

Comment on Bream Bay Sand Extraction Application

Attn: Expert Consenting Panel Bream Bay Sand Extraction Application
c/- Environmental Protection Authority (EPA)
Private Bag 63002
Waterloo Quay
Wellington 6140

From: Northland Regional Council

Northland Regional Council (NRC) thanks the panel for inviting comment in respect of the Bream Bay Extraction Application by MBL Limited applied for under the Fast-track Approvals Act 2024 (FTA).

Council recognises the significant concerns regarding the proposed sand extraction activity, expressed by iwi, hapū, the local community, and our district council counterparts.

We acknowledge the depth of opposition and emphasise the importance for decision makers to carefully consider these perspectives before making any decisions. We are mindful that processes under the FTA may create a risk that affected community views are not fully considered, especially when they are not provided the opportunity to participate in the decision-making process. Our commentary on the proposed is therefore both from the perspective of council's role in representing the interests of its communities, and from a technical standpoint in our role as a regulatory authority.

Based on the concerns expressed by the communities council represents, the impacts of the proposal on the rights and interest of our Te Tiriti partners, and the uncertainty associated with the impact of the proposal on marine ecology, NRC opposes the proposal.

In order to assist the Expert Panel in considering the application, we have attached technical peer review documents commissioned by NRC regarding Coastal Ecology and Coastal Geomorphology relating to the application. We also attach an economics assessment supplied to council by Bream Bay Guardians Group. That assessment has been reviewed by NRC's in-house economics staff who are of the view that the counter economic argument has merit. However, NRC did not commission a technical peer review of economic matters.

Marine Ecology

Dr Sharon De Luca from Boffa Miskell is an expert in Marine Ecology and has provided a review of a range of ecological issues (Refer Attachment 1).

The initial review by Dr De Luca raised several issues regarding the draft technical reports and these were passed on the MBL Ltd prior to lodgement. The applicants have responded to these comments in Attachment 5 of the substantive application. However, several issues remain from Dr De Luca's perspective.

Dr De Luca's overall conclusion is:

"While many matters raised through peer review have been satisfactorily addressed, I retain moderate concern regarding the ecological value assessment and the inadequacy of the control sites, and high concern regarding the adequacy of the proposed monitoring within the sand extraction area. These issues are material to the interpretation of level of effect and warrant careful consideration."

We urge the panel to consider the points made by Dr De Luca, and to give careful attention to the findings of the marine ecology assessment, particularly the concerns regarding ecological value, the adequacy of control sites, and the robustness of proposed monitoring within the sand extraction area.

Coastal Geomorphology

Professor Mark Dickson from Auckland University is an expert in Coastal Processes and Geomorphology and has provided a review of this aspect of the application (Attachment 2). The initial review by Dr Dickson also raised some issues which were referred to MBL. His review of the substantive application concludes that:

“Based on what I have read about the morphodynamic depth of closure and the shoreface shape at Te Ākau Bream Bay, I speculate that to mitigate potential shoreline consequences of sand extraction over a 100-year period, sand extraction might need to occur seaward of the 45-year maximum outer depth of closure calculation, rather than the 45-year average outer depth of closure calculation.”

The review by Dr Dickson underscores the need to give careful consideration to the proposed sand extraction boundary in order to mitigate the impacts of the proposal on the shoreline of Bream Bay. He has also noted that recent bathymetric LIDAR is available for the Bream Bay area and this has not been referred to or analysed in the applicant’s assessment.

We recommend that the panel seek further independent advice with respect to the adequacy of the proposed mitigation measures because there remains uncertainty as to the potential impacts of the proposal on coastal geomorphology.

Economics

In addition to the reviews engaged by NRC, we have been provided with a review of the applicant’s economics assessment commissioned by Bream Bay Guardians (Refer Attachment 3). This review challenges the findings of the MBL Economics report prepared by M. E. Consulting, raising concerns with the methodology and conclusions. We have subsequently had the council’s economic advisor review this report and he has concluded that it raises legitimate concerns regarding the economic outcomes.

NRC has not commissioned an independent expert to provide a formal peer review of economic outcomes but considers the evidence provided to date fails to clearly establish the regional or national economic benefits from the application. It also does not clearly set out the availability of alternative sand supplies within the broader context of the Northland and Auckland regions, which we consider to be a critical consideration for determining economic benefit

Given the fundamental importance of economic benefit to the purpose of the Fast Track legislation, we recommend and that the expert panel seek further independent economic advice.

Cultural Impacts

We note iwi and hapū have raised a range of significant concerns in the Cultural Impact Assessments (CIA) provided as part of the application. NRC is aware that a MoU has been agreed between the applicant and Te Parawhau ki Tai. However, we note a number of concerns raised by Patuharakeke and Ngātiwai Trust Board remain unresolved. Patuharakeke for example identify a number of specific cultural impacts on Rangatiratanga and Kaitiakitanga. In addition, the CIA prepared by Ngātiwai Trust Board seeks that the application be declined or should it go ahead, be subject to a comprehensive set of cultural mitigation measures.

Although these matters are for the iwi/hapū to articulate, NRC’s submission on the Fast Track Approvals Bill pointed to the risks the legislation would create in respect of failing to provide for the protection of the rights and interests of iwi and hapū. We therefore request that the expert panel pay particular attention to concerns raised in the CIAs; and consider whether there may be other iwi/hapū who should be invited to comment in addition to those that have submitted a CIA.

Monitoring and Conditions

While NRC is unable to support the proposal, should the panel approve the application, NRC requests that a robust monitoring regime is put in place by way of consent conditions. Dr De Luca has identified that this is required to establish accurate baseline data, keep track of the scale of effects related to the activity and identify any unanticipated effects.

Monitoring of the benthic environment within the sand extraction area is critical to test the validity of the natural recovery assumptions relied on by MBL. These assumptions form a key component of the effects assessment and require empirical verification.

Monitoring addresses the public and hapū/iwi concerns about damage to the marine environment in the short and long term and provides data to base future decisions on. In particular, Dr De Luca has prepared a memo with a proposed monitoring regime to be included in the Marine Ecology Management Plan condition. A copy of this is included below as Attachment 4.

Given the uncertainty around environmental, cultural and economic/market effects over time, a reduced consent duration is considered appropriate should the consent be granted.

Conclusion

In light of the substantial concerns raised by both independent experts and the local community we oppose the sand extraction activity proposed by MBL Ltd.

The ecological, geomorphological, and economic reviews all highlight uncertainties and risks that have not been adequately addressed. These findings, together with the community's concern about the long-term impacts on Bream Bay, reinforce the need for a precautionary approach when determining the proposal.



Name: Pita Tipene

Title: Chair, Northland Regional Council

Date: 7 May 2026



Memorandum

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Attention: Ingrid Kuindersma

Company: Northland Regional Council (NRC)

Date: 15 September 2025

From: Dr Sharon De Luca

Message Ref: Peer Review Proposed McCallum sand mining at Bream Bay

Project No: BM250630

I have been provided with the following reports by NRC:

1. Bioresearches (2025) Assessment of Ecological Effects. Report for McCallum Bros Limited.
2. Bioresearches (2024) Te Ākau Bream Bay Sand Area, 2024 Initial Sand Extraction Assessment, February – March 2024. Report for McCallum Bros Limited.
3. NIWA (2025a). Sand extraction in Te Ākau Bream Bay. Potential effects on seabirds and shorebirds. Prepared for McCallum Bros Limited.
4. Boyd (2025). Assessment of Effects on Fish and Fisheries in Te Ākau Bream Bay. Prepared for McCallum Bros Limited.
5. SLR (2025). Te Ākau Bream Bay Sand Extraction. Marine Mammal Environmental Impact Assessment. Prepared for McCallum Bros Limited.
6. SLR (2025). Te Ākau Bream Bay Sand Extraction. Water Quality Assessment of Environmental Effects. Prepared for McCallum Bros Limited.
7. NIWA (2025b) Cup Corals and Schedule 7 of the Fast-track Approvals Act 2024. Prepared for McCallum Bros Limited.

Main points from review of marine ecology

(see Table 1 below for further detail):

1. The assessment states that each ecological feature was assessed using a spreadsheet template by assigning a score based on professional judgement (with justification) to attributes listed in table Why was this spreadsheet not provided in the assessment? Provide please spreadsheet?
2. Statistical design issues:
 - a. Bioresearches note that the differences in biota between North and South control areas could make comparing differences over time difficult. How is this mitigated?
 - b. Is this difficulty with biota differences addressed with respect to assessing the second stage of the project?

- c. At the time of sampling, more replication was suggested to balance the design. Was this done? Please outline the statistical approach as it stands now?

3. Ecological values

- a. I agree with ecological values for benthic macrofauna, sharks & rays and marine reptiles. I disagree with the benthic habitat (stated as just fauna in the assessment) has moderate ecological value - I would value it as **high**, given the diverse and abundant benthic invertebrates, presence of protected cup corals, sand grain sizes, low contaminant levels, low degree of modification, few invasive species, water quality high, fish abundance and diversity high (as per EIANZ marine ecological values guidelines).
- b. At the ZOI the effect on the benthic habitat is **high** until natural recovery >3 years (needs to be monitored rather than just assumed), and then during recovery probably reduces to **low** if recovery occurring as expected.
- c. I disagree with the separate ecological values for fish (just because the fish species are common, and there are no at-risk or declining fish species, doesn't make the values low). The values appropriate for the habitat type, should be at least **moderate** or **high**.

This is supported by The Fish and Fisheries Assessment which states "diverse fish community of Te Akau Bream Bay, comprised of populations of common inshore species, including demersal and pelagic mobile species".

- d. Stoney Corals - Bioresarches state that the presence of these solitary stoney corals in the sand extraction area does not increase the ecological value of the site, as they are not complex habitat forming corals. These coral species do not have to be complex habitat forming corals to be ecologically valuable. These corals provide microhabitats for small invertebrates and are important for biodiversity and as indicator species (Holland et al., 2020) and therefore add to the ecological values of the site.

NIWA (2025b) report provides an assessment of cup corals. This report concludes that the sand extraction activity proposed is likely to minor to negligible impact on the populations within Aotearoa New Zealand of either *Sphenotrochus ralpae* or *Kionotrochus suteri*. I defer to the NIWA report authored by Beaumont as the best available assessment.

I have no review comments on the avifauna, fish and fisheries, nor the marine mammal assessment.

Table 1: Marine Ecology Peer Review

	Review Point	Question
Bioresearches (2025) Report Structure (marine values)	Suggest the authors create a table of marine assessment criteria from EIANZ 2025 in first column and the assigned ecological value next column, and final column with reference to the paragraph in the ecological assessment and could include mitigation.	Suggest table for clarity is provided.
Bioresearches (2025) Table 1	The first statement says each ecological feature was assessed using a spreadsheet template by assigning a score based on professional judgement (with justification) to attributes listed in table 1. Why was this spreadsheet not provided?	This is a gap in the assessment.
Bioresearches (2025) Page i	0.001% loss of seabed habitat from the sand extraction area.	How is this calculated? At what scale?
Bioresearches (2025) page iii	The differences in biota between N&S control areas, which could make comparing differences over time difficult, stated there are no alternative controls areas are obvious.	Why are alternative control sites not obvious? What has been considered?
		With the proposal to undertake second stage if no significant or unexpected adverse effects arising from the extraction identified through the monitoring programme - is this difficulty in the baseline adequately addressed?
Bioresearches (2025) page 3	At the time of sampling, it was suggested more replication was needed in the control area to balance the statistical design.	Was replication design imbalance addressed?
Bioresearches (2025) Table 1	Please finish the statement about shellfish flesh (9 th row)?	Was shellfish flesh tested for contaminants?

Bioreseaches (2025) Section 6, page 58	Ecological Values	<p>Agree with ecological values for benthic macrofauna, sharks & rays and marine reptiles. I disagree with the benthic habitat (stated as just fauna) has moderate ecological value - I would value it as high, given the diverse and abundant benthic invertebrates, sand grain sizes, low contaminant levels, low degree of modification, few invasive species, water quality high, fish abundance and diversity high.</p> <p>I disagree with the separate ecological values for fish (just because the fish species are common, and there are no at-risk or declining fish species, doesn't make the values low. It makes the values appropriate for the habitat type, so at least moderate or high.</p>
Bioreseaches (2025) Section 6, page 58	Ecological Values	<p>At the ZOI the effect on the benthic habitat is high until natural recovery >3 years (needs to be monitored rather than just assumed), and then during recovery probably reduces to low if recovery occurring as expected.</p>
Bioreseaches (2025) Section 6, page 58	Ecological Values	<p>What is the scale of assessment - the ZOI or Bream Bay or both?</p>
Bioresearches (2024) 3.3	Titled "Surficial Sediment Quality"	<p>Sediment was composited from the dredge tows - 100mm deep sediments were mixed and subsampled – these samples were <u>not</u> surficial – the top 2-3cm is usual for surficial.</p> <p>The top 2-3 cm of sediment is considered the recent deposition, perhaps this part of the report should be re-interpreted as Total Sediment Quality (top 100mm) not Surficial?</p>
Bioreseaches (2024) 2.2.4	sensitive species NIWA (2013)	<p>The reference to NIWA (2013) discusses sensitive benthic <u>communities</u>, which is different to sensitive <u>species</u>. In the EIANZ 2025 (your table 1) criteria the reference is to sensitive versus</p>

		tolerant species, with respect to tolerant to mud and contaminants. Please reframe this discussion to sensitive species <u>not</u> sensitive communities.
Bioreseaches (2024) 3.4.1.1	Diversity and number of individuals (abundance)	Were the North and South control sites assemblages different to each other (as well as difference to the extraction site)?
Bioreseaches (2024)	"previous experience sampling in similar habitats has shown that brachiopods are sometimes found attached to Carrier Shell".	Please give reference
Bioreseaches (2024) 3.4.2.2	"soft shore benthic biota usually between 10-20 taxa per sample"	What was the standard size sample? It is not clear. Were the cup corals identified in drop camera or ponar dredge tows?
Bioreseaches (2024) 3.4.2.3	Shannon Wiener showed high diversity in Bream Bay. Bream Bay has high diversity of taxa (more so than Pakiri) but typical of the Whangarei Heads area.	
Bioreseaches (2024)	Diversity in the northern control area statistically higher than the southern and remote control areas, but mean diversity from all control areas combined were within the range reported from the sand extraction area.	Does this mean the mean diversity of northern control, southern control and remote control areas were not statistically different the mean diversity from the extraction area?
Bioreseaches (2024) Figures G.7 and G.6		I cannot interpret these plots
Bioreseaches (2024) Figure G.4	Control north samples seems to be isolated from the majority of the samples, as does control remote (CR) (less so Control South (CS).	Please discuss these differences in detail.
Bioreseaches (2024) stress in MDS	2D MDS plots with values below 0.15 are generally "good" fit, whereas values above this are not good fits. Almost all the MDS plots produced have stress scores significantly above the value that is considered a good fit to the data.	Discuss the stress in 2D and 3D plots, perhaps in terms of Dugard et al 2010. Please discuss the usefulness of these multivariate plots?

