BEFORE THE BOARD OF INQUIRY
TAMARIND DEVELOPMENT DRILLING APPLICATIONS

EEZ100016

IN THE MATTER	of the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012
AND	
IN THE MATTER	of a Board of Inquiry appointed under s52 of the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 to decide on Tamarind Taranaki Limited's marine consent and marine discharge consent applications

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STATEMENT OF EXPERT EVIDENCE OF BRIAN ALFRED KING FOR TAMARIND TARANAKI LIMITED

Dated: 20 July 2018

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MAY IT PLEASE THE BOARD

Executive Summary

1. The RPS Reports discussed in this evidence quantified the potential fate of a maximum credible unplanned discharge of Tui Crude Oil and Marine Diesel into the marine environment at their offshore drilling locations. The approach adopted in this report used sophisticated models and datasets to ensure realism and summarised hundreds of spill simulations to understand a broad range of potential outcomes.

2. The results indicated that any seabed release of crude oil would be rapidly transported to near surface waters in a turbulent bubble plume created by the corresponding gas release. At the surface, the gas would be lost to the atmosphere, while the crude would be mixed into near surface waters to form surface slicks.

3. Some of the crude oil would be removed from the sea surface within a few days by evaporation or naturally dispersed and diluted down through the water column. Crude residues would continue to drift as surface slicks that may be dispersed later by wind events exceeding 10 knots. During calmer conditions this natural dispersion will be reduced, leaving a potential for visible slicks to remain on the surface.

4. From the one hundred simulations conducted, all of these demonstrated that some surface oil can reach shorelines from a 110 day release particularly during periods of persistent moderate onshore winds. Some of the scenarios did predict that during periods of persistent moderate onshore winds, surface slicks may reach shorelines with as little as a 56 hour travel time. From the 100 hundred simulations conducted, shoreline volumes were found to be patchy and no more than 1% of the total spill volume for any defined shoreline. The simulations also quantified that if surface slicks were to reach shore, they would have weathered completely or significantly before doing so, hence they would reach shorelines as patches of solidified waxes and would do so only after some time of prevailing moderate onshore winds. Once onshore the wax flakes may melt. During strong winds, surface slicks are entrained into the water column and are naturally dispersed.

1. Introduction

1.1 My full name is Brian Alfred King.

1.2 I have PhD in Oceanography and a BSc (majoring in Mathematics), both from James Cook University of North Queensland, Australia.

1.3 I am currently employed as an oceanographer and mathematical modeller by RPS Australia West PTY Limited ('RPS') and have held that position since 1998.

1.4 My previous experience was that of Senior Research Scientist (again oceanography and mathematical modeler) for the Australian Institute of Marine Science (AIMS). My experience relevant to this report is the culmination of 26 years' experience setting up and supplying oil spill modelling systems to the region including Australia, New Zealand, Papua New Guinea, Malaysia, Vietnam, China, Indonesia, Thailand, Japan and Far East Russia. Specifically, I have been active in setting up and supporting the data feeds and oil spill and search and rescue models operated by Maritime New Zealand. Further, I have been on call for spill events and have responded to call outs for spill incidents and other marine emergencies since 1995, including an actual 'loss of well control' spill over an 11 week period. I was also the oil spill expert supporting Shell Todd's Marine Consent Application in 2015. More generally, I have 31 years of experience in studying water circulation and mixing in freshwater and marine environments at a research level. Finally, I have published many peer reviewed papers on oil spill model application and assessment and hundreds of commissioned studies on this subject, including dozens of independent expert witness reports on oil spill outcomes for port authorities, petroleum companies, state and federal governments.

1.5 My role in relation to Tamarind's applications has been as a consultant oceanographer and mathematical modeler. Specifically, RPS was engaged to carry out a sediment dispersion modelling study to provide guidance on the seabed deposition and in-water total suspended solids concentrations from drill cuttings and drilling muds discharges and to carry out quantitative oil spill modelling for wells in the Tui Field. This evidence supplements the two reports I prepared for Tamarind which annexed to the Impact Assessment and titled ‘Drill Cuttings and Muds Dispersion Modelling’, 12 February 2018 (Annexure E) and ‘Oil Spill Modelling’ dated 21 March 2018 and ‘110-Day Oil Spill Modelling’ dated 21 March 2018 (Annexure F). These reports were co-authored with Nathan Benfer of RPS. I will refer to the two oil spill modelling reports collectively as the “RPS Reports” in my evidence.

1.6 I have read the following information in preparation of my evidence:

1.6.1 The Marine Consent Application and Marine Discharge Consent Application (the “Applications”) and the Impact Assessment and Annexures, which accompanied the Applications (the “IA”), in particular, the sections that relate to the description of the activity, the dispersion of drill cuttings and muds and the dispersion of vessel spills and oil spills.

