Assessment of Marine Sediments Adjacent to Fisherman Islands 2021

Reference: R.B23621.013.01.MarineSediment_2021.docx
Date: January 2022
Confidential

Document Control Sheet

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	Title:	Assessment of Marine Sediments Adjacent to Fisherman Islands 2021
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Synopsis: **Findings of the 2021 marine sediment monitoring program at the Port of Brisbane, Queensland. Comparison with historical data points from 1992, 1998, 2009, and 2015 were used to determine broad scale sediment shifts within the study area.**

REVISION/CHECKING HISTORY

Revision Number	Date	Checked by		Issued by	
0	30th September 2021	DLR	[signature]	DLR	[signature]
1	28th January 2022			BEH	[signature]

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Executive Summary

Background

The Port of Brisbane Pty Ltd has its main port infrastructure at Fisherman Islands, a group of small deltaic islands reclaimed at the mouth of the Brisbane River. Previous studies have identified the potential for port reclamation works to cause localised changes to intertidal and subtidal habitats in the vicinity of Fisherman Islands. Such changes included modification of bed sediment characteristics and sedimentation processes through potential alterations to tidal current dynamics and the direction of freshwater flow from the Brisbane River.

The main objectives of the study were to describe the broad scale spatial patterns in sediment particle size composition within the vicinity of Fisherman Islands and to identify potential temporal changes in sediment patterns by comparing the results of the present study with previous investigations (WBM 1992, WBM 1998, BMT WBM 2010; 2015).

A total of 37 sites were sampled for the analysis of particle size distribution (PSD) in the present survey. The sampling methodology and sites were consistent with previous studies undertaken by BMT WBM within the study area. Surface samples were collected using a van Veen grab and analysed for PSD by sieve analysis (minimum sieve size = 0.075mm). In addition, the free-fall penetrometer (FFP) was deployed at 53 sample sites. The FFP is capable of *in situ* geotechnical investigation of the uppermost seabed layers with analysis based on high resolution deceleration-time signatures.

Findings

The overall long-term trend of increasing fines in the period 1998 to 2015 were largely reversed in 2021. With no major flood events, and only ex-Cyclone Debbie in 2017 bringing strong winds and waves, much of the mud observed in 2015 had largely been dispersed from the study area.

The area that continued to see a continued long-term increase in mud content was the south-eastern edge of the FPE seawall. The more quiescent nature of nearshore areas of Fisherman Islands represents a depositional environment and will tend to slowly accumulate muds over long timeframes. This is supported by previous modelling (WBM 2000), which suggested a reduction in flow velocities at the south-eastern edge of the seawall and potential increase in silty material during particular wind and tidal regimes.

Previous modelling also suggested an increase in flow velocities across the truncated north-western FPE seawall, which has been designed to minimise local disturbance of the seabed. The sample site at this location showing no major changes in PSD.

The largest shifts in particle size distribution were observed at the mouth of Boat Passage. The dramatic increase in mud content observed between 2009-2015 was reversed in 2021. This includes the intertidal flats to the southeast of the mangroves which saw a transition back to 2009 mud percentages. This area is also highly influenced by seagrass species *Z. muelleri* and *H. spinulosa*; who's ability to retain fine particulate gives credence to 2015 results being largely influenced by extreme weather events since lower mud content in seagrass meadows over time is atypical.

Two other areas of interest were the shallow shoal extending from the FPE to the channel east of St. Helena Island, and the channel itself. The shoal has been attributed to a remnant of the Brisbane River mouth, and largely consists of medium sands that experience high current velocities and is exposed to wind waves from the north-east.

This area has remained consistent over time. The channel that runs north south to the east of St. Helena and Green Islands saw a decrease in muds in 2015 that reversed course and increased in 2021. Analysis of the Free-Fall Penetrometer deceleration patterns revealed a shallow layer (20cm) of unconsolidated muds over sand in the deeper sections.

Overall, broad scale sediment patterns in the study area conform to patterns in seabed bathymetry and hydrodynamic processes. Fine sediment fractions were more abundant in sheltered areas and in deeper channels. Medium sands were the dominant sediment type in the study area and mainly found in offshore intertidal areas between Fisherman and St Helena Islands. Higher bed shear stresses are common in these relatively exposed and shallow areas and wave action is expected to be higher compared to sheltered nearshore areas and deeper channels.

Key Findings:

- Sediments PSD in 2021 largely returned to ‘baseline’ conditions observed prior to 2011 and 2013 flood events.
- A continued increase in mud around the south-eastern edge of the FPE seawall was observed, in agreement with past modelling of wind and wave alterations caused by the expansion of Fisherman Islands.
- No major change to the particle size distribution was observed at the north-eastern tip of the FPE seawall (i.e. seawall truncation).
- Large variations in particle size distribution occurred spatially and temporally at the mouth of Boat Passage. This was likely influenced by channel migration, intertidal flats, seagrass meadow dynamics and flood events.
- The free-fall penetrometer was successfully able to determine surficial sediment types which generally fell into three categories: mud, sand, mud over sand.

Contents

List of Figures

List of Tables

1 Introduction

1.1 Background

The Port of Brisbane Pty Ltd (PBPL) has its main port infrastructure at Fisherman Islands, situated at the mouth of the Brisbane River. The port facilities at the river mouth have been established on land reclaimed over a shallow sub-tidal river delta containing a series of low-lying mangrove islands, collectively called Fisherman Islands. As shown in Figure 1-1, reclamation has largely been a continuous process since the 1960's with major steps forward in the mid-1990's ("Superbund") and early 2000's (Future Port Expansion – FPE). Since completion of the FPE seawall the Port of Brisbane has continued to monitor sediments within the Waterloo Bay/ Fisherman Islands area on a broad spatial scale.

An investigation on the hydrodynamics and sedimentary characteristics (WBM 1992) and Impact Assessment Studies (WBM 2000) had identified the potential for port expansion works to cause localised changes to intertidal and subtidal habitats in the vicinity of Fisherman Islands. Such changes included the modification of bed sediment characteristics and sedimentation processes through altering tidal current dynamics and the direction of freshwater flow from the Brisbane River.

An investigation conducted by WBM (1998) found minor shifts in sediment composition post construction of port reclamation works in the mid-1990s. Further investigations by WBM BMT in 2009 and 2015 indicated that the former saw no major broad scale changes in sediment patterns. However, the latter investigation in 2015 was conducted post flood, major flooding in 2011 and minor flooding in 2013. Consistent with these large-scale fluvial disturbances, an increased mud proportion and larger variation overall was recorded.

1.2 Study Aims and Objectives

The present study was commissioned by the PBPL and is a continuation of the BMT WBM (2015) study. The study aims to catalogue spatial and temporal changes in the characteristics of bed sediments adjacent to Fisherman Islands through ongoing surveys of particle size distribution (PSD) of marine sediment.

The specific objectives of this study were to:

- Identify and describe broad scale spatial patterns in sediment grain size composition, and using a free-fall penetrometer, the sediment hardness within the vicinity of Fisherman Islands;
- Describe temporal changes to sediment grain size composition based on data collected in the present study and previous studies in the Fisherman Islands area (WBM 1992, WBM 1998, BMT WBM 2010, BMT WBM 2015); and
- Discuss any evidence of changes to sediment grain size that may have resulted from the Port of Brisbane's activities.

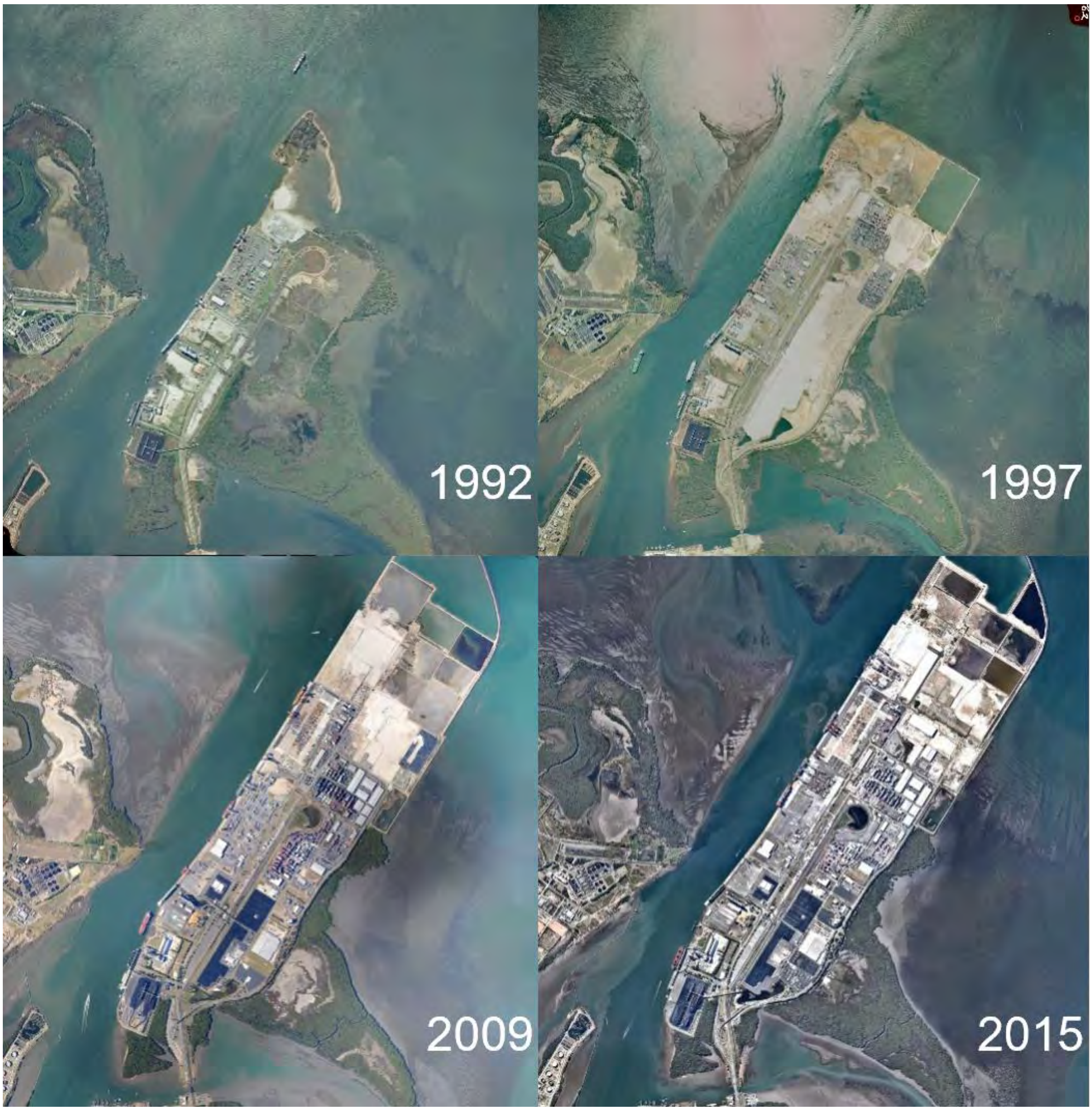

Figure 1-1 Aerial photography of Fisherman Islands over the course of previous marine sediment investigations (Imagery courtesy of QImagery and Nearmaps)

2 Methodology

2.1 Particle Size Distribution Analysis

2.1.1 Sampling Design and Sample Collection

The PSD sampling methodology and site locations of the 2021 survey are consistent with methodologies used in previous studies undertaken by BMT WBM within the study area (WBM 1992, WBM 1998, BMT WBM 2010; 2015). A total of 37 PSD sites were sampled in the present survey (refer to Figure 1-1). Some sites previously sampled in 1992 and 1998 were not sampled in subsequent surveys, namely sites 1, 3, and G that are now situated within the FPE reclamation area, and site S on the Brisbane River.

Location and navigation to sites was undertaken using a Garmin GPSMap 78. Sediment samples were collected using a stainless steel Van Veen grab with a surface gape of 0.028m^2. Only whole grab samples (i.e. those in which the sampler jaws remained closed following the sample capture) were retained for analysis. Sediment and collected overlying waters were placed into a plastic sample tray. BMT WBM (2010) have determined that small-scale variability observed between duplicate samples collected at each site within the study area averaged 3-4% (±3%). To account for this small-scale variation within sites at least three grabs were collected at each site. These replicate samples were then homogenised and a subsample of this material (weighing at least 2 kilograms) was transferred into pre-labelled plastic zip locked bags to provide a single representative sample at each site. The van Veen grab, sample trays and utensils were rinsed with seawater between samples to avoid cross contamination of samples.

During collection, samples were photographed, and the following details recorded on standardised pro-forma (Appendix A):

- Sample weight;
- Sediment colour;
- Sediment odour;
- Plasticity;
- Field texture (i.e. fine sand, coarse sand, silts, shell fragments etc);
- % shell fragments present;
- Presence of organic material or any foreign objects; and
- Presence of any marine flora and fauna.

Title:

PSD analysis sampling sites 2021

Figure: 2-1

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BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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2.1.2 Laboratory Analysis

Sediment samples were sent to ALS Environmental for analysis of PSD. Sediments were passed through a series of Australian standard sieves identifying particle size down to 0.075 mm. Furthermore, sample moisture was measured at all sites.

Six samples were also analysed through hydrometer analysis to determine particle size down to 1 µm. This further analysis was undertaken to allow an estimation of the proportion of material within smaller size categories. Particle density was also measured in the six samples subject to hydrometric analysis was conducted. Sites for hydrometric analysis were chosen based on results of previous years to allow comparison of this data between sampling campaigns.

2.1.3 Data Analysis

PSD data from the present study and previous WBM studies were collated. Since PSD data from all studies were determined using the same Australian standard sieves, direct data comparisons can be made between studies.

The PSD results are described hereafter for the percentage composition of the particle size fractions shown in Table 2-1. Some comparisons collate the three sand categories into one; and D_{50} is also used in analysis which represents the 50% cumulative percentile value. The term 'mud' has previously been used to describe the particle size fractions under 0.075 mm (including silts and clays); however, the term 'mud' can have several meanings, yet for consistency across reporting we will continue to use this terminology unless otherwise noted.

Table 2-1 Particle grain size fractions adopted in the present study. *Clay fraction was measured at six sites

Size Fraction	Sediment size
Clay*	Grain size less than 0.002 mm
Clays/Silts	Grain size less than 0.075 mm
Fine grain sand	Grain size of 0.075 mm to 0.15 mm
Medium grain sand	Grain size of 0.15 mm to 0.60 mm
Coarse grain sand	Grain size of 0.60 mm to 2.36 mm
Shell grit/gravel	Grain size over 2.36 mm

Data were collated into GIS to illustrate the following spatial and temporal trends:

- Distribution of silt/clays, fine sands, medium sands, coarse sand and shell grit/gravel; and
- % change in proportion of silt/clays and fine sand, medium sand and coarse sand material between each sampling episode.

WBM (1998) study used different criteria to describe the bounds/limits for the various particle size fractions described in Table 2-1. The results presented here conform with more widely accepted methods for defining sediment fractions/classes and are consistent with BMT WBM (2010; 2015). Data from all years are based on the same sediment fraction classes to enable direct comparisons among years.

2.2 Penetrometer

A free-fall penetrometer (FFP) was used to gauge seabed geotechnical characteristics. The FFP is a small torpedo shaped device that is deployed *in situ* and able to extract the geotechnical characteristics of surficial sediment from a deceleration profile upon impact. This allows for a very high-resolution qualitative dataset for the top layer of sediment up to the maximum depth of penetration.

The most common and valued tool in terrestrial *in situ* testing is the standard penetration test (SPT). The SPT measures the strength or stiffness of the soil in the form of a blow count. A falling hammer drives a probe into the soil, measuring the blow count determines the resistance to dynamic penetration. A sufficient step up in complexity is the cone penetration test (CPT). A metal probe is (usually) hydraulically pushed into the ground at a steady rate while penetration resistance is measured. However, neither of these tools is ideally suited to the highly energetic marine coastal zone like the FFP.

The BlueDrop FFP is a small (63cm long), light (9.15 kg) torpedo shaped instrument design to collect in situ measurements of surficial seafloor sediments. The probe has eight sampling instruments: one pressure gauge (PSI), two horizontal accelerometers (+/- 55 g x and y), and five vertical accelerometers (± 1.7 g, 18 g, 50 g, 200 g, 250 g). The sampling rate is 2kHz at a resolution of 24 bit, allowing for all eight sensors to record simultaneously. The pressure gauge is located just behind the tip of the device and protected with a porous ring membrane. The accelerometers measuring gravitation acceleration/deceleration, can create a high-resolution picture of the top layers of sediment creating a deceleration-time signature of the seabed (Albatal and Stark 2017) that can be used to identify the sediment types along with overall geotechnical characteristics. The acceleration, combined with the surface area of the penetrometers cone, velocity upon sediment entry, and time of sediment penetration combine to give the user substantial information on the seabeds surficial sediment qualities, including Quasi Static Bearing Capacity, and Firmness Factor (F_f) (Mulukutla *et al.* 2011). F_f is defined by the following equation: a

$$\mathrm{Ff} = \frac{a_{max}}{g t_t v_i}$$

where a_{max} is the peak acceleration in m/s^2, g is the acceleration due to gravity in m/s^2, v_i is the impact velocity in m/s and t_t is the total duration of embedment in seconds. By using F_f we can account for shallower drops (<2 m) not reaching terminal velocity and still compare among sites.

The penetrometer was deployed at the Seagrass Monitoring Program sample sites (BMT 2021) and the PSD sample sites with a minimum depth of ~2 m during the field acquisition. This allowed for a greater sample spacing and data to be used across studies. Three samples were conducted at each location and the results were averaged and F_f calculated.

3 Results

3.1 Spatial Patterns 2021

This section describes spatial patterns in PSD measured in 2021. Particle size analysis results of cumulative distribution plots for all study sites are provided in Appendix B.

3.1.1 Patterns in Size Fraction

Figure 3-1 is a ternary diagram of PSD showing % mud, sand, and gravel measured at each site. The dominant sediment class was sand, followed by mud. Very little gravel was present across all sites.

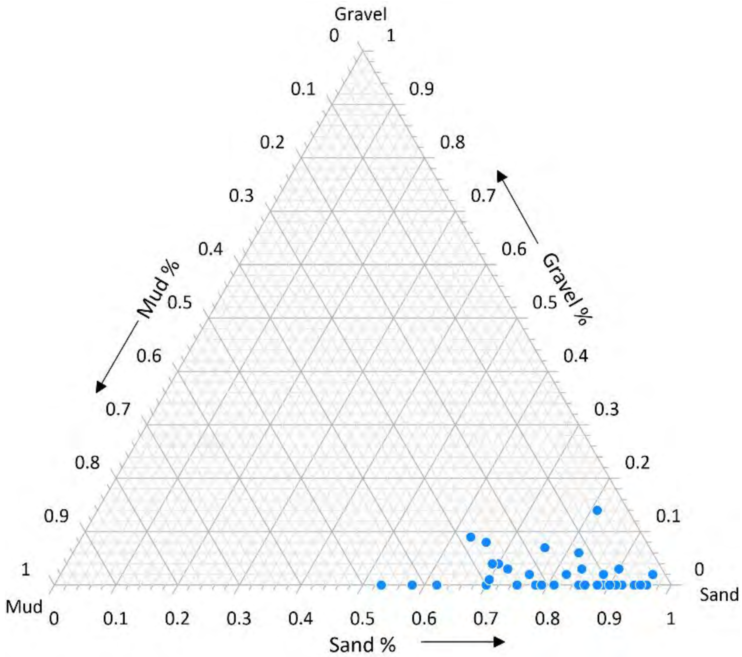


Figure 3-1 Ternary particle size distribution showing % sand (bottom right), % mud (bottom left), and % gravel (top)

Figure 3-2 presents median (D_{50}) sediment grain size contours interpolated from PSD samples. Smaller fraction sizes were prevalent in the deeper channel west of St. Helena and Green Islands, and in the area west of the boundary of between the FPE seawall and mangroves (adjacent to the bird hide). Predominantly sandy sediments were present along the FPE seawall and the sand shoal extending between Fisherman Islands towards St. Helena Island. Larger particle sizes were also dominant on intertidal flats to the north of Boat Passage.

3.1.1.1 Silt/Clays

Figure 3-3 shows the distribution of all particle grain size classes. Silt/clays (<0.075 mm) were generally most prevalent (>25%) in the deeper channel area west of St. Helena and Green Islands. Silt/clays were also prevalent at sites at the mouth of Boat Passage, and adjacent to Fisherman Islands (A, E, F, 7) and shallow mangrove regions (11, 16). The proportion of silt/clay ranged between 2% at site 9 and 47% at site 22.

Hydrometer analyses were undertaken on samples from sites 6, 11, 16, B, O, and P. The results indicated an average clay content (<0.002 mm) of 10% and ranging between 4% at sites B and O and 23% at site 6.

3.1.1.2 Fine Sand

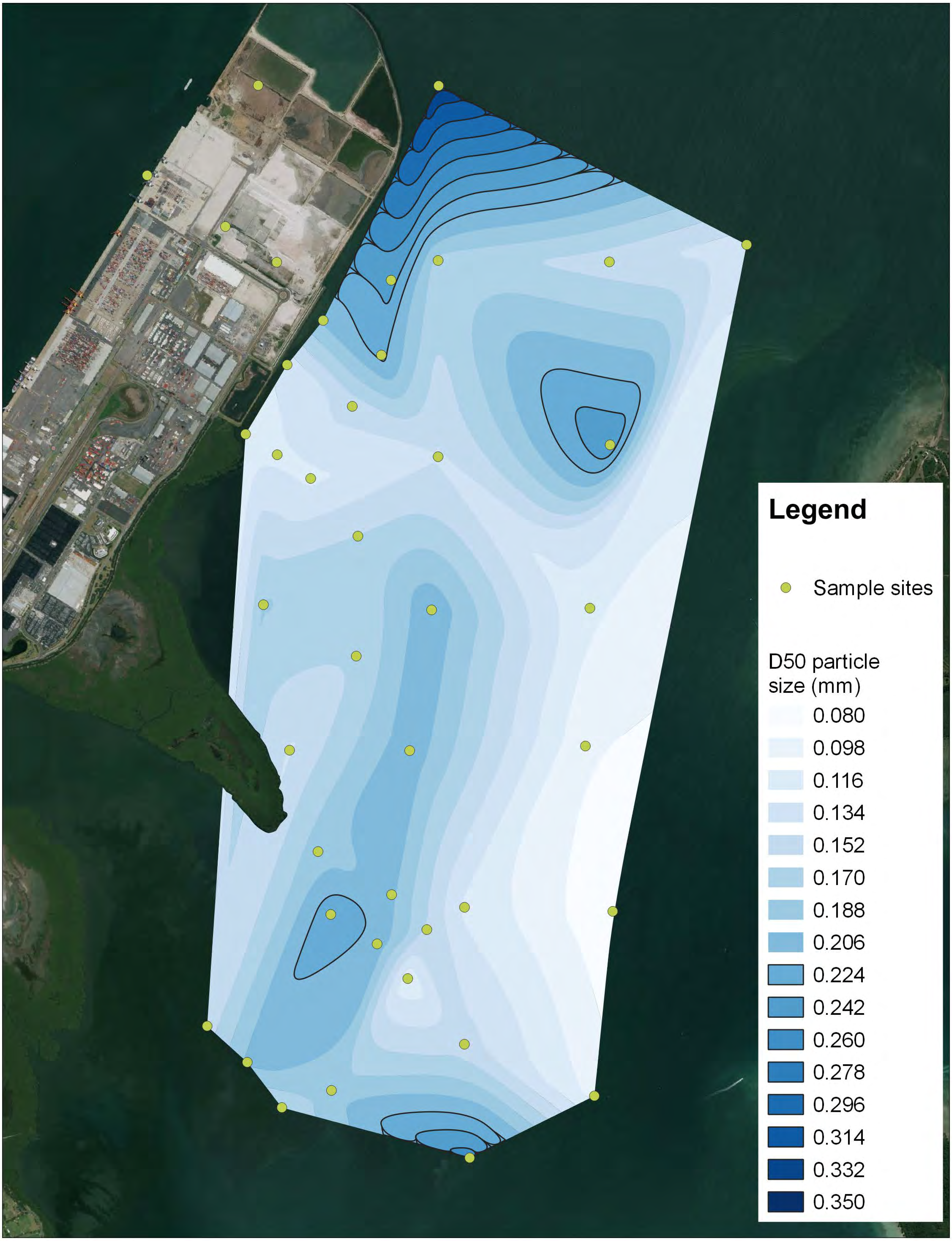
The proportion of fine sands (Figure 3-3) ranged between 4% at sites 2 and 9, and 73% at site 26. Fine sands displayed similar spatial patterns to silts, with the highest finer sand proportions recorded in the deeper channel area west of St. Helena and Green Islands (6, 13, 18, 22, 26). This pattern continues at the south side of Boat Passage having sites (24, P, Q, R) averaging just over 30% fine sand. Areas adjacent to Fisherman Islands (7, A, B, E, F) and the mangroves (11, 16, K) also had a higher proportion of fine sand, but this proportion declined with increasing distance from mangroves (C, H).

