coffey
A TETRA TECH COMPANY

Environmental Protection Authority

Review of Oil Spill Modelling Expert Evidence

Tamarind Taranaki Ltd. Application EEZ100016

When you
think with a
global mind
problems
get smaller

This page has been left intentionally blank

Review of EEZ100016 Oil Spill Modelling Expert Evidence

Prepared for
Environmental Protection Authority

Prepared by

Coffey Services (NZ) Limited

131 Wrights Road, Addington
Christchurch 8140 New Zealand
t: 64 3 374 9600

773-AKLEN218442

Quality information

Revision history

Revision	Description	Date	Originator	Reviewer	Approver
1	Issued for Review	31/08/2018	JMR, AH	JAS	EW

Distribution

Report Status	No. of copies	Format	Distributed to	Date
v1 draft	1	PDF	Ben Moginie	31/08/2018

Table of Contents

Acronyms

ADCP	Acoustic Doppler Current Profiler – An instrument used for measuring ocean currents
ASA	Applied Science Associates, now RPS ASA
APASA	Asia-Pacific offices of ASA
CFSR	Climate Forecast System Reanalysis
HYCOM	Hybrid Coordinate Ocean Model
IOA	Index of Agreement. A statistical measure of model skill
MDO	Marine Diesel Oil
MTBE	Methyl tert-butyl ether
RPS	RPS Group Plc.
STB	Stock Tank Barrels – a barrel of oil at surface conditions

1. Introduction

Coffey Services (NZ) Limited, a Tetra Tech Company, (Coffey) was engaged by the New Zealand Environmental Protection Authority to conduct a technical review of the oil spill modelling reports in Tamarind Taranaki Limited's application for marine consent and marine discharge consent, EEZ100016. The initial review resulted in a 26 June 2018 report titled "Technical Review of Oil Spill Modelling" and is referred to as the 'Coffey Report'.

EPA subsequently engaged Coffey to examine the Applicant's additional evidence and any submitters' evidence concerning oil spills and modelling thereof. The conclusions reached in this review of expert evidence supersede those in the 26 June 2018 Coffey Report.

1.1. Qualifications and experience

1.1.1. Justin Rogers

I have a Bachelor of Arts in Earth and Environmental Science from Wesleyan University and a Master of Science in Oceanography from the University of Rhode Island. I have been working for Tetra Tech since 2008 applying hydrodynamic models to engineering and scientific projects. In 2016, I transferred to Coffey's office in Christchurch. I have expert knowledge of coastal oceanography, limnology, and sediment transport modelling, with a focus on pollutant fate and transport.

Specific projects relevant to this review include:

- Modelling of oil spills off the British Columbia coast using Tetra Tech's spill tracking model and public domain coastline type and meteorological data.
- Developing hydrodynamic models in support of complete oil transport and weathering study for potential oil spills in the St. Lawrence River, Canada.
- Developing hydrodynamic models in support of complete oil transport and weathering study for potential oil spills in the Salish Sea, including the Lower Fraser River, Vancouver, Canada.
- Applied stochastic hydrodynamic models, field judgement, and risk analysis to identify potential areas of risk to the public from sewer overflows at multiple locations.

I confirm that I have read the Expert Witness Code of Conduct. I have complied with the Code of Conduct in preparing this report. This report is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this report.

1.1.2. Aurelien Hospital

I have a Master of Marine Engineering from the Institute of Engineering Sciences of Toulon and the Var, and a second Master of Physical Oceanography from the University of Toulon and the Var. I have been working for Tetra Tech since 2008, focusing on numerical modelling to support environmental studies and engineering design. I have expert knowledge of oceanography, oil spill transport and weathering and more generally pollutant tracking.

Specific projects relevant to this review include:

- Modelling the fate and behaviour of diluted bitumen spills off the British Columbia's coast and in the Fraser River estuarine system, using Tetra Tech's spill tracking model.
- Modelling the fate and behaviour of spills of light, medium and heavy crude oil in the Bay of Fundy and in the St Lawrence River, Canada, using Tetra Tech's spill tracking model.

- Participating in stakeholder engagement as technical expert in support of an area risk assessment of ship-source oil spills in Northern British Columbia, Canada.
- Modelling the fate and behaviour of spills ranging from volatile to heavy oils in Northern British Columbia, Canada.
- Providing technical support following an MTBE spill in Galveston Bay, Houston, USA.

I confirm that I have read the Expert Witness Code of Conduct. I have complied with the Code of Conduct in preparing this report. This report is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this report.

1.1.3. Dr James Stronach

I have a Ph.D. in Physical Oceanography from the University of British Columbia. I have been working for Tetra Tech since 2006, and have been working for similar companies since 1979. The focus of my work has been the use and improvement of numerical hydrodynamic models to inform marine operations, including navigation, search and rescue, oil spill behaviour, dispersion of contaminants such as sewage and mine tailings and engineering design.

