ATTACHMENT TWENTY
Concrete Suitability Statement (Paul Donoghue)

McCALLUM BROS LTD
Established 1904

SUPPORTING STATEMENT OF PAUL DONOGHUE IN SUPPORT OF McCALLUM BROS LIMITED APPLICATION TO FAST TRACK A SAND EXTRACTION CONSENT FROM A SITE IN TE ĀKAU BREAM BAY

Background

1. My name is Paul Donoghue, and I have been engaged by McCallum Bros Limited (MBL) to provide:

   a) An assessment of the requirement for marine sand for the Auckland Concrete Market; and an

   b) An assessment of the sand from the Te Ākau Bream Bay embayment for supply to Auckland concrete manufacturers to meet this requirement.

2. I am a Registered Engineering Associate and a NZCE (Civil), I hold a National Diploma Civil Engineering from Technikon Witwatersrand, Johannesburg and National Higher Diploma Material Testing from Technikon Pretoria, both from South Africa. I have spent over 36 years in the concrete industry with 16 years in New Zealand and 20 years internationally between South Africa and Dubai.

3. I am employed by Concrete New Zealand as the Manager – Training and Certification and the chair of the plant audit committee which oversees the plant audit scheme to ensure all concrete plants maintain their audit status in accordance with NZS3104:2021. I am also the convenor of the Concrete New Zealand Health and Safety Forum, the Cement Technical Committee and the Ready-mix Technical Committee.

4. Alongside my role with Concrete New Zealand, I am an independent plant engineer, where my role involves the evaluation of raw materials and designing concrete mixes for some of the independent Ready Mix Concrete producers. I also provide consulting services and dispute resolution services based on technical assessment and interpretation of standards and specifications.

5. Prior to these two roles, I was a plant engineer for Firth Industries for 15 years and have considerable experience in concrete mix design and optimisation with available aggregates within New Zealand, specifically the Waikato, the Bay of Plenty, Hawkes Bay and the Taranaki regions. Additionally, my plant engineer role with Firth included troubleshooting and resolving issues of a technical nature with my fellow plant

engineers throughout New Zealand.

6. As part of the preparation of my statement, I helped prepare a composite sample of the Te Ākau Bream Bay sand from the 227 individual samples obtained from Te Ākau Bream Bay. I compared the composite sample with other sand from other sources used for manufacturing concrete in the Auckland and Central North Island. There is a photograph of the sand from the composite sample marked **Figure 1**. I also utilised the services of the Fletcher Building's Research and Development Laboratory in Christchurch to undertake a series of trial concrete mixes to determine the suitability of the Te Ākau Bream Bay sand for use in a standard, medium strength 30MPa (megapascals[1]) concrete mix of the type commonly used in large infrastructure and commercial projects. It is important in such projects that the concrete used is pumpable, durable and compactable. Concrete strengths vary from lower strength 20 MPa for footpaths and driveways, high strength 30-40MPa for greater loads and structural elements to 50 and 60 MPa specialist high specification concrete for applications such as the tunnel rings used in the Waterview Tunnel and the pipes and concrete used in the Central Rail Link project.

7. I have been asked to prepare an expert assessment that covers various aspects of the manufacture of concrete and the use of various sands that are available to the Auckland market, including the suitability of Te Ākau Bream Bay sand for use in the manufacture of concrete, particularly high strength ready mix concrete.

Summary of Findings

8. Te Ākau Bream Bay sand is a natural marine sourced sand that is suitable for use in concretes of all strengths and mix designs. Importantly, due to the material's particle size, shape and mineralogy, it has all the qualities essential for making concrete that is pumpable, durable and self-compacting where required. It is therefore particularly well suited for making high strength and specialist concrete mixes. The manufacture of concrete consumes approximately 80% of the total fine sand usage in Auckland (approximately 630,000 of the 780,000 total tonnes of fine sand supplied to the Auckland market). Of the 630,000 tonne of fine sand required for concrete manufacture over 90% is marine sand. This fine sand volume does not include the

[1] In the context of concrete, MPa stands for megapascals, and it is the unit of measurement for compressive strength.

PAP7 or manufactured sand portion of the concrete mix[2].

9. Sands that are currently being supplied to the Auckland concrete industry for making high strength concrete include marine sand from a former offshore extraction site at Pākiri and from a site in the Kaipara Harbour. Some dune sand from Tomarata is also used by one Auckland manufacturer.

10. Other sources of natural sand such as Waikato River sands are not used for high strength concrete in the Auckland market for two main reasons. The first is the obvious issue of distance, and extra cartage costs to most of the Auckland concrete plants. The second is that, due to their volcanic origin, Waikato River sands have a high silica content, which makes them subject to alkali silica reaction. This is a major detrimental reaction that occurs as a result of the interaction between the high silicate content in sand and the alkalinity of the cement in the concrete mix (Adesina, 2020). This chemical reaction produces an expansive gel after the cement has set, which then causes internal pressure leading to expansion and cracking of the concrete (Glass, 2003).

11. Recycled materials such as crushed recycled concrete and crushed glass are not produced in sufficient quantities to supply the concrete industry and in any event are not able to be used to make concrete suitable for anything but low-grade concrete mixes (e.g. concrete pathways).

12. One Auckland concrete plant has recently started using manufactured "sand" (crushed rock) as a replacement for a proportion of the natural sand component in some grades of concrete. However, as New Zealand and overseas experience shows, manufactured sand does not have the distribution of particle sizes necessary to achieve the pumpability and self-compaction required to make satisfactory high strength and specialist concrete mixes if used without the addition of natural sand.

13. Marine sands make up the majority of the sand supply in the Auckland region and are a long-term proven source of supply. Their high quality and physical characteristics lend themselves well to the manufacture of all concrete but in particular the high strength concretes required to construct the future commercial and infrastructure

[2] In the concrete industry the terms "fine sand" or "fine aggregate" are often used in a more general sense to include both fine sand and PAP7 as a way of easily distinguishing between the sand and finer aggregate proportions of a concrete mix on the one hand (ie up to 7mm), from the coarser aggregate fractions on the other hand, (ie everything over 7mm). That is not the sense in which I use the term "fine sand" in this statement.)

needs of Auckland and other regions such as Northland, the Waikato and the Bay of Plenty. With existing marine sand resource consents either having expired or close to expiring, Auckland needs to locate suitable options for its future growth needs. In that respect, Te Akau Bream Bay sand can be used as a suitable replacement for current or previously used sands.

14. Marine sourced natural sands such as Te Ākau Bream Bay sand provide the Auckland concrete industry with a high-quality source of natural sand with low to no alkali silica risk that is ideal for the high strength and specialised concrete mixes that are used in infrastructure and heavy commercial projects. I am aware from my direct involvement in the Auckland concrete industry that Auckland has faced shortages of marine sand in recent years and is likely to do so again as economic conditions and infrastructure and other development pick up. In my assessment, if Te Ākau Bream Bay sand is made available to the market in sufficient volumes it will play a significant part in meeting the needs of the Auckland concrete industry for the foreseeable future, as well as further afield such as Bay of Plenty and Northland.

15. The reduction in cement volumes possible with Te Ākau Bream Bay Sand and the proposal to transport the sand directly by sea from the extraction site to a central distribution depot at the Port of Auckland or other destination Port would contribute to significant reductions in greenhouse gas emissions by eliminating the thousands of truck and trailer trips a year which would otherwise be necessary to transport similar volumes of sand from other sources.

Code of Conduct

16. Although this is not a hearing before the Environment Court, I record that I have read and agree to comply with the Environment Court's Code of Conduct for Expert Witnesses as specified in the Environment Court's Practice Note 2023 as relevant to preparation of a report for this Fast-track application. In particular, I confirm that the contents and statements of fact in this report are within my area of expertise and own knowledge, except where I state that I rely upon the evidence or reports of other expert witnesses lodged forming part of the project's application material. I have not omitted to consider any material facts known to me that might alter or detract from the opinions expressed.

Scope of Evidence

17. My evidence covers various aspects of concrete manufacture, and the use of sand as follows:

a) Concrete manufacture and the raw materials used for concrete
b) Concrete sand resources available in New Zealand
c) The Characteristics of Te Ākau Bream Bay sand
d) Sources of Sand Available to the Auckland Market
e) Other Possible Sources of Sand to the Auckland Market, including:
   i. sand in the Auckland Region
   ii. sand in Northland and the Far North
   iii. sand in the Waikato
   iv. sand in the Bay of Plenty
   v. recycled Concrete
   vi. recycled Glass
   vii. manufactured sand
f) Greenhouse Gas Emissions
g) Conclusion

Concrete Manufacture and the Raw Materials used for Concrete

18. The Ministry of Business Innovation and Employment (MBIE) has identified 'Aggregate & Sand' in the Critical Minerals List as one of the many types of minerals that are essential to New Zealand's economy and vulnerable to supply risk (MBIE, 2025). Aggregate and sand are critical ingredients in concrete production, playing a key role in its strength, durability and compactability. The following paragraphs of this statement describe the use of sand to produce concrete, the importance of marine sand as the main source of natural sand available to the Auckland market marine sand and the different types of concrete sand resources.

19. Second only to water, concrete is the most consumed material, with three tonnes per year used for every person in the world (Gagg, 2014, Aggarwal-Khan, 2022). Concrete is used extensively across a range of infrastructure and building projects in Auckland and all regions of New Zealand.

20. Concrete is typically composed of a mix of coarse aggregate, finer aggregate, sand, cement as the binding agent and water and admixtures. Concrete mixes can vary from region to region based on geography, climate, available material, and specific project needs. In Auckland, the aggregate portion in a typical high strength 30MPa

concrete mix is a blend of a coarse crushed stone with particles from 8mm to 19mm in size, a finer aggregate called PAP7 which is manufactured crushed rock fines from 0.075mm to 7mm in size and natural marine sand from 0.075mm to 3mm in size.

21. In general terms, a typical cubic metre of concrete of 30MPa strength weighs approximately 2,400 kilograms. The approximate mix of ingredients used in Auckland for 30MPa concrete is 1,000kg (40%) of coarse aggregates, 500kg (21%) of finer aggregates called PAP7, 410kg (17%) of natural sand, 340kg (14%) of cement and 190kg (8%) of water and concrete admixtures depending on the moisture content of the materials and the application the concrete is being used for.

22. The aggregate portion of the concrete should be a well graded mix of different particle sizes, ranging from 0.075mm up to 19mm nominal size. The coarse aggregates (8-19mm) are cheap, strong and take up a large volume in the mass of the concrete. However, the gaps (voids) between these larger particles must be filled by smaller particles. The finer aggregates or PAP7 fill in some of these voids and the natural sand the rest to achieve good particle packing and a dense, solid concrete matrix. The particle shape and size of the natural sand in particular helps the concrete to flow and compact into the shape required and this is a core reason why the particle size and shape of the sand is so important.

