BEFORE THE ENVIRONMENTAL PROTECTION AUTHORITY
AT WELLINGTON

IN THE MATTER	of the Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012 (**EEZ Act**)
AND	
IN THE MATTER	of an application for marine consent under section 38 of the EEZ Act by Trans-Tasman Resources Limited to undertake iron ore and processing operations offshore in the South Taranaki Bight
BETWEEN	**Trans-Tasman Resources Limited** Applicant
AND	**Environmental Protection Authority** EPA
AND	**Fisheries Inshore New Zealand Limited, New Zealand Federation of Commercial Fishermen Inc., Talley's Group Limited, Southern Inshore Fisheries Management Company Limited and Cloudy Bay Clams Limited** Fisheries Submitters

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PRIMARY EXPERT EVIDENCE OFJORIS GERARD LEONARD JORISSEN ON LABORATORY TESTING AND PLUME MODELLING FOR FISHERIES SUBMITTERS

DATED: 23rd January 2017

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SUMMARY OF EVIDENCE

1. My name is Joris Gerard Leonard Jorissen. I am a senior coastal engineer at Jacobs Australia Pty Limited in Brisbane.

2. My evidence relates to the investigations undertaken to assess the potential sediment plume resulting from Trans-Tasman Resources Limited's (**TTR**) proposed mining activity and is aimed at providing a review of the approaches and methods used by TTR to estimate the potential suspended sediment plume in order to establish whether or not the sediment plume predictions provided as part of TTR's application for marine consents can be relied upon to assess the environmental impacts of the proposed mining activity.

3. In order to estimate the potential suspended sediment plume resulting from the proposed mining activity, TTR has broadly adopted the following approach:

   (a) Review the development proposal and re-assess the representation of the proposed mining operations in the sediment plume assessments;

   (b) Undertake a series of laboratory tests to assess the settling behaviour of the sediments being released in the sea;

   (c) Undertake numerical modelling to simulate nearfield plume behaviour of sediment discharged in the sea in order to identify the proportion of suspended fine sediments that are likely to deposit in the mining pit;

   (d) Consider the above to revise the sediment source terms adopted in the plume dispersion modelling; and

   (e) Re-run the sediment plume model using the revised source terms and analyse the model results.

4. I consider the overall strategy and adopted approach appropriate for its intended use and that the additional work presents an advancement compared to the assessments undertaken as part of TTR's 2013 application. The investigations undertaken to estimate the settling behaviour of the suspended sediments are considered appropriate. In particular, the decision to model the sediment according to sinking rate rather than its nominal particle size is a major advancement compared to earlier investigations, as it provides a more realistic representation of the settling behaviour of the tailings. However, there remain some key issues around the sediment plume modelling undertaken and specifically how the effects of the mining activity have been represented therein.

Laboratory Tests

The laboratory tests carried out by HR Wallingford (**HRW**) (2014) are considered comprehensive and thorough. However, the interpretation in terms of proportioning the sediment between the four nominated settling fractions, as documented in NIWA (2015a), is considered more appropriate than that proposed by HRW (2014) or applied in the plume modelling. Adopting the NIWA interpretation could result in a larger sediment plume than reported.

Source Terms for Plume Modelling

5. The suspended fine sediments resulting from the mining operations are input into the dispersion model as a temporally constant point source load, representing the average rate of discharge during the mining operations. Application of a temporally constant rate that represents the average rate of release will underestimate the release of fine sediments during certain mining operations, different material compositions or different mining pit configurations, and overestimate during other periods. As a consequence, the plume model may underestimate the temporal variability in the sediment plume characteristics, which could mean that the plume model predictions understate the impacts for less frequent occurrences. For example, the Suspended Sediment Concentration (**SSC**) impacts that will be exceeded 1% of the time (i.e. the 99th percentile SSC impacts) could be significantly larger than those reported.

Rebuttal of TTR's Evidence

6. NIWA (2015a) and HRW (2014) provide different interpretations of these results of the settling tests undertaken by HRW. In the 2015 sediment plume modelling, the average value of the estimates by HRW and NIWA have been adopted to determine the suspended sediment loads resulting from the return of mining tailings from the mining vessel. It is my opinion that NIWA provides a more accurate interpretation of the settling tests, and would be a better basis for the definition of the source term for the sediment plume modelling. Adopting the NIWA interpretation could result in a larger sediment plume than reported.