3.1.1.3 Medium Sand

Medium sand was the dominant particle fraction within the study area (Figure 3-3). Intertidal areas north of the mouth of Boat passage had the highest proportion of medium sand, with site 20 having 88%. Sample sites adjacent to the FPE seawall also had a high medium sand content (>65%) as well as site 9 (82%) on the shoal close to St. Helena Island.

3.1.1.4 Coarse Sand and Shell Grit/Gravel

The larger grain size classes represented a minor proportion of the PSD, averaging 3% and 2% for coarse sand and gravel respectively. The highest proportion of coarser fractions was recorded at site 2 located near the truncated curvature of the FPE seawall and site 29 in the channel west of Green Island and the most south eastern sample site. Site 2 had 12% coarse sand and 7% gravel. Site 29 contained 6% coarse sand and 14% gravel.



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2021 smoothed contour lines of sample sites D50 particle size distribution

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Percentage pie chart PSD from 2021 sampling.

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3.1.2 Bulk Density

Bulk density was analysed in six samples. Bulk density ranged from 0.818 t/m^3 to 1.360 t/m^3 (Table 3-1), and was negatively correlated with silt content (r = -0.96, p = 0.001). This trend reflects the higher proportion of pore space in fine sediment fractions compared with coarser sediment.

Table 3-1 Bulk Density Measurements and Corresponding Sediment Type

Sample	Bulk Density (t/m^3)	Clay (%)	Silt (%)	Sands (%)	Gravel (%)
6	0.818	23	14	62	0
11	0.996	13	8	77	2
16	1.090	9	5	86	0
B	1.360	4	1	94	1
O	1.250	4	2	91	3
P	1.180	8	3	89	0

3.1.3 Penetrometer

Free-fall penetrometer (FFP) metrics are presented in Appendix C, and results are summarised for selected metrics in Figure 3-4 (deceleration profiles) and Figure 3-6 (firmness factor - F_f). A total of 159 samples were collected at 53 sites (triplicates), nine of which were coincident with PSD sites.

The FFP results were largely consistent with trends in PSD, with some exceptions. The areas with the highest F_f were the sandy shoal on the edge of the deeper channel west of St. Helena Island. This shoal is continuous towards the FPE seawall and sites here have higher percentages of medium sand (9, C, D, H). Areas north of the shoal and in deeper waters largely consist of unconsolidated mud layers allowing for penetration depths exceeding 65 cm (as opposed to hard sand, > 10 cm). Areas south of the shoal on the edge of the navigation channel west of St. Helena Island consistently had F_f values approaching 10. This is the result of unconsolidated mud layers overtop harder sand, which can be seen in Figure 3-4. The comparison of deceleration profiles captures the three distinct profiles seen across the survey area: sand, mud, and mud over sand.

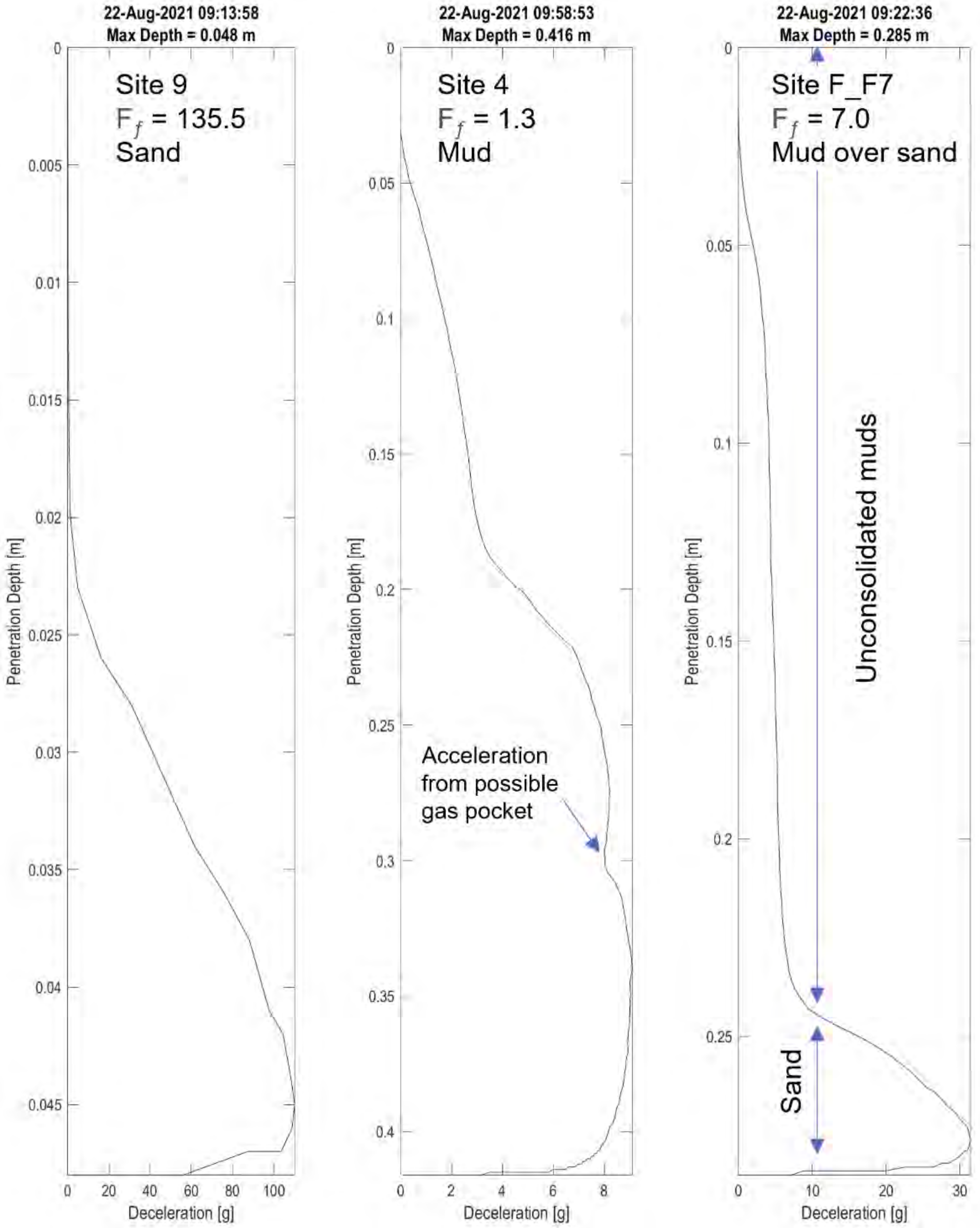
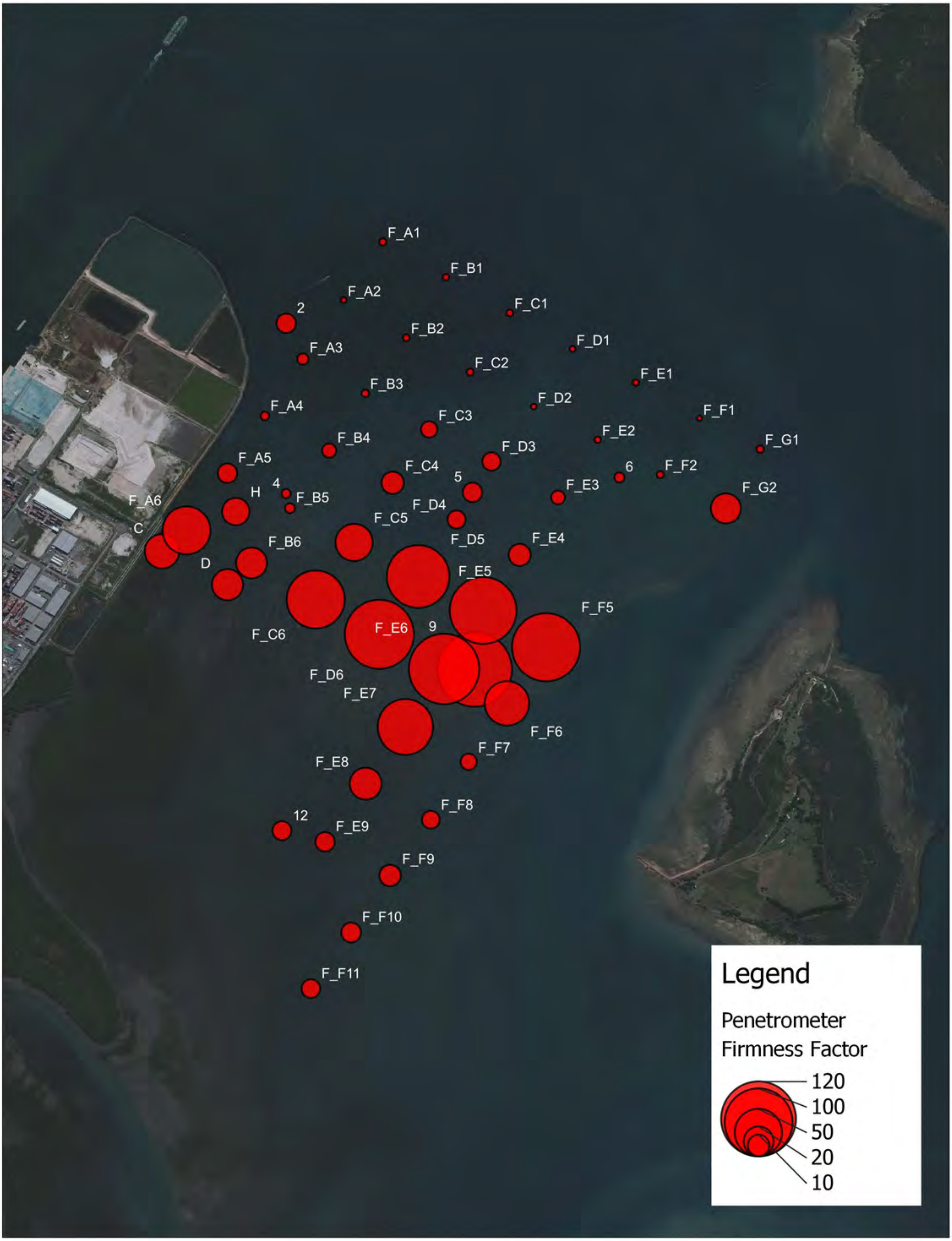


Figure 3-4 The three main deceleration profiles seen across the survey region, sand, mud, mud over sand. Note x and y axis scales vary across the three graphs



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Firmness Factor for Penetrometer drops

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3.2 Temporal Patterns

Temporal patterns are described with reference to results of surveys conducted in 1992 (WBM 1992), 1998 (WBM 1998) 2009 (BMT WBM 2010), 2015 (BMT WBM 2015) and the present study.

The average (+/- standard error of the mean) proportion of silt/clay, sand and gravel fraction in each year is shown in Figure 3-6. To allows like for like comparisons within different sediment classes, sites were grouped into two substrate classes:

- muddy sites – >50% cumulative sediment passing through the 0.15 mm sieve
- sandy sites - <50% cumulative sediment pass through the 0.15 mm sieve.

In both substrate classes, a higher proportion of mud was observed in 1992 and 2015 than other years. By contrast, the average mud content in 1998, 2009, and 2021 was similar among years, but the large standard deviation show there was a high degree of variation among sampling sites within years.

PSD plots for each site and year are presented in Figure 3-7 to Figure 3-13. Figures 3-x through 3-present smoothed contour lines represent the % change from survey to survey. Muds, fine sand, and medium sand are represented. There was little change in the larger sediment classes, therefore these data are not presented.

In terms of sites displaying large temporal changes in sediment grain size:

- Site 6 (Figure 3-14), the most north-eastern sample site close to the St. Helena Island channel, displayed:
  - A decrease of 28% in muds from 2015 to 2021 with an increase in fine sands (21%) over the same period with all other sediment types staying largely the same
  - A decrease of 19% in muds since 2009 and an increase in fine sands (19%) over the same period with all other sediment types staying largely the same
- Site 13 (Figure 3-15), located on the opposite side of the channel from the St. Helena Island pier, displayed:
  - A decrease of 17% in muds from 2015 to 2021, a reduction in fine sand (-13%), an increase of 29% medium sand, and coarse sand and gravel remaining constant
  - A decrease of 29% muds since 2009, a slight decrease in fine sands (-2%) and a large increase in medium sand (30%) with remaining classes staying the same
- Site 24 (Figure 3-16), at the mouth of Boat Passage, displayed:
  - A decrease of 88% muds from 2015 to 2021, an increase of 24% fine sands, a 65% increase in medium sands, and the remaining sediment classes staying the same
  - A decrease of 40% muds since 2009 with a corresponding increase in fine sand (11%) and medium sand (34%), and the remaining sediment classes staying the same
  - From 1992 to 2009, site 24 remained within a consistent proportional range (46%-65%) of mud with a large increase in 2015 containing 94% mud followed by the present day of 6% in 2021

- *Zostera muelleri* and *Halophila ovalis* were also present in the 2021 sediment sample, but was not recorded in samples in previous years.

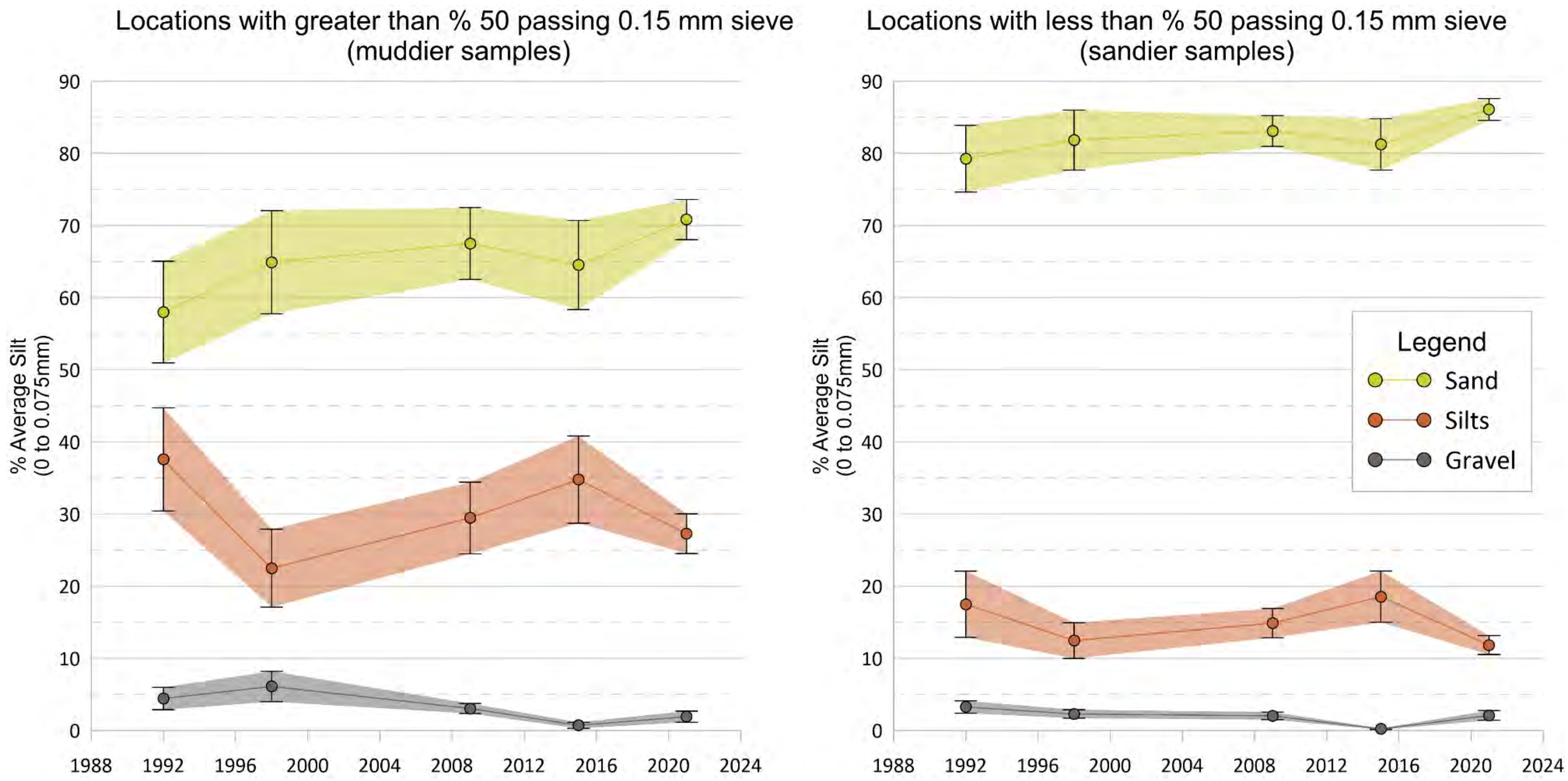


Figure 3-6 Mean percentage of silt (bottom), sand (middle), and gravel (top), over time with Standard Error of the Mean error bars. Graph separation is based on 2021 percentages of sites whereby % 50 of sediment passed through the 0.15 mm sieve (6, 7, 13, 16, 18, 21, 22, 26, A, E, F, Q) and less than % 50 passing through the 0.15 mm sieve (2, 4, 5, 8, 9, 11, 12, 17, 20, 24, 25, 29, B, C, D, H, I, J, K, L, M, N, O, P, R)

