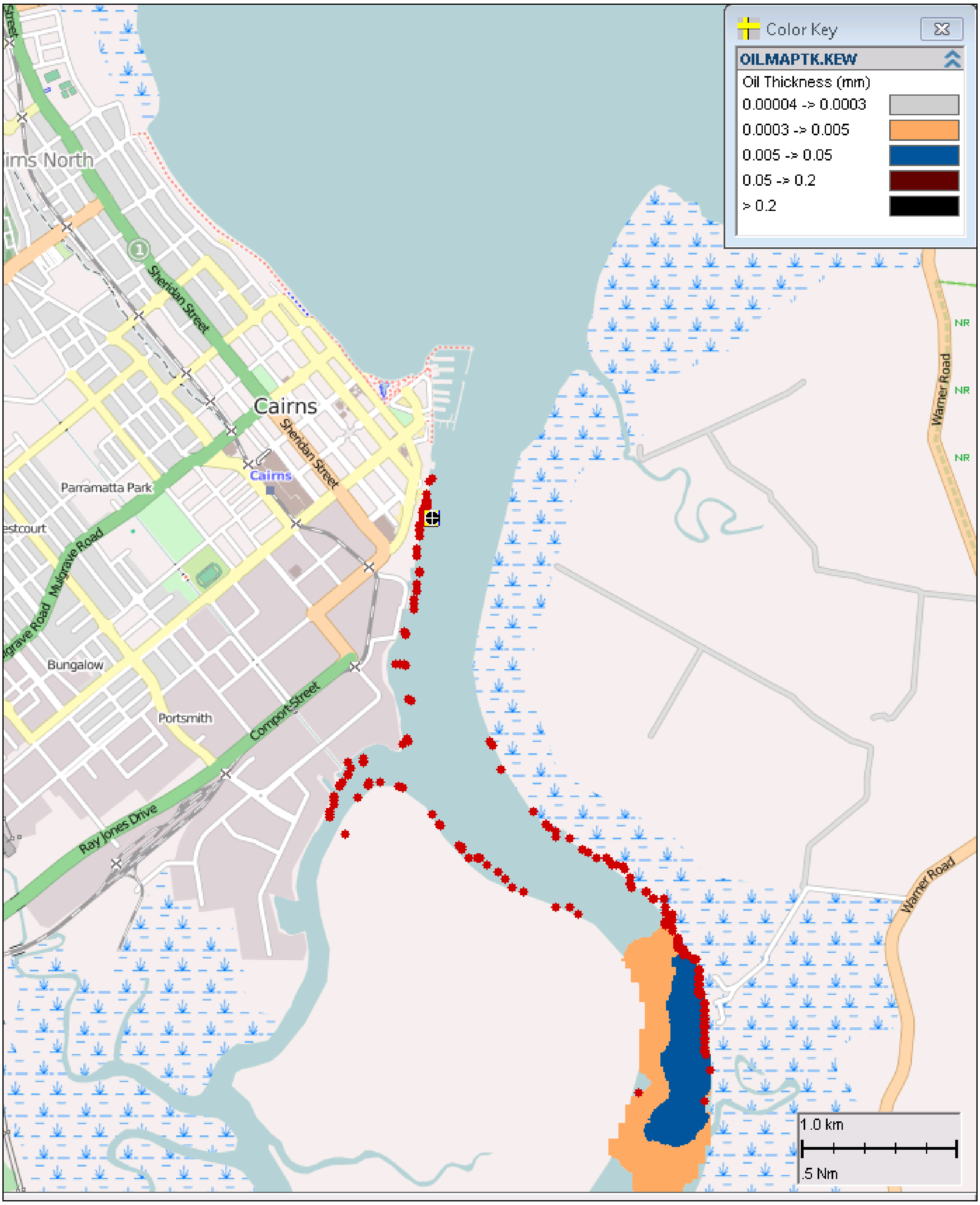

Figure 8: Figure above shows a snapshot of a worst case spill after 6 hours. In this example the spill moved into the estuary with the incoming tide. The red dots along the shoreline show the position of oil stranded on shorelines.

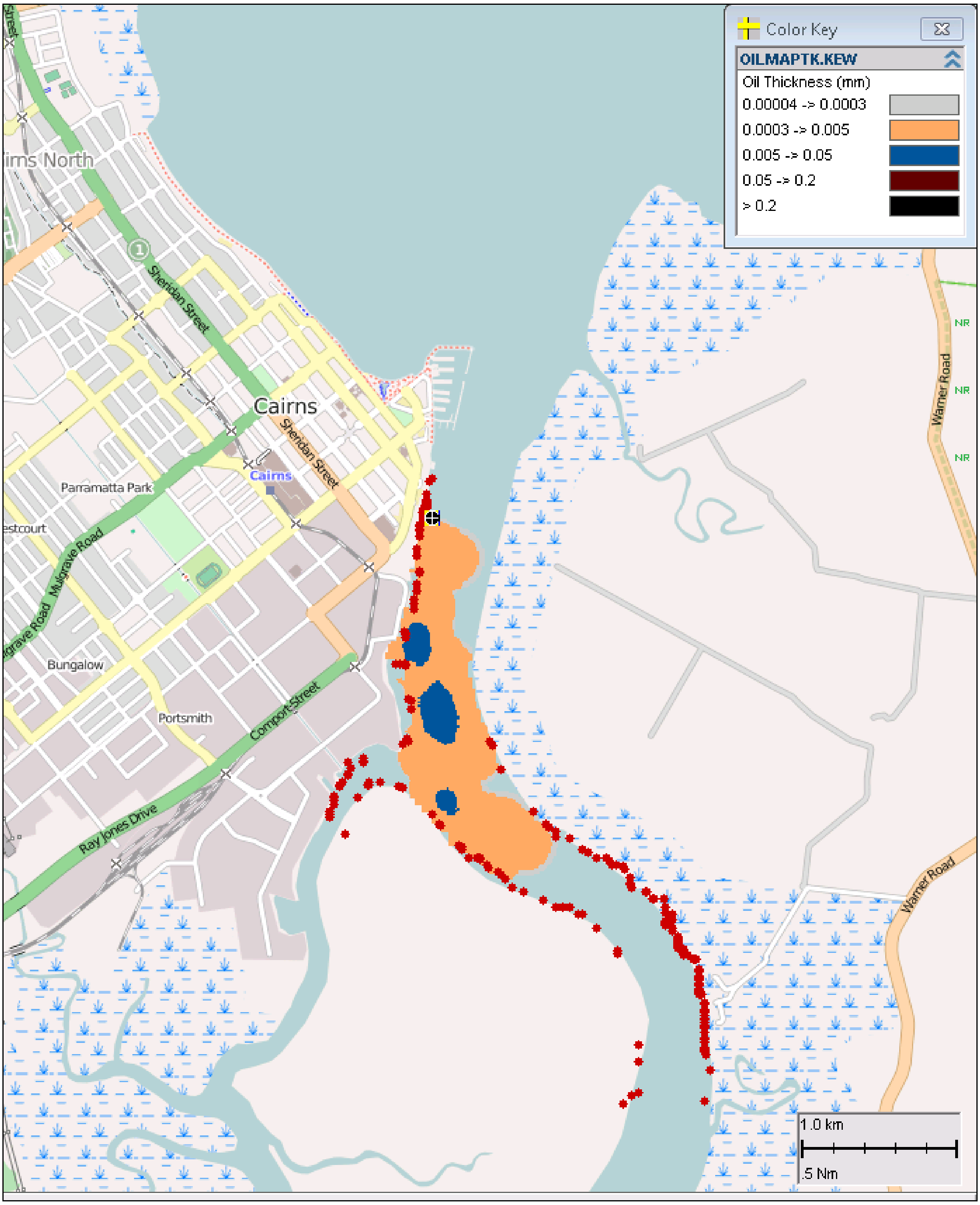

Figure 9: Figure above shows a snapshot of a worst case spill after 9 hours. In this example the spill moved into the estuary with the incoming tide and then back out of the estuary with the outgoing tide that followed. The red dots along the shoreline show the position of oil stranded on shorelines.

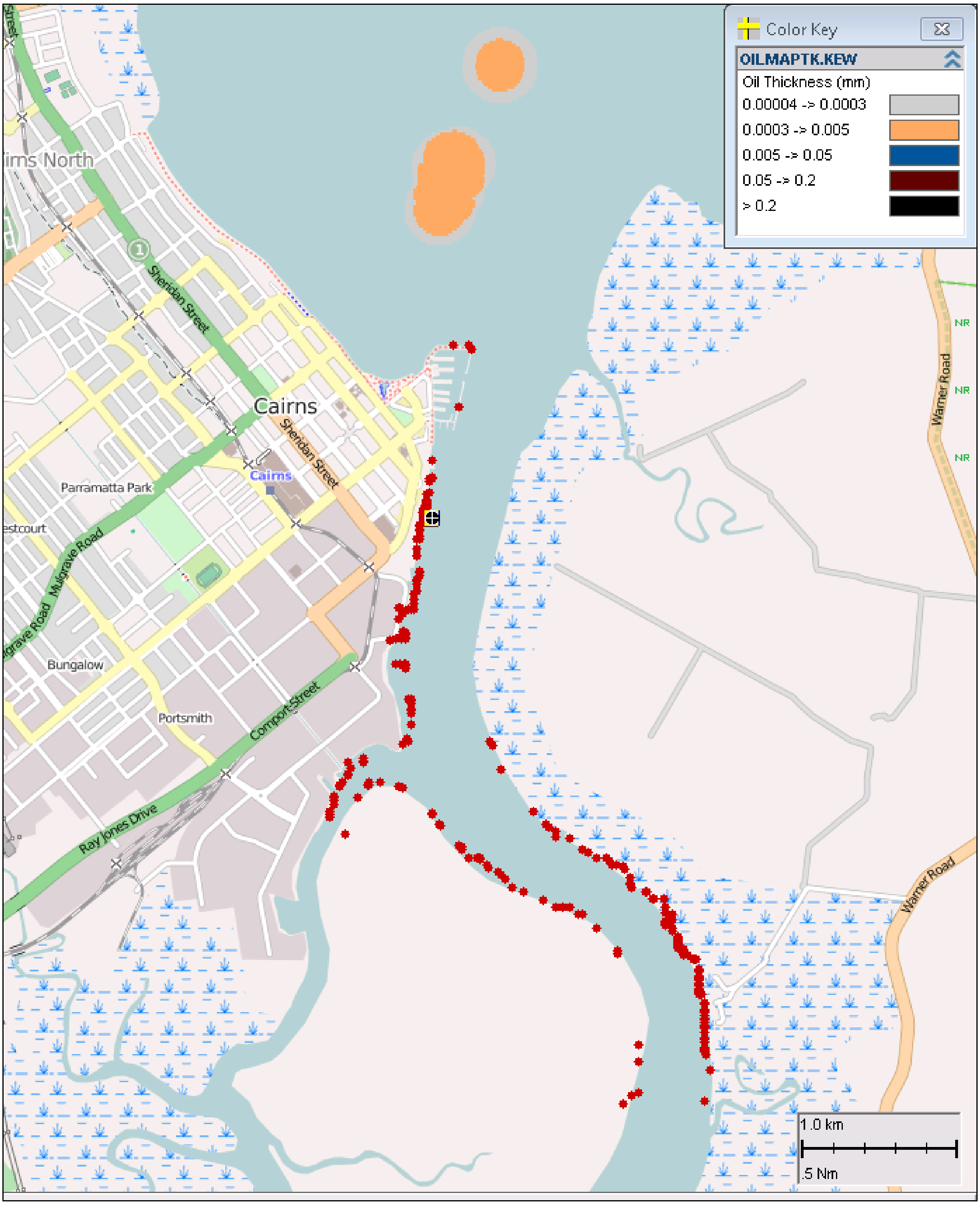

Figure 10: Figure above shows a snapshot of a worst case spill after 12 hours. In this example the spill moved into the estuary with the incoming tide and then out of the estuary with the outgoing tide that followed. The red dots along the shoreline show the position of oil stranded on shorelines.

Figure 11: The figure above shows the final shoreline strandings (indicated by red dots) of this worst—case spill at Wharf 3. The water surface swept by slicks (> 40 nm) over the duration of the spill is indicated by the grey dots.

8.1.2 Winter Stochastic: Maximum Credible Spill during Fuel Transfer

The stochastic modelling of 200 spill simulations of the winter season was collectively analysed which quantified the probability of sea surface exposure and minimum time before exposure. Note the probability figures shown in this report summarised the likely exposure for each grid cell as a colour coding. For example, the grid cells with a 10% probability were exposed to 20 of the 200 trajectories and the cells with a higher probability of oiling were exposed during a greater number of spill trajectories, up to 100% at the release site.

Figure 12 to Figure 13 show the probability of sea surface exposure to heavy oiling and heavy sheens (being the 10 micron threshold), and any visible sheens (0.5 micron threshold) and the calculated minimum time before exposure. These results demonstrate that excusion away from the spill site is tidally driven in the estuary. These figures also demonstrate that spill migration is significantly controlled by the close proximity of shorelines, which will hold up oil as the tidal currents attempt to push it backwards and forwards within the estuarine section of Cairns Harbour. Any oil that does escape being trapped by the shorelines and estuary, will be pushed towards the Cairns foreshore and mangroves adjacent to the Cairns airport due to the prevailing wind direction during this season.

Table 2 summaries the shoreline statistics which demonstrates that 100 out of 100 simulations made shoreline contact predominantly due to the close proximity of shorelines in this estuarune section of Cairns Harbour. The results also demonstrate that this type of oil is highly persistent without significant volumes of volatile components and hence remains adhesive over time and does not readily evaporate.

Table 2: Summary of shoreline contact from this scenario tracked to the 0.5 μm threshold being the extent of visible oil as per AMSA Guidelines (2013).

