BEFORE THE ENVIRONMENTAL PROTECTION AUTHORITY
AT WELLINGTON

IN THE MATTER of the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012

AND

IN THE MATTER of a decision-making committee appointed to reconsider a marine consent application by Trans Tasman Resources Limited to undertake iron ore extraction and processing operations offshore in the South Taranaki Bight

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EXPERT EVIDENCE OF HELEN SKYE MACDONALD ON BEHALF OF TRANS TASMAN RESOURCES LIMITED

19 MAY 2023

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EXECUTIVE SUMMARY

1. My evidence relates to the sediment plume generated by the mining activity as investigated in a sediment plume model developed at the National Institute of Water and Atmospheric Research. The model shows that the suspension of fine sediments generated by the mining activity has an effect only in regions near the mining site and diminishes near the coastal regions where background sediment levels are much higher than those produced by mining activities.

2. Considerable work has been performed to understand the model uncertainties. In particular, the model circulation compared well to observations. The modelled background sediments were also compared to observations, and it was determined that the model errors were small when compared to the magnitude of the difference between coastal background sediments and the sediments in the modelled mining plume.

3. The mining plume cannot be directly measured for comparison, and a worst-case scenario was performed to determine how bad the plume could become with respect to the uncertainties. This worst-case scenario produced only a small increase in the size of the original sediment plume produced in Hadfield and Macdonald (2015).

4. Background sediments were high near the coast and decreased with distance offshore. The sediment plume generated from mining was high compared to the background sediments at the mining site. However, the sediment concentration in the plume become much smaller than the sediment produced by background processes as the plume moved into the coastal region.

5. The pre commencement conditions set by the previous decision making committee include developing an

operational sediment plume model. When used in conjunction with ongoing data collection, this will provide more information needed for ongoing monitoring. These conditions are needed to keep the model up-to-date over the passage of time and should not be seen as a deficiency in the original modelling assessment.

INTRODUCTION

Qualifications and experience

1. My name is Helen Macdonald. I am an ocean numerical modeller working for the National Institute of Water and Atmospheric Research (**NIWA**). I hold the degrees of Bachelor of Science (Physical Oceanography) and PhD in Science (Mathematics) from the University of New South Wales in Australia. I have had over 10 years' experience in ocean modelling.

2. I helped to prepare three reports submitted as evidence for Trans-Tasman Resources Limited (**TTR**) before a Decision-making Committee in 2017:

   (a) Hadfield, M.G. and Macdonald, H.S. (2015). Sediment Plume Modelling, 117 p.

   (b) Macdonald, H.S and Hadfield, M.G. (2017). South Taranaki Bight Sediment Plume Modelling Worst Case Scenario, 51 p.

   (c) Macdonald, H.S., Hadfield, M.G. and MacDiarmid A.B. (2017). Responses to questions raised in Appendix 1 of DMC Minute 41, 39 p.

3. I am familiar with the sediment plume model used at NIWA and I setup and ran the worst-case scenario. Mark Hadfield setup the original model and I am familiar with the model, having taken over from him once he retired. My expertise is in ocean modelling with a focus on ocean circulation. When given the behaviour of a material (e.g., sinking velocity) I can use numerical modelling to infer where it will go but I am not an expert in sediment behaviour. I consider Dr Mike Dearnaley to be the expert in sediment behaviour. In particular he understands the sediment plume behaviour in the nearfield (within 3 km of the mining operations) and I consulted with him

about the parameters used in the worst-case scenario. He was also consulted on and reviewed the original model set up by Mark Hadfield.

Code of conduct

4. I confirm that I have read the Code of Conduct for Expert Witnesses as contained in the Environment Court Practice Note dated 1 January 2023. I agree to comply with this Code. This evidence is within my area of expertise, except where I state that I am relying upon the specified evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

SCOPE OF EVIDENCE

5. I have been asked to provide evidence taking into account the decision of the Supreme Court in *Trans-Tasman Resources Ltd v Taranaki-Whanganui Conservation Board and Others* [2021] NZSC 127.