INTRODUCTION

Qualifications and experience

7. My name is Joris Gerard Leonard Jorissen. I am a senior coastal engineer at Jacobs Australia Pty Limited in Brisbane, Australia (part of **Jacobs** engineering group) since August 2016. I hold the degree of Master of Science (Civil Engineering, specialisation coastal engineering) from Delft University of Technology in the Netherlands awarded in 2002.

8. I have over 15 years of professional experience in coastal engineering. My specialist area is the assessment of coastal processes, particularly the numerical modelling of waves, hydrodynamics and sediment transport processes. I have led a number of studies into the effects of dredging projects in the marine environment, including the numerical modelling of sediment plumes and the assessment of sediment source terms from different types of dredging and disposal activities[1].

9. Prior to joining Jacobs I was employed by BMT WBM in Australia for over nine years as a senior coastal engineer. Before joining BMT WBM I worked for Delft University of Technology, Rijkswaterstaat in the Netherlands and then Capita Symonds and AECOM (formerly Scott Wilson) in the UK. From 2008 to 2010, I was also a lecturer in coastal engineering at Queensland University of Technology.

Code of conduct

10. I have read the Environment Court Code of Conduct for expert witnesses and agree to comply with it.

11. I confirm that the topics and opinions addressed in this statement are within my area of expertise except where I state that I have relied on the evidence of other persons. I have not omitted to consider materials or facts known to me that might alter or detract from the opinions I have expressed.

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[1] Yarra River Dredge Plume Modelling Study, Garden Island Marine Impact Study, Eden Breakwater Wharf Extension – Dredge Impact Study, Mud Island Dredge Material Placement Investigation

Background to Evidence Preparation

12. I have been retained by the Fisheries Submitters to prepare a statement of evidence on my review of the approaches and methods used by TTR to estimate the potential suspended sediment plume in order to establish whether or not the sediment plume predictions provided as part of TTR's application can be relied upon to assess the environmental impacts of the proposed mining activity.

13. In preparing this evidence I have read the following documents:

(a) TTR – South Taranaki Bight Offshore Iron Sand Extraction and Processing Project, Impact Assessment, dated August 2016;

(b) HR Wallingford (2014), Support to Trans-Tasman Resources: Laboratory testing of sediment, DDM7316-RT002-R01-00, October 2014;

(c) HR Wallingford (2015), Support to Trans-Tasman Resources Source terms and sediment properties for plume dispersion modelling, DDM7316-RT004-R01-00, October 2015;

(d) NIWA (2013), South Taranaki Bight Iron Sand Extraction Sediment Plume Modelling, Phase 3 studies, Report prepared by NIWA for Trans-Tasman Resources, October 2013;

(e) NIWA (2015a), Memorandum - Contribution to source terms report for TTR, M. Pinkerton, NIWA, 4 September 2015;

(f) NIWA (2015b), South Taranaki Bight Iron Sand Extraction Sediment Plume Modelling, NIWA Report WLG2015-22, NIWA, October 2015;

(g) Expert Evidence of Michael Dearnaley on behalf of Trans-Tasman Resources Limited, dated 15 December 2016;

(h) Evidence of Shawn Thompson on behalf of Trans-Tasman Resources Limited, First Statement – Project Description, dated 16 December 2016 (2016a);

(i) Evidence of Shawn Thompson on behalf of Trans-Tasman Resources Limited, Second Statement – Operational Description, dated 16 December 2016 (2016b);

(j) Expert evidence of Terry Hume on behalf of Trans-Tasman Resources Limited, dated 15 December 2016;

(k) SKM (2013) Review of technical reports relating to TTR (2013) marine consent application. Oceanographic processes and the physical environment for the New Zealand Environmental Protection Authority; and

(l) Primary expert evidence of Dr Greg Barbara on Marine Ecology for the Fisheries Submitters, dated 23 January 2017.

BACKGROUND TO PROPOSAL

14. TTR is seeking marine consent to undertake iron ore extraction and processing operations in an area located 22 to 36 km off the coastline of South Taranaki in water between 20 and 42 m deep. TTR proposes to extract up to 50 million tonnes of seabed material per year for processing on an Integrated Mining Vessel (**IMV**). The seabed material will be dredged from the seabed using two subsea sediment extraction devices (referred to as crawlers) that pump the dredged material as slurry to the IMV.

15. The processing on board the IMV will involve separation of the ore from the seabed material and seawater and includes screening, magnetic separation, classification, grinding and rinsing with fresh water. It is expected that approximately 10% of the dredged material (by volume) will be processed into iron ore concentrate for export. The remaining 90% of the extracted sediment (approximately 45 million tonnes per year) will be returned to the seabed via a pipeline, which discharges the sediment/seawater mixture at a point of discharge close to the sea bed (around 4 m above the bed).

