BHP

Saraji Mine

Progressive Rehabilitation and Closure Plan

Environmental Geochemical Characterisation and Risk Assessment of Mineral Waste

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EXECUTIVE SUMMARY

This report serves to document and discuss the environmental geochemical characteristics of mineral waste materials associated with Saraji Mine (SRM), as supporting information for the progressive rehabilitation and closure plan (PRCP) for SRM.

The objective of the assessment is to evaluate the geochemical nature of mineral waste currently at SRM and mineral waste likely to be present at closure, and identify relevant environmental issues/opportunities that may be associated with mining, handling and storing mineral waste to inform appropriate rehabilitation and management strategies.

SRM administration and industrial area is located approximately 50 kilometres (km) south of Moranbah township and about 20 km north of Dysart township, in central Queensland. The site is located south of Peak Downs Mine (PDM) and north of Saraji South Mine (SSM) [previously called Norwich Park Mine] – both of which are operated by BHP Mitsubishi Alliance Pty Ltd (BMA). SRM is flanked on the east and west by pastoral leases. SRM commenced operations in 1974.

SRM comprises typical open-pit coal mining facilities, such as open pits, waste rock (spoil) dumps, tailings storage facilities (TSFs), stockpiles, coal processing facilities, rail loadout facilities, process water and raw water dams, surface water drains and administration areas.

Current activities of relevance to this waste characterisation report comprise:

- Disposal of spoil to in-pit spoil dumps behind the active mining face (in-pit low-wall spoil disposal);
- Current disposal of tailings to Ramp 2/3 TSF;
- Historic disposal of tailings to four above-ground and in-pit TSFs (TSF no. 2, TSF no. 3, TSF no. 4, Ramp 6);
- Short-term storage of run of mine (ROM) coal on the ROM Pad;
- ROM coal processing at the coal handling and preparation plant (CHPP), which produces two mineral waste types:
    - Tailings. Clay, silt and very fine to medium-grain sized sand material produced from processing ROM coal, and disposed into TSFs;
    - Rejects. Coarse sand to cobble-sized material produced from processing ROM coal, and disposed (buried) within spoil dumps.
- Short-term storage of product coal on the product coal stockpile, awaiting off-site transport by rail;
- The operation of raw water and process water dams and sediment control structures as stipulated in the EA.

The mine domains of direct relevance to mineral waste characterisation and management at SRM at closure are:

- Pits (grouped as per the four residual voids):
    - Jacaranda Pit / Bauhinia Pit. Includes current Acacia Pit, which will be backfilled as mining progresses;
    - Coolibah Pit / Dogwood Pit (North and South);
    - Ebony Pit / Grevillea Pit;
    - Hakea Pit.
- Spoil dumps (grouped as per the four residual voids and associated spoil landforms):
    - Jacaranda and Bauhinia dumps. Includes current Acacia spoil dump, which will be merged into Jacaranda pit spoil as mining progresses;
    - Coolibah and Dogwood dumps;
    - Ebony and Grevillea dumps;
    - Hakea dump.

- TSFs:
  - Ramp 2/3 TSF (current active TSF; will be buried beneath Jacaranda-Bauhinia spoil landform);
  - Ramp 6 TSF (historic facility; will be buried beneath Coolibah-Dogwood spoil landform);
  - TSF no. 2 (historic facility – closed and partially capped; will be buried beneath Coolibah-Dogwood spoil landform);
  - TSF no. 3 (historic facility – closed and rehabilitated; will remain as a rehabilitated TSF landform);
  - TSF no. 4 (historic facility – closed and rehabilitated, will be buried beneath Coolibah-Dogwood spoil landform).
- Coal stockpiles: ROM coal pad and stockpile; Product coal pad and stockpile.

SRM has three main types of mineral waste, and the geochemical characteristics and potential hazards associated with mineral waste materials on site are discussed by type:

- Spoil (overburden and interburden) currently comprises approximately 97% of all mineral waste at SRM and includes weathered waste (Tertiary and Permian-age – in approximately equal proportions) and fresh (unweathered) waste (all Permian-age). Approximately 85% of spoil is fresh and the remaining (approximately 15%) is weathered/oxidised.
- Tailings are generated at the CHPP from processing ROM coal and typically represent the clay, silt and fine sand fractions of ROM waste. Throughout operations at SRM, tailings has been disposed as a slurry into a number of TSFs – the current (active) TSF being Ramp 2/3. Tailings comprises approximately 0.5% of all mineral waste at SRM. Current tailings are derived from ROM coal from SRM. Future tailings will be derived from ROM coal from SRM and SSM.
- Rejects are generated at the CHPP from processing ROM coal and typically represents coarser and rockier seam roof, partings and floor material. Rejects are trucked to spoil dumps and disposed (buried) within spoil. Reject comprises approximately 2.4% of all mineral waste at SRM – with this approximated proportion expected for the remaining life of asset mine plan. Current rejects are derived from ROM coal from SRM. Future rejects will be derived from ROM coal from SRM and SSM.

Coal is also included in the assessment; however, coal is generally not considered mineral waste, with the exception of small quantities of sub-economic seams that may report to the spoil dump, and remnant coal exposed on pit highwalls (such as in residual voids).

Mineral waste samples have undergone environmental geochemical characterisation and assessment with regard to their potential to generate acid and metalliferous drainage (AMD), which comprises acid drainage (AD), neutral and metalliferous drainage (NMD) and/or saline drainage (SD) [salinity due to sulphate derived from sulphide oxidation]. Additionally, samples have been assessed with regard to their potential to generate salinity (non-oxidative) and, for spoil materials, their sodicity and dispersion potential.

AMD Potential of Mineral Waste and Coal Material Types

AMD Potential of Spoil – non-carbonaceous

Non-carbonaceous spoil, which comprises about 95% of spoil, is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage), which is typical for sedimentary materials in the Bowen Basin.

The total S (S) concentration of non-carbonaceous spoil is generally low, with a 90th percentile total S concentration of 0.52%. As such, and combined with moderate to high acid neutralising capacity (ANC) values, approximately 86% of non-carbonaceous spoil samples tested (606 out of 706 samples) were classified as non-acid forming (NAF), with a further 2% of samples classified as UC(NAF) [uncertain, but expected to be NAF] or NAF-S [NAF, but with total S greater than 1%].

Eighty-eight out of 706 samples (12% of non-carbonaceous spoil samples) were classified as either potentially acid forming (PAF), PAF-LC [PAF, low capacity] or UC(PAF) [uncertain, but expected to be PAF or PAF-LC]. Almost all of the non-carbonaceous spoil samples classified as PAF, PAF-LC or UC(PAF) were closely associated with coal seams and could potentially end up as coarse reject if mined with ROM coal.

The test-work undertaken has demonstrated that the ANC for the non-carbonaceous spoil is generally expected to be about 30-70% available under field conditions, with iron-dolomite being the main carbonate mineral contributing to the acid buffering potential of the spoil. Overall, non-carbonaceous spoil has excess acid neutralising capacity and is expected to be bulk acid consuming.

Total metal and metalloid concentrations from 118 non-carbonaceous spoil samples tested are very low compared to average element abundance in soil in the earth's crust. Eleven samples assayed (out of 118 samples) had significant enrichment with respect to beryllium (Be) and 12 samples had significant enrichment with regard to S, which was consistent with the geochemical data. The enrichment in Be in a small number of samples is not cause for concern. Almost all samples had minor enrichment with respect to Be – which is typical for Bowen Basin sedimentary materials. Four (out of 118) samples had significant enrichment with regard to arsenic (As) and mercury (Hg) and one of these four samples also had significant enrichment with regard to barium (Ba) and selenium (Se). There was no correlation found between AMD classifications of the non-carbonaceous spoil samples compared to elemental enrichment. In summary, non-carbonaceous spoil has low enrichment in total metals and metalloids compared to unmineralised rocks.

Soluble multi-element results (from 71 samples) indicate that leachate from non-carbonaceous spoil is expected to contain low concentrations of soluble metals and metalloids. Five samples – mostly all classified as PAF (of some type) – produced moderate soluble metal concentrations, having slightly elevated soluble concentrations in the leachate for one or more of the following elements: aluminium (Al), iron (Fe), cobalt (Co), manganese (Mn), nickel (Ni) and/or zinc (Zn). Peroxide leaching undertaken on eight non-carbonaceous spoil samples showed that PAF material, when oxidised, has the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

Based on the results, non-carbonaceous spoil – which comprises the large majority of spoil – has a low potential to generate AMD as either AD and/or NMD and/or SD. A small proportion of non-carbonaceous spoil does have a higher potential to generate AMD, however when mixed and distributed amongst the broader spoil material the overall potential for non-carbonaceous spoil to generate AMD is low.

AMD Potential of Spoil – carbonaceous

Carbonaceous spoil represents less than 5% of spoil material at SRM and typically includes carbonaceous siltstone, carbonaceous sandstone, carbonaceous mudstone and coaly shale, but also includes similar coaly and carbonaceous materials other than coal. Carbonaceous spoil is commonly associated with (and close to) coal seams.

Carbonaceous spoil – as a bulk material – is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage), similar to non-carbonaceous spoil.

The total S concentration of carbonaceous spoil is low-moderate, with a 90th percentile total S concentration of 0.99% (from 97 samples). Three samples had moderate total S (and Scr) concentrations and seven samples had high total S concentrations (S > 1.5%). Combined with generally low ANC values (median 16 kg H_2SO_4/t) and relatively low maximum potential acidity (MPA) values (median 7.0 kg H_2SO_4/t), approximately 73% of carbonaceous spoil samples (71 out of 97 samples) were classified as NAF, one sample was classified as UC(NAF) and one sample was classified as NAF-S.

Approximately 25% of carbonaceous spoil samples (24 out of 97 samples) were classified as PAF, PAF-LC or UC(PAF). Almost all of the carbonaceous spoil samples classified as PAF, PAF-LC or UC(PAF) were closely associated with coal seams and could potentially end up as coarse reject if mined with ROM coal.

Limited information suggests that ANC in carbonaceous spoil is expected to be about 13% to 42% available under field conditions, with iron-dolomite being the main carbonate mineral contributing to the acid buffering potential of the spoil. Overall, carbonaceous spoil has relatively limited acid neutralising capacity.

Total metal and metalloid concentrations from 10 carbonaceous spoil samples tested are very low compared to average element abundance in soil in the earth's crust, and very similar to the assay concentrations from non-carbonaceous spoil. Two samples assayed (out of 10 samples) had significant enrichment with respect to Ba. There was no correlation found between AMD classifications of the carbonaceous spoil samples compared to

elemental enrichment. In summary, carbonaceous spoil has low enrichment in total metals and metalloids compared to unmineralised rocks.

Soluble multi-element results (from 15 samples) indicate that leachate from carbonaceous spoil is expected to contain low concentrations of soluble metals and metalloids – similar to the non-carbonaceous spoil samples. Peroxide leaching undertaken on one weathered carbonaceous spoil sample shows that this PAF sample, when oxidised, has the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

Based on the results, carbonaceous spoil has a generally low potential to generate AD and/or NMD and/or SD. A small proportion of this material type – mostly associated with coal seams – has some potential to generate low-level AD and/or NMD and/or SD.

AMD Potential of Tailings

The geochemical characteristics differed between fresh tailings from the CHPP versus aged tailings from the older TSFs (TSF no. 2, TSF no. 3 and TSF no. 4) for different parameters – particularly total S (and, by inference, MPA), ANC and pH, however the overall geochemical (AMD) hazard posed by tailings from the two sources (fresh vs aged) was generally similar.

Fresh (CHPP) tailings – representative of tailings in Ramp 2/3 TSF – is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage). Comparatively, aged tailings from TSF no. 2, TSF no. 3 and TSF no. 4 is likely to generate slightly lower pH contact water – typically in the range of near-neutral to alkaline, but some aged tailings could generate weakly acid contact water.

The total S concentration of fresh (CHPP) tailings is generally moderate, with median and 75th percentile total S concentrations of 1.25% and 1.52%. As such, fresh tailings samples produced moderate MPA values. Comparatively, aged (TSF) tailings generally had low to low-moderate total S concentrations, with median and 75th percentile total S concentrations of 0.42% and 0.49% - and produced correspondingly low to low-moderate MPA values.

In the fresh (CHPP) tailings samples about 70% (on average) of the total S is present as sulphide (Scr). Comparatively, only 34% (on average) of the total S is present as Scr in the aged (TSF) tailings samples. The difference in the proportion of total S as Scr between fresh versus aged tailings is typical and expected – indicating that the aged tailings in the TSF are being oxidised since deposition (sulphide oxidised to sulphate).

Just as there were significant differences between the total S concentrations in fresh (CHPP) versus aged (TSF) tailings, so too with the ANC values of fresh versus aged tailings. Fresh (CHPP) tailings had generally high ANC values (median 37 kg H_2SO_4/t) compared to aged (TSF) tailings, which had generally very low to low ANC values (median 6 kg H_2SO_4/t). The reason behind the lower ANC observed in aged tailings (compared to fresh tailings) is not well understood. It may be due to ANC being consumed via buffering of acidity generated by sulphide oxidation and/or sulphate leaching; and/or it could be related to inherent differences in the geochemical properties of the coal from earlier mining compared to recent mining.

In the fresh (CHPP) tailings samples, ANC is generally expected to be about 50-90% available under field conditions, with iron-dolomite and dolomite as the main neutralising minerals contributing to the acid buffering of fresh tailings. ANC availability for aged (TSF) tailings was unable to be determined.

As a bulk material, tailings (fresh and aged) have generally low negative to low positive net acid producing potential (NAPP) values, with median NAPP values of 3.4 and 7.6 kg H_2SO_4/t for the fresh and aged tailings, respectively. Tailings – of both types – had a wide range of net acid generation (NAG) pH values with 39% and 64% of fresh and aged tailings, respectively, having NAGpH values less than pH 4.5.

The above characteristics resulted in 44% of tailings samples being classified as NAF of some type. Overall, 55% of tailings samples were classified as PAF of some type – with 26% classified as PAF-LC, 22% classified as UC(PAF) [of which most were aged tailings] and the remaining 7% classified as PAF.

Oxygen consumption (OxCon) test-work undertaken on five tailings samples found that the two fresh (CHPP) tailings samples – initially classified as NAF and NAF-S – had very low pyrite oxidation rates and, consequently, a low potential for AMD (confirming the NAF classifications). Comparatively, the three aged (TSF) tailings samples –

initially classified as PAF-LC, UC(PAF) and PAF – had much higher pyrite oxidation rates and posed a moderate risk of generating AD – confirming the general 'PAF' classification of these samples.

There is a level of uncertainty surrounding the AMD classification of 34% (about one-third) of the tailings samples and, as such, these samples have been tentatively classified as UC(NAF) or UC(PAF) based on comparing the data available for these samples with the results from similar tailings samples where more detailed geochemical test-work has been undertaken. Despite this potential shortcoming, the classification of the tailings samples is considered to be conservative and classifying 56% of the tailings samples as PAF (of some sort) is almost certainly an upper limit.

With few exceptions, the total metal and metalloid concentrations from 44 tailings samples tested are generally low compared to average element abundance in soil in the earth's crust. About half of the fresh (CHPP) tailings samples were significantly enriched with regard to S, which is consistent with the ABA data showing higher total S concentrations in fresh (CHPP) samples compared to aged (TSF) samples. About half of the tailings samples had minor enrichment with regard to Se and/or Be. There was no correlation found between AMD classifications of the tailings samples compared to elemental enrichment.

Solubility data indicates that leachate from tailings under freshwater (deionised water) leaching conditions is expected to contain low concentrations of soluble metals and metalloids – for most tailings materials. Some tailings samples produced moderately to weakly acidic leachate with moderate soluble metals and metalloid concentrations following a freshwater leach. Under saline leaching conditions, tailings produced low concentrations of soluble metals and metalloids.

Peroxide leaching undertaken on 28 tailings samples showed that when exposed to highly oxidising conditions a significant proportion of tailings can produce highly to weakly acidic leachate with moderate soluble metals and metalloid concentrations. However, a significant proportion of tailings appeared to be influenced to some degree by the presence of organic acids, due to the samples' high organic carbon concentration. This likely accounts to some degree for the acidity and 'elevated' soluble metals and metalloid concentrations evident in these tailings. Nevertheless, PAF tailings [including tailings classified as UC(PAF)] have typically produced moderate soluble metals and metalloid concentrations from the freshwater and peroxide leaching tests, indicating that these PAF materials have the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

Based on the results, at least half of tailings has a moderate to high potential to generate AMD as either AD and/or NMD and/or SD, whereas the remaining half has a relatively low potential to generate AMD as either AD and/or NMD and/or SD. As such, as a bulk material, tailings has a moderate potential to generate AMD as either AD and/or NMD and/or SD.

AMD Potential of Rejects

Fresh rejects (from the CHPP) are expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage). Aged rejects (from the TSFs and Ramp 4 rejects area) has slightly lower pH compared to fresh rejects, and is expected to generate pH-alkaline contact water (run-off and seepage).

The total S concentration of rejects is generally low to low-moderate – higher in fresh (CHPP) rejects (median 0.72%) compared to aged rejects from the TSFs and Ramp 4 rejects area (median 0.47%). ANC data is generally only available for fresh (CHPP) rejects and is generally moderate ANC (median 26 kg H_2SO_4/t), which is only marginally higher than the MPA of these same samples (median 22 kg H_2SO_4/t). However, NAG data for fresh (CHPP) rejects samples shows that 78% of fresh rejects samples have NAGpH values greater than pH 4.5.

The above characteristics resulted in 87% of rejects samples being classified as NAF, NAF-S or UC(NAF) – of which most of the fresh (CHPP) samples were classified as NAF and most of the aged (TSF) samples were classified as UC(NAF). Ten 10 rejects samples were classified as 'PAF' to some degree.

The test-work demonstrated that the ANC for the fresh (CHPP) rejects is generally expected to be about 30-100% available under field conditions, with iron-dolomite and dolomite being the main carbonate mineral contributing to the acid buffering potential of the rejects. Overall, fresh (CHPP) rejects has excess acid neutralising capacity.

The total metal and metalloid concentrations from 17 fresh (CHPP) rejects samples are generally low compared to average element abundance in soil in the earth's crust, and the assay results are very similar to total metal and

metalloid concentrations from tailings samples – i.e. about half of the fresh (CHPP) rejects samples were significantly enriched with regard to S, which is consistent with the ABA data for these samples. About half of the fresh (CHPP) rejects samples had minor enrichment with regard to Se and/or Be. There was no correlation found between AMD classifications of the rejects samples compared to elemental enrichment.

Solubility data indicates that leachate from fresh (CHPP) rejects under freshwater (deionised water) and saline water leaching conditions is expected to contain low concentrations of soluble metals and metalloids.

Kinetic column leaching data obtained over a 12-week leaching period of one rejects sample (classified as PAF-LC) and four 'potential rejects' samples (classified as UC(PAF), PAF-LC or PAF) found that leachate from all samples remained pH circum-neutral to alkaline, with low sulphate release rates and low soluble metals and metalloid concentrations. These results suggest that these samples would be expected to have relatively long lag times until potential acid generation, if any, occurs.

Peroxide leaching undertaken on six rejects samples of mixed NAF to PAF classifications showed that all except one of the rejects samples (a NAF sample) produced moderately to weakly acidic leachate with moderate soluble metals and metalloid concentrations. At least one of the 'PAF' rejects samples appears to be influenced to some degree by the presence of organic acids, due to the samples' high organic carbon concentration. This may account – to some degree – for the acidity and 'elevated' soluble metals and metalloid concentrations evident in this sample – and potentially others where no extended boil NAG data is available to confirm the influence of organic carbon. Nevertheless, PAF rejects [including rejects classified as UC(PAF)] have typically produced moderate soluble metals and metalloid concentrations from the peroxide leaching tests, indicating that these PAF materials have the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

Based on the results, a small proportion of rejects has a moderate to high potential to generate AMD as either AD and/or NMD and/or SD, whereas bulk rejects has a relatively low to low-moderate potential to generate AMD as either AD and/or NMD and/or SD. As such, as a bulk material, rejects has a low-moderate potential to generate AMD as either AD and/or NMD and/or SD.

AMD Potential of Coal

Coal is not regarded as waste and ROM coal remains on-site for a relatively short period of time. However, some minor coal seams/plys will report directly as waste, and remnant coal (seams) will be exposed on the highwalls of residual voids at closure.

Coal represents about 8% of all lithological material at SRM (i.e. about 8% of the highwall meterage; refer to **Section 7.1.3**) and, assuming the large majority all of this will report as ROM coal, we can conservatively assume that coal will represent a very small proportion of mineral waste. Most waste 'coal' will more than likely report as either rejects or tailings.

ROM coal, as a bulk material, is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage).

The total S concentration of coal is generally low to low-moderate, with a median and 90th percentile total S concentration of 0.43% and 1.15%, respectively. The total S distribution in the coal geochemical samples tested (n=223) is comparable to the total S distribution in the coal quality database samples (n=9070). Approximately 20% (median value) of the total S is present as sulphide (Scr), however the proportion of total S as sulphide (from 176 samples) ranges from just over 1% (almost no sulphide) to 84% (predominantly sulphide).

Coal samples have a wide range of ANC values from less than 0.5 to 160 kg H_2SO_4/t, however the median ANC is low (10 kg H_2SO_4/t) and the median MPA is similar to the ANC (13 kg H_2SO_4/t). As such, 57% of coal samples were classified as NAF with a further 5% classified as UC(NAF) and the remaining 38% of samples classified as PAF, PAF-LC or UC(PAF). Samples classified as PAF, PAF-LC or UC(PAF) were from all seam groups, however the Harrow Creek (upper and lower) and Dysart (upper and lower) seam groups currently and historically comprise the majority of coal mined at SRM.

There is a level of uncertainty surrounding the AMD classification of approximately 30 coal samples (about 14% of samples) and, as such, approximately two-thirds of these samples have been tentatively classified as UC(PAF) [and the remaining third classified as UC(NAF)] based on comparing the data available for these samples with the results from samples where extensive geochemical test-work has been undertaken. Despite this potential

shortcoming, the classification of the samples is conservative and classifying approximately 38% of coal samples as PAF (to some degree) is almost certainly an upper limit. The generally low sulphur concentrations in coal samples indicate that the sulphate loads from sulphide oxidation would likely be low.

Assay data available for 19 coal samples show that the total metal and metalloid concentrations are generally low compared to average element abundance in soil in the earth's crust. Six (out of 19) coal samples were significantly enriched with regard to one or more of Be and/or S. The level of S enrichment in these samples is consistent with the ABA data for these same samples. The enrichment in Be in a small number of samples is not cause for concern. Three of the same coal samples were also enriched with one or more of As, Hg and/or Se – again, such enrichment in a very small number of samples is not cause for concern.

Soluble multi-element results from 14 coal samples tested indicate that contact water (run-off and seepage) from coal is expected to contain low concentrations of soluble metals and metalloids. Peroxide leaching undertaken on seven PAF or PAF-LC coal samples showed five of the seven samples to be acid generating and producing leachate with moderate soluble metal and metalloid concentrations. One PAF-LC sample was pH-neutral, however generated moderate soluble metal and metalloid concentrations. Both of the NAF/NAF-S coal samples produced leachate with moderate soluble metal and metalloid concentrations. These results indicating that PAF coal is capable of generating AD and/or NMD and some NAF coal is capable of generating NMD.

Based on the results, and as a bulk material, ROM coal is assessed as having a moderate potential to generate AMD as either AD, NMD and/or SD. A small proportion of coal would have a moderate to high potential to generate AMD.

Salinity, Sodicity and Dispersion Potential of Mineral Waste and Coal Material Types

Salinity, Sodicity and Dispersion Potential of Spoil – non-carbonaceous

Non-carbonaceous spoil has $EC_{1:5}$ values (from 1603 mostly fresh non-carbonaceous samples) ranging from a very low 44 microSiemens per centimeter (µS/cm) to a very high 6130 µS/cm, with median and 90^{th} percentile $EC_{1:5}$ values of 587 and 1403 µS/cm, and has very low total S concentrations. On this basis, contact water (run-off and seepage) is expected to be generally slightly to moderately saline, mostly as a result of dissolution of geogenic salts more so than from sulphide oxidation (sulphate salinity).

Non-carbonaceous spoil samples (n=101) had modest cation exchange capacity (CEC) values and generally high exchangeable sodium percentage (ESP) values, resulting in almost all samples being classified as 'strongly sodic' and the few remaining samples being classified as 'sodic'. Non-carbonaceous spoil is expected to be strongly sodic with potential for dispersion (based on the high sodicity values). A sub-set of these samples (n=60) also underwent Emerson aggregate class testing to directly measure dispersion, which found that about 17% of the samples displayed 'some dispersion'. The remaining bulk of the samples had Emerson aggregate class values suggesting the samples were non-dispersive.

Salinity, Sodicity and Dispersion Potential of Spoil – carbonaceous

Carbonaceous spoil has $EC_{1:5}$ values (from 225 samples, which were almost all fresh carbonaceous samples) ranging from 64 to 3220 µS/cm, with median and 90^{th} percentile $EC_{1:5}$ values of 733 and 1559 µS/cm, and has generally low total S concentrations. On this basis, contact water (run-off and seepage) is expected to be similar to non-carbonaceous spoil. That is, generally slightly to moderately saline, mostly as a result of dissolution of geogenic salts more so than from sulphide oxidation (sulphate salinity).

Carbonaceous spoil samples (n=5) had similarly modest CEC and generally high ESP values comparable to non-carbonaceous samples, resulting in all samples being classified as 'strongly sodic'. As such, and based solely on the high sodicity values, carbonaceous spoil is expected to be strongly sodic with potential for dispersion. Five of these samples also underwent Emerson aggregate class testing to directly measure dispersion, which found that all of the five samples were non-dispersive – indicating that despite being strongly sodic, carbonaceous spoil is not expected to be highly dispersive.

Salinity Potential of Tailings

Tailings samples (n=295) have $EC_{1:5}$ values ranging from 70 to 3490 µS/cm, with median and 90th percentile $EC_{1:5}$ values of 540 and 1292 µS/cm, respectively. Fresh (CHPP) tailings samples (n=103) are generally slightly to moderately saline, whereas aged (TSF) tailings (n=192) have lower $EC_{1:5}$ values and are generally non-saline to slightly saline. Most fresh (CHPP) tailings have moderate total S concentrations, whereas most aged (TSF) tailings have low total S concentrations; therefore, based on the total S concentration from fresh tailings, the potential for SD (from sulphide oxidation) is moderate.

Salinity Potential of Rejects

Rejects samples (n=77) have $EC_{1:5}$ values ranging from 205 to 1340 µS/cm, with median and 90th percentile $EC_{1:5}$ values of 558 and 787 µS/cm, respectively. On this basis, contact water (run-off and seepage) from most rejects is expected to be slightly to moderately saline (<900 µS/cm). A very small number of rejects samples produced moderately saline leachate. Most rejects have low-moderate total S concentrations, therefore the potential for SD (via sulphide oxidation) from rejects is low to low-moderate.

Salinity Potential of Coal

Coal samples (n=163) have $EC_{1:5}$ values ranging from 16 to 3100 µS/cm, with median and 90th percentile $EC_{1:5}$ values of 256 and 1015 µS/cm, respectively, and has generally low to low-moderate total S concentrations. On this basis, contact water (run-off and seepage) from coal, as a bulk material, is expected to be non-saline to slightly saline, either as a result of dissolution of geogenic salts and/or from sulphide oxidation (sulphate salinity). A small number of coal samples produced moderately saline leachate.

Geochemical Source Hazard Assessment of Material Types

A geochemical source hazard assessment was applied to the source material types comprising carbonaceous and non-carbonaceous spoil, tailings, rejects and coal (where relevant). The source hazard score is a formula devised by the authors that takes into account the propensity (ability) to generate AMD, the AMD capacity (severity) and the quantity (volume/tonnage) of material that could produce AMD. The AMD source hazard scores are as follows:

- Spoil – non-carbonaceous: AMD source hazard score = **Low** to **Low-Moderate**
- Spoil – carbonaceous: AMD source hazard score = **Low-Moderate**
- Tailings: AMD source hazard score = **Moderate** to **Moderate-High**
- Rejects: AMD source hazard score = **Moderate**
- Coal: AMD source hazard score = **Moderate**

When combined, and taking into account the proportion of PAF material of each type relative to the total proportion of all materials in a final landform (spoil landform or TSF landform) and the residual voids, the AMD hazard score for the landforms, void highwalls and void floors at closure has been determined.

Spoil landforms

There are four spoil landforms at SRM that will remain at closure:

- Jacaranda-Bauhinia;
- Coolibah-Dogwood;
- Ebony-Grevillea; and
- Hakea.

Each landform has a similar construction, comprising mined overburden and interburden disposed behind the active mining face to form a low-wall spoil dump, which will be reshaped to form a final spoil landform. Coolibah-Dogwood and Hakea landforms are approximately half the size of Jacaranda-Bauhinia and Ebony-Grevillea landforms.

Ramp 2/3 TSF will be buried beneath Jacaranda-Bauhinia spoil landform and Ramp 6 TSF, TSF no. 2 and TSF no. 4 will be buried beneath Coolibah-Dogwood spoil landform. Ebony-Grevillea and Hakea landforms have no current or historic TSFs within their footprint. The volume of tailings within the TSFs are known (approximately) and the proportion that these TSFs comprise within their final landforms (relative to spoil and reject in the same landform) is taken into account in the assessment.

Rejects has been disposed into each spoil dump during operations and comprise approximately 2.4% of the mineral waste, with spoil comprising approximately 97%. Tailings/TSFs located within the Jacaranda-Bauhinia and Coolibah-Dogwood spoil landforms comprise less than 1% of the mineral waste within these spoil landforms.

Taking into account material quantities (proportions), the AMD hazard scores for the final spoil landforms are as follows:

- Jacaranda-Bauhinia spoil landform poses a **Low** AMD hazard, with AMD generation rated as **Highly Unlikely**. However, the intrinsic AMD hazard of Ramp 2/3 TSF, which will be contained (buried) within this spoil landform is rated moderate-high with the likelihood to generate AMD rated probable/likely. The AMD risk of the Ramp 2/3 TSF once incorporated within the Jacaranda-Bauhinia spoil landform is expected to decrease as the TSF is being dumped over and buried within the spoil landform.
- Coolibah-Dogwood spoil landform poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**. However, the intrinsic AMD hazard of TSF no. 2, TSF no. 4 and Ramp 6 TSF, which will be contained (buried) within this spoil landform is rated moderate-high with the likelihood to generate AMD rated probable/likely. The AMD risk of the TSFs once incorporated within the Coolibah-Dogwood spoil landform is expected to decrease as the TSFs are being dumped over and buried within the spoil landform.
- Ebony-Grevillea spoil landform poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**.
- Hakea spoil landform poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**.

TSF landform

TSF no. 3 will remain as a stand-alone landform at closure, and is located to the west of the current Northern Haul Road approximately 2 km north of the CHPP. TSF no. 3 is a 'turkey's nest' style TSF with confining embankments on all sides of similar height (average 13 m); it operated from approximately 1981 to 1985.

This TSF has undergone rehabilitation and revegetation since decommissioning. Additional rehabilitation (maintenance and corrective actions) may be required at or prior to closure based on rehabilitation monitoring, however, the assumption is that the TSF will remain more-or-less 'as is' at closure and will not undergo significant rehabilitation works (e.g. not requiring additional significant capping or surface works).

The source materials within this facility includes tailings, which comprise approximately 81% of the landform, capped by a 2-3m spoil 'cover' (average 2.5 m cover thickness). The embankments are 'earth fill', with rock facing (rock armour) on the outer faces. TSF no. 3 has a total volume of approximately 4.5 Mm^3.

The source hazard assessment for the mineral wastes within TSF no. 3 landform has utilised the same general methodology as applied to the spoil landforms. The source hazard assessment has found the mixed spoil (cover) poses a Low AMD source hazard, and tailings within the TSF landforms pose a Moderate AMD source hazard. On this basis, and taking into account material quantities (proportions):

- TSF no. 3 landform poses a **Moderate** AMD hazard, with AMD generation rated as **Probable/Likely**. The hazard lies with the tailings, not the spoil cap/cover or embankments.

The AMD hazard score for the tailings materials is considered to be conservative and the landform domain AMD hazard score for TSF no. 3 is also considered to be conservative.

Residual voids

There are four open pits at SRM that will remain at closure as residual voids:

- Jacaranda-Bauhinia void: approximately 4.3 km long; approximately 230 m deep (at closure);
- Coolibah-Dogwood void: approximately 5.2 km long; approximately 200 m deep (at closure);

- Ebony-Grevillea void: approximately 5.4 km long; approximately 250 m deep (at closure); and
- Hakea void: approximately 3.4 km long; approximately 140 m deep (at closure).

Excluding the Hakea residual void, the floor of all residual voids at closure will be the Dysart Lower (DL) seam group, which is currently the floor of each pit. The floor of Hakea residual void at closure will be the Harrow Creek Upper (HCU) seam group. The current floor of the Hakea Pit is the Harrow Creek Lower (HCL) seam group.

Environmental geochemical data, coal quality data and drill-hole geological logs have been used to aid in the assessment of AMD risk associated with residual void highwalls and floors.

The residual void highwall and floor assessment found that approximately 15% to 16% of the void highwall and approximately 37% to 44% of the void floor – for all voids – is estimated to be PAF, which includes material classified as UC(PAF) and PAF-LC. As such, the assessment has found that AMD generation from the void highwalls is **Unlikely**, however AMD generation from the void floors is **Probable/Likely** until such time that the floors become submerged by water reporting to the voids as rainfall and/or groundwater (post-closure).

Geochemical Source-Pathway-Receptor (SPR) Assessment

The source-pathway-receptor (SPR) assessment includes the likelihood of the event occurring (e.g. the likelihood of AMD impacting a local creek), the severity of the event (should it occur) and the calculated risk rating (likelihood times severity). A risk rating was calculated for the final spoil landforms, final TSF landform and the residual voids with respect to plausible surface water and groundwater receptors.

Conceptual site model and conceptual facility models

A post-mining conceptual site model (CSM), which applies generically to the spoil landforms and their respective residual voids at SRM, and the relationship that spoil landforms and residual voids have with surface water and groundwater in the district, has been produced by SLR Consulting (2022).

The CSM assists with the SPR assessment with regard to potential environmental geochemical impacts from mineral waste facilities.

Specific to TSFs, there are two types of ‘residual’ TSFs at SRM post-closure: TSFs that will be buried by spoil and become part of a spoil landform at closure; and a stand-alone TSF that will remain in its current status as a capped TSF landform and will not be buried by (become part of) a spoil landform.

- TSFs buried (by spoil) within a spoil landform and forming a component of the spoil landform are represented by Ramp 2/3 TSF, Ramp 6 TSF, TSF no. 2 and TSF no. 4. The concentrated nature of tailings mineral wastes located at the base of the spoil landform warrants discussion with respect to SPR assessment. As such, a conceptual facility model (CFM) has been developed for each of the four buried TSFs:
    - Ramp 2/3 TSF situated within the western zone of Jacaranda-Bauhinia spoil landform;
    - TSF no. 2 situated within the north-western zone of Coolibah-Dogwood spoil landform;
    - TSF no. 4 situated within the north-western zone of Coolibah-Dogwood spoil landform; and
    - Ramp 6 TSF situated within the northern zone of Coolibah-Dogwood spoil landform.
- The stand-alone TSF no. 3 landform is already capped/covered and will remain more-or-less ‘as is’ post-closure as a rehabilitated landform with an expected post-mining land use (PMLU) classification. It is assumed that relatively minor additional remediation may be undertaken on this facility prior to closure. A CFM has been developed for TSF no. 3.

Plausible pathways and receptors

Note: the assessment of shallow groundwater at SRM – particularly where shallow permeable strata may be not present in some areas, discontinuous and/or not interconnected – is limited by/to the distribution of the shallow bore network, which is sporadic. Therefore, despite the apparent low likelihood of substantial connection between shallow permeable strata and surface water features, the SPR assessment has adopted a highly conservative approach and assumed a plausible pathway may exist between shallow permeable strata and surface water

features. Thus, with regard to the four spoil landforms, the plausible mechanisms for AMD affected water and/or non-oxidative salinity, if any, to report to receptors are:

- Surface water run-off from spoil landforms into creeks (various creeks, depending on the proximity of creeks to the landform);
- Seepage from the spoil landforms via shallow permeable strata into creeks (various creeks, depending on the proximity of creeks to the landform);
- Seepage from the spoil landforms into the residual voids; and
- Surface water run-off and seepage from void highwalls into residual voids.

With regard to the TSF no. 3 landform, the plausible mechanisms for AMD affected water and/or non-oxidative salinity, if any, to report to receptors are:

- Surface water run-off from the landform into Barrett Creek;
- Seepage from the landform via shallow permeable strata into Barrett Creek; and
- Seepage from the landform via groundwater into residual voids.

The SPR has conservatively assumed that shallow permeable strata are a plausible pathway linking a potential AMD source to deeper groundwater via downwards migration and linking a potential AMD source to nearby creeks via lateral migration. However, shallow permeable strata are assumed to be an *implausible final receptor* from run-off and seepage from final landforms and final voids. That is, the assumption based on information available is that AMD (source) entering shallow permeable strata (however (un)likely) will ultimately find its' way into deeper groundwater and/or local surface water features.

SPR risk rating of final spoil landforms

There are plausible surface water and residual void receptors associated with final spoil landforms; and the run-off and seepage pathways linking the sources (final spoil landforms) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from final spoil landforms is **Low**. Where landforms contain buried tailings, such as Jacaranda-Bauhinia landform with Ramp 2/3 TSF and Coolibah-Dogwood landform with Ramp 6 TSF, TSF no. 2 and TSF no. 4, the risk rating with respect to AMD making its way via shallow permeable strata into surface water features close to the buried TSFs was rated as **Low to Medium**. With respect to non-oxidative salinity the overall SPR risk from final spoil landforms is rated as **Low to Medium**.

SPR risk rating of final TSF landform

There are plausible surface water and residual void receptors; and the run-off and seepage pathways linking the source (TSF no. 3 landform) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from the TSF landform is **Low to Low-Medium**. With respect to non-oxidative salinity the overall SPR risk from the TSF landform is rated as **Low**.

SPR risk rating of residual voids

The final receptor for seepage from the spoil landform (for each spoil landform) and run-off from the highwall (of each void) is the void lake / residual void. The AMD assessment has found that it's unlikely that undiluted salinity or AMD from a flooded post-closure residual void floor would impact on residual void water quality to any significant degree, as other processes such as evapoconcentration are the key drivers of void lake water quality. Therefore, the AMD SPR risk rating on the overall water quality of the residual voids is **Low**.

Water reporting to residual voids is expected to remain within the residual voids (excluding evaporative loss). Modelling undertaken by SLR (2022) shows that seepage from the void lake (of each void) into groundwater, if any, would be limited.

Management and Rehabilitation Measures

The assessment has found that the environmental risks posed by spoil landforms likely to be present at closure are generally low. The environmental risk associated with tailings buried within the Jacaranda-Bauhinia landform, tailings buried within the Coolibah-Dogwood landform, and the TSF no. 3 landform is generally low to medium. As such, no specific AMD management measures (e.g. alkaline amendment or engineered capping systems) are expected to be required to manage mineral wastes during rehabilitation and closure – outside of operational mixing/burial of PAF waste amongst NAF waste, spoil placement and landform reshaping activities already proposed (refer below and to the main volume of the PRCP). Decommissioning and rehabilitation activities related to mineral waste will be addressed as part of the milestone criteria for infrastructure, remediation of contaminated land, landform design, surface preparation and revegetation, where necessary.

Proposed mineral waste management and rehabilitation activities of relevance to this waste characterisation report comprise the following actions. Refer to the main volume of the PRCP for detailed information:

- Pits: will remain as residual voids under four groups:
    - Jacaranda-Bauhinia void;
    - Coolibah-Dogwood void;
    - Ebony-Grevillea void; and
    - Hakea void.
- Spoil dumps: will be reshaped into four final spoil landforms and seeded.
- TSF no. 3 (above ground): will remain ‘as is’ as a final TSF landform, subject to maintenance and/or corrective actions identified through ongoing monitoring.
- All other TSFs (Ramp 2/3 TSF, Ramp 6 TSF, TSF no. 2 and TSF no. 4): Covered by spoil during operations. The final spoil cover thickness over tailings will be variable due to the spoil landform designs. The optimal thickness of spoil cover to manage water and/or oxygen ingress will be determined following further assessment prior to covering.
- Rejects: Managed during operations (disposed within spoil) and progressively covered by spoil. No additional remediation for the rejects (at closure) is required. The optimal thickness of spoil cover to manage the AMD hazard of rejects will be determined following further assessment prior to covering.
- ROM pad: Remove remnant coal from the ROM Pad and dispose within spoil. The former ROM Pad will be reshaped, covered with soil, ripped and seeded.
- Coal stockpile: Remove remnant coal from the coal stockpile pad and dispose within spoil. Cover with suitable soil material, rip and seed.

GLOSSARY OF TERMS

Key terms and definitions as used in this report are listed below:

Acid	A measure of hydrogen ion (H^+) concentration in water; generally expressed as pH.
Acidity	A measure of hydrogen concentration and latent acidity generated by metal hydroxylation, expressed as mg/L.
Acid-Base Account (ABA)	Evaluation of the balance between acid generation and acid neutralisation processes. Generally determined by the maximum potential acidity (MPA) and the inherent acid neutralising capacity (ANC), as defined below. See also ANC and MPA.
AMD	Acid and metalliferous drainage. AMD has three components: acid drainage (AD), pH-neutral and metalliferous drainage (NMD) and/or sulphide-derived saline drainage (SD) – and/or any combination of these, all generated by sulphide oxidation processes +/- neutralisation reactions.
ANC	Acid neutralising capacity, expressed as kg H_2SO_4 per tonne of rock/material. A measure of a sample's maximum potential ability to neutralise acid.
ANC/MPA ratio	Ratio of the acid neutralising capacity (ANC) to the maximum potential acidity (MPA) of a sample. Used to assess the risk of a sample generating acid conditions. See also ANC and MPA.
CFM	Conceptual facility model.
CHPP	Coal handling and preparation plant.
Co-Disposal	The practice of disposing different waste types together. For example, disposing coarse reject amongst spoil.
CSM	Conceptual site model.
EC	Electrical conductivity, expressed as µS/cm.
Interburden	Potential spoil material located between mined coal seams. See also Overburden, Mineral waste and Spoil.
Kinetic test	Procedure used to measure the geochemical/weathering behaviour of a sample of mine material over time.
Mineral waste	Material comprising mine spoil, ± coarse/fine reject, ± waste coal. Sometimes called 'mine waste' or 'mining waste'.
MPA	Maximum potential acidity. Calculated by multiplying the total sulphur (S) content of a sample by 30.6 (stoichiometric factor) and expressed as kg H_2SO_4 per tonne of rock/material (kg H_2SO_4/t). Assumes all sulphur is present as sulphide and will oxidise to generate acid.
NAF	Non-acid forming. Geochemical classification criterion for a sample that would not generate acid conditions. A sample classified as NAF may, or may not, have a significant sulphur content but the availability of neutralising material within the sample is more than adequate to neutralise all the acid that theoretically could be produced by any contained sulphide minerals. As such, material classified as NAF is considered unlikely to be a source of acid(ic) drainage, however NAF material may still develop NMD and/or SD, depending on sulphur concentration.

NAG	Net acid generating test. A pulp sample is reacted with hydrogen peroxide to encourage rapid oxidation. Any acid generated through oxidation may be consumed by neutralising components in the sample. Any remaining acidity (after neutralising material is consumed) is measured and expressed as kg H_2SO_4/t. At the conclusion of the NAG test the resulting liquor is called peroxide (NAG) leachate, and can be analysed for various parameters, such as soluble metals.
NAPP	Net acid producing potential, expressed as kg H_2SO_4 per tonne of rock/material (kg H_2SO_4/t). Calculated by subtracting the ANC from the MPA.
NMD	Neutral and metalliferous drainage. A component of AMD, NMD occurs where drainage is pH-neutral or higher yet contains elevated trace metals and metalloids in solution.
Org S	Organic sulphur.
Overburden	Mineral (mining) waste located above (overburden proper) or between (interburden) coal seams and reports to spoil dumps. Typically comprises non-coaly and non-carbonaceous material, such as sandstone, siltstone and claystone/mudstone, but also includes a small percentage of carbonaceous material (e.g. carbonaceous siltstone) and sub-economic waste coal.
OxCon	Oxygen consumption test. A type of kinetic (dynamic) test for estimating the sulphide oxidation rates, acidity generation rates and carbonate neutralisation rates for sulphidic geological materials.
PAF	Potentially acid forming. Geochemical classification criterion for a sample that has the potential to generate acid conditions. A sample classified as PAF has an acid generating potential (MPA) that exceeds the inherent acid neutralising capacity (ANC) of the material. This means that such a material is likely to generate acidic drainage (AD) if exposed to atmospheric conditions. See also PAF-LC.
PAF-LC	Potentially acid forming (low capacity). Geochemical classification criterion for a sample that has the potential to generate relatively low-level AD.
PRCP	Progressive rehabilitation and closure plan.
Product coal	Coal produced from the CHPP after being washed/processed. Coal that is ready for sale.
Rejects	Coarse sand to cobble-sized rock material produced during coal processing. Rejects are typically associated with the roof, floor and partings of coal seams and are separated from ROM coal in the CHPP. Rejects produced at SRM are disposed within spoil dumps.
ROM	Run-of-Mine. The term given to mined coal before being processed at the CHPP.
ROM pad	Location where ROM coal is temporarily stored pending processing at the CHPP.
S	Sulphur.
Scr	Chromium reducible sulphur. Analytical procedure to determine the sulphide-sulphur concentration in a sample. This typically represents the proportion of sulphur associated with sulphide (reactive) minerals.
SD	Saline drainage. A component of AMD, SD occurs where drainage is saline due to elevated sulphate as a result of sulphide oxidation and neutralisation reactions.
SO_4	Sulphate.
Spoil	Rock material overlying and between ‘target’ coal seams, which will report as waste. Waste rock overlying a coal seam is called overburden. Waste rock between mined coal seams is called interburden. See also Overburden and Interburden.
Spoil dump	In-pit or out-of-pit landform containing mineral waste.

SPR	Source-pathway-receptor.
SRM	Saraji Mine. The name of the site subject to this PRCP.
Static test	Procedure for characterising the geochemical nature of a sample at one point in time. Static tests may include measurements of mineral and chemical composition of a sample and the Acid-Base Account.
Tailings	Very fine to medium grained sand, silt and clay-sized material, which is commonly coaly and carbonaceous, produced during coal washing. Tailings are associated with coal seams and are separated from ROM coal in the CHPP. Tailings produced at SRM are disposed within Tailings Storage Facilities (TSFs – also called tailings dams).
TSF	Tailings storage facility. A dam or pit used to dispose tailings, which are delivered to the TSF as a slurry. The tailings solid forms a 'beach' and the water drains to one end of the TSF in an area referred to as the decant pond. The decant water is recycled back into the mine water management system. At SRM, tailings have been disposed into several above-ground and in-pit TSFs – the current (operational) TSF being Ramp 2/3 TSF.
Uncertain	In the context of classifying a material (sample) as NAF or PAF. An 'Uncertain' (UC) classification applies when there is an apparent conflict in results such that neither NAF nor PAF classification can be given, or there is insufficient information to unequivocally classify as NAF or PAF. UC samples are sometimes given a tentative sub-classification, such as UC(NAF) or UC(PAF) where preliminary data suggests the sample may be NAF or PAF, respectively.
Waste coal	Sub-economical coal that reports directly to the spoil dumps as waste (i.e. not ROM coal). Waste coal can be fresh or weathered (oxidised). All weathered/oxidised and coked (cindered) coal is waste.
Water extract	A method to determine the water-soluble parameters in soil. Solid samples undergo a bottle leach method where 10 g of pulped solid (85% passing 75 µm) is combined with 20 grams or 50 grams of water (leaching fluid) into a glass bottle. Depending on the type of leaching undertaken the leaching fluid may be deionised water (DI water extract) or saline water (saline water extract). The 1:2 or 1:5 solution (1 part solid to 2 or 5 parts water) is tumbled end-over-end for one hour. Solutes are leached from the soil by the continuous suspension and agitation. The water extract solution is measured for pH and electrical conductivity (EC) prior to filtering for solute analysis (e.g. metals/metalloids and major ions).

1 Introduction and Context

This report serves to document and discuss the environmental geochemical characteristics of mineral waste materials associated with Saraji Mine (SRM), as defined under the current Environmental Authority (EA) EPML00862313, held by BHP Billiton Mitsubishi Alliance (BMA). In this report the term 'mineral waste' refers to all geologic material generated by or associated with SRM during the course of mining, handling and processing coal.

It is a requirement of a Progressive Rehabilitation and Closure Plan (PRCP) that mineral waste is adequately characterised such that appropriate rehabilitation strategies can be selected and implemented. The PRCP guidance document: "*Guideline – Progressive Rehabilitation and Closure Plans*" (DES, 2021) outlines the requirements and considerations for producing a PRCP, including documenting the relevant aspects of mineral waste characterisation for the purposes of PRCPs.

1.1 Approach

The general approach to mineral waste characterisation and assessment includes the following key steps:

- Briefly describe the current/existing background information for SRM of relevance to the generation and ultimate storage/disposal of mineral waste materials;
- Document the methodology used to characterise mineral waste materials (samples);
- Present and discuss the geochemical results;
- Describe the potential environmental geochemical hazards with respect to mineral waste materials;
- Present the conceptual site model (CSM), which illustrates the relationship between AMD and salinity sources, potential environmental and human health receptors and plausible pathways between the AMD and salinity sources and the receptors (Source-Pathway-Receptor [SPR]) at closure;
- Present the acid and metalliferous drainage (AMD) and salinity SPR risk assessment undertaken on the mineral waste materials;
- Outline the AMD specific management and rehabilitation measures proposed for mineral waste materials; and
- Outline a forward work plan to address any gaps identified from the assessment.

1.2 Objective

The objective of the assessment is to evaluate the geochemical nature of mineral waste currently at SRM and mineral waste likely to be present at closure, and identify relevant environmental issues/opportunities that may be associated with mining, handling and storing mineral waste to inform appropriate rehabilitation and management strategies.

2 Background

2.1 Site Overview

SRM is located within the northern region of the Bowen Basin approximately 50 kilometres (km) south of Moranbah township and about 20 km north of Dysart township, in Central Queensland. SRM is located south of Peak Downs Mine (PDM) and north of Saraji South Mine (SSM) [previously called Norwich Park Mine] – both of which are operated by BHP Mitsubishi Alliance Pty Ltd (BMA). SRM is flanked on the east and west by pastoral leases. SRM commenced operations in 1974.

SRM comprises typical open-pit coal mining facilities, such as open pits, waste rock (spoil) dumps, tailings storage facilities (TSFs), stockpiles, coal processing facilities, rail loadout facilities, process water and raw water dams, surface water drains and administration areas. The key facilities and natural features at SRM of relevance to this waste characterisation report are shown on **Figure 1**. [Also shown on **Figure 1** are geochemical sampling locations and the locations of geological sections along and across each pit group].

Current activities of relevance to this waste characterisation report comprise:

- Disposal of spoil to in-pit spoil dumps behind the active mining face (in-pit low-wall spoil disposal);
- Current disposal of tailings to Ramp 2/3 TSF;
- Historic disposal of tailings to three above-ground TSFs (TSF 2, TSF 3 and TSF 4) and Ramp 6 TSF;
- Short-term storage of run of mine (ROM) coal on the ROM Pad;
- ROM coal processing at the coal handling and preparation plant (CHPP), which produces two mineral waste types:
    - Tailings: clay, silt and fine-to-medium grain sand material produced from washing ROM coal, and disposed as a slurry into TSFs.
    - Rejects: coarse grain sand, gravel and cobble-sized material produced from processing ROM coal, and disposed (buried) within spoil dumps.
- Short-term storage of product coal on the Product Coal Stockpile, awaiting off-site transport by rail;
- The operation of raw water and process water dams and sediment control structures as stipulated in the EA.

An overview of the proposed mineral waste management and rehabilitation activities of relevance to this waste characterisation report are outlined in **Section 8**. Refer to the main volume of the PRCP for detailed information:

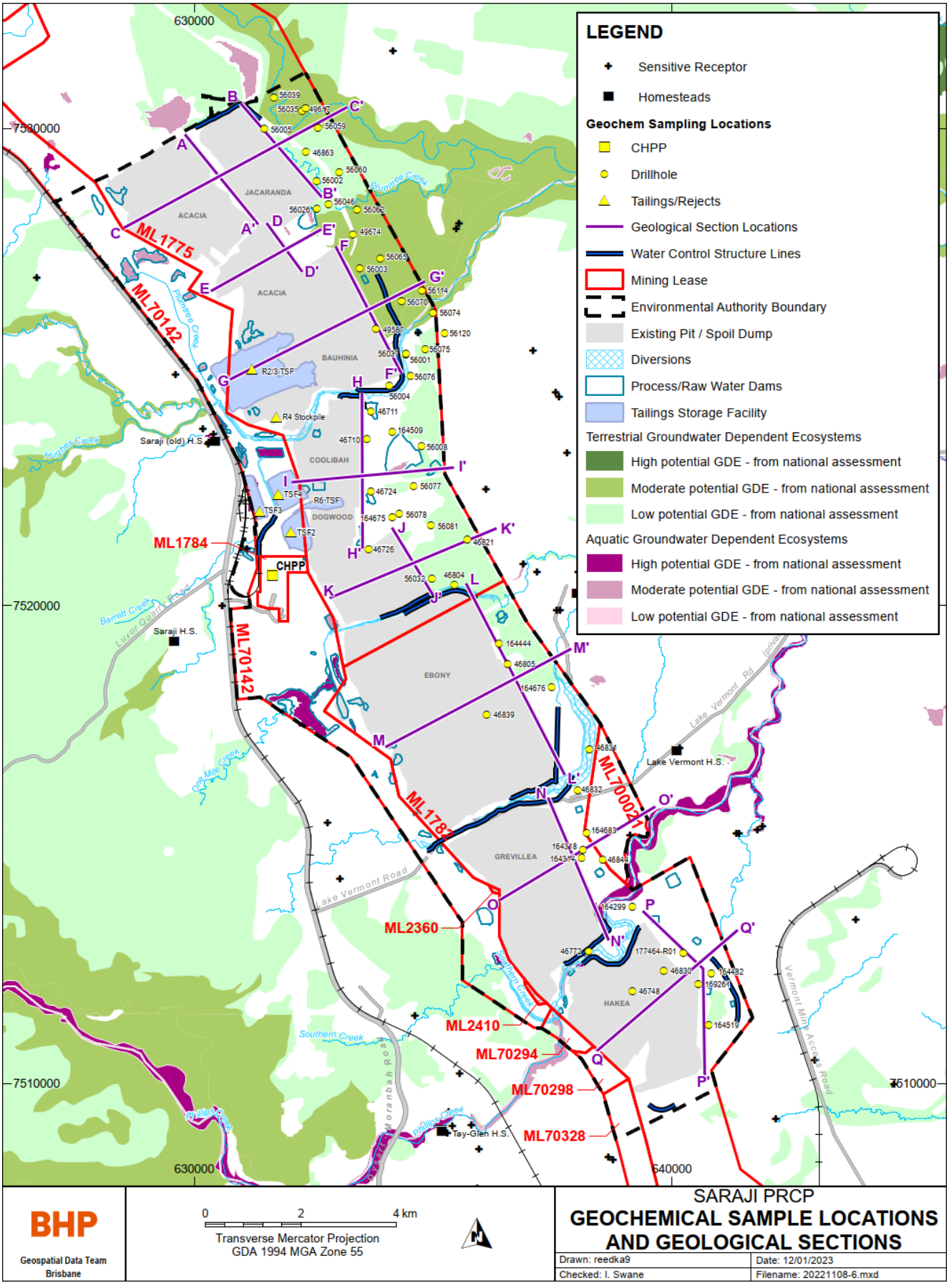


Figure 1. Project layout, geochemical sample locations and locations of geological sections

2.2 Mine Domains

The mine domains of direct relevance to mineral waste characterisation and management at SRM are:

- Residual voids (pits remaining at end of mine life):
    - Jacaranda-Bauhinia residual void;
    - Coolibah-Dogwood residual void;
    - Ebony-Grevillea residual void;
    - Hakea residual void.

  Acacia Pit, located west of Jacaranda and Bauhinia pits, will be backfilled during operations and, as such, will form part of the Jacaranda-Bauhinia spoil landform at closure.
- Spoil landforms:
    - Jacaranda-Bauhinia spoil landform, which will include Ramp 2/3 TSF;
    - Coolibah-Dogwood spoil landform, which will include Ramp 6 TSF, TSF no. 2 and TSF no.4;
    - Ebony-Grevillea spoil landform;
    - Hakea spoil landform.

  Ramp 2/3 TSF (the current/active TSF), Ramp 6 TSF, TSF no. 2 and TSF no. 4 will be buried by spoil during operation and will be incorporated by their corresponding landform as described above.

  Note: these spoil landforms are not ‘discrete’ (completely stand-alone) features. Instead, they should be thought of as zones within a single landform with a hummocky, rolling topography – higher spoil areas behind (west of) each residual void, where mining occurred – and lower between voids, where pit ramps were located.
- TSF landform:
    - TSF no. 3 (inactive/decommissioned; above-ground facility);

  TSF no. 3 (inactive for many years) has been partially rehabilitated/revegetated and will remain in the current state, subject to additional rehabilitation and revegetation required at closure.
- Coal stockpiles: ROM coal pad and stockpile; and Product coal pad and stockpile.

2.2.1 Material Types and Quantities

SRM has three main types of mineral waste, and the geochemical characteristics and potential hazards associated with mineral waste materials on site are discussed by type:

- Spoil (overburden and interburden) currently comprises approximately 97% of all mineral waste at SRM and includes weathered waste (Tertiary and Permian-age – in approximately equal proportions) and fresh (unweathered) waste (all Permian-age). Approximately 85% of spoil is fresh and the remaining (approximately 15%) is weathered/oxidised.
- Tailings is generated at the CHPP from processing ROM coal and typically represents the clay, silt and fine sand fractions of ROM waste. Throughout operations at SRM, tailings has been disposed as a slurry into a number of TSFs – the current (active) TSF being Ramp 2/3. Tailings comprises approximately 0.5% of all mineral waste at SRM.
- Rejects are generated at the CHPP from processing ROM coal and typically represents coarser and rockier seam roof, partings and floor material. Rejects are trucked to spoil dumps and disposed (buried) within spoil. Reject comprises approximately 2.4% of all mineral waste at SRM.

Coal is also included in the assessment; however, it is understood that coal is generally not considered mineral waste. Coal is primarily representative of ROM coal, however is also representative of potential waste coal from sub-economic seams and remnant coal exposed on pit highwalls (such as in final voids).

2.3 Baseline Information

2.3.1 Topography

The regional topography of the Bowen Basin is dominated by flat to gently sloping landforms and low rolling hills. SRM is located on the western edge of the Isaac River Valley, which is a broad valley approximately 30 km wide and generally oriented north to south. Topography across the valley in the vicinity of SRM varies from approximately 200 m elevation along the Isaac River east of SRM to approximately 450 m elevation along portions of the Denham Range that define the western edge of the valley. This variation in elevation is over a distance of approximately 25 to 30 km and represents an average gradient of approximately 1v:100h. The relatively steep slopes associated with the Denham Range contrast with the extensive flat areas along the base of the valley. Drainage along the western slopes of the valley generally takes the form of deeply incised gullies flowing east and north-east towards the Isaac River.

The topography of the mine site is generally flat to undulating. Elevation across SRM ranges from approximately 200 m Australian Height Datum (AHD) in the west to 160 m in the east and surface slopes are typically less than 1% grading east-northeast towards the Isaac River, which is the most prominent regional drainage feature.

2.3.2 Climate

The following information about climate is general and provided for broad context. Refer to the main volume of the PRCP for detailed information about climate at SRM.

SRM is located within Queensland's semi-arid climatic zone, which is characterised by high summer temperatures, warm dry winters and generally distinct wet and dry seasons; with higher rainfall and higher evaporation occurring over the summer months (December to February). Climate data (rainfall, evaporation and temperature) is available from Moranbah Airport (located approximately 27 km north of SRM) and Moranbah Water Treatment Plant, located approximately 50 km north of SRM.

Median maximum temperatures range from approximately 24°C in June/July to 34°C in December/January, with minimum temperatures ranging from approximately 9°C in July to 22°C in January. The average annual rainfall and evaporation are approximately 600 and 2000 mm per year, respectively, with evaporation greatly exceeding rainfall. The evaporation rate is highest in the summer months - mean daily rate of approximately 8 mm in January, and lowest in the cooler months - mean daily rate of approximately 3 mm in June. Rainfall events are often associated with thunderstorms, which are typically short-lived, intense and have variable coverage. Sustained rainfall over a large landscape area is experienced when tropical lows with cyclonic activity occur in coastal area. However, periods of prolonged drought do occur within the region.

2.3.3 Geology

SRM is located on the western limb of the northern Bowen Basin. The Bowen Basin in the area is characterised by a relatively thin accumulation of sediments, gentle easterly dips and minor to moderate deformation. The lithology at SRM is characterised by typical basin-fill sediments, comprising mudstone, claystone, siltstone, sandstone (typically fine- to medium-grained), carbonaceous sediments and coal seams. Minor basalt is encountered within Tertiary-age material. The depth to base of weathering averages about 20 m below natural surface but ranges from about 10 m to 30 m below natural surface, depending on the local topography.

In coal environments (i.e. at coal mines) fresh carbonaceous materials typically have higher sulphide concentrations compared with fresh non-carbonaceous materials and, as such, typically pose a greater environmental geochemical hazard compared with fresh non-carbonaceous material. Comparatively, non-carbonaceous lithologies are essentially void of (or have negligible) carbonaceous material and thus have low or nil sulphide mineral concentration. The key exception is that non-carbonaceous materials located within coal seams or immediately above and below (within, say, 0.5m of) coal seams tend to have a higher sulphide concentration compared to bulk overburden/interburden located away from seams.

The coal bearing sequences are the Permian-age Moranbah Coal Measures, comprising the following seam groups in stratigraphic order, from youngest to oldest:

- Q / R / S [minor upper seams; mostly in the weathered zone; currently only encountered just below base of weathering in Grevillea and Hakea pits]
- P seam [mined in all pits, but within the weathered zone in Acacia, Bauhinia, Coolibah and Dogwood pits]
- Harrow Creek Upper (HCU) and Harrow Creek Lower (HCL) [mined in all pits]
- Dysart Upper (DU) Dysart Lower (DL) [mined in all pits except Hakea]

The Q/R/S/P seams are associated with a marine transgression (a brackish environment), whilst the Harrow Creek and Dysart seams are interpreted to have formed in fresh(er) water basins.

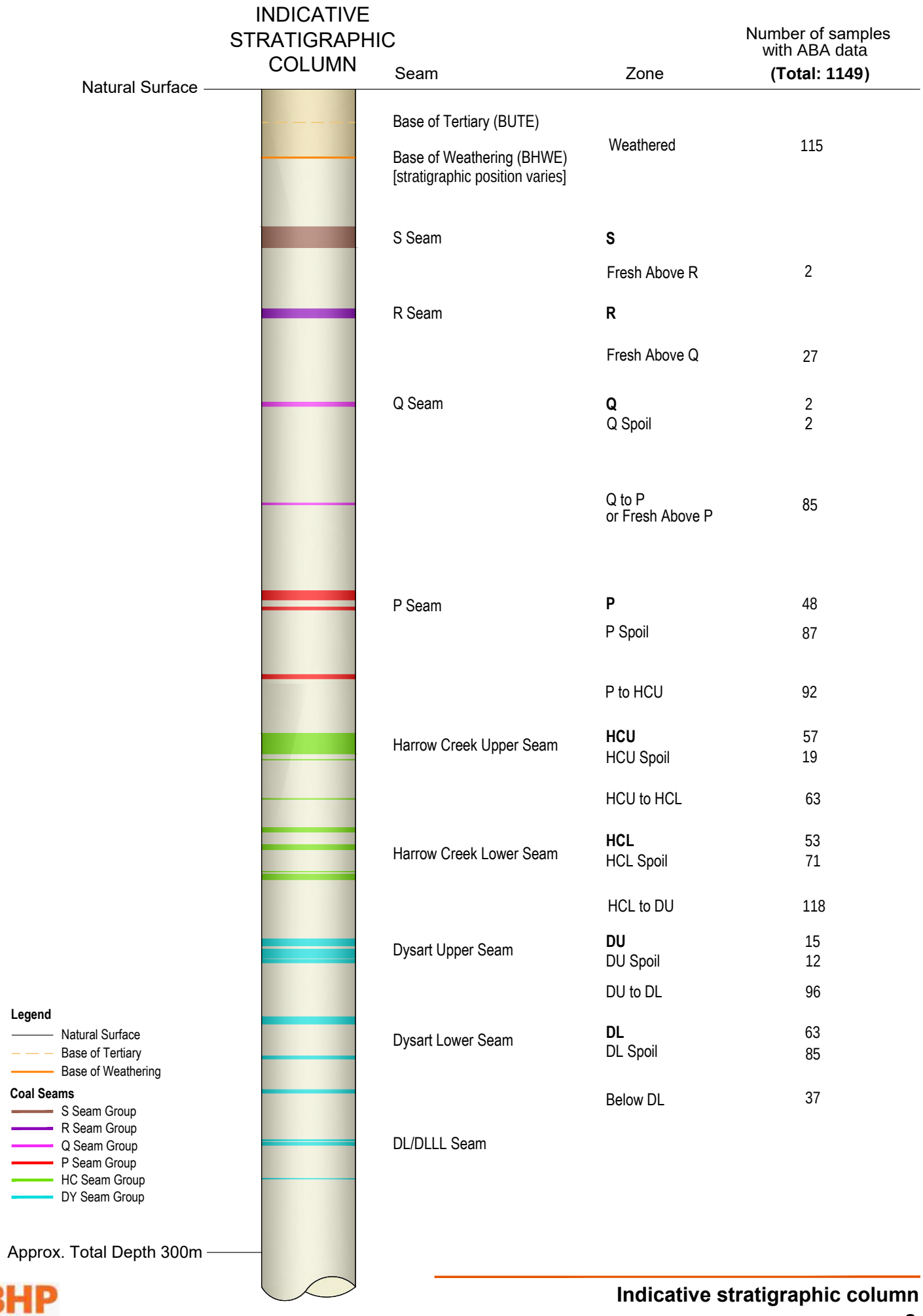
Non-mined seams below the DL include the DLL and DLLL groups. Seam splitting is prevalent along the length (north-south) of all pits, and continuing north and south into neighbouring PDM and SSM. Overlying the Moranbah Coal Measures is a thin veneer of Quaternary- and Tertiary-age sediments. Throughout the region, the Quaternary and Tertiary sediments are highly weathered, semi-consolidated and typically comprise sand, clay and gravel.

To date, most of the coal mined at SRM has been from the Harrow Creek (HCU/HCL) and Dysart (DU/DL) seam groups, with a small amount of P seam being mined from Jacaranda, Ebony, Grevillea and Hakea pits. As mining progresses eastwards (down-dip) the upper seams such as the HCU seam group, followed by the P seam group (and potentially Q-R-S seam group), will become more prevalent.

An indicative stratigraphic column showing the seam groups is provided in **Figure 2**, which also includes the number of geochemical samples collected from each overburden and interburden zone, and also from within each seam group (refer to **Section 4.2** for information regarding sample collection). Geological long-sections (indicatively north-south) along the current highwall of the pits are provided at **Figures 3 to 6** and geological cross-sections (indicatively west-east) through the pits (including current topography) are provided at **Figures 7 to 9**. Refer to **Figure 1** for section locations. The seam groups are shown in the geological sections. Note: Acacia Pit (north and south) [**Figure 3**] will merge with Jacaranda and Bauhinia pits during operations and, as such, will not exist at closure. In this part of the site, the residual void will be Jacaranda-Bauhinia pit/void.

Due to the eastward dip of the seams and the nature of the seams splitting and coalescing, the location of the weathered zone shown in the stratigraphic column (**Figure 2**) varies from pit to pit (north to south) and also from west (start of mining) to east (current and future mining). Refer to the geological long- and cross-sections in **Figures 3 to 9**.

Underlying the Moranbah Coal Measures is the Permian Back Creek Group, which has geological similarities with the host rock of the Moranbah Coal Measures (i.e. quartzose to lithic sandstone, siltstone, carbonaceous shale and minor coal).



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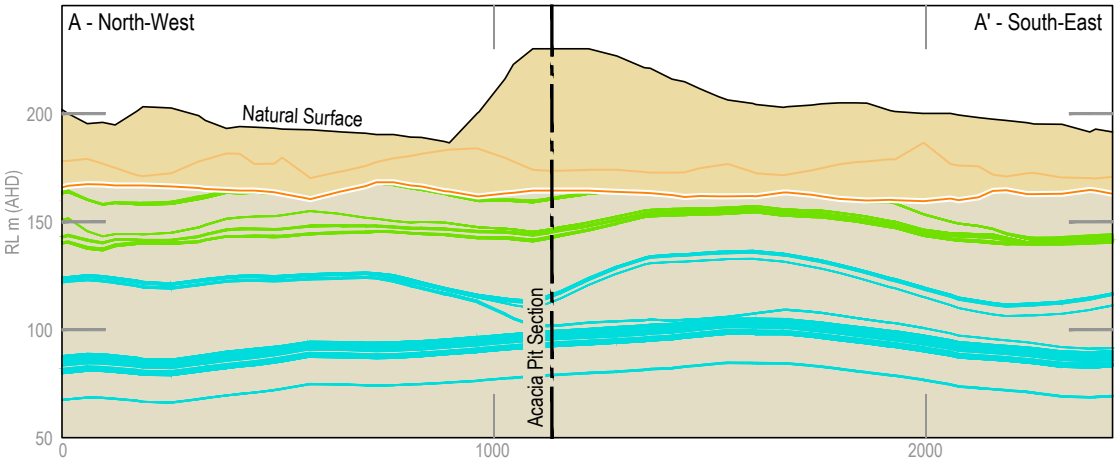
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Indicative stratigraphic column

Figure **2**

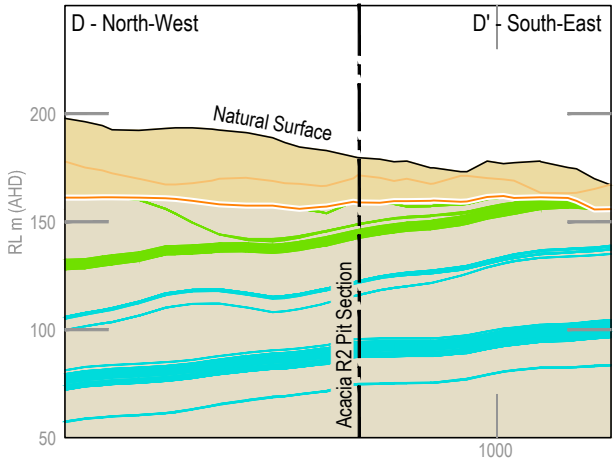
LONG SECTION | ACACIA PIT

Viewed Looking North-East (Vertical Exaggeration x5)



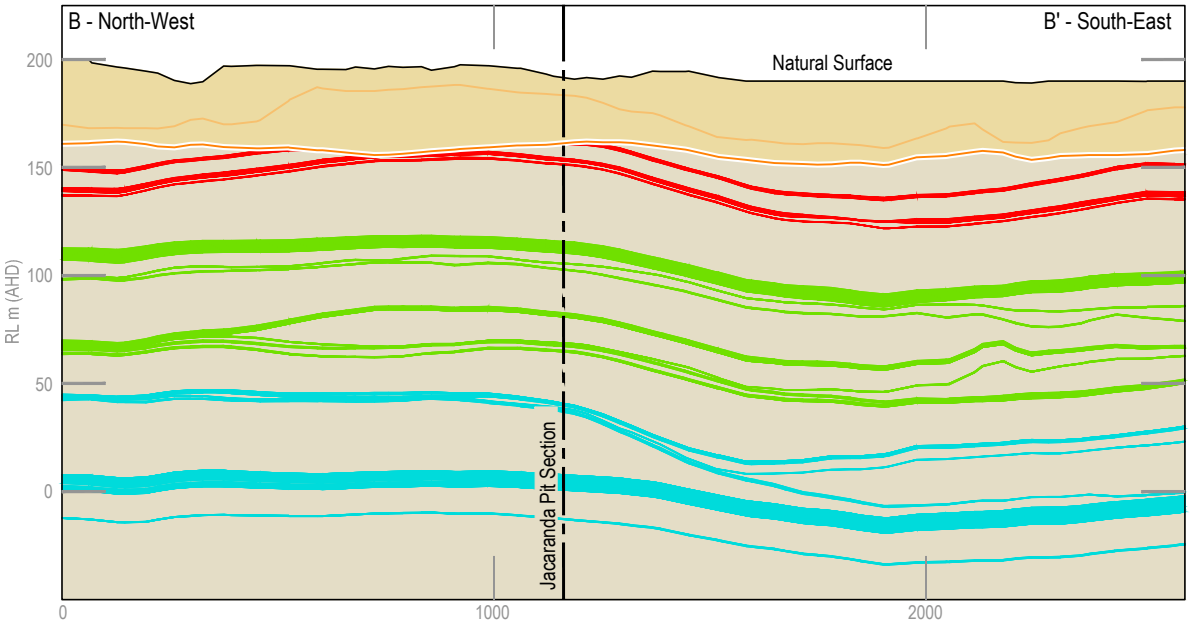
LONG SECTION | R1A PIT

Viewed Looking North-East (Vertical Exaggeration x5)



LONG SECTION | JACARANDA PIT

Viewed Looking North-East (Vertical Exaggeration x5)



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering

Coal Seams

- S Seam Group
- R Seam Group
- Q Seam Group
- P Seam Group
- H Seam Group
- D Seam Group
- C Seam Group

Vertical Scale

0 — 100m

Horizontal Scale

0 — 500m

(V/H = 5:1)

BHP

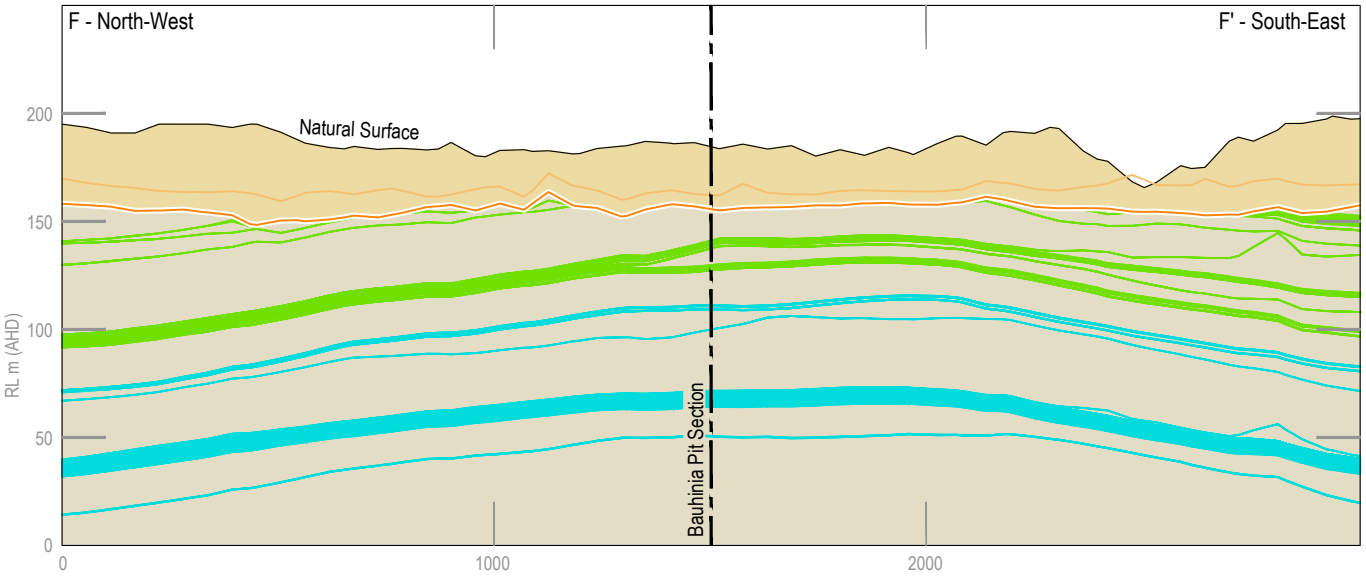
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Pit highwall long-sections

Figure **3**

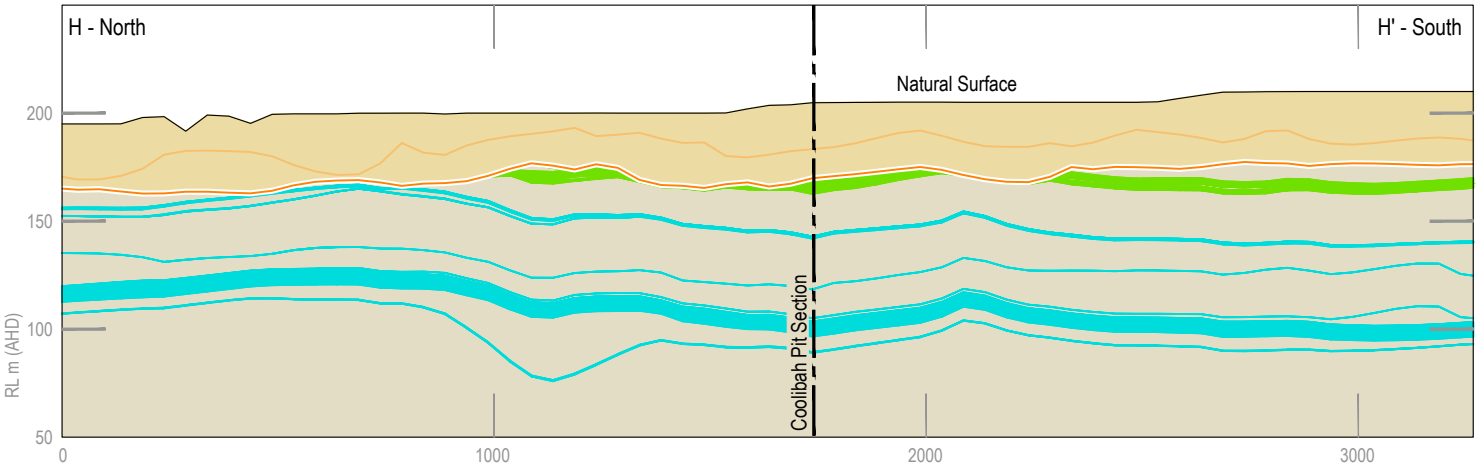
LONG SECTION | BAUHINIA PIT

Viewed Looking North-East (Vertical Exaggeration x5)



LONG SECTION | COOLIBAH PIT

Viewed Looking East (Vertical Exaggeration x5)



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering

Coal Seams

- S Seam Group
- R Seam Group
- Q Seam Group
- P Seam Group
- H Seam Group
- D Seam Group
- C Seam Group

Vertical Scale

0 — 100m

Horizontal Scale

0 — 500m

(V/H = 5:1)

BHP

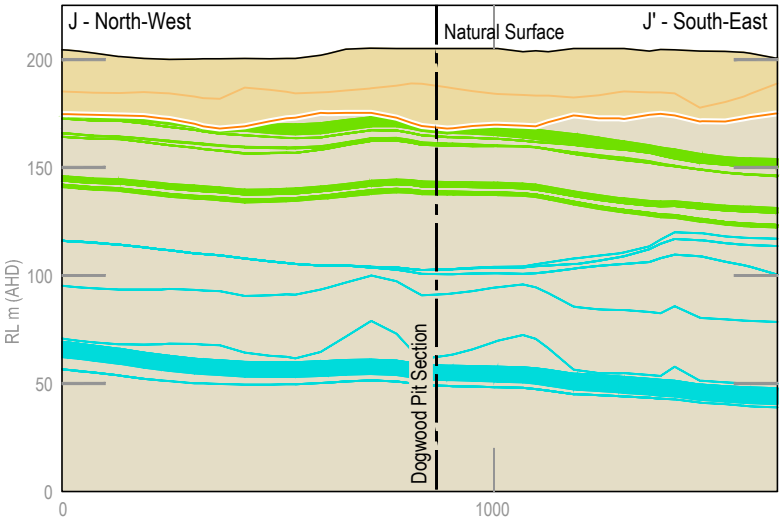
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Pit highwall long-sections

Figure **4**

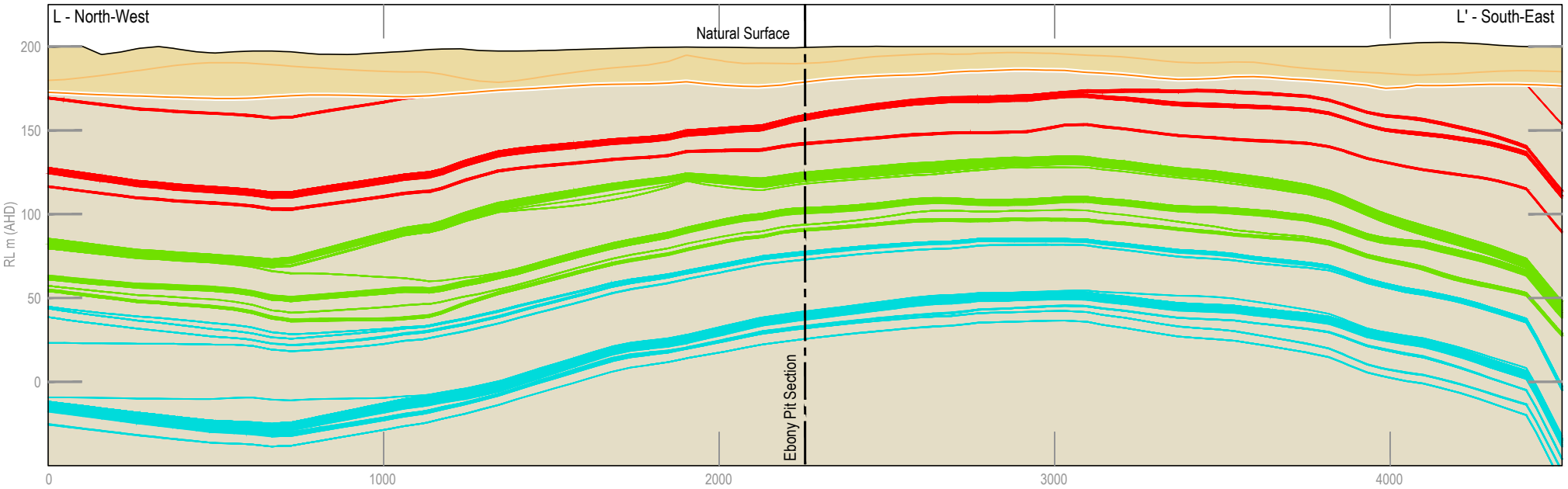
LONG SECTION | DOGWOOD PIT

Viewed Looking North-East (Vertical Exaggeration x5)



LONG SECTION | EBONY PIT

Viewed Looking North-East (Vertical Exaggeration x5)



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering

Coal Seams

- S Seam Group
- R Seam Group
- Q Seam Group
- P Seam Group
- H Seam Group
- D Seam Group
- C Seam Group

Vertical Scale

0 — 100m

Horizontal Scale

0 — 500m

(V/H = 5:1)

BHP

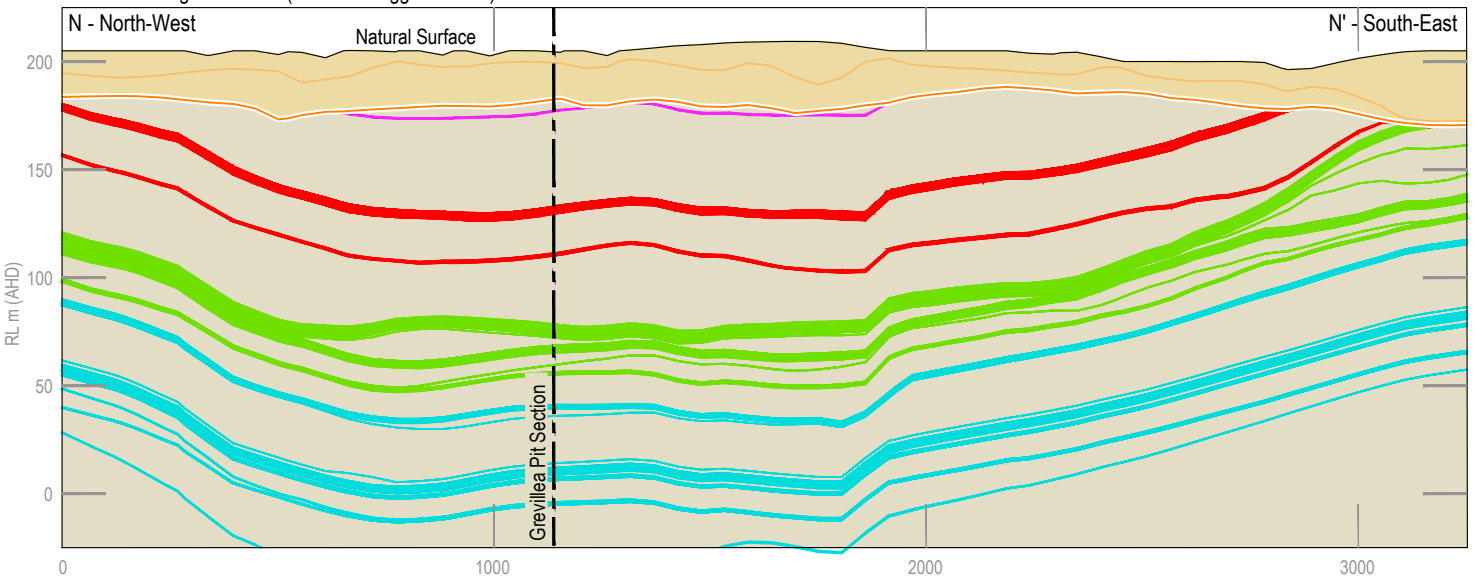
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Pit highwall long-sections

Figure **5**

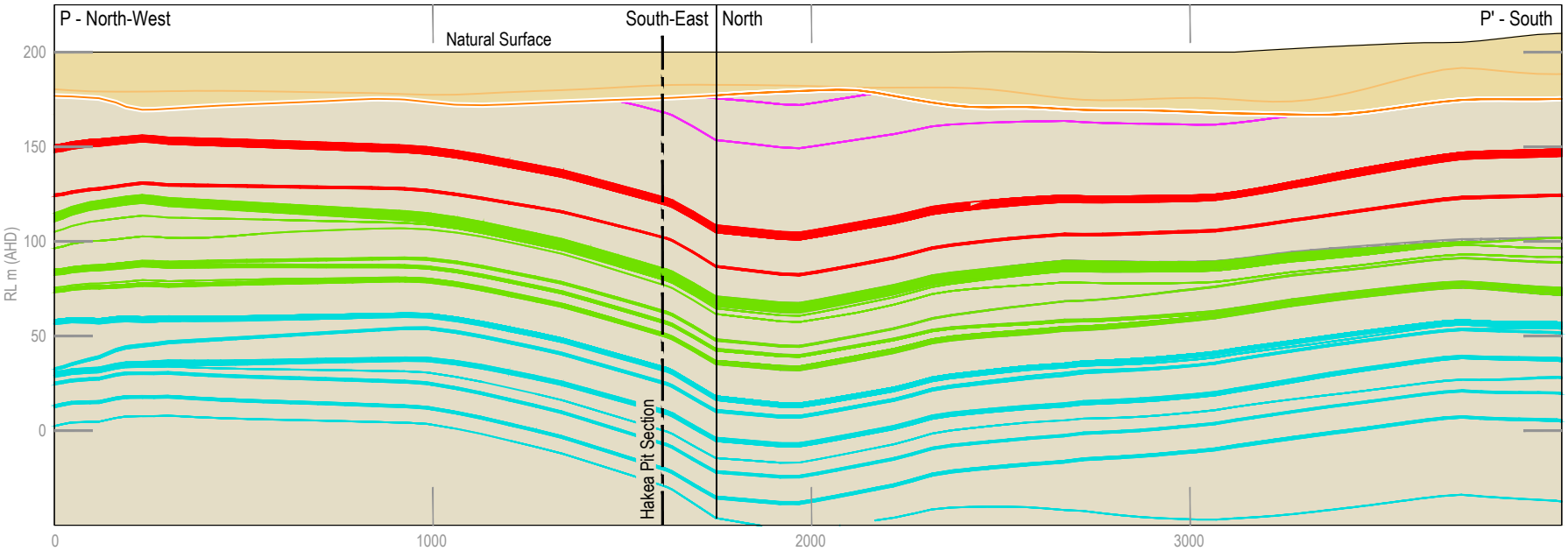
LONG SECTION | GREVILLEA PIT

Viewed Looking North-East (Vertical Exaggeration x5)



LONG SECTION | HAKEA PIT

Viewed Looking North-East (Vertical Exaggeration x5)



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering

Coal Seams

- S Seam Group
- R Seam Group
- Q Seam Group
- P Seam Group
- H Seam Group
- D Seam Group
- C Seam Group

Vertical Scale

0 — 100m

Horizontal Scale

0 — 500m

(V/H = 5:1)

BHP

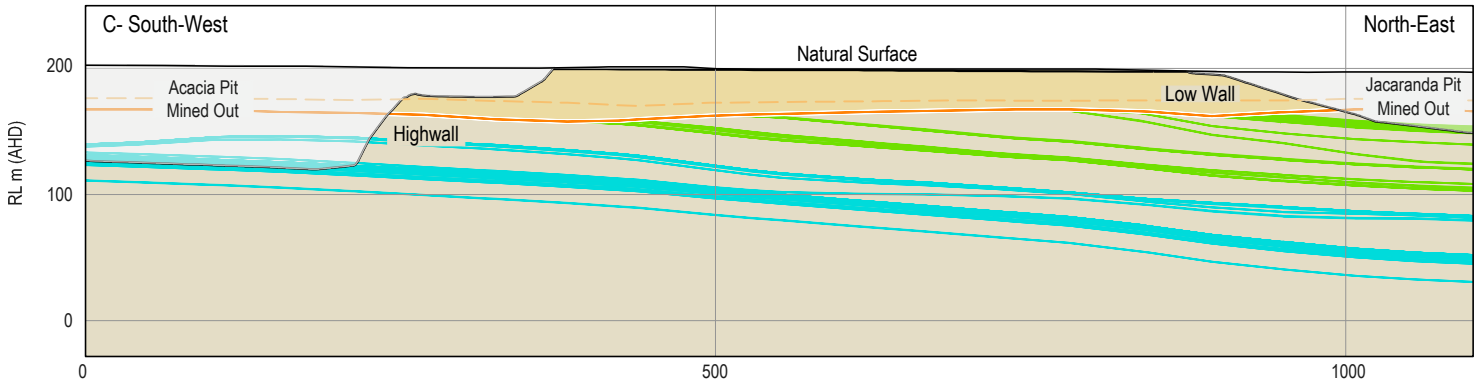
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Pit highwall long-sections

Figure 6

CROSS SECTION | ACACIA PIT

Viewed Looking North-West



Legend

- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams

- S Seam Group
- R Seam Group
- Q Seam Group
- P Seam Group
- H Seam Group
- D Seam Group
- C Seam Group

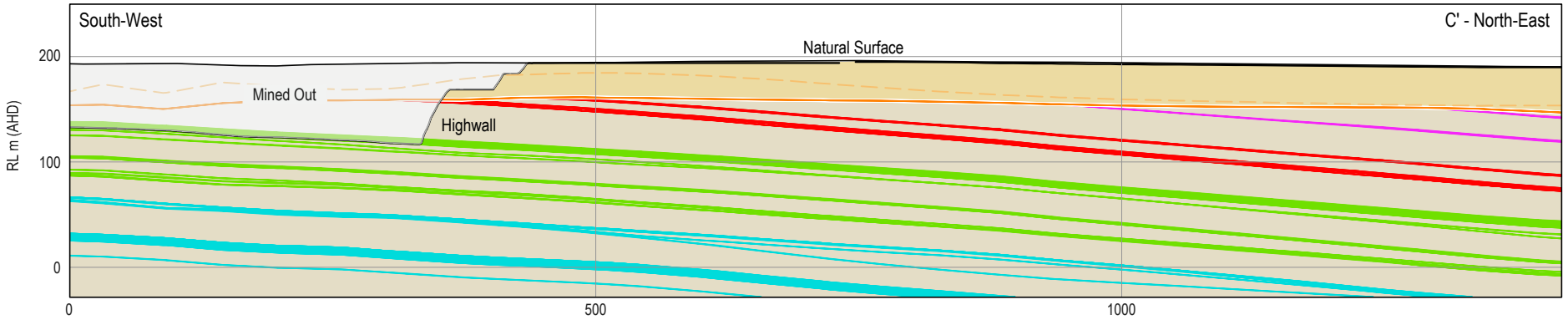
Horizontal Scale

(V/H = 1)

0 100 200 300m

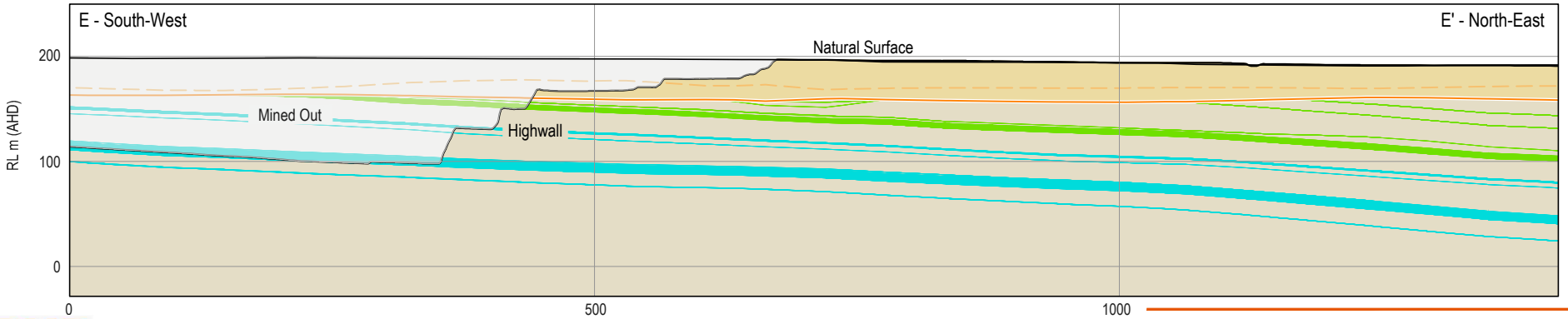
CROSS SECTION | JACARANDA PIT

Viewed Looking North-West



CROSS SECTION | ACACIA PIT Ramp 2

Viewed Looking North-West



BHP

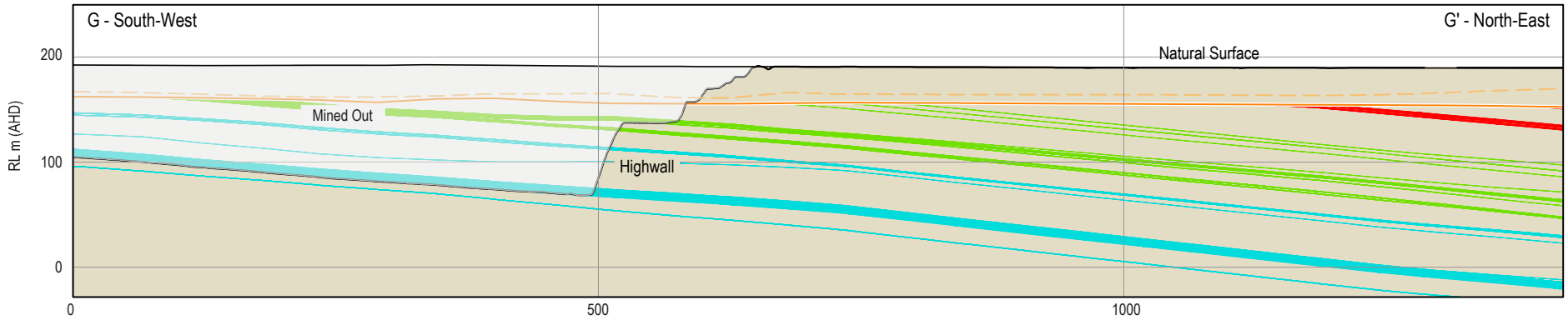
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Pit cross-sections

Figure **7**

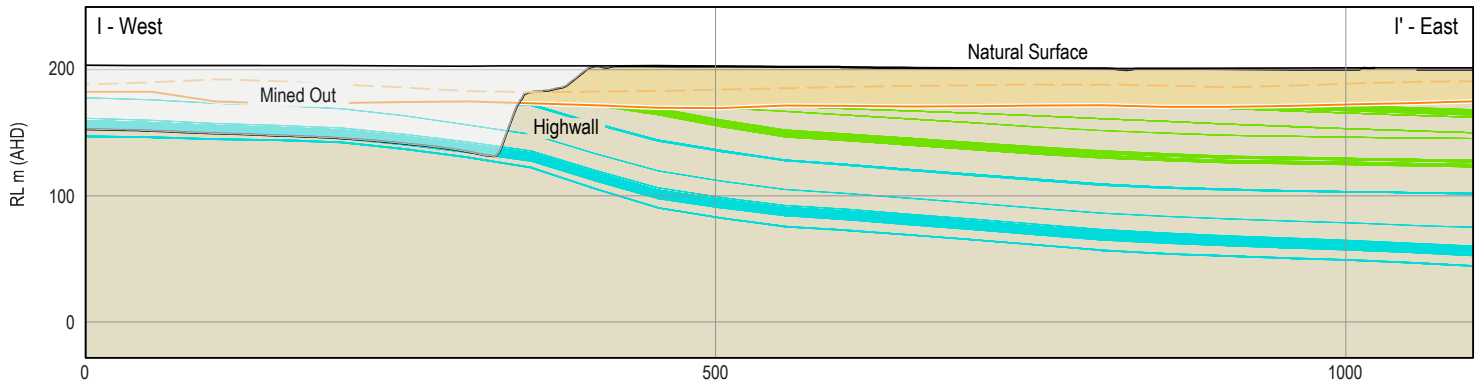
CROSS SECTION | BAUHINIA PIT

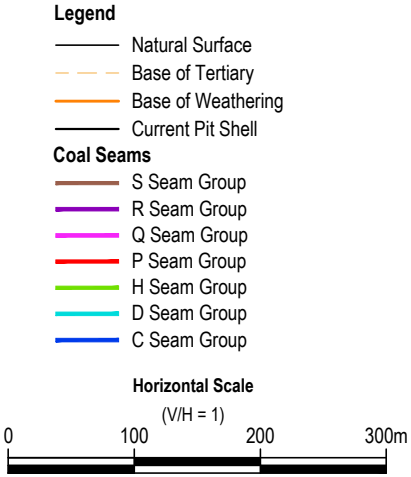
Viewed Looking North-West



CROSS SECTION | COOLIBAH PIT

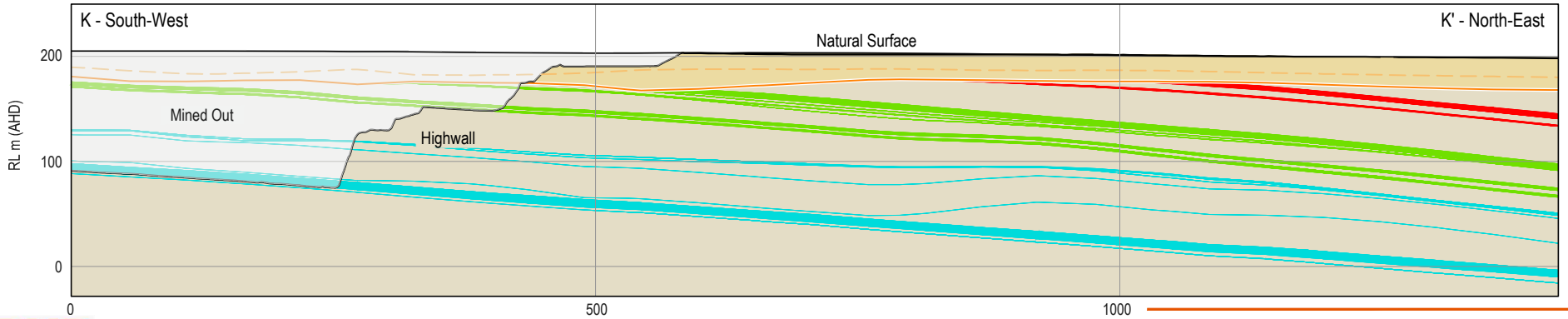
Viewed Looking North





CROSS SECTION | DOGWOOD PIT

Viewed Looking North-West



BHP

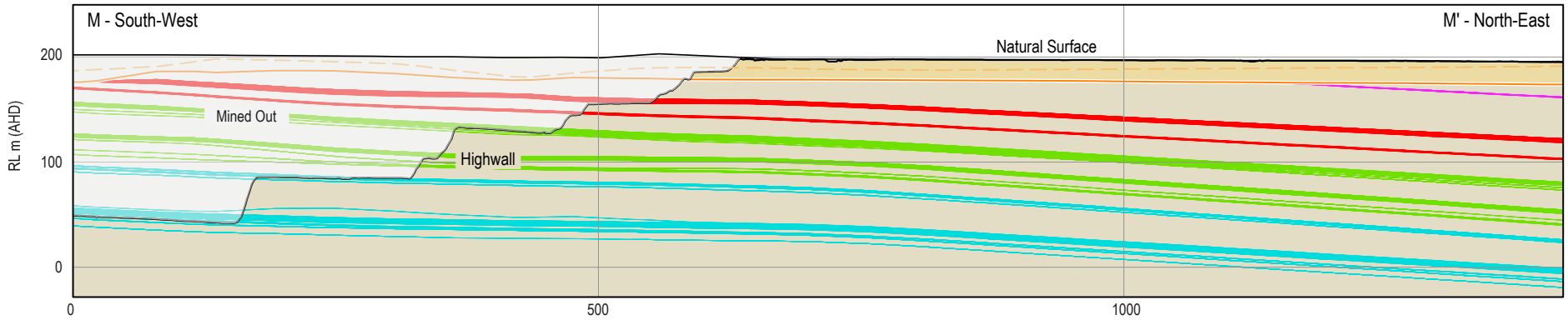
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Pit cross-sections

Figure **8**

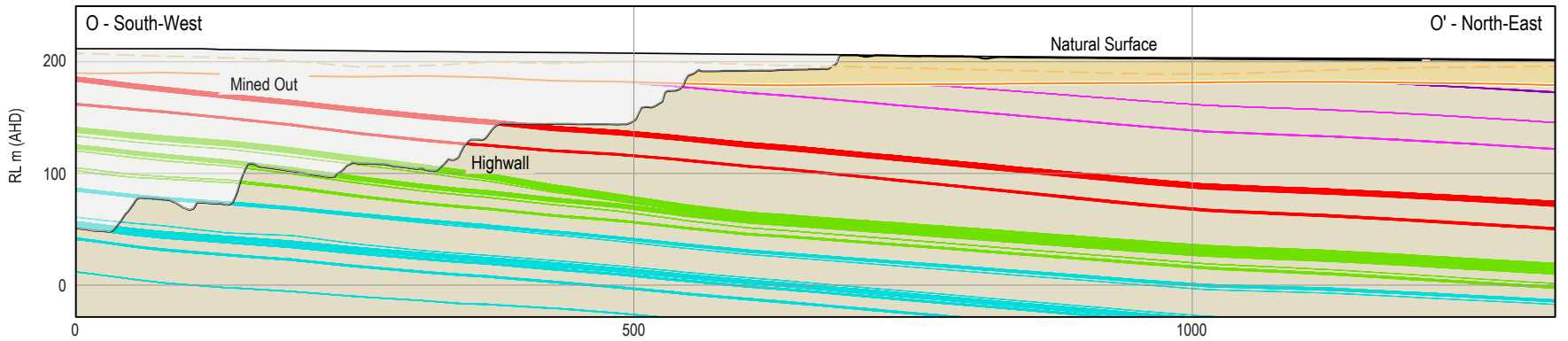
CROSS SECTION | EBONY PIT

Viewed Looking North-West



CROSS SECTION | GREVILLLEA PIT

Viewed Looking North-West



Legend

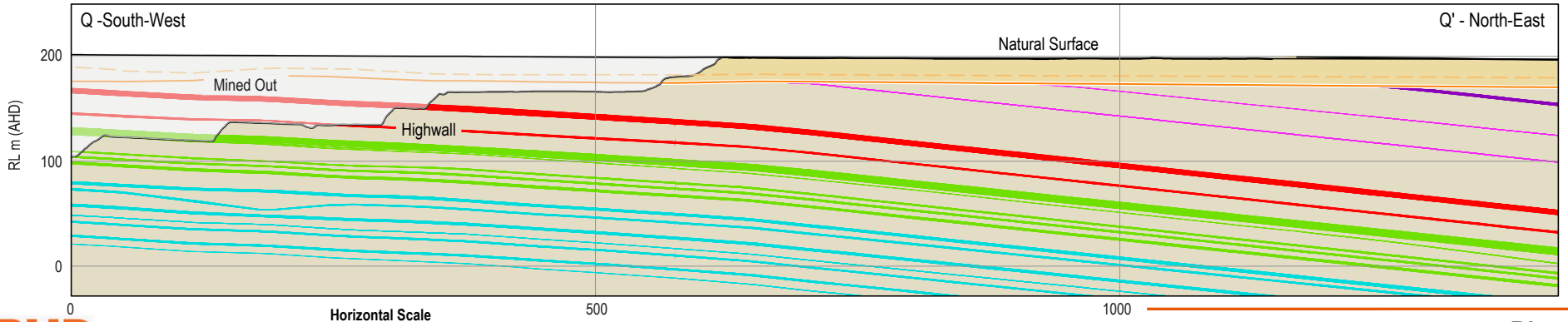
- Natural Surface
- Base of Tertiary
- Base of Weathering
- Current Pit Shell

Coal Seams

- S Seam Group
- R Seam Group
- Q Seam Group
- P Seam Group
- H Seam Group
- D Seam Group
- C Seam Group

CROSS SECTION | HAKEA PIT

Viewed Looking North-West



Horizontal Scale

(V/H = 1)

0 100 200 300m

BHP

Minserve CAD File: Bhpb008m02.dwg

Pit cross-sections

Figure **9**

2.3.4 Surface Water / Hydrology

The following information about surface water / hydrology is general and provided for broad context. Refer to the main volume of the PRCP for detailed information about surface water quality at SRM.

The catchment for the SRM watercourses begins in the Cherwell Range and Denham Ranges west of SRM at an elevation of approximately 380 m and flows downstream to meet the Isaac River east of SRM at an elevation of approximately 200 m.

All watercourses within SRM are tributaries of Isaac River and part of Fitzroy basin. The Isaac River is the major watercourse downstream and to the east of SRM. The creeks at SRM, from north to south, are shown on **Figure 1** and include:

- Boomerang Creek, which forms a natural boundary between SRM and neighbouring PDM;
- Plumtree Creek (west), flowing into SRM from the west and is diverted at the western ML boundary into Hughes Creek;
- Plumtree Creek (east), flows from Jacaranda Pit highwall southeast towards (and into) Boomerang Creek;
- Hughes Creek, which flows west to east across the site between Bauhinia and Coolibah pits. On the far eastern side of the ML, Hughes Creek flows into Boomerang Creek;
- Barrett Creek, a minor tributary located west of the CHPP that flows north into Hughes Creek;
- One Mile Creek, which flows west to east across the site between Dogwood and Ebony pits;
- Spring Creek, which flows west to east across the site between Ebony and Grevillea pits. On the eastern side of the site Spring Creek flows into One Mile Creek;
- Southern Creek, a minor tributary flowing into SRM from the west, which flows into Phillips Creek; and
- Phillips Creek, which flows west to east across the site between Grevillea and Hakea pits.

Of the above creeks, Boomerang Creek, Hughes Creek One Mile Creek, Spring Creek and Phillips Creek are the most significant watercourses within and surrounding SRM; Plumtree, Barret and Southern creeks – as well as other minor and un-named tributaries – flow into one of these five key watercourses. Post-closure, Spring Creek is diverted south into Phillips Creek.

2.3.5 Groundwater / Hydrogeology

The following information about groundwater / hydrogeology is general and provided for broad context. Refer to the main volume of the PRCP for detailed information about groundwater quality at SRM.

An aquifer is defined as a groundwater bearing formation sufficiently permeable to transmit and yield water in usable quantities. The Quaternary alluvial formations, Tertiary sediment and basalt formations, and the Permian coal measures generally yield low sustainable volumes of poor-quality water. As such, these formations are not recognised as ‘true’ aquifers in the area. However, for the purpose of the discussion, groundwater-bearing zones at SRM are referred to as aquifers.

The main factors influencing natural groundwater levels are groundwater recharge, evapo-transpiration and regional flow patterns. Due to the heterogeneity and discontinuity of the Quaternary alluvium aquifers and Tertiary sediment and basalt aquifers, the groundwater flow direction in these aquifers cannot be determined on a regional scale – and is likely to be topographically controlled, flowing from higher elevations to lower elevations. The ‘pre-mining’ groundwater flow direction within the Permian coal seams is generally west to east across the site, and consistent with recharge into sub-cropping seams west of SRM.

The physico-chemical results from groundwater sampling at SRM indicate the water chemistry is typically pH-neutral for all geological formations. Groundwater associated with coal seams and Tertiary basalt have variable salinity levels (measured as electrical conductivity), ranging from brackish to saline, while the alluvium groundwaters are typically fresh to brackish. The existing (background) concentrations of some dissolved metals in the groundwater are above the water quality guidelines for freshwater ecosystems (ANZG, 2018; QWQG 2006).

Elevated concentrations of some elements in groundwater in Permian coal measures in the Bowen Basin are not uncommon and are considered to be naturally occurring.

The water quality from the monitoring wells located at and close to SRM indicates that, generally, the water is unsuitable for human consumption as assessed against the Australian Drinking Water Guidelines (HMRC-NRMMC 2011). Local groundwater use is primarily for livestock purposes owing to the variable salinity levels and generally low yields.

The hydrogeological units at SRM are outlined in **Table 1**.

Table 1. Hydrogeological units at SRM

Age	Geological Unit	Aquifer
Quaternary	Undifferentiated alluvium (mainly clay, silt, sand and gravels)	• Sand and gravel deposits within the alluvium forming unconfined aquifer; • Localised at and near to SRM along Hughes Creek, One Mile Creek and Philips Creek
Quaternary to Tertiary	Regolith: Undifferentiated colluvium and weathered units (clay, silt, sand, and weathered sandstone/siltstone)	Unconfined and largely unsaturated unit. Minor saturated zones.
Permian	Moranbah Coal Measures [Interburden] Mainly sandstone, siltstone and claystone	The low-permeability sandstone and siltstone interburden units (between coal seams) are typically dry or very low yielding (i.e. have aquitard properties).
	Moranbah Coal Measures [coal seams]	The coal seams are identified as the primary aquifer; associated with secondary porosity through cracks and fissures.

2.3.6 Potential Environmental and Human Health Receptors

A conceptual environmental geochemical model (source-pathway-receptor (SPR) model) for SRM identified the potential environmental and human health receptors and is discussed within this report. Of relevance to this assessment (i.e. hazards and risks posed by AMD), the following potential receptors are noted:

Potential surface water receptors

The primary surface water feature in the district is the Isaac River, located over 15 km east and downstream of SRM. The northern half of the site (Jacaranda-Bauhinia-Coolibah) drains to Boomerang and Hughes creeks. The central area (Dogwood-Ebony) drains to One Mile Creek and the southern area (Grevillea-Hakea) drains to Phillips Creek. All of these creeks eventually drain into the Isaac River. SRM shares the Isaac River Catchment with several other coal mines upstream and downstream.

Potential groundwater receptors

Aquatic and terrestrial groundwater dependent ecosystems (from national assessment) are shown in **Figure 1**.

Potential domestic (human) receptors

There are three homesteads located in close proximity to SRM. The nearest homestead is located approximately 400 m west of the ML boundary at approximately Bauhinia Pit. Two other homesteads are located less than 2 km west of the ML boundary at the approximate location of the CHPP and west of the ML boundary at Hakea Pit. These three homesteads are all located upstream (via surface water) and upgradient (via groundwater) from SRM.

There are no homesteads located east SRM within a 5 km distance of the ML boundary. The nearest infrastructure east of the ML boundary (apart from livestock dams) is Lake Vermont Coal Mine (operated by Jellinbah Group), located approximately 7 km east of Grevillea-Hakea pits.

2.3.7 Acid and Metalliferous Drainage

Environmental geochemical information with regard to AMD from mineral waste materials at SRM has been sourced from the BHP Coal Geochemical Database (hereafter called 'the geochemical database') and is presented and discussed within this report.

2.3.8 Salinity, Sodicity and Dispersion

Environmental geochemical information with regard to salinity, sodicity and dispersion of mineral waste materials at SRM has been sourced from the geochemical database and is presented and discussed within this report. Refer to the main volume of the PRCP for detailed information about soils and rehabilitation of spoil dumps at SRM.

3 Potential Environmental Geochemical Hazards

3.1 Acid and Metalliferous Drainage

The term 'AMD' is used to describe low-quality seepage or drainage (from soil and rock) that has been affected by the oxidation of sulphide minerals (primarily pyrite and marcasite) and/or by the dissolution of acid generating sulphate minerals (primarily alunite and jarosite) and associated neutralisation reactions, if any. The term AMD is used to describe any drainage type affected by this process.

AMD may be produced when sulphide minerals (such as pyrite) are exposed to oxygen and water. Oxidation of sulphide minerals may result in the production of acid(ity), sulphate (SO_4) and, depending on mineralogy, the release of metals and salinity. AMD comprises three key components, which are defined below as per recognised Australian and international guidelines (INAP, 2009[1]; DIIS, 2016[2]). BHP (2019) has adopted these recognised definitions:

- Acid drainage (AD): where contact water is acidic and, in most cases, also contains 'elevated' concentrations of metals and metalloids. This drainage type is generated when the acid generating capacity exceeds the acid neutralisation capacity of a sample.
- Neutral and metalliferous drainage (NMD): where contact water is pH-neutral/alkaline and contains 'elevated' concentrations of metals and metalloids. This drainage type is generated when the acid neutralising capacity exceeds the acid generating capacity of a sample.
- Saline drainage (SD): where contact water contains elevated sulphate concentration due to oxidation of sulphide minerals, and very low metal/metalloid concentration. This drainage type is generated when the acid neutralising capacity vastly exceeds the acid generating capacity of a sample with high sulphide concentration.

Whether contact water is impacted by AD, NMD and/or SD largely depends on the relative proportion of acid generating minerals (sulphides / sulphates) and acid neutralising minerals (carbonates) in the source materials.

3.2 Salinity, Sodicity and Dispersion

An assessment of salinity characteristics of mineral waste materials has been undertaken on materials using available EC data from the geochemical database. An assessment of sodicity and dispersion characteristics of potential final landform materials has also been undertaken using exchangeable cation and Emerson Class data from overburden/interburden samples (data obtained from the geochemical database). Salinity released from the dissolution of geogenic salts (non-oxidative) is a separate and distinct process from SD associated with sulphide oxidation.

1 INAP, 2009. Global Acid Rock Drainage Guide.

2 DIIS, 2016. Preventing Acid and Metalliferous Drainage. Handbook from Australian Federal Government's Leading Practice Sustainable Development Program for the Mining Industry. https://www.industry.gov.au/data-and-publications/leading-practice-handbook-preventing-acid-and-metalliferous-drainage.

4 Assessment Methodology

This section provides the methodology used for the geochemical characterisation and assessment of spoil, tailings and rejects (mineral wastes) and coal at SRM.

4.1 Information Review

Sampling and laboratory test-work has been undertaken by BHP and consultants throughout the development and operation of SRM. The geochemical database contains all available geochemical data for mineral waste samples. All data has been compiled and reviewed by BHP specifically to support the PRCP, to provide a unified and consistent interpretation of all available data. Past characterisation reports are superseded by this review and assessment undertaken to support the PRCP.

4.2 Sample Collection

Drill-hole Samples – representing spoil, ROM coal, pit walls and pit floor

All data used to assess spoil and ROM coal (and pit walls and floor) has been derived from drill-hole sampling. Drill-hole samples have been collected from 56 drill-holes located throughout SRM (shown in **Figure 1**), dating from 2005 through to the most recent drill-hole sampling at SRM undertaken in early 2022.

The drillholes are distributed along strike (approximately north-south) and, as such, intersect all mined geological units along the entire site, with sampling undertaken from surface to full drill-hole depth (approximately to below the lowest mined seam). As such, the drill-hole samples that have undergone test-work are representative of the geology/stratigraphy at SRM from existing mining (disturbance) areas.

The SRM coal resource model provides an estimate of coal resources from current pit highwall through to the eastern extent of the mine (near the eastern ML boundary). The resource model indicates that – at closure – the proportion of coal versus non-coal in the highwall of the residual voids is broadly consistent with the current proportions on the pit highwalls. The model also shows that the proportion of each seam group is expected to be broadly similar to current seam group proportions on the highwall of the current pits – with the exception of an increase in Q seam coal exposed on the highwall of Jacaranda, Ebony, Grevillea and Hakea pits at closure; and an increase in P seam coal exposed on the highwall of Bauhinia and Dogwood pits at closure. As such, it is reasonable to assume that the mineral waste types assessed, and their relative proportions, are representative of the mineral waste types and proportions likely to be present at closure.

Geochemical data comprising, at minimum, total S and ANC results, is available for 1149 drill-hole samples collected from 53 drill-holes. An additional 1109 samples have pH and electrical conductivity (EC) results only. Geochemical samples (n=1149) collected and tested were sourced from the following key mineral waste domains:

- Weathered, non-carbonaceous spoil. 106 samples.
- Weathered, carbonaceous spoil, including weathered coal. 9 samples.
- Fresh, non-carbonaceous spoil. 710 samples.
- Fresh, carbonaceous spoil. 101 samples. These samples typically include carbonaceous siltstone, carbonaceous sandstone, carbonaceous mudstone and coaly shale, but also includes similar coaly and carbonaceous materials other than coal. Approximately 50 % of these samples were collected from the programs specifically targeting coal seams. As such, a large proportion of these samples represents seam roof, parting and floor.
- Fresh, coal. 223 samples. Approximately half of these samples were collected from the BMA coal quality program specifically targeting coal seams.

Samples were collected from chip- and core-drilling. Drill-chip samples were typically collected at set intervals (e.g. every 1 or 2 m) or within targeted sampling zones. Drill-core samples were collected as discrete samples – typically a 15-25 cm interval of core within targeted sampling zones. Most drill-core samples were collected semi-

continuously across the entire stratigraphic sequence, with greater emphasis placed on those stratigraphy's posing a greater AMD hazard, such as carbonaceous spoil plus material located within and very close to coal seams, which includes roof/parting/floor (carbonaceous and non-carbonaceous), and coal.

Of the 926 spoil samples, 483 samples (52 % of spoil samples) were sampled close to seams – typically interburden or parting between plys of the same seam group. As such, seam and near-seam zones were proportionally oversampled (relative to sampling of thick overburden/interburden areas well away from seams) to target seam zones that were interpreted as posing a higher AMD hazard compared to general spoil well away from seams.

It is understood that most fresh coal will report to ROM coal and be processed. A small fraction of coal will be mined as spoil (waste) due to coal quality and mining considerations, and a small proportion of coal will remain exposed in seams on pit walls and floor at closure. The coal samples discussed herein represent 'pure' coal and do not include associated roof, parting and floor samples that would ordinarily be mined with the seam as ROM coal. Carbonaceous roof, parting or floor samples are included in the 'fresh, carbonaceous' sample group.

The geochemical sampling locations are shown on **Figure 1** (site layout) and the number of drill-hole samples from each stratigraphic zone is shown on **Figure 2** (indicative stratigraphic column).

Tailings Samples – representing very fine to fine-grained coal process waste

Geochemical data is available (within the geochemical database) for 296 tailings samples, comprising 105 'fresh' tailings samples collected from the CHPP and 192 'aged' tailings samples collected from geotechnical investigation drillholes within several TSFs. Tailings data are presented and discussed as two groups being representative of:

- Fresh (CHPP) tailings samples; and
- Aged (TSF) tailings samples.

Tailings samples collected from the CHPP are deemed to be representative of 'fresh' tailings currently and recently produced at SRM. Tailings samples collected from TSFs are deemed to be representative of 'aged' tailings within the TSFs at SRM.

Of the 192 tailings samples collected from TSFs, only 14 samples (all from one drillhole at TSF 2) were logged as being below the phreatic surface (water table) recorded in the investigation drill-hole at the time of drilling and sampling. Most TSF tailings samples were logged as 'moist'.

Rejects Samples – representing mid- to very coarse coal process waste

Geochemical data is available (within the geochemical database) for 76 rejects samples, comprising 41 'fresh' rejects samples collected from the CHPP, 32 'aged' rejects samples collected from geotechnical investigation drill-holes within Ramp 2-3 tailings storage facility (TSF) and three rejects samples collected from the Ramp 4 (R4) in-pit rejects area. Rejects data are presented and discussed as two groups being representative of:

- Fresh (CHPP) rejects samples; and
- Aged (TSF and R4) rejects samples. These samples were logged as 'dry' to 'moist' at the time of collection.

Rejects samples collected from the CHPP are deemed to be representative of 'fresh' rejects currently and recently produced at SRM. Rejects samples collected from Ramp 2-3 TSF and R4 rejects area are deemed to be representative of 'aged' rejects that may be found in TSFs or at rejects disposal areas awaiting burial/rehabilitation.

Other Samples

Geochemical data is available (within the geochemical database) for 60 'fill' samples and eight 'natural ground' samples collected from geotechnical investigation drillholes within the above-ground TSFs (TSF 3 and TSF 4). Fill material comprises the spoil cap/cover on top of tailings in each facility. Fill samples were collected and analysed as part of the geotechnical investigations. Fill samples were logged as 'dry' to 'dry/moist' at the time of collection. At the base of the investigation drillholes (base of the TSFs, below the base tailings) natural ground was encountered and was also sampled as part of the investigations. Natural ground samples were logged as 'moist' at the time of collection.

4.3 Sample Characterisation

The aim of the environmental geochemical test-work is to understand the geochemical characteristics of the mineral waste materials with respect to AMD, geogenic salinity, erosion and dispersion potential; and to inform management and closure options for these materials.

A phased approach was implemented to define the geochemical behaviour of the key material types generated at SRM, as discussed below.

Solid Samples – Static Tests

Tailings, rejects and overburden (spoil) samples have generally undergone similar test-work methods. Test-work was generally undertaken in stages, with most samples being subjected to 'screening' tests followed by more detailed test-work undertaken on selected samples.

The vast majority of the samples have undergone 'screening' tests (stage 1 tests) for:

- pH and electrical conductivity (EC) on 1:5 w:v water extracts (on pulps [85% passing 75 microns]);
- Net acid producing potential (NAPP) test, which comprises total sulphur (total S) and acid neutralising capacity (ANC) determination. The NAPP test provides the fundamental information about the theoretical maximum amount of acid-producing and acid-neutralising material that a sample could produce;

Based on the results of the screening tests, selected samples were subjected to some or all of the following tests:

- Total carbon (total C), and organic carbon (C-org);
- Total sulphate (SO_4);
- Sulphide (chromium reducible sulphur – Scr) – a test to determine the proportion of total S present as sulphide;
- Acid buffering characterisation curve (ABCC) - a test to determine the proportion of ANC that's in a readily-available form and to provide an indication of the carbonate mineralogy of the neutralising material;
- Net Acid Generation (NAG) [single addition] - a test that encourages the oxidation of a sample to determine if acid can be produced, and how much acid could be produced;
- Sequential net acid generation test (S-NAG) – a refinement of the single addition NAG test to resolve potential issues associated with incomplete oxidation of samples with high sulphide concentrations;
- Extended boil net acid generation test (NAG Extended) – a refinement of the NAG test to resolve uncertainty due to potential organic acid interference (where non-acid generating organic acids can provide false positive results in the NAG test);
- Total metals and metalloids by 4-acid (mixed) or 2-acid (aqua regia) digest with analysis by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and/or Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) and Flow Injection Mercury System (FIMS);
- Quantitative x-ray diffraction (QXRD) – to determine the mineralogical composition;
- Short-term leaching tests, including:
    - Deionised water extract leach procedure – a 1 hour end-over-end bottle leach at 1:5 w:v (solid:water) ratio using de-ionised water, with filtered leachate analysed for:
        - Major and minor ions [calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), SO_4, chloride (Cl) and fluoride (F)];
        - Alkalinity [total alkalinity, bicarbonate (HCO_3) and carbonate (CO_3)] and Acidity (pH dependent);
        - Soluble metals and metalloids [approximately 28 elements by ICP-MS, ICP-AES and FIMS].
    - Saline water extract leach procedure – a 1 hour end-over-end bottle leach at 1:5 w:v (solid:water) ratio using saline water (2 g/L NaCl), with filtered leachate analysed for the soluble analytes listed above.
    - Peroxide (NAG) leach – analysis of the solution on completion of the NAG or NAG Extended test, with filtered leachate analysed for the same (or similar) suite of soluble analytes as listed above.

- Exchangeable cations (Calcium [Ca], Magnesium [Mg], Sodium [Na], Potassium [K]) (with pre-treatment for salinity, if required). Results were used to calculate the cation exchange capacity (CEC);
- Emerson Aggregate Class testing.

For most samples, excluding some historical samples/data, laboratory test work was undertaken by ALS Environmental (ALS) Brisbane, using National Association of Testing Authorities (NATA) accredited methods (where such accreditation exists). Mineralogical analysis (QXRD) was undertaken by a university (research) mineralogical laboratory in Melbourne (via Earth Systems Consulting).

Solid Samples – Kinetic OxCon Tests

Oxygen consumption and carbon dioxide (CO_2) generation (OxCon) test-work was undertaken by Earth Systems (Melbourne) on five tailings samples: two samples from the CHPP and three samples from TSF drillholes. The samples were selected on the basis of earlier static test results.

OxCon is a laboratory-scale kinetic geochemical test for the estimation of sulphide oxidation rates, acidity generation rates and carbonate neutralisation rates for sulphidic geological materials.

Prior to the OxCon test the sample is 'washed' to remove any pre-existing salts and oxidation products (e.g. sulphate). Test-work then involves isolating a known mass of sulphide-bearing material in a known volume of oxygen inside a sealed vessel and allowing sulphide oxidation to proceed. Once the test is initiated, oxygen in the vessel is consumed via sulphide oxidation. Oxygen consumption is measured directly on an hourly basis and logged over the test-work period (1-8 weeks, depending upon the sample). Carbon dioxide generation is measured hourly and logged for estimation of the extent of acid neutralisation by carbonate minerals or the rate of biological organic carbon oxidation, if any, during testing.

At the conclusion of the OxCon test, the solid undergoes a bottle leaching procedure at a 1:2 solid:water ratio and the leachate was analysed to determine the pH, acidity/alkalinity and concentration of soluble metals/metalloids and salts.

Solid Samples – Kinetic Leaching Tests

Free-draining kinetic column leaching data is available for six composite samples comprising one seam roof composite sample (H16 [HCU]), three seam floor composite samples (H16 [HCU], D14 and D24 [DL]), one coal composite sample (H16 / D24 / D14) and one rejects sample from the R4 rejects area. The samples were selected for column leaching test-work on the basis of earlier static test results.

Column leaching is a laboratory-scale kinetic geochemical test for the estimation of sulphide oxidation rates, acidity generation rates and element leaching – over time – for geological materials. The intent of the column leaching program was to characterise leachate from samples subjected to routine wetting and drying cycles, which simulates exposure to 'atmospheric conditions'. Crushed samples are loosely packed into a two litre funnel and a known quantity/mass of deionised water is slowly added to the top of each sample and the water allowed to slowly free-drain through the sample matrix and collected as 'column leachate'. The leachate collected from each column test was analysed to determine the pH, acidity/alkalinity and concentration of soluble metals/metalloids and salts. Between leaching (wetting) events the sample matrix was allowed to dry and oxidise using heat lamps. The column leaching test method was based upon a modified AMIRA (2002) method. The six column leaching tests underwent approximately fortnightly leaching over 12 weeks (seven leaching events, including week 0).

Tailings Liquor Samples

Tailings samples collected from the CHPP are collected as a slurry – representative of the tailings slurry that reports to TSFs for disposal. At the TSF the water drains to one end of the TSF – called a decant pond/area – and is collected for re-use in the CHPP. Geochemical data is available (in the geochemical database) for tailings liquor from 12 sampling events undertaken at the CHPP between January and April 2022. The liquor samples were analysed for a typical suite of water quality parameters, such as pH and EC, major cations and anions and soluble metals and metalloids.

4.4 Geochemical Source Hazard Assessment

Geochemical data was assessed with regard to the samples potential to generate AMD. Only after making such an assessment to understand the potential AMD hazard can appropriate AMD specific management measures be formulated to adequately mitigate the risks, as required.

AMD Classification

The Acid-Base Account (ABA) method was used to assess the acid-neutralising and acid-generating characteristics of the samples in order to determine an acid (AD) classification for the mineral waste materials.

The maximum potential acidity (MPA) and acid neutralising capacity (ANC) represent each side of the acid-base account. MPA is calculated from total S and is the theoretical maximum potential acidity that can be generated if all of the S, assumed to be associated entirely with pyritic sulphide, is able to oxidise and generate acid (H_2SO_4). ANC represents the theoretical maximum amount of acid-neutralising capacity of a sample assuming all neutralising material is in a readily available form. The net acid producing potential (NAPP) is the difference between the MPA and the ANC. In simple terms, a negative NAPP indicates an excess of ANC and the sample is likely to be non-acid forming (NAF) and a positive NAPP indicates an excess of MPA and the sample is likely to be potentially acid forming (PAF) – though there can be exceptions to this simplified interpretation. Note that NAF samples have the potential to generate NMD and SD, depending on the sulphur concentration.

Sample classification of mineral waste material follows some general rules. Samples were initially classified using Total S, NAPP and ANC/MPA ratio (and NAG data, where available), into three broad categories:

NAF Non-acid Forming;

PAF Potentially Acid Forming;

Uncertain Those samples with inconclusive results, leading to a degree of uncertainty about their ability to generate acid

Where available, additional geochemical information such as pH, Scr, ABCC, NAG extended and NAG sequential results were used to resolve acid classification uncertainties. The general approach was to build in a level of conservatism in the preliminary classification, as shown in **Table 2**.

Table 2. Preliminary AMD classification criteria

Preliminary classification	Sulphur %	NAPP kg H_2SO_4/t	ANC/MPA ratio	NAGpH (if data available)
NAF	≤ 0.01	-	-	-
	≤ 1	< 0	≥ 2	-
	≤ 1	< 0	-	≥ 4.5
NAF-Sulphur (NAF-S)	> 1	< 0	≥ 2	-
	> 1	< 0	-	≥ 4.5
PAF – Low Capacity (PAF-LC)	≤ 1	≥ 0 and < 10	< 2	-
	-	≥ 0 and < 10	-	< 4.5
PAF	-	≥ 10	< 2	-
	-	≥ 10	-	< 4.5
Uncertain	Any result outside of the above criteria, or results that appear to significantly conflict with the expected result based on lithology or mineralogy			

Ninety-eight (98) tailings, rejects and fill samples from the TSFs had only $pH_{1:5}$, $EC_{1:5}$ and total S data available (but no ANC or NAG data). As such, these 98 samples were not able to be classified as per the criteria in Table 2.

A classification was then assigned by comparing $pH_{1:5}$, $EC_{1:5}$ and total S values of the sample to its nearest neighbour (where detailed ABA data was available) and infer a classification based on geochemical similarities.

Sulphur Category

To ensure a consistent approach to describe the samples geochemical characteristics, specific total S cut-off values were used to discuss sulphur data, as shown in **Table 3**.

Table 3. Sulphur category and associated cut-off

Sulphur category	Total S wt. %
Very low	< 0.1
Low	0.1 – 0.5
Low-moderate	0.5 – 1.0
Moderate	1.0 – 1.5
High	> 1.5

ANC Category

To ensure a consistent approach to describe the samples geochemical characteristics, specific ANC cut-off values were used to discuss ANC data as shown in **Table 4**.

Table 4. ANC category and associated cut-off

ANC category	ANC kg H_2SO_4/t
Very low	< 5
Low	5 - 15
Moderate	15 - 30
High	30 - 50
Very high	> 50

Soil Salinity

The term ‘soil’ salinity (and ‘soil’ pH – refer below) is an industry-adopted term to refer to the salinity and pH measured on any solid geologic matrix, such as soil, spoil, rock, sediment, tailings, reject, etc. That is, in this context, the term ‘soil’ applies to all solid samples, not just shallow surface (root zone) material.

Classifying whether a sample/material is non-saline, highly saline, or somewhere in between will depend upon the methods used to measure soil salinity. Soil salinity data is obtained from a 1:5 (w:v) [and 1:2 w:v] water extract procedure typically on pulp samples (pulping the sample minimises the potential to underestimate salinity on sandy samples/materials). The soil salinity classes shown in **Table 5** are expressed in units of microSiemens per centimetre (µS/cm) and are based on a 1:5 w:v method. These soil salinity classes are used as an indicative guide. The classes are broadly based on soil salinity classes reported by DME (1995).

Table 5. Soil salinity classification

Soil salinity classification	EC1:5 µS/cm
Non-saline	< 450
Slightly saline	450 - 900
Moderately saline	900 - 2000
Saline	2000 - 4000
Strongly saline	> 4000

Soil pH type

Classifying whether a sample/material is acid, pH-neutral or alkaline or somewhere in between will depend upon the methods used to measure soil pH. Soil pH data is obtained from a 1:5 (w:v) [and in a small number of cases 1:2 w:v] water extract procedure typically on pulp samples. The soil pH types shown in **Table 6** are based on a 1:5 w:v method. These soil pH types are used as an indicative guide.

Table 6. Soil pH type and associated cut-off

Soil pH type	pH1:5
Highly acid	< 3.0
Moderately acid	3.0 – 4.5
Weakly acid	4.5 – 6.0
Near neutral	6.0 – 7.5
Alkaline	7.5 – 9.0
Highly alkaline	> 9.0

Mineralogy

Mineralogical data (QXRD) provides supporting information for the geochemical data, particularly with regard to sulphide and carbonate mineralogy of a sample, showing results for mineralogical forms (e.g. what sulphide or carbonate minerals are present) and their concentrations (reported in weight %). These data are also used to validate the results from ABCC test-work and assist with interpretation of the ABA data.

Element Enrichment

The total concentration for each element were compared to average element abundance in soil in the earth's crust (Bowen, 1979) to measure how the total elemental concentrations in the samples compare against average elemental concentrations in unmineralised soil (worldwide). Such a comparison is undertaken to identify samples that contain what may be regarded as 'elevated' concentrations of metals and metalloids to identify potential element of concern. However, enrichment in any metals/metalloids in the solids, does not translate to enhanced leachability or mobilization and/or bioavailability of that specific element.

From the comparison with average crustal abundance in rocks a geochemical abundance index (GAI) was calculated. The GAI quantifies an assay result for a particular element in terms of the average abundance for that element (in sedimentary rocks). The index, based on a log 2 scale, is expressed in seven integer increments (0 to 6), which correspond to enrichment factors from 0 to over 96 times average crustal abundance, as shown in **Table 7**.

Table 7. Geochemical abundance index (GAI)

GAI	Enrichment factor	GAI	Enrichment factor
0	Less than 3-fold enrichment	**4**	24 to 48-fold enrichment
1	3 to 6-fold enrichment	**5**	48 to 96-fold enrichment
2	6 to 12-fold enrichment	**6**	Greater than 96-fold enrichment
3	12 to 24-fold enrichment		

As a general rule, a GAI greater than or equal to three indicates enrichment compared to unmineralised soil that may warrant further investigation to assess their mobility under laboratory conditions.

Elements identified as enriched may not necessarily be a concern for revegetation and rehabilitation, human and animal health or drainage water quality. Similarly, if an element is not enriched it does not mean it would not be mobilised, because under some conditions (e.g. low pH, reducing conditions) the geochemical behaviour of metals/metalloids such as Al, As, Cu, Cd and Zn can change (i.e. become less or more mobile).

Solubility

Metal/metalloid mobility from samples has been assessed using deionised water, 'saline' water and peroxide (NAG) leaching methods. The deionised and saline water leaches assess the initial solubility under fresh water and saline water conditions, whereas the peroxide leach assesses the solubility after the samples have been oxidised. The objective of the saline leaching procedure is to better mimic the brackish to moderately saline water commonly used in the CHPP to process ROM coal.

The solubility data from bottle leaching provides an indication of likely solubility/release of salt and metals/metalloids under field pH and redox (oxidation) conditions (and/or saline or low-pH conditions, where applicable). Peroxide (NAG) leachate data provides an indication of potential acidity and concentrations of metals and metalloids that could be released from samples that are fully and rapidly oxidised. This test provides an assumed 'worst case' scenario in term of metal/metalloid mobility. Solubility data from OxCon and KLC testing provides an indication of likely solubility/release of salt and metals/metalloids when the samples are oxidised and can be used to estimate release rates.

To ensure a consistent approach to describe the samples geochemical characteristics, specific concentration cut-off values were used to discuss leachate composition as shown in **Table 8**. These same concentration cut-off values were also applied to tailings liquor data.

Table 8. Soluble trace element concentration category and associated cut-off

Classification	Trace element soluble concentration mg/L
Close to detection	≤ 0.001
Very low	> 0.001 – 0.05
Low	> 0.05 – 0.1
Moderate	> 0.1 – 1.0
High	> 1.0 – 10
Very high	> 10

A classification scheme initially developed by Ficklin *et al*. (1992) has been adapted to summarise major attributes of the solubility data by plotting pH against soluble metal and metalloid concentrations for groups of elements, with the classification scheme shown in **Figure 10**. The soluble metal and metalloid concentrations are shown as the sum of soluble metal concentrations for base metals (Cd + Co + Cu + Ni + Pb + Zn) and/or the sum of soluble As +

Mn + Mo + Se. These two groups of elements are chosen because they remain in solution across a wide range of pH and are not only associated with AD conditions, but also with NMD/SD conditions.

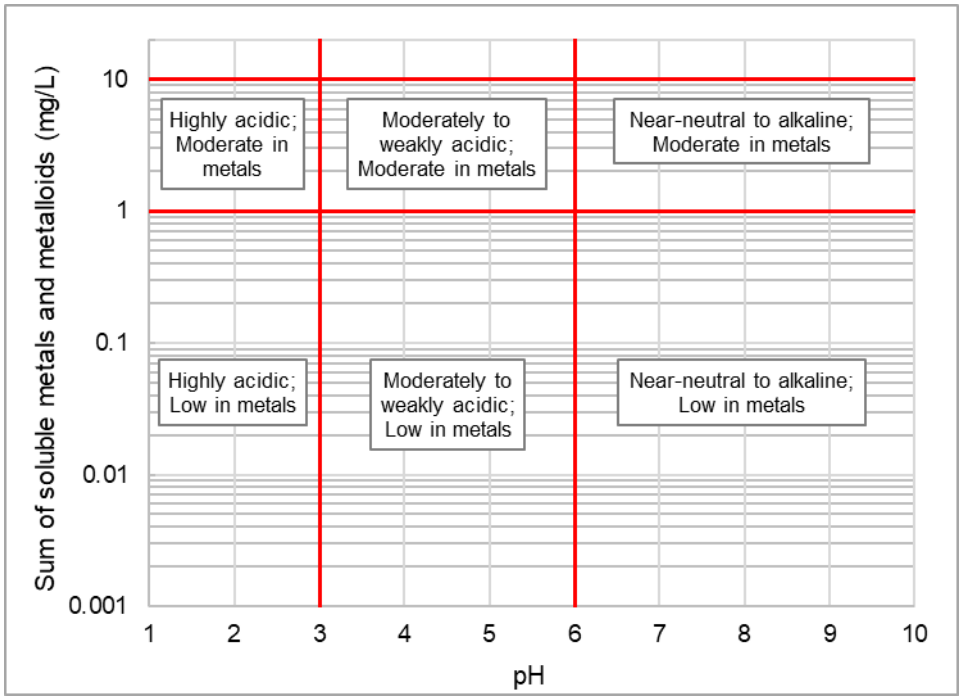


Figure 10. Classification of soluble metals and metalloids as a function of pH

No comparison is made between leachate results and water quality guideline values, such as ANZG (2018), as such a comparison is inappropriate. The guideline values provided in ANZG (2018) are for receiving water environments (e.g. creeks), whereas the soluble element data in this assessment is 'point source' obtained from a finely pulped sample subjected to rigorous and artificial extraction to obtain a concentration approaching 'near maximum'. Furthermore, contact water will undergo a number of geochemical reactions along a pathway from source to receptor, including: retardation, adsorption and precipitation – and also likely dilution, which will attenuate the concentration as seepage/contact water migrates from the source. These processes are not accounted for in a laboratory setting.

Sodicity and Dispersion

Potential spoil samples (representing material that is likely to report to final landform surface) are broadly classified with respect to sodicity on the basis of the exchangeable sodium percentage (ESP) value, as shown in **Table 9** (after Northcote and Skene, 1972; Isbell, 2002):

Table 9. Sodicity classification

Sodicity classification	ESP %
Non-sodic	≤ 6
Sodic	6 – 14
Strongly sodic	> 14

The sodicity will depend upon a range of factors, such as clay mineralogy, soil sodium concentration, soil salinity and irrigation water (rainwater) chemistry, which may enhance or limit that potential for soil to be sodic or become sodic over time. Therefore, values of 6% ESP and 14% ESP to represent soils as being sodic or strongly sodic are

used as a general guide only and should not be taken as definitive. Sodicity assessments only apply to materials likely to report to final landform surfaces, such as overburden/interburden (i.e. not coal reject or waste coal).

Sodicity information is broadly used to understand potential revegetation and dispersion aspects, and is supported by Emerson Aggregate Class test information, which provides a direct measure of soil slaking and dispersion based on the Standards Australia (2017) classification. Soils are divided into classes on the basis of their coherence in water and presence (or absence) of calcium-rich minerals (**Table 10**). Slaking occurs when dry soil crumbs, after being immersed in deionised water, break up and run along the bottom of the beaker into a flat pile. Most dry soil crumbs slake when immersed in deionised water. Dispersion describes the tendency for the clay fraction of a soil to go into colloidal suspension in deionised water. Materials are generally regarded as being dispersive (or prone to dispersion) if they have an Emerson Class number of three or less.