Specific projects relevant to this review include:

- Modelling the fate and behaviour of diluted bitumen spills off the British Columbia's coast and in the Fraser River estuarine system, using Tetra Tech's spill tracking model.
- Modelling the fate and behaviour of spills of light, medium and heavy crude oil in the Bay of Fundy and in the St Lawrence River, Canada, using Tetra Tech's spill tracking model.
- Participating in stakeholder engagement as technical expert in support of an area risk assessment of ship-source oil spills in Northern British Columbia, Canada.
- Modelling the fate and behaviour of spills ranging from volatile to heavy oils in Northern British Columbia, Canada.

I confirm that I have read the Expert Witness Code of Conduct. I have complied with the Code of Conduct in preparing this report. This report is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed in this report.

2. Documents reviewed

The following documents in Tamarind Taranaki Limited's applications for marine consent and marine discharge consent were reviewed.

- ERM - Impact Assessment, Sections 7.1 and 7.2.
- RPS APASA 2018a. Report titled 'Tamarind Resources – Tui Field Oil Spill Modelling' (21 March 2018).
- RPS APASA 2018b. Report titled 'Tamarind Resources – Tui Field 110-Day Oil Spill Modelling' (21 March 2018).

The spill modelling reports are similar except for the duration considered, and are discussed together. The following documents in the "Further information requests and response" and "Applicant's Evidence" phases of the application were reviewed:

- EPA (2018). Request for Further Information from Tamarind Taranaki Limited (Tamarind). Letter dated 10 July 2018.
- RPS APASA (2018c). 'Tamarind Resources - Tui Field Oil Spill Modelling - Vessel Spill and 110-Day Loss of Well Control (June to January). Report dated 13 July 2018
- King Evidence (2018). Statement of Expert Evidence of Brian Alfred King For Tamarind Taranaki Limited (20 July 2018).
- Statement of Non-Expert Evidence of Iain Alastair McCallum for Tamarind Taranaki Limited (20 July 2018)

Note that in this review 'RPS Table 1' refers to a table in the Tamarind Resources – Tui Field Oil Spill Modelling report (RPS report), which covers a marine diesel oil spill and a 45-day well blowout scenario. References to the 110-day report, which covers a longer well blowout scenario, have been made explicitly. The subsequent modelling report covering the months of June to January is referred to as the RPS APASA Winter Report.

3. Technical comments on oil spill modelling

The technical review has focused on the tools used by RPS for the study, the inputs to the model, as well as the results.

A risk matrix with two axes is used to focus the review on the severity of an information deficit or technical deficiency (y-axis), and the potential impact of the issue on decision making (x-axis).

A deficiency is ranked low, medium or high in severity based on the reviewers' experience and comparison of the report's technical content with international best practices. An information deficit is ranked on the same axis, when there is not enough information to determine whether there is or is not a deficiency.

The potential impact on decision-making ranks low, medium or high to the degree that the issue could materially affect the results of the study. In the context of this study, decision-making is affected by the accuracy and results of the stochastic modelling, including shoreline oiling, sub-surface exposure, and areal extent affected by a potential spill.

The risk matrices from the initial Coffey Report are retained in this Expert Evidence Review to show how the subsequent evidence has changed our original conclusions.

3.1. Project descriptions, oil types and scenarios

In general, the choices of oil spill model, input data sources, and spill location are appropriate, as described in RPS Sections 1, 2, 6 and 7.

Modelled scenarios include a 200 m^3 release of marine diesel oil (MDO) via a support ship collision, a 45-day (56,721 m^3) release of Tui Crude via well blowout, and a 110-day (104,068 m^3) release of Tui Crude via well blowout.

The initial season modelled includes the months of March and April, which are proposed for drilling, and one month on either side. Subsequent modelling (RPS APASA Tamarind Winter Report) simulated the months from June to January.

The MDO spill scenario is well justified in the Impact Assessment.

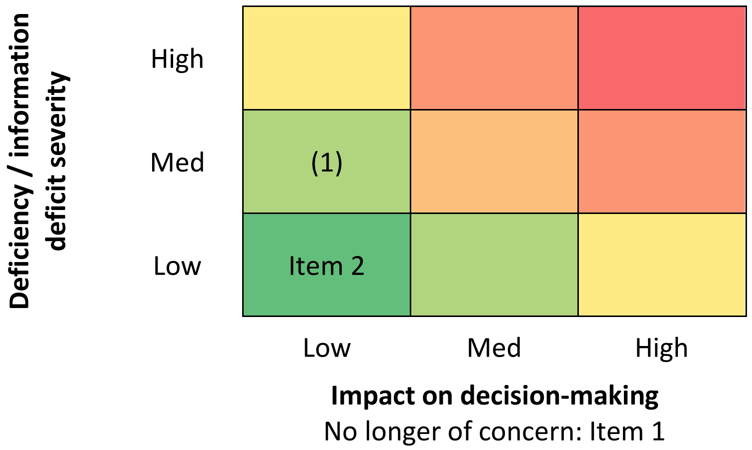
The dynamic reservoir simulation modelling scenario used to generate the release rate is described qualitatively in the McCallum Evidence as well as quantitatively in the King Evidence. Modelling assumes that during a blowout, the well would initially produce 19,803 bbl/day, or about nine times the current oil production rate. The initial release rate and reduction in flow rate over time appears realistic compared with Navigatus Consulting (2015).