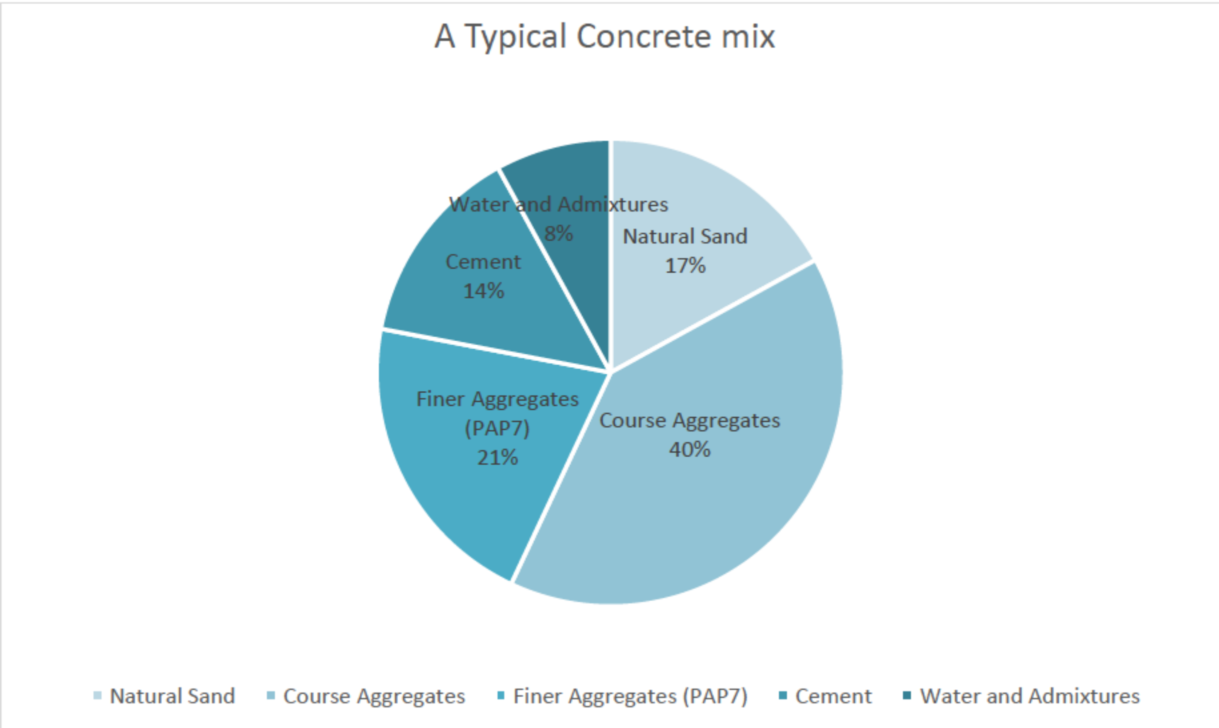

Figure 1: Proportions of a Typical 30MPa Concrete Mix

23. Outside of Auckland, particularly where alluvial (river and pit) sands are used, the

proportion of PAP7 to sand is slightly different due to the increased coarseness of the sand. In these regions high strength concretes require more cement. If good particle packing is achieved using suitable natural sands such as marine or dune sand, it can allow a reduction in the amount of cement required for a particular strength. This is important as cement is not only the most expensive component in the concrete mix, but cement manufacture is also the most emissions intensive activity and highest contributor to greenhouse gas emissions in the concrete making process.

24. Sand sized particles will always be required to make concrete and the better their shape and mineralogy then the better the quality of the concrete that can be made. For Auckland, marine sands are particularly suitable in this respect and their use has been proven over a long period of time. For high performance concrete applications, the availability of marine sands as a constituent is essential to the concrete manufacturing industry.

Concrete Sand Resources Available in New Zealand

25. Aggregate and sand resources vary significantly throughout New Zealand due to the varied geological make-up of the country. Most parts of the country in the North Island (Hawke's Bay, Manawatū, Wairarapa, Whanganui and Wellington districts) and South Island (Canterbury, Otago, Westland, and Southland) use washed and screened materials that originate directly from the river systems or from alluvial riverbed quarries.

26. In the North Island (from Taupō to the Waikato), the most commonly used sand is from old riverbeds and volcanic sand deposits. These sand sources are common but require sophisticated washing plants to remove the softer pumice and other lightweight particles from the sand. This sand is also fine and requires blending with coarser crushed rock to ensure the correct blend for a concrete mix. This sand is not generally suitable for higher strength concrete (greater than 50 MPa) due to the potential to cause alkali silica reactions in the concrete.

27. There are very few gravel-bearing braided river systems in Auckland and north of Auckland that have the types of material found in the central, eastern, and southern regions of the country (i.e. areas south of Taupō). This means that concrete materials will generally come from riverine crushed rock sources (sedimentary sandstones e.g. greywacke) where hard rock quarries are typically located. The aggregate from these crushed material sources does not on its own make good concrete and there are

significant issues when used without the addition of a finer and well-shaped sand. Shape is an important consideration in the selection of a fine material for use in concrete. Too angular a particle results in poor finishing and greater potential for bleed water as the particles do not “pack” as well. However, too round a particle shape results in more voids and an inability to bind as the particles do not “lock together” as well. Natural marine sands tend to be sub-angular to rounded so sit in the middle of the two extremes and are ideal for supplying the finer fractions required.

28. In the Auckland region, coastal marine sands have been used in the manufacture of concrete for nearly a century. The use of Auckland marine sand as part of the mix for concrete is also familiar to government and local authorities and has a proven track record as Auckland marine sand has been the sand constituent in all of the large infrastructure and commercial projects in Auckland and in many parts of the upper North Island over the years. This includes the Sky Tower, Newmarket Viaduct, Waterview Tunnel, City Rail Link, and Central Interceptor, to name a few. Auckland marine sand has also been used as the sand component in infrastructure developments in other regions due to the absence of suitable, locally available, high specification sand in those areas. For example, Pākiri sand was used for the high strength concrete in the Tauranga – Mt. Maunganui bridge and expressway, in the new Kopu Bridge, in extensions to the Port of Tauranga and in extensions to the wharves at the Port of Napier.

29. Pākiri sand (extracted by MBL) has also historically been used in many precast structural building elements such as tunnel segments, bridge beams, pipes, or railway sleepers that are used across the whole of the North Island. Many of these elements are used in major infrastructure projects which are stringently specified and often required to perform for a 100-year design life. Hynds Pipes supplies high specification concrete pipes, culvert systems and tanks for sewage, wastewater, drainage and other water management systems throughout the North Island. All these products are made with marine sand, including stockpiled Pākiri sand.

30. The primary source of natural sand for concrete production in the Auckland Region is marine sand extracted under resource consents from Pākiri on the East Coast (now surrendered) and the Kaipara Harbour on the West Coast.

The Characteristics of Te Ākau Bream Bay Sand

31. Te Ākau Bream Bay sand is a fine, well-shaped, quartz/feldspar sand and contains

strong particles; see **Figure 2** below. The sand contains some silt, but this will be removed by the washing process which is a necessary part of the extraction process of sand extraction by the *William Fraser*. This is the same process as is currently used at Pākiri. There are also some minor shell fragments and chlorides of insufficient quantity to be detrimental or of any material concern. It is of a similar provenance as Pākiri sand, as described in the petrographic report **(Appendix 1)**. Chloride risk is easily managed by washing and over New Zealand's concrete history, there have never been any test results showing chloride levels in concrete near or above the limits specified in NZS 3101 (New Zealand Standard for Concrete Structures).

32. The main constituents of the coastal marine sands used in Auckland are quartz and feldspar. Both of these materials are inert and do not react with the alkalis in the cement which is of significant importance when considering the long-term durability of concrete, particularly in high strength concrete that requires a higher proportion of cement. The cleanness of the marine sands also means that the risks of plastic shrinkage and long-term drying shrinkage are reduced. To explain these concepts:

   a) Plastic shrinkage means when concrete is still fresh/wet or “plastic” and used in flat slabs there will be a layer of water form on top of the concrete. This water is called bleed water. Having a correctly graded sand, and thus mix, means the rate of bleed is controlled. If the bleed rate is wrong and the rate of evaporation is too high, the bleed water is lost to the concrete very quickly. This typically happens on hot windy days, causing cracks to form in the plastic or wet concrete.

   b) Long-term drying shrinkage refers to the fact that all concrete shrinks with time. This is mostly due to moisture loss within the concrete. Having clean sands with a good particle shape, consistent grading and very few ultra-fine particles helps reduce the initial water demand for a mix and leads to a lower water content which helps reduce long-term drying shrinkage.

33. MBL obtained the sand samples that were used for this report via the use of 227 small grab samples from identified locations spread evenly over the proposed extraction area at Te Ākau Bream Bay. These samples weighed approximately 500 grams each. Although there were differences between each sample, they were all well within the expected range of a natural concrete sand used by the industry. Under my supervision, each sample was split, with one portion of each sample being retained and the other part combined to produce a single representative sample that was used to determine the suitability of the sand to meet New Zealand concrete standards.

Figure 2: Bream Bay Sand

34. The combined sample was sent to the Stevenson's Concrete and Aggregate test facility in Drury, Auckland**,** to test for compliance with the respective national standards and additional requirements as requested by concrete producers for marine sand. The results can be seen in **Appendix 2,** which demonstrates that Te Ākau Bream Bay sand meets or exceeds the minimum requirements of the various concrete standards.

35. Once this testing was complete, a series of comparative concrete trials were undertaken using a standard high strength 30MPa concrete pump mix at the Fletcher Building Research and Development Laboratory in Christchurch. A mix of this design is commonly being produced daily in Auckland concrete manufacturing plants.

36. The purpose of the trial was to compare the performance of a concrete mix using Te Ākau Bream Bay sand with Kaipara Harbour marine sand which is currently the most commonly used sand in Auckland concrete mixes. The replacement of Kaipara sand with Te Ākau Bream Bay sand was made on a 1:1 basis (dry mass). All coarse aggregates, finer aggregates (PAP7), cement, water and admixture amounts were consistent for both mixes.

37. Two trials were undertaken, each with two test mixes, the first being a like for like comparison using Kaipara Harbour sand and the second involving some variations in both Kaipara and Te Akau Bream Bay mixes to produce an improved concrete based on the results of the first trial. The results of both trials show that Te Ākau Bream Bay

sand produces an excellent and cost-efficient high strength concrete.

38. The initial trial results showed that whilst the two test mixes in the first trial made suitable concrete, a lower quantity of the Te Ākau Bream Bay sand in the blend would produce a better-quality concrete. The target in the second trial was to reduce the cement content compared with the first trial whilst maintaining or improving the final strength of the concrete.

39. With that in mind, the two test mixes were modified accordingly in the second trial with the cement content reduced to 286 kg/cubic metre of concrete for both mixes with a reduced amount of Te Ākau Bream Bay sand in the fourth mix. This mix showed that a lower proportion of Te Ākau Bream Bay sand (33% of the total fines content) in the fine aggregate mix produced a well-balanced concrete with a lower overall cement content. Details of both trials and the four test mixes are shown in **Appendix 3**.