Risk from Maximum Credible Spill during Fuel Transfer				
Release	**Probability of contact to any shoreline (%)**	**Time to first reach any shoreline (minutes)**	**Average volume of oil to reach shore for single trajectory (m^3)**	**Largest volume of oil to reach shore for single trajectory (m^3)**
Wharf 3	100	1 to 12	23	26

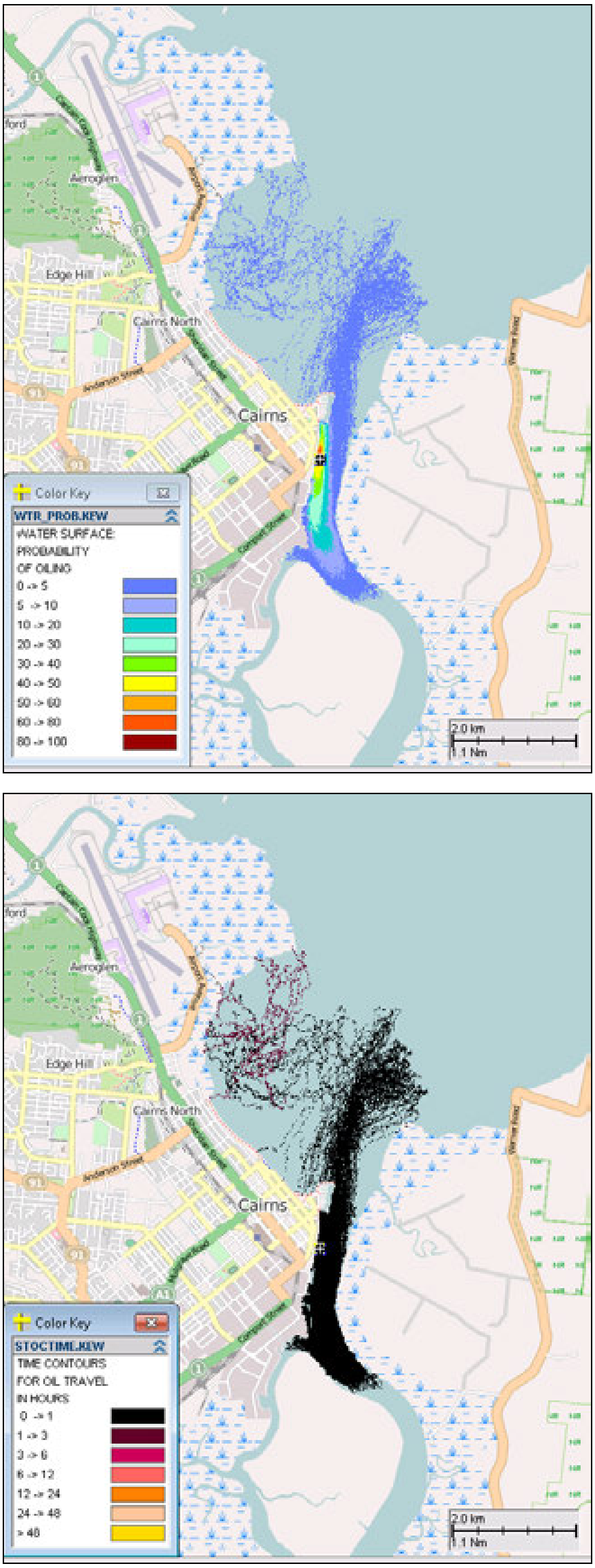

Figure 12: Map showing the model calculated probability or risk of sea surface and shoreline exposure to heavy oiling and heavy sheens above 10 µm (upper image) and minimum time to exposure (lower image) by combining 200 simulations of a 38 m^3 spill of IFO at Wharf 3 during winter.

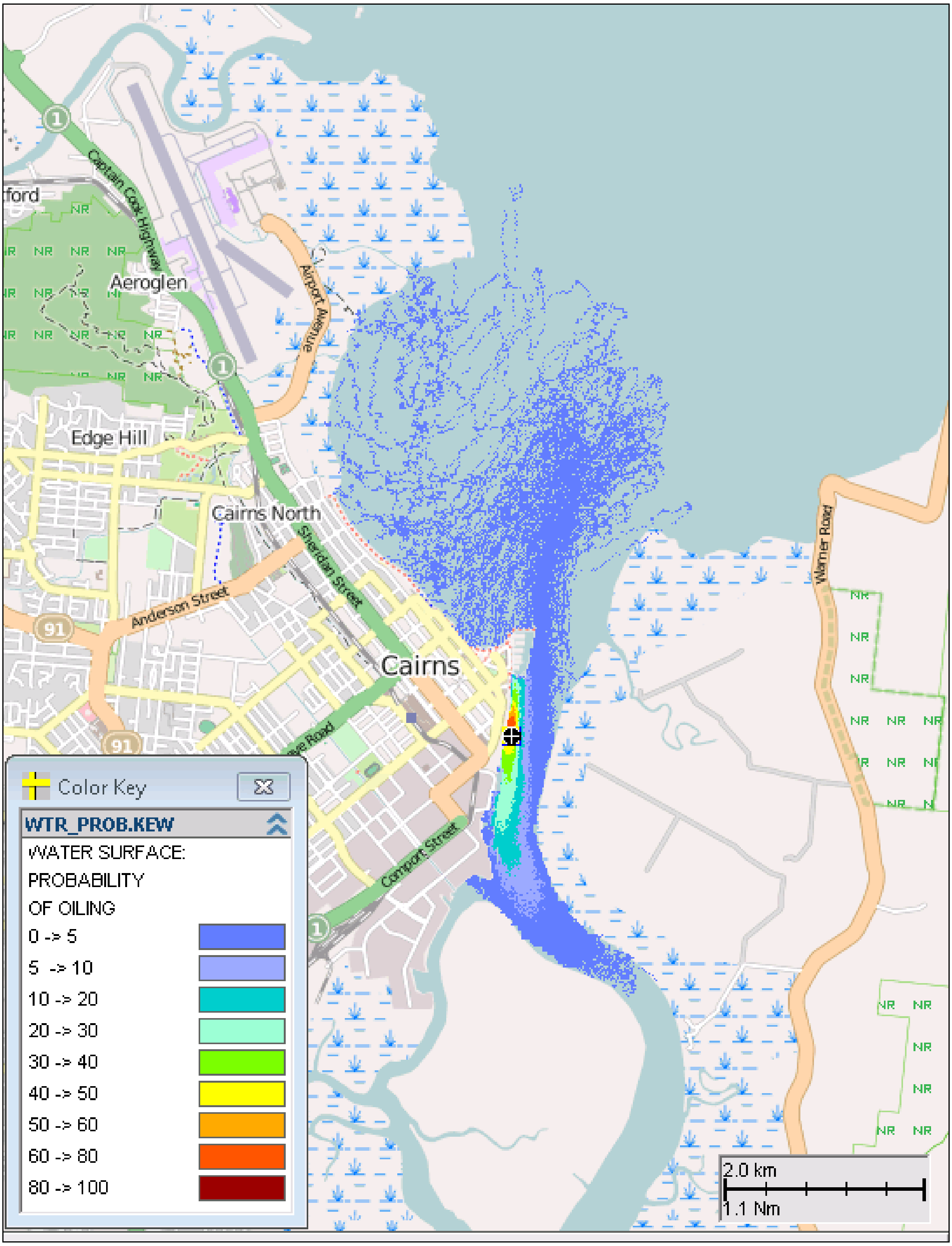

Figure 13: Map showing the model calculated probability or risk of sea surface and shoreline exposure to any visible oil above 0.5 µm (lower) by combining 200 simulations of a 38 m^3 spill of IFO at Wharf 3 during winter.

8.1.3 Summer Stochastic: Maximum Credible Spill during Fuel Transfer

The stochastic modelling of 200 spill simulations during the summer season was collectively analysed to quantify the probability of sea surface exposure and minimum time before exposure. Note the probability figures shown in this report summarised the likely exposure for each grid cell as a colour coding. For example, the grid cells with a 10% probability were exposed to 20 of the 200 trajectories and the cells with a higher probability of oiling were exposed during a greater number of spill trajectories, up to 100% at the release site.

Figure 14 to Figure 15 show the probability of sea surface exposure to heavy oiling and heavy sheens (being the 10 micron threshold), and any visible sheens (0.5 micron threshold) and the calculated minimum time before exposure. These results demonstrate that excusion away from the spill site is tidally driven in the estuary. These figures also demonstrate that spill migration is significantly controlled by the close proximity of shorelines, which will hold up oil as the tidal currents attempt to push it backwards and forwards within the estuarine section of the Cairns Harbour. Any oil that escapes shoreline trapping by the estuary, will be pushed by the prevailing wind direction during this season (typically weaker and more variably than winter).

Table 3 summaries the shoreline statistics which demonstrates that 100 out of 100 simulations made shoreline contact predominantly due to the close proximity of shorelines in this estuarune section of Cairns Harbour. The results also demonstrate that this type of oil is highly persistent without significant volumes of volatile components and hence remains adhesive over time and does not readily evaporate.

Table 3: Summary of shoreline contact from this scenario tracked to the 0.5 μm threshold being the extent of visible oil as per AMSA Guidelines (2013).

Risk from Maximum Credible Spill during Fuel Transfer				
Release	**Probability of contact to any shoreline (%)**	**Time to first reach any shoreline (minutes)**	**Average volume of oil to reach shore for single trajectory (m^3)**	**Largest volume of oil to reach shore for single trajectory (m^3)**
Wharf 3	100	1 to 42	22	26

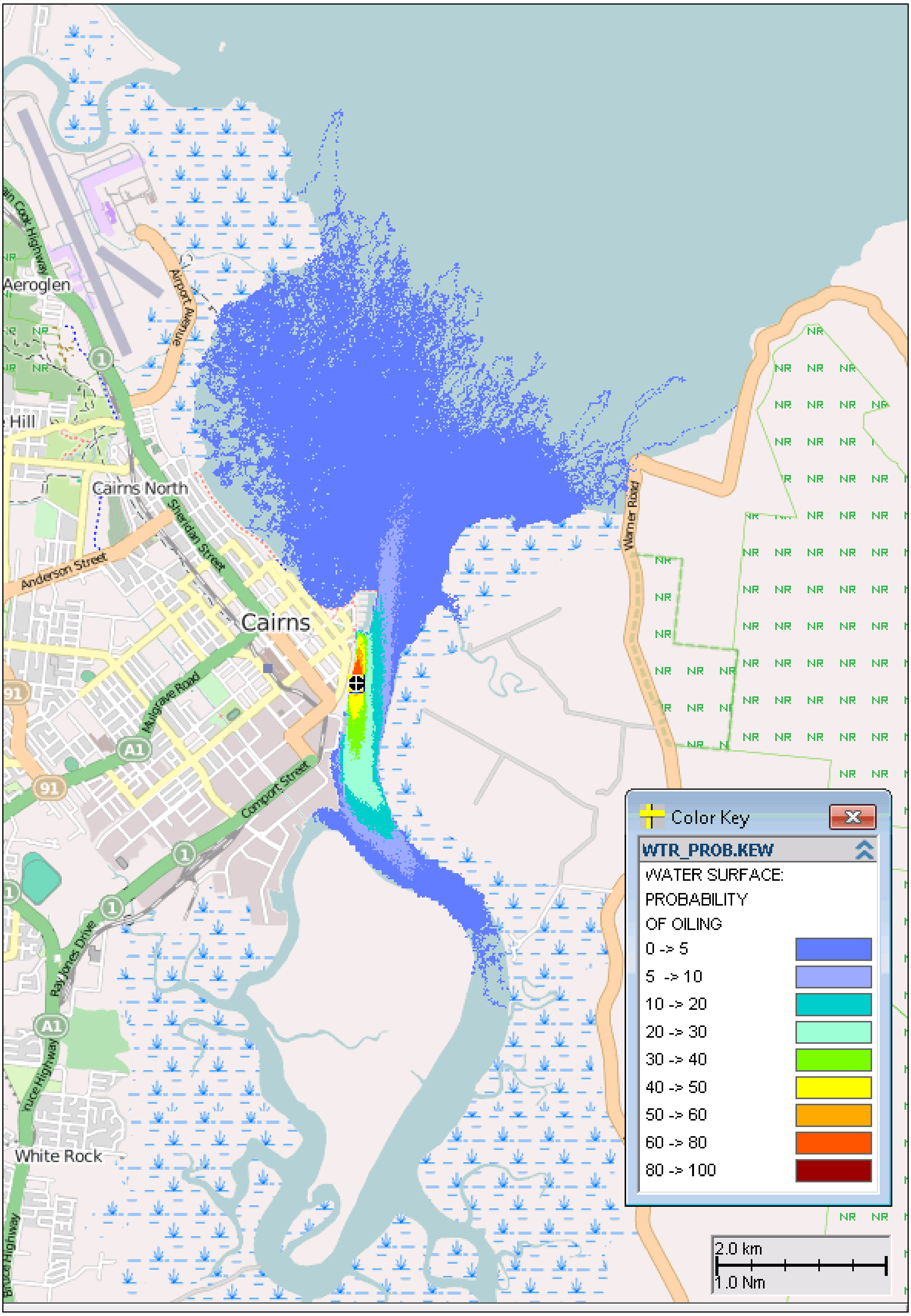

Figure 14: Map showing the model calculated probability or risk of sea surface and shoreline exposure to heavy oiling and heavy sheens above 10 µm by combining 200 simulations of a 38 m^3 spill of IFO at the Wharf 3 during summer.

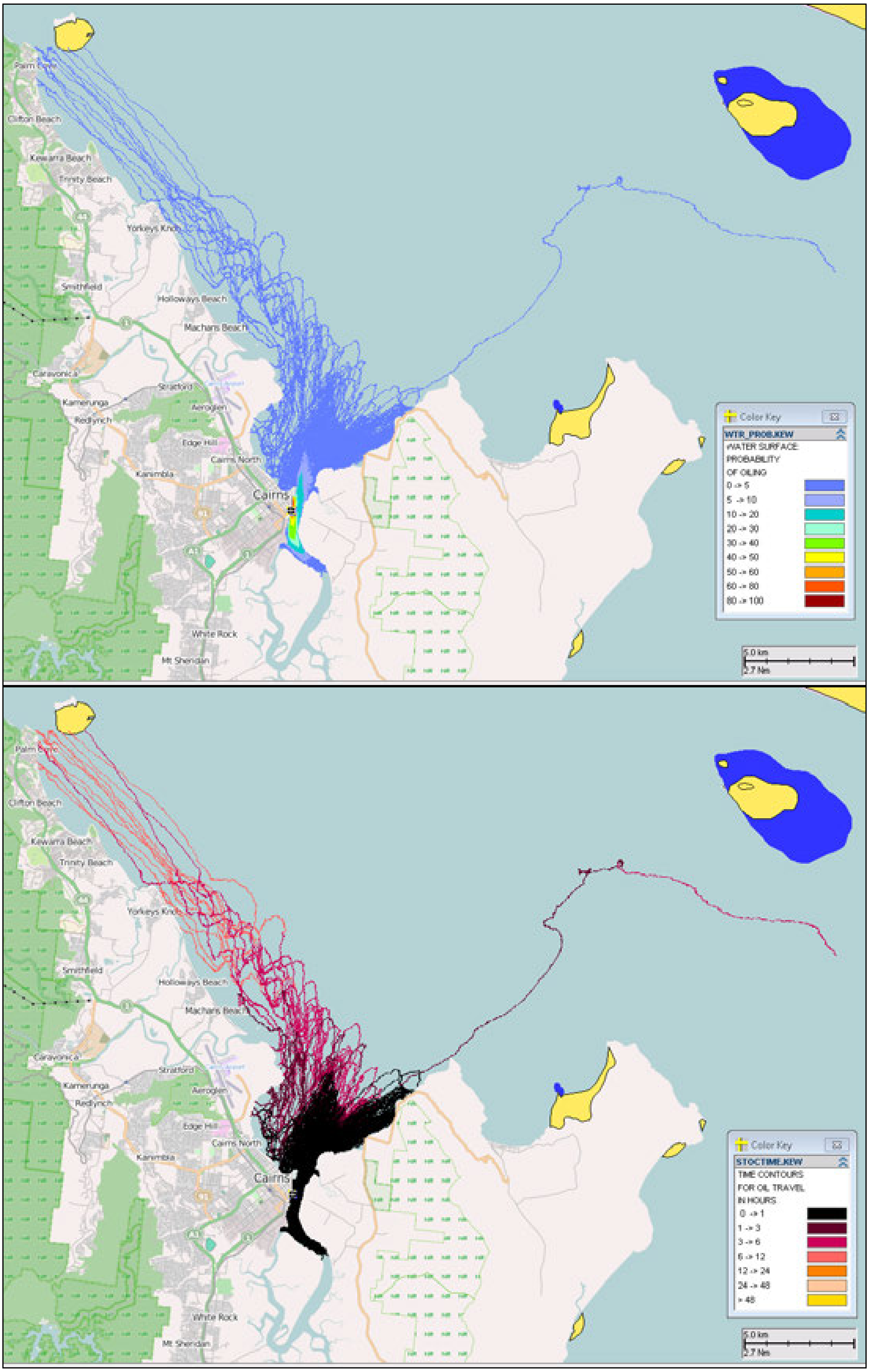

Figure 15: Map showing the model calculated probability or risk of sea surface and shoreline exposure to any visible oil above 0.5 µm (upper) and minimum time to exposure above 0.5 µm (lower) by combining 200 simulations of a 38 m^3 spill of IFO at Wharf 3 during summer.