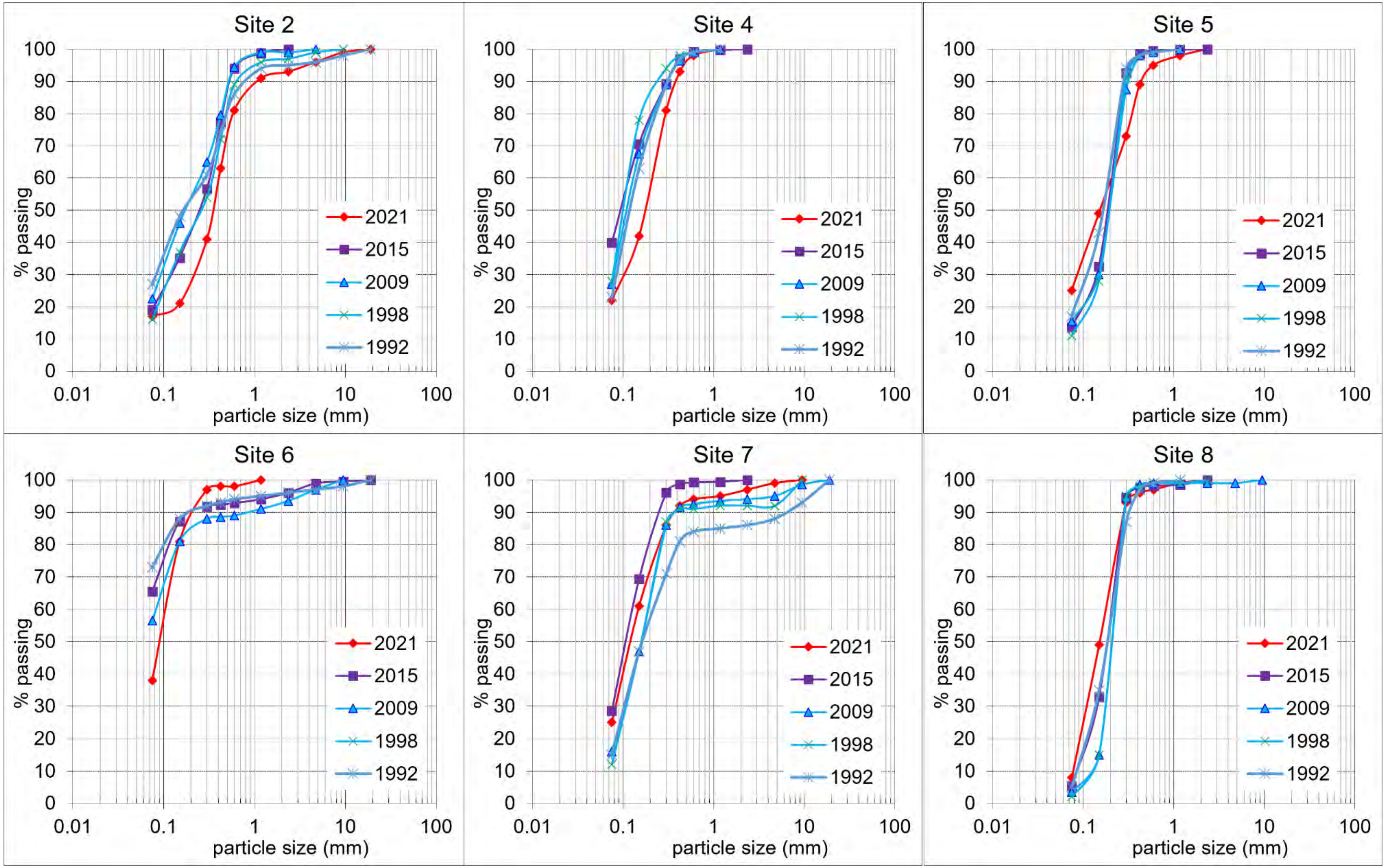


Figure 3-7 Cumulative sediment mass passing each sieve size - sites 2 to 8

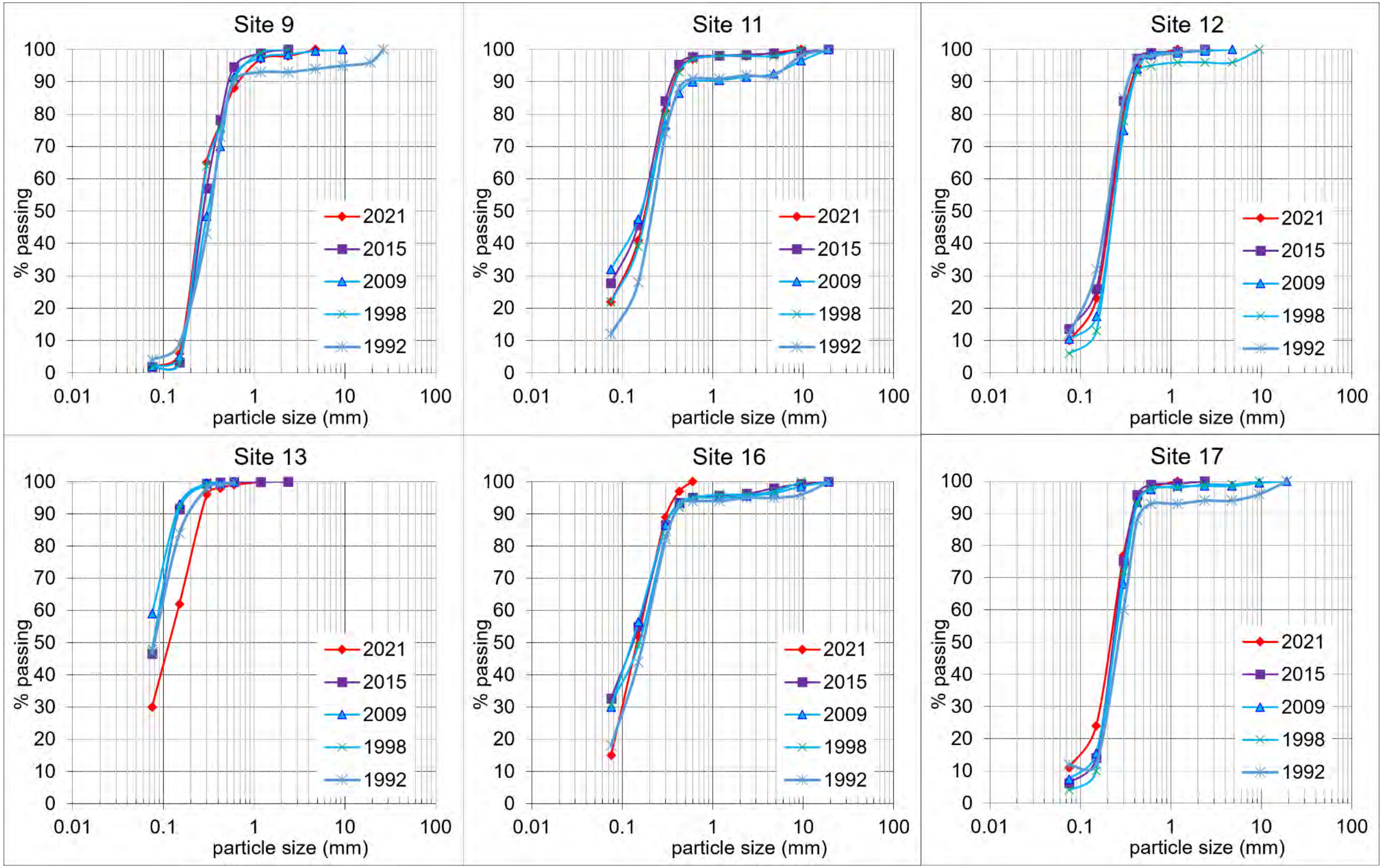


Figure 3-8 Cumulative sediment mass passing each sieve size - sites 9 to 17

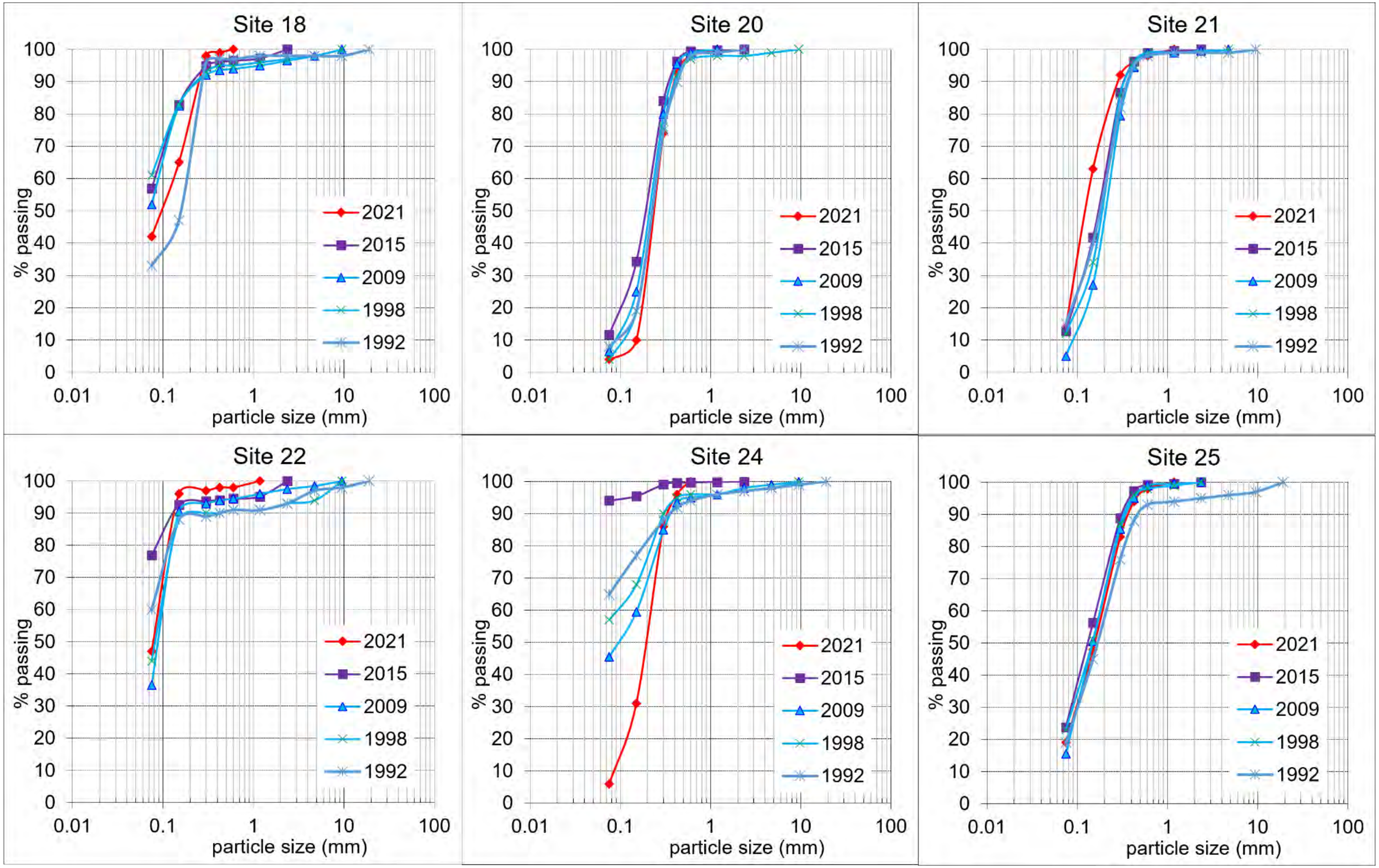


Figure 3-9 Cumulative sediment mass passing each sieve size - sites 18 to 25

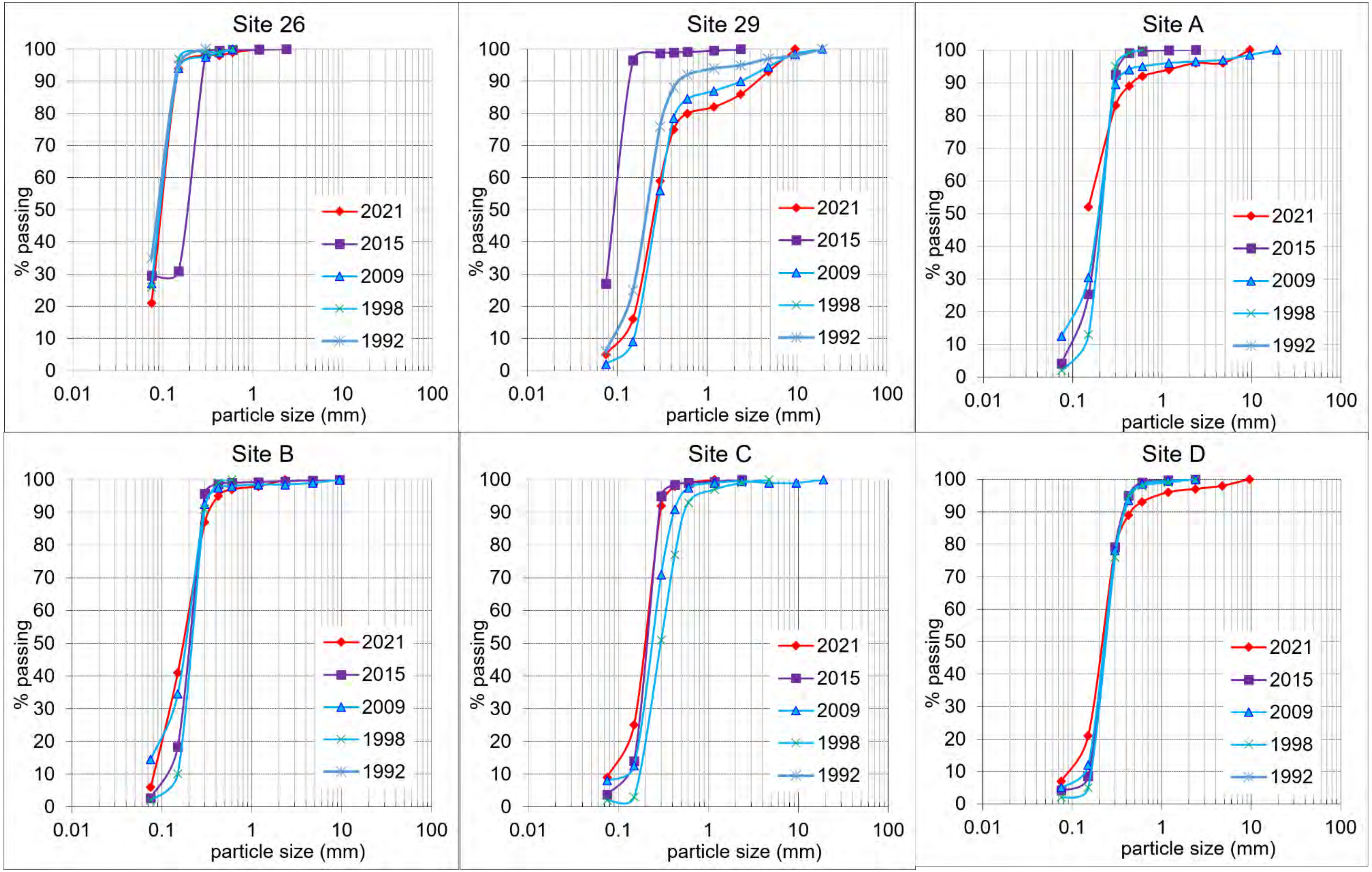


Figure 3-10 Cumulative sediment mass passing each sieve size - sites 25 to C

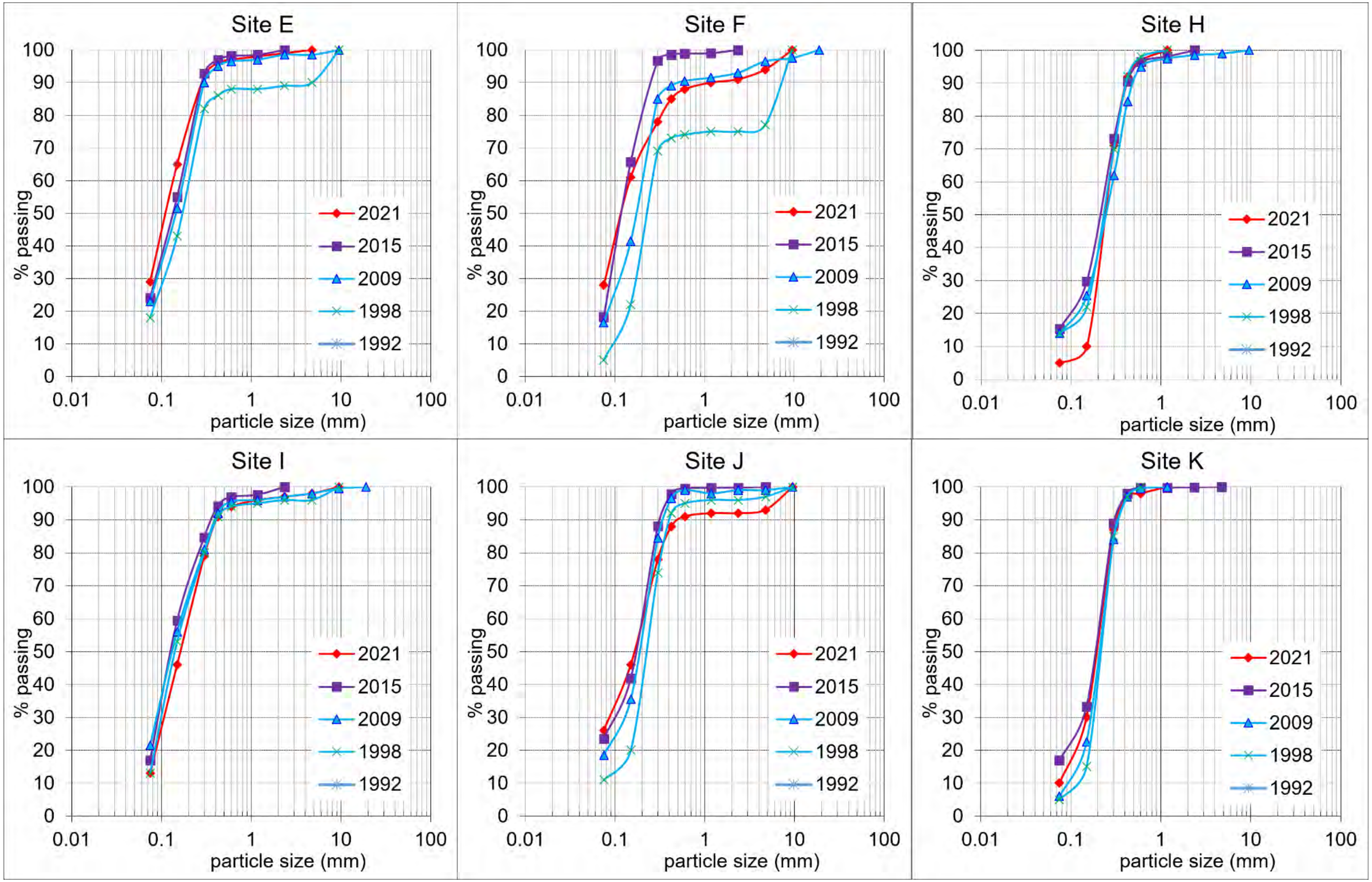


Figure 3-11 Cumulative sediment mass passing each sieve size - sites D to J

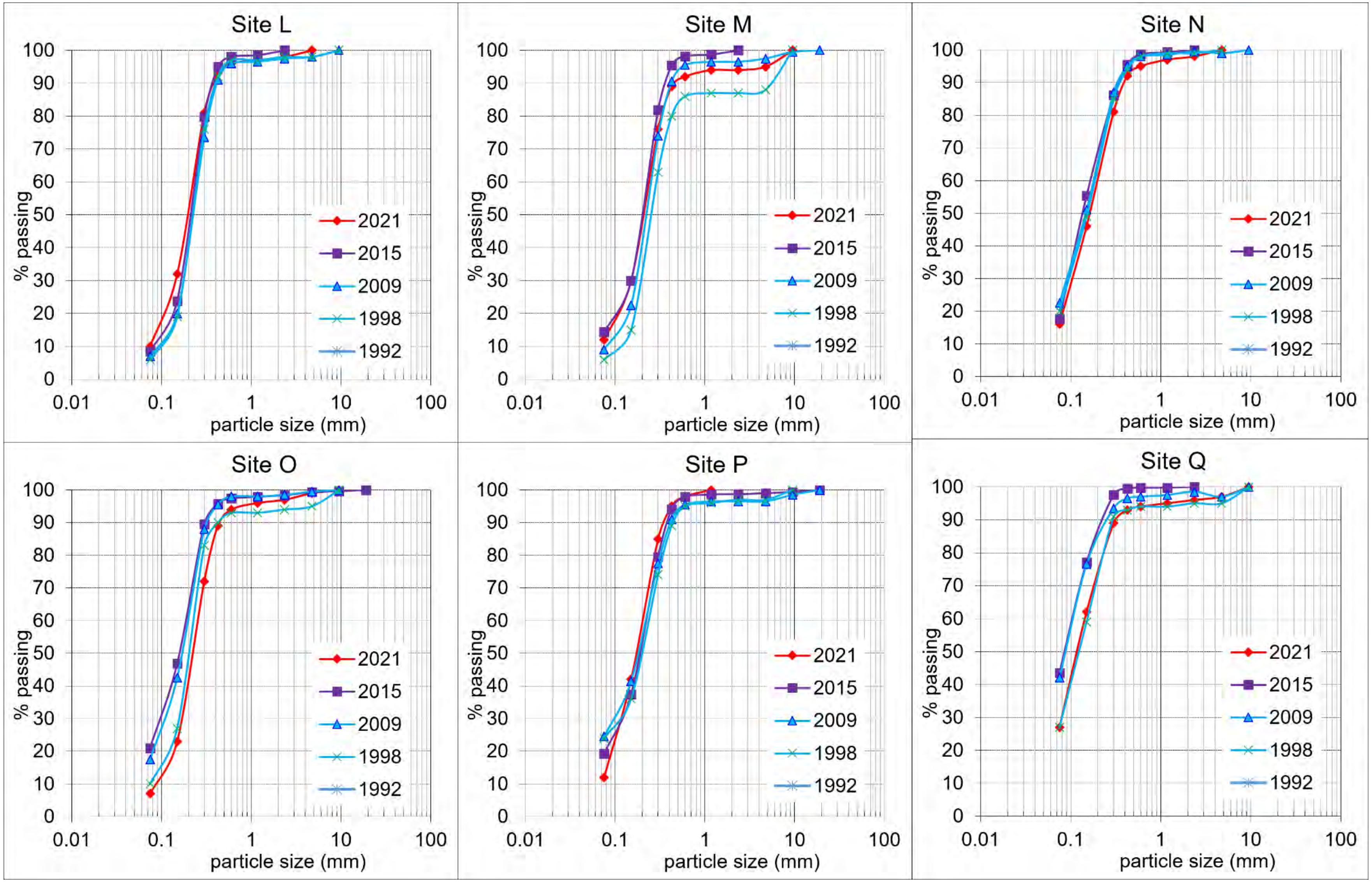


Figure 3-12 Cumulative sediment mass passing each sieve size - sites K to P

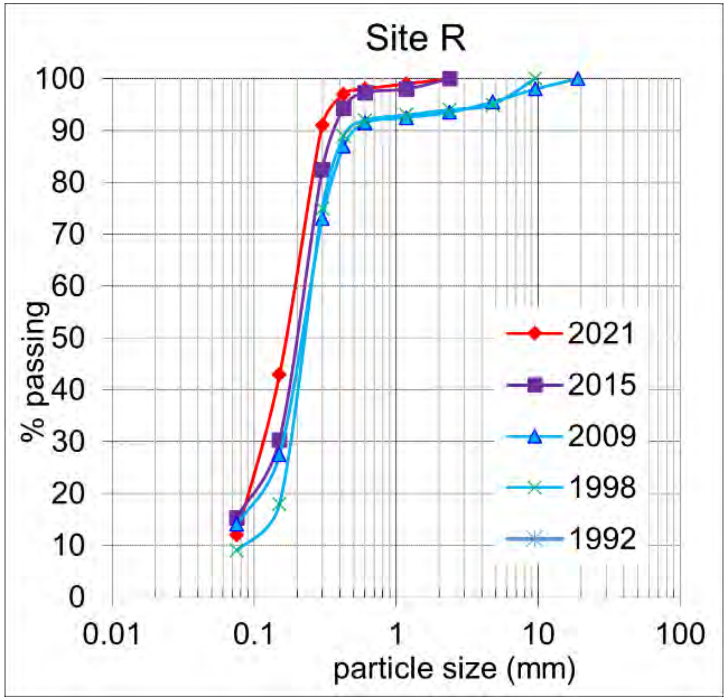


Figure 3-13 Cumulative sediment mass passing each sieve size - site R

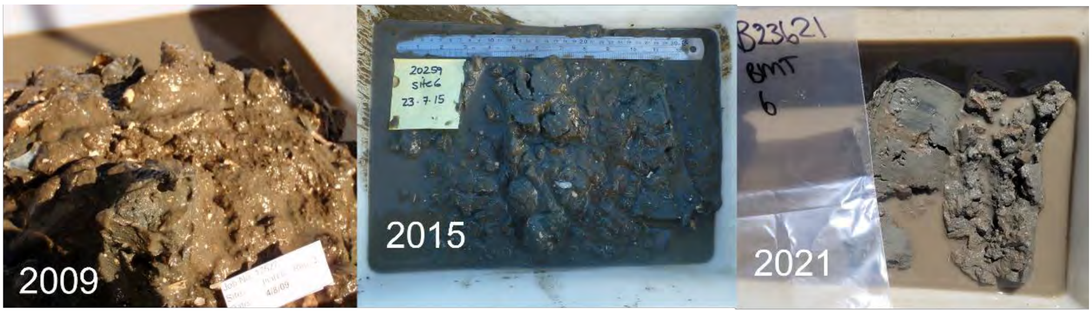


Figure 3-14 Site 6 sample photos showing comparison of 2009, 2015, and 2021. Mud percentage was respectively 57%, 67%, and 38%. Fine sand percentage was 25%, 22%, and 43% respectively.

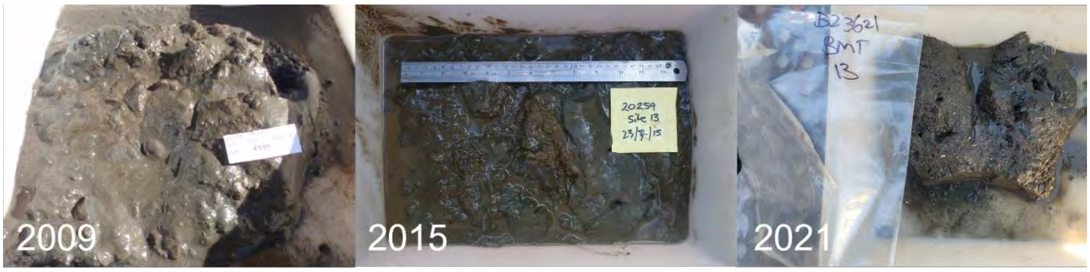


Figure 3-15 Site 13 sample photos showing comparison of 2009, 2015, and 2021. Mud percentage was respectively 59%, 47%, and 30%. Fine sand percentage was 34%, 45%, and 32% respectively.

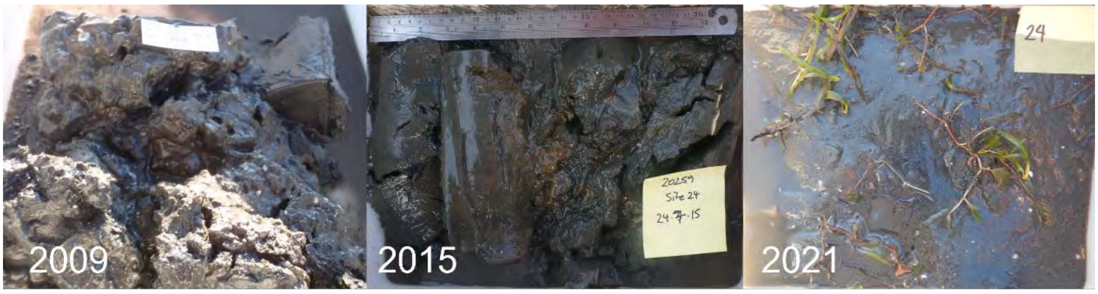
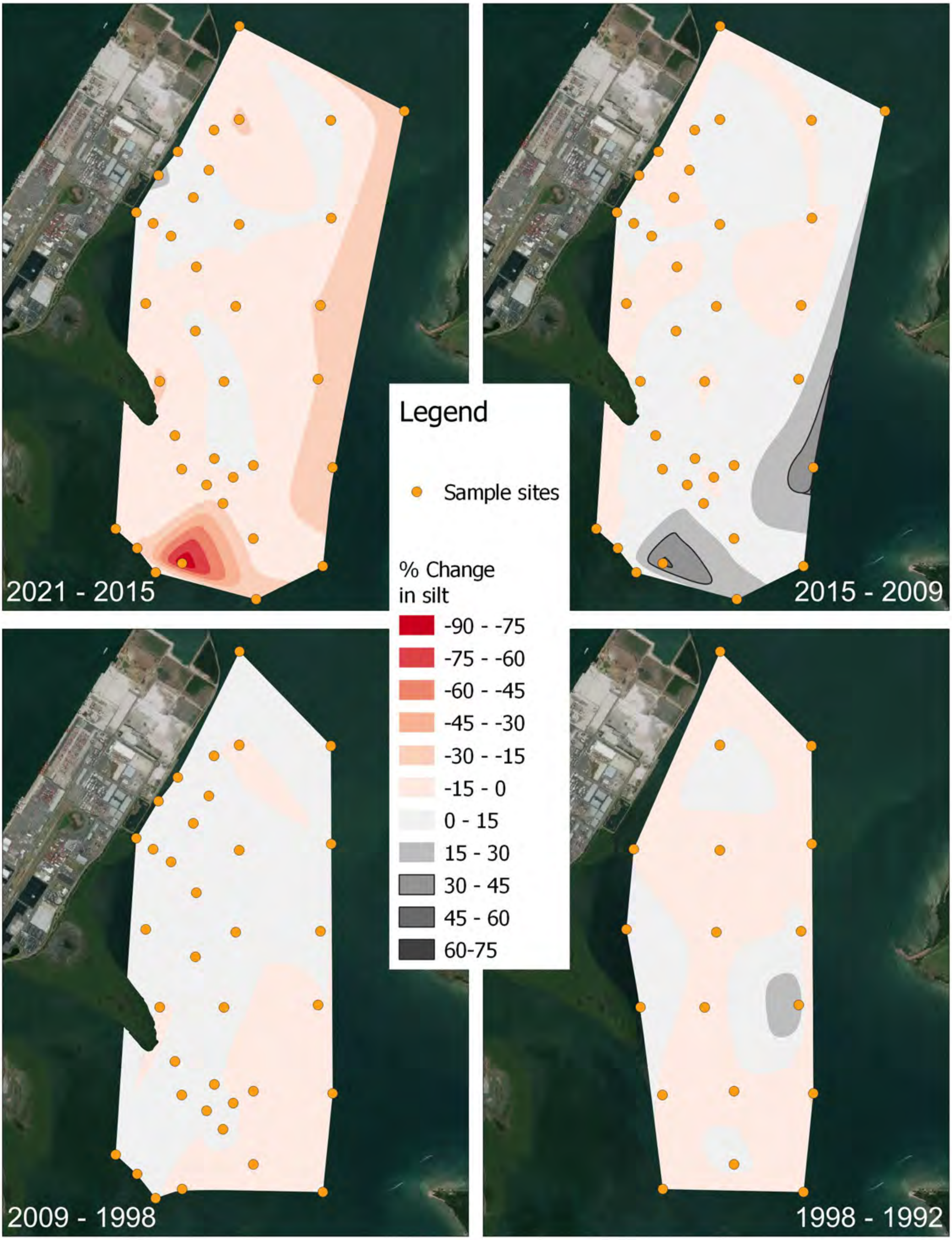


Figure 3-16 Site 24 sample photos showing comparison of 2009, 2015, and 2021. Mud percentage was respectively 46%, 94%, 6%. Fine sand percentage was 14%, 1%, and 25% respectively.