1.6.2 The statements of evidence by:

a) Mr Jason Peacock;
b) Mr Iain McCallum;
c) Dr Simon Childerhouse;
d) Dr. Sharon de Luca;
e) Ms Nicola Gibbs;
f) Dr David Thompson;
g) Dr Alison Lane;
h) Dr Alison MacDiarmid; and
i) Mr Fraser Colegrave.

1.6.3 Submissions.

1.6.4 Proposed consent conditions.

1.6.5 EPA Key Issues Report, dated July 2018.

1.6.6 The following independent reviews commissioned by the EPA (the “technical reviews”):

a. Technical Review of Oil Spill Modelling, prepared by Coffey Services (NZ) Limited, dated 26 June 2018 (the "Coffey Report");

b. Technical Review and Analysis of Operational Activities associated with Sidetrack Development Drilling and Marine Discharge Consent - Assessment Report, prepared by Oil and Gas Solutions Pty Limited, dated 22 May 2018 (the "OGS Report"); and

c. Review of Marine Environmental Impact Assessment, prepared by SEAPEN Marine Environmental Services, dated 26 May 2018 (the "SEAPEN Report").

1.6.7 Tamarind's '*Response to the Board's Request for Further Information under section 54 EEZ Act'*, dated July 2018 (the "RFI Response").

1.7 In order to provide the best available information and to account for the possibility that drilling activities may occur outside the February to May period, Tamarind also engaged RPS to carry out quantitative oil spill modelling for the months of June to January. RPS has prepared a further report, titled '*Oil Spill Modelling – Vessel Spill and 110-Day Loss of Well Control (June to January)*', dated 13 July 2018, which outlines the results of this modelling (the "RPS Winter Report"). A copy of this report has been provided to the Board by Tamarind as further information and was attached to the RFI Response. I will discuss the modelling we undertook in order to prepare this report further below.

Code of conduct

1.8 I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court of New Zealand Practice Note 2014 and that I have complied with it when preparing my evidence. Other than when I state I am relying on the advice of another person, this evidence is entirely within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

1.9 My qualifications as an expert witness are set out above. The issues addressed in this brief relate to the application for a marine consent and marine discharge consent and are matters within my area of expertise.

Scope of evidence

1.10 In this evidence, I will discuss the following:

(a) An overview of the RPS role in the project;
(b) An overview of an oil spill at Tui;
(c) The Taranaki regional wind and current data;
(d) Data validation;
(e) An overview of the oil spill models and methods;
(f) Oil spill weathering – model predictions;
(g) Oil spill fate and environmental risk of exposure – model predictions;
(h) Likelihood of shoreline stranding of oil;
(i) Likely dispersion behaviour of an oil spill at Tui; and
(j) Response to the EPA's Reviews.

2. An overview of the RPS role in the project

2.1 It is current international best practice to develop oil spill contingency plans from 100s of spill simulations, using sophisticated spill models, of the maximum credible spill scenario (see AMSA 2015a). To ensure realism, the models are set up to incorporate the physical and chemical properties of the oil and the actual weather and ocean conditions of the potential spill site. The models employed by RPS in preparing the RPS reports were created using 100s of spill simulations and incorporated the physical and chemical properties of the oil and the actual weather and ocean conditions of the region.

2.2 RPS was commissioned to quantify the potential fate of Tui Crude in the marine environment from a maximum credible 'loss of well-control' scenario, being a seabed escape of gas and crude oil at their Tui, Amokura and Pateke sites in the offshore Taranaki Basin. Based on the proximity of the wells to land, and the potential maximum oil release rates, Amokura-2H was chosen as the representative (and worst case) scenario for this modelling study. The final worst case scenario, including calculations and measurements of flow rates and the chemical composition of a maximum credible release, were supplied to RPS as a 654,516 STB[1] (104,059 m^3) of Tui Crude released during a hypothetical loss of well control incident over 110 days. The evidence of Mr McCallum explains why these parameters were identified by Tamarind Taranaki Limited. Further, additional modelling was undertaken to assess the oil spill risk associated with a 200m^3 release of diesel from a vessel incident, simulating the largest bunker tank rupture on an anchor handling vessel that may be used on the project.

3. An overview of an oil spill at Tui

3.1 Tui crude has a density of 808 kg/m^3 (API gravity of 43.5) and a dynamic viscosity of 3.186 cP at 40ºC. Although it is classified as a Group II oil according to the International Tankers Owners Pollution Federation (ITOPF, 2014) classifications (up to 70% will evaporate), it does have a high wax content of 17.3%, which will result in this oil turning in to wax and solidifying into small waxy flakes after extended periods (days to weeks) in the marine environment.