		Are the MDS plots useful in differentiating between groups?
Bioreseaches (2024) Figure 22		What is this figure telling us?
Bioreseaches (2024) Table G.11 and G12		What are these tables telling us?
Bioreseaches (2024) page 49 3.4.2.4.4	There is a statistically different biotic composition between extraction and control areas	How will that be treated in the monitoring?
Bioreseaches (2024) page 50 para 2	The biota communities between extraction and controls could lead to issues comparing differences over time.	What is the solution?
Bioreseaches (2024) page 50 and 51	Corals - Bioresearches state that the presence of these solitary corals does not increase the ecological value of the site, as they are not complex habitat forming corals.	NIWA (2025b) covers cup coral assessment. I disagree that the presence of cup corals do not add to the ecological value of the site.
Bioreseaches (2025) Section 6, page 58	Ecological Values	Agree with ecological values for benthic macrofauna, sharks & rays and marine reptiles. I disagree with the benthic habitat (stated as just fauna) has moderate ecological value - I would value it as high , given the diverse and abundant benthic invertebrates, sand grain sizes, low contaminant levels, low degree of modification, few invasive species, water quality high, fish abundance and diversity high. I disagree with the separate ecological values for fish (just because the fish species are common, and there are no at-risk or declining fish species, doesn't make the values low. It makes the values appropriate for the habitat type, so at least moderate or high .

Bioreseaches (2025) Section 6, page 58	Ecological Values	At the ZOI the effect on the benthic habitat is high until natural recovery >3 years (needs to be monitored rather than just assumed), and then during recovery probably reduces to low if recovery occurring as expected.
Bioreseaches (2025) Section 6, page 58	Ecological Values	What is the scale of assessment - the ZOI or Bream Bay or both?
Bioreseaches (2025) Section 6, page 59	Monitoring	Higher extraction levels - monitoring and setting of trigger levels to ensure system can cope. Please provide more detail?

Memorandum

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Attention: Ingrid Kuindersma

Company: NRC

Date: 26 February 2026

From: Dr Sharon De Luca (reviewed by Dr Tommaso Alestra)

Message Ref: Peer Review Responses to MBL Responses to Questions/Queries

Project No: BM250630

Overall expert conclusion

This memo was prepared after reviewing the replies and revised assessment provided by MBL in response to my peer review outlined in a previous memo (issued on 15 September 2025). While many matters raised through peer review have been satisfactorily addressed, I retain moderate concern regarding the ecological value assessment and the inadequacy of the control sites, and high concern regarding the adequacy of the proposed monitoring within the sand extraction area. These issues are material to the interpretation of level of effect and warrant careful consideration.

1. Benthic habitat and fish ecological values are understated - MODERATE concern

I consider that the ecological values of the benthic invertebrate communities and associated fish assemblages have been understated when evaluated against the EIANZ marine ecological value criteria and broader ecological processes and functions.

In my view, a balanced evaluation of EIANZ marine valuation criteria¹ is required. Relevant criteria for this project include, and are not limited to:

- Abundance and diversity of benthic invertebrates relative to habitat type,
- Sediment grain size and quality,
- Presence of sediment contaminants,
- Invasive species,
- Threatened or at-risk species,
- Fish communities,
- Water quality, and

¹The EIANZ criteria for soft-sediment marine habitats are not biased (as stated by MBL) to estuaries but include all soft sediment habitats. The marine ecological valuation guidelines have been peer reviewed by marine ecologists from various regional councils and other consultancies. Support of the guidelines was given by all involved.

- Degree of modification.

When these criteria are applied to the data presented, I consider that the benthic habitat ecological values are more appropriately classified as High, rather than Moderate, noting that overall value classification is ultimately a matter of expert judgement based on the EIANZ guidelines.

In addition, the assessment places substantial weight on the conclusion that benthic habitats and associated fauna within the proposed extraction area are of low to moderate ecological value, primarily on the basis that benthic habitats are described as widespread and representative of regional sandy seabed environments, with no rare, threatened, or uniquely distinctive benthic taxa identified. Ecological value is not limited to rarity or uniqueness, and commonality and large habitat size does not necessarily equate to low ecological value. Other key aspects such as functional importance, trophic role, connectivity and contribution to broader ecological processes have not been adequately considered in the assessment.

As for benthic habitats, the ecological values of fish communities have been understated relying solely on the fact that the fish species present are common. I do not agree with the conclusion that fish assemblages have Low ecological value. The fact that species composition and abundances are typical for this habitat type supports, at a minimum, a Moderate ecological value, i.e., common does not equate to low ecological value. Fish also contribute to numerous key ecological processes at the site and in the wider marine environment which have not been adequately considered in the assessment. Further, I think it is inappropriate to separate the assessment of fish community composition from the benthic environment ecological value assessment, as these components are assessed collectively under the EIANZ soft sediment marine ecological value framework, and they are ecologically connected in the near-benthic environment.

Because ecological value is treated as low to moderate in the assessment it is concluded that adverse effects are generally minor to moderate and acceptable. However, if benthic invertebrate/faunal communities and associated fish were assessed as having high ecological value, which I consider to be the appropriate value based on the EIANZ marine ecological valuation guidelines and the information presented in the assessment, the same magnitude of physical disturbance (assessed as low at ZOI and negligible in Bream Bay by MBL) would likely lead to higher levels of effect. It is my opinion that the magnitude of effect should be assessed as moderate² (to be confirmed in the annual monitoring of dredged track). Moderate effects are defined by EIANZ as “Loss or alteration one or more key elements/features of the existing baseline conditions such that the post-development character, composition and/or attributes will be partially changed”. In the application, it is anticipated there will be loss/alteration of benthic invertebrate assemblages.

The temporal nature of adverse effects has not been adequately assessed. However, MBL accept the adverse effects on benthic communities would be high. In the short-term (3 years) effects on the benthic community is estimated to cause 14% mortality of benthic biota in 22.5% of the sand extraction area. The recovery period needs monitoring in order to confirm this estimate, as does the composition of the benthic community following dredging.

In summary, the ecological value assessment appears to rely on flawed interpretation of ecological values, emphasising habitat commonality and absence of rare species while giving limited consideration to functional, trophic, and wider scale ecological processes. A more accurate and balanced assessment of ecological values would lead to more precautionary conclusions regarding the level of adverse effects.

2. Differences in benthic biota composition between control and impact sites - MODERATE concern

There are substantive differences in benthic community composition between the northern and southern control sites and the proposed sand extraction area. These pre-existing differences limit the ability to directly compare assemblage composition among sites over time.

² Magnitude of effects detailed in Table 12 of the Assessment of Effects on Benthic Communities.

I acknowledge MBL’s position that identifying control sites with similar environmental characteristics to the impact area has been difficult, and that control sites are rarely ideal.

Despite this constraint, it remains possible to test hypotheses relating to differences in temporal trends between the impact site and control sites, with respect to diversity and abundance metrics, as well as levels of dissimilarity in community composition. In my opinion, this should be the primary focus of the benthic fauna statistical analyses moving forward.

3. Post disturbance monitoring of benthic habitat within the sand extraction area - HIGH concern

The report places strong emphasis on recovery potential and recolonisation rates to support conclusions of limited long-term effects. Nonetheless, temporary loss of habitat and biota of high ecological value can still constitute a significant adverse effect. The assessment does not make this distinction and only addresses long-term effects.

Within dredge tracks, the benthic community will be subject to at least partial fauna removal, representing a high level of effect, notwithstanding the expectation that effect severity should reduce over time through natural recolonisation.

Monitoring of the benthic environment within the sand extraction area is critical to test the validity of the natural recovery assumptions relied upon by MBL. These assumptions form a key component of the effects assessment and require empirical verification.

I agree that monitoring should be targeted to dredge track locations, rather than relying solely on broader area-wide surveys. In my opinion, monitoring within an active sand extraction area can be appropriately designed to ensure safety and avoid interference with extraction operations.

Benthic monitoring should occur annually of representative dredged areas (at least 10% of dredged tracks, five grab samples per track) dredged in the previous 12 months (Year 1). Year 2 monitoring should occur annually in representative area dredged in the second year plus those sites monitored after Year 1. The year 3 monitoring should occur annually in representative area dredged in the third year plus those sites monitored after Year 1 and Year 2. The monitoring of areas dredged in Year 2 and 3 will require 1 and 2 further years monitoring to comply with the condition that monitoring is undertaken for three years after dredging (Table 1). Control sites should also be monitored with the same replication. This approach allows three years of monitoring data for each of the three years of dredging. In order to understand benthic community recovery, which MBL accept there is a paucity of scientific literature covering this topic, monitoring at Year 1 and Year 2 sites could continue until three years after Year 3 monitoring is completed (optional in Table 1).

Table 1: Proposed schedule for monitoring representative areas³ within dredged tracks

	March/April after Year 1 dredging (impact and control)	March/April after Year 2 dredging (impact and control)	March/April after Year 3 dredging (impact and control)
Year 1	✓		
Year 2	✓	✓	
Year 3	✓	✓	✓
Year 4	✓ (optional)	✓	✓
Year 5	✓ (optional)	✓ (optional)	✓

Appendix 1: Responses to each item in the peer review questions/issues raised

This section sets out my response to MBL's replies to the peer review comments contained within the Consultation Summary (pages 59–73). My comments focus on whether the responses adequately address the matters raised and whether any residual concerns remain.

Overall, the majority of peer review comments have been adequately addressed. However, several matters remain for which I retain moderate to high residual concern, as set out below.

Question / Comment from Consultation Summary (page 59-73)	Peer Reviewer further comment	Rationale	MBL's reply/amendments	Residual concerns
1	MBL did not include an additional column with reference to the paragraph number of the Assessment of Ecological Effects (AEE), also stating mitigation proposed, as requested.	The additional columns would have aided with the clarity of the assessment.	Not supplied by MBL	Low
2	Spreadsheet template assigning score based on professional judgement (with justification) to attributes listed in Table 1.	Spreadsheet not supplied and the "collection of assessments" used instead was not made clear.	MBL removed reference to "spreadsheet" from Table 1, as no formal spreadsheet was used, rather a collection of assessments.	Low
3	Calculation error of area of disturbance of track disturbance compared to area of sand extraction.	Error corrected for each track. However, 3.4km ² of benthic habitat disturbance (section 6.2.4) per year, of a total of the 15.4km ² of extraction area is 22.5% of the extraction area. Over three years this is 67.5% of the extraction area. With the proposed increase in volume after three years (subject to no significant adverse effects detected), can	0.001% corrected to 0.135%	Low

		MBL state what is the percentage of habitat disturbed each year at that point?		
4	Differences in biota composition between the N&S control sites could make comparison of differences difficult.	<p>MBL state there are no similar habitats for control sites. I understand control sites are rarely perfect.</p> <p>Generally, I would suggest adding further control sites to get a handle on the spatial diversity of benthic communities.</p> <p>Despite the pre-existing differences between controls and impact site, it is possible to hypothesise that changes in community composition, diversity and abundance will follow different trends at impact and control sites. This should be the focus of the benthic fauna statistical analyses moving forward.</p>	MBL state that it was difficult identifying the two control sites used in the assessment due to lack of appropriately similar sites to the extraction area.	Moderate
5		As above		Moderate
6		As above		Moderate
7	Replication imbalance	Many multivariate data analysis programmes can deal with replication imbalance.	MBL state that Permanova statistical tests can deal with designs that are no balanced.	Low
8	Shellfish flesh testing	Corrected text to refer to sediment contaminant testing.	Shellfish flesh was not analysed.	N/A
9	Ecological Values	I do not agree that there are no suitable criteria in the EIANZ marine value assessment	There are no suitable criteria in the EIANZ marine value assessment guidelines.	Moderate

		<p>guidelines. It is the ecologist's job to determine which EIANZ criteria are relevant to the particular habitat and propose additional criteria if they consider it appropriate. The relevant criteria include abundance and diversity for the habitat type, grain size, sediment contaminants, invasive species, Threatened or At Risk species, water quality, degree of modification.</p> <p>These criteria, in my opinion, place the benthic habitat marine ecological values as High not Moderate. However, this overarching value is down to expert opinion.</p> <p>I would not have separated the fish community composition from the benthic environment ecological value assessment. They are part of the same criteria in the soft sediment marine ecological values criteria, and ecologically connected in the near-benthic environment</p> <p>I disagree that the fish assemblages have Low ecological value, based on the fact that the species and abundances are typical for this type of habitat. In my expert opinion, the fish</p>		
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		<p>assemblages being as expected in this region and habitat type warrants at least a Moderate ecological value.</p> <p>I conclude that the ecological values have been valued too low based on the EIANZ criteria and the information presented in the assessment</p>		
10	Monitoring ecological values in the ZOI	<p>The effect within the dredge tracks will be destruction of, at least part of, the benthic community, which is a high level of effect, but in time the effect level will decrease with natural recolonisation. Monitoring of the benthic assemblages with the dredge tracks is essential to test this hypothesis. I agree that the monitoring would need to be targeted to track locations not general area wide survey.</p> <p>Why is recovery monitoring in the active sand extraction area difficult?</p> <p>Monitoring within a recently (e.g. a year after dredging) dredged area can be planned to make sure it can be done in a safe way that does not impinge on the extraction activities.</p>	<p>MBL state adverse effects could be high in the dredged track, but only a [small] proportion (actually 22.5%) of the sand extraction area will be dredged in any one year.</p>	High
11	ZOI	ZOI unclear.	<p>MBL state the scale of assessment is Bream Bay and the ZOI</p>	N/A