Oil concentration is discussed in many units in RPS Section 6: g/m^2, litres per km^2, m^3/km^2, and g/m^2 again. Some of these units are related by oil density. The report would still benefit from RPS Tables 8 and 9 providing approximate oil thicknesses as in the King Evidence.

3.1.1. Risk matrix

The Coffey Report noted two main items of concern with respect to RPS Sections 1, 2 and 6. These concerns are placed in Risk Matrix 3.1 that considers the degree of deficiency or information deficit, and the potential impact on decision making. The previous placement of each item is noted in parentheses "()" and the updated placement in plain text.

- Item 1: Release rate. A reference has now been provided in the McCallum Evidence for the blow-out release rate and decline in rate over time. The release rate is a key input for the entire study. This item is no longer of concern because a suitable reference has been provided.
- Item 2: Units. Oil concentration units have been translated in the text of the King Evidence to approximate thickness in microns and descriptions of the degree of shoreline oiling. The impact on decision making remains low because a suitable table would be clearer.



Risk Matrix 3.1 – Oil Types, Scenarios and Initial Release

3.2. Current models and inputs

An oil spill model requires long-term, realistic records of currents across the region of interest, and these data are described in RPS Section 3. The currents of interest occur on two timescales. Tidal currents are the well-understood ebb and flow of water as the coastal ocean responds to the phases of moon and sun. In New Zealand they are dominated by the lunar semidiurnal tide, which rises and falls every 12 hours and 25 minutes. Currents that are **not** strictly tidal in nature can be driven by winds, regional oceanographic patterns, supply of freshwater (estuarine circulation) and other forcings. These non-tidal flows can be called regional, ocean, subtidal, and/or residual currents, although there are distinctions between these terms. In this review, regional and residual are used interchangeably.

In the RPS APASA Tamarind report, regional currents were obtained from the HYCOM model, which has approximately 8.25 km resolution with an output frequency of once per day. Tidal currents were generated by RPS' HYDROMAP model.

3.2.1. HYDROMAP

The HYDROMAP model was used to simulate tidal currents, a component of oil transport. The validation provided shows tidal elevations at nine locations around New Zealand. The Index of Agreement (IOA), sometimes termed as model skill, is an appropriate statistic for validation, but a higher agreement would be expected from a well-calibrated tidal model, with 1.0 being a perfect agreement. The IOA values average 0.94 in this comparison (RPS Table 2). Similar tables in modelling studies RPS APASA (2014) and RPS APASA (2017) have much better agreements, with IOA values around 0.99.

The typographical error noted previously is still present in RPS APASA's Winter Report Figures 6-8, where the figure legend states that the predicted tide is blue, and observed is red, but the figure caption states the opposite. The King Evidence indicates which labels are correct, and explains that the resolution and accuracy of the HYDROMAP model used in the Tamarind studies was reduced in the harbours where validation tidal height data are located due to feedback from a different client. The model consistently under predicts tidal elevation and range in the validation locations.

A model's skill in reproducing tide heights does not necessarily translate into skill reproducing currents, which are more difficult to match. No validation of tidal currents is provided for HYDROMAP. The lack of validation of tidal currents remains a concern.

3.2.2. HYCOM

The King Evidence corrects the previous RPS APASA Tamarind Reports' omission of the HYCOM model period of record. Ten years of HYCOM data were used, aligned correctly in time with the wind and HYDROMAP models.

While it is not unreasonable to rely on HYCOM, checking the residual currents against local New Zealand shelf data would strengthen the report. If no current validation data was available it should be stated in the report.

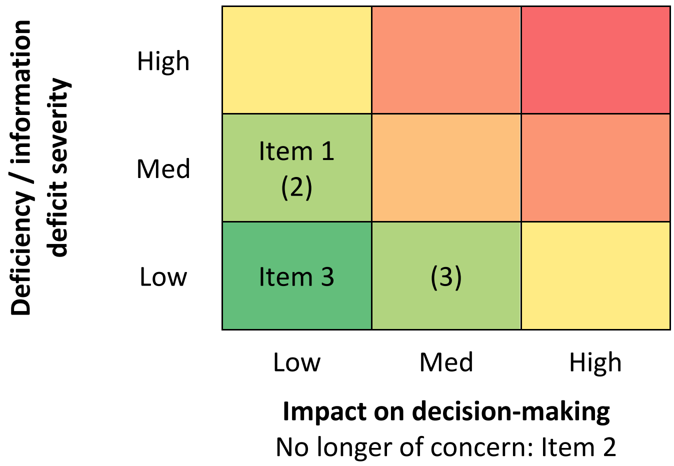
3.2.3. Combined currents

The King Evidence confirms how the tidal and regional currents were correctly combined. The relative importance of each component of the combined currents is not explained. Data available in NIWA (2012) suggests that the transport is dominated by the residual currents, with only small excursions from the tide. Discussion of the tidal excursion at the well site and representative sites throughout the stochastic envelope would better describe the currents.