3.2 Marine diesel oil (MDO) used for the vessel spill simulation has an API of 37.6, density of 829 kg/m^3 (API gravity of 37.6) and a low viscosity of 4.0 cP at 25ºC, also classifying it as a Group II oil like Tui Crude. MDO is characterised by a larger mixture (95%) of high and semi- to low-volatiles and contains less (approximately 5%) persistent hydrocarbons. It is important to note that some heavy components contained in marine diesel oil have a strong tendency to physically entrain into the upper water column in the presence of moderate winds (i.e. >12 knots) and breaking waves but can re-float to the surface if these energies abate since diesel has a lower pour point[2] than Tui Crude.

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[1] Standard Barrels

[2] The temperature at which a liquid loses its flow characteristics.

4. The Taranaki regional wind and current data

4.1 The spill models used in the RPS Reports were set up with data from the Taranaki region as summarised below.

4.2 The monthly temperature and salinity profiles of the water column near the release sites were obtained from the World Ocean Atlas 2013 database produced by NOAA's National Oceanographic Data Centre (Levitus et al., 2013). These show that monthly average sea-surface temperatures near the release sites vary over the course of the year from a minimum of 13.0°C (August) to a maximum of 19.1°C (March).

4.3 High resolution wind data was sourced from the National Centre for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR; see Saha et al., 2010) for the 10 year study period 2003 to 2012. The CFSR wind model is a fully coupled, data-assimilative hind cast model representing the interaction between the earth's oceans, land and atmosphere. The gridded wind data output is available at ¼ of a degree resolution (~33 km) and 1-hourly time intervals. The wind node closest to the release site demonstrated two predominant (general) directions; 1) south-westerly winds during August to February and 2) south-westerly and south-easterly during March to July. Further, monthly average wind speeds at this location range from 15–19 knots and the monthly maximum wind speeds range from 41–54 knots. Further, the strength of the wind is such that its direction will often influence the direction of surface slicks when wind speeds are average or greater. Hence for persistent periods of southwest winds, surface slicks will most likely migrate closer to shore and for persistent periods of southeast winds, surface slicks will most likely migrate further from any shorelines.

4.4 Data describing the flow of ocean currents for the same period as the wind data (2003 to 2012) was obtained from a dataset known as HYCOM (Hybrid Coordinate Ocean Model by Chassignet et al., 2007), which is operated by an ongoing global research consortium, sponsored by the Global Ocean Data Assimilation Experiment (GODAE). HYCOM is a data-assimilative, three-dimensional ocean model that is run as a hindcast (for a past period), assimilating time-varying observations of sea-surface height, currents, in-situ temperature and salinity measurements (Chassignet et al., 2009). The use of this dataset is considered best practice for deepwater oil spill response and planning purposes. It is currently used by Maritime New Zealand and the Australian Maritime Safety Authority for these purposes and for search and rescue.

4.5 Data describing the tidal behaviour over the region was determined at high resolution from satellite measured altimetry data (known as TOPEX/Poseidon 7.2 dataset) which provided estimates of the eight dominant tidal constituents. The Topex-Poseidon satellite data is produced and quality controlled by NASA (National Aeronautics and Space Administration). The satellites, equipped with two highly accurate altimeters, capable of taking sea level measurements accurate to less than ± 5 cm, measured oceanic surface elevations (and the resultant tides) for over 13 years (1992–2005). The tidal currents are also used by Maritime New Zealand and other government agencies for the purposes of oil spill response and search and rescue planning at sea.

5. Data validation

5.1 The RPS Reports show a validation of the tidal water levels from the modelling dataset against nine widespread coastal measurements sites which indicated an index of agreement of 0.91 to 0.98 across all sites and demonstrates an acceptable level accuracy.

5.2 Finally, the RPS APASA 2014 study for the Maui B Consent Application reported a drifter track validation using the above-mentioned wind and current and tidal datasets, when combined, for the Taranaki region. This demonstrates the ability of the models and their datasets to represent the observed drift patterns in the Taranaki region.

6. An overview of the oil spill models and methods

6.1 The RPS Reports used “state of the art” models, known as OILMAPDEEP and SIMAP, which simulate the fate of both gases and fluids from a seabed release, and each model was set up for the local environmental conditions at the Tamarind Drilling Sites. Many simulated releases of Maximum Credible

Spill Volumes (100 in total for each spill scenario), using 10 years of historical data for the region, were undertaken by RPS to robustly quantify the range of possible outcomes. The models and methodology used are those accepted by the regulators in many countries around the world, including the USA, Australian and New Zealand Governments and are considered "International Best Practice" in quantifying the range of risks associated with any potential oil spill incident. OILMAPDEEP has been recently validated against the Macondo Incident in the Gulf of Mexico. SIMAP was developed for the US Government as part of their Oil Pollution Act 1990 and has been recently validated against the Macondo Incident.