Title:

Percentage silt difference: negative (red) contours reflect less silt, positive (darker) contours reflect more silt.

Figure: **3-17**

Rev: **A**

N

0 0.5 1 1.5 2 km

BMT

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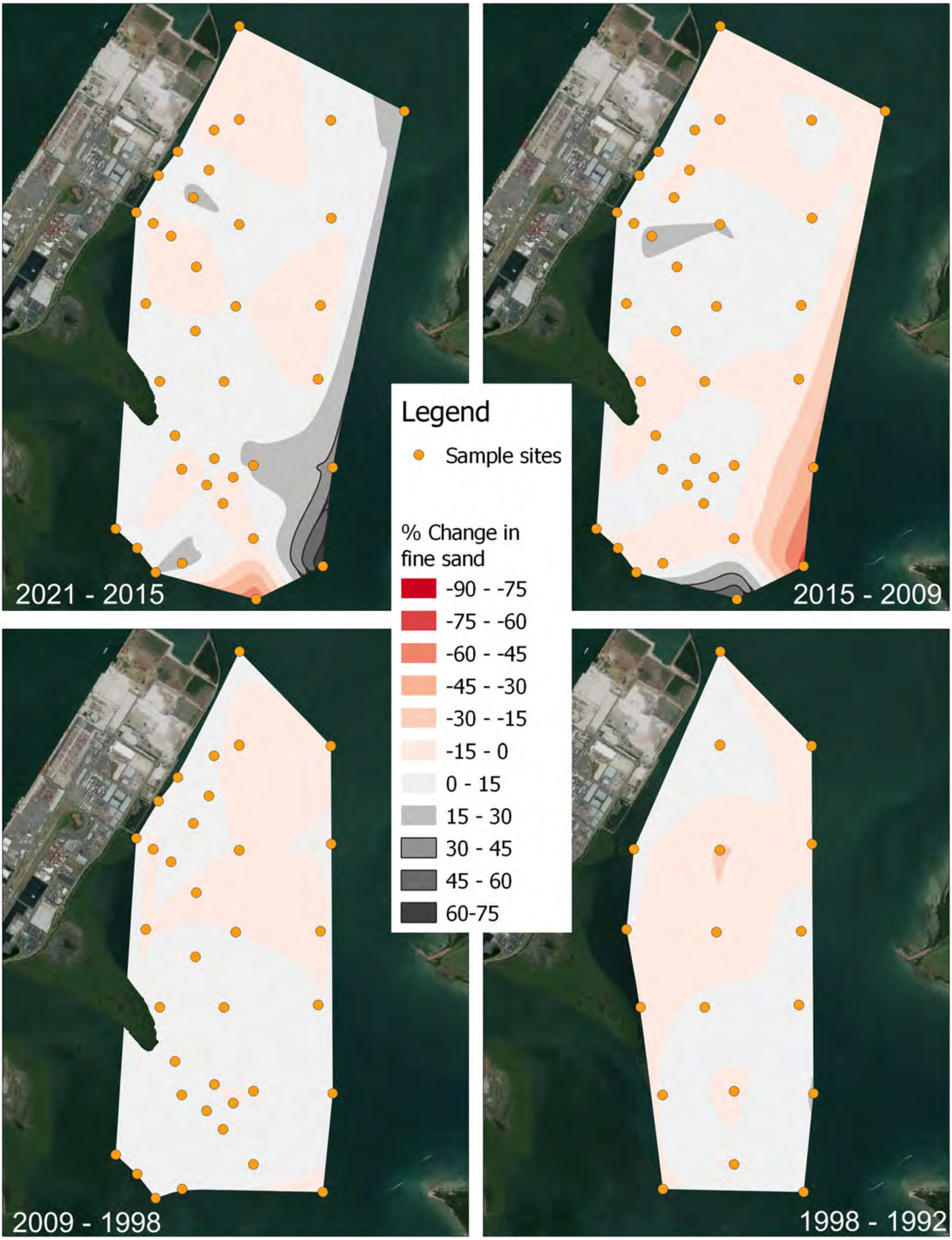

Title:

Percentage fine sand difference: negative (red) contours reflect less fine sand, positive (darker) contours reflect more fine sand.

Figure: **3-18**

Rev: **A**

N

0 0.5 1 1.5 2 km

BMT
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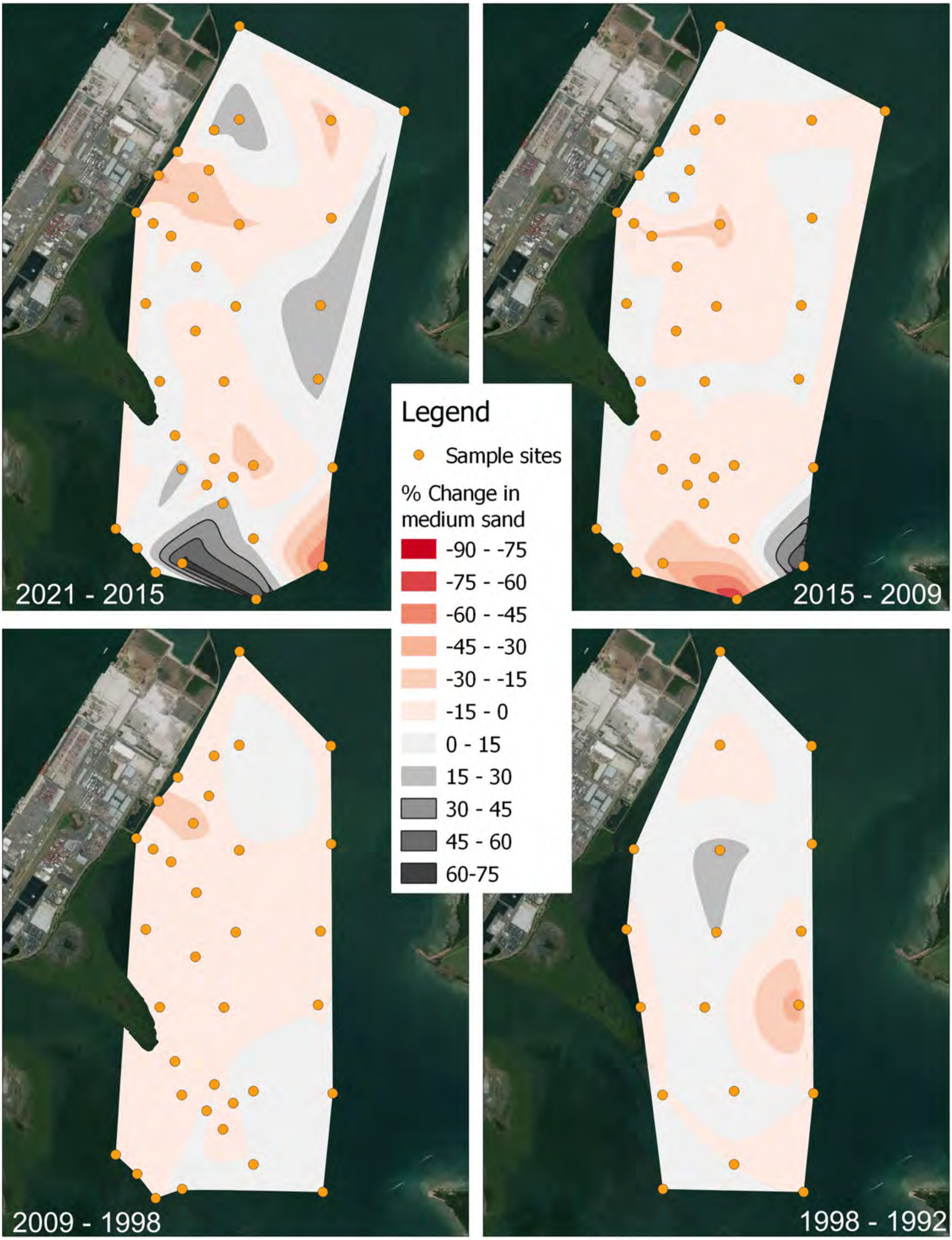

Title:

Percentage medium sand difference: negative (red) contours reflect less medium sand, positive (darker) contours reflect more medium sand.

Figure: **3-19**

Rev: **A**

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4 Discussion

4.1 Spatial Patterns

4.1.1 PSD

The variability among sites in sediment particle size distribution in 2021 was consistent with the findings of previous studies for the Port of Brisbane by WBM (1992, 1998, 2000) and BMT WBM (2010), as well as O'Brien *et al.* (2011) and Lockington *et al.* (2016) (Figure 4-1).

Sedimentation patterns and net movement of sediments in the Fisherman Islands area are dictated by the prevailing waves and currents as well as river discharges. The study area is relatively sheltered from waves from the southeast to east by Green, St Helena and Mud Islands. Generally, the wave climate along the southern side of the study area is low (less than 0.5 metre) with corresponding low capacity for sediment resuspension from the bed. This is conducive to settling of fine silty material characteristic of that area. Areas with high mud content (>25%) were predominantly found in the following areas:

- The deeper channel area west of St. Helena and Green Islands – WBM (2000) also found that this area had mixed and variable sediments, depending on tidal conditions, sediment supply and relict sub-surface sediments, which can be highly variable over time and space. Low rates of sand supply is thought be important in maintaining mud sediments in this area. Stratification in this region is further discussed in section 4.1.1.
- Nearshore sheltered areas directly adjacent to Fisherman Islands and south of the shoal – WBM (2000) found that this area was significantly sheltered from waves by St Helena and Green Islands and had low bed sheer stress. The sheltering effect results in low bed sheer stress, allowing fine sediments to settle onto the seafloor. Furthermore, accretion of fine sediments in this area may be facilitated by dense seagrass cover in this area, which can lead to a reduction of near-bed current velocities (WBM 1998, Orth *et al*. 2006). The FPE also provides partial protection of nearshore environments from dominant north-east winds and fluvial outflows from the Brisbane River, promoting suitable conditions for mud accumulation in these areas.

The area with the lowest mud content was parts of the shoal (site 9) and the intertidal flats to the north of the mouth of Boat Passage (i.e. sites K, 20, L, M, O, N, O). This particular intertidal region had less the 10% mud. Sites located on the shoal extending east-west between the eastern margin of the FPE and St Helena Island (i.e. sites C, B, D, 8 and 9) continued to consistently have lower mud content (>15%). WBM (1998, 2000), citing Stephens (1992), suggested that the sandy deposits in this area were remnants of the original river mouth delta. The shoal experiences high current velocities and is exposed to wind waves from the north-east (WBM 2000). During high wind and wave events (including storms), fine sediment is resuspended and ultimately transported to more quiescent (i.e. sheltered and/or deeper) areas. This reworking of sediments prevents the permanent settlement of muds on the shoal, leaving higher sand content sediments (with occasional shell fragments) on the bed (WBM 1992).

Coarse sand and gravel do not represent a significant proportion of sediments at the sampling sites, reflecting both a lack of a significant supply of coarse material to this area, together with low bed sheer stress in more quiescent sections of the study area.

4.1.2 Penetrometer

The FFP is a rapid, cost effective assessment tool that can provide high resolution geotechnical data in water depths >2 m. This depth restriction meant the FFP results are restricted to subtidal waters north-east and east of Fisherman Islands. A total of 159 samples were collected at 53 sites, nine of which were coincident with PSD sites (Table 4-1).

The FFP resolved the following:

- The sandy shoal near the St. Helena Island channel to the FPE seawall (sites 9, C, D, H) had high F_f values. As discussed in Section 4.1, this shoal is likely the sandy remnants of the original river mouth delta.
- The FFP samples next to the channel west of St. Helena and Green Islands (F_F7 to F_F11) consistently show F_f values ~10. Closer examination of the deceleration pattern shows an unconsolidated layer (~20 cm) overtop sand. These sites do not correspond directly with PSD sample sites.

There was no significant correlation between PSD and F_f ($r = 0.29$; $p > 0.1$) (Table 4-1). Confounding effects are the previously mentioned mud over sand, and in the case of site 2 (Coarse sand and gravel = 19%), a sample outlier resulted in a poor representation of the average sediment conditions at this location.

Table 4-1 Sediment D50 comparison with FFP F_f.

PSD sample site	D_{50}	Firmness Factor
2	0.351	7.9
4	0.181	1.19
5	0.156	7.97
6	0.139	1.6
9	0.262	118.46
12	0.221	7.54
C	0.206	26.55
D	0.225	21.69
H	0.248	16.64

4.2 Temporal Patterns

Previous surveys in the study area have identified a trend of increasing mud at many of the sites, especially between 2009 and 2015. The trend between 2015 and 2021 was generally reversed, with 24 of the 37 PSD sites showing a reduction in mud content, and a corresponding increase in the fine sand fraction. Furthermore, sediment types in 2021 were more consistent with those recorded in 2009, immediately prior to the 2011/2013 floods.

Sites with the largest changes were:

- The mouth of Boat Passage (sites 24, 26, 29) experienced large swings in muds, with site 24 seeing an increase of 49% between 2009-2015, which was reversed between 2015-2021 (88% reduction in muds). This site is located near the edge of the channel and may be subject to channel migration and high current velocities. Seagrass was recorded at this site in 2021, which appears to have new colonised this area. As seagrass typically traps finer sediments, it is possible that this site may see an increase in finer sediments in the future.
- Ten sites (11, 16, 18, F, H, J, M, O, Q, R) that were noted in 2015 as showing a long-term trend of increased mud content, mostly had a reduction in mud content between 2015-20 (except sites F and J). The reversal in trend continues when comparing these same sites with 2009. Sites F and J along with M, and R are the only exceptions to the decreasing trend in mud since 2009.
- The largest increase in mud was found adjacent to the FPE seawall, site A. Site A saw an increase in 22% between 2015-2021, and an increase of 14% between 2009-21. This trend of increasing mud was also observed at nearby locations (8, B, C, D, E, F), but to a lesser extent (average increase of 4.8% compared to 2015).

The 2015 results are consistent with the findings of O'Brien *et al.* (2012) and Lockington *et al.* (2017), both of whom documented large increases in proportion of muds in western and central Moreton Bay between 1997 and 2011 (Figure 4-1). They found that the largest changes occurred at the mouth of Brisbane River, as well as nearshore environments in southern Moreton Bay and Deception Bay. Only a small number of sites were sampled by both studies in the study area, but results were broadly consistent with the present study.

O'Brien *et al.* (2012) suggested that the January 2011 floods were a key driver of observed changes in muds between 1997 and 2011. The 2011 flood event was the largest by far in the period 1992-2015, although freshes and smaller flood events (e.g. 2013) during this period may also to sediment loading in the study area. Similar findings were reported for the 1974 flood, when five million tonnes of fluvial mud were washed downstream, producing a five-metre-thick blanket of pro-delta mud in sub-tidal areas (to about 10-15 m depth) of western Moreton Bay (Heckel *et al*. 1979; Jones and Stephens 1981).

These extreme events ascribe to previous results, but 2021 all but largely reversed the increases seen in muddy deposits. Outside of large flooding events, WBM (2000) suggested that the net long-term pattern in the quiescent nearshore environments of Fisherman Islands was one of slow progressive fluvial mud accretion, leading to the slow progression of the mangrove shoreline. This general pattern may continue, but when comparing the mud content from 2021 to 1998, the average difference is 0.3%. This does not necessarily discount the hypothesis, as localized changes within the study region are capable of large swings in PSD. Future studies will assist with normalizing a baseline within the region and confirm long term trends outside of the anomalous 2015 spike in fine particulate matter.

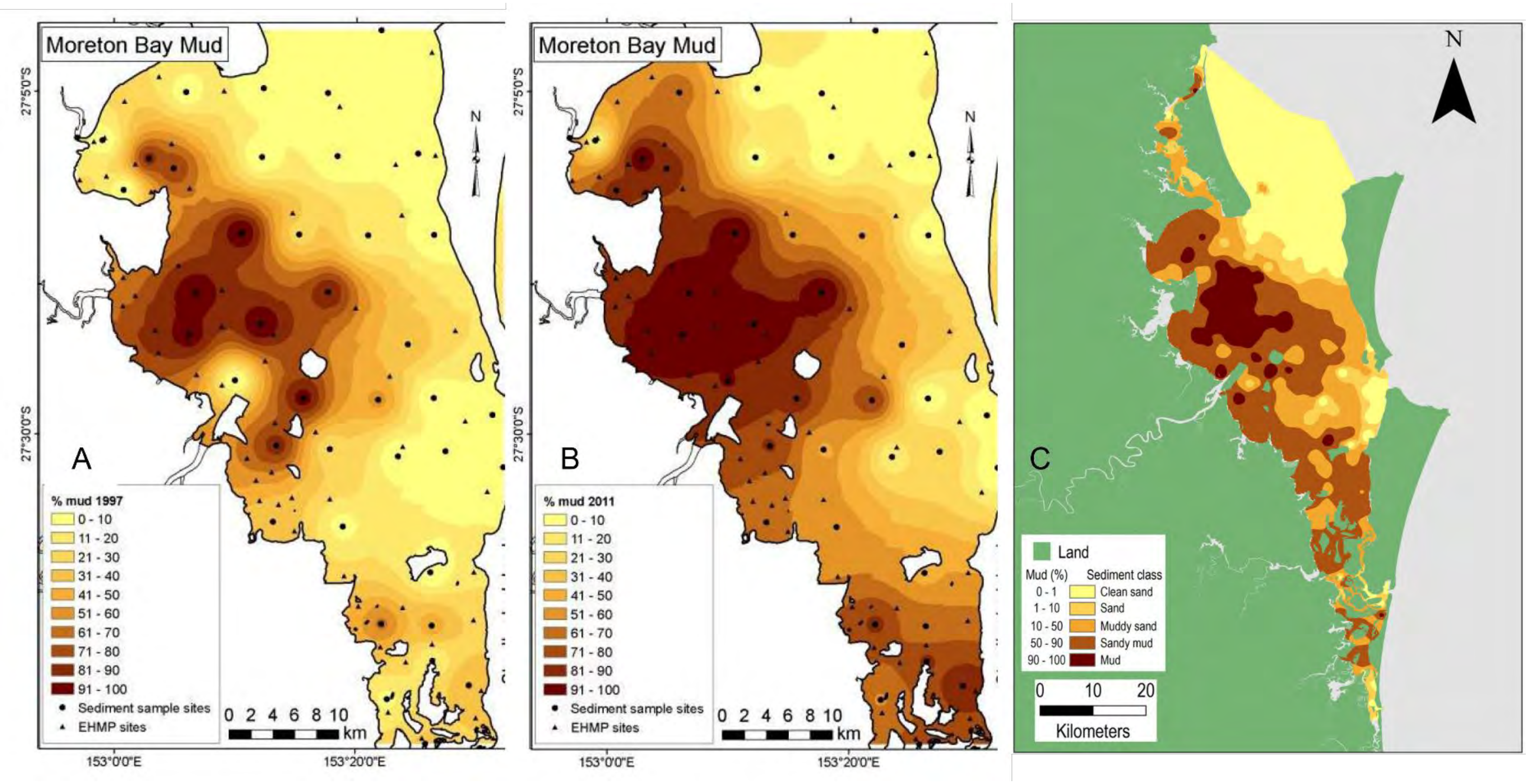

Figure 4-1 Percentage of mud in Moreton Bay during 1997, 2011, and 2015 (A & B reproduced from O'Brian *et al.* 2012 and C from Lockington *et al.* 2017)

4.3 Influence of Port Operations

The FPE influences hydrodynamic conditions (and therefore the sedimentary environment) in the study area. The FPE has an effect of (i) diverting flood flows in a northerly direction into Moreton Bay, and (ii) partially sheltering nearshore areas from north-easterly winds prevailing in spring and summer (WBM 2000). BMT WBM (2014) suggested that these alterations to hydrodynamic conditions have favoured the expansion of seagrass meadows in northern sections of the study area. This has been largely confirmed in BMT (2021) showing long term trends of recovery and expansion in seagrass meadows.

WBM (2000) predicted that the degree of impact on the patterns of tidal currents around the FPE would be generally slight and localised. The truncation and rounding of the northeastern corner was predicted to allow smooth unimpeded tidal flow to and from northern Waterloo Bay, thereby minimising effects of currents, flushing and sedimentation. Sampling undertaken at the north-east tip of Fisherman Islands (site 2) confirms that there have been no major temporal changes in sediment particle grain size at this location. However, FFP drops at this location were variable and inconclusive in determining surficial sediment type and stratification.

Modelling results presented in WBM (2000) suggest the area around the southeast edge of the FPE seawall would experience a reduction in current velocities. Reduced current velocities were predicted to occur during ebbing and flooding tides during northerly wind/wave conditions, and under such conditions, deposition of silty material could be expected to occur. BMT WBM (2008) found that localised accumulation of muds near the south-eastern edge of the FPE seawall between 1992/98, 2009, and 2015 (i.e., sites A, E, and F) consistent with these predictions. The present study found that these sites continued the long-term trend of increasing fine sediment in this area.

4.4 Recommendations

By using the same methodology and sample sites that have largely been adhered to since 1998 (an additional 17 sites were added since 1992), temporal patterns can be readily determined. However, as demonstrated by the FFP methodology, increase site replication can provide a more robust fine-scale assessment of sediment dynamics.

It is recommended that the same sites should continue to be sampled, and that additional sites be located in:

- poorly represented areas, especially nearshore areas immediately adjacent to mangroves at Fisherman Islands, and shoals and channel environments at Boat Passage
- areas likely to experience small-scale spatial gradients, particularly those of differing depth, extents of seagrass meadows, and channels.

It is also recommended that PSD data collected for the sediment SAP program be integrated into the marine sediment monitoring program.

5 Conclusions

- The results of the present study demonstrate that patterns in sediment grain size are dynamic in time and space.
- The results in 2015 were largely anomalous and attributed to large scale flooding in 2011 and to a lesser degree 2013. These increases were largely reversed in 2021 with greater alignment to previous studies from 1992 to 2009.
- The consistent increase in muds located near the quiescent nearshore areas around the south-eastern edge of the FPE seawall have continued in agreement of past modelling of wind and wave alterations caused by the expansion of Fisherman Islands
- Flooding, channel migration, and expansion in seagrass meadows have all potentially contributed to large scale swings in PSD observed at the mouth of Boat Passage.
- Sediment types in the channel area west of St. Helena and Green Islands have largely been consistent over time. 2015 saw in decrease in muds with an increase in 2021. Closer examination of the FFP deceleration plots reveals a layer of unconsolidated muds over sand.
- No consistent, major changes in mud content were observed over time at the north-eastern tip of the FPE (i.e. the seawall truncation). This area is exposed to local waves from the northeast and strong tidal currents, which do not favour the settlement and/or trapping of muds.
- The sites located on the shoal extending east-west between the eastern margin of the FPE and St Helena Island consisted of high proportions of medium sands. High bed shear stress is common in these shallow, exposed areas and wave action is expected to prevent the settlement of muds on these shoals. The grid based FFP drops allow for a great connection of data, showing the shoal as consistent across this area.
- Modelling results presented in WBM (2000) have proven correct, however, inter-annual changes in prevailing wind and wave climate will influence sediment patterns along with sampling error due to small-scale variability in sediments (BMT WBM 2008).