Table 10. Emerson classifications

Class	Description	Class	Description
1	Slaking and complete dispersion	5	No calcite or gypsum present; dispersion
2	Slaking and some dispersion	6	No calcite or gypsum present; flocculation
3	Dispersion [remoulded]	7	Non-slaking and swelling
4	Calcite or gypsum present; dispersion	8	Non-slaking and non-swelling

4.4.1 Using Coal Quality Data for AMD Classification

Coal quality data has been used to aid with the assessment of AMD hazard associated with coal seams. In particular, the BHP coal quality database was used to supplement the geochemical database and provide additional understanding of the AMD potential of likely ROM coal, remnant coal, waste coal and rejects. Coal plys were grouped into their respective seam groups on a per-pit basis, such as P seam group, HC Upper, HC Lower, etc. for each pit group.

Total S concentrations can be used conservatively to assess the AMD hazard for any given sample; thus, statistical analyses were conducted on total S as a function of seam group and for all seams combined to define the AMD hazard of coal. The data were used to understand the sulphur grade range for each seam group to gain an understanding of the potential AMD hazard posed by each coal seam group (and by inference, potential tailing and reject materials). The results were then compared with detailed geochemical data available for coal, rejects and tailings to ‘calibrate’ the coal quality total sulphur data.

Coal samples from less than 20m depth were assumed to be completely or predominantly oxidised and were interpreted as ‘weathered carbonaceous spoil’ and, therefore, excluded from the assessment of potential ROM coal. For context, of the 31,093m of drill-hole data available (for this assessment) from the coal quality database, approximately 267m of drill-hole data were from less than 20m deep and, as such, assigned as ‘weathered coal’. Acid producing sulphate minerals, such as jarosite, may be present within weathered coal and carbonaceous material, however, mineralogical data available from SRM and nearby Peak Downs Mine and Caval Ridge Mine suggests that jarosite is an insignificant mineral within the Moranbah Coal Measures.

4.4.2 Residual Void Highwall Assessment

An assessment of the AMD hazard associated with exposures of all lithological materials, such as remnant coal, weathered materials, fresh non-carbonaceous and carbonaceous overburden was undertaken – being representative of the highwall of the residual void associated with a given pit group.

The frequency of occurrence of relevant material types within each pit was determined from the stratigraphic distribution within selected drill holes under the assumption that the frequency of distribution of each material type is broadly indicative of their respective surface exposures on current highwalls. For example, if HC Upper seam group had a frequency of occurrence (by meters) of 5% in the drill-hole data set, then the assumption is that the

same coal seam group would represent approximately 5% of the surface exposure on the highwall. This method – whilst being relatively simple – provides an acceptable approximation with regard to which seam groups or mineral waste types are most likely to be significantly present in pit walls versus those material types most likely present in relatively minor proportions.

The following method was used for estimating the proportion of key material domains on the highwalls in each pit:

Exploration drill-holes in proximity to the current/recent highwall/s were selected by BHP Coal Geology Planners for each pit. The holes extended to depths approximating future pit floor depths. Acacia/Jacaranda/Bauhinia pit group used data from 138 drillholes; Coolibah/Dogwood pit groups used data from 46 drillholes; Ebony/Grevillea pit group used data from 190 drillholes; and Hakea Pit used data from 28 drillholes.

Stratigraphy, age, weathering, location with respect to the water table, and major stratigraphic horizons (as recorded in the BHP coal geology database) were used to assign individual (discrete) lithological units to a material domain as follows:

- Weathered, non-carbonaceous (Tertiary);
- Weathered, non-carbonaceous (Permian);
- Weathered, carbonaceous [includes weathered coal];
- Fresh, non-carbonaceous;
- Fresh, carbonaceous;
- Fresh, coal.

Coal plys were grouped into their respective seam groups, such as P seam group, HC Upper, HC Lower, etc.

For each pit group highwall, a statistical assessment was conducted on each drill-hole sub-set (as applicable to each pit group) to summarise the frequency of occurrence of drill core intervals as a function of each of the material groups listed above.

The inherent AMD hazard of each material group listed above was inferred from the geochemical database and coal quality database for similar material types. The combined AMD hazard for the material groups likely to be exposed on the highwall was then used to estimate the AMD hazard of the highwall at each pit.

The pit highwall AMD hazard assessment is based on data being representative of current and near-future mining (indicatively now to 10 years). The SRM coal resource model was used to estimate coal resources and overburden/interburden proportion from current pit highwall through to the eastern extent of the mine (near the eastern ML boundary).

The resource model indicates that – at closure – the proportion of coal versus non-coal in the highwall of the residual voids is broadly consistent with the current proportions on the pit highwalls. The model shows that the proportion of each seam group at closure is consistent with the current pit wall exposure estimate, with the exception of minor increases in the proportion of Q seam (within Jacaranda, Ebony, Grevillea and Hakea pits) and P seam (within Bauhinia and Dogwood pits).

Therefore, the overall AMD hazard posed by the pit highwall and floor of the residual voids at end of mining is expected to be similar to that shown in the current highwalls and pits.

4.4.3 Residual Void Floor Assessment

An assessment of the AMD hazard associated with exposures of remnant coal on the floor of each pit group was undertaken – being representative of the floor of the residual void associated with a given pit group.

As explained in **Section 4.4.1** coal quality data was assessed to understand the potential AMD hazard associated with coal. For the task of assessing the AMD hazard specific to pit floors (on a pit-group basis), only the coal quality data from the seam group likely to form the pit floors at a given pit group was assessed. At SRM, the DY Lower seam group forms the floor of all pits.

It is acknowledged that there are generally minor geochemical differences between the various plys of any given seam group. Also, the AMD hazard of the floor of a pit may change depending on whether a significant proportion of the pit floor resides on coal(ly) or non-carbonaceous material. Furthermore, the AMD hazard of any pit floor is not just associated with its surface exposure, but more so with the composition of the sub-drill zone, which represents an extensively fractured coal / interburden comprising the upper sections of a pit floor. For this assessment, the AMD hazard was estimated only for assumed surface exposures of coal / plys.

4.4.4 TSF Assessment

At closure, only TSF no. 3 will remain as a discrete facility (TSF landform). This TSF is non-operational and has undergone rehabilitation – although some additional rehabilitation/revegetation may be undertaken prior to mine closure. All other TSFs will be buried by spoil during mining operations and therefore, at closure, will not require specific remediation or rehabilitation as they will be lie beneath the Jacaranda-Bauhinia spoil landform (in the case of Ramp 2/3 TSF) and the Coolibah-Dogwood spoil landform (in the case of TSF no. 2, TSF no. 4 and Ramp 6 TSF). Geochemical data from samples collected from TSF no. 3 was used to assess the geochemical AMD source hazard of this facility.

4.4.5 AMD Hazard Scoring

Estimating the AMD hazard is the first step in estimating the geochemical risk associated with potential sulphide oxidation of mineral wastes. The authors have developed an internal procedure to standardise the AMD hazard assessment to maintain consistency across all BHP coal sites and material domains, with the process described below.

AMD hazard scoring and the AMD geochemical likelihood ranking describe the Geochemical Hazard. The former describes the hazard for AMD generation and the latter describes the likelihood of an AMD event to occur.

A source material is a distinct material type (e.g. non-carbonaceous spoil or rejects or tailings), whereas a landform is a domain comprising one or more source material types (e.g. rejects disposed within non-carbonaceous spoil). AMD hazard scorings are assigned using individual source materials reporting to a landform as well as to landform domain properties as a whole.

The likelihood of a landform developing AMD was determined based on the AMD hazard scoring of a landform. AMD hazard scores (**Table 11**) are estimated by analysing three key components, which are used to describe the geochemical hazard of a source material/landform:

1. Geochemical propensity to generate AMD;
2. AMD capacity; and
3. AMD quantity.

In undertaking the AMD hazard assessment, the assumption is that the source materials (within the landforms) will predominantly be dry or moist, but not wet or saturated. That is, the landforms will be unsaturated. This assumption is realistic, since most spoil landforms and aged (inactive) TSF landforms are generally unsaturated. This assumption is also conservative, since the potential for oxidation (to some degree) is assumed.

Table 11. AMD hazard scoring matrix

Component	Rating	Category	Definition
Propensity for AMD generation All material types/domains - Non-carb. - Coaly & carb. - Reject Per spoil landform and TSF landform	1	Implausible	Geochemical properties suggest that the vast majority of the material has a negligible potential for AMD generation (less than 5% of the samples identified at potential for AMD in the samples set)
	5	Plausible	Geochemical properties suggest that significant proportion of the material may have potential for AMD generation (5-40% of the samples identified at potential for AMD in the samples set)
	7	Expected	Geochemical properties strongly suggest that the material has a high potential for AMD generation but has not yet been observed in the field (due to lag time) - (>40% of the samples identified at potential for AMD in the samples set)
	15	Certain	AMD issues have been observed in the field
AMD **Capacity** All material types/domains - Non-carb. - Coaly & carb. - Reject Per spoil landform and TSF landform	1	Low	Source has a negligible potential for AMD generation with 75th percentile total S less than 0.1%
	3	Low-Moderate (NMD)	Dominant AMD sources contain material that will likely generate NMD and/or SD (related to sulphide oxidation). Assumed to be bulk NAF but sulphide bearing, with NAF samples having 75th percentile total S greater than 1%
	5	Moderate	Dominant AMD sources with 75th percentile total S concentration ranging 0.2-0.5% and with potential to generate AD.
	7	Moderate-High	Dominant AMD sources with 75th percentile total S ranging 0.5-1% and with potential to generate AD.
	10	High	Dominant potential AMD sources with 75th percentile total S >1% and with potential to generate AD.
AMD **Quantity** All material types/domains: - Non-carb. - Coaly & carb. - Reject Per spoil landform and TSF landform	1	Low	All material rated LOW for AMD capacity; or less than 5% of waste is rated LOW-MODERATE for AMD Capacity
	3	Low-Moderate	Less than 5% of mineral waste rated as MODERATE for AMD capacity
	5	Moderate	Greater than 5% of mineral waste rated as LOW-MODERATE or MODERATE for AMD capacity
	7	Moderate-High	Less than 5% of mineral waste rated as MODERATE-HIGH or HIGH for AMD capacity
	10	High	Greater than 5% of mineral waste rated as MODERATE-HIGH or HIGH for AMD capacity
AMD **Quantity** Residual void (pit) highwall & floor Per residual void	1	Low	Less than 10% of drill-hole meters (or less than 10% of pit floor exposure) are classified as PAF
	3	Low-Moderate	Between 10% and 30% of drill-hole meters (or 10-30% of pit floor exposure) are classified as PAF
	7	Moderate-High	Greater than 30% of drill-hole meters (or greater than 30% of pit floor exposure) are classified as PAF
	10	High	Observed AMD on highwall or floor of pit or AMD affected water in pit

AMD Propensity is the geochemical propensity of a given material type to generate AMD. The propensity to generate AMD is determined based on the proportion of samples that have expressed potential for AMD as determined from laboratory test-work and the subsequent assessment – the higher the percentage of materials that can generate AMD within a sample set, the greater the AMD propensity.

AMD Capacity represents the 'severity' of AMD generation, with total S concentrations used as a proxy for scoring this component, which represents a conservative approach as some sulphur is associated with non-acid generating minerals. For example, the higher the total S concentration in materials with potential for AMD, the higher the hazard, the higher the score. Furthermore, the AMD capacity also takes into account the type of drainage a source material can produce, i.e. AD, NMD and/or SD, where discrimination or prediction is possible. The various drainage types should be differentiated (where the data allows) to reflect the difference in impact severity and difficulty to manage or treat. For example, on an equal quantity basis, AD is likely going to cause more severe impacts than NMD or SD and therefore is assigned a higher score.

As a first approximation the AMD Capacity of each material type is estimated based on 75th percentile value of the total S concentration for the samples classified as PAF. This is a conservative assumption, as not all total S is associated with reactive minerals and choosing the S-75th percentile value to assess the AMD capacity will attract a higher AMD Capacity scoring. For example, if two material types had the same proportion of samples with the same propensity for AMD, but one has a higher total S concentration associated with PAF materials, then this sample would receive a higher AMD Capacity score. The tool is also applied to NMD/SD type waste in the same manner.

AMD Quantity is the amount of material (tonnages) that has the potential to generate AMD. The greater the tonnage of AMD generating material the greater the hazard scoring. The AMD Quantity scores are assigned to material types for each landform.

4.4.6 AMD Likelihood Ranking

AMD hazard ranking is estimated by analysing two key components:

1. AMD source material hazard rating; and

2. AMD landform domain hazard rating.

AMD source material hazard rating: Describes the likelihood for AMD generation by the respective material type. It is estimated from the weighted combined scores of each component used to describe the AMD source hazard:

- Propensity to generate AMD. Assigned a 50% weighting (weighting = 1);
- AMD capacity. Assigned a 25% weighting (weighting = 0.5); and
- AMD quantity. Assigned a 25% weighting (weighting = 0.5).

AMD landform domain hazard rating: Describes the likelihood for AMD generation by landform domain (spoil landforms and TSF no. 3 landform) and residual voids. It is estimated from the AMD source material hazard scores for each material type assumed to be present within that specific landform. At closure, SRM has four residual void domains, four spoil landform domains and one TSF landform domain, as listed in **Section 2.2**.

- **Spoil landforms**: the AMD landform score estimated using the weighted average of the AMD source material scores and the PAF and NAF-S quantities (as a proportion of total waste within the landform) likely to report to the landform from each material type. Note that only five drill-hole samples (out of 999 samples in total) were classified as NAF-S. As such, the proportion of NAF-S samples in spoil dumps is insignificant relative to PAF samples and other NAF samples.
- **TSF no. 3 landform**: the AMD landform score estimated using the weighted average of the AMD source material scores and the PAF and NAF-S quantities (as a proportion of total waste within the landform) likely to report to the landform from each material type. Note that no samples were classified as NAF-S, therefore the scoring applied to PAF samples only. At the TSF there was only two source materials: general spoil (as cover material) and tailings.

- **Residual voids**: the AMD landform score estimated from the average of the AMD source material hazard scores for each material type likely to be exposed on the highwall or floor of each residual void.

To support the assessment of the AMD closure risks, the AMD hazard scores as determined in **Section 4.4.1** are assigned likelihood rankings (**Table 12**) as consistent as possible with BHP risk management methodology, which is aligned with ISO 31000. ISO 31000 is a family of standards relating to risk management codified by the International Organization for Standardization.

Table 12. AMD hazard ranking and landform AMD likelihood ranking

AMD hazard ranking	Landform AMD likelihood ranking
0 - 5	Highly Unlikely: Highly unusual; may occur in extreme circumstances
5 - 10	Unlikely: Known to occur, but only rarely
10 - 15	Probable: May occur
15 - 20	Likely: Could easily occur
>20	Highly Likely: Expected to occur

For landform domains (including pits) with AMD hazard ranking greater than 10, a conservative likelihood ranking of 'Likely' should initially be assigned if no kinetic data are available to provide a time frame for AMD generation. This likelihood ranking can be revised as more data, such as kinetic or field data, becomes available.

5 Results

Environmental geochemical data sufficient to enable a sample to be classified with respect to AMD hazard (e.g. NAF, PAF or a sub-classification) is available for 934 overburden/interburden (spoil) samples, 225 coal samples, 238 tailings samples and 45 reject samples – all of which have undergone a range of environmental geochemical tests. The samples are representative of the following mineral waste and coal groups:

Spoil

- Weathered Non-carbonaceous: Weathered non-carbonaceous overburden. 108 drill-hole samples;
- Weathered Carbonaceous: Weathered carb. overburden [includes weathered coal]. 9 drill-hole samples;
- Fresh, Non-carbonaceous: Fresh non-carbonaceous overburden/interburden. 716 drill-hole samples;
- Fresh, Carbonaceous: Fresh carbonaceous overburden/interburden. 101 drill-hole samples

Coal

- Fresh Coal: Fresh coal, representative of ROM coal. 225 drill-hole samples

Tailings

- Fresh: Fresh tailings from the CHPP. 105 samples;
- Aged: Aged tailings from the TSFs. 133 drill-hole samples

Rejects

- Fresh: Fresh rejects from the CHPP. 41 samples;
- Aged: Aged rejects from Ramp 4 (R4) in-pit rejects area. 4 samples.

Limited environmental geochemical data is available for a further 1112 spoil/coal samples and 32 rejects samples. Such limited data may include pH and EC data only, for example, where there is insufficient information to classify a sample with respect to AMD hazard. This data is used throughout the assessment where possible.

Additional to the above waste material types, geochemical data is also available for 60 'fill' samples and 8 'natural ground' samples collected from geotechnical investigation drill-holes within the TSFs. The fill samples are likely spoil used to cover tailings at some point during deposition. The natural samples represent the base of TSF (i.e. natural ground) encountered during geotechnical investigations. This data is presented in the figures/graphs herein for context, however is not discussed in great detail.

5.1 Mineralogy

Data is available for 50 samples, comprising: 15 spoil samples, 22 tailings samples, 6 rejects samples, 6 fill samples and 1 natural ground sample that underwent mineralogical analysis by Quantitative X-Ray Diffraction (QXRD).

The samples were selected to cover a broad range of mineral waste types. The results are summarised in **Figure 11** (spoil, fill and natural ground samples) and **Figure 12** (tailings and rejects samples). Most samples are dominated by clay and quartz minerals (silicate group minerals) and non-crystalline (amorphous) material, variable contributions of carbonate and other silicate minerals.

Amorphous (non-crystalline) material was detected in all samples, but generally present in greater proportions in the tailings and rejects samples (median = 33%) compared to the spoil, fill and natural ground samples (median = 24%). The nature of the non-crystalline material is largely unknown, although for tailings and carbonaceous waste it may be associated with organic carbon.

Most spoil (plus fill and natural ground) samples have low sulphide mineral proportions as expected – typically less than 0.5%. Sulphide, where present, is present as pyrite. All samples have low sulphate concentrations, which is mostly present as alunite and jarosite.

Two non-carbonaceous 'spoil' samples – a seam roof sample and a seam parting – have high sulphide (pyrite) concentrations (4.3% and 8.4%, respectively) and were specifically selected for mineralogical test-work because of their high total S concentrations. Given the proximity of these two samples to coal, it's likely these two samples would be mined as part of ROM coal and, therefore, are likely to represent 'potential' reject more so than spoil. That is, these two samples are likely representative of rejects and not typical spoil.

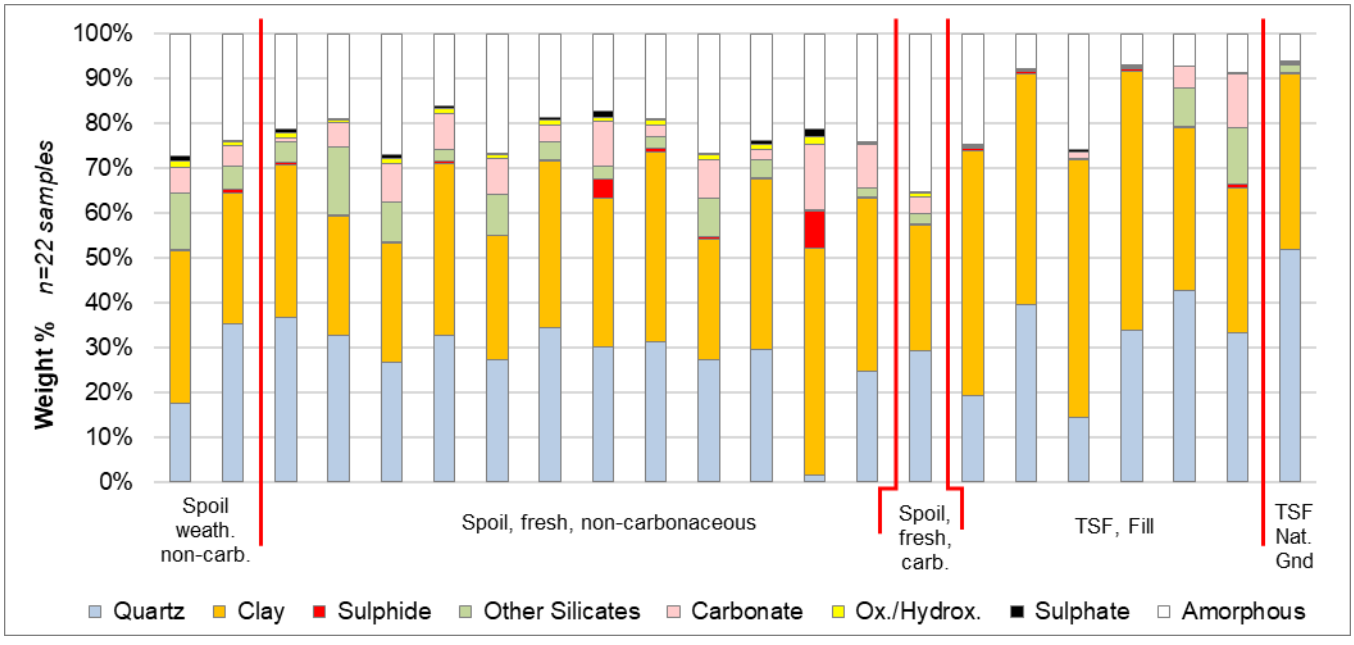


Figure 11. Mineral distribution within spoil, TSF fill and TSF natural ground samples

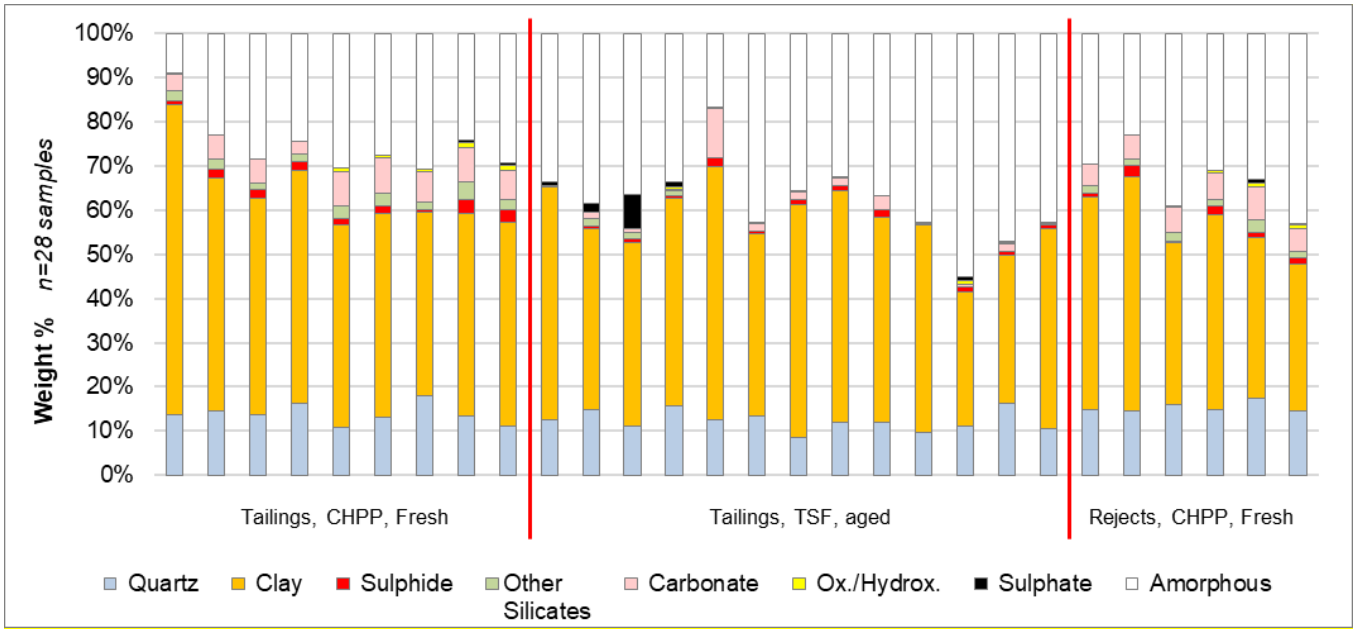


Figure 12. Mineral distribution within tailings, rejects and TSF fill samples

The tailings and rejects samples generally have higher sulphide concentrations compared to the spoil samples, with 10 of the 28 samples having greater than 1.5% sulphide (as pyrite) – and half of these samples (5 samples) having greater than 2% pyrite. Most tailings and rejects samples have low sulphate concentrations, which is present as bassanite and jarosite. The TSF dry tailings samples had the highest sulphate concentrations, suggesting sulphide oxidation has occurred.

Across all material types, carbonate group minerals predominantly comprise ankerite (Fe-dolomite) and siderite in variable proportions, with lesser calcite. ABCC data for the same samples with QXRD data indicated that iron-dolomite, dolomite and siderite were the likely dominant carbonate minerals, which is broadly consistent with the mineralogy data. Most fill samples from within the TSFs generally had low carbonate concentrations, as did the tailings samples from the TSFs. The 'fresh' tailings and rejects samples from the CHPP had much higher carbonate concentrations compared to the tailings in the TSFs. The reason for this is unclear.

Tailings liquor has a generally low alkalinity (as discussed in **Section 5.6**), therefore water from the CHPP is not likely to be a significant contributor to the carbonate present in tailings and rejects samples from the CHPP. It is possible that the newer CHPP samples represent waste from ROM coal that contains more carbonate compared to historic (older) ROM coal – represented by 'deeper' tailings in the old TSFs (TSF no. 2, TSF no. 3 and TSF no. 4).

In summary the key acid generating mineral is pyrite, and the key acid neutralising minerals are iron-dolomite/ dolomite and calcite. Although siderite is a carbonate, it provides no net acid neutralising capacity.

5.2 Acid-Base Accounting (Potential for AMD)

Acid-base accounting (ABA) is a theoretical balance between the potential for a sample to generate acid and neutralise acid, and is expressed in units of kilograms of sulphuric acid per tonne of sample (kg H_2SO_4/t). The ABA results for the samples that underwent geochemical characterisation are statistically summarised in

Table 13 (spoil), **Table 14** (tailings) and **Table 15** (CHPP and R4 reject, coal, TSF fill and TSF natural ground) and discussed in the following sections. Only total S data is available for TSF rejects material. Full results can be provided on request.

Table 13. ABA results statistics for spoil samples

		Total S[1]	Scr[2] (S)	ANC	MPA[3]	NAPP	ANC/MPA	NAGpH[4]
		%		kg H_2SO_4/t			ratio	pH units
Spoil Weath[5]., non-carb[6].	Count (*n*)	*106*	*14*	*120*	*106*	*106*	*106*	*6*
	Maximum	0.52	0.46	278	16	2.5	447	7.9
	95th percentile	0.36	0.43	138	11	0.9	144	7.8
	75th percentile	0.05	0.36	58	1.5	-4.9	36	7.6
	Median	0.03	0.21	14	0.9	-9.1	13	7.2
	25th percentile	0.02	0.14	5.4	0.6	-64	5.6	6.0
	5th percentile	0.01	0.09	<0.5	0.3	-136	0.3	4.7
	Minimum	0.01	0.06	<0.5	0.3	-277	0.1	4.4
Spoil Weath., carb.	Count (*n*)	*9*	*5*	*9*	*9*	*9*	*9*	*4*
	Maximum	6.48	5.58	82	198	193	13	8.0
	95th percentile	4.15	4.53	62	127	121	13	7.5
	75th percentile	0.50	0.33	27	15	2.4	6.9	5.5
	Median	0.31	0.33	7.7	9.5	-7.1	4.7	4.1
	25th percentile	0.18	0.16	7.1	5.5	-20	0.7	3.1
	5th percentile	0.02	0.15	5.6	0.6	-52	0.1	2.1
	Minimum	0.02	0.14	5.4	0.6	-70	<0.1	1.9
Spoil Fresh, non-carb.	Count (*n*)	*710*	*227*	*710*	*710*	*710*	*710*	*174*
	Maximum	8.54	6.92	533	262	140	795	8.9
	95th percentile	0.89	1.55	144	27	14	153	8.1
	75th percentile	0.21	0.38	61	6.4	-11	44	7.8
	Median	0.06	0.15	33	1.8	-27	13	7.2
	25th percentile	0.03	0.04	16	0.9	-58	4.5	5.2
	5th percentile	0.02	0.02	6.3	0.6	-142	0.4	2.4
	Minimum	<0.01	<0.01	<0.5	0.2	-529	<0.1	1.9
Spoil Fresh, Carb.	Count (*n*)	*101*	*62*	*101*	*101*	*101*	*101*	*36*
	Maximum	7.49	3.91	286	229	221	78	8.2
	95th percentile	2.09	1.90	56	64	59	18	7.9
	75th percentile	0.39	0.19	25	12	-0.2	6.9	7.7
	Median	0.22	0.10	17	6.7	-10	3.2	7.2
	25th percentile	0.09	0.04	10	2.8	-17	1.0	5.0
	5th percentile	0.05	0.02	4.7	1.5	-50	0.1	2.8
	Minimum	0.03	0.01	<0.5	0.9	-282	<0.1	2.3
Spoil ALL	Count (*n*)	*926*	*308 (308)*	*940*	*926*	*926*	*926*	*220*
	Maximum	8.54	6.92 (8.54)	533	262	221	795	8.9
	95th percentile	0.89	1.62 (1.93)	141	27	14	135	8.1
	75th percentile	0.22	0.36 (0.50)	57	6.7	-7.8	34	7.8
	Median	0.06	0.14 (0.23)	26	1.8	-23	11	7.2
	25th percentile	0.03	0.05 (0.10)	13	0.9	-53	3.4	4.9
	5th percentile	0.02	0.02 (0.04)	4.4	0.6	-136	0.3	2.4
	Minimum	<0.01	<0.01 (0.02)	<0.5	0.2	-529	<0.1	1.9

[1] Total S values less than laboratory limit of reporting (LOR) were assigned a value of 0.5xLOR for statistical calculations.
[2] Scr was generally measured on potential spoil and coal samples with total S greater than 0.1%. Values in parentheses are the total S statistics for samples with Scr results.
[3] MPA calculated from total S.
[4] NAGpH is final pH as NAG single addition and/or NAG extended and/or Stage 1 Seq. NAG.
[5] Weath.: weathered;
[6] Carb.: carbonaceous.

Table 14. ABA results statistics for tailings samples

		Total S[1]	Scr[2] (S)	ANC	MPA[3]	NAPP	ANC/MPA	NAGpH[4]
		%		kg H_2SO_4/t			ratio	pH units
Tailings CHPP Fresh	Count (*n*)	*105*	*102*	*105*	*105*	*105*	*105*	*46*
	Maximum	3.69	1.60	73	113	71	2.5	8.8
	95th percentile	1.93	1.46	55	59	26	1.6	8.5
	75th percentile	1.52	1.15	46	47	11	1.2	7.0
	Median	1.25	0.89	37	38	3.4	0.9	4.9
	25th percentile	1.01	0.73	28	31	-6.4	0.7	3.8
	5th percentile	0.78	0.47	18	24	-19	0.5	2.8
	Minimum	0.53	0.24	9.7	16	-38	0.3	2.7
Tailings TSF Aged	Count (*n*)	*192*	*112*	*128*	*192*	*128*	*128*	*69*
	Maximum	7.74	1.94	16	237	69	1.5	6.8
	95th percentile	0.81	0.57	11	25	20	0.9	6.5
	75th percentile	0.49	0.23	9.1	15	11	0.6	5.0
	Median	0.42	0.12	6.4	13	7.6	0.4	3.9
	25th percentile	0.36	0.08	3.5	11	5.1	0.3	3.0
	5th percentile	0.26	0.02	0.8	8.0	0.6	0.1	2.6
	Minimum	0.01	<0.01	<0.5	0.3	-3.6	<0.1	1.0
Tailings ALL	Count (*n*)	*297*	*214 (214)*	*233*	*297*	*233*	*233*	*115*
	Maximum	7.74	1.94 (3.69)	73	237	71	2.5	8.8
	95th percentile	1.80	1.41 (1.87)	54	55	24	1.5	8.0
	75th percentile	1.14	0.90 (1.27)	34	35	11	0.9	5.6
	Median	0.52	0.44 (0.76)	10	16	6.6	0.6	4.3
	25th percentile	0.39	0.12 (0.43)	6.0	12	1.2	0.4	3.2
	5th percentile	0.28	0.03 (0.31)	1.8	8.6	-14	0.2	2.6
	Minimum	0.01	<0.01 (0.21)	<0.5	0.3	-38	<0.1	1.0

[1] Total S values less than laboratory limit of reporting (LOR) were assigned a value of 0.5xLOR for statistical calculations.
[2] Scr was generally measured on potential spoil and coal samples with total S greater than 0.1%. Values in parentheses are the total S statistics for samples with Scr results.
[3] MPA calculated from total S.
[4] NAGpH is final pH as NAG single addition and/or NAG extended and/or Stage 1 Seq. NAG.

Table 15. ABA results statistics for rejects, coal, TSF fill and natural ground samples

		Total S[1]	Scr[2] (S)	ANC	MPA[3]	NAPP	ANC/MPA	NAGpH[4]
		%		kg H_2SO_4/t			ratio	pH units
Rejects CHPP	Count (*n*)	*41*	*38*	*41*	*41*	*41*	*41*	*41*
	Maximum	1.88	1.51	59	58	31	2.4	8.4
	95th percentile	1.32	0.98	42	40	15	2.1	8.3
	75th percentile	0.84	0.60	30	26	0.9	1.4	7.6
	Median	0.72	0.47	26	22	-5.6	1.2	6.2
	25th percentile	0.63	0.41	23	19	-8.3	1.0	4.9
	5th percentile	0.49	0.25	13	15	-17	0.5	3.5
	Minimum	0.40	0.19	12	12	-23	0.4	2.5
Rejects Ramp 4	*Count (n)*	*35*	*3*	*3*	*35*	*3*	*3*	*0*
	Maximum	1.88	1.06	50	58	26	1.4	
	95th percentile	1.15	-	-	35	-	-	-
	75th percentile	0.56	-	-	17	-	-	-
	Median	0.47	0.93	10	14	5.4	0.6	-
	25th percentile	0.40	-	-	12	-	-	-
	5th percentile	0.34	-	-	10	-	-	-
	Minimum	0.33	0.16	9.3	10	-15	0.3	-
Coal	Count (*n*)	*223*	*176 (176)*	*223*	*223*	*223*	*223*	*78*
	Maximum	4.73	2.51 (4.00)	160	145	147	33	8.5
	95th percentile	1.71	0.95 (1.60)	38	52	46	4.3	7.7
	75th percentile	0.55	0.18 (0.56)	16	17	9.4	1.3	6.8
	Median	0.43	0.08 (0.43)	10	13	3.1	0.8	4.6
	25th percentile	0.34	0.04 (0.36)	6.4	10	-2.9	0.4	2.8
	5th percentile	0.22	0.02 (0.27)	0.8	6.7	-26	<0.1	2.2
	Minimum	0.05	<0.01 (0.13)	<0.5	1.5	-144	<0.1	1.7
TSF Fill	Count (*n*)	*60*	*13*	*52*	*60*	*52*	*52*	*3*
	Maximum	0.46	0.06	75	14	11	61	6.9
	95th percentile	0.26	0.05	31	8.1	5.0	31	6.8
	75th percentile	0.05	0.04	7.1	1.6	-0.8	8.0	6.4
	Median	0.03	0.03	4.2	0.9	-2.5	3.5	5.8
	25th percentile	0.02	0.02	2.0	0.6	-4.2	1.8	5.7
	5th percentile	0.01	<0.01	<0.5	0.3	-30	<0.1	5.5
	Minimum	<0.01	<0.01	<0.5	<0.3	-74	<0.1	5.5
Natural Ground *(base of TSF)*	Count (*n*)	*8*	*0*	*6*	*8*	*6*	*6*	*0*
	Maximum	0.03	-	2.5	0.9	0.9	16	-
	95th percentile	0.03	-	2.1	0.8	0.8	13	-
	75th percentile	0.02	-	0.7	0.6	0.6	1.1	-
	Median	0.02	-	<0.5	0.6	0.6	0.4	-
	25th percentile	<0.01	-	<0.5	<0.3	0	0.4	-
	5th percentile	<0.01	-	<0.5	<0.3	-1.8	0.3	-
	Minimum	<0.01	-	<0.5	<0.3	-2.3	0.3	-

[1] Total S values less than laboratory limit of reporting (LOR) were assigned a value of 0.5xLOR for statistical calculations.
[2] Scr was generally measured on potential spoil and coal samples with total S greater than 0.1%. Values in parentheses are the total S statistics for samples with Scr results.
[3] MPA calculated from total S.
[4] NAGpH is final pH as NAG single addition and/or NAG extended and/or Stage 1 Seq. NAG.

Sulphur and Sulphide

The total sulphur (total S) distribution for all samples is presented in **Figure 13**. The total S concentration of spoil samples was generally very low to low – with a very low median value of 0.06% and low-moderate 95th percentile value of 0.89%. Carbonaceous spoil samples had higher total S values compared to non-carbonaceous spoil. Of the 926 spoil samples, 27 samples (approximately 3% of samples) had high total S values (greater than 1.5%) and of these 27 samples, 17 samples were closely associated with seams (i.e. parting or thicker interburden between plys). This means that only 1% of the spoil samples with high total S are not closely associated with coal seams.

Total S concentration of most rejects and tailings samples was generally higher than most spoil samples, but similar to coal samples. However, as evident in **Figure 13**, CHPP tailings had markedly higher total S concentration compared to tailings samples from the TSFs, and similarly – although not as pronounced – the total S concentration of fresh (CHPP) rejects was higher than aged rejects from the TSFs and R4 rejects area. Total S concentration within the aged (TSF) tailings is generally consistent with depth and spatial distribution. Therefore, differences between Total S in fresh (CHPP) tailings versus aged (TSF) tailings is likely due to ROM coal geochemistry.

Fill material in the TSFs and natural ground samples from beneath the TSFs all have generally very low total S concentrations, as expected. Fill samples have total S distribution similar to spoil – as also expected.

Coal samples selected for test-work had relatively low to low-moderate total S values, with median, 75th and 90th percentile values of 0.43%, 0.55%, and 1.15 %, respectively. This sample subset has a total S distribution statistically equivalent to that of the larger BHP coal quality database. In particular, the 9070 coal samples from the SRM coal quality database have median, 75th and 90th percentile total S values of 0.59%, 0.65% and 0.85%, respectively. Thus, the total S distribution in coal from the smaller geochemical dataset (n=223) is comparable to the total S distribution in coal from the much larger coal quality dataset (n=9070), although the subset of coal samples has a higher 95th percentile total S value.

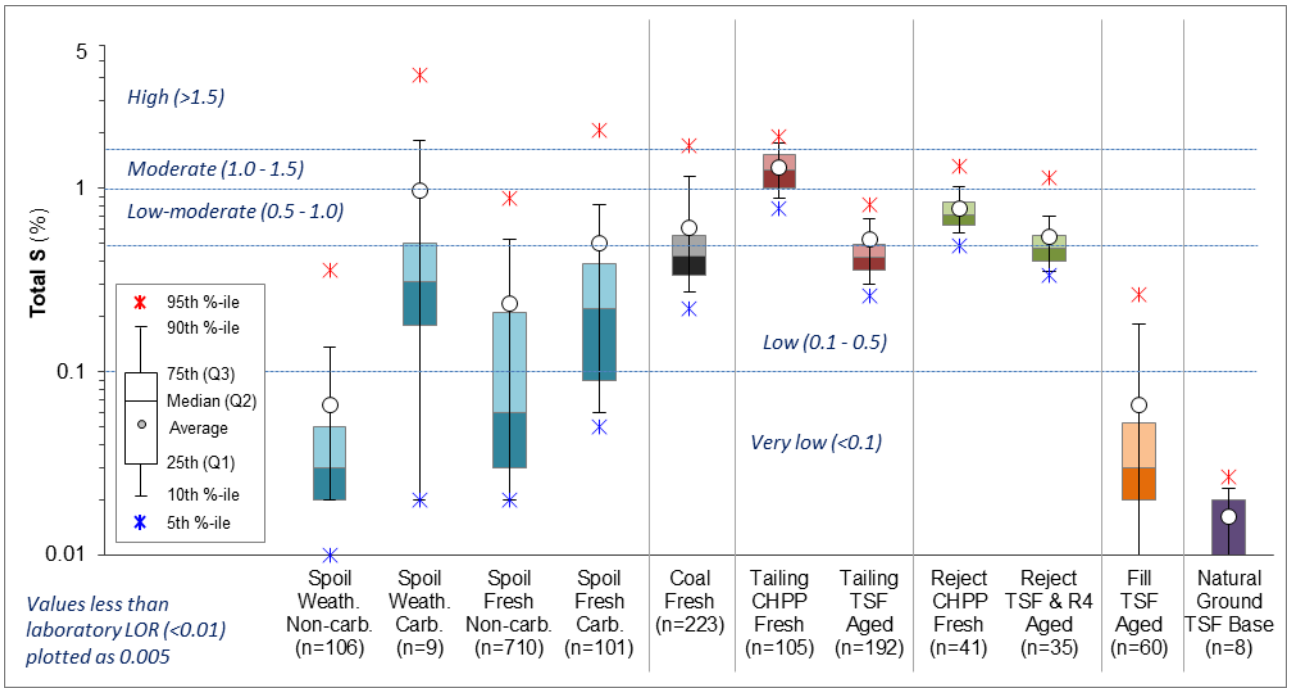


Figure 13. Sulphur (S) distribution

Chromium reducible sulphur (Scr) data is available for 308 spoil samples, 214 tailings samples, 41 rejects samples (almost all of these rejects samples are from the CHPP) and 176 coal samples. Scr was generally measured on samples with total S values greater than 0.1%. Where sulphide was measured in weathered samples, this was generally only in those samples described as being 'slightly' weathered. The total S and Scr distribution for spoil and coal samples is shown at **Figure 14** and for tailings, rejects and TSF fill samples at **Figure 15**.

As evident in **Figure 15** the fresh (CHPP) tailings and rejects samples have Scr values only marginally lower than the total S values from the same samples; and the three aged rejects samples from the R4 rejects area also have Scr values similar to the total S values – indicating that sulphide comprises a significant proportion of the total S concentration of these materials. Comparatively, the Scr values of the aged (TSF) tailings and the fill samples is much lower than the total S concentration for these samples, suggesting that the aged samples have likely oxidised to some extent. No Scr data is available for rejects from the TSFs.

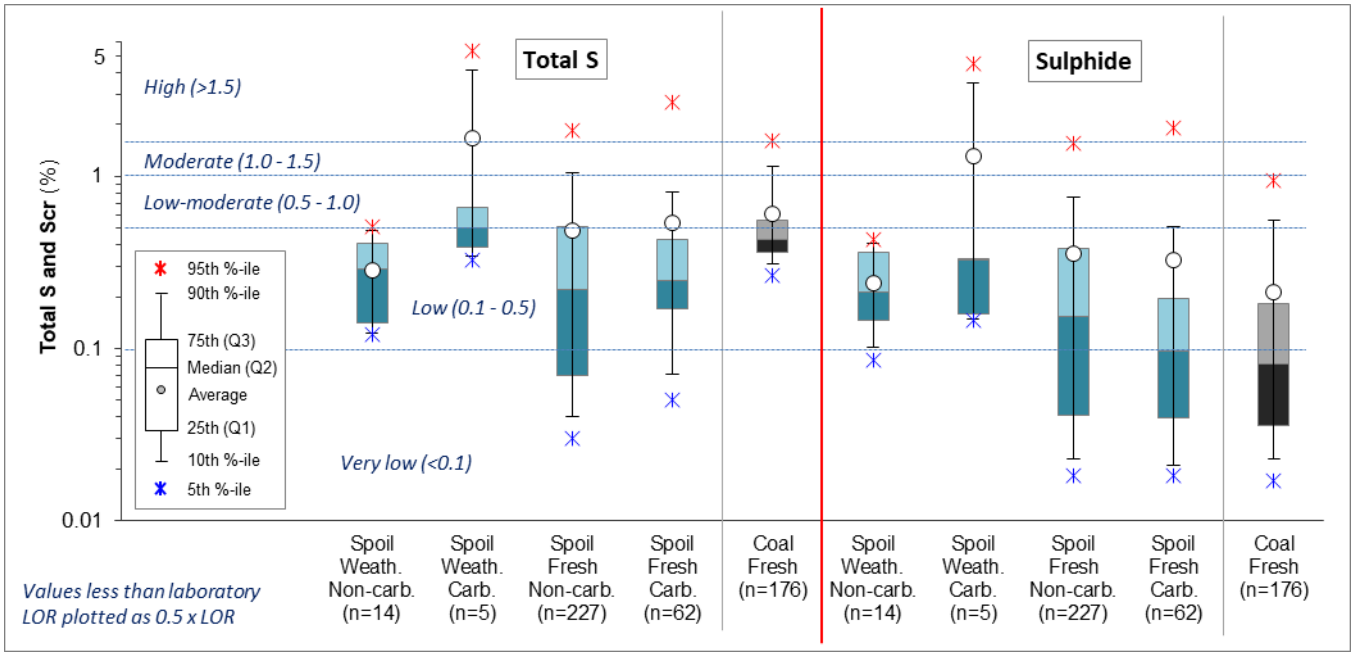


Figure 14. Sulphur (S) and sulphide (Scr) distribution of spoil and coal samples

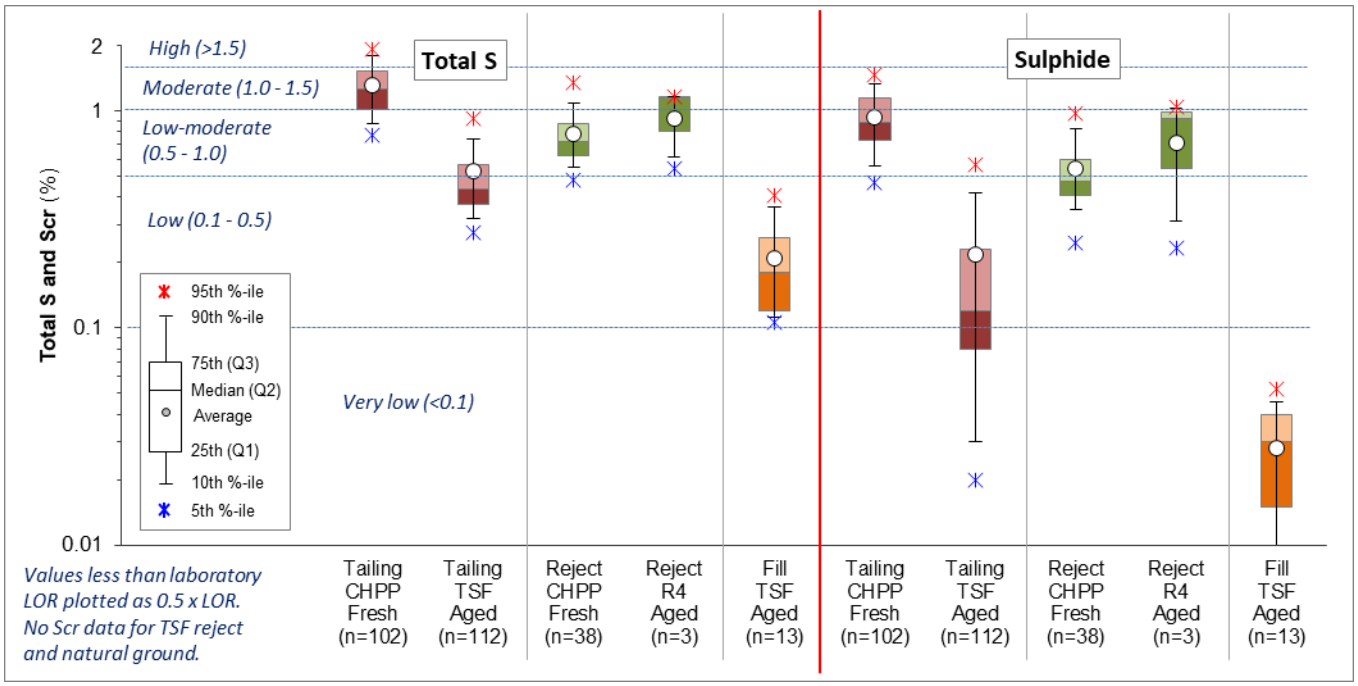


Figure 15. Sulphur (S) and sulphide (Scr) distribution of tailings, CHPP rejects and TSF fill samples

The relationship between Scr versus total S for spoil and coal samples where Scr data is available is shown in **Figure 16**. As a proportion of total S, Scr accounts for 72% (median value) of total S in spoil samples and 20% in coal samples. Of the spoil samples, Scr accounts for 76% (median value) of total S in non-carbonaceous spoil and

47% of total S in carbonaceous spoil. This means that the proportion of acid generating sulphur is generally lowest in the coal and – to a lesser extent – the carbonaceous samples due to a greater proportion of these samples likely containing organic sulphur, compared to the non-carbonaceous samples (of which most were fresh and unoxidised). These results indicate that the maximum potential acidity (MPA) that could be generated by most samples from these material domains is generally low and that using total S as an indication of AMD hazard will result in a conservative outcome.

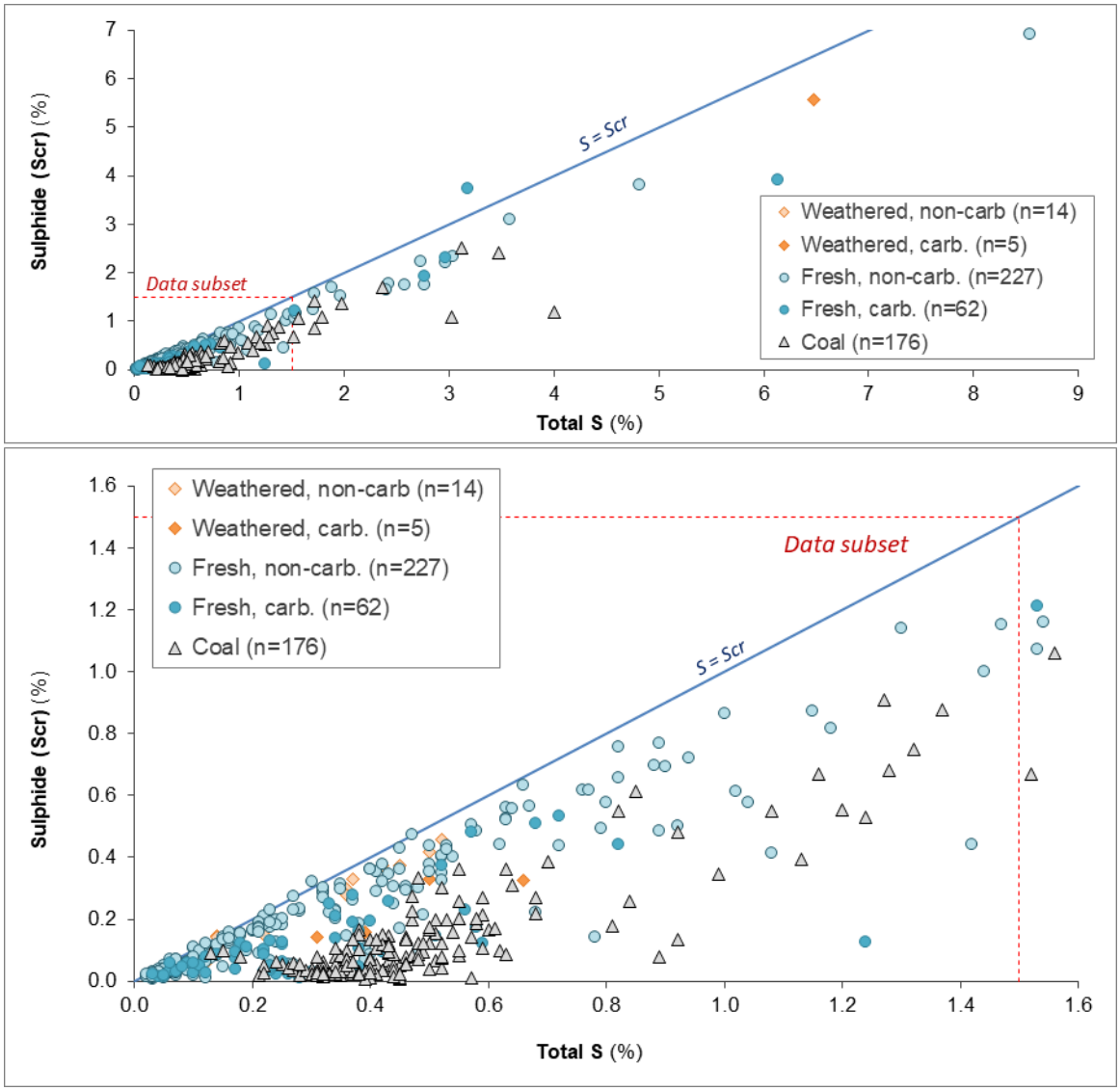


Figure 16. Sulphide (Scr) versus sulphur (S) for spoil and coal samples

The relationship between Scr versus total S for tailings, reject and TSF fill samples where Scr data is available is shown in **Figure 17**. As a proportion of total S, Scr accounts for 71% (median value) of total S in fresh (CHPP) tailings samples, 67% in fresh (CHPP) rejects samples, 32% in aged (TSF) tailings samples and 16% in aged (TSF) fill samples. These results indicate that using total S as an indication of AMD hazard for the tailings and rejects samples will result in a conservative outcome.

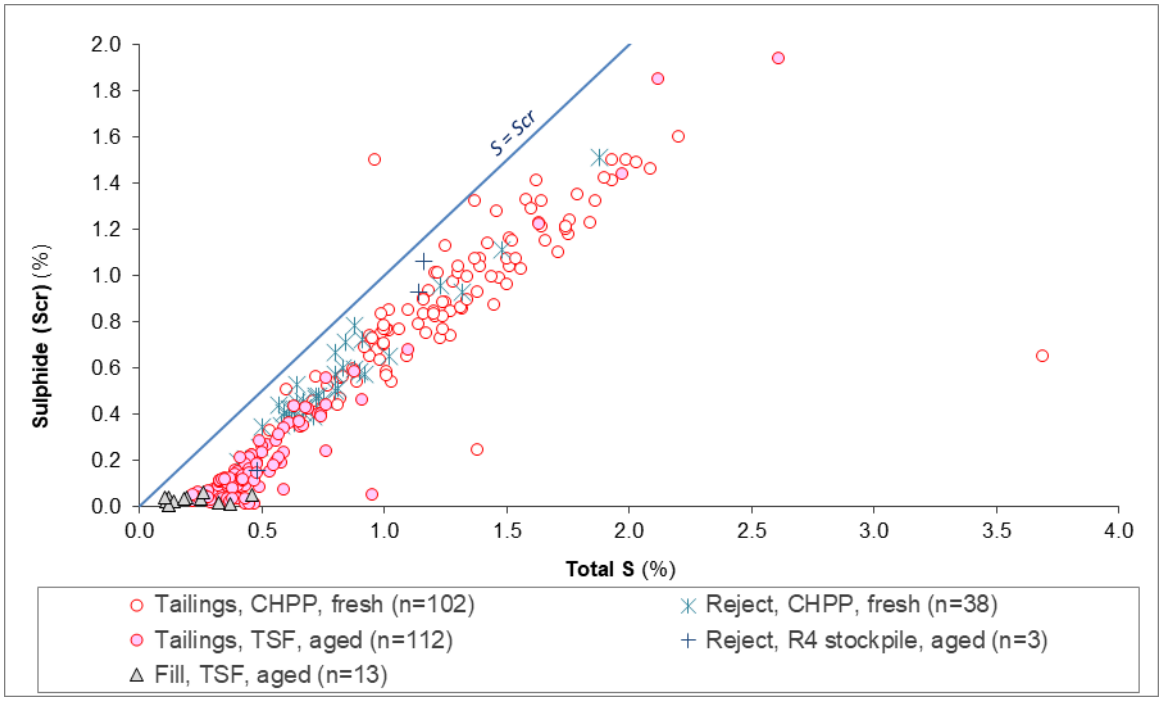


Figure 17. Sulphide (Scr) versus sulphur (S) for tailings, rejects and fill (TSF) samples

Maximum Potential Acidity

MPA is calculated from total S, therefore the MPA distribution for each material type mimics the total S distribution for the same samples (refer to **Figure 13**). Due to the generally very low to low total S (and Scr) values for spoil samples the MPA was correspondingly low, with a 75th and 95th percentile MPA values of 6.7 and 27 kg H_2SO_4/t, respectively (n=926 samples). As such, spoil represented by these samples is expected to have negligible potential to generate acid/acidity and negligible potential to release sulphate-derived salinity from sulphide oxidation. The small proportion of spoil with 'high' MPA (as a result of the high total S) would be well mixed throughout the bulk spoil and, as such, would not lead to spoil generating acid/acidity or sulphate-derived salinity.

Coal samples (n=223) produced MPA values generally higher than spoil – as expected by the higher total S values of coal samples. Coal samples had 75th and 95th percentile MPA values of 17 and 52 kg H_2SO_4/t, respectively. As discussed above, the proportion of total S associated with sulphide minerals in coal samples is low (20% of total S as Scr), with most sulphur associated with organic sulphur. Therefore, MPA values calculated from total S for coal samples is very conservative. For comparison, the 95th percentile MPA value for coal samples calculated from Scr (n=176) is 29 kg H_2SO_4/t – i.e. about half of the 95th percentile MPA value calculated from total S.

Tailings and rejects had a wide range of total S values – ranging from low to moderate – depending on the material sub-type, which resulted in a correspondingly wide range of MPA values. For example, fresh (CHPP) tailings had a 75th percentile MPA of 47 kg H_2SO_4/t (n=105 samples). Comparatively, aged tailings and rejects from the TSFs had a 75th percentile MPA of 16 kg H_2SO_4/t (n=228). Fresh (CHPP) rejects had a 75th percentile MPA of 26 kg H_2SO_4/t (n=41).

Acid Neutralising Capacity

The ANC distribution for all samples is presented in **Figure 18**. The ANC values of spoil samples are typically well in excess of the MPA values and span a very large range, from less than 0.5 to 533 kg H_2SO_4/t, with a moderate to high median ANC value for spoil samples of 26 kg H_2SO_4/t and a 10th percentile value of 6.9 kg H_2SO_4/t, respectively. In other words, 90% of spoil samples have an ANC greater than 6.9 kg H_2SO_4/t which, if all ANC was readily available, would neutralise the acidity generated by material containing 0.23 wt% S.

The ANC for the fresh (CHPP) tailings and rejects samples was generally moderate to high, with 10th percentile values of 22 and 17 kg H_2SO_4/t for tailings and rejects, respectively. Comparatively, aged (TSF) tailings had lower ANC distribution – generally very low to low, as evident in **Figure 18**. The three aged rejects samples from R4

rejects area had ANC values of 9.3, 9.7 and 50 kg H_2SO_4/t (i.e. generally within a similar range to the fresh (CHPP) rejects samples).

Coal samples had a wide range of ANC values from very low to high, but low overall with median and 10th percentile ANC values of 10 and 3 kg H_2SO_4/t, respectively.

Fill samples from the TSFs generally had very low to low ANC values and natural ground samples from the base of the TSFs had very low ANC values.

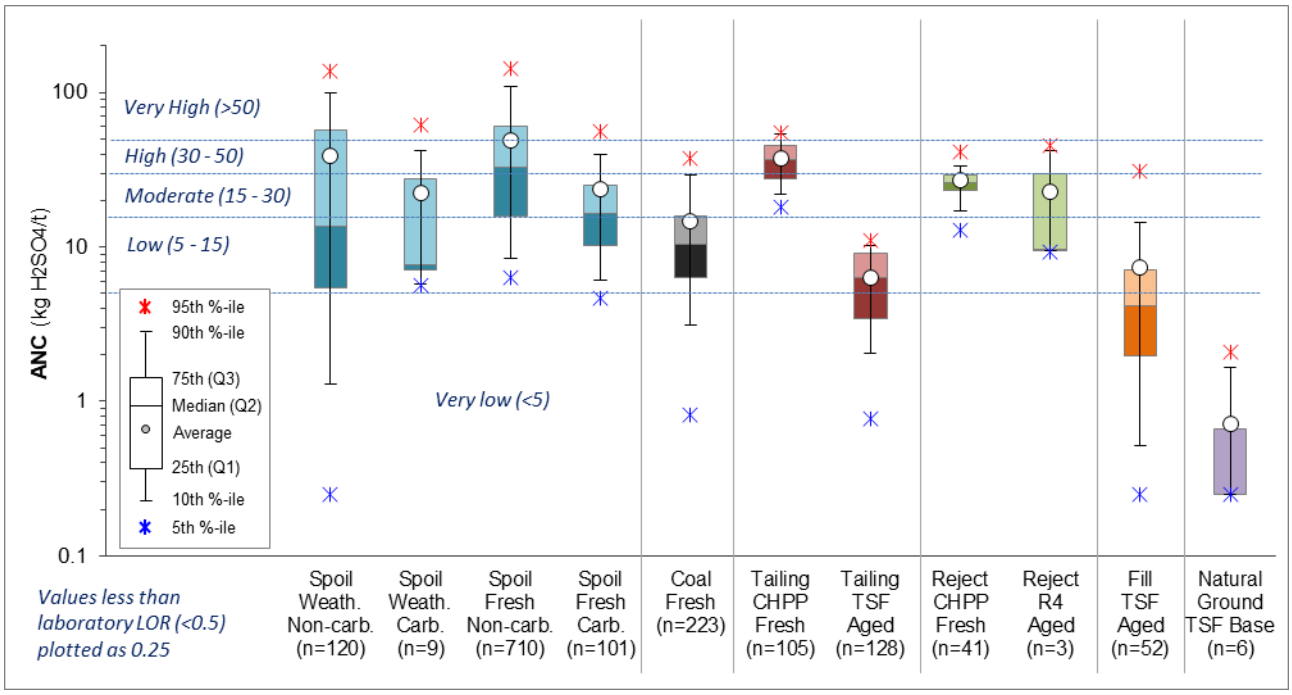


Figure 18. Acid neutralising capacity (ANC) distribution

It is worth mentioning that of the 710 fresh non-carbonaceous spoil samples (with ANC data), 212 samples (data) are associated with coal seams – typically as interburden or thicker parting intervals between plys (of the same seam) or as roof, thin parting or floor samples. These 212 samples associated with seams have a median ANC value of 19 kg H_2SO_4/t. Comparatively, the remaining 498 fresh, non-carbonaceous samples have a median ANC of 38 kg H_2SO_4/t (i.e. twice the amount of the 'near seam' samples). This result suggests that fresh, non-carbonaceous spoil material associated with seams has much lower ANC (generally), compared to fresh, carbonaceous spoil not associated with coal seams (i.e. well away from the seams). For the same two sample groups (i.e. near-seam versus distal to seams) the median total S was similarly different, reflecting the generally higher sulphur concentration associated with seams – that is, the 'near seam' samples had a median total S of 0.10 % S whereas the samples distal to seams had a median total S of 0.05 % S, half that of the samples well away from seams.

Comparatively, of the 101 fresh carbonaceous spoil samples, approximately half (54 out of 101 samples) were associated with seams (within approximately 1m above and below seams). The samples associated with seams had a median ANC of 17 kg H_2SO_4/t and the samples away from seams had a similar median ANC of 15 kg H_2SO_4/t. Both groups had the same median total S values (0.22 % S for the 'near seam' samples and 0.22 % S for samples away from seams).

Available Acid Neutralising Capacity

The availability of neutralising material is generally determined by the mineralogy of the sample – with calcite and dolomite (carbonate minerals) being more readily-available to neutralise acidity compared with, for example, silicates. Siderite, although a carbonate, has no net acid neutralising capacity. As such, ANC assumes that all ANC is readily available to neutralise acid, when this is rarely the case. Hence, ABCC (and mineralogical) test-work is undertaken to understand the effective ANC.

Acid buffering characterisation curve (ABCC) tests were undertaken on 31 spoil samples, 21 fresh (CHPP) tailings samples and 16 fresh (CHPP) rejects samples to assess the proportion of ANC that may be 'readily available' (i.e. short-acting) in these materials under field conditions and provide some indication of what carbonate minerals are providing the ANC. 'Ready availability' is regarded as the proportion of ANC that is available for buffering reaction at pH 4.5. The results are summarised in **Figure 19** ***top, middle*** and ***bottom*** for spoil, tailings and rejects samples, respectively.

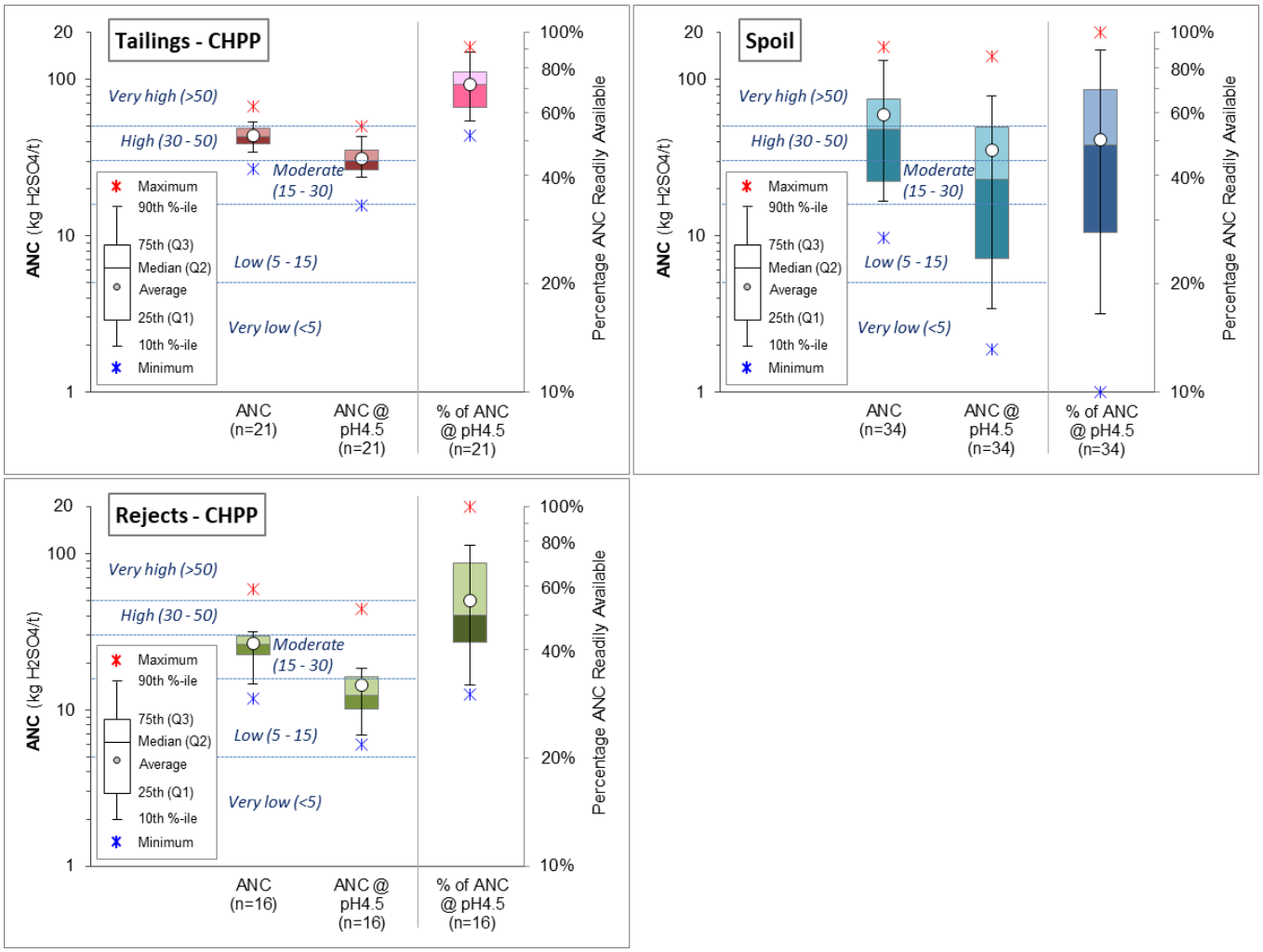


Figure 19. Distribution of acid neutralising capacity (ANC) [total], ANC at pH4.5 and proportion (%) of ANC expected to be readily available for spoil, tailings and rejects samples

For the 31 spoil samples where ABCC data is available, the results showed that the proportion of ANC likely available under field conditions ranged from 10% to nominally 100% of the ANC, with a median of approximately 40%[3].

For the 21 fresh (CHPP) tailings samples where ABCC data is available, the results showed that the proportion of ANC likely available under field conditions ranged from 52% to 91% of the ANC, with a median of approximately 72%. No ABCC data is available for aged tailings samples from the TSFs.

For the 16 fresh (CHPP) rejects samples where ABCC data is available, the results showed that the proportion of ANC likely available under field conditions ranged from 30% to nominally 100% of the ANC, with a median of approximately 50%. ABCC data is available for one aged rejects sample from R4 rejects area, which found that

3 Because the ABCC test is a separate test to the ANC test – performed on different sample splits – it is possible to achieve results with greater than 100% ANC being readily available for the same sample. Such a result effectively means that all of the ANC for that sample is in a readily available form (i.e. a practical maximum of 100% availability). Similarly, at the lower end, the lowest 'readily available' amount may actually be slightly greater.

about 56% of the ANC was likely to be available under field conditions. No ABCC data is available for aged rejects samples from the TSFs.

ABCC data is also available for three aged fill samples from the TSFs (results not shown in Figure 19). For these three samples, the proportion of ANC likely available under field conditions was quite varied: 18%, 64% and nominally 100% (average 61%).

The relationship between ANC @ pH 4.5 [i.e. ABCC ANC] and ANC [total] (for samples where ABCC data is available) is shown in **Figure 20**.

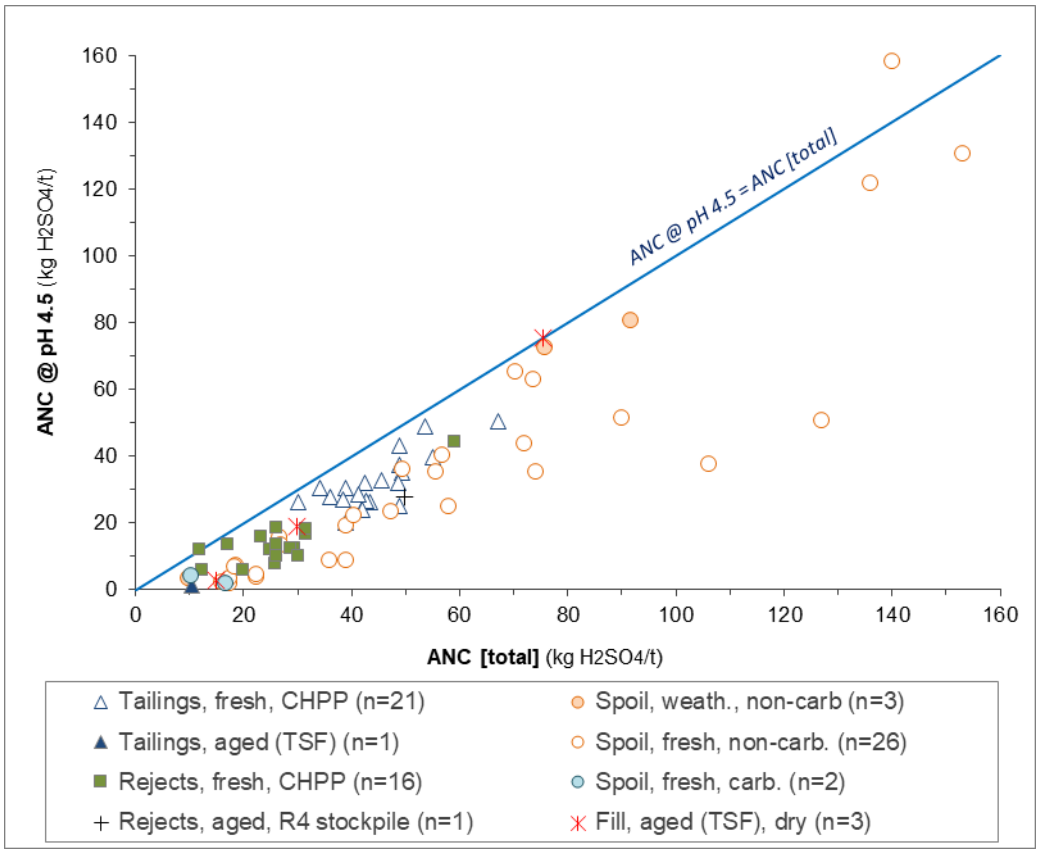


Figure 20. ABCC ANC [ANC @ pH 4.5] versus ANC

The shape of the ABCC curves (the reaction rate) can also be used to infer likely carbonate mineralogy based on standard curves/data for different carbonate minerals at varying ANC values. ABCC reaction rate curves can be provided on request. For the spoil samples, iron dolomite (Fe-dolomite) appears to be the dominant carbonate mineral (based on the ABCC curves), with minor siderite. Siderite is fairly common throughout the Permian sediments of the Bowen Basin, albeit in generally relatively small amounts. Several samples appear to have trace amounts of dolomite. For the tailings and rejects samples, Fe-dolomite and dolomite are the dominant carbonate minerals (based on the ABCC curves), with less siderite than appears to be present in the spoil samples.

Based on the above, and supported by the QXRD data (**Section 5.1**), the carbonate mineral in bulk spoil, tailings and rejects is likely to be Fe-dolomite +/- siderite with varying influence from dolomite.

ANC / MPA Ratio

Generally, those samples with an ANC/MPA ratio greater than two are considered to have a negligible/low risk of acid generation (DIIS, 2016; INAP, 2009[4]), especially where sulphide concentrations are very low and reactive ANC is moderate to high – as is the case with the potential spoil samples.

4 INAP (2009) considers that mine materials with an ANC/MPA ratio greater than two are likely to be NAF unless significant preferential exposure of sulphide minerals occurs along fracture planes, in combination with insufficiently reactive ANC.

The results, illustrated in **Figure 21**, show that 756 of the 926 spoil samples (82% of spoil samples) have an ANC/MPA ratio greater than two – noting that 77% of all spoil samples are fresh, non-carbonaceous. Approximately 61% of fresh carbonaceous spoil samples (62 out of 101 samples) have an ANC/MPA ratio greater than two. Fill samples (from the TSF) had a similar range of ANC/MPA ratios to spoil samples.

As discussed earlier, the ANC of the fresh non-carbonaceous spoil samples associated with coal seams was much lower, and the total S much higher, compared to the fresh non-carbonaceous spoil samples well away from seams. As such, the ANC/MPA ratios of the fresh non-carbonaceous samples are generally lower for samples (material) closer to seams compared to those materials further away from seams. For fresh carbonaceous samples the results were more evenly divided between samples close to seams versus those further away from seams.

All tailings and rejects samples and most natural ground samples from beneath the TSFs had ANC/MPA ratios less than or equal to two; as did most coal samples.

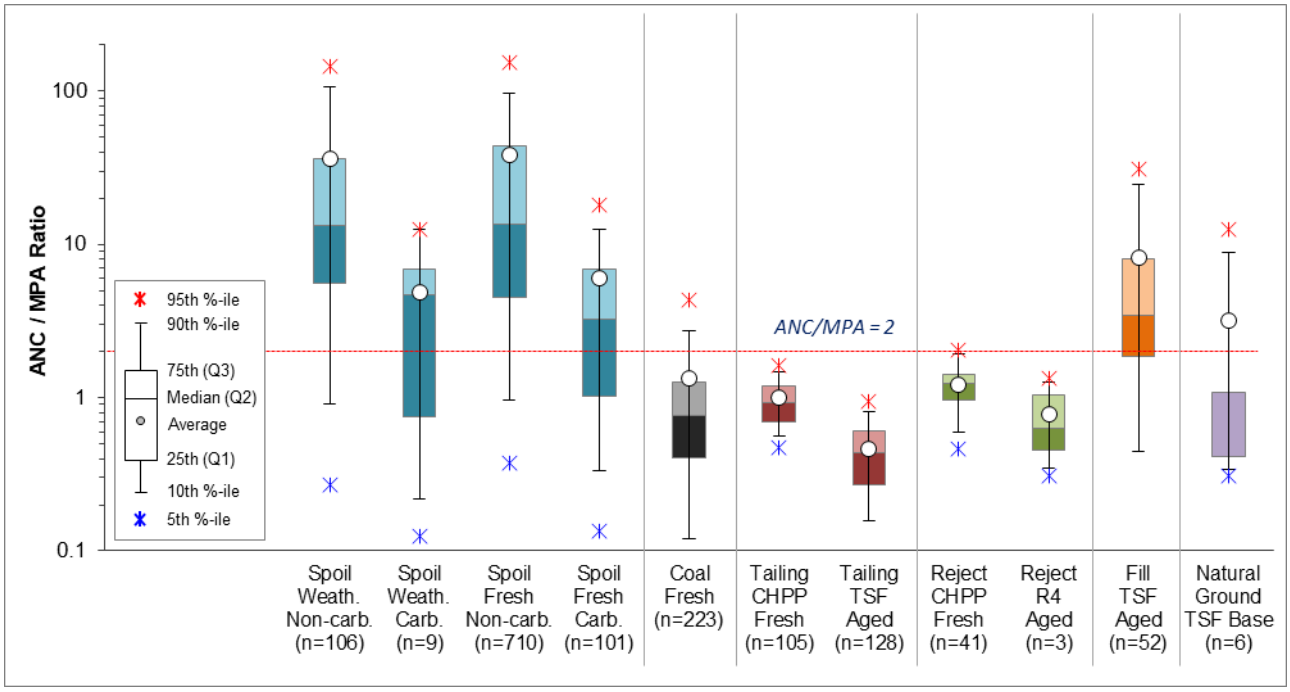


Figure 21. Distribution of the ratio of acid neutralising capacity (ANC) to maximum potential acidity (MPA) [ANC/MPA ratio]

Net Acid Producing Potential

The NAPP distribution for all samples is presented in **Figure 22**. Based on the generally low MPA and higher ANC values (relative to the MPA), the calculated NAPP values are negative for the large majority of spoil samples. Some carbonaceous spoil samples (those samples more closely associated with seams) have low positive NAPP values. The results indicate that, overall, there is significantly excess neutralising capacity (ANC) compared to potential acidity (MPA) for spoil samples.

All other sample types (i.e. coal, tailings, rejects, fill and natural ground samples) have a mix of low negative and low positive NAPP values. Almost all aged (TSF) tailings samples, 56 % of fresh (CHPP) tailings samples, 27 % of fresh (CHPP) rejects samples and 64 % of coal samples are NAPP positive.

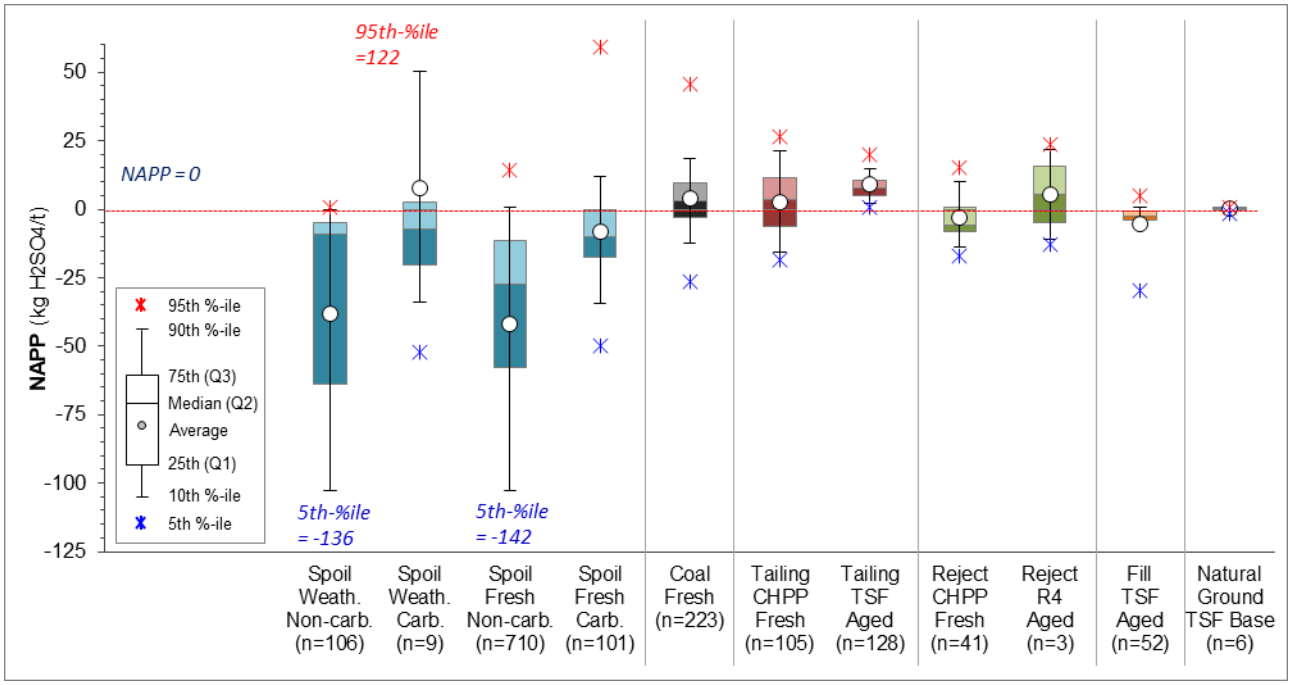


Figure 22. Distribution of net acid producing potential (NAPP)

Net Acid Generation Capacity

NAG test results are used in conjunction with NAPP values in determining the acid classification of samples. The calculated NAPP value assumes that all sulphur (present as sulphide) will oxidise to generate acid (MPA) and that all neutralising material in a sample is in a readily available form to neutralise any acid that could be generated (ANC). Unlike the theoretical basis of the NAPP test, in a NAG test a sample is encouraged to oxidise by reaction with hydrogen peroxide and any acid generated through oxidation may be consumed by neutralising components in the sample. Any remaining acidity is measured and expressed as kg H_2SO_4/t.

Samples with NAGpH values greater than pH 4.5 are considered to be NAF. Samples with NAGpH values less than or equal to pH 4.5 (i.e. acid-generating) would also be expected to have measurable NAG capacity (i.e. NAG capacity greater than 0.1 kg H_2SO_4/t). As a guide, NAG capacity values between 0.1 and 5 kg H_2SO_4/t are considered 'low capacity' (AMIRA, 2002).

NAG test data is available for 220 spoil samples, 78 coal samples, 115 tailings samples, 41 rejects samples [and three fill samples from TSFs] – with the NAGpH distribution for these samples shown in **Figure 23**. Of the samples tested; 76% of spoil, 53% of coal, 61% of fresh (CHPP) tailings and 78% of fresh (CHPP) rejects samples tested had NAGpH values greater than pH4.5. Comparatively, only 36% of aged (TSF) tailings samples [where NAG tests were undertaken] had NAGpH values greater than pH4.5. All three aged (TSF) fill samples tested had NAGpH values greater than pH4.5.

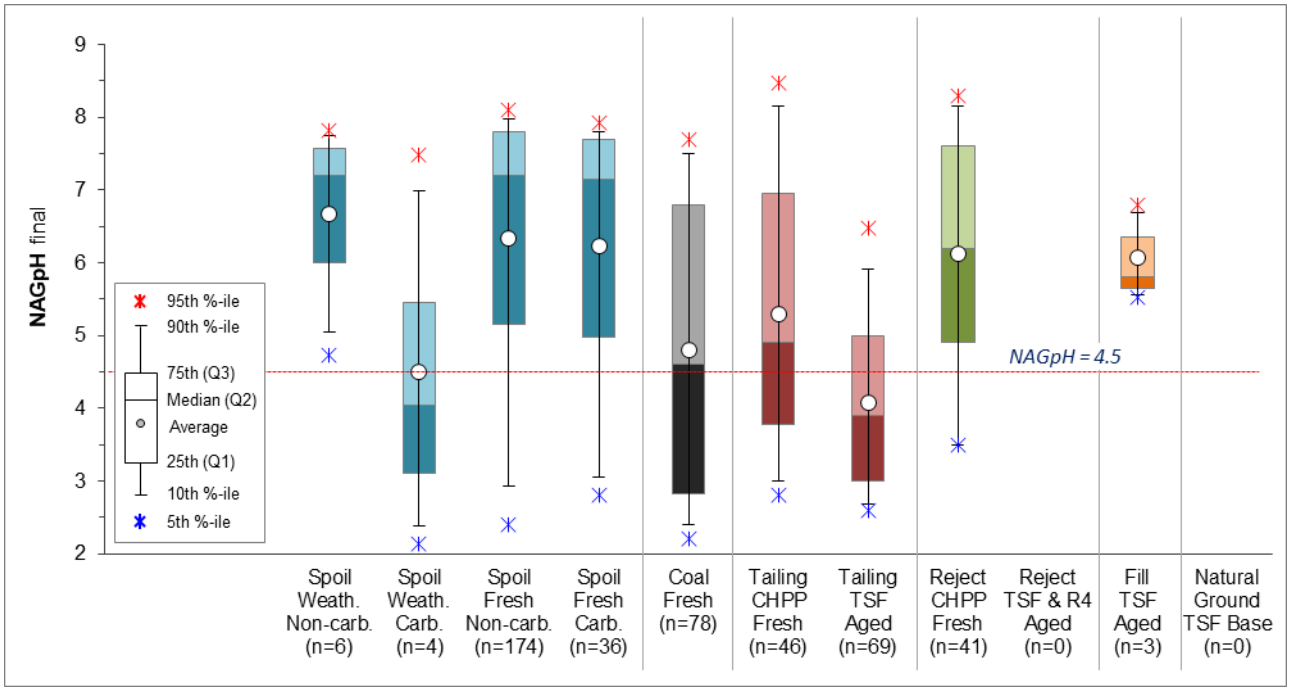


Figure 23. Distribution of net acid generation pH (NAG single or NAG Extended or Stage 1 NAG Sequential)

As per general practice, especially with some of the 'historic' data, NAG tests tend to be undertaken on samples with higher total S values and/or those samples potentially considered to have a greater potential to generate AMD, such as samples closely associated with coal seams. As such, the proportion of samples with NAGpH values less than pH4.5 is not representing the actual proportion of material in the field that can generate acid conditions, but is indicative of the type of material (based on total S and ANC concentrations) that may generate AD under field conditions.

The NAG test can be influenced by organic acid (i.e. organic acid can produce NAGpH between approximately pH 4 to 4.5, thus providing a 'false positive' for sulphuric acid). Organic acid is typically produced by samples with high organic carbon content – such as coal and highly carbonaceous samples. To attempt to resolve some of the uncertainty with the 'single addition' NAG test for coaly and highly carbonaceous samples, 108 samples underwent an Extended Boil NAG method (NAG Extended). These samples included coal (59 samples), tailings (39 samples), rejects (6 samples) and 4 carbonaceous spoil samples.

Fifty-three (53) of these 108 samples (or 49% of samples) returned Extended NAGpH values greater than pH4.5, suggesting that for approximately half of the mostly coal and tailings samples tested the acidity generated in the 'single addition' NAG test was associated with the oxidation of organic carbon and not with sulphide oxidation.

AMD Classification

The ABA results presented in this section have been used to classify the acid forming nature of the samples following the classification criteria outlined in **Section 4.4**. Additional relevant data, such as ABCC and Extended NAG test results were used to aid in the classification of samples where there was uncertainty following the preliminary AMD classification. The acid forming nature of these samples is summarised in **Table 16**.

Spoil

The classifications in **Table 16** show that 87% of spoil samples were classified as NAF or were expected to be NAF (and have been classified as UC(NAF)). These spoil samples (and spoil material represented by these samples) have very low sulphur concentration, significant excess ANC (relative to the MPA) and clearly have negligible capacity to generate AMD.

Twelve percent (12%) of spoil samples (123 out of 934 samples) were classified as PAF, PAF-LC or UC(PAF) – of which all of these 123 'PAF' samples were closely associated with seams as intraseam interburden or within a

couple of metres above or below seams. This result strongly shows that PAF spoil is very closely associated with seams (and may report to the CHPP as part of ROM coal and leave the CHPP as rejects). Spoil away from seams is clearly NAF.

Data show that potential spoil, as a bulk material, would be overwhelmingly NAF – and essentially all spoil away from seams (which is the overwhelming bulk of spoil) is expected to be NAF. Furthermore, the very low sulphur concentrations in spoil indicates that the sulphate concentration that could be generated in spoil from sulphide oxidation (in addition to any salinity unrelated to sulphide oxidation) would also be very low. PAF spoil is most likely to be closely associated with seams, as seam roof, parting or floor, which may largely report to the CHPP as ROM coal and leave the CHPP as rejects. PAF spoil is also likely to be associated with thicker interburden zones between seam plys of the same seam group. That is, PAF spoil is rarely encountered well away from seams.

Table 16. Geochemical classification of samples

Material Type	NAF	NAF-S	UC(NAF)	UC(PAF)	PAF-LC	PAF
	Number and (%) of samples					
Spoil, weath, non-carb. (n=108)	94 (87%)	0	0	1 (~1%)	11 (10%)	2 (~2%)
Spoil, weathered carbonaceous (n=9)	7 (78%)	0	0	0	1 (11%)	1 (11%)
Spoil, fresh non-carbonaceous (n=716)	620 (87%)	3 (<1%)	9 (~1%)	21 (~3%)	25 (~4%)	38 (~5%)
Spoil, fresh carbonaceous (n=101)	76 (75%)	1 (~1%)	1 (~1%)	8 (8%)	6 (6%)	9 (9%)
Spoil [all] (n=934)	*797 (86%)*	*4 (<1%)*	*10 (~1%)*	*30 (~3%)*	*43 (~5%)*	*42 (~5%)*
	811 (87%)			*123 (13%)*		
Coal (n=225)	127 (57%)	1 (<1%)	11 (~5%)	20 (9%)	43 (19%)	23 (10%)
	139 (62%)			*86 (38%)*		
Tailings, fresh, CHPP (n=105)	8 (~8%)	31 (30%)	17 (16%) *>1%S = 10*	32 (30%)	8 (~8%)	9 (~9%)
Tailings, aged, TSF (n=192)	34 (18%)	0	43 (22%)	34 (18%)	70 (36%)	11 (~6%)
Tailings [all] (n=297)	*42 (14%)*	*31 (10%)*	*60 (20%)*	*66 (22%)*	*78 (26%)*	*20 (~7%)*
	133 (45%)			*134 (55%)*		
Rejects, fresh, CHPP (n=41)	27 (66%)	2 (~5%)	6 (15%)	3 (~7%)	2 (~5%)	1 (~2%)
Rejects, aged, TSF and Ramp 4 (n=36)	0	0	32 (89%)	1 (~3%)	0	3 (~8%)
Rejects [all] (n=77)	27 (35%)	2 (~3%)	38 (49%)	4 (~5%)	2 (~3%)	4 (~5%)
	67 (87%)			*10 (13%)*		
Fill, aged (TSF), dry to moist (n=60)	39 (65%)	0	6 (10%)	0	15 (25%)	0
Natural ground beneath TSFs (n=8)	3 (38%)	0	4 (50%)	0	1 (~2%)	0

* Insufficient data available to geochemically classify aged rejects samples collected from the TSFs.

Coal

Coal samples had marginally higher total S values and marginally lower ANC compared to spoil, which resulted in 38% of coal samples being classified as PAF, PAF-LC or UC(PAF). The proportion of PAF, PAF-LC and UC(PAF) samples is comparable across all coal seam groups being mined at SRM. It is worth noting that at least two-thirds of the coal samples classified as some form of 'PAF' showed limited or uncertain capacity to generate acidity,

suggesting that 'PAF' coal is unlikely to generate significant acid(ity). Furthermore, the Scr content of coal samples was generally low, suggesting that the 'PAF' (including PAF sub-groups) classification is conservative for most coal samples. On the other side of the acid-base account, it is recognised that ANC is likely an overestimate, however the AMD classification already takes this into account by assuming ANC is only 50% available (i.e. the classification uses an ANC/MPA ratio of 2).

Approximately 62% of coal samples tested (139 out of 225 samples) were classified as NAF or UC(NAF), and seam material represented by these samples has very low sulphur values, excess ANC (relative to the MPA) and clearly has no capacity to generate acidity or release significant sulphate from sulphide oxidation.

These results suggest that coal represented by these samples and stored on a ROM pad, located within pit walls and un-economic coal seam material reporting as spoil (mixed with non-coal spoil) would likely be bulk NAF. A small proportion of coal (from all seam groups) poses a greater, but relatively low AMD source hazard. As mentioned earlier, the Harrow Creek and Dysart seams comprise the majority of coal at SRM. Future mining is expected to uncover a greater proportion of P and Q seams than currently mined.

Tailings

Slightly over half of all tailings samples were classified as PAF, PAF-LC or UC(PAF) – mostly comprised of moist to wet tailings samples from the TSFs (assumed relatively unoxidised) and fresh (CHPP) tailings samples, of which a high proportion were classified as UC(PAF). Approximately 7% of tailings samples were classified as PAF; i.e. compared to a much larger proportion classified as PAF-LC or UC(PAF).

From an acid generating perspective a significant proportion of tailings pose a potential source hazard with respect to AD and/or NMD/SD. Given the relatively high proportion of 'PAF' tailings samples classified as UC(PAF) or PAF-LC, 'PAF', tailings are expected to generate low to moderate acidity loads.

Rejects

The results show that 87% of rejects samples were classified as NAF, NAF-S or UC(NAF) – of which most of the fresh (CHPP) samples were classified as NAF and most of the aged (TSF) samples were classified as UC(NAF). Of the 10 samples with some type of broader 'PAF' classification, four were classified as PAF, two as PAF-LC and four as UC(PAF). From an acid generating perspective a relatively small proportion of rejects (approximately 13% of 77 samples) pose a potential source hazard with respect to AD and/or NMD/SD.

Fill and Natural Ground

Fill samples from within the TSFs were predominantly NAF (or UC(NAF)), with 25% of fill samples conservatively classified as PAF-LC. Fill material is assumed to be spoil placed at various times over parts of the TSF during construction phases of TSF raises or as a temporary cover. Data show that fill material within the TSFs would be predominantly NAF. Furthermore, the very low sulphur concentrations in fill indicates that the sulphate concentration that could be generated in fill from sulphide oxidation (in addition to any salinity unrelated to sulphide oxidation) would also be very low.

Eight natural ground samples (from beneath the TSFs) also have very low sulphur and were all classified as NAF or UC(NAF), except for one sample conservatively classified as PAF-LC.

5.3 Total Metals and Metalloids

Multi-element (metal and metalloid) data is available for 225 samples, comprising 128 spoil samples [20 weathered non-carbonaceous, 2 weathered carbonaceous, 96 fresh non-carbonaceous and 10 fresh carbonaceous], 19 coal samples, 17 rejects samples [16 fresh samples from the CHPP and 1 aged sample from the R4 rejects area], 44 tailings samples [24 fresh CHPP samples and 20 aged TSF samples], 15 aged TSF fill samples and 2 natural ground samples. The degree of enrichment with respect to elements potentially of environmental interest for the spoil, coal, reject and tailings materials is shown in **Figure 24**.

The GAI values show that 23 (out of 128) spoil samples and six (out of 19) coal samples were significantly enriched [GAI ≥3] with regard to one or more of beryllium (Be) and/or sulphur (S). The level of S enrichment in these samples is consistent with the ABA data for these same samples. The enrichment in Be in a small number of

samples is not cause for concern. Five of the same spoil samples and three of the same coal samples were also enriched with one or more of arsenic (As), mercury (Hg) and/or Selenium (Se) – again, such enrichment in a very small number of samples is not cause for concern.

With regard to the degree of element enrichment in tailings and rejects samples, 22 out of 24 fresh (CHPP) tailings samples were significantly enriched in S, with the degree of enrichment consistent with the ABA data for these same samples. Comparatively, only one aged (TSF) tailings sample (out of 20) was significantly enriched with regard to S. Of the 17 rejects samples (16 of which were fresh (CHPP)), nine fresh (CHPP) rejects samples were significantly enriched in S – again, consistent with the ABA data for these same samples. One fresh (CHPP) rejects sample was also significantly enriched with regard to As and Se.

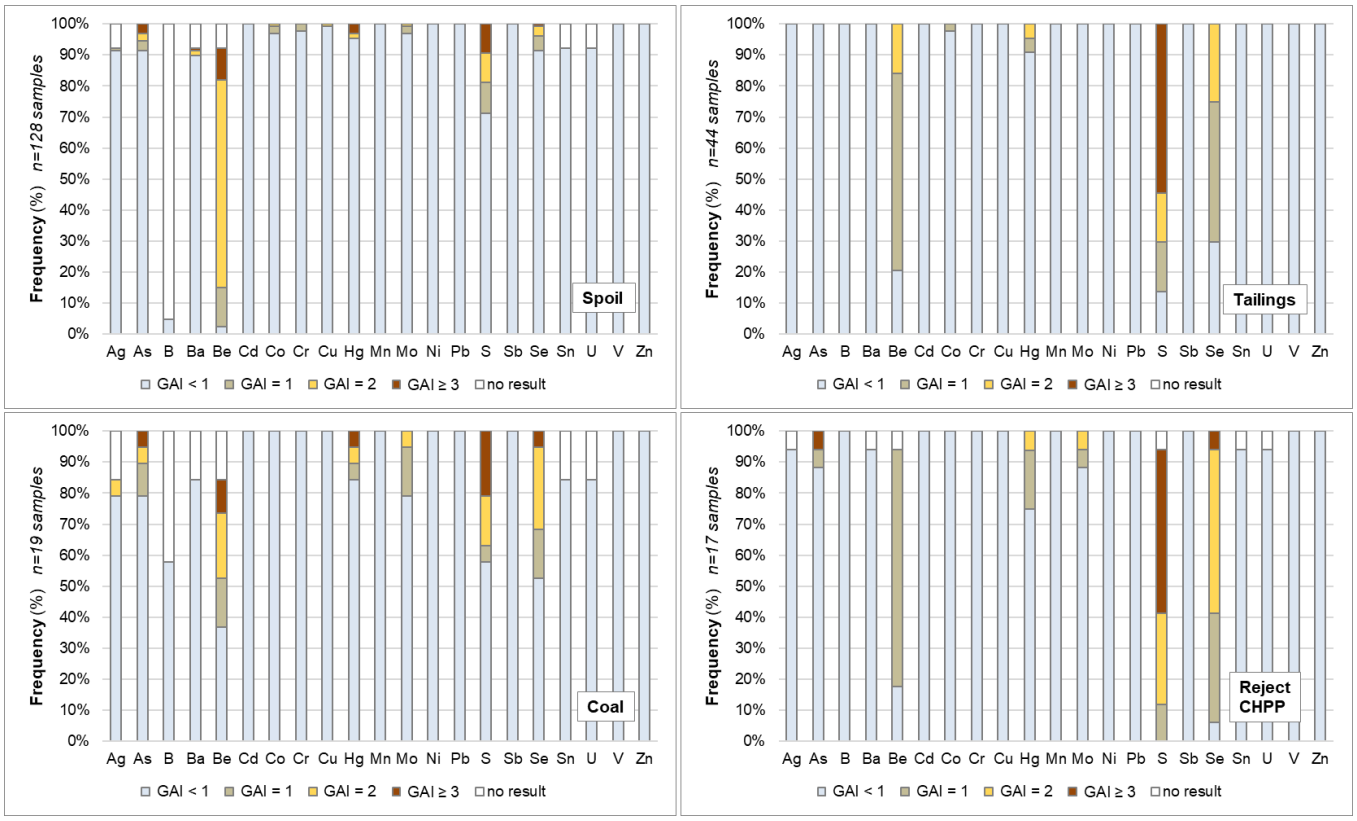


Figure 24. Frequency distribution of geochemical abundance indices (GAI) of selected elements in spoil and coal

The GAI values also show that a considerable number of samples tested (of all material types) had minor enrichment (GAI = 1 or 2) with regard to one or more of Be, S and/or Se, and a much small number of samples had minor enrichment with regard to one or more of As, Hg and/or molybdenum (Mo).

Fill samples (from the TSFs) and natural ground samples from below the TSFs had low levels of enrichment in one or more of Be, cobalt (Co), S and/or Se.

Overall, the results suggest that bulk mineral waste materials have generally low levels of metal and metalloid enrichment, which is consistent with Permian-age coal measures throughout eastern Australia. A small proportion of samples (of all material types) have a higher degree of enrichment in some metals – notably Be – however enrichment in Be in these materials in not cause for concern.

5.4 Initial Solubility in Deionised Water

To evaluate the initial solubility of multi-elements in samples, water extract test results for pH and EC are available for 2310 samples, comprising: 1734 spoil samples, 136 coal samples, 295 tailings samples, 77 rejects samples, 60 fill (TSF) samples and 8 natural ground samples. Test results for major ions and soluble metals/metalloids are

available for 82 spoil samples, 14 coal samples, 39 tailings samples, 17 rejects samples, 15 TSF fill samples and two natural ground samples.

Therefore, a large dataset is available to assess the potential for leaching of salt and environmentally important elements from mineral wastes (spoil, tailings and rejects) and coal at SRM. Water extract tests provide a preliminary indication of the elements that may be readily mobilised from any given material type.

The samples underwent a 1:5 w:v (solid:water) deionised water bottle leach procedure on fine pulps. Note that the use of fine pulped materials in water extract tests will enable a high level of reaction and dissolution. The results from these tests are summarised and discussed below. Tabulated results can be provided on request.

The test-work has found that the mineral wastes are pH-alkaline, generally non-saline to slightly saline and have very low concentrations of soluble metals and metalloid concentrations – within the range typical for Permian sedimentary materials in Queensland. For most samples, the soluble metals and metalloids are at concentrations below or marginally above the laboratory limit of reporting (LOR).

Electrical Conductivity (EC) and pH

EC and pH data is available for 2431 samples at 1:5 w:v on pulp (**Figure 25**).

The $EC_{1:5}$ of 1857 spoil samples spanned a large range from 44 to 6130 µS/cm, with median, 75th and 90th percentile $EC_{1:5}$ values of 600, 932 and 1436 µS/cm, respectively. As evident in **Figure 25** the fresh (unweathered) samples, which comprise the greatest proportion of spoil, have slightly greater range of $EC_{1:5}$ values compared to the weathered samples, however spoil – as a bulk material – is generally slightly saline. Non-carbonaceous spoil samples have a 75th percentile $EC_{1:5}$ of 908 µS/cm. Carbonaceous spoil samples have a 75th percentile $EC_{1:5}$ of 1080 µS/cm. These $EC_{1:5}$ results are common (if not typical) for Bowen Basin Permian and Tertiary material in the region.

Coal samples (n=163) are generally non-saline to slightly saline. Fresh (CHPP) tailings samples (n=103) are generally slightly to moderately saline, whereas aged (TSF) tailings (n=192) have lower $EC_{1:5}$ values and are generally non-saline to slightly saline. Rejects samples (n=77) are also generally non-saline to slightly saline, with $EC_{1:5}$ values comparable to 'moist to wet' tailings from the TSFs. Fresh (CHPP) rejects samples had marginally lower $EC_{1:5}$ values compared to aged rejects samples from the TSFs (and R4 rejects area), however the differences aren't significant. Rejects samples (all) have a 75th percentile $EC_{1:5}$ of 633 µS/cm. Tailings samples (all) have a 75th percentile $EC_{1:5}$ of 754 µS/cm.

The pH distribution by material type (**Figure 25**) shows most samples to be generally alkaline to highly alkaline, with the notable exception being the aged (TSF) tailings samples, which had lower pHs to put them in the range of 'near-neutral' to alkaline. Some aged (TSF) tailings samples were weakly acidic. These pH results are common – if not typical – for Bowen Basin Permian and Tertiary material in the region.

Of the 2431 samples, 103 samples (4% of samples) had $pH_{1:5}$ values less than 6.0. Of these, 78 samples were weakly acid with $pH_{1:5}$ values between 4.5 and 6.0 and 24 samples were moderately acid with $pH_{1:5}$ values between 3.0 and 4.5. Combined, these comprised 23 weathered spoil samples, 34 fresh spoil samples, 8 coal samples, 26 aged (TSF) tailings samples, 10 aged (TSF) fill samples and one natural ground sample. One coal sample was highly acid, with a $pH_{1:5}$ value of 2.8. As discussed earlier, samples with no other geochemical data apart from $pH_{1:5}$ and $EC_{1:5}$, and with $pH_{1:5}$ values less than or equal to pH 4.5 were classified as PAF.

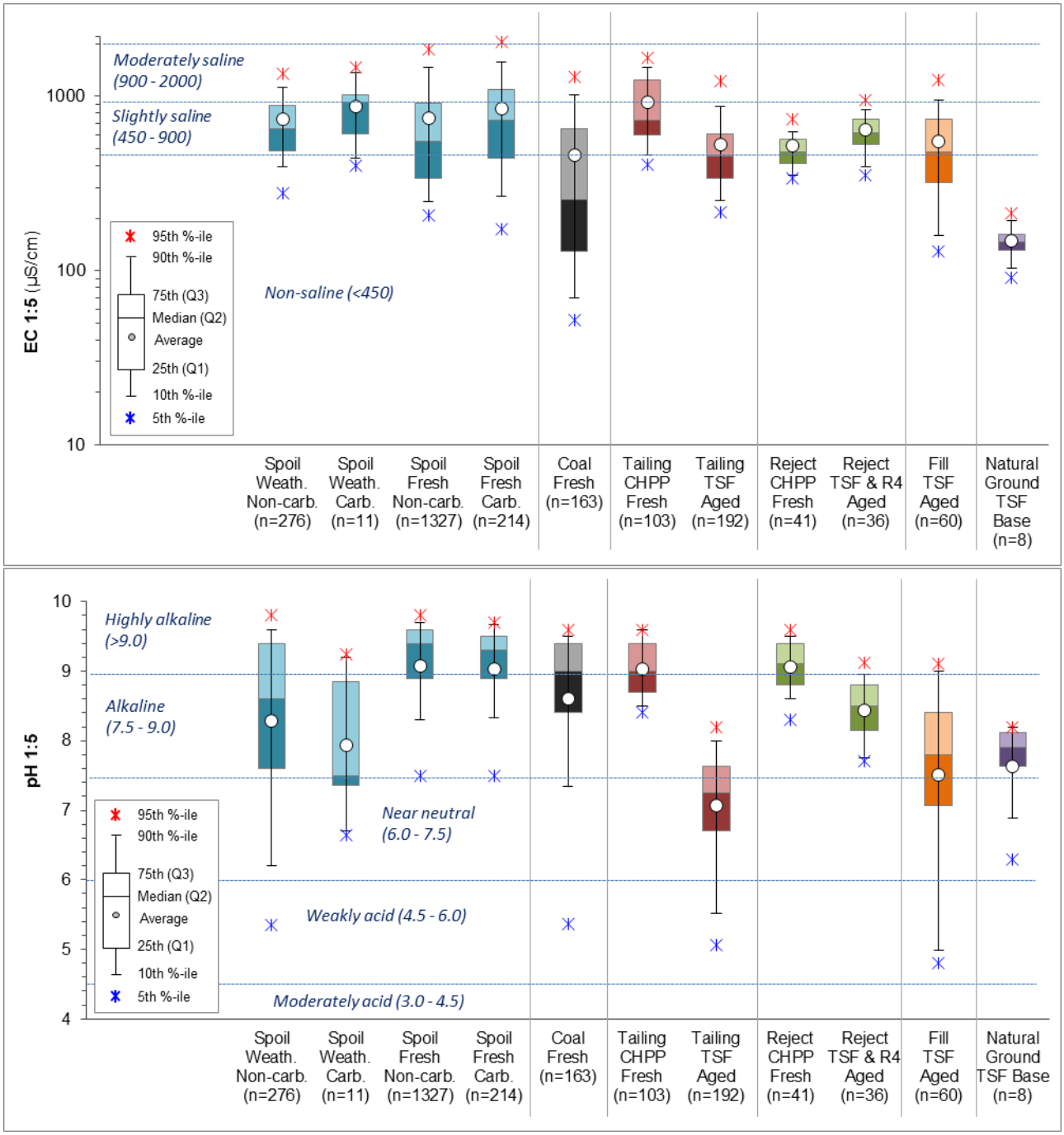


Figure 25. Electrical conductivity (EC) and pH distribution

Soluble Metals and Metalloids

Deionised water extract (leaching) data for major ions and a broad suite of metals/metalloids is available for 82 spoil samples, 14 coal samples, 39 tailings samples, 17 rejects samples, 15 aged (TSF) fill samples and two natural ground samples. All samples underwent a 1:5 w:v (solid:water) water extract procedure on pulps. The samples were collected under different sampling programs with different objectives and, as such, some of the samples were analysed by a higher resolution method (ICP-MS) compared to other samples (analysed by ICP-AES). Thus, the samples analysed by ICP-AES have laboratory LOR values that are generally greater than the laboratory LOR for samples analysed by ICP-MS. Most samples were analysed under the higher resolution ICP-MS method.

The sum of 16 environmentally important elements are plotted as a function of pH in **Figure 26**, in a modified version of what is referred to as a Ficklin plot (after Ficklin *et al*., 1992). The 16 selected metals/metalloids comprise: aluminium [Al], antimony [Sb], arsenic [As], cadmium [Cd], cobalt [Co], chromium [Cr], copper [Cu], lead [Pb], mercury [Hg], manganese [Mn], molybdenum [Mo], nickel [Ni], selenium [Se], uranium [U], vanadium [V] and zinc [Zn].

As evident in **Figure 26**, of the 169 samples 156 samples have low soluble metals concentrations and have alkaline to highly alkaline pH. Three spoil samples, six tailings samples, one coal sample and two fill samples have moderate soluble metals concentrations associated with weakly acidic pH (pH 4.5 to 6.0). One spoil sample had a concentration sum of 15.1 mg/L associated with a weakly acidic pH and, as such, is classified as having a moderate to high metals concentration. Of the five spoil samples and one coal sample with moderate or moderate to high metals concentrations, five of the six samples were classified as PAF. The spoil sample classified as NAF was pH alkaline and had a sum of metals concentration of 1.24 mg/L. Of the six tailings samples with moderate metals concentrations, five were classified as PAF-LC and one sample classified as PAF.

In pH-neutral to alkaline waters, many metals/metalloids cannot remain in solution and, thus, trace metal/metalloid concentrations are generally low. Comparatively, in acid(ic) waters, many metals/metalloids are highly soluble and remain in solution and, thus, trace metal/metalloid concentrations are generally high. Notable exceptions to these general rules include elements such as As, Mn, Sb and Se, which remain soluble through a wide pH range. Other trace metals that are somewhat soluble under pH-neutral to alkaline conditions include Cd, Cr, Mo and Zn. As such, under the pH-alkaline conditions of the leach, the mobility of these elements would not be inhibited.

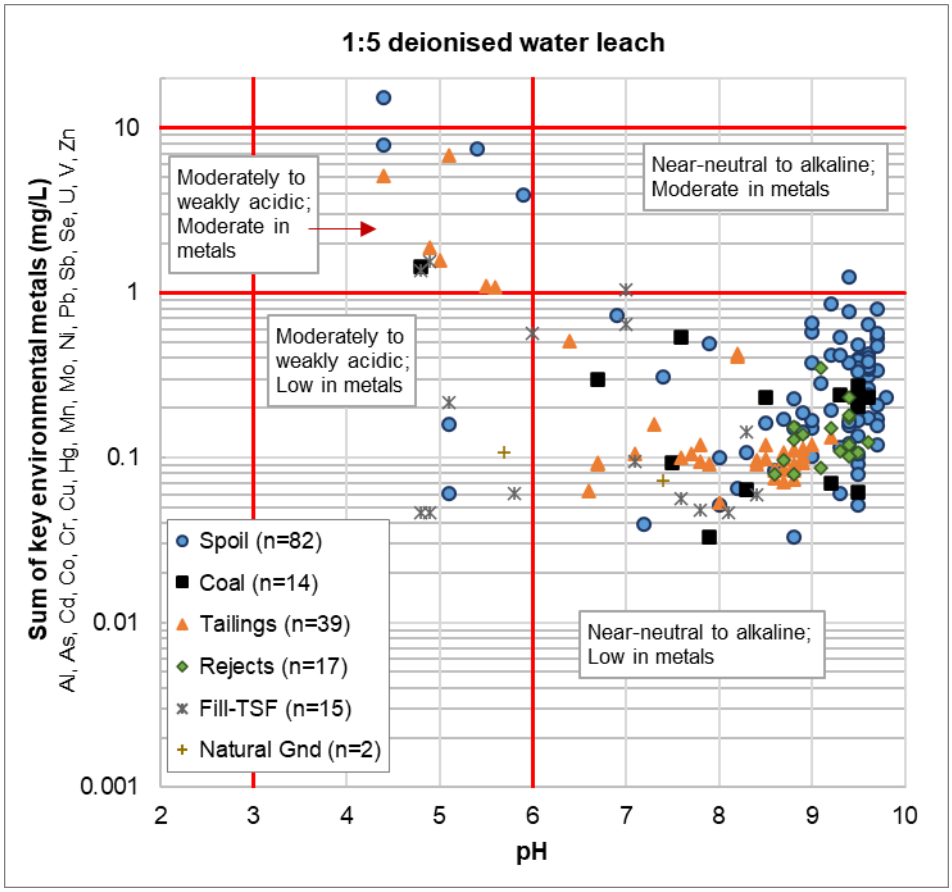


Figure 26. Sum of key environmental metals versus pH in deionised water extracts

The median concentrations of major ions and environmentally important metals/metalloids in deionised water extracts are shown in **Table 17** for spoil, coal, tailings and rejects.

Limited deionised water extract (leaching) data is available for an additional 41 spoil samples, three coal samples and 59 tailings samples. The water extract data for these additional 103 samples does not have solubility information for several of the key 16 elements identified in **Figure 26** and, as such, these samples have been

excluded from the dataset shown in **Figure 26** (and **Table 17**). Where data is available for these samples it is consistent with the information presented.

Table 17. Median concentrations of major ions and selected elements in deionised water extracts for spoil, coal, tailings and rejects

Median concentration mg/L	**Spoil** (n=82)	**Coal** (n=14)	**Tailings** (n=39)	**Reject** (n=17)
≤ 0.0001	Cd, Hg	Cd, Hg	Hg	Hg
≤ 0.001	Be, Bi, Co, Cr, Cu, Mn, Ni, Pb, Sn, U	As, Be, Bi, Co, Cr, Cu, Ni, Pb, Sb, Sn, U	As, Be, Bi, Cd, Co, Cr, Cu, Ni, Pb, Sb, U	Be, Bi, Cd, Co, Cr, Cu, Mn, Ni, Pb, U
≤ 0.01	As, Sb, Se, V, Zn	Mn, Se, V, Zn	Al, Se, Sn, V, Zn	As, Ba, Sb, Sn, V, Zn
≤ 0.1	Al, B, Ba, Fe, Mo	Al, B, Ba, Fe, Mo	B, Ba, Fe, Mn, Mo	Al, B, Fe, Mo, Se
≤ 1.0	F	F	F	F
≤ 10	Ca, Mg, K	Cl, Ca, Mg, K	K	Ca, Mg, K
≤ 100	SO_4, Cl, Na	SO_4, Na	Ca, Mg	Cl
≤ 1000	-	-	SO_4, Cl, Na	SO_4, Na

5.5 ‘Saline’ Water Solubility of Tailings and Rejects

Fifteen (15) tailings and 14 rejects samples underwent a 1:5 w:v (solid:water) mildly saline (brackish) water extract procedure on pulps using a 2 g/L sodium chloride (NaCl) leaching solution. This leach was undertaken to determine the solubility of metals and metalloids under ‘brackish’ conditions – which better simulate the normal (brackish) water quality of the CHPP process water. Note that the salinity of CHPP process water varies from fresh to brackish on a day-to-day basis depending upon the source of the water from within the mine water management system.

The sum of the concentration of 16 environmentally important elements are plotted as a function of pH from the saline leach solution for tailings and rejects in **Figure 27**. The 16 selected metals/metalloids are the same elements as per the 1:5 deionised water leach. As evident in **Figure 27** the soluble metals and metalloid concentrations were very low and, in most cases, very similar to the concentrations from the de-ionised water (freshwater) leaching tests for these same samples. All samples had near-neutral to alkaline pH and were low in metals. For essentially all elements and major ions (excluding chloride and sodium) there was little difference between the soluble concentrations in the ‘brackish’ leachate compared to the freshwater leachate.

The results have shown that the solubility of tailings and rejects is low under ‘brackish’ leaching conditions.

5.6 Characteristics of Tailings Liquor (Water)

Water quality data for tailings liquor is available for 12 tailings slurry samples collected from the CHPP (at the thickener underflow). All 12 samples were taken from the tailings slurry for 12 of the 15 tailings samples that underwent a saline leach. The sum of the concentration of 16 environmentally important elements are plotted as a function of pH from the tailings liquor solution in **Figure 27** (along with the data for the saline leach solutions). The 16 selected metals/metalloids are the same elements as per the 1:5 deionised water leach, saline water leach and peroxide leach.

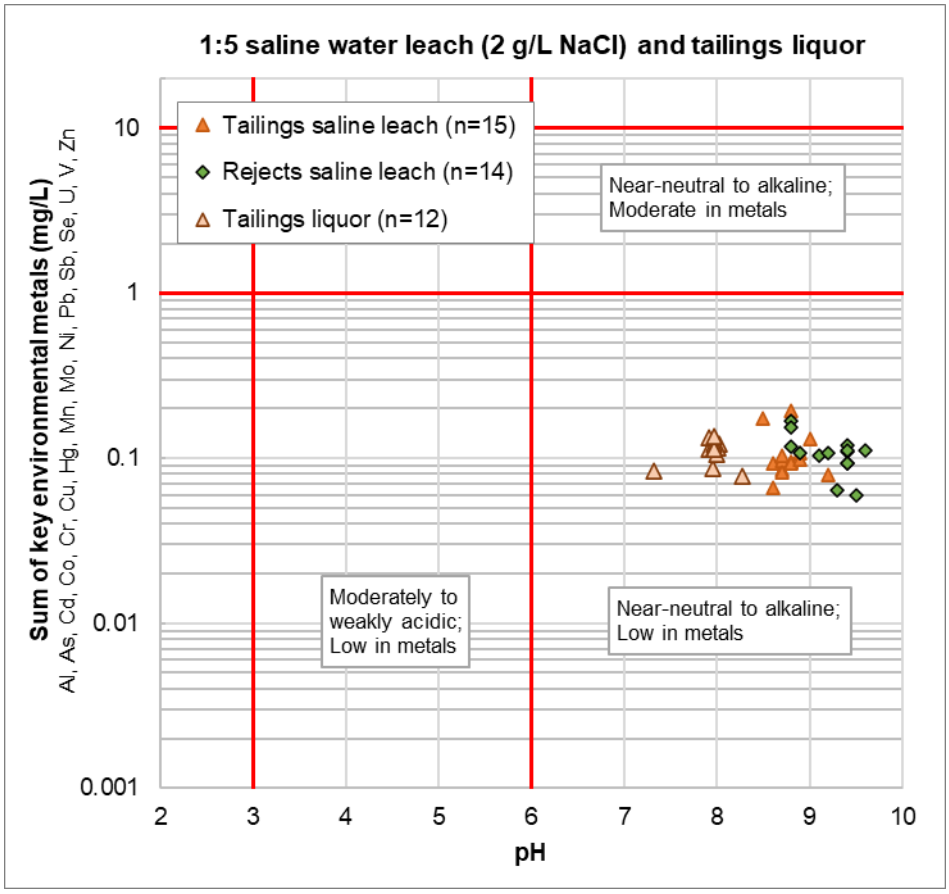


Figure 27. Sum of key environmental metals versus pH in saline water extracts and tailings liquor

As evident in **Figure 27** all liquor samples have near neutral to alkaline pH and low soluble metals concentrations. The liquor is highly saline, with EC values ranging from 9870 to 10,500 µS/cm (median = 10,300 µS/cm) and a median total dissolved solids (TDS) of 7100 mg/L. The dominant cation is Na and the dominant anions are Cl and SO_4 (equally dominant).

By comparison, the 2 g/L NaCl saline leach solution was much less saline, with a median TDS for tailings and rejects 'saline' leach samples of 2800 mg/L and 2300 mg/L, respectively; i.e. roughly one third the salinity of the tailings liquor. The dominant cations and anions in the saline leach were Na and Cl, respectively, as expected due to the NaCl used to create the saline solution.

5.7 Peroxide Leachate Solutions

Peroxide leachate (NAG leach) data is available for:

- 1 weathered carbonaceous spoil sample classified as PAF;
- 8 fresh non-carbonaceous spoil samples: five samples classified as PAF, one sample classified as PAF-LC and two samples classified as NAF-S;
- 9 coal samples: five samples classified as PAF, two samples classified as PAF-LC, one sample classified as NAF-S and one sample classified as NAF;
- 28 tailings samples of mixed classifications (NAF to PAF, including UC(NAF) and UC(PAF));
- 6 rejects samples of mixed classifications (NAF to PAF, including UC(NAF) and UC(PAF)); and
- 2 fill samples from the TSFs, one classified as NAF and the other as PAF-LC.

Peroxide leachate is the solution remaining from a single addition (standard) NAG test after the sample has been oxidised with peroxide to encourage oxidation and neutralising reactions, if ANC is available. The test encourages

complete and rapid oxidation, with the resulting leach representing and assumed 'worse case' scenario in term of metal/metalloid mobility. The purpose of this test is to understand what metals/metalloids can be mobilised following full oxidation. The samples submitted for this test were selected to assess the hazard of similar waste type or to assist clarifying borderline geochemical properties.

It must be noted that samples with potentially high organic carbon concentrations, such as coal, some tailings and some reject samples, may be influenced by organic acids producing acidity and correspondingly elevated soluble metals concentrations unrelated to AMD. As such, the results for coaly and highly carbonaceous samples should be interpreted with this in mind.

The sum of the concentration of 16 environmentally important elements are plotted as a function of pH from the peroxide leachate solution in **Figure 28**. The 16 selected metals/metalloids are the same elements as per the 1:5 deionised water leach and the saline leach.

As evident in **Figure 28** most samples have highly acidic to weakly acidic pH and moderate soluble metals concentrations – primarily due to the low pH enhancing solubility. Of the six samples plotting with low metals and near-neutral to alkaline pH, the spoil sample and the three tailings samples were classified as NAF-S, the rejects sample was classified as NAF and the coal sample classified as PAF-LC. The fill sample plotting with low metals but weakly acidic pH (pH 5.31) was classified as PAF-LC. Seven of the eight spoil samples plotting with moderate metals concentrations were non-carbonaceous, however were all classified as PAF (of some type) and were all closely associated with coal seams as intraseam spoil or situated close to seam roof/floor.

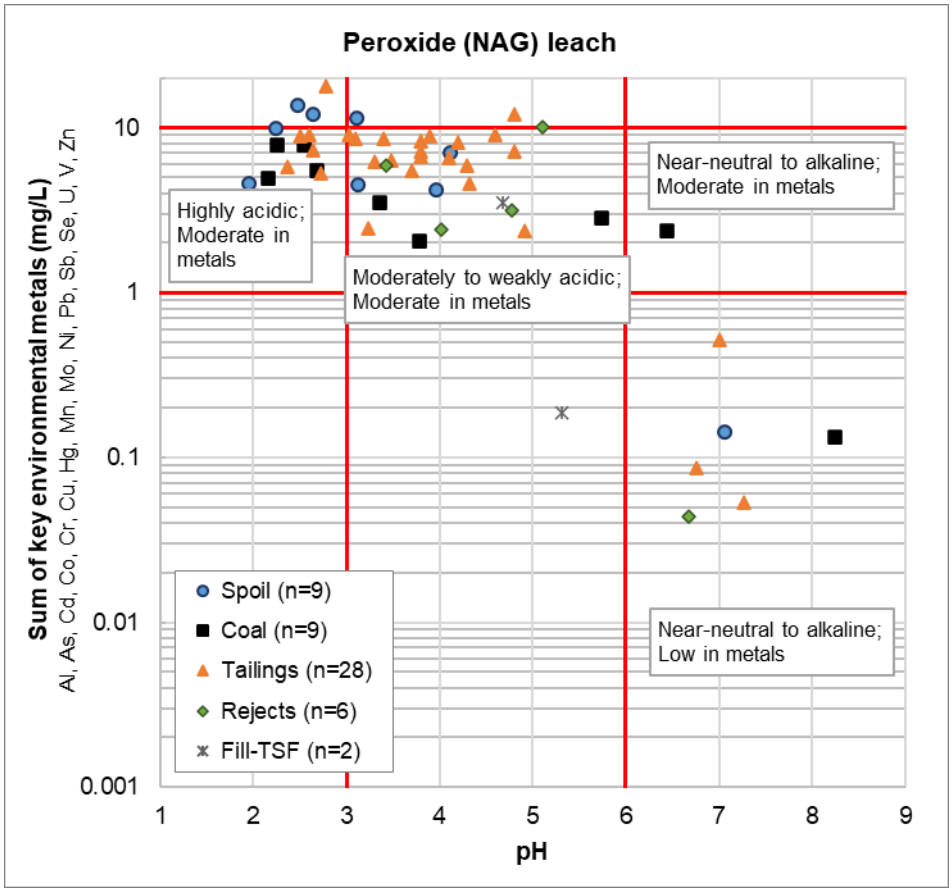


Figure 28. Sum of key environmental metals versus pH in peroxide (NAG) leachate solution

Most of the tailings samples were highly to weakly acidic and had moderate metals concentrations. Extended NAG test results are available for 14 of the 28 tailings samples that underwent peroxide leaching. Of these, six samples (all with moderate metals and low pH) had extended NAG test results that showed the presence of organic acids in these samples (i.e. producing extended NAGpH values greater than pH 4.5). Therefore, it's reasonable to conclude

that these six samples (i.e. approximately a quarter of the tailings samples subjected to peroxide leaching) may be producing elevated metals as a result of organic 'acidity', not from AMD.

The median concentrations of major ions and environmentally important metals/metalloids in peroxide leachate solution from spoil, coal, tailings and reject samples are shown in **Table 18**.

Compared to the 1:5 deionised water extract solutions, the median concentration of several metals and metalloids in the peroxide leach is higher, notably SO_4 in the spoil and coal samples (but remaining much the same for the tailings and rejects samples) and Al, Cu, Fe, Mn and Ni in most samples. However, for most samples, the concentrations of all other elements and major ions are comparable to the deionised water solubility concentrations.

The results suggest that under acid/acidic conditions, materials are capable of generating elevated metal and metalloid loads for several metals/metalloids, however the SO_4 (and salinity) loads are not expected to be high. These data suggest that if PAF/PAF-LC material is allowed to oxidise without ANC available to buffer acidity, material similar to that tested might mobilise metals and metalloids at elevated concentrations, over time.

Table 18. Median concentrations of major ions and selected elements in peroxide (NAG) leachate solution

Median concentration mg/L	**Spoil** (n=9)	**Coal** (n=9)	**Tailings** (n=28)	**Reject** (n=6)
≤ 0.0001	Hg	Hg	Hg	Hg
≤ 0.001	Ag, Bi, Cd, Mo, Sb, Sn	Ag, Bi, Cd, Mo, Sb, Sn, U	Ag, Bi, Sb, Sn	Ag, As, Bi, Cd, Mo, Pb, Sb, Sn, U
≤ 0.01	As, Be, Pb, Se, U, V	As, Be, Co, Ni, V	As, Be, Cd, Mo, Se, U	Be, Cr, V
≤ 0.1	B, Ba, Co, Cr, Cu	B, Ba, Cr, Cu, Pb, Se	Co, Cr, Ni, Pb, V	Ba, Co, Ni, Se
≤ 1.0	F, Ni, Zn	F, Zn	F, B, Ba, Cu, Mn, Zn	F, Al, B, Cu, Zn
≤ 10	Cl, K, Al, Mn	Cl, Ca, Mg, K, Al, Mn	Cl, Mg, K, Al	Cl, K, Fe, Mn
≤ 100	Ca, Mg, Na, Fe	Na, Fe	Ca, Na, Fe	Ca, Mg, Na
≤ 1000	SO_4	SO_4	SO_4	SO_4

5.8 Cation Exchange Capacity, Sodicity and Dispersion of Spoil

Exchangeable cation concentrations are used to evaluate the potential 'soil quality' of materials. Exchangeable cation data [as cation exchange capacity (CEC)] is available for 106 spoil samples and exchangeable sodium percentage (ESP) data is available for 149 spoil samples. The results are summarised in **Figure 29**.

The CEC spans a modest range from 2 to 17 milliequivalents per 100 grams (meq/100g), with a relatively low median CEC value of 6 meq/100g. There was generally little difference between the CEC of the different spoil types.

The ESP results range from 2 % to 52 %, with a median ESP of 32 %. Approximately 95% of samples had ESP values greater than 14 %. Therefore, based on the ESP values alone, essentially all spoil is regarded as being 'strongly sodic' and, as such, a significant proportion of mine spoil at SRM can be expected to have potential for dispersion.

A subset of 65 spoil samples also underwent Emerson aggregate class tests to determine whether these samples were dispersive. Emerson aggregate class tests are a direct measure of soil dispersion, whereas ESP values are used as an indirect measure of the *potential* for a sample to have structural stability problems and hence *may be* dispersive. The results show one sample (out of 65) was 'completely dispersive' (Class 1) and about 14 % of

samples (9 out of 65 samples) had some dispersion [slaking] (Class 2). One sample had an Emerson Class of 4 non dispersion [calcite or gypsum present]. The remaining 83 % of the samples had Emerson Class 7 and 8 values (non-slaking). Refer to **Section 4.4** for class descriptions. These results are generally inconsistent with the dispersion predictions from the CEC and ESP results, which suggested that most spoil would be dispersive – whereas the Emerson Class results suggest that most spoil is non-dispersive.

Based on the CEC, ESP and Emerson aggregate class test results, a significant proportion of spoil at SRM is expected to be strongly sodic, however the dispersivity of spoil may vary.

These exchangeable cation (and Emerson aggregate class) results are common for Bowen Basin Permian and Tertiary material in the region – and highlight that spoil is likely to have mixed sodicity and dispersion potential.

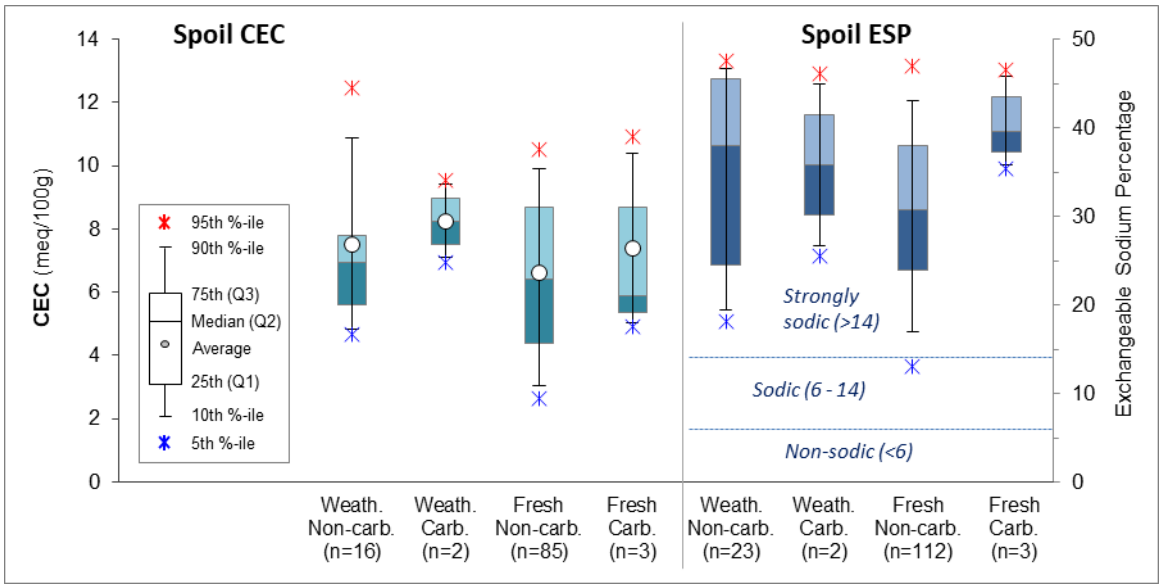


Figure 29. Cation exchange capacity (CEC) and exchangeable sodium percentage (ESP) of spoil

5.9 Kinetic Column Leaching

Free-draining kinetic column leaching test-work data is available for six composite samples comprising one seam roof composite sample (H16 [HCU]), three seam floor composite samples (H16 [HCU], D14 and D24 [DL]), one coal composite sample (H16 / D24 / D14) and one rejects sample from the R4 rejects area. The seam roof and seam floor samples may be considered to be representative of 'potential' rejects material should these roof and floor zones be mined as part of ROM coal. The samples were selected for column leaching test-work on the basis of earlier static test results. The ABA data for the six composite samples was relatively simplistic and, as such, all six samples were initially (and conservatively) classified as UC(PAF), PAF-LC or PAF. Seven leaching events were undertaken over a 12-week period. The results are summarised as follows:

The sum of the concentration of 13 environmentally important elements are plotted as a function of pH from the column leaching solutions in **Figure 30**. The 13 selected metals/metalloids are similar to the elements as per the 1:5 deionised water leach, saline leach and peroxide leach, except that no column leaching data is available for Hg, U and V [it would be expected that the concentration of Hg, U and V would be low – consistent with the static multi-element results for these same samples]. As evident in **Figure 30** all samples have low soluble metals concentrations and all except one sample (first flush [week 0] leach of the H16 floor sample) have near-neutral to alkaline pH. The pH in leachate from all samples increased (or remained the same/similar) throughout the leaching period (i.e. from week 0 to week 12).

The salinity of the samples (column leachate) ranged from non-saline to moderately saline, with the coal sample producing the lowest salinity and was classified as non-saline. The rejects and 'potential rejects' samples produced slightly to moderately saline leachate.

The sulphate release rates throughout the leaching program ranged from a very low average 4.4 mg/kg per 'flush event' for the coal sample through to a moderate average 163 mg/kg per flush event for the H16 floor sample. The remaining three 'potential rejects' samples had much lower average sulphate release rates of 36, 68 and 90 mg/kg per flush event. The rejects sample had an average sulphate release rate of 150 mg/kg per flush event.

The column leaching results showed that none of the samples were acid forming throughout the 12-week leaching period or generated significant concentrations of salts or soluble metals/metalloids throughout the 12-week leaching period, suggesting that the materials represented by these samples likely have long lag times until the onset of AMD conditions.

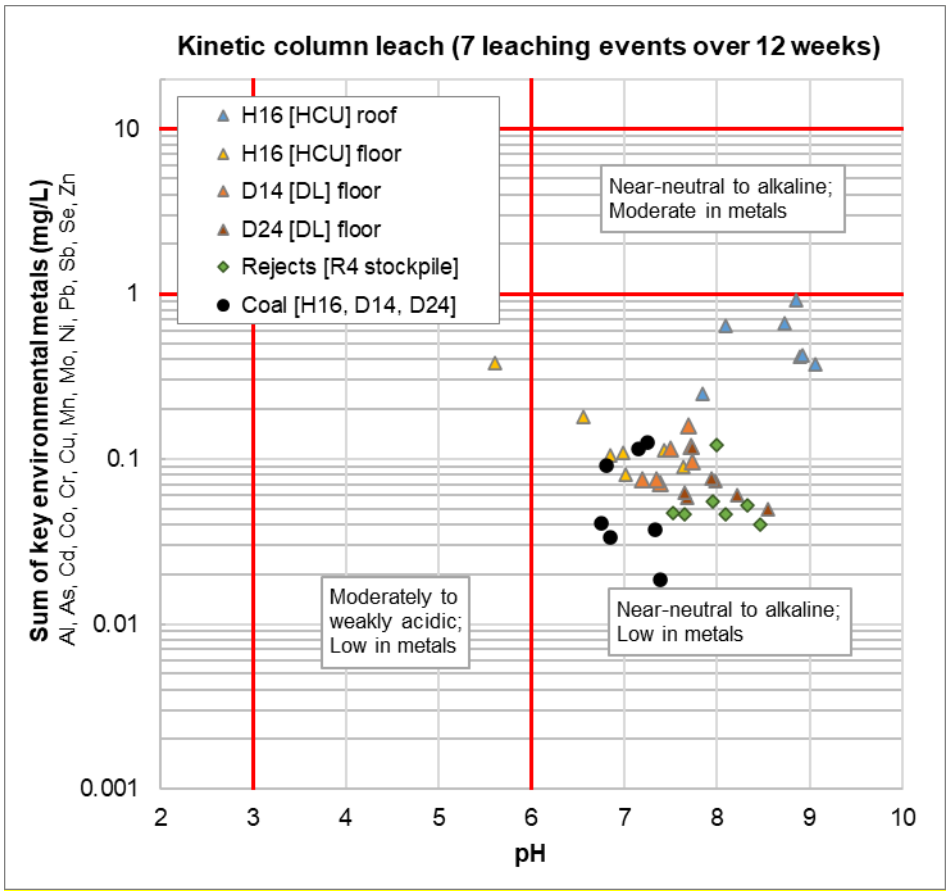


Figure 30. Sum of key environmental metals versus pH in kinetic column leachate solutions

5.10 OxCon Test-work

Data is available for OxCon test-work undertaken on five tailings samples, comprising two fresh (CHPP) tailings samples (one of which was a composite of three samples and the other a single discrete sample) and three 'moist to wet' aged tailings samples from TSF no. 3. Based on the static test-work alone (i.e. prior to the OxCon testing) the fresh (CHPP) samples were classified as NAF-S and the aged (TSF no. 3) samples were classified as PAF, UC(PAF) and PAF-LC.

The test-work – summarised in **Table 19** – found that the two fresh (CHPP) tailings samples were confirmed as NAF and are unlikely to generate AD or NMD (negligible risk) and posed a low risk of generating SD. The three aged (TSF no. 3) tailings samples were confirmed as PAF or PAF-LC and were found to pose a moderate risk of generating AD and a low risk of generating SD.

At the conclusion of the OxCon test, the solid underwent a bottle leaching procedure at a 1:2 solid:water ratio and the leachate was analysed to determine the pH, acidity/alkalinity and concentration of soluble metals/metalloids and salts. The sum of the concentration of 16 environmentally important elements are plotted as a function of pH from the post-OxCon leachate solution in **Figure 31**. The 16 selected metals/metalloids are the same elements as per the 1:5 deionised water leach, saline leach and peroxide leach.

As evident in **Figure 31** the two CHPP tailings samples have near-neutral to alkaline pH and low soluble metals concentrations. Comparatively, the three tailings samples from TSF no. 3 have moderately to weakly acidic pH and moderate soluble metals concentrations – primarily due to the low pH enhancing solubility.

Table 19. Summary of OxCon results for tailings samples

Sample ID	Source	Avg. O2 consumption rate (mmol O_2/kg/day)	Max. acidity generation rate (kg H_2SO_4/t/year)	Pyrite oxidation rate (wt.% pyrite/year)	Longevity of sulphide oxidation (years)	Lag time until ANC consumed (years)	Peak net acidity generation rate (kg H_2SO_4/t/year)
SRM C1	CHPP	0.29	5.5	24.0	15	n/a	<0.1
SRM_Tail 09/12/2020	CHPP	0.26	5.0	14.3	27	n/a	<0.1
TSF3 CPT07 14-14.5m	TSF 3	0.46	8.8	40.4	10	~ 3	3.1
TSF3 CPT07 16-16.5m	TSF 3	0.78	15.0	74.2	6	~ 1	7.5
TSF3 CPT07 18.5-19m	TSF 3	0.90	17.2	93.7	5	~ 2	4.1

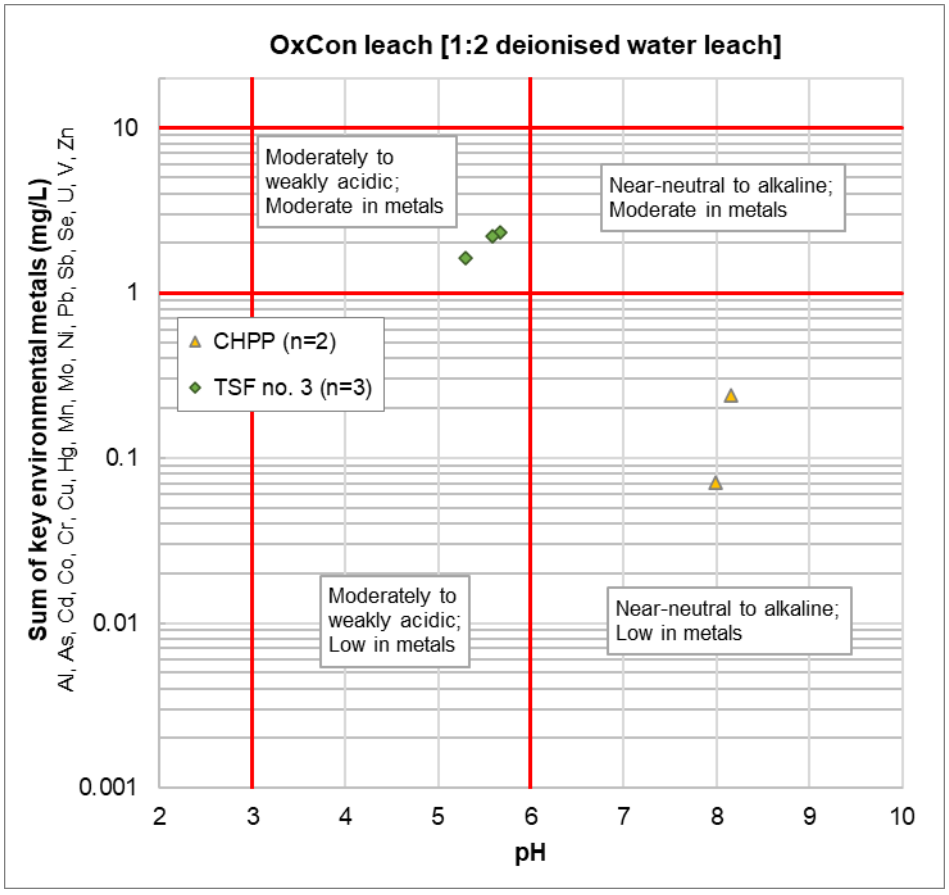


Figure 31. Sum of key environmental metals versus pH in OxCon leachate solution

6 Discussion

The geochemical characteristics of overburden/interburden (potential spoil), tailings and coarse reject from SRM have been assessed – as have the characteristics of coal samples that may report as ROM coal or as waste to the spoil dumps. The assessment was undertaken to understand the environmental geochemical characteristics of these samples, as being representative of their respective mineral waste types.

Spoil comprises the significant majority (approximately 97%) of mineral waste at SRM and will continue to do so for the expected life of the operation. Combined tailings and rejects (comprised of approximately 70% rejects and 30% tailings), will comprise the remaining 3% (approximately) of all mineral waste over the life of the operation. Spoil is overwhelmingly comprised of non-carbonaceous material. Carbonaceous spoil (of which almost all is unweathered) comprises less than 5% of spoil.

6.1 AMD Potential of Mineral Waste and Coal Material Types

AMD Potential of Spoil – non-carbonaceous

Non-carbonaceous spoil, which comprises about 95% of spoil, is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage), which is typical for sedimentary materials in the Bowen Basin.