7. Oil Spill Weathering – Model Predictions

7.1 The RPS reports and the laboratory analysis of the Tui Crude Oil shows that any seabed release of crude oil would be rapidly transported to near surface waters in a turbulent bubble plume created by the corresponding gas release. At the surface, the gas would be lost to the atmosphere, while the crude would be mixed into near surface waters to form surface slicks due to its buoyant density of 808 kg/m^3 being significantly lighter than ambient seawater.

7.2 The modelling also indicated that the surface slicks are likely to be more common during calmer weather and will naturally disperse again during strong winds (that is, no surface slicks will be evident as the crude oil will be mixed down into the water column).

7.3 The diesel modelling is a surface release simulation and hence any diesel spill will form a heavy sheen once spilt. The diesel is predicted to evaporate significantly while on the surface and but will also disperse significantly during moderate to strong wind events as well. If strong wind events abate quickly, it is possible that the diesel slicks can resurface to a degree.

8. Oil spill fate and environmental risk of exposure – model predictions

8.1 From the 100 simulations of each of the maximum credible spill scenarios undertaken for the RPS Reports, it was possible to quantify the range of possible outcomes from the range of weather and ocean conditions in the region, including an understanding of the worst-case outcome from a maximum credible release scenario. Collectively, these many simulations can define the likelihood of which areas surrounding a spill location may be exposed to surface slicks or sub-surface dispersed oil, and which areas are unlikely to be exposed at all.

8.2 The results of the modelling show that a seabed release of Tui Crude oil is unlikely to form any thick surface slicks more than 46-58 km from the release location. The worst case of the many simulations conducted for this maximum credible scenario (the worst of the worst) indicated the potential that isolated thin visible slicks may be detectable as far as 395 km away but far offshore. These thin slicks would be completely weathered and would be isolated patches of small solid white wax flakes.

9. Likelihood of shoreline stranding of oil

9.1 From the 100 simulations conducted for a maximum credible release all simulations demonstrated that winds and currents can bring some crude oil ashore as events, that is, when the conditions are right, surface slicks will reach shorelines as visible slicks. The Taranaki Region was predicted by the modelling to be the highest risk for oil reaching shore during persistent onshore light to moderate winds.

9.2 The simulations also quantified, that when surface slicks did reach shore, they would have weathered, hence would reach shorelines as patches of solidified small wax flakes and only after some time of prevailing onshore winds. This is because the distance and location of the Tamarind sites from shore, means that oil has to travel for at least 2.3 days (56 hours) as a surface slick, while evaporating, to reach the closest shorelines. Once onshore, the wax flakes may melt.

10. Likely dispersion behaviour of an oil spill at Tui

10.1 From the one hundred simulations conducted for each scenario, the results indicated that overall, the majority of the liquid crude oil would be removed from the marine environment by evaporation. A significant amount of the residues that are not evaporated would be naturally dispersed by the high turbulence and energetic mixing from the gas plume. Any crude oil slicks that do form at the surface may be mixed down back into the water column when winds become moderate to strong, due to breaking wave action. These wind-dispersed oils form subsurface plumes that would initially be at concentrations of less than 10 ppm down to 10m and less again over time when mixing down to depths below 10m due to dilution. Over time, this natural dispersion means that dilution of the subsurface plumes will continue to reduce concentrations with depth of penetration and move away with the currents as they dilute.

11. Response to EPA Key Issues Report and Technical Reviews

11.1 The EPA's Key Issues Report sets out three key issues that were identified in the Coffey Report, which it says require clarification:

a) Timelines of hindcast datasets used;

b) Environmental thresholds used;

c) Mass balance.

11.2 In regards to paragraph 101(a) of the EPA Key Issues Report with respect to the hind cast data timelines used in modelling, we note some ambiguous text due to a typographic error in the original RPS Reports made the hind cast data timelines unclear[3]. It is best practice to ensure the hindcast datasets are synchronised/coupled and we agree with the Coffey Report on that matter. We can confirm that we have used the entire HYCOM dataset and CFSR dataset and tidal current dataset (reconstruction from HYDROMAP) for the entire 10 year period 2003 to 2012. Further, we can confirm that the assessments conducted use these entire datatsets in a synchronised/coupled manner so that the start dates and end dates always correspond amongst the datasets within the model. Thus there is no artificial behaviour in the spill trajectories in the RPS Reports and the modelling has

[3] Refer to section 3.3 in the RPS Reports, which reads: "For this study, the HYCOM hindcast currents were obtained for the year 2012". The text should have read: "For this study, the HYCOM hindcast currents were obtained for the years 2003-2012".

been conducted using best practice including full synchronisation/coupling throughout the assessment, including all months and days of each year.

11.3 With respect to paragraph 101(b) of the EPA Key Issues Report regarding the environmental thresholds used in the modelling, it is important to note that the thresholds used by RPS are typical for best practice assessments in recent years. It should also be noted that the studies compared to this study are older, and while the reports for the current consent application use different lower thresholds, we consider these current thresholds as best practice in 2018.