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Appendix A Sediment log and photographs

Site No.	Date	Time	Colour	Odour	Palasticity	Field Texture	% Shell	% Seagrass	% Macroalgae	% Organics
P	22/08/2021	8:10	Grey Brown	Fishy	Low	Muddy Sand	3	15	-	5
Q	22/08/2021	8:21	Dark Grey		Moderate	Sandy Mud	-	15	15	-
R	22/08/2021	8:41	Dark Grey	Fishy	Low	Sandy Mud	3	20	-	-
24	22/08/2021	8:50	Dark Grey	Fishy	Low	Muddy Sand	5	25	2	5
29	22/08/2021	9:05	Dark Grey	Fishy	Low	Shelly/ Muddy Sand	20	5	2	-
20	22/08/2021	9:17	Dark Grey	Normal	Low	Fine Sand	5	-	-	1
M	22/08/2021	9:27	Dark Grey	Normal	Low	Fine Sand w/ Mud	1	30	-	-
K	22/08/2021	9:39	Dark Grey	Normal	Low - Moderate	Fine Sand w/ Mud	-	10	-	-
16	22/08/2021	9:53	Dark Brown	Slight Sulphur	Low	Fine Sand w/ Mud	-	5	-	-
11	22/08/2021	10:05	Black Brown	Slight Sulphur	Medium – High	Mud w/ Fine Sand	1	80	-	-
F	22/08/2021	10:22	Dark Brown	Slight Sulphur	Medium	Sandy Mud	20	80	-	-
7	22/08/2021	10:32	Dark Brown	Slight Sulphur	Low	Sandy Mud	1	80	-	-
E	22/08/2021	10:43	Dark Brown	Normal	Low	Sandy Mud	5	40	2	1

Site No.	Date	Time	Colour	Odour	Palasticity	Field Texture	% Shell	% Seagrass	% Macroalgae	% Organics
A	22/08/2021	10:54	Dark Brown & Black	Normal	Medium	Sandy Mud	3	25	-	-
C	22/08/2021	11:04	Dark Brown	Normal	Low	Muddy Sand (Fine)	5	2	-	-
H	22/08/2021	11:13	Dark Brown	Normal	Low	Muddy Sand	1	5	2	-
D	22/08/2021	11:24	Dark Brown	Normal	Low	Muddy Sand	5	10	5	-
B	22/08/2021	11:33	Dark Brown	Normal	Low	Fine Sand w/ Mud	5	40	-	-
8	22/08/2021	11:46	Dark Brown & Black	Normal	Low	Fine Sand w/ Mud	2	30	20	-
I	22/08/2021	12:01	Dark Brown	Normal	Low	Fine Sand w/ Mud	5	15	25	-
12	22/08/2021	12:10	Dark Brown	Normal	Low	Fine Sand w/ Mud	1	30	1	1
J	22/08/2021	12:19	Dark Brown	Normal	Low	Fine Sand w/ Mud	2	50	2	5
17	22/08/2021	12:29	Dark Brown	Normal	Low	Fine Sand w/ Mud	2	15	10	1
L	22/08/2021	12:39	Dark Brown	Normal	Low	Fine Sand	2	25	-	-
N	22/08/2021	12:49	Dark Brown	Normal	Medium	Sandy Mud	3	30	-	-
O	22/08/2021	13:00	Dark Brown	Normal	Low	Fine Sand	5	20	0	-

Site No.	Date	Time	Colour	Odour	Palasticity	Field Texture	% Shell	% Seagrass	% Macroalgae	% Organics
25	22/08/2021	13:14	Dark Brown	Normal	Low	Muddy Sand (fine)	1	10	20	-
26	22/08/2021	13:30	Dark Brown	Normal	Medium – High	Muddy Sand (fine)	1	10	-	-
21	22/08/2021	13:45	Dark Brown	Normal	Medium – High	Muddy Sand (fine)	1	5	1	5

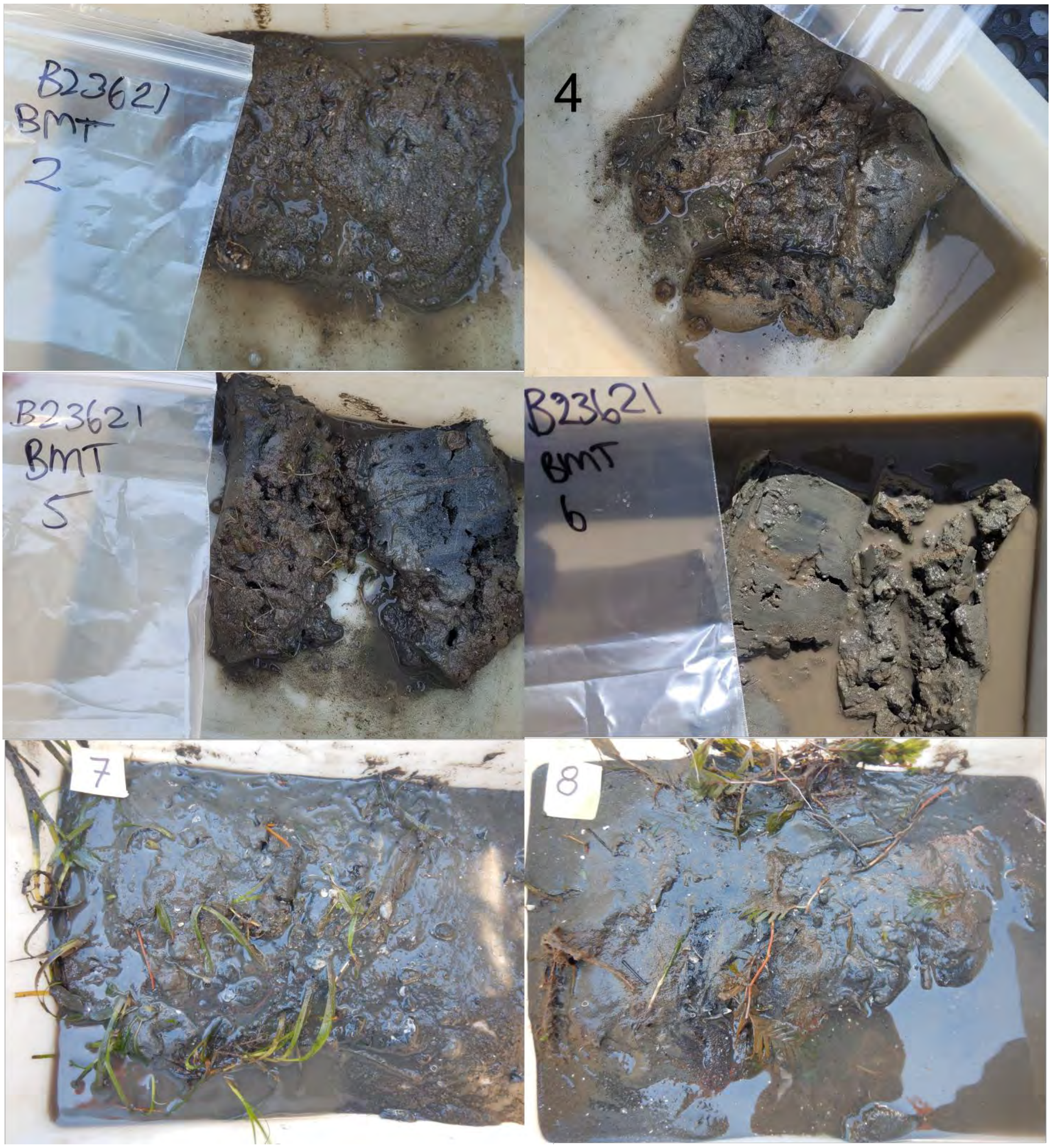

Figure A-1 Sample photos – sites 2, 4, 5, 6, 7, and 8

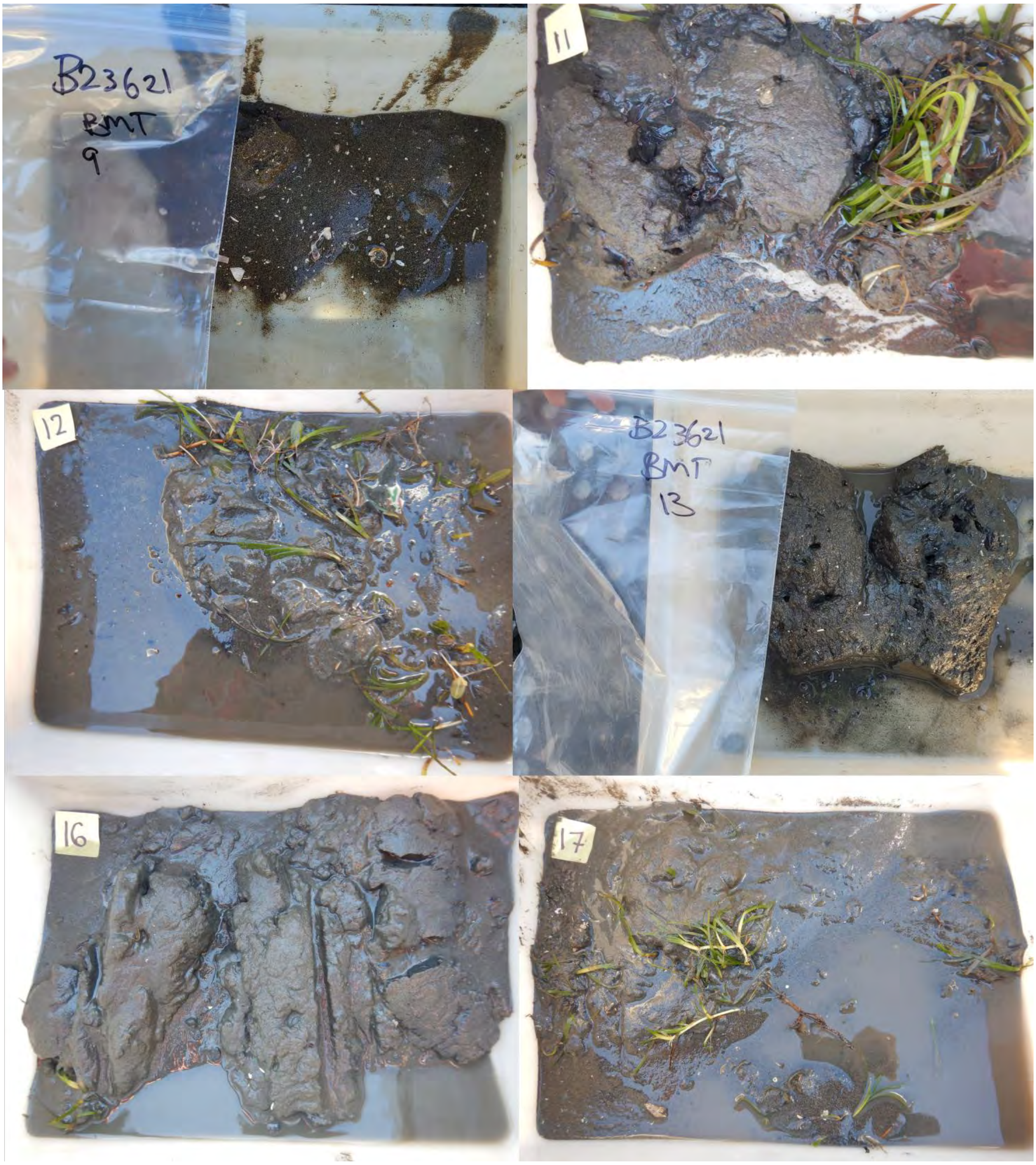

Figure A-2 Sample photos (cont.) – 9, 11, 12, 13, 16, and 17

Figure A-3 Sample photos (cont.) – 18, 20, 21, 22, 24, and 25

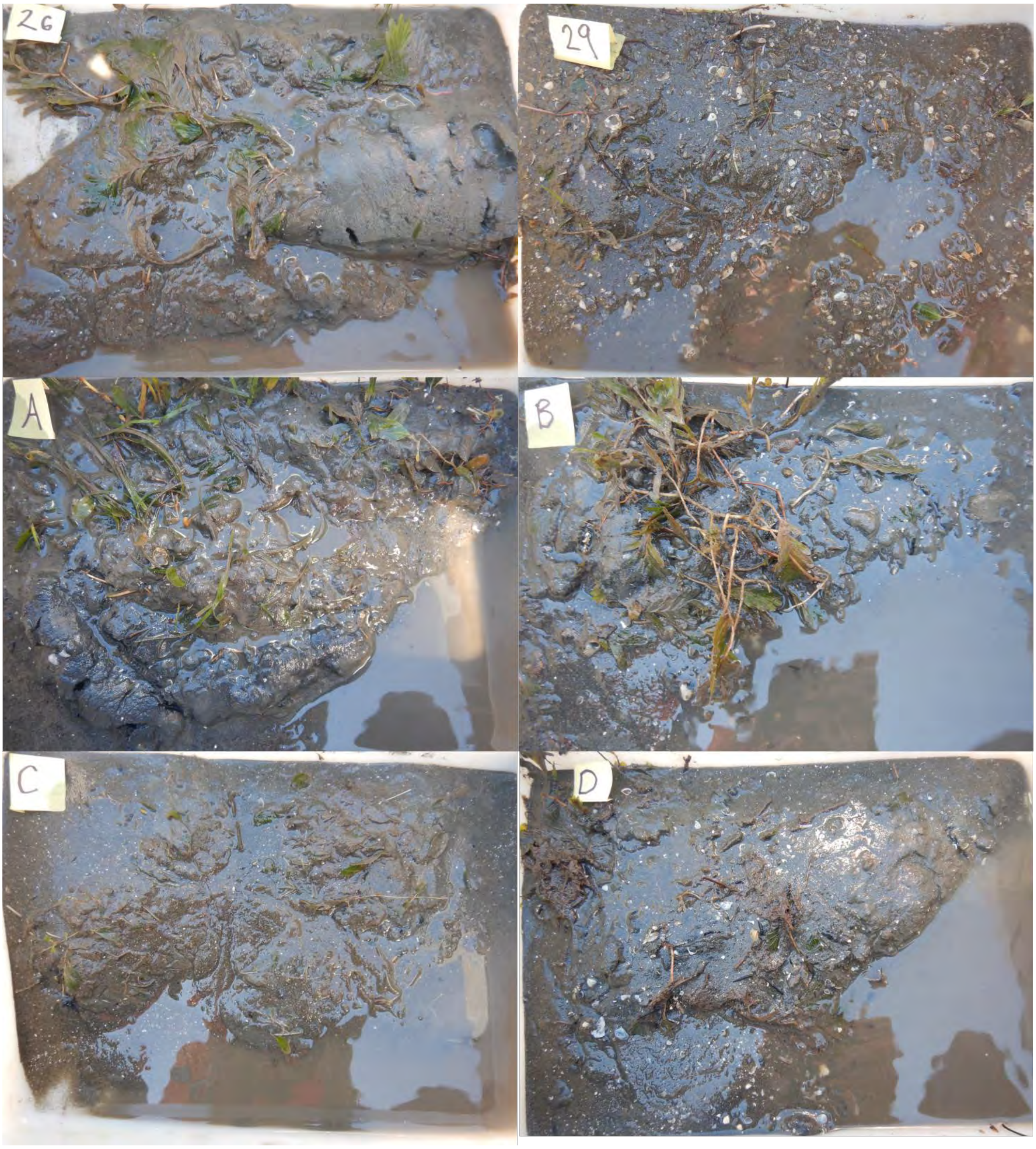

Figure A-4 Sample photos (cont.) – 26, 29, A, B, C, and D

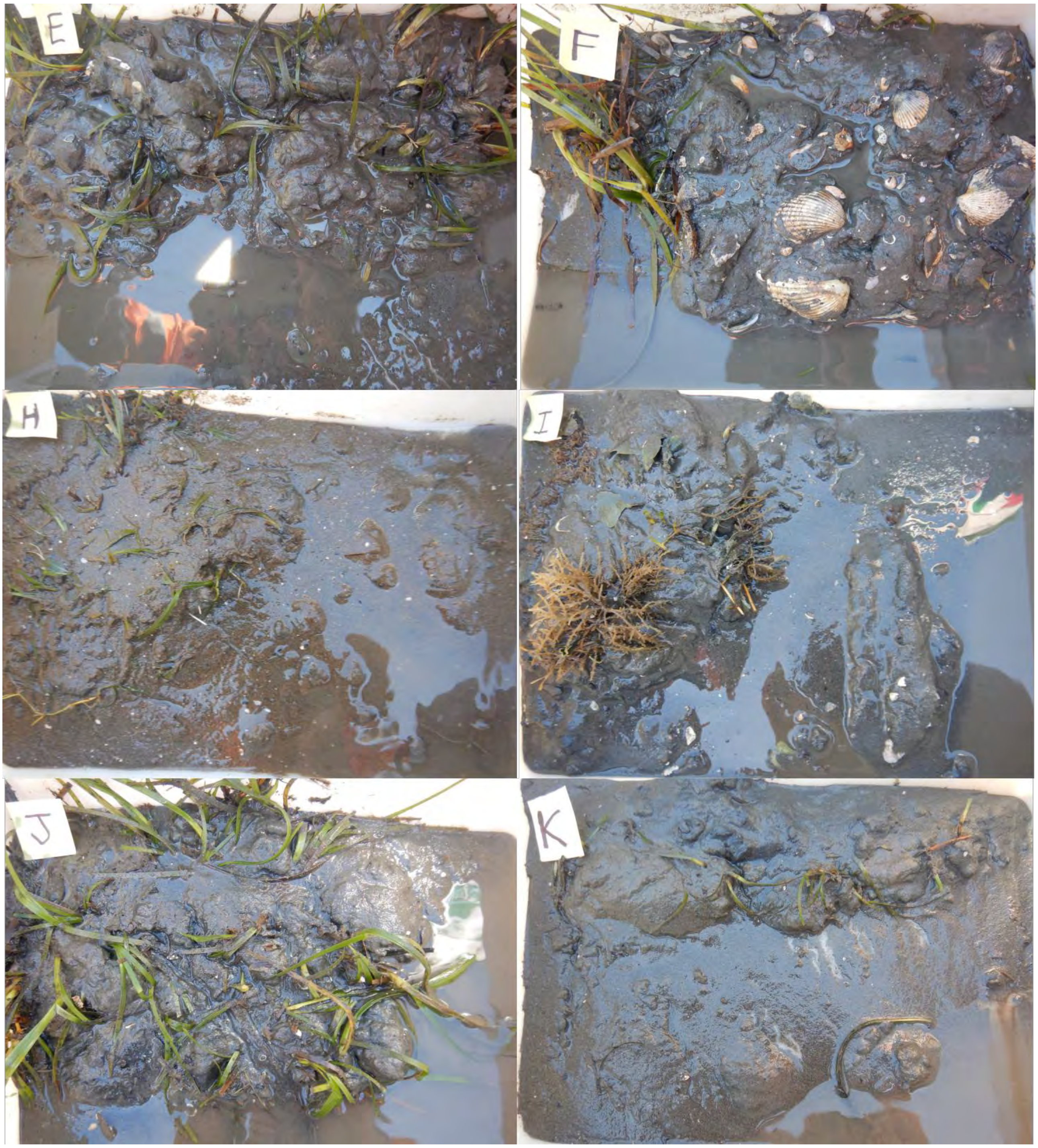

Figure A-5 Sample photos (cont.) – E, F, H, I, J, and K

Figure A-6 Sample photos (cont.) – L, M, N, O, P, and Q

Figure A-7 Sample photos (cont.) - R

Appendix B 2021 PSD sieve data

Certificate of Analysis

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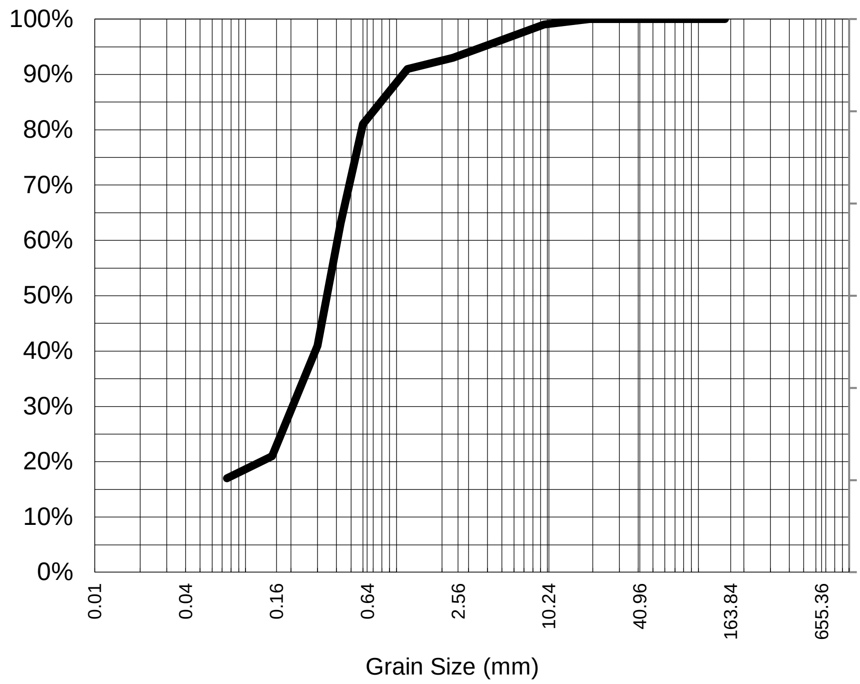
ALS Environmental

Brisbane QLD

CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-001 / PSD
PROJECT:	B23621	**SAMPLE ID:**	2

Particle Size Distribution



Particle Size (mm)	% Passing
19.0	100%
9.50	99%
4.75	96%
2.36	93%
1.18	91%
0.600	81%
0.425	63%
0.300	41%
0.150	21%
0.075	17%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.351

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

NATA Accreditation: 825 Site: Brisbane
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Satish Trivedi
Soil Senior Chemist
Authorised Signatory

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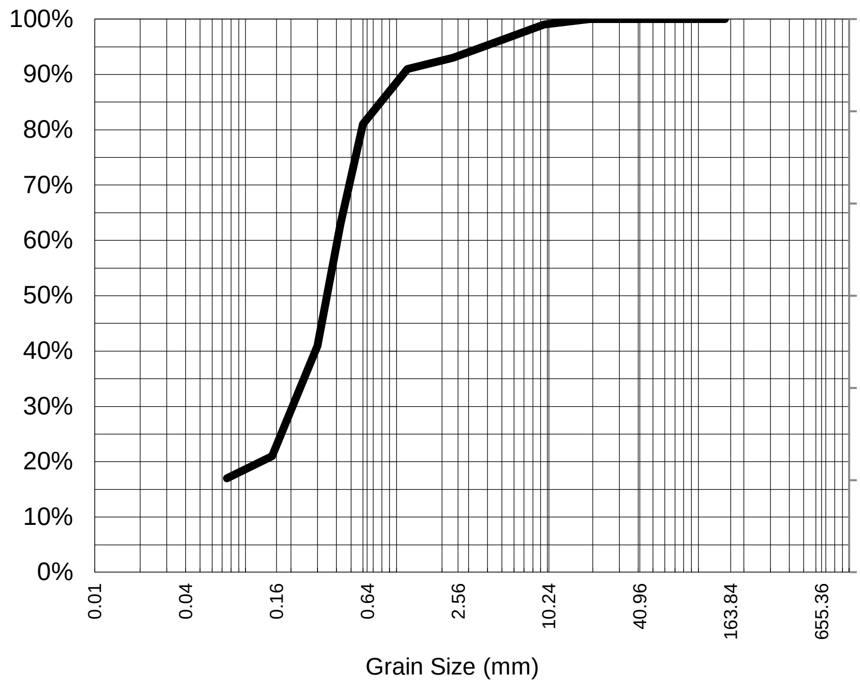
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-001DUP / PSD
PROJECT:	B23621	**SAMPLE ID:**	2

Particle Size Distribution



Particle Size (mm)	% Passing
19.0	100%
9.50	99%
4.75	96%
2.36	93%
1.18	91%
0.600	81%
0.425	63%
0.300	41%
0.150	21%
0.075	17%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.351

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

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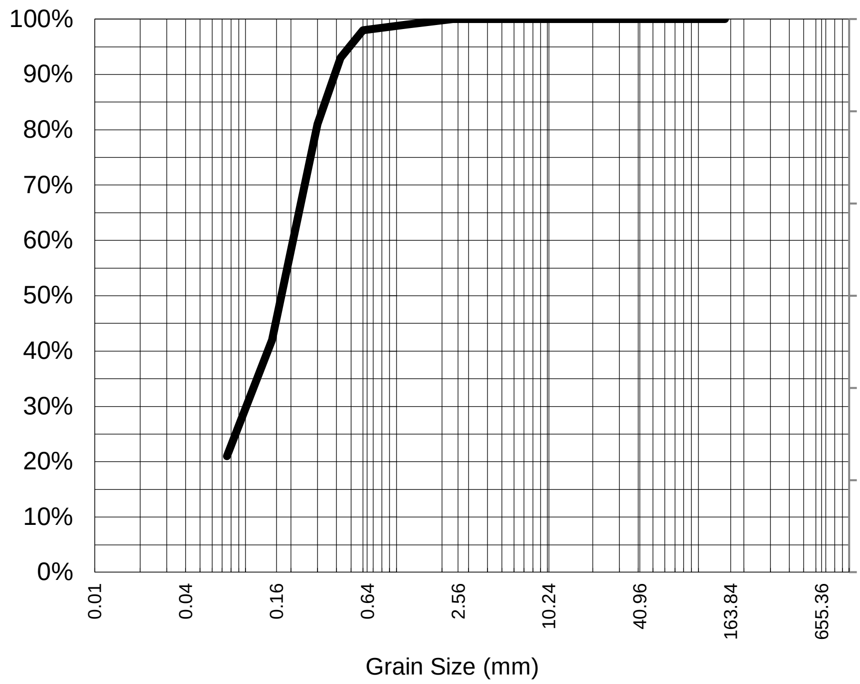
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-002 / PSD
PROJECT:	B23621	**SAMPLE ID:**	4

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	98%
0.425	93%
0.300	81%
0.150	42%
0.075	21%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.181