16. The disposal of tailings will occur by combining the discharges of de-ored sandy material (1,863kg/s with an estimated fine sediment content of 0.4% of the sediment discharge) with the discharge from the hydro-cyclone operation (86kg/s with an estimated fine sediment content of 67.4% of the sediment

discharge). By fine sediments, I mean material with a particle size of less than 38microns. The combined discharge is approximately 10.2m^3/s and contains approximately 191kg/m^3 of sediment. The rest of the discharge is seawater.

ASSESSMENT APPROACH ADOPTED BY TTR

17. Broadly, the following approach was adopted by TTR to refine the sediment plume modelling:

(a) Review the development proposal and re-assess the representation of the proposed mining operations in the sediment plume assessments;

(b) Undertake a series of laboratory tests to assess the settling behaviour of the sediments being released in the sea;

(c) Undertake numerical modelling to simulate nearfield plume behaviour of sediment discharged in the sea in order to identify the proportion of suspended fine sediments that are likely to deposit in the mining pit;

(d) Consider the above analyses to revise the sediment source terms adopted in the plume dispersion modelling; and

(e) Re-run the sediment plume model using the revised source terms and analyse the model results.

LABORATORY TESTS

18. For the assessment of the potential suspended sediment plume that may result from the proposed mining activity, consideration of the fine sediments is essential as this fraction settles the most slowly and therefore has the potential to be transported the greatest distances in suspension from the point of release and contribute the most to the sediment plume.

19. Using samples of sediment material provided by TTR, a series of laboratory experiments were undertaken by HRW to assess the settling velocity, flocculation and critical stress for deposition and erosion of various fractions of the proposed tailings material to be returned to the seabed.

20. As part of the laboratory tests, particle size distribution (**PSD**) analysis of tailings material supplied by TTR was also undertaken. Figures 3.1 to 3.3 of HRW (2014) report indicate that:

(a) the post-grind tailings material contains about 30 to 45% of material with a particle size of less than 38microns;

(b) the pre-grind ultra-fines material contains about 78 to 97% of material with a particle size of less than 38microns; and

(c) the bulk tailings material contains about 72 to 92% of material with a particle size of less than 38microns for the bulk tailings.

21. These levels of fines and ultra-fines are consistent with the percentages reported by Orpin (2012) in the previous TTR application (SKM 2013). However, these percentages are not consistent with the sediment size grading derived by TTR for the tailings rejected by the iron sand extraction process. The size grading derived by TTR (and adopted in the plume modelling) indicates that the tailings from the hydro-cyclone process contain approximately 67.4% of material with a particle size of less than 38microns and the sediment discharge of de-ored sandy material approximately 0.4% of material with a particle size of less than 38microns.

22. The settling tests demonstrated that some fine sediment from the tailings will be subject to flocculation when suspended in the sea water column. Flocculation is the process whereby individual particles combine together to form larger particles with a greater settling velocity than that of the constituent particles in the floc. This process occurs naturally with most fine sediments and does not require addition of chemicals.

23. The settling tests indicate that the settling velocities of the fine fractions of the bulk tailings material (“sediment 3”) are significantly greater than the settling velocities assumed for the fine fractions of the tailings in the 2013 plume modelling (NIWA, 2013). Nevertheless, the tests did demonstrate that a small portion of the “sample 3” material is likely to settle very slowly with settling velocities of less than 0.032mm/s.

24. I consider the laboratory tests carried out by HRW (2014) comprehensive and thorough, and provide a good basis to estimate the settling behaviour of the suspended sediments. In particular, the decision to model the sediment according to sinking rate rather than its nominal particle size is considered a major advancement compared to earlier investigations, as it is a more direct way to determine the settling velocity of the sediments and thus should provide a more realistic representation of the settling behaviour of the tailings.

25. However, interpretation of the laboratory test results appears to be ambiguous with NIWA and HRW providing a different proportioning of the fine sediment over the settling velocity classes, based on the same settling test results. HRW (2014) concludes that around 6% of the fine sediments have a settling velocity of less than 0.032mm/s, while NIWA (2015) concludes 16% of the material has a settling velocity of less than 0.032mm/s.