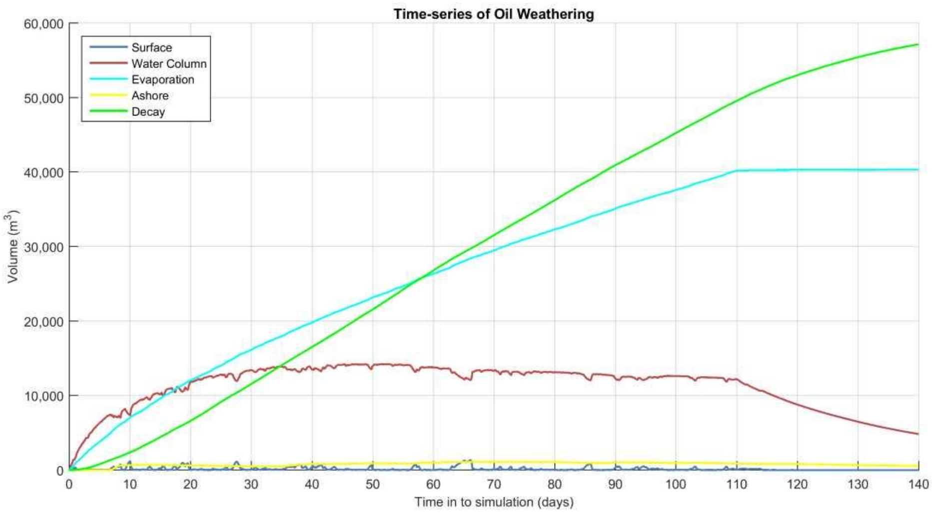
11.4 Specifically, the Australian Maritime Safety Authority provided more recent guidance for best practice in planning for an offshore oil spill following experiences with the Montara and Deepwater Horizon/Macondo spills (AMSA 2015a and 2015b). AMSA concluded that a minimum of 0.5 g/m^2 (which closely equates to 0.5 μm) was the limit of detectable oil in the coastal and offshore environment, and the 100 g/m^2 was the limit of actionable oil on the shorelines. Hence these thresholds were used in the RPS Reports and are used in all our assessments since 2015 and are considered current best practice.

11.5 The 100 g/m^2 threshold (~100 μm) is recommended in the Australian Maritime Safety Authority's (AMSA) Foreshore Assessment Guide (AMSA 2015b) as the acceptable minimum shoreline thickness that does not inhibit the potential for recovery and is best remediated by natural coastal processes alone. The 100 g/m^2 threshold has been selected in the RPS reports to define the zone of potential moderate contact on the shorelines and is also referred to as the limit for actionable shoreline oil. The RPS reports also use a lower shoreline threshold of 10 g/m^2 (approximately 10 μm) which is an order of magnitude below any ecologically important shoreline threshold (100 g/m^2). This lower level is often reported as it is more indicative of the shorelines perceived to be affected due to stranded oil visibility and hence the potential to trigger temporary closures of shorelines as a precautionary measure only. At these levels and the Tui Crude oil type that will likely form waxy flakes when it comes ashore, 10 g/m^2 is equivalent to 10 x 1 ml droplets (if it remelts) or 10 very small flakes per square meter of shoreline, which is very low coverage at this level. The ability to detect oil on shore lower than these levels is unlikely hence we use 10 g/m^2 extensively as the current best practice lower threshold for shoreline reporting following AMSA 2015b.

11.6 To better assess the potential for sea surface exposure, each of the 100 spill trajectories was tracked to a minimum of 0.5 g/m^2, which equates approximately to an average thickness of ~0.5 μm. Oil of this thickness is described as a silvery to rainbow sheen in appearance, according to the Bonn Agreement Oil Appearance Code (Bonn Agreement 2009) and is also considered the practical limit of observing oil in the marine environment (AMSA, 2015a). This threshold is considered below levels which would cause environmental harm and it is more indicative of the areas perceived to be affected due to the visibility of oil sheen on the sea surface and potential to trigger temporary closures of areas (i.e. fishing grounds) as a precautionary measure. We define this lowest threshold as the potential extent for socio economic impact. Hence, the 0.5 g/m^2 threshold has been selected to define the zone of potential low exposure on the sea surface in the RPS reports. Please also note that the Bonn Agreement Oil Appearance Code (Bonn Agreement 2009) for the very low level of 0.04 μm is defined as a thickness that can only been seen under ideal viewing conditions which are possible for a harbour spill but unlikely in the coastal environment and is no longer used in best practice assessments for oil spill contingency planning.