3.2.4. Risk matrix

Three items of concern with RPS Section 3 were placed in Risk Matrix 3.2 for this section. One has been completely addressed.

- Item 1: Validation. Validation of the tidal elevations were less skilled than expected, and compared to other RPS reporting. The reasons behind the tidal elevation model skill were identified in the King Evidence. There remains no discussion of either model's skill in reproducing tidal and regional currents, which is an information deficit. The impact on decision-making is low because tidal currents are less relevant on the temporal and spatial scales of interest and there are few practical alternatives to the HYCOM model currently available for regional currents.
- Item 2: Labelling. The tidal elevation graphs have conflicting labels, which have been explained in the King Evidence. This item is no longer a concern, though could have been fixed in the RPS APASA Winter Report.
- Item 3: Averaging and Combinations. The presentation of currents does not split out the tidal and non-tidal magnitudes, but the method of averaging has been clarified by the King Evidence. Concerns over the tidal and non-tidal validation are expressed in Item 1 above, and the impact of this presentation aspect is low.



Risk Matrix 3.2 – Currents

3.3. Wind models and inputs

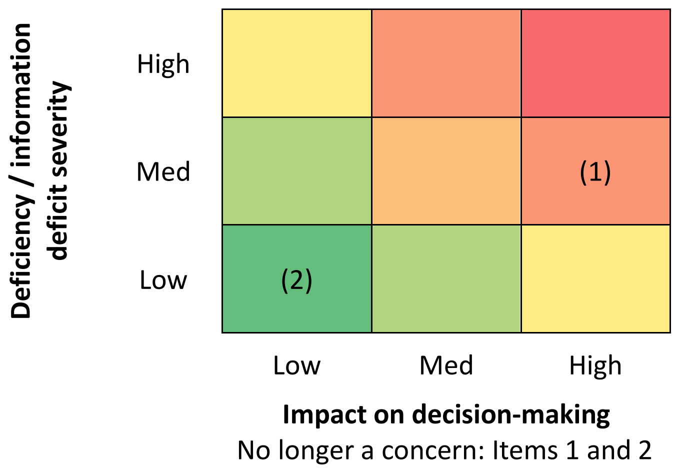
Wind is a major factor in the movement of surface oil slicks, and the wind inputs to oil spill modelling are described in RPS Section 4. The CFSR wind hindcast model is appropriate, and reasonable validations thereof can be found in the literature. The method by which 10 years of wind data is combined with hydrodynamic results are described in the King Evidence.

As discussed in the HYCOM section above, it is reasonable to use these wind data but some sort of validation in New Zealand offshore waters would strengthen the report.

3.3.1. Risk matrix

Two items of concern were placed in Risk Matrix 3.3 for this section. Both have been addressed by the King Evidence.

- Item 1 – Decoupling. Decoupling of winds and residual currents is no longer a concern as explained in the King Evidence.
- Item 2 – Averaging. The method of averaging was specified in the King Evidence.



Risk Matrix 3.3 – Winds

3.4. Stochastic methods

3.4.1. Model settings

The minimum thickness for tracking considered in the RPS APASA Tamarind report was 0.5 µm for oil on surface (RPS Section 6.2.1). That is, once a part of the slick became less than 0.5 µm thick, that part of the slick was omitted from the results. This thickness can still be significant from an environmental impact perspective, but is adequate from a mitigation response aspect. Based on RPS APASA Tamarind Table 6, the omission of any thickness less than 0.5 µm means that the RPS APASA Tamarind report did not consider a sheen on surface for exposure calculation. The AMSA (2015a) reference does suggest a 10 micron threshold for ecologically relevant surface slick model results analysis, and it is recognized that the 0.5 µm value is an appropriate threshold if visibility and potential for ecological harm is the intent of the modelling exercise.

Similarly, the minimum concentration of oil on the shoreline for tracking was set to 10 g/m^2 in the RPS APASA Tamarind modelling. The King Evidence cites AMSA (2015b) and states that 10 g/m^2 is an order of magnitude below the threshold for ecological impact. AMSA (2015b) does not characterize oil thickness in terms of ecological impact but in regard to the balance between oiling and clean-up impact, which is an important concept when responding to an event.

The dissolved hydrocarbon threshold of 6 ppb is discussed in the King Evidence and considered by RPS APASA to be a conservative threshold. This and the above exposure thresholds are generally lower in North American jurisdictions.

