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| **UNDER** | the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 |
| **IN THE MATTER** | of a reconsideration of evidence by a decision-making committee appointed to consider a marine consent application by Trans Tasman Resources Limited to undertake iron ore extraction from the seabed in the South Taranaki Bight |
| **BETWEEN** | **TRANS-TASMAN RESOURCES LIMITED**<br>Applicant |
| **AND** | **KIWIS AGAINST SEABED MINING INCORPORATED**<br>Submitter |
| **AND** | **GREENPEACE AOTEAROA LIMITED**<br>Submitter |

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**STATEMENT OF EVIDENCE OF PROFESSOR JOHN LUICK**
**ON BEHALF OF KASM AND GREENPEACE**
**Dated 06 October 2023**

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**Counsel Acting:**

[redacted]

[redacted]

## Introduction

1. My name is John Luick.

2. I have a doctorate in physical oceanography. I have a consulting business (Austides Consulting) and am the sole Director of Tridel Australia Pty Ltd.

3. I have been asked by KASM and Greenpeace to prepare this statement of evidence on plume modelling and specifically on the process of flocculation.

4. I have the following qualifications and experience relevant to this application:
    a. For 20 years I have been running ocean hydrodynamic and particle tracking models.
    b. I have completed more than ten projects involving particle or plume tracking, including flocculation as a prescribed variable.

5. My CV is attached and marked as **Appendix A**.

## Code of Conduct

6. 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

7. I have been asked to:
    a) Review and comment on the evidence on plume modelling and the process of flocculation provided by Trans-Tasman Resources Limited as part of their original application. I understand that the Supreme Court expressed concern that the information available to the previous DMC about the sediment plume was incomplete and/or uncertain. I address those concerns with particular regard to flocculation.

b) Review and comment on the updated evidence provided by Trans-Tasman Resources Limited, dated 19 May 2023 relating to plume modelling.

8. I have considered the following statements of evidence in preparing this document:
   a. NIWA 2015: "Sediment Plume Modelling", by Mark Hadfield and Helen MacDonald, NIWA.
   b. HRW 2015: "Source terms and sediment properties for plume dispersion modelling", HR Wallingford, 2015.
   c. Macdonald, H.S and Hadfield, M.G. (2017). South Taranaki Bight Sediment Plume Modelling Worst-Case Scenario, 51 p.
   d. Statements of evidence of Dougal Greer dated:
      i. Greer, D., 2017a, Expert Evidence of Dougal Greer on Behalf of Kiwis Against Seabed Mining Incorporated 24 January2017.
      ii. Greer, D., 2017b, Expert Evidence of Dougal Greer on Behalf of Kiwis Against Seabed Mining Incorporated 27 March 2017.
   e. Statement of evidence of Helen MacDonald dated:
      i. MacDonald, H, Statement of Evidence, dated 19 May 2023.

9. I have reviewed the evidence of Dougal Greer and refer to his statements regarding his key critiques of the plume model.

**Shortcomings in the Plume Model and reliance on the process of Flocculation**

10. I have reviewed the Hadfield and Macdonald report submitted as part of the initial application which described the plume modelling that had been undertaken and described the reliance placed on the process of flocculation (Hadfield and Macdonald, 2015).

11. It is common practice to consider the process of flocculation within plume models, in estimating the particle sinking velocities. The approach taken by

the above authors, in which the vertical settling velocities are based on laboratory experiments, is standard practice.

12. I have identified the following shortcomings in the assessment of plume dispersal provided in the application for consent. In my opinion, the technical reports reflect a genuine attempt to predict the sediment plume and deposition patterns. However, I have several questions regarding the sediment plume:

    a. The NIWA 2015[1] report represents two sources, one of which is termed a "suspended source". On p 28 it is stated that the discharge is 4-6 m from the bottom (p 28), and after discharge, the plume descends to the bottom and forms a bottom attached plume of a few metres thickness. This is not reflected in Figures 5.2, 5.4, 5.5, and 5.6. None of those figures indicate a bottom attached plume. They do show uniform mixing in the vertical over the course of a day or two, followed by a bottom-detached plume. That raises the question of whether ROMS under-estimates the effective density of the plume, which is comprised of local (neutrally buoyant) seawater with suspended sediment, and hence should sink as anticipated on p 28.

    b. The sediment settling rates determined by HRW 2015[2] were used in the modelling described in NIWA 2015. HRW 2015 concluded that, when flocculation is accounted for, a proportion of the finest fraction settles between 0.01 to 0.1 mm/s (between about 1 to 10 metres per day). However, in their analysis, neither the jar nor annular flume tests account for time dependent flocculation rates. Flocculation is concentration dependent. In the real ocean, as particles floc and settle out, the concentration decreases, so the flocculation rate reduces, and therefore the settling velocity of the remaining (finest) fraction decreases. In

[1] NIWA 2015: "Sediment Plume Modelling", by Mark Hadfield and Helen MacDonald, NIWA.
[2] HRW 2015: "Source terms and sediment properties for plume dispersion modelling", HR Wallingford, 2015.

particular, fine particles drifting out into the mid-Bight, will remain in suspension for many months, accumulating over time.

c. I agree with Dougal Greer's point, made in his Statement of Evidence, that HRW 2015's sediment sampling scheme was too sparse, given the likely spatial variability in sediment types. This may not be a fatal flaw, but it is an important weakness which could have been resolved by additional sampling in the time elapsed since the second application in 2016.