11.7 Studies indicate that the dissolved aromatic compounds (typically the mono-aromatic hydrocarbons and the two and three ring poly-aromatic hydrocarbons) are commonly the largest contributor to the toxicity of solutions generated by mixing oil into water (Di Toro et al., 2007). The exposure level (threshold concentration over a given duration) was used to assess the potential for exposure to sub-sea habitats and species by entrained and dissolved aromatic hydrocarbons. The threshold value for species toxicity in the water column is based on global data from French et al. (1999) and French-McCay (2002, 2003), which showed that species sensitivity (fish and invertebrates) to dissolved aromatics exposure > 4 days (96-hour LC50) under different environmental conditions varied from 6 to 400 μg/l (ppb) with an average of 50 ppb. This range covered 95% of aquatic organisms tested, which included species during sensitive life stages (eggs and larvae). Hence, a minimum threshold of 6 parts per billion (ppb) over 96-hours or equivalent was used to assess in-water low exposure zones (see also, Engelhardt, 1983; Geraci and St. Aubin, 1988; Tsvetnenko, 1998). Again, we consider 6 ppb to be a conservative threshold and we use it extensively in recent years for these types of assessment following AMSA 2015a.

11.8 With respect to paragraph 101(c) of the EPA Key Issues report regarding end of simulation metrics not being presented in the form of mass balance, it is helpful to look at examples of the fates graphs for one of the spill simulations conducted as shown below. The example below shows the scenario that produced the maximum volume of oil ashore during any of the simulations conducted. The time series below shows that the residual oil components are significantly dispersed at sea due to the dispersive nature of the Tui Crude Oil (typically a waxy residual oil below its pour point) which is then available for decay over time. Due to the varying currents, the crude dispersed into the water column occurs most often in deep water, allowing for dilution. Being a light crude, there is also significant and rapid evaporation of the volatile components. Sea surface exposure only occurs during light wind conditions and hence minimizing the volumes coming ashore.



11.9 Specifically the mass balance (above) of this example demonstrates that the spill initially occurred during rough weather and mixes into near surface waters of the water column due to the high energy mixing. In this example, some oil comes ashore after 8 days as this rough weather abates and surface slicks start to form around day 7. Over time, the high energy moderate to rough weather events come (no surface slicks and subsurface oil is mixed deeper and moved around) and go (near surface water column oil floats to makes surface slicks). Ultimately, the degree of mixing in this offshore region ensures that crude oil and diesel is dispersed while allowing for some evaporation and decay. Further, the flow rate of the spill reduces with time, and hence prevents any accumulation within the water column after day 30 as shown in the above example time series. Other mass balances show similar patterns, just the timing of the moderate to rough weather events changes for each simulation.

11.10 A number of other matters were also identified in the Coffey Report, which require clarification. I respond to each matter as follows:

(a) Section 3.1 – "*It is not clear how many months were used in the modelling. Presumably a spill could continue into June or July*".

Response: The full 10 year hindcast dataset was used as input to the model. To cover the 140 day run period, all months were used, so if the spill continued into June and July, that June and July data was used in a synchronised/coupled manner in the modelling. In order to ensure the best available information is available, RPS has now also carried out modelling for the period June to January. The RPS Winter Report is attached to Tamarind's RFI Response.

(b) Section 3.1.1 – "*Oil concentration units should be consistent, or related in the introductory tables and images*".

Response: The units do vary in the reporting and we use units corresponding to their associated references. For example, units of thickness are related to the physics of the appearance of oil on the surface as a thin film, and are only used when referencing the Bonn Agreement Code. The units regarding surface oil and shoreline oil as g/m^2 relate to the references (which are also in g/m^2) that support the thresholds applied in this study and are the main units used throughout the report. The relationship between thickness and g/m^2 is the oil density, which changes over time during each simulation, hence g/m^2 is the most accurate unit to use.

(c) Section 3.2.1 and 3.2.4 – "*Validation of the tidal elevations. – the report should provide the tide height validation statistics for the months used in the study*".

Response: The HYDROMAP dataset is constructed and updated when new satellite data or bathymetry data becomes available, hence periodically over the years. For the New Zealand region, feedback from Maritime New Zealand is also incorporated into any updates. Some feedback from Maritime New Zealand is that high resolution within the ports unnecessarily slows down access to this dataset via the internet for Search and Rescue cases, hence, harbours where tide gauges are located are now at a slightly lower resolution in comparison to RPS APASA 2014, but the offshore components of the grids remain the same. Further, the comparison with tidal stations is undertaken when these new datasets are created, hence is an arbitrary month related to the previous update. The RPS Winter Report now includes simulations using January tides. The tidal elevations from the database creation are not saved, so it was not a simple task to redo the comparison for another month. However, the HYDROMAP dataset is in use by Maritime New Zealand on a daily basis, so it is regularly tested for all months of the year in an ongoing operational way.