The RPS APASA Tamarind report conducted modelling of 100 spills for both the blowout scenario and the marine diesel spill. This appears appropriate for the blowout scenario, which takes place over many weeks. The patchiness of the MDO results in the RPS APASA Winter Report and the singular case where MDO reached the shoreline demonstrates 100 simulations over an 8-month time frame did not provide smooth stochastic results.

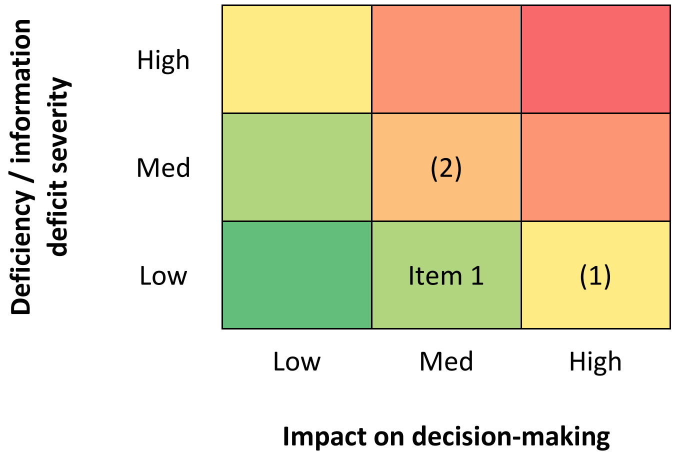
3.4.2. Periods of record

Ten years of regional currents, tidal currents and wind data were used, which provides a wide variety of potential meteorological conditions to support the stochastic modelling. The King Evidence corrected a typographical error that resulted in an unclear understanding of the data used.

3.4.3. Risk matrix

Two items of concern were placed in Risk Matrix 3.4 for this section. The previous concern over periods of record was addressed by the King Evidence.

- Item 1: Thresholds. The potential discrepancy of using a higher threshold to assess exposure and produce maps of oil presence can have a significant impact. Other similar studies located in North America considered a threshold ten times lower, which could significantly change the amount of oil reported to reach the shore, as well as the exposure on the surface and in the water column. However, as described in the King Evidence, the report follows the AMSA guidelines. As a result, the impact on decision-making is reduced from high to moderate. It should be noted that these thresholds indicated in the AMSA guidelines are appropriate for a response and mitigation-driven study, and could be more stringent when considering environmental impact. Jurisdictional differences in thresholds are behind this concern and are a matter for the NZ regulatory bodies to decide.
- Item 2: Periods of Record. The period of record for HYCOM was corrected in the King Evidence, and was a reporting rather than a modelling omission. This item is no longer of concern.



Risk Matrix 3.4 – Stochastics

3.5. Oil trajectories

The reviewers are confident that the SIMAP model can correctly ingest wind and current data and compute trajectories, but the provided tables and wind roses do not allow a good understanding of the time scales involved. A separate consideration of tidal and residual currents is preferable. The method of averaging that produced the tables was discussed in the King Evidence.

No risk matrix was produced for this section, as the concerns (wind and current data) have been discussed in Section 3.2.

3.6. Oil weathering

This section focuses on the weathering, i.e. physical and chemical degradation of the oil, and is mainly concerned with RPS report(s) Section 7 and onward.

3.6.1. Mass balance

The mass balance for the worst-case 200 m^3 MDO surface release was provided in the King Evidence. The RPS APASA Winter Report showed one stochastic scenario in which MDO reached the shore, where the previous RPS report indicated that no shoreline was contacted.

Regarding the well blowout stochastic modelling, only the amount reaching shoreline was provided in the RPS APASA Tamarind reporting. The King Evidence has provided a complete mass balance for one scenario with an accompanying narrative. The mass balance indicates that the dominant fate of the oil is decay, followed by evaporation and then the water column. The decay is typically hard to quantify since it is a function of the initial bacterial population and subsequent bacterial growth. Modelling typically uses a first-order decay approach based on the mass of hydrocarbons. The amount of oil decaying appears on the high side. If there is a known bacterial population in the region due to past or continual releases of hydrocarbons, then this decay amount makes sense.

3.6.2. Depuration

The mechanism of depuration refers to "*the rate of removal due to the ability of the organism to expel or metabolise hydrocarbons*" (RPS APASA Tamarind Reports). The depuration rate was set to reduce to 1% of the initial concentration over one week, assuming no additional exposure would occur.

The King Evidence provides a reference for the depuration rate (Solbakken et al. 1984) that measured the retention and expulsion of the hydrocarbon phenanthrene by flounder. It is not known whether local species show similar behaviour. An updated reference for this number would be more credible. As shown on RPS Figure 15, the effect of depuration is extremely significant. Should the depuration rate be lower, oil concentrations in the water column would be higher.