8.2 Most Probable Spill during Fuel Transfer

Stochastic spill modeling was also used for the quantitative risk assessment for a Fuel Transfer Accident, but at a volume more likely to result from a fuel transfer accident. This lower release volume relates to a smaller incident involving a spill of IFO 180/380 at coupling point near Wharf 3 while pumping IFO between the onshore tank and a vessel (145º 46' 49.8"E 16º 55' 37.6"S) resulting in a most probable loss of 7.6 m^3 of IFO over 6 minutes (360 sec x 21 L/s = 7.6 m^3). Given that the maximum credible scenario of this same scenario indicated little seasonality in the risk profile between winter and summer, a winter case was only undertaken here as it provided a slightly worst-case average volume onshore of the two seasons.

8.2.1 Winter Stochastic: Most Probable Spill during Fuel Transfer

The stochastic modelling of 200 spill simulations of the winter season was collectively analysed which quantified the probability of sea surface exposure and minimum time before exposure. Note the probability figures shown in this report summarised the likely exposure for each grid cell as a colour coding. For example, the grid cells with a 10% probability were exposed to 20 of the 200 trajectories and the cells with a higher probability of oiling were exposed during a greater number of spill trajectories, up to 100% at the release site.

Figure 16 to Figure 19 show the probability of sea surface exposure to heavy oiling and heavy sheens (being the 10 micron threshold), and any visible sheens (0.5 micron threshold) and the calculated minimum time before exposure. These results demonstrate that excusion away from the spill site is tidally driven in the estuary. These figures also demonstrate that spill migration is significantly controlled by the close proximity of shorelines, which will hold up oil as the tidal currents attempt to push it backwards and forwards within the estuarine section of Cairns Harbour. Any oil that does escape being trapped by the shorelines and estuary, will be pushed towards the Cairns foreshore and mangroves adjacent to the Cairns airport due to the prevailing wind direction during this season. Hence the risk of exposure is similar to the maximum credible spill volume, despite being 20 lower in volume.

Table 5 summaries the shoreline statistics which again demonstrates that 100 out of 100 simulations made shoreline contact predominantly due to the close proximity of shorelines in the estuarune section of Cairns Harbour.

Table 4: Summary of shoreline contact from this scenario tracked to the 0.5 µm threshold being the extent of visible oil as per AMSA Guidelines (2013).

Risk from Most Probable Spill Volume during Fuel Transfer				
Release	**Probability of contact to any shoreline (%)**	**Time to first reach any shoreline (min)**	**Average volume of oil to reach shore for single trajectory (m^3)**	**Largest volume of oil to reach shore for single trajectory (m^3)**
Wharf 3	100	1 to 12	6.6	7.1

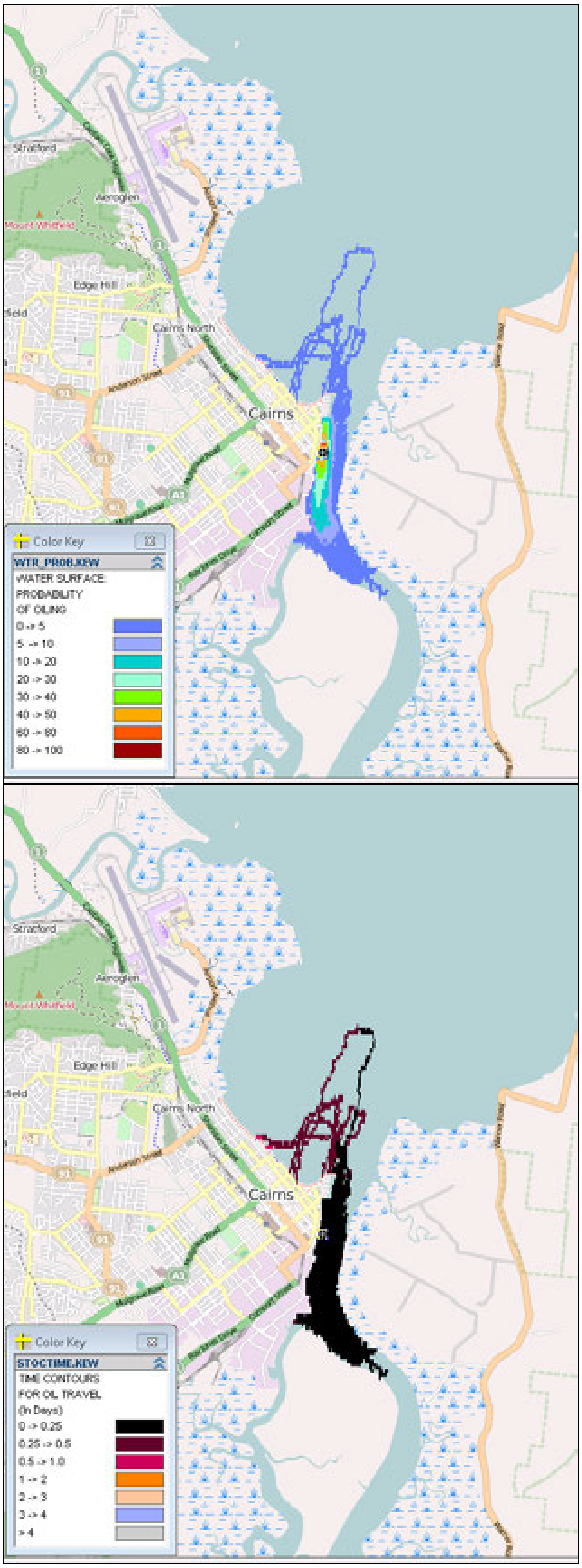

Figure 16: Map showing the model calculated probability or risk of sea surface and shoreline exposure to heavy oiling and heavy sheens above 10 µm (upper image) and minimum time to exposure (lower image) by combining 200 simulations of a 7.6 m^3 *spill of IFO at Wharf 3 during winter.*

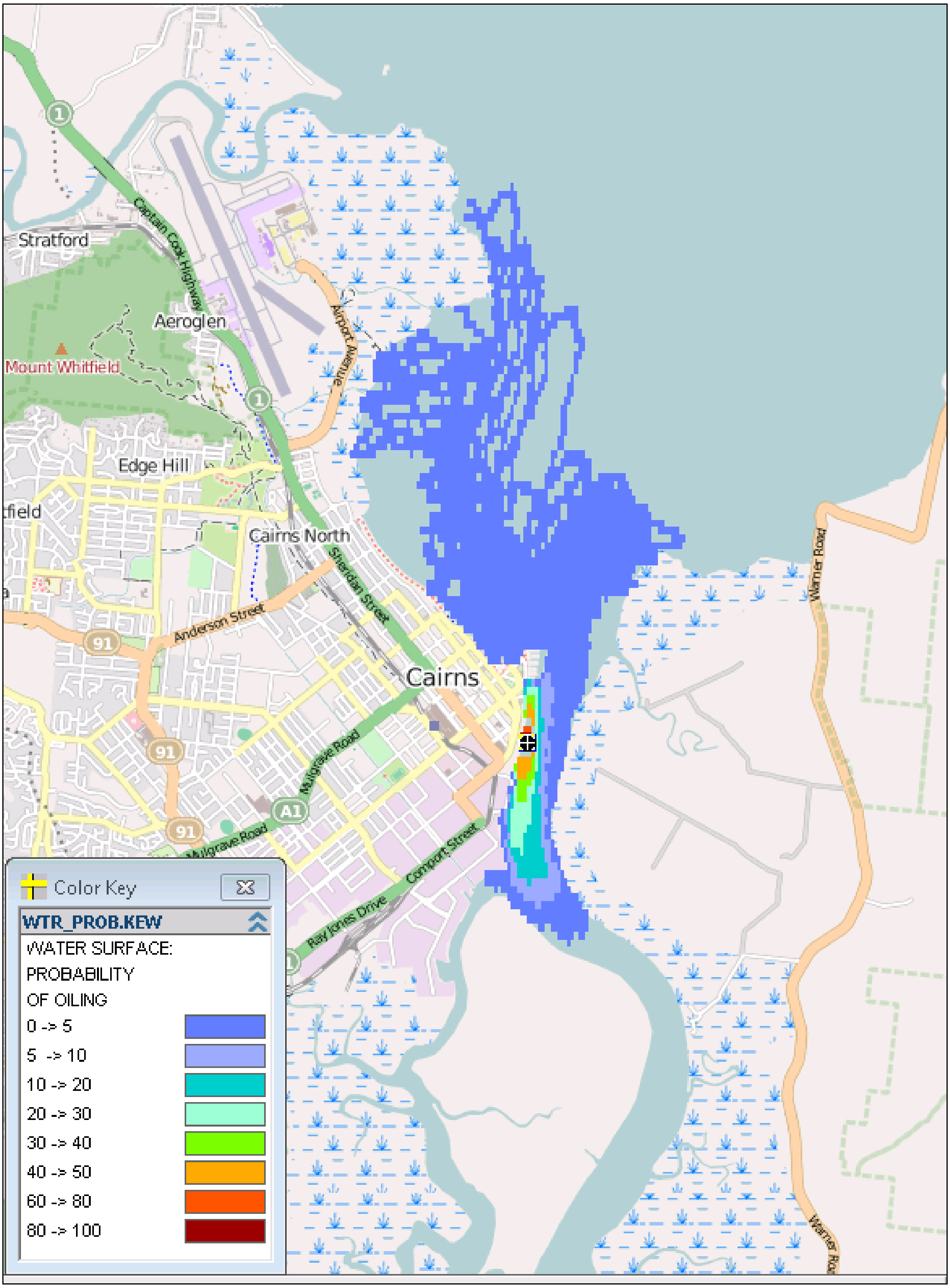

Figure 17: Map showing the model calculated probability or risk of sea surface and shoreline exposure to any visible oil above 0.5 µm (lower) by combining 200 simulations of a 7.6 m^3 spill of IFO at the Wharf 3 during winter.

8.3 Maximum Credible Spill from Collision in the Channel

Stochastic spill modeling was used for the winter season and summer season quantitative risk assessment for a collision of an IFO supply vessel involving a spill of IFO 180/380 between the outer channel and inner channel - resulting in a maximum credible loss of up to 700 m^3 of IFO over 1 hour.

The worst-case single spill simulation was selected from the 400 simulations carried out for each both seasons. The basis of selection was typically to demonstrate how the largest volume ashore occurred from the many simulations (200 for each season).

8.3.1 Worst-Case Single Spill Results

The worst-case volume on shore from a maximum credible 700 cubic metres spill of IFO 180/380 from a supply vessel moving between the outer channel and inner channel was 402 cubic metres, almost all ashore within 7 days of release. The scenario and the wind and current conditions that produced that outcome is detailed in the sequence of maps below. The red dots along the shoreline show the position of oil stranded on shorelines.

Figure 19 to Figure 25 shows the time sequence of oil movement from the spill event. Under summer wind conditions, any spill in the channel initially drifted with the wind while oscillating backwards and forwards with the tidal currents (Figure 19). The length of the spill is attributable to a moving ship rather than winds or currents. The slick within the first hour is significantly true colour (Black) and discontinuous true colour (Transparent Black) along the outer edges of the slick. Within 6 hours (Figure 20) about 10% of the volume of spilt oil had adhered to the shorelines south of the channel due to the northerly winds; the slick at this time had lost mass due to evaporation and remained as a discontinuous true colour (Transparent Black) surrounded by heavy sheens. Northerly winds continued to push oil slowly ashore to the south of the channel over the next 6 hours (Figure 21). Within 12 hours about 30% of the volume of spilt oil had adhered to the shorelines and inter tidal areas; the slick had also lost mass due to evaporation and was now patches of discontinuous true colour (Transparent Black) surrounded by heavy and rainbow colour sheens. Over the next 3 days (72 hours, Figure 22 and Figure 23) winds calmed and the slick slowly moved backwards and forwards with the incoming and outgoing tides but without any significant drift. By day-3 the volatile components of the oil ashore evaporated and the slick spread to below 10 microns (ecological threshold). Visible oil was mostly composed of rainbow coloured sheens. Oil ashore had reached its peak volume within 72 hours. Over the next 2 days (Figure 24) winds remained calm before changing to a slightly moderate southeast wind. This wind started to move the remaining surface oil towards the shorelines west of the channel. After 5 days the slick continued to spread to less than a few microns in thickness (below the ecological threshold); visible oil was still composed of rainbow coloured sheens. Winds continued as slight to moderate from the southeast over the next 2 days (Figure 25) which pushed the remaining surface oil towards the shorelines north of the channel. By day-7, the slick continued to spread to below 1 micron in thickness (below the ecological threshold and almost below detection from aircraft), but visible at ground level as weathered sheens.

Figure 18 shows an example weathering graph detailing the time history of oil partitioning into different states from the worst case spill. The graph indicated that the spilt fuel oil would evaporate but most significantly, would lose mass from surface oil to stranded oil over time.

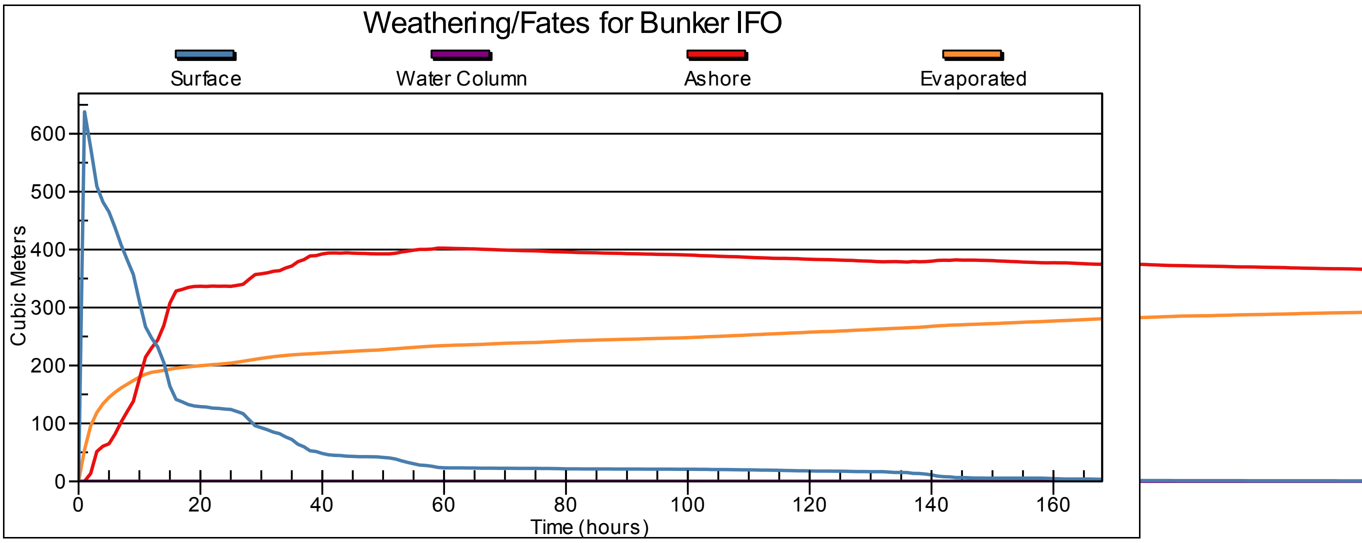

Figure 18: An oil weathering graph from an oil spill involving 700 m^3 of IFO over 1 hour during a collision incident..