(d) Section 3.2.4 – "*Labelling – the tidal elevation graphs have conflicting labels making the direction of error unknown*."

Response: The blue line is predicted elevation and the red line is observed elevation. The figure is correct, but the legend has the typographic error.

(e) Section 3.2.4 – "*Averaging and combinations – the presentation of currents does not split out the tidal and no-tidal magnitudes and the method of averaging is not specified. The summary of input data is oversimplified*."

Response: The data summary tables present a simple arithmetic average. The plot that follows is more relevant and is % occurrence of a given current speed flowing in a given direction from the combined tides and residual currents for each month. No averaging is involved.

Given that the loss of well control scenarios modelled are 45 days and 110 days in length, these run times involve multiple months and hence have expanded beyond the monthly influences. The monthly analysis is more relevant to the diesel spill simulation due to its much shorter time frame. Having said that, the presentation of currents is not averaged in the current rose figure, simply an occurrence plot on a monthly basis that was included in the reporting for completeness rather than relevance to the modelling. These types of current summaries are more useful if a response is required, so we include them for the oil spill contingency planning that follows our reporting.

(f) Section 3.3.1 – "*Decoupling of winds and residual currents could potentially under-predict travel distances or produce unrealistic trajectories*."

Response: We agree. No decoupling took place in the RPS Reports, see my response at 11.2 above and section 4 above for more details.

(g) Section 3.4.3 – "*Oil slick thickness threshold – using a higher threshold has the potential to hide results. 10g/m2 is conservation for impact on shoreline habitat, 1g/m2 represents the threshold for socioeconomic impact*."

Response: We believe that recent best practice are the thresholds used in the RPS Reports. See my response at 11.3 to 11.7 above for more details.

(h) Section 3.4.3 – "*Periods of record - The four months used for modelling are not statistically representative of the long-term variability in ocean currents. Area of effect could be in a different direction from that modelled*."

Response: To clarify, 10 full years of HYCOM data was used in the modelling (not 4 months, but all 120 months were used). No decoupling took place in the RPS Reports, see my response at 11.2 above and section 4 above for more details.

(i) Section 3.6.4 – "*Mass balance – the mass balance for the 200m^3 MDO surface release is not provided*."

Response: An example diesel spill mass balance is shown below.

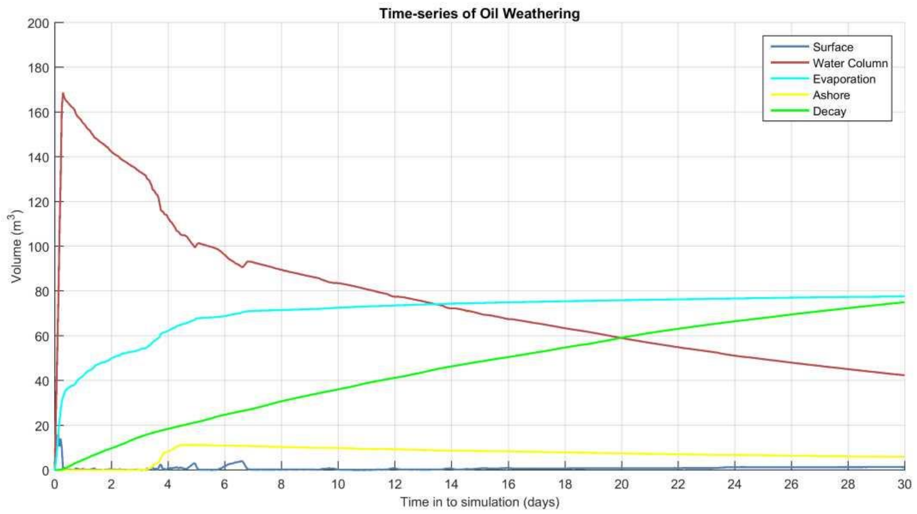


Figure 2 - **Mass balance of worst case diesel spill**. The examples show a spill occurring during strong winds and rough weather, hence the surface spill is rapidly mixed into the water column initially. The example shows the weather abating around day 3 and surface slicks and shoreline stranding begin to occur above threshold levels after day 4. Ultimately the water column oil is lost to evaporation and decay over time.

(j) Section 3.6.4 – "*Depuration – a clear explanation on the value of the depuration parameter, with adequate literature/past experience is required*."

For this study, the decay coefficient was set so that the exposure would fall to 1% of an initial concentration over one week, given no further exposure. The 1% selected for this study and all our reports in recent years is the median value of the range detailed in Solbakken et al., 1984. The sensitivity of this parameter is greater near the release site and less sensitive the further away from the release site since the number of occurrences of exposure to dispersed oil and dissolved oil reduced with distance from the spill site.

(k) Section 3.6.4 – "*Emulsification – no indication in the RPS report that this was taken into account*."