12	Trigger level monitoring	9.2 and 9.3 of the benthic community are appropriate	Absolute trigger levels hard to define in a temporally variable habitat.	Low
13	Surficial Sediment Quality		Renamed Seabed Sediment	N/A
14	Sensitive species vs community	It is possible to determine sensitivity/tolerance of species to disturbance from the literature. For example, <i>Paphies australis</i> is sensitive to exposure to suspended sediment of 80mg/L over a period of 13 days.	No response	Low
15	Diversity and abundance	There were missing analyses.	Statistical testing between areas has been added	N/A
16	Reference to Carrier Shells	Missing reference.	Reference added	N/A
17	Cup corals	The method of survey was not clear for cup corals.	Clarified found in ponar samples	N/A
18	Bream Bay Shannon-Wiener (SW) diversity	Not clear whether SW was considered high in Bream Bay.	Confirmed SW is High	N/A
19	Diversity statistics	MDS stress not clear.	Clarified	N/A
20	Figures G6 and G7	MDS stress not clear.	MDS plots stress means the graphs were not a good fit. Graphs don't help with understanding.	N/A
21	Use of MDS plots to discriminate groups	Usefulness of MDS plots unclear.	MBL stated MDS plots in the body of the report were useful but the MDS plots in the appendices not so useful.	N/A

ATTACHMENT 2 : Peer Review of coastal geomorphology and coastal processes



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21 Sept. 25

Dear Ingrid,

Below I have provided a peer review on the application documents relating to coastal geomorphology and coastal processes for the Bream Bay Sand Mining Fast Track Application. I have also provided a mark-up of the report 'Te Akau Bream Bay Sand Extraction: Coastal Process Effects Assessment', which contains additional comments and minor corrections (see 'Te Ākau Bream Bay Coastal Processes AEE - Draft for Consultation (Clean) MD.pdf'). I have consulted the document 'Sand Extraction Operation Plan - Draft for Consultation (Clean).pdf' but have based my review below on the T&T technical report 'Te Akau Bream Bay Sand Extraction: Coastal Process Effects Assessment' which is where my expertise lies.

My comments below represent a peer review of the T&T report and are strictly limited to the potential effects on coastal geomorphology and coastal processes.

Consistency and clarity in terminology

The report requires editing to ensure consistency and clarity in terminology in relation to the shoreface and boundaries between different zones.

Figure E.1-1 refers to the 'upper shoreface', 'lower shoreface' and 'offshore'. The accompanying text within the Executive summary notes that the upper shoreface has dynamic annual-scale changes in bed level and the lower shoreface has 'significant wave induced sediment transport, which is connected to the beach over decadal timescales'. It then refers to an 'offshore zone or continental shelf' that is seaward of the lower shoreface and has 'negligible net wave induced sediment transport'.

Figure E.1-2 usefully provides (i) quantitative delineation of the qualitative boundaries identified in Figure E.1-1, and (ii) further subdivision of the lower shoreface zone. It describes 'zone 1' as the upper shoreface, and the lower shoreface subdivided into zones 2 and 3. For consistency with Figure E.1-1 it would be useful to add to this figure a 'zone 4' which is the 'offshore' shown in Figure E.1-1. This 'offshore' zone 4 could also be added in the bullets below 'Technical assessment' within the Executive summary.

Later in the report (section 5.2) the terms ‘outer’ and ‘inner’ shoreface are used. These terms should be removed and replaced with the terms used in the Executive summary. In section 4.3, for clarity, specific mention should be made of zones 1, 2 and 3 in the bullet points.

Distinguishing zonal boundaries – the lower shoreface

There has been discussion within the scientific literature regarding terminology to describe the shoreface. Hamon-Kerivel et al (2020) proposed to standardize definitions as follows: “The shoreface is made up of two morphodynamically distinct units, namely the upper and lower shoreface. They are divided by the [inner] DoC and the outer limit of the lower shoreface is the threshold at which waves start to significantly impact the bottom at the mesoscale. We propose to use the Valiente et al. (2019) depth of transport (DoT) as a calculable boundary for the outer limit of the shoreface at the mesoscale.”

The T&T report has adopted, in general terms, the approach put forward by Hamon-Kerivel et al (2020) and Valiente et al. (2019). However, an innovation appears to be the separation of the lower shoreface into two zones comprised of a landward section that has ‘frequent sediment transport but negligible profile change’, and a seaward section that has ‘infrequent sediment transport’. The report should clarify whether previous studies have also made this separation within the lower shoreface zone.

The report usefully derives boundaries between the four zones quantitatively:

- The boundary between zone 1 and zone 2 (i.e. between annually changing profiles within the upper shoreface and decadal changing profiles in the landward part of the lower shoreface) is defined by the inner DoC (depth of closure) calculation (inner Hallermeier equation, eq. 2 p40).
- The boundary between zone 2 and 3 (i.e. between frequent and infrequent sediment transport within the lower shoreface) is defined by the 90th percentile DoT (depth of transport); this approach is based on wave bed shear stress and is described in section 4.2.1.
- The boundary between zone 3 and the offshore zone (zone 4) (i.e. between infrequent and negligible sediment transport) is defined by the 45-year average outer DoC (outer Hallermeier equation, eq. 1 p5 & eq. 3 p41).

The boundary between the upper and lower shoreface (zones 1 and 2) is consistent with other approaches (e.g. Hamon-Kerivel et al 2020). However, definitions of the other boundaries require some further clarification.

The report states within the Executive summary that ‘We present two definitions [meaning (1) the DoT and (2) the outer DoC] for the seaward limit for the lower shoreface.’ By ‘seaward limit of the lower shoreface’ the report is referring to the boundary between zone 3 (lower shoreface) and 4 (offshore). But this is not consistent with the bullet points above this text that state that the DoT has been used to separate zones 2 and 3 (i.e. frequent and infrequent sediment transport).

Section 2.1 notes that ‘Hamon-Kerivel (2020) adopted the depth of transport (DoT) as the seaward limit for the lower shoreface’, apparently referring to the boundary between zones 3 and 4. Fig 9 in the review paper by Hamon-Kerivel et al (2020) [note *et al* is required in the T&T report but is missing] shows the seaward-most boundary (between zones 3 and 4) as DoT, and the boundary between zones 1 and 2 as the [inner] DoC. The T&T report has modified this figure as Figure 2-1 by annotating the DoC as ‘inner DoC’ and adding ‘outer DoC’ to the DoT boundary. The T&T report explains (p4) that ‘The DoT is the recommended method for defining the seaward limit of the lower shoreface in a recent coastal geomorphology review paper (Hamon-Kerivel, 2020), instead of the outer DoC’. Valiente et al 2019 noted (p71) that the outer DoC

calculation is usually associated with a depth that ‘corresponds best with the upper-plane bed limit under extreme wave conditions, or DoT’.

The points above imply that the DoT and outer DoC are two approaches to defining the boundary between zones 3 and 4. Hence, clearer explanation is required as to the basis for using the DoT to subdivide the lower shoreface into two zones (zones 2 and 3) while retaining the outer DoC calculation as the boundary between zones 3 and 4. Some attempts at explanation are provided, for instance: ‘In recent literature, this [the DoT method] is interpreted to be a lower shoreface zone of frequent sediment transport and is the preferred definition of the shoreface’. Ultimately, it is not clear exactly how the report has transitioned from having DoT as the boundary between zones 3 and 4 in Figure 2-1 to then moving the DoT boundary landward within the lower shoreface in Figure E.1-2. A further attempt at explanation is provided on p56 (quoted below), but I find the wording confusing. My understanding of the overall approach used by T&T is that the DoT has been used to distinguish *within* the lower shoreface, which is not what is said in the quoted text below. Perhaps there is a difference between the 90th percentile DoT and DoT? The report is not clear about this.

p56 ‘The DoT method provides a more robust assessment of profile zonation based on wave induced shear stress. Results for Te Ākau Bream Bay show the lower shoreface as being defined by a shear stress threshold that [is] located landward of the outer DoC. To account for annual variability, climate change and currents, a conservative approach was used to adopt the 90 percentile DoT (p90 DoT) as a definition of the lower shoreface. The p90 DoT point is interpreted as a area of frequent sediment transport, which is useful for interpreting a lower shoreface boundary. The more traditional and conservative definition of the lower shoreface boundary is the mean outer DoC, which was used to inform the offshore boundary at Pākiri.’

The approach of subdividing the lower shoreface into two zones of frequent and infrequent sediment transport is interesting and potentially useful. However, the report could more clearly explain (a) why it has done this, in the context of the proposed sand extraction, and (b) the exact approach used, and how this differs from what others have done (e.g. Valiente et al 2019 and Hamon-Kerivel et al 2020). The act of identifying two zones within the ‘lower shoreface’ means that in some places within the report (e.g. the summary Section 4.3) it is unclear whether zone 2 or zone 3 are being referred to, or whether both are being referred to collectively. I was left somewhat unsure about the importance of the distinction between areas of ‘frequent’ and ‘infrequent’ wave induced sediment transport.

Distinguishing zonal boundaries – the outer depth of closure

Discussion of the value adopted for outer DoC is provided in section 4.1.3. An argument is made (p44) that the ‘long-term average outer DoC appears suitable for informing the seaward limit of the lower surface in the context of a sand extraction effects assessment, as the average value is consistent with changes in profile shape and sediment texture, whereas the annual values are highly sensitive to the extended plateau’. This argument could be challenged on two bases:

- 1) Strictly speaking, the DoC equation itself is not sensitive to slope (see section below: ‘DoC equation sensitivity to slope’).
- 2) It is suggested in Figure 4-3 and within the text, that there is a coarsening of sediment toward the outer DoC, and that this supports the idea that outer DoC is close to the mean outer DoC calculated point because ‘lighter grains are more prone to being swept away, with coarser sediments being stranded until extreme events’. Is there a significant change in sediment size? This could be shown with error bars around the sediment size data. Why does Profile 4 not have the same coarsening trend as indicated in Profile 2?

An alternative interpretation of these figures is possible: the figures appear to show coarsening of sediment at distances beyond (seaward) of about 6 km, which also corresponds to an increase in the profile slope. This area is within the proposed extraction area. A scientifically reasonable argument could be made that the outer DoC should be plotted near this area (i.e. about 23-24 m depth) associated with these changes in slope and sediment size. Why is this alternative interpretation less reasonable than using the mean outer DoC?

DoC equation sensitivity to slope

The report notes in section 4.1.3 and in other places, that the outer DoC equation is sensitive 'to the gradual sloping lower shoreface' (p42). It is then argued that 'More investigation is therefore undertaken using the depth of transport method.'

Strictly speaking, it is not correct to say that the DoC equation is directly sensitive to the slope. The equation has terms for wave height and period and grain size and so is sensitive to these variables. It is more correct to say that the output of the equation (i.e. depth) is sensitive to the slope, because a small change in depth on a gentle slope can result in large horizontal distance.

The DoT method, similar to the DoC equations, use wave and sediment characteristics, but adds the influence of tidal currents and more directly evaluates of shear stress mobilises sediments across changing water depths. As explained in section 4.2.3, this method involves 'identifying the depth at which the bed shear stress associated with these wave conditions first exceeds the critical bed shear stress...'. Unless I have misunderstood something, it appears that outputs from the DoT method are sensitive to slope in the same way that outputs from DoC are?

The point above may seem academic, but the report implies that sensitivity to slope is a reason to use DoT. The DoT method is better justified based on its improved physics-based approach and the inclusion of tidal velocities.

Ridges and swales

The ridges and swales shown in Figure 3-6 are interesting morphological features. Further discussion and investigation of these features is necessary. What are the likely formative processes associated with these features? What is their sedimentology and what does this indicate? In the description of subsurface sediment cores (3.5.3) the report notes that 'Facies 2 seabed level is undulating, possibly part of an irregular dune system'. Is this related to the ridges and swales shown in Figure 3-6? Does the existence of a ridge system in the bathymetric survey imply a Holocene sedimentary 'drape' across some pre-existing Pleistocene structure?

A key point here is to distinguish whether these ridges are active or relict features? Are they 'modern' in the sense that they are being actively formed by sediment transport processes, or are they inherited features?

Underprediction of wave height

Comparison of Table 3.8 (modelled waves) and Table 3.9 (measured waves) shows that waves modelled over a 45-year hindcast period are smaller (for the large waves) than those recorded during a 16-year

observation window, and the difference is considerable (e.g. for maximum Hs, 5.85 m at Profile 1 v 7m at Alpha buoy). Figures 3.17 and 3.18 shows how modelled Hs differs from measured Hs.

The model underprediction issue is further highlighted by the extreme event analysis (3.8.3): the 200-year model extreme is smaller than wave heights observed in a 16-year observation window. The report notes that the scatter is large but that ‘the average ratio was calculated to be 1.4’.