26. In the NIWA (2015) sediment plume modelling, the average value of the estimates by HRW and NIWA has been adopted to determine the suspended sediment loads resulting from the return of mining tailings to the seabed from the mining vessel. It is my opinion that the NIWA interpretation provides a more accurate interpretation of the settling tests, because both the bucket test and the beaker test yielded a percentage of fine material that settling velocity of less than 0.03mm/s of at least 9.4%, and would therefore be a better basis for the definition of the source term for the sediment plume modelling. Adopting the NIWA interpretation could result in a larger sediment plume than reported.

SOURCE TERMS FOR PLUME MODELLING

27. Dearnaley (2016) states that the main source for release of fine sediments into the water column resulting from the mining operations is the return of mining tailings from the IMV. In his evidence at paragraphs [46] to [52], he provides estimates of other additional sources of fine material due to the mining activity and concludes at paragraph [53] that the combined contribution of these additional sources, in terms of suspended sediment loads, is insignificant compared to the load associated with the return of mining tailings. I concur with this statement.

28. TTR proposes to return mining tailings from the IMV via a discharge pipe that will discharge the mining tailings close to the seabed (around 4 m above the bed). The discharge from the hydro-cyclone will be mixed with the de-ored sand discharge to form a high density fluid before releasing it into the ocean. By releasing the tailings as a high density fluid near the sea bed, much of the material released, once on the seabed, will simply remain there as a density layer, which is heavier than ambient seawater and mixes poorly with the overlying waters. It is expected that the density layer will become a few metres thick and will spread over much of the mining pit.

29. HRW (2015) carried out numerical modelling to examine the behaviour of the suspended fines released into the mining pit. Two different numerical models were used to assess the fate of material with different settling velocities. The pit simulated was 300m in length and had a width of 300m in one model and a width of 900m in the other. Only one depth of the mining pit, namely 5m, was considered in both numerical models. No assessment of the sediment plume was made for when the materials are being discharged above the level of the pre-works sea bed to form mounds up to 9 metres high above the sea bed. Releasing the material above the edges of the pit will have more significant effects on the plume.

30. The modelling by HRW demonstrated that the trapping capacity of the mining pit, and thus the amount of fine sediment entering the water column as a passive sediment plume, is sensitive to the width of the pit and the prevailing wave and current conditions, in particular the trapping capacity of the sediment fraction with a nominal settling velocity of 0.1mm/s.

31. The trapping capacity of the pit is also expected to be sensitive to the depth of the mining pit and the height of the point of discharge of the discharge pipe, and as the proposed mining depth is expected to vary between 2 and 11m and occasional overfilling of the pit could occur, there is uncertainty whether or not the adopted trapping characteristics are representative for the entire mining operation. It is likely that there will be situations whereby the proportion of fine sediments escaping the pit will be significantly higher than those adopted in the source term study. As a result, it is possible that the suspended sediment loads applied to the sediment plume model could be

significantly underestimated during some periods and overestimated during other periods.

32. **Table 1** below provides a summary of the source rates adopted in the 2015 sediment plume modelling, the rates proposed by HRW (2014) and NIWA (2015a) and those adopted in the 2013 sediment plume modelling (NIWA, 2013). The table indicates that, in the 2015 plume modelling, a total of 22.9kg/s of fine sediments is assumed to be released from the mining area in a passive plume when the IMV is discharging mining tailings. With an indicated operational up-time of 80%, this corresponds to an annual release of about 0.6 million tonnes of fine sediments. Based on an assumed averaged in-situ fines content of 2.0% of the seabed material and an annual production of 50 million tonnes, this implies that about 60% of the total fines being excavated from the seabed would be released from the mining area in a passive plume. I consider such proportion of fine sediments being released plausible.

Table 1: Source terms for sediment plume modelling

Source	**Sediment size range (μm)**	**Nominal settling velocity (mm/s)**[2]	**Source rate proposed in HR Wallingford (2014)**	**Source rate proposed in NIWA (2015b)**	**Source rate adopted in 2015 plume modelling (NIWA, 2015a)**	**Source rate adopted in 2013 plume modelling (NIWA, 2013)**
Overflow (hydro-cyclone)	39 – 90	10	0	0	0	24.6
Overflow (hydro-cyclone)	16 – 38	1	0.4	2.5	1.45	25.7
Overflow (hydro-cyclone)	8 – 16	0.1	16.1	13.6	12.55	20.3
Overflow (hydro-cyclone)	< 8	0.01	3.3	8.7	6.00	28.5

2 Note that the adopted settling velocity for the '16-38μm' and '39-90μm' sediment size classes differs in the 2013 modelling study – Refer to Table 3-4 of NIWA (2013) for adopted settling velocities.