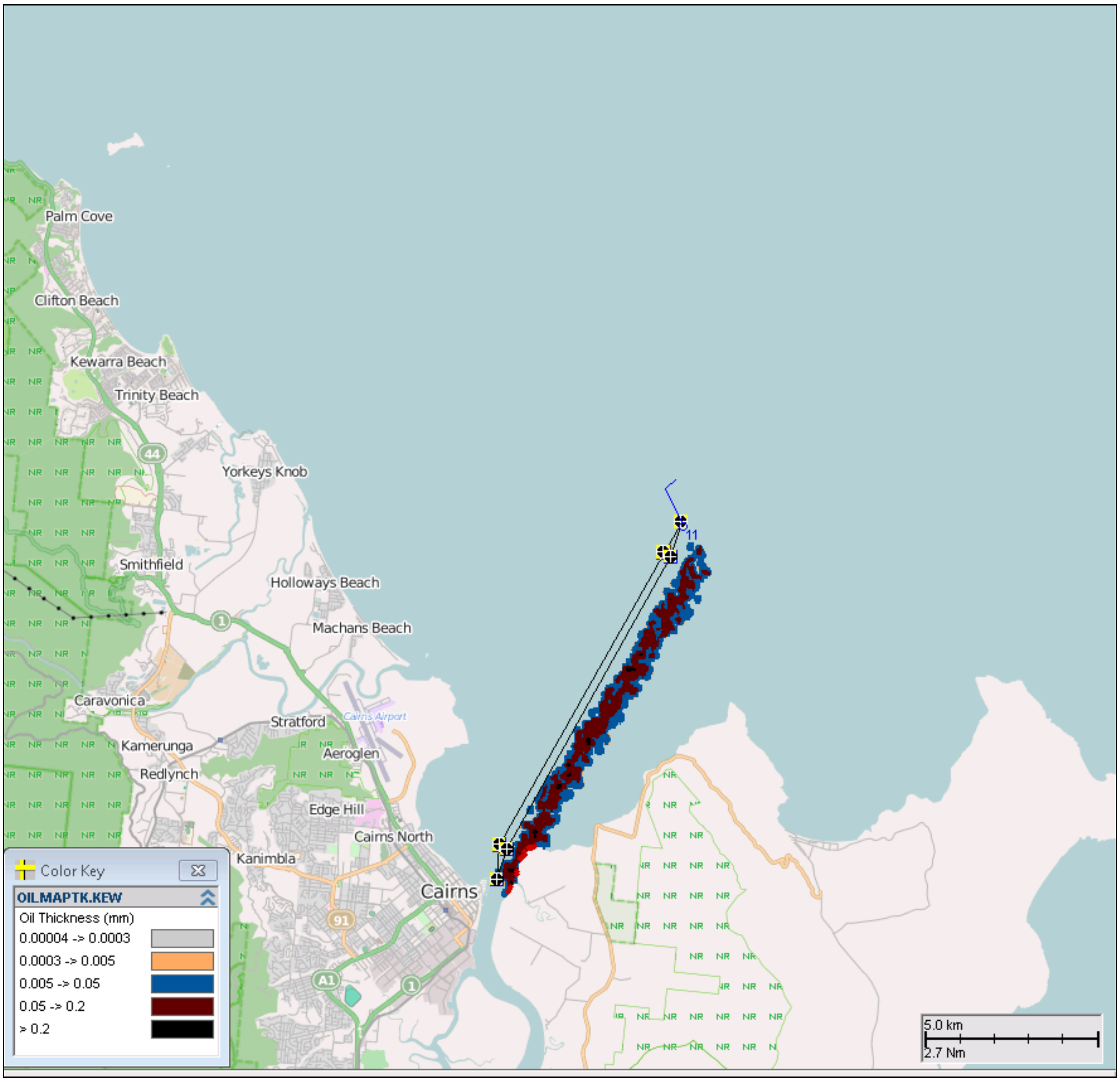

Figure 19: Snapshot of a worst case spill in the channel during summer after 2 hours from a 700 m^3 of IFO over 1 hour during a collision incident.. Also shown (as the black polygon) is the sea channel and a wind vector. The wind for this scenario during the summer was a NW wind at 11 knots. The red dots along the shoreline show the position of oil stranded on shorelines.

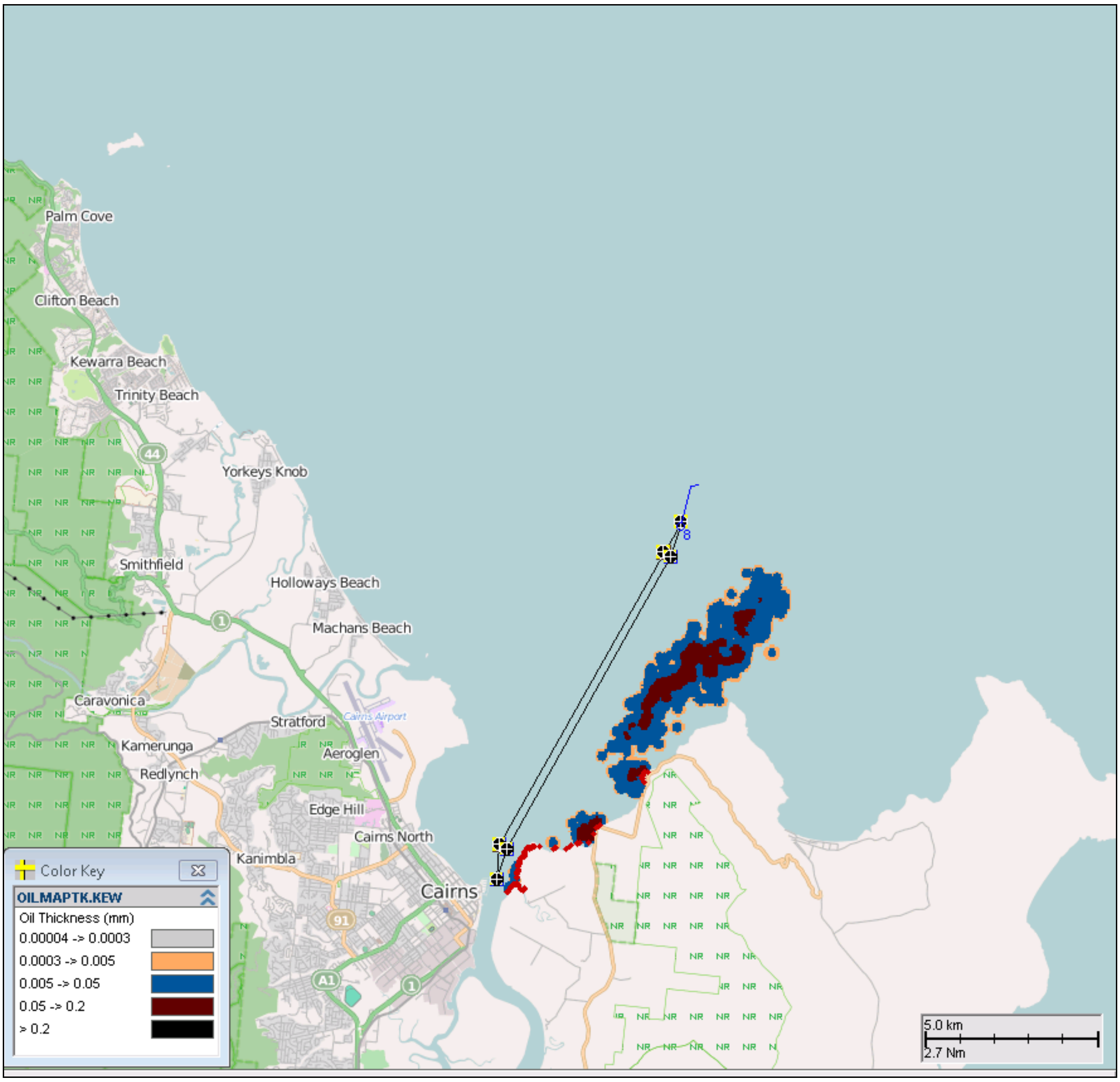

Figure 20: Snapshot of a worst case spill in the channel after 6 hours from a 700 m^3 of IFO over 1 hour during a collision incident. Red dots along the shoreline showing the position of oil stranded on shorelines.

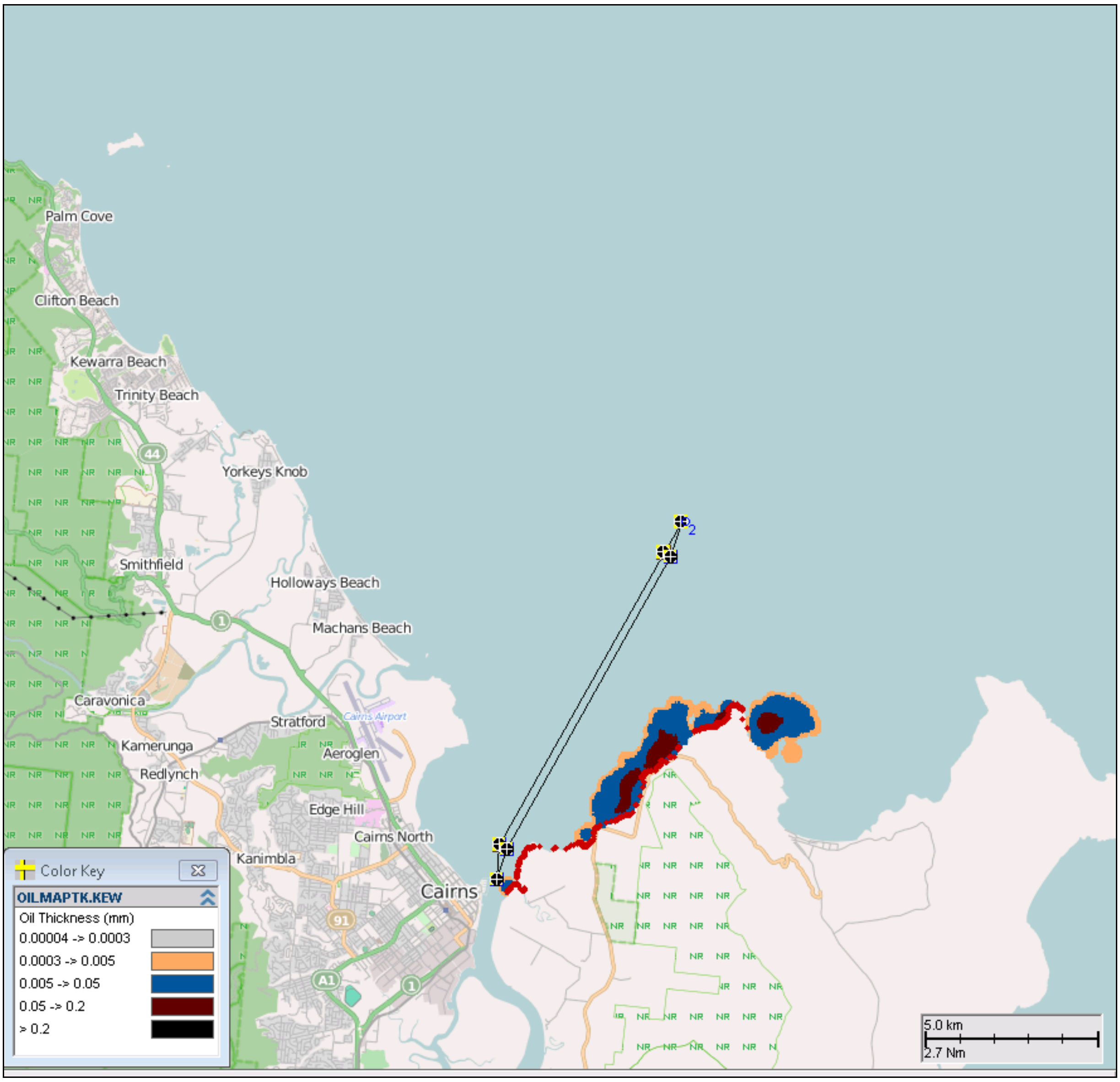

Figure 21: Snapshot of a worst case spill in the channel after 12 hours from a 700 m^3 of IFO over 1 hour during a collision incident. Red dots along the shoreline showing the position of oil stranded on shorelines.