The total S concentration of non-carbonaceous spoil is generally low, with a 90th percentile total S concentration of 0.52%. As such, and combined with moderate to high ANC values (median 31 kg H_2SO_4/t), which is significantly higher than the MPA (median 1.8 kg H_2SO_4/t), approximately 86% of non-carbonaceous spoil samples tested (606 out of 706 samples) were classified as NAF, with a further 2% of samples classified as UC(NAF) or NAF-S. Eighty-eight out of 706 samples (12% of non-carbonaceous spoil samples) were classified as PAF, PAF-LC or UC(PAF). Almost all of the non-carbonaceous spoil samples classified as PAF, PAF-LC or UC(PAF) were closely associated with coal seams and could potentially end up as coarse reject if mined with ROM coal.

The test-work undertaken has demonstrated that the ANC for the non-carbonaceous spoil is generally expected to be about 30-70% available under field conditions, with iron-dolomite being the main carbonate mineral contributing to the acid buffering potential of the spoil. Overall, non-carbonaceous spoil has excess acid neutralising capacity and is expected to be bulk acid consuming.

Total metal and metalloid concentrations from 118 non-carbonaceous spoil samples tested are very low compared to average element abundance in soil in the earth's crust. Eleven samples assayed (out of 118 samples) had significant (GAI≥3) enrichment with respect to Be and 12 samples had significant enrichment with regard to S, which was consistent with the geochemical data. Almost all samples had minor enrichment (GAI=1 or 2) with respect to Be – which is typical for Bowen Basin sedimentary materials. Four (out of 118) samples had significant enrichment with regard to As and Hg and one of these four samples also had significant enrichment with regard to Ba and Se. There was no correlation found between AMD classifications of the non-carbonaceous spoil samples compared to elemental enrichment. In summary, non-carbonaceous spoil (as a bulk material) has low enrichment in total metals and metalloids compared to unmineralised rocks.

Soluble multi-element results (from 71 samples) indicate that leachate from non-carbonaceous spoil is expected to contain low concentrations of soluble metals and metalloids. Five samples – mostly all classified as PAF (of some type) – produced moderate soluble metal concentrations, having slightly elevated soluble concentrations in the leachate for one or more of the following elements: Al, Fe, Co, Mn, Ni and/or Zn. Peroxide leaching undertaken on eight non-carbonaceous spoil samples showed that PAF material has the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

Based on the results, non-carbonaceous spoil – which comprises the large majority of spoil – has a low potential to generate AMD as either AD and/or NMD and/or SD. A small proportion of non-carbonaceous spoil does have a higher potential to generate AMD, however when mixed and distributed amongst the broader spoil material the overall potential for non-carbonaceous spoil to generate AMD is low.

AMD Potential of Spoil – carbonaceous

Carbonaceous spoil represents less than 5% of spoil material at SRM and – as a bulk material – is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage), similar to non-carbonaceous spoil.

The total S concentration of carbonaceous spoil is low-moderate, with a 90th percentile total S concentration of 0.99% (from 97 samples). Three samples had moderate total S (and Scr) concentrations and seven samples had high total S concentrations (S > 1.5%). Combined with generally low ANC values (median 16 kg H_2SO_4/t) and relatively low MPA values (median 7.0 kg H_2SO_4/t), approximately 73% of carbonaceous spoil samples (71 out of 97 samples) were classified as NAF, one sample was classified as UC(NAF) and one sample was classified as NAF-S. Approximately 25% of carbonaceous spoil samples (24 out of 97 samples) were classified as PAF, PAF-LC or UC(PAF). Almost all of the carbonaceous spoil samples classified as PAF, PAF-LC or UC(PAF) were closely associated with coal seams and could potentially end up as coarse reject if mined with ROM coal.

ABCC data is only available for two carbonaceous spoil samples, which shows that ANC in these samples is expected to be about 13% to 42% available under field conditions, with iron-dolomite being the main carbonate mineral contributing to the acid buffering potential of the spoil. Overall, carbonaceous spoil has relatively limited acid neutralising capacity.

Total metal and metalloid concentrations from 10 carbonaceous spoil samples tested are very low compared to average element abundance in soil in the earth's crust, and very similar to the assay concentrations from non-carbonaceous spoil. Two samples assayed (out of 10 samples) had significant (GAI≥3) enrichment with respect to Ba. There was no correlation found between AMD classifications of the carbonaceous spoil samples compared to elemental enrichment. In summary, carbonaceous spoil has low enrichment in total metals and metalloids compared to unmineralised rocks.

Soluble multi-element results (from 15 samples) indicate that leachate from carbonaceous spoil is expected to contain low concentrations of soluble metals and metalloids – similar to the non-carbonaceous spoil samples. Peroxide leaching undertaken on one weathered carbonaceous spoil sample shows that this PAF sample has the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

Based on the results, carbonaceous spoil has a generally low potential to generate AD and/or NMD and/or SD. A small proportion of this material type – mostly associated with coal seams – has some potential to generate low-level AD and/or NMD and/or SD.

AMD Potential of Tailings

The geochemical characteristics differed between fresh tailings from the CHPP versus aged tailings from the older TSFs (TSF no. 2, TSF no. 3 and TSF no. 4) for different parameters – particularly total S (and, by inference, MPA), ANC and pH, however the overall geochemical (AMD) hazard posed by tailings from the two sources (fresh vs aged) was generally similar. As such, the discussion that follows only differentiates between the two tailings sources where the differences between the two sources was significant for some parameters and worthy of discussion. Else, the AMD potential of tailings are discussed as a bulk material.

Fresh (new) tailings – representative of tailings in Ramp 2/3 TSF – is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage). Comparatively, tailings from TSF no. 2, TSF no. 3 and TSF no. 4 (aged tailings) is likely to generate slightly lower pH contact water – typically in the range of near-neutral to alkaline, but some aged tailings could generate weakly acid contact water.

The total S concentration of fresh tailings is generally moderate, with median and 75th percentile total S concentrations of 1.25% and 1.52%. As such, fresh tailings samples produced moderate MPA values. Comparatively, aged tailings generally had low to low-moderate total S concentrations, with median and 75th percentile total S concentrations of 0.42% and 0.49% - and produced correspondingly low to low-moderate MPA values. The reason for the higher total S concentrations in fresh (new) tailings compared to aged tailings is unclear. Potential processes that could account for a change in total S concentration between fresh CHPP tailings and aged TSF tailings are:

- Change in geochemistry of ROM coal being processed (i.e. ROM coal becoming more S-rich over time due to a change in the relative proportions of the various coal seams/plys being mined and processed);

- Addition of sulphate via salt precipitation within tailings during drying / evaporation of slurry water (liquor) [laboratory bias];
- Partial sulphur loss from aged tailings due to leaching of sulphate minerals, such as jarosite, alunite and/or gypsum.

In the fresh tailings samples about 70% (on average) of the total S is present as sulphide (Scr). Comparatively, only 34% (on average) of the total S is present as Scr in the aged tailings samples. The difference in the proportion of total S as Scr between fresh versus aged tailings is typical and expected – indicating that the tailings in the TSF are being oxidised since deposition (sulphide oxidised to sulphate).

Just as there were significant differences between the total S concentrations in fresh (CHPP) versus aged (TSF) tailings, so too with the ANC values of fresh versus aged tailings. Fresh (CHPP) tailings had generally high ANC values (median 37 kg H_2SO_4/t) compared to aged (TSF) tailings, which had generally very low to low ANC values (median 6 kg H_2SO_4/t). The reason behind the lower ANC observed in aged tailings (compared to fresh tailings) is not well understood. It may be due to ANC being consumed via buffering of acidity generated by sulphide oxidation and/or sulphate leaching; and/or it could be related to inherent differences in the geochemical properties of the coal from earlier mining compared to recent mining.

In the fresh tailings samples, ANC is generally expected to be about 50-90% available under field conditions (median = 72% from 21 ABCC results), with iron-dolomite and dolomite as the main neutralising minerals contributing to the acid buffering of fresh tailings. No ABCC data was available for aged tailings.

As a bulk material, tailings (fresh and aged) have generally low negative to low positive NAPP values, with median NAPP values of 3.4 and 7.6 kg H_2SO_4/t for the fresh and aged tailings, respectively. Tailings – of both types – had a wide range of NAGpH values with 39% and 64% of fresh and aged tailings, respectively, having NAGpH values less than pH 4.5.

The above characteristics resulted in 44% of tailings samples being classified as NAF of some type. Overall, 55% of tailings samples were classified as PAF of some type – with 26% classified as PAF-LC, 22% classified as UC(PAF) [of which most were aged tailings] and the remaining 7% classified as PAF.

OxCon test-work undertaken by Earth Systems on five tailings samples found that the two fresh (CHPP) tailings samples – initially classified as NAF and NAF-S – had very low pyrite oxidation rates and, consequently, a low potential for AMD (confirming the NAF classifications). Comparatively, the three aged tailings samples – initially classified as PAF-LC, UC(PAF) and PAF – had much higher pyrite oxidation rates and posed a moderate risk of generating AD – confirming the general ‘PAF’ classification of these samples.

There is a level of uncertainty surrounding the AMD classification of 34% (about one-third) of the tailings samples and, as such, these samples have been tentatively classified as UC(NAF) or UC(PAF) based on comparing the data available for these samples with the results from similar tailings samples where more detailed geochemical test-work has been undertaken. Despite this potential shortcoming, the classification of the tailings samples is considered to be conservative and classifying 56% of the tailings samples as PAF (of some sort) is almost certainly an upper limit.

With few exceptions, the total metal and metalloid concentrations from 44 tailings samples tested are generally low compared to average element abundance in soil in the earth’s crust. About half of the fresh (CHPP) tailings samples were significantly enriched (GAI ≥3) with regard to S, which is consistent with the ABA data showing higher total S concentrations in fresh (CHPP) samples compared to aged (TSF) samples. About half of the tailings samples had minor enrichment (GAI = 1 or 2) with regard to Se and/or Be. There was no correlation found between AMD classifications of the tailings samples compared to elemental enrichment.

Solubility data indicates that leachate from tailings under freshwater (deionised water) leaching conditions is expected to contain low concentrations of soluble metals and metalloids – for most tailings materials. Some tailings samples produced moderately to weakly acidic leachate with moderate soluble metals and metalloid concentrations following a freshwater leach. Under saline leaching conditions, tailings produced low concentrations of soluble metals and metalloids.

Peroxide leaching undertaken on 28 tailings samples showed that when exposed to highly oxidising conditions a significant proportion of tailings can produce highly to weakly acidic leachate with moderate soluble metals and

metalloid concentrations. However, a significant proportion of tailings appeared to be influenced to some degree by the presence of organic acids, due to the samples' high organic carbon concentration. This likely accounts to some degree for the acidity and 'elevated' soluble metals and metalloid concentrations evident in these tailings. Nevertheless, PAF tailings [including tailings classified as UC(PAF)] have typically produced moderate soluble metals and metalloid concentrations from the freshwater and peroxide leaching tests, indicating that these PAF materials have the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

Based on the results, at least half of tailings has a moderate to high potential to generate AMD as either AD and/or NMD and/or SD, whereas the remaining half has a relatively low potential to generate AMD as either AD and/or NMD and/or SD. As such, as a bulk material, tailings has a moderate potential to generate AMD as either AD and/or NMD and/or SD.

AMD Potential of Rejects

Fresh rejects (from the CHPP) are expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage). Aged rejects (from the TSFs and Ramp 4 rejects area) has slightly lower pH compared to fresh rejects, and is expected to generate pH-alkaline contact water (run-off and seepage).

The total S concentration of rejects is generally low to low-moderate – higher in fresh (CHPP) rejects (median 0.72%) compared to aged rejects from the TSFs and Ramp 4 rejects area (median 0.47%). ANC data is generally only available for fresh (CHPP) rejects and is generally moderate ANC (median 26 kg H_2SO_4/t), which is only marginally higher than the MPA of these same samples (median 22 kg H_2SO_4/t). However, NAG data for fresh (CHPP) rejects samples shows that 78% of fresh rejects samples have NAGpH values greater than pH 4.5.

The above characteristics resulted in 87% of rejects samples being classified as NAF, NAF-S or UC(NAF) – of which most of the fresh (CHPP) samples were classified as NAF and most of the aged (TSF) samples were classified as UC(NAF). Ten 10 rejects samples were classified as 'PAF' to some degree.

The test-work demonstrated that the ANC for fresh (CHPP) rejects is generally expected to be about 30-100% available under field conditions (median = 50% from 16 ABCC results), with iron-dolomite and dolomite being the main carbonate mineral contributing to the acid buffering potential of the rejects. Overall, fresh (CHPP) rejects has excess acid neutralising capacity.

The total metal and metalloid concentrations from 17 fresh (CHPP) rejects samples are generally low compared to average element abundance in soil in the earth's crust, and the assay results are very similar to total metal and metalloid concentrations from tailings samples – i.e. about half of the fresh (CHPP) rejects samples were significantly enriched (GAI ≥3) with regard to S, which is consistent with the ABA data for these samples. About half of the fresh (CHPP) rejects samples had minor enrichment (GAI = 1 or 2) with regard to Se and/or Be. There was no correlation found between AMD classifications of the rejects samples compared to elemental enrichment.

Solubility data indicates that leachate from fresh (CHPP) rejects under freshwater (deionised water) and saline water leaching conditions is expected to contain low concentrations of soluble metals and metalloids.

Kinetic column leaching data obtained over a 12-week leaching period of one rejects sample (classified as PAF-LC) and four 'potential rejects' samples (classified as UC(PAF), PAF-LC or PAF) found that leachate from all samples remained pH circum-neutral to alkaline, with low sulphate release rates and low soluble metals and metalloid concentrations. These results suggest that these samples – should/if they eventually be shown to generate acid drainage – would be expected to have relatively long lag times until potential acid generation occurs.

Peroxide leaching undertaken on six rejects samples of mixed NAF to PAF classifications showed that all except one of the rejects samples (a NAF sample) produced moderately to weakly acidic leachate with moderate soluble metals and metalloid concentrations. At least one of the 'PAF' rejects samples appears to be influenced to some degree by the presence of organic acids, due to the samples' high organic carbon concentration. This may account – to some degree – for the acidity and 'elevated' soluble metals and metalloid concentrations evident in this sample – and potentially others where no extended boil NAG is available to confirm. Nevertheless, PAF rejects [including rejects classified as UC(PAF)] have typically produced moderate soluble metals and metalloid concentrations from the peroxide leaching tests, indicating that these PAF materials have the potential to generate low pH leachate (AD) with elevated sulphate and soluble metal and metalloid concentrations.

Based on the results, a small proportion of rejects has a moderate to high potential to generate AMD as either AD and/or NMD and/or SD, whereas bulk rejects has a relatively low to low-moderate potential to generate AMD as either AD and/or NMD and/or SD. As such, as a bulk material, rejects has a low-moderate potential to generate AMD as either AD and/or NMD and/or SD.

AMD Potential of Coal

Coal is not regarded as waste and ROM coal remains on-site for a relatively short period of time. However, some minor coal seams/plys will report directly as waste, and remnant coal (seams) will be exposed on the highwalls of residual voids at closure.

Coal represents about 8% of all lithological material at SRM (i.e. about 8% of the highwall meterage; refer to **Section 7.1.3**) and, assuming the large majority all of this will report as ROM coal, we can conservatively assume that coal will represent a very small proportion of mineral waste (i.e. 1-2% at the most). Most waste 'coal' will more than likely report as either coarse reject or tailings.

ROM coal, as a bulk material, is expected to generate pH-alkaline to highly alkaline contact water (run-off and seepage).

The total S concentration of coal is generally low to low-moderate, with a median and 90th percentile total S concentration of 0.43% and 1.15%, respectively. The total S distribution in the coal geochemical samples tested (n=223) is comparable to the total S distribution in the coal quality database samples (n=9070). Approximately 20% (median value) of the total S is present as sulphide (Scr), however the proportion of total S as sulphide (from 176 samples) ranges from just over 1% (almost no sulphide) to 84% (predominantly sulphide).

Coal samples have a wide range of ANC values from less than 0.5 to 160 kg H_2SO_4/t, however the median ANC is low (10 kg H_2SO_4/t) and the median MPA is similar to the ANC (13 kg H_2SO_4/t). As such, 57% of coal samples were classified as NAF with a further 5% classified as UC(NAF) and the remaining 38% of samples classified as PAF, PAF-LC or UC(PAF). Samples classified as PAF, PAF-LC or UC(PAF) were from all seam groups, however the Harrow Creek (upper and lower) and Dysart (upper and lower) seam groups currently and historically comprise the majority of coal mined at SRM.

There is a level of uncertainty surrounding the AMD classification of approximately 30 coal samples (about 14% of samples) and, as such, approximately two-thirds of these samples have been tentatively classified as UC(PAF) [and the remaining third classified as UC(NAF)] based on comparing the data available for these samples with the results from samples where extensive geochemical test-work has been undertaken. Despite this potential shortcoming, the classification of the samples is conservative and classifying approximately 38% of coal samples as PAF (to some degree) is almost certainly an upper limit. The generally low sulphur concentrations in coal samples indicate that the sulphate loads from sulphide oxidation would likely be low.

Assay data available for 19 coal samples show that the total metal and metalloid concentrations are generally low compared to average element abundance in soil in the earth's crust. Six (out of 19) coal samples were significantly enriched [GAI ≥3] with regard to one or more of Be and/or S. The level of S enrichment in these samples is consistent with the ABA data for these same samples. The enrichment in Be in a small number of samples is not cause for concern. Three of the same coal samples were also enriched with one or more of As, Hg and/or Se – again, such enrichment in a very small number of samples is not cause for concern.

Soluble multi-element results from 14 coal samples tested indicate that contact water (run-off and seepage) from coal is expected to contain low concentrations of soluble metals and metalloids. Peroxide leaching undertaken on seven PAF or PAF-LC coal samples showed five of the seven samples to be acid generating and producing leachate with moderate soluble metal and metalloid concentrations. One PAF-LC sample was pH-neutral, however generated moderate soluble metal and metalloid concentrations. Both of the NAF/NAF-S coal samples produced leachate with moderate soluble metal and metalloid concentrations. These results indicating that PAF coal is capable of generating AD and/or NMD and some NAF coal is capable of generating NMD.

Based on the results, and as a bulk material, ROM coal is assessed as having a moderate potential to generate AMD as either AD, NMD and/or SD. A small proportion of coal would have a moderate to high potential to generate AMD.

6.2 Salinity, Sodicity and Dispersion Potential of Mineral Waste and Coal Material types

Salinity, Sodicity and Dispersion Potential of Spoil – non-carbonaceous

Non-carbonaceous spoil has $EC_{1:5}$ values (from 1603 mostly fresh non-carbonaceous samples) ranging from a very low 44 µS/cm to a very high 6130 µS/cm, with median and 90th percentile $EC_{1:5}$ values of 587 and 1403 µS/cm, and has very low total S concentrations. On this basis, contact water (run-off and seepage) is expected to be generally slightly to moderately saline, mostly as a result of dissolution of geogenic salts more so than from sulphide oxidation (sulphate salinity).

Non-carbonaceous spoil samples (n=101) had modest CEC values and generally high ESP values, resulting in almost all samples being classified as 'strongly sodic' and the few remaining samples being classified as 'sodic'. Non-carbonaceous spoil is expected to be strongly sodic with potential for dispersion (based on the high sodicity values). A sub-set of these samples (n=60) also underwent Emerson aggregate class testing to directly measure dispersion, which found that about 17% of the samples displayed 'some dispersion'. The remaining bulk of the samples had Emerson aggregate class values suggesting the samples were non-dispersive.

Salinity, Sodicity and Dispersion Potential of Spoil – carbonaceous

Carbonaceous spoil has $EC_{1:5}$ values (from 225 samples, which were almost all fresh carbonaceous samples) ranging from 64 to 3220 µS/cm, with median and 90th percentile $EC_{1:5}$ values of 733 and 1559 µS/cm, and has generally low total S concentrations. On this basis, contact water (run-off and seepage) is expected to be similar to non-carbonaceous spoil. That is, generally slightly to moderately saline, mostly as a result of dissolution of geogenic salts more so than from sulphide oxidation (sulphate salinity).

Carbonaceous spoil samples (n=5) had similarly modest CEC and generally high ESP values comparable to non-carbonaceous samples, resulting in all samples being classified as 'strongly sodic'. As such, and based solely on the high sodicity values, carbonaceous spoil is expected to be strongly sodic with potential for dispersion. Five of these samples also underwent Emerson aggregate class testing to directly measure dispersion, which found that all of the five samples were non-dispersive – indicating that despite being strongly sodic, carbonaceous spoil is not expected to be highly dispersive.

Salinity Potential of Tailings

Tailings samples (n=295) have $EC_{1:5}$ values ranging from 70 to 3490 µS/cm, with median and 90th percentile $EC_{1:5}$ values of 540 and 1292 µS/cm, respectively. Fresh (CHPP) tailings samples (n=103) are generally slightly to moderately saline, whereas aged (TSF) tailings (n=192) have lower $EC_{1:5}$ values and are generally non-saline to slightly saline. Most fresh (CHPP) tailings have moderate total S concentrations, whereas most aged (TSF) tailings have low total S concentrations; therefore, based on the total S concentration from fresh tailings, the potential for SD (from sulphide oxidation) is moderate.

Salinity Potential of Rejects

Rejects samples (n=77) have $EC_{1:5}$ values ranging from 205 to 1340 µS/cm, with median and 90th percentile $EC_{1:5}$ values of 558 and 787 µS/cm, respectively. On this basis, contact water (run-off and seepage) from most rejects material is expected to be non-saline to slightly saline (<900 µS/cm). A very small number of rejects samples produced moderately saline leachate. Most rejects have low-moderate total S concentrations, therefore the potential for SD (from sulphide oxidation) is low to low-moderate.

Salinity Potential of Coal

Coal samples (n=163) have $EC_{1:5}$ values ranging from 16 to 3100 µS/cm, with median and 90th percentile $EC_{1:5}$ values of 256 and 1015 µS/cm, respectively, and has generally low to low-moderate total S concentrations. On this basis, contact water (run-off and seepage) from coal, as a bulk material, is expected to be non-saline to slightly saline, either as a result of dissolution of geogenic salts and/or from sulphide oxidation (sulphate salinity). A small number of coal samples produced moderately saline leachate.

7 Risk Assessment

7.1 Geochemical Source Hazard Assessment of Material Types

7.1.1 Spoil Landforms

There are four spoil landforms at SRM that will remain at closure:

- Jacaranda-Bauhinia;
- Coolibah-Dogwood;
- Ebony-Grevillea; and
- Hakea.

Each landform has a similar construction, comprising mined overburden and interburden disposed behind the active mining face to form a low-wall spoil dump. Rejects has been disposed into each spoil dump during operations, however approximately 90% of rejects (to date) is disposed at dedicated rejects disposal areas, with the remaining 10% co-disposed (widely distributed) throughout general spoil at each spoil dump. Rejects comprise approximately 2.4% of the mineral waste, with spoil comprising approximately 97%. Tailings/TSFs located within the Jacaranda-Bauhinia and Coolibah-Dogwood spoil landforms comprise less than 1% of the mineral waste within these spoil landforms. The general layout of the spoil landforms (and residual voids) at closure is shown in **Figure 32**, which shows that Jacaranda-Bauhinia and Ebony-Grevillea spoil landforms are much larger than Coolibah-Dogwood and Hakea spoil landforms. At closure, the current spoil dumps will be reshaped and seeded (refer to the PRC Plan for spoil dump rehabilitation details).

Apart from size and rejects disposal locations, the other key distinguishing difference between the four landforms is that Ramp 2/3 TSF will be buried beneath Jacaranda-Bauhinia spoil landform and Ramp 6 TSF, TSF no. 2 and TSF no. 4 will be buried beneath Coolibah-Dogwood spoil landform. The remaining two spoil landforms (Ebony-Grevillea and Hakea) have no current or historic TSFs within their footprint. The locations of the TSFs are shown on **Figure 32**. The volume of tailings within the TSFs are known (approximately) and the proportion that these TSFs comprise within their final landforms (relative to spoil and reject in the same landform) is taken into account in the assessment.

The source materials within the spoil dumps comprise weathered and fresh materials, with fresh materials representing the large majority of mineral waste. The proportion of fresh material to weathered material will increase slightly as mining progresses and the pits become deeper (thus mining more fresh material). The geochemical assessment has found that, from an environmental geochemical perspective, the geochemical differences between weathered and fresh materials are relatively minor. As such, the geochemical source hazard assessment has combined weathered and fresh materials, as appropriate. Furthermore, assuming all material is ‘fresh’ adds a degree of conservatism to the assessment, since fresh carbonaceous material poses a greater AMD hazard compared to weathered carbonaceous material.

The source hazard assessment methodology outlined in **Section 4.4.5** (AMD hazard scoring) and **Section 4.4.6** (AMD likelihood ranking) has been applied to the spoil, rejects and tailings materials (where rejects and tailings/TSFs will form part of a landform). Based on the coal geology database for SRM, carbonaceous spoil (overburden/interburden) comprises between 4% and 13% of all spoil within each landform (i.e. excluding the rejects and tailings components of each landform), with non-carbonaceous spoil comprising the remaining 87% to 96% (approximately) of all spoil. Assuming some fresh coal material currently assigned as ‘coal’ is not mined as ROM coal but remains as waste coal, the proportion of coaly and carbonaceous overburden in each landform is likely to be slightly higher. However, coal comprises approximately 7% of the stratigraphy at SRM, therefore if a very small amount of coal was to report as ‘waste’ the increase to the proportion of carbonaceous spoil would minimal.

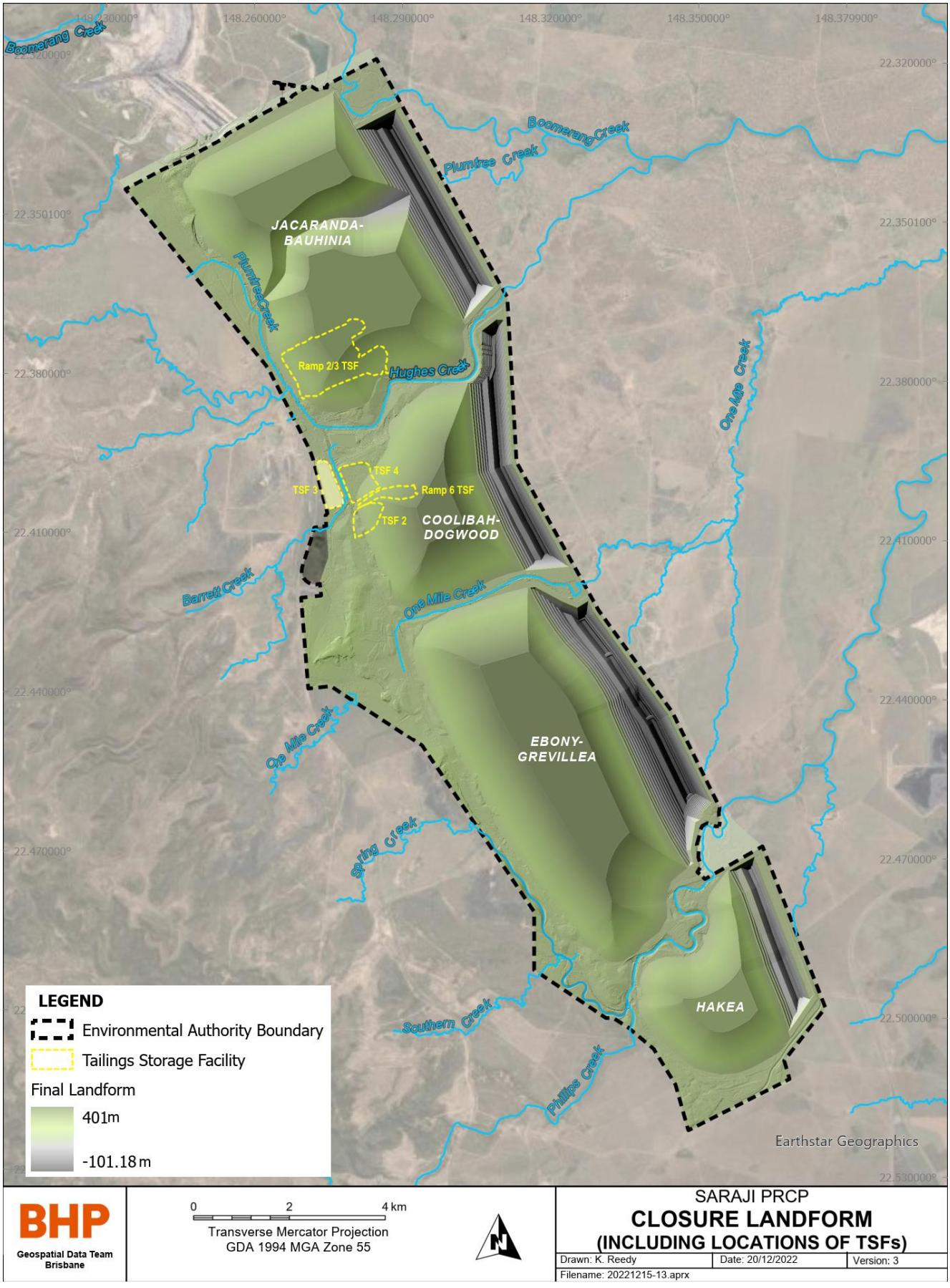


Figure 32. Closure landform

The total rejects volume to date plus the estimated reject volume for the remaining life of mine (i.e. total rejects producing for life of mine) is approximately 2.4% of the total spoil landform volume at closure. The exact disposal locations of all historic rejects is unclear and the exact disposal locations of future rejects is also unknown. Most (90% of) rejects in modern times have been disposed into specified rejects disposal areas at each spoil dump, with the remaining 10% of rejects more widely distributed throughout general spoil. However, whether similar rejects disposal practices occurred during the early years of mining is unknown. As such, the assessment assumes that rejects comprise 2.4% of each landform irrespective of whether any particular landform holds a greater or lesser proportion of rejects compared to another landform. Despite this potential shortcoming, differences in actual rejects proportions between the four spoil landforms (compared to the nominal '2.4%' proportion applied) would be expected to be relatively small – and negligible relative to the overall quantity of rejects compared to general spoil. As such, for the purposes of the geochemical source hazard assessment, assuming that each landform is comprised of 2.4% rejects is a reasonable assumption.

The source materials, and their approximate proportions within each spoil landform, based on geological, mining and coal processing information, comprise:

Jacaranda-Bauhinia

- Overburden/interburden – non-carbonaceous (84%);
- Overburden/interburden – coaly and carbonaceous [excluding potential ROM coal] (13%);
- Rejects (2.45%)
- Ramp 2/3 TSF [predominantly tailings, minor rejects] (0.9%)

Coolibah-Dogwood

- Overburden/interburden – non-carbonaceous (85%);
- Overburden/interburden – coaly and carbonaceous [excluding potential ROM coal] (12%);
- Rejects (2.4%)
- Ramp 6 TSF, TSF no. 2 and TSF no. 4 [predominantly tailings, minor rejects] (0.5%)

Ebony-Grevillea

- Overburden/interburden – non-carbonaceous (89%);
- Overburden/interburden – coaly and carbonaceous [excluding potential ROM coal] (9%);
- Rejects (2.4%)

Hakea

- Overburden/interburden – non-carbonaceous (93%);
- Overburden/interburden – coaly and carbonaceous [excluding potential ROM coal] (4.9%);
- Rejects (2.4%).

The source hazard assessment, summarised in **Table 20** for Jacaranda-Bauhinia landform, **Table 21** for Coolibah-Dogwood landform, **Table 22** for Ebony-Grevillea landform and **Table 23** for Hakea landform, has found that non-carbonaceous spoil poses a Low-Moderate AMD source hazard, carbonaceous/coaly spoil poses a Low-Moderate AMD source hazard, reject poses a Moderate AMD source hazard and tailings/TSFs within the landforms (where applicable) pose a Moderate-High AMD source hazard.

It is known that almost all of the PAF samples in overburden/interburden from drill-hole sampling were associated with seams as either roof, parting, floor or otherwise near-seam material (<1.5m above or below coal). As such, it is likely that a significant proportion of these materials types (represented by these PAF spoil samples) would be mined as part of ROM coal and would therefore end up as rejects instead of spoil. As such, the AMD hazard score for spoil materials in each landform is considered to be highly conservative and the final landform domain AMD hazard score also highly conservative.

On this basis, and taking into account material quantities (proportions):

- Jacaranda-Bauhinia spoil landform poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**. However, the intrinsic AMD hazard of Ramp 2/3 TSF, which will be contained (buried) within this spoil landform is rated moderate-high with the likelihood to generate AMD rated probable/likely. The AMD risk of the Ramp 2/3 TSF once incorporated within the Jacaranda-Bauhinia spoil landform is expected to decrease as the TSF is being dumped over and buried within the spoil landform.
- Coolibah-Dogwood spoil landform poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**. However, the intrinsic AMD hazard of TSF no. 2, TSF no. 4 and Ramp 6 TSF, which will be contained (buried) within this spoil landform is rated moderate-high with the likelihood to generate AMD rated probable/likely. The AMD risk of the TSFs once incorporated within the Coolibah-Dogwood spoil landform is expected to decrease as the TSFs are being dumped over and buried within the spoil landform.
- Ebony-Grevillea spoil landform poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**.
- Hakea spoil landform poses a **Low-Moderate** AMD hazard, with AMD generation rated as **Unlikely**.

7.1.2 TSF Landforms

TSF no. 3 will remain as a stand-alone landform at closure, and is located to the west of the current Northern Haul Road approximately 2 km north of the CHPP. TSF no. 3 is a ‘turkey’s nest’ style TSF with confining embankments on all sides of similar height (average 13 m); it operated from approximately 1981 to 1985.

This TSF has undergone rehabilitation and revegetation since decommissioning. Additional rehabilitation (maintenance and corrective actions) may be required at or prior to closure based on rehabilitation monitoring, however, the assumption is that the TSF will remain more-or-less ‘as is’ at closure and will not undergo significant rehabilitation works (e.g. not requiring additional significant capping or surface works).

The source materials within this facility includes tailings, which comprise approximately 81% of the landform, capped by a 2-3m spoil ‘cover’ (average 2.5 m cover thickness). The embankments are ‘earth fill’, with rock facing (rock armour) on the outer faces. TSF no. 3 has a total volume of approximately 4.5 Mm^3.

The source hazard assessment for the mineral wastes within TSF no. 3 landform has utilised the same general methodology as applied to the spoil landforms. The source hazard assessment has found the mixed spoil (cover) poses a Low AMD source hazard, and tailings within the TSF landforms pose a Moderate AMD source hazard. On this basis, and taking into account material quantities (proportions):

- TSF no. 3 landform poses a **Moderate** AMD hazard, with AMD generation rated as **Probable/Likely**. The hazard lies with the tailings, not the spoil cap/cover or embankments.

The AMD hazard score for the tailings materials is considered to be conservative and the landform domain AMD hazard score for TSF no. 3 is also considered to be conservative.

Table 20. AMD hazard scoring for source materials and likelihood for AMD generation from Jacaranda-Bauhinia final landform

Landform components	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity	AMD capacity rating	AMD quantity rating	AMD source hazard scoring	Landform domain AMD hazard score	Likelihood for AMD generation from Jacaranda-Bauhinia spoil landform
Non-carbonaceous spoil Distributed throughout	*84%*	*12%*	*10.0%*	Total S is low (75th percentile = 0.18%). NAF samples have a 75th percentile total S value of 0.12%, whereas PAF samples have a 75th percentile total S value of 1.12%. 75th percentile EC of non-carbonaceous spoil = 908 µS/cm. All PAF material is associated with seams - as parting or within 1.5m (typically) above and below seams. Non-carbonaceous spoil comprises approximately 84% of mineral waste in the landform. ANC is largely available under field conditions.	**5** Plausible	**3** Low-Moderate	**3** Low-Moderate	**8** Low-Moderate	**5.2** Low-Moderate	General spoil is overwhelmingly NAF with generally very low sulphur, excess neutralising capacity and low soluble metals concentration. Higher S materials are associated with seams. Essentially all PAF 'spoil' material is associated with seams - as parting or within 1.5m (typically) above and below seams and, as such, (and also due to seams being over-sampled) the percentage of 'PAF' spoil samples is not respresentative of the overall percentage of PAF in general spoil. The hazard for AMD generation in the landform is based on 2.4% of the landform being rejects, of which 13% is conservatively estimated to be PAF; and approximately 13% of the landform is carbonaceous spoil associated with coal seams, of which 23% is conservatively estimated to be PAF. Over half of the tailings at Ramp 2/3 TSF are PAF. The TSF comprises a very small (insignificant) proportion of the landform, however the tailings are concentrated in a small area. Therefore, there is an AMD risk associated with the buried tailings that must be considered. Overall, about 14% of the final landform is conservatively estimated to be either PAF, PAF-LC or UC(PAF) material, and almost all of this is associated with near-seam spoil (and in-seam spoil), rejects and tailings. All rejects, tailings and carbonaceous spoil is buried well within non-carbonaceous spoil. Tailings and rejects are concentrated at the base of the landform (i.e. buried deeply). The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 914 µS/cm. The hazard for AMD generation from Jacaranda-Bauhinia spoil landform at SRM is considered to be **LOW-MODERATE**. However, the AMD source hazard for buried tailings within Ramp 2/3 TSF is **MODERATE-HIGH**. The likelihood for AMD generation from the final Jacaranda-Bauhinia spoil landform at SRM is rated **UNLIKELY**. However, the likelihood for AMD generation from buried tailings within Ramp 2/3 TSF is **PROBABLE/LIKELY**.
Coaly and/or carbonaceous spoil Distributed throughout	*13%*	*23%*	*2.9%*	Up to 23% of coaly and carbonaceous spoil is conservatively classified as PAF, PAF-LC or UC(PAF). AMD capacity is based on a 75th percentile S value of 0.40%. NAF samples have a 75th percentile S value of 0.28%, whereas PAF samples have a 75th percentile S value of 2.26%. 75th percentile EC of carbonaceous spoil = 1080 µS/cm. AMD quantity conservatively assumes proportion of PAF carbonaceous spoil samples approximates the proportion of carbonaceous spoil that is PAF. Assumes all carbonaceous spoil is distributed amongst non-carbonaceous spoil.	**5** Plausible	**5** Moderate	**5** Moderate	**10** Low-Moderate		
Rejects Currently predominantly located at Ramps 0 to 4 within the spoil dump area. Future rejects assumed to be broadly distributed throughout landform.	*2.4%*	*13%*	*0.3%*	13% of rejects samples are conservatively classified as PAF, PAF-LC or UC(PAF). AMD capacity is based on a 75th percentile S value of 0.79%. 75th percentile EC of rejects = 633 µS/cm. Some rejects samples will generate AD. AMD quantity assumes proportion of PAF rejects samples approximates the proportion of rejects that are PAF. Rejects disposed within predominantly non-carbonaceous and NAF spoil.	**5** Plausible	**7** Moderate-High	**10** High	**14** Moderate		
Tailings Ramp 2/3 TSF at base of landform	*0.9%*	*55%*	*0.5%*	55% of all tailings are conservatively classified as PAF, PAF-LC or UC(PAF). Tailings comprise a very small proportion of the overall spoil landform (less than 1%) - however are concentrated in one area (Ramp 2/3 TSF). 75th percentile EC of tailings = 754 µS/cm. AMD capacity is based on a 75th percentile S value of 1.14%. Some tailings samples will generate AD. AMD quantity assumes proportion of PAF tailings samples approximates the proportion of tailings that are PAF. Tailings (TSF) will be buried by predominantly non-carbonaceous and NAF spoil.	**7** Expected	**10** High	**10** High	**17** Moderate-High		

Table 21. AMD hazard scoring for source materials and likelihood for AMD generation from Coolibah-Dogwood final landform

Landform components	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity	AMD capacity rating	AMD quantity rating	AMD source hazard scoring	Landform domain AMD hazard score	Likelihood for AMD generation from Coolibah-Dogwood spoil landform
Non-carbonaceous spoil Distributed throughout	*85%*	*12%*	*10.2%*	Total S is low (75th percentile = 0.18%). NAF samples have a 75th percentile total S value of 0.12%, whereas PAF samples have a 75th percentile total S value of 1.12%. 75th percentile EC of non-carbonaceous spoil = 908 µS/cm. All PAF material is associated with seams - as parting or within 1.5m (typically) above and below seams. Non-carbonaceous spoil comprises approximately 85% of mineral waste in the landform. ANC is largely available under field conditions.	**5** Plausible	**3** Low-Moderate	**3** Low-Moderate	**8** Low-Moderate	**5.4** Low-Moderate	General spoil is overwhelmingly NAF with generally very low sulphur, excess neutralising capacity and low soluble metals concentration. Higher S materials are associated with seams. Essentially all PAF 'spoil' material is associated with seams - as parting or within 1.5m (typically) above and below seams and, as such, (and also due to seams being over-sampled) the percentage of 'PAF' spoil samples is not respresentative of the overall percentage of PAF in general spoil. The hazard for AMD generation in the landform is based on 2.4% of the landform being rejects, of which 13% is conservatively estimated to be PAF; and approximately 12% of the landform is carbonaceous spoil associated with coal seams, of which 23% is conservatively estimated to be PAF. Tailings comprise less than 0.5% of the landform. Over half of the combined tailings at Ramp 6 TSF, TSF no. 2 and TSF no. 4 are expected to be PAF. Ramp 6 TSF and TSF no. 2 are very small. TSF no. 4 is small- to medium-sized. Combined, these TSFs comprise a very small (insignificant) proportion of the landform (less than 0.5%), however the tailings are concentrated in three small areas. Therefore, there is an AMD risk associated with the buried tailings that must be considered. Overall, about 13% of the final landform is conservatively estimated to be either PAF, PAF-LC or UC(PAF) material, and almost all of this is associated with near-seam spoil (and in-seam spoil), rejects and tailings. All rejects, tailings and carbonaceous spoil is buried well within non-carbonaceous spoil. Tailings and rejects are concentrated at the base of the landform (i.e. buried deeply). The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 914 µS/cm. The hazard for AMD generation from Coolibah-Dogwood spoil landform at SRM is considered to be **LOW-MODERATE**. However, the AMD source hazard for buried tailings within TSF no. 2, TSF no. 4 and Ramp 6 TSF is **MODERATE-HIGH**. The likelihood for AMD generation from the final Coolibah-Dogwood spoil landform at SRM is rated **UNLIKELY**. However, the likelihood for AMD generation from buried tailings within TSF no. 2, TSF no. 4 and Ramp 6 TSF is **PROBABLE/LIKELY**.
Coaly and/or carbonaceous spoil Distributed throughout	*12%*	*23%*	*2.6%*	Up to 23% of coaly and carbonaceous spoil is conservatively classified as PAF, PAF-LC or UC(PAF). AMD capacity is based on a 75th percentile S value of 0.40%. NAF samples have a 75th percentile S value of 0.28%, whereas PAF samples have a 75th percentile S value of 2.26%. 75th percentile EC of carbonaceous spoil = 1080 µS/cm. AMD quantity conservatively assumes proportion of PAF carbonaceous spoil samples approximates the proportion of carbonaceous spoil that is PAF. Assumes all carbonaceous spoil is distributed amongst non-carbonaceous spoil.	**5** Plausible	**5** Moderate	**5** Moderate	**10** Low-Moderate		
Reject Currently predominantly located at Ramps 5 to 8 within the spoil dump area. Future rejects assumed to be broadly distributed throughout landform.	*2.4%*	*13%*	*0.3%*	13% of rejects samples are conservatively classified as PAF, PAF-LC or UC(PAF). AMD capacity is based on a 75th percentile S value of 0.79%. 75th percentile EC of rejects = 633 µS/cm. Some rejects samples will generate AD. AMD quantity assumes proportion of PAF rejects samples approximates the proportion of rejects that are PAF. Rejects disposed within predominantly non-carbonaceous and NAF spoil.	**5** Plausible	**7** Moderate-High	**10** High	**14** Moderate		
Tailings Ramp 6 TSF, TSF no. 2 and TSF no. 4 - all at base of landform	*0.5%*	*55%*	*0.3%*	55% of all tailings are conservatively classified as PAF, PAF-LC or UC(PAF). Tailings comprise a very small proportion of the overall spoil landform (less than 0.5%) - however are concentrated in three areas (Ramp 6 TSF, TSF no. 2 and TSF no. 4). 75th percentile EC of tailings = 754 µS/cm. AMD capacity is based on a 75th percentile S value of 1.14%. Some tailings samples will generate AD. AMD quantity assumes proportion of PAF tailings samples approximates the proportion of tailings that are PAF. Tailings (TSFs) will be buried by predominantly non-carbonaceous and NAF spoil.	**7** Expected	**10** High	**10** High	**17** Moderate-High		

Table 22. AMD hazard scoring for source materials and likelihood for AMD generation from Ebony-Grevillea final landform

Landform components	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity	AMD capacity rating	AMD quantity rating	AMD source hazard scoring	Landform domain AMD hazard score	Likelihood for AMD generation from Ebony-Grevillea spoil landform
Non-carbonaceous spoil Distributed throughout	*89%*	*12%*	*11%*	Total S is low (75th percentile = 0.18%). NAF samples have a 75th percentile total S value of 0.12%, whereas PAF samples have a 75th percentile total S value of 1.12%. 75th percentile EC of non-carbonaceous spoil = 908 µS/cm. All PAF material is associated with seams - as parting or within 1.5m (typically) above and below seams. Non-carbonaceous spoil comprises approximately 89% of mineral waste in the landform. ANC is largely available under field conditions.	**5** Plausible	**3** Low-Moderate	**3** Low-Moderate	**8** Low-Moderate	**6.0** Low-Moderate	General spoil is overwhelmingly NAF with generally very low sulphur, excess neutralising capacity and low soluble metals concentration. Higher S materials are associated with seams. Essentially all PAF 'spoil' material is associated with seams - as parting or within 1.5m (typically) above and below seams and, as such, (and also due to seams being over-sampled) the percentage of 'PAF' spoil samples is not respresentative of the overall percentage of PAF in general spoil. The hazard for AMD generation in the landform is based on 2.4% of the landform being rejects, of which 13% is conservatively estimated to be PAF; and approximately 9% of the landform is carbonaceous spoil associated with coal seams, of which 23% is conservatively estimated to be PAF. Overall, about 13% of the final landform is conservatively estimated to be either PAF, PAF-LC or UC(PAF) material, and almost all of this is associated with near-seam spoil and rejects. All rejects and carbonaceous spoil is buried well within non-carbonaceous spoil. Rejects are mostly concentrated at the base of the landform (i.e. buried deeply). The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 909 µS/cm. The hazard for AMD generation from Ebony-Grevillea spoil landform at SRM is considered to be **LOW-MODERATE**. The likelihood for AMD generation from the final Ebony-Grevillea spoil landform at SRM is rated **UNLIKELY**.
Coaly and/or carbonaceous spoil Distributed throughout	*8.8%*	*23%*	*2.0%*	Up to 23% of coaly and carbonaceous spoil is conservatively classified as PAF, PAF-LC or UC(PAF). AMD capacity is based on a 75th percentile S value of 0.40%. NAF samples have a 75th percentile S value of 0.28%, whereas PAF samples have a 75th percentile S value of 2.26%. 75th percentile EC of carbonaceous spoil = 1080 µS/cm. AMD quantity conservatively assumes proportion of PAF carbonaceous spoil samples approximates the proportion of carbonaceous spoil that is PAF. Assumes all carbonaceous spoil is distributed amongst non-carbonaceous spoil.	**5** Plausible	**5** Moderate	**5** Moderate	**10** Low-Moderate		
Reject Currently predominantly located at Ramps 9 to 14 within the spoil dump area. Future rejects assumed to be broadly distributed throughout landform.	*2.4%*	*13%*	*0.3%*	13% of rejects samples are conservatively classified as PAF, PAF-LC or UC(PAF). AMD capacity is based on a 75th percentile S value of 0.79%. 75th percentile EC of rejects = 633 µS/cm. Some rejects samples will generate AD. AMD quantity assumes proportion of PAF rejects samples approximates the proportion of rejects that are PAF. Rejects disposed within predominantly non-carbonaceous and NAF spoil.	**5** Plausible	**7** Moderate-High	**10** High	**14** Moderate		
Tailings No tailings disposed into Ebony-Grevillea landform	*0%*	*0%*	*0%*	No tailings disposed into Ebony-Grevillea landform	**n/a**	**n/a**	**n/a**	**n/a**		

Table 23. AMD hazard scoring for source materials and likelihood for AMD generation from Hakea final landform

Landform components	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity	AMD capacity rating	AMD quantity rating	AMD source hazard scoring	Landform domain AMD hazard score	Likelihood for AMD generation from Hakea spoil landform
Non-carbonaceous spoil Distributed throughout	*93%*	*12%*	*11%*	Total S is low (75th percentile = 0.18%). NAF samples have a 75th percentile total S value of 0.12%, whereas PAF samples have a 75th percentile total S value of 1.12%. 75th percentile EC of non-carbonaceous spoil = 908 µS/cm. All PAF material is associated with seams - as parting or within 1.5m (typically) above and below seams. Non-carbonaceous spoil comprises approximately 93% of mineral waste in the landform. ANC is largely available under field conditions.	**5** Plausible	**3** Low-Moderate	**3** Low-Moderate	**8** Low-Moderate	**6.6** Low-Moderate	General spoil is overwhelmingly NAF with generally very low sulphur, excess neutralising capacity and low soluble metals concentration. Higher S materials are associated with seams. Essentially all PAF 'spoil' material is associated with seams - as parting or within 1.5m (typically) above and below seams and, as such, (and also due to seams being over-sampled) the percentage of 'PAF' spoil samples is not respresentative of the overall percentage of PAF in general spoil. The hazard for AMD generation in the landform is based on 2.4% of the landform being rejects, of which 13% is conservatively estimated to be PAF; and approximately 5% of the landform is carbonaceous spoil associated with coal seams, of which 23% is conservatively estimated to be PAF. Overall, about 12% of the final landform is conservatively estimated to be either PAF, PAF-LC or UC(PAF) material, and almost all of this is associated with near-seam spoil (and in-seam spoil) and rejects. All rejects and carbonaceous spoil is buried well within non-carbonaceous spoil. Rejects are mostly concentrated at the base of the landform (i.e. buried deeply). The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 902 µS/cm. The hazard for AMD generation from Hakea spoil landform at SRM is considered to be **LOW-MODERATE**. The likelihood for AMD generation from the final Hakea spoil landform at SRM is rated **UNLIKELY**.
Coaly and/or carbonaceous spoil Distributed throughout	*4.9%*	*23%*	*1.1%*	Up to 23% of coaly and carbonaceous spoil is conservatively classified as PAF, PAF-LC or UC(PAF). AMD capacity is based on a 75th percentile S value of 0.40%. NAF samples have a 75th percentile S value of 0.28%, whereas PAF samples have a 75th percentile S value of 2.26%. 75th percentile EC of carbonaceous spoil = 1080 µS/cm. AMD quantity conservatively assumes proportion of PAF carbonaceous spoil samples approximates the proportion of carbonaceous spoil that is PAF. Assumes all carbonaceous spoil is distributed amongst non-carbonaceous spoil.	**5** Plausible	**5** Moderate	**5** Moderate	**10** Low-Moderate		
Reject Currently predominantly located at Ramp 15 and 16 within the spoil dump area. Future rejects assumed to be broadly distributed throughout landform.	*2.4%*	*13%*	*0.3%*	13% of rejects samples are conservatively classified as PAF, PAF-LC or UC(PAF). AMD capacity is based on a 75th percentile S value of 0.79%. 75th percentile EC of rejects = 633 µS/cm. Some rejects samples will generate AD. AMD quantity assumes proportion of PAF rejects samples approximates the proportion of rejects that are PAF. Rejects disposed within predominantly non-carbonaceous and NAF spoil.	**5** Plausible	**7** Moderate-High	**10** High	**14** Moderate		
Tailings No tailings disposed into Hakea landform	*0%*	*0%*	*0%*	No tailings disposed into Hakea landform	**n/a**	**n/a**	**n/a**	**n/a**		

Table 24. AMD hazard scoring for source materials and likelihood for AMD generation from TSF no. 3 landform

TSF no. 3: Landform components	Estimated material proportion within landform	% of samples classified as PAF	% of material in landform estimated to be PAF	Comment	AMD propensity	AMD capacity rating	AMD quantity rating	AMD source hazard scoring	Landform domain AMD hazard score	Likelihood for AMD generation from TSF no. 3 landform
Cover material (general spoil)	*19%*	*0%*	*0.0%*	Based on data from 31 cover samples from TSF no. 3: Total S is very low (75th percentile = 0.03%). All samples classified as NAF. Cover material comprises approximately 19% of the mineral waste in the landform, and all situated at the top of the landform. Assuming the cover material is comprised of general spoil, it is reasonably assumed that ANC is largely available under field conditions.	**1** Implausible	**1** Low	**1** Low	**2** Low	**13** Moderate	Cover material (general spoil) is all NAF with very low sulphur, excess neutralising capacity and low soluble metals concentration. The hazard for AMD generation in the landform is based on the majority (81%) of the landform being tailings of which 79% is conservatively estimated to be PAF. Of the 'PAF' samples, 92% are UC(PAF) or PAF-LC and, as such, are considered to have a relatively moderate capacity to generate significant acidity. Overall, about 64% of the TSF no. 3 landform is conservatively estimated to be either PAF, PAF-LC or UC(PAF) material - all of which is tailings. The 75th percentile EC of the landform (based on the EC of the source materials proportionally represented) is estimated at 787 µS/cm. The hazard for AMD generation from TSF no. 3 landform at SRM is conservatively considered to be **MODERATE**. The likelihood for AMD generation from TSF no. 3 landform at SRM is conservatively rated **PROBABLE/LIKELY**.
Tailings	*81%*	*79%*	*64%*	Based on data from 94 tailings samples from TSF no. 3: Up to 79% of tailings from TSF 3 are conservatively classified as PAF, PAF-LC or UC(PAF). AMD capacity is based on a 75th percentile S value of 0.57% for all TSF no. 3 tailings. NAF samples have a low 75th percentile S value of 0.38%. PAF samples have a low-moderate 75th percentile S value of 0.63%. Conservatively assumes proportion of PAF tailings samples approximates the proportion of tailings in TSF no. 3 that are PAF. Assumes equal distribution of PAF/NAF tailings throughout the TSF.	**7** Expected	**7** Moderate-High	**10** High	**16** Moderate		

7.1.3 Residual Voids – Exposed Walls and Floor

There are four pits at SRM that will remain at closure as residual voids:

- Jacaranda-Bauhinia void approximately 4.3 km long; approximately 230 m deep (at closure);
- Coolibah-Dogwood void approximately 5.2 km long; approximately 200 m deep (at closure);
- Ebony-Grevillea void approximately 5.4 km long; approximately 250 m deep (at closure); and
- Hakea void approximately 3.4 km long; approximately 140 m deep (at closure).

Excluding the Hakea residual void, the floor of all residual voids at closure will be the Dysart Lower (DL) seam group, which is currently the floor of each pit. The floor of Hakea residual void at closure will be the Harrow Creek Upper (HCU) seam group (refer to the PRC Plan for spoil dump rehabilitation details). The current floor of the Hakea Pit is the Harrow Creek Lower (HCL) seam group.

Environmental geochemical data, coal quality data and drill-hole geological logs have been used to aid in the assessment of AMD risk associated with residual void highwalls and floors, as explained in **Sections 4.4.1** to **4.4.3**.

The source materials within the highwall and floor of each residual void comprise weathered and fresh materials, although fresh materials make up the large majority of exposure material. The depth of weathering is generally consistent across the site. Therefore, as mining progresses and pits become deeper, the proportion of fresh material to weathered material will increase – thus the highwall will have a greater proportion of fresh material to weathered material at end of mining.

The statistical distribution of residual void highwall materials and the proportion of exposed coal seam (groups) is shown in **Figure 33** for current Jacaranda-Bauhinia Pit, **Figure 34** for current Coolibah-Dogwood Pit, **Figure 35** for current Ebony-Grevillea Pit and **Figure 36** for current Hakea pit.

The residual void highwall AMD hazard assessment is based on data being representative of current and near-future mining (indicatively now to 10 years). The SRM coal resource model is used to estimate coal resources from current pit highwall through to the eastern extent of the mine (near the eastern ML boundary). The resource model indicates that – at closure – the proportion of coal versus non-coal in the highwall of all four voids is consistent with the current proportions on the pit highwalls. The model also shows that the proportion of each seam group is expected to be similar to current seam group proportions on the highwall of all voids. As such, the proportions of the various mineral waste types on the residual void highwall and floor (of all voids) is not expected to change significantly from those shown in the current pits. Therefore, the overall AMD hazard posed by the highwall and floor (of all residual voids) at end of mining is expected to be similar to that shown for the current pits.

Based on the information from the coal geology database, all current pit highwalls are dominated by weathered and fresh non-carbonaceous materials. Ebony-Grevillea pit has a much lower proportion of weathered non-carbonaceous material compared to the other pits and, as such, also has a much smaller proportion of weathered material overall compared to the other pits. The composition (proportions) of the seam groups exposed on the highwalls in the four pits are shown as the small pie chart in each of **Figures 33 to 36**. Harrow Creek seam (upper and lower combined) comprises approximately half of the exposed coal in Jacaranda-Bauhinia and Ebony-Grevillea pits, is almost not present in the database in Coolibah-Dogwood pit and comprises 92% of the coal/seams in Hakea pit. The proportion of Dysart seams (upper and lower combined) varies considerably, as does the presence of P seam. In Jacaranda-Bauhinia pit, P seam comprises about 25% of the exposed coal, and about 13% and 8% of exposed coal in Ebony-Grevillea and Hakea pits. Overall, remnant coal (seams) are expected to comprise about 6% to 9% of the highwalls in the residual voids.

Note that the source hazard assessment methodology outlined in **Sections 4.4.1** to **4.4.6** has been applied to the materials expected to be exposed on the pit highwalls and floor at closure.

The residual void highwall and floor assessment, summarised in **Table 25** for Jacaranda-Bauhinia void, **Table 26** for Coolibah-Dogwood void, **Table 27** for Ebony-Grevillea void and **Table 28** for Hakea void, show that approximately 15% to 16% of the void highwall and approximately 37% to 44% of the void floor – for all voids – is estimated to be PAF, which includes material classified as UC(PAF) and PAF-LC. As such, the assessment has found that AMD generation from the void highwalls is **Unlikely**, however AMD generation from the void floors is **Probable/Likely** until such time that the floors become submerged by groundwater (post-closure).

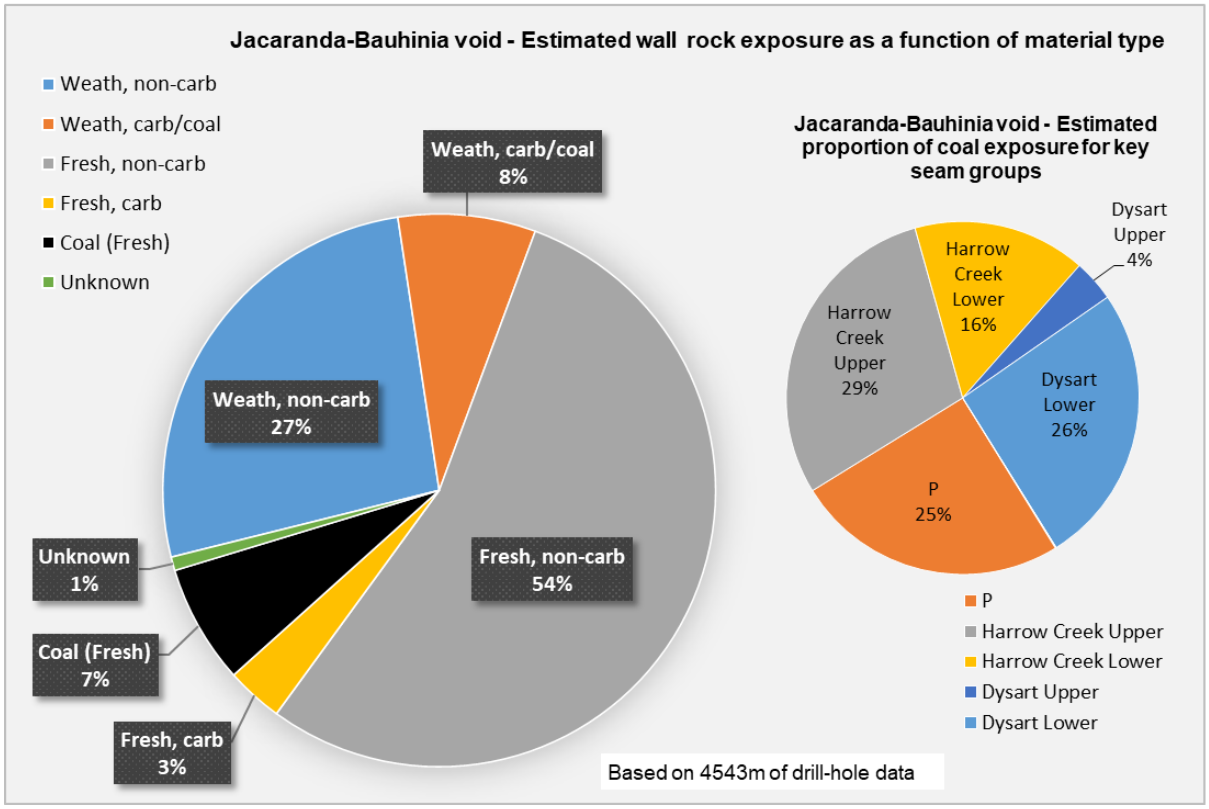


Figure 33. Estimated Jacaranda-Bauhinia residual void highwall exposure by material type and proportion of coal exposure

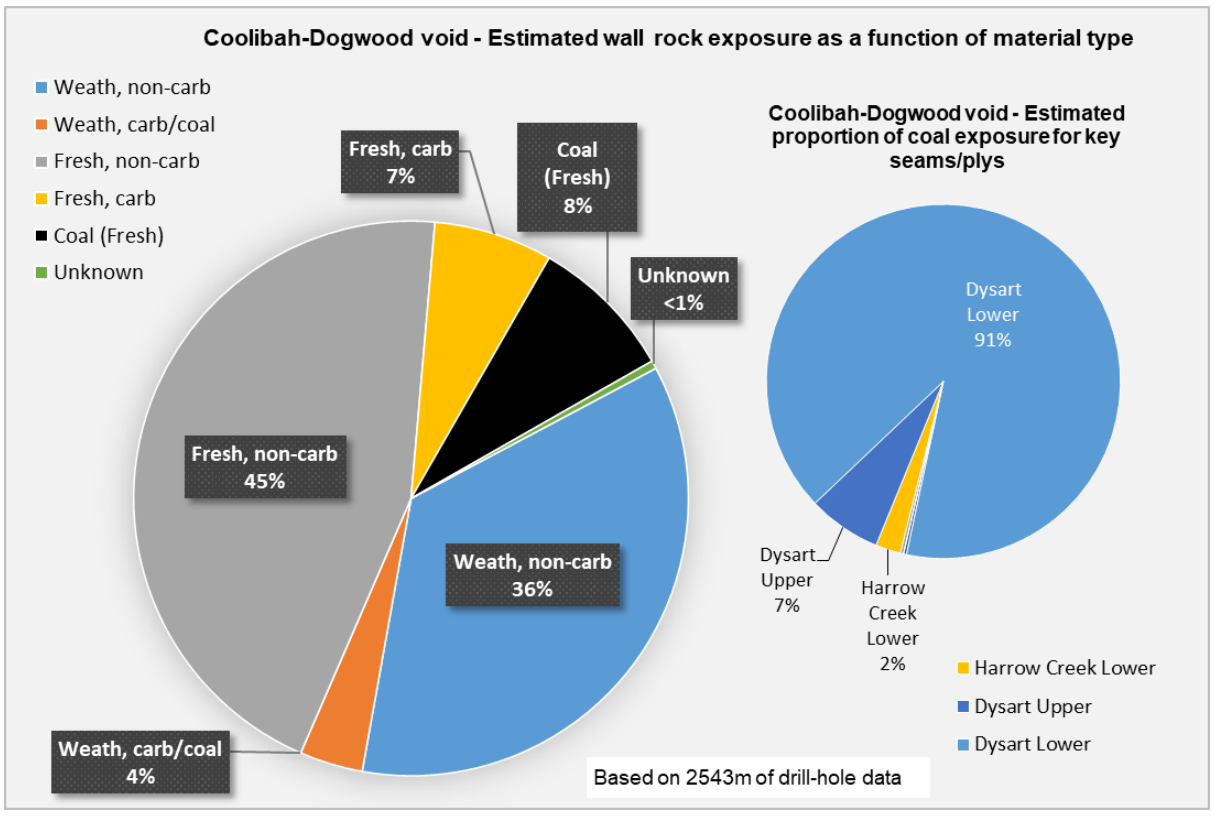


Figure 34. Estimated Coolibah-Dogwood residual void highwall exposure by material type and proportion of coal exposure

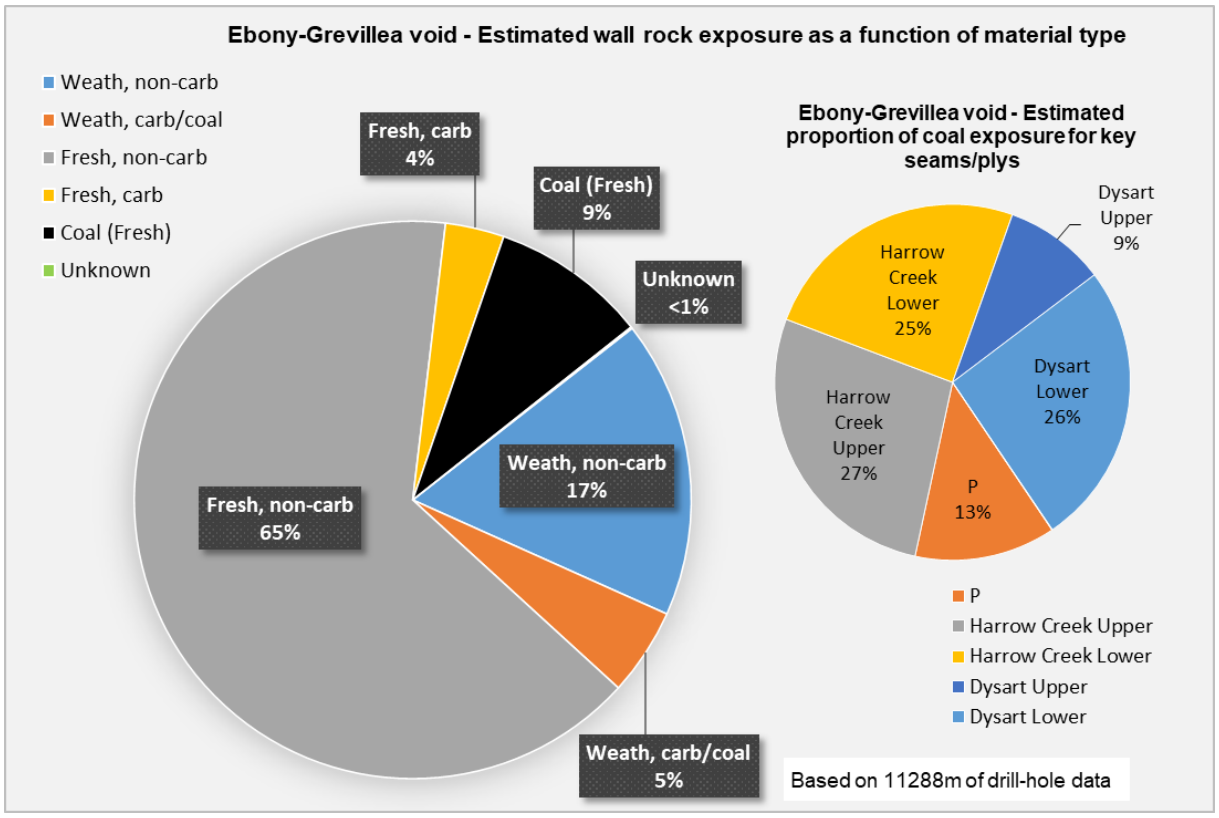


Figure 35. Estimated Ebony-Grevillea residual void highwall exposure by material type and proportion of coal exposure

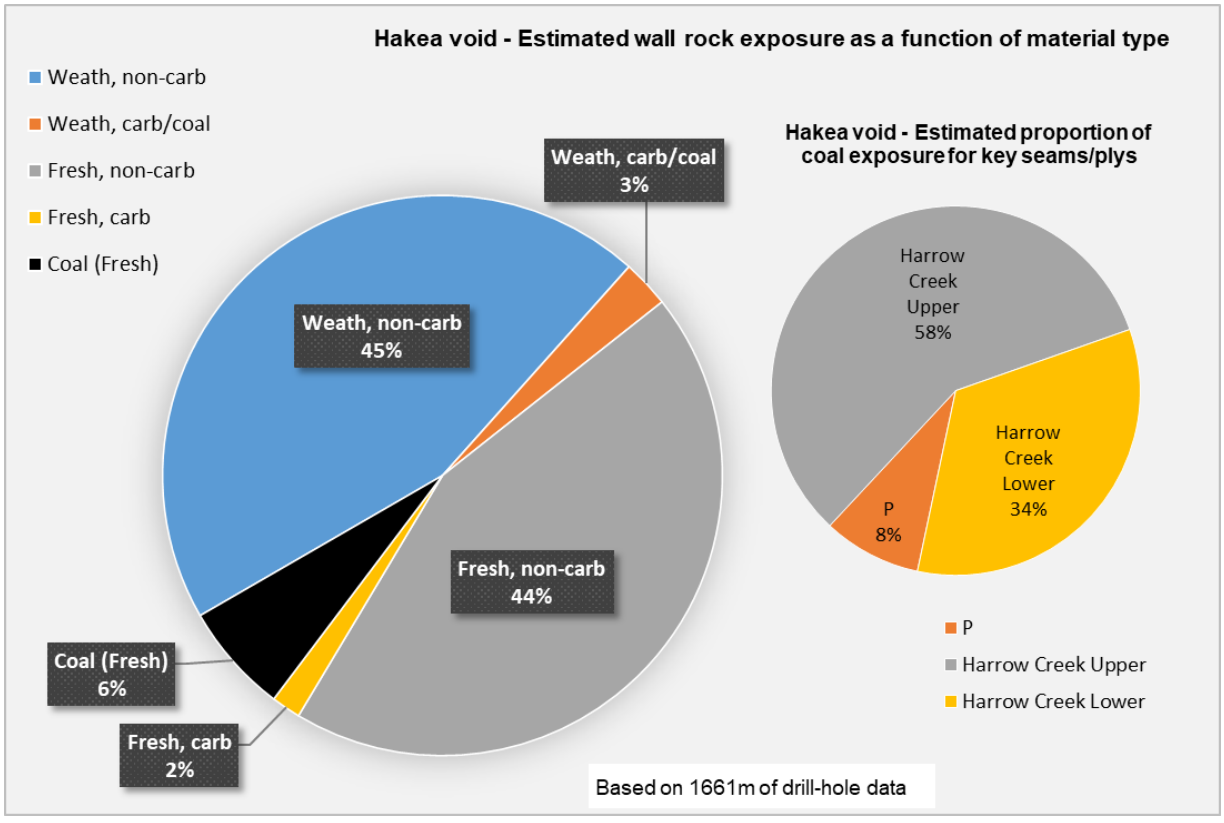


Figure 36. Estimated Hakea residual void highwall exposure by material type and proportion of coal exposure

Table 25. AMD hazard scoring for source materials and likelihood for AMD generation from Jacaranda-Bauhinia residual void walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table	Below current water table	Proportion of drill-hole meterage (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on highwall	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	AMD Source Material Hazard Score	Likelihood for AMD generation from Jacaranda-Bauhinia void highwall
Jacaranda-Bauhinia Void Highwall	Weathered, non-carbonaceous	*27%*	*76% (where known)*	*5.2% (where known)*	*0%*	*13%*	Approximately 13% of weathered non-carbonaceous samples (14 samples out of 108) were UC(PAF), PAF-LC or PAF [mostly PAF-LC] (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF.	*3.5%*	This material is expected to comprise approximately 27% of the pit wall material by meterage. All weathered material. Assumed to be non-mineralised, with very low concentrations of reactive sulphide minerals. Small proportion of samples may be PAF (if so, likely low capacity). The potential for AMD from acid sulphate minerals (e.g. jarosite) is very low or negligible. Likely source of ANC. The 75th percentile total S value is 0.05%.	1	1	1	**2**	Fresh in-situ non-carbonaceous rock is expected to have excess acid neutralising capacity, which should be sufficient to buffer AMD released from potential AMD sources exposed on the highwall, if any. The potential exposure of PAF materials on the highwall is estimated to represent approximately 15% (vertical meterage). PAF domains are expected to be largely confined to coal horizons/seams. However, these will be embededd in a matrix of NAF and ANC-rich materials. Pit wall run-off reporting to the residual void is unlikely to produce acidity. The hazard for AMD generation from Jacaranda-Bauhinia void highwall = **LOW**. The likelihood for AMD generation from Jacaranda-Bauhinia void highwall = **UNLIKELY**
	Weathered, carbonaceous & coaly	*8.0%*	*2.1% (where known)*	*0.4% (where known)*	*0%*	*22%*	Two out of 9 weathered carbonaceous or coaly samples were PAF-LC and PAF (data from geochemical database). It is expected that weathered material is completely or prodominantly oxidised and, as such, this material is predominantly NAF or would pose a low AMD hazard. Little information is available for where this material lies with respect to the water table.	*1.8%*	This material is expected to comprise approximately 8% of the pit wall material by meterage. Two (out of 9) samples were PAF, and do not contain significant sulphide minerals. PAF materials likely to be low capacity (i.e. PAF-LC). The potential for AMD from acid sulphate salts is low. The 75th percentile total S value is 0.50%.	5	3	1	**7**	
	Fresh, non-carbonaceous	*54%*	*23% (where known)*	*62% (where known)*	*54%*	*12%*	Approximately 12% of fresh, non-carbonaceous samples were PAF (data from geochemical database) [84 out of 716 samples]. Water table depths are not available for some highwall drillholes, however where known, approximately 23% of this material is currently above the water table and would be potentially subject to oxidation.	*6.5%*	This material is estimated to comprise approximately 54% of the pit wall material by meterage. Overall, fresh, non-carbonaceous spoil is overwhelmingly NAF with excess ANC. This material is likely to be an important source of ANC. 12% of samples were PAF (of some type), and all were closely associated with coal seams (as roof, parting or floor). This material horizon is overwhelmingly NAF. The 75th percentile total S value for this material is 0.21%. 75th percentile total value for NAF and PAF samples is 0.12% and 1.12%, respectively.	5	10	1	**11**	
	Fresh, carbonaceous	*3.3%*	*16% (where known)*	*70% (where known)*	*3%*	*23%*	23 out of 101 samples (23% of samples) were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 16% of this material is currently above the water table and would be potentially subject to oxidation.	*0.8%*	Generation of AMD from fresh carbonaceous units cannot be excluded as 23% of the samples tested were classed as PAF. However, this material is estimated to comprise approximately 3% of the pit wall material. Some carbonaceous overburden has excess ANC. The 75th percentile value for S in all carbonaceous samples is 0.39% and in PAF samples is 2.26% (23 PAF samples out of 101 samples in geochemical database).	5	10	1	**11**	
	Coal (fresh)	*7.1%*	*16% (where known)*	*68% (where known)*	*7%*	*38%*	86 out of 225 samples (7% of samples) were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 16% of this material is currently above the water table and would be potentially subject to oxidation.	*2.7%*	Fresh coal is expected to comprise about 7% of the pit wall material by meterage. Geochemical data is available for 225 coal samples sourced from across SRM seams. Of these, 23 samples were PAF and 63 were PAF-LC or UC(PAF) [i.e. 38% were PAF of some type]. The 75th percentile S value for PAF coal samples is 1.2%. The 75th percentile S value for all coal samples is low at 0.55%. With regard to the much larger coal quality database (n=9070 samples), the 75th percentile total S value is 0.65% - consistent with the smaller geochemical database. The dominant seams/plys exposed on the highwall are the P seam, HC and DY Upper and Lower seam groups.	5	10	1	***11***	
	Unknown	*0.8%*	*91%*	*9%*	*0%*	*0%*	Lithology unknown. All below base of weathering (ie. fresh)	*n/a*	Negligible proportion; all within weathered zone. Assume no PAF; and/or negligible.	1	1	1	***2***	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							15%						

Material domain	Material type	Proportion of exposure on pit floor % (assumed)	Above current water table	Below current water table	% Exposure (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on pit floor	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	Likelihood for AMD generation from exposed Jacaranda-Bauhinia void floor
Jacaranda-Bauhinia Void Floor	Coal: DY Lower seam	*100%*	*0%*	*100%*	*100%*	*44%*	PAF proportion estimated by applying a total S 'cut-off' of 0.58% to the coal quality data for DY Lower seam samples (4016 samples). The S cut-off was based on the median total S value for PAF coal and reject samples (combined) from the geochemical database. Based on the geochemical database, 38% of 225 coal samples were PAF, therefore the estimate of 44% of the pit floor being PAF (based on a Total S value of >0.58% as representing PAF material) is likely to be conservative. All pit floor is below the water table and would become submerged shortly after mining ceases.	*44%*	The floor of Jacaranda-Bauhinia void is likely to be DY Lower seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.62% (based on 4016 DY Lower samples in the coal quality database). Conservatively, 44% of DY Lower seam coal samples from SRM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from a significant proportion of the pit floor cannot be excluded - assuming the entire pit floor comprises purely coal material. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	5	7	7	**12**	Conservatively, approximately 44% of the pit floor may comprise PAF coal. The geochemical hazard for the void floor to develop AMD is moderate if the entire pit floor comprises purely coal material (unlikely) and if the coal floor remains exposed to air (unlikely). As such, the actual AMD hazard post-closure will likely be lower than indicated. Conservatively, the likelihood for AMD generation from exposed Jacaranda-Bauhinia void floor = **PROBABLE/LIKELY**

Table 26. AMD hazard scoring for source materials and likelihood for AMD generation from Coolibah-Dogwood residual void walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table	Below current water table	Proportion of drill-hole meterage (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on highwall	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	AMD Source Material Hazard Score	Likelihood for AMD generation from Coolibah-Dogwood void highwall
Coolibah-Dogwood void highwall	Weathered, non-carbonaceous	*36%*	*44% (where known)*	*0.2% (where known)*	*0%*	*13%*	Approximately 13% of weathered non-carbonaceous samples (14 samples out of 108) were UC(PAF), PAF-LC or PAF [mostly PAF-LC] (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF.	*4.7%*	This material is expected to comprise approximately 36% of the pit wall material by meterage. All weathered material. Assumed to be non-mineralised, with very low concentrations of reactive sulphide minerals. Small proportion of samples may be PAF (if so, likely low capacity). The potential for AMD from acid sulphate minerals (e.g. jarosite) is very low or negligible. Likely source of ANC. The 75th percentile total S value is 0.05%.	1	1	1	**2**	Fresh in-situ non-carbonaceous rock is expected to have excess acid neutralising capacity, which should be sufficient to buffer AMD released from potential AMD sources exposed on the highwall, if any. The potential exposure of PAF materials on the highwall is estimated to represent approximately 16% (vertical meterage). PAF domains are expected to be largely confined to coal horizons/seams. However, these will be embededd in a matrix of NAF and ANC-rich materials. Pit wall run-off reporting to the residual void is unlikely to produce acidity. The hazard for AMD generation from Coolibah-Dogwood void highwall = **LOW**. The likelihood for AMD generation from Coolibah-Dogwood void highwall = **UNLIKELY**
	Weathered, carbonaceous & coaly	*3.7%*	*5.7% (where known)*	*0% (where known)*	*0%*	*22%*	Two out of 9 weathered carbonaceous or coaly samples were PAF-LC and PAF (data from geochemical database). It is expected that weathered material is completely or prodominantly oxidised and, as such, this material is predominantly NAF or would pose a low AMD hazard. Little information is available for where this material lies with respect to the water table.	*0.8%*	This material is expected to comprise less than 4% of the pit wall material by meterage. Two (out of 9) samples were PAF, and do not contain significant sulphide minerals. PAF materials likely to be low capacity (i.e. PAF-LC). The potential for AMD from acid sulphate salts is low. The 75th percentile total S value is 0.50%.	5	3	1	**7**	
	Fresh, non-carbonaceous	*45%*	*29% (where known)*	*24% (where known)*	*45%*	*12%*	Approximately 12% of fresh, non-carbonaceous samples were PAF (data from geochemical database) [84 out of 716 samples]. Water table depths are not available for some highwall drillholes, however where known, approximately 29% of this material is currently above the water table and would be potentially subject to oxidation.	*5.4%*	This material is estimated to comprise approximately 45% of the pit wall material by meterage. Overall, fresh, non-carbonaceous spoil is overwhelmingly NAF with excess ANC. This material is likely to be an important source of ANC. 12% of samples were PAF (of some type), and all were closely associated with coal seams (as roof, parting or floor). This material horizon is overwhelmingly NAF. The 75th percentile total S value for this material is 0.21%. 75th percentile total value for NAF and PAF samples is 0.12% and 1.12%, respectively.	5	10	1	**11**	
	Fresh, carbonaceous	*6.9%*	*8% (where known)*	*41% (where known)*	*7%*	*23%*	23 out of 101 samples (23% of samples) were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 8% of this material is currently above the water table and would be potentially subject to oxidation.	*1.6%*	Generation of AMD from fresh carbonaceous units cannot be excluded as 23% of the samples tested were classed as PAF. However, some carbonaceous overburden has excess ANC. The 75th percentile value for S in all carbonaceous samples is 0.39% and in PAF samples is 2.26% (23 PAF samples out of 101 samples in geochemical database).	5	10	1	**11**	
	Coal (fresh)	*8.5%*	*1% (where known)*	*48% (where known)*	*9%*	*38%*	86 out of 225 samples (7% of samples) were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, only 1% of this material is currently above the water table and would be potentially subject to oxidation.	*3.2%*	Fresh coal is expected to comprise about 9% of the pit wall material by meterage. Geochemical data is available for 225 coal samples sourced from across SRM seams. Of these, 23 samples were PAF and 63 were PAF-LC or UC(PAF) [i.e. 38% were PAF of some type]. The 75th percentile S value for PAF coal samples is 1.2%. The 75th percentile S value for all coal samples is low at 0.55%. With regard to the much larger coal quality database (n=9070 samples), the 75th percentile total S value is 0.65% - consistent with the smaller geochemical database. The dominant seams/plys exposed on the highwall are the P seam, HC and DY Upper and Lower seam groups.	5	10	1	***11***	
	Unknown	*0.5%*	*99%*	*1%*	*1%*	*0%*	Lithology unknown. All above base of weathering (ie. fresh)	*0%*	Negligible proportion; all within weathered zone. Assume no PAF; and/or negligible.	1	1	1	***2***	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							16%						

Material domain	Material type	Proportion of exposure on pit floor % (assumed)	Above current water table	Below current water table	% Exposure (below base of weathering)	% of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on pit floor	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	Likelihood for AMD generation from exposed Coolibah-Dogwood void floor
Coolibah-Dogwood void floor	Coal: DY Lower seam	*100%*	*0%*	*100%*	*100%*	*44%*	PAF proportion estimated by applying a total S 'cut-off' of 0.58% to the coal quality data for DY Lower seam samples (4016 samples). The S cut-off was based on the median total S value for PAF coal and reject samples (combined) from the geochemical database. Based on the geochemical database, 38% of 225 coal samples were PAF, therefore the estimate of 44% of the pit floor being PAF (based on a Total S value of >0.58% as representing PAF material) is likely to be conservative. All pit floor is below the water table and would become submerged shortly after mining ceases.	*44%*	The floor of Coolibah-Dogwood void is likely to be DY Lower seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.62% (based on 4016 DY Lower samples in the coal quality database). Conservatively, 44% of DY Lower seam coal samples from SRM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from a significant proportion of the pit floor cannot be excluded - assuming the entire pit floor comprises purely coal material. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	5	7	7	**12**	Conservatively, approximately 44% of the pit floor may comprise PAF coal. The geochemical hazard for the void floor to develop AMD is moderate if the entire pit floor comprises purely coal material (unlikely) and if the coal floor remains exposed to air (unlikely). As such, the actual AMD hazard post-closure will likely be lower than indicated. Conservatively, the likelihood for AMD generation from exposed Coolibah-Dogwood void floor = **PROBABLE/LIKELY**

Table 27. AMD hazard scoring for source materials and likelihood for AMD generation from Ebony-Grevillea residual void walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table	Below current water table	Proportion of drill-hole meterage (below base of weathering)	%of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on highwall	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	AMD Source Material Hazard Score	Likelihood for AMD generation from Ebony-Grevillea void highwall
Ebony-Grevillea void highwall	Weathered, non-carbonaceous	*17%*	*67% (where known)*	*5.3% (where known)*	*0%*	*13%*	Approximately 13% of weathered non-carbonaceous samples (14 samples out of 108) were UC(PAF), PAF-LC or PAF [mostly PAF-LC] (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF.	*2.2%*	This material is expected to comprise approximately 17% of the pit wall material by meterage. All weathered material. Assumed to be non-mineralised, with very low concentrations of reactive sulphide minerals. Small proportion of samples may be PAF (if so, likely low capacity). The potential for AMD from acid sulphate minerals (e.g. jarosite) is very low or negligible. Likely source of ANC. The 75th percentile total S value is 0.05%.	1	1	1	**2**	Fresh in-situ non-carbonaceous rock is expected to have excess acid neutralising capacity, which should be sufficient to buffer AMD released from potential AMD sources exposed on the highwall, if any. The potential exposure of PAF materials on the highwall is estimated to represent approximately 15% (vertical meterage). PAF domains are expected to be largely confined to coal horizons/seams. However, these will be embededd in a matrix of NAF and ANC-rich materials. Pit wall run-off reporting to the residual void is unlikely to produce acidity. The hazard for AMD generation from Ebony-Grevillea void highwall = **LOW**. The likelihood for AMD generation from Ebony-Grevillea void highwall = **UNLIKELY**
	Weathered, carbonaceous & coaly	*5.1%*	*14% (where known)*	*71% (where known)*	*0%*	*22%*	Two out of 9 weathered carbonaceous or coaly samples were PAF-LC and PAF (data from geochemical database). It is expected that weathered material is completely or prodominantly oxidised and, as such, this material is predominantly NAF or would pose a low AMD hazard. Little information is available for where this material lies with respect to the water table.	*1.1%*	This material is expected to comprise approximately 5% of the pit wall material by meterage. Two (out of 9) samples were PAF, and do not contain significant sulphide minerals. PAF materials likely to be low capacity (i.e. PAF-LC). The potential for AMD from acid sulphate salts is low. The 75th percentile total S value is 0.50%.	5	3	1	**7**	
	Fresh, non-carbonaceous	*65%*	*9.6% (where known)*	*80% (where known)*	*65%*	*12%*	Approximately 12% of fresh, non-carbonaceous samples were PAF (data from geochemical database) [84 out of 716 samples]. Water table depths are not available for some highwall drillholes, however where known, less than 10% of this material is currently above the water table and would be potentially subject to oxidation.	*7.8%*	This material is estimated to comprise approximately 65% of the pit wall material by meterage. Overall, fresh, non-carbonaceous spoil is overwhelmingly NAF with excess ANC. This material is likely to be an important source of ANC. 12% of samples were PAF (of some type), and all were closely associated with coal seams (as roof, parting or floor). This material horizon is overwhelmingly NAF. The 75th percentile total S value for this material is 0.21%. 75th percentile total value for NAF and PAF samples is 0.12% and 1.12%, respectively.	5	10	1	**11**	
	Fresh, carbonaceous	*3.4%*	*11% (where known)*	*85% (where known)*	*3%*	*23%*	23 out of 101 samples (23% of samples) were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 11% of this material is currently above the water table and would be potentially subject to oxidation.	*0.8%*	Generation of AMD from fresh carbonaceous units cannot be excluded as 23% of the samples tested were classed as PAF. However, this material is estimated to comprise approximately 4% of the pit wall material. Some carbonaceous overburden has excess ANC. The 75th percentile value for S in all carbonaceous samples is 0.39% and in PAF samples is 2.26% (23 PAF samples out of 101 samples in geochemical database).	5	10	1	**11**	
	Coal (fresh)	*9.0%*	*7.8% (where known)*	*79% (where known)*	*9%*	*38%*	86 out of 225 samples (7% of samples) were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, less than 10% of this material is currently above the water table and would be potentially subject to oxidation.	*3.4%*	Fresh coal is expected to comprise about 9% of the pit wall material by meterage. Geochemical data is available for 225 coal samples sourced from across SRM seams. Of these, 23 samples were PAF and 63 were PAF-LC or UC(PAF) [i.e. 38% were PAF of some type]. The 75th percentile S value for PAF coal samples is 1.2%. The 75th percentile S value for all coal samples is low at 0.55%. With regard to the much larger coal quality database (n=9070 samples), the 75th percentile total S value is 0.65% - consistent with the smaller geochemical database. The dominant seams/plys exposed on the highwall are the P seam, HC and DY Upper and Lower seam groups.	5	10	1	***11***	
	Unknown	*0.1%*	*14%*	*67%*	*0.1%*	*0%*	Lithology unknown. All below base of weathering (ie. fresh)	*0%*	Negligible proportion; fresh, but mostly below water table; Assume negligible PAF.	1	1	1	***2***	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							15%						

Material domain	Material type	Proportion of exposure on pit floor % (assumed)	Above current water table	Below current water table	%Exposure (below base of weathering)	%of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on pit floor	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	Likelihood for AMD generation from exposed Ebony-Grevillea void floor	
Ebony-Grevillea void floor	Coal: DY Lower seam	*100%*	*0%*	*100%*	*100%*	*44%*	PAF proportion estimated by applying a total S 'cut-off' of 0.58% to the coal quality data for DY Lower seam samples (4016 samples). The S cut-off was based on the median total S value for PAF coal and reject samples (combined) from the geochemical database. Based on the geochemical database, 38% of 225 coal samples were PAF, therefore the estimate of 44% of the pit floor being PAF (based on a Total S value of >0.58% as representing PAF material) is likely to be conservative. All pit floor is below the water table and would become submerged shortly after mining ceases.	*44%*	The floor of Ebony-Grevillea void is likely to be DY Lower seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.62% (based on 4016 DY Lower samples in the coal quality database). Conservatively, 44% of DY Lower seam coal samples from SRM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from a significant proportion of the pit floor cannot be excluded - assuming the entire pit floor comprises purely coal material. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	5	7	7	**12**	Conservatively, approximately 44% of the pit floor may comprise PAF coal. The geochemical hazard for the void floor to develop AMD is moderate if the entire pit floor comprises purely coal material (unlikely) and if the coal floor remains exposed to air (unlikely). As such, the actual AMD hazard post-closure will likely be lower than indicated. Conservatively, the likelihood for AMD generation from exposed Ebony-Grevillea void floor = **PROBABLE/LIKELY**

Table 28. AMD hazard scoring for source materials and likelihood for AMD generation from Hakea residual void walls and floor

Material domain	Material type	Proportion of drill-hole meterage on highwall by material type %	Above current water table	Below current water table	Proportion of drill-hole meterage (below base of weathering)	%of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on highwall	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	AMD Source Material Hazard Score	Likelihood for AMD generation from Hakea void highwall
Hakea void highwall	Weathered, non-carbonaceous	*45%*	*83% (where known)*	*4.8% (where known)*	*0%*	*13%*	Approximately 13% of weathered non-carbonaceous samples (14 samples out of 108) were UC(PAF), PAF-LC or PAF [mostly PAF-LC] (data from geochemical database). It is expected that weathered material is completely or predominantly oxidised and, as such, this material is overwhelmingly NAF.	*5.8%*	This material is expected to comprise approximately 45% of the pit wall material by meterage. All weathered material. Assumed to be non-mineralised, with very low concentrations of reactive sulphide minerals. Small proportion of samples may be PAF (if so, likely low capacity). The potential for AMD from acid sulphate minerals (e.g. jarosite) is very low or negligible. Likely source of ANC. The 75th percentile total S value is 0.05%.	1	1	1	**2**	Fresh in-situ non-carbonaceous rock is expected to have excess acid neutralising capacity, which should be sufficient to buffer AMD released from potential AMD sources exposed on the highwall, if any. The potential exposure of PAF materials on the highwall is estimated to represent approximately 15% (vertical meterage). PAF domains are expected to be largely confined to coal horizons/seams. However, these will be embededd in a matrix of NAF and ANC-rich materials. Pit wall run-off reporting to the residual void is unlikely to produce acidity. The hazard for AMD generation from Hakea void highwall = **LOW**. The likelihood for AMD generation from Hakea void highwall = **UNLIKELY**
	Weathered, carbonaceous & coaly	*2.7%*	*65% (where known)*	*0% (where known)*	*0%*	*22%*	Two out of 9 weathered carbonaceous or coaly samples were PAF-LC and PAF (data from geochemical database). It is expected that weathered material is completely or prodominantly oxidised and, as such, this material is predominantly NAF or would pose a low AMD hazard. Little information is available for where this material lies with respect to the water table.	*0.6%*	This material is expected to comprise approximately 3% of the pit wall material by meterage. Two (out of 9) samples were PAF, and do not contain significant sulphide minerals. PAF materials likely to be low capacity (i.e. PAF-LC). The potential for AMD from acid sulphate salts is low. The 75th percentile total S value is 0.50%.	5	3	1	**7**	
	Fresh, non-carbonaceous	*44%*	*14% (where known)*	*83% (where known)*	*44%*	*12%*	Approximately 12% of fresh, non-carbonaceous samples were PAF (data from geochemical database) [84 out of 716 samples]. Water table depths are not available for some highwall drillholes, however where known, approximately 14% of this material is currently above the water table and would be potentially subject to oxidation.	*5.3%*	This material is estimated to comprise approximately 44% of the pit wall material by meterage. Overall, fresh, non-carbonaceous spoil is overwhelmingly NAF with excess ANC. This material is likely to be an important source of ANC. 12% of samples were PAF (of some type), and all were closely associated with coal seams (as roof, parting or floor). This material horizon is overwhelmingly NAF. The 75th percentile total S value for this material is 0.21%. 75th percentile total value for NAF and PAF samples is 0.12% and 1.12%, respectively.	5	10	1	**11**	
	Fresh, carbonaceous	*1.7%*	*8.0% (where known)*	*86% (where known)*	*1.7%*	*23%*	23 out of 101 samples (23% of samples) were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 8% of this material is currently above the water table and would be potentially subject to oxidation.	*0.4%*	Generation of AMD from fresh carbonaceous units cannot be excluded as 23% of the samples tested were classed as PAF. However, this material is estimated to comprise approximately 2% of the pit wall material. Some carbonaceous overburden has excess ANC. The 75th percentile value for S in all carbonaceous samples is 0.39% and in PAF samples is 2.26% (23 PAF samples out of 101 samples in geochemical database).	5	10	1	**11**	
	Coal (fresh)	*6.4%*	*5.9% (where known)*	*93% (where known)*	*6.4%*	*38%*	86 out of 225 samples (7% of samples) were UC(PAF), PAF-LC or PAF (data from geochemical database). Water table depths are not available for some highwall drillholes, however where known, approximately 6% of this material is currently above the water table and would be potentially subject to oxidation.	*2.4%*	Fresh coal is expected to comprise about 6% of the pit wall material by meterage. Geochemical data is available for 225 coal samples sourced from across SRM seams. Of these, 23 samples were PAF and 63 were PAF-LC or UC(PAF) [i.e. 38% were PAF of some type]. The 75th percentile S value for PAF coal samples is 1.2%. The 75th percentile S value for all coal samples is low at 0.55%. With regard to the much larger coal quality database (n=9070 samples), the 75th percentile total S value is 0.65% - consistent with the smaller geochemical database. The dominant seams/plys exposed on the highwall are the P seam, HC and DY Upper and Lower seam groups.	5	10	1	***11***	
	Unknown	*0.1%*	*0%*	*100%*	*0.1%*	*0%*	Lithology unknown. All below base of weathering (ie. fresh)	*0%*	Negligible proportion; all fresh, but all below water table; Assume negligible PAF.	1	1	1	***2***	
	Estimated frequency of occurrence of PAF drill-hole intervals - assuming representativeness of surface exposure by drill-hole data							15%						

Material domain	Material type	Proportion of exposure on pit floor % (assumed)	Above current water table	Below current water table	%Exposure (below base of weathering)	%of PAF sample by material type (environmental and/or coal database)	Comment	Estimated % PAF exposure on pit floor	Comment	Geochemical Propensity for AMD	AMD Capacity Rating	AMD Quantity Rating	Likelihood for AMD generation from exposed Hakea void floor	
Hakea void floor	Coal: HC Upper seam	*100%*	*0%*	*100%*	*100%*	*37%*	PAF proportion estimated by applying a total S 'cut-off' of 0.58% to the coal quality data for HC Upper seam samples (3593 samples). The S cut-off was based on the median total S value for PAF coal and reject samples (combined) from the geochemical database. Based on the geochemical database, 38% of 225 coal samples were PAF, therefore the estimate of 37% of the pit floor being PAF (based on a Total S value of >0.58% as representing PAF material) closely correlates with the coal geochemical data. All pit floor is below the water table and would become submerged shortly after mining ceases.	*37%*	The floor of Hakea void is likely to be HC Upper seam group materials (coaly and carbonaceous materials), which has a 75th percentile total S value of 0.61% (based on 3593 HC Upper samples in the coal quality database). Conservatively, 37% of HC Upper seam coal samples from SRM have been classified as PAF and, combined with the relatively low ANC in coal itself, the potential for AMD generation from a significant proportion of the pit floor cannot be excluded - assuming the entire pit floor comprises purely coal material. No allowance for pit flooding has been taken into account in this hazard assessment. Refer to report body for discussion regarding pit flooding.	5	7	7	**12**	Conservatively, approximately 37% of the pit floor may comprise PAF coal. The geochemical hazard for the void floor to develop AMD is moderate if the entire pit floor comprises purely coal material (unlikely) and if the coal floor remains exposed to air (unlikely). As such, the actual AMD hazard post-closure will likely be lower than indicated. Conservatively, the likelihood for AMD generation from exposed Hakea void floor = **PROBABLE/LIKELY**

7.2 Geochemical Source-Pathway-Risk Assessment

7.2.1 Conceptual Site Model and Conceptual Facility Models

A post-mining conceptual site model (CSM), which applies to the spoil landforms and their respective residual voids and the relationship these facilities have with surface water and groundwater in the district, has been produced by SLR Consultants (2022) (**Figure 37)**. The CSM assists with the source-pathway-receptor (SPR) assessment with regard to potential environmental geochemical impacts from mineral waste facilities. The CSM, which focuses on the relationship with surface water and groundwater (these being the most relevant pathways and receptors for AMD and salinity), is used to illustrate the relationship between potential sources of run-off and seepage (e.g. spoil, tailings), plausible receptors (e.g. creeks, groundwater) and the pathways between the two (e.g. seepage, drainage).

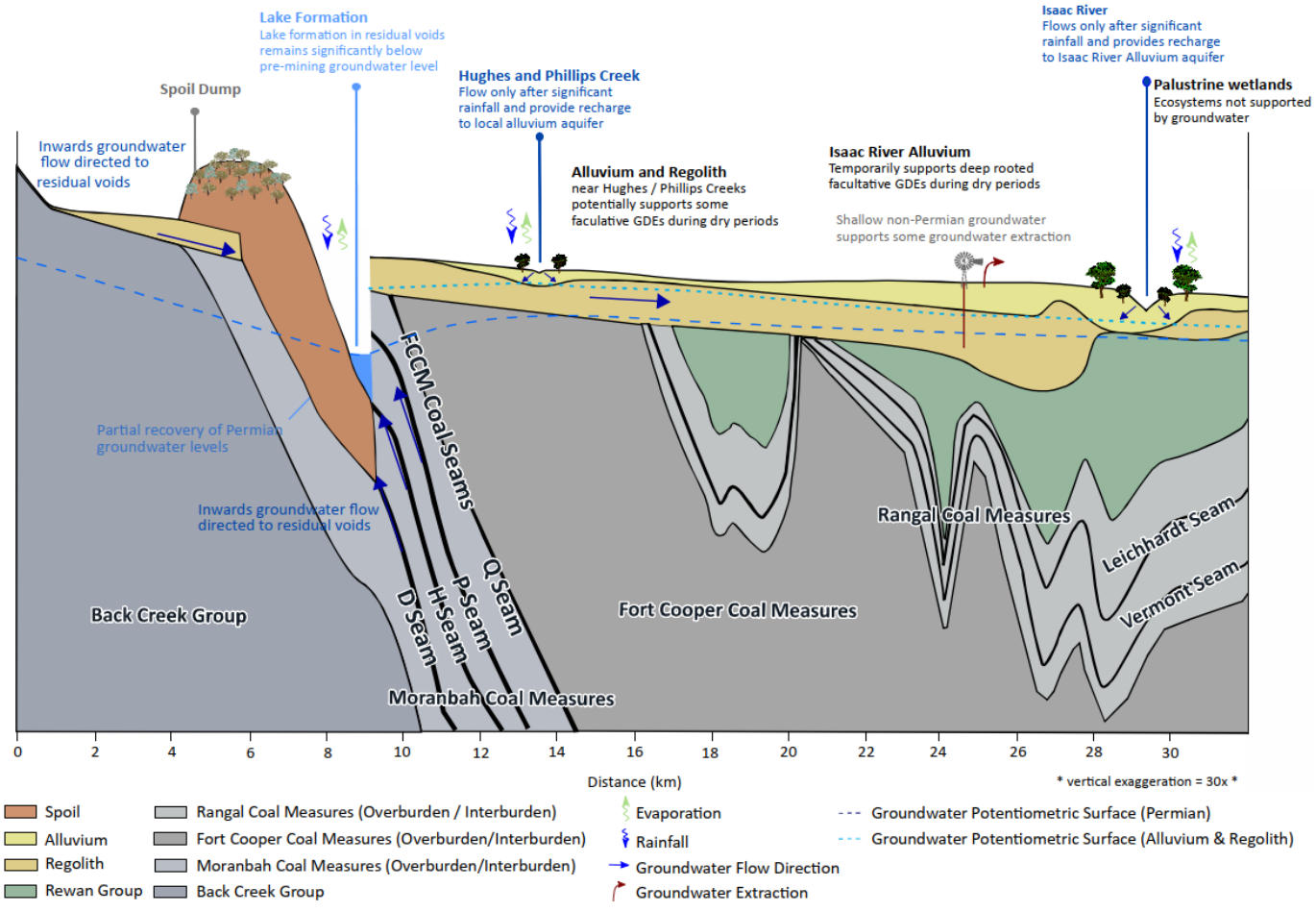


Figure 37. Source-Pathway-Receptor (SPR) conceptual site model post-mining
(SLR, 2023)

Permian groundwater flow at SRM is towards the east and largely follows the coal seams down-dip. Shallower groundwater that is likely associated with shallow permeable strata is likely to flow in a direction that broadly mimics surface topography. Groundwater modelling undertaken by SLR (2022) shows the residual voids will ultimately be groundwater 'sinks' – that is, the residual voids will be receptors of run-off and seepage from the final landforms and run-off from void highwalls, as illustrated in the CSM (**Figure 37**). The residual voids are classified as non-use management areas (NUMAs). The spoil landforms are located behind (west of) the residual voids and will drain into the voids. Seepage from the spoil landforms and the highwalls of the residual voids reports to the residual void. As

such, the floor of residual voids (i.e. pit floors) are not likely AMD sources for groundwater or surface water receptors.

The hydrogeological assessment undertaken for the PRCP (SLR, 2022) indicates that the nearest 'true' alluvial aquifer of any significant spatial extent is along the Isaac River floodplain, over 15 km east of SRM. The assessment indicates there may be shallow permeable strata present sporadically along (and/or near to) several creeks at SRM and – where present – shallow groundwater is expected to be well below the base of all creeks in the area; suggesting that connectivity between shallow permeable strata and surface water features at SRM is unlikely. Furthermore, modelling (including particle tracking) undertaken by SLR for the PRCP found no evidence of connectivity between groundwater and surface water features. The model suggests that shallow groundwater (and by extension shallow seepage) migrating through the site from the western side of the pit voids will be eventually report to the mine pits. The general downward migration of shallow groundwater (and seepage) into deeper groundwater and towards the mine pits (residual voids) is logical, given the very large drawdown (sink) of the pits.

The assessment of shallow groundwater at SRM – particularly where shallow permeable strata may not be present in some areas, may be discontinuous and/or not interconnected – is limited by/to the distribution of the shallow bore network, which is sporadic. Therefore, despite the apparent low likelihood of substantial connection between shallow permeable strata and surface water features, the SPR assessment has adopted a highly conservative approach and assumed a plausible pathway may exist between shallow permeable strata and surface water features.

The Isaac River and adjacent wetlands are not plausible receptors of undiluted run-off and seepage from spoil landforms and seepage from residual voids due to physical distance (over 15 km) and/or lack of a connecting pathway.

Specific to TSFs, there are two types of 'residual' TSFs at SRM post-closure: TSFs that will be buried by spoil and become part of a spoil landform at closure; and a stand-alone TSF that will remain in its current state as a capped TSF landform and will not be buried by (become part of) a spoil landform.

- TSFs buried (by spoil) within a spoil landform and forming a component of the spoil landform are represented by Ramp 2/3 TSF, Ramp 6 TSF, TSF no. 2 and TSF no. 4. The concentrated nature of tailings mineral wastes (which have a Moderate-High AMD source hazard) located at the base of the spoil landform warrants discussion with respect to SPR assessment. As such, a conceptual facility model (CFM) has been developed for each of the four buried TSFs:
    - Ramp 2/3 TSF situated within the western zone of Jacaranda-Bauhinia spoil landform (**Figure 38**)
    - TSF no. 2 situated within the north-western zone of Coolibah-Dogwood spoil landform (**Figure 39**)
    - Ramp 6 TSF, situated within the northern zone of Coolibah-Dogwood spoil landform (**Figure 40**)
    - TSF no. 4 situated within the north-western zone of Coolibah-Dogwood spoil landform (**Figure 41**).
- The stand-alone TSF landform, represented by TSF no. 3 is already capped/covered and will remain more-or-less 'as is' post-closure as rehabilitated landform with an expected post-mining land use (PMLU) classification. It is assumed that relatively minor additional remediation may be undertaken on this facility prior to closure. TSF no. 3 landform has a Moderate AMD source hazard with the likelihood of AMD generation from the landform rated as Probably/Likely. As such, this landform requires discussion with respect to SPR assessment. The CFM for TSF no. 3, and the relationship with the Coolibah-Dogwood spoil landform (and TSF no. 4) is provided in **Figure 41**.

With regard to the post-closure mineral waste facilities (spoil landforms, TSF landforms and residual voids) plus the component of spoil landforms where TSFs are buried, the plausible mechanisms for AMD affected water and/or non-oxidative salinity to report to receptors are identified in **Table 29**.

The geochemical source hazard assessment (**Section 7.1**) found that the spoil landforms, which are comprised of approximately 82% to 89% non-carbonaceous spoil, had an AMD hazard score of 'Low' to 'Low-Moderate', with AMD generation from the spoil landforms rated as 'Highly Unlikely' to 'Unlikely'. The TSF no. 3 landform had an AMD hazard score of 'Moderate', with AMD generation from the TSF no. 3 landform rated as 'Probable/Likely'.

*Note: the intent of the simplified CFM illustrations shown as **Figures 38 to 41** are to conceptualise potential surface water run-off and seepage pathways between key landform domains and potential receptors. The CFM figures are not to scale and may not be a true representation of the system at each location.*

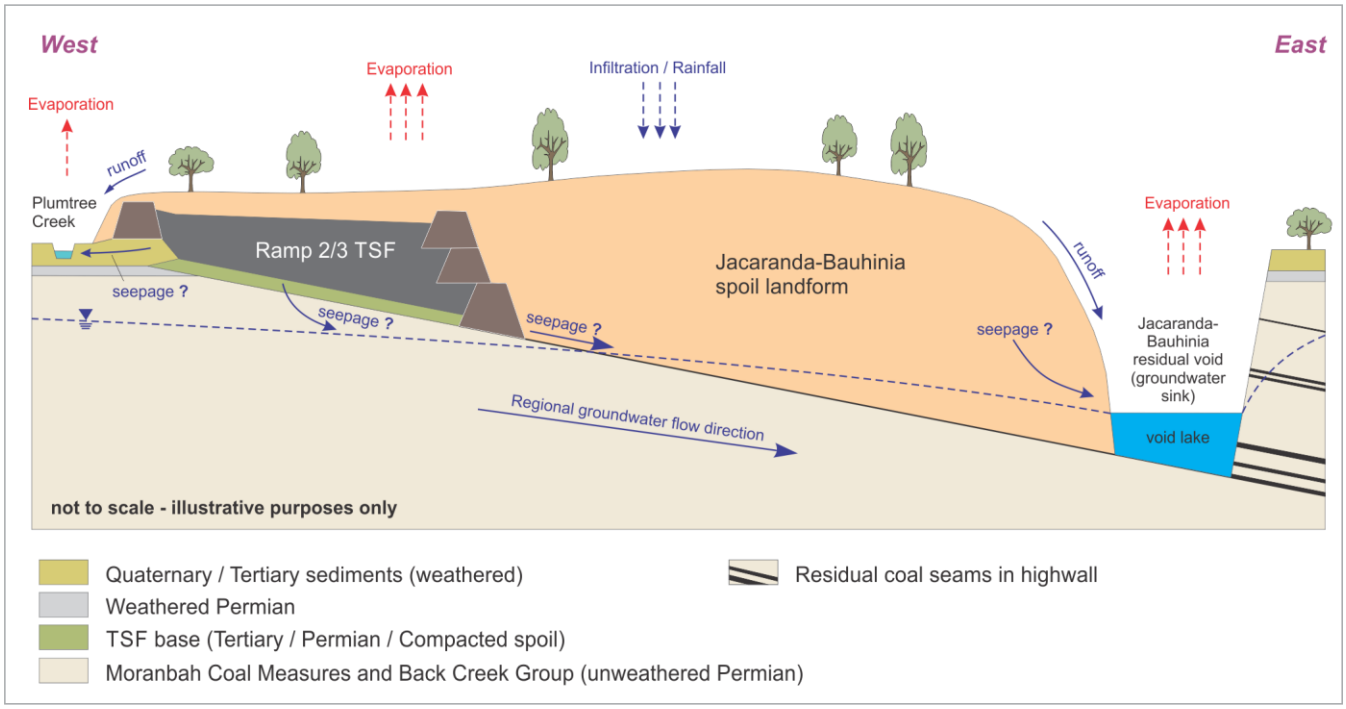


Figure 38. Post-closure Source-Pathway-Receptor (SPR) conceptual facility model (CFM) for Ramp 2/3 TSF buried within the Jacaranda-Bauhinia spoil landform

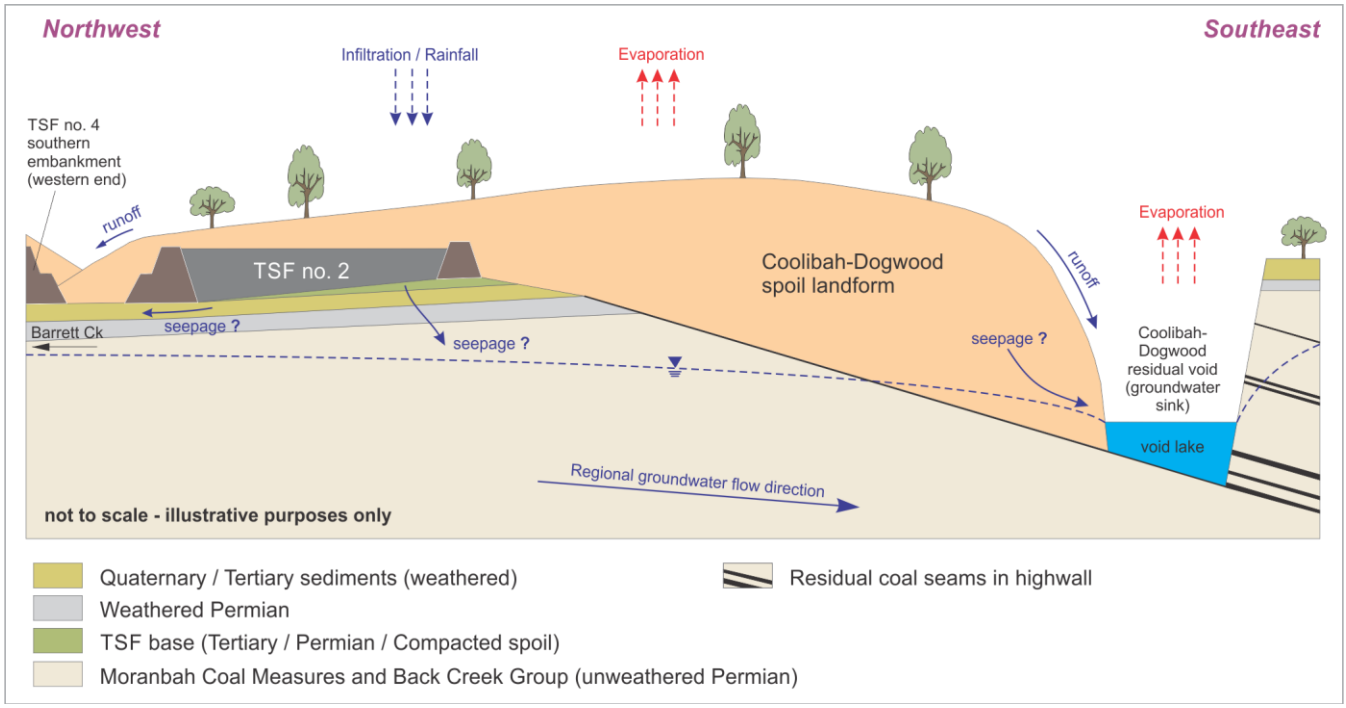


Figure 39. Post-closure Source-Pathway-Receptor (SPR) conceptual facility model (CFM) for TSF no. 2 buried within the Coolibah-Dogwood spoil landform

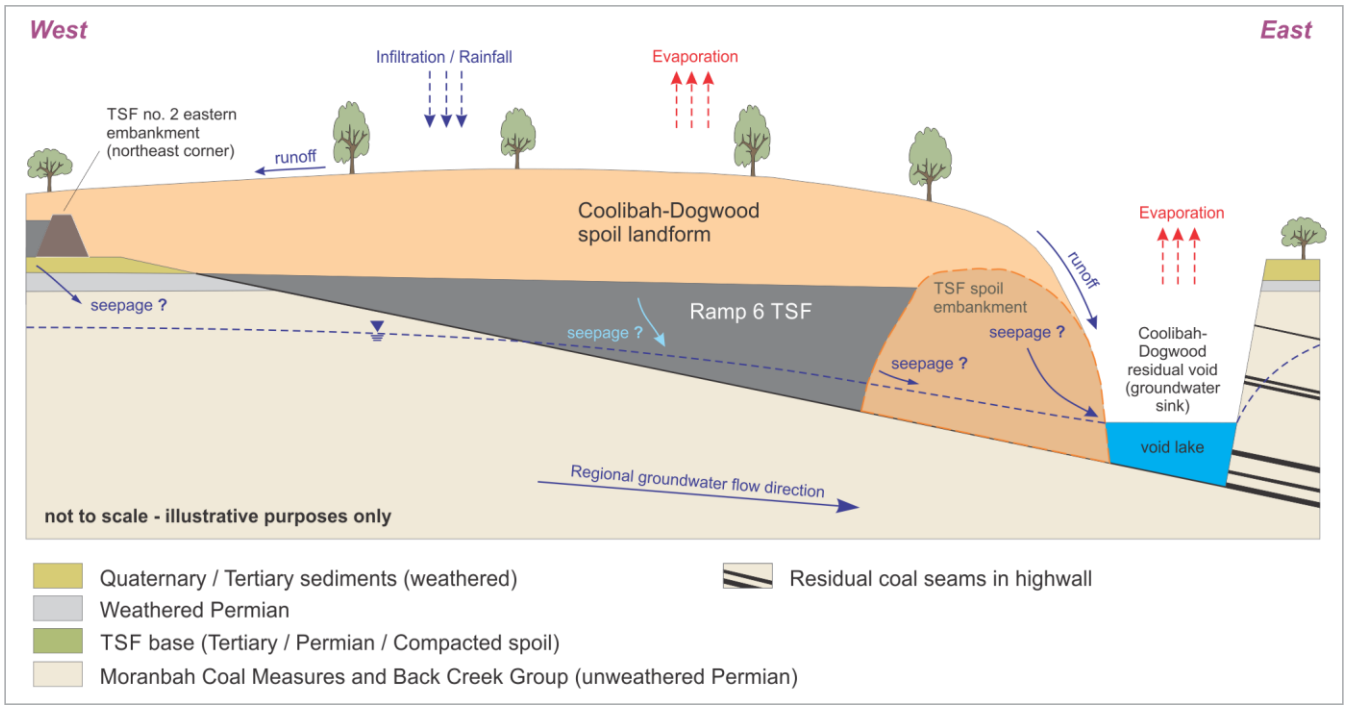


Figure 40. Post-closure Source-Pathway-Receptor (SPR) conceptual facility model (CFM) for Ramp 6 TSF buried within the Coolibah-Dogwood spoil landform

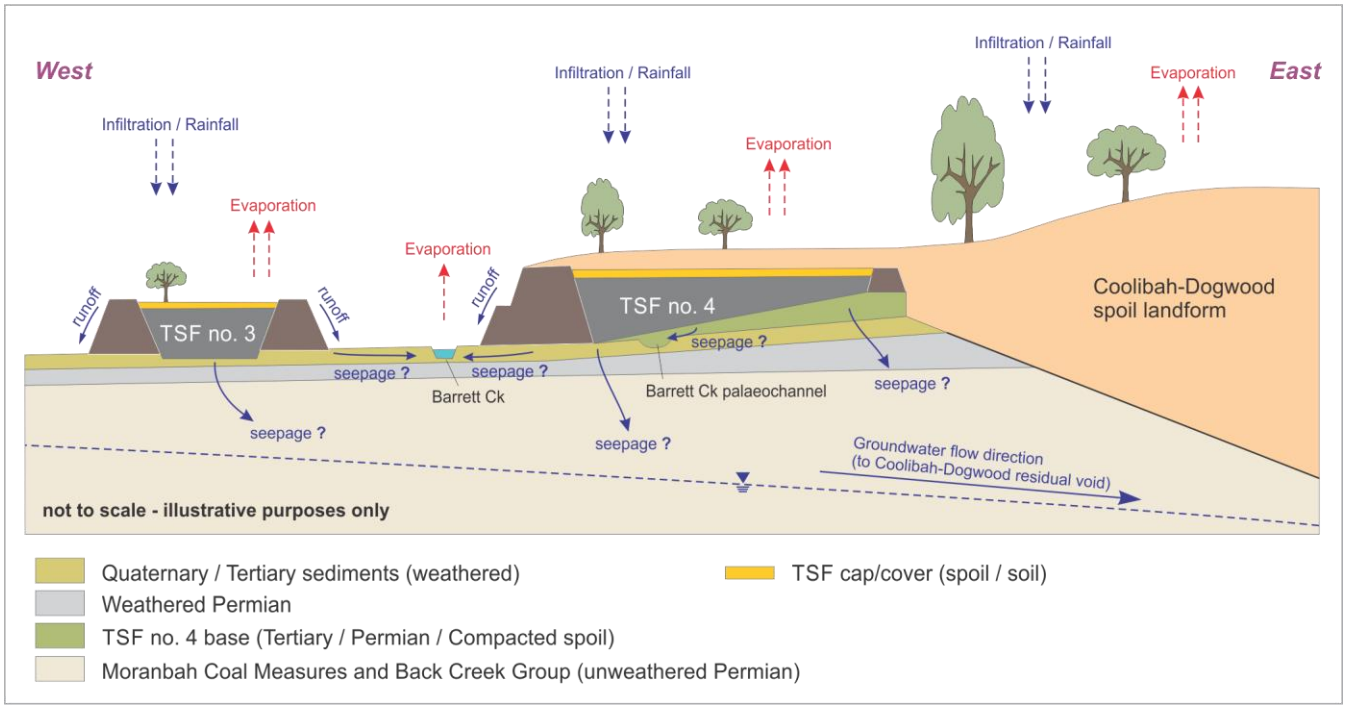


Figure 41. Post-closure Source-Pathway-Receptor (SPR) conceptual facility model (CFM) for TSF no. 3 and TSF no. 4 landforms

Table 29. Sources, potential receptors and potential pathways between the source and receptor (post-closure)

Sources	Potential Pathways	Potential Receptors
Spoil landforms		
Jacaranda-Bauhinia	Surface water [run-off]	• Boomerang Creek[1] (northern toe) / Plumtree Creek[2] (western toe) / Hughes Creek (southern toe) • Jacaranda-Bauhinia residual void
	Seepage [shallow permeable strata]	• Boomerang Creek[1] (northern toe) / Plumtree Creek[2] (western toe) / Hughes Creek (southern toe)
	Seepage [groundwater]	• Jacaranda-Bauhinia residual void
Coolibah-Dogwood	Surface water [run-off]	• Hughes Creek (northern toe) / Barrett Creek[2] (western toe) / One Mile Creek (southern toe) • Coolibah-Dogwood residual void
	Seepage [shallow permeable strata]	• Hughes Creek (northern toe) / Barrett Creek[2] (western toe) / One Mile Creek (southern toe)
	Seepage [groundwater]	• Coolibah-Dogwood residual void
Ebony-Grevillea	Surface water [run-off]	• One Mile Creek (northern toe) / Spring Creek[3] (western toe) / Philips Creek[4] (southern toe) • Ebony-Grevillea residual void
	Seepage [shallow permeable strata]	• One Mile Creek (northern toe) / Spring Creek[3] (western toe) / Philips Creek[4] (southern toe)
	Seepage [groundwater]	• Ebony-Grevillea residual void
Hakea	Surface water [run-off]	• Philips Creek (northern toe) • Hakea residual void
	Seepage [shallow permeable strata]	• Philips Creek (northern toe)
	Seepage [groundwater]	• Hakea residual void

Table notes:

1. Boomerang Creek is approximately the border/boundary with PDM north of SRM, and receives flow (input) from both SRM and PDM.
2. Barrett Creek and Plumtree Creek are tributaries of Hughes Creek.
3. Spring Creek currently flows east between Grevillea and Ebony pits. At closure, Spring Creek is diverted south into Southern Creek, a tributary of Philips Creek.
4. Includes Southern Creek at southwest of landform. Southern Creek flows into Philips Creek at southwestern corner of Ebony-Grevillea spoil landform.

Table 29 continued…

Sources	Potential Pathways	Potential Receptors
TSF landform		
TSF no. 3	Surface water [run-off]	• Barrett Creek[1] [via surface water run-off]
	Seepage [shallow permeable strata]	• Barrett Creek[1] [via shallow groundwater]
	Seepage [groundwater]	• Coolibah-Dogwood residual void [via deeper/Permian groundwater]
Void highwalls		
Jacaranda-Bauhinia	Surface water [run-off]	Jacaranda-Bauhinia residual void
Coolibah-Dogwood	Surface water [run-off]	Coolibah-Dogwood residual void
Ebony-Grevillea	Surface water [run-off]	Ebony-Grevillea residual void
Hakea	Surface water [run-off]	Hakea residual void

1. Barrett Creek is a tributary of Hughes Creek.

The BHP residual risk rating heat map (**Table 30**) has been adopted to assess the risks associated with SPR from the four spoil landforms and two TSF landforms. In reference to the Risk Matrix, the SPR assessment includes the likelihood of the event occurring, the severity of the event (should it occur) and the calculated risk rating (likelihood X severity).

Table 30. Risk matrix for SPR assessment

Risk Rating = Likelihood x Severity		Severity				
		S1	S2	S3	S4	S5
Likelihood	Highly Likely	Medium	Medium to High	High	High	High
	Likely	Low to Medium	Medium	Medium to High	High	High
	Probable	Low	Low to Medium	Medium	Medium to High	High
	Unlikely	Low	Low	Low to Medium	Medium	Medium to High
	Highly Unlikely	Low	Low	Low	Low to Medium	Medium

The risk rating for the spoil landforms with respect to plausible surface water receptors is shown in **Tables 31 to 34** and discussed in **Section 7.2.2**. The risk rating for the TSF no. 3 landform with respect to plausible surface water receptors is shown in **Table 35** and discussed in **Section 7.2.3**. The risk rating for the residual voids with respect to the void receptor is shown in **Table 36** and discussed in **Section7.2.4**. The potential impact of seepage, if any, from the residual voids into the Permian groundwater aquifer is discussed in the void closure plan (WSP, 2022).

The overall rating of the Source assessment showed that the risk rating for AMD to impact receptors is generally Low. The risk rating for non-oxidative salinity to impact receptors is conservatively rated as Low or Low to Medium, based on a 75th percentile EC value applied to the source.

The assessment shows that all receptors are generally at low risk of direct environmental impact from mineral waste with respect to AMD (including acid/acidity, NMD and SD), however the assessment has shown that surface water receptors are conservatively at low to medium risk of direct environmental impact from mineral waste with respect to non-oxidative salinity. These risk ratings were assigned with consideration for the key aspects for each key facility/domain.

7.2.2 Final spoil landforms

Source materials hazard

The spoil landforms are comprised of approximately 82 to 90% non-carbonaceous overburden/interburden with coaly and carbonaceous material (predominantly in the form of carbonaceous spoil and reject) comprising the remaining 10 to 18% of the final landforms. Non-carbonaceous overburden/interburden from Permian-age material in the Bowen Basin is widely recognised as posing a low to low-moderate AMD risk. Rejects at SRM poses a moderate AMD hazard, however it is disposed (encapsulated) well within general spoil and does not report to final landform surfaces. During landform reshaping, reject disposal areas not already buried (covered by spoil) will be covered by spoil. Refer to **Section 8** for rejects management measures.

Tailings at SRM pose a moderate-high AMD hazard, however comprise less than 0.5% of each spoil landform (where tailings are present), and tailings are also disposed (encapsulated) well within general spoil and do not report to final landform surfaces. The greatest environmental hazard/risk associated with tailings disposed into landforms is due to their concentration in a relatively small area (within TSFs). That is, unlike rejects that are co-disposed and distributed throughout spoil and/or largely deeply buried by spoil, TSFs within spoil landforms (e.g. Ramp 2/3 TSF) are concentrated pockets of moderate-high AMD hazard material located further away from the

residual void on the western side of the spoil landform and, generally, under a thinner spoil cover (compared to very thick spoil cover adjacent to the residual void). Ramp 2/3 TSF, Ramp 6 TSF, TSF no. 2 and TSF no. 4 will each be buried (covered) by spoil. Refer to **Section 8** for TSF/tailings management measures.

Source materials generally have low to low-moderate EC values and are expected to produce slightly saline (potentially slightly to moderately saline) run-off and seepage, with release of (non-oxidative) salinity rated as a low-moderate hazard. The overall low to low-moderate total S and generally excess ANC of the combined mineral waste – for most landforms – results in an 'Unlikely' hazard score for AMD generation. With respect to non-oxidative salinity, most spoil landforms have a conservative hazard score of 'Unlikely' to 'Probable'.

Pathways

Surface water

Surface water receptors (ephemeral creeks) are located adjacent to each spoil landform – ranging from less than 100m to approximately 400m from landform edges. It is plausible for surface water run-off from final rehabilitated landforms to reach these creeks. Refer to **Figure 1** and **Tables 31 to 34** for surface water receptors associated with each spoil landform. TSFs and rejects located within landforms will be buried by several metres of spoil, therefore all run-off will be from general spoil (overburden/interburden) material and no tailings or rejects will be exposed to (or at risk of) surface water run-off.

Seepage / Groundwater

The water table is expected to intersect the deeper zones of each in-pit final landform within the Permian Moranbah Coal Measures (SLR, 2022). However, groundwater is captured by the residual void (as a groundwater sink). Therefore, although a direct connection is expected to exist between deeper parts of the final landforms and groundwater (the water table), this groundwater will report to the residual void – not to the broader aquifer.

As discussed in **Section 7.2.1**, it is plausible for seepage from the near-surface and unsaturated zone of the in-pit final landforms to migrate downwards into the water table. It is also plausible (however likely) that seepage may occur into discontinuous shallow permeable strata locally associated with existing creeks or palaeodrainage channels. Due to the highly discontinuous and/or not interconnected nature of shallow permeable strata at SRM, the understanding surrounding any potential link between shallow groundwater and surface water is limited. As such, whether seepage into shallow permeable strata would continue further downwards into deeper groundwater (primary aquifer) or, instead, report to nearby surface water features, is also somewhat unclear. Despite this potential limitation, the overall groundwater gradient at SRM is downwards and towards (into) the residual voids. Therefore, it is reasonably assumed that seepage from final landforms into shallow groundwater would reach a surface water receptor is 'Unlikely'.

In summary, the SPR has assumed a plausible (although unlikely) local seepage pathway *may* exist between a landform – such as seepage from a buried TSF – via shallow permeable strata into a nearby surface water receptor (ephemeral creek). Refer to **Figures 38 to 41** and **Tables 31 to 34** for conceptual shallow seepage pathways and nearby surface water receptors associated with each spoil landform and **Table 36** for groundwater pathways to the residual voids.

Receptors

Plausible receptors identified in this qualitative assessment include ephemeral creeks and the residual voids. Refer to **Figures 38 to 41** and **Tables 31 to 34** for surface water receptors associated with each spoil landform and **Table 36** for residual void receptors. Due to the geochemical nature of the final landforms, the likelihood of AMD from spoil landforms to impact on the water quality of surface water receptors and on the water quality of residual voids has been rated unlikely. The likelihood of non-oxidative salinity from spoil landforms to impact on the water quality of surface water receptors (via surface water run-off) has been rated probable, however the severity is low, hence the risk rating is low to medium.

Consideration was also made to people living in the homesteads near the project area. The nearest homestead is located approximately 400 m west of the ML boundary at approximately Bauhinia Pit. Two other homesteads are located less than 2 km west of the ML boundary at the approximate location of the CHPP and west of the ML boundary at Hakea Pit. As these three homesteads are located upstream (via surface water) and upgradient (via

groundwater) from SRM, the potential for these homesteads to be impacted by AMD or saline drainage from the final spoil landforms is implausible.

SPR risk rating of final spoil landforms

There are plausible surface water and residual void receptors; and the run-off and seepage pathways linking the sources (final spoil landforms) to these receptors have been identified. With respect to AMD, the overall SPR risk rating from final spoil landforms is **Low**. Where landforms contain buried tailings, such as Jacaranda-Bauhinia landform with Ramp 2/3 TSF and Coolibah-Dogwood landform with Ramp 6 TSF, TSF no. 2 and TSF no. 4, the risk rating with respect to AMD potentially making its way via shallow permeable strata into surface water features close to the buried TSFs was rated as **Low to Medium**. With respect to non-oxidative salinity the overall SPR risk from final spoil landforms is rated as **Low to Medium**.

7.2.3 Final TSF landform (TSF no. 3)

Source materials hazard

The TSF no. 3 landform is comprised of approximately 81% tailings with the remainder being a 'spoil' cap/cover on the facility. Tailings within TSF no. 3 pose a moderate AMD hazard and are capped/covered with general spoil (thickness minimum 2m; average 2.5m), which generally poses a low AMD hazard. The long-term (post-closure) function of the current cap/cover of the TSF is unknown, but for the purposes of the SPR assessment is assumed to be adequate (currently) and, prior to closure, may require minor remediation to ensure long-term function.

Source materials generally have low to low-moderate EC values and are expected to produce slightly to moderately saline run-off and seepage, with release of (non-oxidative) salinity rated as a low-moderate to moderate hazard. Tailings in TSF no. 3 have a 'Probable/Likely' hazard score for AMD generation. With respect to non-oxidative salinity, the TSF landform has a conservative hazard score of 'Unlikely'.

Pathways

Surface water

Barrett Creek (an ephemeral creek) is located to the east of (and less than 100m from) TSF no. 3 landform and flows north into Hughes Creek. It is likely that surface water run-off from TSF no. 3 landform will reach Barrett Creek. Refer to **Figure 1**, **Figure 41** and **Table 35** for surface water receptors associated with TSF no. 3 landform. The TSF is covered by a spoil cap, therefore all run-off will be from general spoil (overburden/interburden) material and no tailings will be exposed to (or at risk of) surface water run-off.

Seepage / Groundwater

As discussed earlier, this assessment has assumed that seepage from TSF no. 3 can migrate downwards into the water table. Groundwater in the vicinity of TSF no. 3 flows towards (and into) Coolibah-Dogwood residual void. The assessment has also conservatively assumed it is plausible (however likely) that seepage may occur into discontinuous shallow permeable strata associated with existing creeks or palaeodrainage channels. Whether seepage into shallow permeable strata would continue further downwards into the deeper (primary) aquifer or, instead, report through the shallow permeable strata into nearby surface water features (in this case, Barrett Creek), is somewhat unclear. Despite this potential limitation, the overall groundwater gradient at SRM is downwards and towards (into) the residual voids. Therefore, it is reasonably assumed 'Unlikely' that seepage from TSF no. 3 landform into shallow permeable strata would 'daylight', long-term, into Barrett Creek.

In summary, the SPR has assumed a plausible (although unlikely) local seepage pathway *may* exist between the TSF no. 3 landform via shallow permeable strata into nearby Barrett Creek (an ephemeral creek) – in addition to seepage pathways into the broader groundwater system that flows into the Coolibah-Dogwood residual void. Refer to **Figure 41** and **Table 35** for conceptual seepage pathways from TSF no. 3 landform into groundwater and nearby surface water receptors and **Table 37** for groundwater pathways to the Coolibah-Dogwood residual void.

Receptors

Plausible (however likely) receptors identified in this qualitative assessment of TSF no. 3 landform include ephemeral Barrett Creek and the Coolibah-Dogwood residual void. Refer to **Figure 41** and **Table 35** for surface water receptors associated with the TSF landform and **Table 37** for the Coolibah-Dogwood residual void receptor. Due to the geochemical nature of the TSF landform and the close proximity of the TSF landform to Barrett Creek, the likelihood of AMD from the TSF landform to impact on the water quality of Barrett Creek (via seepage) has been rated unlikely, and the likelihood of AMD from the TSF landform to impact on the water quality of the Coolibah-Dogwood residual void has been rated unlikely. The likelihood of non-oxidative salinity from the TSF landform to impact on the water quality of surface water receptors has been rated unlikely.

Consideration was also made to people living in the homesteads near the project area. As discussed earlier, all homesteads 'close' to SRM are located upgradient (surface water and groundwater) from SRM and the potential for these homesteads to be impacted by AMD or saline drainage from the final TSF landforms is implausible.

SPR risk rating of final TSF landforms

There are plausible surface water and residual void receptors; and the run-off and seepage pathways linking the sources (TSF no. 3 landform) to these receptors have been identified. With respect to AMD the overall SPR risk rating from the TSF landform is **Low to Low-Medium**. With respect to non-oxidative salinity the overall SPR risk from the TSF landform is rated as **Low**.

7.2.4 Residual voids

Source materials hazard

The surfaces of residual void highwalls are comprised of approximately 81% to 89% non-carbonaceous overburden/ interburden, 4.5% to 11% carbonaceous overburden/interburden (incl. sub-economic seams reporting to waste) and about 6% to 9% coal (seams). Approximately 22% to 48% of the current pit highwalls are weathered material. Fresh and weathered non-carbonaceous overburden/interburden material in the Bowen Basin is widely recognised as posing a low AMD risk. Coal seams at SRM pose a low to moderate AMD risk, with the exception of the P that seam poses a moderate to high AMD risk.

Generally, highwall materials have low to low-moderate EC values, with release of (non-oxidative) salinity rated as a low- to low-moderate hazard.

Overall, the hazard for AMD residual void highwall material is low and the likelihood for AMD generation from residual void highwalls is 'Unlikely'.

Void floor from Jacaranda-Bauhinia void, Coolibah-Dogwood void and Ebony-Grevillea void is comprised of DY Lower seam and is conservatively estimated to comprise approximately 44% PAF coal – assuming 100% of the floor is coal and not some other material. The Hakea void floor is comprised of Harrow Creek seam and is estimated to comprise approximately 37% PAF coal. The void floors, as described, pose a moderate AMD hazard – which does not take into account likely mitigating factors, such as void floor flooding. After flooding, the void floor would be expected to pose a low AMD hazard.

Pathways

Surface water

There are no plausible pathways between the residual voids and surface water. Surface water run-off from the void highwall (of each void) will report to the void lake (of each void) and, therefore, will remain within the residual void.

Seepage

The residual voids will act as groundwater sinks and the water table will intersect the deeper zones of the residual voids, resulting in the formation of a relatively small void lake in each void (SLR, 2022; and **Figure 37**) that will submerge the void floor and lower section of the void highwall. For each void, seepage from the spoil landform and run-off from the highwall will report to the residual void.

Receptors

Modelling undertaken by SLR (2022) shows the final voids to be 'sinks' – receiving surface water run-off and seepage from spoil landforms and surface water run-off from void highwalls. Each residual void is expected to receive inflow from the Permian groundwater aquifer. The water quality of the void and potential impact of water seeping, if any, from the residual voids into the Permian groundwater aquifer will be discussed in the void closure plan (WPS, 2022).

Due to the geochemical nature of the materials exposed in the highwall of each void, the likelihood of undiluted salinity or AMD (if any) to impact on residual void water quality has been rated highly unlikely.

The floor of each residual void will be covered post-closure by water as rainfall and groundwater reporting to the void will form a void lake. As such, PAF coal will no longer be exposed to atmospheric conditions and the risk of AMD being generated is greatly reduced. The likelihood of undiluted salinity or AMD from a flooded post-closure residual void floor to impact on residual void water quality to any significant degree has been rated unlikely.

Consideration was also made to people living in the homesteads near the project area, of which the nearest plausible receptors are all located west of SRM and up-gradient with respect to groundwater flow (i.e. groundwater flows away from the nearest homesteads). As such, the potential for these homesteads to be impacted by AMD from the residual voids is implausible.

SPR risk rating of residual voids

The final receptor for seepage from the spoil landform (for each spoil landform) and run-off from the highwall (of each void) is the void lake / residual void. The AMD assessment has found that it's unlikely that undiluted salinity or AMD from a flooded post-closure residual void floor would impact on residual void water quality to any significant degree, as other processes such as evapoconcentration (SLR, 2022) are the key drivers of void lake water quality. Therefore, the AMD SPR risk rating on the overall water quality of the residual voids is **Low**.

Water reporting to residual voids is expected to remain within the residual voids (excluding evaporative loss). Modelling undertaken by SLR (2022) shows that seepage from the void lake (of each void) into groundwater, if any, would be limited.