40. If Te Ākau Bream Bay sand is made available, I am confident that it will play an essential role in the Auckland ready mix concrete market and, to a lesser extent in Northland, the Waikato and Bay of Plenty and other North Island regions for use in projects where high performance concrete and long service life are required such as for tunnels, bridges and other heavy commercial projects of regional or national significance.

41. As mentioned above, Te Ākau Bream Bay sand is also a quartz feldspar sand and shares all the positive properties of the Kaipara Harbour and Pākiri marine sands currently in use in Auckland.

Sources of Sand Available to the Auckland Market

Auckland Sources of Sand

42. What I would define as the Auckland regional market for sand for concrete manufacture contains 25 principal plants located from Silverdale in the north to Bombay in the south. A list of the plants, their locations and the kind of aggregate and sand they use in making their concrete is attached as **Appendix 4**. The list does not include the smaller makers of precast and other concrete products who do not produce ready-mix concrete commercially.

43. As **Appendix 4** shows, all but two of the plants use natural marine or dune sand and, of those 22 plants only the Allied Penrose plant uses manufactured sand in its concrete mixes. Allied Penrose is using manufactured sand as a complete

replacement for PAP7 and natural marine sand in many of its concrete mixes but continues to use marine or dune sand in specialist and some high strength mixes. That is because there is no complete substitute for natural sand available for making specialist and high strength concrete. The only two Auckland plants which do not use marine or dune sand are the TT Concrete plant at Mangere and Holcim at Bombay. TT Concrete uses Waikato relict river sand from a quarry in Tuakau and Holcim Bombay uses a different source of Waikato relict river sand from its own quarry in Mercer. Both of these plants are relatively small manufacturers.

44. Another factor relevant to the supply of sand to Auckland plants is that sister plants do support each other in achieve delivery targets and, therefore, there is a strong tendency for plants in the same company group to use the same sand to ensure that mixes supplied to customers meet consistent specifications.

45. As per **Appendix 4**, the current sources of marine and dune sand now available from within the Auckland region to Auckland plants are from the Kaipara Harbour, Pākiri and the Tomarata quarry. The only Auckland plants using Tomarata sand are the two Bridgeman plants. This is not surprising given the extra trucking costs in delivering the sand into Auckland from Tomarata. The Tomarata quarry supplies several plants within the Northland market from Wellsford and further to the north. This is the area in which supply from Tomarata is economic in trucking terms. Supplies of sand from MBL's former extraction site at Pākiri are likely to be exhausted within the next 6 months.

46. I am aware through my day-to-day involvement in the industry that a matter of concern to Auckland manufacturers is that, as supply of marine sand from Pākiri has reduced, the Auckland market has become increasingly reliant on marine sand from the Kaipara Harbour. In approximately 6 months Kaipara sand will be the only source of marine sand available in Auckland. This raises three distinct difficulties:

(a) Sand extraction from the Kaipara is controlled by the Atlas Group of Companies via its subsidiary Mt Rex Shipping (Atlas Group). The Atlas group also operates 5 concrete plants within the Auckland market and is therefore a direct competitor with most of its customers (see **Appendix 4**). The possible undesirable complications of a competitor in the market for ready-mix concrete having a monopoly over the supply of a vital ingredient are fairly obvious.

(b) The second issue is that the current resource consents held by Mt Rex Shipping Co. Ltd and Winstone Aggregates for extraction from the Kaipara are due to expire in 2027 and there is no certainty that they will be renewed. It is my understanding that new resource consent applications for the continuation of sand mining in the Kaipara Harbour have not been lodged to date.

(c) The third concerning aspect of reliance on Kaipara sand is that security of supply issues arise from dependence on production from one location on the west coast of the North Island. Extraction of sand from the Kaipara is undertaken by Mt. Rex Shipping Co. Ltd which is a subsidiary member of the Atlas Group. Extraction is by dredge barge which must navigate both the Harbour and the Kaipara River in getting to and from the extraction site and the Mt. Rex depot near Helensville. The Kaipara Harbour is subject to severe weather conditions, rough seas and strong tidal currents. The Kaipara River is narrow and shallow in parts and is subject to tidal variations which limit the time for outward and return trips. It would only take a serious accident to the barge or blockage of the river by weather conditions or a natural disaster to limit or stop production from the Kaipara and cause serious sand supply issues in Auckland. Such shortages could have disastrous implications for major development projects. One of the advantages of MBL's Te Ākau Bream Bay proposal is that it would provide marine sand from an entirely separate east coast location and so greatly reduce the risk of short supply and its potential consequences for major development and infrastructure projects in the Auckland region and beyond.

(d) Given the operational challenges with sand extraction from the Kaipara Harbour and the period remaining under the current consents, it is my opinion that for high performance concrete applications, the availability of marine sands as a constituent is essential to the concrete manufacturing industry. There is a functional need for a marine sand source on the east coast of the North Island, in close proximity to the Port of Auckland which will meet the marine sand requirements for the city. This is particularly important given the recent surrender of MBL's Pākiri consent.

Other Possible Sources of Sand to the Auckland Market

Sources within the Auckland region

47. Sandglass Corporation Ltd at Tomarata also has a consent to extract 84,000m^3 of dune sand per year. Based on known industry conversion rates this would equate to about 150,000 tonne of available sand per year. However, the site has not been developed for the production of sand and has no infrastructure, plant, or equipment.

Also, the distances and trucking costs involved in providing supply to the Auckland market are the same as faced by the Tomarata quarry as described above.

48. There is a small relict dune quarry at Woodhill which produces a very fine sand. While it is possible to make some kinds of concrete with this type of sand, it would mean an increase in water demand and an increase in cement content. No ready mix concrete plant I am aware of has accepted this sand for making concrete. While I do not have information about the amount it can supply per annum, I consider it is unlikely to be used in Auckland due to its unfavourable performance characteristics and distance from most plants in the Auckland market.

Sources in Northland and the Far North

49. There are several land-based sand quarries north of Tomarata that supply Northland and Far North concrete plants. These are not feasible sources of supply to the Auckland market for a number of reasons, the main ones being distance and trucking costs, limited size of the resource and lack of spare production capacity.

Sources in the Waikato

50. In the Waikato region, the sands suitable for making concrete are Waikato river sand or relict river sand. There are several issues with this material. The existing quarries are struggling at present to maintain supply to the Waikato region and there would be a limited capacity to supply the Auckland market. Due to coarser particle sizes than Auckland natural marine sands, using a Waikato sand would also mean the fine sand demand in a cubic metre of concrete would increase by as much as one third and this would need to come from a different source with likely increases in cost to the manufacturer.

51. As explained above, Waikato sands are also at high risk of causing an alkali silica reaction and can only be used for high strength concrete by the addition of a Supplementary Cementitious Material (SCM). These SCMs are either Fly Ash (FA) or Micro Silica (MS) also known as Condensed Silica Fume (CSF) and Ground Granulated Blast Furnace Slag (GGBS). Any of these products may be used as specified in NZS3101 to control the alkali silica reaction issue. Currently, all three of these products are imported and have handling issues if not used in bulk and not all plants are set up to store these materials in that manner.

52. The 2021 revision of the Concrete New Zealand document TR3 Alkali Silica Reaction increased the maximum limit on allowable alkalis in cement meaning that mixes could

use a higher amount of cement without having to resort to the use of SCMs. However, the types of cement in New Zealand currently have Sodium Equivalent (NaEq) contents varying between 0.47% and 0.59%. This is the measure of alkalis in the cement (the limit of acceptable alkalis is 0.6%). This higher NaEq value limits the amount of cement permitted in a mix. This average value has increased over the last two years somewhat negating the increased allowable limits set in TR3 (Concrete NZ, 2022).

Bay of Plenty

53. As to any other alternative sources of sand located further afield such as in the Bay of Plenty, I do not consider these are feasible due to the distance from Auckland plants and the significant additional transport costs. Sand from the Bay of Plenty also shares qualities which I earlier raised at paragraphs 50 to 52 about the use of Waikato sand.

54. In the Bay of Plenty/Tauranga there is also currently a lack of sand availability due to consenting constraints and any surplus sand would be used in that local market first. Sand is extracted from time to time from the Tauranga Harbour and attempts have been made to use it in concrete. However, I understand from MBL who were directly involved in these attempts that its use for anything more than low strength concrete applications proved impracticable due to severe problems with potential alkali silica reaction.

Recycled Concrete

55. Recycled concrete waste can be crushed so as to make it suitable for some of the aggregate used in concrete manufacture. However, there is insufficient recycled concrete aggregate available and being produced in Auckland to permit much additional supply for concrete manufacture. Also, crushed concrete has several other uses including hard fill, compacted fill, base materials for roads and footpaths and drainage. Demand for these products limits the supply available to concrete manufacturers and puts pressure on the cost of the product. Fine aggregate produced from recycled concrete is weaker than fine crushed rock and natural sand so that its suitability is limited to lower grade concrete; for example the 20MPa blends used to make footpaths and walkways. The porous surface texture of crushed concrete also drastically increases the water demand of the concrete mix resulting in the need for a higher cement content thus increasing both the carbon footprint and the cost of making the concrete. Recycled concrete can only be used in small quantities of a mix and is usually restricted to providing part of the coarse aggregate. It is not a substitute

for the finer fractions of PAP7 or the natural sand in any concrete and it is not suitable for high strength concrete or specialised mixes.

Recycled Glass

56. While recycled glass can be made into sand, there are issues with alkali silica reaction in the concrete if the proportion is too high and with the sugars and glues found on the glass due to the contents of what was being held in the bottle. These sugars and glues cause concrete retardation[3] and setting time problems for the concrete. There is also insufficient volume of recycled glass available to make any contribution to solving the sand issue as most of it is recycled to be re-made into bottles.

Manufactured Sand

57. Manufactured aggregates for concrete manufacture are made from crushing rock at quarries and vary from coarse stone to finer "PAP" products. More recently, there has been some production of what the industry has termed "manufactured sand", which is capable of replacing all or some of the natural sand component of some concretes depending on the strength, characteristics, and application of the concrete being made.

58. There are potential limitations on the use of manufactured sand relating to its particle shape, distribution of particle sizes, and other factors. These make it less suitable for higher strength concrete and specialist mixes particularly where pumping or a higher level of self-compaction are required.

59. Engineered sand products of this type are finer than the larger particles of PAP7 and can be used as a constituent of concrete, mainly as a substitute for PAP7 and in some concrete mixes to partly or fully replace natural sand. Although the use of manufactured sand is limited in the Auckland Market and throughout New Zealand, it has been used for many years in countries where natural sand resources are either depleted or not available in sufficient volumes to keep up with market demand.

60. There has been a significant improvement in the engineering of crushing and processing equipment over the last 10 years. This has led to a lot of work being done with regards to optimising manufactured sands for use in concrete. I am aware that in New Zealand, Kayasand and their local competitor Mimico have the equipment and processes to produce a sand suitable for use in concrete but neither of these products

[3] In concrete, "retardation" refers to the process of slowing down the setting and hardening time of the concrete mix.

in my opinion can produce a sand with sufficient volumes of particles with the required particle size distribution and shape required for high strength concrete and specialist mixes. A natural marine sand is needed to achieve a satisfactory high strength mix.