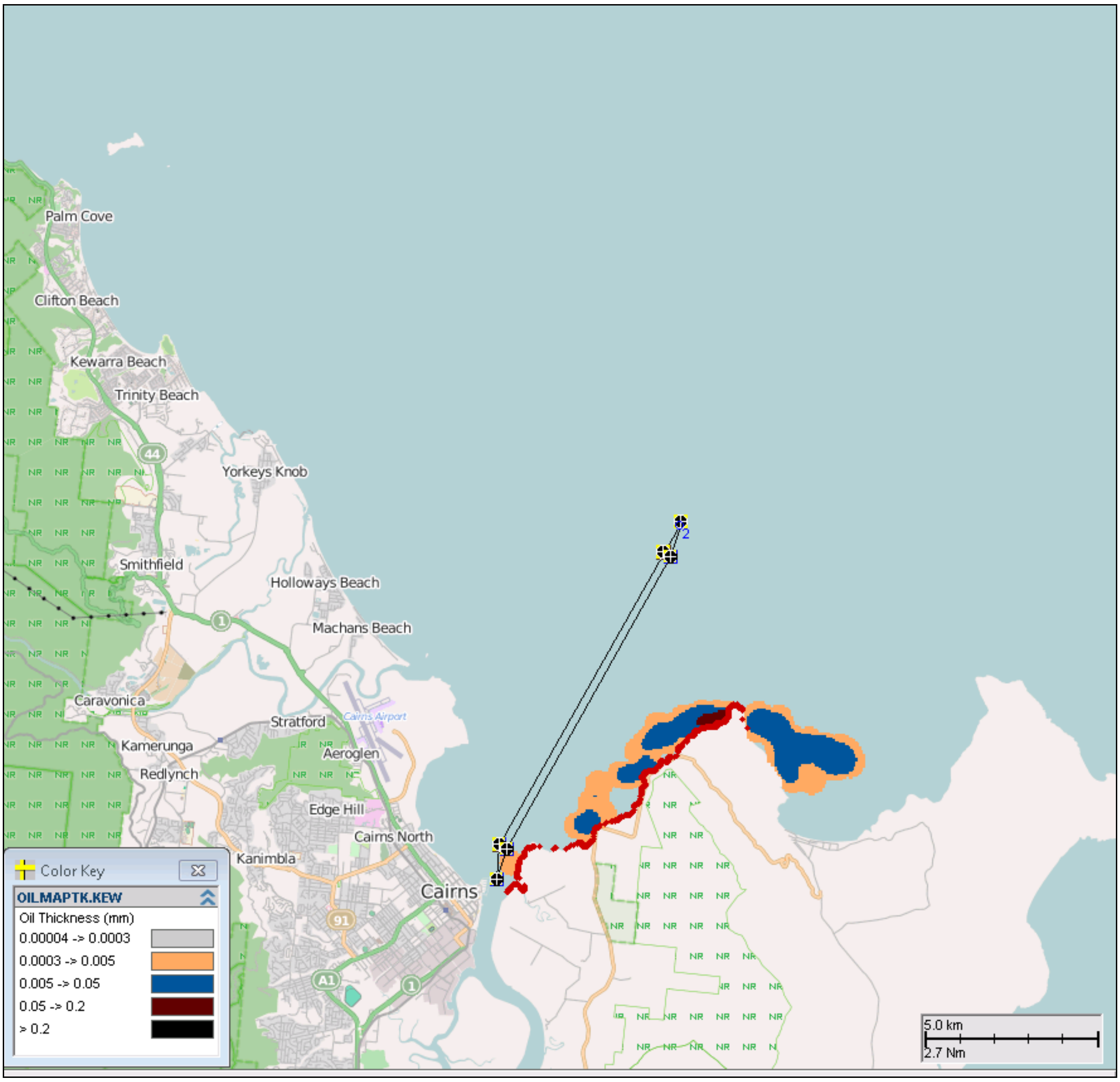

Figure 22: Figure above shows a snapshot of a worst case spill in the channel after 24 hours from a 700 m^3 of IFO over 1 hour during a collision incident. Red dots along the shoreline indicate the position of oil stranded aground

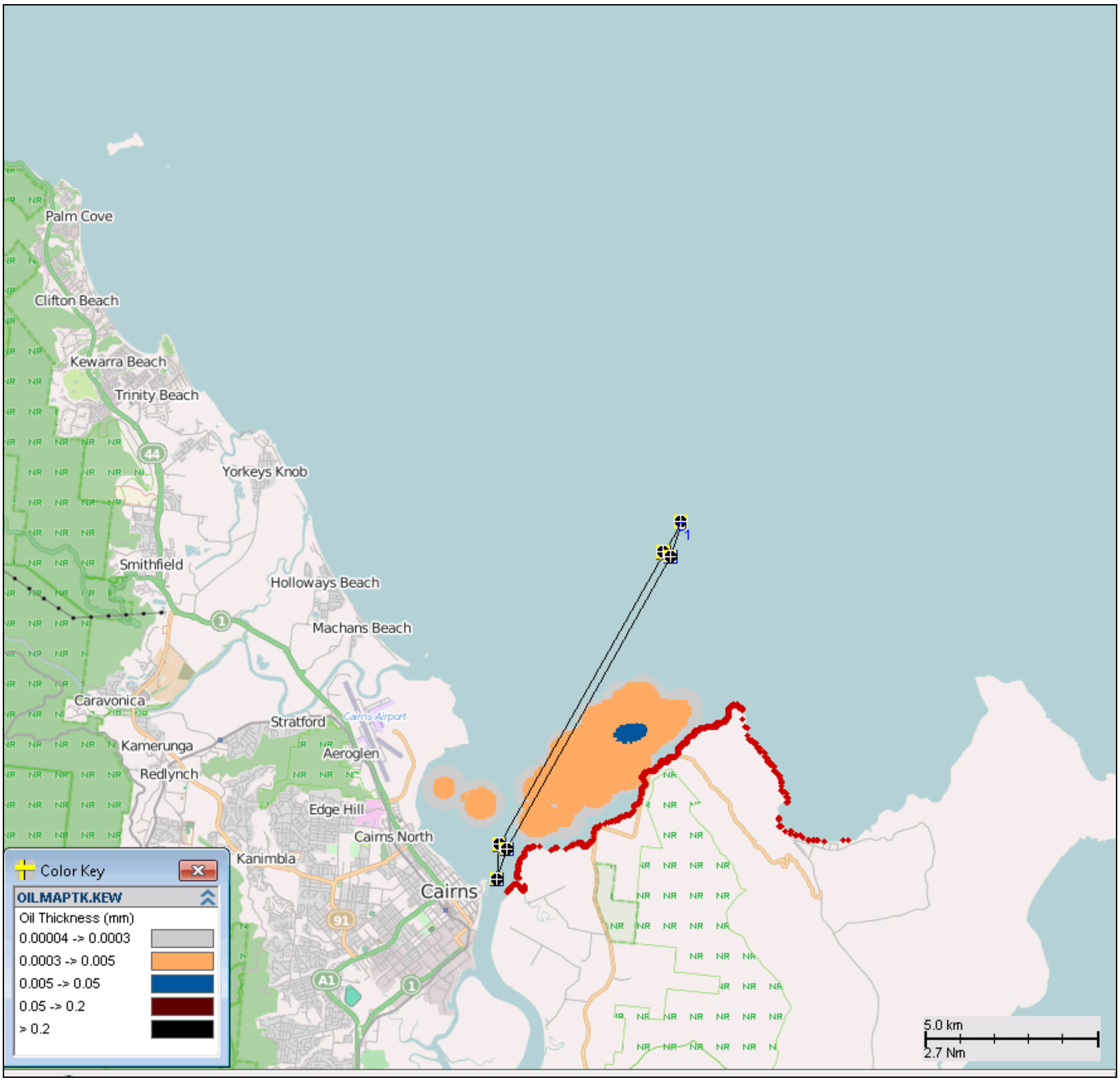

Figure 23: Snapshot of a worst case spill in the channel after 72 hours from a 700 m^3 of IFO over 1 hour during a collision incident. The red dots along the shoreline indicate the position of oil stranded aground which reached its peak volume.

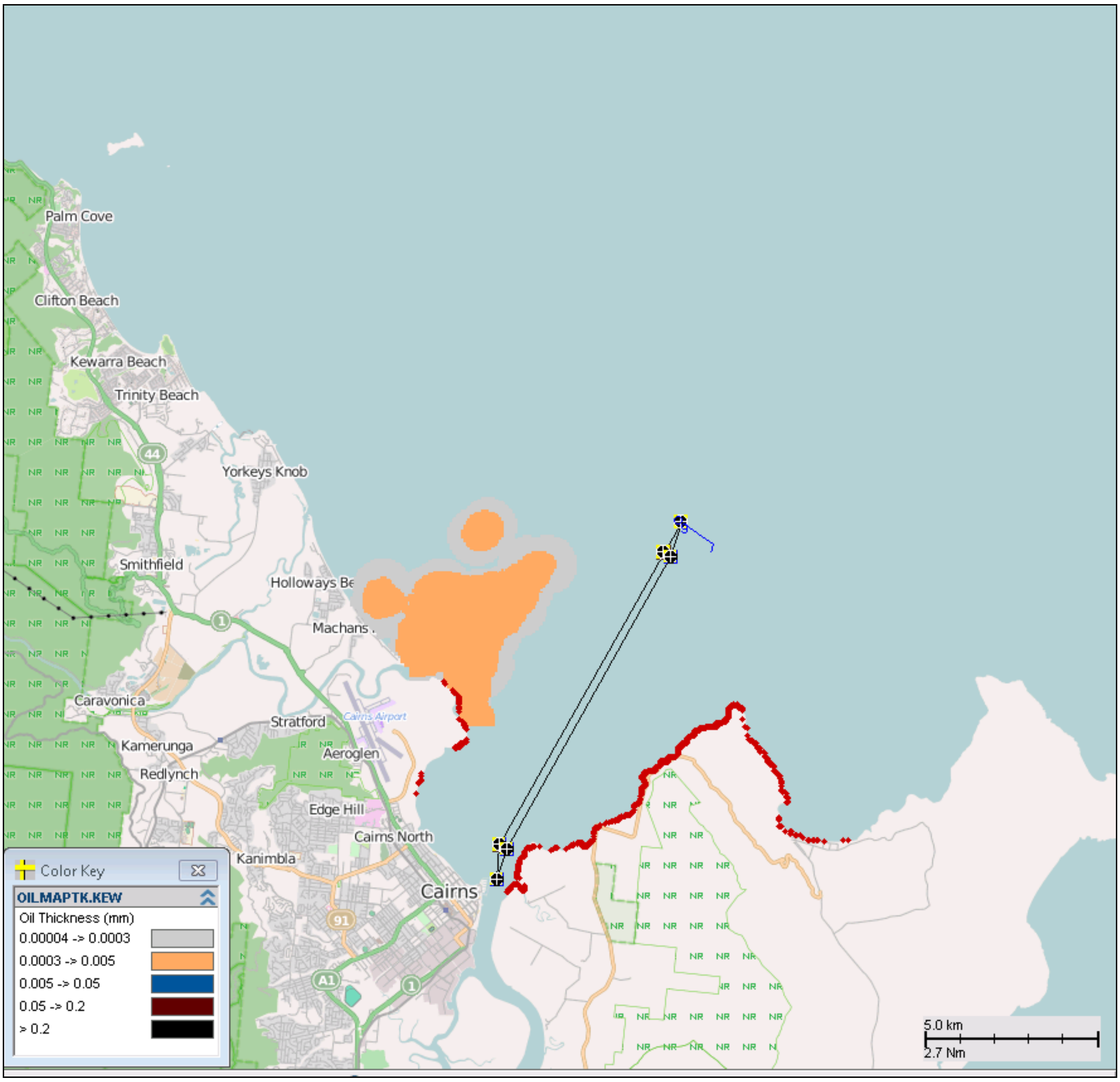

Figure 24: Snapshot of a worst case spill in the channel after 5 days from a 700 m^3 of IFO over 1 hour during a collision incident. Red dots along the shoreline indicate the position of oil stranded aground.

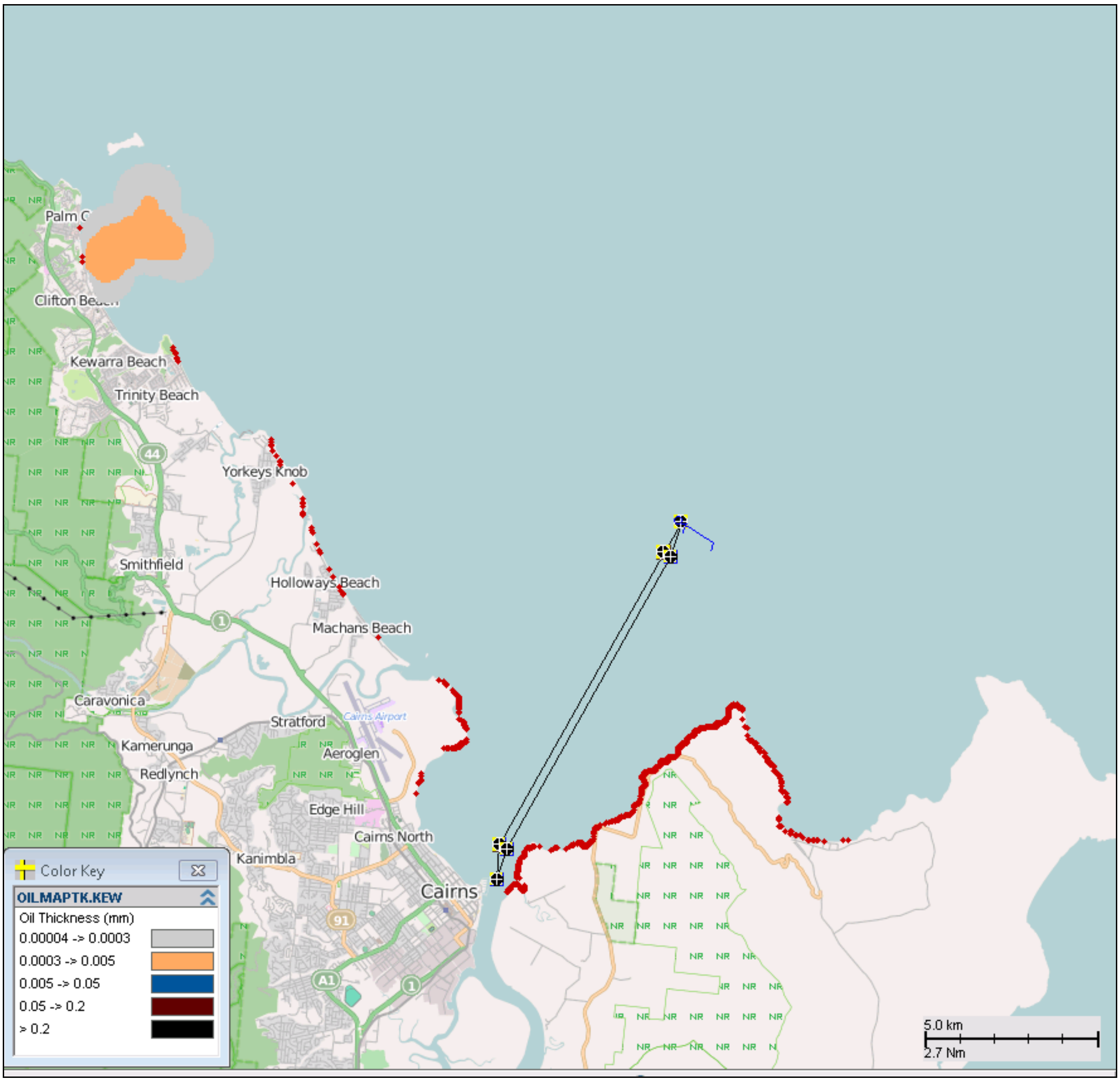

Figure 25: Snapshot of a worst case spill in the channel after 7 days from a 700 m^3 of IFO over 1 hour during a collision incident. Red dots along the shoreline indicate the position of oil stranded aground

8.3.2 Winter Stochastic: Maximum Credible Spill from Collision in Channel

The stochastic modelling of 200 spill simulations of this winter season was collectively analysed which quantified the probability of sea surface exposure and minimum time before exposure. Note the probability figures shown in this report summarised the likely exposure for each grid cell as a colour coding. For example, the grid cells with a 10% probability were exposed to 20 of the 200 trajectories and the cells with a higher probability of oiling were exposed during a greater number of spill trajectories, up to 100% at the release site.

Figure 26 to Figure 28 show the probability of sea surface exposure to heavy oiling and heavy sheens (being the 10 micron threshold), and any visible sheens (0.5 micron threshold) and the calculated minimum time before exposure. These results demonstrate that excusion away from the spill site is typically wind driven in this coastal region. These figures demonstrate that 100% of spills are pushed parallel and/or back onto the coast by the prevailing winds, most commonly near Cairns, while less than 10 of the 200 spills (5%) made it as far as Wonga Beach (just north of Mossman). Finally, none of 200 runs for winter reached the inshore reefs (regardless of threshold) thus indicated no risk to the offshore reefs from a channel spill during the winter months.