6. In particular, I understand the Supreme Court expressed concern that the information available to the previous DMC about the sediment plume was incomplete and/or uncertain. I address that concern. I do not address the effects of the sediment plume, which is covered in the evidence of others.

UPDATING EVIDENCE

7. There is no new relevant information since the 2017 evidence. It has been over 5 years since the sediment plume modelling was completed. There is updated model code, and atmospheric forcing available. However, these updates will not substantially alter the results presented in the initial assessment as these results were driven by large scale oceanic currents and tides which will not change substantially with the available updates.

EVIDENCE ON EXISTING ENVIRONMENT RELEVANT TO SEDIMENT MODELLING

The sediment plume model results

8. The report submitted in the initial application described the model setup, performed a model/data comparison, and investigated the effect of the mining plume (Hadfield and Macdonald, 2015).[1]

9. There are two types of sediments released during mining operations; de-ored sand released back into the mining pit and suspended sediments. The suspended sediments travel the furthest and have the greatest potential to affect the surrounding environment. The modelling performed by NIWA relates to the movement of suspended sediments.

10. The model has been used to track and display sediments at concentrations that are too small to be detected. For example, the figures in Hadfield and Macdonald (2015) display sediment deposition on the seabed that is much less than the thickness of a human hair. To understand the size of the potential effect of the sediment plume, the background sediments are used as a comparator to demonstrate the size of the effect of the sediments. The median (50th percentile) and the 99th percentile show how often the water column reaches a certain concentration. For example, in a figure showing the "99th percentile", the ocean sediment concentration will exceed the values shown in the figure 1% of the time. In a figure showing the median, the ocean sediment concentrations will exceed the value shown in the figure 50% of the time. Figures 3.6 to 3.15 in Macdonald and

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[1] Hadfield, M.G. and Macdonald, H.S. (2015). Sediment Plume Modelling, 117 p. https://www.epa.govt.nz/assets/FileAPI/proposal/EEZ000011/Applicants-proposal-documents/8e6049938f/NIWA-Sediment-Plume-Modelling-Report-Full-version.pdf

Hadfield (2017)[2] are examples of timeseries that demonstrate these percentiles.

11. Figure 5.8 to 5.12 and 5.25 to 5.29 in Hadfield and Macdonald, (2015) show the effect of the mining plume. There is variability in the location of the mining sediment plume (shown in Figures 5.1 to 5.7 and 5.19 to 5.24) but the most common direction of the plume is to the east and southeast, along the coastline.

12. The suspended sediment concentration (**SSC**) is greatest within a few kilometres of the mining site and reaches 8.25 mg/L in the surface and 45 mg/L in the bottom for the 99th percentiles (where the 99th percentile represents the more extreme values). These values are larger than the surface background value (<10 mg/L) and comparable for near bottom background values (<150 mg/L).

13. The magnitude of the plume reduces rapidly with distance whilst the background sediment values increase. In the surface for the 99th percentile this plume reduces to 2.8 mg/L 20 km away from the source, and in the bottom, the value reduces to 6-7 mg/L near Whanganui. These values are less than background sediment concentration in the surface (5 mg/L at the mining site, increasing to >200 mg/L at the coast) and bottom (200 mg/L at the mining site, increasing to >1000 mg/L near the coast).

14. The best way to visualise the effect of the mining plume is to directly compare panel A with Panel C on Figures 5.8 to 5.11 and 5.25 to 5.28 in Hadfield and Macdonald (2015). There is a transition zone that occurs in the background sediment concentrations between higher near-shore values and lower off-shore values (Panel A). The addition of mining sediments

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[2] Macdonald, H.S and Hadfield, M.G. (2017). South Taranaki Bight Sediment Plume Modelling Worst Case Scenario, 51 p. https://www.epa.govt.nz/assets/FileAPI/proposal/EEZ000011/Evidence/ac41266d7d/TTRL-Appendix-to-HRW-Report.pdf

(Panel C) mean that the contours of background sediments is pushed offshore along the coast between Hawera and Whanganui. Whilst these panels are a visual representation of the sediment plume, the model can track sediments to very small concentrations and these panels do not represent what will be visible when viewing the plume in situ. See Pinkerton and Gall (2015)[3] for a representation of what will actually be seen.