Table 31. Source-Pathway-Receptor (SPR) assessment of Jacaranda-Bauhinia spoil landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Jacaranda-Bauhinia spoil landform (post-closure) Comprised of approximately 82% non-carbonaceous spoil; approximately 12% carbonaceous spoil; approximately 5% reject; and less than 1% tailings (tailings located at Ramp 2/3 TSF). *AMD source hazard of landform is **Low*** *Salinity (non-oxidative) source hazard of landform: **Probable*** *[AMD source hazard of tailings alone is **Moderate-High**. This has implications for potential seepage from buried tailings within Ramp 2/3 TSF]*	From Jacaranda-Bauhinia spoil landform via surface water run-off into ephemeral Boomerang Creek. Distance <100m to receptor (north). *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Probable***	Ephemeral creek (via surface water run-off): Boomerang Creek @ northern side of Jacaranda-Bauhinia landform. *Potential for AMD to reach Boomerang Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Boomerang Creek: **Probable***	**Acid/acidic drainage:** Low pH water impacting Boomerang Creek [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Boomerang Creek [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Boomerang Creek [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Boomerang Creek [via run-off]	Probable	S2	Low to Medium
	From Jacaranda-Bauhinia landform via seepage into shallow permeable strata then into ephemeral Boomerang Creek. Distance <100m to receptor (north). Ramp 2/3 TSF is located over 4 km from Boomerang Creek. *Potential for AMD to enter shallow permeable strata: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater: **Probable***	Ephemeral creek (via shallow permeable strata: Boomerang Creek @ northern side of Jacaranda-Bauhinia landform. *Potential for AMD to reach Boomerang Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Boomerang Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Boomerang Creek [via seepage]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Boomerang Creek [via seepage]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Boomerang Creek [via seepage]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Boomerang Creek [via seepage]	Unlikely	S2	Low
	From Jacaranda-Bauhinia spoil landform via surface water run-off into ephemeral Plumtree Creek. Distance ~200-400m to receptor (west). *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Probable***	Ephemeral creek (via surface water run-off): Plumtree Creek @ western side of Jacaranda-Bauhinia landform. *Potential for AMD to reach Plumtree Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Plumtree Creek: **Probable***	**Acid/acidic drainage:** Low pH water impacting Plumtree Creek [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Plumtree Creek [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Plumtree Creek [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Plumtree Creek [via run-off]	Probable	S2	Low to Medium
	From Jacaranda-Bauhinia spoil landform via seepage into shallow permeable strata then into ephemeral Plumtree Creek. Distance ~200-400m to receptor (west). *Potential for AMD to enter shallow permeable strata: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater: **Probable***	Ephemeral creek (via shallow permeable strata): Plumtree Creek @ western side of Jacaranda-Bauhinia landform. *Potential for AMD to reach Plumtree Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Plumtree Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Plumtree Creek [via seepage] Risk primarily lies with seepage from buried tailings within Ramp 2/3 TSF	Unlikely	S3	Low to Medium
			Neutral metalliferous drainage: Metals and metalloids impacting Plumtree Creek [via seepage] Risk primarily lies with seepage from buried tailings within Ramp 2/3 TSF	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Plumtree Creek [via seepage] Risk primarily lies with seepage from buried tailings within Ramp 2/3 TSF	Unlikely	S3	Low to Medium
			Saline drainage (non-oxidative): Salt impacting Plumtree Creek [via seepage]	Unlikely	S2	Low
	From Jacaranda-Bauhinia spoil landform via surface water run-off into ephemeral Hughes Creek. Distance <100m to receptor (south). *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Probable***	Ephemeral creek (via surface water run-off): Hughes Creek @ southern side of Jacaranda-Bauhinia landform. *Potential for AMD to reach Hughes Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Hughes Creek: **Probable***	**Acid/acidic drainage:** Low pH water impacting Hughes Creek [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Hughes Creek [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Hughes Creek [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Hughes Creek [via run-off]	Probable	S2	Low to Medium
	From Jacaranda-Bauhinia spoil landform via seepage into shallow permeable strata then into ephemeral Hughes Creek. Distance <100m to receptor (south). *Potential for AMD to enter shallow permeable strata: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater: **Probable***	Ephemeral creek (via shallow permeable strata): Hughes Creek @ southern side of Jacaranda-Bauhinia landform. *Potential for AMD to reach Hughes Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Hughes Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Hughes Creek [via seepage] Risk primarily lies with seepage from buried tailings within Ramp 2/3 TSF	Unlikely	S3	Low to Medium
			Neutral metalliferous drainage: Metals and metalloids impacting Hughes Creek [via seepage] Risk primarily lies with seepage from buried tailings within Ramp 2/3 TSF	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Hughes Creek [via seepage] Risk primarily lies with seepage from buried tailings within Ramp 2/3 TSF	Unlikely	S3	Low to Medium
			Saline drainage (non-oxidative): Salt impacting Hughes Creek [via seepage]	Unlikely	S2	Low

Table 32. Source-Pathway-Receptor (SPR) assessment of Coolibah-Dogwood spoil landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Coolibah-Dogwood spoil landform (post-closure) Comprised of approximately 83% non-carbonaceous spoil; approximately 11% carbonaceous spoil; approximately 5% reject; and less than 0.5% tailings (tailings located at TSF no. 2, TSF no. 4 and Ramp 6 TSF). *AMD source hazard of landform is **Low-Moderate*** *Salinity (non-oxidative) source hazard of landform: **Probable*** *[AMD source hazard of tailings alone is **Moderate-High**. This has implications for potential seepage from buried tailings within TSF no. 2, TSF no. 4 and Ramp 6 TSF]*	From Coolibah-Dogwood spoil landform via surface water run-off into ephemeral Hughes Creek. Distance <100m to receptor (north) *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Probable***	Ephemeral creek (via surface water run-off): Hughes Creek @ northern side of Coolibah-Dogwood landform. *Potential for AMD to reach Hughes Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Hughes Creek: **Probable***	**Acid/acidic drainage:** Low pH water impacting Hughes Creek [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Hughes Creek [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Hughes Creek [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Hughes Creek [via run-off]	Probable	S2	Low to Medium
	From Coolibah-Dogwood spoil landform via seepage into shallow permeable strata then into ephemeral Hughes Creek. Distance <100m to receptor (north). Ramp 6 TSF, TSF no. 2 and TSF no. 4 are located over 1.3 km from Hughes Creek. *Potential for AMD to enter shallow permeable strata: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater: **Probable***	Ephemeral creek (via shallow permeable strata): Hughes Creek @ northern side of Coolibah-Dogwood landform. *Potential for AMD to reach Hughes Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Hughes Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Hughes Creek [via seepage]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Hughes Creek [via seepage]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Hughes Creek [via seepage]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Hughes Creek [via seepage]	Unlikely	S2	Low
	From Coolibah-Dogwood spoil landform via surface water run-off into ephemeral Barrett Creek. Distance ~100m to receptor (northwest). TSF no. 4 is located <50m from Barrett Creek. *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Probable***	Ephemeral creek (via surface water run-off): Barrett Creek @ north-western side of Coolibah-Dogwood landform. *Potential for AMD to reach Barrett Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Barrett Creek: **Probable***	**Acid/acidic drainage:** Low pH water impacting Barrett Creek [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting Barrett Creek [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Barrett Creek [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting Barrett Creek [via run-off]	Probable	S2	Low to Medium
	From Coolibah-Dogwood spoil landform via seepage into shallow permeable strata then into ephemeral Barrett Creek. Distance ~100m to receptor (northwest). TSF no. 4 is located <50m from Barrett Creek. *Potential for AMD to enter shallow permeable strata: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater: **Probable***	Ephemeral creek (via shallow permeable strata): Barrett Creek @ north-western side of Coolibah-Dogwood landform; and adjacent to western embankment of TSF no. 4. *Potential for AMD to reach Barrett Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Barrett Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting Barrett Creek [via seepage] Risk primarily lies with seepage from buried tailings within TSF no. 2, TSF no. 4 and Ramp 6 TSF	Unlikely	S3	Low to Medium
			Neutral metalliferous drainage: Metals and metalloids impacting Barrett Creek [via seepage] Risk primarily lies with seepage from buried tailings within TSF no. 2, TSF no. 4 and Ramp 6 TSF	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Barrett Creek [via seepage] Risk primarily lies with seepage from buried tailings within TSF no. 2, TSF no. 4 and Ramp 6 TSF	Unlikely	S3	Low to Medium
			Saline drainage (non-oxidative): Salt impacting Barrett Creek [via seepage]	Unlikely	S2	Low
	From Coolibah-Dogwood spoil landform via surface water run-off into ephemeral One Mile Creek. Distance <100m to receptor (south) *Potential for AMD to enter surface water run-off: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off: **Probable***	Ephemeral creek (via surface water run-off): One Mile Creek @ southern side of Coolibah-Dogwood landform. *Potential for AMD to reach One Mile Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach One Mile Creek: **Probable***	**Acid/acidic drainage:** Low pH water impacting One Mile Creek [via run-off]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting One Mile Creek [via run-off]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting One Mile Creek [via run-off]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting One Mile Creek [via run-off]	Probable	S2	Low to Medium
	From Coolibah-Dogwood spoil landform via seepage into shallow permeable strata then into ephemeral One Mile Creek. Distance <100m to receptor (south). Ramp 6 TSF, TSF no. 2 and TSF no. 4 are located over 2 km from One Mile Creek. *Potential for AMD to enter shallow permeable strata: **Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater: **Probable***	Ephemeral creek (via shallow permeable strata): One Mile Creek @ southern side of Coolibah-Dogwood landform. *Potential for AMD to reach One Mile Creek: **Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach One Mile Creek: **Unlikely***	**Acid/acidic drainage:** Low pH water impacting One Mile Creek [via seepage]	Highly Unlikely	S2	Low
			Neutral metalliferous drainage: Metals and metalloids impacting One Mile Creek [via seepage]	Unlikely	S2	Low
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting One Mile Creek [via seepage]	Highly Unlikely	S2	Low
			Saline drainage (non-oxidative): Salt impacting One Mile Creek [via seepage]	Unlikely	S2	Low

Table 33. Source-Pathway-Receptor (SPR) assessment of Ebony-Grevillea spoil landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Ebony-Grevillea spoil landform (post-closure) Comprised of approximately 86% non-carbonaceous spoil; approximately 9% carbonaceous spoil and approximately 5% reject. No tailings. *AMD source hazard is **Low-Moderate*** *Salinity (non-oxidative) source hazard:* ***Probable***	From Ebony-Grevillea spoil landform via surface water run-off into ephemeral One Mile Creek. Distance <100m to receptor (north) *Potential for AMD to enter surface water run-off:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off:* ***Probable***	Ephemeral creek (via surface water run-off): One Mile Creek @ northern side of Ebony-Grevillea landform. *Potential for AMD to reach One Mile Creek:* ***Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach One Mile Creek:* ***Probable***	**Acid/acidic drainage:** Low pH water impacting One Mile Creek [via run-off]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting One Mile Creek [via run-off]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting One Mile Creek [via run-off]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting One Mile Creek [via run-off]	Probable	S2	**Low to Medium**
	From Ebony-Grevillea spoil landform via seepage into shallow permeable strata then into ephemeral One Mile Creek. Distance <100m to receptor (north) *Potential for AMD to enter shallow permeable strata:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater:* ***Probable***	Ephemeral creek (via shallow permeable strata): One Mile Creek @ northern side of Ebony-Grevillea landform. *Potential for AMD to reach One Mile Creek:* ***Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach One Mile Creek:* ***Unlikely***	**Acid/acidic drainage:** Low pH water impacting One Mile Creek [via seepage]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting One Mile Creek [via seepage]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting One Mile Creek [via seepage]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting One Mile Creek [via seepage]	Unlikely	S2	**Low**
	From Ebony-Grevillea spoil landform via surface water run-off into ephemeral Spring Creek (a tributary of Philips Creek). Distance ~200m to receptor (west) *Potential for AMD to enter surface water run-off:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off:* ***Probable***	Ephemeral creek (via surface water run-off): Spring Creek @ western side of Ebony-Grevillea landform. *Potential for AMD to reach Spring Creek:* ***Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Spring Creek:* ***Probable***	**Acid/acidic drainage:** Low pH water impacting Spring Creek [via run-off]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Spring Creek [via run-off]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Spring Creek [via run-off]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Spring Creek [via run-off]	Probable	S2	**Low to Medium**
	From Ebony-Grevillea spoil landform via seepage into shallow permeable strata then into ephemeral Spring Creek (a tributary of Philips Creek). Distance ~200m to receptor (west) *Potential for AMD to enter shallow permeable strata:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater:* ***Probable***	Ephemeral creek (via shallow permeable strata): Spring Creek @ western side of Ebony-Grevillea landform. *Potential for AMD to reach Spring Creek:* ***Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Spring Creek:* ***Unlikely***	**Acid/acidic drainage:** Low pH water impacting Spring Creek [via seepage]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Spring Creek [via seepage]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Spring Creek [via seepage]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Spring Creek [via seepage]	Unlikely	S2	**Low**
	From Ebony-Grevillea spoil landform via surface water run-off into ephemeral Philips Creek. Distance <100m to receptor (south) *Potential for AMD to enter surface water run-off:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off:* ***Probable***	Ephemeral creek (via surface water run-off): Philips Creek @ southern side of Ebony-Grevillea landform. *Potential for AMD to reach Phillips Creek:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Phillips Creek:* ***Probable***	**Acid/acidic drainage:** Low pH water impacting Phillips Creek [via run-off]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Phillips Creek [via run-off]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Phillips Creek [via run-off]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Phillips Creek [via run-off]	Probable	S2	**Low to Medium**
	From Ebony-Grevillea spoil landform via seepage into shallow permeable strata then into ephemeral Philips Creek. Distance <100m to receptor (south) *Potential for AMD to enter shallow permeable strata:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater:* ***Probable***	Ephemeral creek (via shallow permeable strata): Philips Creek @ southern side of Ebony-Grevillea landform. *Potential for AMD to reach Phillips Creek:* ***Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Phillips Creek:* ***Highly Unlikely***	**Acid/acidic drainage:** Low pH water impacting Phillips Creek [via seepage]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Phillips Creek [via seepage]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Phillips Creek [via seepage]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative): Salt impacting Phillips Creek [via seepage]	Unlikely	S2	**Low**

Table 34. Source-Pathway-Receptor (SPR) assessment of Hakea spoil landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Hakea spoil landform (post-closure) Comprised of approximately 90% non-carbonaceous spoil; approximately 5% carbonaceous spoil and approximately 5% reject. No tailings. *AMD source hazard is* ***Low-Moderate*** *Salinity (non-oxidative) source hazard:* ***Probable***	From Hakea spoil landform via surface water run-off into ephemeral Philips Creek. Distance <100m to receptor (north) *Potential for AMD to enter surface water run-off:* ***Unlikely*** *Potential for salt (non-oxidative) >900µS/cm to enter surface water run-off:* ***Probable***	Ephemeral creek (via surface water run-off): Philips Creek @ northern side of Hakea landform. *Potential for AMD to reach Phillips Creek:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Phillips Creek:* ***Probable***	**Acid/acidic drainage** Low pH water impacting Phillips Creek [via run-off]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage Metals and metalloids impacting Phillips Creek [via run-off]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation) Salt (sulphate) impacting Phillips Creek [via run-off]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative) Salt impacting Phillips Creek [via run-off]	Probable	S2	**Low to Medium**
	From Hakea spoil landform via seepage into shallow permeable strata then into ephemeral Philips Creek. Distance <100m to receptor (north) *Potential for AMD to enter shallow permeable strata:* ***Unlikely****.* *Potential for salt (non-oxidative) >900µS/cm to enter shallow groundwater:* ***Probable***	Ephemeral creek (via shallow permeable strata): Philips Creek @ northern side of Hakea landform. *Potential for AMD to reach Phillips Creek:* ***Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Phillips Creek:* ***Highly Unlikely***	**Acid/acidic drainage** Low pH water impacting Phillips Creek [via seepage]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage Metals and metalloids impacting Phillips Creek [via seepage]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation) Salt (sulphate) impacting Phillips Creek [via seepage]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative) Salt impacting Phillips Creek [via seepage]	Unlikely	S2	**Low**

Table 35. Source-Pathway-Receptor (SPR) assessment of TSF no. 3 landform: surface water receptors via run-off and via shallow permeable strata (shallow groundwater)

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
TSF no. 3 landform (post-closure) Comprised of approximately 81% tailings and capped/covered with approximately 2-3m of spoil (which comprises the remaining 19% of the TSF landform). *AMD source hazard is* ***Moderate*** *Salinity (non-oxidative) source hazard:* ***Unlikely***	From TSF no. 3 landform via surface water run-off into ephemeral Barrett Creek. Distance ~100 m to receptor (east of TSF landform). Tailings are capped/covered by spoil. *Potential for AMD to enter surface water run-off:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter surface water run-off:* ***Unlikely***	Ephemeral creek (via surface water run-off): Barrett Creek @ eastern side of TSF no. 3 landform. *Potential for AMD to reach Barrett Creek:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Barrett Creek:* ***Unlikely***	**Acid/acidic drainage** Low pH water impacting Barrett Creek [via run-off]	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage Metals and metalloids impacting Barrett Creek [via run-off]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation) Salt (sulphate) impacting Barrett Creek [via run-off]	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative) Salt impacting Barrett Creek [via run-off]	Unlikely	S2	**Low**
	From TSF no. 3 landform via seepage into shallow permeable strata then into ephemeral Barrett Creek. Distance ~100 m to receptor (east) *Potential for AMD to enter shallow permeable strata:* ***Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter shallow groundwater:* ***Unlikely***	Ephemeral creek (via shallow permeable strata): Barrett Creek @ eastern side of TSF no. 3 landform. *Potential for AMD to reach Barrett Creek:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach Barrett Creek:* ***Unlikely***	**Acid/acidic drainage** Low pH water impacting Barrett Creek [via seepage]	Unlikely	S3	**Low to Medium**
			Neutral metalliferous drainage Metals and metalloids impacting Barrett Creek [via seepage]	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation) Salt (sulphate) impacting Barrett Creek [via seepage]	Unlikely	S2	**Low**
			Saline drainage (non-oxidative) Salt impacting Barrett Creek [via seepage]	Unlikely	S2	**Low**

Table 36. Source-Pathway-Receptor (SPR) assessment of spoil landforms: residual void receptors

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Jacaranda-Bauhinia spoil landform (post-closure) Approximate composition: 82% non-carb. spoil; 12% carb. spoil; 5% reject and <1% tailings (Ramp 2/3 TSF). Tailings are concentrated in one area. *AMD source hazard:* ***Low*** *Salinity (non-oxidative) source hazard:* ***Probable***	Seepage / percolation into groundwater, which flows into Jacaranda-Bauhinia residual void. Residual void is expected to intersect the water table. Residual void is a groundwater 'sink', drawing all groundwater within landform catchment towards the residual void. Percolation/seepage from buried TSFs is likely. *Potential for AMD to enter groundwater:* ***Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater:* ***Probable***	Jacaranda-Bauhinia residual void (NUMA) *Potential for AMD to reach residual void:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void:* ***Unlikely***	**Acid/acidic drainage:** Low pH water impacting Jacaranda-Bauhinia residual void water quality	Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Jacaranda-Bauhinia residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Jacaranda-Bauhinia residual void water quality	Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Jacaranda-Bauhinia residual void water quality	Unlikely	S2	**Low**
Coolibah-Dogwood spoil landform (post-closure) Approximate composition: 83% non-carb. spoil; 11% carb. spoil; 5% reject and <0.5% tailings (TSF no. 2, TSF no. 4 and Ramp 6 TSF). Tailings are concentrated in one area. *AMD source hazard:* ***Low-Moderate*** *Salinity (non-oxidative) source hazard:* ***Probable***	Seepage / percolation into groundwater, which flows into Coolibah-Dogwood residual void. Residual void is expected to intersect the water table. Residual void is a groundwater 'sink', drawing all groundwater within landform catchment towards the residual void. Percolation/seepage from buried TSFs is likely. *Potential for AMD to enter groundwater:* ***Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater:* ***Probable***	Coolibah-Dogwood residual void (NUMA) *Potential for AMD to reach residual void:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void:* ***Unlikely***	**Acid/acidic drainage:** Low pH water impacting Coolibah-Dogwood residual void water quality	Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Coolibah-Dogwood residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Coolibah-Dogwood residual void water quality	Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Coolibah-Dogwood residual void water quality	Unlikely	S2	**Low**
Ebony-Grevillea spoil landform (post-closure) Approximate composition: 86% non-carb. spoil; 9% carb. spoil and 5% reject. No tailings. *AMD source hazard:* ***Low-Moderate*** *Salinity (non-oxidative) source hazard:* ***Probable***	Seepage / percolation into groundwater, which flows into Ebony-Grevillea residual void. Residual void is expected to intersect the water table. Residual void is a groundwater 'sink', drawing all groundwater within landform catchment towards the residual void. *Potential for AMD to enter groundwater:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater:* ***Probable***	Ebony-Grevillea residual void (NUMA) *Potential for AMD to reach residual void:* ***Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void:* ***Unlikely***	**Acid/acidic drainage:** Low pH water impacting Ebony-Grevillea residual void water quality	Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Ebony-Grevillea residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Ebony-Grevillea residual void water quality	Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Ebony-Grevillea residual void water quality	Unlikely	S2	**Low**
Hakea spoil landform (post-closure) Approximate composition: 90% non-carb. spoil; 5% carb. spoil and 5% reject. No tailings. *AMD source hazard:* ***Low-Moderate*** *Salinity (non-oxidative) source hazard:* ***Probable***	Seepage / percolation into groundwater, which flows into Hakea residual void. Residual void is expected to intersect the water table. Residual void is a groundwater 'sink', drawing all groundwater within landform catchment towards the residual void. *Potential for AMD to enter groundwater:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater:* ***Probable***	Hakea residual void (NUMA) *Potential for AMD to reach residual void:* ***Highly Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void:* ***Unlikely***	**Acid/acidic drainage:** Low pH water impacting Hakea residual void water quality	Unlikely	S1	**Low**
			Neutral metalliferous drainage: Metals and metalloids impacting Hakea residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation): Salt (sulphate) impacting Hakea residual void water quality	Unlikely	S1	**Low**
			Saline drainage (non-oxidative): Salt impacting Hakea residual void water quality	Unlikely	S2	**Low**

Table 37. Source-Pathway-Receptor (SPR) assessment of TSF no. 3 landform: residual void receptors

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
TSF no. 3 landform (post-closure) Comprised of approximately 81% tailings and 19% 'cover' material (general spoil). *AMD source hazard:* ***Moderate*** *Salinity (non-oxidative) source hazard:* ***Unlikely***	Seepage / percolation into groundwater, which flows into Coolibah-Dogwood residual void. Residual void is expected to intersect the water table. Residual void is a groundwater 'sink', drawing all groundwater within landform catchment towards the residual void. Percolation/seepage from TSF no.3 landform is rated as likely. *Potential for AMD to enter groundwater:* ***Probable*** *Potential for salt (non-oxidative) >900 µS/cm to enter groundwater:* ***Unlikely***	Coolibah-Dogwood residual void (NUMA) *Potential for AMD to reach residual void:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach residual void:* ***Unlikely***	**Acid/acidic drainage** Low pH water impacting Coolibah-Dogwood residual void water quality	Highly Unlikely	S2	**Low**
			Neutral metalliferous drainage Metals and metalloids impacting Coolibah-Dogwood residual void water quality	Unlikely	S2	**Low**
			Saline drainage (from sulphide oxidation) Salt (sulphate) impacting Coolibah-Dogwood residual void water quality	Highly Unlikely	S2	**Low**
			Saline drainage (non-oxidative) Salt impacting Coolibah-Dogwood residual void water quality	Unlikely	S1	**Low**

Table 38. Source-Pathway-Receptor (SPR) assessment of residual void highwall and floor: residual void receptor

Source	Pathway	Receptor	Event / potential harm	Likelihood of Event	Severity of Event	Risk Rating
Highwall and floor of residual voids (post-closure) Highwalls of the residual voids are comprised of approximately: • 82 to 89% non-carbonaceous overburden/interburden; • 5 to 11% carbonaceous overburden/interburden; • 6 to 9% coal (residual coal seams). PAF exposure on highwalls conservatively estimated at approximately 15% (vertical meterage). A proportion of this will be in lower seams, which will be submerged. PAF exposure on pit floors conservatively estimated at approximately 37 to 44%, however pit floors will be submerged. *AMD source hazard from exposed highwalls and submerged pit floors:* ***Low*** *Salinity (non-oxidative) source hazard:* ***Unlikely***	Surface water run-off from highwall into residual voids. All voids are groundwater sinks. *Potential for AMD to enter pathway:* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to enter pathway:* ***Unlikely***	Residual voids (NUMA) *Potential for AMD to reach receptor (residual voids):* ***Unlikely*** *Potential for salt (non-oxidative) >900 µS/cm to reach receptor (residual voids):* ***Unlikely***	**Acid/acidic drainage** Low pH water impacting residual void water quality	Highly Unlikely	S1	**Low**
			Neutral metalliferous drainage Metals impacting residual void water quality	Unlikely	S1	**Low**
			Saline drainage (from sulphide oxidation) Salt (sulphate) impacting residual void water quality	Highly Unlikely	S1	**Low**
			Saline drainage Salt impacting residual void water quality	Unlikely	S1	**Low**

8 Management and Rehabilitation Measures

The assessment has found that the environmental risks posed by spoil landforms likely to be present at closure are generally low. The environmental risk associated with tailings buried within the Jacaranda-Bauhinia landform, tailings buried within the Coolibah-Dogwood landform, and the TSF no. 3 landform is generally low to medium. As such, no specific AMD management measures (e.g. alkaline amendment or engineered capping systems) are expected to be required to manage mineral wastes during rehabilitation and closure – outside of operational mixing/burial of PAF waste amongst NAF waste, spoil placement and landform reshaping activities already proposed (refer below and to the main volume of the PRCP). Decommissioning and rehabilitation activities related to mineral waste will be addressed as part of the milestone criteria for infrastructure, remediation of contaminated land, landform design, surface preparation and revegetation, where necessary.

Proposed mineral waste management and rehabilitation activities of relevance to this waste characterisation report comprise the following actions. Refer to the main volume of the PRCP for detailed information:

- Pits: will remain as residual voids under four groups:
    - Jacaranda-Bauhinia void;
    - Coolibah-Dogwood void;
    - Ebony-Grevillea void; and
    - Hakea void.
- Spoil dumps: will be reshaped into four final spoil landforms and seeded.
- TSF no. 3 (above ground): will remain ‘as is’ as a final TSF landform, subject to maintenance and/or corrective actions identified through ongoing monitoring.
- All other TSFs (Ramp 2/3 TSF, Ramp 6 TSF, TSF no. 2 and TSF no. 4): Covered by spoil during operations. The final spoil cover thickness over tailings will be variable due to the spoil landform designs. The optimal thickness of spoil cover to manage water and/or oxygen ingress will be determined following further assessment prior to covering.
- Rejects: Managed during operations (disposed within spoil) and progressively covered by spoil. No additional remediation for the rejects (at closure) is required. The optimal thickness of spoil cover to manage the AMD hazard of rejects will be determined following further assessment prior to covering.
- ROM pad: Remove remnant coal from the ROM Pad and dispose within spoil. The former ROM Pad will be reshaped, covered with soil, ripped and seeded.
- Coal stockpile: Remove remnant coal from the coal stockpile pad and dispose within spoil. Cover with suitable soil material, rip and seed.

9 Forward Work Program

The environmental geochemical characterisation and assessment of mineral waste samples outlined in this report is representative of the mineral waste materials likely to require rehabilitation at closure. However, BHP will continue to undertake sampling of likely mineral waste materials (and subsequent characterisation and assessment of those samples) from SRM during operations and into decommissioning – to validate the findings of the current assessment, ensure the risks continue to be understood and the management measures proposed are commensurate with the risks. Where required, management measures will be revised and implemented.

Further work may also be required prior to closure to better understand the relationship between shallow and deeper groundwater at SRM and between shallow groundwater and surface water systems at SRM – particularly in the vicinity of TSF landforms (TSF no. 3) and where tailings are buried within spoil landforms (tailings from Ramp 2/3 TSF, Ramp 6 TSF, TSF no. 2 and TSF no. 4).

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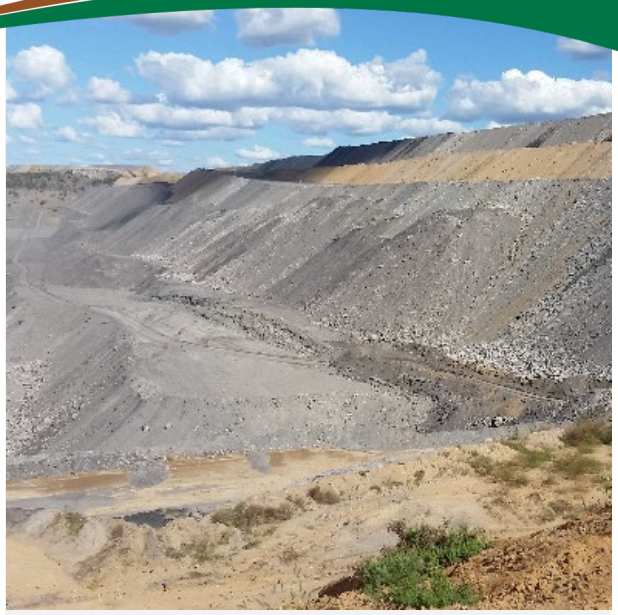
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Landloch



EROSION AND LANDFORM EVOLUTION SIMULATIONS TO SUPPORT WASTE LANDFORM DESIGN: SARAJI MINE

November 2022

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1 SUMMARY

For waste landforms at Saraji Mine, Landloch Pty Ltd has completed:

a) initial WEPP runoff/erosion model simulations;
b) derivation of parameters for the SIBERIA landform evolution model; and
c) landform evolution simulations for 3-D waste landforms provided by BHP.

All WEPP simulations considered:

- batter slopes 200 m high,
- gradients ranging from 15% to 30%, and
- vegetation cover levels ranging from 30 to 90% surface contact cover.

Erodibility data for materials considered in WEPP simulations were largely sourced from previous Saraji studies, and included:

- Topsoil SO1, which is a clay soil
- Topsoil SO2, which is a sandy clay loam with very high infiltration capacity.
- Topsoil SO13, which is a highly sodic and dispersive sandy loam, with very low infiltration capacity.
- Mudstone waste SO3, which is fairly fine textured and somewhat susceptible to rill detachment.
- Sandstone waste SO7. This material had been excavated for about 10 years and the rock was fairly durable.
- Permian waste CR6, which is a moderately fine Permian waste (data sourced from Caval Ridge Mine), and is representative of moderately well-structured waste also present at Saraji that could be used as an alternative growth medium if suitably amended.

In deriving and applying SIBERIA parameters, it was assumed that:

- Topsoil SO1 will be used for rehabilitation works associated with Grevillea and Hakea (south) landforms
- Topsoil SO2 will be used for rehabilitation works associated with Coolibah, Dogwood and Ebony (mid site) landforms.
- Alternative growth medium with properties consistent with CR6 will be used for rehabilitation works associated with Jacaranda and Bauhinia landforms.
- Alternative growth medium with properties consistent with SO7 and amendment to create a growth medium will be used to construct low walls and ramp walls for all pits.

It is considered that those simulations cover all options being considered for Saraji. SIBERIA output showed most batter slopes erode at rates below target levels. Some batters formed using alternative growth media based on CR6 show erosion rates only slightly above the conservative target rate adopted, and are considered acceptable as there is confidence that vegetative cover levels achieved in practice will exceed those assumed for the simulations.

2 INTRODUCTION

2.1 Overview

Landloch has been engaged by BMA to carry out specific specialist studies for soils and capping, landform design and cover design, to provide information for the subsequent compilation of transitional Progressive Rehabilitation and Closure Plans (PRCPs) for its existing operational coal assets located within the Bowen Basin.

This report specifically considers the design of stable waste landforms on the Saraji Mine.

2.2 Objectives of landform design

The key consideration for landform design is to demonstrate that the landforms can confidently be expected to be stable over the long term, while supporting the target Post Mining Land Use (PMLU).

As part of that assessment, this study reports:

- Materials to be used in landform rehabilitation and their erodibility;
- Erosion assessments for a range of material and slope profile options, considering interactions between soil erodibility, rainfall erosivity, landform height, gradient and vegetation cover to identify options that will achieve acceptable erosion rates over a 100-year period; and
- Landform evolution simulations using the SIBERIA landform evolution model (LEM) to assess stability of 3-dimensional waste landform designs over a period of 300 years.

3 LANDFORM STUDY METHODS

The landform study consisted of four stages:

a) Sourcing and review of input data and information;
b) Simulations of runoff and erosion for a range of landform options using the WEPP model (Flanagan and Livingston 1995);
c) Derivation of parameters for the SIBERIA LEM (Willgoose et al. 1989); and
d) Landform evolution simulations using SIBERIA for landforms provided by BHP.

3.1 Data sources

Soil erodibility parameters for the WEPP runoff/erosion model were taken from a previous study for the Saraji Mine and a similar study for the Caval Ridge Mine:

- Landloch (2018a). Soil and waste erodibility and landform design: Saraji Mine.
- Landloch (2018b). Soil and waste erodibility and landform design: Caval Ridge Mine.

3.1.1 Topsoils

From the first study, parameters were taken for three Saraji topsoils:

- Topsoil SO1, which is a clay soil with moderate runoff potential relative to the other topsoils considered, and possibly high sediment transport capacity in runoff due to its fine texture. Importantly, it is also likely to be the most productive of any of the Saraji topsoils in terms of ability to grow grass and to achieve a high level of surface cover.
- Topsoil SO2, which is a sandy clay loam with very high infiltration capacity compared to the other topsoils considered. It is likely to be reasonably productive for grass and other plant growth.
- Topsoil SO13, which is a highly sodic and dispersive sandy loam, with very low infiltration capacity due to its dispersive properties. It is likely to be an extremely poor growth medium due to both physical and chemical limitations. Amendment to reduce sodicity will be essential, but it is unlikely that this soil would support high levels of vegetation cover.

Geographically, assessment of existing topsoil stockpiles indicates:

- Pits Grevillea and Hakea (South portion of the mine) are primarily vertosols with medium to heavy clays. The largest stockpiles on the mine are located below Hakea pit and will most likely service the majority of rehabilitation in the southern areas. Most stockpile soils there are dark clays, which correspond with topsoil SO1.
- Pits Coolibah, Dogwood and Ebony (Middle portion of mine) are variable with all 3 topsoil types present but the dominant soils are clay loams to light clays, which correspond with topsoil SO2.
- Pits Acacia, Jacaranda and Bauhinia (North portion of the mine) are primarily sandy loams to sandy clay loams which correspond with topsoil SO13.

Figure 1 shows the three topsoils considered immediately after exposure to high intensity simulated rain.



Figure 1: Rainfall simulator plots immediately following application of rain to topsoils (L-R) S01, S02, and SO13

3.1.2 Wastes

From the first study, parameters were taken for two Saraji wastes:

- Mudstone waste SO3, which is fairly fine textured and has a relatively high rill detachment parameter.
- Sandstone waste SO7. This material had been excavated for about 10 years and the rock was fairly durable.

From the second study, parameters were taken for:

- Permian waste CR6, which is a moderately fine Permian waste (data sourced from Caval Ridge Mine), representative of similar material at Saraji. It was used as an indicator of moderately well-structured waste that could be used as an alternative growth medium if suitably amended.



Figure 2: Rainfall simulator plots immediately following application of rain to wastes (L-R) S03, S07, and CR6.

3.1.3 Parameters used

In all cases, erodibility parameters had been determined experimentally, and included:

- Effective hydraulic conductivity;
- Interrill erodibility;
- Rill erodibility;
- Critical flow shear stress for initiation of rilling.

3.2 WEPP simulations

3.2.1 Slopes and materials

WEPP simulations were carried out for:

- Batter slopes 200 m high, at 15% gradient, surfaced with topsoils SO1 and SO2 at gradients of 15% and 20% with a range of vegetation cover levels.
- Batter slopes 200 m high, at 15% gradient, surfaced with topsoil SO13 with a range of vegetation cover levels.

- Batter slopes 200 m high, at selected gradients from 15% to 30%, surfaced with either:
    - Waste rock S03 mixed with a manufactured growth medium with 50% vegetation cover;
    - Coarse waste rock SO7 mixed with a manufactured growth medium with 30% to 70% vegetation cover; or
    - Waste rock CR6 mixed with a manufactured growth medium with 50% to 70% vegetation cover.

In considering rocky material (waste) mixed with topsoil, input parameters used the hydraulic conductivity of the soil and the critical flow shear stress of the rocky material (consistent with Landloch's unpublished data for such mixtures). Where addition of amendments to waste to create an alternative growth medium is considered, the base input parameters used were those of the waste that is planned to be amended.

3.2.2 Vegetation impacts

Impacts of vegetation cover on infiltration rates were estimated using the relationship between vegetative cover reported by Kato et al. (2009), and direct impacts of cover on erosion rates were estimated using Cover (C) factors for the Revised Universal Soil Loss Equation (RUSLE) (Renard et al. (1993) listed in Rosewell (1993).

Most of the monitoring reports available for Saraji provide limited information with respect to groundcover levels achieved in rehabilitated areas as they report total groundcover including rock and timber. The most useful vegetation data are presented in Eco Logical Australia (2019). They show:

- 73-100% vegetative cover on woodland sites (which include some sites prepared with coarse rock cover); and
- 78-100% cover on established cattle grazing sites (typically established on soils of clay or loamy texture).

Nonetheless, it can be concluded that vegetative cover levels ≥70% appear to be achievable on most rehabilitation carried out on Saraji Mine. As a conservative approach, cover levels ranging from 30–50% for materials of relatively low fertility (wastes) to 50–70% for more fertile materials (topsoils) have been applied in erosion simulations.

3.2.3 Assumptions with respect to effects of cover on erosion

Two points should be noted:

a) In considering "vegetation cover" or "surface cover," this report specifically considers contact cover of vegetation on the soil surface. Practically, this means a combination of grass cover and anchored (not readily moved) surface litter.

b) Considerations of surface cover do not include rock. Where rocky materials have had erodibility measured experimentally and those parameters are used in WEPP simulations, then effects of the rock are already accounted for within the parameters used.

3.2.4 Climate

All simulations used a synthetic 100-year climate file prepared to match all relevant characteristics of Moranbah climate.

3.2.5 Key assumptions – landforms and vegetation

The simulations are based on two key assumptions:

a) There will be no uncontrolled discharge of runoff from landform tops onto outer batter slopes; and
b) The assumed vegetative cover levels will be achieved sustainably, with those levels being set as triggers for investigation and remedial action should monitoring indicate that they are not being achieved.

It should be recognised there are also underlying assumptions of good rehabilitation practice such that:

- there will not be discharges of concentrated flows onto any batter slopes at any point of their rehabilitation;
- batter slopes will not be formed with flow-concentrating profiles (e.g. variations in surface elevation such that there is cross-slope concentration of flow into consistent depressions running downslope);
- any cross-slope ripping will be carried out strictly on the contour; and
- soil management (including stripping, stockpiling, replacement, amendment, and fertilisation) will be carried out effectively to maximise early and continuing plant growth.

3.2.6 Soil loss targets

This study used runoff, and erosion modelling to identify landform options that would erode at rates low enough to provide long-term stability. Effectively, the landforms are planned to be consistent with tolerable rates of soil loss. Wischmeier and Smith (1978) defined tolerable soil loss for cropland as "the maximum rate of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely."

A value of 11.2 t/ha/y averaged over an area of interest is often cited as a tolerable soil loss rate, but that value was derived by US soil conservation agencies for deep, fertile cultivated soils, and has little relevance to most rehabilitated minesites. Using similar criteria to those applied for crop land, a lower soil loss tolerance value of 4.5 t/ha/y was developed by US agencies for erosion of rangeland soils and shallow cultivated soils (Wight and Siddoway 1979).

Lower tolerance values are relevant to rangeland and minesite situations, as not only are the soils shallower and more susceptible to fertility decline, but the lack of regular tillage or disturbance means that any rills or points of scour that form are more likely to extend and develop into gullies over time. These are typically of concern for minesite landforms where there is no bedrock layer at depth to limit long-term depths of incision.

For that reason, a key priority in setting a tolerable erosion target is the prevention of significant rill or gully development. On that basis, for slopes where long-term erosion risk (for a range of reasons) is considered high, then a maximum rate of erosion of 5 t/ha/y at any point on the batter slopes being modelled has commonly been applied by Landloch on the basis that - at that value - rilling is largely if not completely absent.

Typically, the high risk category includes slopes where the overall landform height is greater than 50 metres, and situations where – due to either or both rainfall limitations or soil fertility concerns – vegetation growth is unlikely to rapidly colonise and stabilise any rills that form.

As the landforms at Saraji are planned to be considerably higher than 50 metres, the adopted target erosion value for this assessment is a maximum at any point of the outer batter slopes of 5 t/ha/y. However, for low wall slopes that drain to pits, there are no potential off-site impacts of erosion, and planned PMLU is typically native vegetation. For those situations, a slightly higher erosion target (a maximum of 10 t/ha/y) has been adopted.

The elimination of rilling greatly reduces the potential for channelised flow to form gullies, and experience to date with a large number of waste landforms designed by Landloch has shown that the target soil loss values adopted have achieved acceptable levels of stability to erosion.

3.3 Derivation of SIBERIA parameters

To run SIBERIA, the parameters β_1, m_1, n_1, β_3, and m_3 are usually needed. However, if the batter area to be modelled is identical to the batter for which erosion data are available for calibration, m_3 and β_3 can be taken as 1.0 (Willgoose, pers. comm.), and a value of n_1 = 1.5 can be adopted for situations where slope gradient does not affect slope erodibility (Willgoose, pers. comm.). Therefore, the two key parameters that require derivation are β_1 and m_1.

Effectively, the β_1 parameter could be described as a "rate parameter", as it primarily controls the rate of sediment movement. The m_1 parameter could be considered as primarily controlling slope length responses. However, in practice, there is interaction between all of the parameters with the result that an almost infinite number of parameter sets will all show the same rate of erosion though some aspects of the pattern of erosion that is predicted will vary. It is for this reason that, where possible, fixed values of n_1 and m_3 are adopted – thereby reducing the difficulty of deriving parameter values.

Input parameters for SIBERIA are typically derived by fitting the various model equations to time series data of runoff and erosion. To generate the necessary data, Landloch has developed method that involves:

a) Run the WEPP model to generate data sets of runoff and erosion for slopes consistent with the proposed landforms and for materials of interest using site specific climate data.
b) Analyse the WEPP output to derive the required SIBERIA input parameters.

This approach ensures that SIBERIA parameters are effectively benchmarked to the WEPP output, and thereby, effectively based on measured erodibility parameters for site materials and on site climate.

3.4 Landform evolution simulations

Proposed final landforms for Saraji Mine were provided by BHP in .dxf format. These landforms were designed on the basis of WEPP model runoff/erosion results for potential surface covers to be applied (Figures 3–6).

All landforms include an area of level dump top that will not discharge onto the adjoining batter slopes. Inclusion of that design feature greatly reduces the risk of high rates of erosion on the adjoining batters and is, therefore, strongly recommended.

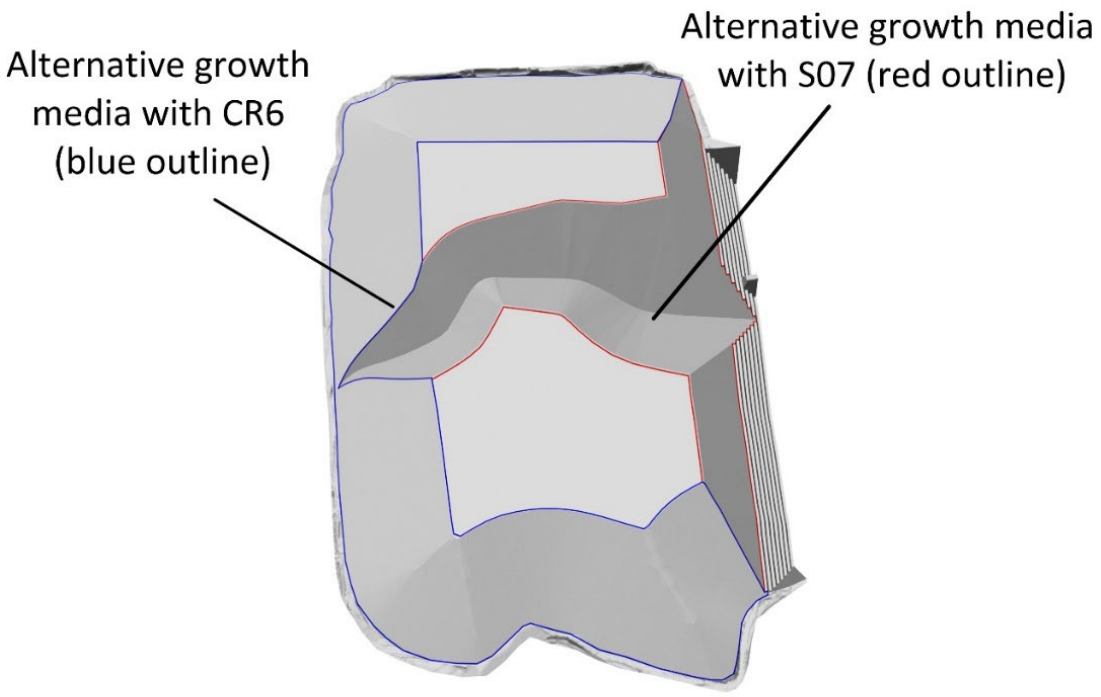


Figure 3: Jacaranda – Bauhinia landforms.

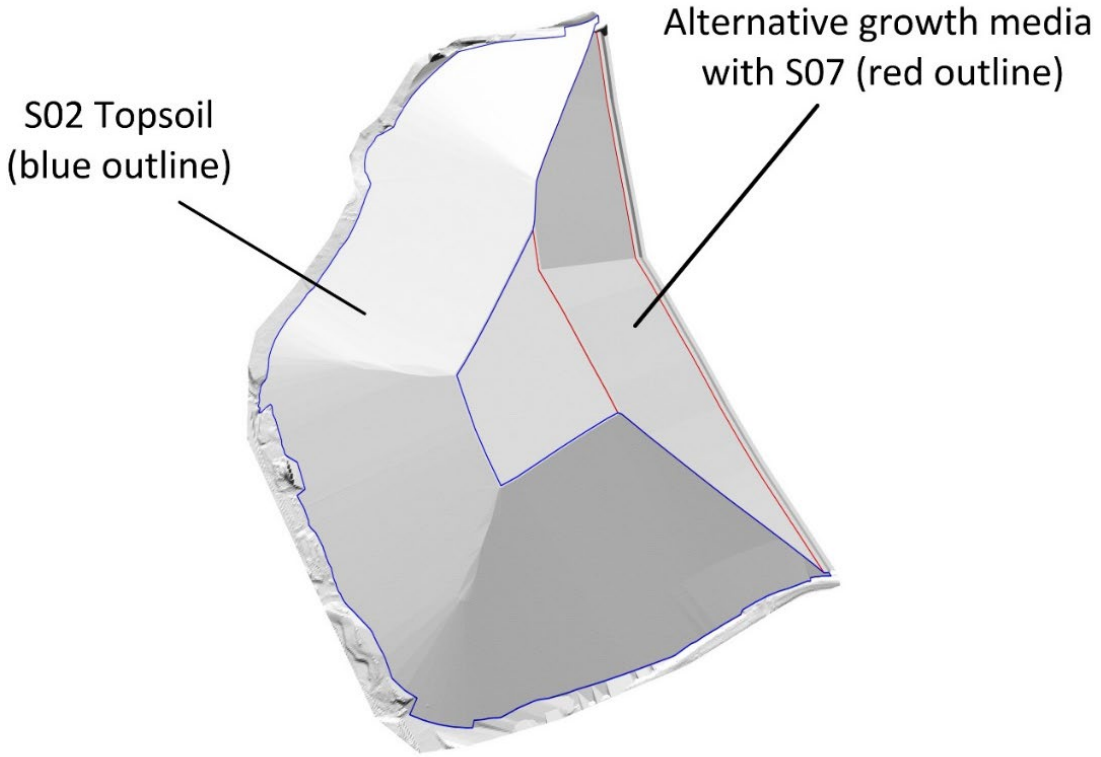


Figure 4: Coolibah – Dogwood landforms.

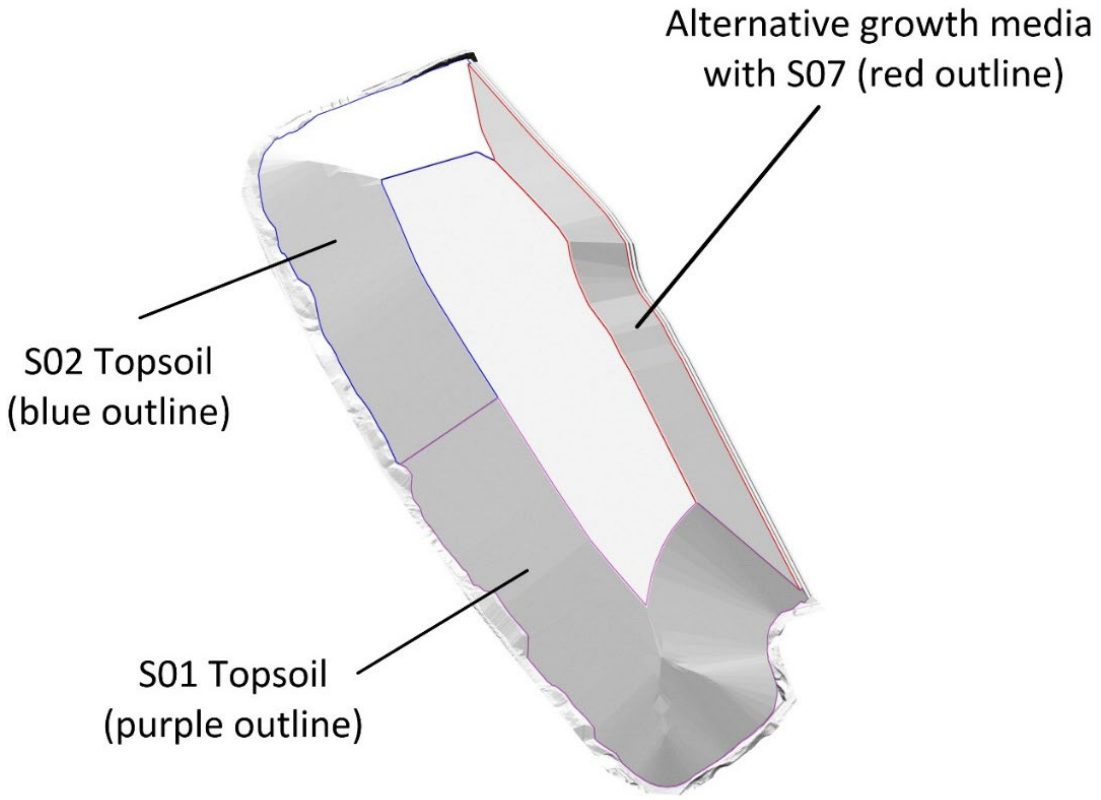


Figure 5: Ebony – Grevillea landforms.

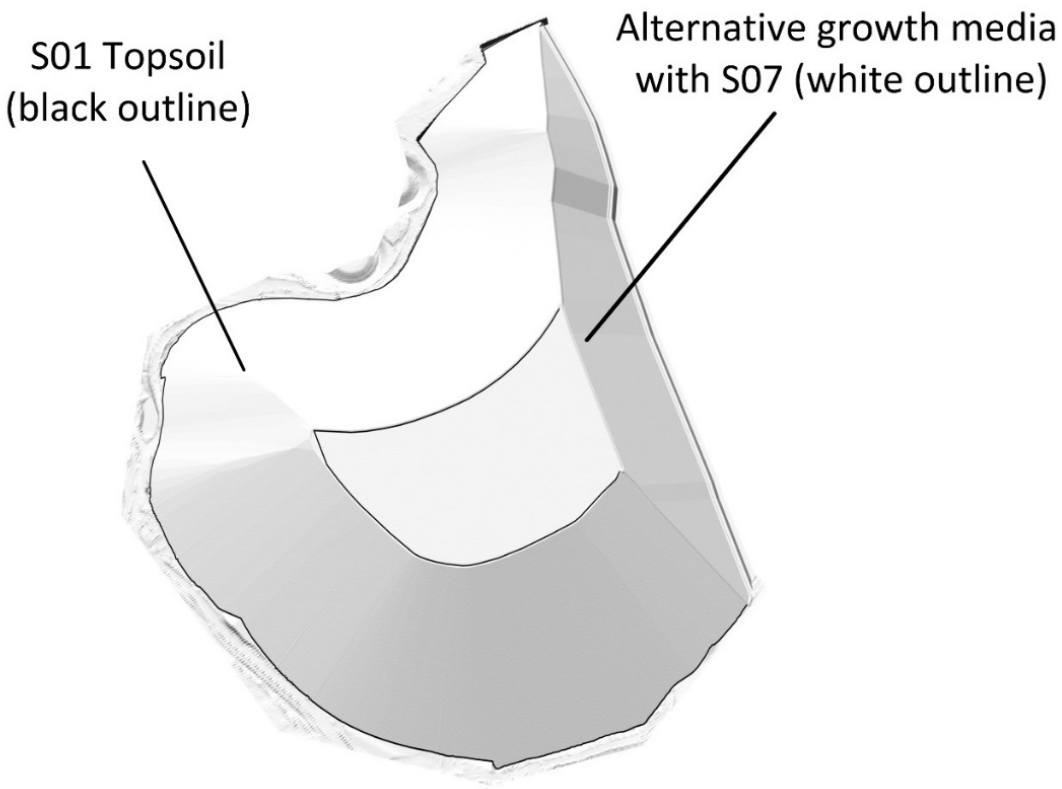


Figure 6: Hakea landform.

Key assumptions in the landform evolution modelling based on WEPP results were:

- Topsoil SO1 will be used for rehabilitation works associated with Grevillea and Hakea (south) landforms
- Topsoil SO2 will be used for rehabilitation works associated with Coolibah, Dogwood and Ebony (mid site) landforms.
- Alternative growth medium with properties consistent with CR6 will be used for rehabilitation works associated with Jacaranda and Bauhinia landforms.
- Alternative growth medium with properties consistent with SO7 and amendment to create a growth medium will be used to construct low walls and ramp walls for all pits.

Using input parameters derived for the materials to be used on the landforms, the SIBERIA model was run for 300 years, with outputs provided at years 50 and 300.

At each output year, visualisations of the rate of erosion and gully development are provided, along with a table that includes rates for each material on the landform. Rates of erosion that exceed 5 t/ha/y or gullying depth that exceeds 0.3 m are highlighted in the visualisations.

4 RESULTS OF WEPP SIMULATIONS

4.1 Outer batter slopes surfaced with vegetated topsoil

Simulations considered a batter height of 200 m.

The target erosion rate for modelling outer batters was a maximum of 5 t/ha/y at any point on the batter slope.

4.1.1 Clay soil (SO1)

For the clay soil, simulations indicate that 200 m high batter slopes on gradients of 15% or 20% will be stable provided a vegetative cover level of 70% can be sustainably achieved (Figures 7 and 8), with achievement of 90% vegetative cover ensuring quite low rates of erosion.

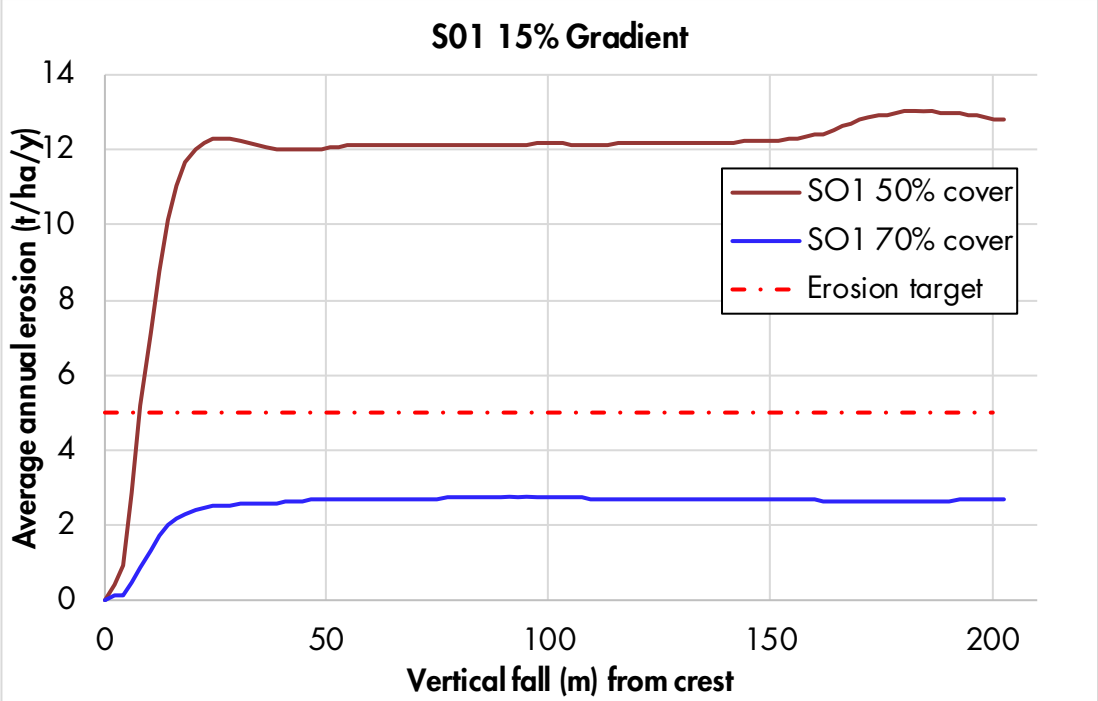


Figure 7: Predicted erosion rates along 15% gradient batter slopes with clay topsoil (SO1) capping.

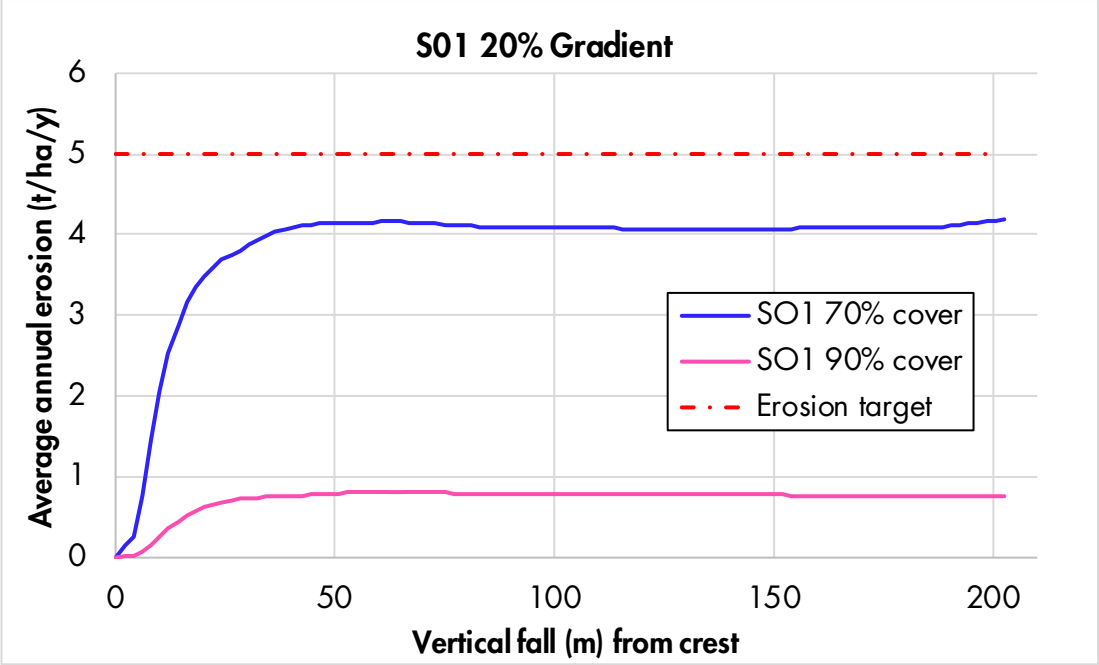


Figure 8: Predicted erosion rates along 20% gradient batter slopes with clay topsoil (SO1) capping.

4.1.2 Sandy clay loam (SO2)

For this soil, simulations (Figures 9 and 10) indicate that 50% vegetation cover will be sufficient to reduce potential erosion rates to less than the target value of 5 t/ha/y at gradients of either 15% or 20%.

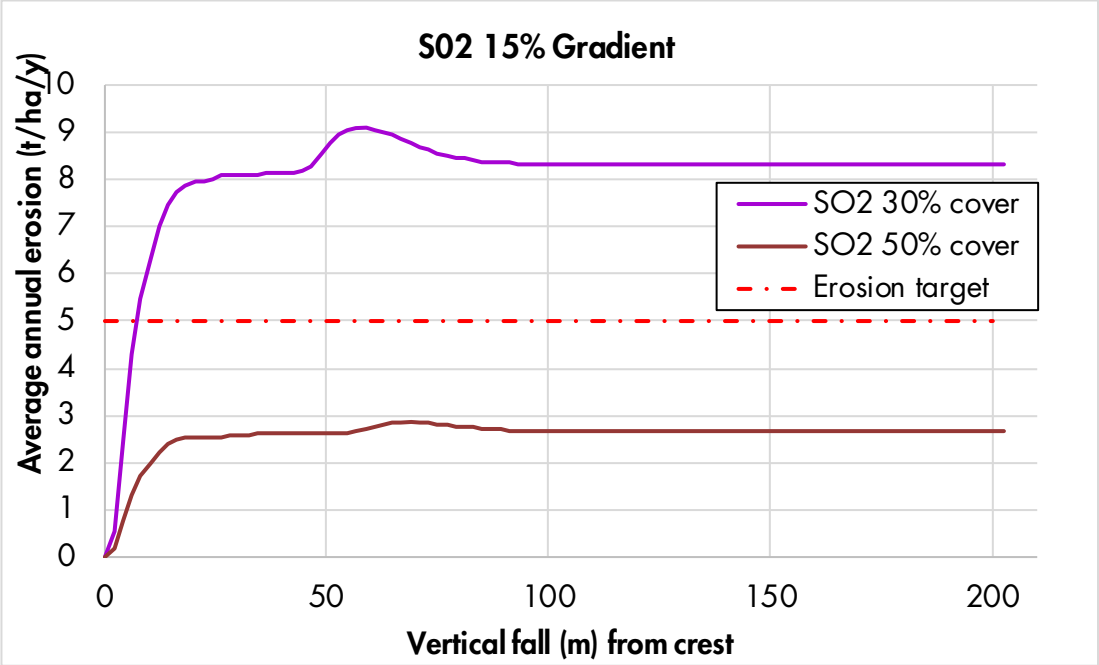


Figure 9: Predicted erosion rates along 15% gradient batter slopes with loamy sand topsoil (SO2) capping.

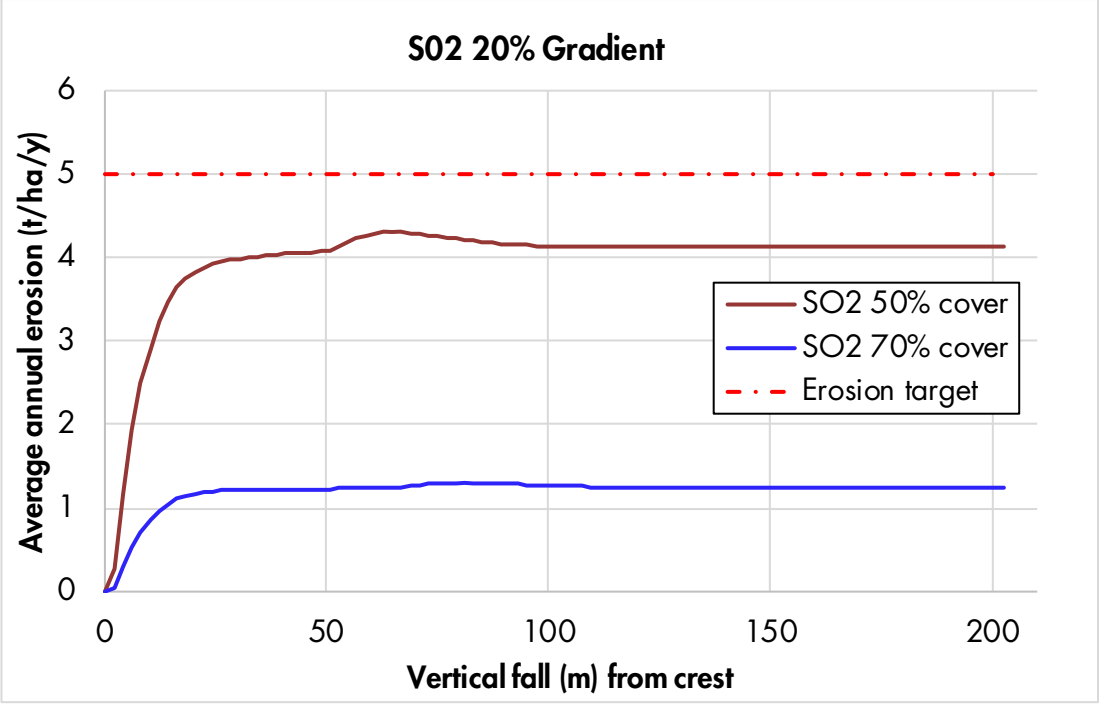


Figure 10: Predicted erosion rates along 20% gradient batter slopes with loamy sand topsoil (SO2) capping.

4.1.3 Sandy clay loam (SO13)

This topsoil is highly sodic (Exchangeable Sodium Percentage (ESP) of 14.9%), with very low Cation Exchange capacity (CEC) (an indicator of low fertility) of 2 m.eq./100 g[1]. Given its sandy texture, its water holding capacity is also likely to be low.

Consequently, it is considered unlikely that this soil will support high levels of vegetation cover and that vegetation establishment will be slow.

Simulations showed high rates of runoff relative to the other topsoils, and indicate that a sustainable minimum of 50% vegetation cover would be required to constrain predicted erosion within target levels (Figure 11). It is likely that sustainable achievement of that cover level will be challenging.

[1] For reference, the Queensland DTMR MRTS16 specification for topsoil (sandy loam to clay loam – Form C) requires an effective CEC of >10 m.eq./100g (DTMR 2014).

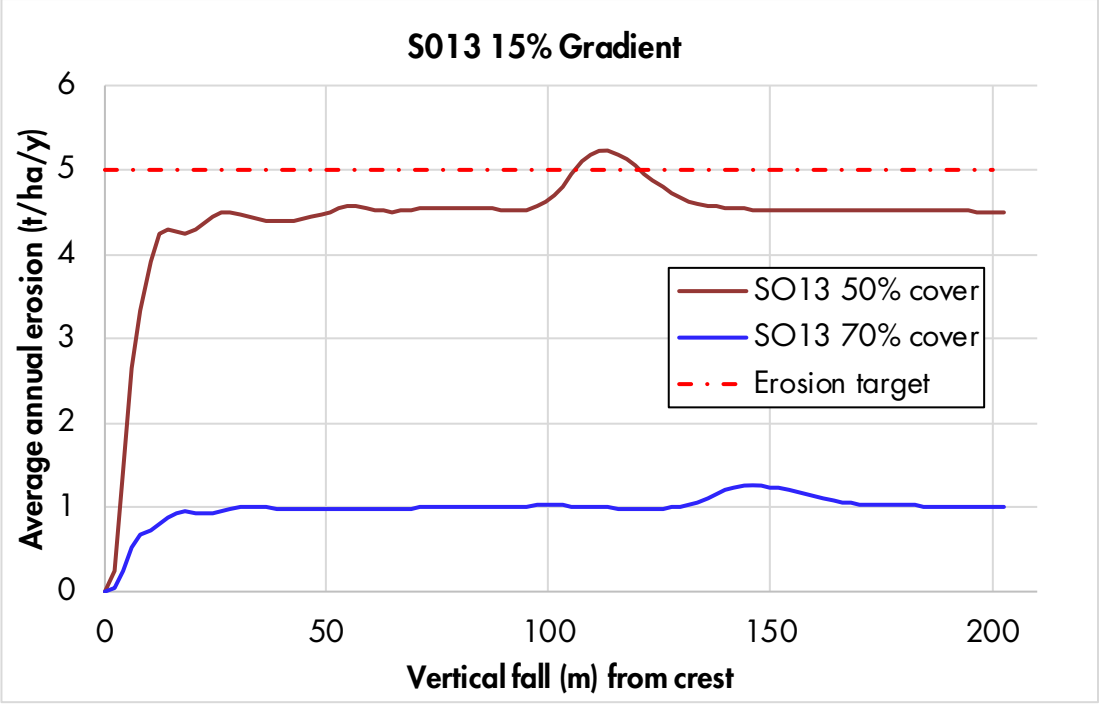


Figure 11: Predicted erosion rates along 15% gradient batter slope with sandy clay loam topsoil (SO13) capping.

4.2 Batter slopes with rock

These simulations considered batter slopes 200 m high, with gradients of 15%, 20%, 25%, and 30%.

4.2.1 Mudstone waste SO3

This material was considered initially, with an assumption that there might be addition of nutrient to enable its use as an alternative growth medium.

Erodibility measurements for this material showed a high rill detachment parameter, which results in relatively high rates of predicted erosion (Figure 12). The simulations indicate that even at relatively low gradient (15%), vegetation cover greater than 50% is required to meet erosion targets.

Given likely low fertility of this material, sustainable achievement of those relatively high levels of cover is considered unlikely, and this material is not a preferred option for use in rehabilitation works.

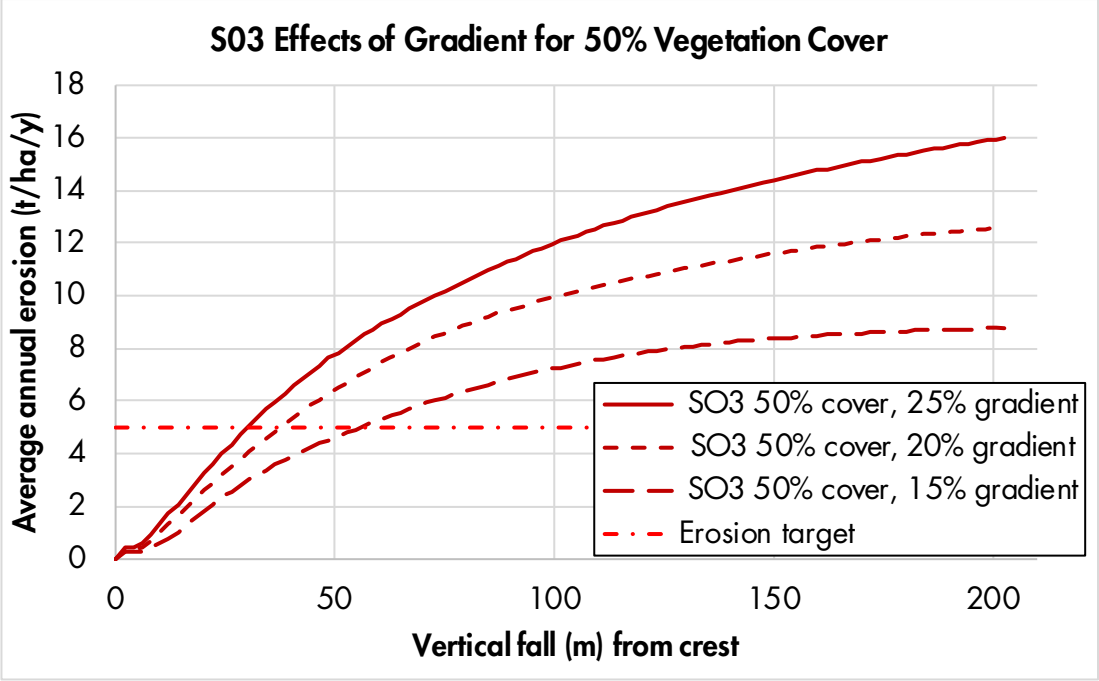


Figure 12: Predicted erosion rates for mudstone waste placed at gradients of 25%, 20%, and 15% and with 50% vegetation cover.

4.2.2 Sandstone waste SO7

A range of slopes are possible with different vegetation levels when creating an alternative growth medium with waste S07. Figure 13 shows that for a 20% gradient, predicted erosion from this material with low vegetative cover (30%) is slightly above the target level, but could be considered acceptable for low wall situations. For steeper gradients, vegetation cover of 50% would give stable slopes on gradients up to 30%, with only very slight exceedance of the target erosion rate at 30% gradient. With 70% cover, batter slopes would be quite stable at gradients up to 30%.

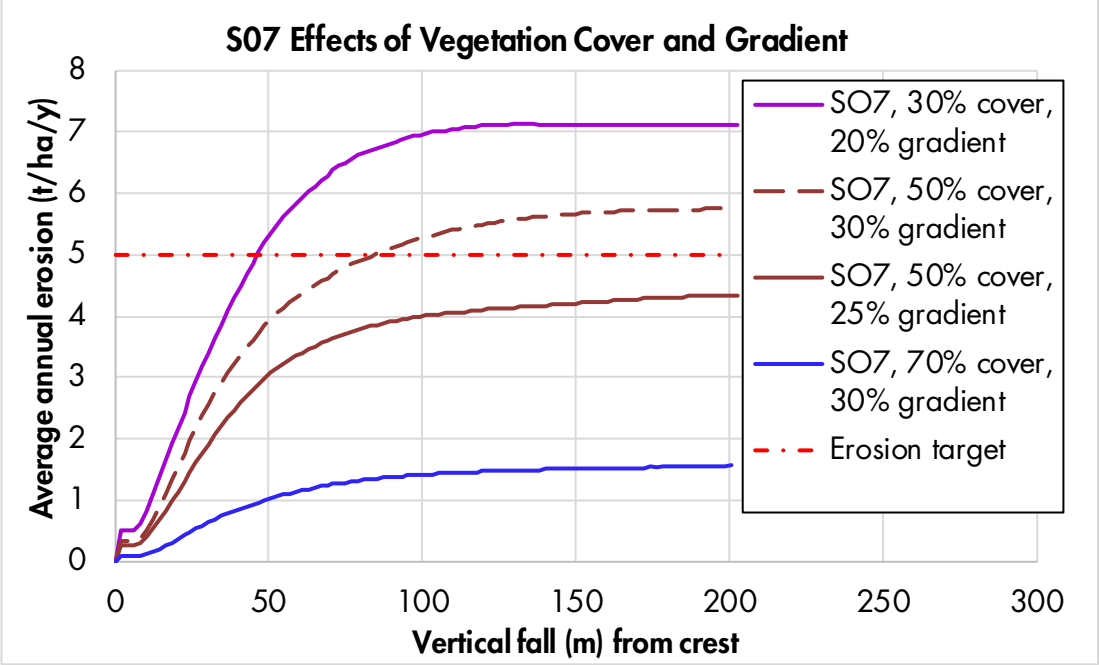


Figure 13: Predicted effects of gradient and vegetation cover on erosion of batter slopes of SO7 amended to function as an alternative growth medium.

4.2.3 CR6

Simulations for an alternative growth medium with properties consistent with CR6 show that confident achievement of target erosion rates will require a vegetative cover level of 70% for 20% gradient whereas a cover level of 50% is suitable for 15% gradient (Figure 14).

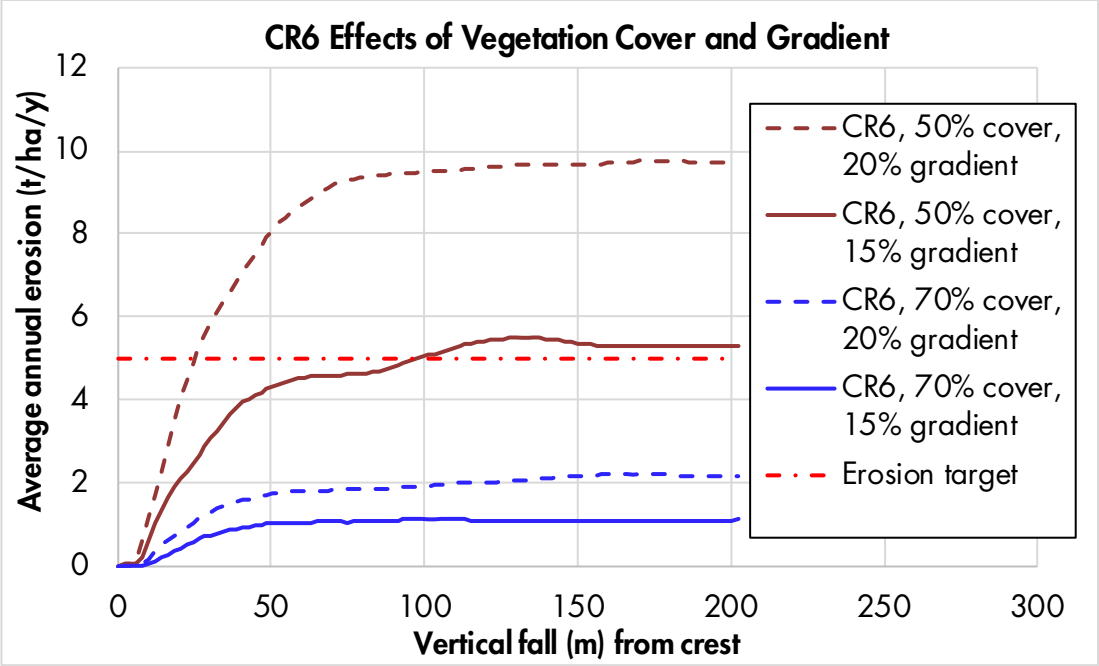


Figure 14: Predicted effects of vegetation cover and gradient on erosion rates for waste CR6 amended to function as an alternative growth medium.

4.3 Landform design

Based on the WEPP simulations, the materials proposed for use in the final landform and for the landform evolution modelling are:

- Topsoil SO1 will be used for rehabilitation works associated with Grevillea and Hakea (south) landforms
- Topsoil SO2 will be used for rehabilitation works associated with Coolibah, Dogwood and Ebony (mid site) landforms.
- Alternative growth medium with properties consistent with CR6 will be used for rehabilitation works associated with Jacaranda and Bauhinia landforms.
- Alternative growth medium with properties consistent with SO7 and amendment to create a growth medium will be used to construct low walls and ramp walls for all pits.

5 SIBERIA PARAMETER DEVELOPMENT

SIBERIA model parameters derived from WEPP simulations are shown in Table 1.

As noted previously (section 3.2.2), the vegetation cover levels assumed are conservative, with some variation to account for lower fertility of the wastes.

It should be noted that the method of deriving parameters attempts to ensure that the m_1 parameter is optimised so that SIBERIA simulations show a similar impact of slope length to that predicted by WEPP. However, because the two models use different methods to consider impacts of slope length, it is not reasonable to expect complete agreement between the two models over the full range of slope lengths considered.

Table 1: Estimated SIBERIA parameters.

Material	Vegetation cover	m_1	β_1	n_1
S01 Topsoil	70%	0.9520	0.00868	1.5
S02 Topsoil	50%	1.0571	0.00577	1.5
Alternative growth media with S07	70%	1.1650	0.00036	1.5
Alternative growth media with CR6	50%	0.9577	0.02312	1.5

6 LANDFORM EVOLUTION OUPUTS

6.1 Jacaranda/Bauhinia landforms

The Jacaranda/Bauhinia landform is planned to be up to about 160m high.

Rehabilitation of this landform is planned to use placement of materials similar to CR6 with added ameliorants to create a growth medium on the outside batters. Modelling has assumed a vegetation cover of 50%, though a level greater than 50% is expected.

The low wall and ramp walls are planned to use materials similar to S07 with added ameliorants to create an alternative growth medium.

Predicted erosion rates shown in Table 2 indicate that at a vegetative cover level of 50%, predicted erosion rates of the batter slopes are slightly above the target level of 5 t/ha/y. However, if vegetative cover achieved is greater than 50% (as is considered likely), then batter slope erosion rates would be acceptable. Predicted erosion rates for the low wall slopes are shown to be well below the target maximum rate. Figures 15 and 16 show SIBERIA output after 50 and 300 years of simulation.

Table 2: Predicted erosion rates and gully depths for the Jacaranda/Bauhinia landforms.

Simulation year	Maximum gully depth (m)	Average erosion (t/ha/y)	Cumulative erosion (mm)
Jacaranda/Bauhinia batter slopes (Alternative growth media with CR6 – 50% cover)			
50	-	8.0	31
100	-	7.6	60
200	-	6.8	111
300	0.3	6.3	159
Jacaranda/Bauhinia low walls and ramps (Alternative growth media with S07 – 70% cover)			
50	-	1.4	5
100	-	1.4	11
200	-	1.3	21
300	-	1.3	31

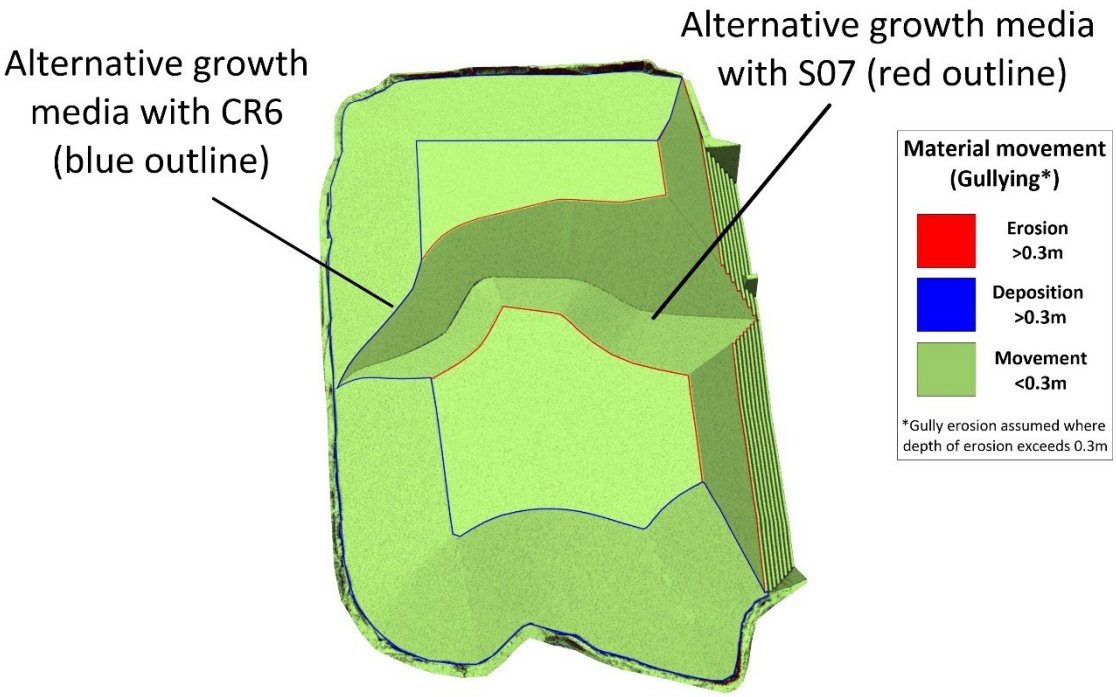


Figure 15: Visualisation of predicted changes in Jacaranda/Bauhinia landforms after 50 years.

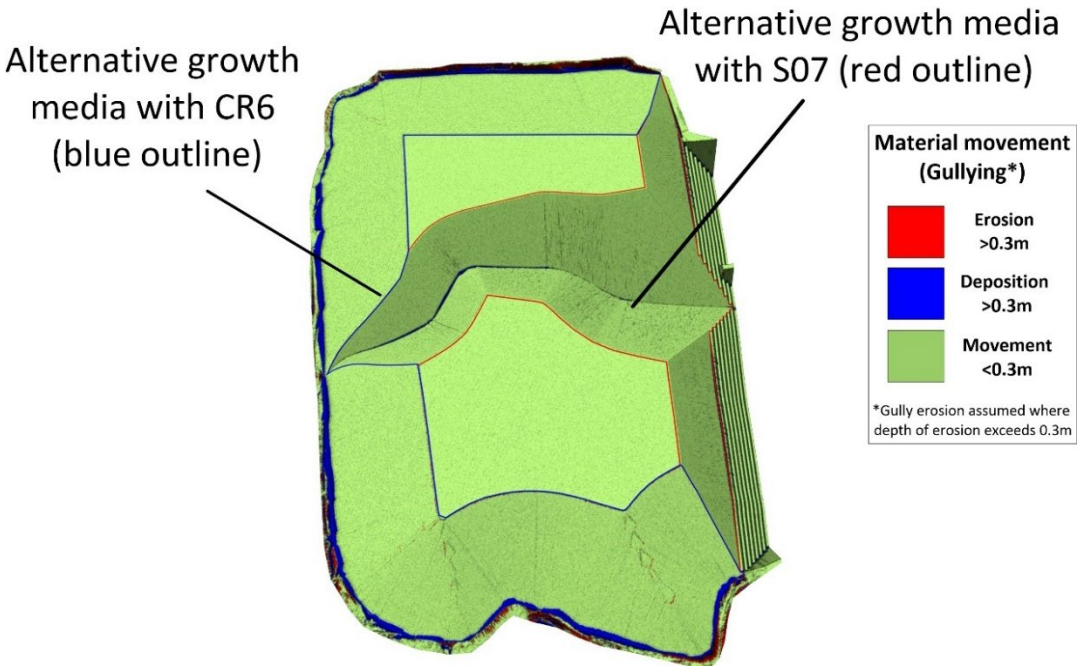


Figure 16: Visualisation of predicted changes in Jacaranda/Bauhinia landforms after 300 years.

6.2 Coolibah/Dogwood landforms

The Coolibah/Dogwood landform is planned to be up to about 200m high. This landform is planned to use topsoil S02 on the outside batters. The low wall and ramp walls are planned to use materials similar to S07 with added ameliorants to create an alternative growth medium. Predicted erosion rates (Table 3) indicate that all slopes will achieve acceptable rates of erosion. Figures 17 and 18 show SIBERIA output after 50 and 300 years of simulation.

Table 3: Predicted erosion rates and gully depths for the Coolibah/Dogwood landforms.

Simulation year	Maximum gully depth (m)	Average erosion (t/ha/y)	Cumulative erosion (mm)
Coolibah/Dogwood batter slopes (S02 Topsoil – 50% cover)			
50	-	4.0	15
100	-	4.0	31
200	-	3.9	61
300	-	3.9	91
Coolibah/Dogwood low walls (Alternative growth media with S07 – 70% cover)			
50	-	1.7	6
100	-	1.7	13
200	-	1.7	26
300	-	1.6	38

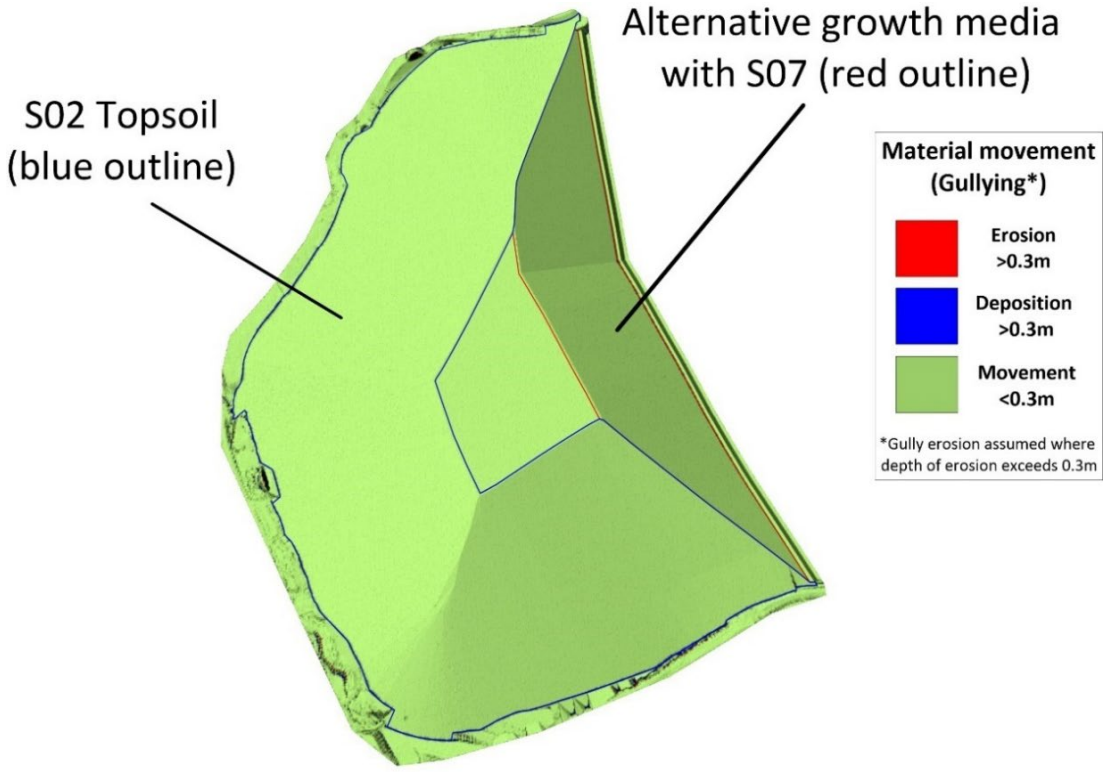


Figure 17: Visualisation of predicted changes in Coolibah/Dogwood landforms after 50 years.

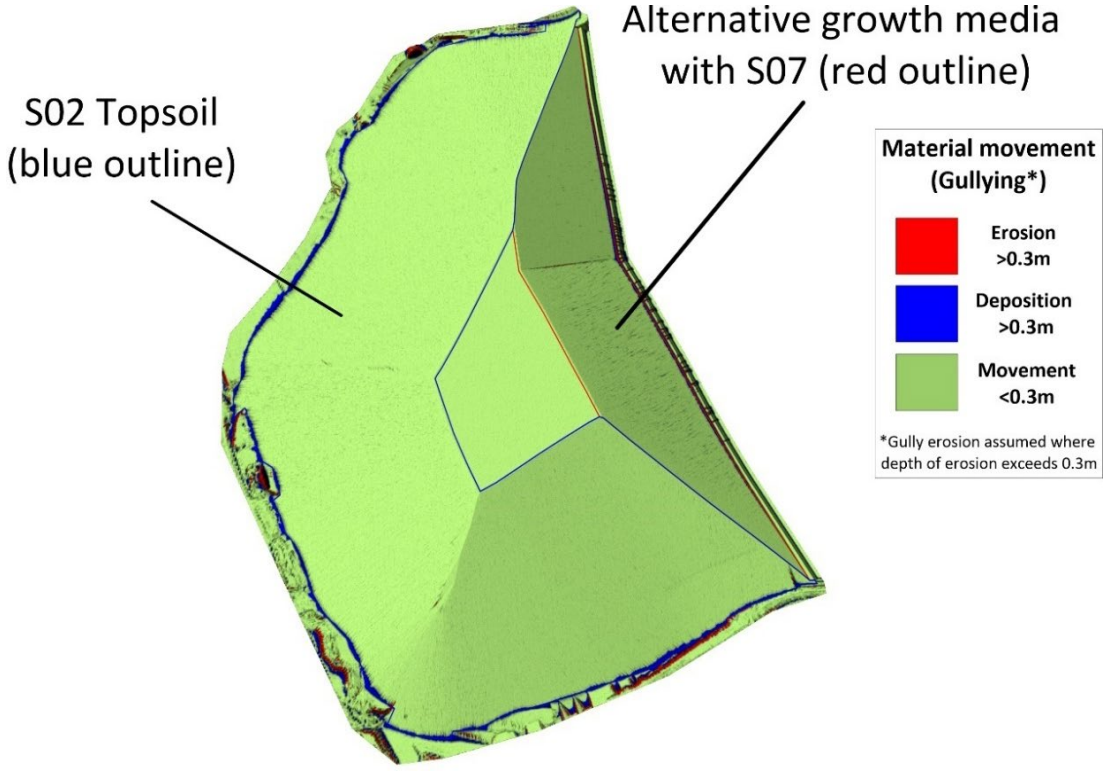


Figure 18: Visualisation of predicted changes in Coolibah/Dogwood landforms after 300 years.

6.3 Ebony/Grevillea landforms

The Ebony/Grevillea landform is planned to be up to about 200m high.

This landform is planned to use topsoil S02 on the outside batters of the north area and topsoil S01 on the south area due to the spread of topsoil across site. The low wall and ramp walls are planned to use materials similar to S07 with added ameliorants to create an alternative growth medium.

Predicted erosion rates (Table 4) are lower than the target maximum rate of 5 t/ha/y. Figures 19 and 20 show SIBERIA output after 50 and 300 years of simulation.

Table 4: Predicted erosion rates and gully depths for the Ebony/Grevillea landforms.

Simulation year	Maximum gully depth (m)	Average erosion (t/ha/y)	Cumulative erosion (mm)
Grevillea batter slopes (S01 Topsoil – 70% cover)			
50	-	3.1	12
100	-	3.1	24
200	-	3.0	47
300	-	3.0	70
Ebony batter slopes (S02 Topsoil – 50% cover)			
50	-	3.9	15
100	-	3.9	30
200	-	3.9	61
300	-	3.9	91
Ebony/Grevillea Low walls (Alternative growth media with S07 – 70% cover)			
50	-	1.7	6
100	-	1.7	13
200	-	1.7	26
300	-	1.7	39

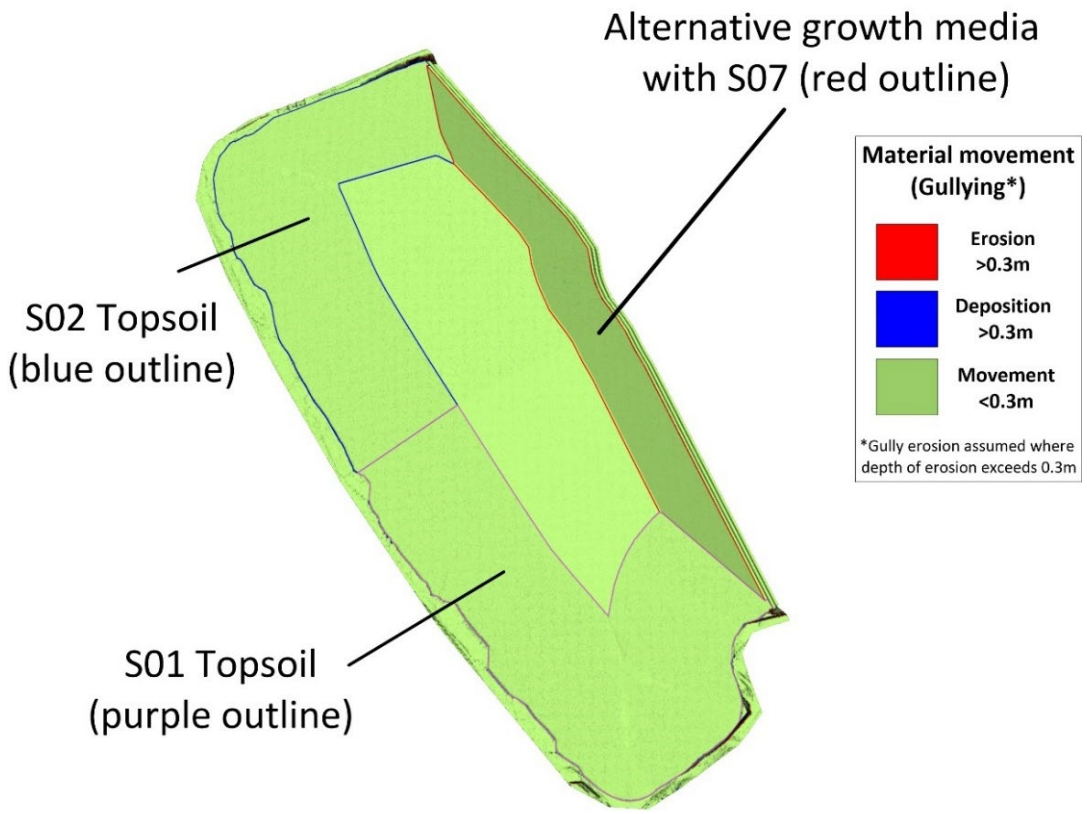


Figure 19: Visualisation of predicted changes in Ebony/Grevillea landforms after 50 years.

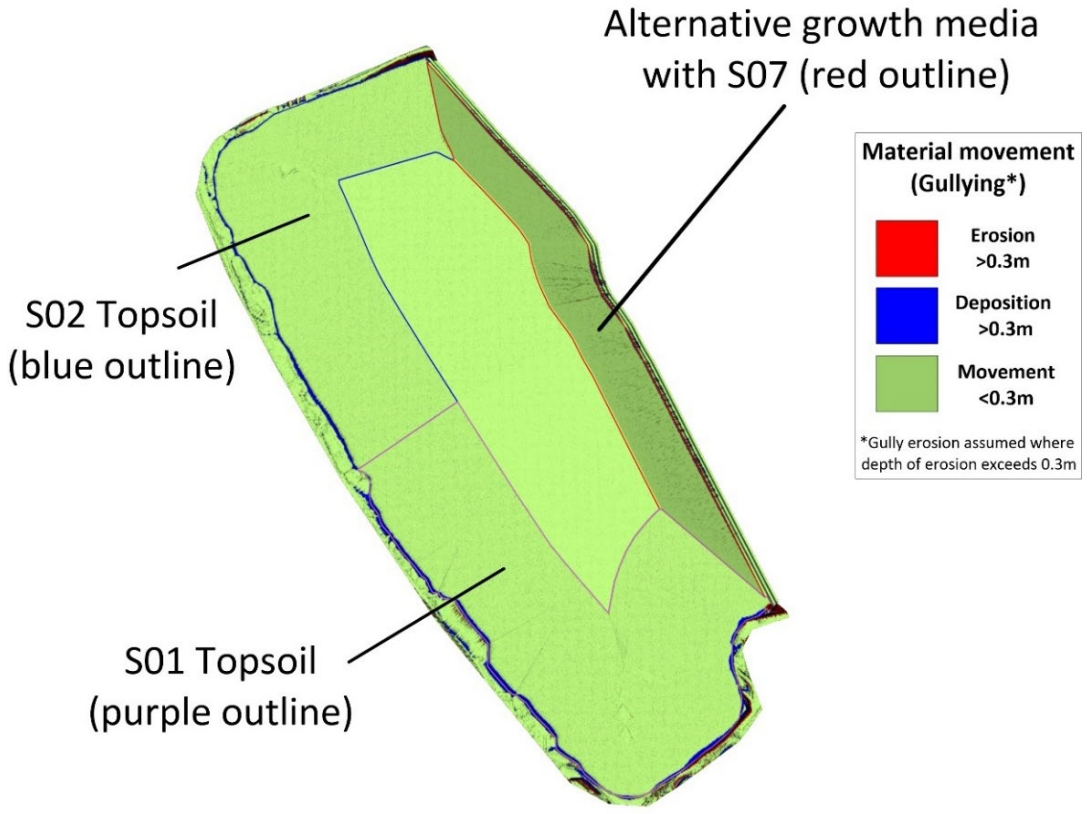


Figure 20: Visualisation of predicted changes in Ebony/Grevillea landforms after 300 years.

6.4 Hakea landform

The Hakea landform is planned to be planned to be up to about 140m high. This landform is planned to use topsoil S01 on outer batter slopes. The low wall and ramp walls are planned to use materials similar to S07 with added ameliorants to create an alternative growth medium. Predicted rates of erosion (Table 5) are less than the target maximum rate of 5 t/ha/y. Figures 21 and 22 show SIBERIA output after 50 and 300 years of simulation.

Table 5: Predicted erosion rates and gully depths for the Hakea landform.

Simulation year	Maximum gully depth (m)	Average erosion (t/ha/y)	Cumulative erosion (mm)
Hakea batter slopes (S01 Topsoil – 70% cover)			
50	-	3.2	12
100	-	3.1	24
200	-	3.1	48
300	-	3.1	72
Hakea low walls (Alternative growth media with S07 – 70% cover)			
50	-	1.7	6
100	-	1.6	13
200	-	1.6	25
300	-	1.5	36

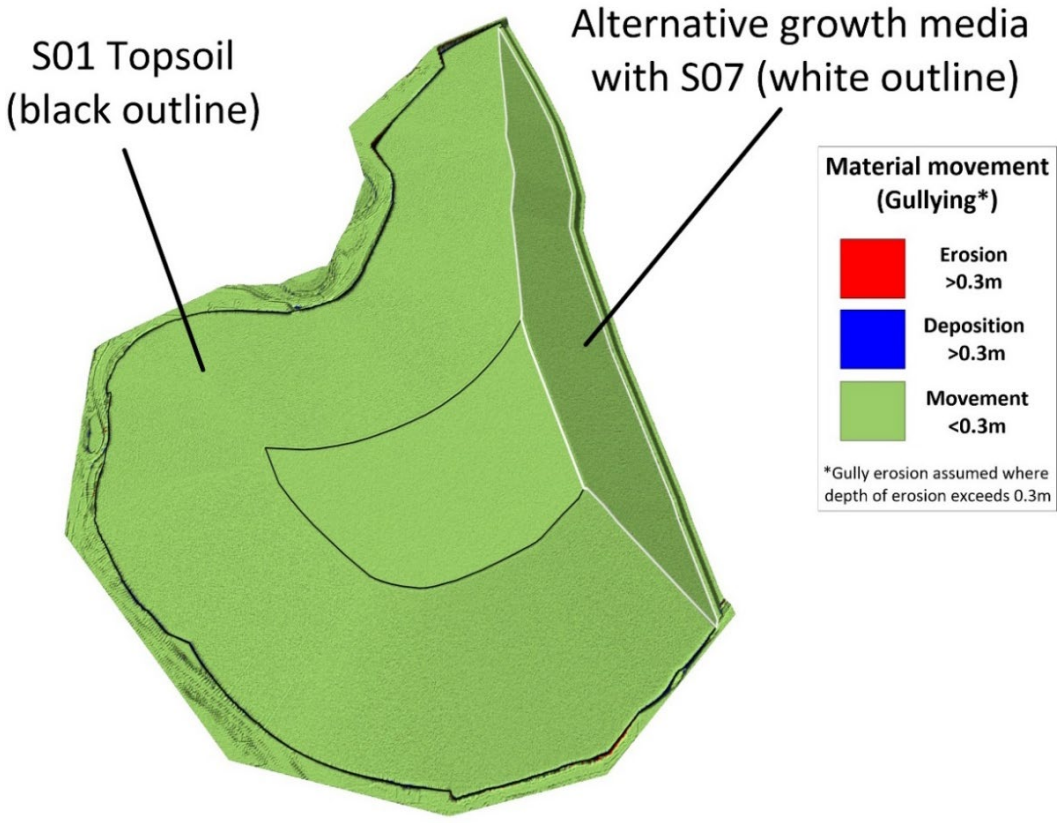


Figure 21: Visualisation of predicted changes in Hakea landform after 50 years.

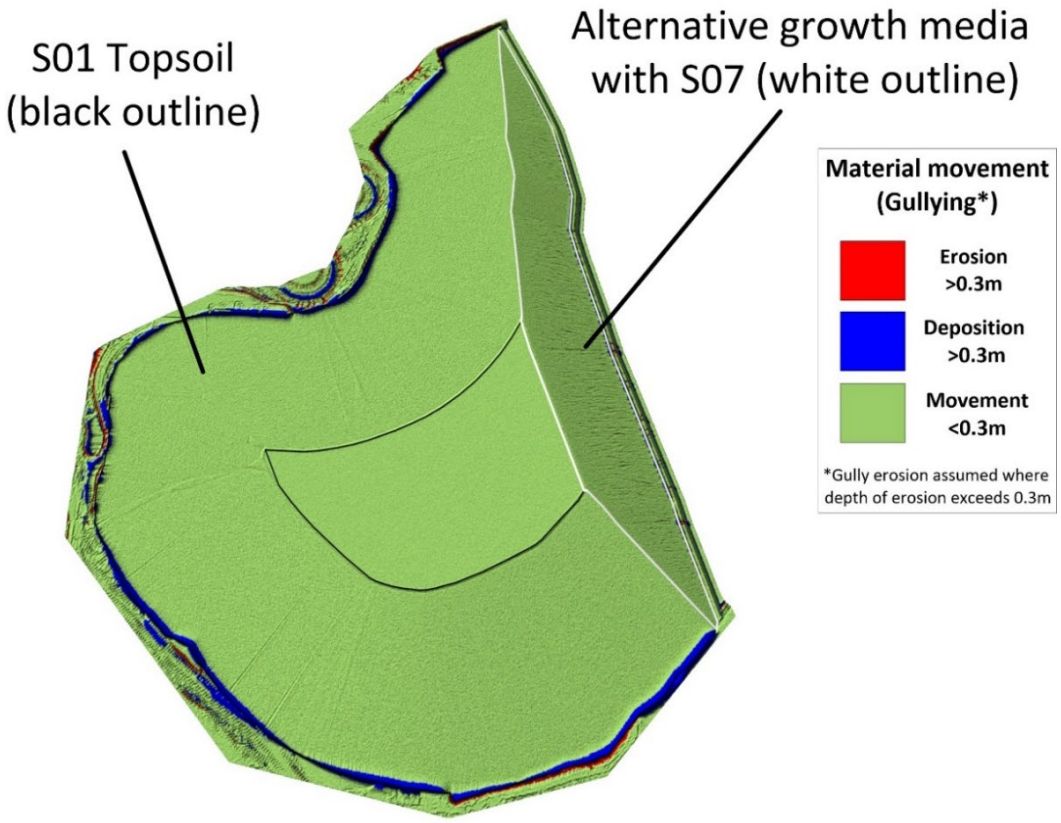


Figure 22: Visualisation of predicted changes in Hakea landform after 300 years.

7 WATER MANAGEMENT

Water management recommendations for waste landforms at Saraji Mine can be summarised as:

- No construction of permanent berms or graded banks and rock chutes on batter slopes. (Temporary berms to be only used where considered absolutely essential.)
- Prevention of discharge from the relatively small areas of level dump top onto the dump slopes.

Simulations of runoff and erosion indicate that – once vegetation is established – there is no requirement for installation of berms or graded banks to reduce slope length and erosion risk. It is anticipated that batter slope rehabilitation will be carried out progressively, working gradually up from the bottom of the slope, so that there will be increasing vegetative cover on lower sections of a slope as the works gradually (over a number of years) move towards the top of the slope.

It should be noted that – on well vegetated surfaces – annual rainfall excess on average will be 2-5% of annual rainfall, so preventing water discharge onto the slopes results in only a very small increase in the amount of water retained on the land surface and made available for vegetation growth.

It is – equally – noted that the quite small increase in drainage to depth that will be caused by retention of runoff on the tops of the landforms will be insignificant, with drainage reporting to the final voids and no potential to cause impacts on water amounts or quality.

8 CONCLUSIONS

Both runoff/erosion simulations using the WEPP model and landform evolution simulations using the SIBERIA model indicate that the proposed waste landforms at Saraji Mine can be expected to be stable over the long term (up to 300 years) provided the target levels of vegetation cover are achieved. (Simulations used site specific data in terms of both materials and climate.)

Water management recommendations for the site include the prevention of discharge from the small areas of level dump tops onto the slopes and avoidance of any permanent bunds or rock chutes on batter slopes.

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PRCP Concept Design Report

Hughes Creek

24 February 2023

M11000_559-REP-005-3

Job no. and Project Name: M11000_474 BHP PRCP SRM Diversions
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Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
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1	18/11/2022	Client Issue	Jess Davies	Ryan Kinnealy	Jess Davies	Ryan Kinnealy
2	02/12/2022	Client Issue	Jess Davies	Ryan Kinnealy	Jess Davies	Ryan Kinnealy
3	24/02/2023	Client Issue	Ciara Kruger	Ryan Kinnealy	Ryan Kinnealy	Ben Kiernan
Signatures						

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1 INTRODUCTION

1.1 CONTEXT

The purpose of this report is to detail the concept design developed for the relinquishment of the Hughes Creek Diversion of Hughes Creek. The diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the Saraji Mine (SRM).

The long-term performance of the diversion under both operating and closure scenarios is assessed within the following objectives, based on requirements from relevant licences and approvals:

- The diversion demonstrates to be in a safe, stable, non-polluting, and self-sustaining state (as per PRCP Closure Criteria and Environmental Authority requirements as per Section 3.3).
- Rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining land use of the 'Watercourse' which is applicable for the watercourse diversion.
- Achieves the key outcomes identified in the Department of Natural Resources, Mines and Energy (DNRME) *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).*

This report details the design requirements for the rehabilitation of the diversion for incorporation into the Progressive Rehabilitation and Closure Plan (PRCP) for PDM as described in the Queensland Department of Environment and Science (DES) *Guideline: Progressive rehabilitation and closure plans (ESR/2019/4964).*

1.2 PURPOSE AND SCOPE

The scope of work for each diversion is comprised of two stages:

- Stage 1: Options Assessment.
- Stage 2: Concept Design on the preferred option outcome from Stage 1.

The purpose of this document is to outline the concept design developed for the preferred diversion option (outcome from Stage 1) to achieve a state of dynamic equilibrium to achieve a relinquishable state for the diversion. The following methodology was conducted:

- A desktop geomorphic assessment of the creek was undertaken using historical aerial imagery and survey to identify options for the closure alignment.
- Review of existing flood studies to determine peak flow rates for design flow events to assess hydraulic performance.
- Hydraulic assessment of the diversion option against the criteria in the *DNRME 2019 Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)*.
- Develop concept design sketches and watercourse diversion spatial polygons for presentation in the PRCP chapter and schedule.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP chapter and schedule.

1.3 DESIGN PROCESS

1.3.1 Concept Design Considerations

The design is concept only, and not at functional level which would be required for approval and construction. The concept design is developed exclusively for PRCP purposes within the limitations of the PRCP, with only permanent design options considered.

To progress the concept design to a functional design level, detailed site-specific information is required including:

- Soil surveys and geotechnical studies.
- Material characterisation for use in erosion protection cover (i.e. rock sizing and composition).
- Site specific revegetation studies.

2 OVERVIEW

2.1 LOCATION

Hughes Creek is an ephemeral tributary of the Isaac River, situated within the Fitzroy River basin. The creek originates in a relatively low relief range to the west of Saraji Mine. The creek flows from west to east, through the north Saraji Mine operations, confluences with Barrett Creek adjacent to Dudley's Dam and eventually joining the Isaac River some 40km west of Saraji Mine.

A 4 km section of Hughes Creek was originally diverted southwards to facilitate mining of Bauhinia Pit. The date of construction of the existing diversion construction is unknown. Refer to Figure 2.1 for the location of the Hughes Creek Diversion.

As part of the PRCP mine closure solution, Barrett Creek to the south is also proposed to be altered to add sinuosity prior to the Hughes Creek confluence. The concept design for the Barrett Creek permanent alignment is being undertaken by Engeny concurrently with Hughes Creek (Engeny, 2022). The current preferred option for Barrett Creek is also shown in Figure 2.1.

ML 1775

ML 70142

ML 1784

ML 1782

Hughes Creek

Barrett Creek

Upstream Reach

Pre-Mining Reach

Hughes Creek Diversion Reach

Downstream Reach

Legend

- Waterway
- Haul Road
- Pre-Mining Reach
- Upstream Reach
- Downstream Reach
- Diversion Reach
- Mining Lease

ENGENY WATER MANAGEMENT

BHP

0 800 1,600

Scale in metres (1:40,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 84, Zone 55

DATE	18/11/2022
DRAWN	CK
JOB NO.	M11000_559

BHP Coal

Saraji Mine
Location of Hughes Creek Diversion
Figure 2.1

A4

C

2.2 PRE-MINING CONDITION

The pre-mining natural upstream, downstream and diversion reaches have been described as follows:

- **Upstream reach –** The upstream reach of the Hughes Creek diversion is outside the mine lease. Much of the riparian, floodplain and hill slopes in the area are either uncleared or have well established regeneration. The upstream drainage network consists of moderate sinuosity alluvial boundaries. The high flow channel varies in capacity with top width ranging from 30-60m and depth from 2 to 5m.
- **Downstream reach –** Downstream of the existing Hughes Creek diversion, the watercourse is comprised of a moderate sinuosity, single channel with moderate capacity. The banks of the channel are predominantly clays and silts and are significantly eroded. The banks are vertical and collapsing largely due to exposed soils and cattle grazing. The floodplain is typically 800 m wide and intersects other smaller watercourses that converge with Hughes Creek further downstream. The low flow channel depths typically range from 5 to 6 m, with top widths around 50 m.
- **Diversion reach (pre-mining)** – The Hughes Creek diversion reach (pre-mining) was approximately 5.5km long. It was gently meandering across the southern extent of what is now the Ramp 3 Tailings Dam and Bauhinia Pit.

The upstream, downstream and diversion reaches of the Hughes Creek diversion at Saraji Mine are shown in Figure 2.1.

2.3 CURRENT CONDITIONS

Monitoring of Hughes Creek diversion has been undertaken since 2009 and was last completed in 2019. As part of the major monitoring, the latest condition of the Hughes Creek diversion has been described as follows (Engeny, 2018):

- Despite rock-armouring throughout most of the diversion, there is continued evidence of geomorphic instability (bank erosion). The dumped rock is not supporting the establishment of groundcover or vegetation. Consequently, the reach is also not developing geomorphic or vegetation features like those in the local landscape.
- The sediment supply from upstream and the upstream diversion reaches is causing aggradation in the low flow channel throughout the diversion. This is most likely a function of sediment oversupply from proximity to spoil dumps and pre-stripping operations.
- Progress has been made to improve the lateral inflow of surface waters into the diversion however areas of instability and poor vegetation coverage remain that will continue to contribute sediment to the diversion in addition to any oversupply of sediment from upstream.

Due to this current condition, it is considered unlikely the existing diversion will achieve a state of dynamic equilibrium and be suitable for relinquishment following closure of the SRM.

3 BASIS FOR CONCEPT DESIGN

There are currently two recognised guidelines for design of watercourse diversions within Queensland.:

- *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (Department of Natural Resources, Mines and Energy (DNRME), 2019).*
- *Criteria for functioning river landscape units in mining and post mining landscapes (Australian Coal Association Research Program (ACARP), 2014).*

Both the DNRME and ACARP Guidelines were developed based on previous research completed by ACARP in the early 2000s which included assessment of existing diversion performance and the development of design and rehabilitation criteria for watercourse diversions.

The DNRME and ACARP Guidelines have both been used to inform the basis of design for the diversion, as summarised in Table 3.1.

Table 3.1: DNRME and ACARP Guidelines used for Design Basis

Guideline	Design Parameter
DNRME	Diversion Design Outcomes and Design Recommendations
	Velocity, shear stress, stream power (39% AEP) guidelines
ACARP	General Design Process
	Stream power (2% AEP event Guideline)

3.1 DNRME GUIDELINES

3.1.1 Diversion Design Outcome Requirements (Permanent Watercourse Diversions)

The diversion design outcome requirements are nominated by DNRME for permanent watercourse diversions and have been used to develop the design for Hughes Creek diversion:

- Outcome 1 – The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
- Outcome 2 – The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.
- Outcome 3 – The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.
- Outcome 4 – The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.
- Outcome 5 – The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

3.1.2 Design Criteria

DNRME recommend the following design criteria in development of permanent watercourse diversions and have been considered in development of the Hughes Creek diversion:

- The watercourse diversion should tie-in with the existing or receiving watercourse within the resource tenure boundary.
- The stability and performance of a watercourse diversion is assisted by vegetation within the watercourse diversion and adjoining floodplain and does not include artificial structures for grade control that requires ongoing maintenance.
- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity.

- The length of the channel should be equivalent to the length of the watercourse it replaces.
- Bed grade/slope should be equivalent to the existing watercourse.
- Batter slopes should be designed to maintain stability through different substrates.

The DNRME Guideline also nominates a set of hydraulic design criteria which have been adapted from the original ACARP research. These hydraulic design criteria were developed based on assessment of existing Bowen Basin streams and watercourse diversions and are considered reflective of stable hydraulic conditions for ephemeral systems in central Queensland. The hydraulic design criteria are summarised in Table 3.2 and include the following:

- Shear stress which is a function of discharge, flow depth and hydraulic gradient and represents the tractive force acting on sediment particles and is used to determine the threshold of motion for sediment. High shear stress provides an indication of potential erosion in cohesive sediments or movement of non-cohesive sediments. It also provides a measure of the ability of vegetation to withstand flow.
- Stream power which is a function of hydraulic gradient, flow width and flow rate and represents the energy available to do work on the channel. High stream power values generally result in elevated erosion potential.
- Velocity which is a function of flow rate and cross-sectional area and is a simplified measure of erosion potential. Generally higher velocities result in higher erosion potential, however stream power and shear stress are more reliable indicators of erosion and sediment transport potential.

Table 3.2: DNRME 2019 Hydraulic Design Criteria

Design Flow Event	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
39% AEP (previously 2-year ARI) - no vegetation	<35	<1.0	<40
39% AEP (previously 2-year ARI) - vegetated	<60	<1.5	<40
2% AEP (previously 50-year ARI)	<150	<2.5	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m^2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

The DNRME hydraulic design criteria summarised in Table 3.2 were adopted as the basis for the concept design. The ACARP value described in Section 3.2 are provided for information only. The ACARP values were referenced when considering stable stream powers and shear stresses during the vegetation establishment phase of the construction.

3.2 ACARP GUIDELINES

ACARP (2014) outlined several approaches to the design of diversion channel dimensions, including:

- The analogous approach, where channel dimensions are selected from a reference reach.
- The hydraulic geometry approach, where dimensions are determined from regression relationships; and
- The analytical approach, where equations are used to calculate continuity, hydraulic resistance, and sediment transport and channel characteristics are determined from field inspection of a reference reach.

In addition to the analogous approach, ACARP (2014) also provides guidance on alluvial channel design parameters which were adapted from ACARP (2002). These hydraulic parameters are intended to be representative of stable watercourses within the Bowen Basin and are summarised in Table 3.3.

Table 3.3: ACARP 2014 Alluvial Channel Design Parameters

Stream Type	Sediment Scenario	Stream Power 39% AEP (W/m^2)	Stream Power 2% AEP (W/m^2)
Alluvial	Supply limited	15-35	50-100
	Transport limited	35-60	80-150
Bedrock controlled	n/a	50-100	100-350

ACARP (2014) also provides recommendations on shear stress thresholds for vegetation used as part of rehabilitation activities. These thresholds are summarised in Table 3.4.

Table 3.4: ACARP 2014 Recommended Vegetation Shear Stress Thresholds

Vegetation Type	Design Shear Stress (N/m^2)
Buffel grass *(Cenchrus ciliaris)*	40
Structurally diverse suite of established native vegetation	120

4 OPTIONS IDENTIFICATION

Engeny identified three potential options for the Diversion (summarised below in Table 4.1). The following criteria were also considered during the development of the concept design:

- Geomorphic features of the pre mining drainage path.
- Upstream and downstream channel geometry and grade.
- Remaining within the ML boundary.
- Impacts to, and from, the final landform.
- Impacts to surrounding drainage paths and catchments.
- Permanent options only.

The objective was to identify suitable options for the rehabilitation of the Diversion, and select a preferred option informed by multi-criteria analysis (MCA) to progress to concept design.

Each option was defined with a concept cross section and longitudinal profile. Civil earthworks modelling was undertaken to confirm the following:

- Alignment of the diversion options.
- The need for potential flood levees (during operations).
- Final landform reconfiguration.
- Reinstatement of the floodplain.
- Proposed tie-in locations to the existing waterway.
- Development of a Class 5 capital cost estimate for construction.

The options identification also included assessment of key risks and opportunities regarding construction staging, potential for impacts to downstream infrastructure and post mining land-use risks in the context of closure.

The three options assessed are shown in Figure 4.1 and summarised in Table 4.1.

Table 4.1: Options Identification Details

Statistic	Option 1	Option 2	Option 3
Description	Divert south towards One Mile Creek through Barrett Creek	Divert east to increase offset of the diversion to Bauhinia Pit.	Diversion retains current alignment. Provide flood protection to prevent pit ingress. Rehabilitation of the diversion reach required.
Likelihood that diversion will achieve state of dynamic equilibrium	Flawed: Diversion flowing against grade	High: Similar grade to the natural environment	High: Similar grade to the natural environment
Diversion constructed through spoil	Yes	No	No
Order of magnitude cost estimate*	N/A	17.8 M**	0**
Ability to isolate diversion from flows during establishment period	No (only ~50% of diversion can be isolated)	No (only ~30% of diversion can be isolated)	No

* Costs estimated based on average $10/m^3.

**Does not include the cost to backfill PRCP void or potential landform works. The original optioneering assumed no earthworks along the existing channel. Subsequent concept engineering has proposed excavation works to formalise the low flow channel and benches, and to flatten overly steep batters. Topsoiling and revegetation of the diversion is also required. It is likely that the construction costs for Option 3 are now in the order of $5 M.



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BHP

0 390 780

Scale in metres (1:19,763 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 84, Zone 55

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JOB NO.	M11000_559

BHP Coal

Saraji Mine
Hughes Creek Diversion Options

Figure 4.1

A4 C

5 OPTIONS ANALYSIS

5.1 MULTI-CRITERIA ANALYSIS FRAMEWORK

A high-level multi-criteria analysis (MCA) was undertaken to rank the identified options for individual criteria as per Figure 5.1 below and determine a preferred option. The weighting of each criterion was determined and agreed upon with a BHP and Engeny collaborative decision group. The individual weightings are summarised in Table 5.1. Based on the score for each criterion against each option, a preferred option is identified.

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Figure 5.1: Ranking Scores for MCA

Table 5.1: Weighting for Individual Screening Criteria

Criteria	Weight
Likelihood that diversion will achieve state of dynamic equilibrium	40%
Diversion constructed through spoil	30%
Order of magnitude cost estimate	20%
Ability to isolate diversion from flows during establishment period	10%

5.2 MULTI-CRITERIA ANALYSIS

The MCA resulted in Option 3 to be carried forward into concept design as a preferred option, since it scored highest out of all three options without a fatal flaw and resulted in the lowest relative risk (see Table 5.2). Refer to Appendix A for the detailed MCA and scoring.

Table 5.2: Multi-Criteria Analysis Outcomes

Item	Option 1	Option 2	Option 3
Overall Weighted Score	-1.3	-0.3	1.1
Relative Risk	Highest Risk	Neutral Risk	Lowest Risk
Fatal Flaw	Yes	No	No

6 CONCEPT DESIGN

6.1 DESIGN PARAMETERS AND PLAN

Table 6.1 describes the parameters within each outcome described in Section 3, forming the design plan for the permanent diversion, in line with the DNRME and ACARP Guideline requirements.

Table 6.1: DNRME and the Australian Coal Association Research Program (ACARP) Parameters Adopted

DNRME Parameters (DNRME, 2019)		Equivalent ACARP Parameters (ACARP, 2014)	
Outcome 1 – The design plan should include a detailed description of: a) the location, function, and description of geomorphic features within the proposed watercourse diversion as well as a revegetation and vegetation management plan.	☒	*Outcome 1 –* Geomorphic and riparian vegetation features of the diverted watercourse and connecting reaches (minimum of 1 km upstream and downstream of proposed tie ins). Vegetation characteristics along the proposed optional watercourse diversions should also be noted.	☒
Outcome 2 – The design plan should include a detailed description of: a) the development and calibration, or sensitivity analysis, of the hydrologic model, including the referencing of methodologies used to generate flood frequency analysis[1] b) any design implications and construction processes that necessitate a lateral disconnectivity of sub-surface flow between the watercourse and an adjacent final void (if proposed). [1] Hydrologic models were originally developed as part of the Saraji Mine Flood Study (Engeny, 2018).	☐ ☒	*Outcome 2 –* Summary of hydrological characteristics including surface water-groundwater interactions and water use. Flow changes along the reach should also be clearly noted.	☒
Outcome 3 – The design plan should include hydraulic modelling results (benchmarked against guideline values for stream power, shear stress and velocity adopted from ACARP, 2002) and analysis identifying depth of inundation. The design plan should include a floodplain of sufficient capacity.	☒	*Outcome 3 –* Summary of hydraulic characteristics along the waterway length. Longitudinal section of stream power with standard cross section increments. A higher frequency of cross sections is required at stream junctions and bifurcations. A table summarising stream powers (in channel and floodplain) at each cross section is also required, along with statistics for the reach. This specifically includes the reach minimum, low quartile, median, mean, upper quartile and maximum values[2]. [2] Only mean stream power values were calculated for comparison with the adopted criteria.	☒ ☐
Outcome 4 – The design plan should include a sediment transport analysis that identifies how the watercourse diversion will manage erosion or deposition events such that they are consistent with the existing sediment regime.	☒	*Outcome 4 –* Sedimentation characteristics. Where the existing reach is aggrading, degrading, or is in equilibrium. Note presence of sediment sources (e.g., main channel bed or bank instabilities, floodplain contributions) and sinks (e.g., flood outs or sediment splays along low gradient sections of the reach, and infilling pools).	☒
Outcome 5 – The design plan should include the specification of spoil placement and sequencing and the settlement process and timing of operation that will ensure the watercourse diversion, once constructed, operates in a stable manner.	☒	*Outcome 5 –* Interaction between watercourse diversion options and mine infrastructure (pipes, pits, culverts, access, etc.) and planning over the life of mine.	☒

It is important to note only benchmark values for shear stress and velocity were adopted from DNRME, 2019. Stream power benchmark values were adopted from ACARP, 2014 due to it being a more contemporary standard that considers impacts of sediment transport.

6.2 DIVERSION ALIGNMENT

Option 3 was identified to be the preferred option alignment using the MCA. The option was further refined to optimise the estimated capital costs and quantify the works associated with rehabilitation of the existing channel. The full concept drawing package for the permanent Hughes Creek diversion is included in Appendix C and the interaction of the design with the PRCP landform in Appendix D.

Typically, the works associated with the channel predominately involve flattening over-steep batters, cleaning out accumulated sediment and formalising the low flow channel. There is an existing reach of the diversion channel, around the south-eastern corner of Bauhinia Pit, that has significant rock lining and batter protection already installed. In this reach, the proposed design formalises the low flow channel and specifies topsoiling directly over the rock to promote revegetation of the channel batters.

6.3 CHANNEL GEOMETRY AND GRADE

The typical upstream and downstream channel cross sections are presented in Figure 6.2 and Figure 6.3 respectively. These dimensions were based on the average natural upstream and downstream channel geometry and grade as assessed in the options identification phase. The location of the reference cross sections is shown in Figure 6.1.

Table 6.2 summarises the selected typical channel cross section selected for the concept design. The concept design drawings in Appendix D show the typical cross sections, longitudinal profile, and footprint of the proposed channel works.

Table 6.2: Detailed Channel Cross Section Geometry For Concept Design

Channel Geometry	Quantity	Comments
Channel Bed Width	6 m	
Bench Width	4 m	
Channel Depth	4 m	Consistent depth of low flow channel at 2 m
Batter Slope	1V:4H	For both the low flow channel and high flow channel batters. As per Section 6.2, the diversion works only involve excavation of in-situ material through the following activities: - Flattening over-steep batters - Cleaning out accumulated sediment and formalising the low flow channel. The batters will then be covered with topsoil, hydromulch and hydroseed (Appendix C) to ensure stability and prompt revegetation of the channel batters.

Downstream Reach

ML 1775

Hughes Creek Diversion Reach

ML 70142

Upstream Reach

ML 1784

Legend

- Reference Cross Sections Locations
- Waterway
- Haul Road
- Upstream Reach
- Diversion Reach
- Downstream Reach
- Mining Lease

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0 400 800

Scale in metres (1:20,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
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Locations of Reference Cross-Sectional Areas

Figure 6.1

A4

C

Figure 6.2: Typical Upstream Channel Cross Section of Hughes Creek

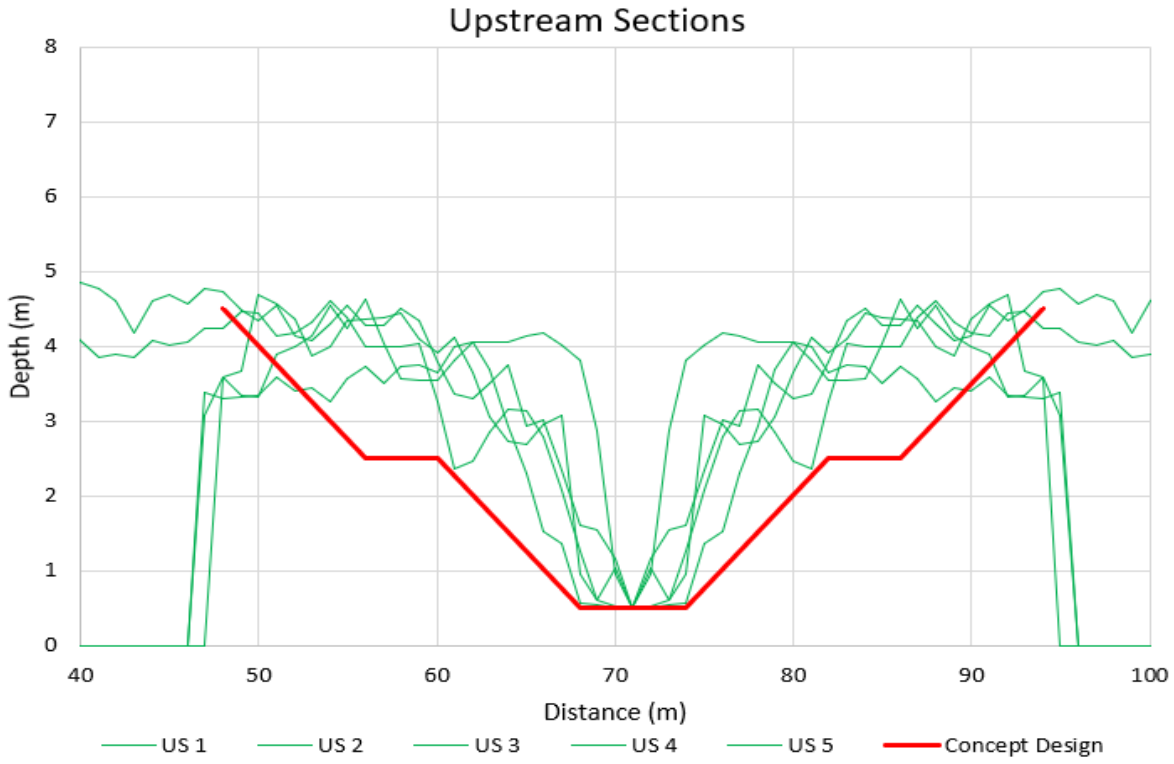
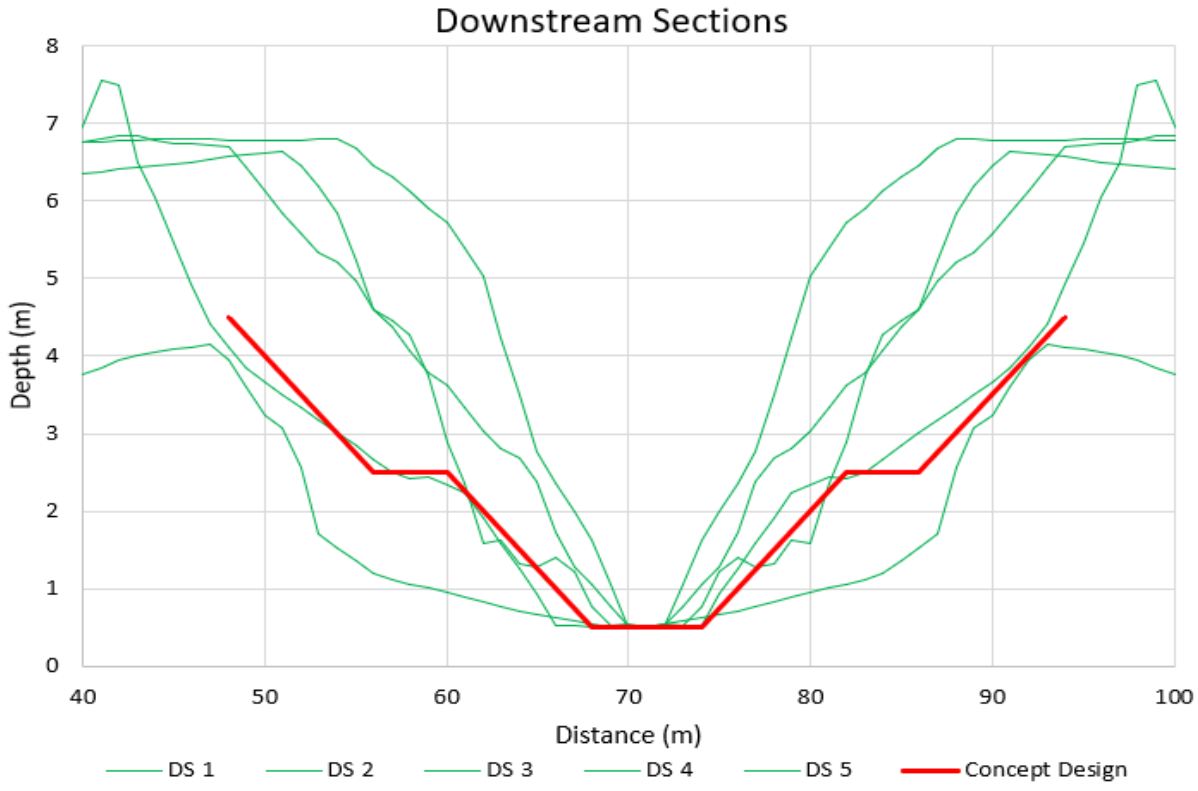


Figure 6.3: Typical Downstream Channel Cross Section of Hughes Creek



The concept design does not seek to add sinuosity to the channel or change the vertical grade. The current diversion closely approximates the pre-mining conditions for the creek. The current length of the diversion is 6,400 m, the pre-mining length for the same reach was approximately 5,700 m. The existing grade of the diversion is 0.18%. The additional length in the channel is not expected to adversely impact sediment transport/deposition within the channel. A longitudinal section for the diversion alignment is included in the concept design drawings in Appendix D.

6.4 HYDROLOGY

A hydrologic model of Hughes Creek was originally developed as part of the Saraji Mine Flood Study (Engeny, 2018). The model was used to estimate flows for the 1% AEP and 0.1% AEP flood events. Peak flows for frequent events (39% AEP and 2% AEP) for the Hughes Creek diversion were estimated using the ACARP (2002) methods and are presented in Table 6.3. The Hughes Creek catchment is presented in Figure 6.4 below.

Legend

- One Mile Creek Subcatchments
- Hughes Creek Subcatchments
- Phillips Creek Subcatchments
- Spring Creek Subcatchments

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BHP

0 3,000 6,000

Scale in metres (1:150,000@ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 66, Zone 55

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map of Catchments
Figure 6.4

A4

C

6.4.1 Frequent Events

The hydrologic model (Engeny, 2018) mentioned above was used to estimate flows through the diversion for the 39% AEP and 2% AEP flow events (refer to Table 6.3) in accordance with the ACARP (2002) method. The ACARP (2002) assessment included a regional flood frequency analysis for a selection of gauged catchments in the Bowen Basin region. From this, a method was developed to estimate flood magnitudes for ungauged catchments, based on catchment area and rainfall intensity. The calculated flood magnitudes for the 39% and 2% AEP events were then used to determine diversion design limits for shear stress, stream power and velocity. This approach has been adopted to determine the flows within the proposed Hughes Creek diversion concept design and have been compared to the ACARP (2002) diversion channel design parameters.

Table 6.3: Hughes Creek Diversion Design Flows

Rainfall Event	Diversion Channel Design Flows (ACARP, 2002) m^3/s
39% AEP (previously 2-year ARI)	85.1
2% AEP (previously 50-year ARI)	293.1

6.4.2 Rare Events

The interaction of a 0.1% AEP flood event and the PRCP landform will be assessed within the PRCP Chapter. This will inform the interaction between the diversion and final voids, landform, and potential impacts to downstream infrastructure, the 0.1% peak flow rate is 1,150 m^3/s (Engeny, 2021).

6.5 HYDRAULICS

Average values were derived from the TUFLOW model for the stream powers, stream velocity and shear stress in the 39% and 2% AEP rainfall event (refer to Table 6.4). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters.

Table 6.4: Diversion Design Criteria Compared to DNRME (2019) Guideline Parameters

	39% AEP (2-year ARI)		2% AEP (50-year ARI)	
Design Criteria	Diversion	DNRME Design Parameter (2019)	Diversion	DNRME Design Parameter (2019)
Stream Power (W/m^2)	49.7	<60	99.3	<150
Stream Velocity (m/s)	1.1	<1.5	1.5	<2.5
Shear Stress (N/m^2)	38.8	<40	58.8	<80[1]

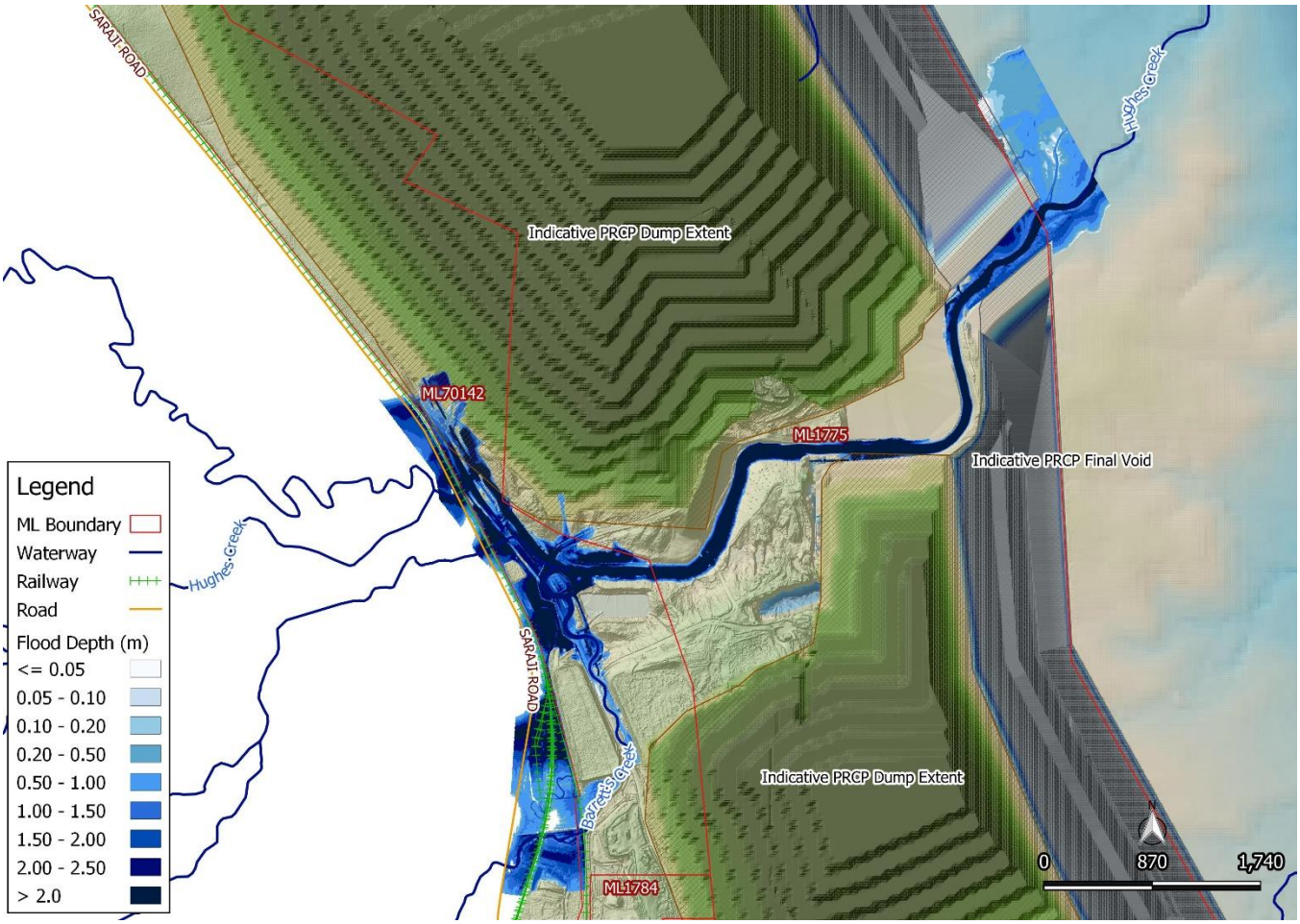
[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m^2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

It can be seen from Table 6.4 that all diversion hydraulic results are (on average) below design parameters. The detailed results for the DNRME guideline design criteria (stream power, velocity, and shear stress) as they vary along the length of the channel are presented graphically in Appendix B.

It is noted that the 39% AEP (2yr ARI) stream power and velocities exceed the DNRME design criteria for stability if the channel remains unvegetated (refer to Table 3.2). Given that the alignment is unable to be taken offline during construction, it will be critical that vegetation of the channel be established following construction to minimise erosion risk during frequent events. The concept design could be optimised in detailed design to further reduce the stream power and velocities in conjunction with a planned diversion revegetation strategy.

The floodplain of the concept diversion design is confined by the PRCP final landform for most of the diversion length, typically with the final dump profile interfacing with either site of the diversion batters. In the downstream reaches at what is now the south-eastern corner of Bauhinia Pit, from chainage 6000 onwards, the concept diversion channel is bound by final voids on either side which poses potential risk for external catchment inflows to voids, the PRCP final landform will need alteration to ensure flood protection to final voids and include sufficient buffer of voids to the downstream reaches to mitigate this risk. The final void backfill is discussed further in Section 6.7.1. The extents and depths of the 0.1% flooding are depicted in Figure 6.5. Please note, the flood assessment was conducted utilising a preliminary final landform design, which has since been amended.

Figure 6.5: 0.1% AEP Flood Event



6.6 RISKS AND MITIGATION MEASURES

Table 6.5 summarises the main risks for the diversion design and its ability to achieve a state of dynamic equilibrium suitable for relinquishment. The consequence and likelihood matrix utilised aligns with the requirements in the BHP Our Requirements Risk Management (v7.4).

Table 6.5: Diversion Risks and Mitigation Measures

Risks	Likelihood	Consequences	Risk Rating and Score	Mitigation Measures	Residual Likelihood	Residual Consequences	Residual Risk Rating and Score
Damage to new diversion channel due to frequent (up to 20% AEP / 5 year ARI) flood events. Diversion alignment unable to be taken offline.	Likely	2	30	Diversion channel constructed during dry season. Detailed revegetation plan to be implemented to promote rapid establishment. Seed mix to include fast establishing species to rapidly stabilise diversion.	Unlikely	2	3
Damage to the new diversion channel due to extreme/rare (0.1% AEP / 1000 year ARI) flood event (mainly overland flow and bank erosion)	Highly Unlikely	2	0.9	Revegetation plan to include large species capable of withstanding shear stresses associated with rare events.	Highly Unlikely	1	0.3
Construction program impacted by frequent flow event (up to 20% AEP / 5 year ARI). Diversion unable to be taken offline	Likely	1	10	Diversion construction to be timed to minimise risk of large flows while still maintaining enough watering to promote vegetation establishment and growth. Potential to construct upstream detention to minimise the peak flows if allowed by existing water licence.	Probable	1	3
Constructability of diversion channel – encountering bedrock, material availability and access	Probable	2	9	Geotechnical investigation as part of functional design, only minor excavation proposed, topsoil available on site	Unlikely	1	1
Difficulty in topsoiling and revegetating channel banks with existing rock armouring	Likely	2	30	Adopt an increased soil depth and detailed revegetation methodology to ensure all air voids filled	Unlikely	2	3
Downstream natural channel within mining lease degraded by grazing and land clearing – no rehabilitation proposed with concept design	Highly Unlikely	2	0.9	Potential to extend design further east to shape batters and promote revegetation.	Highly Unlikely	1	0.3
Flood ingress to final voids	Likely	2	30	Provide flood protection land structure in final landform design to ensure no flooding ingress in 0.1% AEP flood with 1.0 m freeboard	Highly Unlikely	2	0.9

6.7 ADDITIONAL DESIGN AND CONSTRUCTION CONSIDERATIONS

6.7.1 Flood Ingress into Final Void and Surface water infrastructure

The final landform will be designed to ensure flood protection to final voids to mitigate this risk. Final voids are to be offset from the creek by a sufficient distance limit seepage into the voids. The PRCP landform will need to be executed to provide flood protection for the Bauhinia Pit, ensuring the 0.1% AEP flood event does not contribute to additional external inflows into the void. The overall intent for the flood protection landform will not require ongoing maintenance to maintain function.

Backfilling of Dudley's Dam is also proposed; and this work is captured in the Barrett Creek PRCP diversion works (M11000_474-REP-001-3 Barrett Creek Concept Design).

6.7.2 Soils

The channel bed and banks are expected to be comprised largely of the surrounding soils, potentially dominated by dispersive sandy to loamy duplex soils. Erosion of the diversion channel is a key risk to the diversion not achieving a state of dynamic equilibrium. Key actions which should be undertaken in detailed design and construction to further quantify and mitigate this risk include:

- A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment.
- The detailed engineering in functional design should specify requirements for cover materials, including rock and rock mulch, to protect diversion batters from erosion.
- Temporary erosion sediment controls should be designed to minimise risk of erosion until vegetation establishment. This plan should be developed and approved by an appropriately qualified person informed by site specific soils data.
- Prior to construction of the new diversion, topsoil should be stripped and stockpiled for later use as a cover in the final diversion to prevent exposure of dispersive soils to surface flows.
- Where required, topsoil should be stabilized by the addition of gypsum to reduce sodicity and erosion potential, and improve physical fertility for vegetation establishment.
- Where required, subsoil should be stabilized by the addition of gypsum to reduce sodicity and erosion potential.
- Where required, fertilizers should be added to topsoil to ensure adequate chemical fertility required for vegetation establishment.
- Soils should be protected by vegetation prior to major flows occurring. A revegetation strategy should be developed to increase likelihood of successful vegetation establishment, and should consider watering and other controls.
- Excess supply of sediment from upstream and adjacent mining activities (spoil dumps, haul roads, coal stockpiles etc.) can impact vegetation establishment within the new diversion. Controls should be established to reduce sediment influx from surrounding landforms during the establishment of the diversion channel.

6.7.3 Revegetation

Hydraulic modelling has demonstrated that the 39% AEP average shear stress of 38.8 N/m^2 is slightly above the DNRME guideline value of 35 N/m^2 for a stable channel with no vegetation (refer Table 3.2). Effective revegetation will be crucial for the long-term stability of the diversion reach. A detailed revegetation plan should be developed for Hughes Creek as it will be critical to prevent uncontrolled erosion in the early years following construction. Particularly given that the diversion alignment is unable to be taken offline for the construction and commissioning phases.