Table 5 summaries the shoreline statistics which demonstrates that 100 out of 100 simulations made shoreline contact predominantly due to the prevelence of onshore winds in this region. The results also demonstrate that this type of oil is highly persistent without significant volumes of volatile components and hence remains adhesive over time and does not readily evaporate.

Table 5: Summary of shoreline contact from this scenario tracked to the 0.5 µm threshold being the extent of visible oil as per AMSA Guidelines (2013).

Risk from Maximum Credible Spill in the Sea Channel				
Release	**Probability of contact to any shoreline (%)**	**Time to first reach any shoreline (hours)**	**Average volume of oil to reach shore for single trajectory (m^3)**	**Largest volume of oil to reach shore for single trajectory (m^3)**
The Sea Channel	100	0.5 to 9	346	400

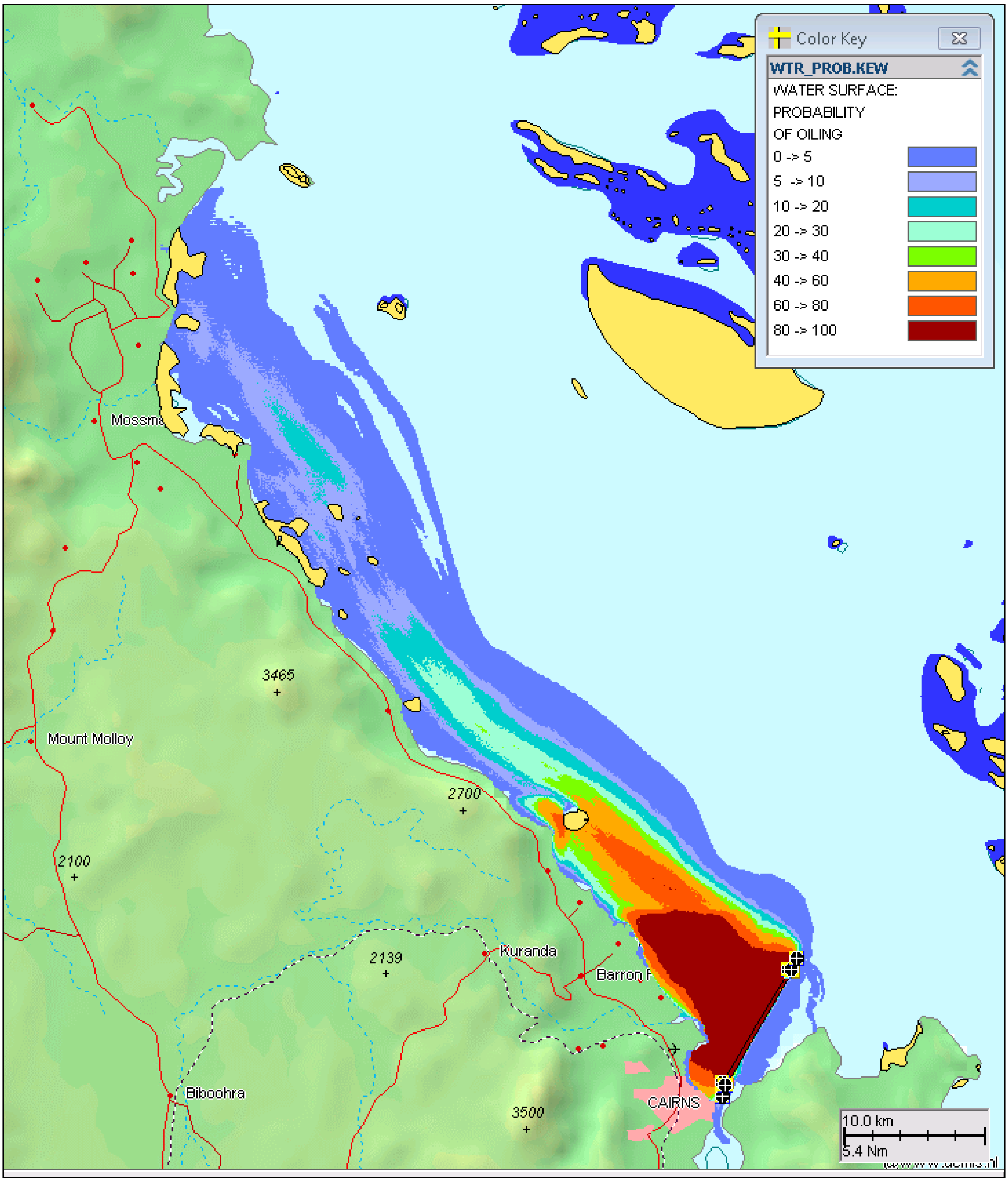

Figure 26: Map showing the model calculated probability or risk of sea surface and shoreline exposure to heavy oiling above 10 µm by combining 200 simulations of a 700 cubic meter spill of IFO along the Channel during Winter.

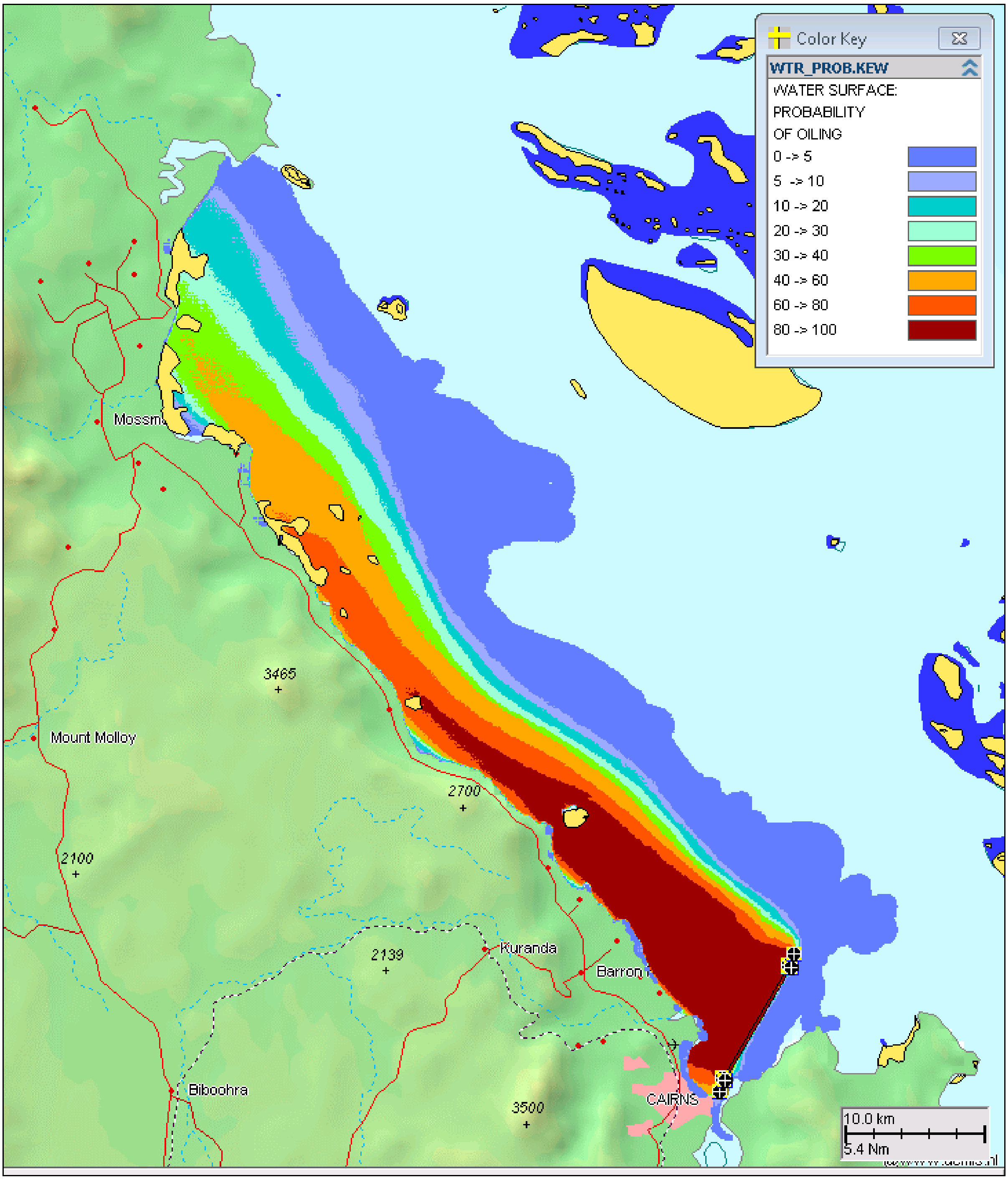

Figure 27: Map showing the model calculated probability or risk of sea surface and shoreline exposure to heavy oiling and heavy sheens above 0.5 µm by combining 200 simulations of a 700 cubic meter spill of IFO along the Channel during winter.

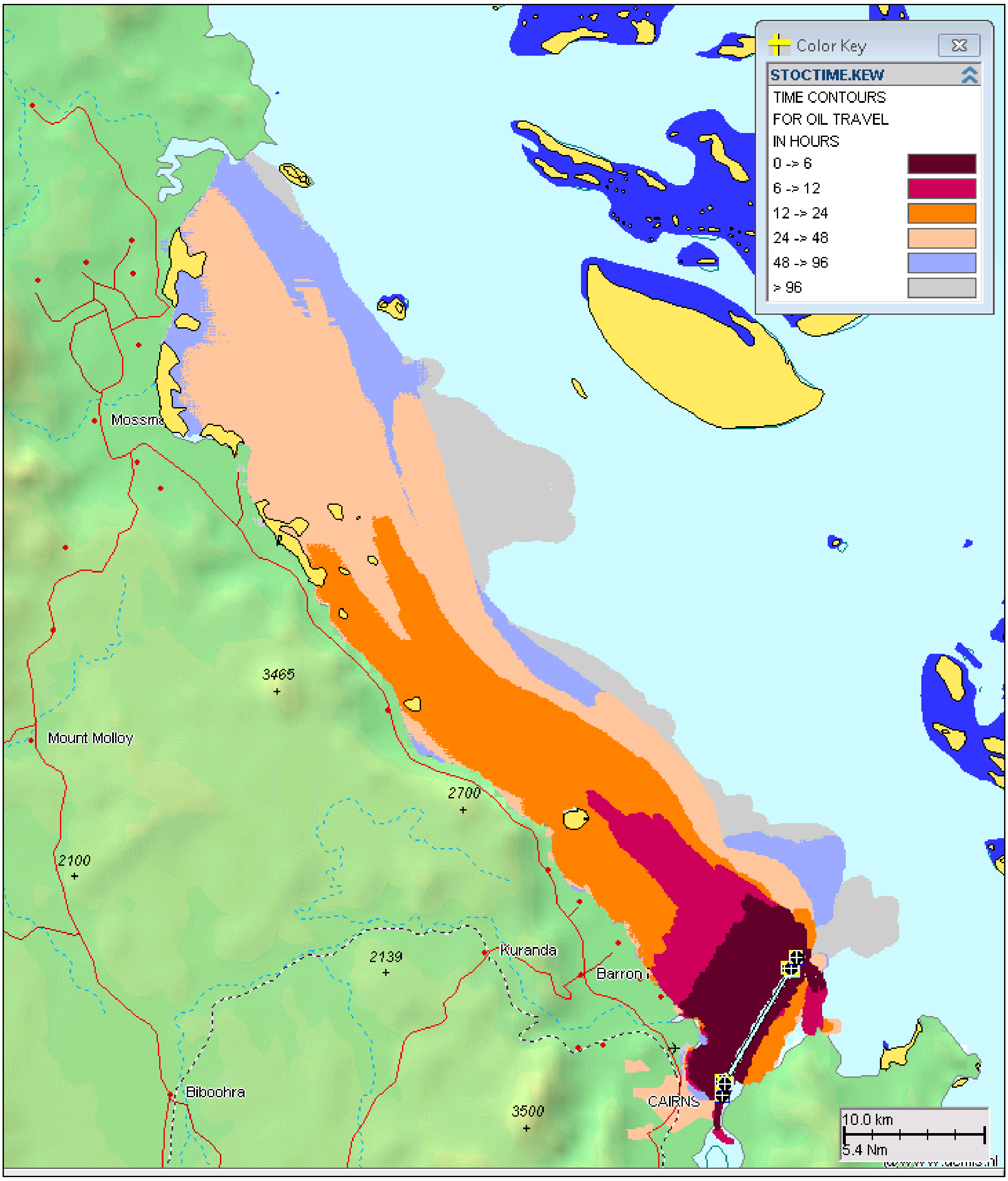

Figure 28: Map showing the model calculated minimum time required before sea surface and shoreline exposure above 0.5 µm from the combination of 200 simulations of a 700 cubic meter spill of IFO along the Channel during winter

8.3.3 Summer Stochastic: Maximum Credible Spill from Collision in Channel

The stochastic modelling of 200 spill simulations of this summer season was collectively analysed which quantified the probability of sea surface exposure and minimum time before exposure. Note the probability figures shown in this report summarised the likely exposure for each grid cell as a colour coding. For example, the grid cells with a 10% probability were exposed to 20 of the 200 trajectories and the cells with a higher probability of oiling were exposed during a greater number of spill trajectories, up to 100% at the release site.

Figure 29 to Figure 31 show the probability of sea surface exposure to heavy oiling and heavy sheens (being the 10 micron threshold), and any visible sheens (0.5 micron threshold) and the calculated minimum time before exposure. These results demonstrate that excusion away from the spill site is typically wind driven in this region. These figures demonstrate that 50% of spills along the channel will reach Yorkeys Knob above the ecological threshold of 10 microns, but would take at least 18 hours before contact. Further afield, the results demonstrate that only 5% of spills will reach as far as Port Douglas above 10 microns, or conversely, 95% of all spills will come ashore before reaching Port Douglas. Finally, 4 out of the 200 runs for summer reached the inshore reefs (Green Island), thus the risk remains very low (2% probability). Three trajectories reached the outer reef (1.5%) and one was entrained into the East Australia Current of the Coral Sea.

Table 6 summaries the shoreline statistics which demonstrates that 100 out of 100 simulations made shoreline contact predominantly due to the prevelence of onshore winds in this region. The results also demonstrate that this type of oil is highly persistent without significant volumes of volatile components and hence remains adhesive over time and does not readily evaporate.

Table 6: Summary of shoreline contact from this scenario tracked to the 0.5 µm threshold being the extent of visible oil as per AMSA Guidelines (2013).