15. The movement of de-ored sand released back into the mining pit source is shown in Figures 5.33 to 5.35 in Hadfield and Macdonald (2015). Some of this sand will be susceptible to resuspension and further movement. A complete description on how detectable the plume is at different distances can be found in section 5.3 of Hadfield and Macdonald (2015). The deposition effect of the plume is largest (37 mm thick) at the mining site, but the effect quickly diminishes with distance. For example, at 10 km distance from the mining site the thickness of the redeposited sand is reduces to around 1 mm thick.

Model uncertainties

16. Models such as these have uncertainties and errors. However, these models can still be used to understand the effect of the mining sediment plume on the system if we can quantify and understand the effect of the uncertainties on the model results.

17. There are 2 models that are coupled together and each of these models produce their own errors and uncertainties:

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[3] Pinkerton, M., Gall, M. Optical effects of an iron-sand mining sediment plume in the South Taranaki Bight region. NIWA client report, 79 pages, 2015. https://www.epa.govt.nz/assets/FileAPI/proposal/EEZ000011/Applicants-proposal-documents-Application-documents/10972f4afb/TTIS065-s158-Report-3d-NIWA-Optical-Effects-Report.pdf

(a) A circulation model that calculates where the currents move the sediment and;

(b) A sediment model that calculates movement of sediments in the water column (e.g., sediment sinking or being resuspended off the ocean bottom under certain conditions).

18. It is simple to assess the accuracy of the circulation model as the circulation can be directly measured. This assessment is presented in Figures 3.1 to 3.5 of Hadfield and Macdonald (2015) and these show that the circulation model only has small errors. This comparison shows that the model is accurate enough to produce a reliable estimate of the movement of sediments as carried by the currents.

19. The sediment model can be split between the background sediments and the mining sediments.

Background Sediments

20. The background sediments are assessed in Figures 4.1 to 4.13 of Hadfield and Macdonald (2015) by comparing measured and remotely sensed estimates of background sediments with modelled background sediments. This shows that the model underestimates the background sediments in some regions and overestimates them in other regions.

21. These over- and under- estimation errors are up to a factor of about 2 for inshore regions which is small compared to the variability in sediments. Background sediment concentrations increase with distance from the mining site to the coast as shown in Figures 4.7 – 4.9 of Hadfield and Macdonald (2015). There is a band of elevated concentrations near the coast with a width of 5–20 km with sediment concentration of 2 to 60 mg/L. The concentrations in the mining plume tend to be smaller by comparison and these concentrations become

very small (at least a factor of 10 less) compared to background errors as the plume approaches the coast. When the concentrations in the mining plume are much less than the errors, the errors will not affect results which show that the mining plume is small compared to background.

22. The model increasingly underestimates the background sediment concentrations with increasing distance offshore, probably due to a lack of sediments coming into the model domain through the boundaries. This error means that all background concentrations are derived only from resuspension and riverine inputs and has the effect of making the mining plume appear to have a greater impact compared to background sediments.

Mining Sediments

23. It is harder to assess the model's representation of the mining plume as observations are not possible unless mining proceeds. A large uncertainty in the sediment model come from the input parameters.

24. To understand the effect of uncertainties of input parameters on the model results, a "worst case scenario" was performed. Five uncertain parameters[4] such as the percentage of ultra fine materials released into the water column were set to a value within their error range but chosen to deliberately enhance the plume.