61. I am aware that countries such as Japan and Australia are using various types of manufactured sand but, in all cases that I am aware of, they are not used without a natural sand in some proportion, particularly in high performance concrete mixes such as those used in infrastructure and large commercial projects.

62. Manufactured sands are made using the same rock feed as is used for making coarse aggregate and PAP7 or they rework the PAP7 material itself. In the Kayasand process, the material is first dried to a moisture content of less than 3%. This drying process is energy intensive and can be problematic especially during longer wet weather spells. Once dried, the material then passes through a crusher and then through an arrangement of air screens. This process leaves particles that are less angular than the finer particles of PAP7 but deficient in some smaller particle size fractions.

63. The only quarry producing manufactured sand in Auckland is the Brookby quarry which uses the wet process promoted by Mimico but with some in-house modifications. Essentially the sand is made by grinding down PAP7 through high pressure rollers after washing to remove the fines. The result is sand with reasonably well shaped particles but also deficient in some small particle size fractions.

64. The Brookby sand is missing sufficient particles in the 150μm to 600μm range compared to natural marine sands. These fractions are critical to providing a good workable concrete (refer American Concrete Institute ACI 211.9R-18, Section 3.2.2) (American Concrete Institute, 2018). Te Ākau Bream Bay and Kaipara sand contain higher proportions of those fractions and both produce concrete that is easy to mix, transport, place, compact and finish, providing high strength and specialised concretes that can be used in 100-year structures with confidence.

65. The preferred amount of material in the 150μm to 600 μm size range is higher when designing more highly engineered concrete, particularly where it needs to be pumped, or where self-compaction is necessary. In manufactured sand, some of these essential size fractions are reduced.

66. A well-proportioned concrete mix will have a good blend of all the required particle sizes and a well-balanced particle size distribution. This is particularly important with

high strength pumped concrete and high specification self-consolidating concrete. The concrete mix must include the right blend of particles in the 150µm to 600µm range. This correct particle size distribution is difficult to achieve when using manufactured sands on their own.

67. The correct amount of fines in a mix also ensures the placer can work and finish the concrete correctly. If there is not enough fine material, then the required surface finish is not achievable. Too much fine material results in “sticky” concrete that is again hard to finish correctly.

68. In mixes where self-compaction is required, particularly where moulds are used as for the precast tunnel rings made by Wilson’s Tunnelling for the Auckland City Rail Link and the high specification pipes made by Hynds Pipes for the Central Interceptor waste water system, a sand with a well-balanced particle size distribution is critical to ensure the correct density is achieved and the required finish can be created on the surfaces of the pre-cast products. In the case of Hynds, it is important to ensure that the product is well compacted so that it retains its impermeability for the lifespan of the project.

69. A blend of a coarse aggregate, finer aggregate in the form of PAP7, some of which could be replaced by manufactured sand, and a natural sand enables the concrete technologist or plant engineer to design a full suite of concrete mixes ranging from a basic 20MPa concrete for house foundations, through to a sophisticated, high strength, self-compacting 80MPa concrete that could be used for the lift shaft of a multi-story development. The blend allows the production of concrete that will produce a surface finish to satisfy the most demanding architect.

70. The different particle characteristics of Brookby PAP7, Te Ākau Bream Bay sand, Kaipara Harbour sand, and Brookby manufactured sand can be seen in **Figure 3** which shows the particle size distribution curve of each product. The deficiency in PAP7 and the Brookby Quarry manufactured sand of fine particles in the 150 to 600micron range compared with the 2 natural sands is obvious to the eye**.**

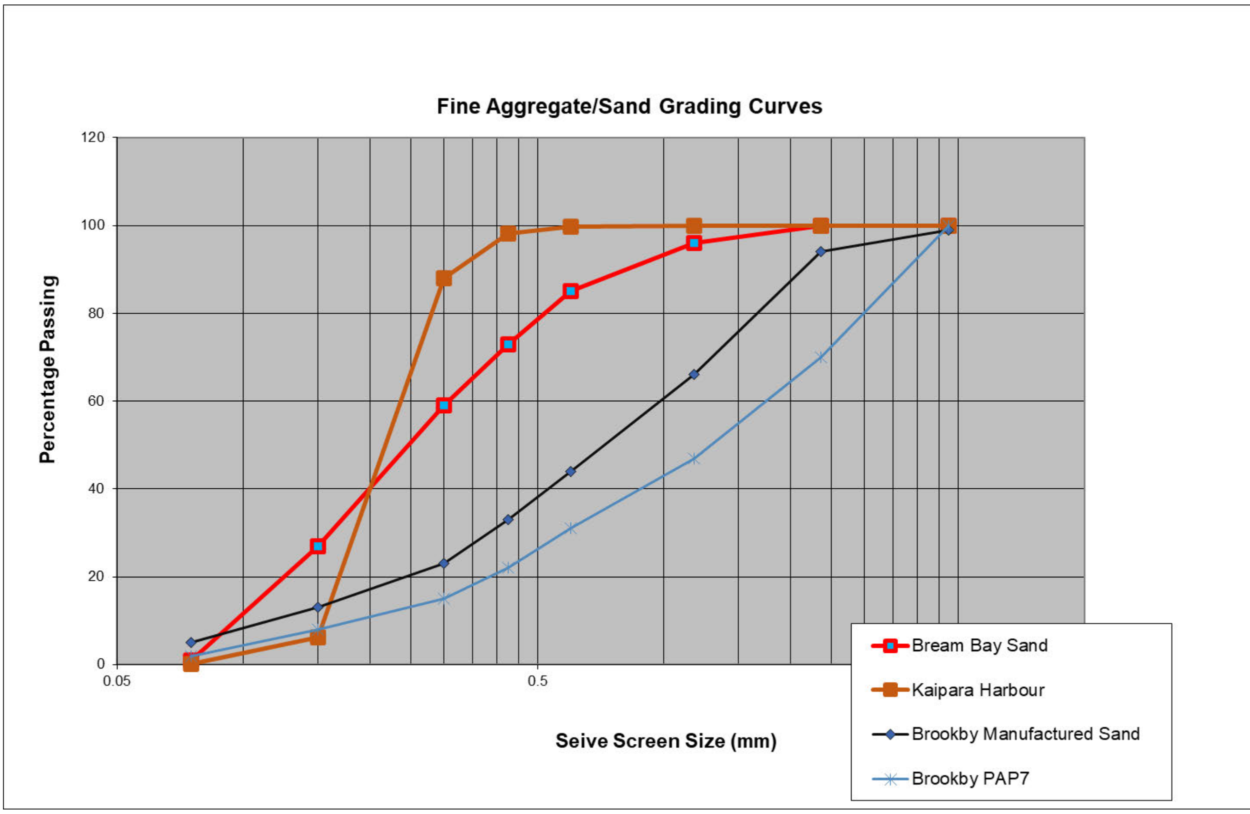

Figure 3: Fine Aggregate Grading Curves – 1 April 2025.

71. Where lower grade concrete is produced using all manufactured sand in the sand component and no natural sand, the product tends to have a significantly lower rate of bleed and total bleed due to an excess of fines passing the 75µm sieve. This is problematic as these very small particles retard the movement of water to the surface of the concrete and slow the bleed rate. Bleed water helps to protect the concrete in the early stages of placement from plastic shrinkage cracking. The benefit of natural sand is that it allows management of the rate of bleed and total bleed.

72. I consider that the quality of the manufactured sand now available in the Auckland market will replace some of the natural sand used in concrete manufacture, particularly in lower grades of concrete. However, it will in no way eliminate the need for and value of a natural sand in producing a good quality high strength concrete. In my opinion, it is unlikely that the market for manufactured sand in Auckland will exceed 150,000 tonnes per annum within the next 5 years. In fact, international experience indicates that even where manufactured sands have been available for many years, a portion of natural sand is still used, particularly in high strength concrete, specialist mixes and where pumpability and self-compaction characteristics are required. In short, a good fine aggregate blend which contains a proportion of natural sand is essential for making high-strength, self-compacting concrete (concrete

with a strength of 40MPa and up) and specialist mixes.

73. The images in **Figure 4** below illustrates (from left to right) some of the physical differences between Brookby PAP7, Brookby manufactured sand, Te Ākau Bream Bay sand, and Kaipara Harbour sand.

Figure 4: Physical Differences between finer Aggregate and Marine Sands used in Auckland

74. A report by Lam (2020), records the results of tests with manufactured sand using Vietnamese limestone rock as the base material. The results of various trial mixes indicated that 100% of the natural sand can be replaced with a manufactured sand for high strength concrete up to 85 MPa. However, the report also concluded that there was a significant loss in the workability of the concrete produced with this 100% manufactured sand mix and that the best concrete was a blend of manufactured sand (crushed rock) and a natural alluvial sand in blend ratios of 30-40% natural sand to 60-70% manufactured sand. The report went on to show this blend ratio produces the best workability and was the optimal blend for both compressive and flexural strengths – both primary design criteria for concrete. This blend ratio was further supported by work undertaken by Mackechnie (Mackechnie, 2024) where he conducted trials in New Zealand using a Kayasand crushing plant to produce a manufactured sand material. The results show very clearly that the best concrete is produced when combining a manufactured sand with natural marine sand.

75. It should also be noted Lam (2020) was based on Vietnamese concrete standards which are quite different from New Zealand standards, and the trial mixes used Vietnamese limestone rock which bears no relation to the rock used in New Zealand as base material for manufactured sand. Limestone is not generally used for making concrete in New Zealand. There are no limestone quarries in the Auckland region and the closest source would be in the South Waikato. Limestone is occasionally used in

decorative concrete but that comes at a premium in terms of cost.

76. All of the conclusions from the tests discussed above show that manufactured sand is not a complete replacement for natural sands. Instead, the manufactured sand largely becomes a replacement for the PAP7 portion of the fine aggregate while the percentage of the natural sand required reduces or remains largely the same depending on the concrete design criteria.

Greenhouse Gas Emissions

77. Cement production is a large contributor to CO_2 emissions with about 950 kg CO_2 produced for each tonne of cement manufactured (it is generally accepted by the concrete industry to be an amount between 940kg – 1000kg per tonne of cement manufactured). Currently the Auckland regional market produces about 1.4 million m^3 of concrete per annum. If the Auckland market was to move to using Waikato sourced sands, it would mean the mixes would have a higher cement content. On average this would mean an increase of about 25kg of cement per cubic metre of concrete, noting some concrete types such as high strength concrete use a higher amount of cement. Reducing cement content in concrete reduces the carbon footprint of any mix. Using the correct blends of material in mixes is very important as this gives the plant engineer the opportunity to reduce the cement content and therefore directly reduce the carbon footprint of the concrete.