Underflow (de-ored sand)	39 – 90	10	0	0	0	50.3
Underflow (de-ored sand)	16 – 38	1	0.1	0.4	0.25	3.2
Underflow (de-ored sand)	8 – 16	0.1	2.3	1.9	1.80	2.4
Underflow (de-ored sand)	< 8	0.01	0. 5	1.2	0.85	3.3

SEDIMENT PLUME MODELLING

33. NIWA has used a suite of nested Regional Ocean Modelling System (**ROMS**) numerical models to examine the farfield behaviour of the sediment plume. The sediment transport model (**SMD**) is driven by model output from NIWA's 'Cape Egmont to Kapiti' hydrodynamic model, which in turn is driven by a broader regional model (the "Cook Strait" model), also developed by NIWA. In the model nesting procedure, the model results of the larger domain provides time- and spatially varying boundary conditions (sea surface height, velocity, temperature, salinity) for the smaller domain model.

34. The ROMS models have been calibrated and validated against a range of data to evaluate the performance of the modelling system in simulating the key sediment transport processes in the South Taranaki Bight. The model evaluation included the comparison of model predictions with measurement data on flow velocity and suspended sediment concentrations at a number of locations. The model evaluation undertaken demonstrates that the modelling system is capable of simulating the key hydrodynamic and sediment transport processes reasonably well, including the natural variability in fine suspended sediment concentrations in the inshore regions, and indicates that the modelling system is a good and useful tool for assessing the potential effects of the mining activity on suspended sediment in the South Taranaki Bight, provided that appropriate source terms to represent the activity are applied to the model.

35. The SMD model was run for a 1000 day period whereby mining suspended sediment sources were introduced during the last 800 days. The results of the sediment plume modelling were analysed to predict SSC and sedimentation on a two year time scale. This is an appropriate time scale to assess the effects of the mining activity during most environmental conditions that are likely to be experienced in the South Taranaki Bight during the operation.

36. The suspended fine sediments resulting from the mining operations are input into the SMD model as a static point source with a temporally constant suspended sediment load, representing the average rate of discharge during the mining operations. As such, the model does not consider the variability of the suspended sediment loads likely to be experienced during the mining activity as a result of the variability in mining operations, material compositions and mining pit configurations. This could mean that the plume model predictions understate the impacts for less frequent occurrences (eg. the 99th percentile/maximum SSC impacts).

CONCLUSIONS

37. I consider the overall strategy and adopted approach appropriate for its intended use and consider that the additional work presents an advancement compared to the assessments undertaken as part of TTR's 2013 application. The investigations undertaken to estimate the settling behaviour of the suspended sediments are considered appropriate. In particular, the decision to model the sediment according to sinking rate rather than its nominal particle size is considered a major advancement compared to earlier investigations, as it provides a more realistic representation of the settling behaviour of the tailings. However, there remain some key issues around the sediment plume modelling undertaken and specifically how the effects of the mining activity have been represented therein.

38. The laboratory tests carried out by HRW (2014) are considered comprehensive and thorough, however the interpretation in terms of proportioning the sediment between the four nominated settling fractions, as documented in NIWA (2015a), is considered more appropriate than that proposed by HRW (2014).

39. NIWA (2015a) and HRW (2014) provide a different interpretation of the results of the settling tests undertaken by HRW. In the 2015 sediment plume modelling, the average value of the estimates by HRW and NIWA have been adopted to determine the suspended sediment loads resulting from the return of mining tailings from the mining vessel. Averaging these results underestimates the loads. It is my opinion that NIWA provides a more accurate interpretation of the settling tests, and would be a better basis for the definition of the source term for the sediment plume modelling. Adopting the NIWA interpretation could result in a larger sediment plume than reported.

40. The suspended fine sediments resulting from the mining operations are input into the dispersion model as a temporally constant point source load, representing the average rate of discharge during the mining operations. Application of a temporally constant rate that represents the average rate of release will underestimate the release of fine sediments during certain mining operations, material compositions or mining pit configurations, and overestimate during other periods. As a consequence, the plume model could underestimate the temporal variability in the sediment plume characteristics, which could mean that the plume model predictions understate the impacts for less frequent occurrences. For example, the SCC impacts that will be exceeded 1% of the time (ie. the 99th percentile SSC impacts) could be significantly larger than those reported.

Dated 23rd day of January 2017

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Joris Jorissen