Given the model underprediction, I concur with the approach taken in the report (p 31) of amplifying model wave heights to calculate DoC and DoT. However, the amplification factor (1.4) should be further justified. Initially I wondered whether the model underprediction might scale with wave height. My back-of-the-envelope calculations based on Figure 3.18 suggest that this is not the case, but I recommend including a plot of underprediction ratio v Hs measured to clarify that. An amplification factor of 1.45 (for instance) instead of 1.4 might have a significant impact of DoC and DoT calculations, so further work justifying this factor and investigating sensitivity is worthwhile. Was any sensitivity testing undertaken on the effect of using 1.4, 1.45 or 1.5 etc for the amplification factor?

The report makes it clear that the inner DoC (section 4.1.1) was calculated with the scaled-up waves, but it is not clear whether the scaled-up waves were used for the outer DoC (4.1.2), and this should be stated.

The report initially implies that the DoT was calculated using unscaled waves (p48): ‘This is based on the un-calibrated hindcast, which is a suitable representation of typical conditions by [but] may under-predict extreme events.’ It is unclear why the uncalibrated hindcast would have been used for the DoT calculations, because it seems clear that the modelling underpredicts generally, not just the extremes? Later (p50), the report says ‘However, the transport values associated with calibrated extreme wave conditions have been factored in the next section to establish the DoT’, and this is apparent on p52. Has the initial use of unscaled waves in any way influenced the adopted DoT values? The wording could be tidied up to avoid confusion.

Possibility of shoreward sediment transport across the outer DoC, ‘convex’ profile and extraction tracks

The section on annual variability (4.1.3) considers a range of possible values for the outer DoC over a 45-year period. In total, ‘91% of annual outer DoC (5 profiles times 45 years) are landward of the proposed extraction area’. This is usefully plotted in Figure 4-2. The implication of the plot is that under relatively rare conditions some sediments from the exchange area could be transported onto the lower shoreface.

This possibility is discussed in section 5.7: ‘Under extreme conditions (e.g. 10-to-100-year return period wave height), there is potential for sediment to be naturally mobilised between the proposed extraction area and lower shoreface.’ Within this context I draw attention to a paper not discussed in the report that supports the notion of sediment transport at depth during extreme storms. Keen et al., 2012 note:

- p308 ‘Observations and modelling of historical severe storms indicate initial thickness on the order of centimetres and horizontal scales of hundreds of kilometres with the thickest beds near the storm centre... They are produced in water depths of 13–100m and consist of mixed resuspended and transported sediment.’
- p298 ‘Offshore transport is dominant for water deeper than 60m but onshore flow prevails for shallower depths. Onshore transport was also noted at a 15m site with a medium sand bottom by Styles & Glenn (2005). The landward transport is as bed load transported by shoaling swell waves in the absence of strong near-bottom currents.’

A key consideration, therefore, is whether the offshore zone (4), the site of proposed extraction area, represents a site of significant sediment recharge to the lower shoreface.

The report notes that some profiles within the study area have a 'convex bulge' in the lower shoreface. It points out that convex shoreface morphologies might indicate sediment abundance (p12, 65). Is it possible that contemporary onshore sediment transport onto the lower shoreface (i.e. across the boundary between offshore zone 4 and lower shoreface zone 3) is contributing to this convex profile? This seems a key point that could be discussed in more depth within the report. Where does the convexity arise from? Is it an inherited artefact? Are contemporary processes (e.g. storms) maintaining the profile via onshore transport?

The report concludes (p65) that even if there is onshore transport from the extraction zone to the lower shoreface, that 'sufficient sediment will remain in the sediment body. This is attributed to the lower shoreface having a convex profile'. The wording is unclear here. The argument appears to be that the lower shoreface has a lot of sand and can therefore keep recharging the coast, but is that convexity maintained through transport from the offshore area? This section continues to say that 'geotechnical investigations show that mobile sand is present below the extraction area to at least 2 m below current level'. This is confusing. The implication is that the offshore zone has a deep *mobile* layer beneath the surface? Please clarify.

In section 5.4.1, in relation to sand extraction tracks, the report notes that (p63) 'wave induced sediment transport does occur in the extraction zone, with the initiation of sediment motion exceeded for 20-30 days per year, and the initiation of ripple formation occurring for 4-6 days per year. Wave induced currents at the seabed of the proposed extraction area are not sufficient to transport sediment particularly far but are sufficient to smooth out perturbations on the seabed caused by the drag head during larger wave conditions'. The implicit argument here is that the sediment transport is sufficient to obscure excavation tracks, but not of sufficient (onshore) magnitude to be a significant recharge to the lower shoreface. To be more confident in this assertion, some modelling could be undertaken to give a sense that there is enough sediment transport to fill in the tracks, while also quantifying what 'particularly far' means, and demonstrating that the offshore zone is not recharging the lower shoreface.

Buffer distances

Having identified inner DoC, DoT and outer DoC points on each profile (Figure 4-8), it is intuitive that these points would then have been mapped spatially in Figure 4.9 (also E.1-3). However, as explained on p57 a different approach has been taken. The inner DoC points (boundary between zone 1 and 2) lie very close to the 10 m isobath, so the 10 m isobath has been mapped on Figure 4.9. This makes sense. The boundary between zone 2 and 3 (frequent and infrequent sediment transport within the lower shoreface) is taken either as the DoT point, or a minimum distance of 1 km from the inner DoC point (the upper shoreface). There is no explanation/justification for the 1 km buffer adopted. Similarly, the boundary between zones 3 and 4 (lower shoreface and offshore zone) is defined either by the outer DoC point or a minimum distance of 3.5 km from the inner DoC point (the upper shoreface). There is no explanation/justification for the 3.5 km buffer.

A minimum buffer distance of 880 m is referred in the Executive summary, but I could not find any explanation of this distance.

In section 5.3 the sand resource area is said to be the 'seaward extent of the lower shoreface (defined by the 45-yr outer DoC), and the seaward boundary is the depth where practical extraction is readily

achievable, and this is taken to be around the 30 m'. It is not clear how this boundary relates to the buffer distances described above (i.e. how does this relate to the minimum of 3.5 km from the inner DoC?). Similarly, on p66 it is not clear whether the outer DoC is being considered, or the outer DoC plus buffer.

Levels of effects

Section 5.2 and Table 5.1 include references to potential impacts on environmental habitat values. The report is focused on coastal processes and morphology, and I have limited my comments specifically to these geomorphological components. In this regard, Table 5.1 should clarify what physical parameters are being referred to in the table where 'No effect' occurs.

Extraction monitoring

The report provides a commentary around monitoring of the proposed extraction specifically in relation to the effects on coastal processes (such as waves and sediment transport) and coastal geomorphology. A key condition relates to track management (p76): 'MBL are proposing to manage extraction lines to avoid track repetition and have a management plan to avoid repeatedly excavation along the same track. Deep tracks are not formed by a single extraction line and using the proposed extraction method with similar extraction volumes from each of the 77 extraction cells the likelihood of repeated extraction of the same area of seabed is avoided'. Some further information would help provide confidence that this is achievable. For instance, the vertical error of the tracks are given, and it would be useful also to provide the horizontal positional error of the tracks.

Regarding wave conditions, the report notes that 'Given the small magnitude of modelled changes to wave height and direction, the results from the MetOcean Solutions model are interpreted to have a negligible effect on wave transmission to the shoreline in a way that affects coastal processes.' The wave modelling is handled in a separate report that I have not reviewed, but it is apparent that in the T&T report that historic waves are underestimated in the existing modelling. I agree that changes in the order of a cm are likely to have negligible effect on waves, but a few extra sentences of justification/framing would be worthwhile. Given the miss-match between measured and modelled conditions, it is also worthwhile considering whether an additional wave buoy should be deployed to complement the North Port buoys, help improve the modelling, and verify whether the extraction has any impact on wave conditions.

Multibeam surveys are planned to investigate changes in profile shape associated with the extraction. The new publicly available LINZ bathymetric LiDAR will also be a useful reference dataset. In addition to the monitoring proposed, it would be useful to have provision for an additional survey if an extreme storm were to occur during the proposed extraction period.

It is interesting that beach monitoring is not proposed. The report argues that it is unlikely that sand extraction at the proposed area has any connection to the shoreline, and therefore monitoring is not required. But is it impossible? My view is that coastal change trends should be monitored. A significant challenge exists in understanding and distinguishing drivers of secular trends in coastal change, and I appreciate the confusion potentially created by this. For beaches in equilibrium, erosion is the expected outcome of future sea level rise, and there is a risk that any observed erosion due to this effect could be impossible to separate from erosion due to a deficit in the local sediment budget, whether that had arisen from some natural variability in the sediment budget, or artificially from extraction. That said, this issue does not justify a decision to not monitor coastal change trends.

Summary statement

Overall, in my professional opinion, the report has utilised appropriate data and methods to consider the relevant effects on coastal processes and geomorphology related to the proposed activity. The report has a section on potential cumulative effects with climate change that is scientifically sound. Overall, the conclusions reached are supported by the evidence presented, but this statement is made with caveats. I have explained in detail above the most important areas of uncertainty, where further work is required, and where alternative interpretations are possible.

Yours sincerely,

Mark Dickson

**References referred to in this review that are not within the T&T report**

Keen, T. R., Slingerland, R. L., Bentley, S. J., Furukawa, Y., Teague, W. J., & Dykes, J. D. (2012). Sediment transport on continental shelves: storm bed formation and preservation in heterogeneous sediments. *Sediments, morphology and sedimentary processes on continental shelves: advances in technologies, research, and applications*, 295-310.



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4 March. 26

Dear Ingrid,

Below I provide additional comments concerning attachment 8 relating to coastal geomorphology and coastal processes (T&T report). My comments are limited to the potential effects on coastal geomorphology and coastal processes and are in addition to my earlier review, dated 21 Sept. 25, that T&T have responded to. The additional comments are intended to help NRC understand the closure depth concept in relation to potential shelf-shoreface-beachface sediment transport. I refer below to scientific papers that are not cited in the T&T report. I was prompted to read this work based on the comments in the T&T report on the convexity of the Te Ākau Bream Bay shoreface profile and the presence of shelf bedforms that are not well understood. In addition, I became aware of an alternate method for calculating a 100-year depth of closure (known as the Morphodynamic Depth of Closure) during a conversation with Dr Kinsela, who I met at a conference in February, and here draw attention to papers that describe this useful concept. Collectively these additional comments provide further framing for NRC to consider when evaluating any possible impacts of the proposed extraction on the coastal sand system. Finally, I refer to a new source of data, the New Zealand Coastal LiDAR 1 m DEM that has only recently been published, and which is relevant for the proposal.

Convex profile - shoreface sand supply at geological timescales

Te Ākau Bream Bay is a prograded coastal sand barrier ('barrier' includes the dunes, beach and shoreface). It is similar to prograded sand barriers in eastern Australia that have been studied in more detail than NZ's barrier systems.

The T&T report notes that 'The primary sediment source for the sandy barrier construction and the ebb tide delta at the entrance to Whangarei Harbour has been the nearshore and inner shelf deposits on the floor of Te Ākau Bream Bay (Schofield, 1970)' but that 'The historic sediment supply that formed the coastal system is no longer active and the current sediment budget is considered functionally closed for this assessment, with negligible sediment inputs to the coast or nearshore.' It is important to test the veracity of this assertion.

Some areas of the shoreface profile in Te Ākau Bream Bay are notably convex (T&T report p12): 'The shoreface profile at Te Ākau Bream Bay best fits the 'convex' morphology type from Hamon-Kerivel et

al., (2020), which they interpret as meaning increased sediment abundance when compared to a concave profile.’ Over geological time scales, a convex shoreface can be an important driver of subaerial beach barrier progradation. A study of several sites in southeastern Australia (Oliver et al., 2020) suggests that (p13) ‘The shoreface appears to be the primary source of sediment promoting shoreline accretion and barrier development in this region’ and ‘At Pedro Beach the lower shoreface is distinctly convex between ~10 and 30 m water depth (Fig. 8). This disequilibrium profile indicates the potential for onshore sand transport.’ In another study of a prograded beach barrier system at Tuncurry, eastern Australia (Kinsela et al., 2016), bathymetric surveys and numerical modelling suggest that a shoreface sand body in 15 to 35 m water depth was primarily (i.e. about 80%) responsible for supplying the beach with the sediment that caused beach barrier progradation over the last 6000 years. They concluded that (p29) ‘Sustained shoreface sand supply in response to remnant disequilibrium morphology likely prevails today at imperceptible rates on some southeast Australian beaches, promoting shoreline stability, and potentially moderating initial shoreline response to sea-level rise.’

The implication of the research from eastern Australia is that the convex lower shoreface is often the main source of sediment driving beach progradation (growth) over thousands of years, and that it might also be important for maintaining beach stability in the present day. This might also be true for the similar prograded barrier at Te Ākau Bream Bay.

Onshore sediment transport

Onshore sediment transport from the shoreface has been demonstrated using short-term field measurements and numerical modelling (Aagard, 2014). However, globally there are relatively few datasets that have the resolution required to help constrain the importance of onshore transport.

Recent mapping of the shoreface in NSW with bathymetric lidar and multibeam echosounder surveys are beginning to reveal relevant dynamics. For instance, Kinsela et al (2022, p1162) note that at some sites ‘the lower shoreface may provide a subtle ongoing sand supply to Perkins Beach that might promote shoreline stability and potentially offset shoreline response to sea level rise’; however, at other sites they suggest ‘a shoreface sand supply is unlikely to be active or significant’.

Whether or not the lower shoreface at Te Ākau Bream Bay represents a sand supply to the shoreline is a question of timescale. It is almost certain that over thousands of years (as acknowledged in the T&T report) the shoreface has been a key driver of beach barrier progradation in the region. Similar, at the scale of a single (normal) year it is almost certain that there is insignificant supply from the lower shoreface to the beach. The timescale between these extremes where the shoreface represents an important onshore sediment supply to the beach is not easy to constrain.

The proposal is to extract sand seaward of the lower shoreface on the shelf (or offshore) zone. Hence, it is critical to understand (1) where that boundary occurs, and (2) whether there is sediment transport across that boundary. Unfortunately, our scientific understanding of sediment transport across this boundary is limited.