78. To put this into context, for the City Rail Link project, the use of Waikato sands would have meant mean an increased consumption of 6,000 tonnes of cement. In CO_2 terms this would mean an increase of approximately 5,500 tonnes produced and that is for the increased cement portion only. This is based on the estimated volume of concrete supplied by Allied Concrete to this project. It does not include the concrete supplied by Wilson Tunnelling or Hynds.

79. The carbon footprint created by concrete is an important consideration as the reduction of CO_2 is a high focus of the industry with most manufacturers seeking ways to reduce their carbon footprint. This is part of the push by the industry to meet the New Zealand Government target of being net-zero for carbon emissions by 2050 (excluding biogenic methane) as part of the Emissions Reduction Plan.

80. The concrete industry is working towards this goal with best practice guidelines being prepared for concrete manufacturers. Some concrete manufacturers are taking steps to make 'low carbon concrete' which requires all inputs of the concrete manufacturing

process to be considered from supply of raw materials to the manufacturing process and delivery of the concrete to its end user.

81. The use of Te Ākau Bream Bay sand helps to reduce greenhouse gas emissions by reducing the emissions required to get the raw material to the concrete manufacturer. This is achieved by barging the sand on the *William Fraser* from Te Ākau Bream Bay directly to the Port of Auckland (or other destination Port), by the efficient delivery from a central location by bulk truck and trailers and by providing a sand that optimises reduced cement usage.

Conclusion

82. If consent is granted, I have no doubt that the Te Ākau Bream Bay sand resource will become a very important part of the concrete supply chain in Auckland in the future. This sand is a very high-quality product that can produce high strength and specialist concrete of the type required for projects of national or regional significance. The proposed extraction volumes are in line with the estimated growth demands of Auckland and provide an alternative natural marine sand resource that greatly improves security of supply to the Auckland market and would avoid the likelihood of future shortages in Auckland if the Te Ākau Bream Bay proposal does not proceed. As I have said above, the availability of marine sands as a constituent of high strength and special mix concrete is essential to the proper functioning of the Auckland concrete manufacturing industry. There is a functional need for a marine sand source on the east coast of the North Island, in close proximity to the Port of Auckland which will allow the marine sand requirements for Auckland to be met.

83. The importance of a secure supply of marine sand is not limited to the Auckland region but extends to many of the regions in the North Island which do not have local access to high quality marine sand suitable for the high strength and specialised mixes of concrete essential to major infrastructure and commercial development. The *William Fraser* provides the significant economic and emissions related advantage of allowing direct delivery by sea from Te Ākau Bream Bay to the Port closest to the point of delivery.

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Appendix 1: Petrographic Analysis of Bream Bay Sand

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28 February 2025
Chief Operating Officer
McCallum Bros Limited
PO Box 71-031
ROSEBANK 1348
Auckland

For: Mr Shayne Elstob

by email: [redacted]

our ref: McCallum-13
your ref: Bream Bay Sand

Dear Mr Elstob,

petrographic assessment of Bream Bay Sand – general characteristics and potential for alkali-aggregate reactivity

We have carried out a petrographic examination of a sand sample labelled as 'Bream Bay Sand' submitted for assessment of alkali-aggregate reactivity potential and suitability as a concrete sand.

The sand sample which weighs 9.7045 kilograms is understood to be representative of the sand-sized fractions (i.e. $\phi = \leq 2.36$ millimetre) amalgamated from 240 Ponar grab samples from Bream Bay, Northland (see Appendix 1 for sample localities). The sample was received on 27 January 2025 as a bulk sample. The sample was checked for homogeneity and was found to be homogeneous. Petrographic analysis was carried out on this sample, which is believed to be representative of the samples collected during the Bream Bay grab sampling campaign.

A description of this sand sample is given in the attached report, which includes an assessment of the alkali-aggregate potential of the sand when used as fine aggregate in Portland cement concrete. The method of assessment follows the recommended practice set out in Clause 6.1 of TR03 Alkali Silica Reaction revised version issued 2021 (TR3 2021) and has been guided by AS 1141.65 which was developed specifically to identify the presence of potentially reactive components in concrete aggregate.

Petrographic examination suggests the Bream Bay sand has a relatively low potential to participate in alkali-aggregate reactions when utilised in concrete. This is an interim conclusion which should be checked via mortar bar testing or by examining historical concrete containing Bream Bay sand as fine aggregate.

Bream Bay sand is petrographically similar to Pakiri Inshore sand which was first used as a concrete sand approximately one hundred years ago. There are no recorded instances of alkali-aggregate reaction involving this sand. No obviously reactive particles have been identified, either by petrographic examination or by X-ray diffractometric analysis (XRD). Potentially reactive particles are present in volumetrically minor quantities slightly above the limit of 1% for reactive particles specified in Section 6.1 of TR3 (p. 27, 2021).

The sand would probably impart high matrix strength in concrete hence would promote high compressive strengths. The presence of felsic volcanic particles may induce slightly higher than average drying shrinkage.

One component of Bream Bay sand, specifically felsic volcanic material, has the potential to participate in alkali-aggregate reactions when utilised in concrete.

Given the presence of a small proportion of acid volcanic particles, it would be prudent to assess potential for alkali-aggregate reactivity via a complementary method such as mortar-bar testing if the sand is to be used in conjunction with cements yielding mixes with an alkali content (Na_2O_e) higher than 2.8 kg m^{-3} (this limit from TR3 (2021) or 3.0 kg m^{-3} (this value from Nsiah-Baafi *et al.* 2019), or with coarse aggregates that could potentially contribute alkalis to the mix.

Please phone if you have any queries.

Yours sincerely,
Forensic and Industrial Science Limited

[redacted]

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PhD MSc PG Dip (Forensic Science)

BREAM BAY SAND: GENERAL PETROGRAPHY AND ASSESSMENT OF POTENTIAL FOR ALKALI-AGGREGATE REACTIVITY IN CONCRETE

general

The sand sample submitted for analysis has been analysed on an as-received basis and is composed of components as tabulated below:

Component	**%**	**Comment**	**reactivity**
Mineral			
quartz	35	coarse monocrystalline, probably volcanic	not reactive
alkali feldspar	10	largely volcanic origin	not reactive
plagioclase feldspar	35	mainly volcanic	not reactive
hornblende	1		not reactive
biotite	0	none observed	not reactive
clinopyroxene	1		not reactive
orthopyroxene	1	probably enstatite	not reactive
magnetite, ulvöspinel	<1	rare, fine grains	not reactive
ilmenite	<1	rare, fine grains	not reactive
Biogenic			
mollusc	6	valve (shell) fragments	not reactive
foraminifera	2	non-agglutinated taxa only	not reactive
echinoid	<<1	plate fragments	not reactive
algae	<<1	calcareous, rare fragments	not reactive
brachiopod	<<1	very rare fragments	not reactive
bryozoa	<<1	rare fragments	not reactive
glauconie	<<1	one grain	not reactive
Lithic			
greywacke, weathered	4	feldspatholithic, contains ?illite-smectite	not reactive
volcanics, andesitic	<1	Rare	not reactive
volcanics, acid	2	well rounded	possibly reactive
metaplutonic	<1	metagabbroid or metadolerite	not reactive
quartz-prehnite vein	<1	probably derived from greywacke	not reactive
chert	<<1	radiolarian, red	not reactive
argillite	<<1	weathered, contains ?illite-smectite	not reactive
unidentified	<1	fine grained, may include acid volcanic	possibly reactive

mineral components

9) Feldspars and quartz comprise the bulk of the sand sample and have petrographic characteristics suggesting a volcanic source. Hornblende and pyroxenes are also probably derived from a volcanic source. It is conceivable that the most abundant mineral components of Bream Bay sand are derived from the Taupo Volcanic Zone. Sources around Bream Bay such as Miocene and Pliocene volcanic units cannot be excluded. Contributions from felsic Cretaceous volcanic units (e.g. equivalents of volcanics at Mt Camel) and Miocene and Pliocene volcanic units cropping out on the Coromandel Peninsula and Great Barrier Island cannot be excluded.

10) Taupo Volcanic Zone components may have been transported via the paleo-Waikato River that prehistorically entered the sea at the Firth of Thames.

11) The abundance of quartz and feldspars in Bream Bay sand suggests it would promote dimensional stability and compressive strength when utilised in concrete.

12) The presence of fine-grained volcanic particles and weathered greywacke may induce higher than average drying shrinkage in concrete incorporating Bream Bay sand. Felsic volcanic particles plus weathered greywacke comprise only ~6% of the sand submitted for examination, and any tendency to increase drying shrinkage is likely to be slight.

biogenic components

13) Most biogenic material appears to be modern and is probably locally derived.

14) The non-foraminiferal biogenic material is well-rounded and appears to be mainly molluscan. The sand-sized biogenic material other than foraminifera is non-friable.

lithic (rock) components

15) Rock particles make up an estimated 6% of the sand examined. Greywacke and volcanic rock types are present.

16) The greywacke is a poorly sorted feldspatholithic sandstone probably derived ultimately from a Northland or Auckland source. It contains a minor phyllosilicate component, possibly illite-smectite.

17) The dominant volcanic particle type within Bream Bay sand is a fine-grained felsic volcanic, probably a rhyolite or rhyodacite. Despite the proximity of the depocenter to *in situ* andesitic volcanics at and around Whangarei Heads, andesitic material is uncommon.

18) Greywacke and volcanic particles present in Bream Bay sand are weathered and oxidised.

19) The felsic volcanic component of Bream Bay sand contains fine material that cannot be positively identified by optical means alone. X-ray diffractometric analysis of a representative fraction of felsic volcanic particles suggests the felsic volcanic material is composed largely of plagioclase feldspar and quartz with no reactive silica phases (tridymite and cristobalite) detected in the material analysed (see Image 13 for diffractogram). Glass and amorphous silica which can be reactive have not been identified by microscopy in any volcanic particles. It should be noted that X-ray diffractometry is not capable of detecting glass or amorphous silica.

20) The greywacke component of Bream Bay sand contain a minor phyllosilicate component. Optical properties of the phyllosilicate phase are consistent with clay, possibly illite-smectite. Positive identification of the phyllosilicate phases would require further X-ray diffractometry which is beyond the scope of this study.

21) The presence of abundant clay minerals in concrete aggregate can lead to relatively high drying shrinkages and associated problems such as dimensional instability of pre-cast and other members (e.g. slab curl).

22) The proportion of clay in the greywacke component of the specimen is not large, and the lithic components themselves make up only ~6% of the total sample, so the sand is unlikely to create dimensional stability problems when used as a fine aggregate.

23) Alteration of greywacke material is consistent with the immediate source being the sandstones and grits of the Waitemata Group that crop out along the Leigh-Pakiri coast. Basal (lowermost) Waitemata Group sediments contain plentiful greywacke detritus.

weathering and friable particles

24) No weathering rinds were observed on any of the particles examined, and no highly friable particles were encountered.

particle rounding

25) Sand particles are subrounded to subangular. Rounder particles promote mix workability but slightly reduce the matrix strength of concrete. Sands made up of particles that are more angular than those in the sample examined (e.g. artificial sands derived from crusher fines) tend to decrease workability and pumpability of concrete.