Risk from Maximum Credible Spill in the Sea Channel				
Release	**Probability of contact to any shoreline (%)**	**Time to first reach any shoreline (hours)**	**Average volume of oil to reach shore for single trajectory (m^3)**	**Largest volume of oil to reach shore for single trajectory (m^3)**
The Sea Channel	100	1 to 95	350	402

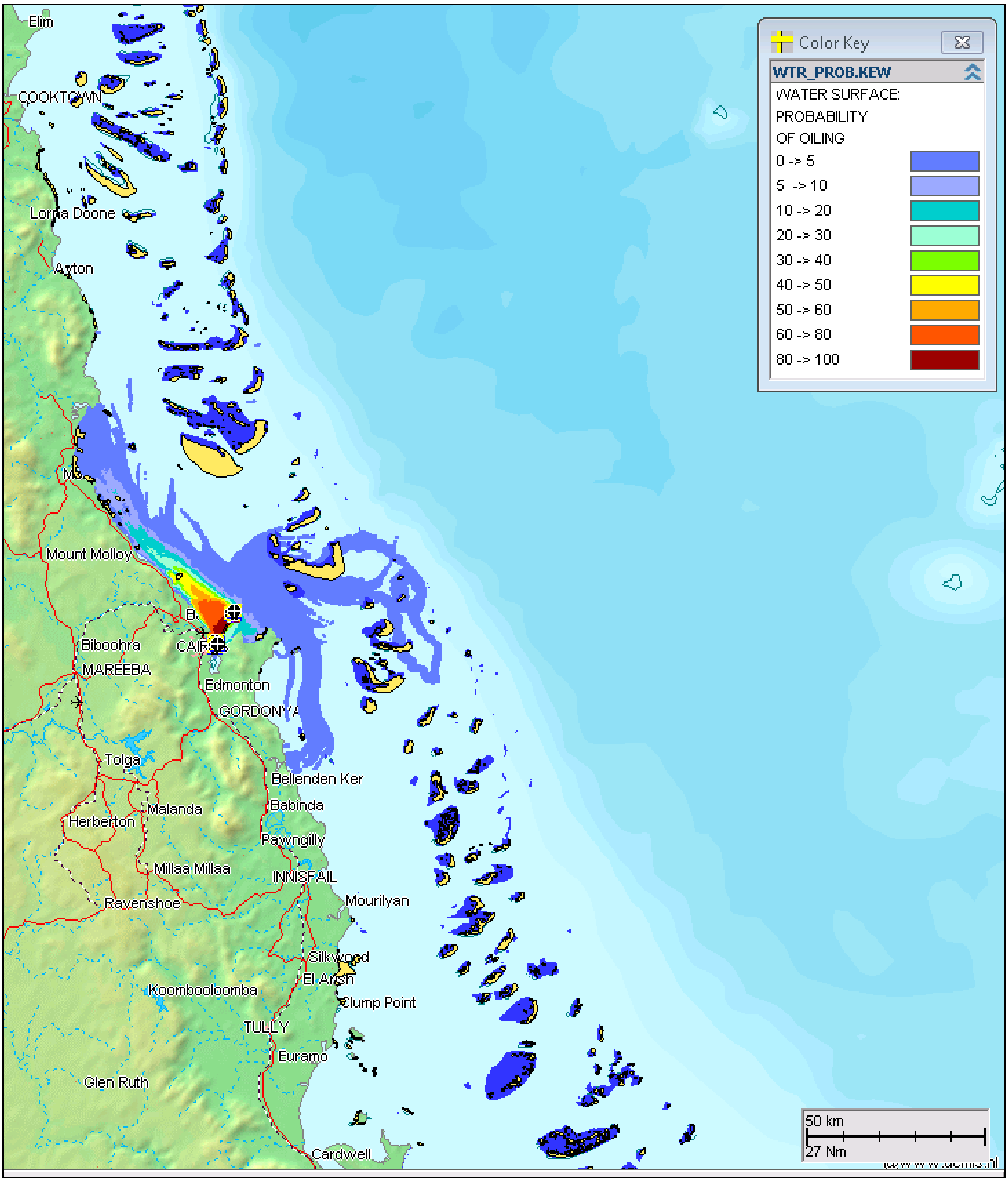

Figure 29: Map showing the model calculated probability or risk of sea surface and shoreline exposure to heavy oiling above 10 µm by combining 200 simulations of a 700 cubic meter spill of IFO along the Channel during Summer.

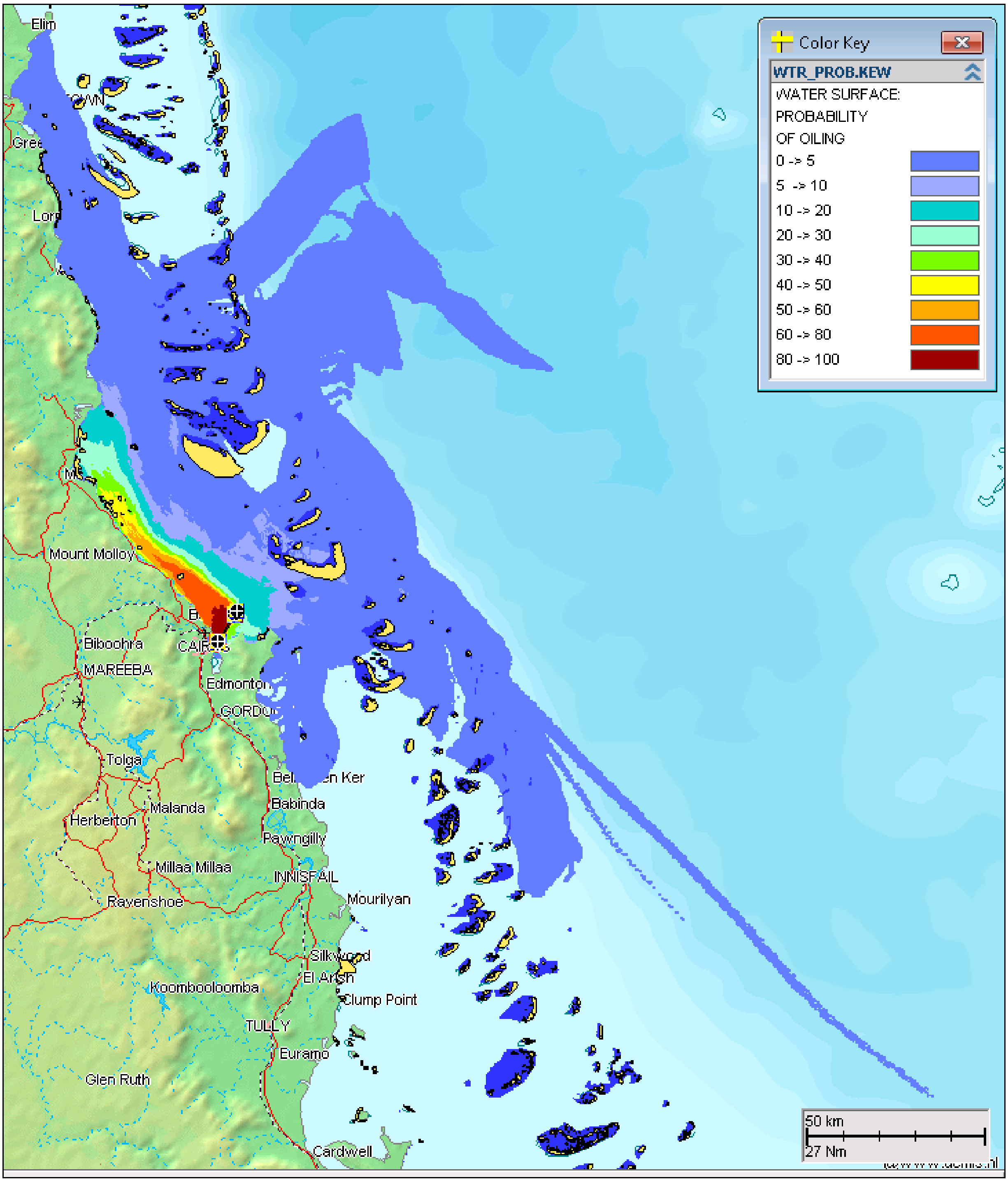

Figure 30: Map showing the model calculated probability or risk of sea surface and shoreline exposure to heavy oiling and heavy sheens above 0.5 µm by combining 200 simulations of a 700 cubic meter spill of IFO along the Channel during summer.

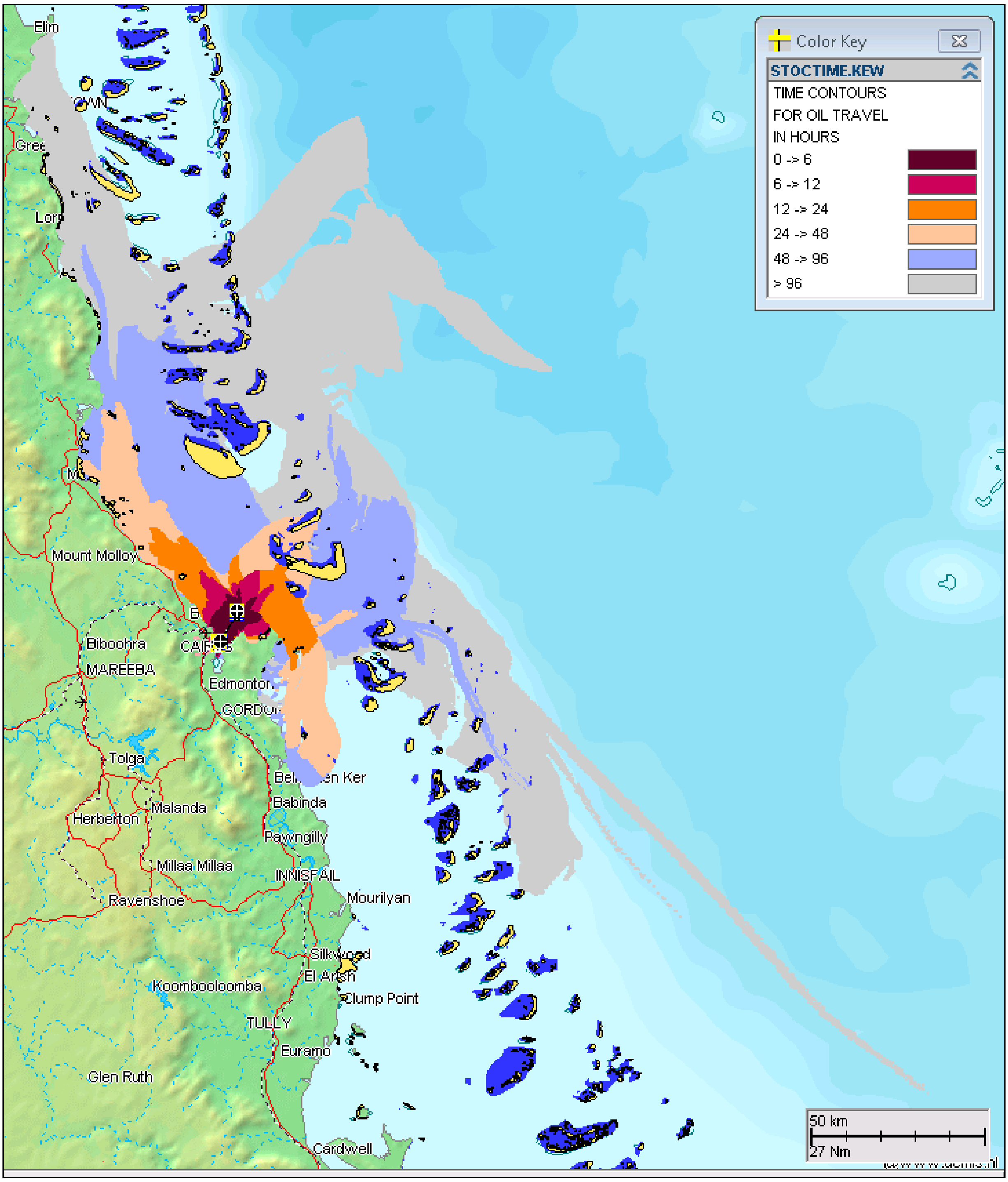

Figure 31: Map showing the model calculated minimum time required before sea surface and shoreline exposure above 0.5 µm from the combination of 200 simulations of a 700 cubic meter spill of IFO along the Channel during summer.

8.4 Most Probable Spill Volume from Collision in the Channel

Stochastic spill modeling was used for the quantitative risk assessment for a collision of an IFO supply vessel between the outer channel and inner channel but for a more likely spill volume, being a 20% loss from one tank (20% of 700 m^3 = of 140 m^3 of IFO over 1 hour. Given that the maximum credible scenario of this same scenario indicated little seasonality in the risk profile between winter and summer cases, a winter case only was undertaken here as previously winter provided a slightly worst-case average volume onshore of the two seasons.

8.4.1 Winter Stochastic: Most Probable Spill from Collision in the Channel

The stochastic modelling of 200 spill simulations of the winter season was collectively analysed which quantified the probability of sea surface exposure and minimum time before exposure. Note the probability figures shown in this report summarised the likely exposure for each grid cell as a colour coding. For example, the grid cells with a 10% probability were exposed to 20 of the 200 trajectories and the cells with a higher probability of oiling were exposed during a greater number of spill trajectories, up to 100% at the release site.

Figure 32 to Figure 34 show the probability of sea surface exposure to heavy oiling and heavy sheens (being the 10 micron threshold), and any visible sheens (0.5 micron threshold) and the calculated minimum time before exposure. These results demonstrate that excusion away from the spill site is typically wind driven in this coastal region. These figures demonstrate that 100% of spills are pushed parallel and/or back onto the coast by the prevailing winds, most commonly near Cairns, while less than 10 of the 200 spills (5%) made it as far as Yorkers Knob as thick oil. Finally, none of 200 runs for winter reached the inshore reefs (regardless of threshold) thus indicated no risk to the offshore reefs from a channel spill during the winter months.

Table 7 summaries the shoreline statistics which demonstrates that 100 out of 100 simulations made shoreline contact predominantly due to the prevelence of onshore winds in this region. The results also demonstrate that this type of oil is highly persistent without significant volumes of volatile components and hence remains adhesive over time and does not readily evaporate.

Table 7: Summary of shoreline contact from this scenario tracked to the 0.5 µm threshold being the extent of visible oil as per AMSA Guidelines (2013).