Shoreface & inner shelf bedforms and sediment transport

Recent bathymetric lidar surveys have revealed asymmetric linear bedforms in 20 to 40 m+ water depths off SE Australia (Kinsela et al., 2023). The ridges lie 1 to 3 m above the seabed, and have a wavelength of 0.5 to 1 km. The proposed extraction area at Te Ākau Bream Bay is in water depths of

about 22 to 34 m and within this area occur ridges with a height above the seafloor of around 2 m and a spacing of about 1.5 km (see T&T report p13).

T&T interpret (p55) the 'convex sections of the lower shoreface and the ridge and swale features along the extraction area boundary are most now likely relict landforms that were formed during times of lower sea level...' and 'Given the wide nature of the lower shoreface, this does not indicate transport from the offshore area to the lower shoreface'.

In contrast, in describing the seafloor ridges in a similar water depth off eastern Australia, Kinsela et al (2023, p408) note 'The sedimentary features identified and described here are the depositional evidence of fluid motions and sediment transport on the dynamic shoreface-inner shelf of the southeast Australian margin. The existence, scale, shape, distribution and complexity of the features was largely unknown prior to recent mapping of the coastal seabed with airborne Lidar.' Their view (p409) is that onshore-directed flows may occur across the shoreface-inner shelf and that these are 'relevant to conceptual and quantitative coastal dynamics and shoreline behaviour models'.

Bathymetric LiDAR is an important new emerging source of data for describing the shoreface and shelf seafloor. LINZ have recently embarked on a programme to map 40% of NZ's coast with this technology <https://www.linz.govt.nz/products-services/data/3d-coastal-mapping> and data for Bream Bay have now been released as part of 'The New Zealand Coastal LiDAR 1m DEM' (Figure 1). T&T probably did not have access to this dataset at the time of doing their work. The publication date I can see on the LINZ Data Service is last updated 16 Feb 2026. I think this dataset should be consulted as a part of this application.

Potential sediment transport between the inner shelf and shoreface has been suggested in some earlier work. At Fire Island, New York, Schwab et al. (2013) described the dynamic nature of the inner continental shelf, including elongate gravelly bedforms in up to 30-m water depth. They stated (p541): 'It is therefore suggested that onshore flux of modern sediment from the inner continental shelf provides the sediment volume required for the maintenance of island stability.' This conclusion was reached on the basis that the offshore shelf sediment was the only source available to balance the coastal sediment budget. However, they also acknowledged (p539) that '...the physical processes controlling the cross-shelf component of sediment flux remain unknown.'

The role of extreme storms

The research literature on extreme storms is relatively sparse, but observations of sediment transport in great depths have been noted. For instance, an extreme storm in San Diego in 1988, thought to be a 1 in 200 year event, had significant impacts on the seafloor at depths of around 25 m (Dayton et al., 1989).

Near Fire Island, Schwab et al., (2017) described seafloor surveys in a period in which Hurricanes Irene and Sandy occurred. Results (quoted from the abstract) 'demonstrate that storm-induced erosion and sediment transport occurred throughout the study area in water depths up to 30 m' and 'Analyses show that significant storm induced erosion and sediment transport occurs far seaward of the 5 to 9 m depth of closure assumed for Fire Island, where it is thought that an onshore-directed sediment flux from the inner continental shelf to the littoral system is required to balance the coastal sediment budget.'

It is possible that extreme storms can transport sediment landward from the shelf to the lower shoreface, and from the lower shoreface to the upper shoreface.

It has recently been shown, with data from Australia the UK and Mexico (Harley et al., 2022), that during extreme storms, the volume of sediment eroded from beaches and dunes was smaller than the amount of sediment that was added to the upper shoreface, because sediment was transported from the lower shoreface to the upper shoreface. Eventually, the material added from the lower to upper shoreface is available to be reworked onto beaches and dunes. Harley et al., (2022) concluded that the recharge of the upper shoreface (from the lower shoreface) is equivalent to offsetting decades of coastal erosion by future sea level rise.

The closure depth concept

The T&T report correctly explains that ‘closure depth’ is a concept. Their Figure 2.1 shows that shoreface zonation limits can vary, meaning that the zones extend further seaward with increasing timescale.

The T&T report adopts a decadal scale timescale. The offshore zone (zone 4), where sand extraction is suggested, occurs seaward of a 45-year average outer depth of closure calculation. Over the scale of decades, they conclude that this offshore zone does not have functional wave induced sediment exchange with the shoreface. They provide a scientific basis for this conclusion that is reasonable based on current knowledge using the DoT and DoC equations (e.g. Hallermeier). However, some scientists have argued that a computed depth of closure (i.e. using Hallermeier) can be shallower than a physical depth of closure that is inferred from geological evidence (see Ortiz and Ashton, 2016). This makes sense, because the relevant depth of closure increases with the timescale adopted, and geological evidence is integrated over long timescales.

An alternative approach to calculating closure depth is the ‘Morphodynamic Depth of Closure’ (MDOC) described by Ortiz and Ashton (2016) and applied by Kinsela et al (2022) in eastern Australia context. This approach can be used to represent a 100-year depth of closure.

It would be interesting for T&T to calculate this metric. In eastern Australia, the inner closure depth is calculated at around 10 to 11 m water depth, whereas the regional active shoreface limit that is expected to be active over a 100-year timeframe ranges between about 24 and 30 m water depth (depending on the weighting applied within the MDOC equation) (see Table 2 within Kinsela et al., 2022). These values can be compared with the values obtained by T&T (see Figure 2 below). Of note, the inner closure depth values are similar (10-11 m Australia, 11-13 m Te Ākau Bream Bay), whereas the average outer closure depth values for Te Ākau Bream Bay are shallower than those obtained using the morphodynamic depth of closure concept for eastern Australia (see Table 2 within Kinsela et al., 2022 and Figure 2 below).

Kinsela et al. (2022) attempted to assess the part of the shoreface that might be active over multiple centuries by examining the convexity of a selected profile (P2, see p1161). They noted that the upper surface of the convexity (~28 m water depth) is very close to their calculated relevant closure depth value (~27m). They argued that ‘This suggests that the upper surface of the convexity is erosional...’ and they speculated that ‘...the lower shoreface may provide a subtle ongoing sand supply to Perkins Beach that might promote shoreline stability and potentially offset shoreline response to sea level rise’.

In Figure 2 I have copied Figure 4.2 from T&T and have roughly superimposed a transparent box at water depth approximately 24 to 30 m, coinciding with a 100-year morphodynamic depth of closure for the east coast of Australia. This zone would be at a different elevation for Te Ākau Bream Bay,

owing to different wave climates (although perhaps not that different, given that the inner depth of closure calculated levels are similar?).

It would be useful for T&T to overlay a 100-year morphodynamic depth of closure for Te Ākau Bream Bay.

It is interesting in Figure 2 that the eastern Australian 100-year closure depth range is similar to (1) the maximum outer depth of closure calculations by T&T, and (2) approximately coincides with the change in offshore slope (the seaward edge of the convexity).

Based on what I have read about the morphodynamic depth of closure and the shoreface shape at Te Ākau Bream Bay, I speculate that to mitigate potential shoreline consequences of sand extraction over a 100-year period, sand extraction might need to occur seaward of the 45-year maximum outer depth of closure calculation, rather than the 45-year average outer depth of closure calculation.

Yours sincerely,

Mark Dickson



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Figure 1 – Screen-shot showing New Zealand Coastal LiDAR 1 m DEM available for download from the LINZ Data Service. Bathymetric LiDAR appear to extend to around 30m water depth.

The screenshot displays the LINZ Data Service interface for the 'New Zealand Coastal LiDAR 1m DEM' layer. The interface includes a header with the Toitū Te Whenua Land Information New Zealand logo and navigation options for 'Data' and 'Map'. A notification banner at the top indicates that the 'NZ Addresses (Pilot)' dataset will become official on 4 March.

The main content area shows the layer title 'New Zealand Coastal LiDAR 1m DEM' and a 'Map' button. Below this, there is an 'Info' tab with a thumbnail map of New Zealand and a 'Data Type' section indicating 'Grid Layer, 1m, 27 Tiles'. A table below the info section provides metadata:

Date Added	Last Updated	Views	Exports	Layer ID
+ 16 Jun 2025	🕒 16 Feb 2026	👁️ 2.1K	↓ 100	📄 122508

Below the table, a description states: 'This layer contains the New Zealand 1m DEM for coastal LiDAR which is an amalgamation of the most current coastal LiDAR surveys. It is current as at the most recent Published date found in the History tab. This data was captured as'.

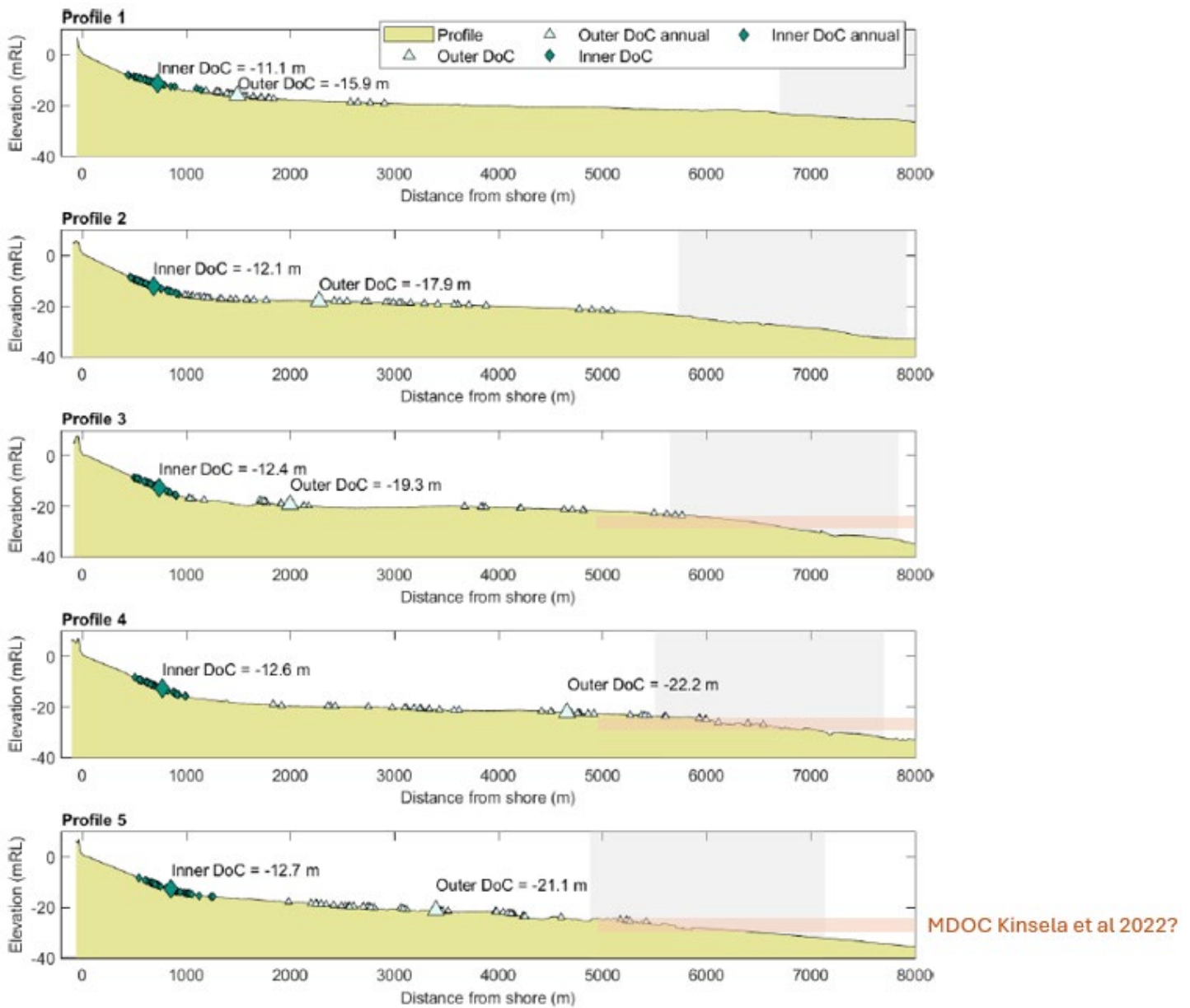
The map shows a dark bathymetric area extending into the water, with labels for 'Ruakākā' and 'Waipō'. A scale bar at the bottom left indicates 3 km and 2 mi. The bottom right corner shows the coordinates '174-5632647, -35-95955010'.

A 'Spatial Query' tool is open on the right, showing a table with the following data:

Tile name	Width	Value
AX31	24000	-31.583999633789062

The 'Spatial Query' tool also includes a 'Tile' radio button option.

Figure 2 – reproduction of Figure 4.2 in T&T with overlaid level of morphodynamic depth of closure (MDOC) calculated for the east coast of Australia by Kinsela et al., 2022.



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Kia ora

Bream Bay Sand Extraction: Assessment of Economic Effects

My name is Hayden Green. For over twenty years, I have worked as an economist across the Asia-Pacific, advising on competition and regulatory matters. Seven years ago, I founded Axiom Economics (see [here](#)), which, under my leadership, has become one of Australasia's leading economic consultancies. Throughout my career, I have prepared numerous expert reports, provided sworn testimony in high-stakes commercial mediations and arbitrations, and reviewed hundreds of economic assessments – including cost-benefit analyses. I am regarded as one of New Zealand's leading experts in this field.¹

I also live in Bream Bay. When I saw news of recent protests against McCallum Brothers Limited's (MBL's) fast-tracked proposal to extract 8.45 to 9 million cubic metres of sand from Bream Bay's seabed (see [here](#)), I took notice. Until then, I confess that I had not paid much attention to the issue, but my curiosity was piqued. I soon found myself reviewing the materials on MBL's website. That led me to an economic assessment prepared by Market Economics (see [here](#)). I read it carefully – and I was not impressed. In my opinion, the report provides no credible indication of the proposal's likely economic impacts.