Response: To clarify, the modelling quantified no emulsification took place for the diesel spill or the Tui Crude oil spill. MDO is manufactured with little residual components and rapidly spreads when spilt on the surface. The Tui Crude Oil has a pour point above ambient water temperatures and more so as it weathers. The residual components of the Tui Crude are significantly wax (more than half of the crude oil residual is wax) which has a pour point higher than ambient temperatures, hence will typically solidify into wax films which will be broken into small waxy flakes by the high mixing conditions of the region. This particulate nature of the residual oil promotes natural dispersion during moderate to rough weather events.

(l) Section 3.7.3 – "*Shoreline retention – the maximum potential shoreline oil retention should be stated*."

Response: The maximum shoreline retention used in the modelling was 25 kg/m^2 while some rocky cliffs can be as low as 2-6 kg/m^2. Hence, from the many hundreds of simulations conducted, there are only a few simulations that report any exceedance of 2 kg/m^2. Thus, there may be some sensitivity to rocky cliffs shoreline type but only for the worst-case volumes ashore that exceed 2 kg/m^2. Hence any error in saturation will be infrequent from the many simulations conducted and would only be an adjacent grid cell out at worst if saturation of the shoreline were to occur in reality.

(m) Section 3.7.3 – "*Amount of oil stranded on shore – the fate of any residual fraction should be stated*."

Response: The RPS report for the MDO spill during the period June to January did produce a worst-case outcome for diesel onshore which triggered the 1% probability of exceedance of 10 g/m^2. It reached shorelines after 118 hours of weathering and had a maximum volume in a few grid cells that totalled 2 m^3 above the threshold and some oil ashore (10 m^3) than was within shoreline cells but below the detectable threshold. See the diesel mass balance above for further details.

(n) Section 3.7.3 – "*Amount of oil stranded on shore – 45 day and 110 day mass balance – the quantities appear low and would be supported by a mass balance*."

Response: The 45 day release is more or less a subset of the 110 day release, just shorter duration and smaller spill volume. The mass balance graph above show that the frequency of the moderate to rough weather events in the region and the oil types means that shoreline volumes and surface slicks are only likely during calmer periods of winds and waves. For this region, those events are less common than moderate to rough conditions, hence natural dispersion of this crude oil is expected, rather than shoreline stranding.

(o) Section 3.8.5 – "*Environmental Dataset – indication of data used for the advection of sub-surface oil*."

Response: HYCOM data is fully three dimensional within the water column. The full 3D dataset describing near surface flows and flows at 10m, 20m, 30m, 50m and 100m were used to advect subsurface oil in the modelling shown in the RPS Reports.

(p) Section 3.8.5 – "*Model used to simulate water column exposure*."

Response: OILMAPDEEP was used to simulate the initial water column exposure but reference to this was initially just omitted from the reporting phase. OILMAPDEEP calculated droplet size distributions for oil which quantified the initial amount of dispersed oil and dissolved aromatics for the SIMAP simulations that followed as well as the plume height in the water column.

(q) Section 3.8.5 – "*Droplet behaviour following release from sub-surface*."

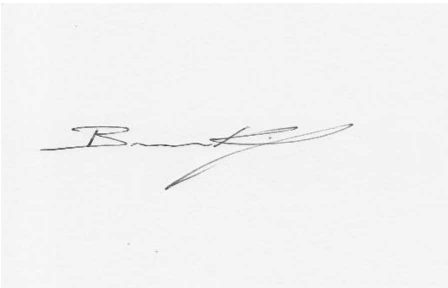
Response: OILMAPDEEP was used to simulate the initial water column exposure as indicated above, so a droplet size distributions for oil was quantified over time using OILMAPDEEP in the RPS Reports. The oil droplets were predicted to be small initially due to the high rate of release but typically increased in size distribution as the volume being spilt lowered over time.

(r) Section 3.8.5 – "*Threshold used to assess water column exposure*."

Response: OILMAPDEEP was used to simulate the initial water column exposure as indicated above, and the plume was predicted to reach near surface waters at all times. Hence water column exposure decreased with depth and oil only reached deep water when moderate to rough weather prevailed. Please also see threshold discussions in 11.3 to 11.7 above.

12. Conclusion

12.1 The work carried out in the RPS reports was undertaken using models (OILMAPDEEP and SIMAP), the methods and analysis that exceeds the ASTM Standard F2067-13 “Standard Practice for Development and Use of Oil Spill Models”. and datasets that exceed the modelling standard as well. Indeed, the choice of hindcast datasets are those used by Maritime New Zealand and are considered best practice. The thresholds are also considered current best practice in recent years. The outcomes described in the RPS Reports are often worst case values, but serve a useful purpose for planning and is best practice for the development of oil spill contingency plans.



DR. BRIAN ALFRED KING
20 July 2018

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