The revegetation for the diversion should be done in accordance with the revegetation plan informed by baseline vegetation surveys. The plan should:

- Specify the method for revegetation considering direct seeding, mulch blanket, direct planting etc. and be informed by the erosion potential, expected velocities of flows and the cover material in selecting the appropriate method.
- The watercourse revegetation species should be based on selecting key framework trees, woody understorey and groundcover species associated with the predominant natural watercourse regional ecosystems occurring upstream and/or downstream of the site as prescribed in the Saraji Mine Progressive Rehabilitation and Closure Plan.

- Revegetation design should focus on re-establishing riparian vegetation for upper banks, mid banks and lower bank (including bank toe) revegetation zones.
- Include Geomorphic and vegetation features like those in the local landscape.
- Consider irrigation and other controls required to promote vegetation establishment in response to carrying climatic conditions.
- Achieve sufficient ground cover to mitigate erosion risk on beds and banks.
- Maintain a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Not require ongoing maintenance.

6.7.4 Monitoring and Maintenance

Monitoring and maintenance of the diversion during the operational and closure phases of the mine is required and should be conducted in accordance with BHPs watercourse diversion monitoring program. The monitoring and maintenance of the diversion during the establishment phase should be done routinely and consider the following (at least):

- Identifying introduced species and weeds for control.
- Success of vegetation establishment and identifying the need for subsequent seeding or planting.
- Climatic conditions which may impact the success of vegetation establishment (i.e., drought).
- Unplanned events which may impact the success of vegetation establishment (i.e., bushfire).
- Monitoring for erosion of beds and banks.
- Sediment transport under low flow conditions to ensure no excess sedimentation.
- Success of temporary erosion and sediment control measures.

The frequency of inspections should be aligned to risk (i.e. increase where control implementation is not suitable), and also following periods of high flow in the diversion.

7 CONCLUSION

The existing Diversion is experiencing increasing bank erosion, lack of geomorphic and vegetation features like those in the local landscape, sediment aggradation and sediment deposition downstream.

The concept design has been developed to meet the requirements of the PRCP and achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the SRM.

Three options for rehabilitation of the Diversion were identified and assessed using the BHP Multi-Criteria Analysis outlined in Section 5. The option selected to proceed to concept design was Option 3, for Hughes Creek to remain on the existing diversion alignment with rehabilitation works to the channel to meet the DNRME design criteria (Section 3). The final concept design, typical cross sections and longitudinal section are presented in Appendix C.

The highest risk to successful performance of the diversion is vegetation failure and subsequent erosion of the banks and bed of the diversion. It is noted that the 39% AEP (2yr ARI) stream power and velocities exceed the DNRME design criteria for stability if the channel remains unvegetated. Given that the alignment is unable to be taken offline during construction, it will be critical that vegetation of the channel be established following construction to minimise erosion risk during frequent events. The concept design could be optimised in detailed design to further reduce the stream power and velocities in conjunction with a planned diversion revegetation strategy. The PRCP landform will also need to ensure the flood protection of final voids located on either side of the downstream sections of the concept design, including sufficient buffer between the downstream reaches and the final voids.

The concept design demonstrates that the watercourse diversion will satisfy the closure objectives identified in the guidelines, for PRCP purposes.

8 QUALIFICATIONS

a) In preparing this document, including all relevant calculation, and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

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Appendix A:
Mulit-Criteria Analysis Details

Figure A.1: Multi-Criteria Analysis Details

Multi-Criteria Analysis - Hughes Creek Diversion

Project: PRCP Diversions FY21 (SRM)
Workshop Date: 25/03/2021

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Criteria	Assumptions/Considerations	Weight	Option 1	Option 2	Option 3	Comments
Likelihood that diversion will achieve state of dynamic equilibrium	Considers the difference between diversion length and grade to natural stream length and grade. Ideally diversion length/grade = natural stream length/grade.	40%	-3	1	1	Option 1 is flawed, since flows from Hughes to One Mile Creek are not possible due to grade. Option 2 achieves a similar grade to the natural environment. Option 3 achieves a similar grade to the natural environment.
Diversion constructed through spoil	For options that interact with the LoA mine plan, it is assumed that mining will occur (even if currently unapproved) then the diversion will be constructed through rehabilitated spoil. It is assumed that the PRCP final landform can be revised to achieve the required offset distances from rehabilitated spoil dumps (although the PRCP final landform would not show spoil dumps associated with currently unapproved mining).	30%	-1	-1	2	Option 1 and 2 - minor spoil interaction Option 3 - no spoil interaction
Order of magnitude cost estimate	Assumes $10/m3 of cut.	20%	0	-1	1	Compared based on direct diversion costs only, excluding the bulk fill costs for partially backfilling voids and flood protection final landform construction.
Ability to isolate diversion from flows during establishment period	Diversion can be isolated from flows if it is constructed offline of the existing diversion.	10%	2	-2	-1	Option 1 - 100% can be isolated from the flows Option 2 - End 30% of the alignment can be isolated Option 3 - follows the same existing diversion alignment
	Overall Weighted Score		-1.3	-0.3	1.1	

Is there a Fatal Flaw?	**Fatal Flaw**	**No**	**No**
Relative Risk	**Highest Risk**	**Neutral Risk**	**Lowest Risk**

Appendix B:
Hydraulic Parameter Modelling Result

Figure B.1: Stream Power TUFLOW Model Results

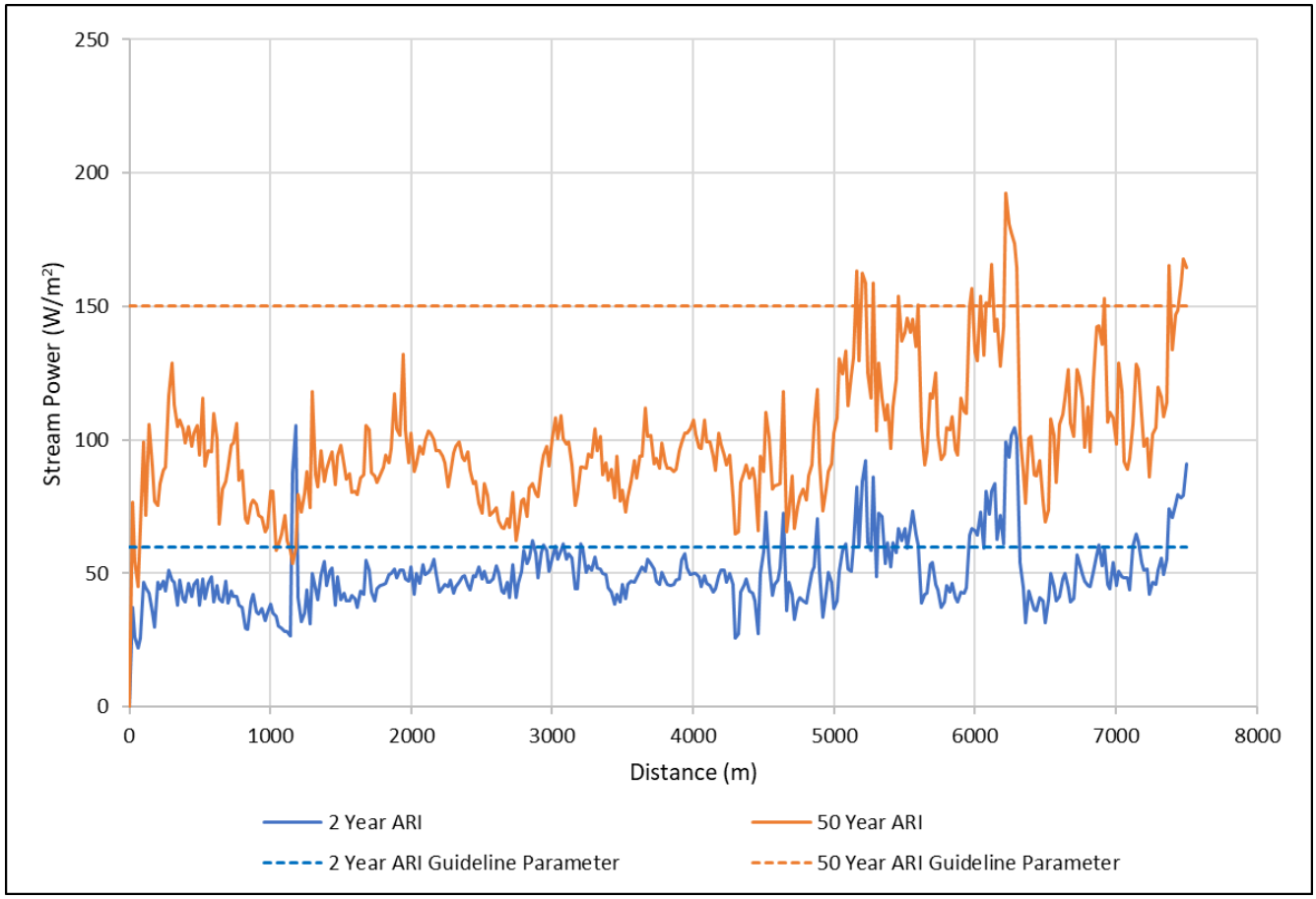


Figure B.2: Velocity TUFLOW Model Results

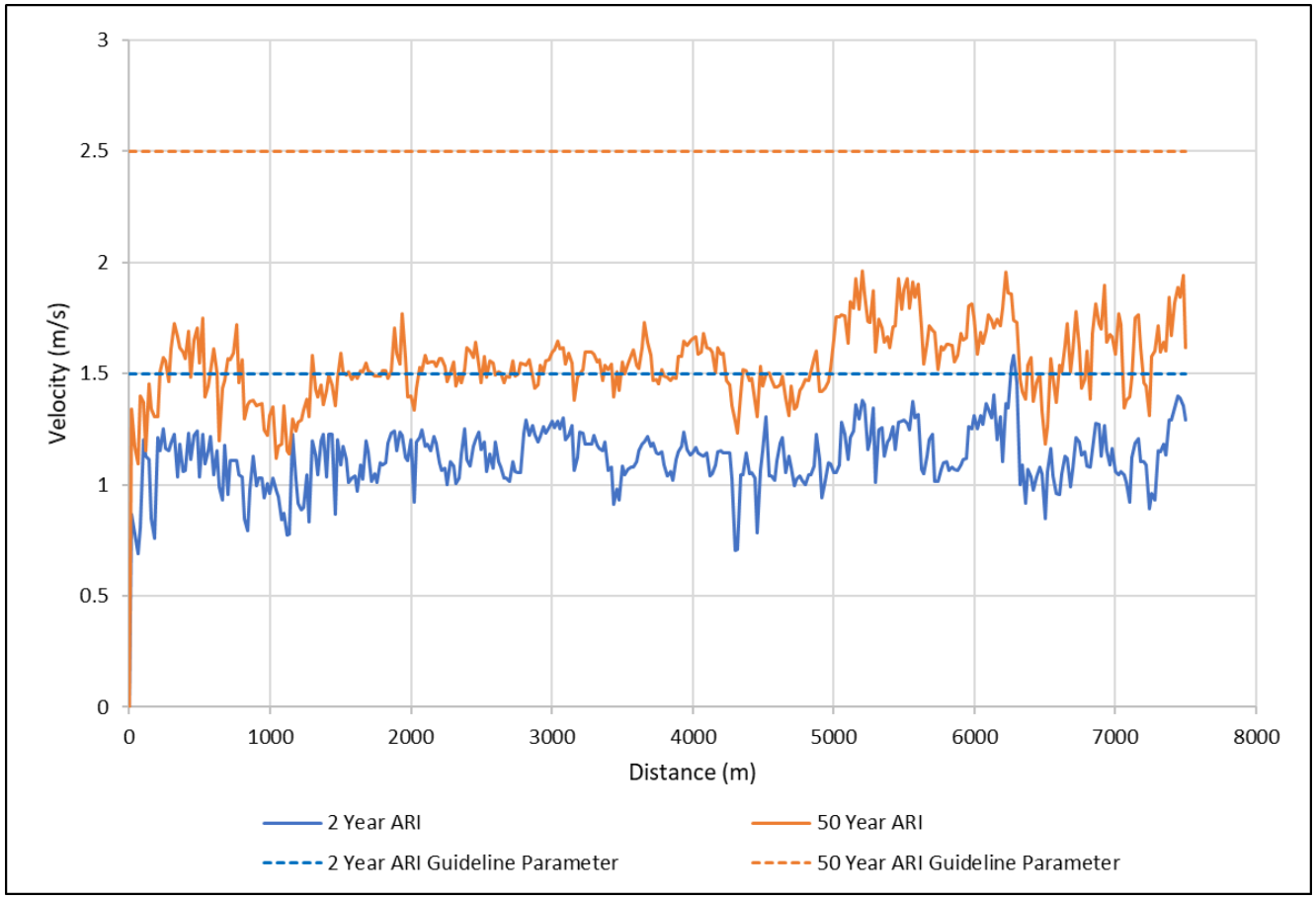
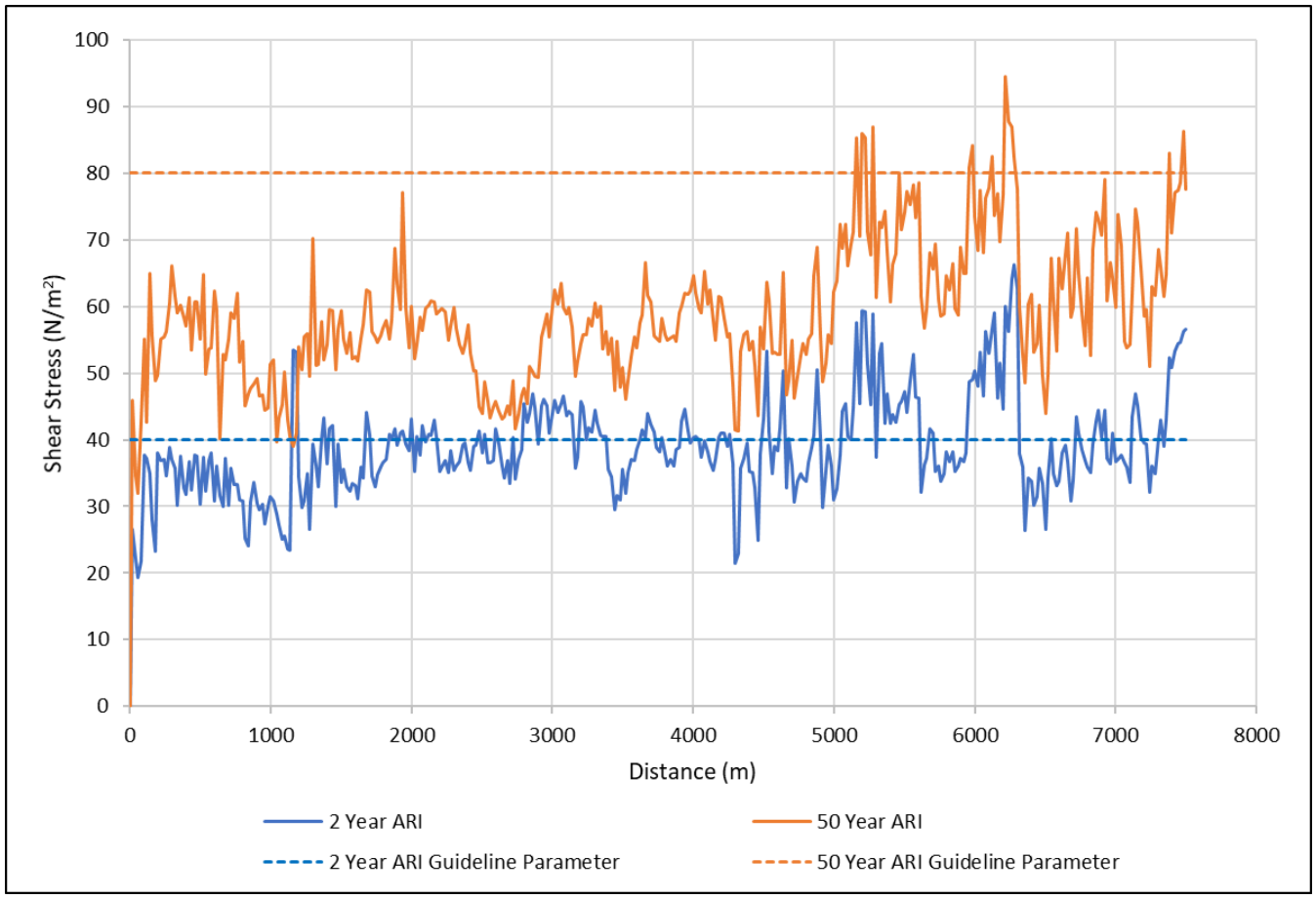


Figure B.3: Shear Stress TUFLOW Model Results



Appendix C:
Preferred Option Concept Design Drawings

HUGHES CREEK

ML70142

ML1775

BAUHINIA PIT

CONTROL LINE MCD07
(HUGHES CREEK DIVERSION)

B
0102

RAMP 3
TAILINGS DAM

HAUL ROAD DRAINAGE REPORTING TO CREEK.
REHABILITATE UPSTREAM IN FINAL LANDFORM

REPROFILE EXISTING ERODED BATTERS.
TOPSOIL, HYDROMULCH AND HYDROSEED

DISTURBED AREA REPORTING DIRECTLY
TO CREEK - REHABILITATE IN FINAL
LANDFORM

HUGHES CREEK

REMOVE ACCUMULATED SEDIMENT, FORMALISE
LOW FLOW CHANNEL, TOPSOIL, HYDROMULCH
AND HYDROSEED ON TOP OF EXISTING DUMPED
ROCK SCOUR PROTECTION

A
0102

HAUL ROAD CROSSINGS
TO BE REMOVED

DUDLEY'S DAM

DAM BACKFILLED AS
PART OF BARRETT'S
CREEK PRCP WORKS

COOLIBAH PIT

BARRETT'S CREEK
REALIGNMENT

0 100 200 300 400 500m
SCALE 1:10000 (A1)
SCALE BEFORE REDUCTION

GENERAL ARRANGEMENT PLAN
SCALE 1:10000

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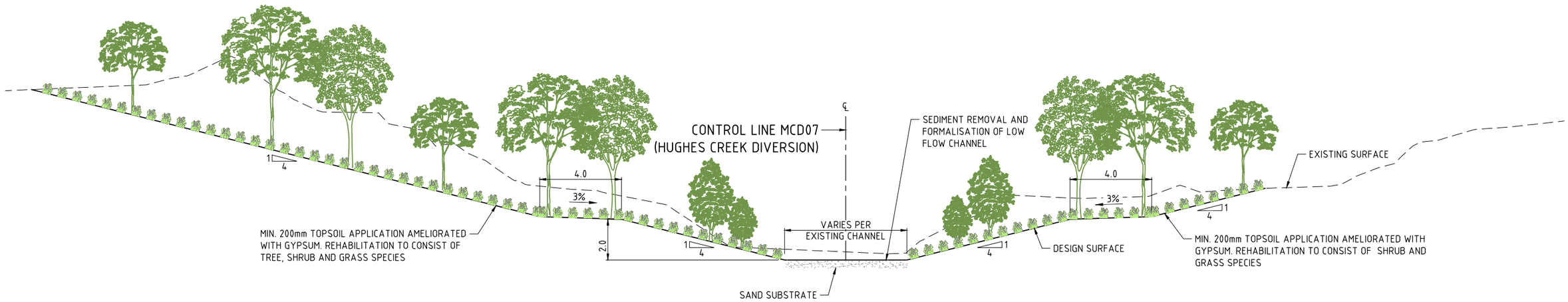
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SARAJI MINE

HUGHES CREEK
GENERAL ARRANGEMENT

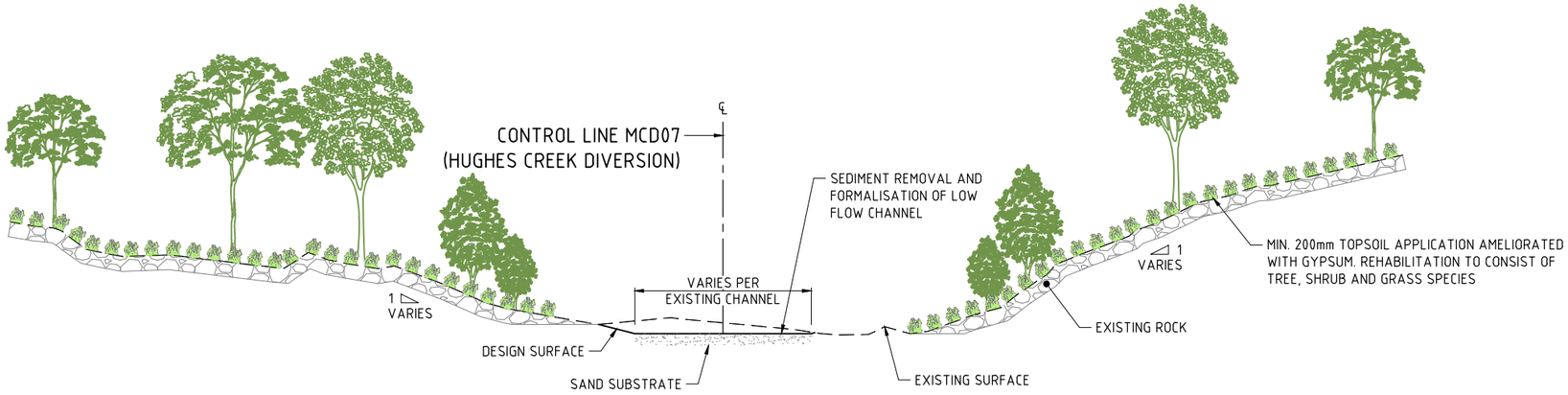
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HUGHES CREEK UPGRADE NORMAL REACH TYPICAL DETAIL

SECTION A
SCALE 1:100 0301



HUGHES CREEK UPGRADE EXISTING ROCK ARMOURED REACH
TYPICAL DETAIL

SECTION B
SCALE 1:100 0301

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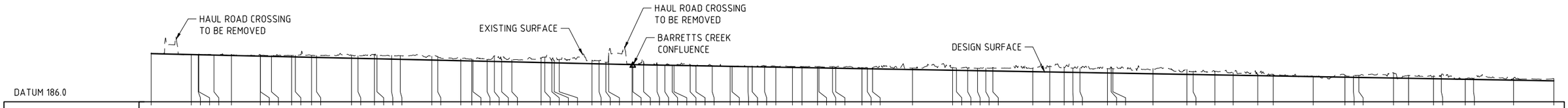
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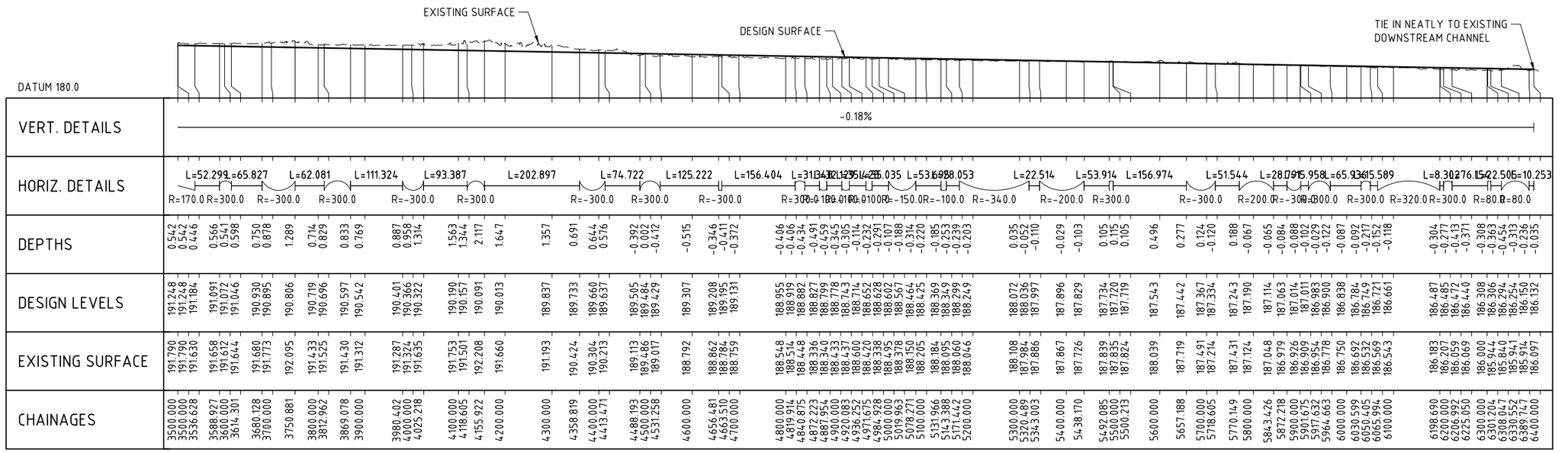
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SARAJI MINE

HUGHES CREEK
TYPICAL SECTIONS AND DETAILS

Original Size A1 | Drg No. M11000-559-SKE-0102 | Rev. REV





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SCALE BEFORE REDUCTION

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SARAJI MINE

HUGHES CREEK
LONGITUDINAL SECTION

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Appendix D:
Concept Design with PRCP Landform Interaction



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0 300 600

Scale in metres 1:15,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 66, Zone 55

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Saraji Mine
Hughes Creek Concept Design with PRCP Landform
Figure D.1

A4

B

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PRCP Concept Design Report

Barrett Creek

16 February 2023

M11000_559-REP-007-3

Job no. and Project Name: BHP PRCP SRM Diversions
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Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
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1	18/11/2022	Client Issue	Jess Davies	Ryan Kinnealy	Jess Davies	Ryan Kinnealy
2	06/12/2022	Client Issue	Jess Davies	Ryan Kinnealy	Jess Davies	Ryan Kinnealy
3	16/02/2023	Client Issue	Ciara Kruger	Ryan Kinnealy	Ryan Kinnealy	Ben Kiernan
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1 INTRODUCTION

1.1 CONTEXT

The purpose of this report is to detail the concept design developed for the relinquishment of the Barrett Creek Diversion. The diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the Saraji Mine (SRM).

The long-term performance of the diversion under both operating and closure scenarios is assessed within the following objectives, based on requirements from relevant licences and approvals:

- The diversion demonstrates to be in a safe, stable, non-polluting, and self-sustaining state (as per PRCP Closure Criteria and Environmental Authority requirements as per Section 3.3).
- Rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining land use of the 'Watercourses' which is applicable for the watercourse diversion.
- Achieves the key outcomes identified in the Department of Natural Resources, Mines and Energy (DNRME) *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019).*

This report details the design requirements for the rehabilitation of the diversion for incorporation into the Progressive Rehabilitation and Closure Plan (PRCP) for SRM as described in the Queensland Department of Environment and Science (DES) *Guideline: Progressive rehabilitation and closure plans (ESR/2019/4964).*

1.2 PURPOSE AND SCOPE

The scope of work for each diversion is comprised of two stages:

- Stage 1: Options Assessment.
- Stage 2: Concept Design on the preferred option outcome from Stage 1.

The purpose of this document is to outline the concept design developed for the preferred diversion option (outcome from Stage 1) to achieve a state of dynamic equilibrium to achieve a relinquishable state for the diversion. The following methodology was conducted:

- A desktop geomorphic assessment of the creek was undertaken using historical aerial imagery and survey to identify options for the closure alignment.
- Review of existing flood studies to determine peak flow rates for design flow events to assess hydraulic performance.
- Hydraulic assessment of the diversion option against the criteria in the *DNRME 2019 Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)*.
- Develop concept design sketches and watercourse diversion spatial polygons for presentation in the PRCP chapter and schedule.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP chapter and schedule.

1.3 DESIGN PROCESS

1.3.1 Concept Design Considerations

The design is concept only, and not at functional level which would be required for approval and construction. The concept design is developed exclusively for PRCP purposes within the limitations of the PRCP, with only permanent design options considered.

To progress the concept design to a functional design level, detailed site-specific information is required including:

- Soil surveys and geotechnical studies.
- Material characterisation for use in erosion protection cover (i.e., rock sizing and composition).
- Site specific revegetation studies.

2 OVERVIEW

2.1 LOCATION

Barrett Creek is an ephemeral watercourse flows into Saraji Mine from the southwest and forms part of the large Hughes Creek catchment. The existing alignment enters the Saraji Mining Lease (ML70142) from the west, crosses Norwich Park Branch railway and runs parallel to the main haul road before flows into Dudley's Dam which ultimately spills to Hughes Creek. The total length of the diversion is 2.57 km and was constructed in 1976 (exact date not specified). Dudley's Dam is an authorised mine affected water release point into Hughes Creek. The existing diversion is authorised by water licence license 30970F. In 2020, water licence (30970F) was amended to include a new Barrett Creek Diversion alignment. This approved temporary realignment is yet to be constructed.

Ramp 2 Low Wall Dam
Ramp 2 Fill Point
R2/3 Tailings Dam
Pre-Mining Reach
Hughes Creek
R4 Sump
Dudley's North
Dudley's Dam
Coolibah Pit
Approved Water Licence Alignment
Barrett Creek
Pre Mining Reach
Evap Dam
Ramp 6 Header Dam
Ramp 8 North Pit
Upstream Reach

Legend

- Waterway
- SRM Haul Road
- Railway
- Pre Mining Barrett Creek
- Pre Mining Hughes Creek
- Barrett Creek Diversion Reach
- Barrett Creek Diversion Approved Alignment
- Upstream Reach

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Scale in metres (1:15,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 84, Zone 55

		BHP Coal
DATE	8/2/2023	Saraji Mine Location of Barrett Creek Diversion at Saraji Mine
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2.2 PRE-MINING CONDITION

The pre-mining natural upstream and diversion reaches have been described as follows:

- **Upstream reach:** natural features of the upstream reach are largely undefined; however, remain predominantly undisturbed.
- **Diversion reach:** the Barrett Creek diversion reach (pre-mining) was approximately 4.86 km in length and consisted of an incised, low flow channel that meandered east of Dudley's Dam and tied into Hughes Creek (pre-mining).

The upstream and diversion reaches of the Barrett Creek diversion at Saraji Mine are shown in Figure 2.1.

2.3 CURRENT CONDITIONS

Monitoring of Barrett Creek diversion has been undertaken since 2012 and was last completed in 2018. As part of the major monitoring, the following observations during 2016 and 2018 monitoring events of the Barrett Creek diversion were noted:

- Dudley's Dam is impacting the sediment transport regime of the downstream waterway.
- Oversupply of sediment from upstream, diversion banks and adjacent spoil piles resulting in aggradation throughout the entire reach.

Based on the current condition of the Barrett Creek diversion, it is highly unlikely that the diversion will achieve the water license relinquishment criteria prior to mine closure without intervention. The approved Barrett Creek realignment is considered temporary for the purpose of mining and has not been designed to achieve the rehabilitation closure criteria.

3 BASIS FOR CONCEPT DESIGN

There are currently two recognised guidelines for design of watercourse diversions within Queensland.:

- *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (Department of Natural Resources, Mines and Energy (DNRME), 2019).*
- *Criteria for functioning river landscape units in mining and post mining landscapes (Australian Coal Association Research Program (ACARP), 2014).*

Both the DNRME and ACARP Guidelines were developed based on previous research completed by ACARP in the early 2000s which included assessment of existing diversion performance and the development of design and rehabilitation criteria for watercourse diversions.

The DNRME and ACARP Guidelines have both been used to inform the basis of design for the diversion, as summarised in Table 3.1.

Table 3.1: DNRME and ACARP Guidelines Used for Design Basis

Guideline	Design Parameter
DNRME	Diversion Design Outcomes and Design Recommendations
	Velocity, shear stress, stream power (39% AEP) guidelines
ACARP	General Design Process
	Stream power (2% AEP event Guideline)

3.1 DNRME GUIDELINES

3.1.1 Diversion Design Outcome Requirements (Permanent Watercourse Diversions)

The diversion design outcome requirements are nominated by DNRME for permanent watercourse diversions and have been used to develop the design for Barrett Creek diversion:

- Outcome 1 - The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
- Outcome 2 - The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.
- Outcome 3 - The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.
- Outcome 4 - The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.
- Outcome 5 - The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

3.1.2 Design Criteria

DNRME recommend the following design criteria in development of permanent watercourse diversions and have been considered in development of the Barrett Creek diversion:

- The watercourse diversion should tie-in with the existing or receiving watercourse within the resource tenure boundary.

- The stability and performance of a watercourse diversion is assisted by vegetation within the watercourse diversion and adjoining floodplain and does not include artificial structures for grade control that requires ongoing maintenance.
- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity.
- The length of the channel should be equivalent to the length of the watercourse it replaces.
- Bed grade/slope should be equivalent to the existing watercourse.
- Batter slopes should be designed to maintain stability through different substrates.

The DNRME Guideline also nominates a set of hydraulic design criteria which have been adapted from the original ACARP research. These hydraulic design criteria were developed based on assessment of existing Bowen Basin streams and watercourse diversions and are considered reflective of stable hydraulic conditions for ephemeral systems in central Queensland. The hydraulic design criteria used in this study are summarised in Table 3.2 and include the following:

- Shear stress which is a function of discharge, flow depth and hydraulic gradient and represents the tractive force acting on sediment particles and is used to determine the threshold of motion for sediment. High shear stress provides an indication of potential erosion in cohesive sediments or movement of non-cohesive sediments. It also provides a measure of the ability of vegetation to withstand flow.
- Stream power which is a function of hydraulic gradient, flow width and flow rate and represents the energy available to do work on the channel. High stream power values generally result in elevated erosion potential.
- Velocity which is a function of flow rate and cross-sectional area and is a simplified measure of erosion potential. Generally higher velocities result in higher erosion potential however stream power and shear stress are more reliable indicators of erosion and sediment transport potential.

Table 3.2: DNRME 2019 Hydraulic Design Criteria

Design Flow Event	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
2-year ARI (no vegetation) (39% AEP)	<35	<1.0	<40
2-year ARI (vegetated) (39% AEP)	<60	<1.5	<40
50-year ARI (2% AEP)	<150	<2.5	<80[1]

1. DNRME values are taken from ACARP 2002 as the <50N/m^2 value in DNRME 2019 is incorrect.

3.2 ACARP GUIDELINES

ACARP (2014) outlined several approaches to the design of diversion channel dimensions, including:

- The analogous approach, where channel dimensions are selected from a reference reach.
- The hydraulic geometry approach, where dimensions are determined from regression relationships; and
- The analytical approach, where equations are used to calculate continuity, hydraulic resistance, and sediment transport and channel characteristics are determined from field inspection of a reference reach.

In addition to the analogous approach, ACARP (2014) also provides guidance on alluvial channel design parameters which were adapted from ACARP (2002). These hydraulic parameters are intended to be representative of stable watercourses within the Bowen Basin and are summarised in Table 3.3.

Table 3.3: ACARP 2014 Alluvial Channel Design Parameters

Stream Type	Stream Power (W/m^2)	Stream Power 39% AEP (W/m^2)	Stream Power 2% AEP (W/m^2)
Alluvial	Supply limited	15-35	50-100
	Transport limited	35-60	80-150
Bedrock controlled	n/a	50-100	100-350

ACARP (2014) also provides recommendations on shear stress thresholds for vegetation used as part of rehabilitation activities. These thresholds are summarised in Table 3.4.

Table 3.4: ACARP 2014 Recommended Vegetation Shear Stress Thresholds

Vegetation Type	Design Shear Stress (N/m^2)
Buffel grass *(Cenchrus ciliaris)*	40
Structurally diverse suite of established native vegetation	120

4 OPTIONS IDENTIFICATION

Engeny identified three potential options for the Diversion (summarised below in Table 4.1). The following criteria were also considered during the development of the concept design:

- Geomorphic features of the pre mining drainage path.
- Upstream and downstream channel geometry and grade.
- Remaining within the ML boundary.
- Impacts to, and from, the final landform.
- Impacts to surrounding drainage paths and catchments.
- Permanent options only.

The objective was to identify suitable options for the rehabilitation of the Diversion, and select a preferred option informed by multi-criteria analysis (MCA) to progress to concept design.

Each option was defined with a concept cross section and longitudinal profile. Civil earthworks modelling was undertaken to confirm the following:

- Alignment of the diversion options.
- The need for potential flood levees (during operations).
- Final landform reconfiguration.
- Reinstatement of the floodplain.
- Proposed tie-in locations to the existing waterway.
- Development of a Class 5 capital cost estimate for construction.

The options identification also included assessment of key risks and opportunities regarding construction staging, potential for impacts to downstream infrastructure and post mining land-use risks in the context of closure.

The three options assessed are shown in Figure 4.1 and summarised in Table 4.1.

Table 4.1: Options Identification Details

Statistic	Option 1	Option 2	Option 3
Description	Divert west between Saraji Road and rail line	Divert through haul road and meander downstream	Maintain existing alignment, meander downstream (decommission/ filling of Dudley's Dam)
Likelihood that diversion will achieve state of dynamic equilibrium	High – channel grade of 0.27%, similar to natural grade	High – channel grade is equivalent to natural grade	Medium – channel grade of 0.42% is slightly higher than the natural grade
Diversion constructed through spoil	No	Yes	Yes
Order of magnitude cost estimate*	$4m	$2.2m	$1.7m
Ability to isolate diversion from flows during establishment period	Yes	Upstream reach can be isolated, approximately 20% of total diversion	Downstream reach can be isolated, approximately 70% of total diversion

*Cost estimate based on average $10/m^3 and Option 3 include quantities to fill 'Dudley's Dam'

Hughes Creek

ML 1775

ML 70142

ML 1784

Legend

- Waterway
- SRM Haul Road
- Pre Mining Reach - Barrett Creek
- Pre Mining Reach - Hughes Creek
- Barrett Creek Diversion Approved Alignment
- Mining Lease

Diversion Alignment Options

- 1
- 2
- 3

ENGENY WATER MANAGEMENT

BHP

0 300 600

Scale in metres (1:15,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 84, Zone 55

DATE	8/2/2023
DRAWN	CK
JOB NO.	M11000_559

BHP Coal

Saraji Mine
Barrett Creek Diversion Realignment Options

Figure 4.1

A4 D

5 OPTIONS ANALYSIS

5.1 MULTI-CRITERIA ANALYSIS FRAMEWORK

A high-level multi-criteria analysis (MCA) was undertaken to rank the identified options for individual criteria as per Figure 5.1 below and determine a preferred option. The weighting of each criteria was determined and agreed upon with a BHP and Engeny collaborative decision group. The individual weightings are summarised in Table 5.1. Based on the score for each criteria against each option, a preferred option is identified.

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Figure 5.1: Ranking Scores for MCA

Table 5.1: Weighting for Individual Screening Criteria

Criteria	Weight
Likelihood that diversion will achieve state of dynamic equilibrium	40%
Diversion constructed through spoil	30%
Order of magnitude cost estimate	20%
Ability to isolate diversion from flows during establishment period	10%

5.2 MULTI-CRITERIA ANALYSIS

The MCA resulted in option 2 to be carried forward into concept design as a preferred option. Option 2 resulted in a neutral relative risk (see Table 5.2). Refer to Appendix A for the detailed MCA and scoring. While option 1 has the highest overall weighted score, it is located outside the current mining lease boundary. This flaw was considered significant enough to dismiss option 1 due to the additional environmental and third-party approvals (e.g., Aurizon) required. Option 2 was therefore considered as the preferred option.

Table 5.2: Multi-Criteria Analysis Outcomes

Item	Option 1	Option 2	Option 3
Overall Weighted Score	0.6	0.0	-0.4
Relative Risk	Lowest Risk	Neutral Risk	Highest Risk
Fatal Flaw	No	No	No

6 CONCEPT DESIGN

6.1 DESIGN PARAMETERS AND PLAN

Table 6.1 describes the parameters within each outcome described in Section 3, forming the design plan for the permanent diversion, in line with the DNRME and ACARP Guideline requirements.

Table 6.1: DNRME and the ACARP Parameters Adopted for Concept Design

DNRME Parameters (DNRME, 2019)		Equivalent ACARP Parameters (ACARP, 2014)	
Outcome 1 – The design plan should include a detailed description of: a) the location, function and description of geomorphic features within the proposed watercourse diversion as well as a revegetation and vegetation management plan.	☒	*Outcome 1 –* Geomorphic and riparian vegetation features of the diverted watercourse and connecting reaches (minimum of 1 km upstream and downstream of proposed tie ins). Vegetation characteristics along the proposed optional watercourse diversions should also be noted.	☒
Outcome 2 – The design plan should include a detailed description of: a) the development and calibration, or sensitivity analysis, of the hydrologic model, including the referencing of methodologies used to generate flood frequency analysis[1] b) any design implications and construction processes that necessitate a lateral dysconnectivity of sub-surface flow between the watercourse and an adjacent final void (if proposed). [1] Hydrologic models were originally developed as part of the Saraji Mine Flood Study (Engeny, 2018).	☐ ☒	*Outcome 2 –* Summary of hydrological characteristics including surface water-groundwater interactions and water use. Flow changes along the reach should also be clearly noted.	☒
Outcome 3 – The design plan should include hydraulic modelling results (benchmarked against guideline values for stream power, shear stress and velocity adopted from ACARP, 2002) and analysis identifying depth of inundation. The design plan should include a floodplain of sufficient capacity.	☒	*Outcome 3 –* Summary of hydraulic characteristics along the waterway length. Longitudinal section of stream power with standard cross section increments. A higher frequency of cross sections is required at stream junctions and bifurcations. A table summarising stream powers (in channel and floodplain) at each cross section is also required, along with statistics for the reach. This specifically includes the reach minimum, low quartile, median, mean, upper quartile and maximum values[2]. [2] Only mean stream power values were calculated for comparison with the adopted criteria.	☒ ☐
Outcome 4 – The design plan should include a sediment transport analysis that identifies how the watercourse diversion will manage erosion or deposition events such that they are consistent with the existing sediment regime.	☒	*Outcome 4 –* Sedimentation characteristics. Where the existing reach is aggrading, degrading, or is in equilibrium. Note presence of sediment sources (e.g., main channel bed or bank instabilities, floodplain contributions) and sinks (e.g., flood outs or sediment splays along low gradient sections of the reach, and infilling pools).	☒
Outcome 5 – The design plan should include the specification of spoil placement and sequencing and the settlement process and timing of operation that will ensure the watercourse diversion, once constructed, operates in a stable manner.	☒	*Outcome 5 –* Interaction between watercourse diversion options and mine infrastructure (pipes, pits, culverts, access, etc.) and planning over the life of mine.	☒

It is important to note only benchmark values for shear stress and velocity were adopted from DNRME, 2019. Stream power benchmark values were adopted from ACARP, 2014 due to it being a more contemporary standard that considers impacts of sediment transport.

6.2 DIVERSION ALIGNMENT

Table 6.1 represents the general arrangement of the preferred concept design option (Option 2) for Barrett Creek Diversion. The primary features include backfilled areas in the upstream area of the diversion and the existing diversion, and filling of Dudley's Dam. Concept design drawings of the preferred option design are included in Appendix C and the concept design and interaction with the PRCP landform in Appendix D.

6.3 CHANNEL GEOMETRY AND GRADE

The typical upstream and downstream (Hughes Creek) channel cross sections are presented in Figure 6.2 and Figure 6.3 respectively. These dimensions were based on the average natural upstream and downstream channel geometry and grade as assessed in the options identification phase. The location of the reference cross sections is shown in Figure 6.1.

Table 6.2 summarises the selected typical channel cross section selected for the concept design. The concept design drawings in Appendix C show the typical cross sections, longitudinal profile, and footprint of the proposed channel works. The length of the proposed diversion will replicate the existing diversion as closely as possible, therefore the gradient of the diversion will remain similar. The pre mining channel grade was estimated to be 0.035%, based on the length of the reach up to the point it ties into Hughes Creek in its current position. Based on a channel length of 2.89km for the diversion design, a grade of 0.035% was able to be achieved.

Table 6.2: Detailed Channel Cross Section Geometry For Concept Design

Channel Geometry	Quantity	Comments
Channel Bed Width	4 m	
Batter Slope	1V:3H	For both the low flow channel and high flow channel batters. Note the diversion is excavated in-situ material with a supporting revegetation plan required to be developed in Functional Design stages.
Channel Depth	3 m	Consistent depth of low flow channel at 2 m
Bench Width	5 m	

Hughes Creek

Hughes Creek

ML 1775

ML 70142

Barrett Creek

Upstream Reach

Barrett Creek

ML 1784

ML 1782

Legend

- Reference Cross Section Locations
- Waterway
- Haul Road
- Upstream Reach
- Diversion Reach
- Mining Lease

ENGENY WATER MANAGEMENT

BHP

0 400 800

Scale in metres (1:20,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 84, Zone 55

DATE	21/11/2022
DRAWN	CK
JOB NO.	M11000_559

BHP Coal

Saraji Mine
Locations of Reference Cross-Sectional Areas
Figure 6.1

A4

C

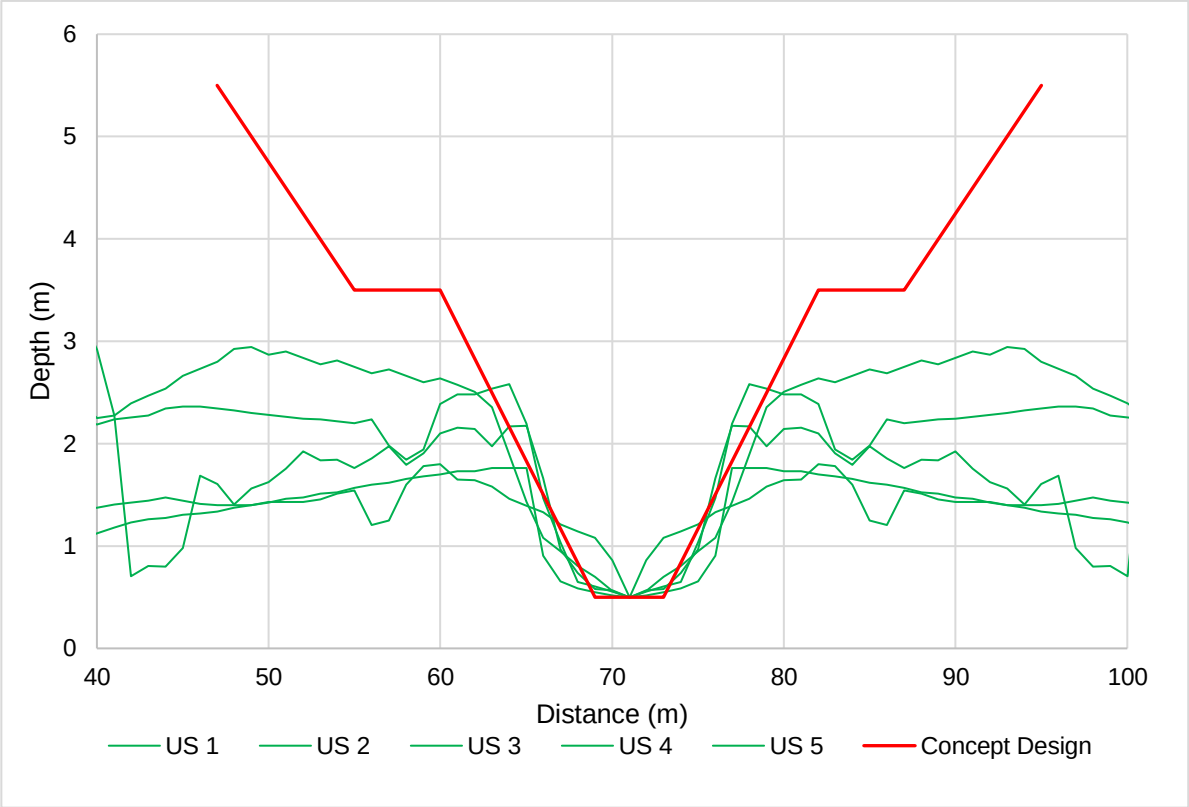


Figure 6.2: Typical Upstream Channel Cross Section of Barrett Creek

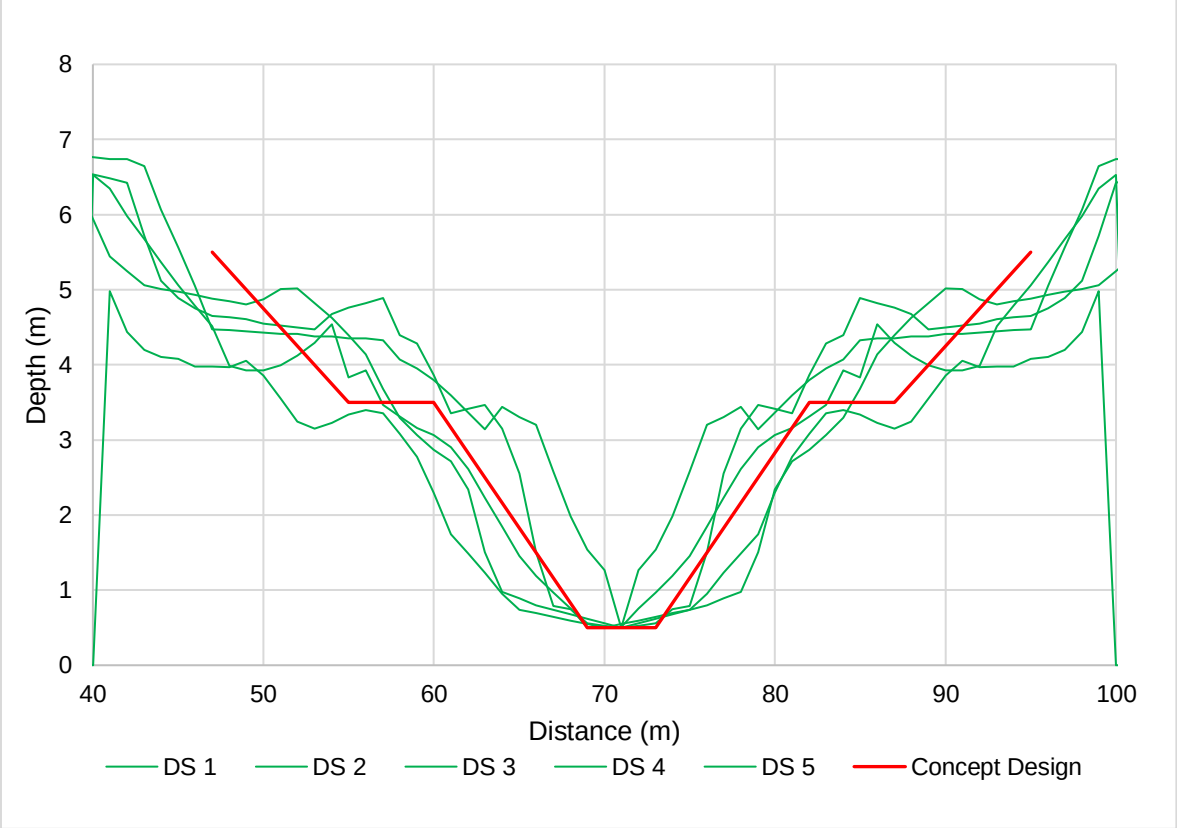


Figure 6.3: Typical Downstream Channel Cross Section of Barrett Creek

6.4 HYDROLOGY

A hydrologic model of Hughes Creek, inclusive of Barrett Creek, was originally developed as part of the Saraji Mine Flood Study (Engeny, 2018) which estimated flows for the 1% AEP and 0.10% AEP flood events. Peak flows for frequent events (39% AEP and 2% AEP) for the Barrett Creek diversion were estimated using the ACARP (2002) methods and are presented in Table 6.3. The Barrett Creek catchment is presented in Figure 6.4 below.

Legend

- One Mile Creek Subcatchments
- Hughes Creek Subcatchments
- Phillips Creek Subcatchments
- Spring Creek Subcatchments

ENGENY WATER MANAGEMENT

BHP

0 3,000 6,000

Scale in metres (1:150,000@ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 66, Zone 55

DATE	18/11/2022
DRAWN	CK
JOB NO.	M11000_474

BHP Coal

Saraji Mine
map of Catchments
Figure 6.4

A4

C

6.4.1 Frequent Events

The hydrologic model mentioned above was used to estimate flows through the diversion for the 39% AEP and 2% AEP flow events (refer to Table 6.3) in accordance with the ACARP (2002) method. The ACARP (2002) assessment included a regional flood frequency analysis for a selection of gauged catchments in the Bowen Basin region. From this, a method was developed to estimate flood magnitudes for ungauged catchments, based on catchment area and rainfall intensity. The calculated flood magnitudes for the 39% AEP and 2% AEP events were then used to determine diversion design limits for shear stress, stream power and velocity. This approach has been adopted to determine the flows within the proposed Barrett Creek diversion concept design and have been compared to the ACARP (2002) diversion channel design parameters.

Table 6.3: Barrett Creek Diversion Design Flows

Rainfall Event	Diversion Channel Design Flows (ACARP, 2002) m^3/s
39% AEP	31.9
2% AEP	79.5

6.4.2 Rare Events

The interaction of a 0.10% AEP flood event and the PRCP closure landform was assessed to inform the interaction between the diversion and final voids, landform and potential impacts to downstream infrastructure. The 0.10% AEP peak flow rate is 1,150 m^3/s (Engeny, 2018).

6.5 HYDRAULICS

Average values were derived from the TUFLOW model for the stream powers, stream velocity and shear stress in a 39% AEP and 2% AEP rainfall event (refer to Table 6.4). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters.

Table 6.4: Diversion Design Criteria Compared to DNRME (2019) Guideline Parameters

	39% AEP		2% AEP	
Design Criteria	Diversion	DNRME Design Parameter (2019)	Diversion	DNRME Design Parameter (2019)
Stream Power (W/m^2)	39.5	<60	49.9	<150
Stream Velocity (m/s)	0.95	<1.5	0.98	<2.5
Shear Stress (N/m^2)	32.7	<40	37.6	<80[1]

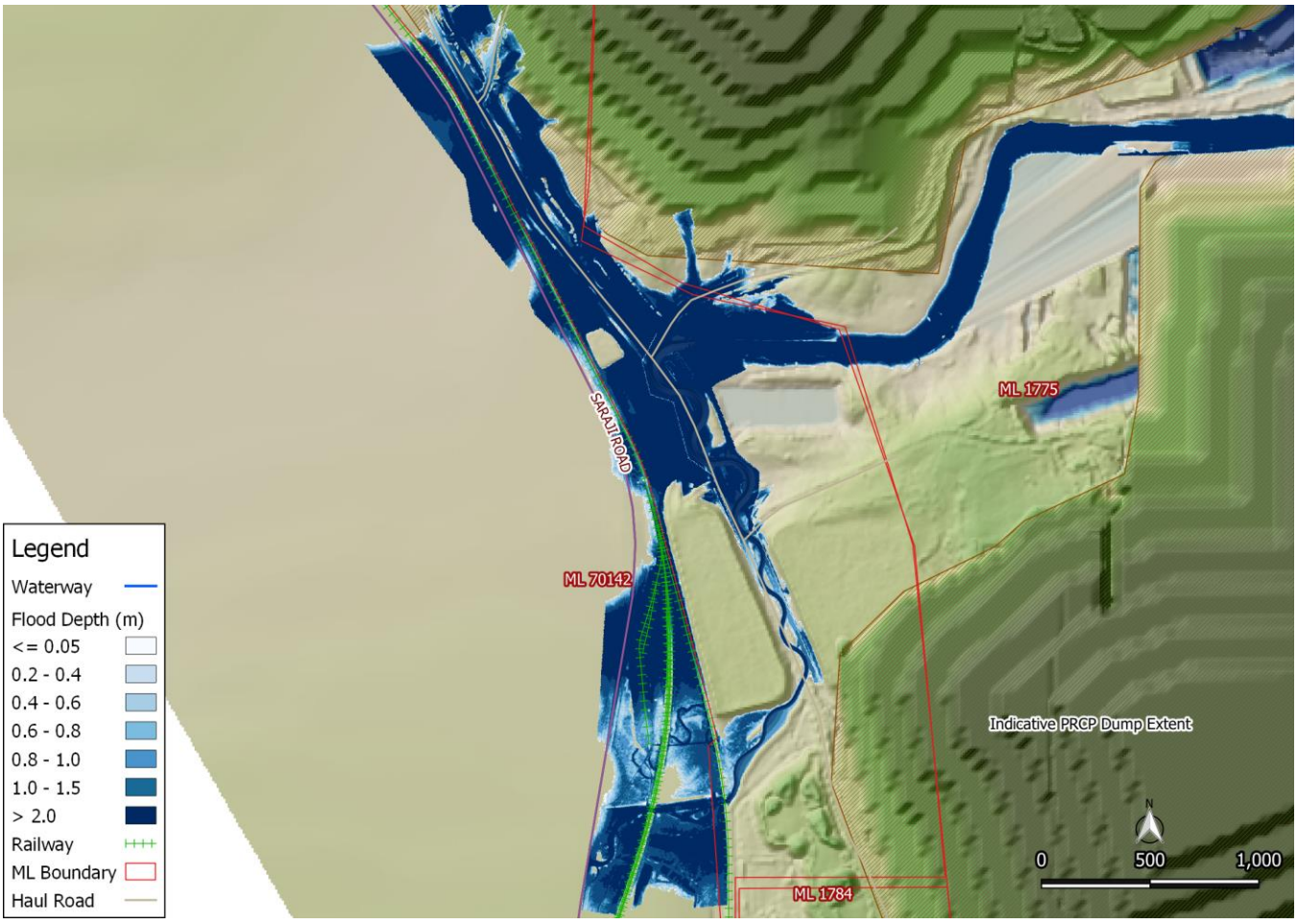
1. *DNRME values are taken from ACARP 2014 as the <50N/m^2 value in DNRME 2019 is incorrect. The ACARP value of <80 N/m2 has been adopted.*

All design criteria values for stream power, stream velocity and shear stress for both 39% AEP and 2% AEP storm events, are within the ACARP (2002) diversion channel design parameters.

Appendix B illustrates the variability for each design parameter along the diversion channel and shows overall lower values at the end of the diversion due to the increase in meander radius.

The final landform will need to ensure the flood protection to final voids. The concept diversion design does interact with rehabilitated mine areas (ie. haul roads) and final landform spoil dumps in the upstream reaches of the design. The flood assessment of the 0.10% AEP flood event shows flows within a wide floodplain within the upstream reaches, confined channel flows in the upstream area of the concept diversion and impacts of Hughes Creek inflows to the tie in point between the concept diversion and Hughes Creek (refer to Figure 6.5). Please note, the flood assessment was conducted utilising a preliminary final landform design, which has since been amended.

Figure 6.5: 0.10% AEP Flood Event



6.6 RISKS AND MITIGATION MEASURES

Table 6.5 summarises the main risks for the diversion design and its ability to achieve a state of dynamic equilibrium suitable for relinquishment. The consequence and likelihood matrix utilised aligns with the requirements in the BHP Our Requirements Risk Management (v7.4).

Table 6.5: Diversion Risks and Mitigation Measures

Risks	Likelihood	Consequences	Risk Rating and Score	Mitigation Measures	Residual Likelihood	Residual Consequences	Residual Risk Rating and Score
Damage to new diversion channel due to rare flood event	Probable	2	9	Diversion channel constructed during dry season	Unlikely	1	1
Constructability of diversion channel – encountering bedrock, material availability and access	Probable	2	9	Geotechnical investigation as part of functional design, topsoil availability on site and construction during dry season (low chance of flood)	Unlikely	1	1
Significant erosion of channel due to rare flood event	Probable	2	9	Construction of channel during dry season or sufficient vegetation establishment prior to wet season	Unlikely	1	1
Vegetation establishment interrupted by rare flow event (wash away of seed and damage to plants)	Probable	2	9	Choosing a seed mix similar to the surrounding environment and apply topsoil treatment allowing for effective plant growth, construction during dry season	Unlikely	1	1
Impacts to rehabilitated tailings storage	Probable	2	30	Diversion channel constructed with sufficient buffer to the TSF embankment, ensuring no impacts during high rainfall events	Unlikely	1	1

6.7 ADDITIONAL DESIGN AND CONSTRUCTION CONSIDERATIONS

6.7.1 Surface water infrastructure

Tailings Dam 3 is a closed Tailing Storage Facility (TSF) and is bound to the east by the northern haul road and to the west by the rail loop. The Barrett Creek concept diversion design is currently in proximity to Tailings Dam 3, particularly along the diversion reach. It is critical that sufficient buffering distance between the concept diversion design and the TSF embankment is included to ensure no impacts to tailings material during large flow events. The closure solution of the TSF is not currently known but will need to consider the proposed solution for the diversion.

The concept design of the Barrett Creek diversion also includes backfilling of Dudley's Dam along with the existing diversion. The concept diversion design will not interact with Dudley's Dam as in the existing diversion, so a backfill level equivalent to the current background surface level of 203m AHD was adopted.



ENGENY WATER MANAGEMENT

BHP

0 300 600

Scale in metres (1:15,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 66, Zone 55

DATE	13/2/2023
DRAWN	CK
JOB NO.	M11000_559

BHP Coal

Saraji Mine
Backfilling Locations of Existing Dams
Figure 6.6

A4

D

6.7.2 Soils

The channel bed and banks are expected to be comprised largely of the surrounding soils, potentially dominated by dispersive sandy to loamy duplex soils. Erosion of the diversion channel is a key risk to the diversion not achieving a state of dynamic equilibrium. Key actions which should be undertaken in detailed design and construction to further quantify and mitigate this risk include:

- A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment.
- The detailed engineering in functional design should specify requirements for cover materials, including rock and rock mulch, to protect diversion batters from erosion.
- Temporary erosion sediment controls should be designed to minimise risk of erosion until vegetation establishment. This plan should be developed and approved by an appropriately qualified person informed by site specific soils data.
- Prior to construction of the new diversion, topsoil should be stripped and stockpiled for later use as a cover in the final diversion to prevent exposure of dispersive soils to surface flows.
- Where required, topsoil should be stabilized by the addition of gypsum to reduce sodicity and erosion potential, and improve physical fertility for vegetation establishment.
- Where required, subsoil should be stabilized by the addition of gypsum to reduce sodicity and erosion potential.
- Where required, fertilizers should be added to topsoil to ensure adequate chemical fertility required for vegetation establishment.
- Soils should be protected by vegetation prior to major flows occurring. A revegetation strategy should be developed to increase likelihood of successful vegetation establishment, and should consider watering and other controls.
- Excess supply of sediment from upstream and adjacent mining activities (spoil dumps, haul roads, coal stockpiles etc.) can impact vegetation establishment within the new diversion. Controls should be established to reduce sediment influx from surrounding landforms during the establishment of the diversion channel.

6.7.3 Revegetation

Hydraulic modelling has demonstrated that the all design criteria values for stream power, stream velocity and shear stress for both 39% AEP and 2% AEP storm events, are within the ACARP (2002) diversion channel design parameters (refer Table 3.2).

Effective revegetation will be crucial for the long-term stability of the diversion reach. A detailed revegetation plan should be developed for Barrett Creek as it will be critical to prevent uncontrolled erosion in the early years following construction. Particularly given that the diversion alignment is unable to be taken offline for the construction and commissioning phases. The revegetation for the diversion should be done in accordance with the revegetation plan informed by baseline vegetation surveys. The plan should:

- Specify the method for revegetation considering direct seeding, mulch blanket, direct planting etc. and be informed by the erosion potential, expected velocities of flows and the cover material in selecting the appropriate method.
- The watercourse revegetation species should be based on selecting key framework trees, woody understorey and groundcover species associated with the predominant natural watercourse regional ecosystems occurring upstream and/or downstream of the site as prescribed in the Saraji Mine Progressive Rehabilitation and Closure Plan.
- Revegetation design should focus on re-establishing riparian vegetation for upper banks, mid banks and lower bank (including bank toe) revegetation zones.
- Include Geomorphic and vegetation features like those in the local landscape.
- Consider irrigation and other controls required to promote vegetation establishment in response to carrying climatic conditions.
- Achieve sufficient ground cover to mitigate erosion risk on beds and banks.
- Maintain a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Not require ongoing maintenance.

6.7.4 Monitoring and Maintenance

Monitoring and maintenance of the diversion during the operational and closure phases of the mine is required and should be conducted in accordance with BHPs watercourse diversion monitoring program. The monitoring and maintenance of the diversion during the establishment phase should be done routinely and consider the following (at least):

- Identifying introduced species and weeds for control.
- Success of vegetation establishment and identifying the need for subsequent seeding or planting.
- Climatic conditions which may impact the success of vegetation establishment (i.e., drought).
- Unplanned events which may impact the success of vegetation establishment (i.e., bushfire).
- Monitoring for erosion of beds and banks.
- Sediment transport under low flow conditions to ensure no excess sedimentation.
- Success of temporary erosion and sediment control measures.

The frequency of inspections should be aligned to risk (i.e. increase where control implementation is not suitable), and also following periods of high flow in the diversion.

7 CONCLUSION

The existing Diversion is experiencing an oversupply of sediment from upstream, diversion banks and adjacent spoil piles resulting in aggradation throughout the entire reach. The downstream waterway sediment transport regime is further impacted by the presence of Dudley's Dam. The approved realignment is considered temporary for the purpose of mining and has not been designed to achieve the rehabilitation closure criteria.

The concept design has been developed to meet the requirements of the PRCP and achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the SRM.

Three options for rehabilitation of the Diversion were identified and assessed using the BHP Multi-Criteria Analysis outlined in Section 5. The option selected to proceed to concept design was Option 2, which includes the construction of a new diversion along the existing haul road to reflect the natural low flow channel and backfilling of Dudley's Dam to meet the DNRME design criteria (Section 3.1). The final concept design, typical cross sections and longitudinal section are presented in Appendix C.

The highest risk to successful performance of the diversion is vegetation failure and subsequent erosion of the banks and bed of the diversion. It is noted that the 39% AEP (2yr ARI) stream power and velocities meet the DNRME design criteria for stability if the channel remains unvegetated. This risk can be mitigated by construction timing and development of a revegetation plan. It is critical that sufficient buffering distance between the concept diversion design and the TSF embankment is included to ensure no impacts to tailings material during large flow events. The closure solution of the TSF is not currently known but will need to consider the proposed solution for the diversion.

The concept design demonstrates that the watercourse diversion will satisfy the closure objectives identified in the guidelines, for PRCP purposes.

8 QUALIFICATIONS

a) In preparing this document, including all relevant calculation and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c) Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d) Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e) This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this Report.

f) If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the Report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

g) This Report does not provide legal advice.

9 REFERENCES

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Appendix A:
Mulit-Criteria Analysis Details

Figure A.1: Multi-Criteria Analysis Details

Multi-Criteria Analysis - Barrett Creek Diversion

Project: PRCP Diversions FY21 (SRM)
Workshop Date: NA

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Criteria	Assumptions/Considerations	Weight	Option 1	Option 2	Option 3	Comments
Likelihood that diversion will achieve state of dynamic equilibrium	Considers the difference between diversion length and grade to natural stream length and grade. Ideally diversion length/grade = natural stream length/grade.	40%	1	1	0	Option 1 results in a lower grade (0.25%) compared to the natural environment (0.37%); however, the diversion is located outside the mining lease boundary. Option 2 achieves a grade (0.37%) equivalent to the natural environment, with the addition of a meander downstream. Option 3 achieves a higher grade (0.42%) to the natural environment, with the addition of a meander downstream.
Diversion constructed through spoil	For options that interact with the LoA mine plan, it is assumed that mining will occur (even if currently unapproved) then the diversion will be constructed through rehabilitated spoil. It is assumed that the PRCP final landform can be revised to achieve the required offset distances from rehabilitated spoil dumps (although the PRCP final landform would not show spoil dumps associated with currently unapproved mining).	30%	1	-1	-1	Option 1 avoids potential future spoil dumps. Option 2 requires decommissioning of the haul road. Additional time contstraint for allowing the diversion to establish. Minor spoil interaction. Option 3 is constructed on the existing alignment. The diversion will likely interact with spoil downstream.
Order of magnitude cost estimate	Assumes $10/m3 of cut.	20%	0	0	0	Option 1, no quantities generated due to the location being outside the mining lease boundary. Option 2 requires decommissioning of the haul road, this cost in addition to closure costs were not considered. Option 3 includes cost to backfill Dudley's Dam.
Ability to isolate diversion from flows during establishment period	Diversion can be isolated from flows if it is constructed offline of the existing diversion.	10%	1	-1	-1	Option 1 can be isolated from flows. Upstream portion of flows for option 2 can be isolated. Downstream portion of flows for option 3 can be isolated.
	Overall Weighted Score		0.8	0.0	-0.4	
	Is there a Fatal Flaw?		No	No	No	
	Relative Risk		Lowest Risk	Neutral Risk	Neutral Risk	

Appendix B:
Hydraulic Parameter Modelling Results

Figure B.1: Stream Power TUFLOW Model Results

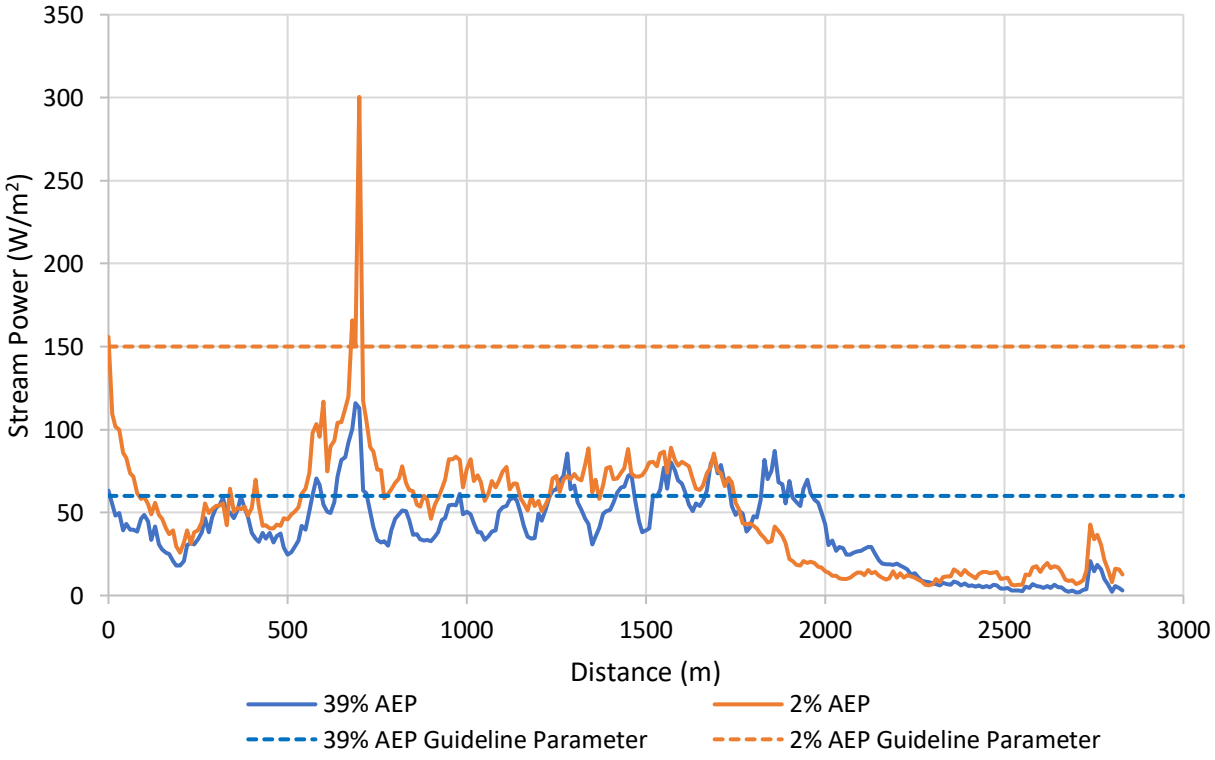


Figure B.2: Velocity TUFLOW Model Results

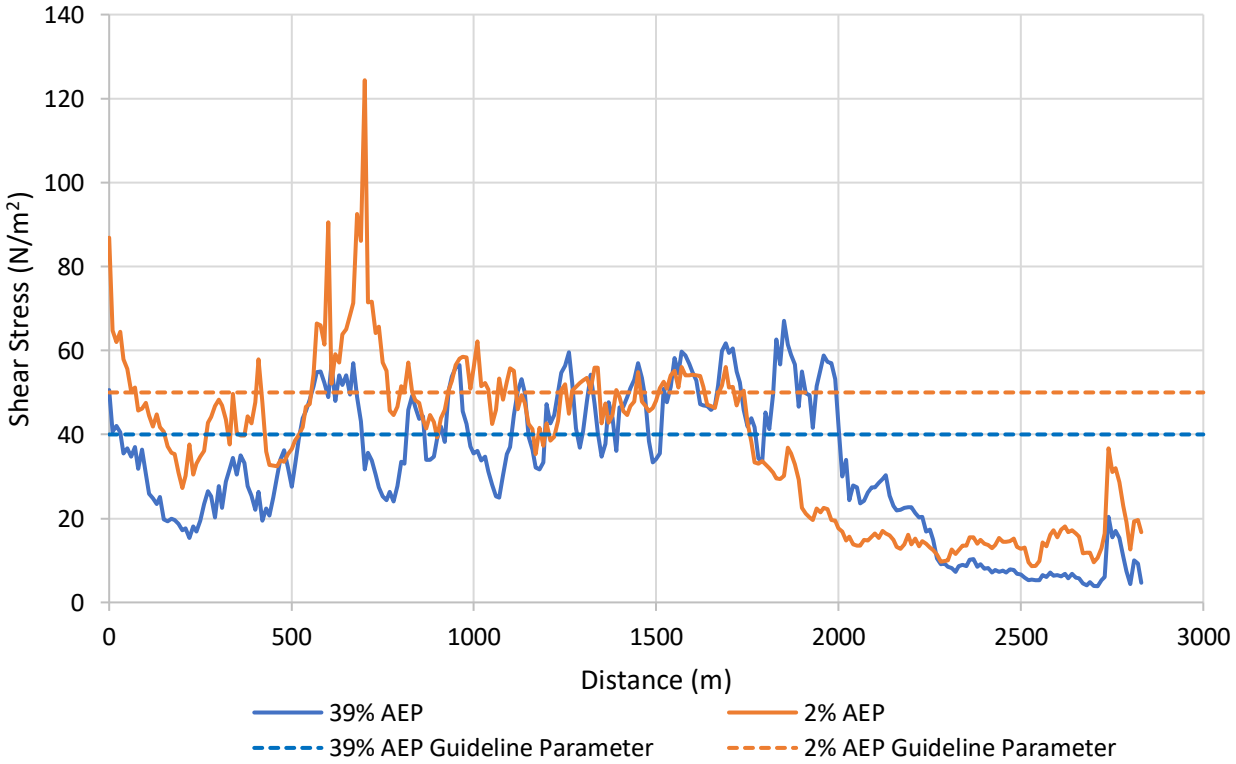
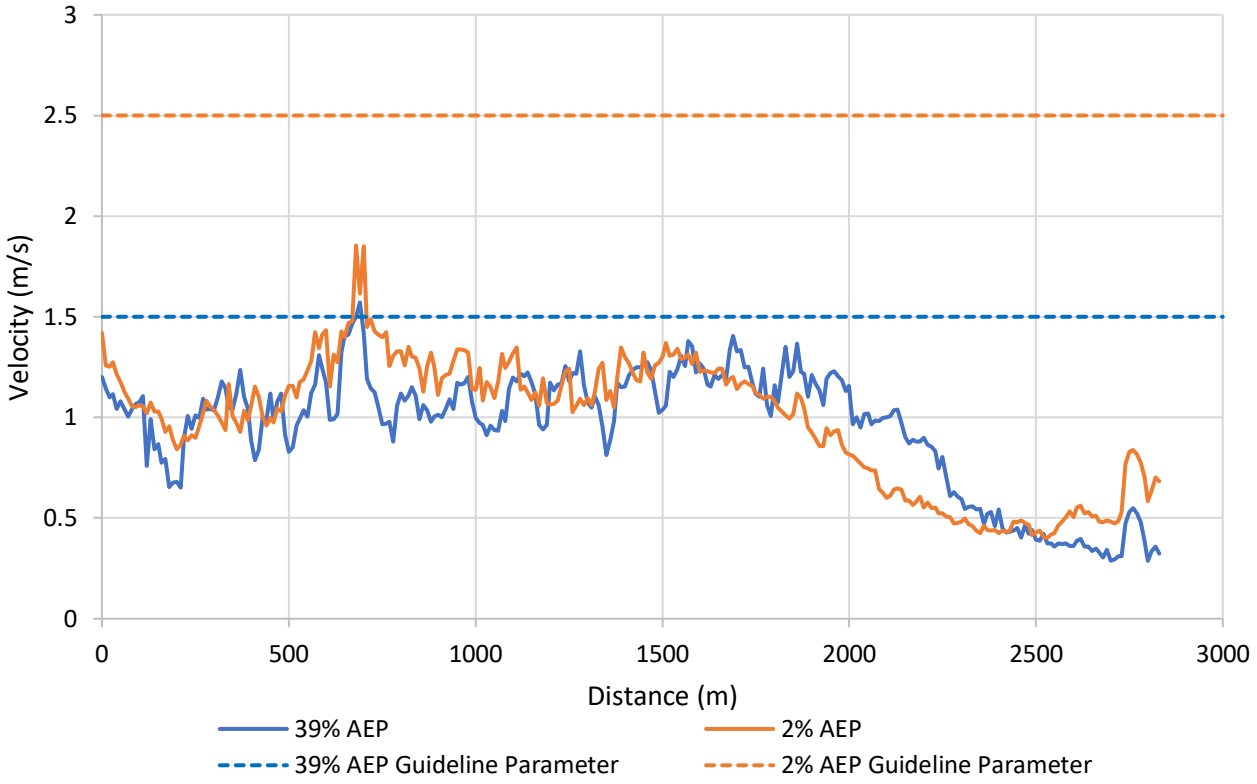


Figure B.3: Shear Stress TUFLOW Model Results



Appendix C:
Preferred Option



GENERAL ARRANGEMENT PLAN
SCALE 1:5000

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SCALE 1:5000 (A1)
SCALE BEFORE REDUCTION

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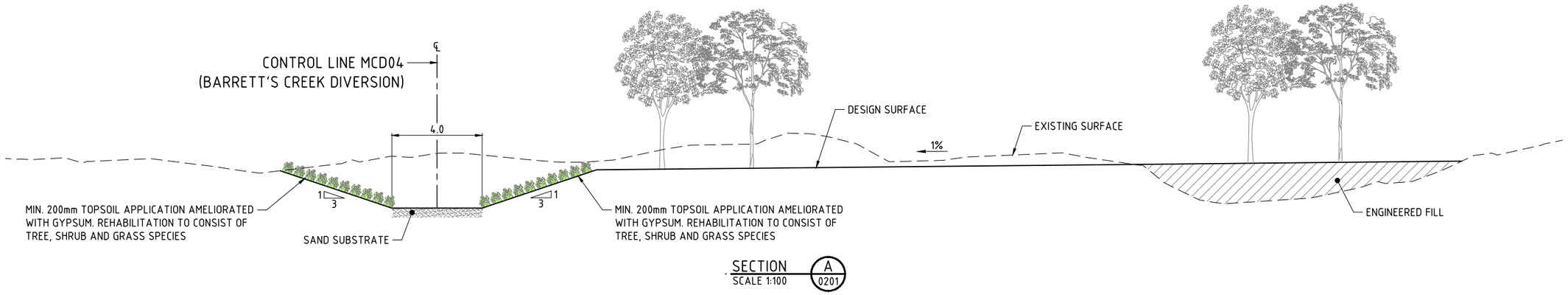
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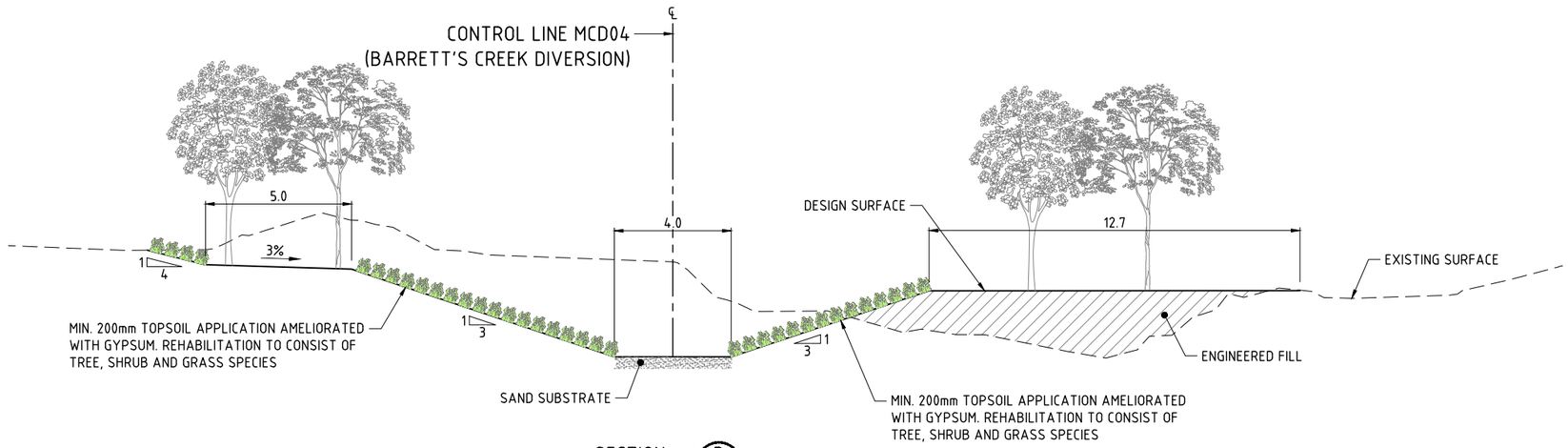
SARAJI MINE

BARRETT'S CREEK
GENERAL ARRANGEMENT

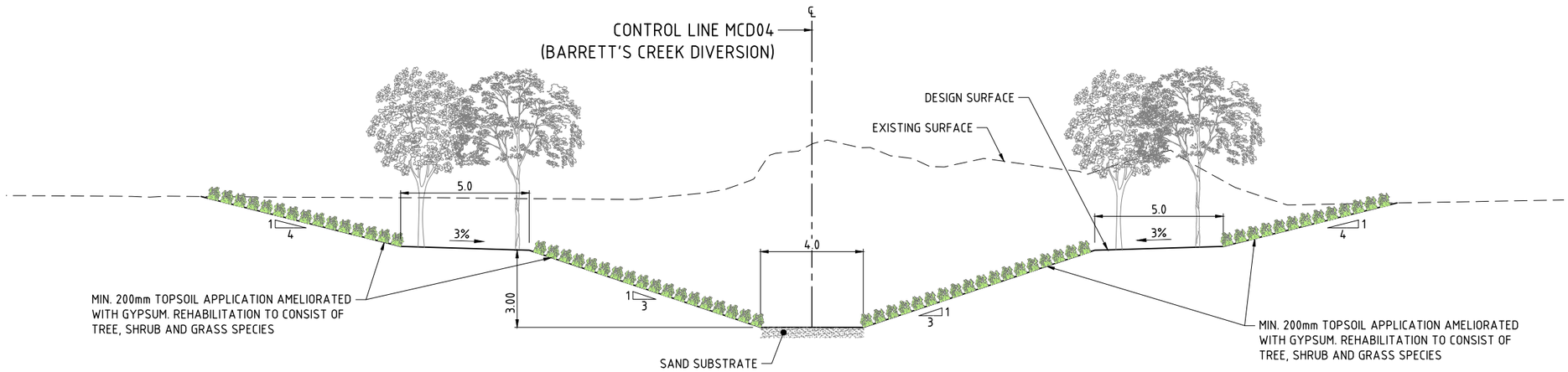
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SECTION A
SCALE 1:100
0201



SECTION B
SCALE 1:100
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SECTION C
SCALE 1:100
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SCALE 1:100 (A1)
SCALE BEFORE REDUCTION

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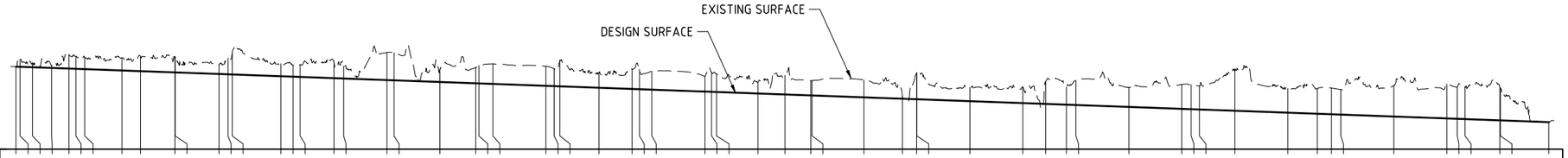
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SARAJI MINE

BARRETT'S CREEK
TYPICAL SECTIONS AND DETAILS

Original Size	Drg No.	Rev.
A1	M11000-474-SKE-0202	A


EXISTING SURFACE
DESIGN SURFACE
DATUM 190.0

| | | |

Appendix D:
Concept Design with PRCP Landform Interaction

Hughes Creek

Barrett Creek

Legend

- Waterway

Final Landform (mAHD)

- 255
- 90
- 100
- 110
- 200
- 200
- 220
- 280

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0 400 800

Scale in metres (1:20,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 66, Zone 55

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Saraji Mine
Barrett Creek Concept Design with PRCP Landform
Figure D.1

A4

D

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PRCP Concept Design Report

One Mile Creek

24 February 2023

M11000_474-REP-003-4

Job no. and Project Name: M11000_474 BHP PRCP SRM Diversions
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Rev	Date	Description	Author	Reviewer	Project Mgr.	Approver
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3	07/12/2022	Client Issue	Jess Davies	Ryan Kinnealy	Jess Davies	Ryan Kinnealy
4	24/02/2023	Client Issue	Ciara Kruger	Ryan Kinnealy	Ryan Kinnealy	Ben Kiernan
Signatures						

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1 INTRODUCTION

1.1 CONTEXT

The purpose of this report is to detail the concept design developed for the relinquishment of the One Mile Creek (One Mile Creek Diversion). The diversion is required to achieve a state of dynamic equilibrium enabling its relinquishment in the post closure landform of the Saraji Mine (SRM).

The long-term performance of the diversion under both operating and closure scenarios is assessed within the following objectives, based on requirements from relevant licences and approvals:

- The diversion demonstrates to be in a safe, stable, non-polluting, and self-sustaining state (as per PRCP Closure Criteria and Environmental Authority requirements as per Section 3.3).
- Rehabilitation requirements (acceptance criteria) include goals, objectives and acceptance criteria for the post mining land use of the 'Watercourse' which is applicable for the watercourse diversion.
- Achieves the key outcomes identified in the Department of Natural Resources, Mines and Energy (DNRME) *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019.*
- Existing water licence diversion objectives generally align with the objectives under the DNRME Guidelines (2019).

This report details the design requirements for the rehabilitation of the diversion for incorporation into the Progressive Rehabilitation and Closure Plan (PRCP) for SRM as described in the Queensland Department of Environment and Science (DES) *Guideline: Progressive rehabilitation and closure plans (ESR/2019/4964).*

1.2 PURPOSE AND SCOPE

The diversion design was undertaken in two stages:

- Stage 1: Options identification and assessment.
- Stage 2: Concept design of the preferred option from Stage 1.

The following methodology was undertaken:

- A desktop geomorphic assessment of the creek was undertaken using historical aerial imagery and survey to identify options for the closure alignment.
- Review of existing flood studies to determine peak flow rates for design flow events to assess hydraulic performance.
- Hydraulic assessment of the diversion option against the criteria in the *DNRME 2019 Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (DNRME, 2019)* (see Section 3.1).
- Develop concept design sketches and watercourse diversion spatial polygons for presentation in the PRCP and Schedule.
- Develop concept design report summarising the design and key information required for inclusion in the PRCP and Schedule.

1.3 DESIGN PROCESS

1.3.1 Concept Design Considerations

The design is concept only, and not at functional level which would be required for approval and construction. The concept design is developed exclusively for PRCP purposes within the limitations of the PRCP, with only permanent design options considered.

To progress the concept design to a functional design level, detailed site-specific information is required including:

- Soil surveys and geotechnical studies.
- Material characterisation for use in erosion protection cover (i.e. rock sizing and composition).
- Site specific revegetation studies.

2 OVERVIEW

2.1 LOCATION

One Mile Creek is an ephemeral watercourse flowing through the SRM from the west to east and joins the Hughes Creek Catchment approximately 20km east of the SRM. The Creek enters an existing dam, One Mile Creek Dam (OMCD), in the west and flows through Campbell's Dam immediately downstream through a narrow corridor between Dogwood Pit and Ebony Pit. The creek joins Hughes Creek to the east, about 20km downstream of the SRM. The total length of the diversion is 3.5 km and was constructed in 1976, with an extension constructed in 2008. The diversion is authorised by water licence 30972F. OMCD was originally built for flood mitigation and is now a staging point for water transfers to Peak Downs Mine. The location of the One Mile Creek Diversion is displayed in Figure 2.1.

N

ML1775

ML1784

One Mile Creek

Diversion Reach

ML1782

Pre-Mining Reach

Campbell's Dam

One Mile Creek Dam

Spring Creek



Legend

- SRM Haul Road
- Waterway
- Pre-mining Reach
- One Mile Creek Diversion Reach
- Mining Lease

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0 400 800

Scale in metres (1:20,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 84, Zone 55

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Saraji Mine
Location of One Mile Creek Diversion
Figure 2.1

A4 B

2.2 PRE-MINING CONDITION

The pre-mining natural upstream, downstream and diversion reaches have been described as follows:

- **Upstream reach** – the upstream reach of One Mile Creek consists of two separate reaches which now drain into OMCD. The reaches had a low sinuosity and sparse riparian zone. Vegetation was continuous surrounding the along these reaches. Prior to mining the two reaches would merge into one channel at the location of the now existing dam embankment.
- **Downstream reach** – the downstream channel of the One Mile Creek diversion comprises of a moderate sinuosity channel. Vegetation is continuous along the downstream with a more distinct riparian zone compared to the upstream reaches. The sediment transport and flow regime of the downstream reach is currently impacted by OMCD due to attenuated flows inhibiting sediment movement through the system.
- **Diversion reach (pre-mining)** – the One Mile Creek diversion reach (pre-mining) was approximately 7.7 km long, meandering through what is now Ebony Pit with moderate sinuosity. Vegetation along the pre-mining diversion reach was continuous, however, less distinct compared to the downstream reach.

2.3 CURRENT CONDITIONS

Monitoring of One Mile Creek diversion has been undertaken since 2009 and was last completed in 2016. As part of the major monitoring, the latest condition of the One Mile Creek diversion has been described as follows (Engeny, 2016):

- The low flow channel is deepening and undercutting diversion banks with minimal presence of natural vegetation features along the diversion reach.
- Erosion issues along existing light vehicle road, haul road and pipeline crossings.

Based on the current condition of the One Mile Creek diversion, it is unlikely that the diversion will achieve the water licence relinquishment criteria prior to mine closure without intervention.

2.3.1 OMCD

The OMCD was originally built in the 1970s for flood mitigation of the surrounding SRM activities. The embankment is approximately 9m high and the dam has a catchment of 20.6 km^2. The dam currently functions as a staging point on the Bingegang Pipeline. The current water license for OMCD (ref: 2766F) authorises the impoundment of up to 900ML of water and to a maximum depth of 5.5m. Under the license conditions, surface water flows into OMCD are to be released downstream at a rate that is equal to the rate at which water is entering, or the unrestricted capacity of the spillway. The current licensing does not provide for the taking of surface water inflows from the dam, only water volumes that are pumped into it through the Bingegang Pipeline.

The Bingegang Pipeline is owned and operated by BMA and utilised to transport raw water from the Nogoa-Mackenzie Scheme approximately 100km to the south east of SRM. The raw water transported through the Bingegang Pipeline is supplied to the township of Dysart, SunWater customers, BMA operated mine sites, other non-BMA mine sites and various landholders in proximity of the pipeline. The OMCD has been identified to have beneficial on-going uses post completion of mining including the on-going operation of the Bingegang Pipeline and potential stock watering. The retention of OMCD will impact the hydraulics of the diversion through limiting sediment migration downstream. Consideration of the altered sediment migration patterns is required within the hydraulic design for the downstream diversion.

3 BASIS FOR CONCEPT DESIGN

There are two recognised guidelines for design of watercourse diversions within Queensland:

- *Guideline: Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000 (Department of Natural Resources, Mines and Energy (DNRME), 2019).*
- *Criteria for functioning river landscape units in mining and post mining landscapes (Australian Coal Association Research Program (ACARP), 2014).*

Both the DNRME and ACARP Guidelines were developed based on previous research by ACARP in the early 2000s, which included assessment of existing diversion performance and the development of design and rehabilitation criteria for watercourse diversions.

The DNRME and ACARP Guidelines have both been used to inform the basis of design for the diversion, as summarised in Table 3.1.

Table 3.1: DNRME and ACARP Guidelines used for Design Basis

Guideline	Design Parameter
DNRME	Diversion Design Outcomes and Design Recommendations
	Velocity, shear stress, stream power (39% AEP) guidelines
ACARP	General Design Process
	Stream power (2% AEP event Guideline)

3.1 DNRME GUIDELINES

3.1.1 Diversion Design Outcome Requirements (Permanent Watercourse Diversions)

The diversion design outcome requirements are nominated by DNRME for permanent watercourse diversions and have been used to develop the design for the One Mile Creek diversion:

- Outcome 1 – The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.
- Outcome 2 – The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.
- Outcome 3 – The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.
- Outcome 4 – The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.
- Outcome 5 – The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.

3.1.2 Design Criteria

DNRME recommend the following design criteria in development of permanent watercourse diversions and have been considered in development of the One Mile Creek diversion:

- The watercourse diversion should tie-in with the existing or receiving watercourse within the resource tenure boundary.
- The stability and performance of a watercourse diversion is assisted by vegetation within the watercourse diversion and adjoining floodplain and does not include artificial structures for grade control that requires ongoing maintenance.
- The channel capacity must be at least equivalent to the natural stream channel capacity existing in that vicinity.

- The length of the channel should be equivalent to the length of the watercourse it replaces.
- Bed grade/slope should be equivalent to the existing watercourse.
- Batter slopes should be designed to maintain stability through different substrates.

The DNRME Guideline also nominates a set of hydraulic design criteria which have been adapted from the original ACARP research. These hydraulic design criteria were developed based on assessment of existing Bowen Basin streams and watercourse diversions and are considered reflective of stable hydraulic conditions for ephemeral systems in central Queensland. The hydraulic design criteria were adopted to develop the One Mile Creek diversion design and are summarised in Table 3.1 and include the following:

- **Shear stress** which is a function of discharge, flow depth and hydraulic gradient and represents the tractive force acting on sediment particles and is used to determine the threshold of motion for sediment. High shear stress provides an indication of potential erosion in cohesive sediments or movement of non-cohesive sediments. It also provides a measure of the ability of vegetation to withstand flow.
- **Stream power** which is a function of hydraulic gradient, flow width and flow rate and represents the energy available to do work on the channel. High stream power values generally result in elevated erosion potential.
- **Velocity** which is a function of flow rate and cross-sectional area and is a simplified measure of erosion potential. Generally higher velocities result in higher erosion potential however stream power and shear stress are more reliable indicators of erosion and sediment transport potential.

Table 3.2: DNRME 2019 Hydraulic Design Criteria

Design Flow Event	Stream Power (W/m^2)	Velocity (m/s)	Shear Stress (N/m^2)
39% AEP (previously 2-year ARI) - no vegetation	<35	<1.0	<40
39% AEP (previously 2-year ARI) - vegetated	<60	<1.5	<40
2% AEP (previously 50-year ARI)	<150	<2.5	<80[1]

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m^2) in the DNRME 2019 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

The DNRME hydraulic design criteria summarised in Table 3.2 were adopted as the basis for the concept design. The ACARP value described in Section 3.2 are provided for information only. The ACARP values were referenced when considering stable stream powers and shear stresses during the vegetation establishment phase of the diversion.

3.2 ACARP GUIDELINES

ACARP (2014) outlined several approaches to the design of diversion channel dimensions, including:

- The analogous approach, where channel dimensions are selected from a reference reach.
- The hydraulic geometry approach, where dimensions are determined from regression relationships; and
- The analytical approach, where equations are used to calculate continuity, hydraulic resistance, and sediment transport and channel characteristics are determined from field inspection of a reference reach.

In addition to the analogous approach, ACARP (2014) also provides guidance on alluvial channel design parameters which were adapted from ACARP (2002). These hydraulic parameters are intended to be representative of stable watercourses within the Bowen Basin and are summarised in Table 3.3. It is recommended that the range (25th to the 75th percentile) of stream powers in the proposed stream lie within the typical values range described in Table 3.3. Stream power values should be no more than 30 % greater than the maximum value shown in Table 3.3.

Table 3.3: ACARP 2014 Alluvial Channel Design Parameters

Stream Type	Sediment Scenario	Stream Power 39% AEP (W/m^2)	Stream Power 2% AEP (W/m^2)
Alluvial	Supply limited	15-35	50-100
	Transport limited	35-60	80-150
Bedrock controlled	n/a	50-100	100-350

ACARP (2014) also provides recommendations on shear stress thresholds for vegetation used as part of rehabilitation activities for diversions. These thresholds are summarised in Table 3.4.

Table 3.4: ACARP 2014 Recommended Vegetation Shear Stress Thresholds

Vegetation Type	Design Shear Stress (N/m^2)
Buffel grass (*Cenchrus ciliaris*)	40
Structurally diverse suite of established native vegetation	120

4 OPTIONS IDENTIFICATION

Engeny identified three potential options for the Diversion (summarised below in Table 4.1). The following criteria were also considered during the development of the concept design:

- Geomorphic features of the pre mining drainage path.
- Upstream and downstream channel geometry and grade.
- Remaining within the ML boundary.
- Impacts to, and from, the final landform.
- Impacts to surrounding drainage paths and catchments.
- Permanent options only.

The objective was to identify suitable options for the rehabilitation of the Diversion, and select a preferred option informed by multi-criteria analysis (MCA) to progress to concept design.

Each option was defined with a concept cross section and longitudinal profile. Civil earthworks modelling was undertaken to confirm the following:

- Alignment of the diversion options.
- The need for potential flood levees (during operations).
- Final landform reconfiguration.
- Reinstatement of the floodplain.
- Proposed tie-in locations to the existing waterway.
- Development of a Class 5 capital cost estimate for construction.

The options identification also included assessment of key risks and opportunities regarding construction staging, potential for impacts to downstream infrastructure and post mining land-use risks in the context of closure.

The three options assessed are shown in Figure 4.1 and summarised in Table 4.1.

Table 4.1: Options Identification Details

Statistic	Option 1	Option 2	Option 3
Description	Retain OMCD embankment and fill in area of Campbell's Dam. Meander new diversion channel upstream.	Remove OMCD embankment and fill in area of Campbell's Dam. Re-instate natural channels along OMCD area. Meander new diversion channel upstream.	Divert channel north into Hughes Creek.
Likelihood that diversion will achieve state of dynamic equilibrium	Medium - Channel grade of 0.31% is 20% steeper than natural slopes at ~0.25%. Impacted by OMCD.	Medium – Channel grade of 0.32% is 22% steeper than natural slopes at ~0.25%	Medium – Channel grade of 0.31% is 19% steeper than natural slopes at ~0.25%. Impacted by OMCD.
Beneficial use and PMLU Benefit	Allows for greater water storage capacity to assist future site rehabilitation operations and future water supply security by keeping OMCD. Retention of the dam also assists in providing water security for the future PMLUs.	Removes OMCD, limiting future storage capacity for rehabilitation works.	Allows for greater water storage capacity to assist future site rehabilitation operations and future water supply security by keeping OMCD. Retention of the dam also assists in providing water security for the future PMLU.
Diversion constructed through spoil	Yes (20% of diversion constructed through consolidated material)	Yes (20% of diversion constructed through consolidated material)	Yes (constructed through parts of spoil and consolidated material)
Order of magnitude cost estimate*	$12M**	$21.7M**	$33M
Ability to isolate diversion from flows during establishment period	No (flow impacted by retention of OMCD)	No	No (only ~50% of diversion can be isolated and flow impacted by retention of OMCD)

*Costs estimated based on average $10/m^3

*Cost for Option 2 includes removal of dam embankment and re-instating natural channel upstream

**Excluding cost for flood protection final landform construction

Evaporation Dam
Coolibah Pit
Evaporation Header Dam
Barrett's Creek
Option 3
divert north into Hughes Creek
ML1775
ML1784
Dogwood Pit
One Mile Creek
ML1782
Option 2
Remove OMCD embankment
Fill in Campbell's Dam
Meander new channel
Ramp 9
Lowwall Dam
Campbell's Dam
ML70142
Option 1
Retain OMCD embankment
Fill in Campbell's Dam
Meander new channel
One Mile Creek Dam
Bulge Dam
Ebony Pit
Ramp 12
Lowwall Dam
Spring Creek

Legend

- SRM Haul Road
- Waterway

Diversion Options

- Option 1
- Option 2
- Option 3
- Mining Lease

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0 400 800

Scale in metres (1:20,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 84, Zone 55

DATE	24/11/2022
DRAWN	CK
JOB NO.	M11000_025

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Saraji Mine
One Mile Creek Diversion Options Figure 4.1

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5 OPTIONS ANALYSIS

5.1 MULTI-CRITERIA ANALYSIS FRAMEWORK

A high-level multi-criteria analysis (MCA) was undertaken to rank the identified options for individual criteria as per Figure 5.1 below and determine a preferred option. The weighting of each criterion was determined and agreed upon with a BHP and Engeny collaborative decision group. The individual weightings are summarised in Table 5.1. Based on the score for each criterion against each option, a preferred option is identified.

-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Figure 5.1: Ranking Scores for MCA

Table 5.1: Weighting for Individual Screening Criteria

Criteria	Weight
Likelihood that diversion will achieve state of dynamic equilibrium	30%
Beneficial use and PMLU benefit	20%
Diversion constructed through spoil	20%
Order of magnitude cost estimate	20%
Ability to isolate diversion from flows during establishment period	10%

5.2 MULTI-CRITERIA ANALYSIS

The MCA resulted in selection of Option 1 to be carried forward into concept design, scoring highest of all three options without a fatal flaw. Option 1 also had the lowest relative risk (see Table 5.2). Refer to Appendix A for the detailed MCA and scoring.

Table 5.2: Multi-Criteria Analysis Outcomes

Item	Option 1	Option 2	Option 3
Overall Weighted Score	0.2	0.0	-0.4
Relative Risk	Lowest Risk	Neutral Risk	Neutral Risk
Fatal Flaw	No	No	No

6 CONCEPT DESIGN

6.1 DESIGN PARAMETERS AND PLAN

Table 6.1 describes the parameters within each outcome requirement outlined in Section 3, forming the design plan for the permanent diversion, in line with the DNRME and ACARP Guideline requirements.

Table 6.1: DNRME and the Australian Coal Association Research Program (ACARP) Parameters Adopted

DNRME Parameters (DNRME, 2019)		Equivalent ACARP Parameters (ACARP, 2014)	
Outcome 1 – The design plan should include a detailed description of: a) the location, function and description of geomorphic features within the proposed watercourse diversion as well as a revegetation and vegetation management plan.	☒	*Outcome 1 –* Geomorphic and riparian vegetation features of the diverted watercourse and connecting reaches (minimum of 1 km upstream and downstream of proposed tie ins). Vegetation characteristics along the proposed optional watercourse diversions should also be noted.	☒
Outcome 2 – The design plan should include a detailed description of: a) the development and calibration, or sensitivity analysis, of the hydrologic model, including the referencing of methodologies used to generate flood frequency analysis[1] b) any design implications and construction processes that necessitate a lateral disconnectivity of sub-surface flow between the watercourse and an adjacent final void (if proposed). [1] Hydrologic models were originally developed as part of the Saraji Mine Flood Study (Engeny, 2018).	☐ ☒	*Outcome 2 –* Summary of hydrological characteristics including surface water-groundwater interactions and water use. Flow changes along the reach should also be clearly noted.	☒
Outcome 3 – The design plan should include hydraulic modelling results (benchmarked against guideline values for stream power, shear stress and velocity adopted from ACARP, 2002) and analysis identifying depth of inundation. The design plan should include a floodplain of sufficient capacity.	☒	*Outcome 3 –* Summary of hydraulic characteristics along the waterway length. Longitudinal section of stream power with standard cross section increments. A higher frequency of cross sections is required at stream junctions and bifurcations. A table summarising stream powers (in channel and floodplain) at each cross section is also required, along with statistics for the reach. This specifically includes the reach minimum, low quartile, median, mean, upper quartile and maximum values[2]. [2] Only mean stream power values were calculated for comparison with the adopted criteria.	☒ ☐
Outcome 4 – The design plan should include a sediment transport analysis that identifies how the watercourse diversion will manage erosion or deposition events such that they are consistent with the existing sediment regime.	☒	*Outcome 4 –* Sedimentation characteristics. Where the existing reach is aggrading, degrading, or is in equilibrium. Note presence of sediment sources (e.g., main channel bed or bank instabilities, floodplain contributions) and sinks (e.g., flood outs or sediment splays along low gradient sections of the reach, and infilling pools).	☒
Outcome 5 – The design plan should include the specification of spoil placement and sequencing and the settlement process and timing of operation that will ensure the watercourse diversion, once constructed, operates in a stable manner.	☒	*Outcome 5 –* Interaction between watercourse diversion options and mine infrastructure (pipes, pits, culverts, access, etc.) and planning over the life of mine.	☒

It is important to note only benchmark values for shear stress and velocity were adopted from DNRME, 2019. Stream power benchmark values were adopted from ACARP, 2014 due to it being a more contemporary standard that considers impacts of sediment transport.

6.2 DIVERSION ALIGNMENT

Option 1 was identified to be the preferred option alignment using the MCA; this includes retaining OMCD to provide future water supply, filling in the area of Campbell's Dam and meandering the diversion along the dam fill footprint and along the existing channel corridor. The alignment and meanders were modified in order to balance the quantities required for cut and fill. Concept design drawings of the preferred option design are included in Appendix C and the concept design and interaction with the PRCP landform in Appendix D.

6.3 CHANNEL GEOMETRY AND GRADE

The locations of the cross-sections taken for the analysis are provided in Figure 6.1. The typical upstream and downstream channel geometries and cross-section dimension for the One Mile Creek realignment concept are presented in Figure 6.2 and Figure 6.3. The concept diversion design dimensions were based on the average natural upstream and downstream channel geometry, where topographic data and arial imagery were used to evaluate the planform and cross section parameters of multiple reference reaches of One Mile Creek. Cross-sectional dimensions were compared and evaluated for a total of 15 cross-section locations.

The grade of the One Mile Creek design concept of 0.31% is similar to the natural upstream and downstream channels, due to the increased length provided by the designed meanders. The upstream tributaries require regrading to re-instate the natural channel grade as well, in combination with the works described in Section 6.2.

Table 6.2 and Appendix C show the detailed geometry and typical cross section of the concept design with longitudinal profile, respectively.

Table 6.2: Detailed Channel Cross Section Geometry

Channel Geometry	Quantity	Comments
Channel Bed Width	4 m	
Batter Slope	1V:4H	For both the low flow channel and high flow channel batters
Channel Depth	1.5 m	Consistent depth of low flow channel at 1.5 m
Bench Width	5 m	



ENGENY WATER MANAGEMENT

BHP

0 500 1,000

Scale in metres (1:25,000 @ A4)

Map Projection: Tranverse Mercator
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Grid: Map Grid of Australia 84, Zone 55

DATE	24/11/2022
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JOB NO.	M11000_025

BHP Coal

Saraji Mine
Locations of Reference Cross-Sectional Areas
Figure 6.1

A4 B

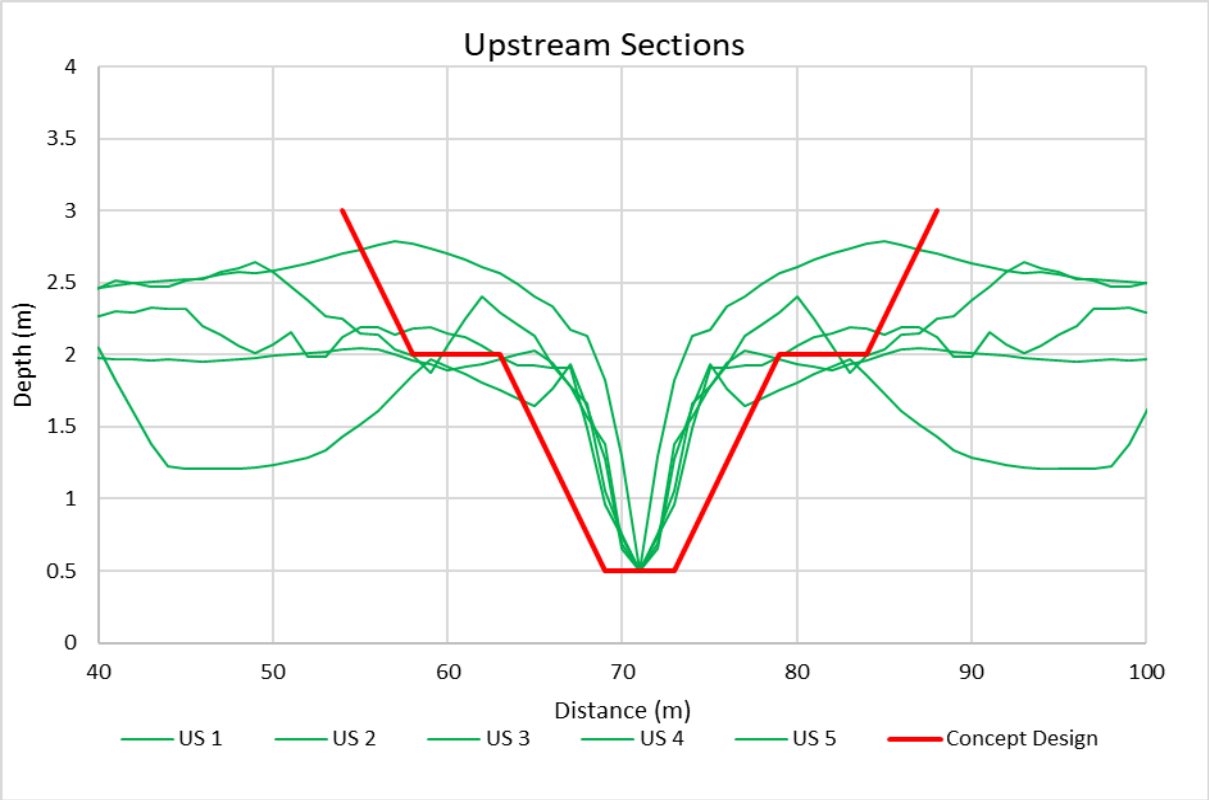


Figure 6.2: Typical Upstream Channel Cross Section of One Mile Creek

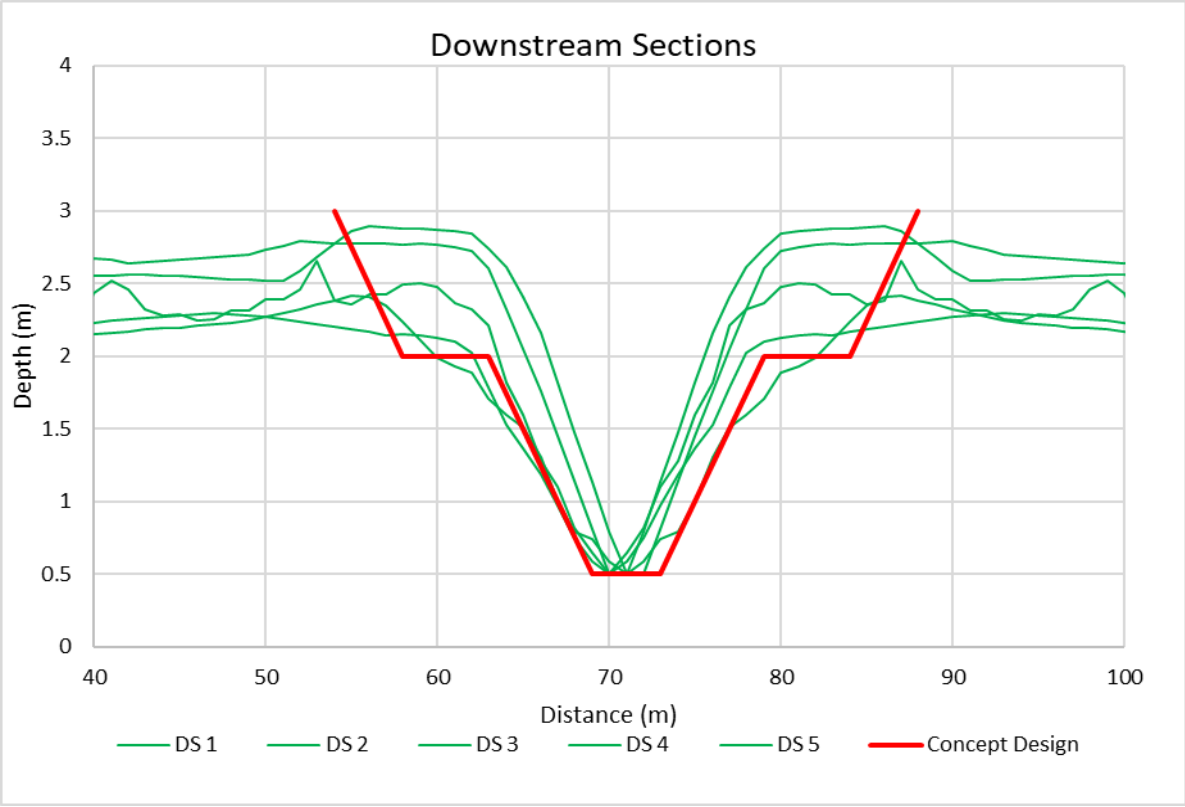


Figure 6.3: Typical Downstream Channel Cross Section of One Mile Creek

6.4 HYDROLOGY

Typically, peak flows for frequent events (39% AEP and 2% AEP) for the rehabilitated diversion are estimated using the ACARP (2002) methods. The ACARP (2002) assessment included a regional flood frequency analysis for a selection of gauged catchments in the Bowen Basin region. From this, a method was developed to estimate flood magnitudes for ungauged catchments, based on catchment area and rainfall intensity. The calculated flood magnitudes for the 39% AEP and 2% AEP are then used to determine diversion design limits for shear stress, stream power and velocity.

The ACARP flows are representative of a regime that is not impacted by onstream. To account for the attenuating affects by OMCD a hydrologic model was used. The One Mile hydrology model was originally developed as part of the Saraji Mine Flood Study (Engeny, 2021) which estimated flows for the 1% AEP and 0.1% AEP flood events. All attenuation effects of existing dams were (including OMCD) modelled in this flood study. This pre-existing hydrology model was utilised to estimate peak flows for 39% AEP and 2% AEP flood events. The One Mile Creek catchment is presented in Figure 6.4 below.

N

Barrett Creek

One Mile Creek Catchment
(27.06 sq.km)

Phillips Creek

Legend

Waterway

One Mile Creek Catchment

ENGENY WATER MANAGEMENT

BHP

0 1,000 2,000

Scale in metres (1:50,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
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Saraji Mine
One Mile Creek Catchment
Figure 6.4

A4

B

6.4.1 Frequent Events

As stated in the previous section the peak flows of frequent events have been determined using an existing hydrologic model for SRM (Engeny, 2021), to accurately represent the attenuation effects of OMCD on the flow regime. The estimated flows calculated by the model can be seen in Table 6.3.

Table 6.3: One Mile Creek Diversion Design Flows

Rainfall Event	Saraji Hydrology Model (Engeny, 2018) Diversion Channel Design Flows m^3/s
39 % AEP	31.6
2% AEP	83.6

6.4.2 Rare Events

The interaction of a 0.1% AEP flood event and the PRCP closure landform will be assessed within the PRCP Chapter. This will inform the interaction between the diversion and final voids, landform and potential impacts to downstream infrastructure, the 1:1000 peak flow rate is 152 m^3/s (Engeny, 2021).

6.5 HYDRAULICS

Stream power is the product of channel slope and discharge. It represents the excess energy available to do work in and on the channel. If there is too much excess energy, then channel erosion may occur. The presence of OMCD in the stream will limit the supply of sediment to the downstream reach of One Mile Creek. In the case of a supply limited system, stream power should remain low to maintain balance of the sediment transport regime. Table 3.3 identifies stream power design parameters for sediment supply limited systems, recommended by the ACARP guidelines.

Stream velocity is calculated by dividing the flow by the cross-sectional area (based on flow depth in the channel). The higher the velocity, the greater the erosive force of a stream and therefore more sediment will be freed and move through the system. Shear stress is an indication of the size of granular material that will begin to move at a particular flow within the diversion reach.

Average values were derived from the TUFLOW model for the stream powers, stream velocity and shear stress in a 39% AEP and 2% AEP rainfall event (refer to Table 6.4). The proposed diversion values have been compared to the DNRME (2019) diversion channel design parameters and ACARP guidelines for supply limited systems.

Table 6.4: Diversion Design Criteria Results

	39% AEP			2% AEP		
Design Criteria	Diversion	DNRME Design Parameter (2019)	ACARP guidelines for supply limited systems	Diversion	DNRME Design Parameter (2019)	ACARP guidelines for supply limited systems
Stream Power (W/m^2)	27	<60	15 - 35	70	<150	50 - 100
Stream Velocity (m/s)	0.9	<1.5	N/A	1.2	<2.5	N/A
Shear Stress (N/m^2)	25	<40	N/A	45	<80	N/A

[1] DNRME values are extracted from ACARP 2002, however the value reported for the 2% AEP shear stress (<50 N/m^2) in the DNRME 2014 is incorrect. The ACARP value of <80 N/m^2 has been adopted.

All diversion concept design parameters are within acceptable limits for both the DNRME (2019) guideline values and ACARP guidelines for supply limited systems.

Appendix B illustrated the variability for each design parameter along the diversion channel and shows that values are predominantly below threshold values along the diversion alignment.

The flood plain of the concept diversion design is confined by the PRCP final landform in a narrow corridor (100-300m) and the final landform will need to ensure the flood protection to final voids. The concept diversion design does interact with rehabilitated mine areas (ie. haul roads, de-commissioned dams) in the upstream reaches and with final landform spoil dumps in the downstream reaches of the design. The flood assessment of the 0.1% AEP flood event shows flows within an open floodplain in the upstream reaches, confined channel flows in the middle section of the design and flows contained with the floodplain of the One Mile Creek downstream reaches (refer to Figure 6.5).

The floodplain within the last 100-200m of the natural One Mile Creek channel is confined by final voids on either side which poses potential risk for external catchment inflows to voids. This risk has been mitigated by utilising the final landform design to provide additional flood protection. Please note, the flood assessment was conducted based on previous recommended changes to the final landform. The final landform has now been updated to meet the previous recommendations, therefore containing the rare event.



ENGENY WATER MANAGEMENT

BHP

0 400 800

Scale in metres (1:20,000 @ A4)

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Grid: Map Grid of Australia 84, Zone 55

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BHP Coal

Saraji Mine
0.1% AEP Flood Event
Figure 6.5

A4 B

6.6 RISKS AND MITIGATION MEASURES

Table 6.5 summarises the main risks for the diversion design and its ability to achieve a state of dynamic equilibrium suitable for relinquishment. The consequence and likelihood matrix utilised aligns with the requirements in the BHP Our Requirements Risk Management (v7.4).

Table 6.5: Diversion Risks and Mitigation Measures

Risks	Likelihood	Consequences	Risk Rating and Score	Mitigation Measures	Residual Likelihood	Residual Consequences	Residual Risk Rating and Score
Retention of OMCD fails to achieve hydrology flow regime required for diversion and results in increased sedimentation and erosion	Unlikely	2	3	Closure planning includes sufficient timing for decommissioning prior to diversion establishment. Clean up works during dry season and revegetation plan of upstream channels.	Unlikely	1	1
Damage to new diversion channel due to extreme flood event	Probable	2	9	Diversion channel constructed during dry season	Unlikely	1	1
Constructability of diversion channel – encountering bedrock, material availability and access	Probable	2	9	Geotechnical investigation as part of functional design, topsoil availability on site and construction during dry season (low chance of flood)	Unlikely	1	1
Significant erosion of channel due to extreme flood event	Probable	2	9	Construction of channel during dry season to allow vegetation establishment prior to wet season	Unlikely	1	1
Vegetation establishment interrupted by extreme flow event (wash away of seed and damage to plants)	Probable	2	9	Choosing a seed mix similar to the surrounding environment and apply topsoil treatment allowing for effective plant growth, construction during dry season	Unlikely	1	1

6.7 ADDITIONAL DESIGN AND CONSTRUCTION CONSIDERATIONS

6.7.1 Backfilling of Existing Dams

The concept design of the One Mile Creek diversion includes backfilling of the existing Campbell's Dam and voids located along the diversion alignment. The Campbell's Dam will need to be backfilled and integrated into the existing surrounding landforms and to match the grade of the diversion channel, refer Figure 6.6. This will ensure flow will not pond between the channel meanders and contributes to diversion flows.

N

One Mile Creek

One Mile Creek

Option 1 &
2 Fill
Area

Legend

Waterway

Backfill Area Options

Option 1 & 2

ENGENY
WATER MANAGEMENT

BHP

0 400 800

Scale in metres (1:20,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 84, Zone 55

DATE	25/11/2022
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BHP Coal

Saraji Mine
Backfilling Locations of Existing Dams Final Landform
Figure 6.6

A4 B

6.7.2 Soils

The channel bed and banks are expected to be comprised largely of the surrounding soils, potentially dominated by dispersive sandy to loamy duplex soils. Erosion of the diversion channel is a key risk to the diversion not achieving a state of dynamic equilibrium. Key actions which should be undertaken in detailed design and construction to further quantify and mitigate this risk include:

- A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment.
- The detailed engineering in functional design should specify requirements for cover materials, including rock and rock mulch, to protect diversion batters from erosion.
- Temporary erosion sediment controls should be designed to minimise risk of erosion until vegetation establishment. This plan should be developed and approved by an appropriately qualified person informed by site specific soils data.
- Prior to construction of the new diversion, topsoil should be stripped and stockpiled for later use as a cover in the final diversion to prevent exposure of dispersive soils to surface flows.
- Where required, topsoil should be stabilized by the addition of gypsum to reduce sodicity and erosion potential, and improve physical fertility for vegetation establishment.
- Where required, subsoil should be stabilized by the addition of gypsum to reduce sodicity and erosion potential.
- Where required, fertilizers should be added to topsoil to ensure adequate chemical fertility required for vegetation establishment.
- Soils should be protected by vegetation prior to major flows occurring. A revegetation strategy should be developed to increase likelihood of successful vegetation establishment, and should consider watering and other controls.
- Excess supply of sediment from upstream and adjacent mining activities (spoil dumps, haul roads, coal stockpiles etc.) can impact vegetation establishment within the new diversion. Controls should be established to reduce sediment influx from surrounding landforms during the establishment of the diversion channel.

6.7.3 Revegetation

Effective revegetation will be crucial for the long-term stability of the diversion reach. A detailed revegetation plan should be developed for One Mile Creek as it will be critical to prevent uncontrolled erosion in the early years following construction. Particularly given that the diversion alignment is unable to be taken offline for the construction and commissioning phases.

The revegetation for the diversion should be done in accordance with the revegetation plan informed by baseline vegetation surveys. The plan should:

- Specify the method for revegetation considering direct seeding, mulch blanket, direct planting etc. and be informed by the erosion potential, expected velocities of flows and the cover material in selecting the appropriate method.
- The watercourse revegetation species should be based on selecting key framework trees, woody understorey and groundcover species associated with the predominant natural watercourse regional ecosystems occurring upstream and/or downstream of the site as prescribed in the SRM Progressive Rehabilitation and Closure Plan.
- Revegetation design should focus on re-establishing riparian vegetation for upper banks, mid banks and lower bank (including bank toe) revegetation zones.
- Include Geomorphic and vegetation features like those in the local landscape.
- Consider irrigation and other controls required to promote vegetation establishment in response to carrying climatic conditions.
- Achieve sufficient ground cover to mitigate erosion risk on beds and banks.
- Maintain a sediment transport regime that does not directly impact on upstream and downstream reaches.
- Not require ongoing maintenance.

6.7.4 Monitoring and Maintenance

Monitoring and maintenance of the diversion during the operational and closure phases of the mine is required and should be conducted in accordance with BHPs watercourse diversion monitoring program. The monitoring and maintenance of the diversion during the establishment phase should be done routinely and consider the following (at least):

- Identifying introduced species and weeds for control.
- Success of vegetation establishment and identifying the need for subsequent seeding or planting.
- Climatic conditions which may impact the success of vegetation establishment (i.e., drought).
- Unplanned events which may impact the success of vegetation establishment (i.e., bushfire).
- Monitoring for erosion of beds and banks.
- Sediment transport under low flow conditions to ensure no excess sedimentation.
- Success of temporary erosion and sediment control measures.

The frequency of inspections should be aligned to risk (i.e. increase where control implementation is not suitable), and also following periods of high flow in the diversion.

7 CONCLUSION

This report illustrates the concept design details and has been prepared in accordance with the requirements of the Department of Natural Resources, Mines and Energy (DNRME) Guideline: *Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000* (DNRME,2019).

The concept design demonstrates that the watercourse diversion will satisfy the closure objectives identified in the guidelines, for PRCP purposes.

Three options for the rehabilitation of One Mile Creek were identified and Option 1 was selected to be carried forward into concept design, utilising the MCA outlined in Section 5. The final concept option design, typical cross sections and longitudinal section are presented in Section 6 and Appendix B. The concept diversion requires backfilling of Campbell's Dam, and the final landform needs to ensure flood protection to final voids, particularly in the last section of the creek corridor. The removal of the adjacent haul road and mining infrastructure is vital to ensure the flows within the creek are not inhibited and achieve a stable, safe, and non-polluting state.

The main risks to the successful performance of the diversion is the limit of sediment supply caused by flow attenuation in OMCD. Stream power has been reduced throughout the diversion by the reduction in stream grade. The designed stream power has been reduced to provide an optimal balance for a supply limited sediment transport regime.

Risk of diversion failure is still present during construction and vegetation establishment phase. These preliminary risks may be mitigated by constructing during the dry season, conducting a detailed soil and vegetation study and complete ongoing monitoring and maintenance.

The concept design replicates the natural upstream and downstream reaches and returns the length of the creek to pre-mining conditions. This provides a more stable geomorphology for the diversion, achieving the closure objectives identified in the DNRME guidelines, for PRCP purposes as summarised in Table 7.1.

Table 7.1: Diversion Satisfaction of DNRME outcomes

	Required Outcome	Design Consideration
1	The permanent watercourse diversion incorporates natural features (including geomorphic and vegetation) present in the landscape and in local watercourses.	The diversion cross section has been designed to replicate the natural geomorphology of the upstream and downstream reaches. The length of the diversion has been increased to reduce the grade of the diversion to pre- mining conditions, improving hydraulic performance. A specific revegetation plan is required to be developed following site detailed studies (soils, revegetation) in subsequent design phases.
2	The permanent watercourse diversion maintains the existing hydrologic characteristics of surface water and groundwater systems.	The diversion has been designed to provide a stable sediment transport regime, ensuring existing hydrologic, surface water and groundwater balance is maintained.
3	The hydraulic characteristics of the permanent watercourse diversion are comparable with other local watercourses and suitable for the region in which the watercourse diversion is located.	The diversion satisfies both DNRME and ACARP hydraulic guideline requirements, meeting appropriate hydraulic conditions for a supply limited system.
4	The permanent watercourse diversion maintains sediment transport and water quality regimes that allow the watercourse diversion to be self-sustaining, while minimising any impacts on upstream and downstream reaches.	The diversion has been designed to be representative of pre-mining geomorphic conditions. The stream power of the diversion has been deigned to mitigate the impact of a sediment supply limited system, creating a self-sustaining flow regime, mitigating impacts on the downstream reach.
5	The permanent watercourse diversion and associated structures maintain equilibrium and functionality and are appropriate for all substrate conditions they encounter.	A detailed soil survey should be conducted in the functional design stage to determine characteristics of topsoil and subsoil within the diversion alignment and any amelioration and erosion protection required during the establishment phase. Vegetation should be established before major flows occur.

8 QUALIFICATIONS

a) In preparing this document, including all relevant calculation, and modelling, Engeny Water Management (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c) Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   i) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d) Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents, and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

e) This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this Report.

f) If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the Report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

g) This Report does not provide legal advice.

9 REFERENCES

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DES. (2019). *Environmental Authority EPML00862313.*

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WaterSolutions. (2007). *One Mile Creek Temporary Diversion Extension – Design Report.*

Appendix A:
Mulit-Criteria Analysis Details

Figure A.1: Multi-Criteria Analysis Details

Multi-Criteria Analysis - One Mile Creek Diversion

Project: PRCP SRM Diversions
Workshop Date: 25/08/2022

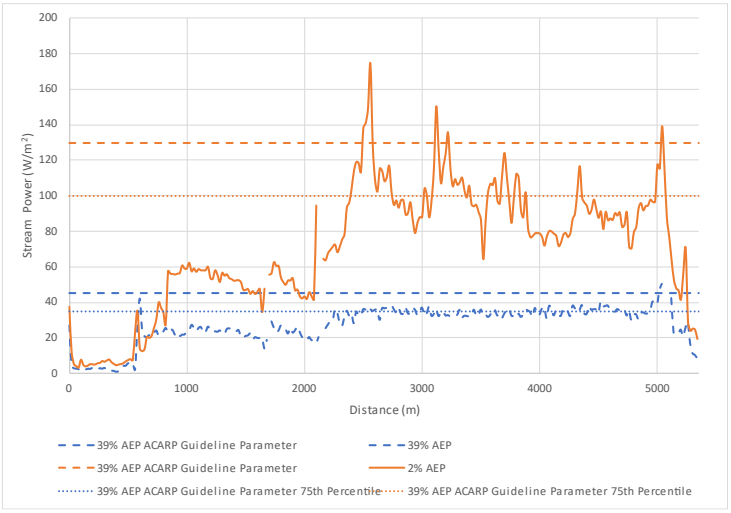
-3	-2	-1	0	1	2
Fatal Flaw	Strongly Negative	Mildly Negative	Neutral	Mildly Positive	Strongly Positive

Criteria	Assumptions/Considerations	Weight	Option 1	Option 2	Option 3	Comments
Likelihood that diversion will achieve state of dynamic equilibrium	Considers the difference between diversion length and grade to natural stream length and grade. Ideally diversion length/grade = natural stream length/grade.	30%	0	1	0	Option 1 Achieves a similar grade to the natural environment. Sediment transport impacted by OMCD embankment. Option 2 Achieves a similar grade to the natural environment. Removal of the dam promotes a natural sediment transport regime. Option 3 Achieves the most similar grade to the natural environment. Sediment transport highly impacted by OMCD embankment.
Beneficial use and PMLU Benefit	The alignment of the chosen diversion option will impede or be of service to the greater rehabilitation works on site.	20%	1	0	1	Option 1 and 3: allows for greater water storage capacity to assist future site rehabilitation operations and future water supply security (i.e. water supply to Peak Downs) by keeping One-Mile Dam. Retention of the dam also assists in providing water security for the future PMLUs Option 2 : Option 2 Removes One-Mile Dam, limiting future storage capacity for rehabilitation works.
Diversion constructed through spoil	For options that interact with the LoA mine plan, it is assumed that mining will occur (even if currently unapproved) then the diversion will be constructed through rehabilitated spoil. It is assumed that the PRCP final landform can be revised to achieve the required offset distances from rehabilitated spoil dumps (although the PRCP final landform would not show spoil dumps associated with currently unapproved mining).	20%	0	0	-1	Option 1 and 2 have about 20% of the diversion cutting through consolidated fill material. Option 3 constructed through spoil as well as consolidated fill material.
Order of magnitude cost estimate	Assumes $10/m3 of cut.	20%	0	-1	-2	Compared based on direct diversion costs only, excluding the bulk fill costs for partially backfilling voids and final landform levee construction.
Ability to isolate diversion from flows during establishment period	Diversion can be isolated from flows if it is constructed offline of the existing diversion.	10%	0	-1	0	Option 1 and 3 flows and establishment are impacted by OMCD retention. Option 2 not able top isolate during establishment period.
	Overall Weighted Score		0.2	-0.0	-0.4	

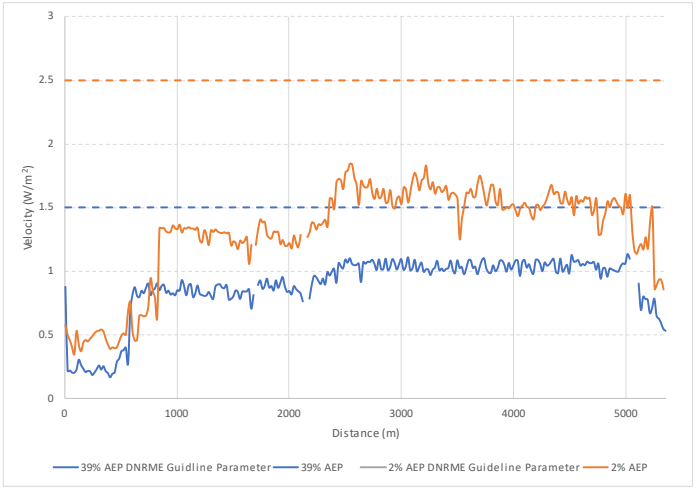
Is there a Fatal Flaw?	No	No	No
Relative Risk	Lowest Risk	Neutral Risk	Neutral Risk

Appendix B:
Hydraulic Parameter Modelling Results

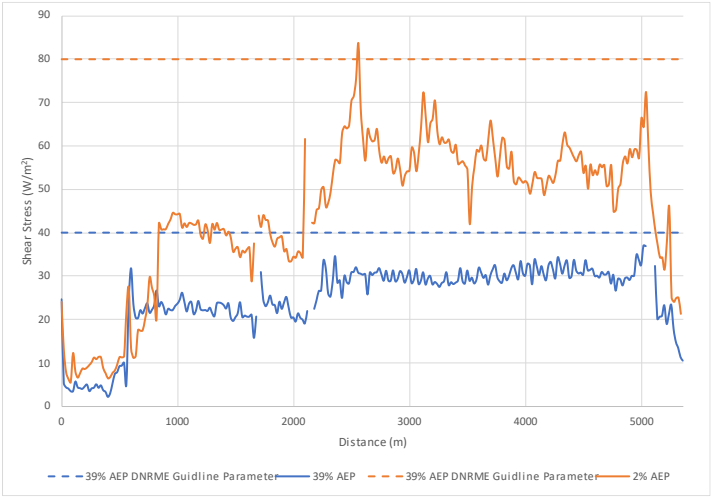
(a) Figure B.1: Stream Power TUFLOW Model Results



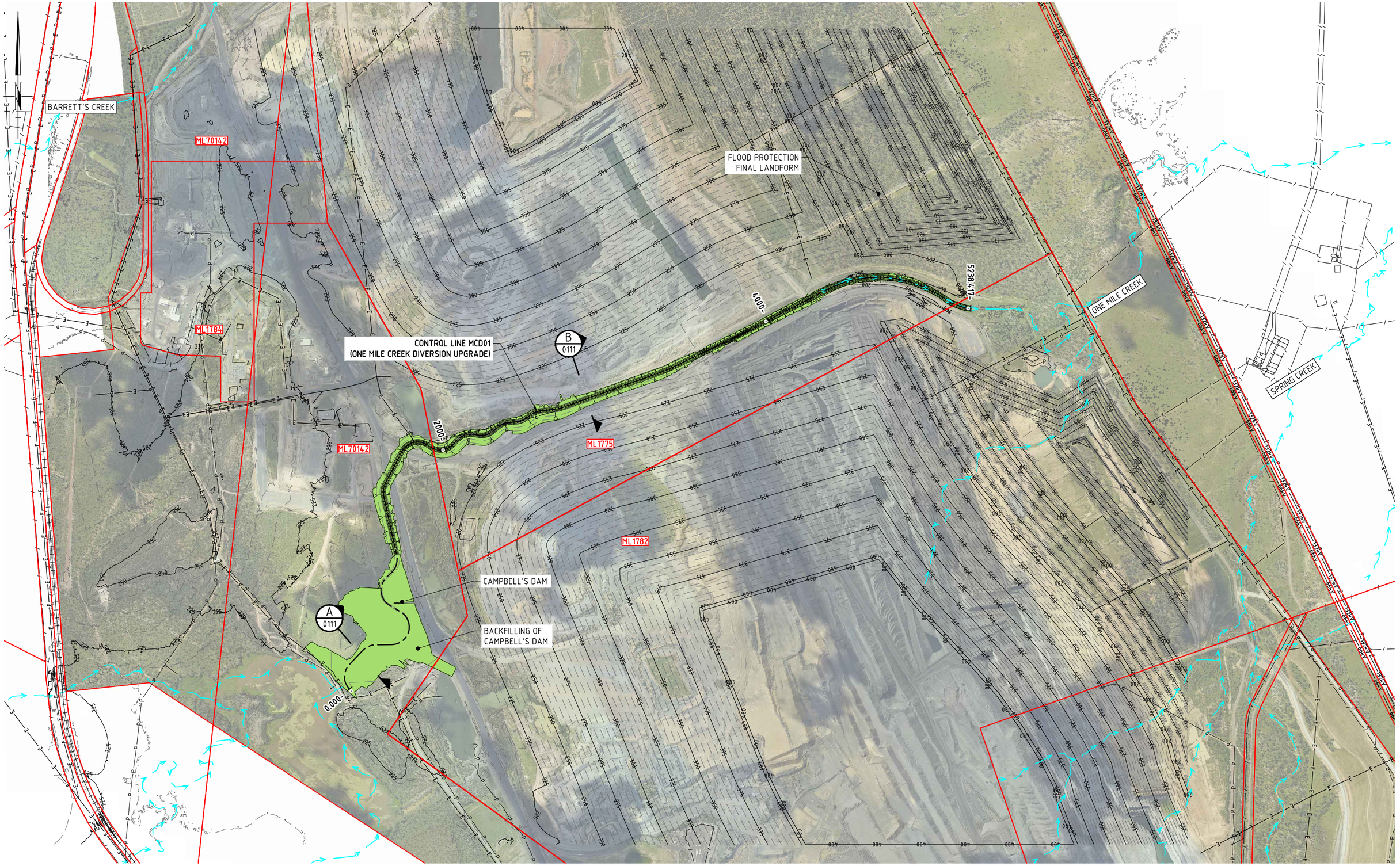
(b) Figure B.9.1: Velocity TUFLOW Model Results



(c) Figure B.9.2: Shear Stress TUFLOW Model Results



Appendix C:
Preferred Option Concept Design Drawings



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REV	BY	DATE	REVISION DESCRIPTION	PM APPD.
A	SA	22.11.2022	FOR REIVEW	-

DOC. NUMBER	DOCUMENT TITLE
REFERENCE DOCUMENTS	

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Level 2
500 Queen St
Brisbane QLD
www.engeny.com.au

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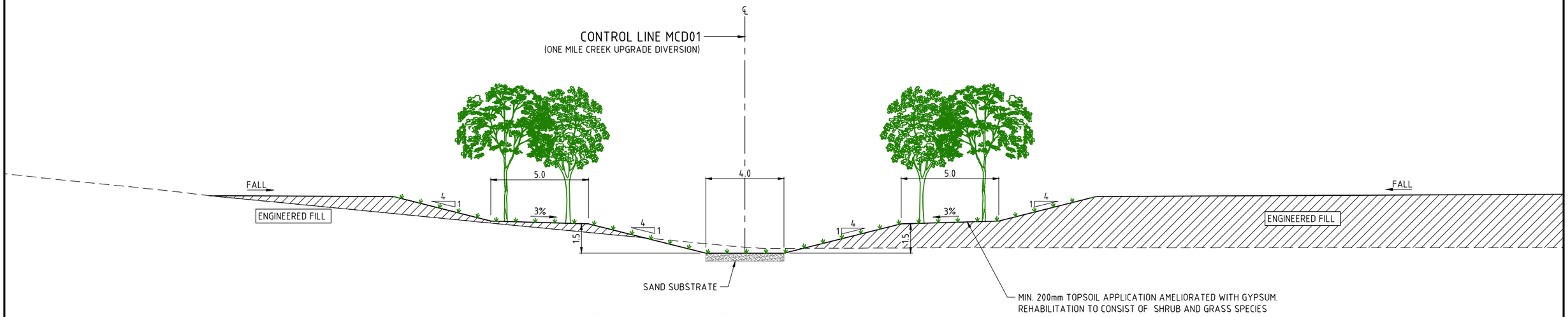
DESIGNED	SA	CHECKED	-	
DRAWN	SA	CHECKED	-	
PM APPD.	-	PD APPD.	-	
RPEQ	-	RPEQ No.	-	

SARAJI MINE

PRCP SRM DIVERSION
ONE MILE CREEK-GENERAL ARRANGEMENT

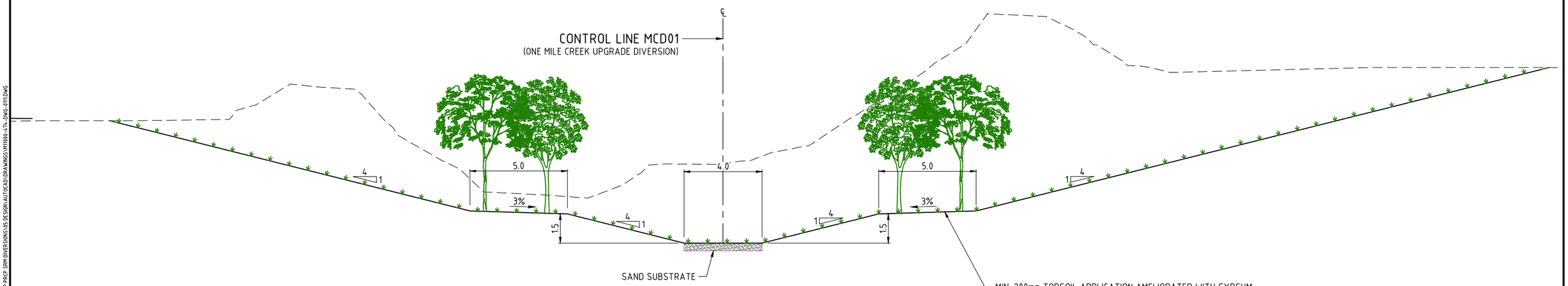
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ONE MILE CREEK DIVERSION UPGRADE SECTION DETAIL

SECTION A
SCALE 1:100 0100



ONE MILE CREEK DIVERSION UPGRADE SECTION DETAIL

SECTION B
SCALE 1:100 0100

LEGEND

EXISTING SURFACE

DESIGN SURFACE

0 1 2 3 4 5m
SCALE 1:100 (A1)
SCALE BEFORE REDUCTION

THIS DRAWING IS CONFIDENTIAL AND SHALL ONLY BE USED BY ENGENY'S CLIENT FOR WHICH IT WAS PREPARED.