1. Overview of biggest shortcomings

I have no objection in principle to mining ventures being granted resource consents and I harbour no animus towards mining businesses; in fact, I have previously advised one of the largest mining companies in the world. However, consents should only be granted when the benefits clearly outweigh the adverse impacts. Market Economics fails to establish this for MBL's proposal. The economic analysis contained in Market Economics' report is manifestly inadequate and deeply flawed. I provide a more fulsome account of the litany of shortcomings below but, in brief, the biggest problems are:

- The analysis rests entirely on the assumption that if sand is not extracted from Bream Bay, an equivalent volume would be sourced from the Kaipara Harbour seabed (the "counterfactual" scenario). This dismisses viable, sustainable land-based alternatives, such as quarry-manufactured sand, despite ample evidence supporting their feasibility.
- If the true counterfactual involved these land-based alternatives, Market Economics' entire analysis would collapse completely, because it would be based on the wrong comparison, rendering its conclusions irrelevant.

¹ For example, I was recently recognised by Lexology Index (formerly Who's Who Legal) as a 2025 'Global Elite Thought Leader' amongst competition economists.

- Even setting aside this fundamental issue, the analysis is opaque, non-replicable, and riddled with errors and omissions – many of which substantially overstate the claimed economic benefits while understating or ignoring the proposal’s costs. Consequently, the net benefit estimates are unreliable, regardless of the “counterfactual”.
- Even if Market Economics’ analysis were taken at face value, any cost savings may accrue primarily to MBL, rather than benefiting Aucklanders or Northlanders at large. It is doubtful that this represents the type of ‘economic benefit’ Parliament intended when enacting the Fast Track legislation.

In short, Market Economics’ estimates are unreliable and provide no sound basis for concluding that the project would deliver a net benefit. I see no reasonable grounds for the adjudicating panel to approve the proposal under these circumstances. The following overview highlights the report’s key shortcomings. While not exhaustive, it demonstrates why the claimed economic benefits cannot be trusted. I offer these views in my personal capacity and have not been compensated for my time.

2. The appropriate counterfactual

The conventional approach to assessing economic impacts is to compare the expected benefits if a proposal proceeds (the ‘factual’) with what would occur if it does not (the ‘counterfactual’). The difference between these scenarios represents the proposal’s estimated net economic impact. This method helps isolate the true effects by accounting for factors that would happen regardless (i.e., in ‘both states of the world’), ensuring a more accurate assessment of costs, benefits and overall economic welfare.

It is important to specify the factual and counterfactual scenarios appropriately. If the counterfactual is not properly specified, the estimated impacts of a proposal can become skewed, leading to misleading conclusions. An inappropriate counterfactual contaminates the entire analysis, rendering all subsequent calculations, assumptions and recommendations unreliable. In short, a flawed starting point results in flawed results, undermining the validity of the exercise. In this case:

- If the proposal proceeds (the ‘**factual**’), it is assumed that MBL would extract 8.45 to 9 million cubic meters of marine sand from Bream Bay over 35 years. That sand would apparently be used to make concrete for Auckland construction projects.
- Market Economics assumes that if the proposal *does not* proceed (the ‘**counterfactual**’), the same volume of marine sand would instead come from existing mining operations in the Kaipara and be delivered by truck – a straightforward one-for-one replacement.

While the factual scenario is straightforward, the counterfactual assumed by Market Economics is much more contentious. In the Environment Court’s July 2023 ruling on MBL’s appeal concerning the Mangawhai-Pākiri embayment (the final judgment is available [here](#)), the three economists involved agreed that the Kaipara source was the “most probable alternative” to Pakiri sand.² Market Economics has adopted the same counterfactual here and essentially ‘re-run’ all the same analyses. In my view, this is a questionable approach that could undermine the validity of its entire report.

² Paragraph 428 of the judgment.

2.1 Other potential sources of sand

While I am not an expert in the economics of sand sourcing, there are legitimate reasons to doubt the counterfactual assumed by Market Economics, especially in light of recent developments. Kaipara-based marine sand no longer appears to be the only viable alternative – if it ever truly was. For instance, in late 2024, fast-track approval was granted for a proposal to extract up to 300,000m³ of sand per year (for up to 35 years) from land-based sand mining operations in Te Arai, near Wellsford (see: [here](#)). This exceeds the ~240,000m³ that MBL would be taking from Bream Bay each year.

This potential additional source was not considered by Market Economics, which is understandable, given the fast-track application was lodged two months *after* the publication of its report. There have also been some important developments in sand manufacturing – including as recently as the last few days. Manufactured sand differs from natural sand in that it is produced by crushing rocks or gravel into sand-sized particles, rather than being extracted from rivers, lakes or beaches. Market Economics had this to say about it in its May report (see page 7):

“Manufactured sand is often raised as a potential alternative to natural sand. Bringing a new product to the market is normally subject to tests to ensure that the alternative meets all the necessary requirements, and to understand/uncover any limitations and nuances. Some of the proponents of manufactured sand have been operating since 2007. However, there is limited evidence of the market taking up manufactured sand as a mainstream option and substitute for natural sand. While manufactured sand is promoted as a possible alternative, it remains in the testing and piloting stages. There are no clear market signals that users (demand) are accepting this new technology and manufactured sand remains a speculative option.”

This statement has not aged well. In February last year, Kaipara Limited launched a manufactured sand plant at Brookby Quarry near Whitford in East Auckland (see [here](#)).³ The company aimed to produce 300,000 tonnes per year, a target it announced earlier this month it has successfully hit, while meeting client specifications. Kaipara now plans to expand production to 500,000 tonnes annually.⁴ For context, this is significantly more than the ~380,000 tonnes per year that MBL would be supplying from Bream Bay.

To borrow a phrase from Market Economics, this is a “clear market signal” that customers are embracing this technology. The global trend further supports this point: Japan has long utilised manufactured sand and is successfully transitioning away from marine sand. Similarly, countries such as Singapore, Australia, the Netherlands, and the United Arab Emirates are increasingly adopting manufactured sand as a sustainable, environmentally friendly alternative. These local and international examples strongly indicate that manufactured sand is both viable and sustainable.

³ Kayasand operates a comparable facility in the Waikato (see [here](#)) that has started supplying sand into the Auckland market. Kayasand also operates a commercial plant in Australia that has produced over 500,000 tonnes of manufactured sand for the Sydney and Illawarra markets as a replacement for dwindling natural sand supplies in that area.

⁴ In an affidavit attached to Market Economics’ report, Mr. Patrick Bridgeman, CEO of Bridgeman Concrete, stated that the company’s experience with manufactured sand had been “unsatisfactory” (see paragraph 17). This claim is difficult to reconcile with Kaipara Limited’s recent decision to nearly double its production capacity. It seems unlikely the company would make such an investment if the product were genuinely “unsatisfactory.”

Ironically, the main barrier to greater local investment in this technology could well be the continued availability of large volumes of marine sand via long-term resource consents. While the private cost of seabed extraction may be lower than quarry-based manufacturing, once the full range of negative externalities – including adverse environmental impacts – are factored in, manufactured sand could easily be the more cost-effective and socially beneficial option.⁵ Declining this application may consequently serve as a catalyst for additional investment and expansion.

The approval process that MBL is currently navigating is specifically designed to interrogate these matters by assessing both private and public costs and benefits in detail. Market Economics' choice of counterfactual prevented a fulsome analysis from being performed. While that decision may have been defensible at the time, it is now clear that other viable sources of supply exist and must be considered. The fact that many of these are land-based has significant implications for the cost-benefit calculus, which I explore below.

More broadly, the seemingly abundant supply from alternative sources undermines the popular narrative that Bream Bay sand is urgently needed to address a looming shortage. I have seen no compelling evidence to suggest such a deficit exists – especially given the recent developments discussed above. I am not certain of the legal implications under the relevant framework, but if its overarching purpose is to fast-track projects badly needed to deliver substantial economic benefits, it is hard to see how MBL's proposal qualifies.

2.2 Potential implications

If alternative land-based sources of supply are feasible – which now appears to be the case – this fundamentally undermines Market Economics' analysis. Its calculations rely on the assumption that all Bream Bay volumes would be replaced by marine sand from the Kaipara. Most of the estimated cost savings stem from the allegedly reduced trucking distances if the sand were sourced from Bream Bay. For example, Market Economics assumes that this would result in:

- **Direct transport cost savings**, since trucking sand over the distances in question is said to be more expensive than shipping by barge (though it has not provided a reliable estimate of those purported savings).
- **Carbon emission savings** from reduced trucking and cement manufacturing (which, in reality, would likely be offset by increased emissions from other sectors through the operation of the Emissions Trading Scheme, resulting in zero savings).
- **Avoided social costs** in the form of reduced road deaths and injuries, which are tied to distance travelled (though Market Economics fails to account for many other relevant social costs that would weigh against the proposal).

⁵ For example, suppose the private cost of manufacturing a tonne of sand at a quarry and delivering it to a concrete plant in Auckland is \$60 (using a simple round number). And suppose the private cost of delivering a tonne of sand from the seabed of Bream Bay to the same concrete plant is \$50, but this comes with an additional \$25 in negative externalities (e.g., environmental damage). In this simple scenario, unless those negative externalities are accounted for, the sand would be supplied from Bream Bay, despite the total economic cost being higher (\$75 for dredged sand versus \$60 for manufactured sand).

As I will detail in sections 3 and 4 (and allude to in the bullets above), Market Economics has not performed any of these calculations properly, making its results unreliable. Serious as these issues are, they become secondary if the counterfactual is flawed. For instance, if Bream Bay volumes would be replaced by land-based alternatives *closer* to concrete plants than Helensville, all the estimated cost savings would diminish or vanish entirely. A plethora of other adverse impacts would also need to be examined, including:

- **Environmental degradation:** sand mining can harm sea floors, erodes coastal protections, and creates plumes that could damage fish populations, surf breaks and the overall marine ecosystem.
- **Impact on local fisheries:** The destruction of marine habitats would negatively impact the ability of locals to fish and feed their whānau, undermining a traditional and culturally significant activity.
- **Threat to tourism:** The degradation of beaches and marine life could diminish Bream Bay's appeal as a tourist destination, leading to fewer visitors and economic losses for local businesses.
- **The opportunity cost of land:** MBL's sand depot would occupy valuable waterfront space in a prime location that could support a wide range of productive uses – these opportunity costs are higher than for almost any other location in the country.
- **Adverse impacts from traffic:** Additional truck movements in Auckland's busy downtown precinct contribute to congestion and noise – already significant problems – and increase the risks of road-related deaths and injuries.⁶

Market Economics does not consider these matters at all in its report. It may have assumed – without explicitly stating so – that the adverse impacts would cancel each other out if marine sand were extracted from either Bream Bay or the Kaipara. In other words, the (unspoken) arithmetic might have been: “The harm to marine life caused by sand mining in Bream Bay would be no worse than the harm in the Kaipara, so the net cost is zero.” I am not convinced that such a simplistic assumption is justifiable, even within the narrow confines of Market Economics' counterfactual.⁷

And Market Economics' approach is plainly wrong if the alternative to Bream Bay sand includes land-based sources of supply – a scenario that seems increasingly plausible given recent developments. While I cannot comment on the exact magnitude of the adverse impacts of sand mining compared to land-based alternatives, it cannot reasonably be denied that those potential costs exist and could be substantial. After all, if such activities are truly costless, why are they being steadily phased out in locations across the globe?

⁶ These risks depend not just on the distance travelled (in the manner assumed by Market Economics) but also on the environment. A 30-tonne truck driving through a dense urban area filled with traffic and pedestrians poses a far greater danger than in sparsely populated industrial or rural settings.

⁷ I see no reason to believe that the adverse costs of sand mining would be identical if an equivalent volume of marine sand were extracted from the Kaipara. It would be highly coincidental if that were the case. Market Economics does not attempt this admittedly difficult (and rather grim) calculation, which represents yet another critical gap in its analysis.

For these reasons, I believe there is a strong case for dismissing the Market Economics report in its entirety, due to the application of an inappropriate counterfactual. The notion that Bream Bay sand would be entirely replaced by Kaipara sand has become increasingly tenuous over time. Furthermore, as I will detail in sections 3 and 4, even if Market Economics' counterfactual were valid, its estimated cost savings would remain unreliable due to more specific errors. In either case, the report offers little to no probative value.

3. Transport cost savings

Most of Market Economics' estimated economic benefits (\$197 million of \$266.5 million) stem from avoided transport costs. MBL plans to transport Bream Bay sand to its Ports of Auckland depot by barge, before trucking it to concrete plants across Auckland. As discussed already, Market Economics assumes that in the counterfactual scenario, an equivalent volume of sand would be trucked from the Winstone/Atlas yards in Helensville (Kaipara) – presumably directly to concrete plants throughout the region.

Transporting sand by barge from Bream Bay, then by truck, is said to be cheaper than trucking it from Helensville. That may be true, but Market Economics' analysis neither proves the point nor offers a reliable estimate of the actual cost savings. Its \$197 million estimate is based on a strikingly brief assessment, lacking detail and explanation. Absent those crucial details it is impossible to know if the calculation has been performed robustly, or if the purported savings have been overstated.

3.1 What should be done

To illustrate the shortcomings in Market Economics' methodology (or lack thereof), it is helpful to briefly outline how transport cost differentials *should* be estimated. This involves a complex, multi-layered calculation. The first step is to identify the sand's delivery points and transport routes, including travel distances. While the origins – Bream Bay and Helensville – are clear, the destinations and specific routes are not.