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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Satish Trivedi
Soil Senior Chemist
Authorised Signatory

Certificate of Analysis

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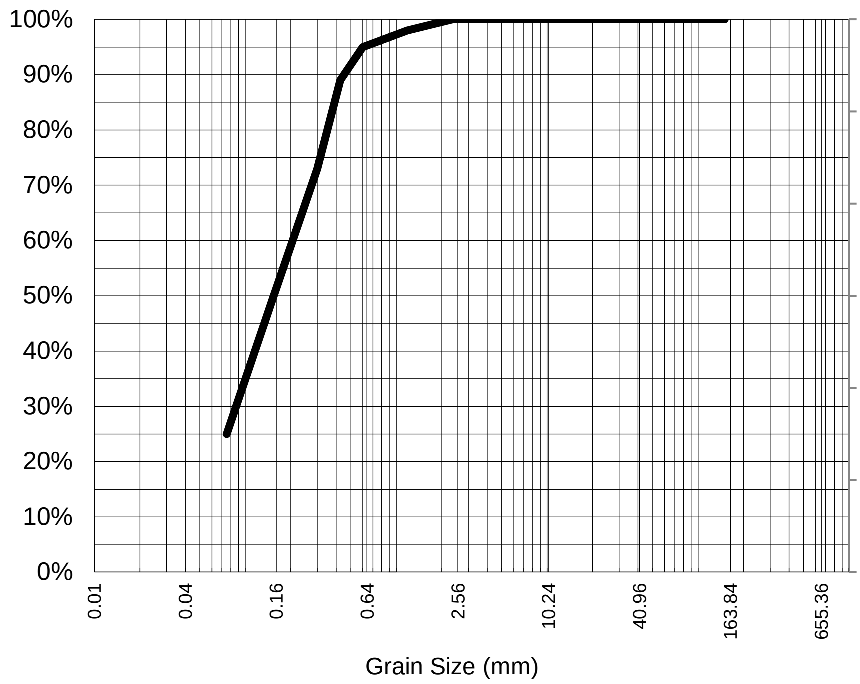
samples.brisbane@alsenviro.com

ALS Environmental

Brisbane QLD

CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-003 / PSD
PROJECT:	B23621	**SAMPLE ID:**	5

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	98%
0.600	95%
0.425	89%
0.300	73%
0.150	49%
0.075	25%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.156

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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CLIENT: CONOR JONES

DATE REPORTED: 1-Sep-2021

COMPANY: BMT COMMERCIAL AUSTRALIA PTY LTD

DATE RECEIVED: 23-Aug-2021

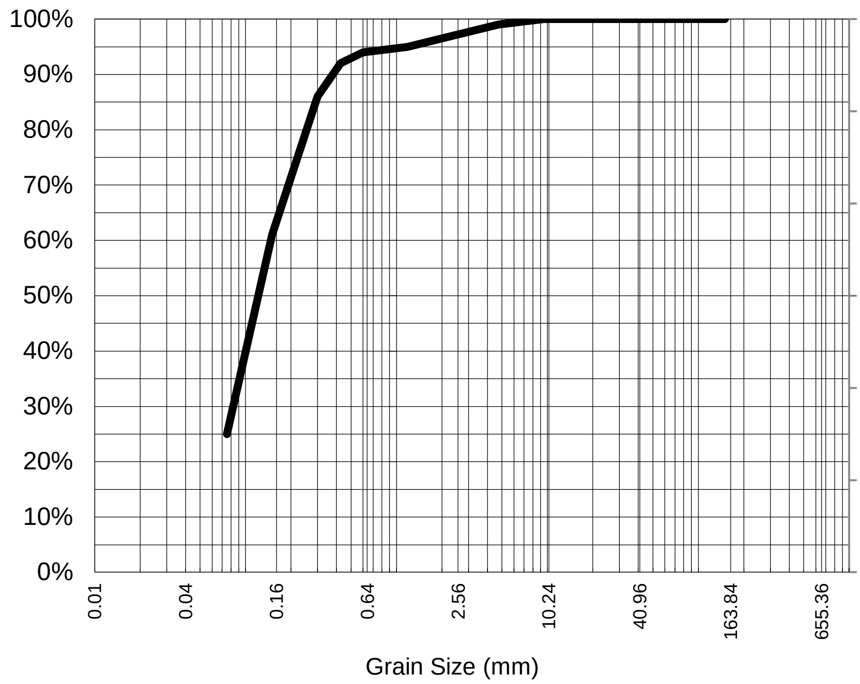
ADDRESS: Po Box 203
Spring Hill
Brisbane Qld

REPORT NO: EB2123707-005 / PSD

PROJECT: B23621

SAMPLE ID: 7

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	99%
2.36	97%
1.18	95%
0.600	94%
0.425	92%
0.300	86%
0.150	61%
0.075	25%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.127

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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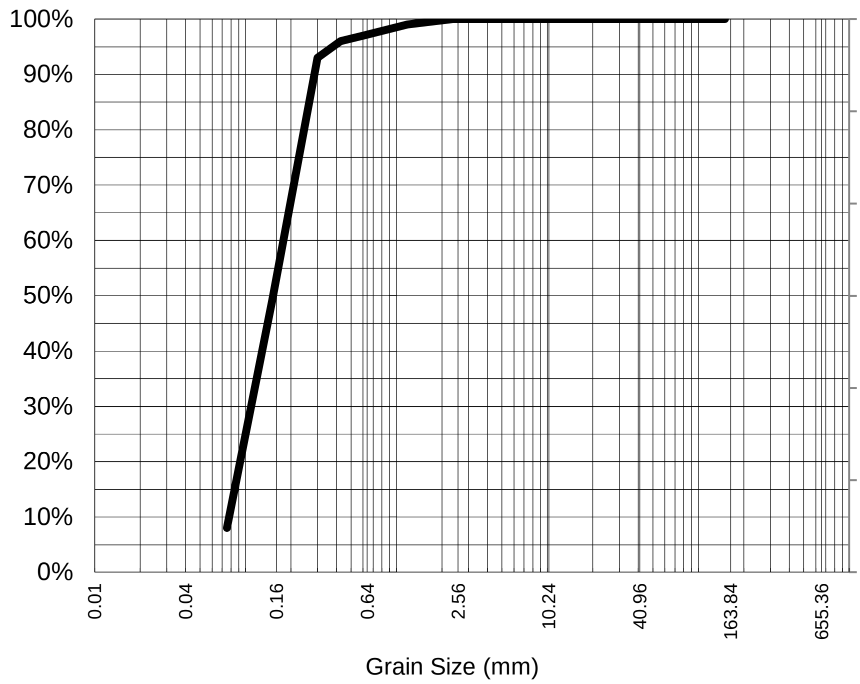
CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-006 / PSD
PROJECT:	B23621	**SAMPLE ID:**	8

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	97%
0.425	96%
0.300	93%
0.150	49%
0.075	8%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.153

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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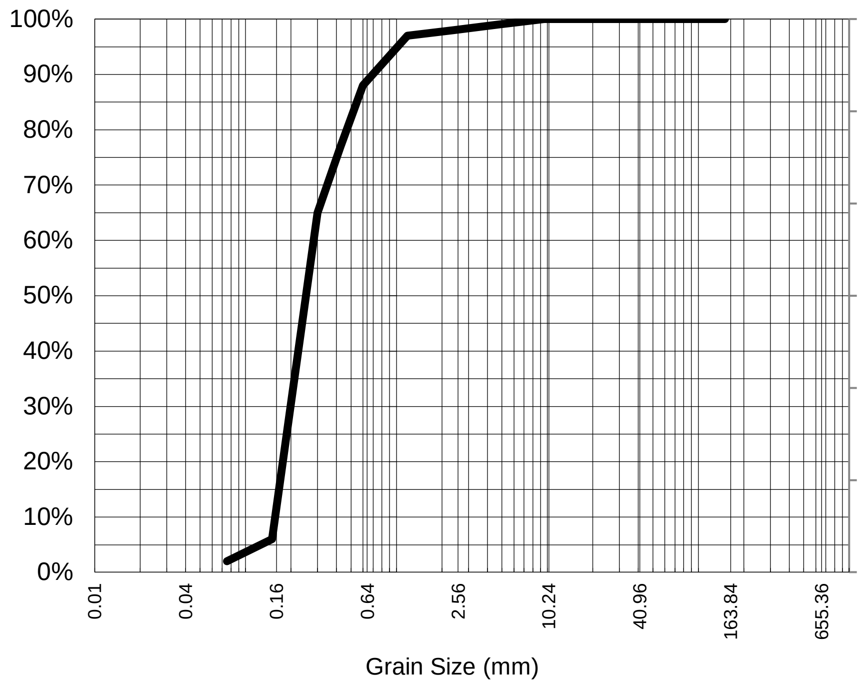
CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-007 / PSD
PROJECT:	B23621	**SAMPLE ID:**	9

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	99%
2.36	98%
1.18	97%
0.600	88%
0.425	77%
0.300	65%
0.150	6%
0.075	2%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.262

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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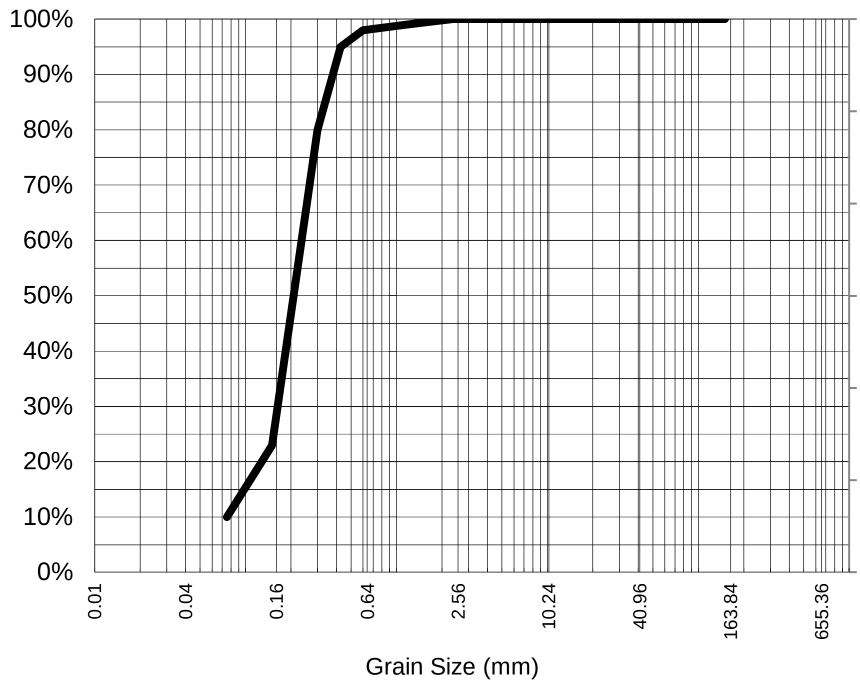
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-009 / PSD
PROJECT:	B23621	**SAMPLE ID:**	12

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	98%
0.425	95%
0.300	80%
0.150	23%
0.075	10%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.221

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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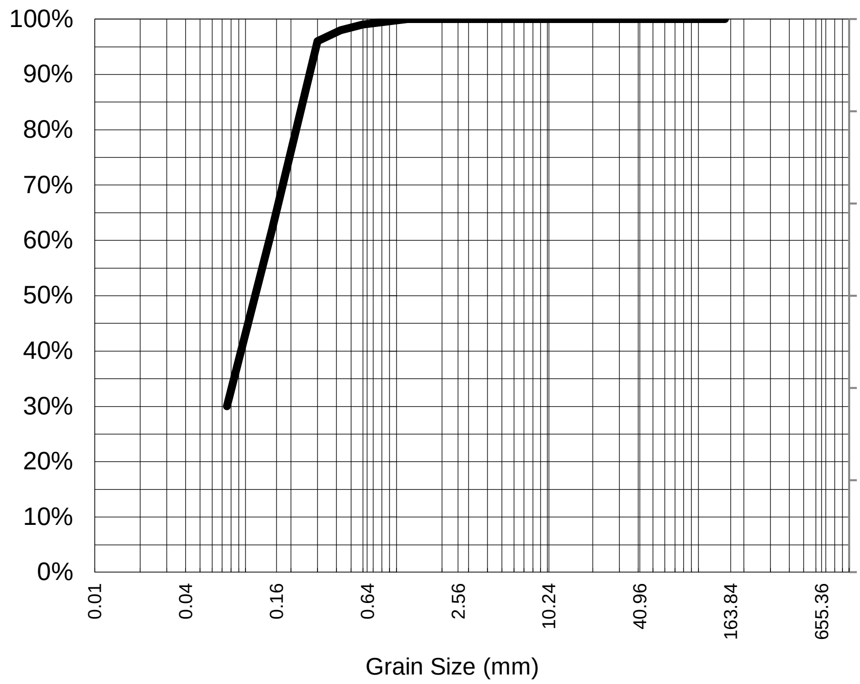
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-010 / PSD
PROJECT:	B23621	**SAMPLE ID:**	13

Particle Size Distribution



Particle Size (mm)	% Passing
1.18	100%
0.600	99%
0.425	98%
0.300	96%
0.150	62%
0.075	30%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.122

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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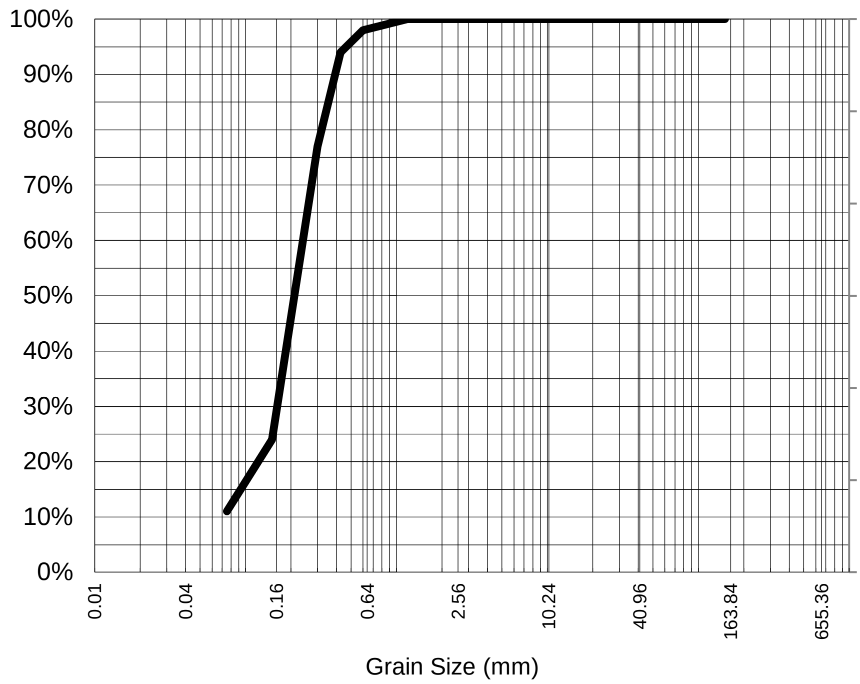
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-012 / PSD
PROJECT:	B23621	**SAMPLE ID:**	17

Particle Size Distribution



Particle Size (mm)	% Passing
1.18	100%
0.600	98%
0.425	94%
0.300	77%
0.150	24%
0.075	11%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.224

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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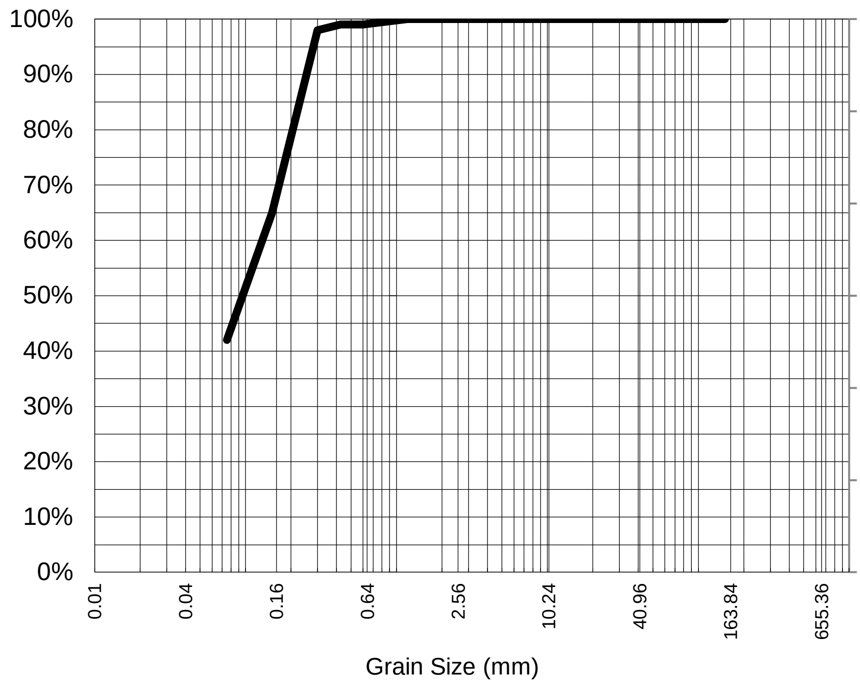
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-013 / PSD
PROJECT:	B23621	**SAMPLE ID:**	18

Particle Size Distribution



Particle Size (mm)	% Passing
1.18	100%
0.600	99%
0.425	99%
0.300	98%
0.150	65%
0.075	42%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.101

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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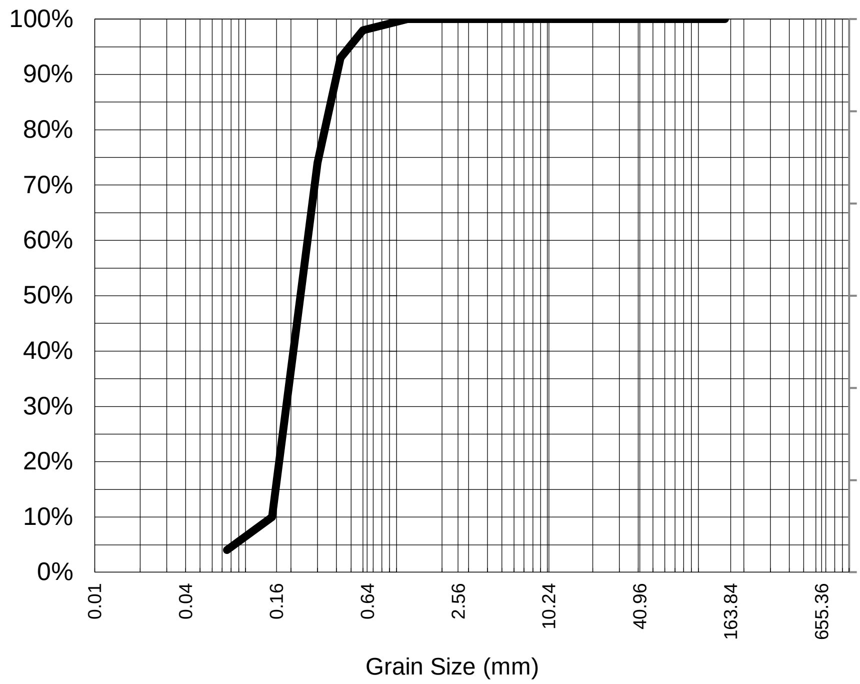
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-014 / PSD
PROJECT:	B23621	**SAMPLE ID:**	20

Particle Size Distribution



Particle Size (mm)	% Passing
1.18	100%
0.600	98%
0.425	93%
0.300	74%
0.150	10%
0.075	4%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.244

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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CLIENT: CONOR JONES

DATE REPORTED: 1-Sep-2021

COMPANY: BMT COMMERCIAL AUSTRALIA PTY LTD

DATE RECEIVED: 23-Aug-2021

ADDRESS: Po Box 203
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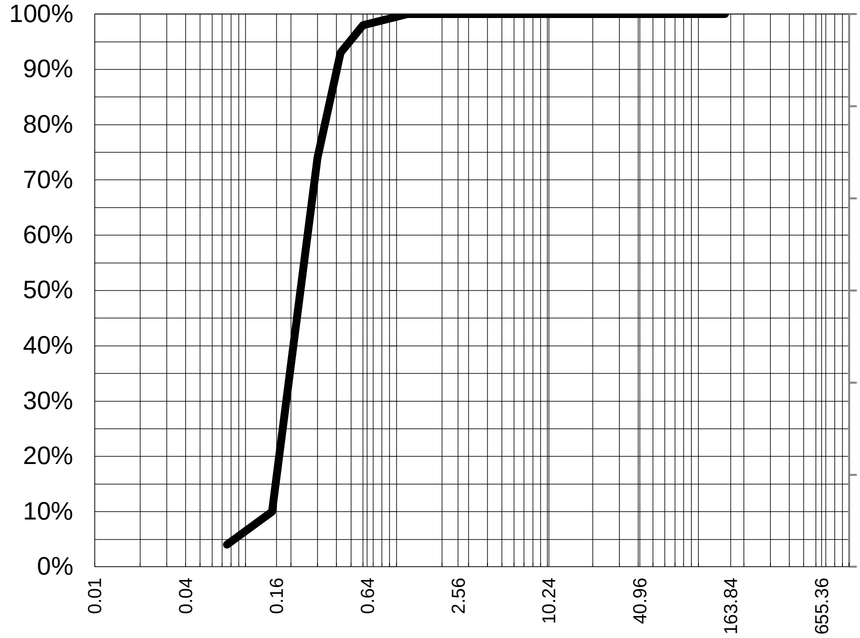
Brisbane Qld

REPORT NO: EB2123707-014DUP / PSD

PROJECT: B23621

SAMPLE ID: 20

Particle Size Distribution



Particle Size (mm)	% Passing
1.18	100%
0.600	98%
0.425	93%
0.300	74%
0.150	10%
0.075	4%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.244

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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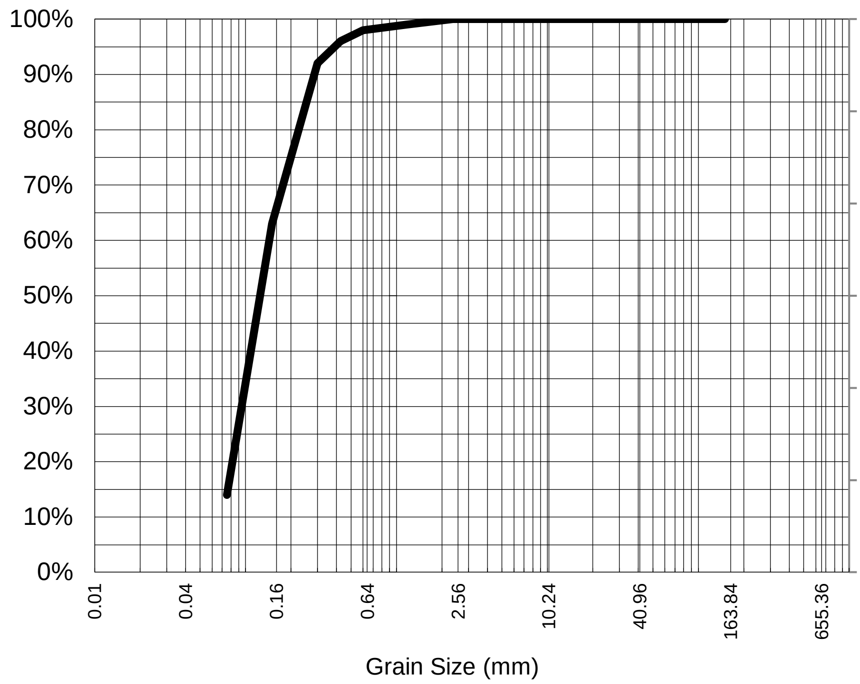
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-015 / PSD
PROJECT:	B23621	**SAMPLE ID:**	21

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	98%
0.425	96%
0.300	92%
0.150	63%
0.075	14%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.130

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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CLIENT: CONOR JONES