Risk from Maximum Credible Spill in the Sea Channel				
Release	**Probability of contact to any shoreline (%)**	**Time to first reach any shoreline (hrs)**	**Average volume of oil to reach shore for single trajectory (m^3)**	**Largest volume of oil to reach shore for single trajectory (m^3)**
The Sea Channel	100	0.5 to 12	105	115

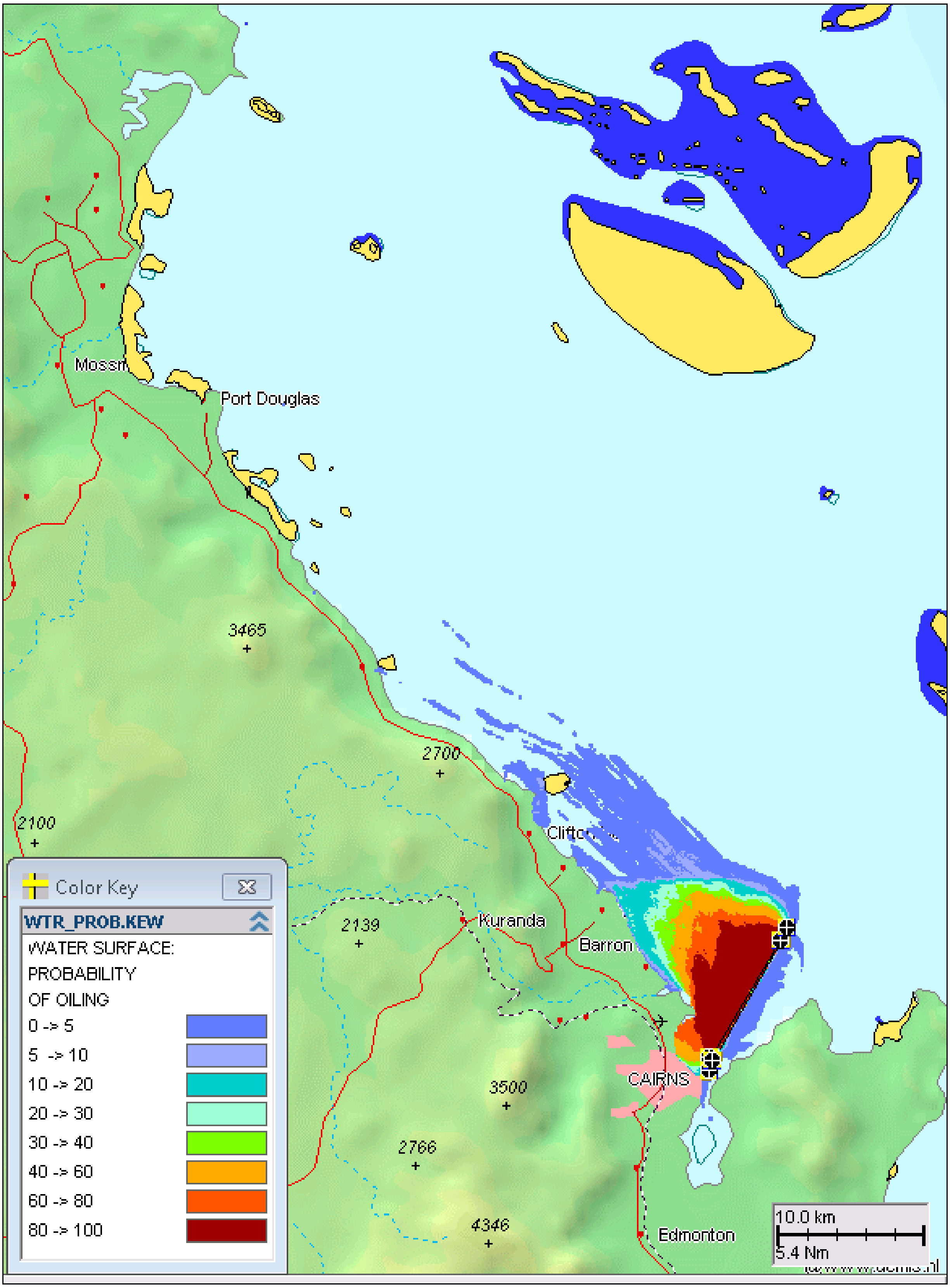

Figure 32: Map showing the model calculated probability or risk of sea surface and shoreline exposure to heavy oiling above 10 µm by combining 200 simulations of a 140 cubic meter spill of IFO along the Channel during Winter.

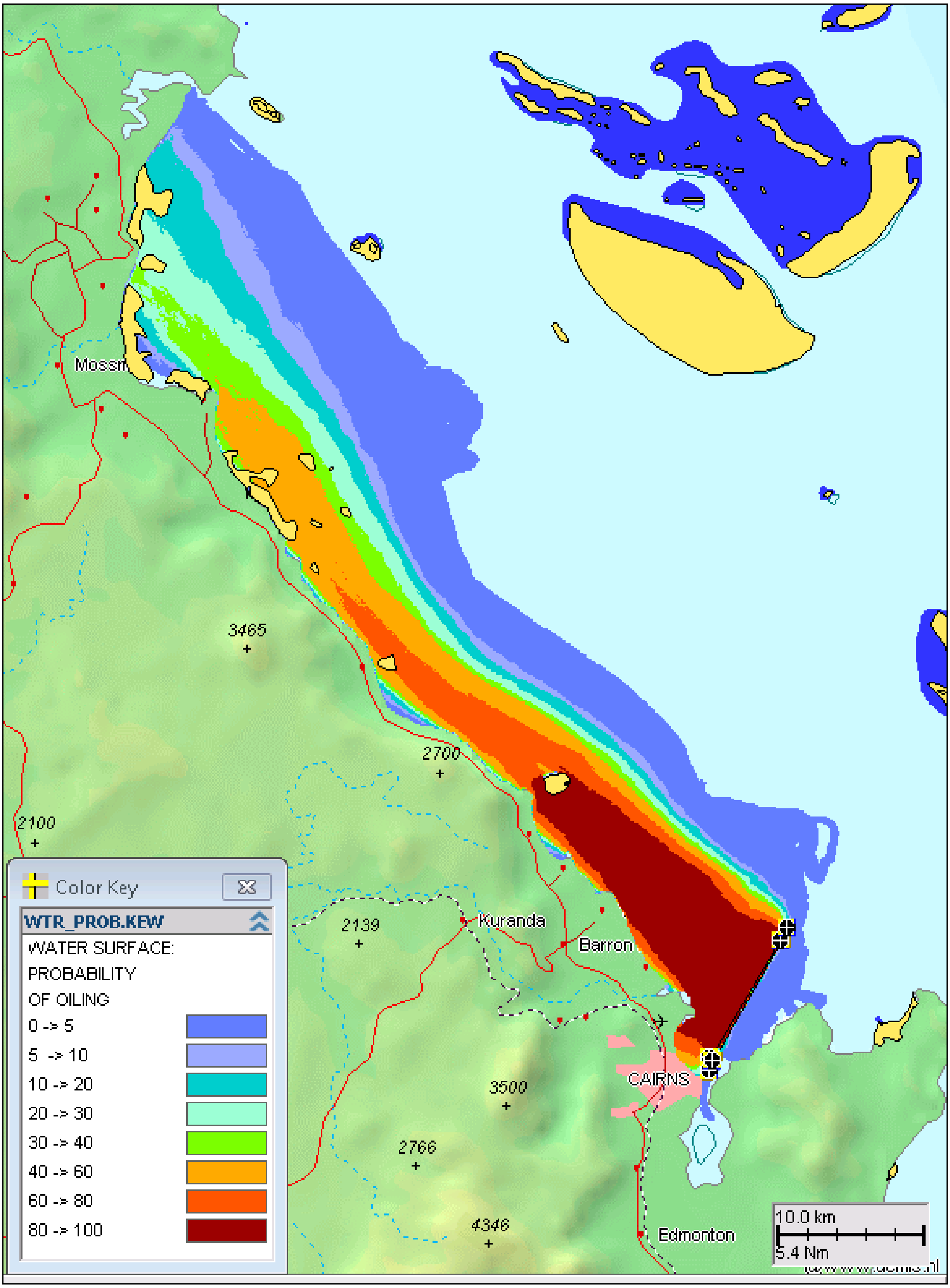

Figure 33: Map showing the model calculated probability or risk of sea surface and shoreline exposure to heavy oiling and heavy sheens above 0.5 µm by combining 200 simulations of a 140 cubic meter spill of IFO along the Channel during winter.

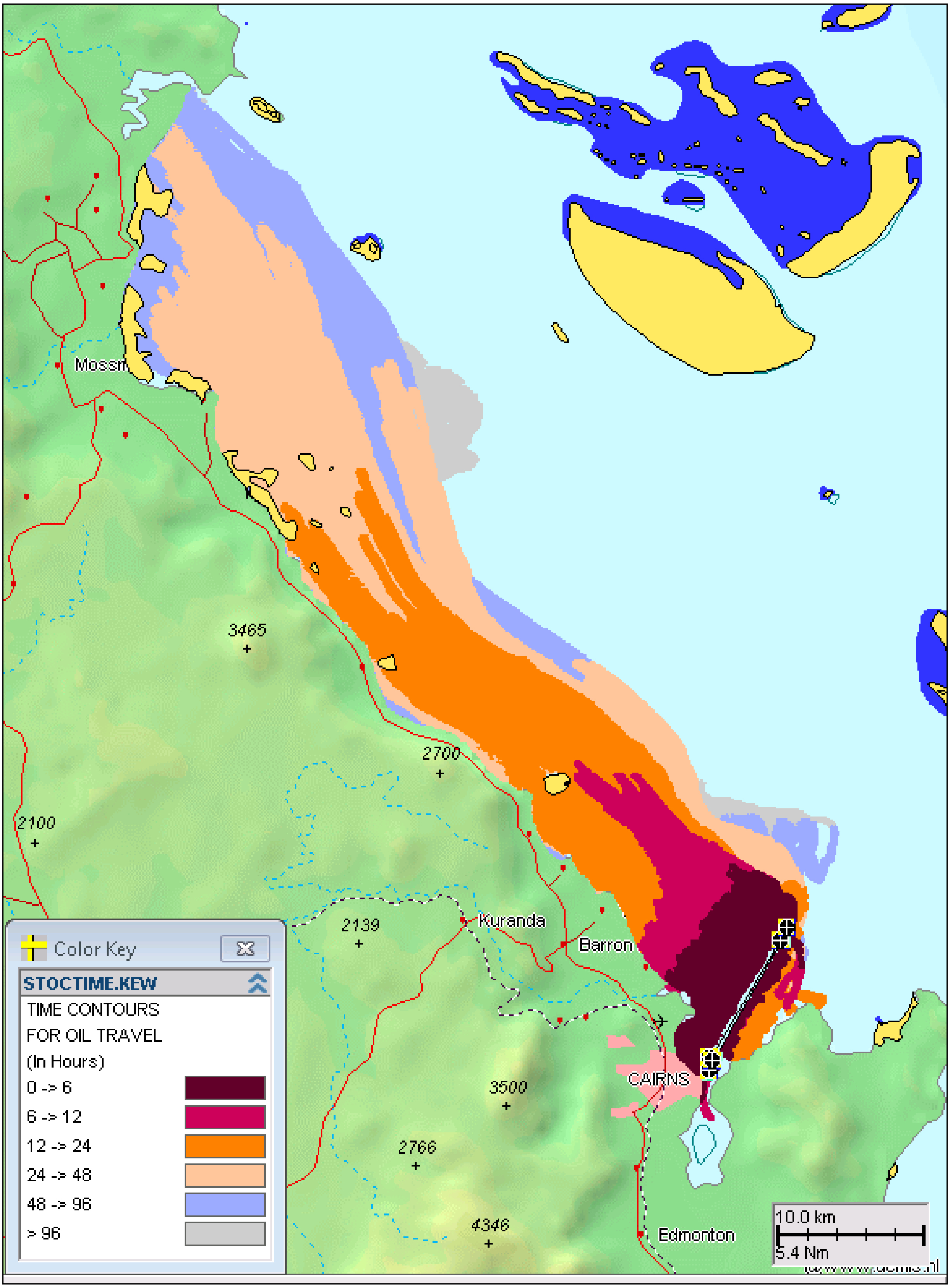

Figure 34: Map showing the model calculated minimum time required before sea surface and shoreline exposure above 0.5 µm from the combination of 200 simulations of a 140 cubic meter spill of IFO along the Channel during winter

9 DISCUSSION

Collectively, this investigation undertook 200 spill simulations for six incident scenarios that cover a range of maximum credible spill volumes and most probable spill volumes and a range of seasons at two sites, making 1,200 simulations in total as part of this study. It is important to note that the modelling did not take into account any spill cleanup and boom controlling capabilities that may be employed to reduce the risks associated with any actual spill of oil within Port Limits. However, some general observations from the oil spill risk assessment can be summarised as follows:

1. Any spill of IFO 180/380 in the tropical conditions of the Port of Cairns was quantified by the modelling undertaken herein to initially be highly evaporative, that is, will lose its light components quickly (more than 25% of total spill volume within the first 10 hours). The modelling also demonstrated that IFO 180/380 will also have slightly more than 50% residual components, so is persistent in the marine environment. These residual components will form tarballs and tarpads, once fully weathered, which will be semi solid. Over time, suspended sediment in the waters of the Port of Cairns may also adhere to the residual oil, potentially causing it to sink after about one or two weeks exposure to any suspended sediments, particular if a spill coincides with a significant rainfall and river discharge event.

2. A significant outcome of the 1,200 simulations undertaken for this study was that any spill within the Port of Cairns will come ashore and more than 50% of any spill volume will be trapped on shorelines. This will include intertidal regions that might be exposed at the time of any surface oil being in that area at the time of exposure.

3. In the estuary of the Port of Cairns (the proposed fuel transfer berth at Wharf 3), the fate of any spill of IFO 180/380 is significantly tidally driven, moving in and out with the tidal currents during the flood and ebb tidal phases. A comparison of the fates of spill during summer and winter demonstrates there is little seasonal difference in terms of the fate of the oil.

4. For any spill at Wharf 3 within the Port of Cairns estuary, wind may have a small influence on the fate of a spill during an ebb tide coinciding with a moderate to strong wind from the south, pushing any surface oil into the nearshore coastal region. In any event, an onshore wind (southeast or northeast) coinciding with a spill Wharf 3 is likely to expose fumes from the high initial evaporation of IFO 180/380 into populated areas on land (Cairns City and adjoining areas along the foreshore and estuary).

5. In the coastal region, in particular, the sea channel, the fate of any spill of IFO 180/380 is significantly wind driven. The predominant wind direction over the Port of Cairns waters is significantly from the southeast. For this wind direction, migration northwestward is possible. The distance that thick oil (> 10 Microns) can migrate northwards is significantly further for a Maximum Credible spill volume in comparison to a Most Probable spill volume.

6. Shorelines north of Cairns are populated, and shoreline impacts occurred in less than 10 hours of release in some simulations of a spill anywhere along the sea channel.

Fresh (<10 hours old) shoreline trapped IFO 180/380 will evaporate even when onshore, creating a hydrocarbon vapour plume that may blow onshore with the wind that brought the oil ashore. The modelling indicated that the vapours may persist for up to 10 days for a Maximum Credible Spill Volume. Further, any surface oil reaching beaches with breaking wave action along the shore were predicted to potentially emulsify, incorporate suspended sediment and sink after a period of days if not recovered and collected before that time.

7. A comparison of the seasonal influences (that is, summer and winter conditions) on spill fate within the region revealed little variance in spill outcomes between summer and winter conditions, other than winds tend to be more variable and overall weaker in summer than winter. For that reason, a very small amount of thick oil (> 10 microns) with small probability (< 5% risk) may move offshore and into the Great Barrier Reef matrix.
8. From the 1,200 simulations undertaken for this study, only 4 simulated spills were predicted to reach the mid shelf reefs of the Great Barrier Reef at thicknesses above 10 microns, indicating a very low to insignificant risk to the offshore reefs from spills within the Port Limits of Cairns.
9. The threshold specified by the Australian Maritime Safety Authority (AMSA 2013 guidelines) for the extent of visible oil at 0.5 microns reflects typical visual pollution, but not ecological risk. 0.5 microns is a very thin film of oil which is visible due to the refractive behaviour of sunlight shining on a thin film on water. Under ideal viewing conditions (calm water and good visibility), films as thin as 0.04 microns (typically silvery sheens) can be visible and may be visible outside of the extents shown herein.

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