In the factual scenario, sand would be transported by barge from Bream Bay to Ports of Auckland, then distributed by truck to concrete plants across the city. A key question is whether MBL knows where the sand will go:

- **If MBL plans to store the sand separately at the port for delivery to specific plants** (e.g., under long-term supply contracts), transport costs could be estimated with reasonable accuracy (at least over the course of those agreements).
- **If the sand is mixed with other sources upon arrival**, tracking its end use becomes impossible. More likely, MBL may simply not know which plants will purchase the sand, requiring assumptions to be made about its final destinations.⁸

The latter scenario seems far more probable. It is unlikely that MBL knows with certainty which plants would purchase the Bream Bay sand over the 35-year consent period or has secured long-term supply contracts, given that the resource consent is pending. This

⁸ A reasonable assumption could be that Bream Bay sand follows the same distribution pattern as MBL's other sand. For instance, if Plant A buys 50%, Plant B 30%, and Plant C 20%, the same proportions might apply.

uncertainty necessitates multiple assumptions about the sand's destinations – assumptions that should be clearly stated, sensitivity tested and justified.

Regardless of MBL's knowledge of final destinations, calculating total transport costs remains complex. It involves multiple routes, plant locations and distances. These costs must then be compared with the analogous costs of trucking an equivalent volume of sand from Helensville (Market Economics' counterfactual). Even if the final destinations were identical, the different origin would require a separate cost matrix. In reality, the destinations would likely differ, further complicating the analysis.

I expect there might also be significant year-to-year variations in the volumes produced by and delivered to each concrete plant. Those fluctuations could depend on, among other things, the location and timing of major construction projects.⁹ Robust transport cost savings estimates may therefore require geographically specific demand forecasts of where concrete will be needed. Estimates for the whole of Auckland may lack the necessary granularity to produce reliable results.

Reliable cost savings can only be assessed after rigorously calculating and comparing total costs for both scenarios over time, accounting for potential year-on-year fluctuations. Such an assessment should be detailed, with clear explanations of key steps, assumptions and supporting logic. A technical appendix with spreadsheets and further modelling details may also be necessary. The analysis should be transparent and replicable to allow proper scrutiny. Market Economics' analysis meets none of these basic standards. It is inadequate for its intended purpose.

3.2 Market Economics provides no methodology

Market Economics' assessment of direct transport cost savings is limited to just three paragraphs. It presents six figures, but these are merely headline results with no explanation of the methodology behind them. If detailed workings exist elsewhere, I have been unable to find them. If this brief assessment constitutes the entirety of the analysis, that is extraordinary. For the reasons outlined earlier, this is not an exercise that can be properly conducted – let alone explained – in three *pages*, much less three *paragraphs*. No details are provided on even the most basic elements of the calculations, including (but not limited to):

- The assumed destinations of the sand in both the factual and counterfactual scenarios, particularly if these differ.
- The volumes of sand assumed to be transported to those destinations over the 35-year period (rather than a single total for all of Auckland, which lacks meaningful detail).
- The basis for the assumed trucking cost of 27c/tonne/km; notably, the “industry information” cited (see page 16) is not disclosed.
- The approach to calculating cost savings over 35 years, including assumptions about any changes in key variables.

⁹ By way of comparison, the quantity of electricity generated by specific plants in New Zealand's wholesale market depends on the amount demanded and the locations of final customers. This varies from year to year, reflecting changes in the overall demand profile.

This is not a methodology. It is simply a set of conclusions with no transparency around how they were derived. The reader is expected to accept the results at face value, without any means to verify or scrutinise them. This is unacceptable and falls well short of the minimum standard required in comparable contexts. If such an opaque approach were presented in an expert economic report before the High Court or a regulatory agency like the Commerce Commission, I am confident it would be dismissed outright – and rightly so. This lack of transparency should, on its own, be grounds for disqualification.

3.3 Market Economics' track record

Market Economics' past track record on this subject provides no confidence that the headline figures have been calculated using an appropriate methodology. For instance, in 2019, it was commissioned by MBL to assess, among other things, the transport cost savings from the Mangawhai-Pākiri embayment proposal (see: [here](#)). The only difference was that the sand was to be shipped by barge from Mangawhai rather than Bream Bay. As I noted earlier, Market Economics' approach in that earlier engagement appears to be largely identical to what it is employing now.

That methodology used in 2019 bears no resemblance to the robust approach I outlined above. Instead, it is alarmingly brief, crudely simplistic and fundamentally flawed. Market Economics estimated that barging sand from Mangawhai instead of trucking it from Helensville (the assumed counterfactual) would save between \$132m to \$165m between 2023 and 2043. Key assumptions underpinning those calculations included:

- Each truck carries an average of 30 tonnes of sand.
- It costs 17 cents to move a tonne of sand 1km.
- Therefore, it costs \$5.10 to move a truckload of sand 1km (17 cents/tonne x 30 tonnes).

This \$5.10 cost figure was then applied to a distance measure to estimate the total transport/trucking cost savings. It is at this point that Market Economics' calculation went seriously off track. For reasons that are hard to fathom, it assumed the transport cost saving was equivalent to the cost of trucking sand 55 km from Helensville to Ports of Auckland – a sum of \$280.50 per trip ($\$5.10/\text{km} \times 55\text{km}$). This figure was then extrapolated over the total Pakiri tonnage, with minor adjustments, to produce a range of \$132m to \$165m.

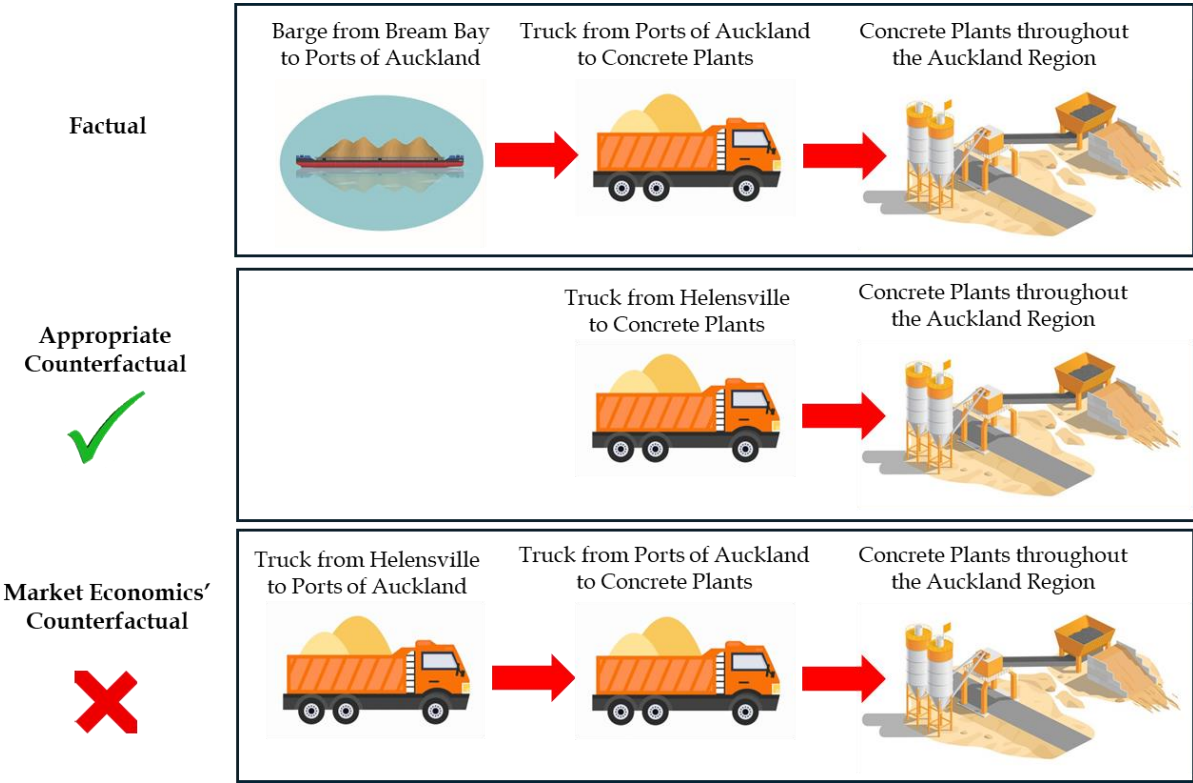
In other words, Market Economics' methodology assumed that, in the counterfactual scenario, trucks would first transport sand from the Winstone/Atlas depot in Helensville to the port – the same intermediary point used for barge deliveries from Mangawhai. From that common waystation, trucks would then deliver sand to its final destinations (i.e., concrete plants), effectively nullifying any delivery cost difference between the factual and counterfactual scenarios for this 'final leg.'

The only difference between the two scenarios, then, was the cost of transporting sand from Helensville to the port under the counterfactual (\$280.50 per trip). But this raises an obvious question: why would trucks leaving Helensville carrying sand first travel to the port before heading to their final destinations? The answer is simple: they would not. Those trips would never occur. I cannot comprehend what Market Economics was thinking when it framed the comparison in this way. It is nonsensical.

As Figure 3.1 illustrates (and as the methodology I outlined earlier demonstrates), the *appropriate* comparison should have been between the cost of delivering sand by barge, then truck to concrete plants (the factual), and the cost of delivering sand directly from Helensville to the plants. These concrete plants are spread across Auckland: from Manukau, Penrose, Albany and Henderson, among other locations.

Some of these plants are closer to Helensville than others, which would reduce the transport cost savings. In certain cases – such as the Henderson and Albany plants – it may even be cheaper to truck sand directly from Helensville than to transport it from Bream Bay. As I outlined earlier, accounting for these complexities requires a careful, detailed calculation. Market Economics’ approach, however, was nothing of the sort. It instead involved an analysis utterly lacking in logic.

Figure 3.1: Market Economics’ flawed 2019 comparison



In my view, this completely undermines the integrity of the estimates in Market Economics’ 2019 analysis. Those figures were meaningless because the methodology was comparing the wrong things. While the opacity of the more recent assessment prevents a definitive conclusion, the serious flaws in the earlier analysis raise an obvious question: how can the panel be confident that Market Economics has not made an error of similar magnitude in its calculations for the Bream Bay proposal? For example:

- **What if** it has simply reused its 2019 framework and again, wrongly, assumed that deliveries from Helensville would be routed via the port?
- **What if** it has unrealistically assumed that all Bream Bay sand would go to the Penrose concrete plant, artificially inflating any transport cost savings?

- **What if** the undisclosed “industry information” underpinning its assumed per-kilometre cost savings is fundamentally flawed – information we cannot verify because it has not been disclosed?
- **What if** it has failed to account for potential changes in transport infrastructure, traffic conditions or fuel costs over the period (e.g., electric trucks may become popular – perhaps ubiquitous), which could significantly alter cost estimates?
- **What if** it has largely ignored potential year-on-year fluctuations in demand and any effects on sand transport patterns, instead relying on a snapshot of current or near-term demand, calculating a present-day saving and applying a discount rate?

The answer is clear: the panel has no way of knowing if the claimed savings are credible or reliable. With no methodology provided – only headline results – these estimates cannot be properly tested. Given the scale of Market Economics’ recent errors on similar matters, there is no basis to assume the results stem from a robust analysis. If anything, the opposite is more likely. It is therefore unreasonable to place any confidence in the estimated transport cost savings. They are wholly unreliable.

Finally, it is critical to note that Market Economics’ assessment is built on the assumption that, in the counterfactual, marine sand would be trucked from Helensville. Even if the analysis were methodologically sound – which we have no way of knowing – it would still be irrelevant if that counterfactual is flawed. For example, if a significant share of Bream Bay marine sand were replaced with manufactured sand, it could dramatically alter the transport cost analysis – potentially reversing the supposed cost savings altogether.

3.4 Beneficiaries of the alleged cost savings

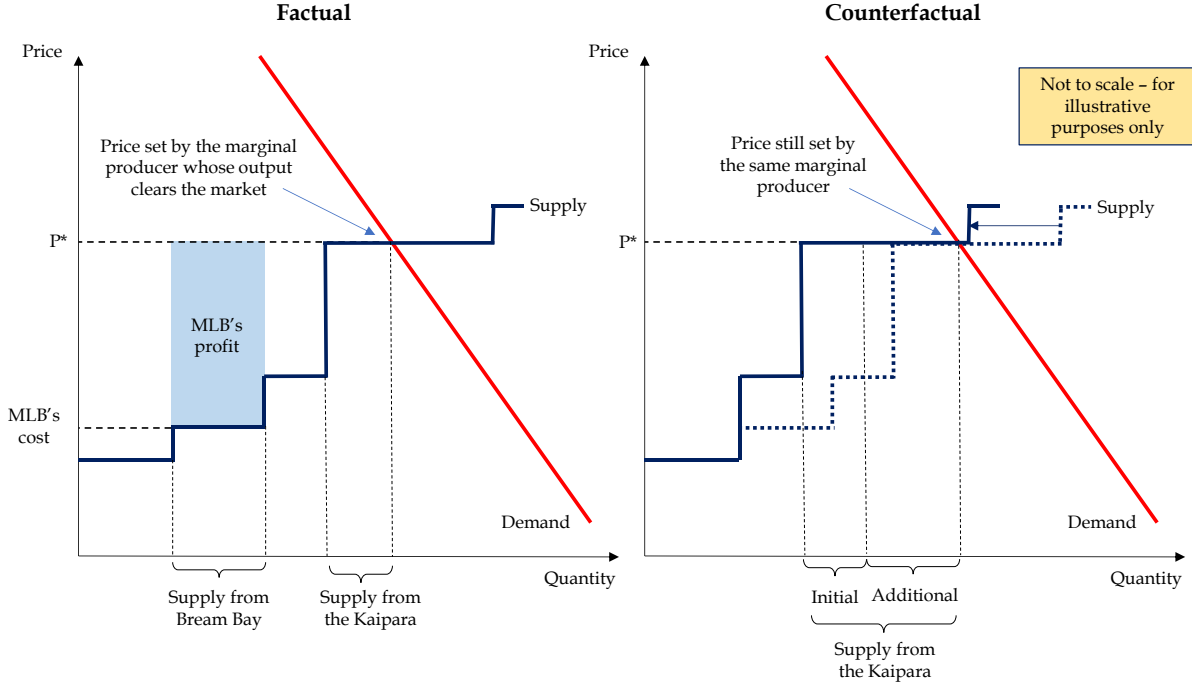
For the reasons outlined above, the \$197 million transport cost saving attributed to the MBL proposal cannot be relied upon. This does not mean that no savings exist, but there is no way to determine their magnitude – or whether they are substantial – based on the work performed to date. But, for the sake of argument, suppose significant savings would materialise if the proposal proceeded (which, to be clear, has not been demonstrated). Who would actually benefit from them?