DATE REPORTED: 1-Sep-2021

COMPANY: BMT COMMERCIAL AUSTRALIA PTY LTD

DATE RECEIVED: 23-Aug-2021

ADDRESS: Po Box 203
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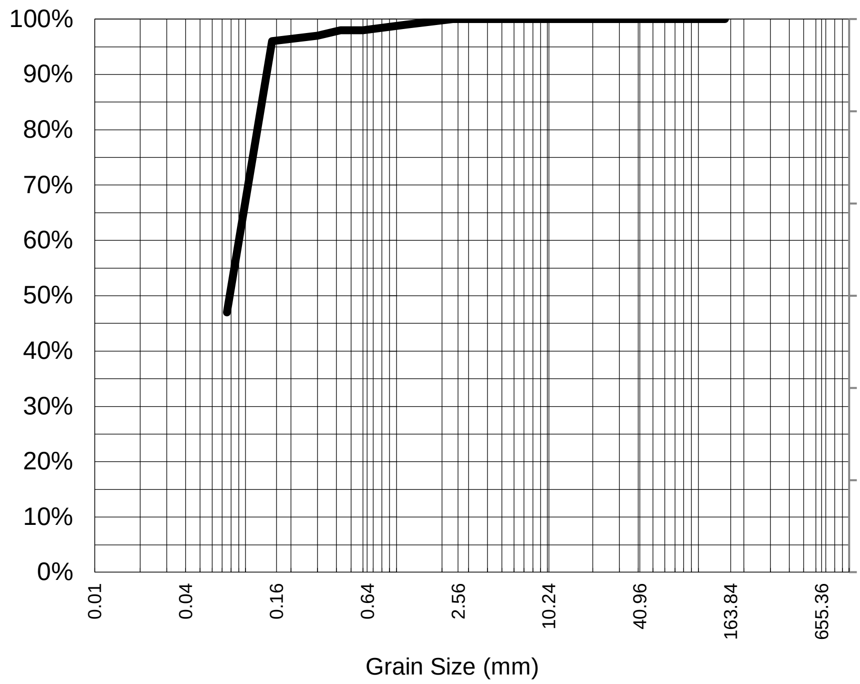
Brisbane Qld

REPORT NO: EB2123707-016 / PSD

PROJECT: B23621

SAMPLE ID: 22

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	98%
0.425	98%
0.300	97%
0.150	96%
0.075	47%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.080

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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CLIENT: CONOR JONES

DATE REPORTED: 1-Sep-2021

COMPANY: BMT COMMERCIAL AUSTRALIA PTY LTD

DATE RECEIVED: 23-Aug-2021

ADDRESS: Po Box 203
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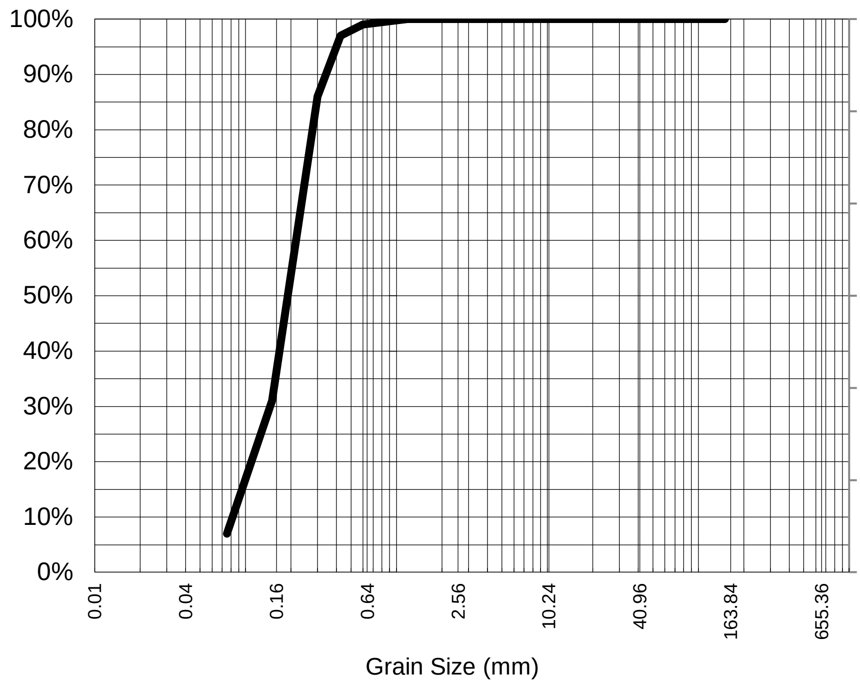
Brisbane Qld

REPORT NO: EB2123707-017 / PSD

PROJECT: B23621

SAMPLE ID: 24

Particle Size Distribution



Particle Size (mm)	% Passing
1.18	100%
0.600	99%
0.425	97%
0.300	86%
0.150	31%
0.075	7%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.202

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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CLIENT: CONOR JONES

DATE REPORTED: 1-Sep-2021

COMPANY: BMT COMMERCIAL AUSTRALIA PTY LTD

DATE RECEIVED: 23-Aug-2021

ADDRESS: Po Box 203
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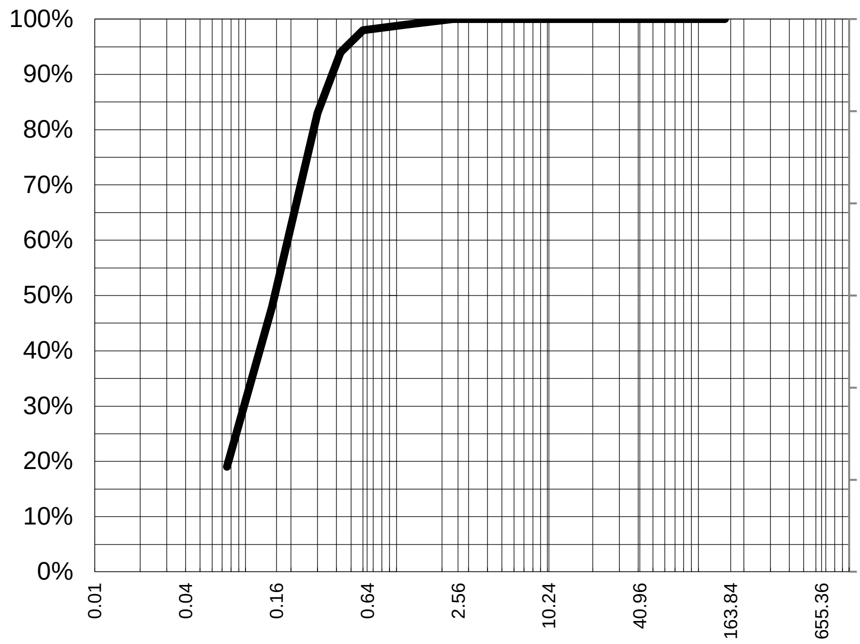
Brisbane Qld

REPORT NO: EB2123707-018 / PSD

PROJECT: B23621

SAMPLE ID: 25

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	98%
0.425	94%
0.300	83%
0.150	48%
0.075	19%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.159

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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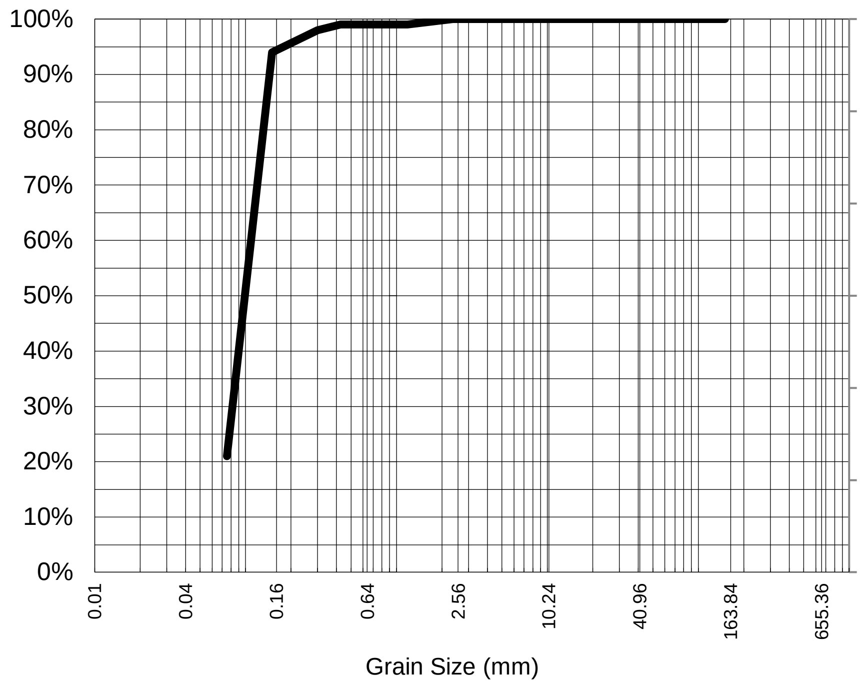
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-019 / PSD
PROJECT:	B23621	**SAMPLE ID:**	26

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	99%
0.425	99%
0.300	98%
0.150	94%
0.075	21%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.105

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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Satish Trivedi
Soil Senior Chemist
Authorised Signatory

Certificate of Analysis

ALS Laboratory Group Pty Ltd
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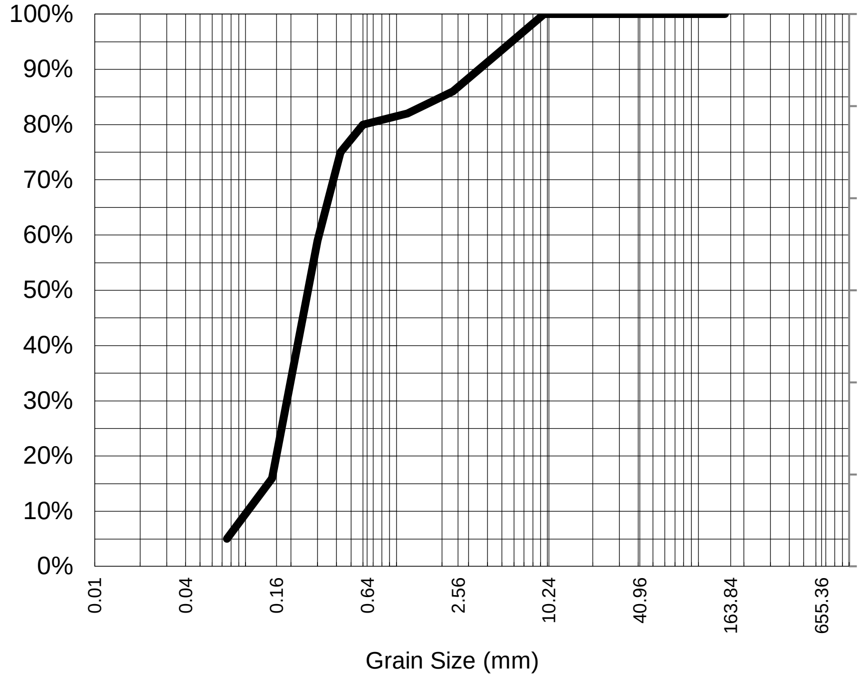
ALS Environmental

Brisbane QLD

CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-020 / PSD
PROJECT:	B23621	**SAMPLE ID:**	29

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	93%
2.36	86%
1.18	82%
0.600	80%
0.425	75%
0.300	59%
0.150	16%
0.075	5%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.269

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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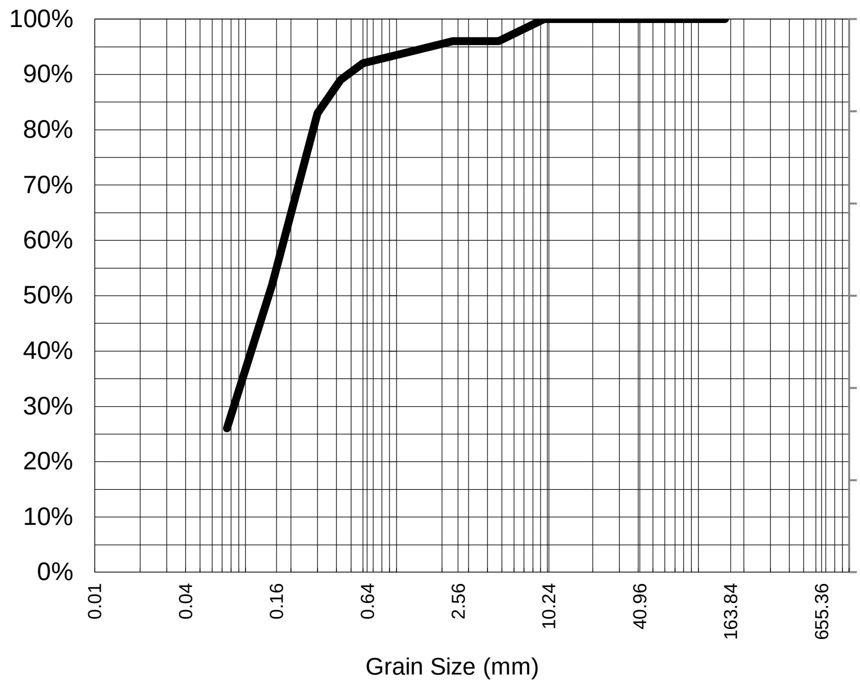
Brisbane QLD

CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-021 / PSD
PROJECT:	B23621	**SAMPLE ID:**	A

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	96%
2.36	96%
1.18	94%
0.600	92%
0.425	89%
0.300	83%
0.150	52%
0.075	26%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.144

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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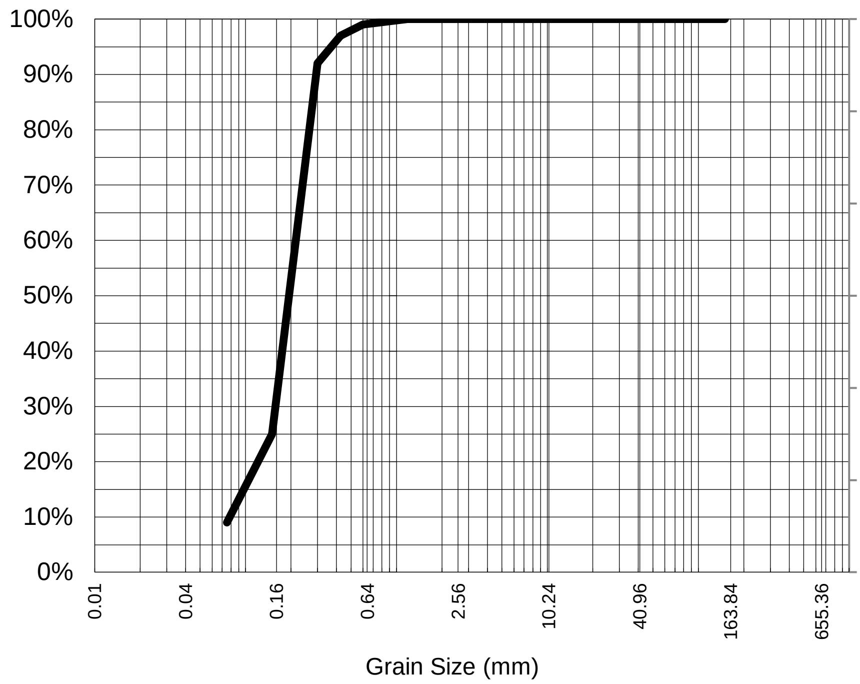
CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-023 / PSD
PROJECT:	B23621	**SAMPLE ID:**	C

Particle Size Distribution



Particle Size (mm)	% Passing
1.18	100%
0.600	99%
0.425	97%
0.300	92%
0.150	25%
0.075	9%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.206

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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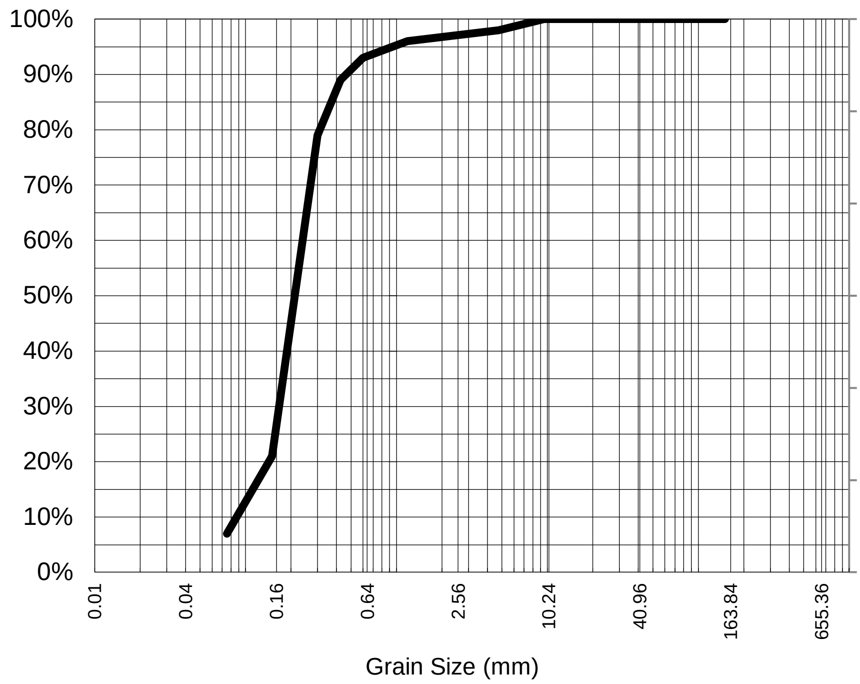
CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-024 / PSD
PROJECT:	B23621	**SAMPLE ID:**	D

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	98%
2.36	97%
1.18	96%
0.600	93%
0.425	89%
0.300	79%
0.150	21%
0.075	7%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.225

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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CLIENT: CONOR JONES

DATE REPORTED: 1-Sep-2021

COMPANY: BMT COMMERCIAL AUSTRALIA PTY LTD

DATE RECEIVED: 23-Aug-2021

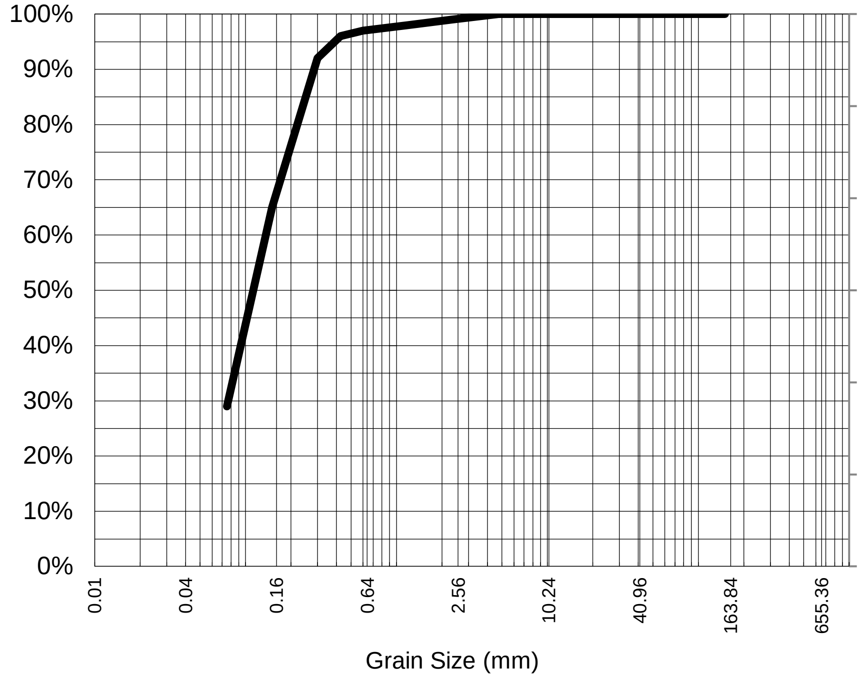
ADDRESS: Po Box 203
Spring Hill
Brisbane Qld

REPORT NO: EB2123707-025 / PSD

PROJECT: B23621

SAMPLE ID: E

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	99%
1.18	98%
0.600	97%
0.425	96%
0.300	92%
0.150	65%
0.075	29%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.119

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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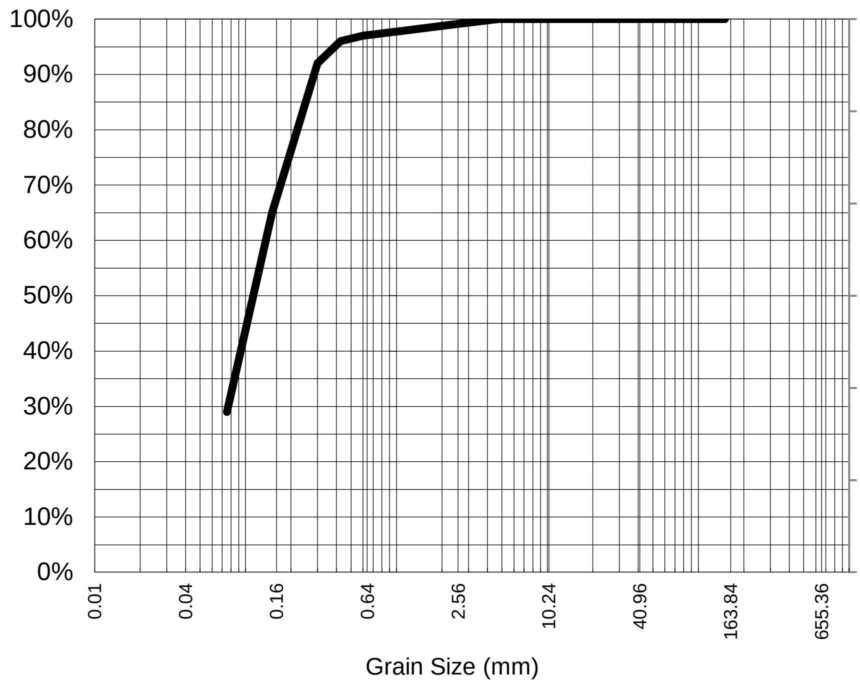
CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-025DUP / PSD
PROJECT:	B23621	**SAMPLE ID:**	E

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	99%
1.18	98%
0.600	97%
0.425	96%
0.300	92%
0.150	65%
0.075	29%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.119

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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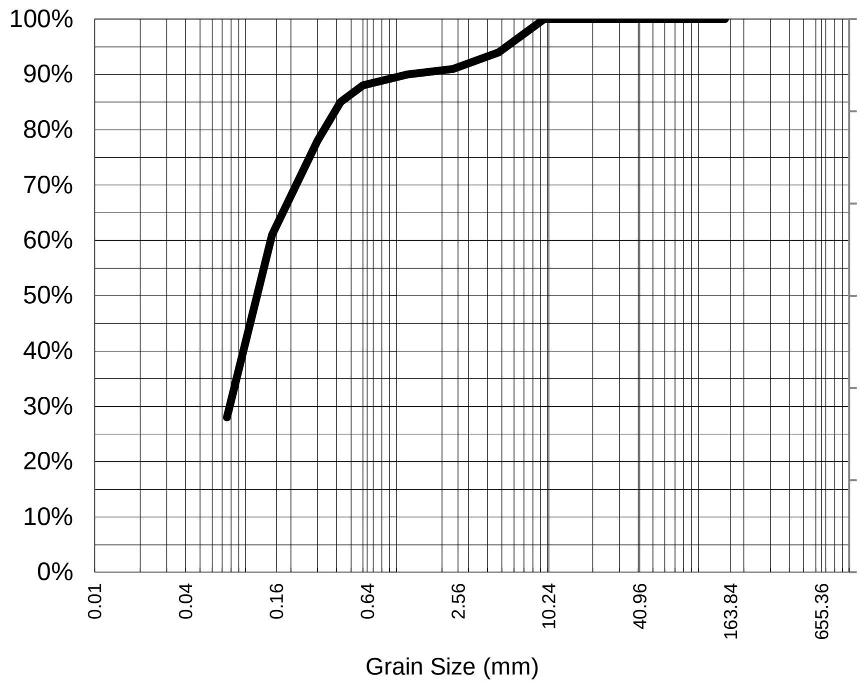
CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-026 / PSD
PROJECT:	B23621	**SAMPLE ID:**	F

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	94%
2.36	91%
1.18	90%
0.600	88%
0.425	85%
0.300	78%
0.150	61%
0.075	28%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.125

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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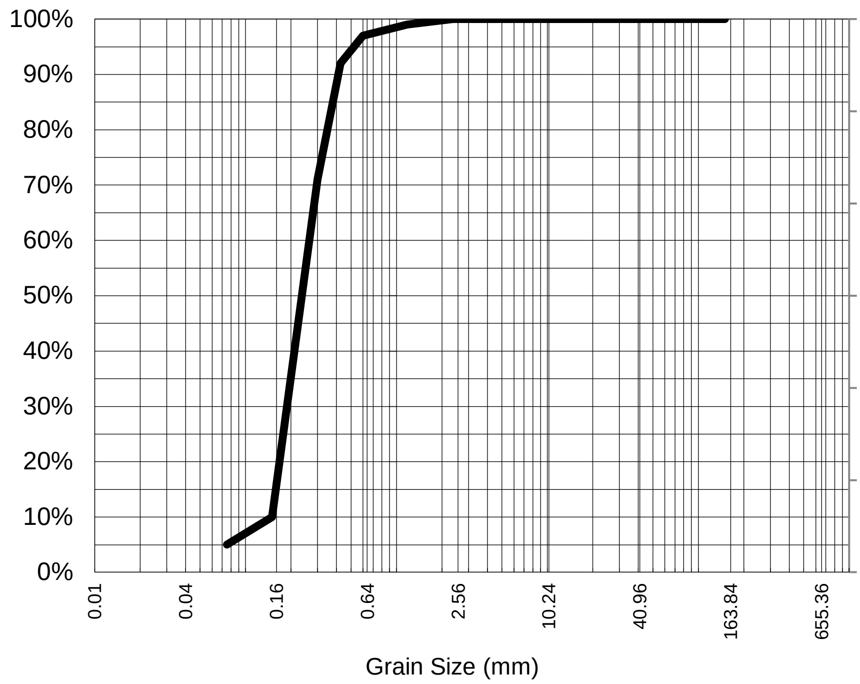
CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-027 / PSD
PROJECT:	B23621	**SAMPLE ID:**	H