REV	BY	DATE	REVISION DESCRIPTION	PM APPD.
A	SA	22.11.2022	FOR REIVEW	-

DOC. NUMBER	DOCUMENT TITLE
REFERENCE DOCUMENTS	

ENGENY WATER MANAGEMENT
Ph. 07 3221 7174
Level 2
500 Queen St
Brisbane QLD
www.engeny.com.au

STATUS
NOT FOR CONSTRUCTION - FOR REVIEW

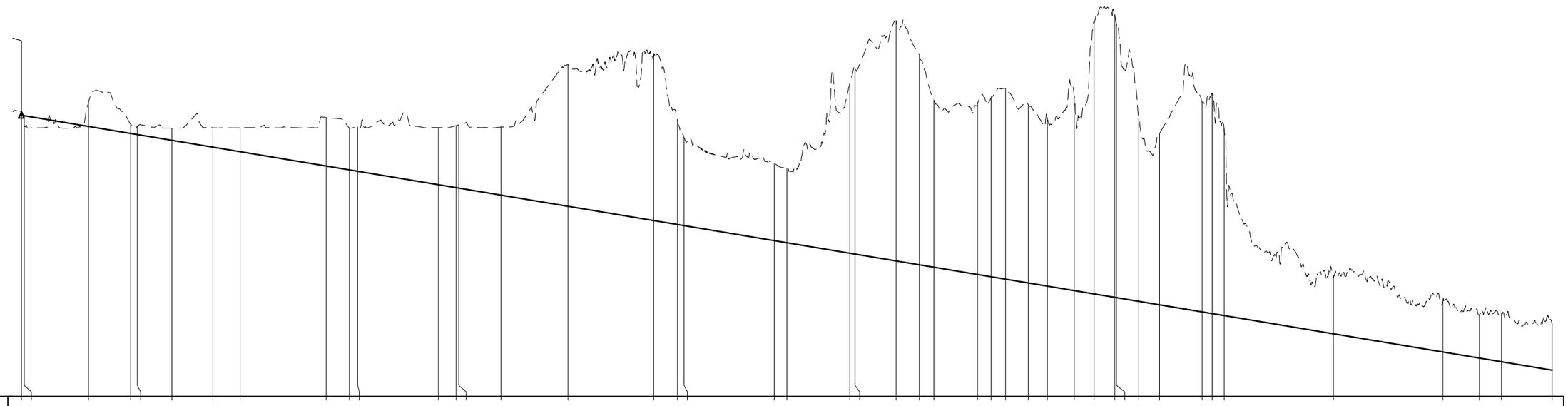
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DRAWN	SA	CHECKED	-
PM APPD.	-	PD APPD.	-
RPEQ	-	RPEQ No.	-

SARAJI MINE

PRCP SRM DIVERSION
ONE MILE CREEK-TYPICAL SECTIONS AND DETAILS

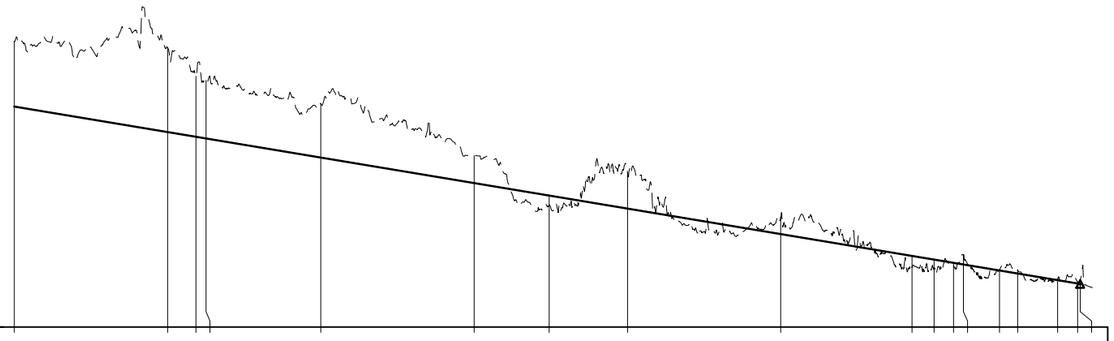
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DATUM 199.0

| | | |



DATUM 193.0

| | | |

Appendix D:
Concept Design with PRCP Landform Interaction

One Mile Creek

Legend

- Waterway

Final Landform (mAHD)

- 255
- 90
- 100
- 110
- 200
- 200
- 220
- 280

ENGENY WATER MANAGEMENT

BHP

0 300 600

Scale in metres (1:15,000 @ A4)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia 84, Zone 55

DATE	24/11/2022
DRAWN	CK
JOB NO.	M11000_025

BHP Coal

Saraji Mine
Closure Landform in the Vicinity of the One Mile Creek Diversion
Figure D.1

A4 B

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WATER MANAGEMENT

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REPORT

Progressive Rehabilitation and Closure Plan

Tailings Storage Facility Description - Saraji Mine

Submitted to:

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480 Queen Street, Brisbane

Submitted by:

Golder Associates Pty Ltd
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PS129499-002-R-Rev0

27 October 2022

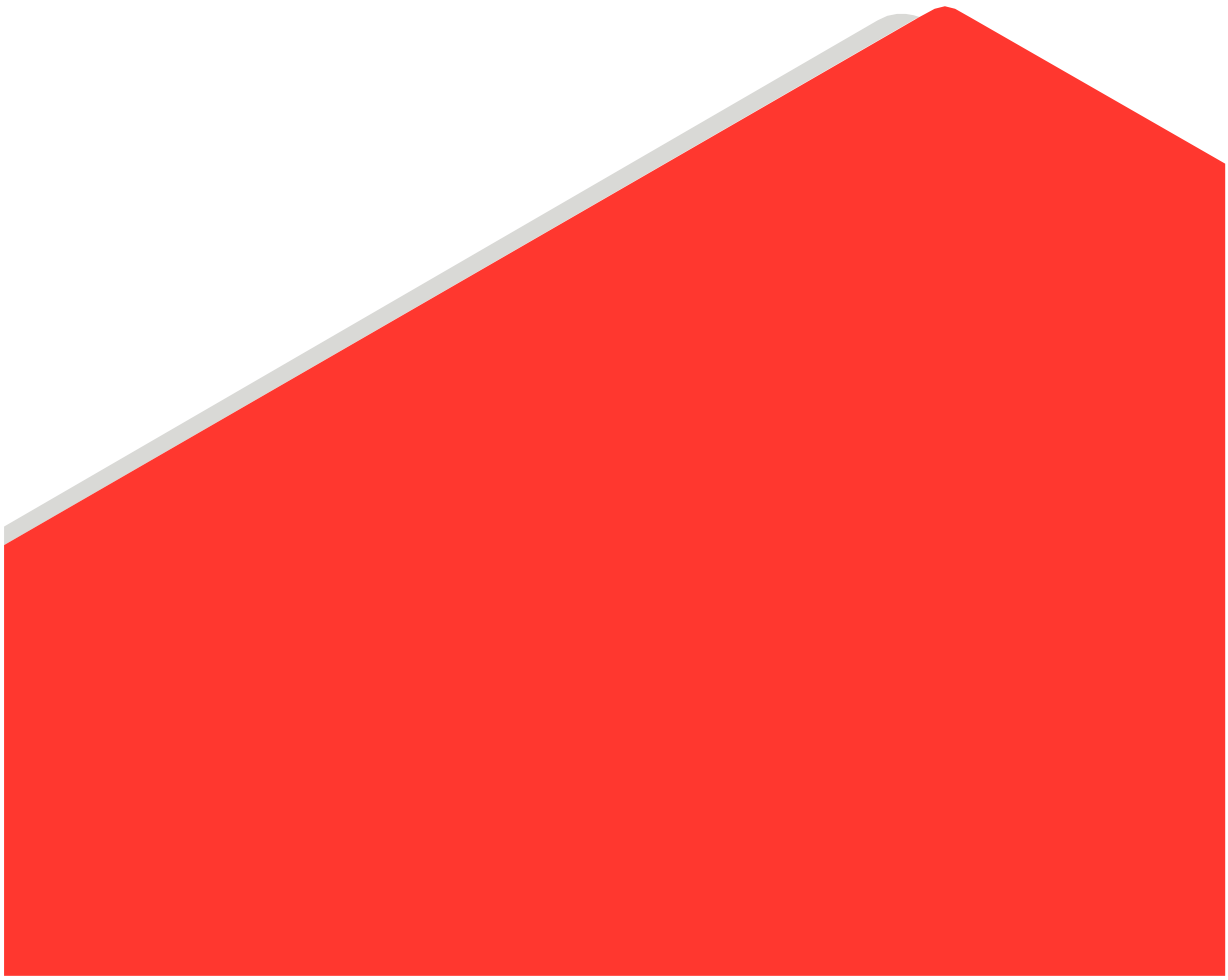


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Sample Locations Ramp 2/3 TSF

APPENDIX B
Laboratory Certificates Ramp 2/3 TSF

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Sample Locations TSF 2

APPENDIX D
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APPENDIX E
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APPENDIX G
Sample Locations TSF 4

APPENDIX H
Laboratory Certificates TSF 4

1.0 INTRODUCTION

BHP Mitsubishi Alliance (BMA) has commissioned Golder Associates Pty Ltd, a member of WSP (WSP Golder), to assist in the delivery of the "Progressive Rehabilitation and Closure Plan (PRCP) Specialist Studies – TSFs". The Tailings Storage Facility (TSF) specialist studies will inform the subsequent compilation of transitional PRCPs for BMA's existing operational coal assets in Queensland (QLD)

Saraji Mine (SRM) is an open-cut coal mine which forms part of BMA's Rangal Coal Measures. Operations at SRM are authorised under Environmental Authority (EA) (EPML00862313), dated 21 June 2021. Holders of an EA are required to submit a PRCP that meets requirements under the *Environmental Protection Act 1994* (EP Act). A Transition Notice has been issued to BMA for SRM and requires a PRCP be submitted to the administering authority by 1 April 2023.

This TSF specialist study comprises the tailings characterisation report for all SRM TSFs. On completion, this report's content will be used by BMA to develop the TSF sections within the sites' PRCP.

This document aligns with regulatory requirements of rehabilitating the land to an identified post-mining land use (PMLU), where applicable, upon cessation of mining activities.

1.1 Purpose

This report presents the tailings characterisation of SRM's five TSFs, as follows:

- Ramp 2/3
- Ramp 6
- TSF 2
- TSF 3
- TSF 4.

The purpose of the report is to summarise the geochemical, rheological and geotechnical parameters of each TSF facility (i.e., the updated closure knowledge base) that could influence the rehabilitation and/or management strategies of SRM, in accordance with the requirements of the Department of Environment and Science (DES) presented within the *Guideline – Progressive rehabilitation and closure plans* (DES, 2019).

1.2 Applicable Guidelines and Standards

SRM operates under an EA (EPML00862313). The conditions within this EA are not facility specific and apply to all TSFs at SRM. Table 1 lists the legislative, legal and statutory obligations and commitments, which are applicable to the SRM TSFs (BHP, 2019).

Table 1: Key obligations and commitments

Key obligations and commitments	
Legislative obligations	▪ Chain of Responsibility (EP Act Amendment) 2016 ▪ Environmental Protection and Biodiversity Conservation Act 1999 ▪ Environmental Protection Act 1994 ▪ Environmental Protection Regulation 1998 ▪ Mineral and Energy Resources (Common Provisions) Act 2014 ▪ Minerals Resources and Energy (Financial Provisioning) Act 2018

Key obligations and commitments	

Legal and statutory commitments / obligations	▪ Environmental Authority EPML00862313
	▪ Mining Leases ML2360 / ML2410
	▪ PRCP Guidelines
	▪ Water Licences:
	  ▪ Barrett Creek Diversion: WL30970F
	  ▪ Hughes Creek Diversion Upstream: WL34358F
	  ▪ Hughes Creek Diversion Downstream: WL426546F
	  ▪ Hughes Creek Diversion Middle: WL52666

2.0 BACKGROUND

2.1 Mine Location

SRM is located in Central Queensland, 30 kilometres (km) north of Dysart in the Bowen Basin and 167 km south-west of Mackay (see Figure 1). SRM forms part of BMA's central region, which also includes Peak Downs Mine (PDM) and Caval Ridge Mine (CVM) to the north, and Norwich Park Mine (NPM) to the south.

2.2 Tenure Ownership

The SRM site comprises the following leases:

- Mining Leases (MLs): ML1775, ML1782, ML1784, ML2360, ML2410, ML70124, ML70294, ML70298, ML70328
- Special Lease (SL): 12/43830
- Term Lease (TL): 233440.

Mining operations use a combination of dragline and truck/shovel equipment to extract metallurgical coal. Most of the coal mining activities occur on ML1775 and ML1782, with a small portion having occurred in ML 2360 and ML 2410. Ancillary services are located on the remaining MLs. BMA is the principal holder of EA EPML00862313.

The distribution of SRM MLs is presented in Figure 1.

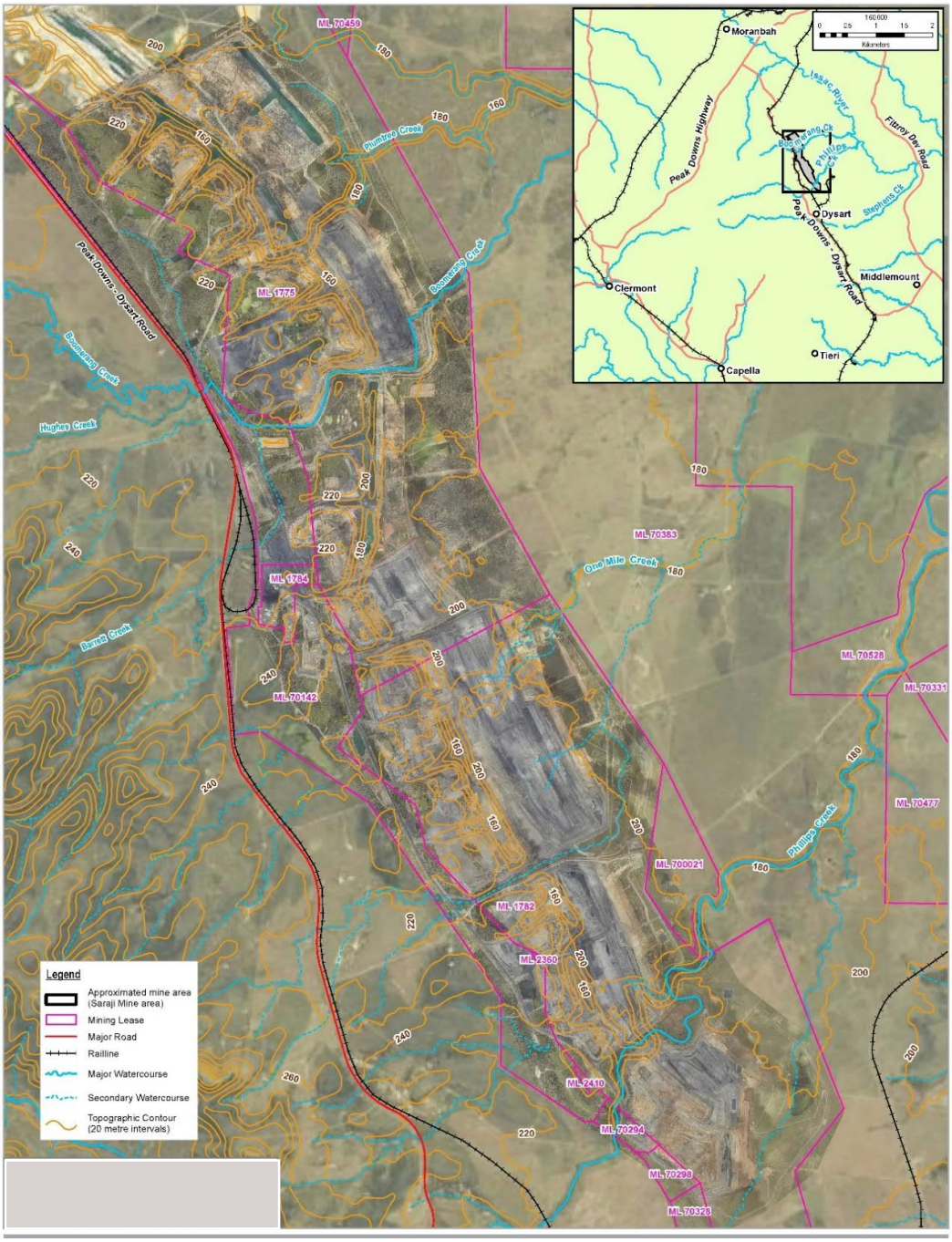


Figure 1: SRM Mining Leases (GHD, 2020)

2.3 Mine Operations

Mining at SRM involves open-cut strip mining in an approximate north-west / south-east direction. Main activities involve removing and stockpiling of topsoil, drilling and blasting of overburden from the pits, and removing overburden. Most of the overburden material is placed in the voids of the previous strips. Currently, there are eight mining pits in various operational stages (Hakea, Grevillea, Ebony, Dogwood, Coolibah, Bauhinia, Acacia and Jacaranda pits). At closure, these pits will remain as four residual voids, namely Jacaranda/Bauhinia Pit, Coolibah /Dogwood Pit, Ebony/Grevillea Pit, and Hakea Pit.

Operations at SRM began in 1974. The currently approved closure date is 2098 (BHP, 2019).

2.4 Ore Processing

At SRM, coal is hauled from the pits to the coal handling and preparation plant (CHPP), run-of-mine (ROM) area or to designated stockpiles. A conveyor then transfers product coal from the CHPP to the train load-out (TLO) area. Fine rejects from the CHPP are disposed in the TSFs and coarse rejects are disposed within the mining spoil or old ramp voids.

After this, product coal is transported by rail to the Hay Point Coal Terminal for export. Annual coal production is approximately 7 million tonnes (Mt).

2.5 Tailings Management

Tailings produced by the processing plants at SRM have been historically managed in five TSFs, as shown in Figure 2. They comprise the following two TSF types:

- In-ramp TSF – a disused mining pit ramps that has been filled with tailings.
- Downslope turkey's nest TSF – above-ground facilities with partial or complete perimeter embankments. The depth of tailings within these facilities is typically less than 20 metres (m). Tailings deposition is generally managed to allow for supernatant water to be collected in decant ponds at one edge of the facility (as opposed to a central decant).

A high-level summary of key information for each TSF is provided in Table 2. Further information and details are provided throughout this report.

Table 2: High-level summary of SRM TSFs

TSF name	Type	Current status	Cover condition	Operational
Ramp 2/3	In-ramp TSF	Active	N/A	Ramp 3: 2003 to ongoing Ramp 2: 2009 to ongoing
Ramp 6	In-ramp TSF	Inactive	Not covered	1998 to 2008 (approx.)
TSF 2	Downslope turkey's nest	Inactive	Partially covered (spoil)	Mid-1970s to late-80s/early-90s
TSF 3	Downslope turkey's nest	Inactive	Fully covered (soil/topsoil)	Mid-1970s to 1985
TSF 4	Downslope turkey's nest	Inactive	Fully covered (soil/topsoil)	1988 to late 90s

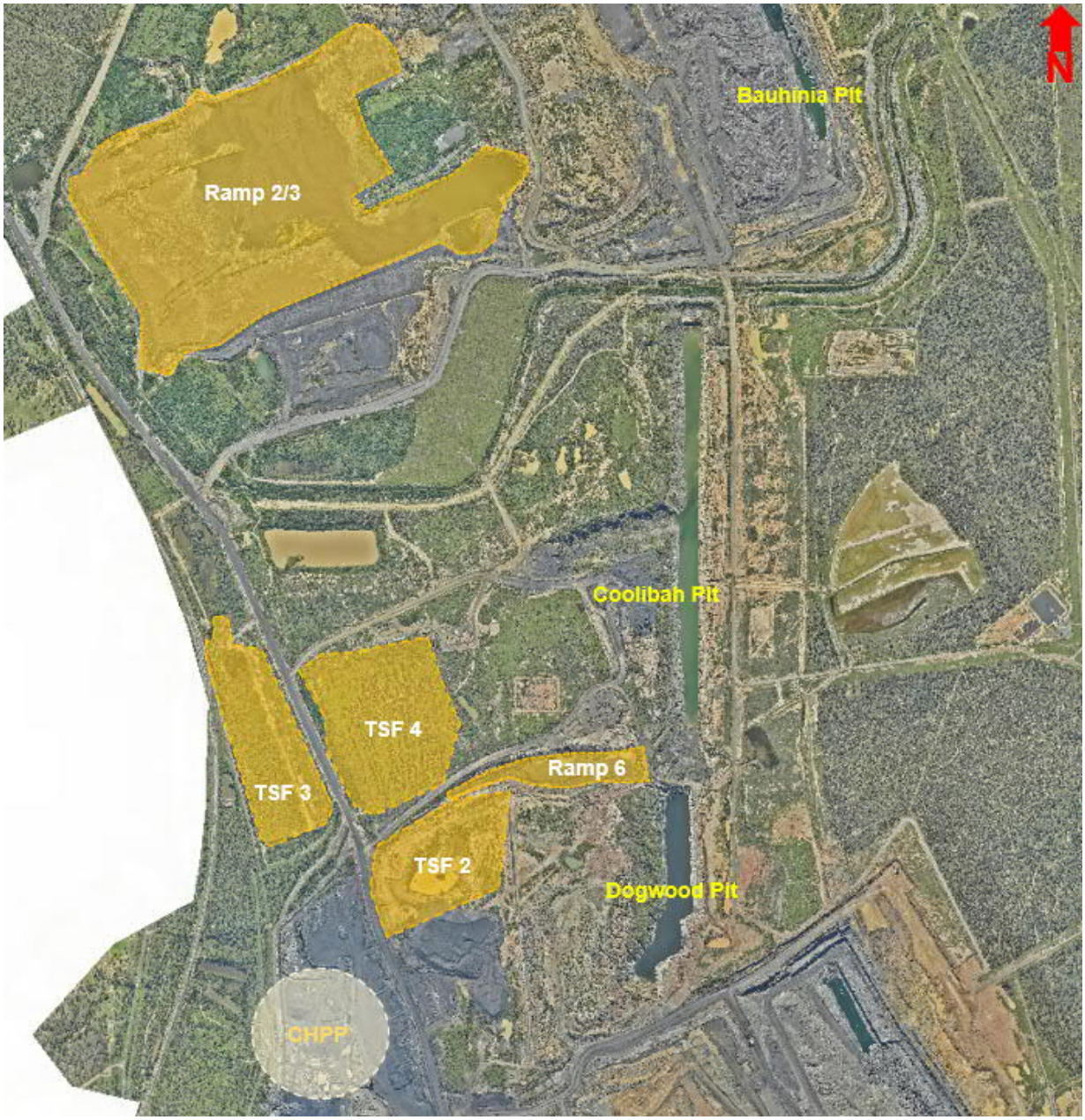


Figure 2: SRM TSF locations

2.6 Environmental Authority Commitments

SRM operates under EA EPML00862313. Conditions within this EA are not facility specific and apply to all TSFs at SRM. BMA has closure obligations, commitments, and current proposed actions to meet or address all SRM licences and approvals. These are identified within the register titled *20180606 REG Closure Commitments Obligations Register v3 (002)* (Golder, 2021). Conditions within this register influencing closure and rehabilitation of the TSFs are shown in Table 3.

Table 3: SRM – Commitments and obligations influencing closure and rehabilitation of the TSFs

Licence/ Approval	Condition no.	Condition	Relevant aspect
EPML00862313	F3	All areas significantly disturbed by mining activities must be rehabilitated to a stable landform with a self-sustaining vegetation cover.	Rehabilitation
	F4	Progressive rehabilitation must commence within two (2) years when areas become available within the operational land.	Rehabilitation
	G27	Dams must not be abandoned, but must be either: a) decommissioned and rehabilitated to achieve compliance with condition G28; or b) be left *in situ* for a beneficial use(s) provided that: it no longer contains contaminants that will migrate into the environment; and it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and the administering authority, the holder of the environmental authority and the landholder agree in writing that the dam will be used by the landholder following the cessation of the environmentally relevant activity(ies).	Regulated structures
	G28	After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria: The landform is safe to humans and fauna. The landform is stable with no subsidence or erosion gullies for at least three (3) years. Any contaminated land (e.g., contaminated soils) is remediated and rehabilitated, not allowing for acid mine drainage. There is no ongoing contamination to waters (including groundwater). Rehabilitation is done in such a manner such that any actual or potential acid sulphate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the *Instructions for treatment and management of acid sulphate soils* (DES, 2021) All significantly disturbed land is reinstated to the pre-disturbed soil suitability class for land that is not being cultivated by the landholder. Groundcover that is not a declared pest species is established and self-sustaining. Vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining.	Rehabilitation

Licence/ Approval	Condition no.	Condition	Relevant aspect
		The maintenance requirements for rehabilitated land is not greater than that required for the land prior to its disturbance caused by carrying out the petroleum activity(ies). For land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within the 3 months of activities being completed.	
Barrett Creek Diversion (WL30970F)	1	The interference with flow authorised by this water licence is considered to be temporary for the purpose of mining until the licensee negotiates acceptance from the Chief Executive for the end of mine life rehabilitation of Barrett Creek.	Surface water
Barrett Creek Diversion (WL30970F)	2a	The licensee must maintain and implement a monitoring and evaluation program that quantifies that the outcomes of the approved design of the inference authorised under the water licence are being achieved; or The licensee must maintain and implement a monitoring and evaluation program that quantifies that the inference authorised under this water licence is meeting or progressing towards achieving the following outcomes: Developing features (including geomorphic and vegetation) present in the landscape and in local watercourses. The watercourse diversion maintains a sediment transport regime that allows the diversion to be self-sustaining and not directly impact on upstream and downstream reaches. The watercourse diversion and associated structures maintain equilibrium and functionality and do not require ongoing maintenance.	Surface water
Barrett Creek Diversion (WL30970F)	5	Relinquishment of this water licence can only occur when it is deemed by the chief executive to satisfy the outcomes in Schedule B condition 2. a). Any request for relinquishment will be negotiated with the chief executive and will require the submission of a final monitoring and evaluation report prepared and certified by a Registered Professional Engineer of Queensland (RPEQ). The report must contain an evaluation of operational and relinquishment monitoring information that demonstrates the diversion has been subjected to a suitable range of flow events determined by the certifier and has achieved the outcomes in Schedule B condition 2. a).	Surface water

Licence/ Approval	Condition no.	Condition	Relevant aspect
Hughes Creek Upstream Diversion (WL34358F)	1a	The interference with flow authorised by this water licence is considered to be temporary for the purpose of mining until the licensee negotiates acceptance from the Chief Executive for the end of mine life rehabilitation of Hughes Creek.	Surface water
Hughes Creek Upstream Diversion (WL34358F)	2a	The licensee must: ▪ Maintain and implement a monitoring and evaluation program that quantifies that the outcomes of the approved design of the inference authorised under the water licence are being achieved. ▪ Maintain and implement a monitoring and evaluation program that quantifies that the inference authorised under this water licence is meeting or progressing towards achieving the following outcomes: ▪ Developing features (including geomorphic and vegetation) present in the landscape and in local watercourses ▪ The watercourse diversion maintains a sediment transport regime that allows the diversion to be self-sustaining and not directly impact on upstream and downstream reaches ▪ The watercourse diversion and associated structures maintain equilibrium and functionality and do not require ongoing maintenance	Surface water
Hughes Creek Upstream Diversion (WL34358F)	5	Relinquishment of this water licence can only occur when it is deemed by the chief executive to satisfy the outcomes in Schedule B condition 2. a). Any request for relinquishment will be negotiated with the chief executive and will require the submission of a final monitoring and evaluation report prepared and certified by a RPEQ. The report must contain an evaluation of operational and relinquishment monitoring information that demonstrates the diversion has been subjected to a suitable range of flow events determined by the certifier and has achieved the outcomes in Schedule B condition 2. a).	Surface water
Hughes Creek Downstream Diversion (WL426546F)	1a	The interference with flow authorised by this water licence is considered to be temporary for the purpose of mining until the licensee negotiates acceptance from the Chief Executive for the end of mine life rehabilitation of Hughes Creek	Surface water

Licence/ Approval	Condition no.	Condition	Relevant aspect
Hughes Creek Downstream Diversion (WL426546F)	2a	The licensee must: ▪ maintain and implement a monitoring and evaluation program that quantifies that the outcomes of the approved design of the inference authorised under the water license are being achieved; ▪ maintain and implement a monitoring and evaluation program that quantifies that the inference authoried under this water license is meeting or progressing towards achieving the following outcomes: ▪ Developing features (including geomorphic and vegetation) present in the landscape and in local watercourses ▪ The watercourse diversion maintains a sediment transport regime that allows the diversion to be self-sustaining and not directly impact on upstream and downstream reaches ▪ The watercourse diversion and associated structures maintain equilibrium and functionality and do not require ongoing maintenance	Surface water
Hughes Creek Downstream Diversion (WL426546F)	5	Relinquishment of this water licence can only occur when it is deemed by the chief executive to satisfy the outcomes in Schedule B condition 2. a). Any request for relinquishment will be negotiated with the chief executive and will require the submission of a final monitoring and evaluation report prepared and certified by a RPEQ. The report must contain an evaluation of operational and relinquishment monitoring information that demonstrate that the diversion has been subjected to a suitable range of flow events determined by the certifier and has achieved the outcomes in Schedule B condition 2. a)	Surface water

3.0 RAMP 2/3 TSF

3.1 Overview of Tailings Facility

Table 4 presents a description of the extent and general arrangement of Ramp 2/3 TSF, as well as the history and governance, TSF classification and monitoring activities.

Figure 3 presents Ramp 2/3 TSF's general arrangement and site locality in relation to surrounding infrastructure.

Table 4: Ramp 2/3 overview

Condition	Detail
Extent and general arrangement of TSF	▪ Regulated structure located approximately 4 km north of the SRM industrial area and approximately 450 m west of Bauhinia Pit ▪ Total catchment area for Ramp 2/3 TSF is approximately 222 hectares (Ha), comprising 175.5 Ha of internal TSF catchment and 46.8 Ha of external catchment ▪ Hughes Creek Diversion runs approximately 200 m and 1 km from the western and southern embankments, respectively ▪ Embankment slopes are 1 vertical (V) to 4 horizontal (H) ▪ Embankment crest currently constructed to an approximate elevation of 215.8 m reduced level (RL) with a crest width of 8 m ▪ Spillway located at the eastern end of the southern embankment with discharge to the Hughes Creek Diversion ▪ Spillway designed to convey the 1:1,000 Annual Exceedance Probability (AEP) storm event with a maximum flow capacity of 14.4 m^3/s and a flow depth of 0.35 m (Golder, 2021) ▪ Decant pond and pumps are located towards the south-east corner ▪ Decant water currently delivered to Jacaranda Pit. The decant return system has a capacity of 170 L/s or 14.7 ML/day ▪ Based on the current Operation, Maintenance and Surveillance Manual (OMS) there are 11 vibrating wire piezometers (VWP) installed in 10 borehole locations, which are available to monitor groundwater levels
History and governance of the TSF	▪ Ramp 2/3 TSF was formerly two separate in-ramp facilities (Ramp 2 TSF and Ramp 3 TSF) ▪ Operation of Ramp 3 TSF started in 2003 ▪ Operation of Ramp 2 TSF started in 2009 ▪ A raise of the TSF in 2013 combined Ramp 2 TSF and Ramp 3 TSF into a single facility, to a maximum embankment crest level of 212 m RL ▪ The latest raise was the Stage 5 raise which was completed in 2019 to 215.8 m RL (a 3 m raise using both upstream and downstream methodology) and is currently active. The expected exhaustion date for the Stage 5 raise is estimated to be in FY26
TSF classification	The current consequence category assessment (CCA) for Ramp 2/3 Stage 5 is as follows: ▪ Australian National Committee on Large Dams (ANCOLD) – Low ▪ DES – Significant ▪ Canadian Dam Association (CDA) – Significant ▪ Global Industry Standard on Tailings Management (GISTM) – Not available The design storage allowance (DSA) volume required is 1,317 ML, plus any net process inputs. In the end of the Stage 5 operations, the DSA volume will only comprise of the rainfall volume (1,317 ML), and the corresponding decant pond level is RL 212.92 m.
Operation and surveillance	Monitoring and surveillance activities are as follows: ▪ Maintaining adequate embankment freeboard from the tailings surface ▪ Maintaining the decant pond in the vicinity of the south-east corner where the decant pond pump is located ▪ Ensuring no water is pooled against the areas of the embankment constructed by upstream raises ▪ Maintaining the decant pond at a minimum level ▪ Conducting periodic inspections in line with applicable OMS manual ▪ Weekly and monthly inspections to monitor the integrity of the dam ▪ Performing seepage management activities

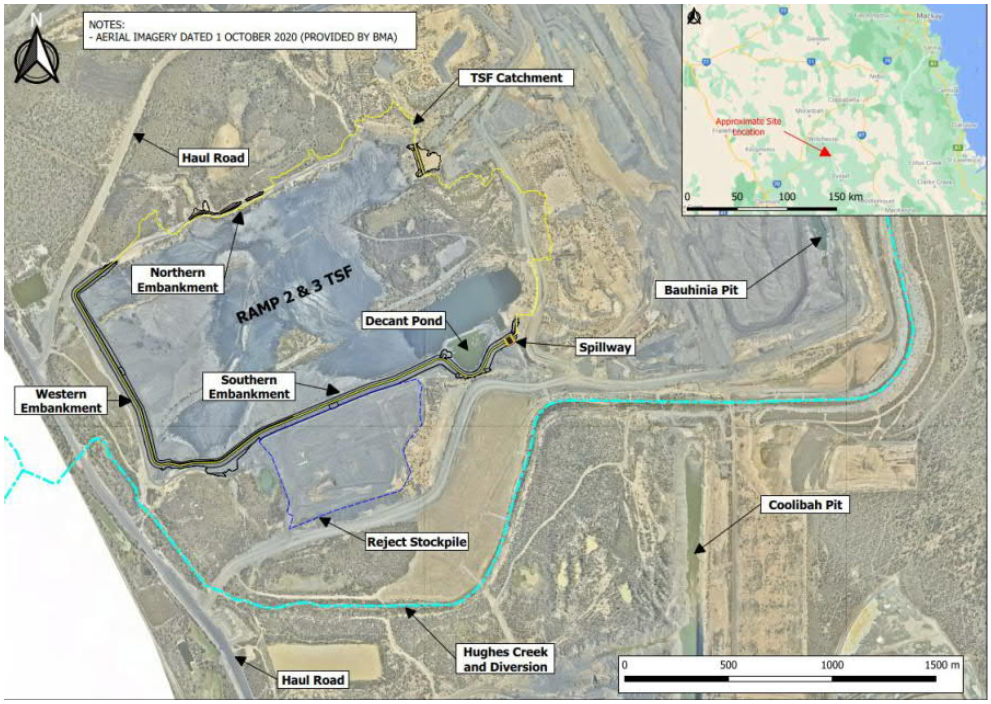


Figure 3: Ramp 2/3 TSF general layout and locality

3.2 Tailings Characterisation

The following sections provide a summary of the tailings characterisation conducted to date. Locations for sampling and testing for tailings characterisation are presented in in Appendix A as high-resolution images for sample points and depths. Laboratory certificate results are presented in Appendix B.

3.2.1 Tailings Geochemical Characterisation

Tailings geochemical properties have been assessed as part of a dedicated mineral waste characterisation project (sampling, analysis and reporting) undertaken by BHP across the Queensland BMA sites (2020 – ongoing). Results of this project are being compiled and will be used in conjunction with the geotechnical and rheology characterisation provided herein. These will inform the development of suitable rehabilitation management strategies in the PRCP.

3.2.2 Rheology

The relationship between yield stress and solids content of the tailings has been assessed through a series of rheological tests conducted on representative samples collected from the impoundment area of Ramp 2/3 TSF as shown in Figure 4.

The rheology test work results for the TSF's Failure Impact Assessments (FIAs) on SRM Ramp 2/3 tailings are shown in Table 5.

Table 5: Ramp 2/3 TSF summarised rheology results FIA

Sample name	Depth (m)	Solid concentration (wt%)	Solid Specific Gravity	Yield Stress (Pa) @55wt%(*)
TP-01	0.4 to 0.6	75.0	1.93	76.82
TP-02	0.3 to 0.5	74.4	1.99	40.46
TP-03	0.3 to 0.5	73.4	1.95	30.85

(*) Note: For reference, calculated yield stress ($\tau_y = ae^{bx}$) of each sample at a solid concentration of 55wt%.

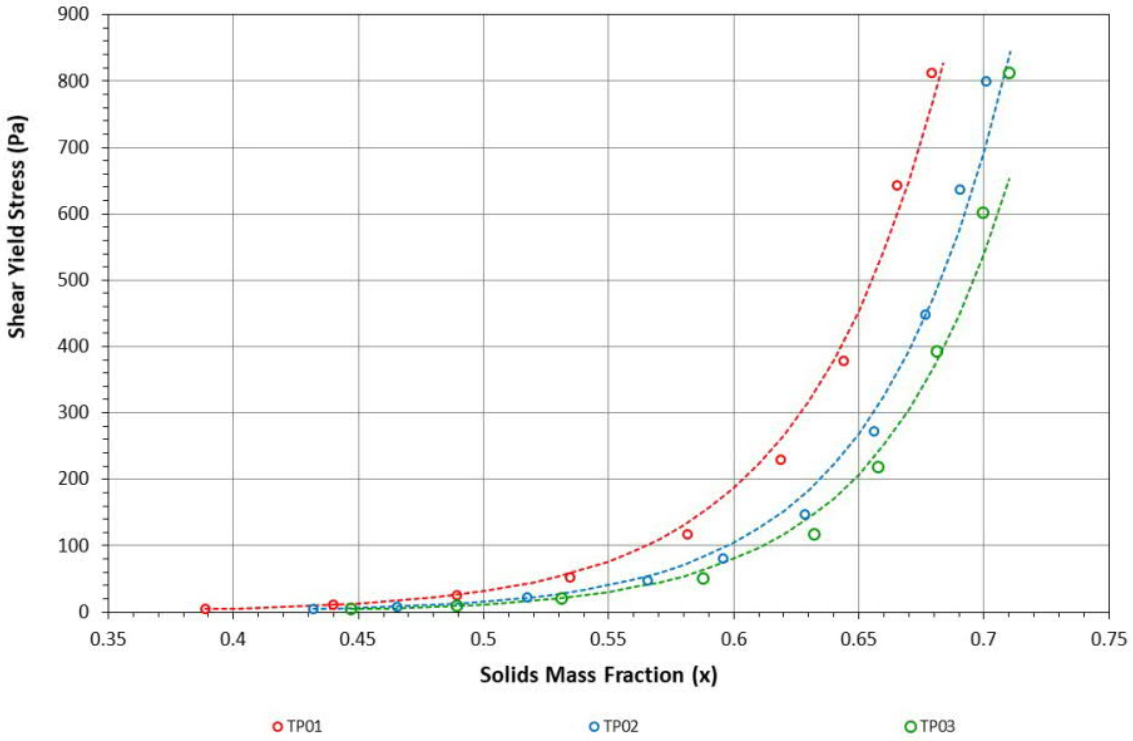


Figure 4: Ramp 2/3 TSF shear yield stress vs mass fraction

The shear stress of the SRM Ramp 2/3 tailings samples is given as a function of shear rate in Figure 5.

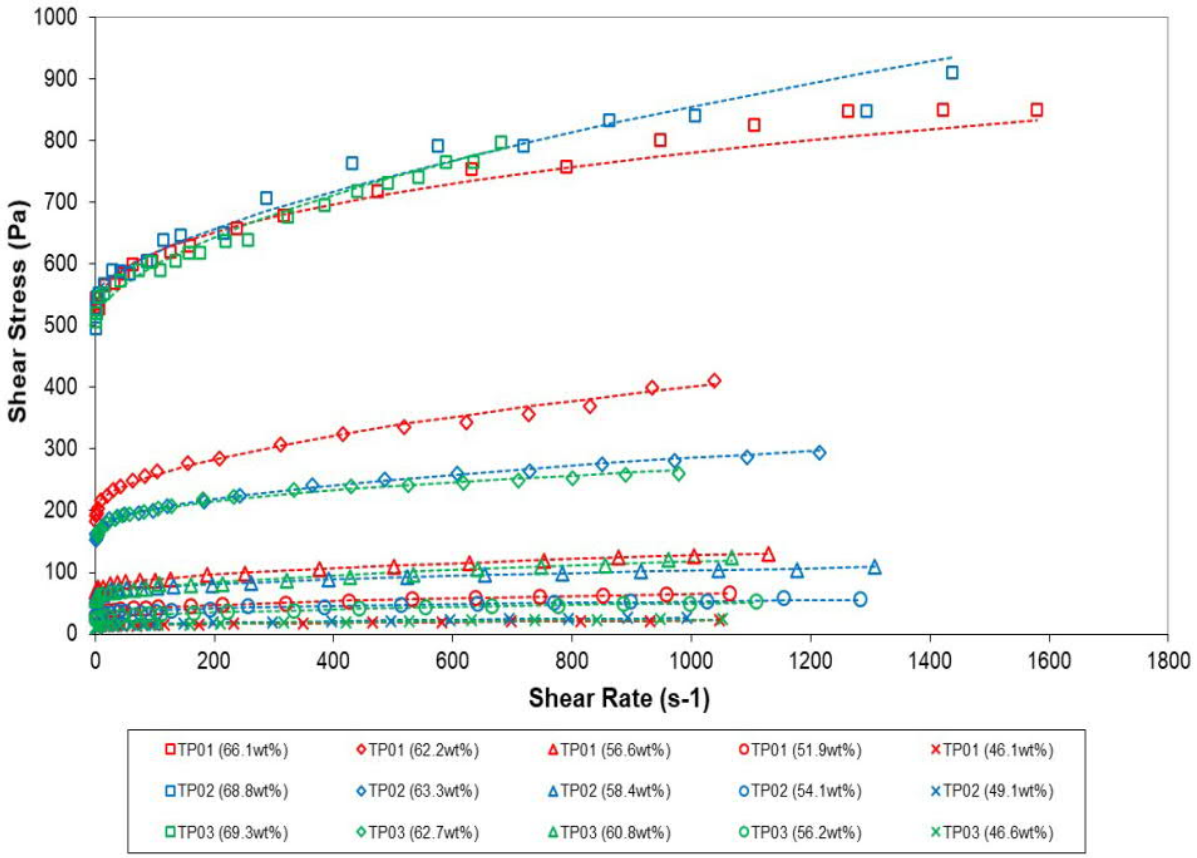


Figure 5: Ramp 2/3 TSF shear stress vs shear rate (all samples)

In shear flow, all samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated. In addition, the shear viscosity decreased by three orders of magnitude across the range of shear rates investigated. No shear history or time dependence was observed on the time scale of testing. However, it should be noted that all samples were fully sheared prior to testing due to the sample collection, subsequent sub-sampling and sample preparation methods (Rheological Consulting Services, 2021).

3.2.3 Particle Size Distribution

The results of particle size distribution tests of the tailings samples are presented in Table 6.

Table 6: Ramp 2/3 TSF particle size distribution test of the tailings samples

Test location	Material	Depth (m BGL*)		Particle size distribution		
		From	To	Clay and silt fines (%)	Sand (%)	Gravel (%)
TL-03	Tailings	5.00	5.65	59.00	41.00	0.00
TL-05	Tailings	6.00	6.60	80.00	19.00	1.00
TL-11	Tailings	12.50	13.15	58.00	42.00	0.00
TL-11	Tailings	15.00	15.65	67.00	32.00	1.00
TP-01	Tailings	0.40	0.60	66.87	33.13	0.00
TP-02	Tailings	0.30	0.50	64.00	36.00	0.00
TP-03	Tailings	0.30	0.50	65.63	34.37	0.00
2016CPT01A	Tailings	0.00	0.50	9.00	91.00	0.00
2016CPT01B	Tailings	0.00	0.50	9.00	90.00	0.00
2016TP04	Tailings	1.10	1.50	19.00	76.00	5.00

*m BGL = metres below ground level

Figure 6 presents particle size distribution curves for individual samples showing typical clay, silt, sand, and gravel bands for the tailings material.

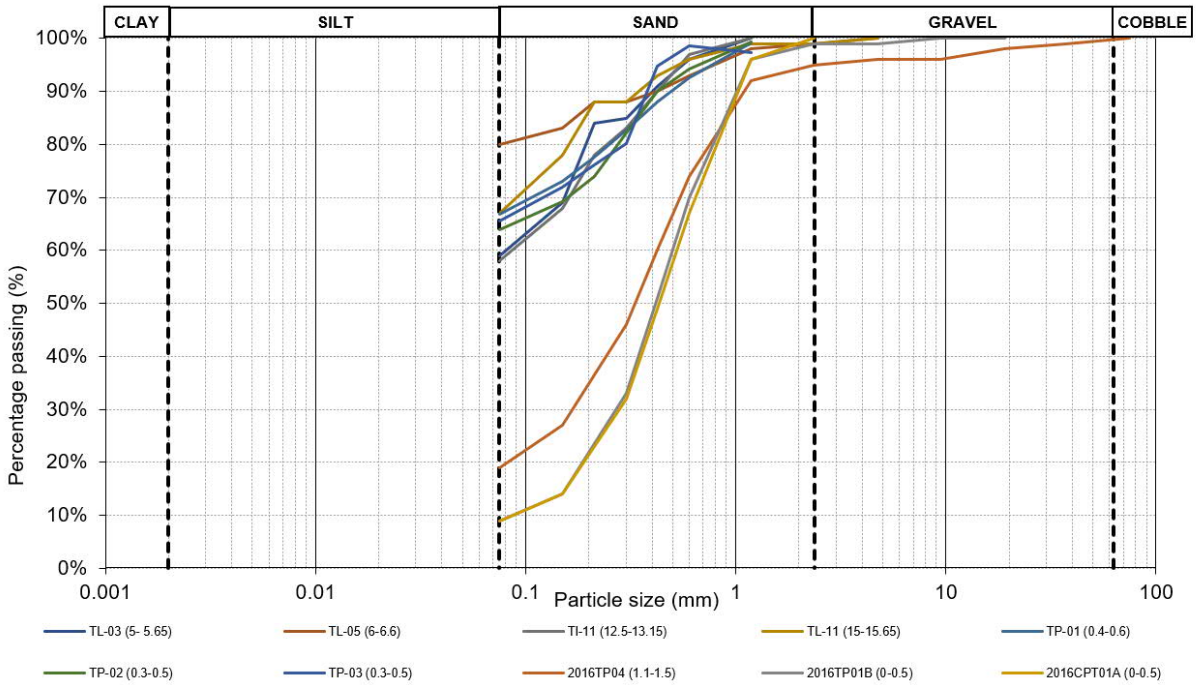


Figure 6: Ramp 2/3 TSF particle size distribution curve, tailings materials

Physical characterisation of the tailings ranges from clayey sand or silty sand to silt or clay of low plasticity (Red Earth, 2022). The results for CPT01A, CPT01B and TP04 classify the tailings as sand non-plastic (SRK, 2017).

3.2.4 Atterberg Limits Testing

Atterberg limits of the tailings are presented in Table 7.

Table 7: Ramp 2/3 TSF Atterberg limits of tailings

Test location	Depth (m BGL)		Atterberg limits		
	From	To	LL (%)	PL (%)	PI (%)
Ramp 2/3-TP-01	0.40	0.60	36	26	9
Ramp 2/3-TP-02	0.30	0.50	34	24	11
Ramp 2/3-TP-03	0.30	0.50	35	24	11

Note: LL = Liquid Limit; PL = Plastic Limit; PI = Plasticity Index.

The plot of results for the Atterberg limits are shown in Figure 7.

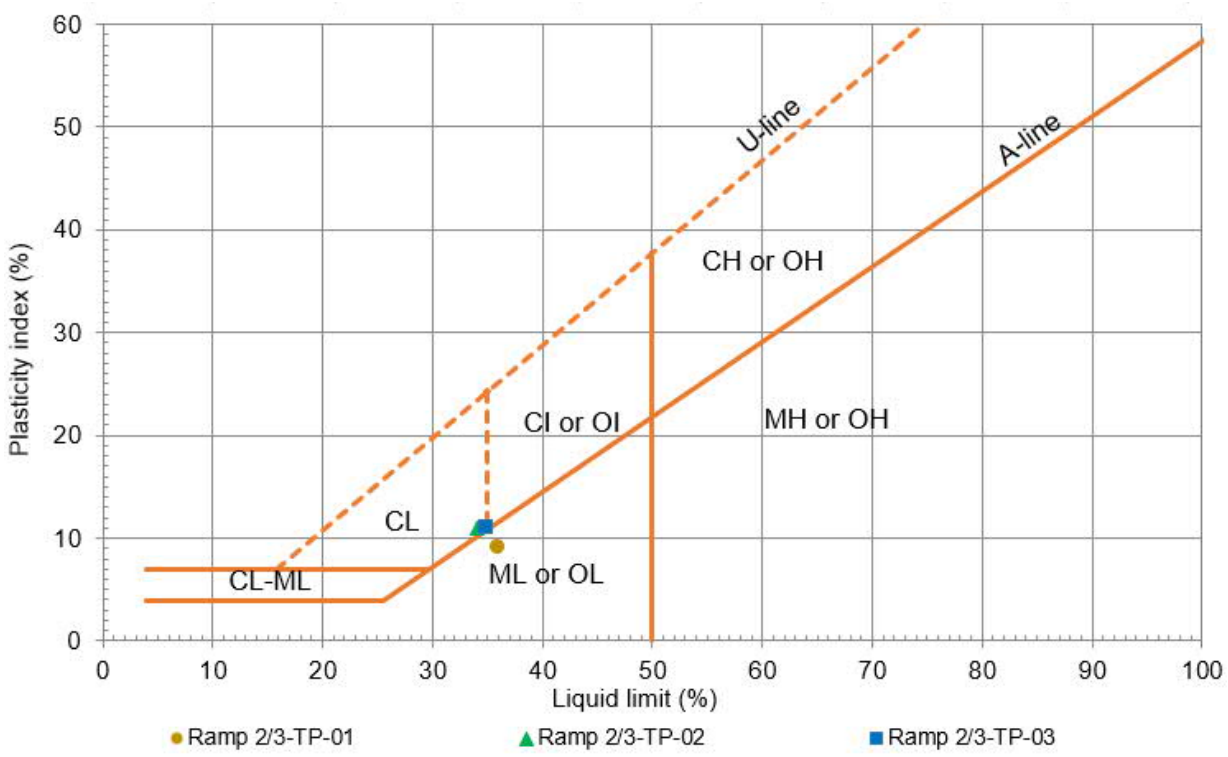


Figure 7: Ramp 2/3 TSF Atterberg limits results

The water content compared to the Atterberg limits suggests an expected plastic behaviour to liquid behaviour (Red Earth, 2022).

3.2.5 Moisture Content and Dry Density

The gravimetric moisture content of the tested tailings is presented in Table 8.

Table 8: Ramp 2/3 TSF moisture content and density profiles

Sample name	Depth (m)		Moisture content (%)	Wet density (t/m^3)	Dry density (t/m^3)
	From	To			
Ramp 2/3-TL-11	12.50	13.15	29.50	1.55	1.20
Ramp 2/3-TL-03	5.00	5.65	26.50	1.58	1.25
Ramp 2/3-TL-03	7.00	7.33	36.70	1.52	1.11
Ramp 2/3 -TL-07	3.70	4.26	28.90	1.52	1.18
Ramp 2/3 -TL-09	4.60	5.25	46.70	1.53	1.05
Ramp 2/3 -TL-11	5.50	6.15	30.90	1.59	1.21
Ramp 2/3 -TL-11	5.50	6.15	27.40	1.58	1.24
Ramp 2/3 -TL-09	4.60	5.25	43.40	1.52	1.06
Ramp 2/3 -TL-07	3.70	4.26	29.90	1.56	1.2
Ramp 2/3 -TL-11	15.00	15.65	28.20	1.62	1.27
Ramp 2/3 -TL-11	12.50	13.15	32.90	1.63	1.23
Ramp 2/3 -TL-05	6.00	6.60	17.90	1.96	1.66
Ramp 2/3 -TL-03	5.00	5.65	33.60	1.49	1.12
Ramp 2/3 -TL-11	15.00	15.65	16.60	2.18	1.87

3.2.6 Shear Strength Testing and Profile

Vane shear test results for undrained shear strength (Su) are presented in Table 9.

Table 9: Ramp 2/3 vane shear test results

Test Location ID	Material/ Unit tested	Test RL (m AHD)	Peak Su (kPa)	Remoulded Su (kPa)	Vane sizes (mm x mm)
Ramp 2/3- TL-01	Tailings	209.72	81.03	38.42	40 x 80
Ramp 2/3- TL-01	Tailings	209.22	175.90	42.13	40 x 80
Ramp 2/3- TL-02	Tailings	212.74	23.34	8.53	40 x 80
Ramp 2/3- TL-02	Tailings	207.84	47.45	12.11	40 x 80
Ramp 2/3- TL-02	Tailings	205.84	43.80	12.70	40 x 80
Ramp 2/3- TL-03	Tailings	208.48	73.64	13.24	40 x 80
Ramp 2/3- TL-03	Tailings	206.48	102.36	14.56	40 x 80
Ramp 2/3- TL-05	Tailings	209.33	106.71	19.88	40 x 80
Ramp 2/3- TL-05	Tailings	205.83	152.10	34.30	40 x 80
Ramp 2/3- TL-07	Tailings	208.40	29.26	9.28	40 x 80
Ramp 2/3- TL-07	Tailings	205.20	134.48	35.95	40 x 80
Ramp 2/3- TL-09	Tailings	207.35	61.60	16.52	40 x 80
Ramp 2/3- TL-09	Tailings	206.05	>372.86	-	40 x 80

Test Location ID	Material/ Unit tested	Test RL (m AHD)	Peak Su (kPa)	Remoulded Su (kPa)	Vane sizes (mm x mm)
Ramp 2/3- TL-10	Tailings	209.85	103.06	36.42	40 x 80
Ramp 2/3- TL-11	Tailings	207.08	131.31	36.98	40 x 80
Ramp 2/3- TL-11	Tailings	205.68	165.66	56.17	40 x 80
Ramp 2/3- TL-13	Tailings	203.96	239.49	58.87	40 x 80
Ramp 2/3- TL-13B	Tailings	198.96	167.51	19.80	40 x 80
Ramp 2/3-TL-13B	Tailings	197.46	177.69	62.24	40 x 80

Table 10 to Table 12 present the triaxial testing and direct simple shear results of the tailings samples.

Table 10: Ramp 2/3 TSF summary of triaxial consolidated undrained test results

Test location ID	Material	Depth (m BGL)	Consolidated undrained triaxial test				
			Wet density (t/m^3)	Dry density (t/m^3)	Initial moisture content (%)	Cohesion (1) c' (kPa)	Friction angle (1) Φ' (°)
Ramp 2/3-TL-11	FILL-TAILINGS	12.50 to 13.15	1.55	1.2	29.5	4.5	35.1
Ramp 2/3-TL-03	FILL-TAILINGS	5.00 to 5.65	1.58	1.25	26.5	9.2	39.5

Table 11: Ramp 2/3 TSF summary of triaxial consolidated drained test results

Test location ID	Material	Depth (m BGL)	Consolidated undrained triaxial test					
			Wet density (t/m^3)	Dry density (t/m^3)	Initial moisture content (%)	Effective stress (kPa)		Max strain (%)
						σ'1	σ'3	
Ramp 2/3-TL-03	FILL-TAILINGS	7.00 to 7.33	1.52	1.11	36.7	271	64	16.47

Table 12: Ramp 2/3 TSF summary of direct simple shear test results

Test location ID	Material	Depth (m BGL)	Wet density (t/m^3)	Dry density (t/m^3)	Max. shear stress (kPa)	Max. excess pore pressure (kPa)	Shear strain at max shear stress (%)	Normal stress at max shear stress (kPa)
Ramp 2/3-TL-07	Tailings	3.70 to 4.26	1.52	1.18	12.50	6.30	24.82	18.66
Ramp 2/3-TL-11	Tailings	5.50 to 6.15	1.59	1.21	28.32	23.40	23.78	16.58
Ramp 2/3-TL-09	Tailings	4.60 to 5.25	1.53	1.05	16.47	22.20	24.55	7.80
Ramp 2/3-TL-07	Tailings	3.70 to 4.26	1.56	1.20	24.17	32.80	24.53	17.28
Ramp 2/3-TL-09	Tailings	4.60 to 5.25	1.52	1.06	22.71	42.40	24.54	17.70
Ramp 2/3-TL-11	Tailings	5.50 to 6.15	1.58	1.24	37.26	18.20	23.82	51.79

The interpreted shear strength profile (Su vs depth) from the raw cone penetration testing (CPT) data, within each 'Shear Strength and Testing Profile Section', is presented in Figure 8 to Figure 23. In addition, vane shear testing data has been included.

Vane Shear (VST) TL-01

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-01	630324.2	7524845	6.104	81.03	38.42
TL-01	630324.2	7524845	6.604	175.9	42.13

CPT data RCPT21-01B

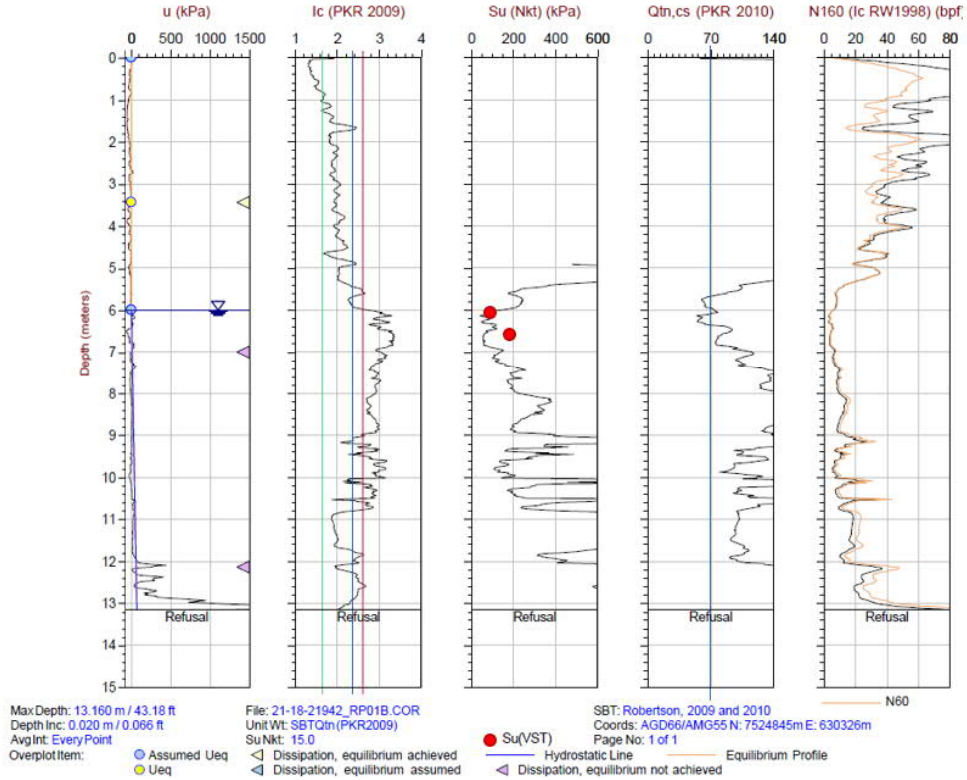


Figure 8: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 01

Vane Shear (VST) TL-02

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-02	630343	7524826	1.1	23.34	8.53
TL-02	630343	7524826	6	47.45	12.11
TL-02	630343	7524826	8	43.8	12.7

CPT data RCPT21-02

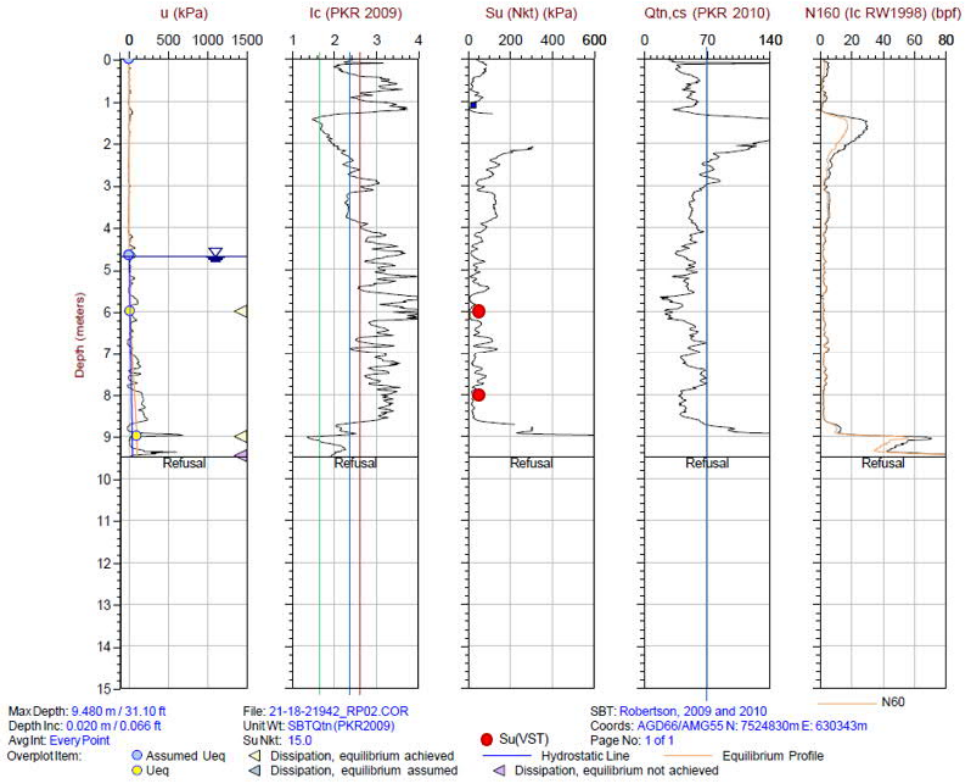


Figure 9: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 02

Vane Shear (VST) TL-03

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-03	630324.7	7524756	5.2	73.64	13.24
TL-03	630324.7	7524756	7.2	102.36	14.56

CPT data RCPT21-03

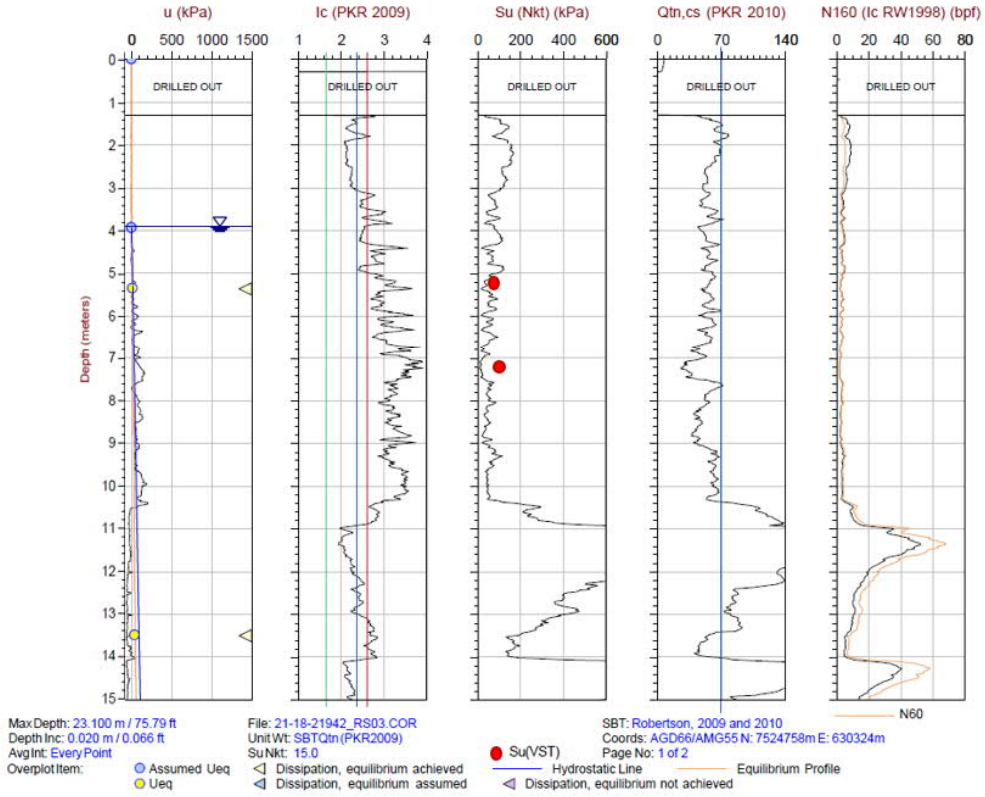


Figure 10: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 03

Vane Shear (VST) TL-05

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-05	630441.6	7524568	3	106.71	19.88
TL-05	630441.6	7524568	6.5	152.1	34.3

CPT data RCPT21-05

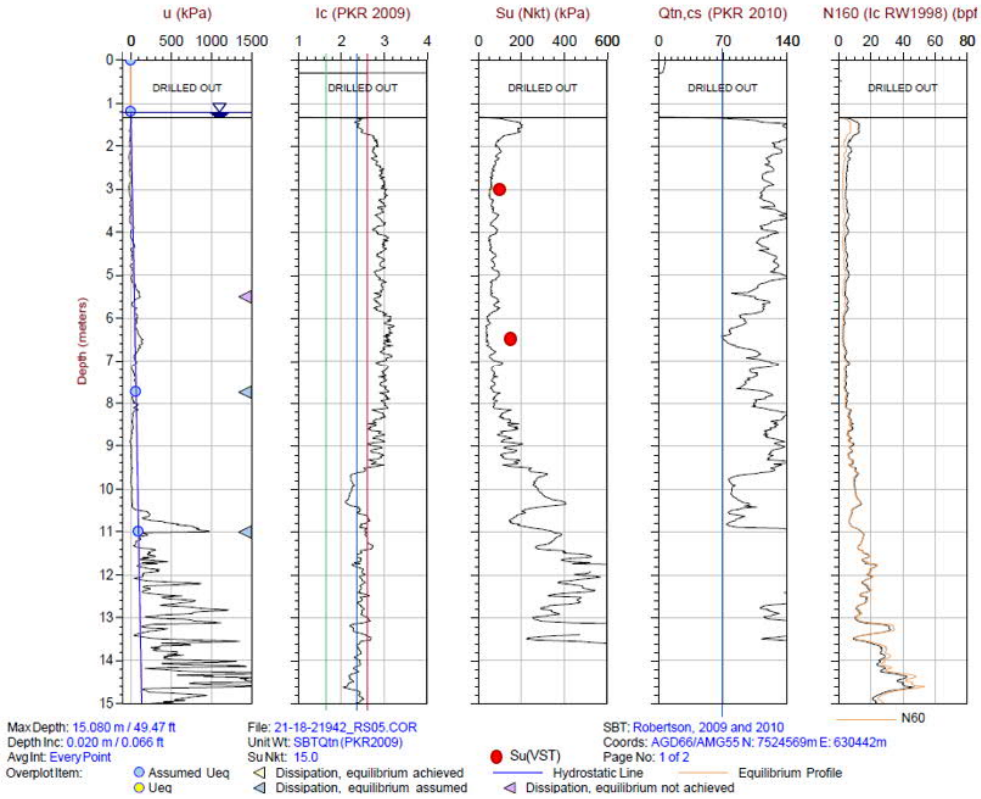


Figure 11: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 05

Vane Shear (VST) TL-07

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-07	630542.6	7524386	3.8	29.26	9.28
TL-07	630542.6	7524386	7	134.48	35.95

CPT data RCPT21-07

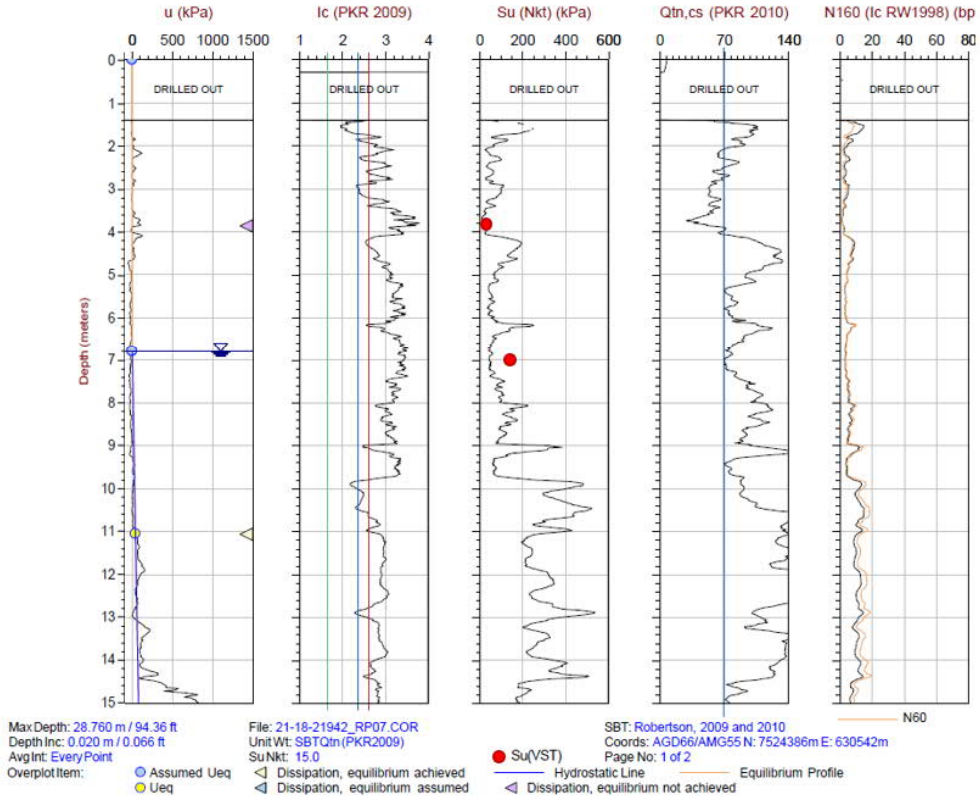


Figure 12: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 07

Vane Shear (VST) TL-08

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-08	630493.7	7524415	6.502	128.68	57.8

CPT data RCPT21-08

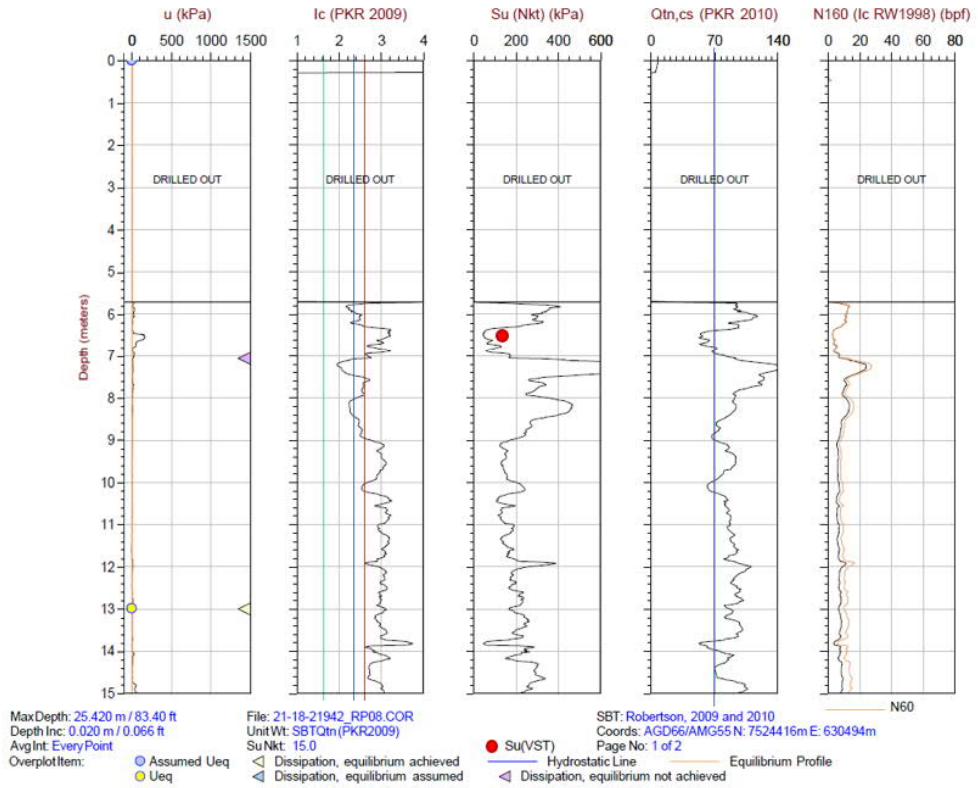


Figure 13: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 08

Vane Shear (VST) TL-09

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-09	630595.8	7524291	4.9	61.6	16.52
TL-09	630595.8	7524291	6.2	>372.86	-

CPT data RCPT21-09

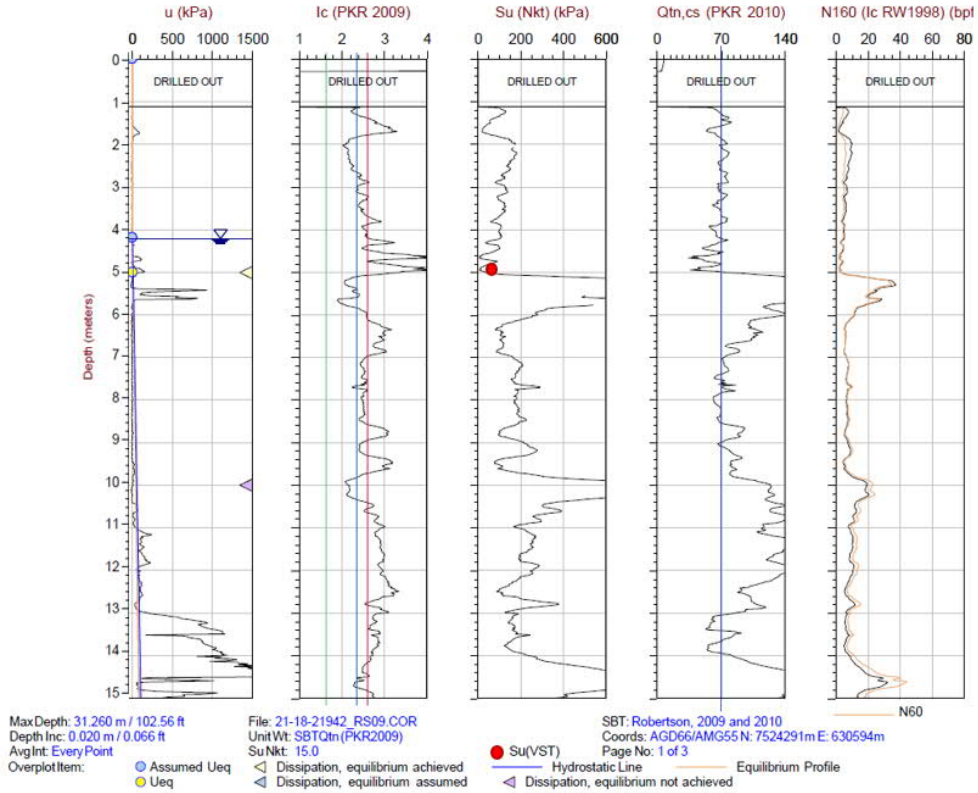


Figure 14: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 09

Vane Shear (VST) TL-10

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-10	630570.9	7524279	5.854	103.06	36.42

CPT data RCPT21-10

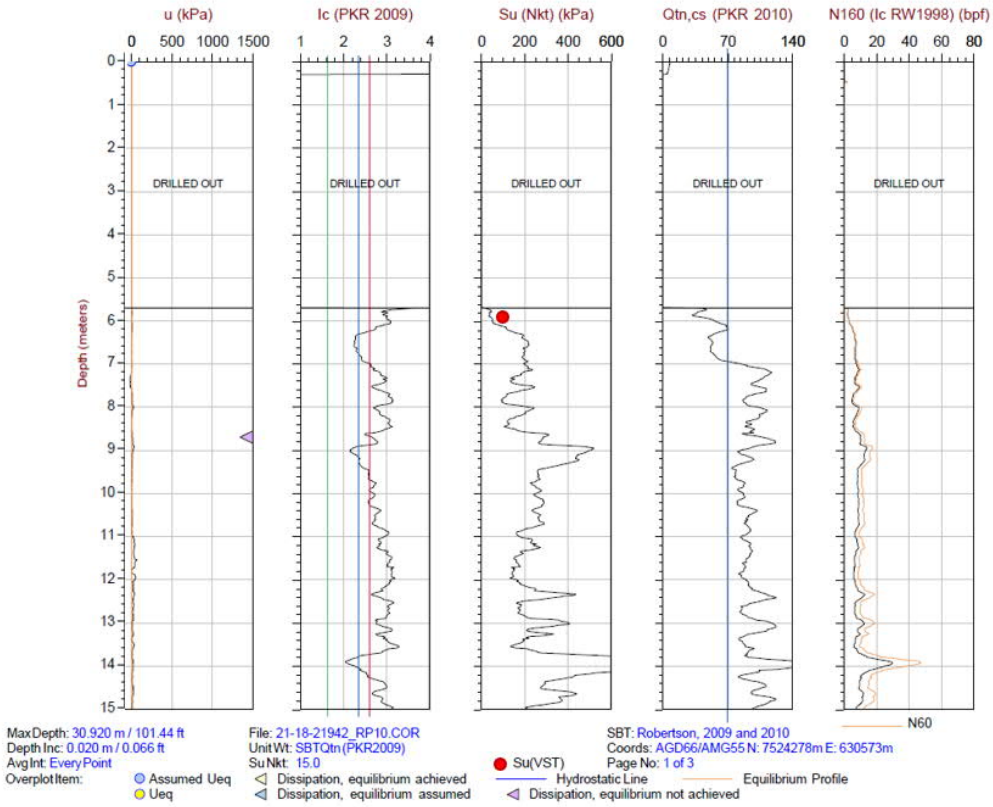


Figure 15: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 10

Vane Shear (VST) TL-11

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-11	630687.2	7524011	3.8	131.31	36.98
TL-11	630687.2	7524011	5.2	165.66	56.17
TL-11	630687.2	7524011	15	201.85	68.33

CPT data RCPT21-11

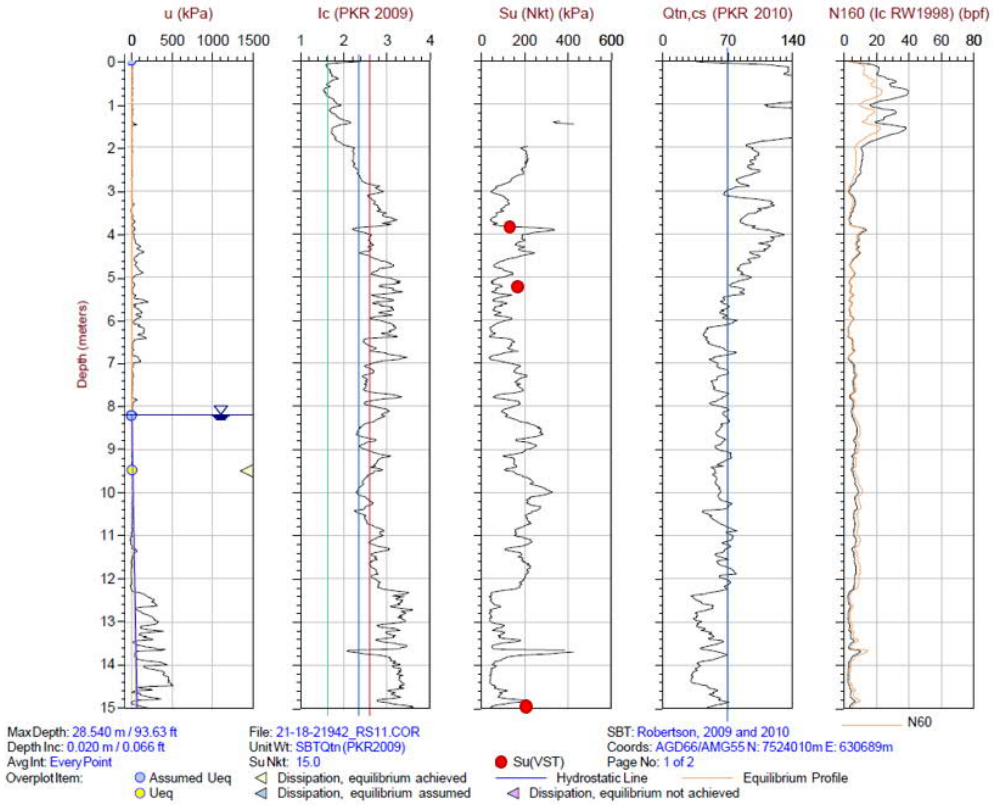


Figure 16: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 11

Vane Shear (VST) TL-12

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-12	630617.1	7524137	6.602	135.07	51.96
TL-12	630617.1	7524137	9.102	138.73	58.15

CPT data RCPT21-12

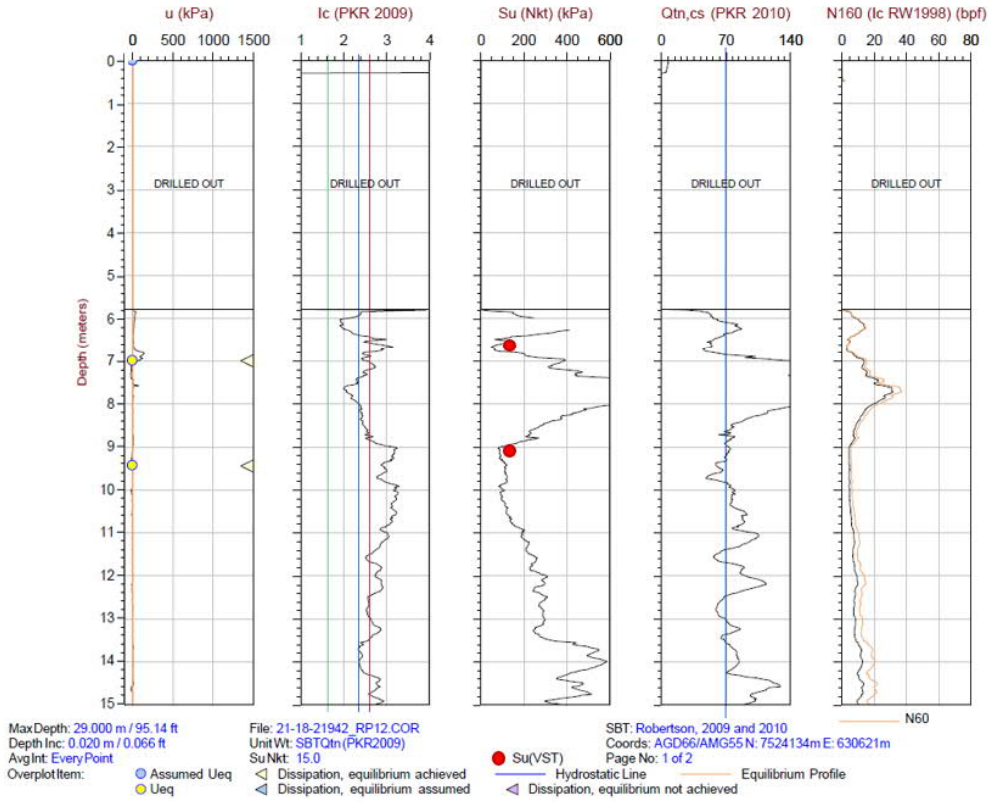


Figure 17: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 12

Vane Shear (VST) TL-13 ●

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-13	630660.3	7523996	12	239.49	58.87
TL-13B	630660.3	7523996		167.51	19.8
TL-13B	630660.3	7523996		177.69	62.24

CPT data RCPT21-13

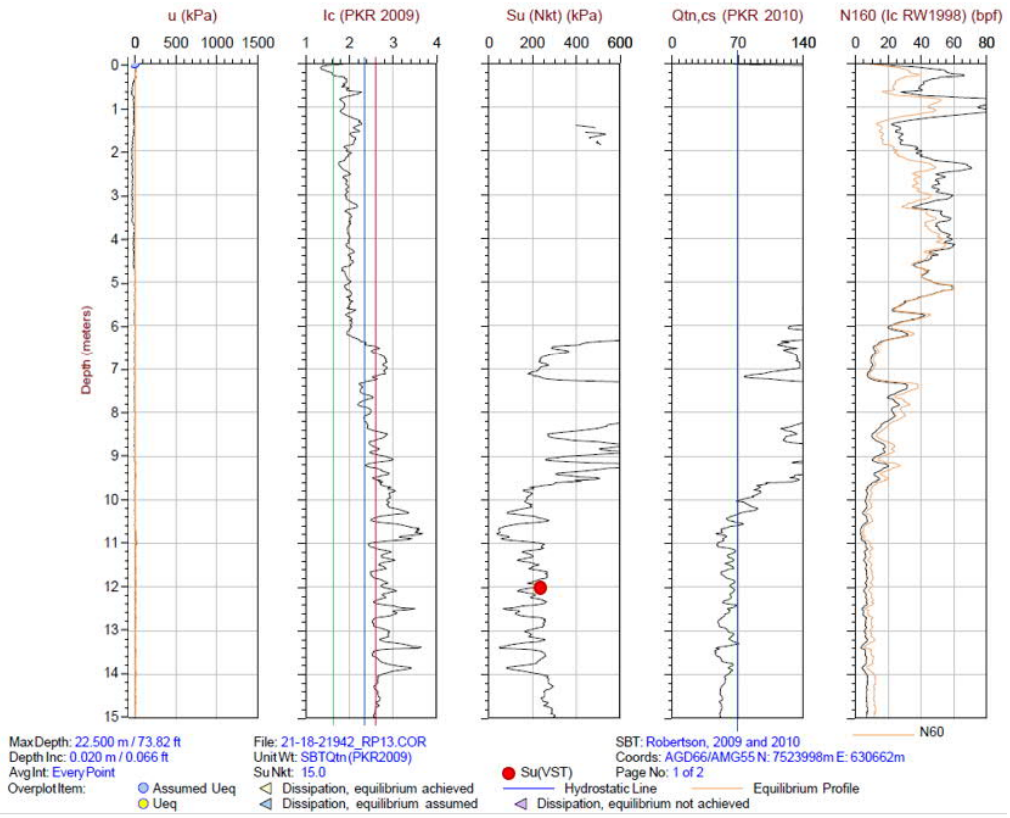


Figure 18: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 13

Vane Shear (VST) TL-13

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-13	630660.3	7523996	12	239.49	58.87
TL-13B	630660.3	7523996		167.51	19.8
TL-13B	630660.3	7523996		177.69	62.24

CPT data RCPT21-13

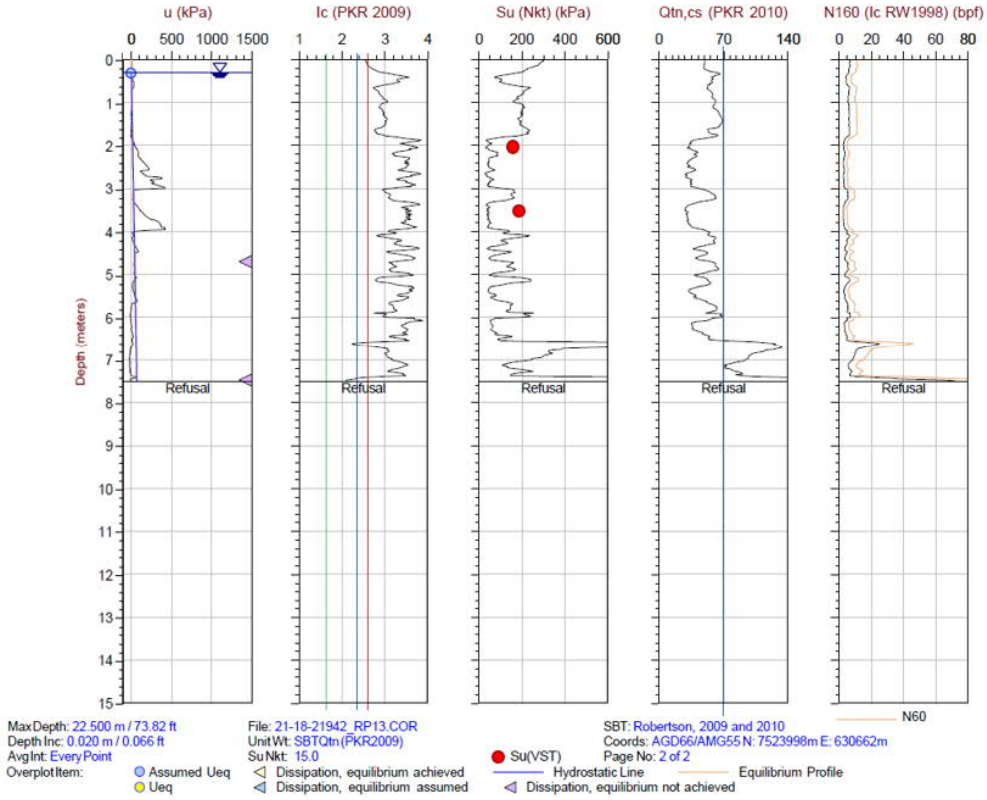


Figure 19: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 13

Vane Shear (VST) TL-19 ●

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-19	632237.2	7524424	5.497	181.33	25.69
TL-19	632237.2	7524424	5.997	110.63	18.87
TL-19	632237.2	7524424	6.997	99.02	24.74
TL-19	632237.2	7524424	8.997	113.08	24.78

CPT data RCPT21-19

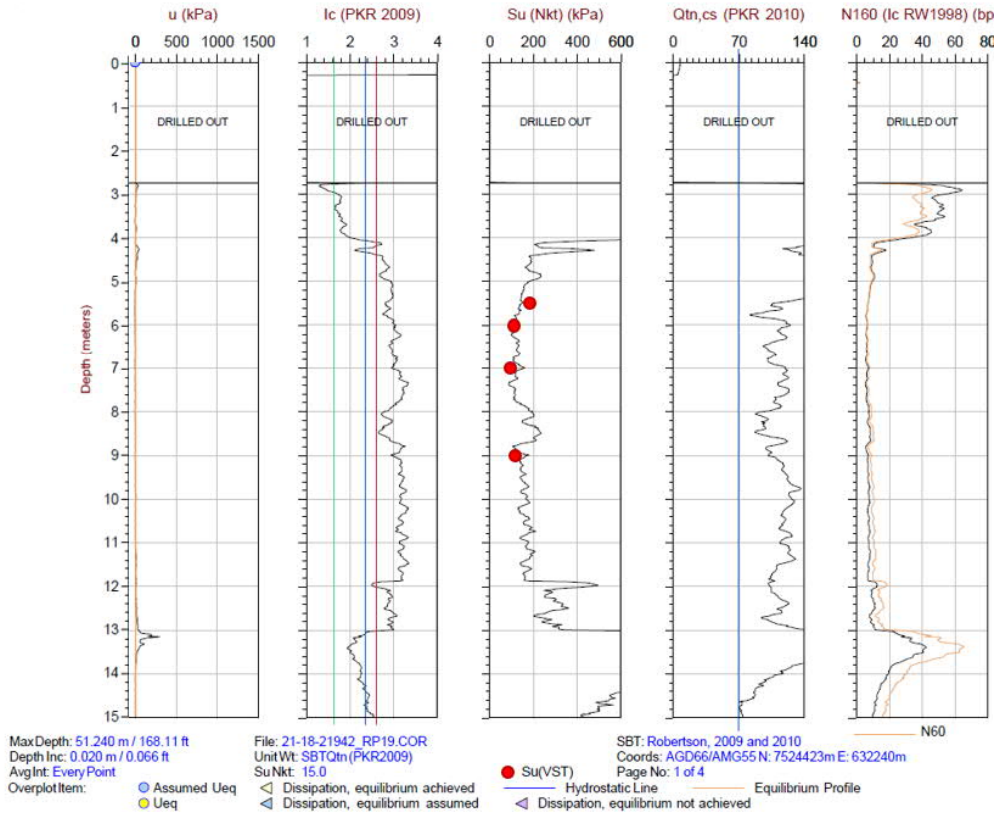


Figure 20: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 19

Vane Shear (VST) TL-22

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-22	632242.4	7524506	9.297	160.37	27.62
TL-22	632242.4	7524506	15.997	183.08	54.59

CPT data RCPT21-22

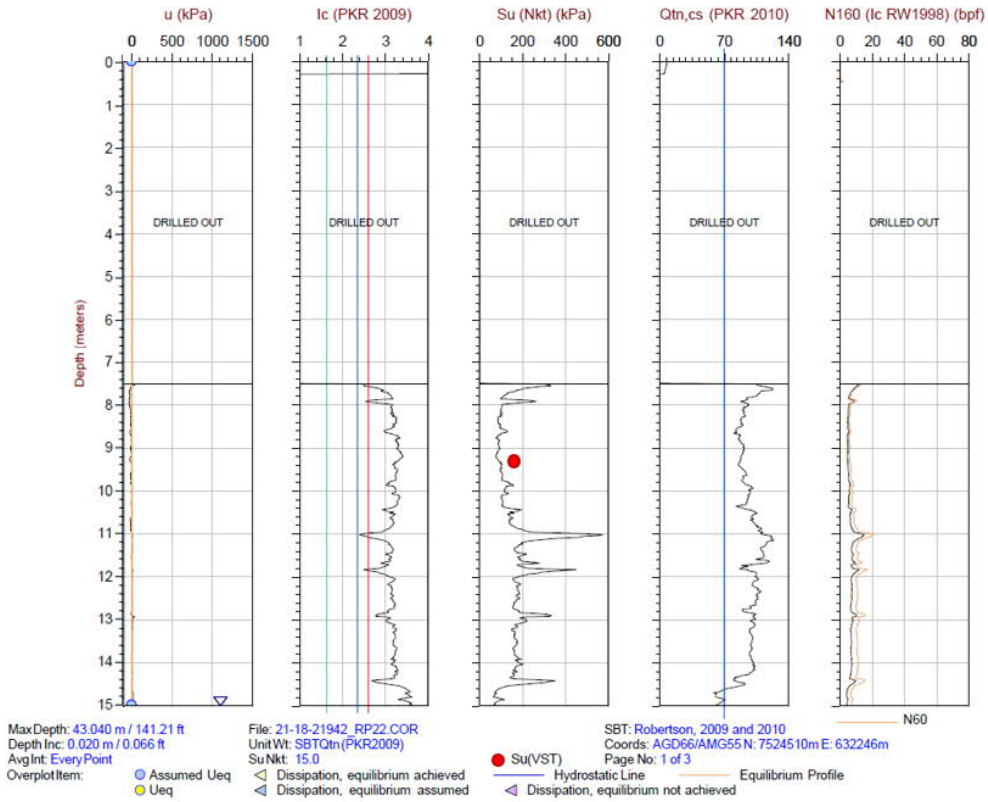


Figure 21: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 22

Vane Shear (VST) TL-24

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-24	632268.8	7524561	10.997	191.22	80.13
TL-24	632268.8	7524561	14.197	278.69	45.49

CPT data RCPT21-24

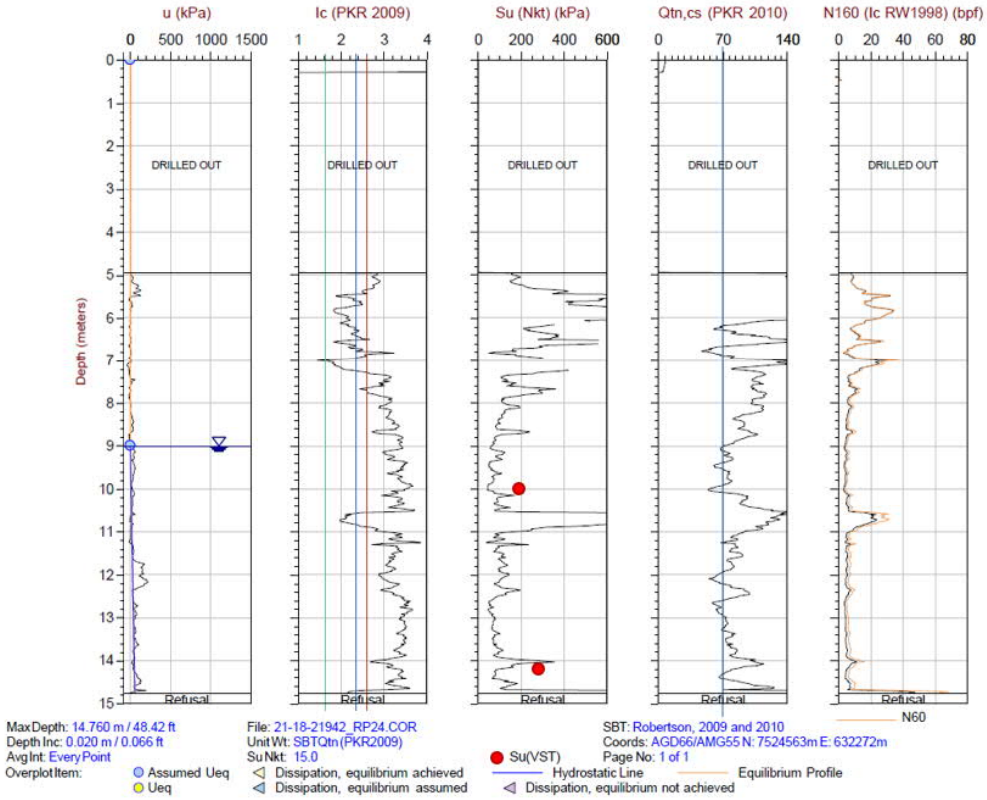


Figure 22: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 24

Vane Shear (VST) TL-27 ●

Test Location ID	Easting (m)	Northing (m)	Depth (m)	Peak Sufv (kPa)	Remoulded Sufv (kPa)
TL-27C	632327	7524560	9.68	182.55	25.46
TL-27C	632327	7524560	10.68	234.12	22.2

CPT data RCPT21-27

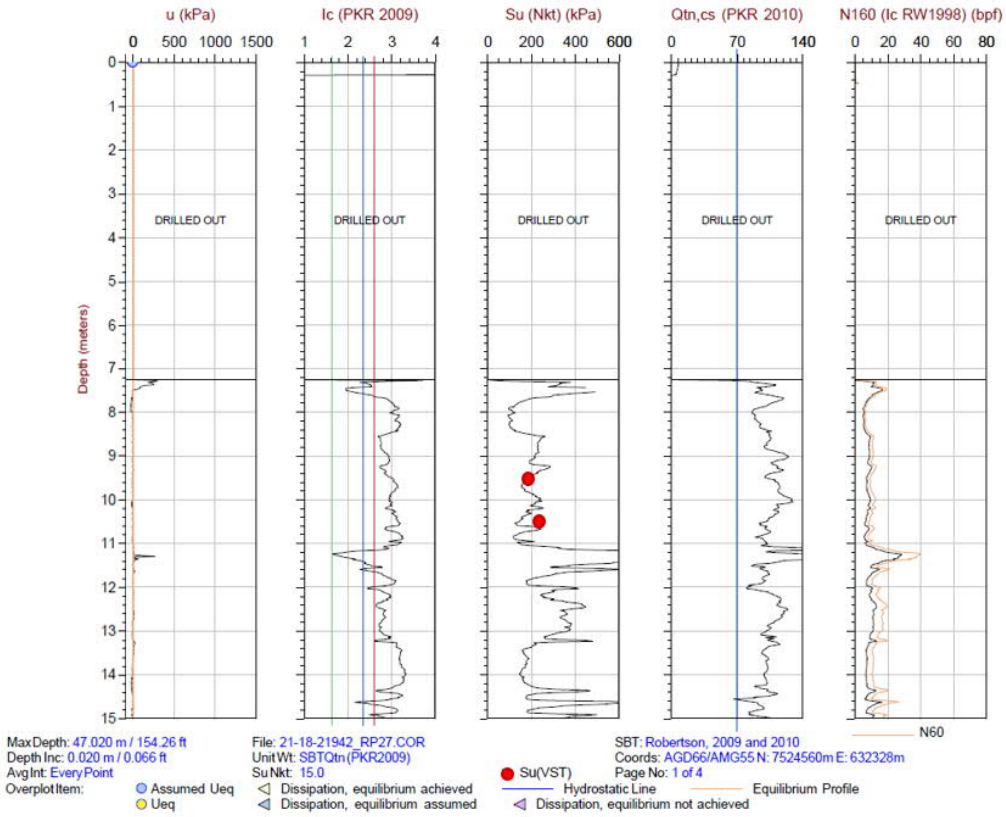


Figure 23: Ramp 2/3 TSF interpreted shear strength profile (Su vs depth) from the raw CPT data 27

3.2.7 Consolidation Testing

Consolidation testing results on tailings samples are presented in Table 16.

Table 13: Ramp 2/3 TSF consolidation testing – raw TL-03 oedometer test results

Test location ID	Material	Depth (m BGL)	Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t50	Cv (m^2/yr) t90	Mv (kPa-1x10-3)	Ca x 10-3	% Consolidation
TL-03	Tailings	5.00-5.65	1	3-6	0.023	1.10E-08	17.17	23.05	1.502	0.41	0.5
			2	6-13	0.040	9.60E-09	31.06	24.70	1.255	0.80	1.3
			3	13-25	0.045	7.40E-09	41.63	33.31	0.715	0.95	2.2
			4	25-50	0.067	6.60E-09	50.88	39.03	0.542	1.20	3.5
			5	50-99	0.087	4.40E-09	51.44	39.09	0.360	1.40	5.2
			6	99-199	0.109	3.50E-09	58.98	49.13	0.228	1.67	7.4
			7	199-400	0.139	2.10E-09	62.10	46.00	0.148	1.93	10.1

Table 14: Ramp 2/3 TSF consolidation testing – raw TL-05 oedometer test results

Test location ID	Material	Depth (m BGL)	Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t50	Cv (m^2/yr) t90	Mv (kPa-1x10-3)	Ca x 10-3	% Consolidation
TL-05	Tailings	6.00-6.60	1	25-50	0.035	1.40E-09	155.36	15.39	0.287	0.50	0.7
			2	50-99	0.049	1.50E-09	242.19	24.14	0.203	0.63	1.7
			3	99-200	0.059	8.90E-10	10.81	23.05	0.125	0.79	2.9
			4	200-400	0.100	6.30E-10	9.43	19.29	0.106	1.28	5.0
			5	400-799	0.121	3.60E-10	8.36	17.84	0.066	1.38	7.5

Table 15: Ramp 2/3 TSF consolidation testing – raw TL-11 oedometer test results

Test location ID	Material	Depth (m BGL)	Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t50	Cv (m^2/yr) t90	Mv (kPa-1x10-3)	Ca x 10-3	% Consolidation
TL-11	Tailings	12.50-13.15	1	3-6	0.014	6.40E-09	3.96	20.80	0.991	0.17	0.3
			2	6-13	0.030	4.70E-09	9.72	14.54	1.043	0.74	1.0
			3	13-25	0.046	3.60E-09	10.36	14.73	0.796	1.02	2.0
			4	25-50	0.072	2.70E-09	11.56	13.61	0.640	1.28	3.5
			5	50-100	0.091	1.70E-09	10.84	13.60	0.411	1.48	5.5
			6	100-199	0.112	1.30E-09	14.94	16.50	0.258	2.36	7.9
			7	199-401	0.165	8.70E-10	12.97	14.28	0.196	3.78	11.6

Table 16: Ramp 2/3 TSF consolidation testing – raw TL-11 oedometer test results

Test location ID	Material	Depth (m BGL)	Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t50	Cv (m^2/yr) t90	Mv (kPa-1x10-3)	Ca x 10-3	% Consolidation
TL-11	Tailings	22.00-22.46	1	5-12	0.012	2.70E-09	17.89	23.38	0.376	0.16	0.2
			2	12-24	0.026	3.10E-09	13.34	24.65	0.400	0.27	0.7
			3	24-50	0.041	2.00E-09	17.14	21.13	0.312	0.67	1.5
			4	50-99	0.072	1.60E-09	15.8	19.40	0.270	0.84	2.8
			5	99-200	0.097	1.10E-09	17.15	19.79	0.183	1.28	4.6
			6	200-399	0.149	7.90E-10	15.16	17.82	0.143	1.94	7.3

3.2.8 Soil Water Characteristic Curve

The results for the soil water characteristic curve (SWCC) on tailings samples is presented in Table 17.

Table 17: Ramp 2/3 TSF SWCC of tailings

Test location ID	Material	Sample depth (m RL)	Volumetric water content (cm^3/cm^3)				
			0 kPA	10 kPA	33 kPA	100 kPA	1500 kPA
Ramp2/3 -TP-01	Tailings	0.40 to 0.60	0.51	0.39	0.30	0.26	0.16
Ramp2/3 -TP-02	Tailings	0.30 to 0.50	0.48	0.38	0.30	0.26	0.18
Ramp2/3 -TP-03	Tailings	0.30 to 0.50	0.56	0.41	0.34	0.29	0.20

The soil water characteristic curve is presented in Figure 24.

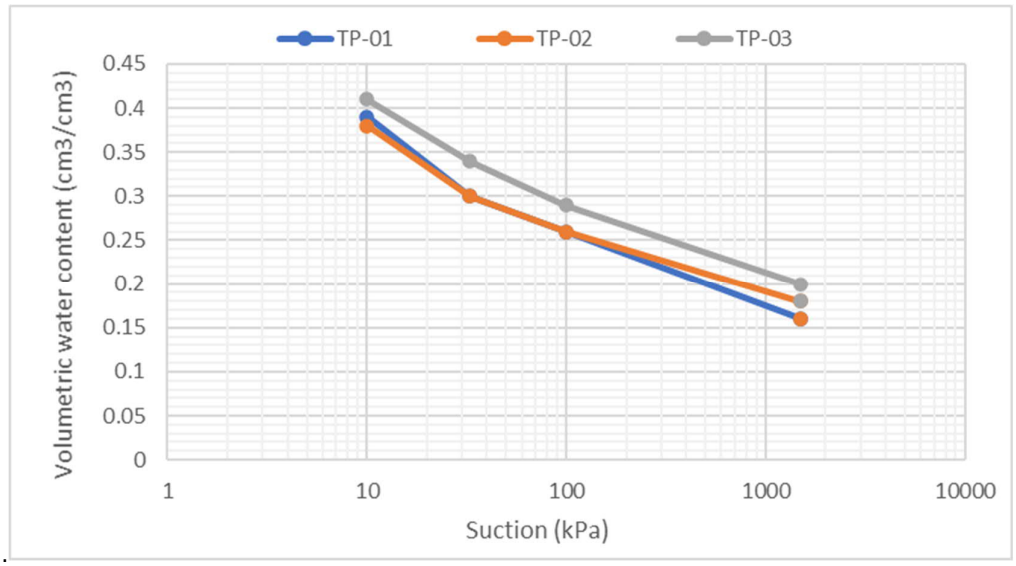


Figure 24: Ramp 2/3 TSF SWCC

3.2.9 Specific gravity

Results for specific gravity are presented in Table 18.

Table 18: Ramp 2/3 TSF specific gravity test results

Sample name	Depth (m)	Solid Specific Gravity
TP-01	0.40 to 0.60	1.93
TP-02	0.30 to 0.50	1.99
TP-03	0.30 to 0.50	1.95
TP-01	0.40 to 0.60	1.76
TP-02	0.30 to 0.50	2.00
TP-03	0.30 to 0.50	1.72
TL-11	5.50 to 6.15	1.96
TL-09	4.60 to 5.25	1.99
TL-07	3.70 to 4.26	1.92

3.3 Tailings Facility Design

3.3.1 Design philosophy

Ramp 2/3 TSF is an amalgamated in-ramp facility, originally starting as two separate in-ramp facilities. Over time, the facility has undergone five embankment raise stages (either downstream, upstream or centreline) with partial perimeter embankments.

Tailings are deposited in such a manner that supernatant water is collected in a decant pond at the south-east corner of the facility.

3.3.2 Design basis

3.3.2.1 Geotechnical design criteria

Ramp 2/3 has retaining embankments to the south and west of the facility and spoil piles to the north and east of the facility. The southern embankment is located adjacent to a historical evaporation field, which contains up to 12 m of coarse rejects over mine spoil. The western embankment is located adjacent to areas of natural Alluvium and topsoil stockpiles. The current slope angles are 1V:4H.

Stability assessments have been completed for all critical sections of the dam to ensure Factors of Safety are within the acceptable criteria shown in Table 19. Figure 25 shows critical sections used for stability analysis.

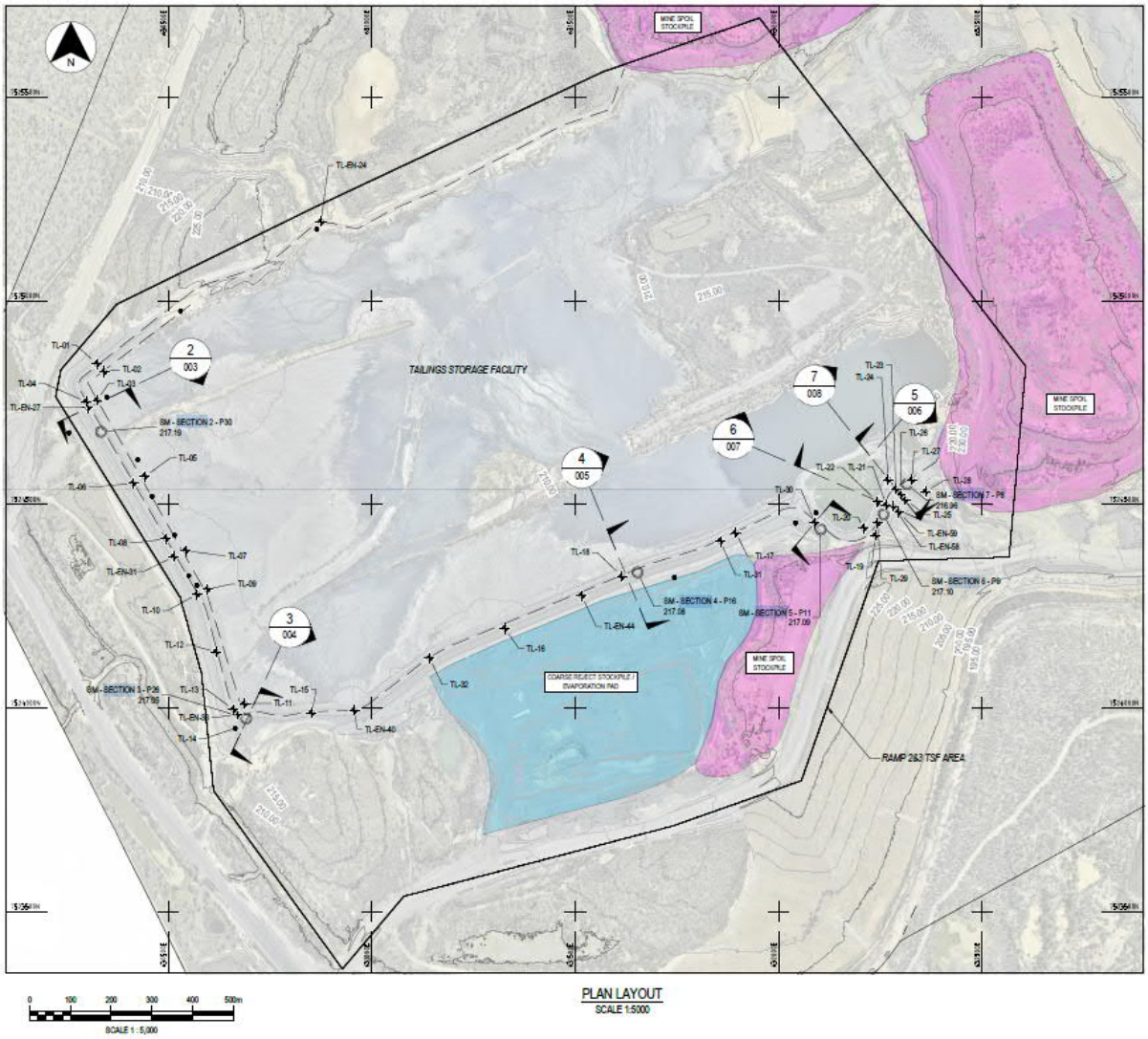


Figure 25: Ramp 2/3 TSF critical sections (Red Earth, 2022)

Table 19 shows the minimum acceptable Factor of Safety (FoS) adopted for the design of the Stage 5 embankment raise (Red Earth, 2022), which were based on ANCOLD guidelines (ANCOLD, 2019).

Table 19: Ramp 2/3 TSF minimum acceptable FoS

Condition	ANCOLD loading condition	Minimum acceptable FoS
End of Construction (EOC)	Short-term undrained (no potential of loss of containment)	1.3
Operational steady state	Long-term drained	1.5
Operational post-seismic	Post-seismic	1.0

The GeoStudio 2021 computer software package 'Slope/W' was utilised to undertake the stability analyses. Slope/W is a two-dimensional slope stability program. It can be used to evaluate the safety factor of circular and non-circular failure surfaces in soil and rock slopes (Red Earth, 2022).

The results indicate that the slopes comply with the criteria described in the design (Red Earth, 2022).

3.3.2.2 Hydraulic loading design criteria

Management of flood water within the TSF basin is managed through a spillway which has been designed for a 1 in 1,000 AEP design flood event in consistency with the operational consequence category of the (SRK, 2017a). The maximum flow over the spillway was modelled as 14.4 m^3/s with a maximum depth of 0.35 m or 214.65 m Australian Height Datum (AHD).

The spillway design criteria are suitable for the operational consequence category (Golder, 2021).

3.3.2.3 Seepage design criteria

There is no seepage control between the eastern spoil piles and Bauhinia Pit. There is about 105 m of head difference between the maximum TSF pond level and current pit floor which is at an elevation of about 105 m AHD (Hatch, 2021). Hatch carried out a seepage analysis and estimated a seepage rate into the pit of 155 L/day per m length.

The ground beneath the TSF has been mined out and replaced with spoil and hauled overburden (SRK, 2017). A palaeochannel associated with the original Hughes Creek alignment likely crossed the southwestern corner of Ramp 2/3 TSF. However, the box cut extents indicate that this would have been entirely removed. This palaeochannel may be present south-west of the TSF footprint towards the Hughes Creek diversion (Golder, 2021).

The following drains and trenches are present in near vicinity of the TSF:

- Sand filter chimney and blanket to intercept and collect seepage at the southern embankment (SRK, 2017a)
- Dedicated toe drain for monitoring seepage at southern embankment (SRK, 2017a).

There are no records of seepage to these drains and trenches. Based on the presence of an elevated phreatic surface in the TSF embankments, and by inference an elevated phreatic profile in the tailings (not confirmed by monitoring), there is expected to be seepage out of the base and sides of the TSF (Golder, 2021a).

3.3.3 TSF operation

The TSF management plan outlines the requirements and methodology for operation, inspection, surveillance and reporting for the Stage 5 operations of the Ramp 2/3 TSF. This plan also presents the requirements to ensure that the TSF is operated in accordance with the objectives of the design (BMA, 2021).

Tailings are deposited into the TSF sub aerially in thin layers to promote drying and consolidation through delivery lines located along the perimeter of the facility (Golder, 2021).The tailings deposition strategy aims to:

- Maintain compliance with the deposition plan and ensure planned maximum tailings levels are not exceeded.
- Maintain adequate embankment freeboard from the tailings surface.
- Maintain the decant pond in the vicinity of the south-east corner where the decant pond pump is located.
- Ensure no water is pooled against the Western Wall where the upstream raise is present.
- Maintain adequate beaching of tailings (thin uniform layers)
- Change the spigot discharge locations regularly to maximise desiccation and consolidation of tailings.

The water management system philosophy aims to:

- Minimise the volume of the decant pond. This results in maximisation of the tailings surface area exposed to evaporation and hence maximisation of tailings density. This subsequently maximises the useable volume within the storage during the life of the facility.
- Minimise the loss of decant water as seepage into the permeable spoil piles forming the perimeter of the TSF.
- Maintain a low seepage surface (phreatic surface) to not negatively affect stability conditions within the eastern spoil piles.
- Reduce the risk of internal erosion and piping failure of the embankments.
- Monitoring, inspections and surveillance activities (Daily, Weekly and Monthly) undertaken in accordance with the maintenance plans and the monitoring and audit requirements, aims to:
  - Maintain adequate embankment freeboard from the tailings surface at discharge spigots.
  - Maintain the decant pond in the vicinity of the south-east corner where the decant pond pump is located.
  - Ensure no water is pooled against the Western Wall where the upstream raise is present.
  - Maintain the decant pond at a minimum level to maintain an adequate FoS associated with the Stage 5 wall raise and safe operation of the gangway.
  - Complete periodic inspections in line with applicable OMS.
  - Conduct weekly and monthly inspections to monitor the integrity of the dam.

    Undertake seepage reduction/control activities.

4.0 RAMP 6 TSF

4.1 Overview of tailings facility

Table 20 presents a description of the extent and general arrangement of the TSF, as well as the history and governance, TSF classification and monitoring activities.

Table 20: Ramp 6 TSF Overview

Condition	Detail
Extent and general arrangement of TSF	▪ The Ramp 6 TSF is an unregulated structure with in-ramp storage configuration, located adjacent to two pits, Dogwood and Coolibah ▪ The embankment separating the structures is referred to as the 'Spoil Embankment' and it has a maximum elevation of 60 m in height from the crest to the estimated pit floor level. The structure's materials are believed to be non-engineered, loosely dumped, random fill ▪ Ramp 6 TSF is not being used for water storage, it does however form part of a stormwater network ▪ The runoff from the CHPP and other industrial area catchments is directed over the surface of the TSF to then decant into Dogwood Pit through the three decant pipes ▪ Ramp 6 TSF has also been reported to often overflow into Dogwood Pit via an informal spillway ▪ The site has two main access routes via Ramp 5 and Ramp 6 from the main haul road to the north-west and west respectively. Although as part of the site traffic management plan, a drill crew is required to access the site via Ramp 5 only

Condition	Detail
History and governance of the TSF	▪ Ramp 6 TSF is currently an inactive in-ramp TSF; it was operational from 1998 to 2008 (approximately) ▪ A topographic low collects runoff from CHPP and other industrial catchment areas ▪ The TSF surface is consistently saturated and not consolidated
TSF classification	More recently an updated CCA was undertaken. Ramp 6 TSF was assessed to be a non-regulated structure and therefore does not need to comply with the DES 2016, Manual's hydraulic design criteria. Ramp 6 TSF therefore does not require a design storage allowance (DSA), mandatory reporting level (MRL), extreme storm storage (ESS), or specific freeboard and spillway allowances (ATCWilliams, 2022) ▪ ANCOLD - Low ▪ DES - Low ▪ CDA – Low ▪ GISTM – Not available.
Operation and surveillance	▪ Fortnightly inspections and when relevant during times of risk (i.e., after rainfall events) ▪ Stability monitoring through the form of unmanned aerial vehicle (UAV) fly overs, borehole monitoring, extensometer readings on the Coolibah south-east corner low wall, and pump crew/mine services inspections ▪ Measurement of extensometers and level differential between selected boreholes (MB03 and MB04) Ramp 6 TSF has four monitoring boreholes in spoil embankment to Coolibah pit, their location is presented in ▪ Inspections – Daily ▪ Typical dam inspections – Fortnightly and/or post rainfall events (Dam Engineer and mine services) and annually (Engineer of Record review) ▪ Audits as required (e.g., when risk profile triggers additional requirements)

Figure 3 presents Ramp 6 TSF's general arrangement and site locality in relation to surrounding infrastructure.

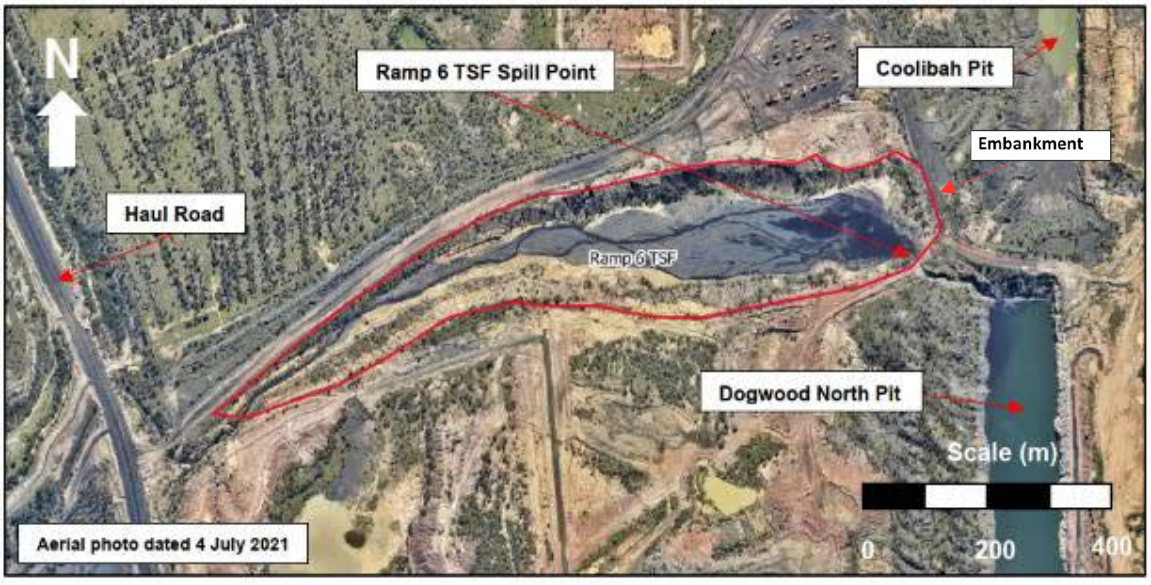


Figure 26: Ramp 6 TSF general layout and locality

4.2 Tailings Characterisation

4.2.1 Tailings geochemical characterisation

As part of refining the closure knowledge base, a dedicated mineral waste characterisation project (sampling, analysis and reporting) has been undertaken by BHP across the Queensland BMA sites (2020 – ongoing). This has included the environmental geochemical characterisation and risk assessment of SRM's TSFs, the outcomes of which are currently being compiled. On completion, this geochemical information will be used in conjunction with the geotechnical and rheology characterisation provided in this report to inform development of suitable rehabilitation management strategies in the PRCP.

4.2.2 Tailings geotechnical characterisation

As part of the closure tailings geotechnical characterisation, the field investigations which were planned to refine Ramp 6 TSF's knowledge base have not been undertaken. This is because there has not been safe access to carry out this activity and complete the characterisation. Therefore, data from nearby TSFs is being used to develop the PRCP.

However, according to the characterisation trends of all SRM TSFs (based on geotechnical investigations), the following conditions are assumed for tailings at Ramp 6 TSF:

- The shear yield stress of all tailings will increase exponentially with solids concentration.
- On the other hand, in a conservative scenario, the yield stress of Ramp 6 tailings could behave like the tailings on Ramp 2/3 TSF – considering the active condition of the TSF. This condition is inferred from the context that surface water has historically been routed through the TSF footprint and across the beach from the plant, preventing solar drying and densification.
- Particle size distribution and material classification is assumed to be similar to Ramp 2/3 TSF, based on the site's particle size distribution results and the inferred condition, as described above. Detailed information is presented in Section 3.2.3

4.3 Tailings Facility Design

4.3.1 Design philosophy

Ramp 6 TSF was originally placed into an access ramp surrounded by spoil dumps. It is closed by a highwall bridge embankment. The main characteristic of this facility is a sloping (typically 10%) floor that will result in large differential settlement, irrespective of whether the tailings discharge has been down-ramp or up-ramp. It also results in a final profile that will be self-draining (HATCH, 2017).

Tailings discharge from the dam embankment to the ramp, forces the decant pond formation at the mouth of the ramp thereby minimising seepage through bund wall and spoils.

4.3.2 Design basis

4.3.2.1 Geotechnical design criteria

The embankment is a non-engineered structure constructed out of spoil material and loosely dumped random fill, which was placed mainly by a dragline but also truck-dumped. It has a maximum height of 60 m with a slope of 1.5H:1V. It contains 2 Mm^3 of tailings. The spillway is also a non-engineered structure that overflows south-east into the Dogwood Pit.

Table 21 shows the minimum acceptable FoS based on ANCOLD guidelines (2019).

Table 21: Ramp 6 TSF minimum acceptable FoS

Condition	ANCOLD loading condition	Minimum acceptable FoS
EOC	Short-term undrained (no potential of loss of containment)	1.3
Operational steady state	Long-term drained	1.5
Operational post-seismic	Post-seismic	1.0

Minor slope instability has been noticed over the past 18 years. The toe of embankment shows signs of runoff and weak material. Stability analysis shows that critical sections do not yield minimum required FoS for undrained behaviour (SRK, 2019) (Golder, 2021).

4.3.2.2 Hydraulic loading design criteria

The 2021 CCA proposed the spillway design be assessed against ANCOLD Guidelines and the GISTM (SRK, 2021).

No engineered spillway or other surface water controls, or designs exists for this facility.

Previous studies noted that the TSF does not have any formally documented drainage/outlet structures to provide conveyance capacity for surface water (primarily comprising rainwater runoff over the catchment) (BMA, 2021a).

4.3.2.3 Seepage design criteria

Figure 27 presents a high-level conceptual site model developed for Ramp 6 TSF, based on the technical analysis of these facilities (Golder, 2021).

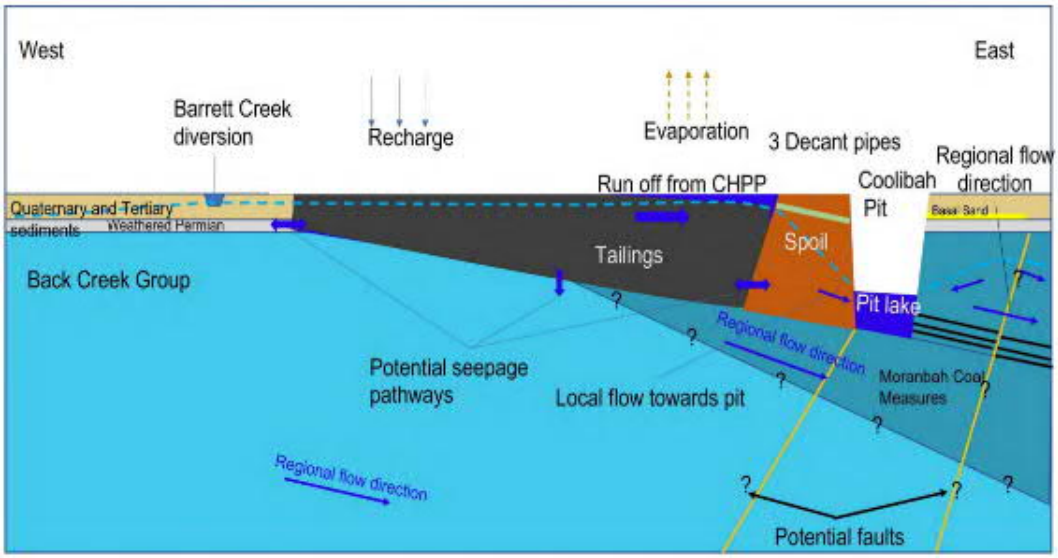


Figure 27: Ramp 6 TSF simplified hydrogeological model of Ramp 6 (not to scale)

Note: Blue arrows indicate the ground flow direction.

Groundwater seepage from Ramp 6 TSF is anticipated toward the east through the following avenues (Golder, 2021c):

- Coolibah Pit through the eastern embankment
- Dogwood North Pit through the eastern embankment
- To the north or south spoil or unidentified geological structures through the sides or the base of the TSF.

4.3.3 TSF operation

Ramp 6 TSF has been inactive since 2008. Only monitoring and surveillance activities are currently undertaken. These include:

- Dam inspections
- Fortnightly and/or post rainfall events (Responsible Dam Engineer and mine services)
- Annually (Engineer of Record review).

5.0 TSF 2

5.1 Overview of Tailings Facility

Table 22 presents descriptions of the extent and general arrangement of the TSF, the history and governance, TSF classification and monitoring activities.

Table 22: TSF 2 overview

Condition	Detail
Extent and general arrangement of TSF	▪ TSF 2 is located at SRM on the eastern side of the Northern Haul Road and southern side of Ramp 6 ▪ The TSF has embankments on the west, north, and for a partial length of the south sides ▪ The ground rises on the east side of the TSF, such that no embankment is required for containment in the east ▪ TSF 2 is partially capped with reject at south side of the facility ▪ Pond present only during wet season ▪ No engineered spillway ▪ There is an unofficial decant pond located at the north-west corner of TSF 2. The presence of this non-managed pond suggests that hydraulic conductivity of the TSF material (and/or the foundation) is likely very low
History and governance of the TSF	▪ Construction of TSF 2's embankments is estimated between 1974 and 1977 (exact date unknown) ▪ Following the creation of the TSF embankments, tailings deposition into the impoundment began and operation ceased sometime between 1986 and 1996 ▪ Between 1996 and 1998, TSF 2 was partially capped, and an uncontrolled fill material was placed above both the tailings and the perimeter embankment
TSF classification	Quantitative CCA not completed yet. Classification not available Design storage allowance (DSA) not available.
Operation and surveillance	There are 12 monitoring bores with Vibrating Wire Piezometers (VWPs) and standpipes, which are part of monitoring network for TSF stability and groundwater monitoring.

Figure 28 shows the extend and layout of TSF 2.

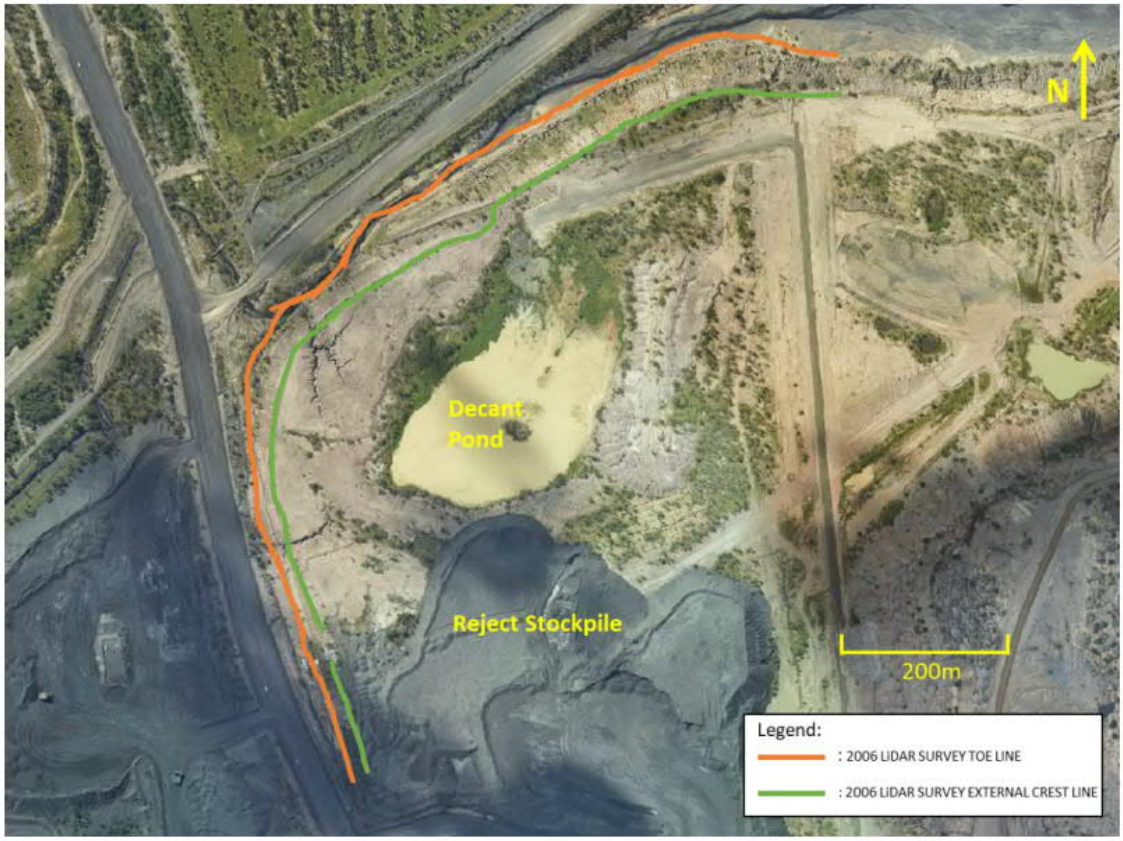


Figure 28: TSF 2 general layout and locality (EDG Consulting, 2021b)

5.2 Tailings Characterisation

Locations for sampling and testing for tailings characterisation are presented in Appendix C in high-resolution images for sample points and depths. Laboratory certificate results are presented in Appendix D.

5.2.1 Tailings geochemical characterisation

As part of refining the closure knowledge base, a dedicated mineral waste characterisation project (sampling, analysis and reporting) has been undertaken by BHP across the Queensland BMA sites (2020 – ongoing). This has included the environmental geochemical characterisation and risk assessment of SRM's TSFs, the outcomes of which are currently being compiled. On completion, this geochemical information will be used in conjunction with the geotechnical and rheology characterisation provided in this report to inform development of suitable rehabilitation management strategies in the PRCP.

5.2.2 Rheology

The solid concentration of tailings samples is shown in Table 23.

Table 23: TSF 2 TSF summarised rheology results

Sample name	Depth (m)	Solid concentration (wt%)	Solid specific gravity	Yield stress (Pa) @55wt%(*)
TSF2-BH07	6.00 to 12.00	75.38	1.60	10
TSF2-CPT06:	11.00 to 13.5	75.96	1.66	41

(*) Note: For reference, calculated yield stress ($\tau_y = ae^{bx}$) of each sample at a solid concentration of 55wt%.

The shear yield stress of all tailings samples increased exponentially with solids concentration across the range of solids concentrations investigated. This correlation is shown in Figure 29.

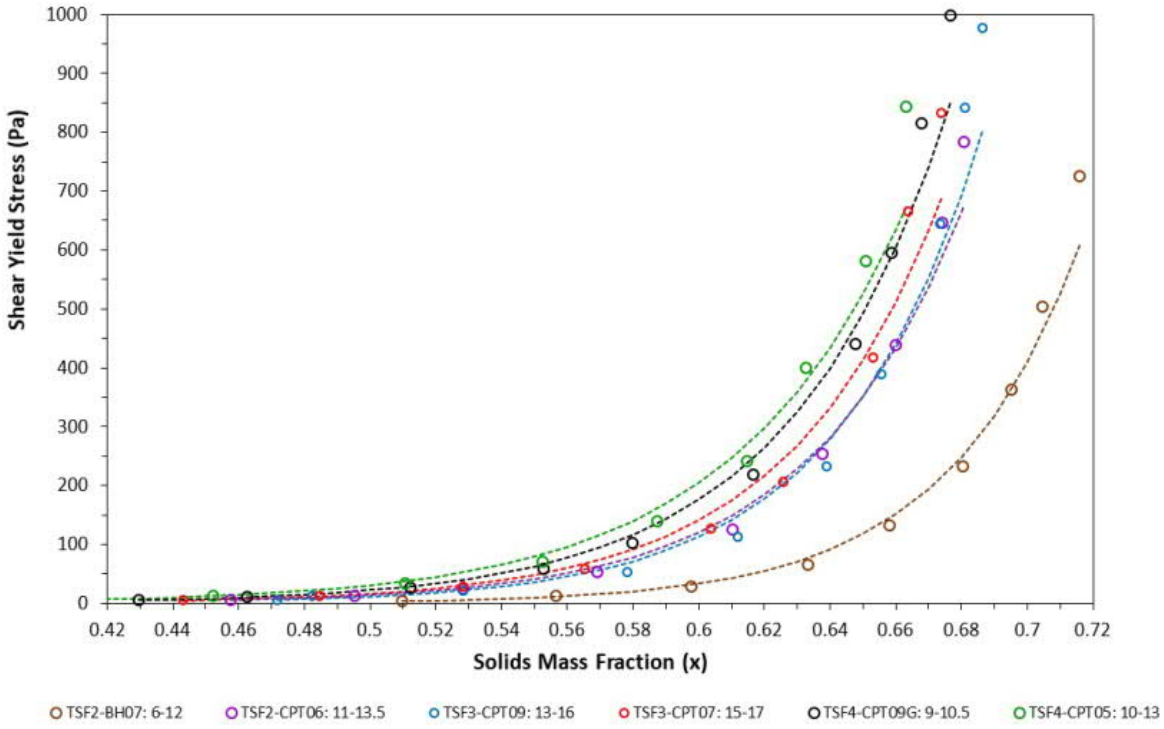


Figure 29: TSF 2 shear yield stress vs mass fraction

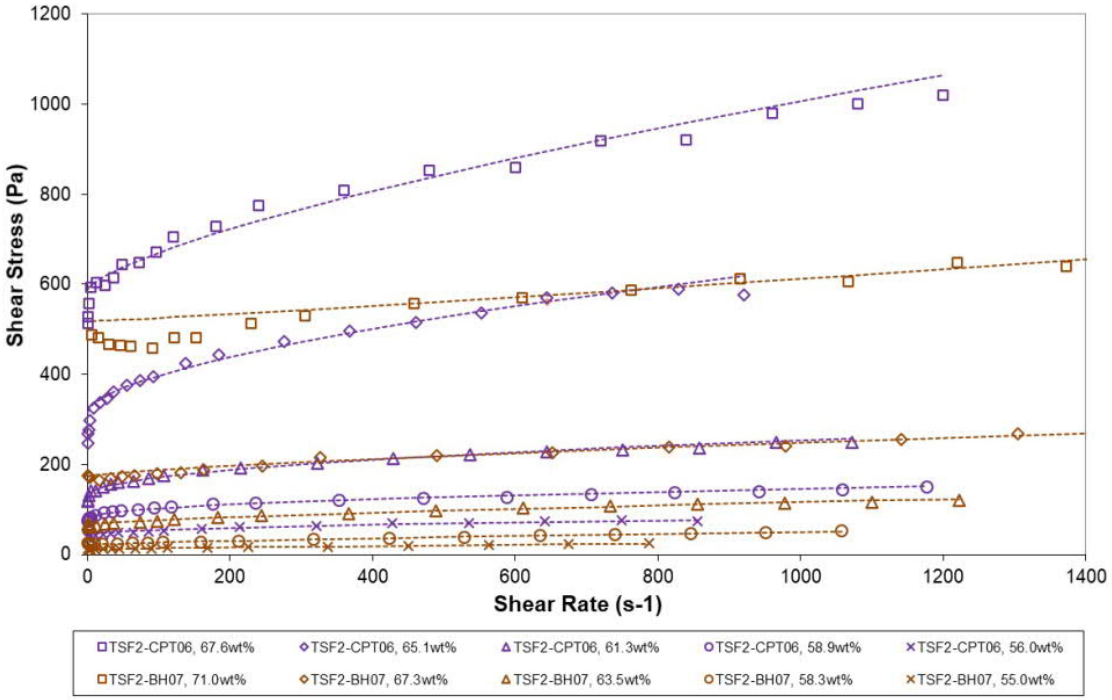


Figure 30: TSF 2 shear stress vs shear rate (all samples)

The two samples from TSF 2 differ from each other significantly. The TSF 2 sample from a shallower depth showed a lower yield stress for a given solids. The TSF2-BH07: 6-12 sample also had the lowest specific gravity. The specific gravity was lower at shallow depths for TSF 2.

In shear flow, both samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates investigated. For all but one sample, no shear history or time dependence was observed on the time scale of testing. However, it should be noted that all samples were fully sheared prior to testing due to the sample collection, subsequent sub-sampling and sample preparation methods. The one notable exception was TSF2-BH07 at 71wt%. This sample showed a decrease in the shear stress as the shear rate increased from zero until approximately $100s^{-1}$ before increasing at higher shear rates. The behaviour was reproducible when the same sample was sheared then retested, possibly indicating a localised (but reversible) structuring of the material – possibly due to the presence of asymmetrical particles aligning in the direction of flow. The origin of the behaviour was not investigated. The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected and the shear stress versus shear rate data was modelled using a Herschel-Bulkley model. The viscosity stress versus shear rate data was well described using a Power Law.

5.2.3 Particle size distribution

The particle size distribution of tailings samples is presented in Table 24.

Table 24: TSF 2 particle size distribution of tailings

Test location	Materials	Depth (m BGL)		Particle size distribution		
		From	To	Clay and silt fines (%)	Sand (%)	Gravel (%)
TSF2-BH01	Tailings	6.00	6.45	81.00	19.00	0.00
TSF2-BH04	Tailings	6.00	6.45	73.00	27.00	0.00
TSF2-BH06	Tailings	9.00	9.45	61.00	39.00	0.00
TSF2-CPT03	Tailings	10.50	10.95	65.00	35.00	0.00
TSF2-BH04	Tailings	8.20	8.70	54.00	45.00	1.00
TSF2-BH04	Tailings	12.00	12.50	100.00	0.00	0.00

Particle size distribution curves for individual samples showing clay, silt, sand, and gravel bands is presented in Figure 31.

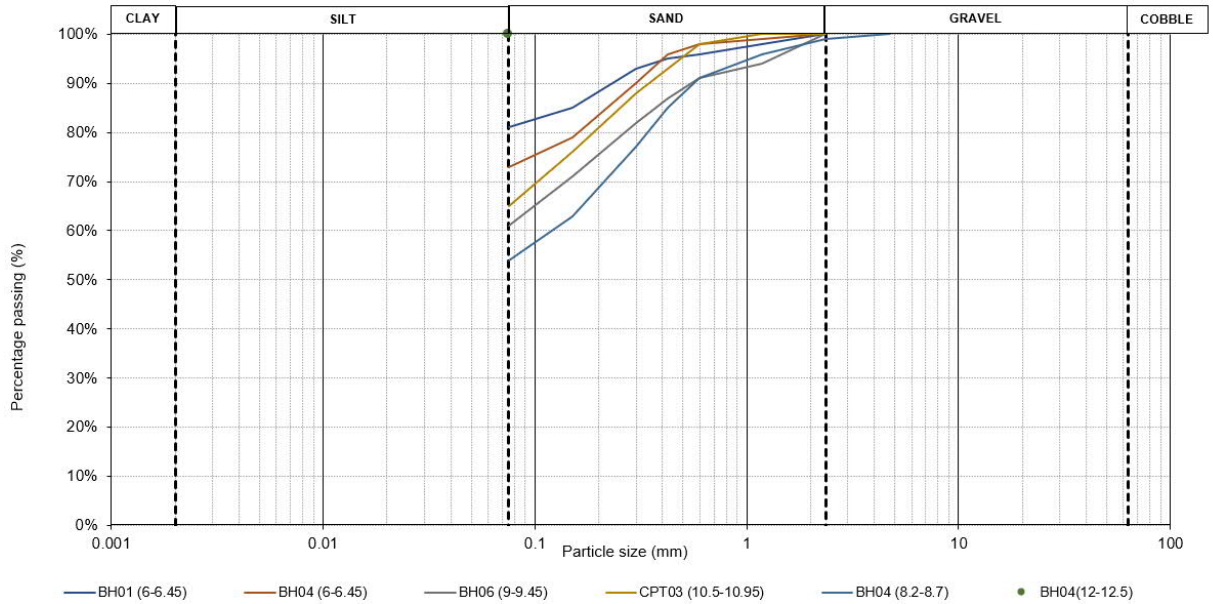


Figure 31: TSF 2 particle size distribution curve

Tests on five samples indicate the percentage of fines content varies between 54% and 81% and that the sand fraction ranges between fine and coarse grained. One sample returned results which contained only fines (i.e., fines fraction of 100% at TSF2-BH04, 12 m to 12.5 m) (EDG Consulting, 2021b).