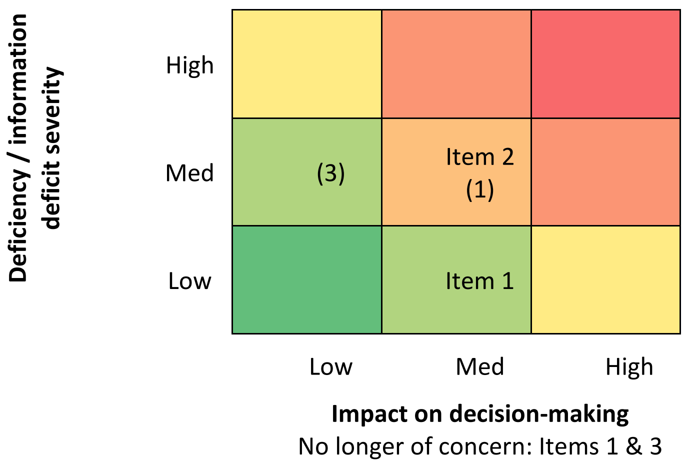
3.6.3. Emulsification process

The King Evidence discussion of wax and pour points clarifies the SIMAP model's consideration of emulsification.

3.6.4. Risk matrix

Three items of concern are placed in Risk Matrix 3.6 for this section.

- Item 1: Mass Balance. A single mass balance was provided for the MDO spill and the winter blowout scenario with the greatest volume of oil ashore. The amount of decayed oil appears on the high side and more information on the decay input parameters would be necessary to fully understand this important fate of oil. The impact on decision-making remains moderate due to how much decay the mass balances show
- Item 2: Depuration. The King Evidence provided more discussion of depuration, but the reference cited is for Norwegian flounder and is over 30 years old. An updated and/or local reference for the depuration rate would be preferable. The impact of decision-making remains moderate, because the impact of the depuration factor on the results is significant.
- Item 3: Emulsification. The King Evidence provided additional information on the consideration of emulsification in the modelling, and this item is no longer of concern.



Risk Matrix 3.6 – Oil weathering

3.7. Shoreline contact results

3.7.1. Shoreline retention

The King Evidence indicated that individual shoreline segments generally did not reach their holding capacity, reducing uncertainty regarding this process.

3.7.2. Amount of oil stranded on shore

The original (summer) RPS APASA Tamarind reports showed that no marine diesel reached the shore. The Winter Report identified one scenario (out of 100) that did result in shoreline oiling by MDO, confirming the concern that a small residual is still potentially present on the shoreline.

The King Evidence quantifies the effect of the choice of shoreline mass threshold. In the MDO scenario that reached shore, 2 m^3 were reported as they concentrated in shoreline cells above the loading reporting threshold. A further 10 m^3 washed ashore but was not reported as it was spread out over various shoreline cells at loadings under the reporting threshold. The mass balance for the MDO spill shown in the King Evidence indicates the total amount onshore (10 m^3), whereas the RPS APASA Winter Report reports 2 m^3, a five-fold reduction in reported oiling due to the choice of thresholds. It is understood that this result is at the very edge of the stochastic probability envelope, occurring in only one out of 100 scenarios.

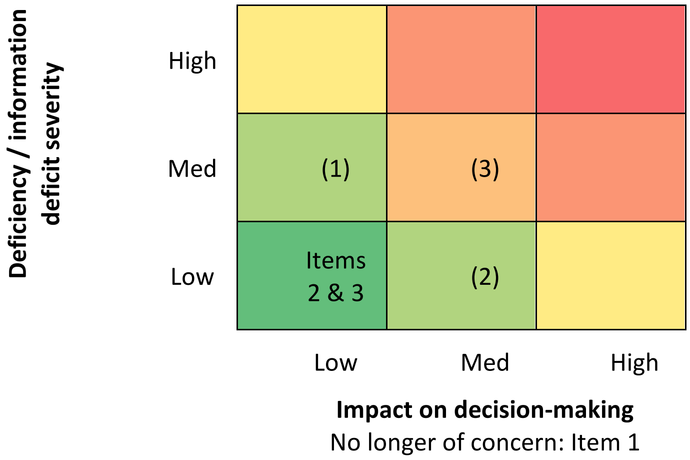
In the well blow-out scenarios, 29% of the crude is classed as ‘persistent’ in RPS APASA Table 12. In RPS APASA Table 15, the 45-day spill results in a maximum shoreline volume of 706 m^3 out of 56,721 m^3 spilled, or 1.2%. For the 110-day spill, the maximum volume ashore was 778 m^3 out of 104,068 m^3 released, or 0.75%. The comparable Table 16 in RPS APASA’s Winter Report shows a maximum of 1,067 m^3 ashore out of 56,721 m^3 spilled, or 1.8%. Examination of the mass balance image provided in the King Evidence indicates approximately 1,230 m^3 ashore. An additional 15% of oil on shore but unreported due to concentrations under the reporting threshold is not a critical item of concern, but reinforces the value of mass balances in understanding the reporting.

The mass balance provided in the King Evidence is a very useful piece of information. That being said, statistics on mass balance should have been presented for the stochastic simulations to obtain a statistical quantification of oil weathering.