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	97%
0.425	92%
0.300	71%
0.150	10%
0.075	5%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.248

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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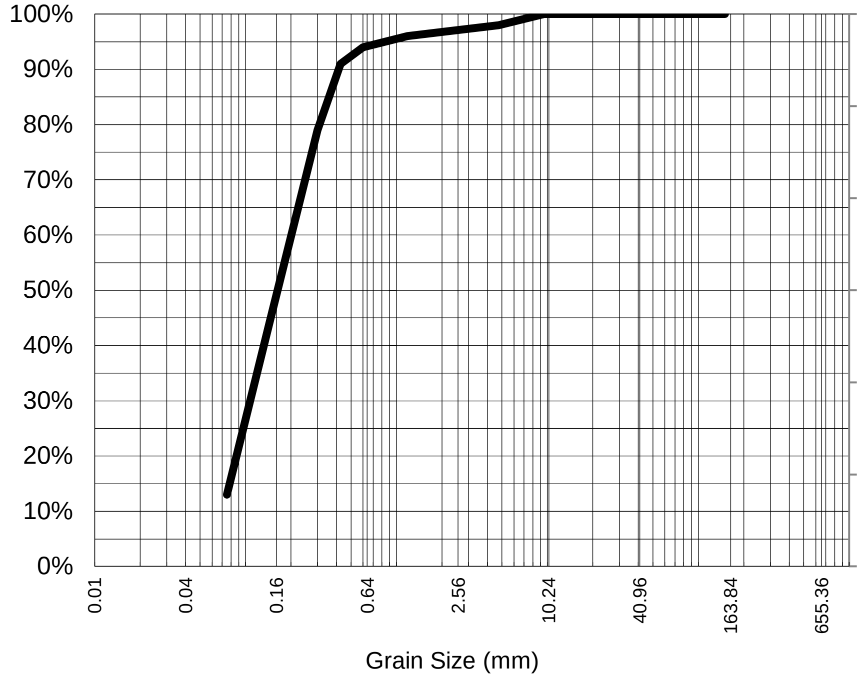
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-028 / PSD
PROJECT:	B23621	**SAMPLE ID:**	I

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	98%
2.36	97%
1.18	96%
0.600	94%
0.425	91%
0.300	79%
0.150	46%
0.075	13%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.168

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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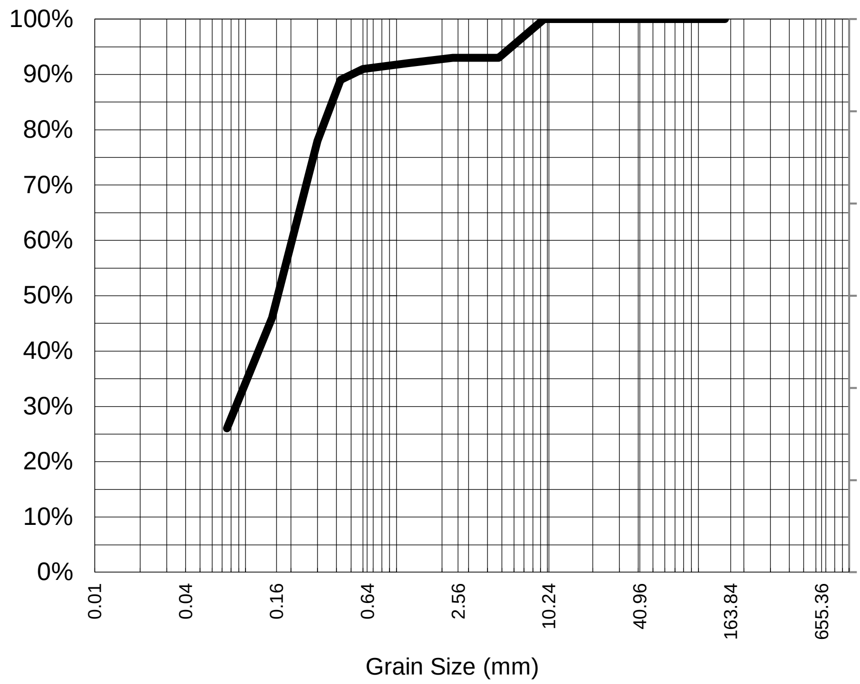
CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-029 / PSD
PROJECT:	B23621	**SAMPLE ID:**	J

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	93%
2.36	93%
1.18	92%
0.600	91%
0.425	89%
0.300	78%
0.150	46%
0.075	26%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.169

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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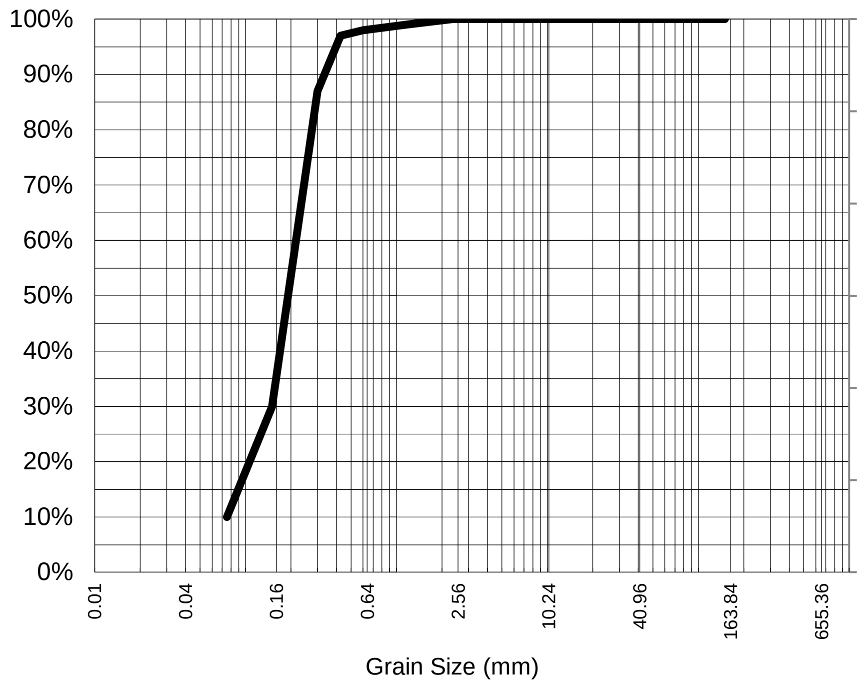
CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-030 / PSD
PROJECT:	B23621	**SAMPLE ID:**	K

Particle Size Distribution



Particle Size (mm)	% Passing
2.36	100%
1.18	99%
0.600	98%
0.425	97%
0.300	87%
0.150	30%
0.075	10%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.203

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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CLIENT: CONOR JONES

DATE REPORTED: 1-Sep-2021

COMPANY: BMT COMMERCIAL AUSTRALIA PTY LTD

DATE RECEIVED: 23-Aug-2021

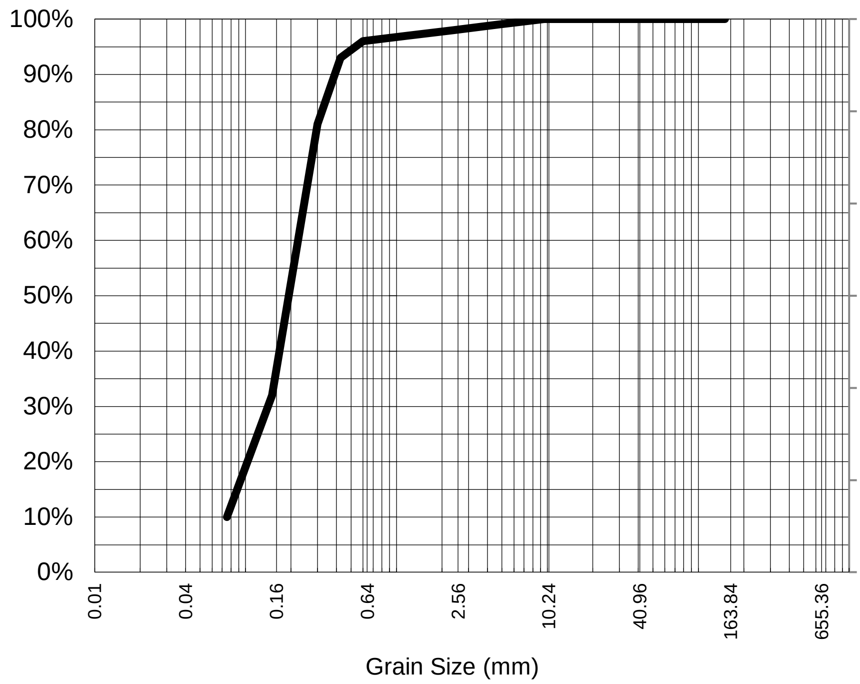
ADDRESS: Po Box 203
Spring Hill
Brisbane Qld

REPORT NO: EB2123707-031 / PSD

PROJECT: B23621

SAMPLE ID: L

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	99%
2.36	98%
1.18	97%
0.600	96%
0.425	93%
0.300	81%
0.150	32%
0.075	10%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.205

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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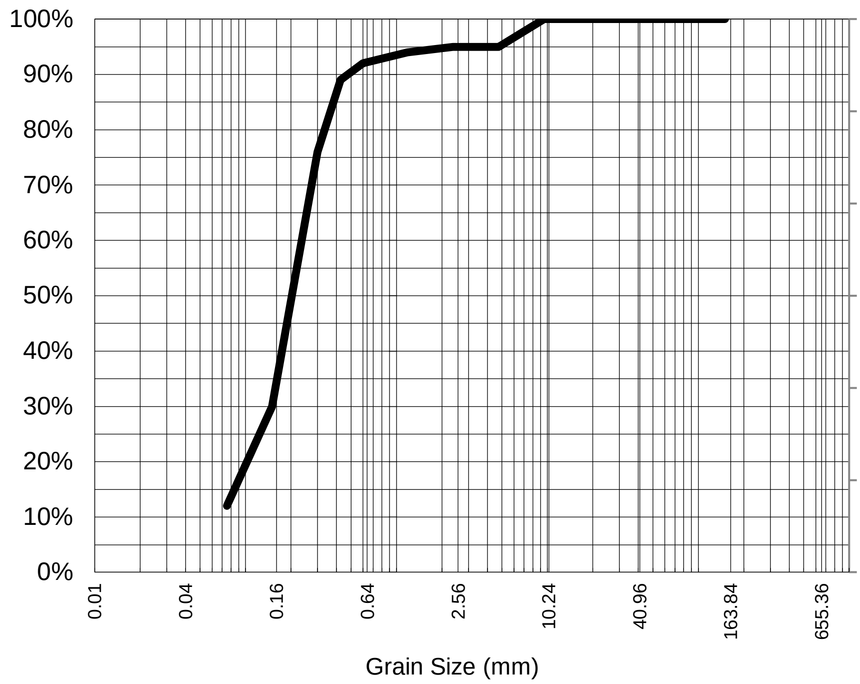
CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-032 / PSD
PROJECT:	B23621	**SAMPLE ID:**	M

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	95%
2.36	95%
1.18	94%
0.600	92%
0.425	89%
0.300	76%
0.150	30%
0.075	12%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.215

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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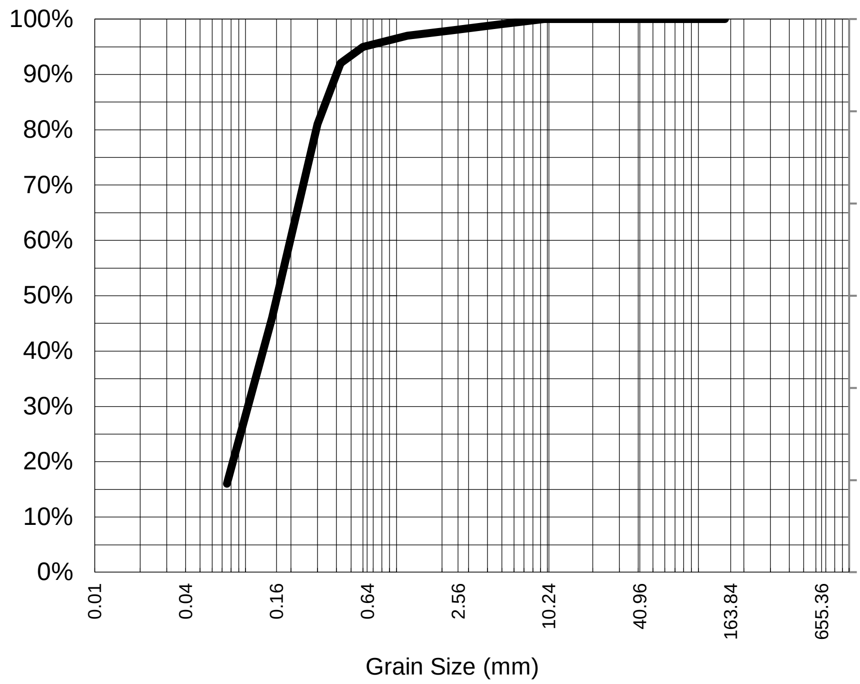
CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-033 / PSD
PROJECT:	B23621	**SAMPLE ID:**	N

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	99%
2.36	98%
1.18	97%
0.600	95%
0.425	92%
0.300	81%
0.150	46%
0.075	16%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.167

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

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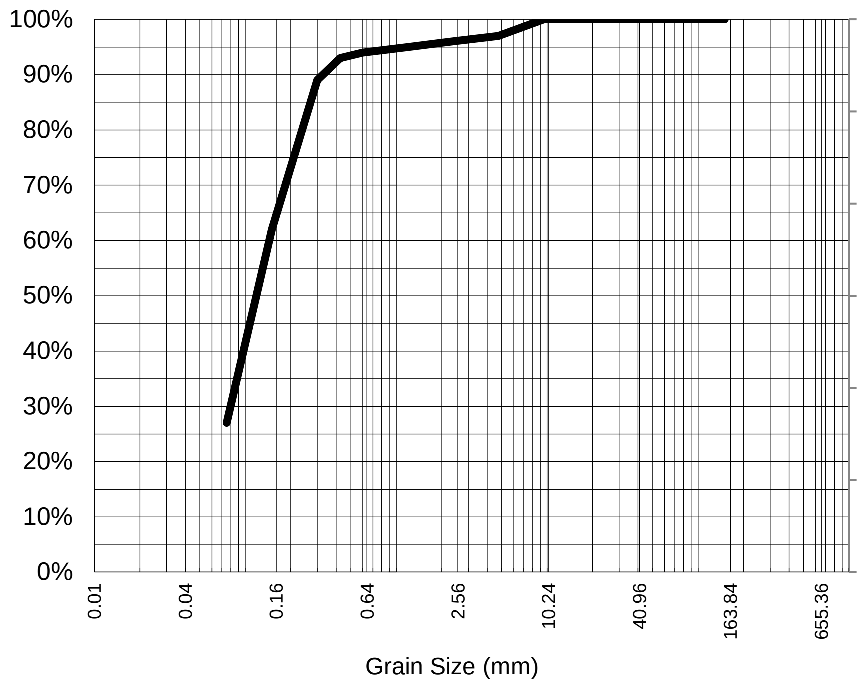
CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-036 / PSD
PROJECT:	B23621	**SAMPLE ID:**	Q

Particle Size Distribution



Particle Size (mm)	% Passing
9.50	100%
4.75	97%
2.36	96%
1.18	95%
0.600	94%
0.425	93%
0.300	89%
0.150	62%
0.075	27%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.124

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

#N/A

NATA Accreditation: 825 Site: Brisbane
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NATA
WORLD RECOGNISED ACCREDITATION

Satish Trivedi
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Certificate of Analysis

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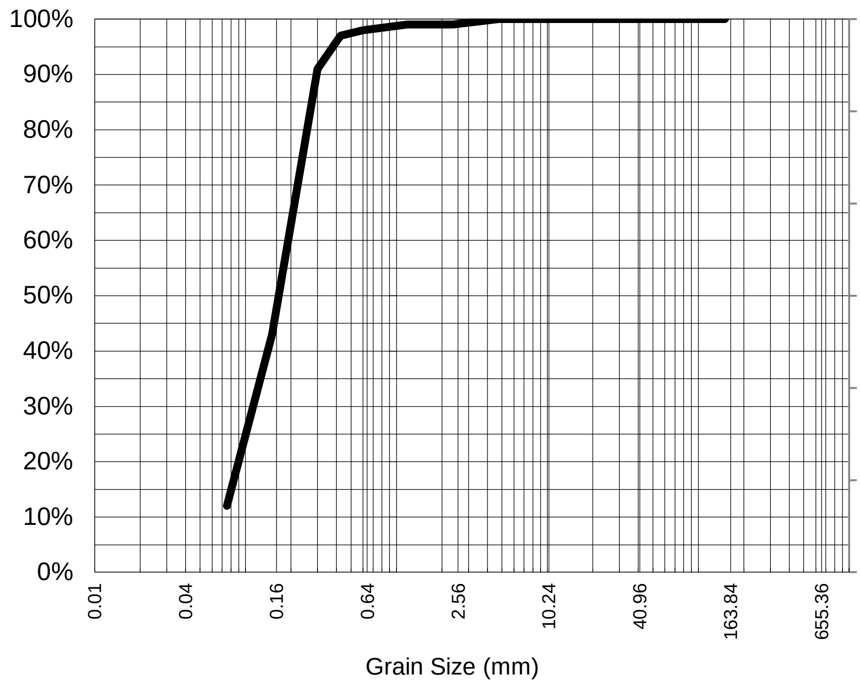
ALS Environmental

Brisbane QLD

CLIENT:	CONOR JONES	**DATE REPORTED:**	1-Sep-2021
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-037 / PSD
PROJECT:	B23621	**SAMPLE ID:**	R

Particle Size Distribution



Particle Size (mm)	% Passing
4.75	100%
2.36	99%
1.18	99%
0.600	98%
0.425	97%
0.300	91%
0.150	43%
0.075	12%

Analysis Notes

Samples analysed as received.

Median Particle Size (mm)*	0.172

Median Particle Size is not covered under the current scope of ALS's NATA accreditation.

Sample Comments:

Analysed: 25-Aug-21

Loss on Pretreatment NA

Limit of Reporting: 1%

Sample Description:

Test Method: AS1289.3.6.2/AS1289.3.6.3

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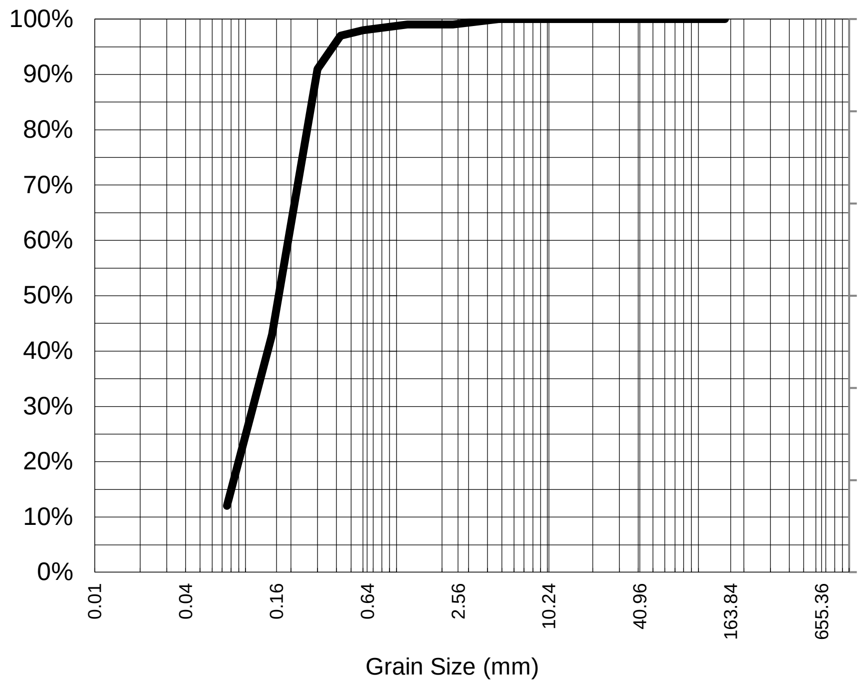
COMPANY:	BMT COMMERCIAL AUSTRALIA PTY LTD	**DATE RECEIVED:**	23-Aug-2021
ADDRESS:	Po Box 203 Spring Hill Brisbane Qld	**REPORT NO:**	EB2123707-037DUP / PSD
PROJECT:	B23621	**SAMPLE ID:**	R

Particle Size Distribution



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Template Version PKV8.0 180919

Appendix C Penetrometer summarized results

Site name	Lat	Long	Maximum Penetration (m)	Maximum Deceleration (g)	Firmness Factor (F_f)
2	-27.354	153.200	0.19	24.86	7.90
4	-27.366	153.200	0.41	8.86	1.19
5	-27.366	153.212	0.24	29.87	7.97
6	-27.365	153.222	0.45	11.09	1.60
9	-27.378	153.213	0.05	98.98	118.46
12	-27.389	153.200	0.16	19.54	7.54
C	-27.370	153.191	0.09	38.39	26.55
D	-27.372	153.196	0.13	43.36	21.69
H	-27.367	153.196	0.14	36.58	16.64
F_A1	-27.349	153.206	0.56	6.84	0.68
F_A2	-27.353	153.204	0.66	5.36	0.43
F_A3	-27.357	153.201	0.34	14.06	2.09
F_A4	-27.361	153.198	0.50	9.65	1.04
F_A5	-27.364	153.196	0.20	24.54	7.89
F_A6	-27.368	153.193	0.08	65.70	51.25
F_B1	-27.351	153.211	0.61	5.88	0.51
F_B2	-27.355	153.208	0.59	6.41	0.58
F_B3	-27.359	153.205	0.54	7.09	0.76
F_B4	-27.363	153.203	0.33	19.08	3.75
F_B5	-27.367	153.200	0.32	9.66	1.49
F_B6	-27.370	153.197	0.13	40.04	21.31
F_C1	-27.354	153.215	0.54	6.23	0.58
F_C2	-27.358	153.212	0.59	6.55	0.62
F_C3	-27.361	153.209	0.30	24.90	5.27
F_C4	-27.365	153.207	0.23	37.52	10.67
F_C5	-27.369	153.204	0.09	50.08	31.18
F_C6	-27.373	153.202	0.06	80.17	74.17
F_D1	-27.356	153.219	0.64	5.50	0.44
F_D2	-27.360	153.217	0.61	5.01	0.43
F_D3	-27.364	153.214	0.26	26.42	6.93

Penetrometer summarized results

Site name	Lat	Long	Maximum Penetration (m)	Maximum Deceleration (g)	Firmness Factor (F_f)
F_D4	-27.368	153.211	0.26	27.18	6.74
F_D5	-27.371	153.209	0.07	96.91	85.84
F_D6	-27.375	153.206	0.06	100.14	102.98
F_E1	-27.358	153.223	0.61	5.78	0.51
F_E2	-27.362	153.221	0.63	6.06	0.54
F_E3	-27.366	153.218	0.34	20.91	3.57
F_E4	-27.370	153.216	0.18	29.47	10.52
F_E5	-27.374	153.213	0.06	99.21	97.07
F_E6	-27.378	153.211	0.05	91.84	107.00
F_E7	-27.382	153.208	0.06	73.22	67.69
F_E8	-27.385	153.205	0.10	39.99	22.85
F_E9	-27.389	153.202	0.18	21.27	7.85
F_F1	-27.361	153.228	0.64	4.95	0.40
F_F10	-27.395	153.204	0.23	26.77	8.20
F_F11	-27.399	153.201	0.17	19.54	7.25
F_F2	-27.364	153.225	0.56	7.08	0.64
F_F5	-27.376	153.217	0.07	105.23	100.43
F_F6	-27.380	153.215	0.09	71.12	44.34
F_F7	-27.384	153.212	0.29	23.93	5.28
F_F8	-27.388	153.210	0.23	21.90	6.48
F_F9	-27.392	153.207	0.19	28.48	9.87
F_G1	-27.363	153.232	0.55	6.52	0.69
F_G2	-27.367	153.230	0.17	43.71	20.15

BMT has a proven record in addressing today's engineering and environmental issues.

Our dedication to developing innovative approaches and solutions enhances our ability to meet our client's most challenging needs.

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