5.2.4 Atterberg limits testing

The Atterberg limits of tailings samples are presented in Table 25.

Table 25: TSF 2 Atterberg limits of tailings (EDG Consulting, 2021c)

Test location ID	Depth (m BGL)		Atterberg limits (%)			
	From	To	LL (%)	PL (%)	PI (%)	LS (%)
TSF2-BH01	6.00	6.45	45	22	23	9.0
			45	22	23	9.0
TSF2-BH03	6.00	6.45	45	23	22	9.0
TSF2-BH04	6.00	6.45	53	17	36	11.5
	8.20	8.70	26	13	13	8.5
TSF2-BH06	9.00	9.45	45	22	23	8.5
TSF2-CPT03	10.50	10.95	25	17	8	11.0

Note: LL = Liquid Limit; PL = Plastic Limit; PI = Plasticity Index: LS = Linear Shrinkage.

The plot of results on Atterberg limits is shown in Figure 32.

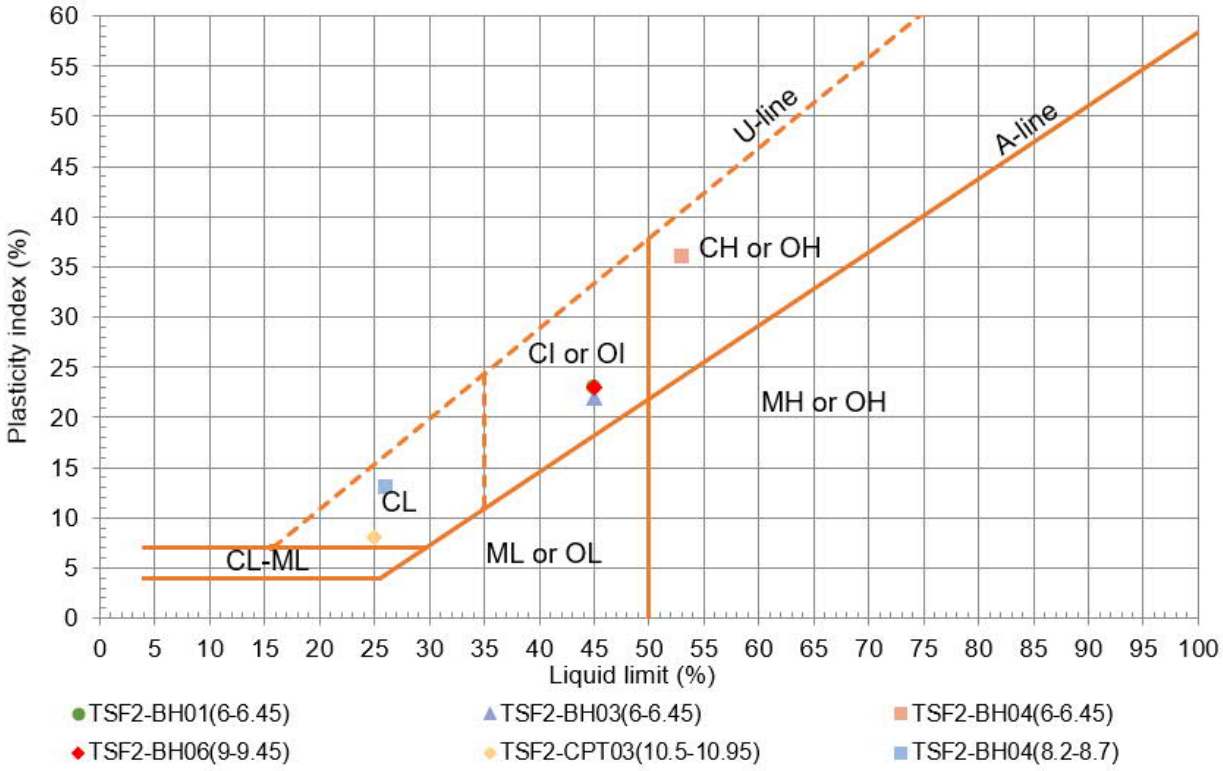


Figure 32: TSF 2 Atterberg limits results

All results plot above the A-Line on the Casagrande Chart. Three results plots as Clay of intermediate plasticity (CI), two results plot as Clay of low plasticity (CL) and one result plots as Clay of high plasticity (CH). (EDG Consulting, 2021b)

5.2.5 Moisture content and dry density profiles

The moisture content of tailings samples is presented in Table 26.

Table 26: TSF 2 moisture content of tailings

Sample name	Depth (m)		Moisture content (%)	Wet density (t/m^3)	Dry density (t/m^3)
	From	To			
TSF2-BH01	6.00	6.45	12.70	2.08	1.85
TSF2-BH04	8.20	8.70	15.60	2.17	1.87
TSF2-BH04	12.00	12.5	37.70	1.51	1.10

5.2.6 Shear strength testing and profile

Vane shear test result are presented in Table 27.

Table 27: TSF 2 vane shear testing results summary on tailings

Test location ID	Depth (m)	Material type	Undisturbed shear strength (kPa)	Remoulded shear strength (kPa)	Vane sizes (mm x mm)
TSF2-BH03	6.0	Tailings	102	45	35 x 70
TSF2-BH06	9.0	Tailings	87	35	35 x 70
TSF2-CPT07	6.5	Tailings	68	21	35 x 70

Note: [1] Vane reached maximum torque.

Pocket results are presented in Table 28.

Table 28: TSF 2 pocket penetrometer results range

Soil type	Shear strength range (kPa)	Notes
Unit 3 Tailings	35 - 75	CPT and vane shear tests are generally more suitable for use in soft soil, the undrained shear strength as measured from Pocket Penetrometer tests has been used with caution

Interpreted shear strength profile (Su vs depth) from the raw CPT and borehole data within each 'Shear Strength and Testing material type' is presented in Figure 33 and Figure 34.

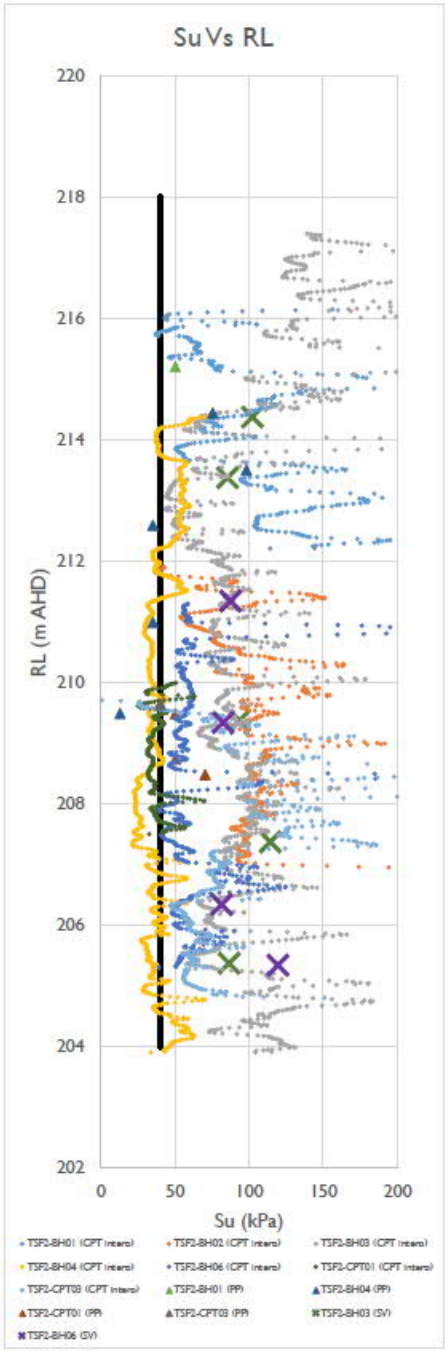


Figure 33: TSF 2 Interpreted shear strength profile for tailings material near embankment

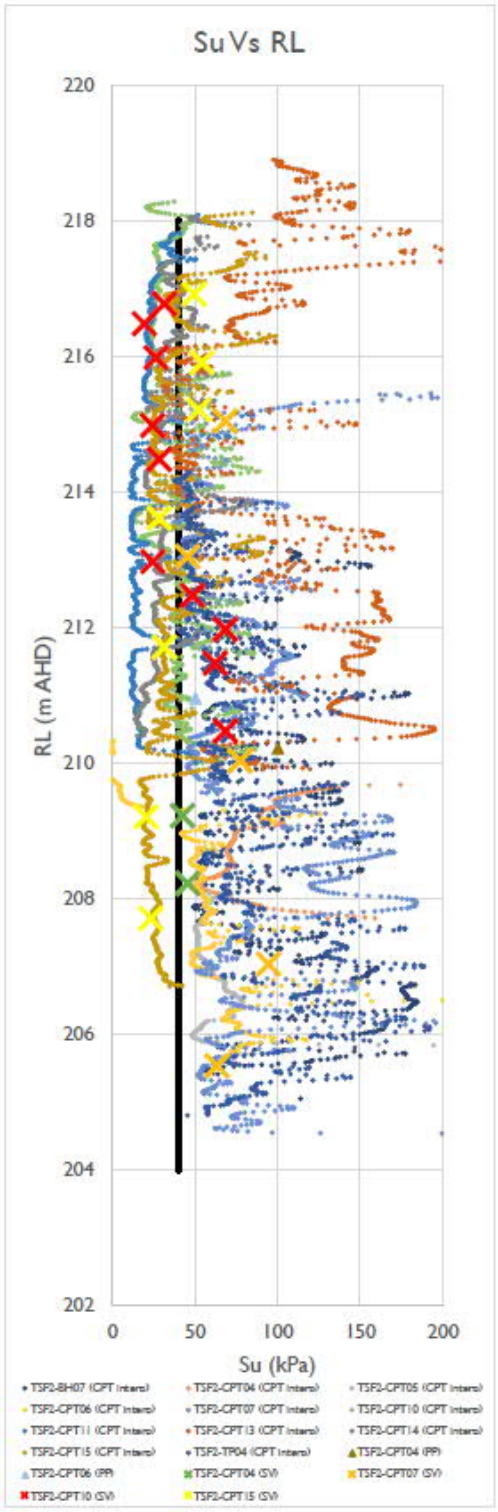


Figure 34: TSF 2 Interpreted shear strength profile for tailings material near decant pond

5.2.7 Consolidation testing

The results of the consolidation testing are presented in Table 29 to Table 30

Table 29: TSF 2 TSF consolidation testing – raw CPT11 oedometer test results

Test location ID	Material	Depth (m BGL)	Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t50	Cv (m^2/yr) t90	Mv (kPa-1x10-3)	Ca x 10-3	% Consolidation
CPT11	Tailings	5.00-5.80	1	6-12	0.035	1.60E-08	59.92	43.50	1.195	0.33	0.7
			2	12-24	0.038	1.30E-08	56.08	65.36	0.654	0.31	1.5
			3	24-50	0.053	1.00E-08	57.87	72.77	0.450	0.42	2.6
			4	50-100	0.065	9.10E-09	107.42	107.44	0.273	0.49	4.0
			5	100-200	0.080	6.10E-09	120.78	116.87	0.169	0.51	5.6
			6	200-401	0.080	2.50E-09	115.57	95.03	0.086	0.86	7.2
			7	401-799	0.113	2.40E-09	102.17	123.55	0.062	1.09	9.5
			8	799-1603	0.135	1.20E-09	122.23	104.50	0.038	1.30	12.3
			9	1603-401	0.013	3.40E-10	238.97	223.96	0.005	0.15	11.8
			10	401-100	0.013	6.00E-10	95.64	95.32	0.020	0.23	11.2

Table 30: TSF 2 TSF consolidation testing – raw CPT14 oedometer test results

Test location ID	Material	Depth (m BGL)	Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t50	Cv (m^2/yr) t90	Mv (kPa-1x10-3)	Ca x 10-3	% Consolidation
CPT14	Tailings	7.00-7.80	1	6 12	0.007	1.40E-09	138.03	21.09	0.214	0.03	0.10
			2	12 26	0.018	3.30E-09	42.99	39.10	0.268	0.27	0.50
			3	26-50	0.058	5.40E-09	70.46	41.13	0.425	0.64	1.50
			4	50-99	0.117	4.80E-09	40.10	35.02	0.446	1.09	3.70
			5	99-201	0.098	2.60E-09	66.02	43.49	0.190	0.78	5.50
			6	201-399	0.119	1.40E-09	42.18	38.56	0.117	1.45	7.70
			7	399-799	0.183	1.40E-09	58.76	47.81	0.093	1.98	11.20
			8	799-1601	0.200	5.70E-10	59.04	35.06	0.053	2.35	14.90
			9	1601-400	0.019	9.80E-11	133.30	45.25	0.007	0.34	14.20
			10	400-98	0.023	5.90E-10	54.96	56.43	0.034	0.72	13.30

5.2.8 Soil water characteristic curve

The SWCC of tailings samples is presented in Table 31.

Table 31: TSF 2 – SWCC of tailings

Test location ID	Material	Sample depth (m RL)	Volumetric water content (cm^3/cm^3)				
			0 kPA	10 kPA	33 kPA	100 kPA	1500 kPA
TSF2-CPT14	Tailings	2.00 to 2.80	0.3139	0.2314	0.2058	0.1829	0.1311
TSF2-CPT11	Tailings	3.00 to 3.70	0.3856	0.2689	0.2359	0.2018	0.1548

The soil water characteristic curve is presented in Figure 35.

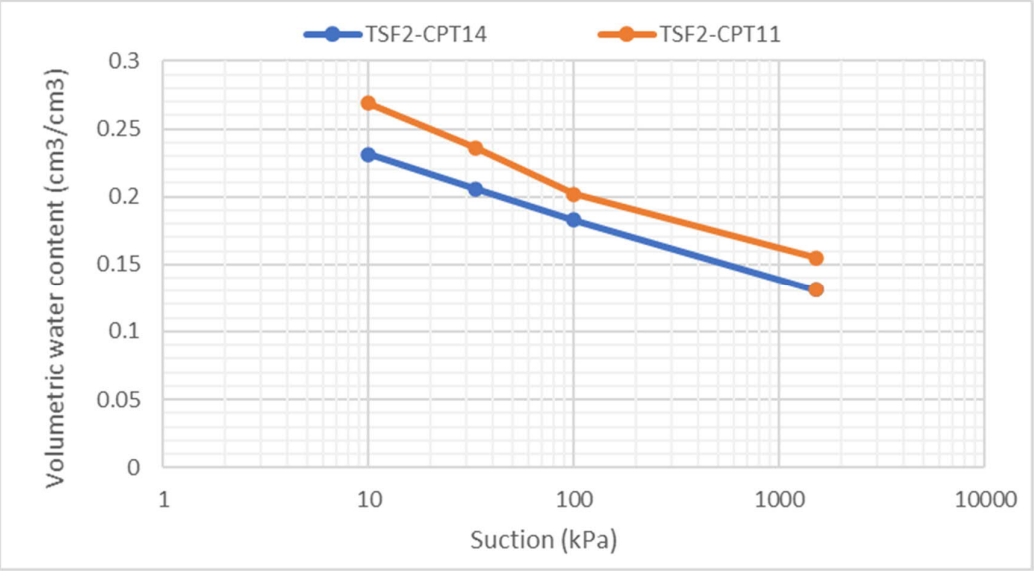


Figure 35: TSF 2 SWCC

5.2.9 Specific gravity

Results for specific gravity are presented in Table 23, Section 5.2.2

5.3 Tailings Facility Design

5.3.1 Design philosophy

TSF 2 has embankments on the west, north, and partial length of the south sides.

TSF 2 is an above-ground facility with partial perimeter embankments on a down slope turkey's nest design, with tailings discharged and settled towards a decant pond area for water management and shaping final surface to minimise cover materials.

5.3.2 Design basis

5.3.2.1 Geotechnical design criteria

Available information in relation to the development of TSF 2 is limited due to the lack of available historical design and construction reports. Based on the distribution of tailings and embankment fill material encountered in the geotechnical investigations, results suggests that the internal slope angle may be slightly steeper than the external slope angle, particularly at the northern TSF 2 embankment. In all the geotechnical investigations across TSF 2, the tailings material was overlying natural material. A significant amount of uncontrolled fill material was found overlying tailings material in the geotechnical investigations. In some areas of TSF 2, particularly adjacent to the embankments, the strata thickness of the uncontrolled fill material exceeds 10 m.

Table 32 shows the minimum acceptable FoS adopted for Stability Analysis Loading Conditions and Design Criteria.

Table 32: TSF 2 minimum acceptable FoS

Condition	Adopted FOS	Minimum acceptable FoS
EOC	Short-term undrained (no potential of loss of containment)	1.3
Operational steady state	Long-term drained	1.5
Operational post-seismic	Post-seismic	1.0

Seismic and post-peak assessment indicates that ground motions expected during a 1:10,000AEP earthquake event (Extreme) do not cause liquefaction or cyclic softening of the foundation Residual Soil, Tailings, Embankment fill or Uncontrolled Fill. (EDG Consulting, 2021b).

5.3.2.2 Hydraulic loading design criteria

The adopted criteria consider meteorological and groundwater environments that could adversely affect the TSF performance. The adopted criteria also considered external loading consistent with both the probable consequence classification based on current conditions and the higher consequence classification (including Extreme) as required by the GISTM (EDG Consulting, 2021b).

No engineered spillway or other surface water controls, or designs, exists for this facility.

5.3.2.3 Seepage design criteria

There is no available documented information regarding the presence or design of any seepage cut-off features or collections systems at TSF 2. From the site investigations undertaken, there is no evidence that any seepage collection such as a seepage cut-off trench is present at TSF 2 (EDG Consulting, 2021b).

A simplified conceptual hydrogeological model of TSF 2 is presented in Figure 36.

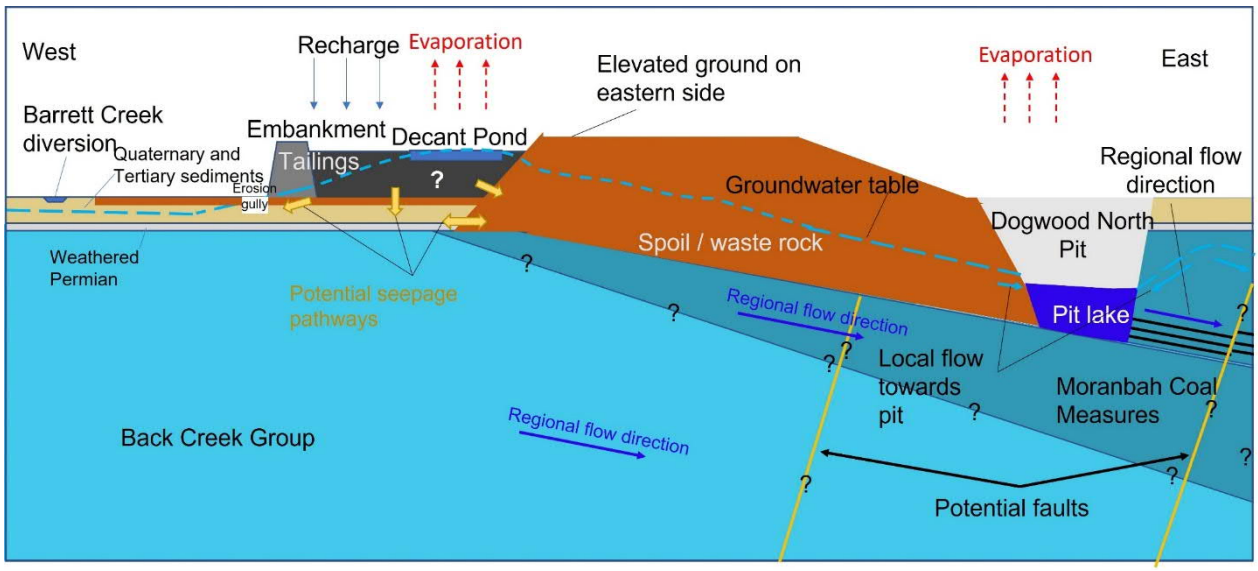


Figure 36: TSF 2 simplified conceptual hydrogeological model (not to scale) in the east-west direction

According to this conceptual model and its location, TSF 2 has the potential to be hydraulically connected to the following nearby mine facilities:

- TSF 4, which is located approximately 400 m to the north
- Ramp 6 TSF, which is located to the north-east
- TSF 3, which is located about 600 m to the north-west
- Dogwood North Pit, which is located about 1 km to the east
- Reject stockpile, immediately south.

The presence of a non-managed pond suggests that hydraulic conductivity of the TSF material (and/or the foundation) is likely very low.

5.3.3 TSF operation

TSF 2 is currently inactive. Only monitoring and surveillance activities are undertaken. These include:

- Dam inspections
- Fortnightly and/or post rainfall events (Responsible Dam Engineer and mine services)
- Annually (Engineer of Record review).

6.0 TSF 3

6.1 Overview of Tailings Facility

Table 33 presents descriptions of the extent and general arrangement of the TSF, the history and governance, TSF classification and monitoring activities.

Table 33: TSF 3 Overview

Condition	Detail
Extent and general arrangement of TSF	■ TSF 3 is a turkey's nest type TSF. It is currently inactive and partially rehabilitated ■ Above-ground facility, confined by embankments that are 12 to 13 m high on all sides ■ Tailings level is at least 10 m below surrounding natural ground level ■ This means that TSF 3 is a hybrid TSF, instead of a standard above-ground facility. (EDG Consulting, 2021d) ■ TSF 3 has a closure spillway at the northern end with no decant structure
History and governance of the TSF	■ TSF 3 was constructed sometime between 1966 to 1977, however the exact date is unknown. It ceased to be an operational TSF around 1985 ■ Historic aerial photographs show that deposition was from the south and that a decant pond (and slimes area) was present in the north ■ The inactive facility was capped between 2009 and 2012; the capping layer is typically 2 to 2.5 m thick (EDG Consulting, 2021e) ■ Vegetation trials occurred on the facility, but information on the objective of the trials or what was planted is unknown. Rehabilitated areas have been not certified ■ The only current closure component is the cover; there is no water reclamation system
TSF classification	Quantitative CCA not completed yet. Classification not available Design storage allowance (DSA) not available.
Operation and surveillance	The business-as-usual activities derived from existing documents, and considered relevant during the inactive period, are as follows: ■ Completing annual inspection reports by the Engineer of Record (EoR) ■ Conducting groundwater level monitoring There are 16 monitoring bores with VWPs and standpipes, which are part of a monitoring network for TSF stability and groundwater monitoring

The general location of TSF 3 is presented in Figure 37.

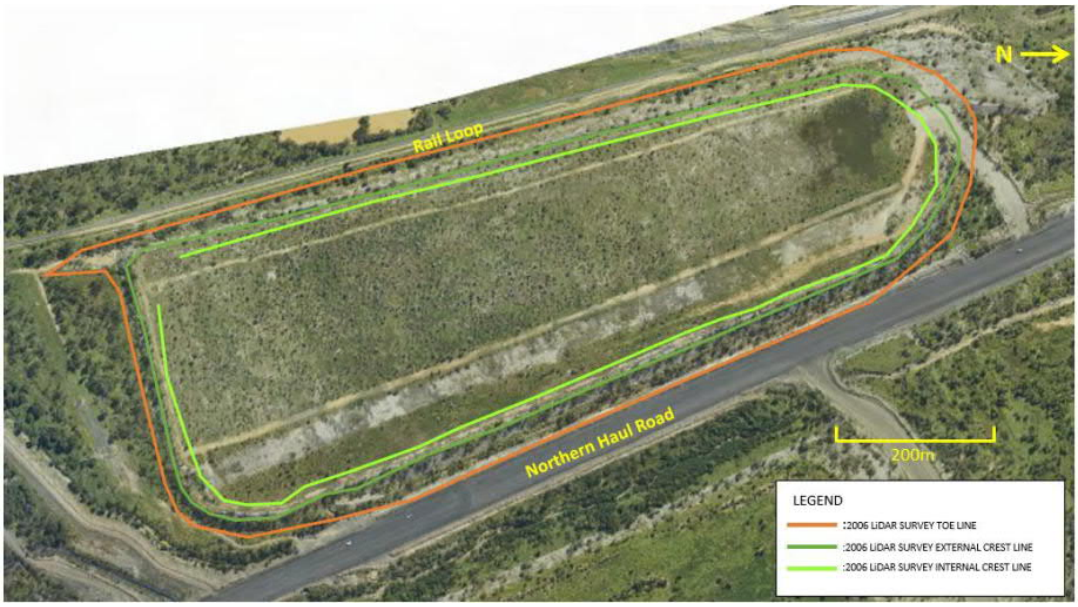


Figure 37: TSF 3 general layout and locality (EDG Consulting, 2021i)

6.2 Tailings Characterisation

Locations for sampling and testing for tailings characterisation are presented in Appendix E in high-resolution images for sample points and depths. Laboratory certificate results are presented in Appendix F.

6.2.1 Tailings geochemical characterisation

As part of refining the closure knowledge base, a dedicated mineral waste characterisation project (sampling, analysis and reporting) has been undertaken by BHP across the Queensland BMA sites (2020 – ongoing). This has included the environmental geochemical characterisation and risk assessment of SRM's TSFs, the outcomes of which are currently being compiled. On completion, this geochemical information will be used in conjunction with the geotechnical and rheology characterisation provided in this report to inform development of suitable rehabilitation management strategies in the PRCP.

6.2.2 Rheology

Solid concentration and rheology information is presented in Table 34.

Table 34: TSF 3 TSF summarised rheology results

Sample name	Depth (m)	Solid concentration (wt%)	Solid specific gravity	Yield stress (Pa) @55wt%(*)
TSF3-CPT09	13 to 16	73.49	1.78	36
TSF3-CPT07	15 to 17	72.92	1.68	48

(*) Note: For reference, calculated yield stress ($\tau_y = ae^{bx}$) of each sample at a solid concentration of 55wt%.

The shear yield stress of all tailings samples increased exponentially with solids concentration across the range of solids concentrations investigated. This correlation is shown in Figure 38.

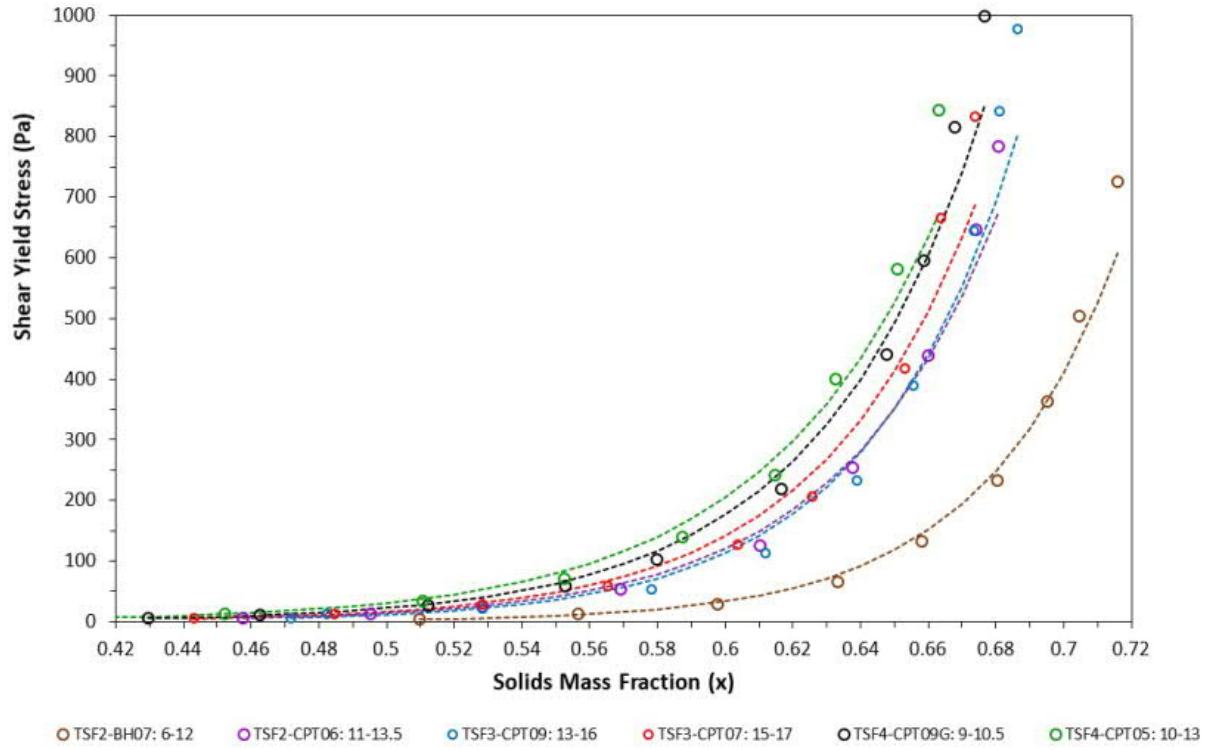


Figure 38: TSF 3 shear yield stress vs mass fraction

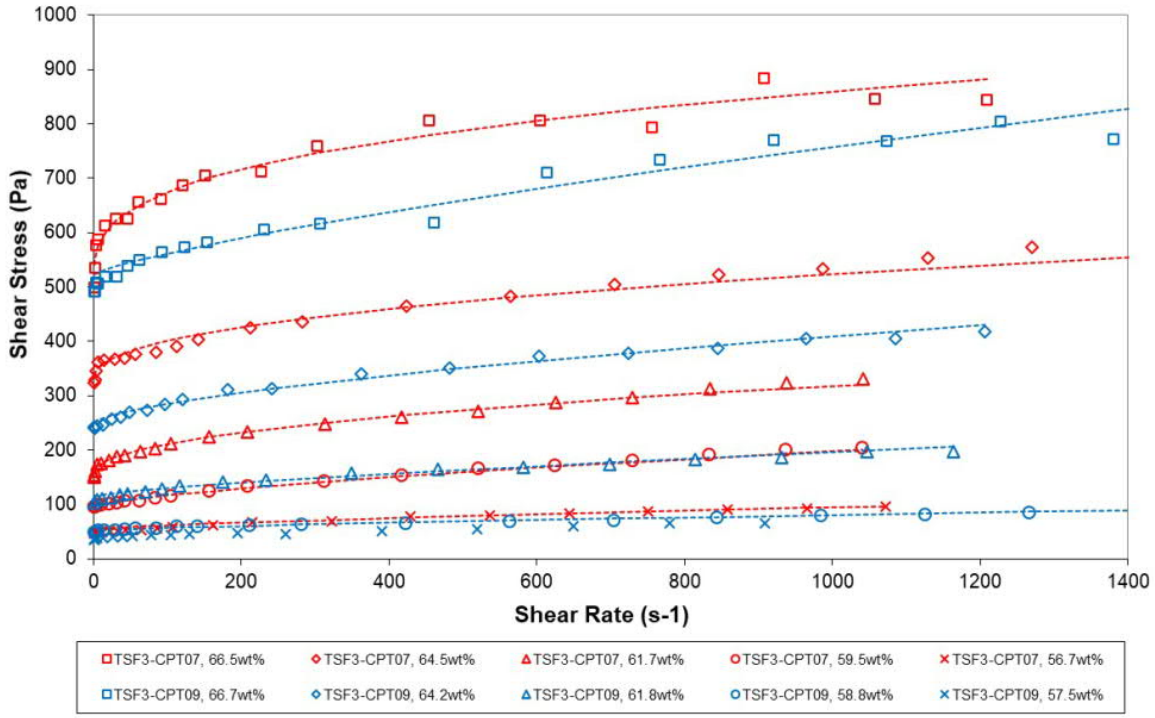


Figure 39: TSF 3 shear stress vs shear rate (All samples)

The yield stress behaviour for the two samples from TSF 3 are similar to each other.

The specific gravity was higher at a shallow depth for TSF 3.

In shear flow, all samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates investigated. For all samples, no shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due to the sample collection, subsequent sub-sampling and sample preparation methods.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected. The shear stress versus shear rate data was modelled using a Herschel-Bulkley model. The viscosity stress versus shear rate data was well described using a Power Law.

6.2.3 Particle size distribution

The particle size distribution of tailings samples from TSF 3 is presented in Table 35.

Table 35: TSF 3 particle size distribution of tailings

Test location	Material	Depth (m BGL)		Particle size distribution		
		From	To	Clay and silt fines (%)	Sand (%)	Gravel (%)
TSF3-BH06A	Tailings	4.5	4.95	79	20	1
TSF3-CPT01	Tailings	3.0	3.45	44	50	6
TSF3-CPT07	Tailings	5.0	5.50	30	70	0
TSF3-CPT09	Tailings	7.0	7.80	27	73	0

Particle size distribution curves for individual samples showing clay, silt, sand, and gravel bands are presented in Figure 40

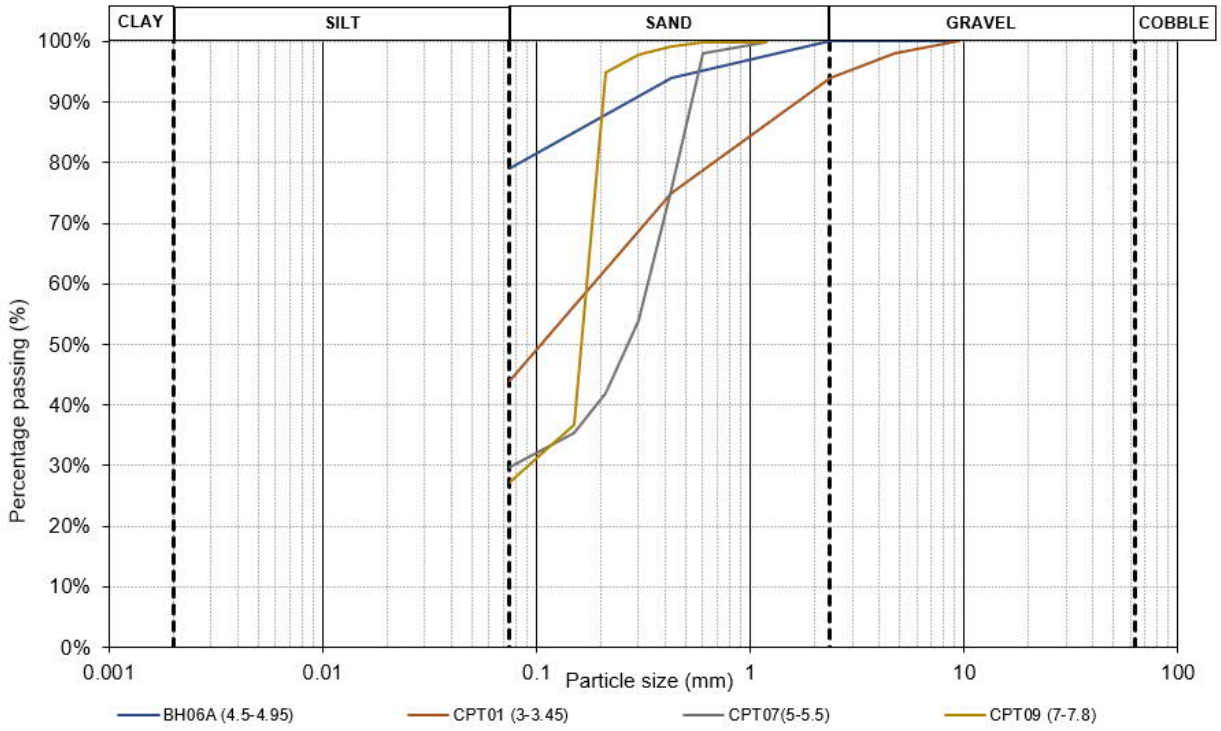


Figure 40: TSF 3 particle size distribution curve

Particle size distribution tests were carried out on six samples of tailings material (EDG Consulting, 2021):

- Three tests returned results with a higher fines content of between 79% and 93% fines (clay and silt size material) and 7% to 21% fine to coarse grained sand.
- Three test returned results with a lower fines content of between 27% and 44% fines (clay and silt size material), 50% to 73% fine to coarse grained sand, and up to 6% fine to medium grained gravel.

6.2.4 Atterberg limits testing

Atterberg limits on tailings samples are presented in Table 36.

Table 36: TSF 3 Atterberg limits on tailings samples

Test location ID	Depth (m BGL)		Atterberg limits (%)			
	From	To	LL (%)	PL (%)	PI (%)	LS (%)
TSF3-BH06A	4.5	4.95	45	24	21	5
TSF3-CPT01	3	3.45	26	18	8	5
TSF3-CPT02	4	4.5	42	23	19	6.5
TSF3-CPT07	5	5.5	40	29	11	-
TSF3-CPT07	10	10.5	42	22	20	5.5
TSF3-CPT09	7	7.8	37	28	9	-
TSF3-CPT09	10	10.8	44	23	21	6.5

Note: LL = Liquid Limit; PL = Plastic Limit; PI = Plasticity Index: LS = Linear Shrinkage.

A plot of results on Atterberg limits is shown in Figure 41.

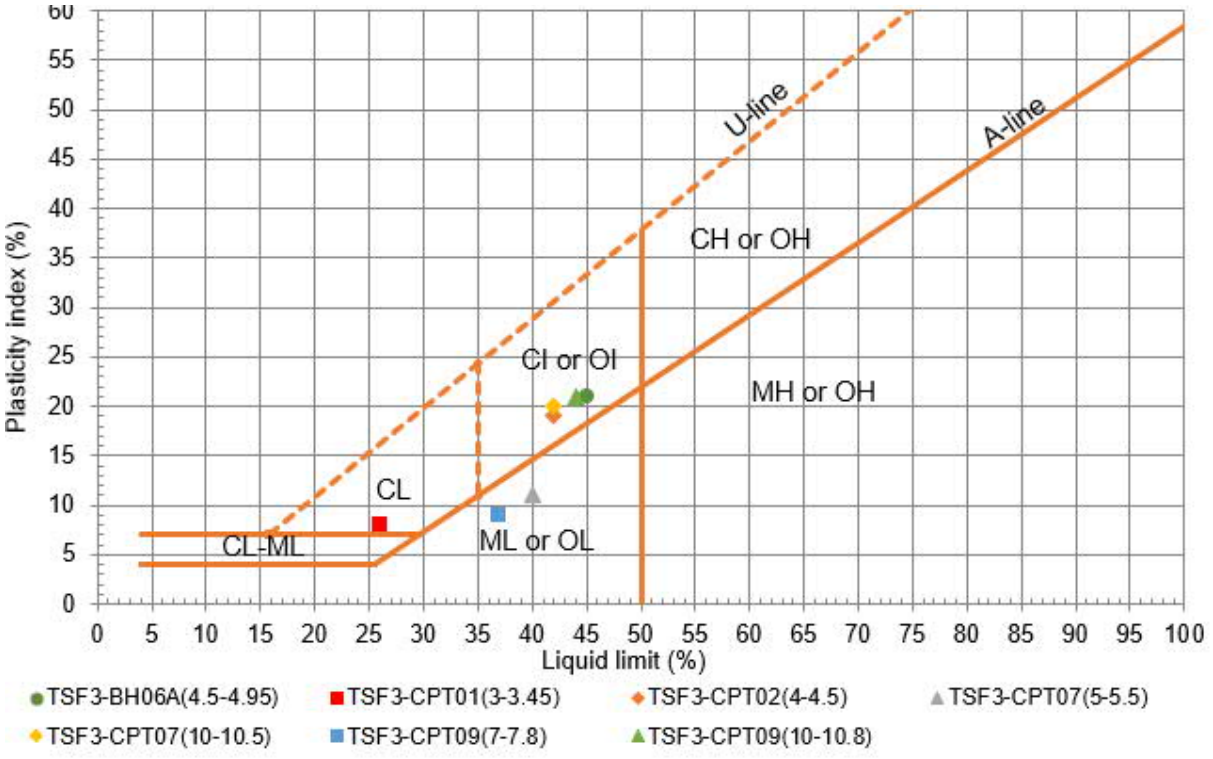


Figure 41: TSF 3 Atterberg limits results

Atterberg limits tests were carried out on the fines fraction of seven samples of tailings material. The results were (EDG Consulting, 2021e):

- Liquid Limit is generally between 42% and 45%, with three results between 26% and 40%.
- Plasticity Index is generally between 19% and 21%, with three results between 8% and 11%.
- Five results plot above the A-Line on the Casagrande Chart. Two results plot below the A-Line on the Casagrande Chart. Four results plot as CI, Clay of intermediate plasticity, one result plots as CL, Clay of low plasticity and two results plot as MI, Silt of intermediate plasticity.

6.2.5 Moisture content and dry density profiles

The moisture content of tailings samples is presented in Table 37.

Table 37: TSF 3 moisture content of tailings

Sample name	Depth (m)		Moisture content (%)	Wet density (t/m³)	Dry density (t/m³)
	From	To			
TSF3-CPT09	10.00	10.80	41.5	1.39	0.98
TSF3-CPT02	4.00	-	23.7	1.48	1.19
TSF3-CPT07	10.00	10.50	31.7	1.49	1.13

6.2.6 Shear strength testing and profile

Table 38 presents the profile and results from shear strength testing.

Table 38: TSF 3 vane shear testing results summary

Test location ID	Depth (m)	Undisturbed shear strength (kPa)	Remoulded shear strength (kPa)	Vane sizes (mm x mm)
TSF3-CPT02	4.8	107	27	35 x 70
	13	144	90	35 x70
	20.3	142	69	35 x70
TSF3-CPT04	10	87	39	35 x70
	18.5	>165[1]	N/A[1]	35 x 70
	21.7	>135[1]	N/A[1]	35 x 70
TSF3-CPT05	6	97	29	35 x 70
	12	107	33	35 x 70
	18.2	137	64	35 x 70
TSF3-CPT08	8	37	22	50 x 100
	12	37	26	50 x 100
	17.5	>194[1]	N/A[1]	35 x 70

Note: [1] Vane reached maximum torque.

Pocket results are presented in Table 39**.**

Table 39: TSF 3 pocket penetrometer results range

Soil type	Shear strength range (kPa)	Note
Unit 3 Tailings	50 to 100	CPT and vane shear tests are generally more suitable for use in soft soil, the undrained shear strength as measured from Pocket Penetrometer tests has been used with caution

Unconsolidated undrained triaxial test results for TSF 3 materials are presented in Table 40.

Table 40: TSF 3 unconsolidated undrained triaxial test

Sample location	Sample type	Sample depth (m)	Yield shear strength (kPa)
TSF3-CPT02	Tailings - Silt	4 to 4.5	134

Interpreted shear strength profile (Su vs depth) from the raw CPT and borehole data within each 'Shear Strength and Testing material type' is presented in Figure 42.

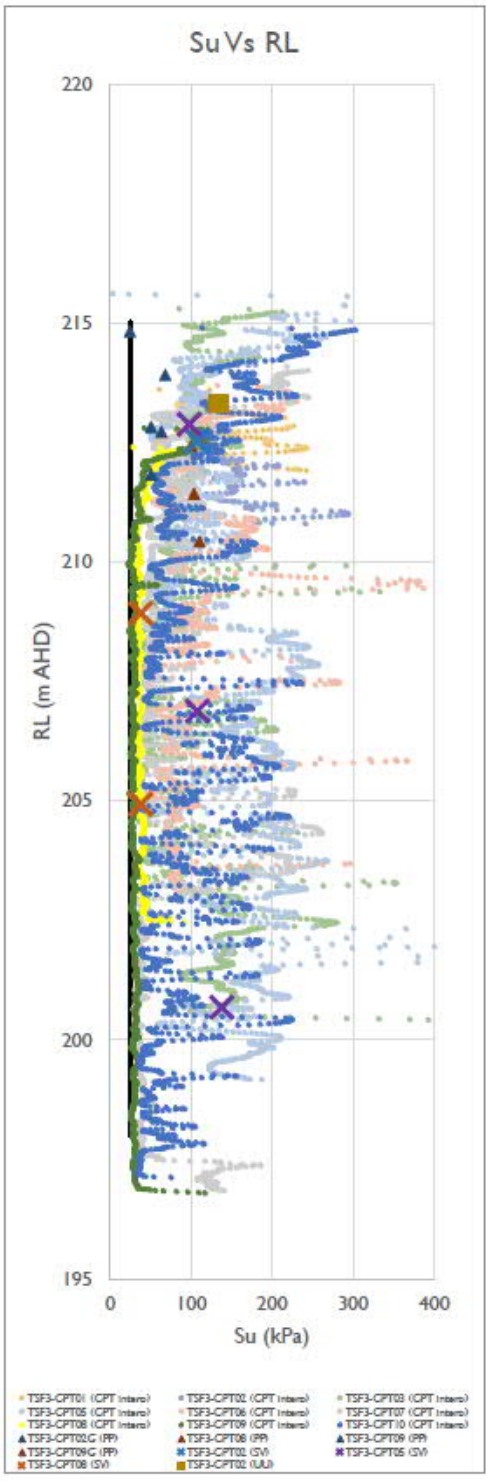


Figure 42: TSF 3 interpreted shear strength profile for tailings material

6.2.7 Consolidation testing

A summary of the raw data from consolidation testing (for the oedometer test results) is presented in Table 41 to Table 42.

Table 41: TSF 3 consolidation testing – raw CPT07 oedometer test results

Test location ID	Material	Depth (m BGL)	Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t50	Cv (m^2/yr) t90	Mv (kPa-1x10-3)	Ca x 10-3	% Consolidation
CPT07	Tailings	10.00-10.50	1	6-13	0.039	1.70E-09	3.23	4.27	1.283	0.61	0.9
			2	13-25	0.058	2.00E-09	5.61	6.85	0.936	0.89	2.0
			3	25-51	0.069	1.90E-09	8.90	10.51	0.570	1.01	3.5
			4	51-99	0.091	1.10E-09	9.11	9.31	0.386	0.87	5.3
			5	99-200	0.098	8.70E-10	14.49	13.16	0.213	1.14	7.3
			6	200-399	0.100	5.80E-10	13.60	16.92	0.111	1.08	9.3
			7	399-800	0.127	3.80E-10	20.02	17.24	0.072	1.27	11.9
			8	800-1603	0.139	2.40E-10	19.96	19.05	0.040	1.64	14.8

Table 42: TSF 3 consolidation testing – raw CPT09 oedometer test results

Test location ID	Material	Depth (m BGL)	Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t50	Cv (m^2/yr) t90	Mv (kPa-1x10-3)	Ca x 10-3	% Consolidation
CPT09	Tailings	10.00-10.80	1	6-13	0.032	6.90E-09	15.27	24.89	0.900	0.34	0.6
			2	13-25	0.029	4.10E-09	25.52	32.36	0.407	0.48	1.1
			3	25-51	0.061	5.00E-09	40.93	36.90	0.434	0.72	2.2
			4	51-100	0.084	3.60E-09	46.47	38.77	0.302	0.92	3.7
			5	100-199	0.148	2.90E-09	32.24	34.02	0.273	0.91	6.3
			6	199-401	0.173	2.30E-09	48.69	44.36	0.164	1.72	9.4
			7	401-799	0.173	9.50E-10	47.43	36.03	0.085	1.69	12.4
			8	799-1599	0.221	6.10E-10	48.30	34.87	0.056	1.65	16.4

6.2.8 Soil water characteristic curve

The SWCC of the tailings is presented in Table 43.

Table 43: TSF 3 SWCC of tailings

Test Location ID	Material	Sample depth (m RL)	Volumetric water content (cm^3/cm^3)				
			0 kPA	10 kPA	33 kPA	100 kPA	1500 kPA
TSF3-CPT09	Tailings	7.00 to 7.80	0.3578	0.2286	0.1759	0.1509	0.1326
TSF3-CPT07	Tailings	5.00 to 5.50	0.3833	0.2146	0.1628	0.1392	0.1120

The SWCC is presented in Figure 43.

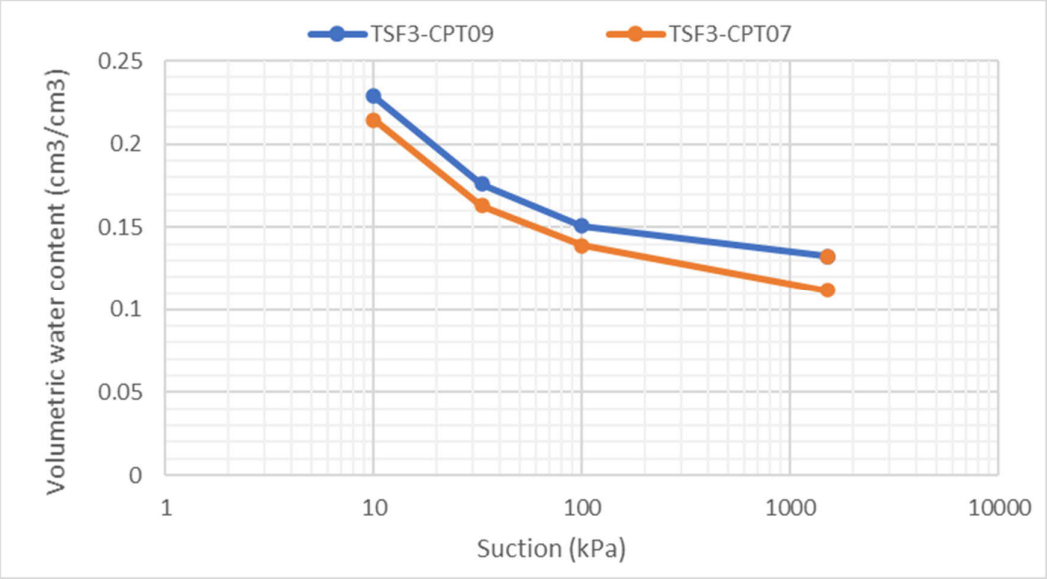


Figure 43: TSF 3 SWCC

6.2.9 Specific gravity

Results for specific gravity are presented in Table 34 in Section 5.2.2

6.3 Tailings Facility Design

6.3.1 Design philosophy

TSF 3 is a turkey's nest style TSF with confining embankments which are up to 13 m in height and a ramp spillway to the north. During operation this configuration means the existing tailings surface is not only shaped to shed water towards the decant pond, but also ongoing settlement accentuates this drainage.

In its current state, it is understood that the surface of the tailings dam was capped with Tertiary/Weathered Permian Material at least 2 m thick and overlain by topsoil. This concept of design allows incident rainfall to be collected and stored (during normal rainfall events) in the cover materials and then released through evapo-transpiration with minimal downward movement to the basal layer of the cover. The store and release cover system is graded to shed extreme rainfall events.

6.3.2 Design basis

6.3.2.1 Geotechnical design criteria

TSF 3 is a turkey's nest type TSF, currently inactive and partially rehabilitated. There is no evidence of staged construction raises. The interpretative geotechnical report (EDG Consulting, 2021i) has assessed a likely sequence of construction and development for TSF 3, based on a combined review of aerial photographs, historical survey LiDAR information, as well as consideration of the latest findings from the geotechnical investigation. These indicate:

- The embankment located around the perimeter was constructed after 1974 and before 1977.
- The 1999 investigations undertaken by Henderson Geotech and 2020 investigations undertaken by EDG found tailings material up to 10 m below original ground level (as known from pre-mining topography). It is inferred that the base of the impoundment was excavated to provide additional capacity and/or source the fill used to construct the embankments.
- Following the development of the TSF 3 embankment, tailings deposition into the impoundment commenced. In approximately 1985, TSF 3 ceased operation.
- Between 2009 and 2012, TSF 3 was fully capped.

Key physical features:

- Maximum embankment height of approximately 13 m
- TSF 3 has a closure spillway at the northern end with no decant structure.

Table 44 shows the minimum acceptable FoS adopted for Stability Analysis Loading Conditions and Design Criteria.

Table 44: TSF 3 minimum acceptable FoS

Condition	Adopted FOS	
EOC	Short-term undrained (no potential of loss of containment)	1.3
Operational steady state	Long-term drained	1.5
Operational post-seismic	Post-seismic	1.0

A stability analysis was performed as part of the geotechnical interpretative report. In general, factors of safety are shown to be compliant with the target FoS (EDG Consulting, 2021e).

6.3.2.2 Hydraulic design criteria

TSF 3 has a closure spillway at the northern end with no decant structure. However, no documented engineered design for the spillway is available to confirm design criteria compliance. There is no CCA, no design loading, and no documented engineering assessment available

6.3.2.3 Seepage design criteria

The TSF was fully capped between 2009 and 2012, the capping layer is typically 2 to 2.5 m thick (EDG Consulting, 2021).

Field investigations interpreted a groundwater level of 1 to 2 m below pre-mining natural ground surface beneath the embankments, and 1 to 2 m above pre-mining natural ground level within the tailings impoundment (EDG Consulting, 2021).

The original alignment of Barrett Creek is understood to have passed to the south of TSF 3 (EDG Consulting, 2021).

6.3.3 TSF operation

TSF 3 is currently inactive and is a closed facility. Only monitoring and surveillance activities are undertaken. These include:

- Dam inspections
- Fortnightly and/or post rainfall events (Responsible Dam Engineer and mine services)
- Annually (Engineer of Record review).

7.0 TSF 4

7.1 Overview of tailings facility

Table 45 presents a description of the extent and general arrangement of TSF, the history and governance, TSF classification and monitoring activities.

Table 45: TSF 4 overview

Condition	Detail
Extent and general arrangement of TSF	▪ TSF 4 is located on the eastern side of the northern haul road, opposite to TSF 3. TSF 4 is a hillside (turkey's nest) style TSF with confining embankments on the north, south, and west sides and small saddle embankments in the east ▪ It is bounded to the north by a ramp, by Ramp 6 to the south and by the northern haul road to the west. The ground level continues to rise to the east as a result of fill placement ▪ Since operations ceased, fill has also been placed over the eastern side of the TSF ▪ There is no closure spillway nor decant pond at TSF 4
History and governance of the TSF	▪ TSF 4 is a turkey's nest type TSF constructed in 1984 ▪ It is currently inactive and partially rehabilitated. Crest elevation is at 207 m RL with a maximum height of 22 m adjacent to Ramp 6. TSF 4 was fully capped between 2006 and 2009 ▪ Along the western embankment, a downstream berm approximately 8 m wide at 208 m RL can be observed from the 2006 LiDAR data. Additional fill has subsequently been placed over this berm, as can be observed from the 2012 LiDAR data
TSF classification	Quantitative CCA not completed yet. Classification not available Design storage allowance (DSA) not available.
Operation and surveillance	The monitoring activities derived from existing documents, and considered relevant during the inactive period, are as follows: ▪ Completing annual inspection reports by the Engineer of Record ▪ Monitoring of groundwater level by monitoring instrumentation (17 VWPs and four standpipes) were installed across TSF 4

The general location of TSF 4 is presented in Figure 44.



Figure 44: TSF 4 Tailings general layout and locality (EDG Consulting, 2021g)

7.2 Tailings Characterisation

Locations for sampling and testing for tailings characterisation are presented in Appendix G in high-resolution images for sample points and depths. Laboratory certificate results are presented in Appendix H.

7.2.1 Tailings geochemical characterisation

As part of refining the closure knowledge base, a dedicated mineral waste characterisation project (sampling, analysis and reporting) has been undertaken by BHP across the Queensland BMA sites (2020 – ongoing). This has included the environmental geochemical characterisation and risk assessment of SRM's TSFs, the outcomes of which are currently being compiled. On completion, this geochemical information will be used in conjunction with the geotechnical and rheology characterisation provided in this report to inform development of suitable rehabilitation management strategies in the PRCP.

7.2.2 Rheology

Solid concentration and rheology information is presented in Table 46.

Table 46: TSF 4 TSF summarised rheology results

Sample name	Depth (m)	Solid concentration (wt%)	Solid specific gravity	Yield stress (Pa) @55wt%(*)
TSF4-CPT09G	9.00 to 10.50	98.62	1.69	63
TSF4-CPT05	10.00 to 13.00	73.85	1.82	80

(*) Note: For reference, calculated yield stress ($\tau_y = ae^{bx}$) of each sample at a solid concentration of 55wt%.

The shear yield stress of all tailings samples increased exponentially with solids concentration across the range of solids concentrations investigated. This correlation is shown in Figure 45.

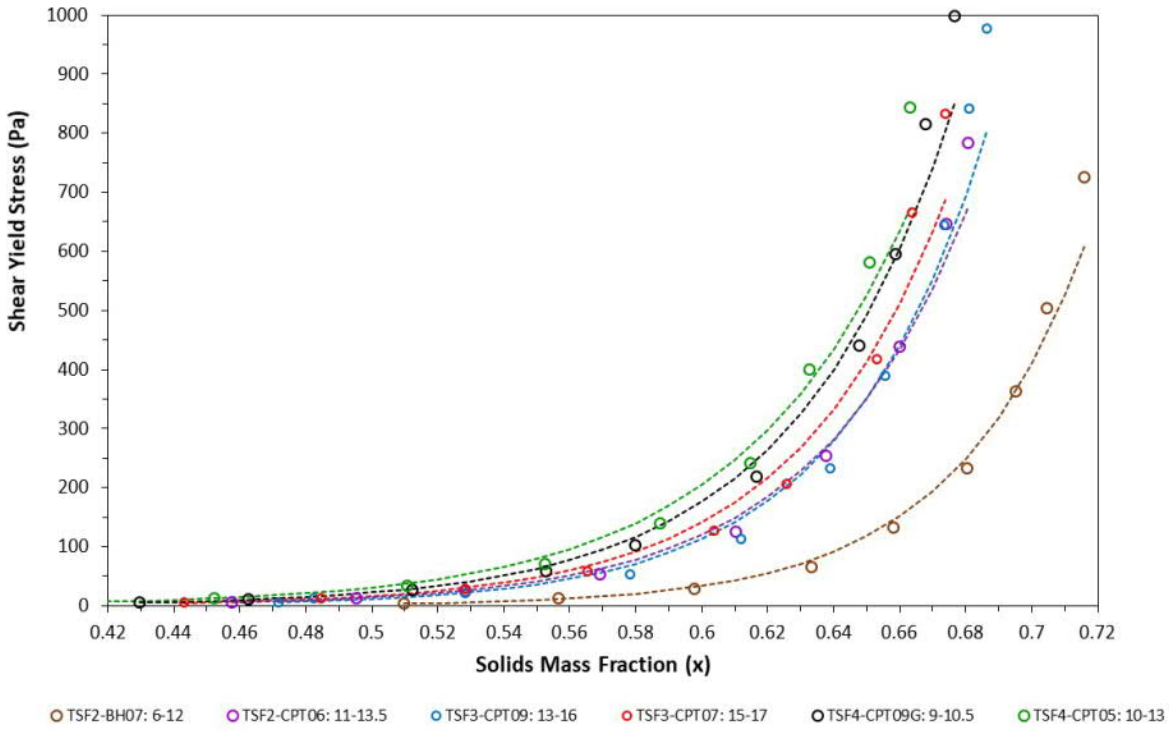


Figure 45: TSF 4 shear yield stress vs mass fraction

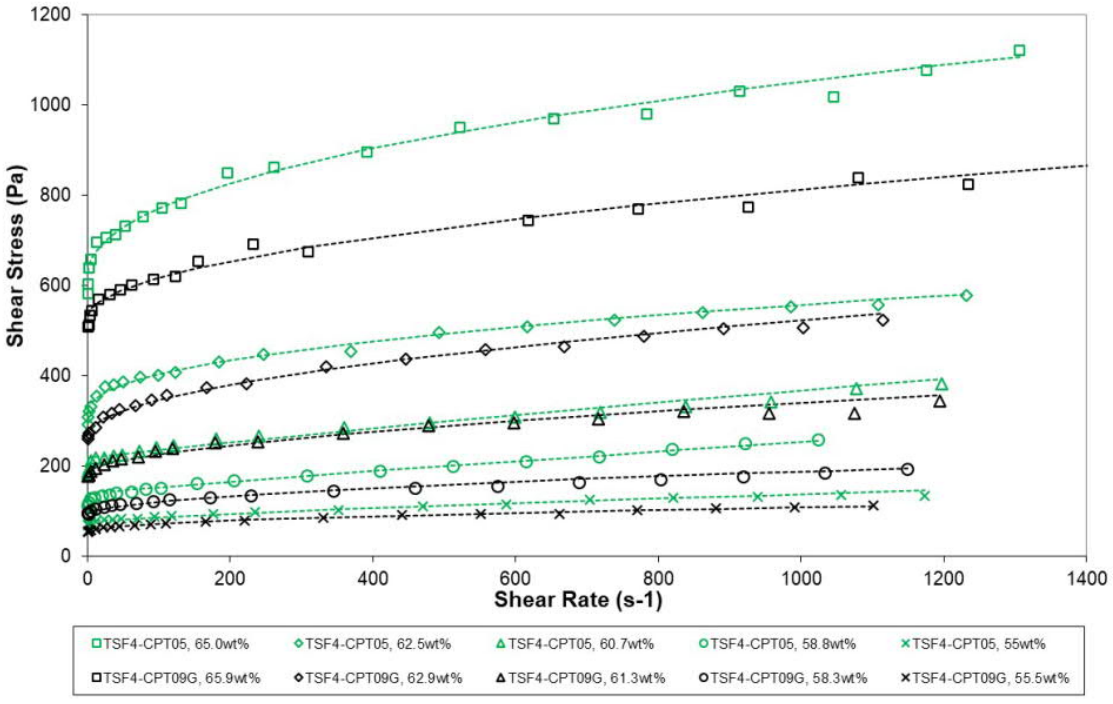


Figure 46: TSF 4 shear stress vs shear rate (All samples).

The yield stress behaviour for the two samples from TSF 4 were similar to each other.

The specific gravity was lower at shallow depths for TSF 4.

In shear flow, all samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates investigated. For all samples, no shear history or time dependence was observed on the time scale of testing. However, it should be noted that all samples were fully sheared prior to testing the sample collection, subsequent sub-sampling and sample preparation methods.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected. The shear stress versus shear rate data was modelled using a Herschel-Bulkley model. The viscosity stress versus shear rate data was well described using a Power Law.

7.2.3 Particle size distribution

The particle size distribution of tailings samples is presented in Table 47.

Table 47: TSF 4 particle size distribution of tailings

Test location	Material	Depth (m BGL)		Particle size distribution		
		From	To	Clay and silt fines (%)	Sand (%)	Gravel (%)
TSF4-CPT03	Tailings	1.50	1.95	58	40	2
TSF4-CPT06	Tailings	8.00	8.80	60	39	1
TSF4-CPT06	Tailings	11.00	11.80	84	16	0
TSF4-CPT07	Tailings	7.50	8.80	92	8	0
TSF4-CPT07	Tailings	10.50	11.30	73	27	0

Particle size distribution curves for individual samples showing clay, silt, sand, and gravel bands is presented in Figure 47.

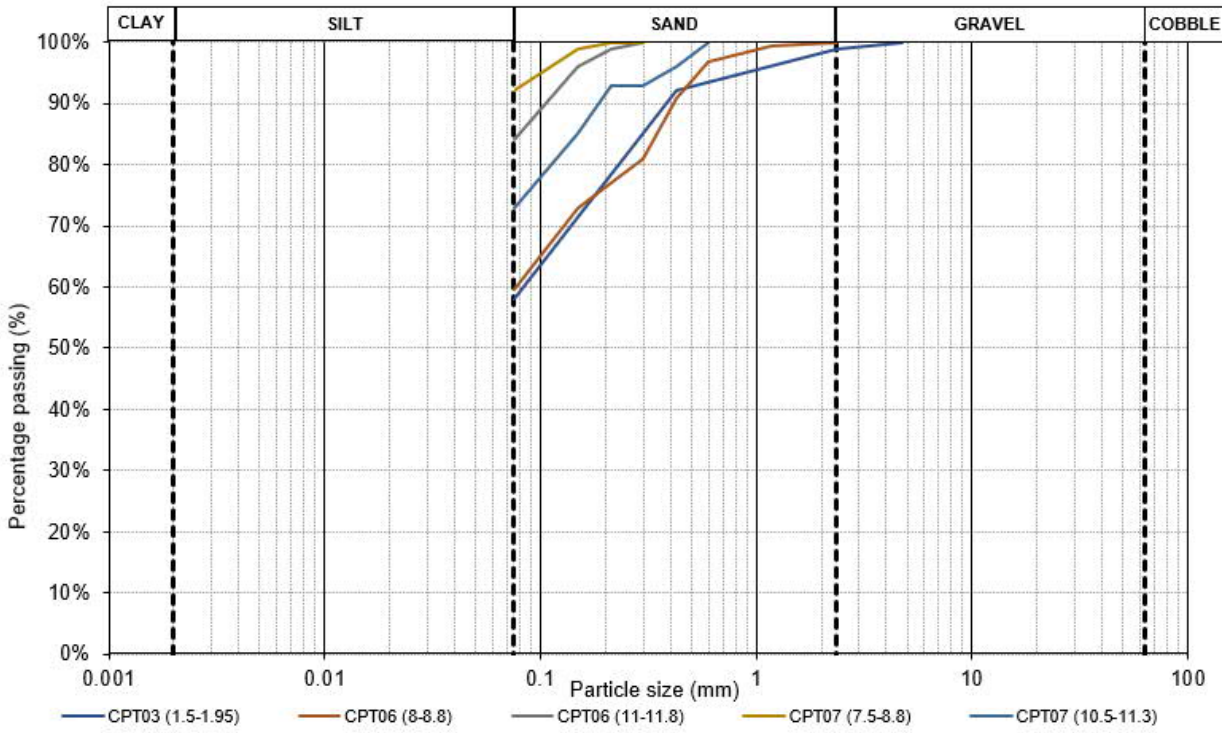


Figure 47: TSF 4 particle size distribution curve

Particle size distribution tests were carried out on five samples of tailings material (EDG Consulting, 2021g):

- Three tests returned results with a higher fines content of between 73% to 92% fines (clay and silt size material), and 8% to 27% of fine to medium grained sand.
- Two tests returned results with a lower fines content of between 58% to 60% fines (clay and silt size material), 40% to 41% fine to coarse grained sand, and up to 1% fine grained gravel.

7.2.4 Atterberg limits testing

The results of the Atterberg limits testing are summarised in Table 48.

Table 48: TSF 4 Atterberg limits of tailings

Test location ID	Depth (m BGL)		Atterberg limits (%)			
	From	To	LL (%)	PL (%)	PI (%)	LS (%)
TSF4-CPT03	1.50	1.95	26	20	6	2.0
TSF4-CPT06	8.00	8.80	35	28	7	-
TSF4-CPT06	11.00	11.80	40	22	18	4.5
TSF4-CPT07	7.50	8.00	41	24	17	6.0
TSF4-CPT07	10.50	11.30	35	22	13	3.5

Note: LL = Liquid Limit; PL = Plastic Limit; PI = Plasticity Index: LS = Linear Shrinkage.

A plot of results on Atterberg limits is shown in Figure 48.

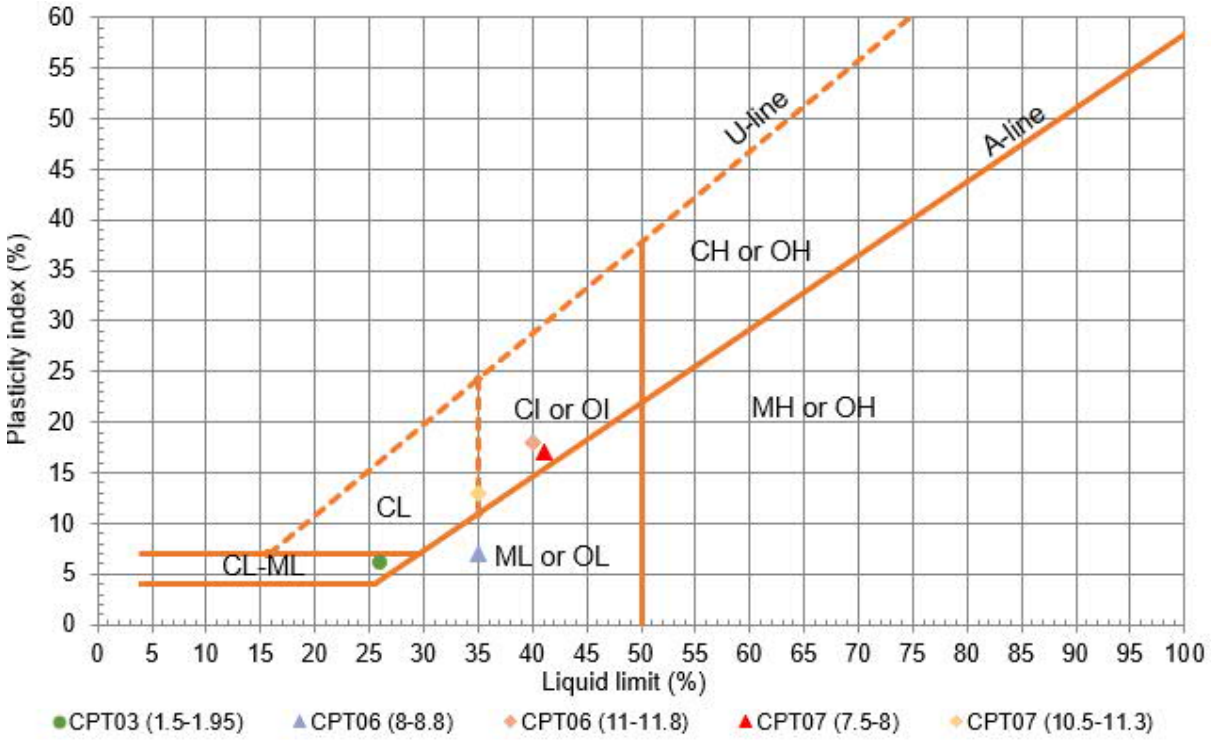


Figure 48: TSF 4 Atterberg limits results

Atterberg limits tests were carried out on the fines fraction of five samples of tailings material. The results were (EDG Consulting, 2021g):

- Liquid Limit generally between 35% and 41%, with one result at 26%.
- Plasticity Index generally between 13% to 18%, with two results at 6% and 7%.
- Four results plots above the A-Line on the Casagrande Chart. One result plot below the A-Line on the Casagrande Chart. Three results plots as CI, Clay of intermediate plasticity, one result plots as CL - ML, Clay/Silt of low plasticity and one result plot as MI, Silt of intermediate plasticity.

7.2.5 Moisture content and dry density profiles

Outlined in Table 49 are the moisture content and dry density profiles for TSF 4.

Table 49: TSF 4 moisture content of tailings

Sample name	Depth (m)		Moisture content (%)	Wet density (t/m^3)	Dry density (t/m^3)
	From	To			
TSF4-CPT07	10.50	-	28.7	1.51	1.17
TSF4-CPT06	11.00	11.80	34.3	1.48	1.10
TSF4-CPT07	7.50	8.00	33.7	1.54	1.15

7.2.6 Shear strength testing and profile

Table 50 presents the profile and results from shear strength testing.

Table 50: TSF 4 vane shear testing results summary

Test Location ID	Depth (m)	Undisturbed shear strength (kPa)	Remoulded shear strength (kPa)	Vane sizes (mm x mm)
TSF4-CPT01	5.8	37	10	50 x 100
	7.5	44	19	50 x 100
	9.0	41	21	50 x 100
	12.0	46	23	50 x 100
	13.5	43	24	50 x 100
TSF4-CPT02	6.4	57	10	50 x 100
	8.5	58	38	50 x 100
	10.9	54	18	50 x 100
	12.7	>82[1]	N/A[1]	50 x 100
TSF4-CPT03	6.0	65	20	50 x 100
	7.9	65	23	50 x 100
	12.0	60	27	50 x 100

Note: [1] Vane reached maximum torque.

Pocket results are presented in Table 51**.**

Table 51: TSF 4 pocket penetrometer results range

Soil type	Shear strength range (kPa)	Note
Unit 4 Tailings	30 to 100	CPT and vane shear tests are generally more suitable for use in soft soil, the undrained shear strength as measured from pocket penetrometer tests has been used with caution

Unconsolidated undrained triaxial test results for TSF 4 materials are presented in Table 52**.**

Table 52: TSF 4 unconsolidated undrained triaxial test

Sample location	Sample type	Sample depth (m)	Yield shear strength (kPa)
TSF4-CPT07	Tailings - Silty clay	10.5 to 11.3	95

Interpreted shear strength profile (Su vs depth) from the raw CPT and borehole data within each 'Shear Strength and Testing material type' is presented in Figure 45.

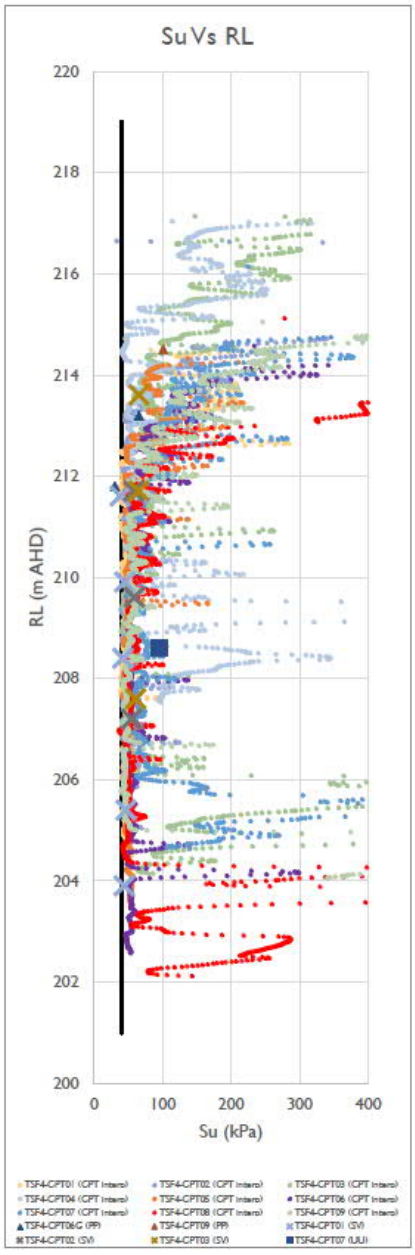


Figure 49: TSF 4 Interpreted shear strength profile for tailings material

7.2.7 Consolidation testing

A summary of the consolidation testing (oedometer test results) is presented in Table 53 to Table 54.

Table 53: TSF 4 consolidation testing – raw CPT06 oedometer test results

Test location ID	Material	Depth (m BGL)	Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t50	Cv (m^2/yr) t90	Mv (kPa-1x10-3)	Ca x 10-3	% Consolidation
CPT06	Tailings	11.00-11.80	1	6-13	0.024	5.10E-09	16.44	20.94	0.779	0.44	0.5
			2	13-24	0.043	3.50E-09	12.82	15.91	0.718	0.60	1.3
			3	24-50	0.052	3.00E-09	23.44	21.62	0.440	0.80	2.5
			4	50-101	0.078	2.00E-09	22.41	19.81	0.328	0.87	4.1
			5	101-200	0.105	1.70E-09	32.33	24.67	0.224	1.05	6.2
			6	200-399	0.075	6.80E-10	33.76	26.59	0.082	0.92	7.7
			7	399-800	0.135	6.10E-10	38.26	26.44	0.075	1.94	10.5
			8	800-1600	0.162	3.10E-10	29.64	21.38	0.046	1.83	13.8

Table 54: TSF 4 TSF consolidation testing – raw CPT07 oedometer test results

Test location ID	Material	Depth (m BGL)	Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t50	Cv (m^2/yr) t90	Mv (kPa-1x10-3)	Ca x 10-3	% Consolidation
CPT07	Tailings	7.50-8.00	1	6-12	0.04	4.10E-09	6.30	9.26	1.412	0.64	0.8
			2	12-24	0.047	3.50E-09	9.01	13.51	0.836	0.87	1.8
			3	24-50	0.063	2.70E-09	13.28	15.55	0.554	1.10	3.3
			4	50-99	0.086	1.90E-09	13.82	16.08	0.378	1.16	5.0
			5	99-199	0.099	1.20E-09	18.77	17.49	0.224	1.39	7.2
			6	199-399	0.11	7.90E-10	22.82	20.22	0.126	1.59	9.5
			7	399-799	0.142	5.80E-10	24.19	22.24	0.084	1.71	12.5
			8	799-1599	0.162	3.10E-10	28.13	20.08	0.049	2.23	16.0

7.2.8 Soil water characteristic curve

A summary of the SWCC results is presented in Table 55.

Table 55: TSF 4 SWCC of tailings

Test location ID	Material	Sample depth (m RL)	Volumetric water content (cm^3/cm^3)				
			0 kPA	10 kPA	33 kPA	100 kPA	1500 kPA
TSF4-CPT06	Tailings	8.00 to 8.80	0.3537	0.2166	0.1578	0.1388	0.0965
TSF4-CPT06	Tailings	11.00 to 11.80	0.3624	0.2638	0.2189	0.1789	0.1547
TSF4-CPT07	Tailings	7.50 to 8.00	0.3806	0.2710	0.2359	0.2017	0.1592

The soil water characteristic curve is presented in Figure 50.

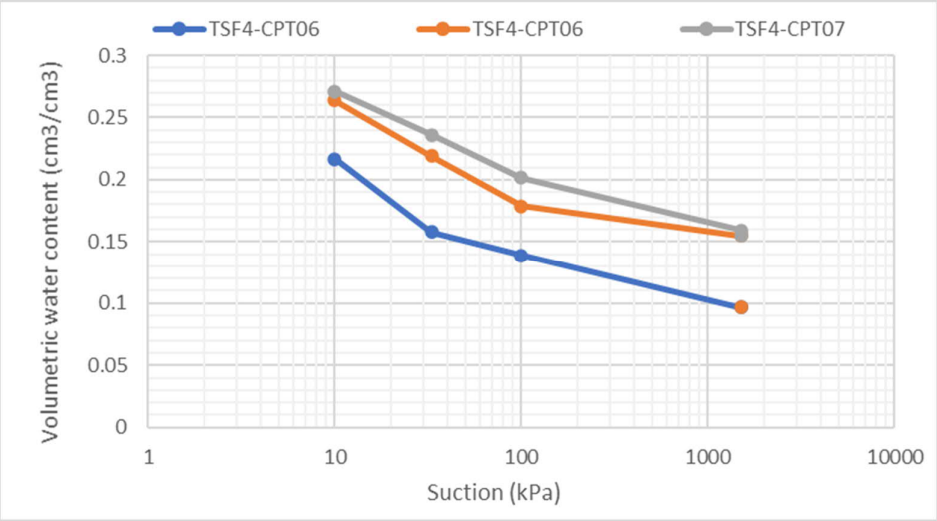


Figure 50: TSF 4 SWCC

7.2.9 Specific gravity

Results for specific gravity are presented in Table 34 in Section 5.2.2

7.3 Tailings Facility Design

7.3.1 Design philosophy

TSF 4 is a hillside turkey's nest style TSF with confining embankments on the north, south, and west sides and small saddle embankments on boxcut spoil in the east.

Currently covered, TSF 4's tailings surface is understood to be capped with a minimum 2 m thick Tertiary/Weathered Permian material overlain by topsoil. The surface is used for vegetation trials. This design concept allows incident rainfall to be collected and stored (during normal rainfall events) in the cover materials and then released through evapo-transpiration with minimal downward movement to the basal layer of the cover. The store and release cover system is graded to shed extreme rainfall events.

7.3.2 Design basis

7.3.2.1 Geotechnical design criteria

TSF 4 is a turkey's nest type TSF constructed in 1984, currently inactive and partially rehabilitated. Crest elevation is at 207 m RL with a maximum height of 22 m adjacent to Ramp 6. It was design with a centre line raise type design, but it has no records.

Key physical features:

- TSF with confining embankments build from coarse rejects
- Steep slopes on northern and western embankments 1.5H:1V
- It does not retain water on surface
- Fully capped facility – 2 m to 2.5 m of cover depth, construction details are unknown
- Revegetated.

Table 56 shows the minimum acceptable FoS adopted for Stability Analysis Loading Conditions and Design Criteria.

Table 56: TSF 4 minimum acceptable FoS

Condition	Adopted FOS	Minimum acceptable FoS
EOC	Short-term undrained (no potential of loss of containment)	1.3
Operational steady state	Long-term drained	1.5
Operational post-seismic	Post-seismic	1.0

Seismic and post-peak assessment indicates that ground motions expected during a 1:10,000AEP earthquake event (Extreme) do not cause liquefaction or cyclic softening of the foundation Residual Soil, Alluvial Soil, Uncontrolled Fill, Tailings, Embankment Fill or Capping Fill. (EDG Consulting, 2021g).

7.3.2.2 Hydraulic design criteria

Surface water management through the store and release cover system. No CCA, no design loading, and no documented engineering assessment available for this facility.

7.3.2.3 Seepage design criteria

The original flow path of Barrett Creek is understood to intersect the footprint of TSF 4 from south-west to north-east.

Based on this fieldwork, the groundwater level is interpreted to be 2 to 3 m below pre-mining natural ground level within the TSF impoundment and below the embankments (EDG Consulting, 2021g). This is except for the south-west corner where the groundwater level is around pre-mining natural ground surface.

7.3.3 TSF operation

TSF 4 is currently inactive and is closed facility. Only monitoring and surveillance activities are being undertaken. These include:

- Dam inspections
- Fortnightly and/or post rainfall events (Responsible Dam Engineer and mine services)
- Annually (Engineer of Record review).

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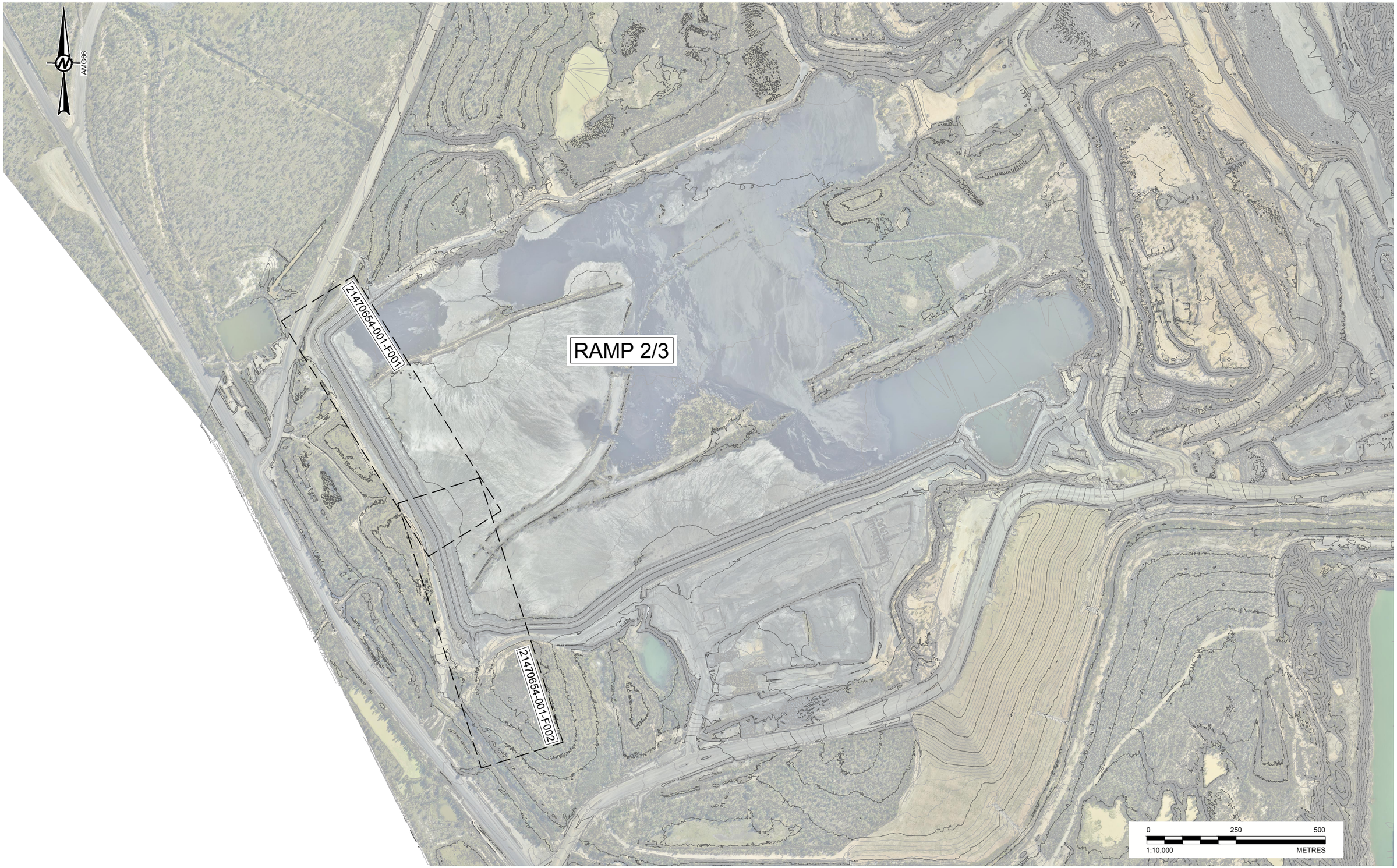
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APPENDIX A

Sample Locations Ramp 2/3 TSF



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BMA

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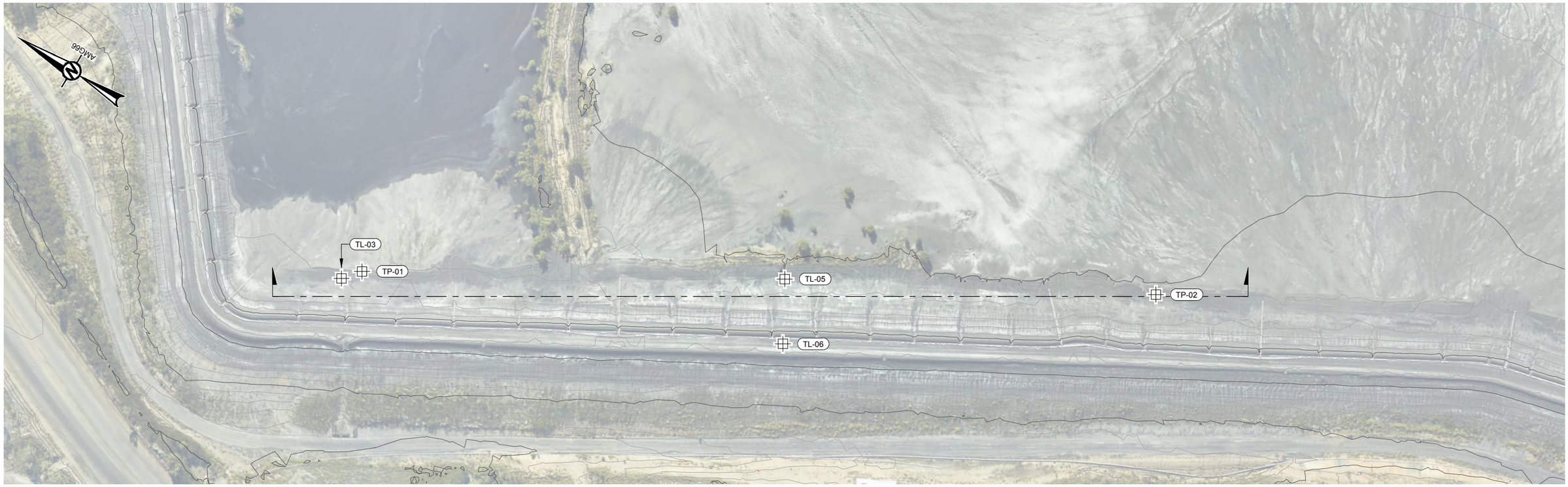
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PROJECT
SARAJI MINE - TAILINGS PRCP
RAMP 2/3

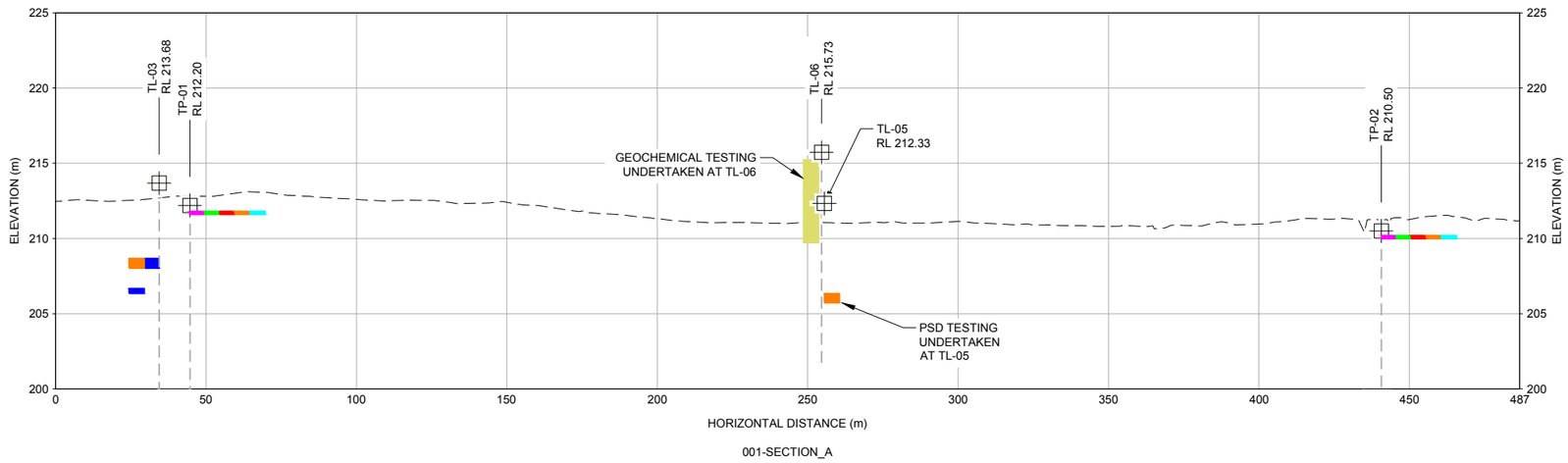
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RAMP 2/3 - COVER SHEET

PROJECT NO.	CONTROL	REV.	FIGURE
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RAMP 2/3 LAYOUT PLAN
SCALE 1:2000



001-SECTION_A

0 50 100
1:2,000 METRES

LEGEND

- EXISTING SURVEY CONTOURS
- EXISTING GROUND PROFILE
- RHEOLOGY TESTING LOCATION
- PSD TESTING LOCATION
- GEOCHEMICAL TESTING LOCATION
- SPECIFIC GRAVITY TESTING LOCATION
- ATTERBERG TESTING LOCATION
- MOISTURE CONTENT AND DRY DENSITY TESTING LOCATION
- SOIL WATER CHARACTERISTIC CURVE LOCATION

CLIENT
BMA

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-09-14
DESIGNED	
PREPARED	DAB
REVIEWED	
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PROJECT
SARAJI MINE - TAILINGS PRCP
RAMP 2/3

TITLE
SAMPLING LOCATIONS PLAN AND SECTION A

PROJECT NO.	CONTROL	REV.	FIGURE
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RAMP 2/3 LAYOUT PLAN
SCALE 1:2000

0 50 100
1:2,000 METRES

LEGEND

- EXISTING SURVEY CONTOURS
- EXISTING GROUND PROFILE
- RHEOLOGY TESTING LOCATION
- PSD TESTING LOCATION
- GEOCHEMICAL TESTING LOCATION
- SPECIFIC GRAVITY TESTING LOCATION
- ATTERBERG TESTING LOCATION
- MOISTURE CONTENT AND DRY DENSITY TESTING LOCATION
- SOIL WATER CHARACTERISTIC CURVE LOCATION

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BMA

CONSULTANT
WSP GOLDER

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PREPARED	DAB
REVIEWED	
APPROVED	

PROJECT
SARAJI MINE - TAILINGS PRCP
RAMP 2/3

TITLE
SAMPLING LOCATIONS PLAN AND SECTION B

PROJECT NO.	CONTROL	REV.	FIGURE
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APPENDIX B

Laboratory Certificates Ramp 2/3 TSF

Rheology Testwork for Tailings Storage Facility Failure Impact Assessments (FIAs) for Saraji Mine Ramp 2/3 Tailings

A Report submitted to:

BHP Mitsubishi Alliance

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25th June 2021

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SUMMARY

BHP Billiton Mitsubishi Alliance owns and operates several coal operations in the Bowen Basin, in Central Queensland, which produces semi-hard coking and hard coking coal products, including the Saraji Mine.

BHP has committed to reducing the inherent risk of all tailings storage facilities (TSFs) across the BMA portfolio. Several internal risk reviews of each of the TSFs have been conducted across BMA. The Saraji Mine (SRM) Ramp 2/3 tailings are sourced from was two parallel adjacent ramps that have been filled with tailings, with a ring dyke around both. It is now a large above ground tailings storage facility. The tailings deposit requires further investigation and assessment works (failure impact analysis, FIA) to better understand the geological setting, historical design, construction, and operation, to understand risk levels. If required, preventative and/or mitigative measures to reduce the TSF's risk profile can then be implemented.

Rheology testing was required to inform parts of the FIA and to this end, samples from the TSF were provided for determination of the tailings physical and rheological properties including the as-received solids content and solids specific gravity. Measurement of the shear yield stress profile and viscous properties of each of the tailings samples over the concentration range of interest to FIA was also conducted.

SRM Ramp 2/3 tailings samples were received at concentrations ranging from approximately 73wt% to 75wt%. Solids SGs ranged from 1.93 to 1.99.

The shear yield stress of all tailings samples tested increased exponentially with solids concentration across the range of solids concentrations investigated and model parameters are provided. The TP01 sample had the highest yield stress for a given solids concentration above approximately 45wt% solids. The TP02 had intermediate values, while the TP03 had the lowest yield stress for all concentrations above approximately 50wt%.

In shear flow, all samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates investigated. No shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due the sample collection, subsequent sub-sampling and sample preparation methods, so irreversible changes due to shearing would not be observed.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected and the shear stress versus shear rate data was modelled using a Herschel-Bulkley model. The viscosity stress versus shear rate data was well described using a Power Law.

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1 INTRODUCTION

BHP Billiton Mitsubishi Alliance owns and operates several coal operations in the Bowen Basin, in Central Queensland, which produces semi-hard coking and hard coking coal products, including the Saraji Mine.

BHP has committed to reducing the inherent risk of all tailings storage facilities (TSFs) across the BMA portfolio. Several internal risk reviews of each of the TSFs have been conducted across BMA. The Saraji (SRM) Ramp 2/3 tailings are sourced from was two parallel adjacent ramps that have been filled with tailings, with a ring dyke around both. It is now a large above ground tailings storage facility. The tailings deposit requires further investigation and assessment works (failure impact analysis, FIA) to better understand the geological setting, historical design, construction, and operation, to understand risk levels. If required, preventative and/or mitigative measures to reduce the TSF's risk profile can then be implemented.

Rheology testing was required to inform parts of the FIA and to this end, samples from the TSF were provided for determination of the tailings physical and rheological properties including the as-received solids content, solids density and tailings in-situ dry density. Measurement of the shear yield stress profile and viscous properties of each of the tailings samples over the concentration range of interest to FIA was also conducted.

2 SAMPLE RECEIPT and PREPARATION

Three samples listed in Table 1 were provided to RCS. Coordinates are shown in Table 1 and the corresponding map is provided as Figure 1 overleaf.

Table 1 Samples received and prepared by RCS

SRM Ramp 2/3				
Bucket Label	**Location**	**Easting**	**Northing**	**Elevation**
TP-01 (x2)	TP-01	630333.1	7524749	212.2
TP-02 (x2)	TP-02	630533.1	7524407	210.5
TP-03 (x2)	TP-03	630672.9	7524048	210.3

Upon receipt, samples were sheared prior to determination of the as received solids concentration.

Prior to yield stress and viscosity testing, samples were concentrated via centrifugation, if required, to a high solids concentration for initial yield stress testing or diluted as required using Melbourne tap water.

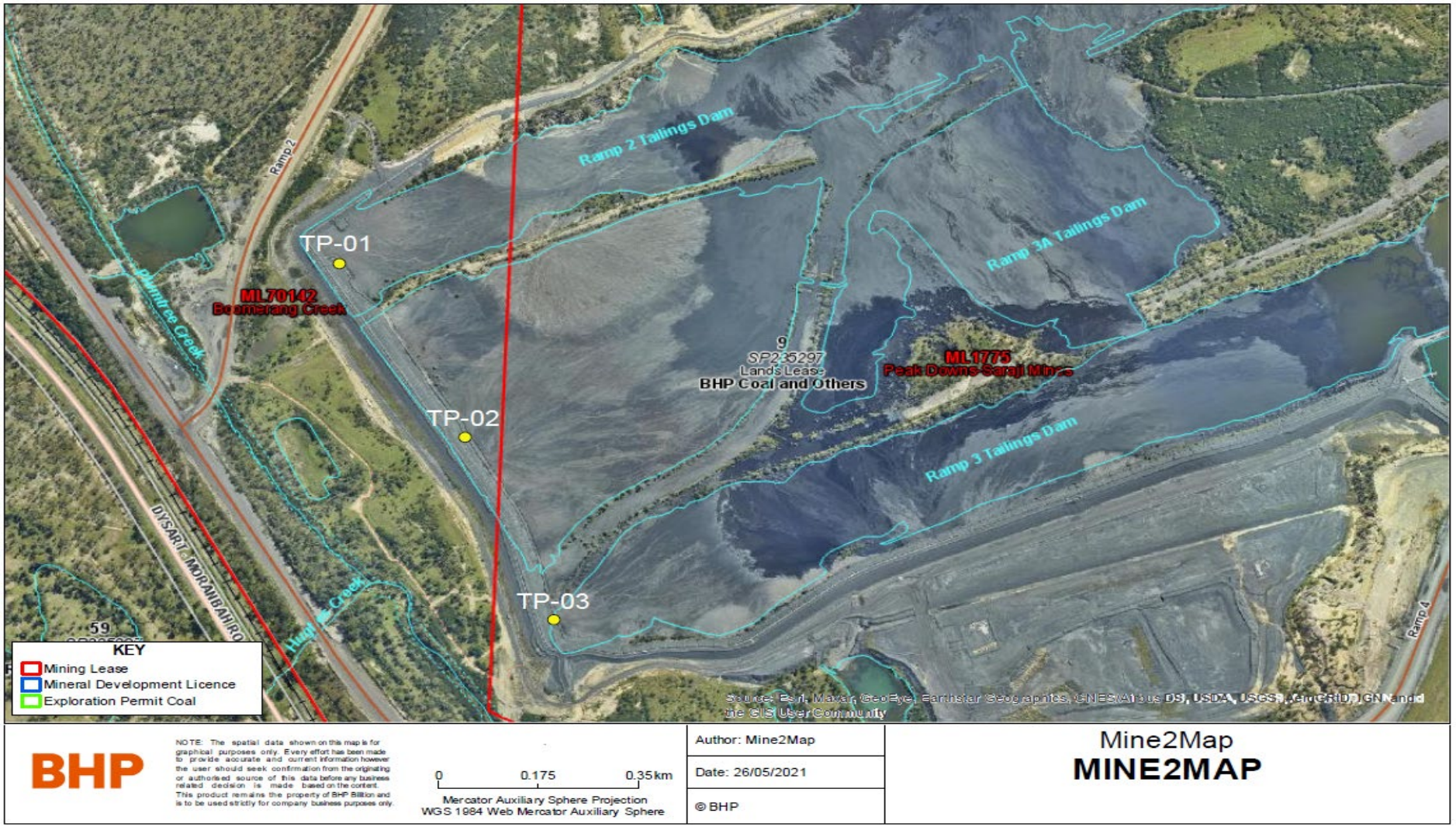


Figure 1. SRM Ramp 2/3 tailings sample sites

3 GRAVIMETRIC ANALYSES

3.1 As received solids concentration

The solids concentration of the prepared samples was determined by oven drying samples to constant dry mass.

Table 2 lists the measured solids concentrations.

Table 2. As received SRM Ramp 2/3 sample solids concentrations.

Sample name	Solids concentration (wt%)
TP-01	75.0
TP-02	74.4
TP-03	73.4

3.2 Specific Gravity

The solids specific gravity of the tailings was determined by measuring the density of a known volume (~100 cm^3) of slurried sample, and subsequently measuring the solids concentration of the slurry via oven drying to constant mass. By separately measuring the density for the water present in the sample under the same conditions, the density of the solid phase may be calculated using Equation 1 and the solids specific gravity subsequently determined. Results for the samples tested are shown in Table 3.

$$\rho_P = \frac{x\rho_s}{\left(1 - \frac{\rho_s}{\rho_L}(1-x)\right)}$$

Equation 1

Where: ρ_P is the particle (solids) density (kgm^{-3})
ρ_s is the slurry density (kgm^{-3})
ρ_L is the liquor density (kgm^{-3})
x is the solids mass fraction (-)

Solids SGs ranged from 1.79 to 2.08.

Table 3. SRM Ramp 2/3 sample gravimetric analysis results

Sample name	Solids SG
TP-01	1.93
TP-02	1.99
TP-03	1.95

4 YIELD STRESS MEASUREMENTS

Yield stress measurements were conducted using the vane-shear method [1-4]. Many workers worldwide have adopted the vane-shear method and confirmed its applicability for numerous types of yield stress materials [5-9].

4.1 Experimental Procedure

Samples to be tested are placed in a plastic container and tapped on the laboratory bench to remove entrained air bubbles. A vane of suitable dimensions for the yield stress range under consideration is selected and attached to the rheometer. The container is placed on a stand under the vane and raised using a manual scissor lift to immerse the vane in the centre of the sample. The vane is then rotated at a rate of 0.2 rpm and the maximum torque response of the sample is recorded. The yield stress is calculated using the maximum torque reading and Equation 1. All yield stress measurements are taken in triplicate to ensure reproducibility of results.

$$\tau_y = \frac{T_m}{\pi D_v^2\left(\frac{L_v}{2}+\frac{D_v}{6}\right)} \qquad \textbf{Equation 2}$$

Where τ_y is the calculated yield stress, T_m is the maximum torque experienced by the vane, D_v is the vane diameter and L_v is the vane length.

To ensure that wall and end effects are absent, vanes of varying dimensions are used for each material. Nguyen and Boger [3] suggest that the diameter and depth of the container should be at least twice as large as the diameter and length of the vane to minimise any effects caused by the rigid boundaries.

4.2 Results and Discussion

The shear yield stress profiles of the SRM Ramp 2/3 tailings are given in Figure 2. The shear yield stress of all tailings samples increased exponentially with solids concentration across the range of solids concentrations investigated.

The yield stress versus solids concentration (mass fraction) curves for the SRM Ramp 2/3 tailings were modelled using an exponential trendline (shown as a dashed line in Figure 2). Model parameters are given in Table 4 below. The TP01 sample had the highest yield stress for a given solids concentration above approximately 45wt% solids. The TP02 had intermediate values, while the TP03 had the lowest yield stress for all concentrations above approximately 50wt%.

Table 4. Yield stress profile model parameters

Sample	Exponential Variables ($\tau_y=ae^{bx}$)	
	a	***b***
TP01	4.3741E-03	17.77
TP02	1.2238E-03	18.92
TP03	8.5935E-04	19.07

Where τ_y is the yield stress (*Pa*) and x is the solids mass fraction.

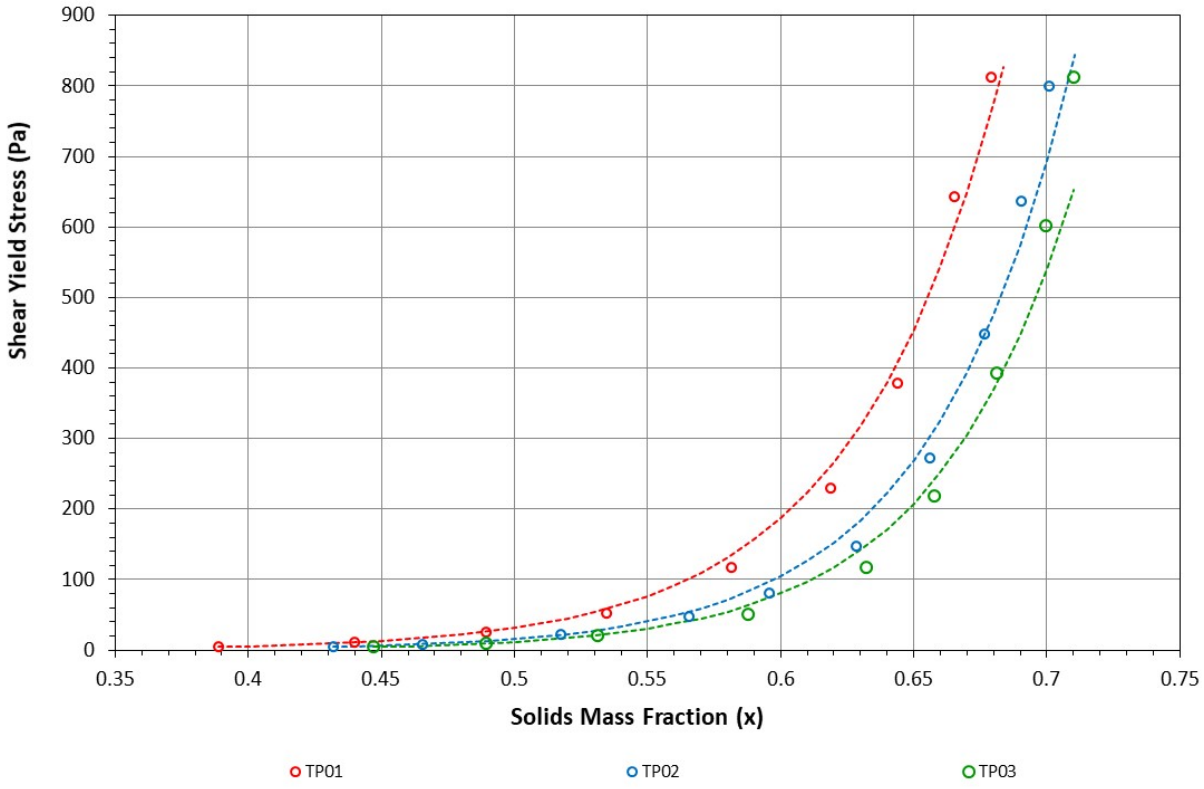


Figure 2 Shear yield stress (τ_y) vs. solids mass fraction (x) for SRM Ramp 2/3P Tailings. See Table A 1 for tabulated data

5 SHEAR STRESS VS SHEAR RATE MEASUREMENTS

The shear stress (hence viscosity) of each of the coal tailings samples was measured as a function of shear rate at five solids concentrations per sample. These solids concentrations were based on yield stress profile results and are shown in Table 5 and were chosen to cover a yield stress range of 10 to 500 Pa.

Measurements were conducted on fully sheared samples at ambient temperature with a Haake VT550 controlled strain rheometer using either vane (for high yield stress) or bob in cup geometry (low yield stress) as appropriate.

Table 5 Measured solids concentrations for SRM Ramp 2/3 tailings flow behaviour testing

Sample	Sample weight fraction (wt%)				
	Min (τ_y=10)	2	3	4	Max* (τ_y=500)
TP01	0.435	0.490	0.545	0.600	0.655
TP02	0.480	0.530	0.580	0.630	0.680
TP03	0.490	0.540	0.590	0.640	0.700

5.1 Experimental Procedure

Samples to be tested were either centrifuged and process water decanted or diluted to achieve the desired solids concentration for the test. Samples were placed in the test vessel and tapped on the laboratory bench to remove entrained air bubbles. The vessel was then placed on a stand under the bob or vane fixture and raised, using a manual scissor lift, to immerse the fixture in the centre of the sample. The fixture was then rotated at a constant rate, N *(rpm)*, and the torque experienced by the fixture was recorded, T *(μNm)*. This process was then repeated at successively increasing rotational rates with the sample homogenised via hand mixing between each measurement. The shear stress was measured at each successive rotational rate and the shear stress vs shear rate relationship (hence viscosity vs shear rate relationship) was determined as per [10] and [11].

5.2 Results and Discussion

The shear stress of the SRM Ramp 2/3 tailings samples is given as a function of shear rate in Figure 3 to Figure 5, and the shear viscosity is given as a function of shear rate in Figure 6. All samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates investigated. No shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due the sample collection, subsequent sub-sampling and sample preparation methods, so irreversible changes due to shearing would not be observed.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected.

The shear stress versus shear rate data was modelled using a Herschel-Bulkley model:

$\tau = \tau_y + K\dot{\gamma}^n$, where τ is the shear stress (*Pa*) and $\dot{\gamma}$ is the shear rate (s^{-1}) (shown as dashed lines in Figure 3 to Figure 5). The parameters for these curves are given in Table A2 in the Appendix. Note that model parameters are only valid over the shear rate range measured.

The viscosity stress versus shear rate data was curve fitted using a Power Law model:

$\eta = a\dot{\gamma}^b$, where η is the shear viscosity (*Pa.s*) and $\dot{\gamma}$ is the shear rate (s^{-1}), (shown as a dashed line in Figure 6). The parameters for these curves are given in Table A3 in the Appendix. Note that model parameters are only valid over the shear rate range measured.

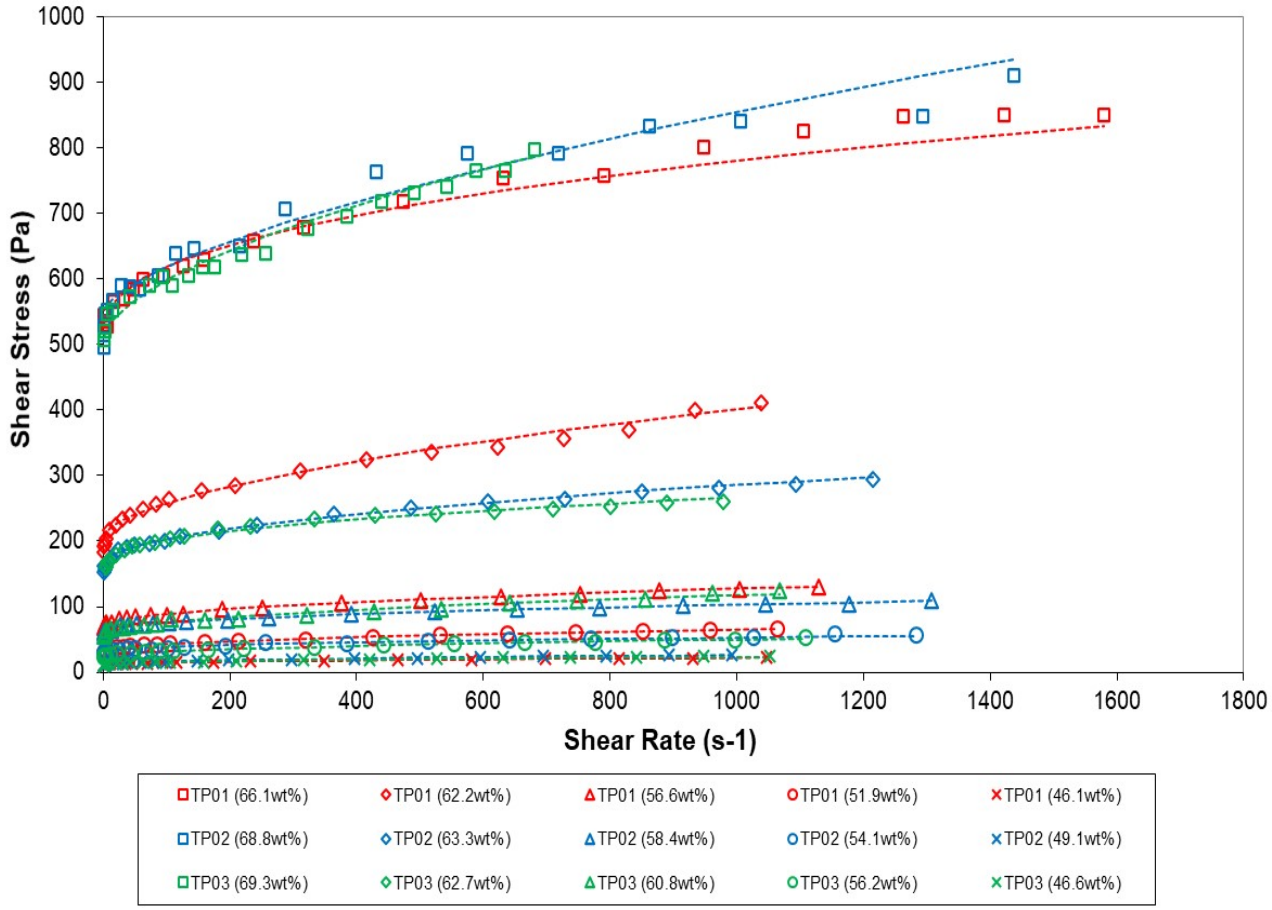


Figure 3 – Shear stress vs. shear rate for all SRM Ramp 2/3 samples.

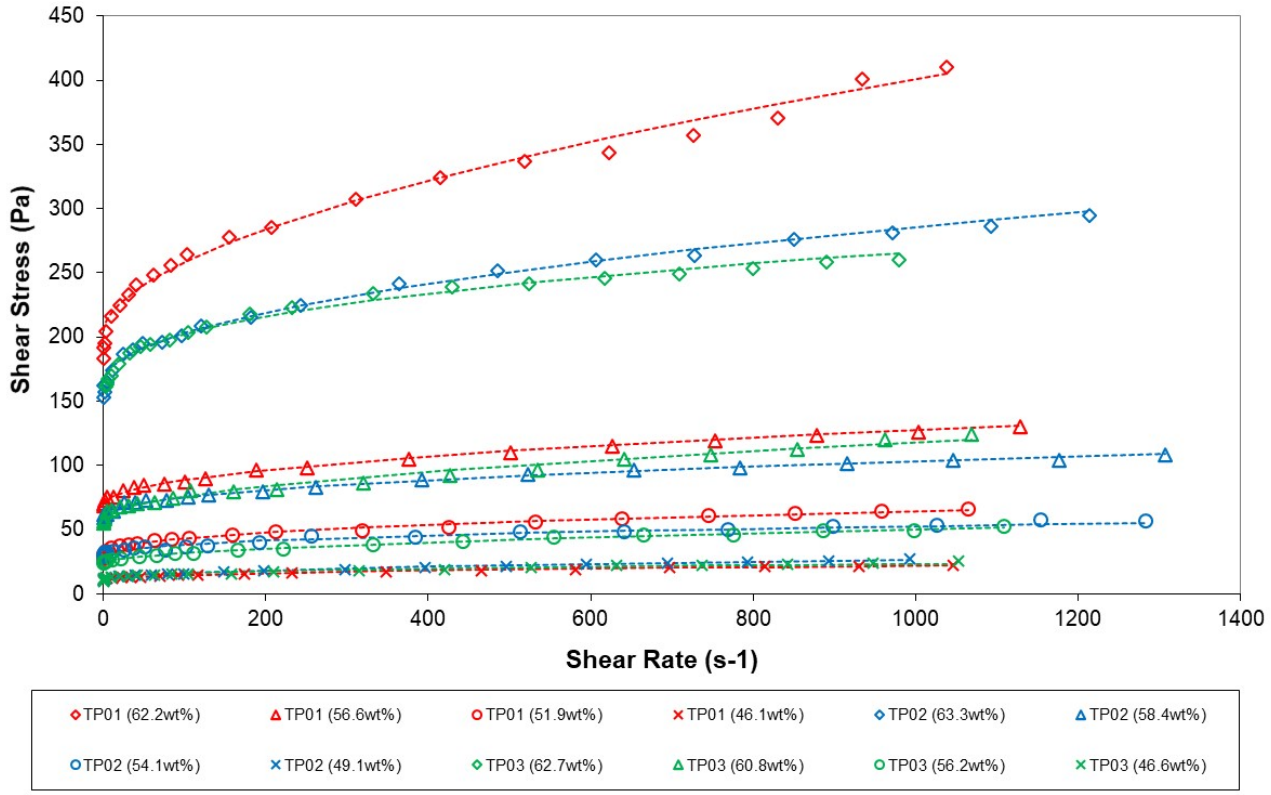


Figure 4 – Shear stress vs. shear rate for low concentration SRM Ramp 2/3 samples.

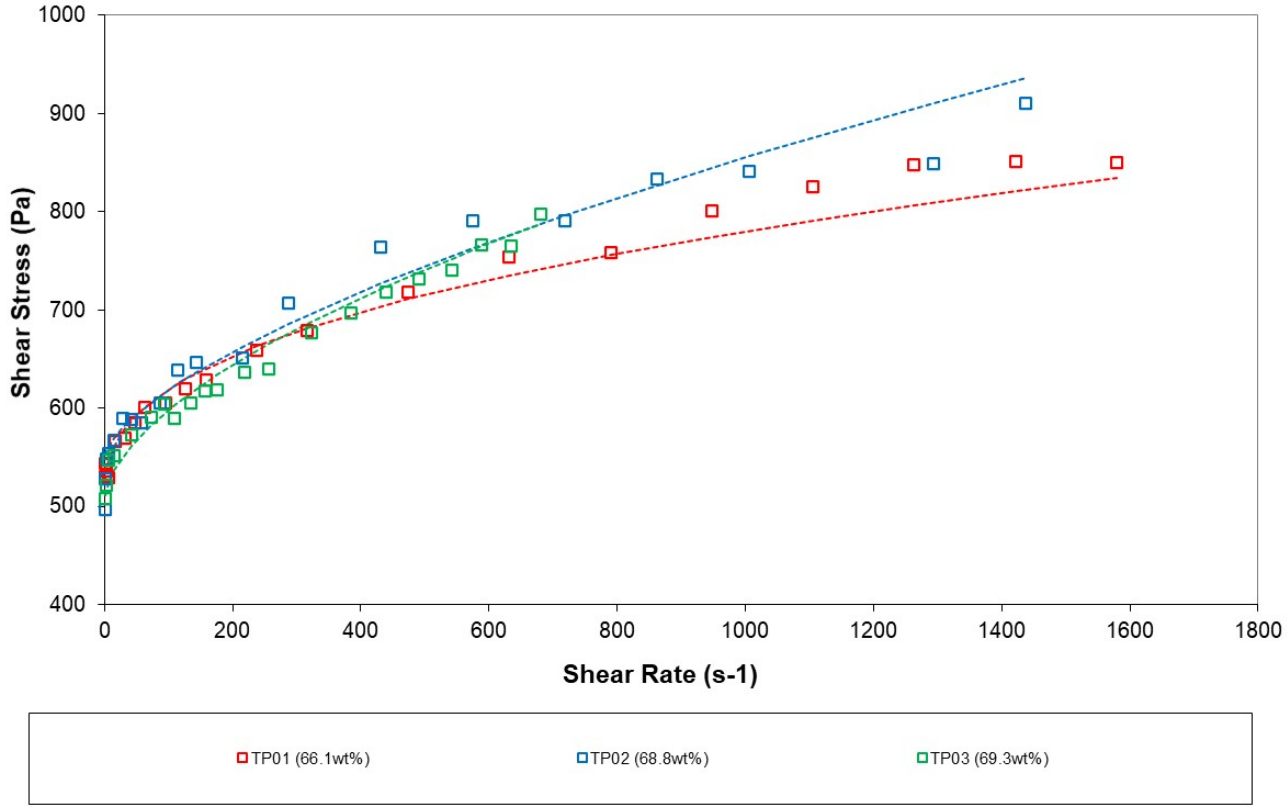


Figure 5 – Shear stress vs. shear rate for high concentration SRM Ramp 2/3 samples.

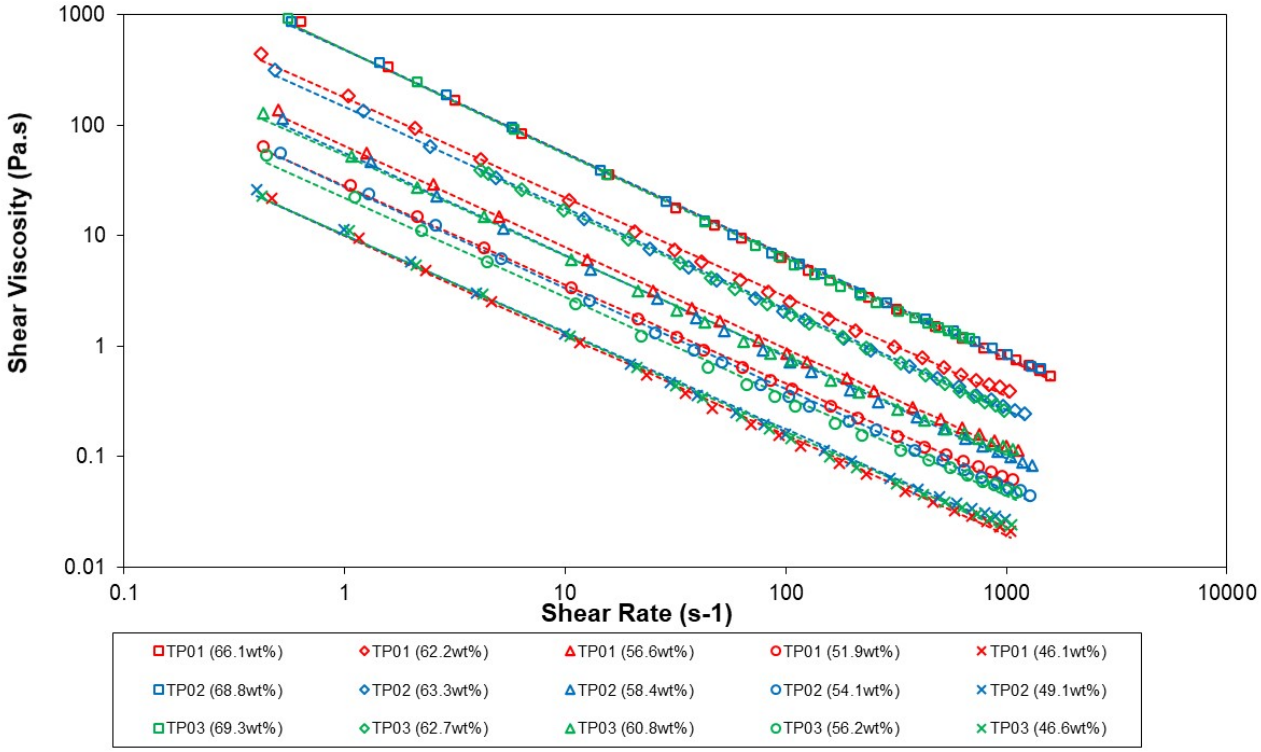


Figure 6 Shear viscosity vs. shear rate for SRM Ramp 2/3 samples.

6 CONCLUSION

SRM Ramp 2/3 tailings samples were received at concentrations ranging from approximately 73wt% to 75wt%. Solids SGs ranged from 1.93 to 1.99.

The shear yield stress of all tailings samples tested increased exponentially with solids concentration across the range of solids concentrations investigated and model parameters are provided. The TP01 sample had the highest yield stress for a given solids concentration above approximately 45wt% solids. The TP02 had intermediate values, while the TP03 had the lowest yield stress for all concentrations above approximately 50wt%.

In shear flow, all samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates investigated. No shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due the sample collection, subsequent sub-sampling and sample preparation methods, so irreversible changes due to shearing would not be observed.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected and the shear stress versus shear rate data was modelled using a Herschel-Bulkley model. The viscosity stress versus shear rate data was well described using a Power Law.

A APPENDIX

A1 Shear Yield Stress Data

Table A 1 - Solids mass fraction (x) versus yield stress (τ_y) data for SRM Ramp 2/3 Samples

TP01		TP02		TP03	
Solids Mass Fraction	Yield Stress	Solids Mass Fraction	Yield Stress	Solids Mass Fraction	Yield Stress
x	τ_y (Pa)	x	τ_y (Pa)	x	τ_y (Pa)
0.389	5.14	0.432	5.14	0.447	5.14
0.440	10.80	0.466	8.23	0.489	10.29
0.489	25.47	0.517	22.90	0.531	20.06
0.534	51.83	0.566	47.07	0.588	51.19
0.581	117.55	0.596	81.54	0.632	118.05
0.619	229.05	0.629	147.90	0.658	218.40
0.644	379.15	0.656	272.15	0.681	392.30
0.665	642.25	0.677	448.55	0.700	602.40
0.679	813.15	0.690	637.15	0.710	812.60
0.684	992.80	0.701	799.20	0.716	1004.00

Shear stress vs shear rate model parameters

The shear stress versus shear rate data was curve fitted using a Herschel-Bulkley model :

$\tau = \tau_y + K\dot{\gamma}^n$, where τ is the shear stress (*Pa*) and $\dot{\gamma}$ is the shear rate (s^{-1}) (shown as a dashed line in Figure 3 to Figure 5). The parameters for these curves are given in Table A2 below. Note that model parameters are only valid over the shear rate range measured.

Table A2 Herschel Bulkley model parameters for SRM Ramp 2/3 rheology testing.

Shear Stress Table:	***Herschel Bulkley Model: $\tau=\tau_y+K\gamma^n$***				
sample	τ_y	***K***	***n***	**min shear rate**	**max shear rate**
TP01 (66.1wt%)	511.7	17.04	0.3992	0.63	1579.25
TP01 (62.2wt%)	203.0	4.26	0.5557	0.42	1037.65
TP01 (56.6wt%)	68.5	2.32	0.4687	0.50	1128.99
TP01 (51.9wt%)	29.3	2.16	0.4031	0.43	1064.17
TP01 (46.1wt%)	10.0	0.68	0.4139	0.46	1046.24
TP02 (68.8wt%)	550.5	3.37	0.6518	0.57	1437.08
TP02 (63.3wt%)	163.3	4.16	0.4897	0.49	1214.00
TP02 (58.4wt%)	60.8	1.71	0.4648	0.52	1307.04
TP02 (54.1wt%)	27.8	1.96	0.3676	0.51	1282.56
TP02 (49.1wt%)	10.0	0.95	0.4097	0.40	992.06
TP03 (69.3wt%)	506.6	6.16	0.5857	0.55	680.02
TP03 (62.7wt%)	159.3	6.93	0.3963	4.12	978.86
TP03 (60.8wt%)	57.6	1.70	0.5163	0.43	1068.35
TP03 (56.2wt%)	24.2	0.62	0.5412	0.44	1108.24
TP03 (46.6wt%)	10.8	0.88	0.3830	0.42	1052.35

The viscosity stress versus shear rate data was curve fitted using a Power Law model: $\eta = a\dot{\gamma}^b$, where η is the shear viscosity (*Pa.s*) and $\dot{\gamma}$ is the shear rate (s^{-1}), (shown as a dashed line in Figure 6). The parameters for these curves are given in Table A3 below. Note that model parameters are only valid over the shear rate range measured.

Table A3. Power law model parameters for SRM Ramp 2/3 rheology testing.