3.7.3. Risk matrix

Three items of concern are placed in Risk Matrix 3.7 for this section.

- Item 1: Shoreline Retention. The maximum potential shoreline oil retention has been clarified by the King Evidence, and its effect on the modelling was put in context. This item is no longer of concern.
- Item 2: Amount of Oil Stranded on Shore – MDO. The RPS Winter Report has improved the understanding of whether MDO can reach the shore. The impact on decision-making is low now that the Winter Report and mass balance has identified the potential for shoreline oiling.
- Item 3: Amount of Oil Stranded on Shore – 45-Day and 110-Day mass balances. The shoreline results have been supported by a mass balance in the King Evidence. Most of the oil that reached the shoreline was reported, while a small amount went unreported in the one scenario where a mass balance was provided. There is still an information deficit due to the limited mass balance information, but the impact on decision-making is low now that the shoreline oil under-reporting thresholds has been better quantified.



Risk Matrix 3.7 – Shoreline contact

3.8. Water column exposure results

3.8.1. Environmental dataset

The RPS report only presents and describes surface currents, but the King Evidence has clarified that subsurface HYCOM currents were used in the modelling, eliminating this concern.

3.8.2. Model used to simulate water column exposure

The original RPS APASA reports did not provide information on whether and how the OILMAPDEEP model was used to represent the initial behaviour of oil in the water column. The RPS APASA Winter Report and the King Evidence have clarified that this near-field model was in fact used throughout but omitted from the reporting. This item is no longer of concern.

3.8.3. Droplet behaviour following release from sub-surface

The RPS APASA Winter Report and the King Evidence provided information on the use of the OILMAPDEEP model and key results regarding droplet size and behaviour. This item is no longer of concern as it was clear in the King Evidence that the same techniques were used in the prior reporting, just omitted from the report.

3.8.4. Threshold used to assess water column exposure

The dissolved exposure maps at the low exposure threshold are an intermediate area in between the low and moderate sea surface exposure maps, indicating that the water column threshold chosen is somewhat consistent with other thresholds chosen for this modelling.

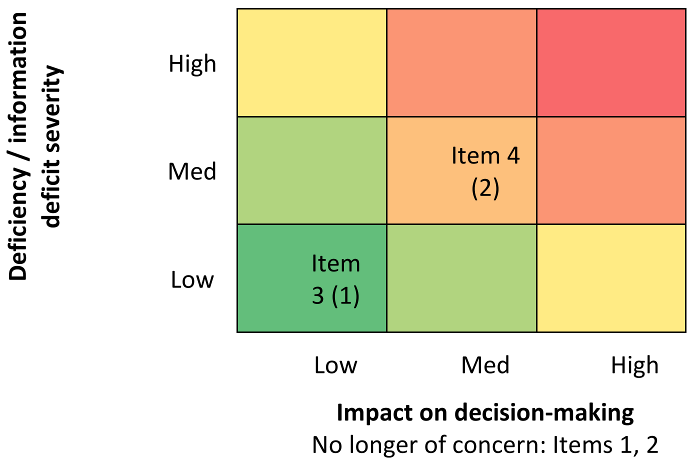
The RPS Reports and King Evidence share the premise that a properly defined LC50 threshold concentration is an appropriate way to characterize the risk to the water column. This approach makes sense for an instantaneous spill, such as the marine diesel scenario that disperses in days.

The hundredfold scaling discussed to turn a chronic exposure threshold into an LC50 seems less appropriate given a spill duration of 45 or 110 days in the blowout scenario. The combination of a threshold 100 times the chronic value and the depuration rate significantly shrinks the potential area affected by a blowout event. This hundredfold scaling is still unclear. More background information should be given to fully support this depuration and LC50 value determination.

3.8.5. Risk matrix

Three items of concern are placed in Risk Matrix 3.8 for this section.

- Item 1: Environmental Dataset. Information regarding the advection of sub-surface oil was provided in the King Evidence. This item is no longer of concern.
- Item 2: Model Used to Simulate Water Column Exposure. The use of the near-field or plume model OILMAPDEEP has been confirmed by the RPS APASA Winter Report and the King Evidence. This item is no longer of concern.
- Item 3: Droplet Behaviour Following Release from Sub-Surface. This item on decision-impact is low, since the potential impact on dissolution was factored in Item 2 above.
- Item 4: Threshold used to Assess Water Column Exposure. A more restrictive threshold, similar to other studies used for environmental impact assessment, could result in different exposure results, particularly deeper in the water column. The impact on decision-making is medium because of the potential for ‘hiding’ results by use of thresholds, as in Section 3.4 Item 1.



Risk Matrix 3.8 – Water column exposure

3.9. Editorial / typographical / spelling

The following editorial issues remain in the RPS Winter Report:

- Throughout: leeching should be leaching.
- STB units should be spelled out in glossary.
- Figure 4 – spelling of ‘hydrodynamic.’