d. I disagree with NIWA 2015's decision to use a nested grid. They used two model grids for hydrodynamic modelling (plus a third grid for sensitivity testing). Their "Cook Strait" grid encompassed the entire Bight at 2 km resolution. From their Figure 2-1a, that grid would have had about 250 x 110 cells (a modest size by today's standards). Their "one-way nested" grid had a 1 km resolution and encompassed the northeastern third of the Bight. Both grids were run with 20 layers in the vertical. By simply doubling the resolution of the Cook Strait grid (rather than restricting the plume modelling to the nested grid), they would have been able to follow the fine fraction long after it left the area enclosed in the nested grid. It appears from NIWA 2015's Figure 2-3 (which is depth-averaged) that there may be a permanent recirculation in mid-Bight. Such a circulation could trap an ever-increasing number of fine particles, leading to an unacceptable long-term Suspended Sediment Concentration (SSC) at mid-Bight. Had NIWA 2015's 1000-day model runs been extended to the full projected lifetime of mining, and had they used a single grid enclosing the entire Bight, rather than restricting their modelling to a small restricted nested grid, they might have seen SSC increase at mid-Bight over time.

e. It is unusual and contrary to best practice to not discuss or identify in the reports that the vertical velocity of a submerged particle is the sum of the settling rate and the vertical velocity of the water (the so-called "upwelling" or "downwelling" velocity). The 3D model used in NIWA 2015 does include vertical velocity, but surface wind forcing, the process that primarily causes it, occurs over an area much larger than the nested plume model, and there is no way to know whether it was simulated at all. (This is another reason to have used only a single grid enclosing the entire bight.) In other words, an important component of the settling velocity was evidently overlooked. For the plume model, if downwelling was under-represented, the settlement rate would be unrealistically low. At mid-Bight, upwelling would tend to hold fine particles in suspension for long periods. Since there was no plume modelling or particle tracking done for the whole of Bight model, we have no way to know if this occurs.

Oddly, the only reference to vertical upwelling or downwelling velocities I found in NIWA 2015 or elsewhere appears to be a minor error. There is a dot point in Section 3 of the NIWA report, which states:

> "*Vertical velocity profiles from acoustic Doppler current profilers (ADCPs) at five sites, shown in Figure 2-1b*."
> Figure 2-1b has nothing to do with vertical velocity.

Much of the NIWA 2015's results could have been verified with order of magnitude estimates. For example, the ocean currents shown in the ADCP data report show frequent westward bursts of about 0.25 m/s (a little over 20 km per day). At a typical 50 metre depth contour, sediment starting from the surface and settling at 10 m/day would settle within 50 days. Sediments starting from halfway down would settle within 25 days. Sediments settling at one tenth the rate would settle within 500 days. A simple reference to the HYCOM model currents would indicate preferred directions. Such an analysis goes far beyond the validation NIWA 2015 presumably did, e.g., validating the horizontal velocities by point comparisons to ADCP data. I would like to see a full order of magnitude analysis of this sort.

**Uncertainty and the Worst-Case Plume Modelling**

13. I understand from legal counsel that a concern with the evidence identified by the Supreme Court was the degree of uncertainty in the plume modelling.

14. At [16] of Helen Macdonald's statement she states:

*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.*

And at [23]
*..... A large uncertainty in the sediment model comes from the input parameters.*

15. I agree with these comments, and I mostly agree that the model matches with the observations at tidal frequencies, and in most of the comparisons shown in Hadfield and MaDonald (2015), Figures 3.1-3.5, with the exception of the scatter plot of Figure 3.4, in which model velocities at mid-depth are often more than double the observations. This model is in water depth of 50 metres or less, so vertical velocity shear may play a role. The discrepancy is not mentioned in the text. Combined with the further uncertainties I have identified above in the input parameters, I conclude that
    a. Flocculation itself is entirely uncertain in the local circumstances. Although laboratory studies, like the ones cited in the NIWA reports, show a linear increase in settling velocities, recent field studies such as Munoz-Royo[3] that account for turbulent shear show that flocculation is not just unpredictable in real situations, but may not be a significant fact in settling rates in the presence of turbulence.
    b. Vertical water velocities (up- or downwelling) may be as large or larger than the particle settling velocities, however this has been entirely ignored in the NIWA reports.

[3] Muñoz-Royo et al (2021) Extent of impact of deep-sea nodule mining midwater plumes is influenced by sediment loading, turbulence and thresholds. Communications Earth and Environment pp 1-16.

c. If the overall circulation in the Taranaki Bight is convergent, then particles will tend to be trapped mid-Bight.
d. Given the uncertainty in flocculation, up- or downwelling, combined with not accounting for convergence, as well as the discussion in 11(b) regarding the uncertainty in the sediment rates, the sedimentation footprint is highly unpredictable, and the finest fraction may remain in suspension for years, accumulating in the mid-Bight over long time periods, potentially to the level where they pose a threat to marine mammals.
e. Had NIWA 2015's 1000-day model runs been extended to the full projected lifetime of mining, and had they used a single grid enclosing the entire Bight, rather than restricting their modelling to a small restricted nested grid, they might have seen SSC increase at mid-Bight over time.

16. I otherwise adopt Mr Greer's comments on the adequacy and any concerns around the worst-case plume model found in Macdonald, H.S and Hadfield, M.G. (2017). South Taranaki Bight Sediment Plume Modelling Worst-Case Scenario, 51 p. My comments are limited to flocculation.

**Dr John Luick**
**October 2023**