26) Particle rounding of the sample examined can be regarded as close to optimal for a concrete sand.

potential for alkali-aggregate reactivity

mineral particles

27) None of the minerals listed in the table above except possibly quartz is implicated in alkali-aggregate reaction. Data published by Grattan-Bellew (1992) and Kerrick and Hooton (1992) suggest that quartz is only problematic when it is strained or has submicroscopic silica along grain boundaries. Quartz of this type has not been observed in the sample.

lithic particles

28) While overseas examples of reactivity of greywacke and argillite aggregate have been described, there have to date been no examples of Northland - Auckland greywacke or argillite reacting adversely in concrete.

29) Felsic volcanics derived from the Taupo Volcanic Zone and elsewhere are known to promote alkali-aggregate reactivity in some Portland cement concretes.

30) The potential for the fine-grained volcanic material in Bream Bay sand to participate in alkali-aggregate reaction or to liberate silica is not clear from examination of the sand itself.

31) Felsic volcanic particles may contain tridymite, cristobalite or both of these reactive minerals. While neither of these minerals has been identified, it is not possible to rule

out by petrographic examination alone that small amounts of fine-grained tridymite or cristobalite are nonetheless present within felsic volcanic particles.

32) In general, New Zealand greywackes are with few exceptions well-suited to use as concrete aggregate and are not prone to alkali-aggregate reaction. This comment applies to greywacke gravel and crushed material and by extension to sand-sized greywacke particles. To quote TR3 (2021) (Appendix F, p. 60): "All the New Zealand greywacke samples test as innocuous. Extensive laboratory testing and field experience confirms that our greywackes are non-reactive in concrete at all alkali levels".

33) While some chert is known to be a problematic aggregate in Portland cement concretes, the chert component of the sand sample examined is very low and the chert is a well-recrystallised and relatively coarse variety. There have to date been no descriptions of New Zealand red cherts reacting in concrete. Red chert from McCallum's Island, Hauraki Gulf, has been extensively used as a concrete aggregate in the Auckland region since 1904 without any documented alkali-aggregate reactivity. The very small chert component of the specimens submitted for study is most unlikely to be reactive.

potential to contribute alkalis to concrete

34) Some natural aggregate types that are not in themselves reactive (i.e. do not react with pore fluids in ordinary Portland cement concretes; see Goguel and St John 1993) nonetheless promote alkali-aggregate reaction by releasing alkalis (Goguel 1996, Bérubé *et al.* 1996). St John *et al.* (1998) have recently established that some New Zealand basalts behave this way.

35) Potentially problematic phases that might contribute alkalis to concrete pore fluid (e.g. nepheline; see Freitag et al. 2000; Freitag 1998, 2002; Goguel and Milestone 1997; and TR3 2021, p. 28) have been specifically sought. None was found.

36) Alkali-bearing minerals present in the sand sample are plagioclase feldspar and alkali feldspar. Feldspar minerals are common in many concrete sands. Feldspars are essentially insoluble and are not known to contribute alkalis to concrete pore fluid when present in aggregate.

37) It should be noted that any inadequately washed marine sand will contribute alkalis to concrete. The sample submitted has not been tested for its soluble alkalis content or chloride content.

potential to liberate silica

38) The following components that have the potential to liberate silica and promote alkali-aggregate reaction when present in concrete have been sought:

a) volcanic glass
b) anthropogenic glass
c) acid volcanics
d) pumice
e) opal
f) silica phases other than quartz (tridymite, cristobalite)
g) biogenic silica such as sponge spicules and diatoms.

39) Acid volcanics are present in Bream Bay sand. While it is not possible to exclude the presence of volcanic glass and reactive silica phases via petrographic examination alone, there is no indication that these problematic components are present, and X-ray diffractometric investigation of the felsic volcanic fraction suggests that tridymite and cristobalite are not present in significant quantities.

40) No other potentially problematic components were found.

conclusion

1) For reasons discussed above, there is a slight theoretical potential for volcanic components of Bream Bay sand to participate in alkali-aggregate reactivity if incorporated into Portland cement concrete containing sufficient alkali.

2) Evidence for innocuous behaviour of a concrete sand can be obtained from a problem-free historical record with no recorded incidents of expansive behaviour or alkali-aggregate reaction. TR03 2021 section 6.1 page 27 notes *"If available, data from …. field experience shall take precedence over petrographic analysis, chemical testing or mortar bar testing".*

3) There is however no known commercial use of Bream Bay sand, and samples of concrete prepared with the material are not available for examination.

4) Results to date suggest that Bream Bay sand is likely to be non-reactive, but further testing, in particular mortar bar testing to establish if the material promotes expansion, would be advisable.

5) If any sand is to be used in a mix design having an alkali content (Na_2O_e) higher than 2.8 kg m^{-3} (this limit from TR3 (2021) or 3.0 kg m^{-3} (this value from Nsiah-Baafi *et al.* 2019), or with coarse aggregates that could potentially contribute alkalis to the mix, it would be prudent to assess potential for alkali-aggregate reactivity via a complementary method such as mortar-bar testing.

6) The potential for alkali-aggregate reactivity of Bream Bay sand is for reasons discussed above regarded as slight, and the fact that X-ray diffractometric investigation has not detected problematic phases means there are no obvious barriers to its use in concrete, However the presence of felsic volcanics at an abundance of approximately 2% means that it would be prudent to carry out mortar bar testing to ensure that use of Bream Bay sand in concrete does not cause deleterious expansion.

[redacted]

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28 February 2025

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IMAGES

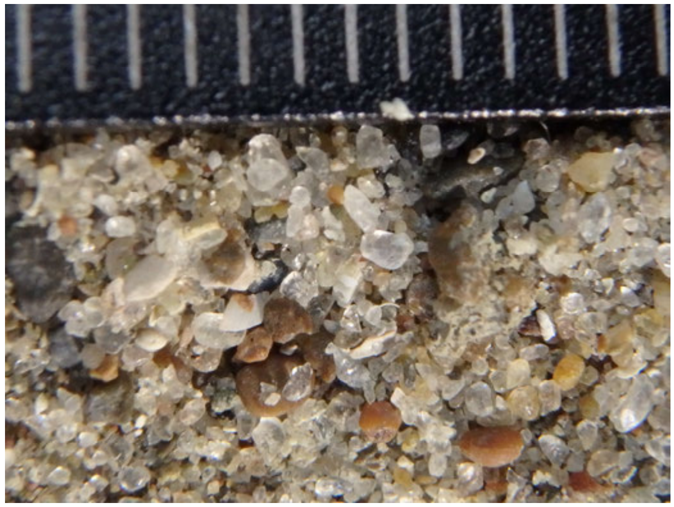


Image 1: Bream Bay sand as submitted. Air-dried. Colourless grains are quartz and feldspar. Small white particles are shell material and foraminifera. Dark grey granules are greywacke. Pale brown granules are felsic volcanics. Scale is in millimetres.

Image 2: Selection of pebbles and granules from coarse fraction of Ponar grab samples of Bream Bay sand. Pale particles at left are felsic volcanics. Grey particles at right are greywacke. All particles are in surface-dry state. Scale is in millimetres and centimetres.

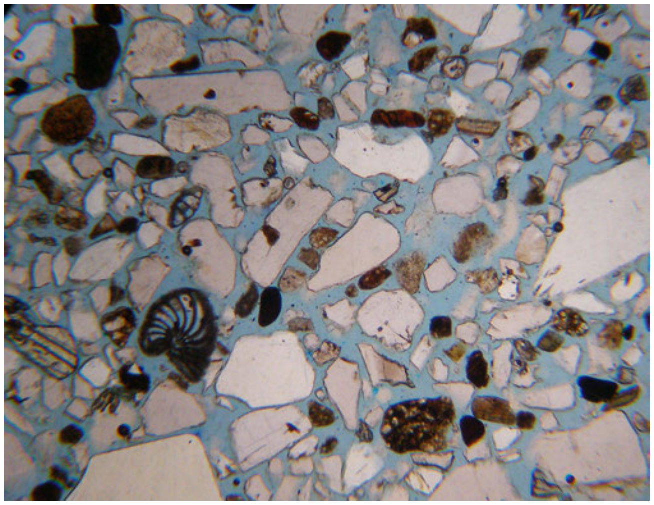


Image 3: Photomicrograph of Bream Bay sand, showing volcanic and sedimentary particles (brown) surrounded by quartz and feldspars (colourless). The biogenic grain lower left) is a foraminiferan. Small mineral grains (translucent browns) are pyroxene and hornblende. Grains are set in pale blue mountant medium. Plane polarised light, width of view 2.6 millimetres.

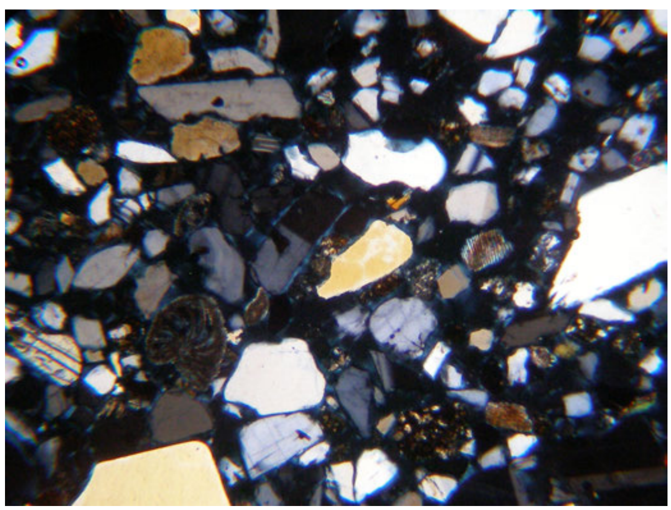


Image 4: Photomicrograph of Bream Bay sand, showing volcanic and sedimentary particles (dark) surrounded by quartz and feldspars (shades of grey, white and cream). Grains are surrounded by dark isotropic mountant medium. Cross polarised light, width of view 2.6 millimetres.

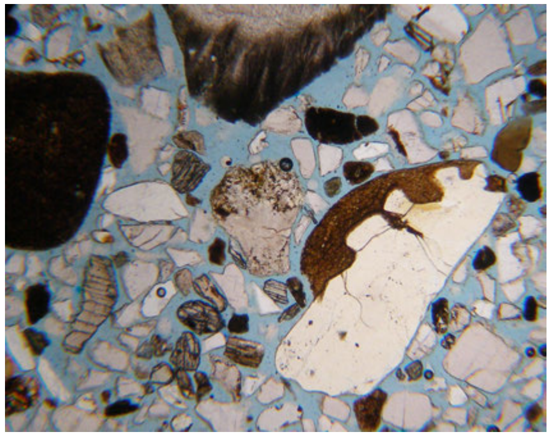


Image 5: Photomicrograph of Bream Bay sand, showing molluscan fragment (shades of brown, top of view) and volcanic and sedimentary particles (brown) surrounded by quartz and feldspars (colourless). The large grain right of centre is a fragment of rhyolite composed of a quartz phenocryst (colourless) with an embayed margin in contact with a remnant of fine-grained quartzofeldspathic matrix (brown). Prominent dark brown particle at left is greywacke. Translucent brown grains are clinopyroxene and orthopyroxene. Grains are set in pale blue mountant medium. Plane polarised light, width of view 2.6 millimetres.