This depends on whether any transport cost savings would translate into lower sand prices, which, in turn, hinges on the identity of the marginal producer. In most competitive markets, the market-clearing price is set by the marginal producer – the last (and most expensive) supplier needed to meet demand. Lower-cost producers supply first but, as demand rises, higher-cost producers are required and the market price adjusts to cover their costs, ensuring all supply is sold and demand is met. Lower-cost producers (‘infra-marginal’ suppliers) consequently earn greater profits as the market price increases.

I have not analysed the supply and demand dynamics for sand, so I cannot offer an informed view on who the marginal producers would be in the factual and counterfactual scenarios. However, Market Economics appears to believe that the marginal units would come from the Kaipara in each instance. I infer this from the fact that its analysis makes no mention of potential price reductions or their downstream effects, either qualitatively or quantitatively. Its estimate of economic benefit is simply equal to the transport cost saving – no more.

If that assumption is correct – and, to be clear, I have not conducted this analysis – it would mean that any transport cost savings achieved by shipping sand from Bream Bay would not affect Auckland’s sand prices. As Figure 3.2 illustrates, the market price (P^*) would be set in both scenarios by the cost of supplying sand from the Kaipara and would therefore remain unchanged in Market Economics’ factual and counterfactual analyses. This would have substantial ramifications for the distribution of any economic benefits.

Figure 3.2: The price is set by the marginal producer



For example, if Kaipara sand is the marginal source of supply in both the factual and counterfactual scenarios, the MBL proposal would have no impact on the price or volume of concrete used in Auckland construction projects. The same structures would be built in the same places at the same times. There may be some resilience benefits from adding another source of supply but, other than that, Aucklanders would be no better off and Northlanders would almost certainly be worse off.

The key difference between the two scenarios is that, in the factual, MBL would capture the entirety of any direct transport cost savings (as shown in Figure 3.2 above), making it the chief – or sole – beneficiary. Economists often adopt a dispassionate view of distributional effects – treating a dollar in the hands of a large corporation as equivalent to a dollar in the hands of a consumer. However, I doubt this is the kind of ‘economic benefit’ Parliament intended to promote when it enacted the Fast Track legislation.

4. Emissions and social costs

Market Economics also claims that the MBL proposal would reduce carbon emissions, road deaths and injuries compared to its counterfactual. Each of these estimates is directly tied to the distance travelled: fewer kilometres of sand transported by truck result in lower emissions and a reduced risk of road-related fatalities and injuries. This means these

estimates are plagued by the same issues that undermined the transport cost savings calculation. To briefly recap, Market Economics' distance calculations:

- are not explained at all in its report, leaving no way to verify whether they were performed correctly; and
- if based on a methodology as flawed as that employed in its 2019 report (see explanation in section 3.3) would be entirely unreliable.

In other words, the same flaws that undermine the reliability of the transport cost estimates also disqualify the environmental and social cost figures. Moreover, the emissions component faces another major problem. New Zealand operates a binding emissions trading scheme (ETS) with a cap-and-trade mechanism (an overview is available [here](#)), and the transport sector is a mandatory participant. Under the ETS, businesses must buy and surrender New Zealand Units (NZUs) before emitting carbon – one NZU allows for the emission of one tonne of carbon.

If the transport sector's emissions are reduced in the way Market Economics suggests, it would result in fewer NZUs being required for that purpose, thus freeing up those units for use by other sectors. In practice, this likely means that any emissions reductions resulting from the proposal would be offset by other businesses acquiring the surplus NZUs and increasing their emissions by the same amount. The net result would be zero net impact on overall emissions. This is a core feature of the 'trading' aspect of the ETS.

The only way that overall emissions would fall is if the New Zealand Government tightened the emissions cap, but it is unrealistic to connect MBL's proposal to such broad national policy changes. There could also be an impact on the price of NZUs, which would create downstream effects, but none of this is considered in Market Economics' simplistic calculation. This suggests a fundamental misunderstanding of the economics of emissions abatement under a cap-and-trade framework.

The same problem afflicts Market Economics' estimate of the cost of additional emissions from cement production. Like the transport sector, cement manufacturing is subject to the ETS. Hence, even if these additional emissions were avoided under the factual scenario, the surplus NZUs would likely be traded, leading to increased emissions elsewhere. As a result, all the emissions-related cost savings presented by Market Economics are entirely illusory, with the true figure likely being zero.

Market Economics also overlooks clear differences in the opportunity cost of land. As noted in section 2.2, MBL's sand depot would occupy valuable waterfront space in a prime location that could support a wide range of productive uses, such as hotels, restaurants and other commercial activities. Downtown Auckland's waterfront real estate is among the most desirable in the country, making the opportunity cost of such use substantial. In comparison, expanding a depot in, say, Helensville would have a negligible opportunity cost, reflecting the stark difference in land values. This holds true for nearly any activity, given the unique value of prime waterfront real estate.

The report also ignores other critical social costs tied to expanding a sand depot in Auckland's busy central city. Increased truck movements would worsen congestion and noise – already significant problems in the CBD. It would also increase the likelihood of

road-related deaths and injuries. These risks depend not just on the distance travelled (in the manner assumed by Market Economics) but also on the environment. A 30-tonne truck driving through a dense urban area filled with traffic and pedestrians poses a far greater danger than in sparsely populated industrial or rural settings.¹⁰

None of these crucial factors are mentioned in the Market Economics report, nor is there any attempt to quantify their impacts. The counterfactual scenario also has a crucial bearing on these costs. As noted earlier, if manufactured sand were to replace some or all of the Bream Bay marine sand – a plausible outcome – it could significantly reduce transport distances and the reliance on trucking. This shift would likely reduce road-related harm and lessen (perhaps even eliminate) the impacts on Auckland’s waterfront precinct.

5. Conclusion

In my view, the economic benefits assessment provided by Market Economics does not provide a sufficient basis to conclude that MBL’s proposal would deliver significant national or regional benefits that outweigh the associated costs:

- The entire analysis is built on the assumption that the alternative to sourcing sand from Bream Bay would be to extract an equivalent volume from the Kaipara harbour seabed. However, this assumption is becoming increasingly tenuous. It is now clear that a variety of abundant land-based alternatives could fill part – or all – of that gap.
- If the true counterfactual involved these land-based alternatives, Market Economics’ entire analysis would collapse completely, because it would be based on the wrong comparison, rendering its conclusions irrelevant.
- Even disregarding this broader issue, the analysis is opaque, cannot be replicated, and contains several serious errors – many of which serve to significantly overstate the potential cost savings. Therefore, regardless of the chosen counterfactual, the benefit estimates are completely unreliable.
- Even if Market Economics’ analysis were taken at face value, any cost savings may accrue primarily to MBL, rather than benefiting Aucklanders or Northlanders at large. It is doubtful that this represents the type of ‘economic benefit’ Parliament intended when enacting the Fast Track legislation.

In short, the economic analysis is manifestly inadequate and demonstrably flawed in several key respects. Given these deficiencies, I fail to see how the adjudicating panel could reasonably conclude that the proposal should be approved.

Yours sincerely



Hayden Green
BCom (Hons), BCom, LLB (Hons)

¹⁰ Tragically, as recently as last week, a pedestrian was killed on the Strand in Parnell by a truck that, based on the photos in the article, appears to be a container rig from the port (see: [here](#)).

ATTACHMENT 4 : Sand Mining Bream Bay - monitoring condition

Memorandum

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Attention: Ingrid Kuindersma

Company: NRC

Date: 01/04/2025

From: Dr Sharon De Luca

Message Ref: Sand Mining Bream Bay – monitoring condition

Project No: BM250630

Below is my proposed monitoring methodology. I thought a condition requiring a Marine Ecology Management Plan could refer to this memo (date and title) instead of putting all this detail into the condition.

Benthic Ecological Monitoring Bream Bay

The purpose of the monitoring programme is to test the assumptions outlined in the AEE in relation to effects on benthic invertebrates and sediment grain size within the dredging area compared to the northern, southern and remote control areas (see Figure 1 of the AEE (Bioresarches (2025))). The monitoring shall be detailed in a Marine Ecology Management Plan.

Despite the control sites not having the same environmental conditions (including habitat type and community composition) as the dredging area (Bioresarches (2025)), it remains possible to test hypotheses relating to differences in temporal trends between the impact site and control sites, with respect to diversity and abundance metrics, as well as levels of dissimilarity in community composition.

Year 1 post dredging – Annual Monitoring

In year 1, the annual benthic habitat monitoring shall be carried out at 10 representative sites within the sand extraction area that have been dredged in the previous 12 months (Year 1 dredging sites), and at 10 sites within each control site. Monitoring will involve sampling of:

1. Benthic infauna – sampled at 10 sites within the dredging area and each control site (northern, southern and remote control) with five ponar grab samples¹ collected per site (40 sites and 200 grab samples in total – 50 from the dredging area and 50 from each control site).
2. Epibenthos – sampled by photographing the seabed within a 0.5 m × 0.5 m quadrat immediately adjacent to each grab location within the dredging area and each control site² (40 quadrats will be photographed in the dredging area and at each control site –(200 photographs in total)).

In addition, towed camera video footage of each dredged track will be collected within the sand extraction area and along comparable lengths of seabed at the control sites to provide a broader characterisation of the benthic environment.

3. Sediment grain size – composite surface sediment (top 5cm) samples shall be collected from each of the 10 sites monitored within the dredged area and each of the northern, southern and remote control sites (40 samples in total) and analysed for sediment grain size composition.

Post dredging Year 2 – Annual Monitoring

In year 2, the annual benthic habitat monitoring of infauna, epibenthos and sediment grain size will be repeated at the Year 1 dredging sites, and an additional 10 sites (dredged in the previous 12 months) will be established (Year 2 dredging sites). Monitoring will be repeated also at the control sites within the northern, southern and remote control areas.

For the Year 1 dredging sites and for the control sites, the location of the 10 sites will be the same as in year 1, while sampling locations for ponar grab samples within each site will be randomly allocated.

In total, 200 ponar grab samples will be collected in year 2, plus 200 quadrat photographs, as well as video footage from Year 1 and Year 2 dredging sites and from the northern and southern control areas.

Post dredging Year 3 – Annual Monitoring

In year 3, the annual benthic habitat monitoring of infauna, epibenthos and sediment grain size will be repeated at the Year 1 and Year 2 dredging sites, and an additional 10 sites (dredged in the previous 12 months) will be established (Year 3 dredging sites). Monitoring will be repeated also at the control sites within the northern and southern control areas.

For the Year 1 and Year 2 dredging sites and for the control sites, the location of the 10 sites within each of the two control areas will be the same as in year 1, while sampling locations for ponar grab samples within each site, will be randomly allocated.

In total, 250 ponar grab samples will be collected in year 3, plus 250 quadrat photographs, as well as video footage from Year 1, Year 2 and Year 3 dredging sites and from the northern and southern control areas.

Post dredging Year 4 and 5 – Annual Monitoring

The Year 2 and Year 3 dredging sites will require 1 and 2 further years of monitoring respectively to comply with the condition that monitoring is undertaken for three years after dredging (Table 1). Monitoring in year 4 and 5 will also continue at the control sites. In order to better understand benthic community recovery, which MBL accept is poorly documented in the scientific literature, monitoring of the Year 1 and Year 2 dredging sites could continue beyond the three-year consent requirement (noted as “optional” in Table 1).

¹ Following the QA/QC protocol previously used for this project. A standard Ponar Grab sampler with a sample area of 250mm x 285mm and depth of 100mm, with sample volume 1-4L samples shall be used. Samples shall be sieved using a 1mm mesh, and the remaining contents stored in >80% ethanol until processed by a qualified taxonomist.

² Photographs will be analysed by a qualified benthic ecologist to quantify the abundance of the benthic organisms visible in each image.

Table 1: Proposed schedule for monitoring dredging and control sites.

	North and South Control sites	Year 1 dredging sites	Year 2 dredging sites	Year 3 dredging sites
Year 1	✓	✓		
Year 2	✓	✓	✓	
Year 3	✓	✓	✓	✓
Year 4	✓	✓ (optional)	✓	✓
Year 5	✓	✓ (optional)	✓ (optional)	✓

Data analyses

Following each round of annual monitoring, benthic community (infauna and epibenthos) and sediment grain size composition data will be graphed and analysed using a combination of univariate and multivariate techniques to assess:

- Recovery at the dredging sites relative to baseline conditions (testing whether impacted communities are returning to their own pre-dredging state)
- Recovery at the dredging sites relative to controls (testing whether the dissimilarity between dredging and control sites is returning to pre-dredging levels)

These analyses will characterise patterns of recovery relative to baseline conditions and to background natural variability across the wider area (quantified by monitoring temporal trends at the control sites).

Response variables for the statistical analyses may include:

- Univariate diversity metrics (e.g. abundance, richness, Shannon-Wiener diversity)
- Measures of dissimilarity (e.g. Bray-Curtis dissimilarity)
- Abundance of key taxa or functional groups
- Multivariate community composition (e.g. using PRIMER)
- Abundance of individual sediment fractions and/or multivariate grain size composition.

The relationship between benthic community structure and sediment grain size may also be explored to assess the extent to which observed biological changes are associated with changes in sediment characteristics.

Data analyses results may inform recommendations for monitoring beyond Year 3 and 5.