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[4] See memo from Dr Dearnaley on 22nd February 2017 for a summary of parameters varied: https://www.epa.govt.nz/assets/FileAPI/proposal/EEZ000011/Evidence-Applicants-evidence/b877c5d2fb/TTRL-Worst-case-parameterisation-for-source-term-for-use-in-sediment-plume-modelling.pdf

25. The parameters used in the worst-case scenario were selected by the sediment expert working group.[5] The new source terms intermittently increase the amounts of fine sediments released into the water column at the mining site. The results from the worst-case scenario did not show a large difference from the original model runs. The best way to visualise the effects of the change in parameters on the mining plume is to compare Figures 5.8 to 5.12 and 5.25 to 5.29 from Hadfield and Macdonald (2015) with Figures 3.16 to 3.19 and 3.24 to 3.27 of Macdonald and Hadfield (2017). In the worst-case scenario, the plume extends slightly further than the plume produced in Hadfield and Macdonald (2015). For example, the medium 1 mg/L threshold moves 6 km outwards from that produced in Hadfield and Macdonald (2015). There is also an increase in the concentration of the plume in some regions during infrequent events (99th percentile). See Macdonald and Hadfield (2017) for a complete description of the differences between the worst-case scenario and the original plume produced in Hadfield and Macdonald (2015).

CONDITIONS

26. One of the conditions (condition 47) involves the creation of an operational sediment plume model (**OSPM**). This condition, combined with condition 43 (which relates to environmental monitoring) is a suitable method to monitor the mining activity with respect to the sediment plume.

27. Models such as the sediment plume model used in TTR's application are subjected to continuous improvements and updates. For example, code needs to be updated to work on modern computing architecture, boundary and atmospheric

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[5] Joint Statement of Experts in the Field of Sediment Plume Modelling – Setting Worst Case Parameters. Before the Environmental Protection Authority, 23rd February, 2017.

forcing conditions as old products are discontinued and model calibrations need improving as more information comes to light and as the systems change (e.g., land-use changes will affect the background sediment concentrations). As a best practice, these sorts of models should be continuously validated against recent data to ensure that the updates to the model and changes to the environment do not degrade the model performance; and that there are no drifts in error over time. These updates are needed regardless of how well the original model performed and should not be seen as a judgement on the fitness-for-purpose of the model used in the original assessments. The model used for TTR assessment has not been used since the sediment modelling reports in 2015[1] and 2017[2] and, hence, these updates have not been performed. The proposed monitoring condition will allow for these updates to occur whilst retaining the quality of the model.

28. The purpose of the OSPM is different to the model used in TTR's environmental assessment and the model setup will have some differences. The model used for the environmental assessment was a hindcast model which produced a single 1000-day simulation of past events. The OSPM will be a forecast model which will produce lots of small forecasts of up to 10 days. The hindcast model was used to produce statistics such as the medium and 99th percentile whereas a forecast model will be used to predict individual events. These differences mean that the assessment used to determine fitness of purpose will likely be different. Additionally, the model inputs (such as atmospheric forcing, riverine discharge, and oceanic boundary conditions) may need to be created using different products as the ones currently used are not available in forecast mode. For example, the method for calculating riverine inputs in Hadfield and Macdonald (2015)[1] uses historical data. Historical data cannot be used for a

forecast and a different method will need to be used to estimate forecast riverine inputs. This new forecast model will need to be validated and calibrated to ensure it meets the standard set by the model used in the original assessment. I consider that the conditions set are suitable in ensuring that this model is fit for purpose. In particular, monitoring for 2 years ahead of mining will ensure that the model is tested against recent background conditions which may have changed since the assessment performed in the 2015 sediment modelling plume report.

CONCLUSIONS

29. The sediment plume modelling, like all models of this sort, has uncertainties and errors. Considerable work has been performed to understand the effect of model uncertainties on the results presented. This includes the worst case scenario modelling in 2017. I have reviewed all of the plume modelling work in light of the Supreme Court's concerns regarding the effects of sediment, and in my view the sediment plume model used in the initial assessment is of good quality and fit for the purpose it was used for. I consider it provides a reliable basis for others to assess the effects of the sediment plume on the environment.

30. I also support the conditions that require pre-commencement monitoring. I do not see these conditions as needed to address any incompleteness or uncertainty in the existing modelling work, but to update the model in accordance with best practice, and to inform the setup of the OSPM.

Helen Skye Macdonald

19 May 2023