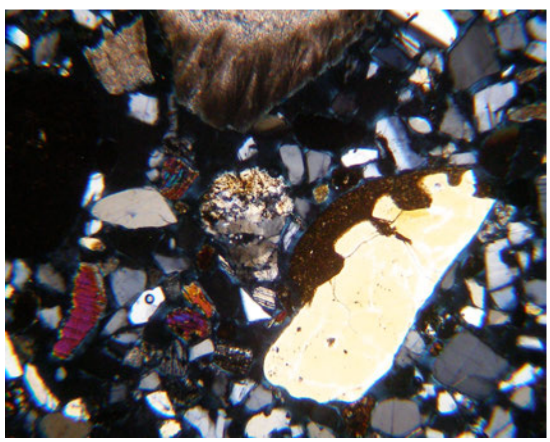


Image 6: Photomicrograph of Bream Bay sand, showing molluscan fragment (top of view) and volcanic and sedimentary particles surrounded by quartz and feldspars (first order grey and white interference colours). The large grain right of centre is a fragment of rhyolite composed of a quartz phenocryst (cream first order interference colours) with an embayed margin in contact with a remnant of fine-grained quartzofeldspathic matrix (brown). Prominent dark particle at left is greywacke. Birefringent grain at lower left showing second-order red colours is clinopyroxene. Grains are set in isotropic mountant medium (dark). Cross polarised light, same field of view as above. Width of view 2.6 millimetres.

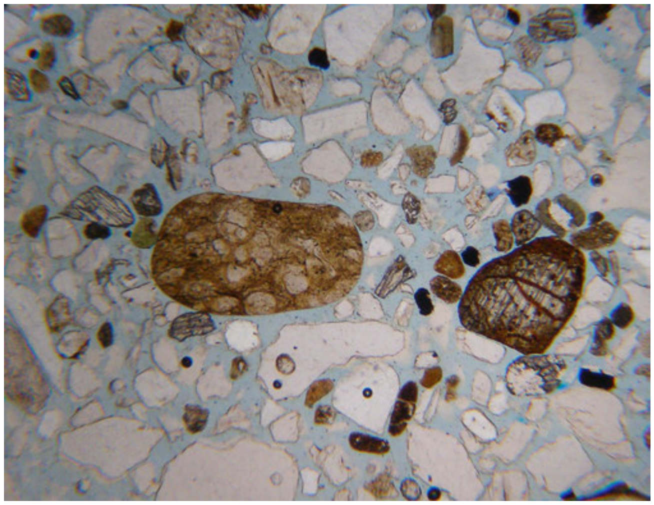


Image 7: Photomicrograph of Bream Bay sand, showing rounded particle of rhyolite (brown, near centre of view) and coarse orthopyroxene (brown, at right) surrounded by quartz and feldspar (colourless), and magnetite and ilmenite (opaque). Prominent mineral grains are clinopyroxene (pale brown) and hornblende (dark brown). Grains are set in pale blue mountant medium. Plane polarised light, width of view 2.6 millimetres.

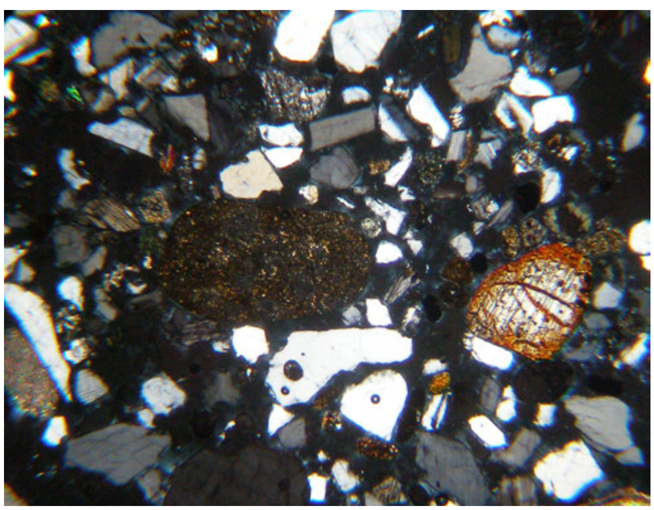


Image 8: Photomicrograph of Bream Bay sand, showing rounded particle of rhyolite (dark, near centre of view) and coarse orthopyroxene (illuminated, at right) surrounded by quartz and feldspar (first-order grey colours). Grains are set in isotropic mountant medium (black). Cross polarised light, same field of view as above. Width of view 2.6 millimetres.

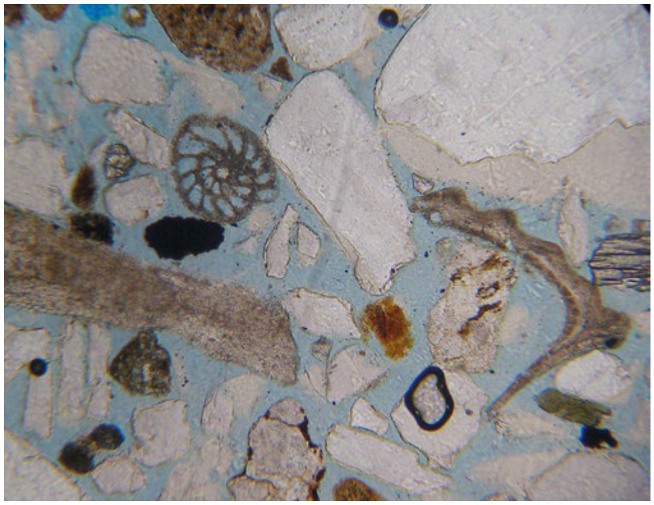


Image 9: Photomicrograph of Bream Bay sand, showing a single foraminiferan (upper left) and coarse molluscan fragments (pale brown and elongate). Colourless grains are quartz and feldspar. Grains are set in pale blue mountant medium. Plane polarised light, width of view 2.6 millimetres.

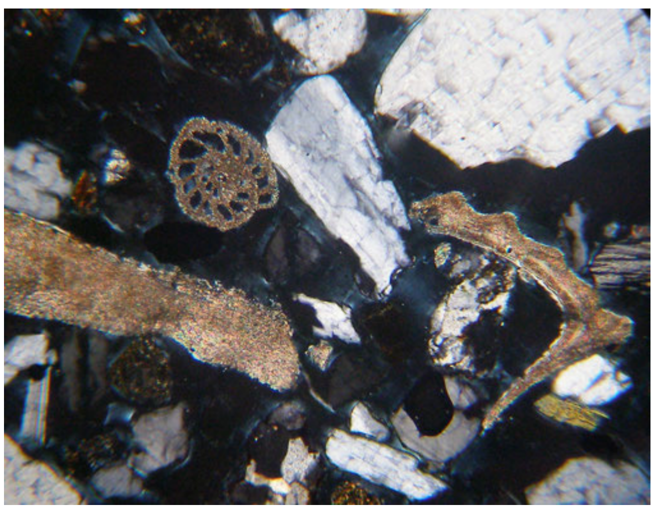


Image 10: Photomicrograph of Bream Bay sand, showing a single foraminiferan (upper left) and coarse molluscan fragments (pale brown and elongate). Quartz and feldspar show first order grey interference colours. Grains are set in isotropic mountant medium (dark). Same field of view as above, crossed polarisers, width of view 2.6 millimetres.

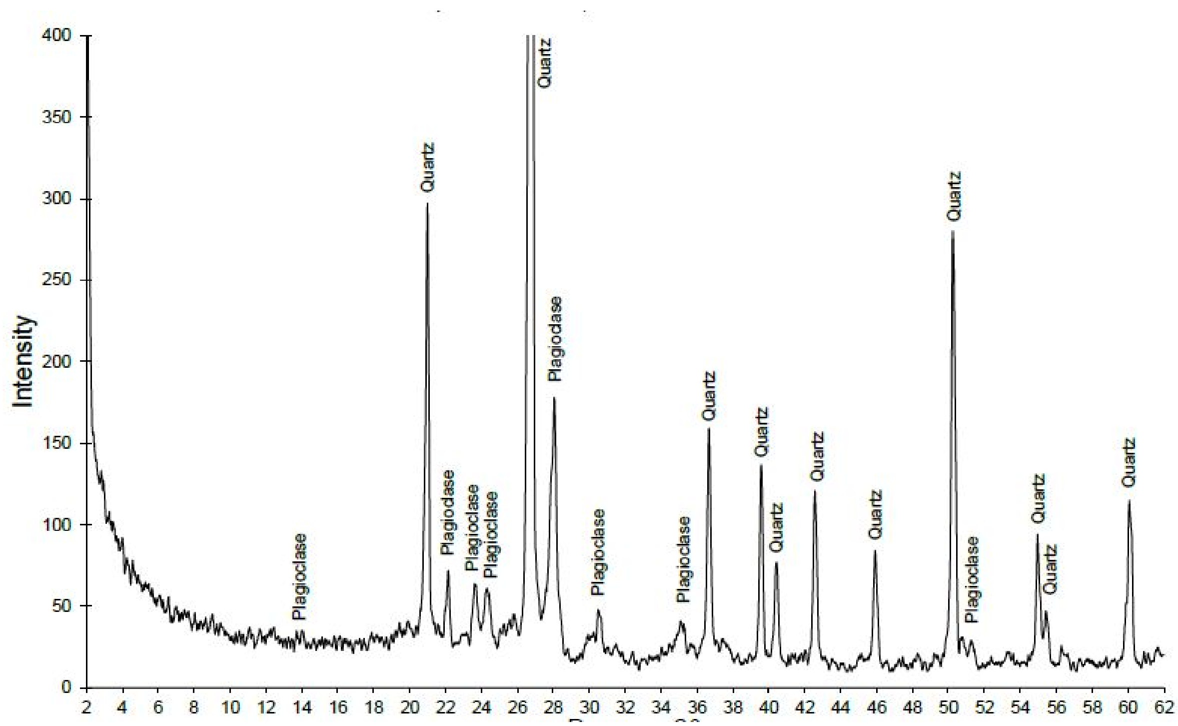
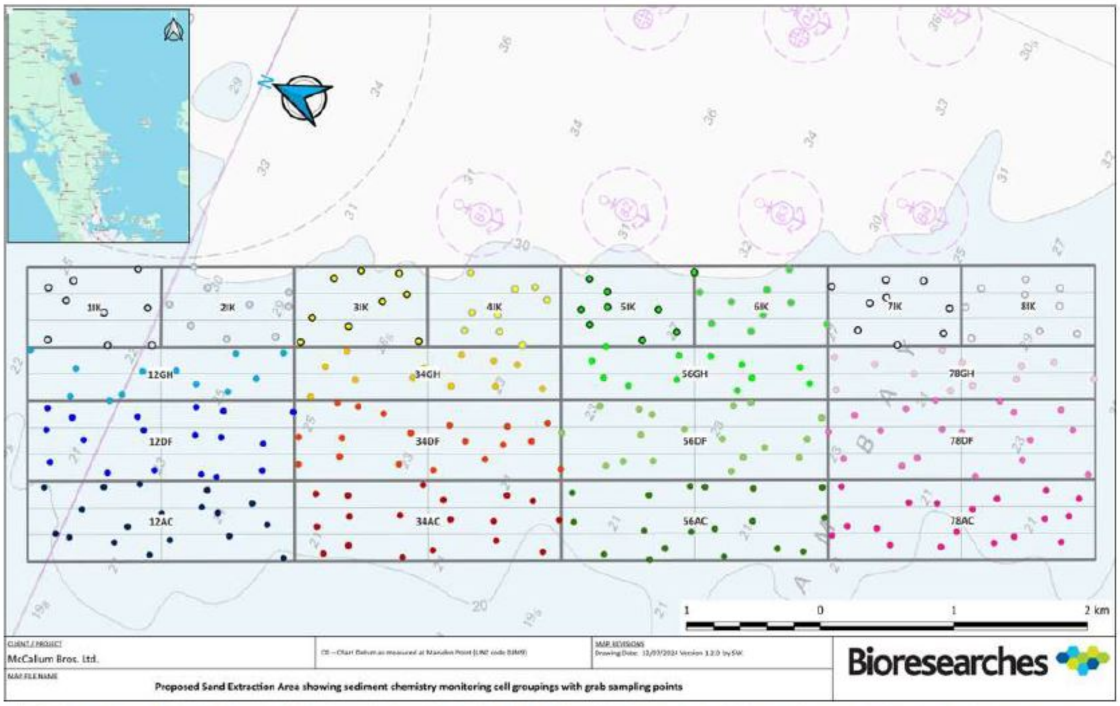