4. Summary of key items

This section identifies the items regarded as key in our original review that have been addressed by additional reporting and the King Evidence. Items that remain of concern are then listed. These key items were selected based on either the deficiency or impact on decision making being high, or both metrics being of medium severity.

4.1. Items addressed

i. The omission of mass balances has been partially addressed in the King Evidence, by showing mass balance plots for the marine diesel and winter blow-out scenarios with the greatest quantity of oil on the shoreline. Section 3.6 Item 1 has been reduced in severity. Section 3.7 Items 1 and 3 still involve an information deficit, but enough additional data has been provided to reduce the impact on decision-making to low.

ii. The advection of the surface oil slick is driven by the winds, surface currents and horizontal diffusion. The previously identified issues related to the current and wind dataset have been resolved by the King Evidence.

iii. The reporting regarding the near-field or plume model, OILMAPDEEP has been updated in the Winter Model and King Evidence.

4.2. Items remaining

i. The hydrodynamic model validation does not consider currents. Nearby tidal and long-term currents, if available, are more important that showing water level validation at distant ports (Section 3.2 Item 1).

ii. The choices regarding exposure thresholds, decay rates and the depuration rate to determine the exposure and probability of oil presence on water surface, shoreline and in the water column combine to reduce the potential area affected. Similar studies in other jurisdictions have considered a threshold ten times lower for oil on water or on the shoreline, for example. The report is suitable for response planning, but the information regarding of environmental impact at sub-lethal and/or chronic exposure levels is limited (Sections 3.6 Item 2 and 3.8 Item 4).

5. Closure

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,

Coffey, a Tetra Tech Company

Prepared by:

Justin Rogers, MSc.
Oceanographer
Direct Line: +64 3-336-5441
Justin.Rogers@coffey.com

Prepared by:

Aurelien Hospital, M.Eng., M.ScTeam
Lead – Oceanography & Limnology
Direct Line: +1 (778) 945-5747
Aurelien.Hospital@tetratech.com

Reviewed by

Jim Stronach, Ph.D., P.Eng.
Principal Technical Specialist
Direct Line: +1 778.945.5849
Jim.Stronach@tetratech.com

6. References

AMSA (2015a) Technical Guideline for the Preparation of Marine Pollution Contingency Plans for Marine and Coastal Facilities Australian Maritime Safety Authority, January 2015.

AMSA (2015b) Australian National Plan Guidance on: Response, Assessment and Termination of Cleaning for Oil Contaminated Foreshores – Reference: NP-GUI-025. August 2015.

Dumpark Ltd (2013), "*Trajectory Analysis of Deep Sea Oil Spill Scenarios in New Zealand Waters*", Report for Greenpeace, October 2013.

ERM (2018). *Tui Field Drilling Activities – Impact Assessment to Support Notified Marine Consent and Marine Discharge Consent Applications.* Report, March 2018.

Navigatus Consulting (2015). *Financial Assurance Review –Integrated Damages Assessment Model*. Report prepared for MBIE and MoT, https://www.transport.govt.nz/assets/Uploads/Sea/Documents/2015-11-30-Financial-Assurance-Review-Main-Report.pdf accessed 4 June 2018.

NIWA (2012). *South Taranaki Bight Iron Sand Mining: Oceanographic Measurements Data Report*. Prepared for Trans-Tasman Resources Ltd. August 2012

HYCOM (2018). *HYCOM + NCODA Global 1/12° Reanalysis (GLBu0.08/expt_19.1).* http://ncss.hycom.org/thredds/ncss/grid/GLBu0.08/expt_19.1/2012/dataset.html accessed 30 May 2018.

MetOcean Solutions (2014). *Oil Spill Trajectory Modelling, Maari Production Well.* Prepared for OMV New Zealand Ltd. May 2014.

RPS APASA (2014), *Maui Field – South Taranaki Basin Quantitative Spill Modelling Study*. Report, 30 October 2014

RPS ASA (2014a), "*Trajectory Modelling in Support of the Shelburne Basin Exploration Drilling Program = Model Description, Approach and Summary of Results*", Report, 27 May 2014. https://www.ceaa.gc.ca/050/documents/p80058/99347E.pdf accessed 5 June 2018

RPS APASA (2017), *Maui Field – South Taranaki Basin Quantitative Spill Modelling Study*. Report, 19 September 2017

Zhao Lin, J.Torlapati, T. King, B. Robinson, M.C. Boufadel and K. Lee (2014a), "*A Numerical Model to Simulate the Droplet Formation Process Resulting from the Release of Diluted Bitumen Products in Marine Environment*", Proceedings from the International Oil Spill Conference, pp. 449-462, 2014a.

Zhao Lin, M.C. Boufadel, E.E. Adams, S.A. Socolofsky and K. Lee (2014b), "*A Numerical Model for Oil Droplet Evolution Emanating from Blowouts*", Proceedings from the International Oil Spill Conference, pp. 561-571, 2014b.