Image 13. X-ray powder diffractogram of representative sand-sized felsic volcanic particles from Bream Bay sand. Only quartz and plagioclase feldspar are detectable. Tridymite and cristobalite (reactive silica phases) were sought but have not been identified, which indicates they are either absent or are present at concentrations below the detection limit for this method (approximately 2% by volume of sample analysed per phase of interest).

APPENDIX 1: SAMPLE LOCATIONS



Ponar grab sample localities, Bream Bay, east coast Northland, New Zealand. Location of area sampled is shown as grey rectangle in inset. Image supplied by McCallum Bros Ltd.

Appendix 2: Stevenson Test Laboratory Test Results for Bream Bay Sand

STEVENSON

Stevenson Aggregates Limited - Laboratory
70 Davies Road, Ramarama, Auckland, 2579
Private Bag 94000, Manukau City, Auckland, 2241
Telephone: 09 984 8600
Facsimile: 09 984 8599
www.stevensonlaboratories.co.nz

Material Test Report

Report No: MAT:DRU24S-05689
Issue No: 1

Client:
MCCALLUM BROS LTD.
PO BOX 71031
ROSEBANK

AUCKLAND 1348
NZ

Project: Production Quality Control

The tests reported herein (unless otherwise indicated) have been performed in accordance with the laboratory's scope of accreditation. Samples are tested as received, in natural condition, unless stated otherwise in the comments. This report may only be reproduced in full.

ACCREDITED IANZ TESTING LABORATORY

The results in this report relate only to the items / samples that were tested

Approved Signatory: James Robinson
(Laboratory Technician)
IANZ Accreditation No:17
Date of Issue: 18/11/2024

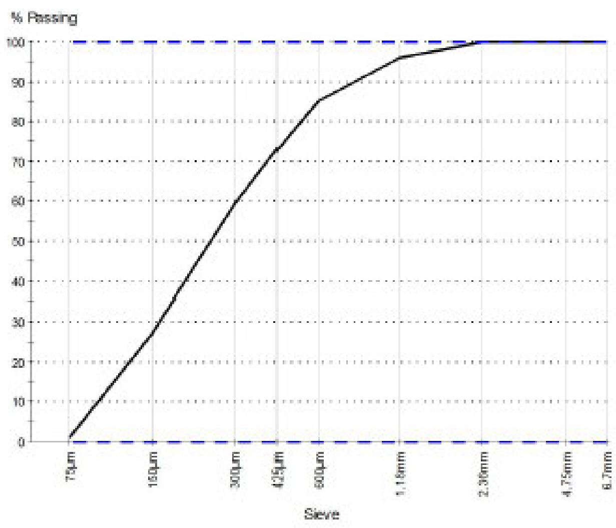
Sample Details

Sample ID:	DRU24S-05689
Client Sample ID:	247821
Lot Number:	Bream Bay
Material:	Sand
Sample Source:	Customer Sample
Site/Sampled From:	Not Specified
Date Sampled:	06/11/2024
Specification:	No Specification (fine all sieves)
Sampled By:	Client
Sampling Method:	As Received - Not Accredited
Technician:	Ashleigh Smith
Sampling Endorsed?:	No

Other Test Results

Description	Method	Result	Limits
Density SSD Basis [kg/m³]	NZS 3111:1986 Test 18	2670	
Density Oven Dry Basis [kg/m³]		2650	
Absorption [%]		0.6	
Date Tested		12/11/2024	
Sand Equivalent	NZS 3111:1986 Test 18	93	
Shaking Method		Mechanical	
Date Tested		8/11/2024	
Mean Flow Rate [s]	NZS 3111:1986 Test 19	22.2	
Voids [%]		46.5	
Percent Oversize Material [%]		0	
NZS 3121 Table 7 Flow Spec [s]			

Particle Size Distribution



Method: NZS 3111:1986 Test 6

Date Tested: 13/11/2024
Tested By: Emma Brosnahan

Sieve Size	% Passing	Limits
6.7mm	100	0 – 100
4.75mm	100	0 – 100
2.36mm	100	0 – 100
1.18mm	96	0 – 100
600µm	85	0 – 100
425µm	73	0 – 100
300µm	59	0 – 100
150µm	27	0 – 100
75µm	1	0 – 100

Comments

Sample condition as received: Natural
Sampling of aggregate and product information is not covered by this report.
Test results apply to sample received.

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Report No: MAT:DRU24S-05689
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Material Test Report

Client:
MCCALLUM BROS LTD.
PO BOX 71031
ROSEBANK

AUCKLAND 1348
NZ

Project: Production Quality Control

The tests reported herein (unless otherwise indicated) have been performed in accordance with the laboratory's scope of accreditation. Samples are tested as received, in natural condition, unless stated otherwise in the comments. This report may only be reproduced in full.

The results in this report relate only to the items / samples that were tested

Approved Signatory: James Robinson
(Laboratory Technician)
IANZ Accreditation No:17
Date of Issue: 18/11/2024

Other Test Results

Description	Method	Result	Limits
Date Tested		13/11/2024	
Fineness Modulus	NZS 3111:1986 Test 6	1.33	
Lightweight Material [%]:	NZS 3111:1986 Test 9	2.5	
Date Tested		18/11/2024	

Comments

Sample condition as received: Natural
Sampling of aggregate and product information is not covered by this report.
Test results apply to sample received.

Appendix 3: Bream Bay Trial Concrete Mixes

		kg/m³ (dry materials)			
Sand Used in Concrete Mix		**Control Kaipara Harbour Sand**	**Bream Bay Sand**	**Control Kaipara Harbour Sand**	**Bream Bay Sand**
Date cast		29-Nov-2024	29-Nov-2024	13-Feb-2025	17-Feb-2025
		Trial 1		Trial 2	
		Mix 1	Mix 2	Mix 3	Mix 4
Free water	litres	165	165	165	165
Total cement	kg	302	302	286	286
19mm Auckland Hunua	kg	390	390	390	390
13mm Auckland Hunua	kg	580	580	580	580
Total Coarse stone	kg	**970**	**970**	**970**	**970**
Pap 7 Auckland Hunua	kg	568	569	572	626
Kaipara marine sand	kg	394	0	398	0
McCallum Bream Bay	kg	0	396	0	308
Total Fine Stone/Sand		**962**	**965**	**970**	**934**
Polyheed 8840	%	0.58	0.58	0.58	0.58
Water cement ratio	ratio	0.55	0.55	0.58	0.58
Trial mix volume	litres	20.0	20.0	20.0	20.0
Slump (NZ3104)	mm	120	110	120	130
Theoretical Density	kg/m³	2401	2404	2372	2357
Design air content	%	1.8	1.8	2.8	3.5
Air content - actual	%	3.2	4.4	2.9	4.2
Yield	litres	1015	1030	1001	1008
Design strength	MPa	30	30	30	30
Strength @ 7 days	MPa	34.7	32.8	30.4	29.4
Strength @ 28 days	MPa	44.6	41.2	38.8	37.3

Appendix 4: Auckland ReadyMix Concrete Plant List and Aggregates Used

Producer	Plant	Coarse aggregate and PAP7	Sand	Manufactured Sand
Allied	Penrose	Brookby	Pākiri Marine[1]	Brookby
Allied	Silverdale	Brookby	Kaipara Marine	
Atlas	Kumeu	Stevenson Drury	Kaipara Marine	
Atlas	Panmure	Stevenson Drury	Kaipara Marine	
Atlas	Silverdale	Stevenson Drury	Kaipara Marine	
Atlas	Takapuna	Stevenson Drury	Kaipara Marine	
Atlas	Wiri	Stevenson Drury	Kaipara Marine	
Bowers Brothers	Riverhead	Stevenson Drury	Kaipara Marine	
Bridgeman	Avondale	Brookby	Tomarata Dune	
Bridgeman	East Tamaki	Brookby	Tomarata Dune	
Bridgeman	Papakura	Brookby	Pākiri Marine: Kaipara Marine (50:50)	
Counties Readymix	Drury	Stevenson Drury	Pākiri Marine	
Firth Industries	Silverdale	Winstone Drury	Kaipara Marine	
Firth Industries	Auckland Airport	Winstone Drury	Kaipara Marine	
Firth Industries	Auckland Central	Winstone Drury	Kaipara Marine	
Firth Industries	Henderson	Winstone Drury	Kaipara Marine	
Firth Industries	Penrose	Winstone Drury	Kaipara Marine	
Firth Industries	Manukua	Winstone Drury	Kaipara Marine	
Firth Industries	Pukekohe	Winstone Drury	Kaipara Marine	
Firth Industries	Waiheke Island	Winstone Drury	Kaipara Marine	
Holcim	Avondale	Brookby	Kaipara Marine	
Holcim	Bombay	Brookby	Waikato River sand	
Hynds	Pokeno	Brookby	Pākiri Marine	
TT Concrete	Mangere	Stevenson Drury	Waikato River	
Wilson Tunneling	East Tamaki	Brookby	Pākiri Marine	

1. Allied Concrete Penrose uses a high proportion of manufactured sand in lower grades of concrete but use a high proportion (10-20% of total constituents) of marine sand in specialist mixes and high strength concretes