Viscosity Table:	***Power Law Model $\eta=K\dot{\gamma}^n$***			
sample	***K***	***n***	**min shear rate**	**max shear rate**
TP01 (66.1wt%)	484.7	-0.9337	0.63	1579.25
TP01 (62.2wt%)	177.0	-0.8991	0.42	1037.65
TP01 (56.6wt%)	64.9	-0.9165	0.50	1128.99
TP01 (51.9wt%)	28.1	-0.8924	0.43	1064.17
TP01 (46.1wt%)	10.0	-0.9037	0.46	1046.24
TP02 (68.8wt%)	480.1	-0.9271	0.57	1437.08
TP02 (63.3wt%)	146.2	-0.9137	0.49	1214.00
TP02 (58.4wt%)	55.8	-0.9199	0.52	1307.04
TP02 (54.1wt%)	27.6	-0.9145	0.51	1282.56
TP02 (49.1wt%)	10.2	-0.8818	0.40	992.06
TP03 (69.3wt%)	481.6	-0.9398	0.55	680.02
TP03 (62.7wt%)	139.3	-0.9125	4.12	978.86
TP03 (60.8wt%)	52.9	-0.9020	0.43	1068.35
TP03 (56.2wt%)	22.0	-0.8978	0.44	1108.24
TP03 (46.6wt%)	10.2	-0.8908	0.42	1052.35

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Trilab
Soil Rock Calibration

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Ph: +61 8 9258 8323

PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	Red Earth Engineering Pty Ltd	**Report No.**	21080558-G
		Workorder No.	9023
Address	108 Bowen Street, Spring Hill, QLD 4000	**Report Date**	13/09/2021
Project	J20100 - Saraji Mine Ramp 2-3		

Sample No.	21080558	21080559	21080560	21080561			
Test Date	6/09/2021	6/09/2021	6/09/2021	6/09/2021			
Client ID	TL-03	TL-05	TL-11	TL-11			
Depth (m)	5.00-5.65	6.00-6.60	12.50-13.15	15.00-15.65			
Moisture (%)	27.7	17.5	28.0	23.1			
AS SIEVE SIZE (mm)	**PERCENT PASSING**						
150							
75							
63							
53							
37.5							
26.5							
19							
13.2							
9.5							
6.7							
4.75		100		100			
2.36		99		99			
1.18	100	98	100	99			
0.600	96	93	97	96			
0.425	91	90	90	93			
0.300	85	88	83	88			
0.212	84	88	78	88			
0.150	69	83	68	78			
0.075	59	80	58	67			

NOTES/REMARKS:

Sample/s supplied by the client

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Park

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.
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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

SOIL WATER ANALYSIS (SWA)

soilwater GROUP
45 Gladstone St
East Perth WA 6006
(08) 9228 3060
(08) 9228 3210
admin@soilwatergroup.com
www.soilwatergroup.com

TEST REPORT

Client: Red Earth Engineering
Client Contact: Michael Deacon
Client Job Title: Saraji Mine Ramp 2 & 3
Client Reference: **J201000**

SWA Job No: JN0760

Date of Analysis: 1st - 27th September 2021
No. Samples Submitted: 3
Sample(s) Condition: Disturbed (loose) sample

METHODOLOGY

- Gravimetric moisture content determined in accordance with AS 1289.2.1.1-2005.
- Atterberg limits determined in accordance with AS1289.3.1.1; AS 1289 3.2.1 & AS 1289.3.3.1.
- Specific gravity (ρ_p) determined in accordance with AS 1289.3.5.1-1995.
- Particle size distribution determined in accordance with AS 4816.1-2002 & AS 1289.3.6.1-1995

TEST RESULTS

SWA ID	**760-1**	**760-2**	**760-3**
Client ID	**TP01, 0.4-0.6m**	**TP02, 0.3-0.5m**	**TP03, 0.3-0.5m**
Grav. Moisture Content (%)	NR	NR	NR
Specific Gravity (g/cm^3)	1.76	2.00	1.72
Particle Size Distribution:			
% Sand (2 - 0.02mm)	68.16	72.06	66.27
% Silt (0.02 - 0.002mm)	19.54	18.27	17.84
% Clay (<0.002mm)	12.30	9.67	15.89
Texture	Loam	Loamy Sand	Loam
Wet Screening:	% Passing		
2mm	100	100	100
1.18mm	99.10	99.42	97.40
0.6mm	92.59	94.20	89.53
0.425mm	87.88	90.08	84.73
0.3mm	82.74	82.10	80.23
0.212mm	77.67	74.04	76.14
0.15mm	73.10	69.18	71.98
0.075mm	66.87	64.00	65.63
Atterberg Limits:			
• Liquid Limit (%, g/g)	35.84	34.22	34.61
• Plastic Limit (%, g/g)	26.35	23.58	23.90
• Plasticity Index	9.49	10.64	10.71

CARDNO (QLD) PTY LTD

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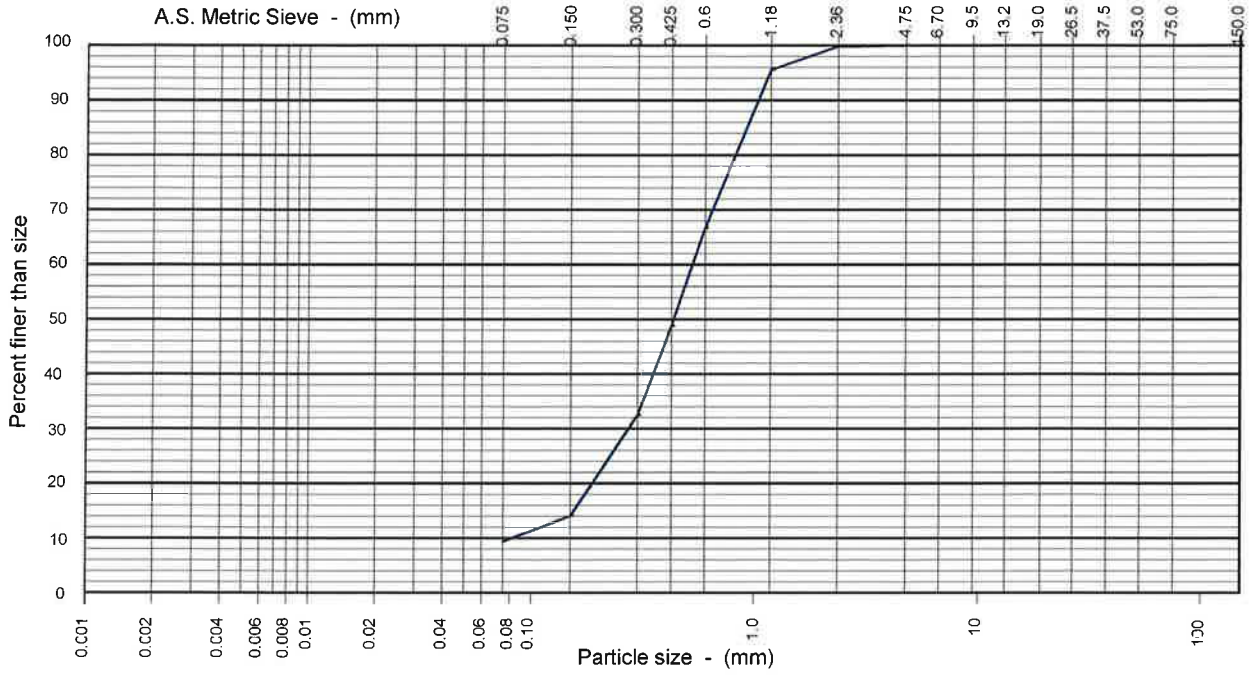
(-/8/16)

71 CONNORS ROAD MACKAY QLD
REPORT ON SOIL CLASSIFICATION

Sheet 1 of 1

Mackay Laboratory

CLIENT:	SRK Consulting (Australasia) Pty Ltd	**JOB NO:**	U24184	**LAB REF NO:**	17-0154ABD
PROJECT:	BMA Saraji Ramp 2/3 Tailings Dam Site (BMA019)	**SAMPLED BY:**	Cardno	**DATE:**	17-27.1.17
LOCATION:	Tailings 1B	**TESTED BY:**	DH,CD	**DATE:**	18-22.2.17
MATERIAL:	Tailings	**CHECKED BY:**	CD,DH	**DATE:**	21.2.17
TEST PROCEDURES:	AS1289.3.1.1,3.2.1,3.3.1,3.4.1,3.6.1,3.8.1	**CLIENT REF:**	-		



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
9				13	45	33	0	0	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0			
37.5			
19.0			
9.5			
4.75			
2.36	100		
1.18	96		
0.600	67		
0.425	49		
0.300	32		
0.150	14		
0.075	9		

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
Not Obtainable	Non Plastic	Non Determinable	-	-

Classification: Sand; fine to coarse grianed

(SM)

Emerson Class No: 4 Temp of Water: 24°C Type of Water Used: Distilled

Sampling Method - AS 1289.1.2.1 (6.5.3)

Preparation History of Atterberg Limits

Sample : ~~Natural~~/Air Dried/~~Oven~~

Sieved: ~~Wet~~/dry

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

NATA

Accredited No. 910

Certificate No. 17-0154A

Date of Issue 21.2.17

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Authorised Signatory D. Hoskins

D. Hoskins

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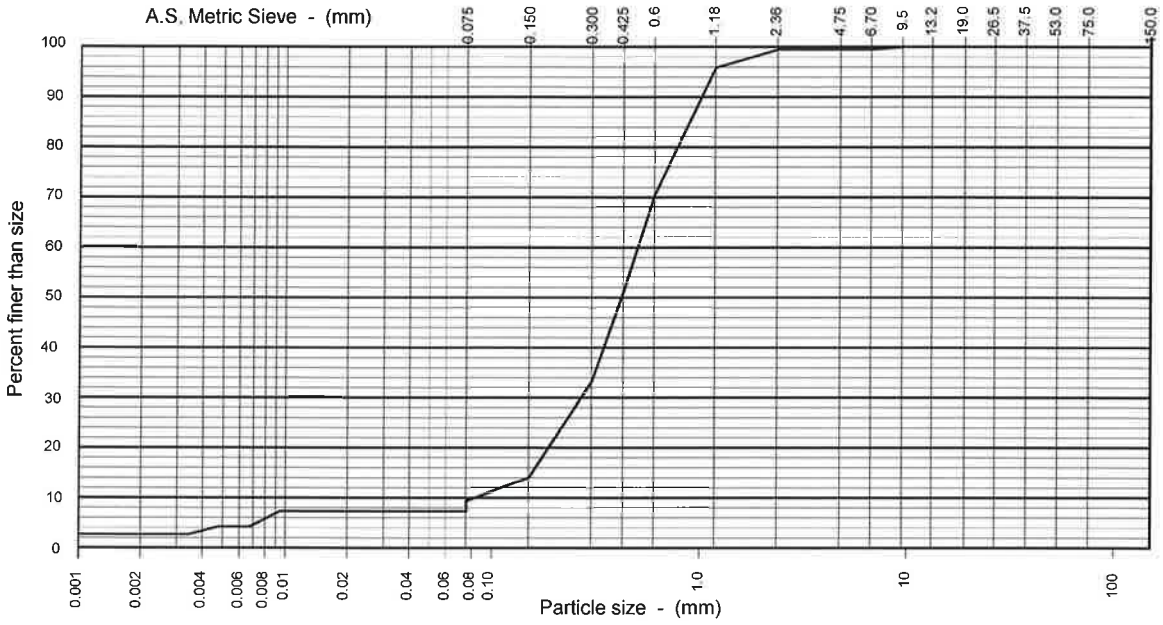
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71 CONNORS ROAD, MACKAY
REPORT ON SOIL CLASSIFICATION

Sheet 1 of 1 — Mackay Laboratory

CLIENT:	SRK Consulting (Australasia) P/L	**JOB NO:**	U24184	**LAB REF NO:**	17-0155ACE
PROJECT:	BMA Saraji Ramp 2/3 Tailins Dam Site (BMA019)	**SAMPLED BY:**	Cardno	**DATE:**	17-27.1.17
LOCATION:	Tailings 2B	**TESTED BY:**	DH,CD	**DATE:**	18-21.2.17
MATERIAL:	Tailings	**CHECKED BY:**	DH	**DATE:**	22.2.17

TEST PROCEDURES: **AS 1289.3.1.1,3.2.1,3.3.1,3.4.1,3.6.1,3.6.3,3.8.1** **CLIENT REF:** -



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
3	1	3	2	13	48	29	1	0	0	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0		0.075	7
75.0		0.053	7
37.5		0.038	7
19.0	100	0.027	7
9.5	100	0.018	7
4.75	99	0.013	7
2.36	99	0.009	7
1.18	96	0.007	4
0.600	70	0.005	4
0.425	51	0.003	3
0.300	33	0.002	3
0.150	14	0.001	3
0.075	9	0.001	3

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
Not Obtainable	Non Plastic	Non Determinable	-	-

Classification: **Sand** (SP)

Emerson Class No.: 4 Temp of Water Used: 24°C Type of Water Used: Distilled

Sampled in accordance: AS1289.1.2.1(6.5.4)

Preparation History of Atterberg Limits

Sample : ~~Natural~~/Air Dried/~~Oven~~

Sieved: ~~Wet~~/dry

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

NATA

Accredited No. 910

Certificate No. 17-0155A

Date of Issue 22.2.17

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Authorised Signatory D. Hoskins

Method of Dispersion: Mechanical

Type of Hydrometer: g/mL

D. Hoskins

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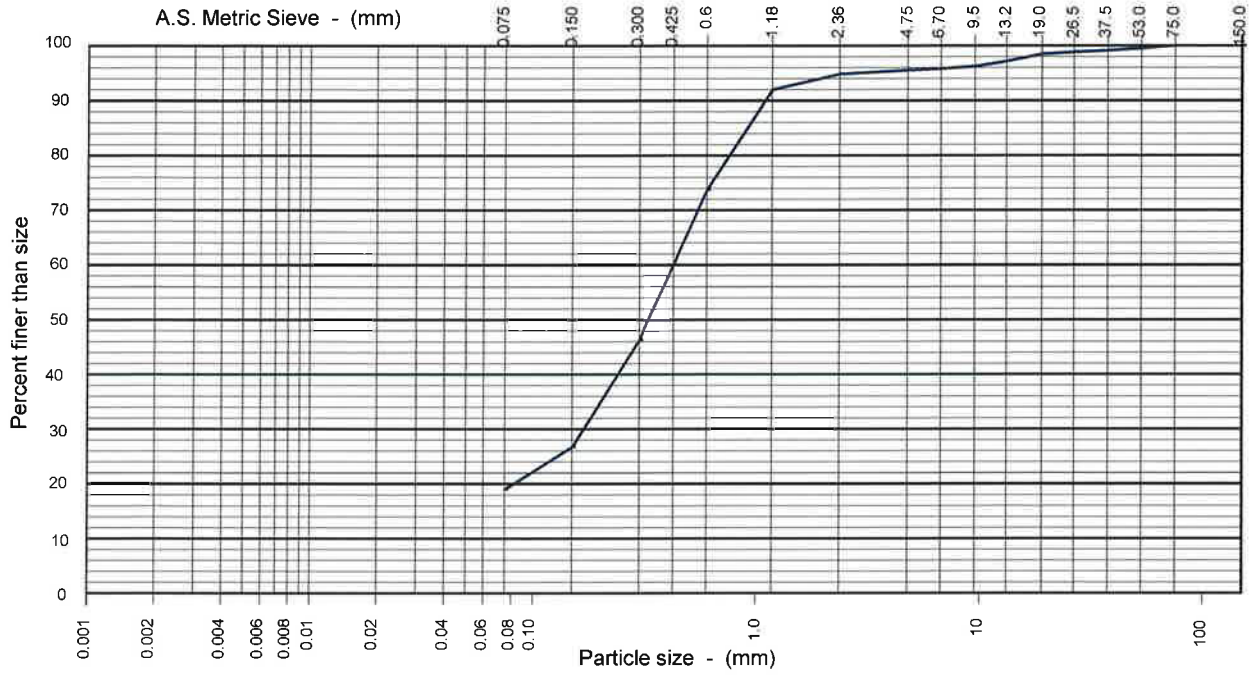
GEO-QF-UNGR 1 G

(-/8/16)

71 CONNORS ROAD MACKAY QLD
REPORT ON SOIL CLASSIFICATION

Sheet 1 of 1 — Mackay Laboratory

CLIENT:	SRK Consulting (Australasia) Pty Ltd	**JOB NO:**	U24184	**LAB REF NO:**	17-0160ABC
PROJECT:	BMA Saraji Ramp 2/3 Tailings Dam Site (BMA019)	**SAMPLED BY:**	Cardno	**DATE:**	17-27.1.17
LOCATION:	Test Pit 04B, Depth 2.20-2.80m	**TESTED BY:**	DH,CD	**DATE:**	18-21.2.17
MATERIAL:	Silty Sand	**CHECKED BY:**	CD,DH	**DATE:**	21.2.17
TEST PROCEDURES:	AS1289.3.1.1,3.2.1,3.3.1,3.4.1,3.6.1,3.8.1			**CLIENT REF:**	-



clay	silt			sand			gravel			cobbles
	fine	medium	coarse	fine	medium	coarse	fine	medium	coarse	
19				16	39	21	1	2	2	0

Particle Size (mm)	Percent Passing (%)	Particle Size (mm)	Percent Passing (%)
150.0			
75.0	100		
37.5	99		
19.0	98		
9.5	96		
4.75	96		
2.36	95		
1.18	92		
0.600	74		
0.425	60		
0.300	46		
0.150	27		
0.075	19		

Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Soil Particle Density (g/cm^3)
Not Obtainable	Non Plastic	Non Determinable	-	-

Classification: Silty Sand; fine to coarse grained (SM)

Emerson Class No: 4 Temp of Water: 24°C Type of Water Used: Distilled

Sampling Method - AS 1289.1.2.1 (6.5.3)

Preparation History of Atterberg Limits

Sample : ~~Natural~~/Air Dried/~~Oven~~

Sieved: ~~Wet~~/dry

Linear Shrinkage Data

Length of Mould (mm) : 250

Sample: -

NATA

Accredited No. 910

Certificate No. 17-0160A

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D. Hoskins

Electric Field Vane Shear Test Plots

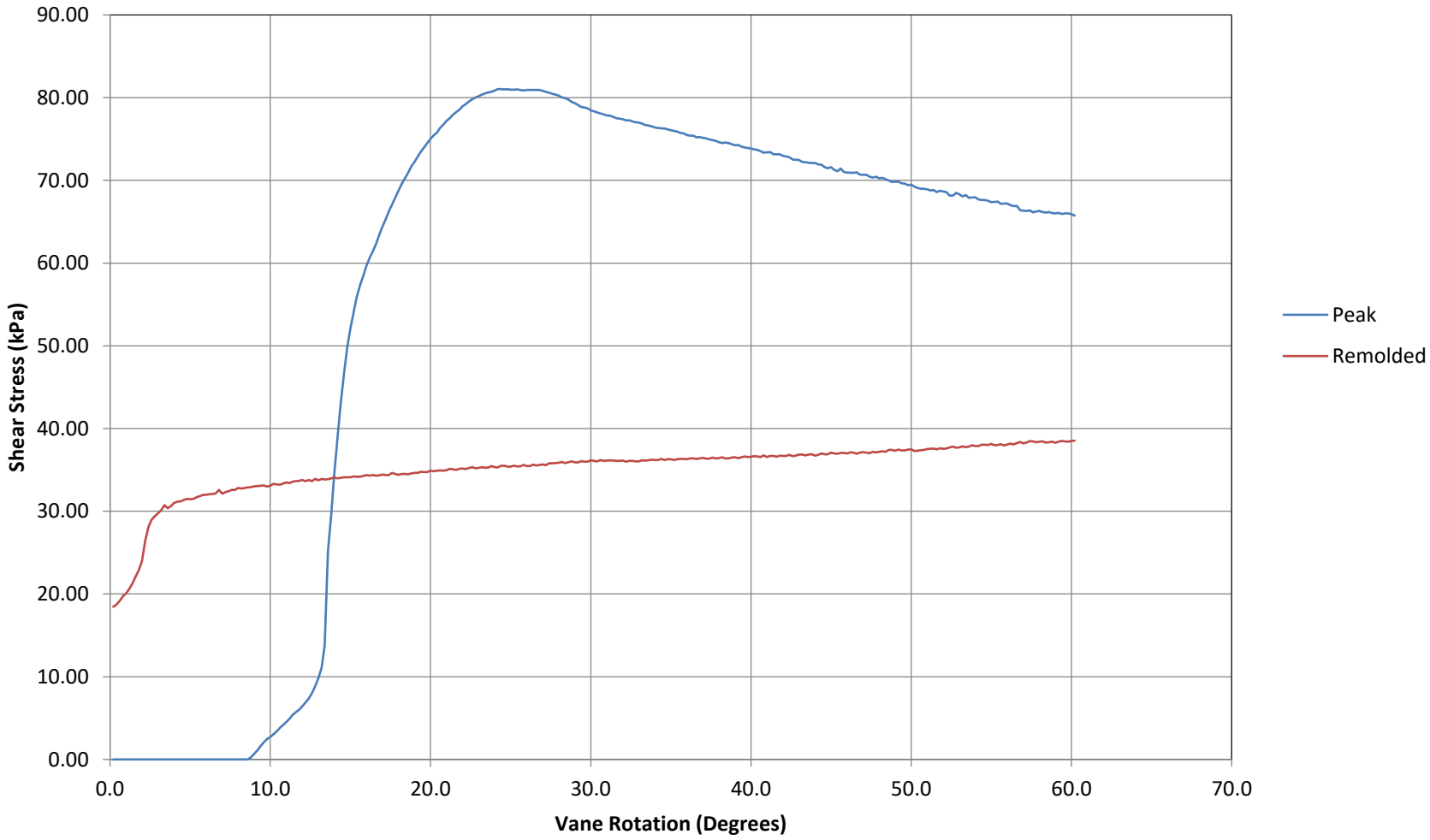
CONETEC

Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-01

Test Date: 17-May-2021 14:49
Test Depth (m): 6.10
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524851
Easting (m): 630337

Vane Shear Test

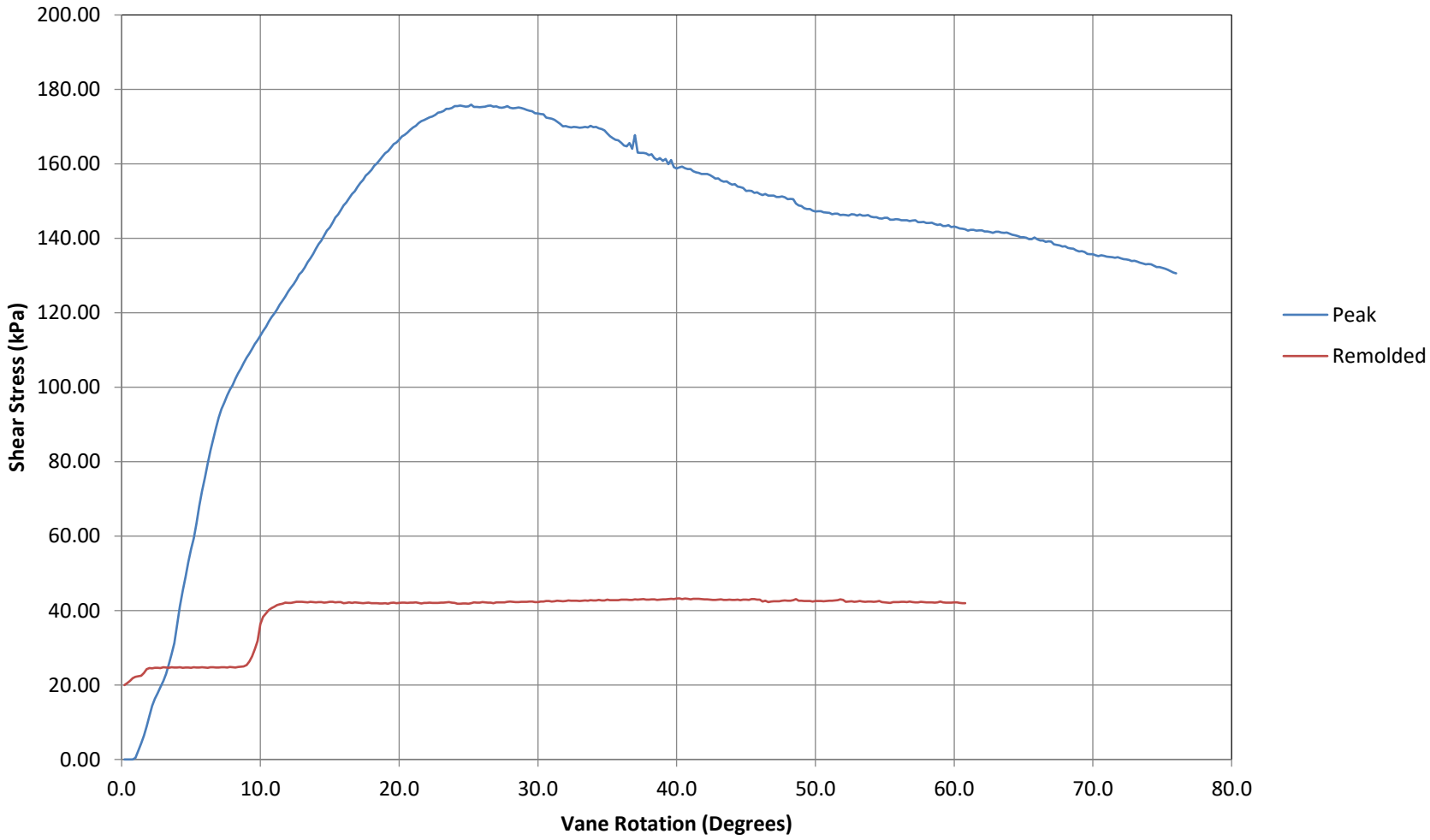


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-01

Test Date: 17-May-2021 15:27
Test Depth (m): 6.60
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524851
Easting (m): 630337

Vane Shear Test

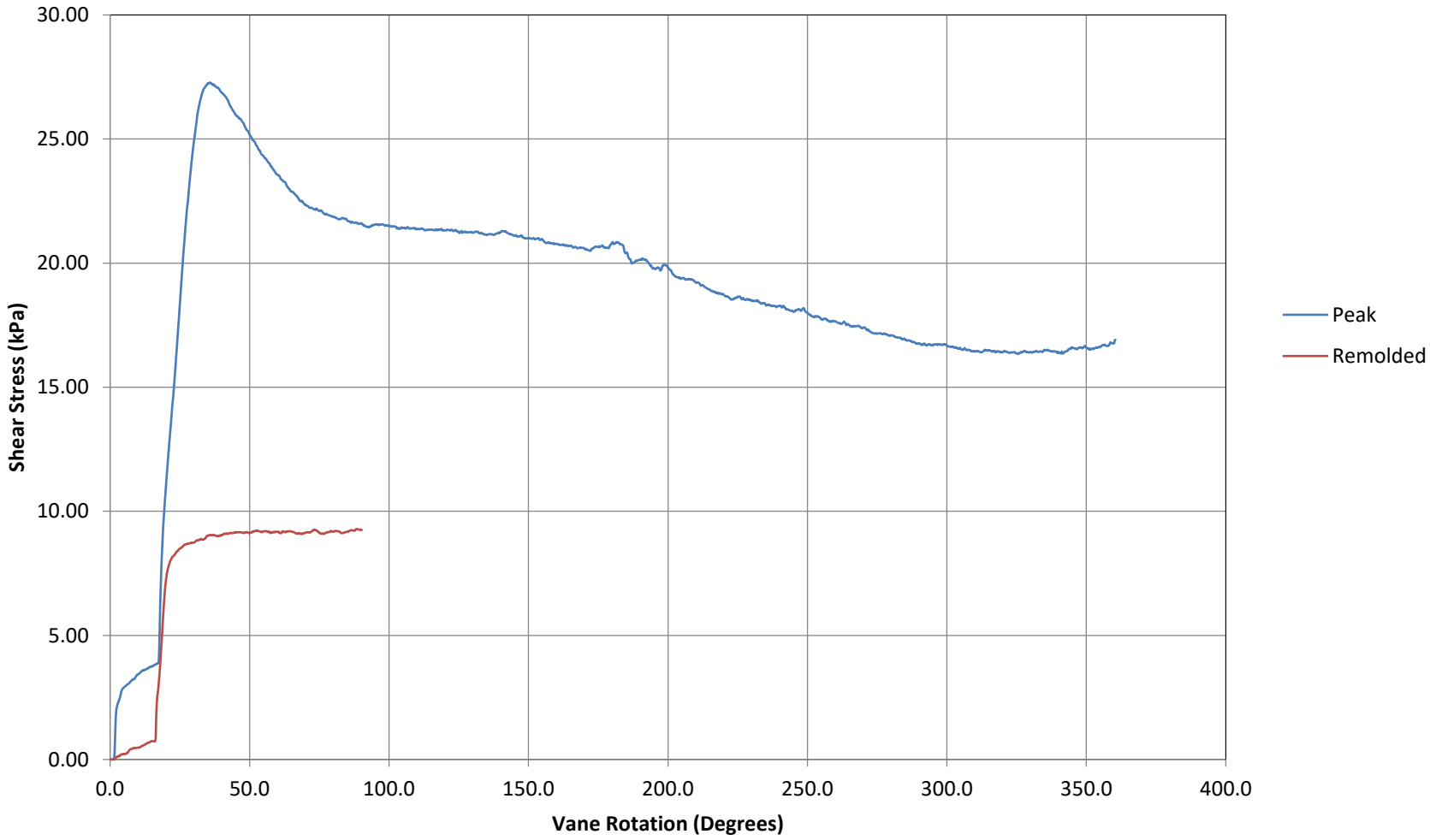


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-02

Test Date: 20-May-2021 09:36
Test Depth (m): 1.10
Vane Type: Adara solid double tapered 60 x 120 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524831
Easting (m): 630346

Vane Shear Test

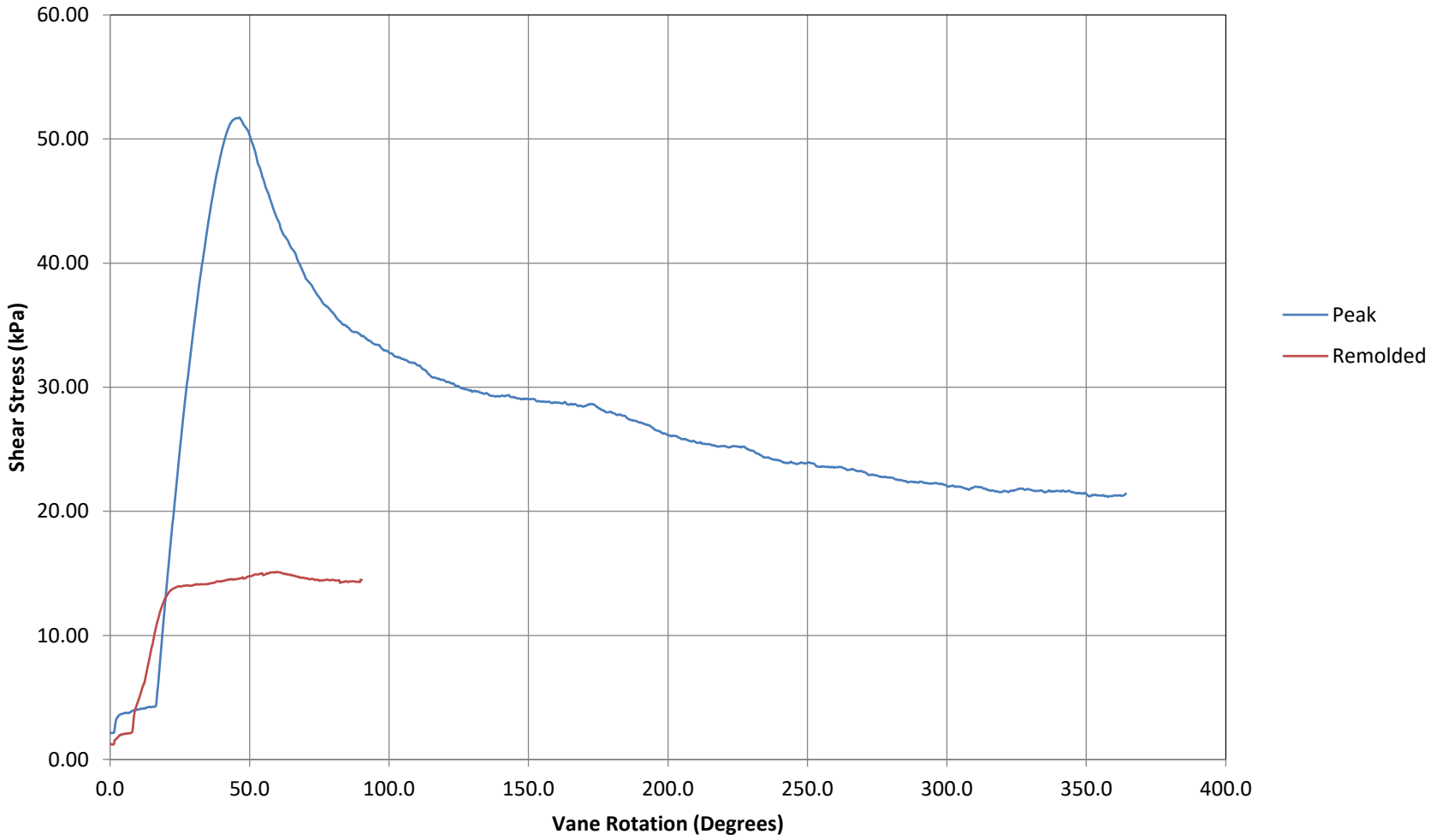


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-02

Test Date: 20-May-2021 11:50
Test Depth (m): 6.00
Vane Type: Adara solid double tapered 60 x 120 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524831
Easting (m): 630346

Vane Shear Test

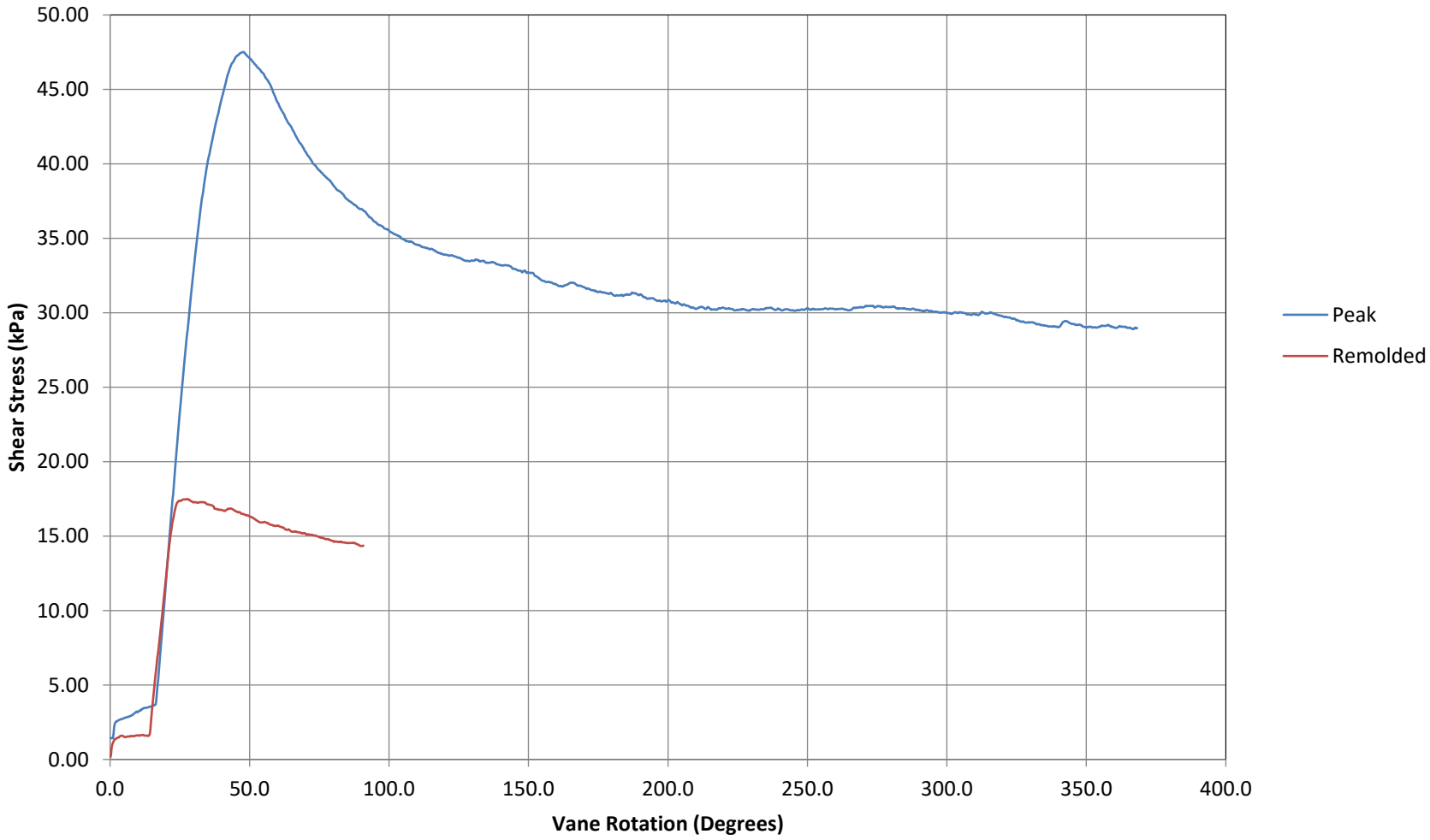


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-02

Test Date: 20-May-2021 13:27
Test Depth (m): 8.00
Vane Type: Adara solid double tapered 60 x 120 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524831
Easting (m): 630346

Vane Shear Test

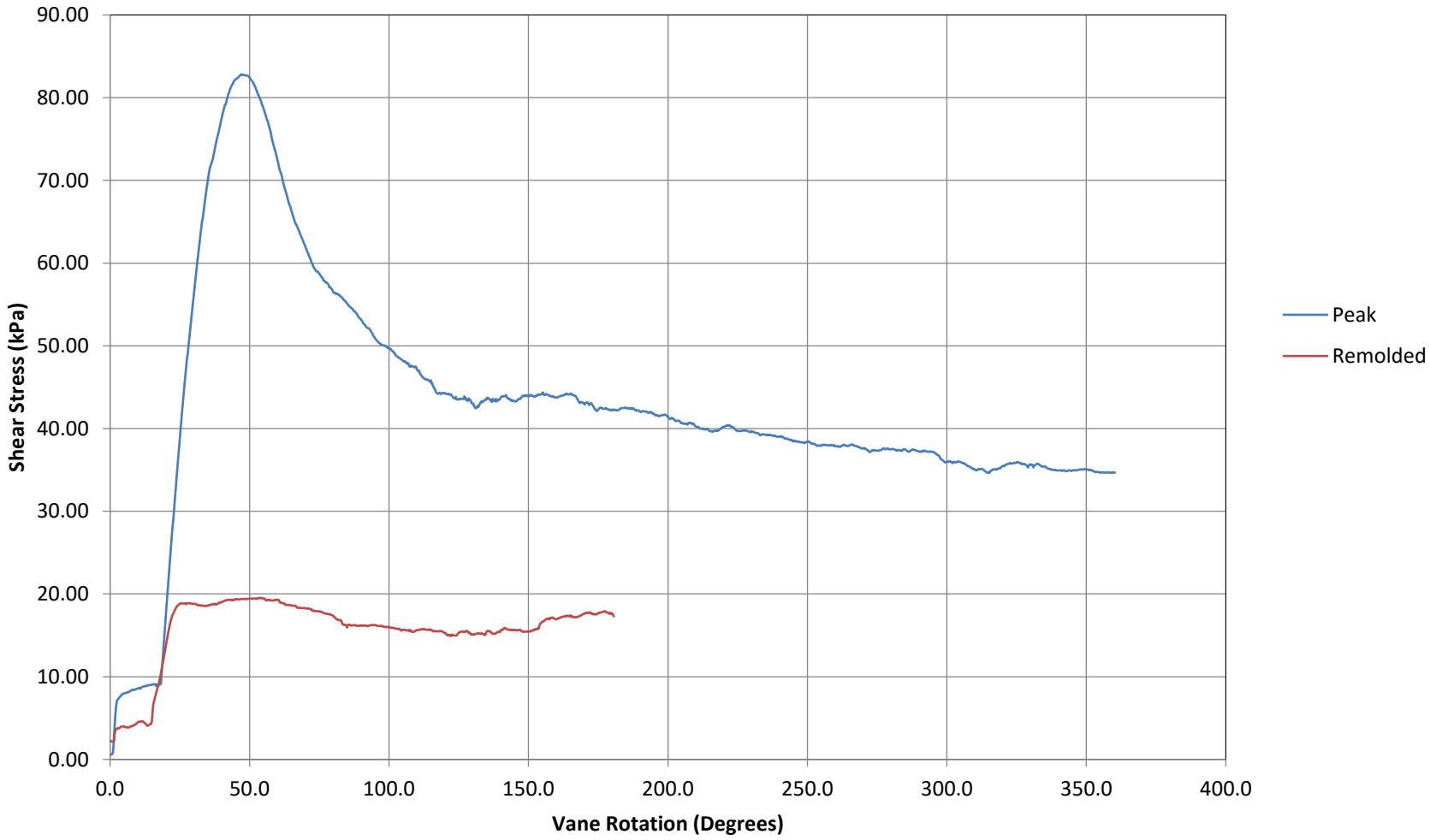


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-03

Test Date: 11-May-2021 09:15
Test Depth (m): 5.20
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524753
Easting (m): 630328

Vane Shear Test

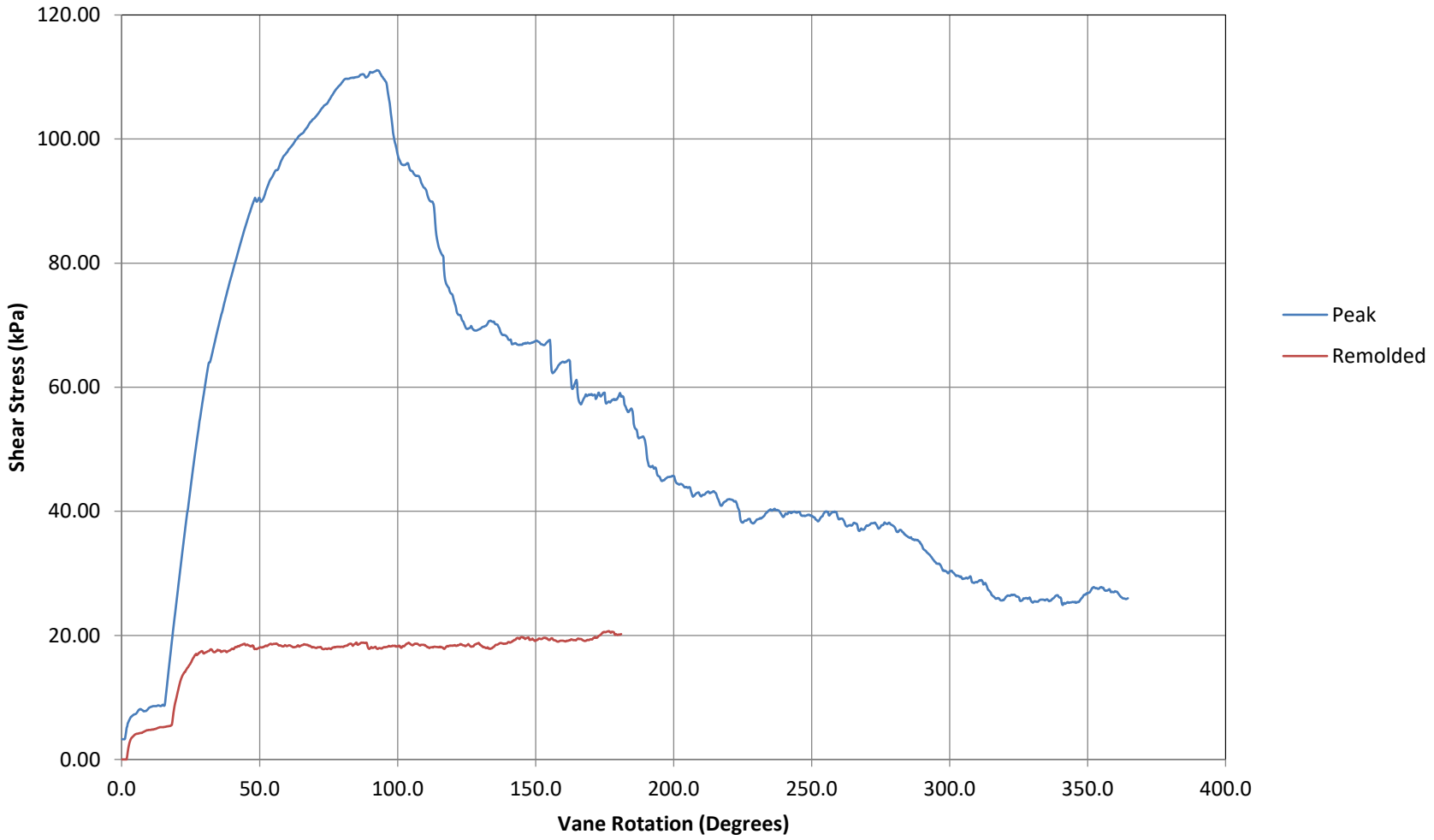


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-03

Test Date: 11-May-2021 11:22
Test Depth (m): 7.20
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524753
Easting (m): 630328

Vane Shear Test

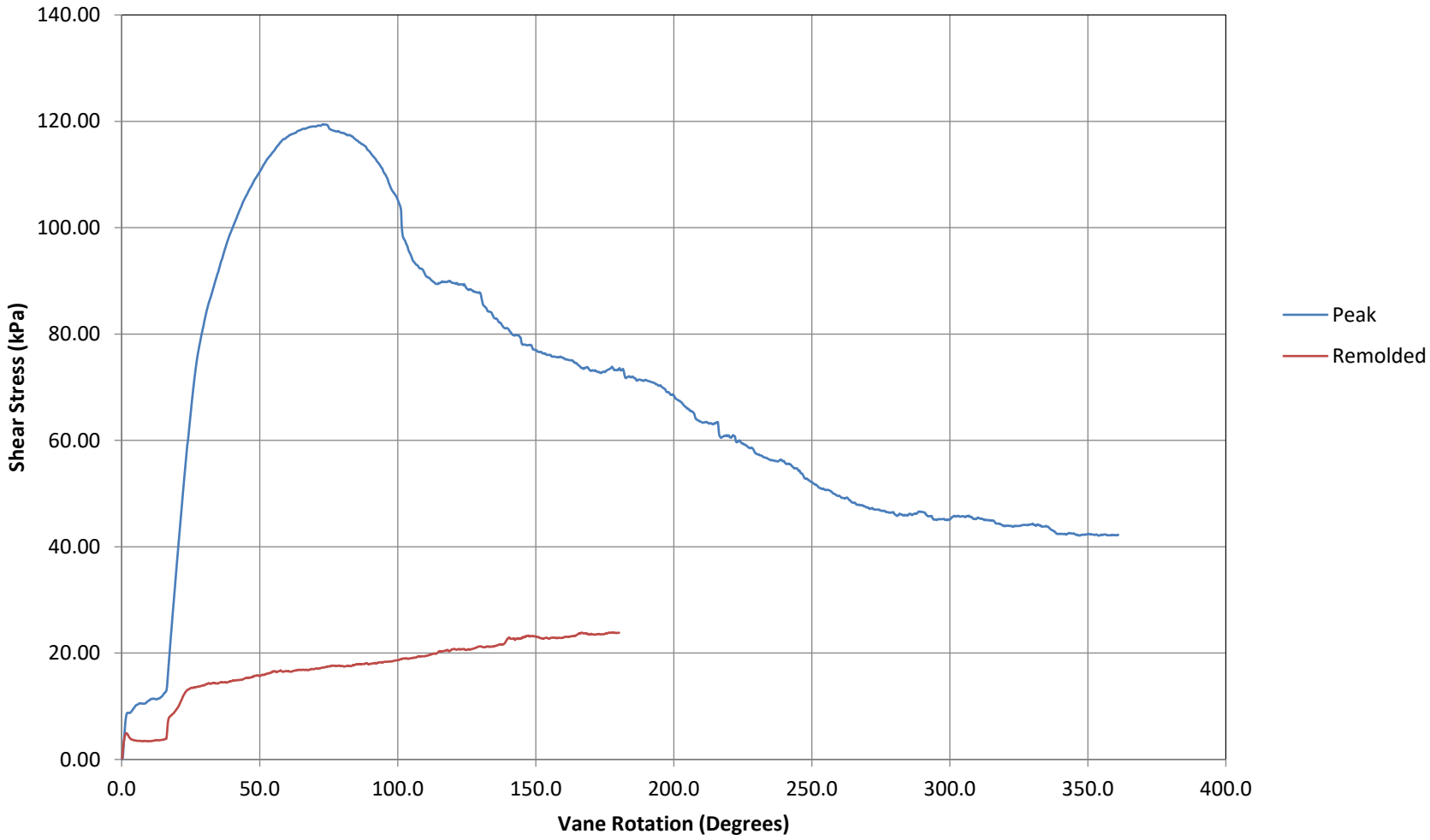


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-05

Test Date: 12-May-2021 10:57
Test Depth (m): 3.00
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524565
Easting (m): 630445

Vane Shear Test

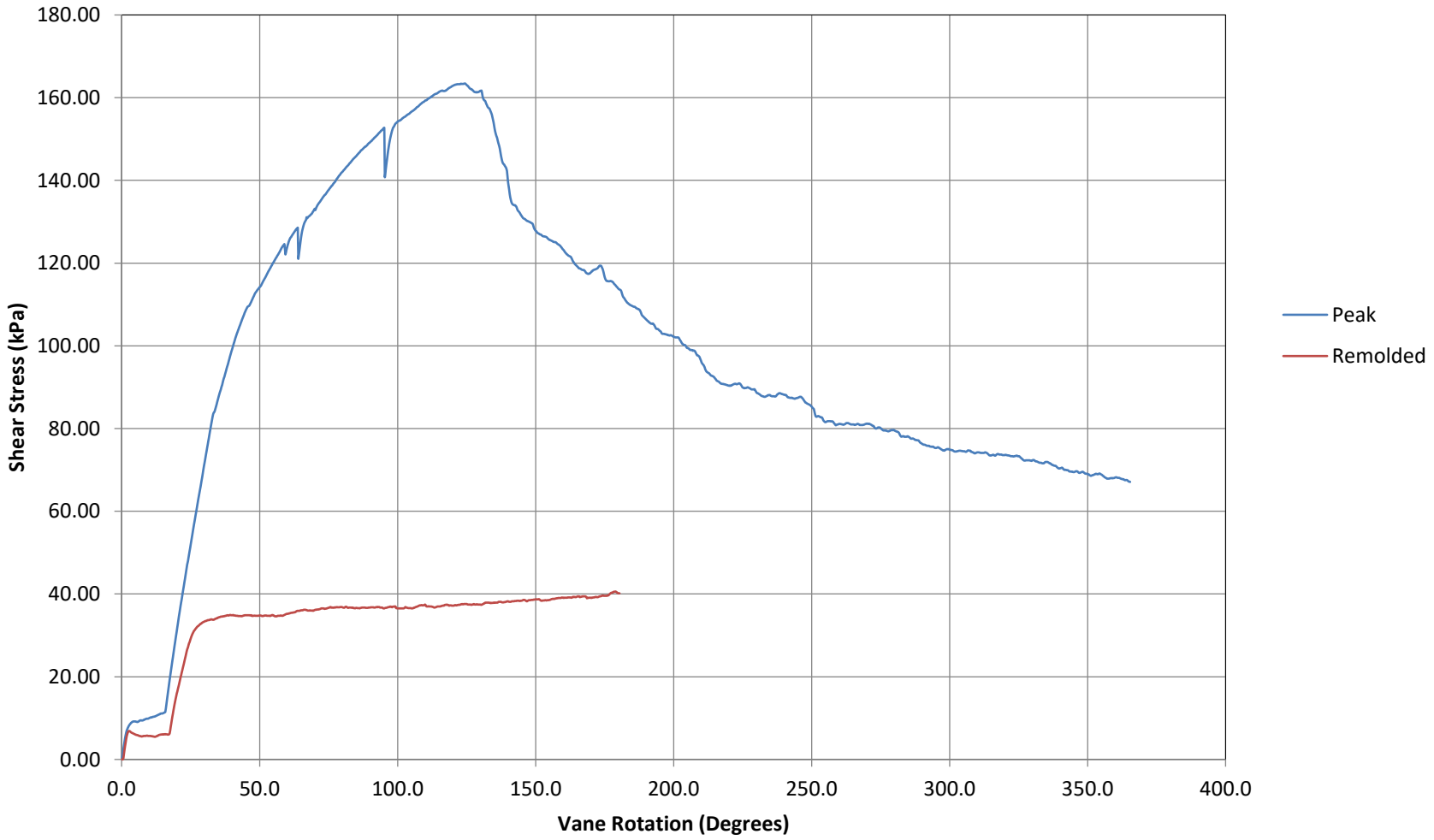


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-05

Test Date: 12-May-2021 12:55
Test Depth (m): 6.50
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524565
Easting (m): 630445

Vane Shear Test

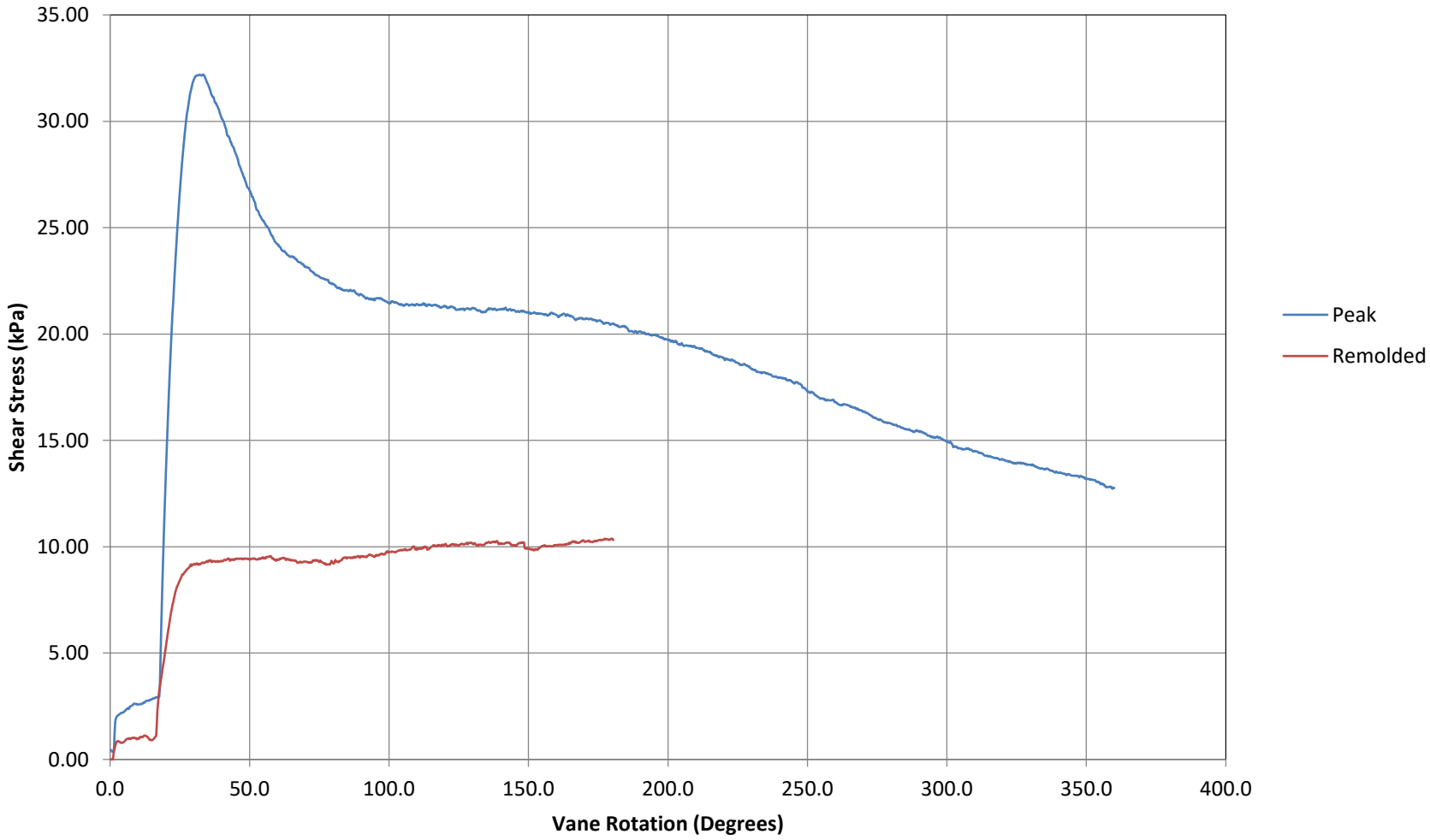


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-07

Test Date: 13-May-2021 12:32
Test Depth (m): 3.80
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524384
Easting (m): 630547

Vane Shear Test

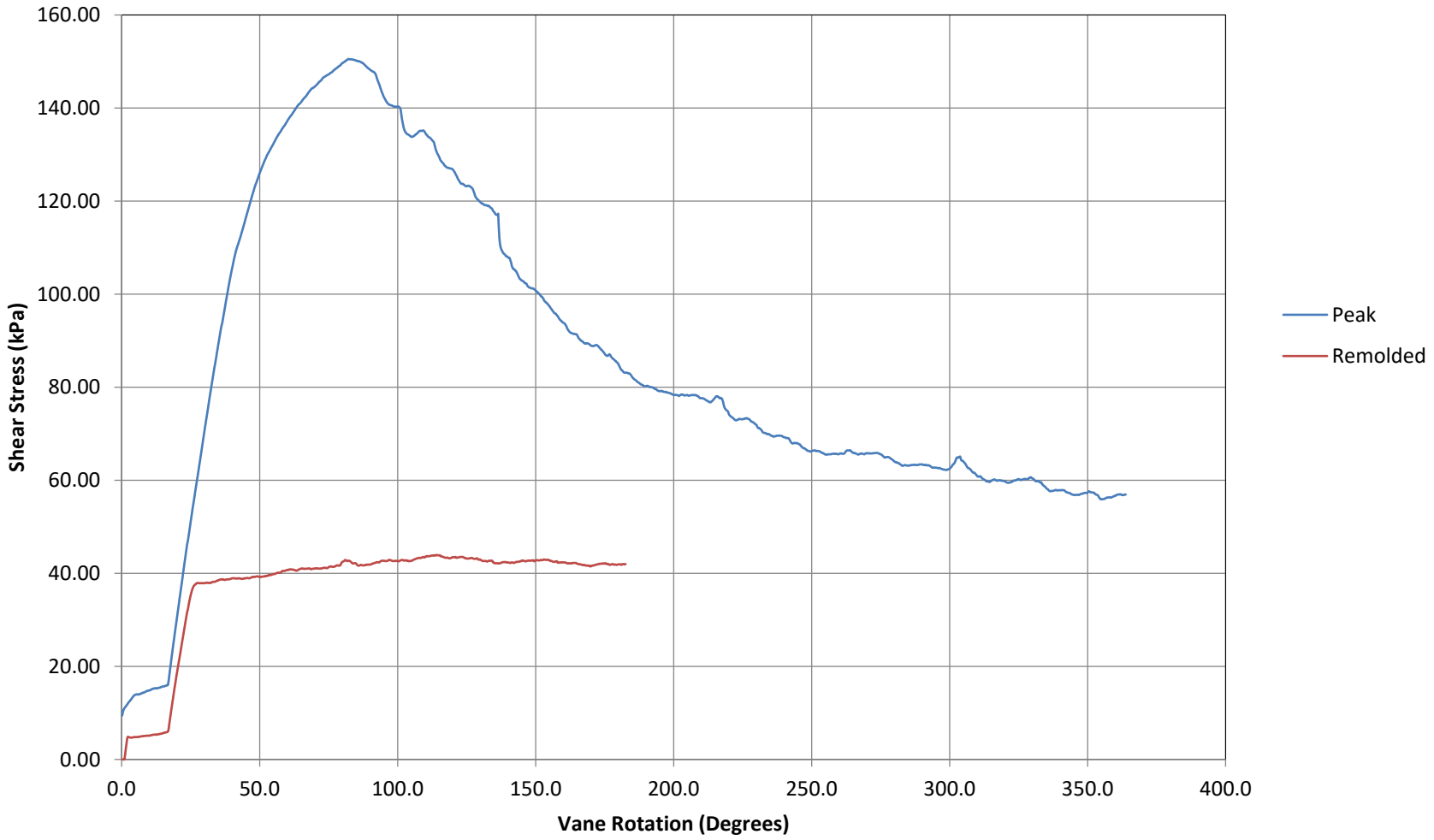


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-07

Test Date: 13-May-2021 14:34
Test Depth (m): 7.00
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524384
Easting (m): 630547

Vane Shear Test

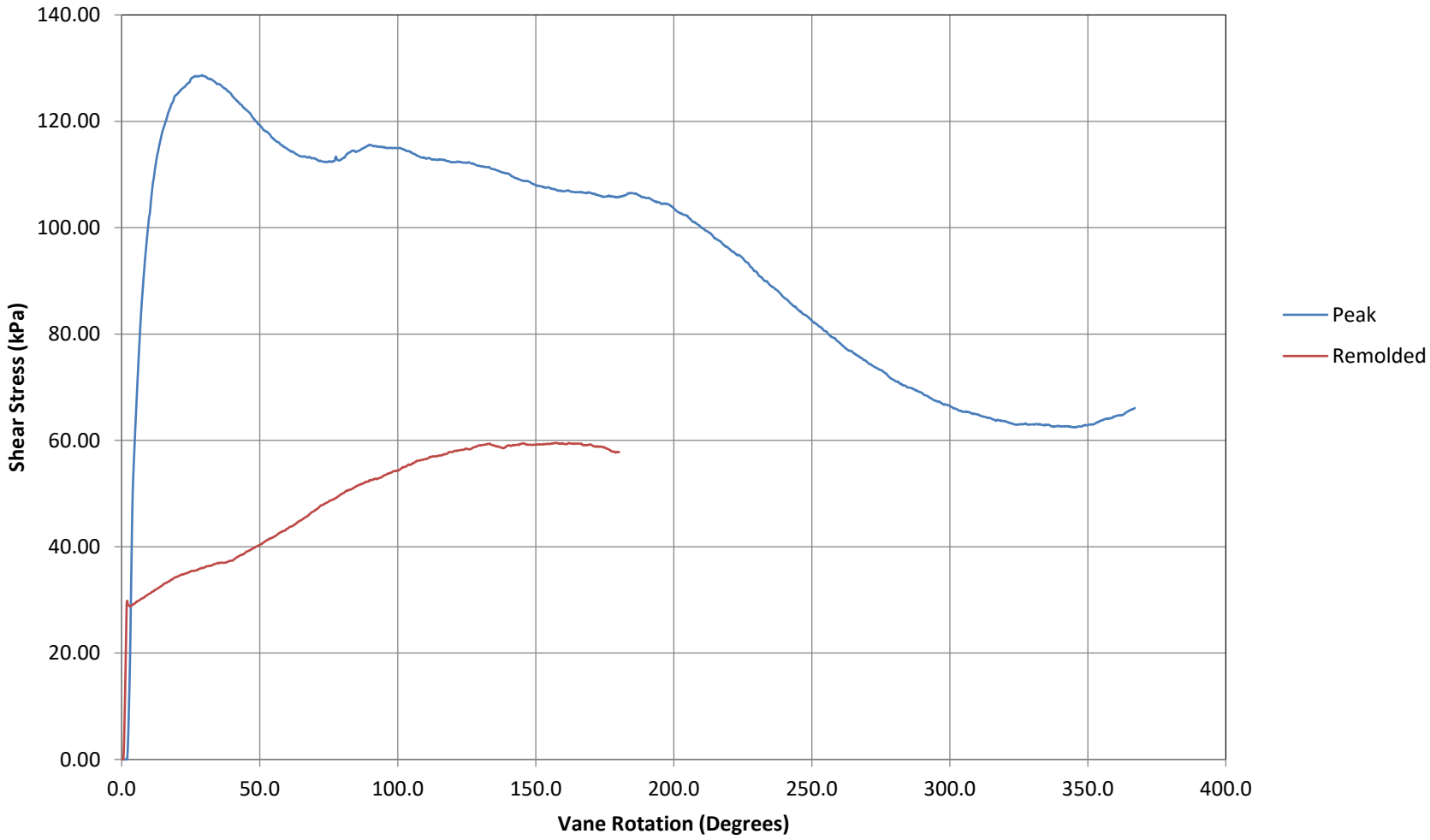


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-08

Test Date: 24-May-2021 12:45
Test Depth (m): 6.50
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524418
Easting (m): 630497

Vane Shear Test

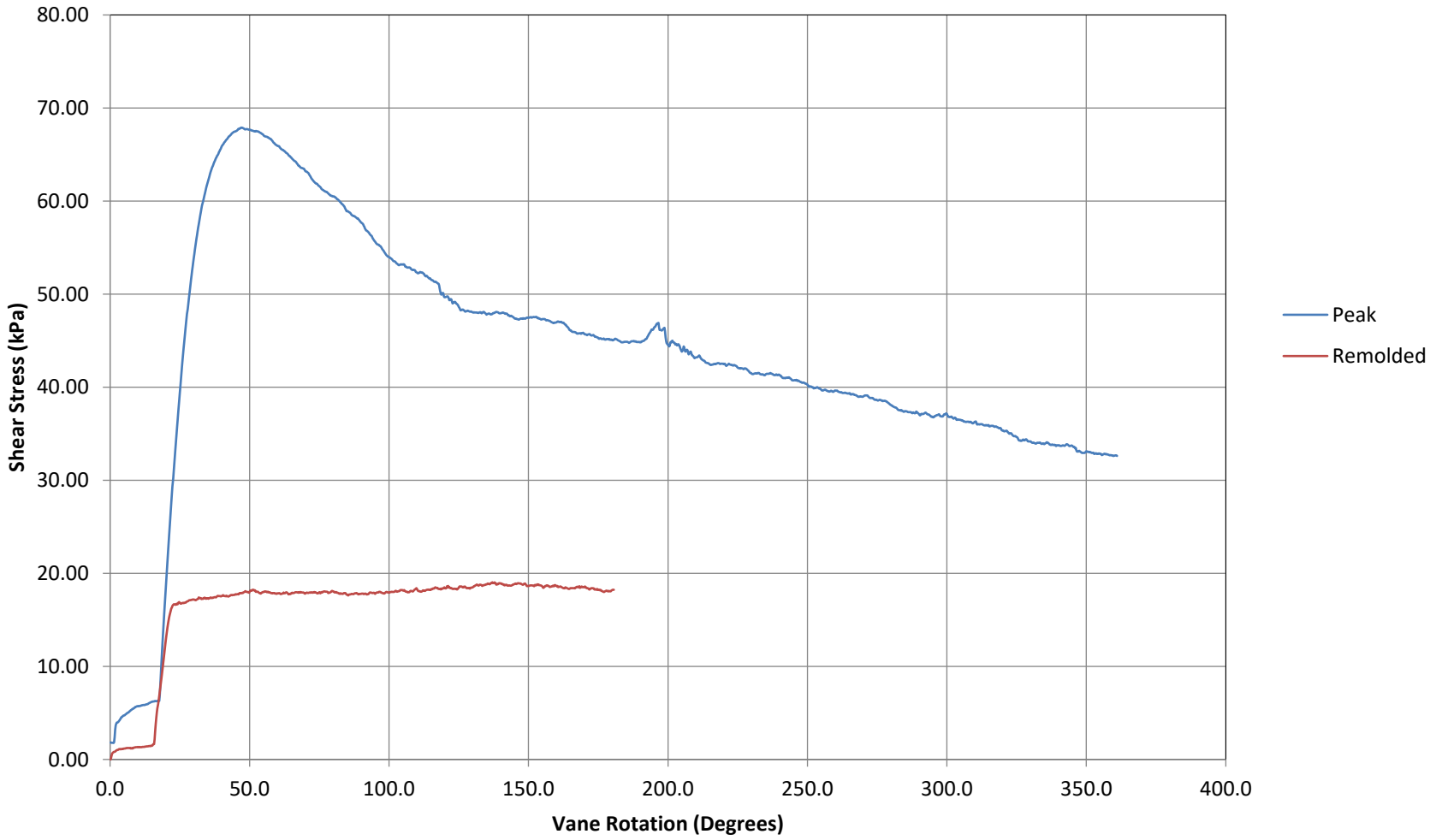


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-09

Test Date: 14-May-2021 08:17
Test Depth (m): 4.90
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524288
Easting (m): 630600

Vane Shear Test

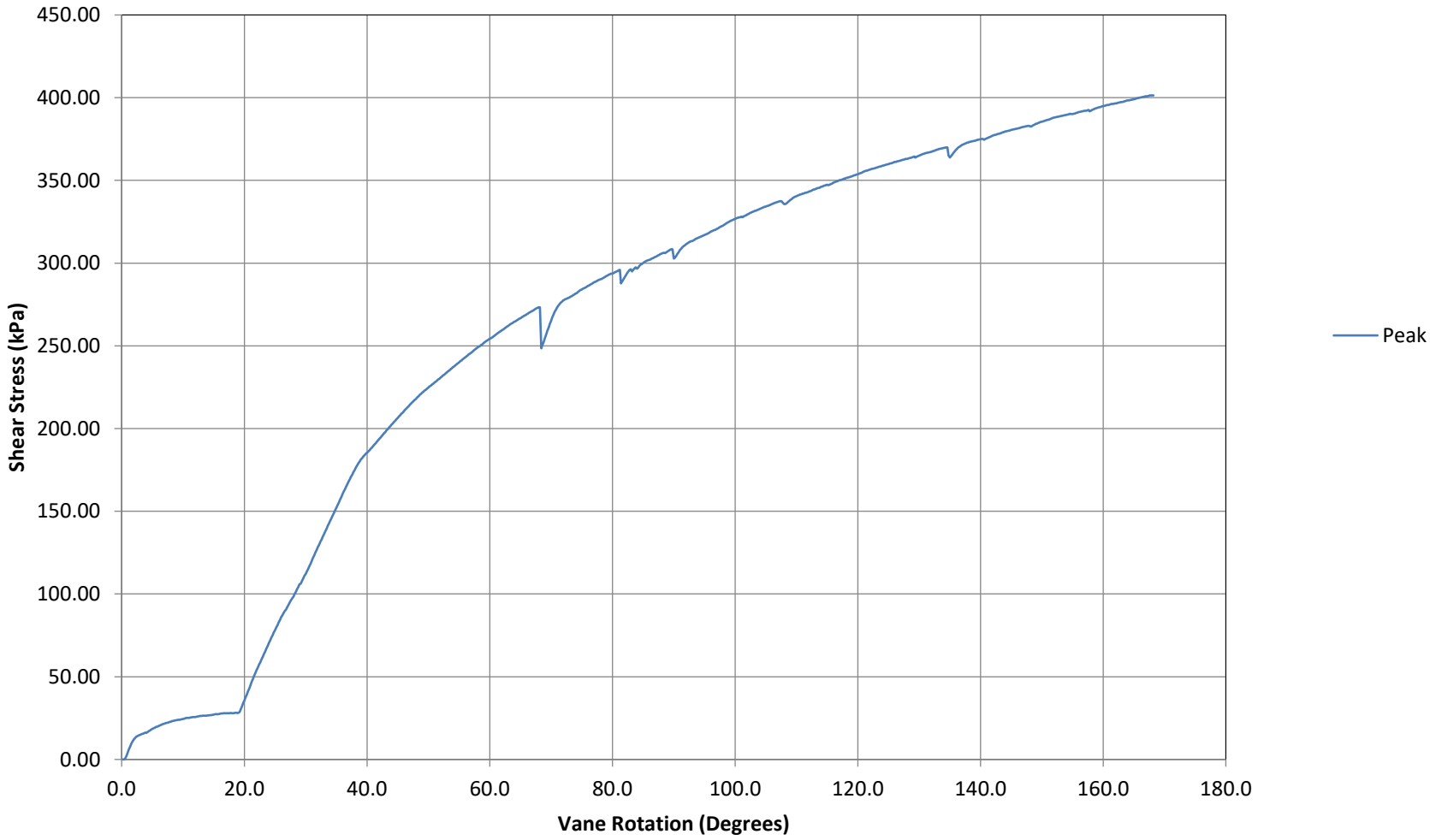


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-09

Test Date: 14-May-2021 10:56
Test Depth (m): 6.20
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524288
Easting (m): 630600

Vane Shear Test

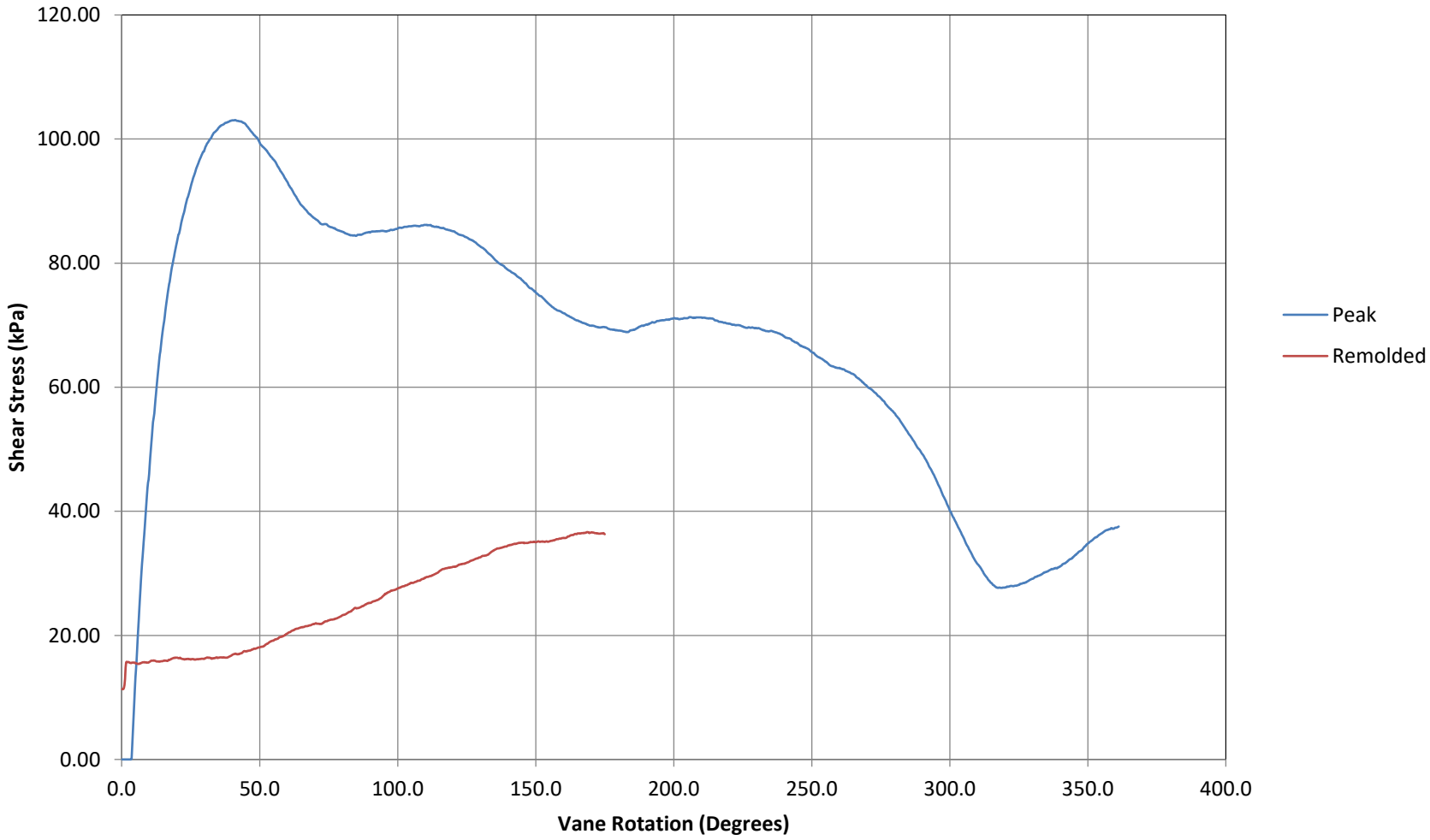


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-10

Test Date: 24-May-2021 15:24
Test Depth (m): 5.85
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524285
Easting (m): 630573

Vane Shear Test

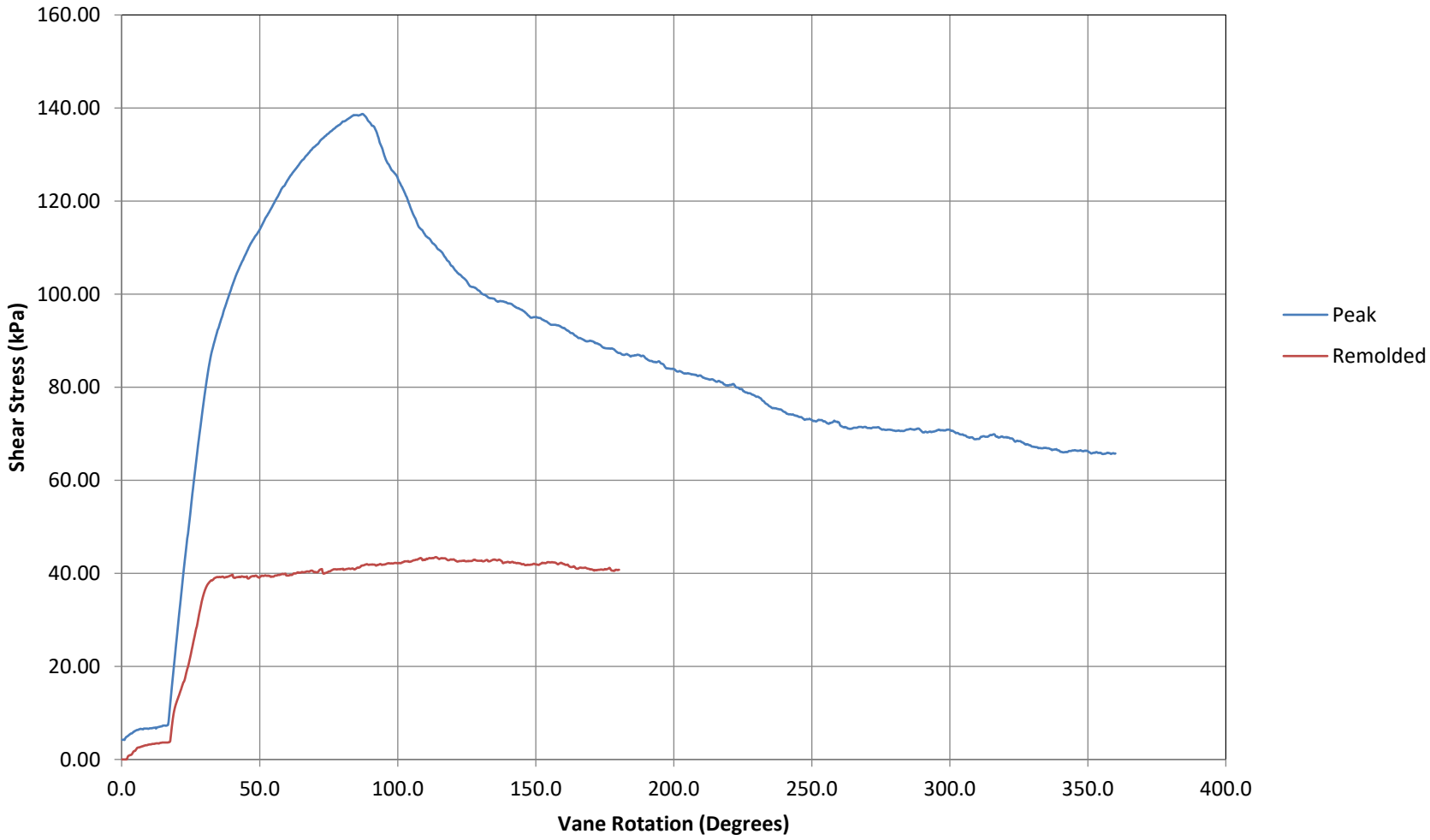


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-11

Test Date: 18-May-2021 15:25
Test Depth (m): 3.80
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524008
Easting (m): 630690

Vane Shear Test

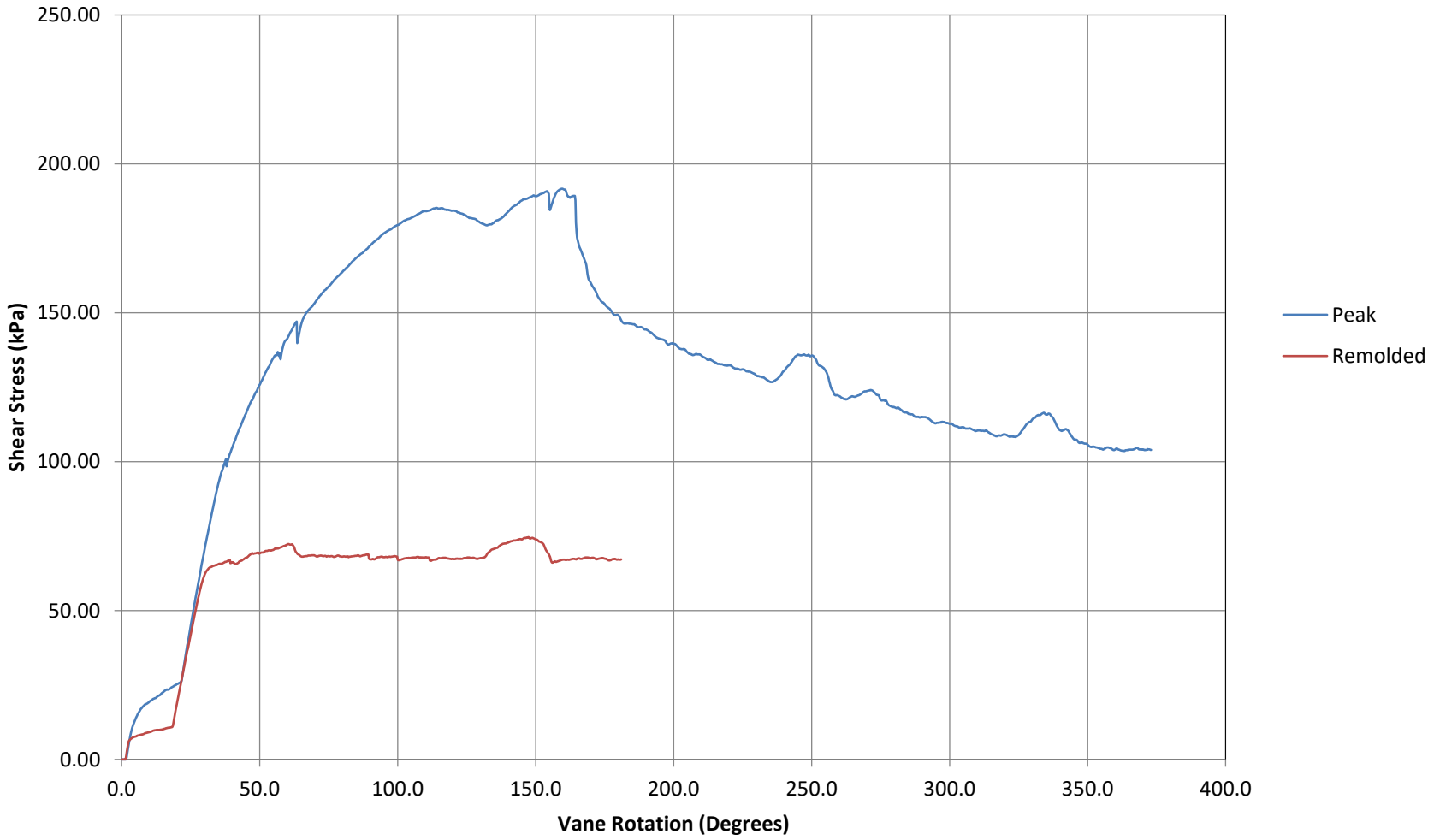


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-11

Test Date: 19-May-2021 07:47
Test Depth (m): 5.20
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524008
Easting (m): 630690

Vane Shear Test

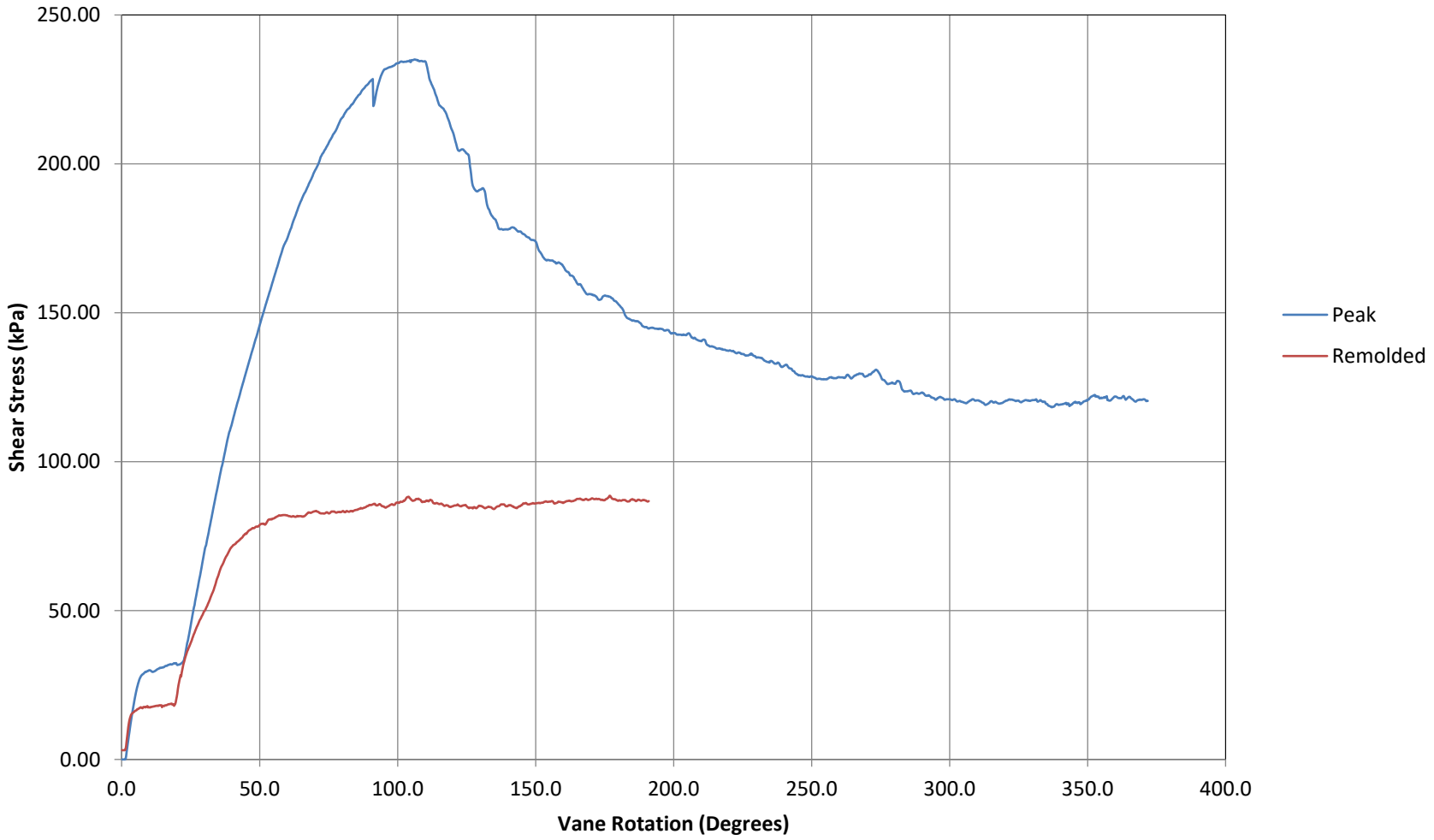


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-11

Test Date: 19-May-2021 12:04
Test Depth (m): 15.00
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524008
Easting (m): 630690

Vane Shear Test

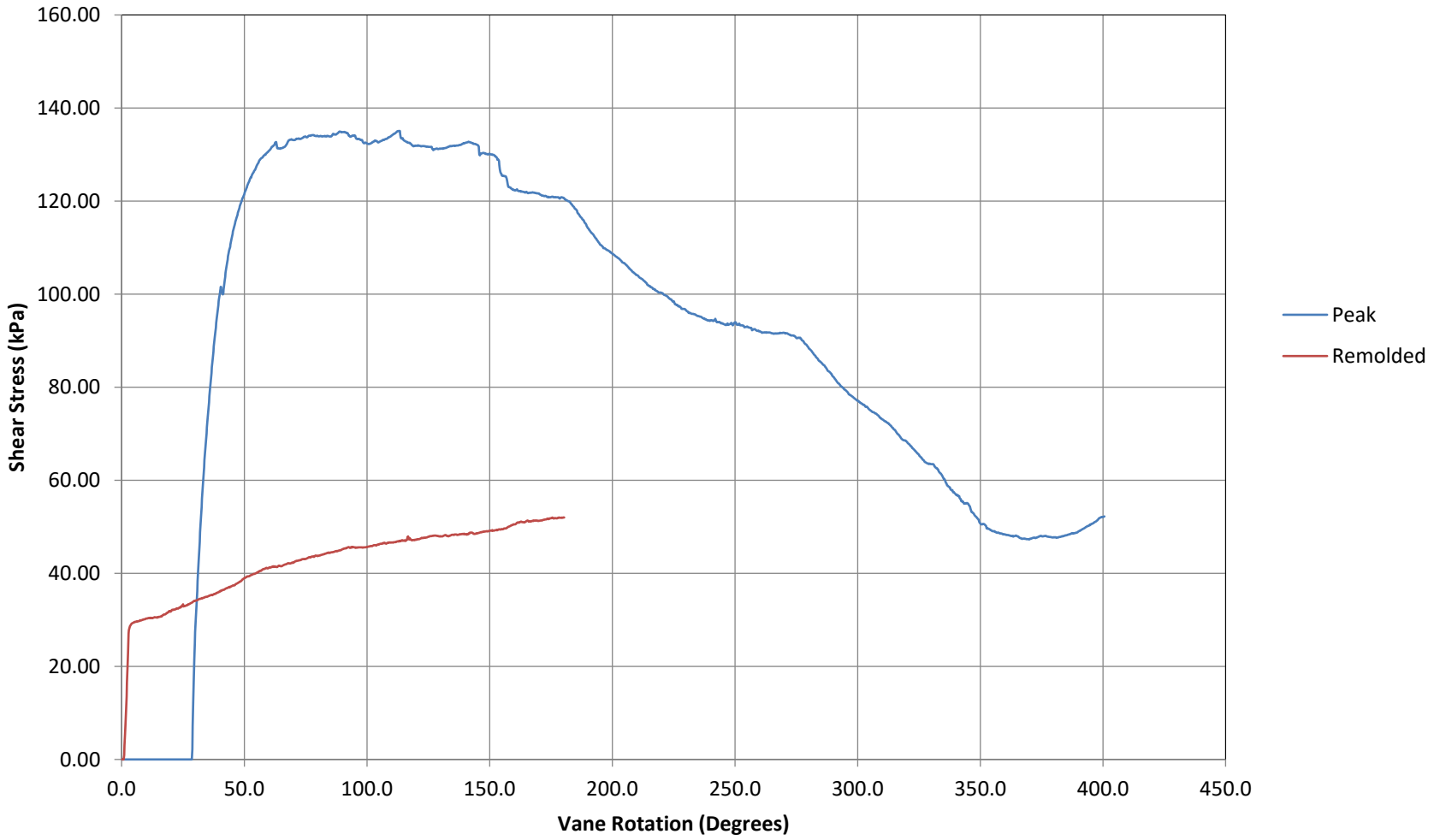


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-12

Test Date: 25-May-2021 08:20
Test Depth (m): 6.60
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524137
Easting (m): 630622

Vane Shear Test

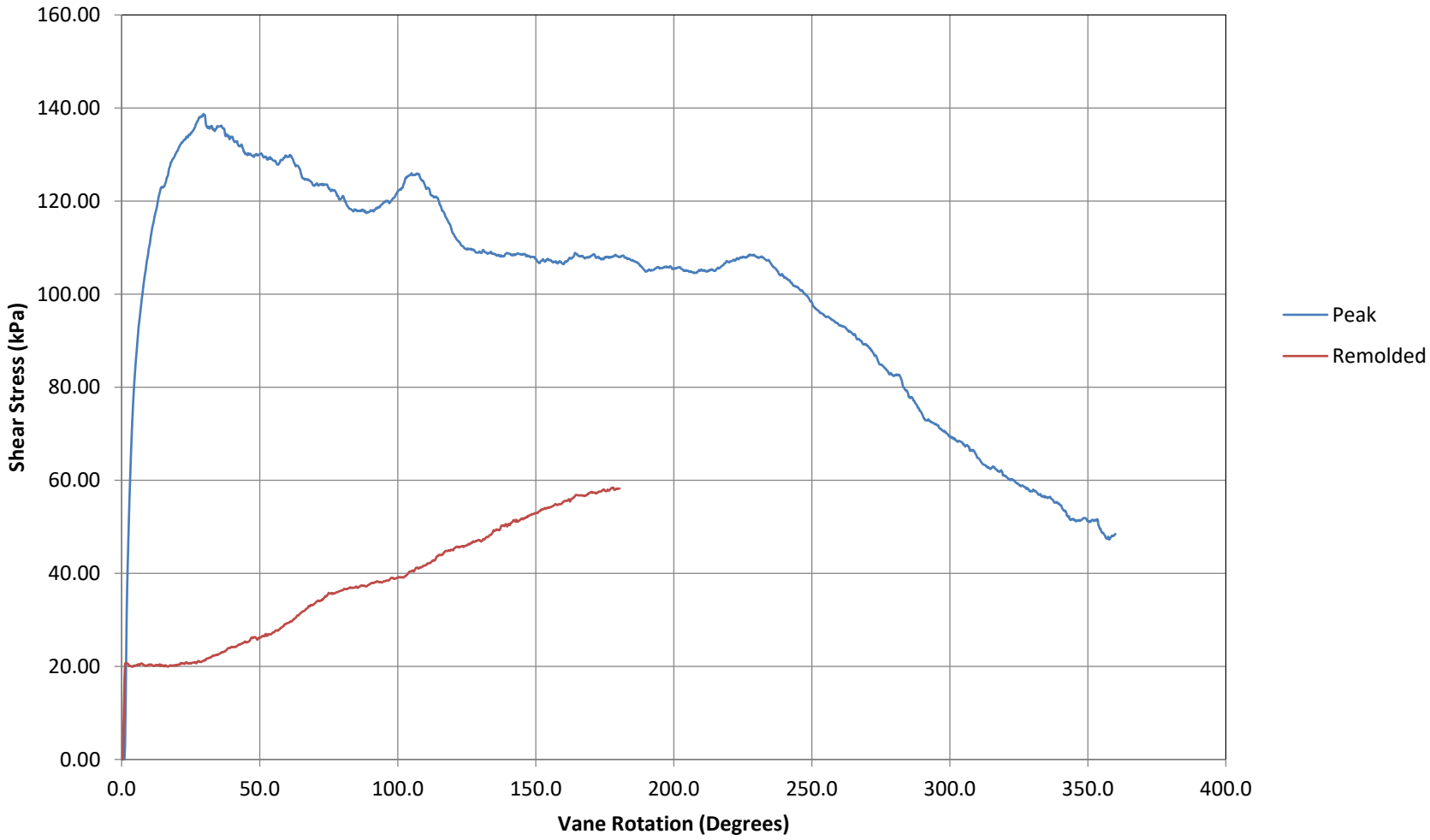


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-12

Test Date: 25-May-2021 10:41
Test Depth (m): 9.10
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524137
Easting (m): 630622

Vane Shear Test

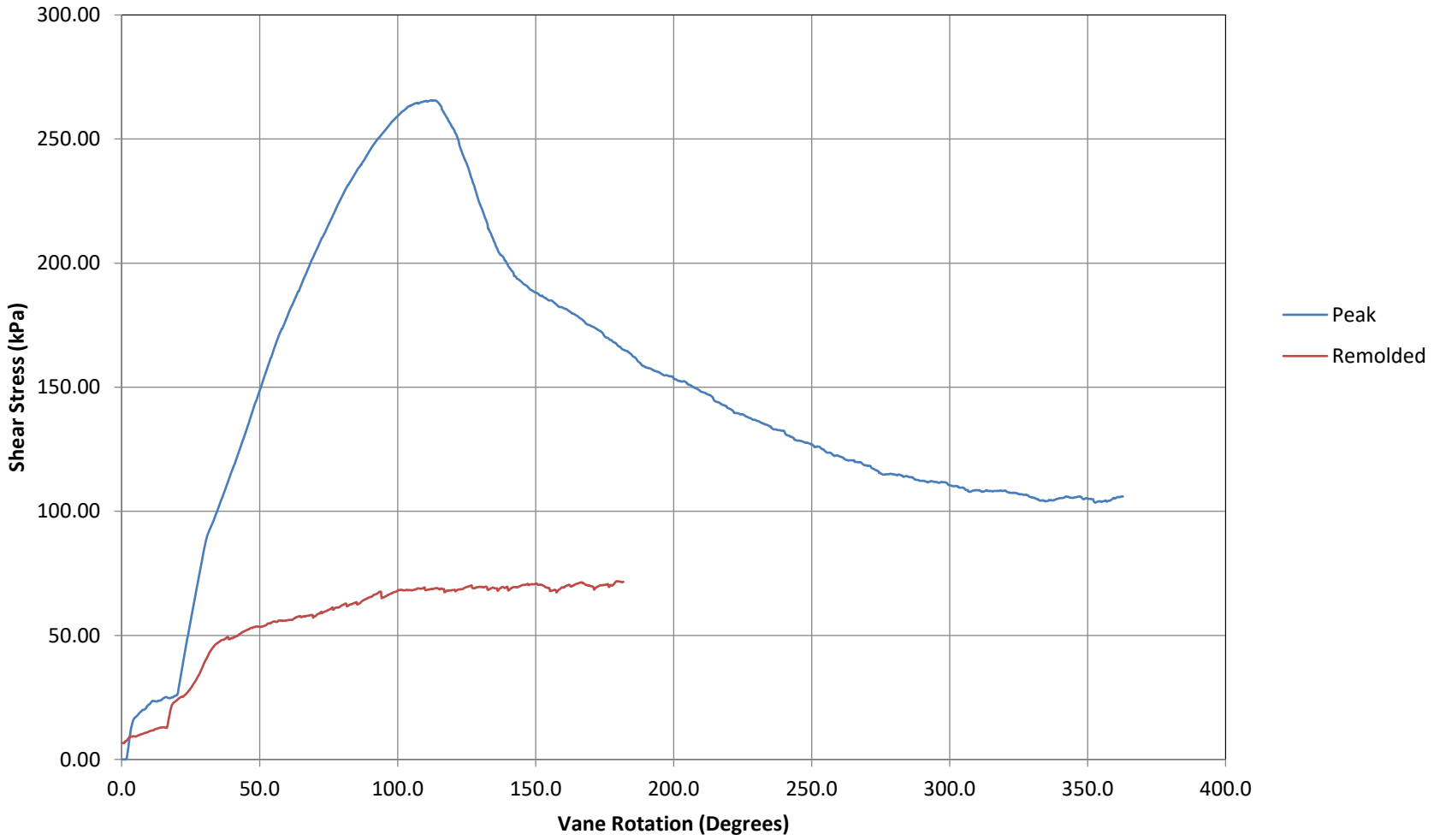


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-13

Test Date: 29-Apr-2021 15:13
Test Depth (m): 12.00
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7523995
Easting (m): 630659

Vane Shear Test

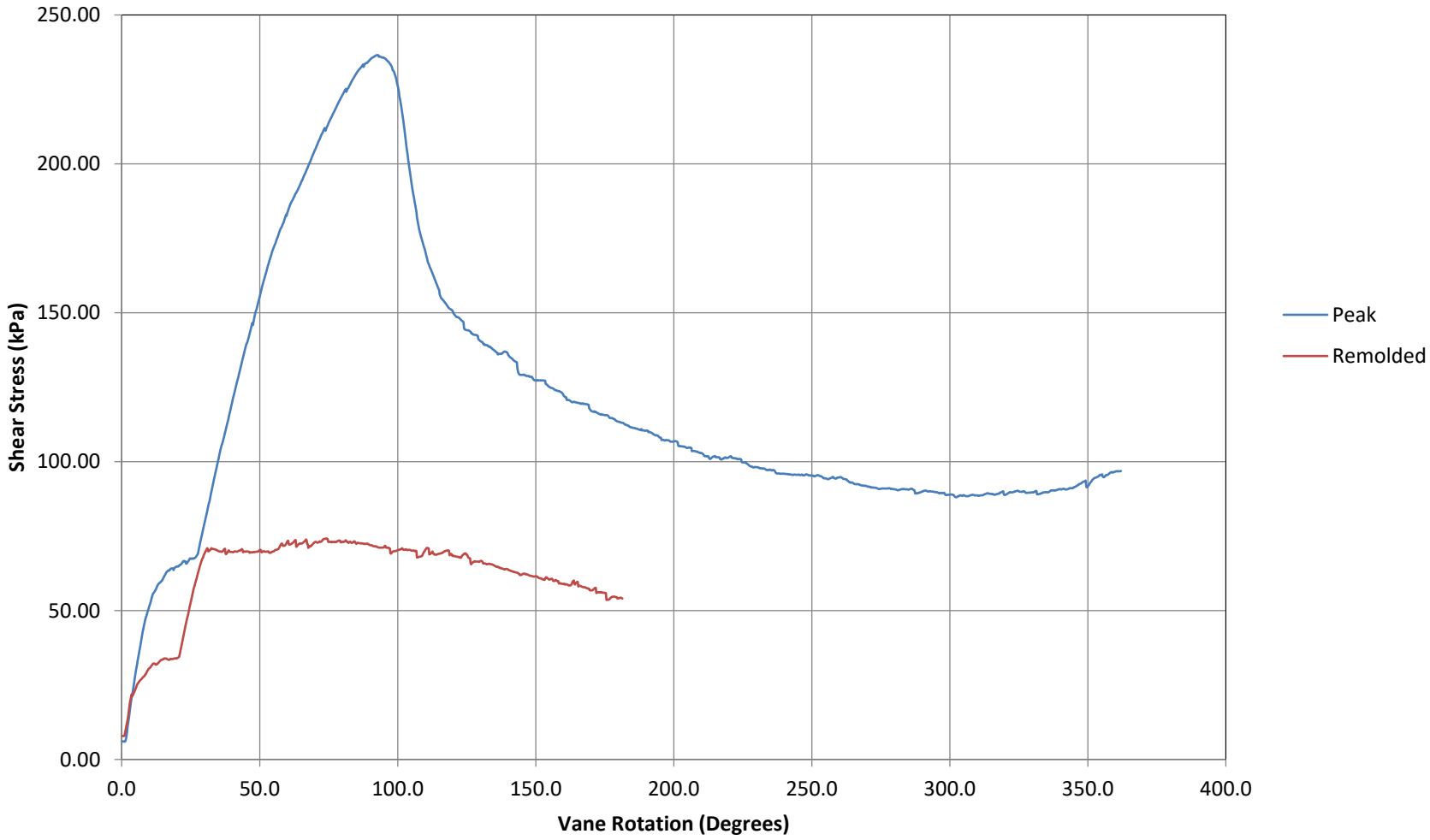


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-13B

Test Date: 30-Apr-2021 08:36
Test Depth (m): 17.00
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7523996
Easting (m): 630659

Vane Shear Test

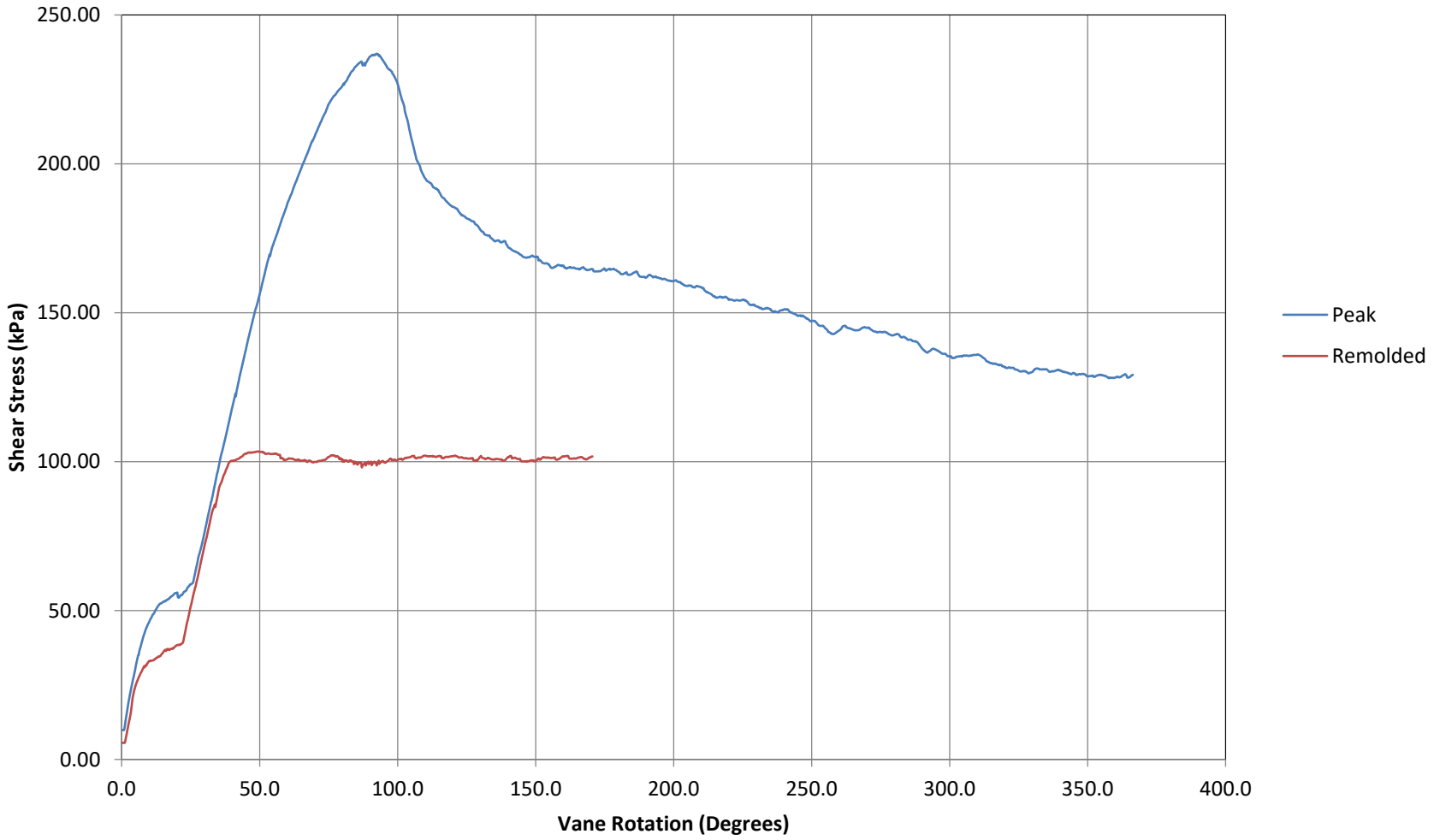


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-13B

Test Date: 03-May-2021 12:49
Test Depth (m): 18.50
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7523996
Easting (m): 630659

Vane Shear Test

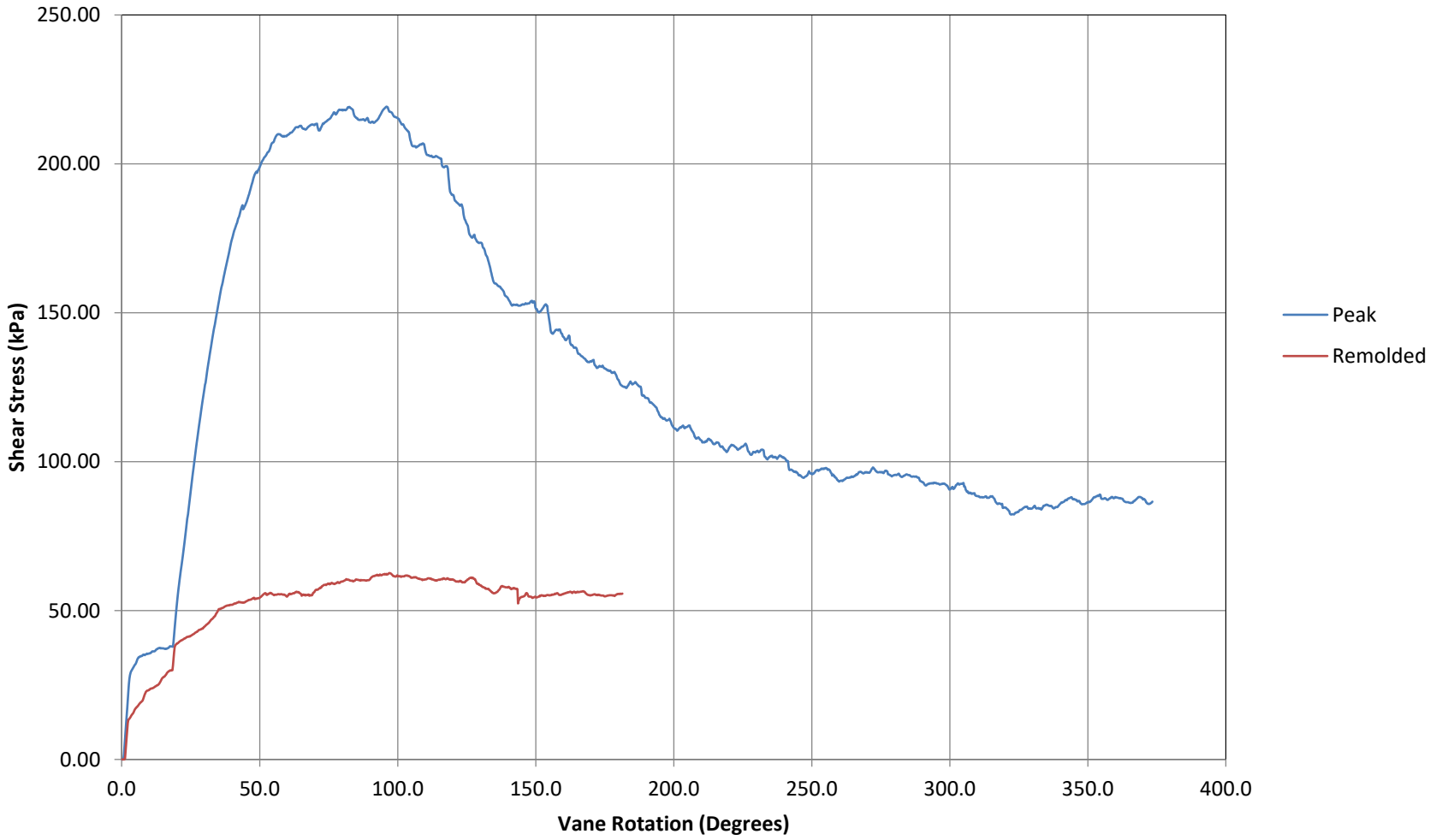


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-19

Test Date: 09-Apr-2021 09:47
Test Depth (m): 5.50
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524423
Easting (m): 632236

Vane Shear Test

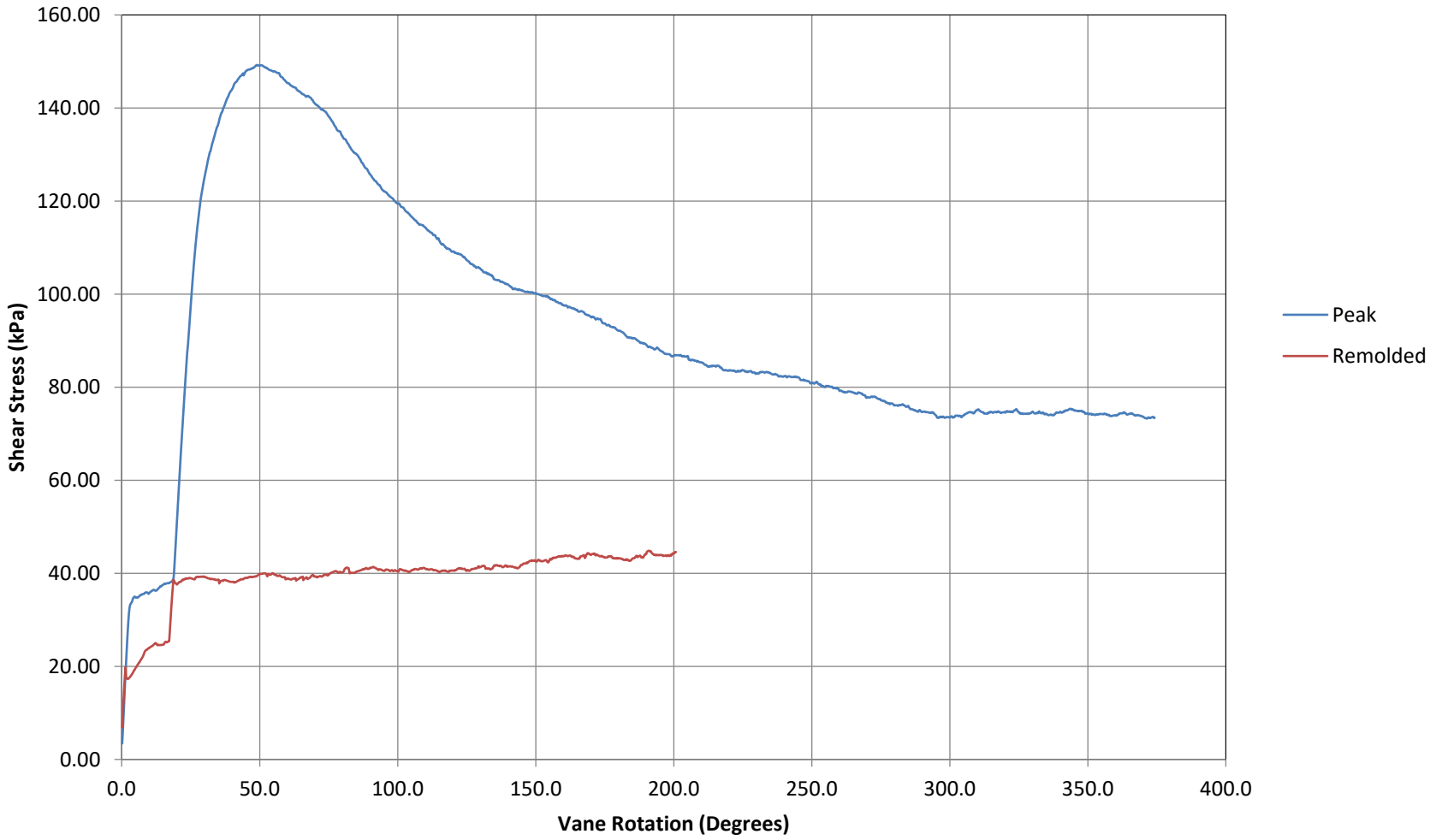


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-19

Test Date: 12-Apr-2021 12:58
Test Depth (m): 6.00
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524423
Easting (m): 632236

Vane Shear Test

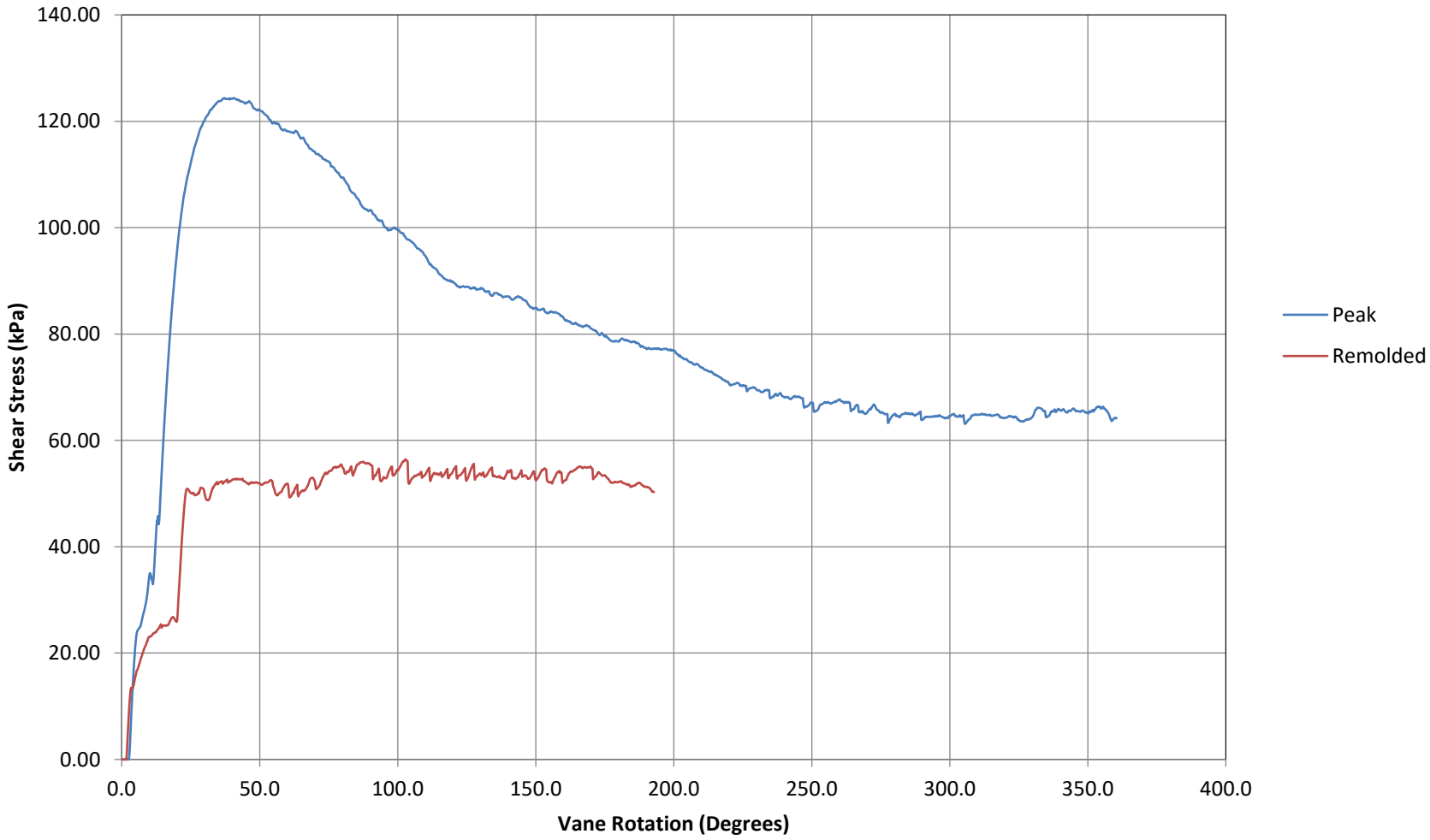


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-19

Test Date: 12-Apr-2021 15:26
Test Depth (m): 7.00
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524423
Easting (m): 632236

Vane Shear Test

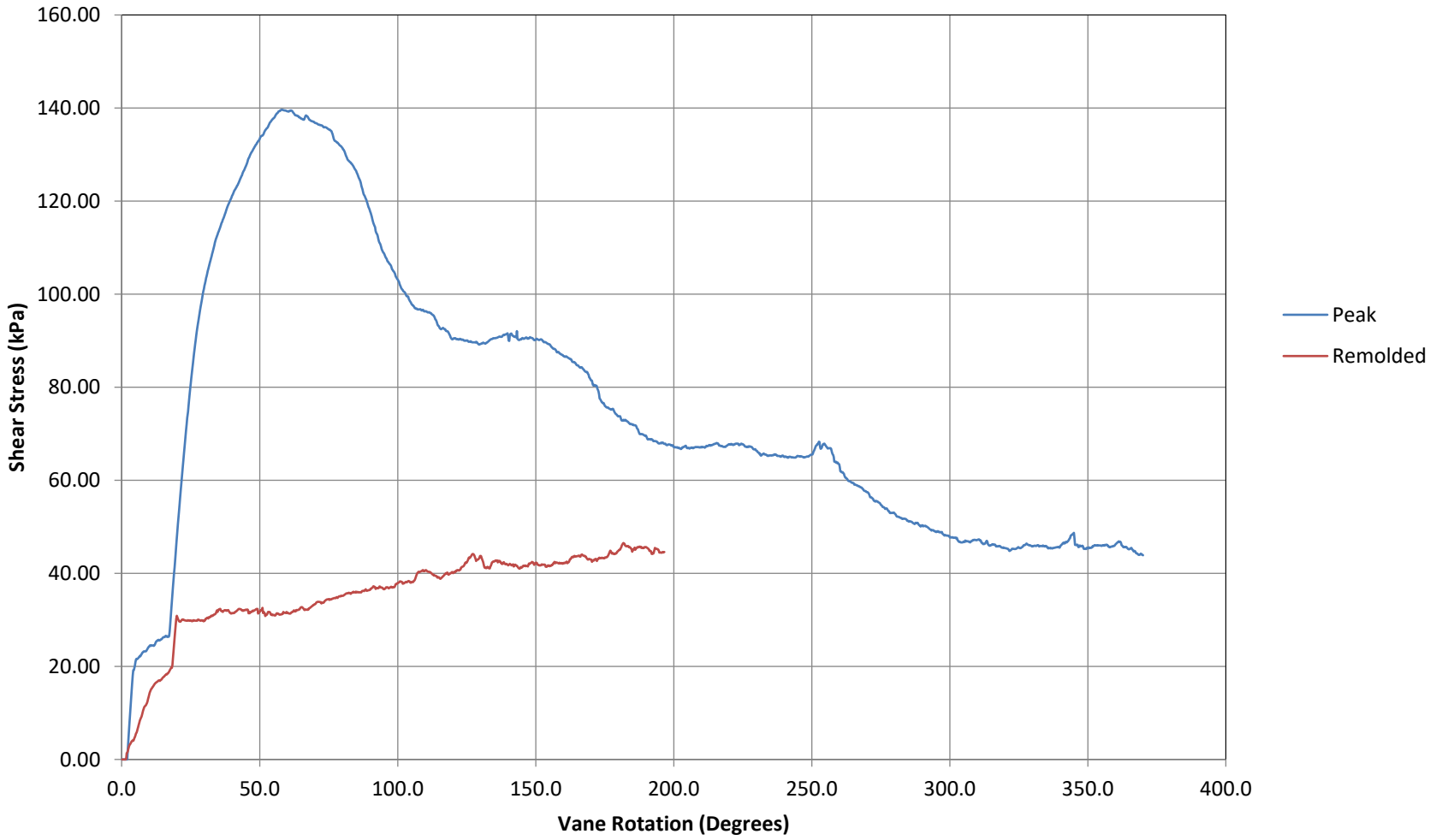


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-19

Test Date: 13-Apr-2021 08:12
Test Depth (m): 9.00
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524423
Easting (m): 632236

Vane Shear Test

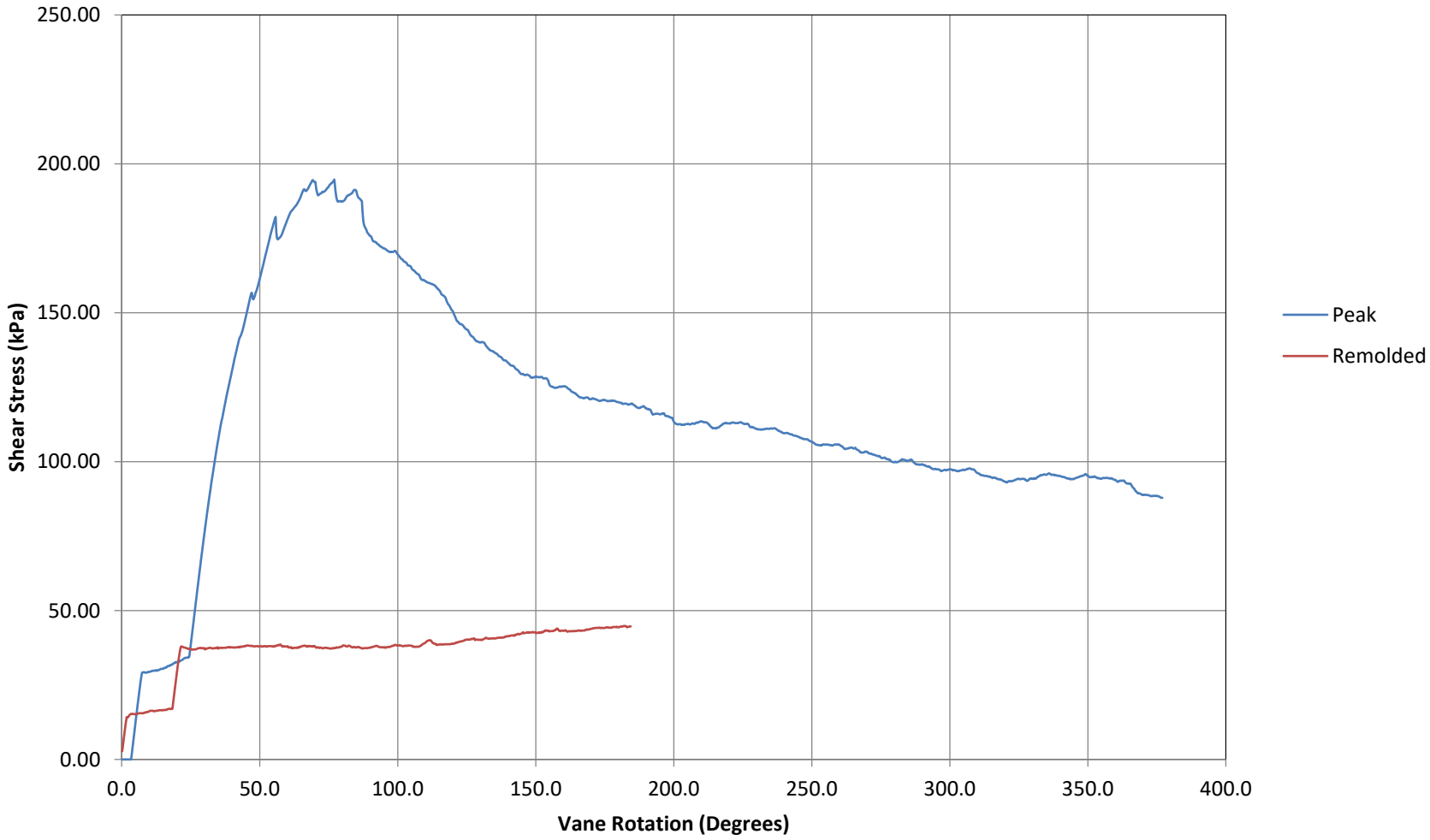


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-22

Test Date: 14-Apr-2021 14:28
Test Depth (m): 9.30
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524509
Easting (m): 632246

Vane Shear Test

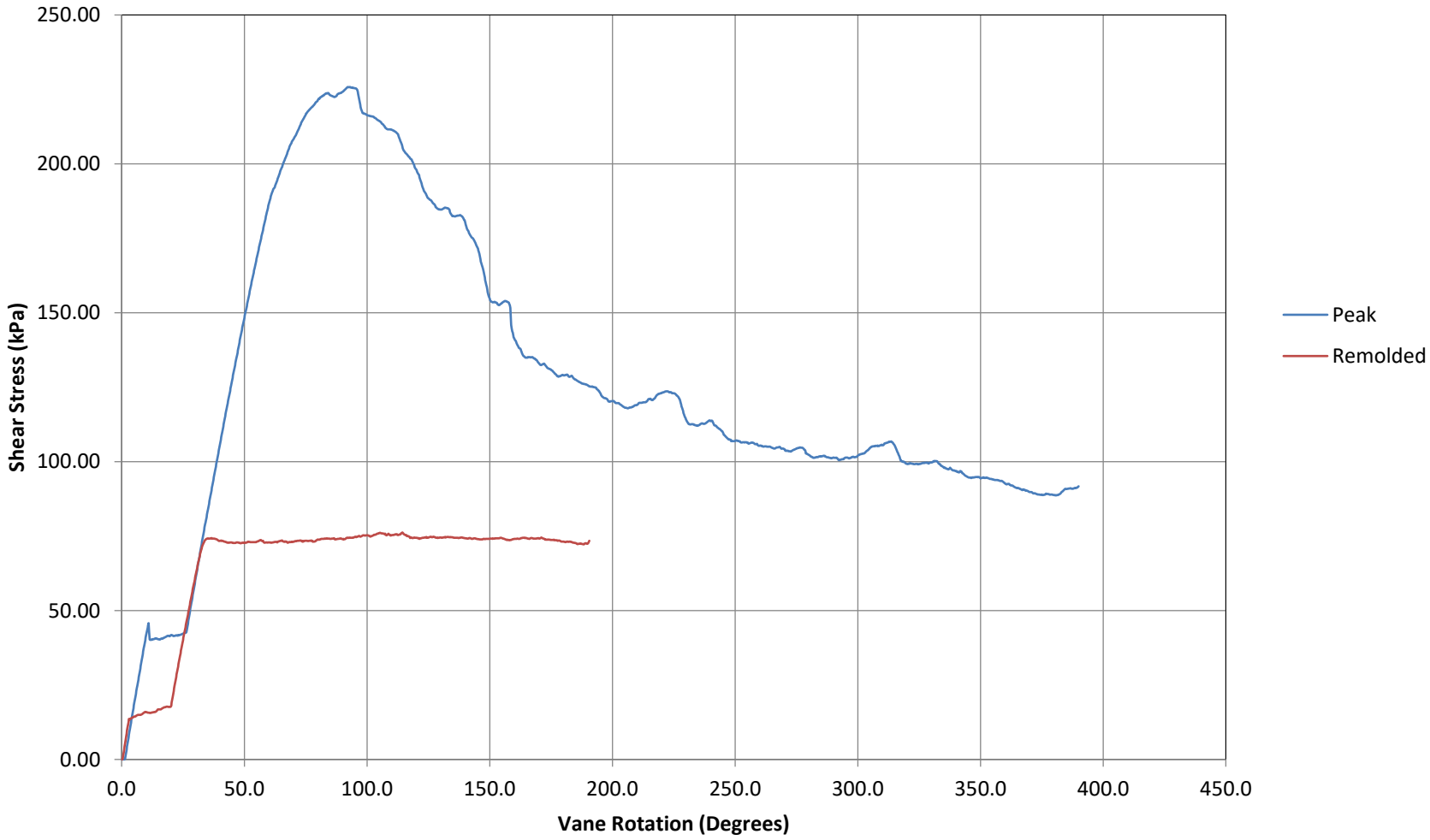


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-22

Test Date: 15-Apr-2021 09:26
Test Depth (m): 16.00
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524509
Easting (m): 632246

Vane Shear Test

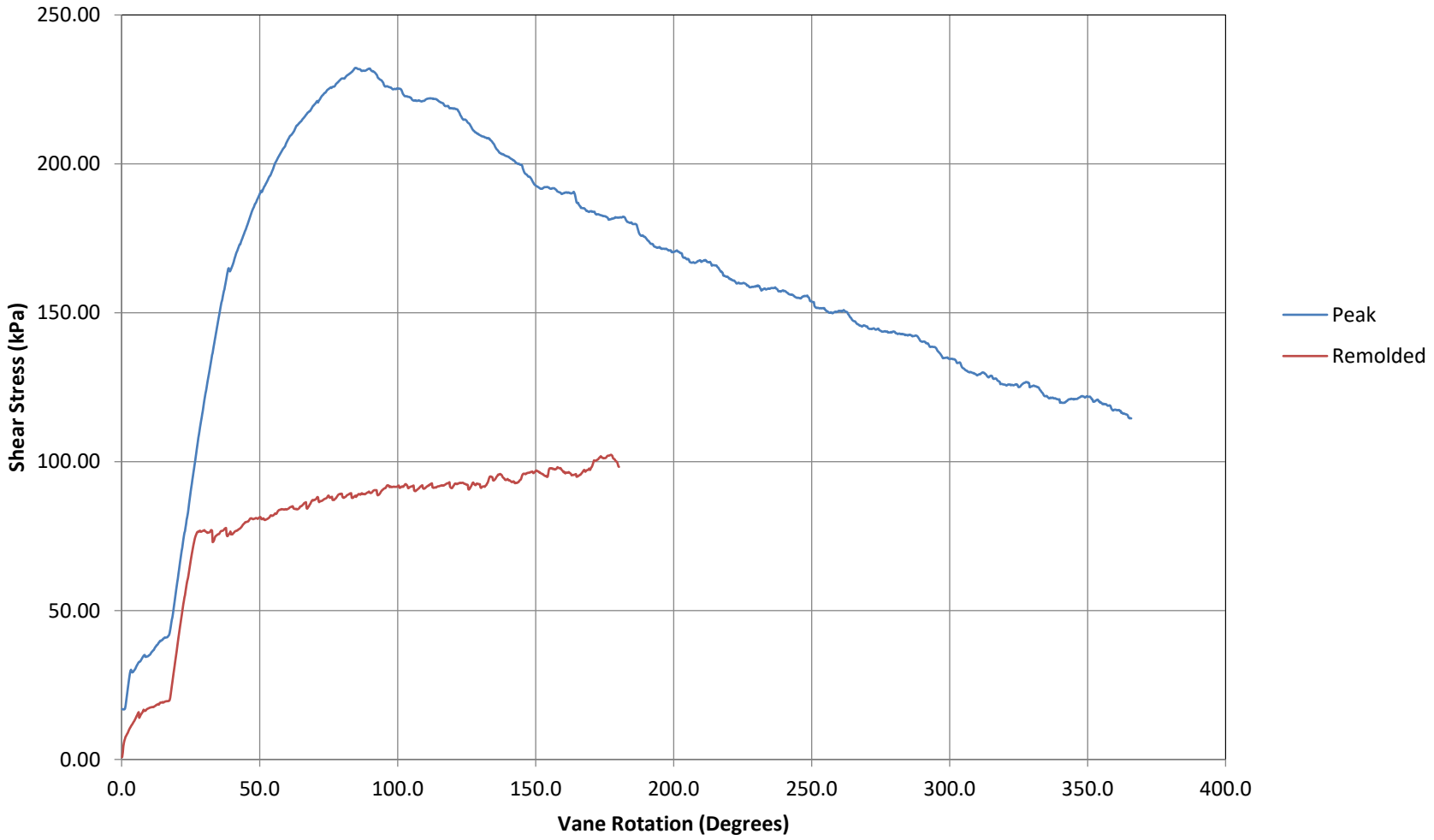


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-24

Test Date: 19-Apr-2021 12:51
Test Depth (m): 11.00
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524562
Easting (m): 632269

Vane Shear Test

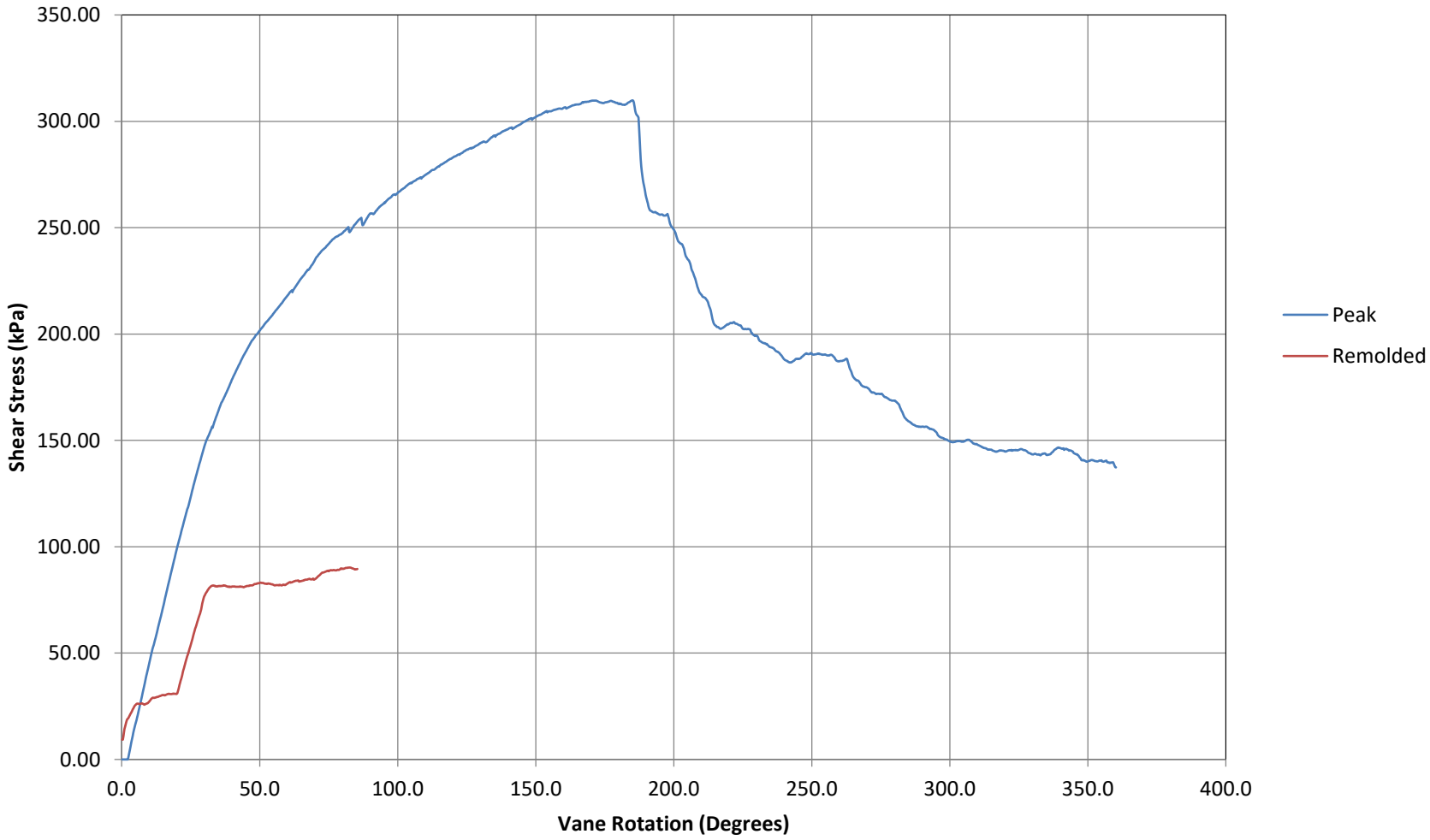


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-24

Test Date: 19-Apr-2021 15:02
Test Depth (m): 14.20
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524562
Easting (m): 632269

Vane Shear Test

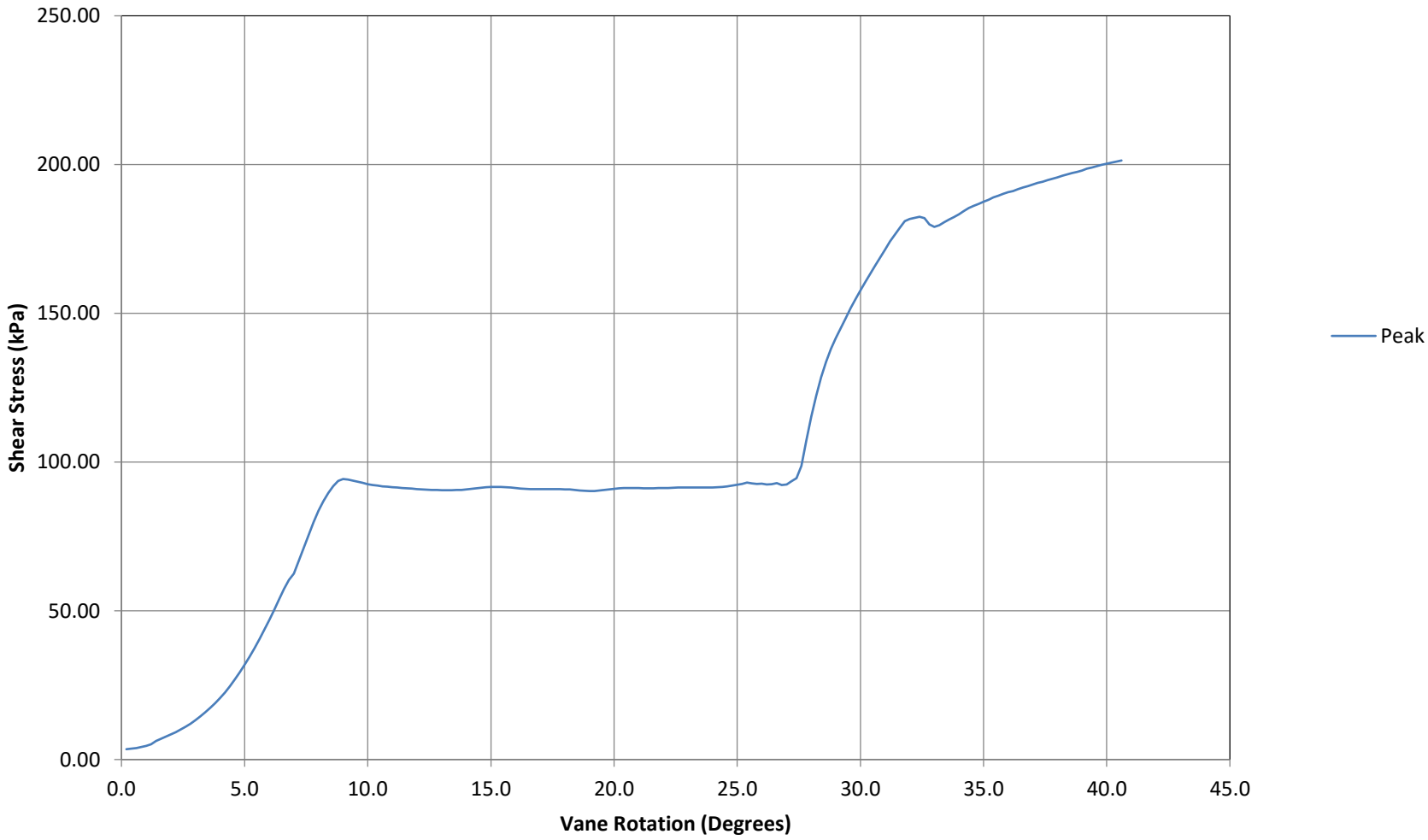


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-27

Test Date: 06-Apr-2021 16:05
Test Depth (m): 8.00
Vane Type: Adara solid double tapered 50 x 100 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524563
Easting (m): 632327

Vane Shear Test

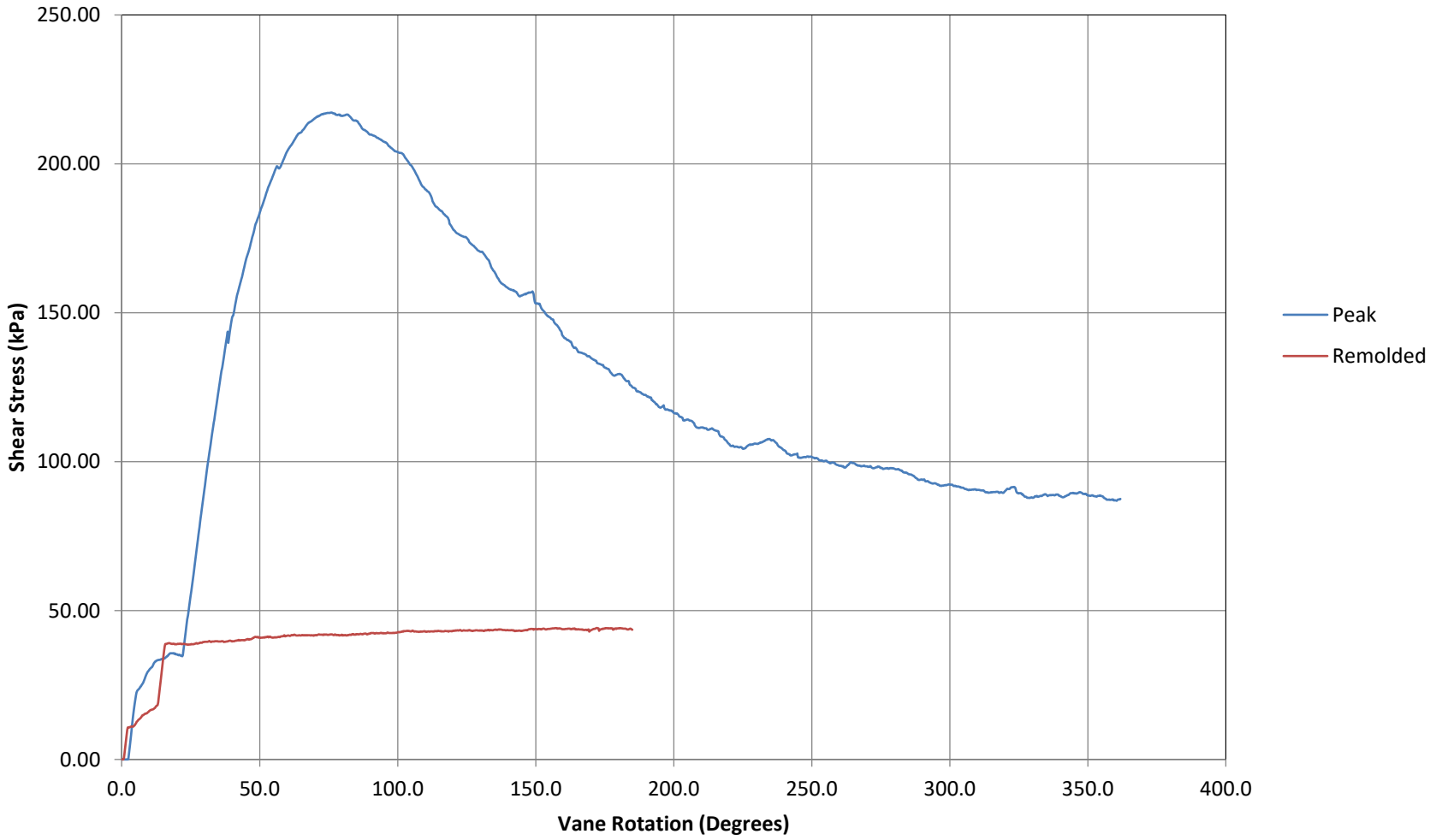


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-27C

Test Date: 07-Apr-2021 14:01
Test Depth (m): 9.50
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524562
Easting (m): 632324

Vane Shear Test

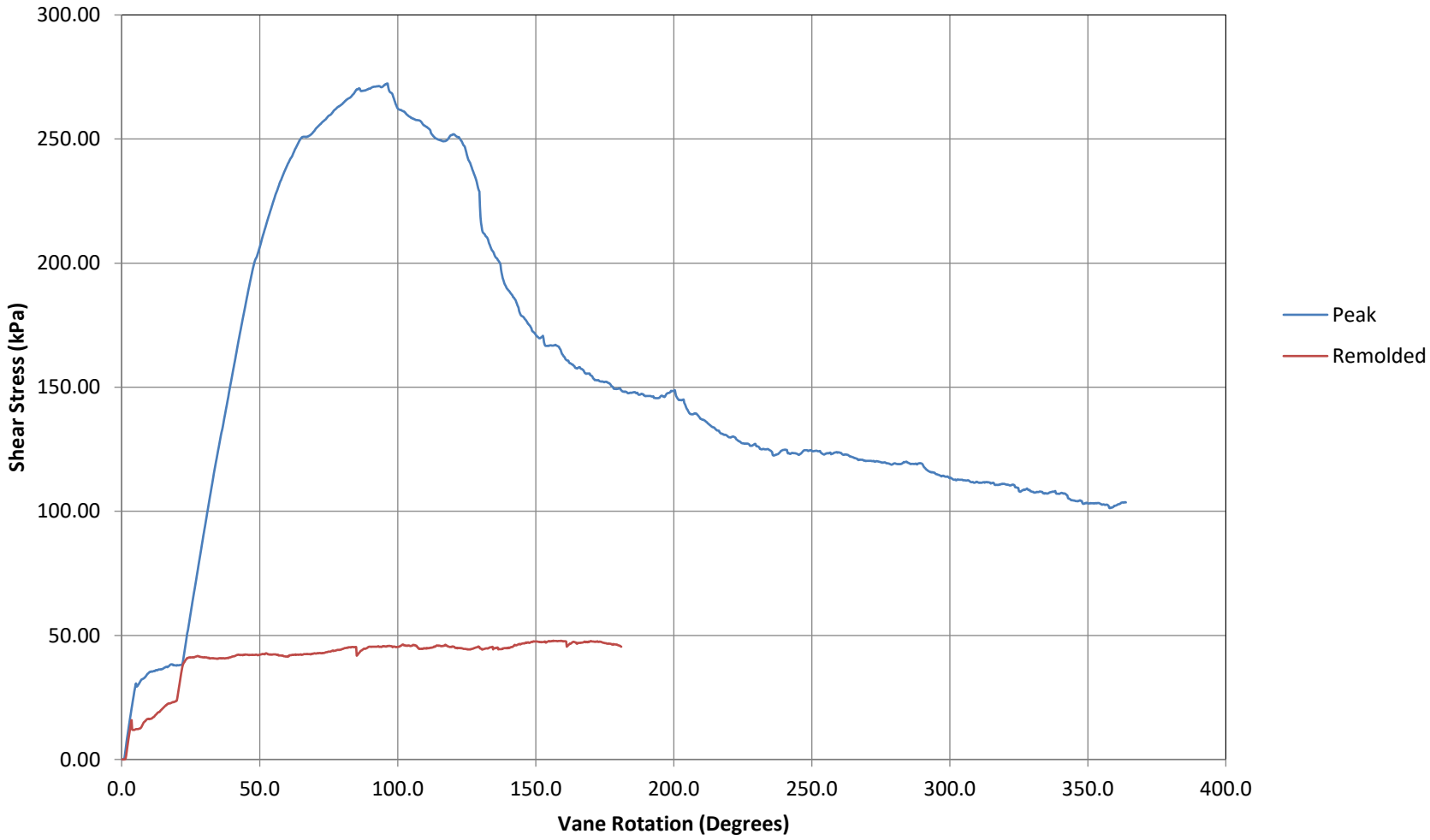


Job Number: 21-18-21942
Client: BHP
Project: Saraji Mine, Ramp 2/3 TSF
Sounding: VST21-27C

Test Date: 07-Apr-2021 16:14
Test Depth (m): 10.50
Vane Type: Adara solid double tapered 40 x 80 mm (45°, 45°)

Coordinate System: AGD66/AMG55
Northing (m): 7524562
Easting (m): 632324

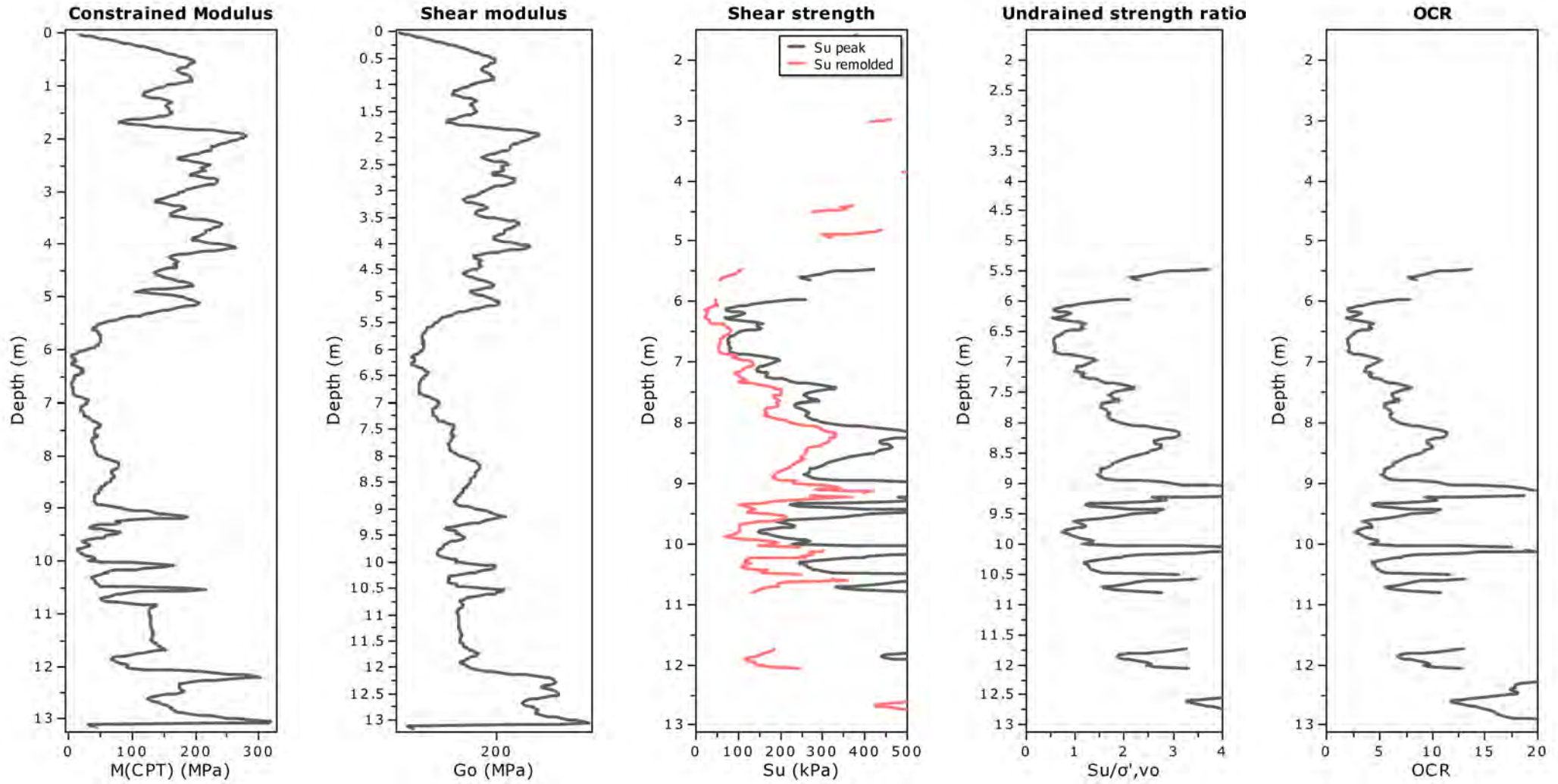
Vane Shear Test



Red Earth Engineering Pty Ltd
108 Bowen Street
Spring Hill: Q4000
Telephone: (07) 3173 1714

CPT: TL-01
Total depth: 13.16 m, Date: 29/06/2021
Surface Elevation: 215.83 m
Coords: X:630324.22, Y:7524844.99
Cone Type:
Cone Operator:

Project: **J20100 BMA Saraji Ramp 2 and 3 TSF Assessment**
Location:



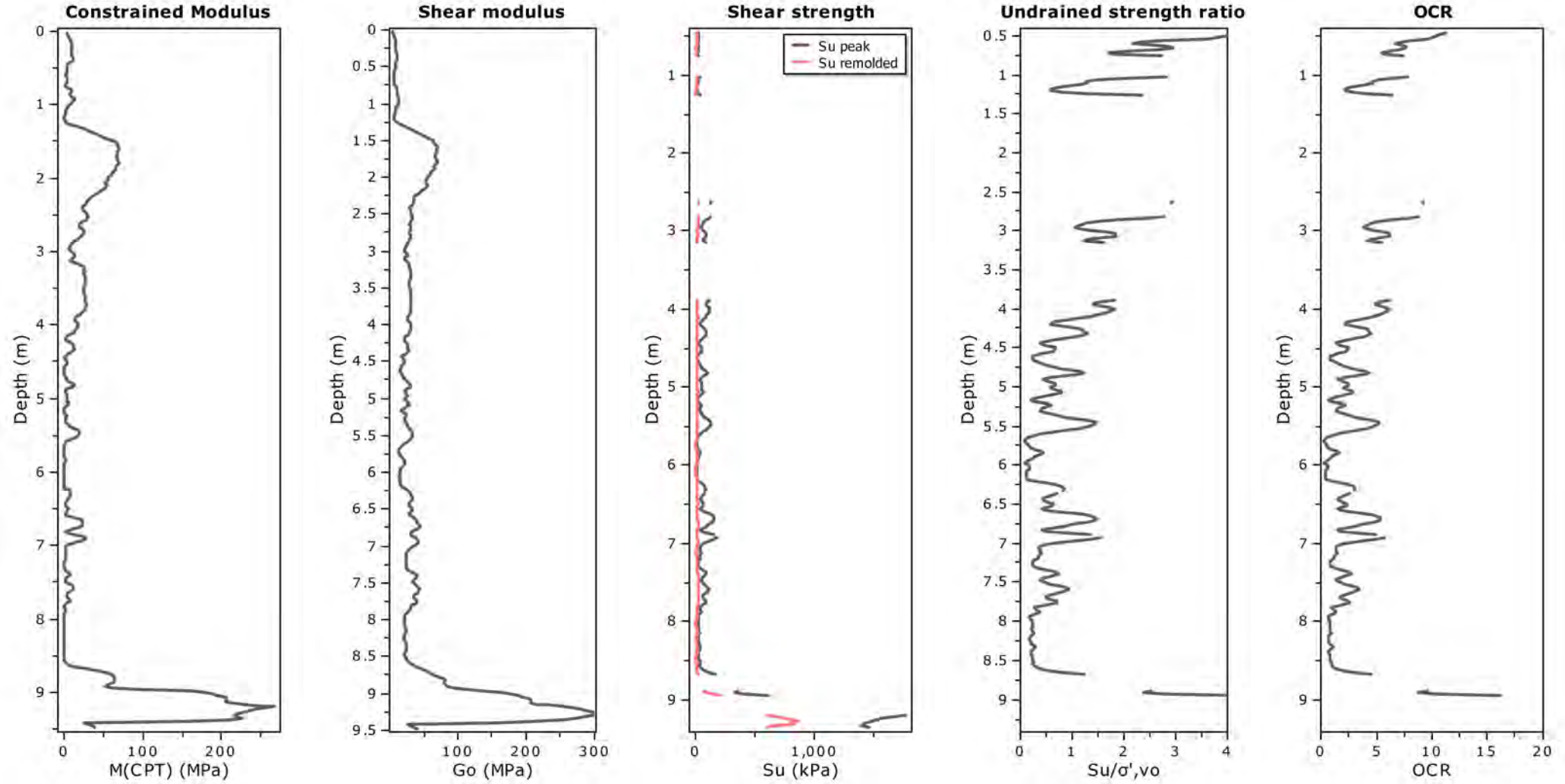
Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 11
OCR factor for clays, N_{kt}: 0.33
Flat Dilatometer Test data

Red Earth Engineering Pty Ltd
108 Bowen Street
Spring Hill: Q4000
Telephone: (07) 3173 1714

CPT: TL-02
Total depth: 9.48 m, Date: 29/06/2021
Surface Elevation: 213.84 m
Coords: X:630343.00, Y:7524826.40
Cone Type:
Cone Operator:

Project: **J20100 BMA Saraji Ramp 2 and 3 TSF Assessment**
Location:



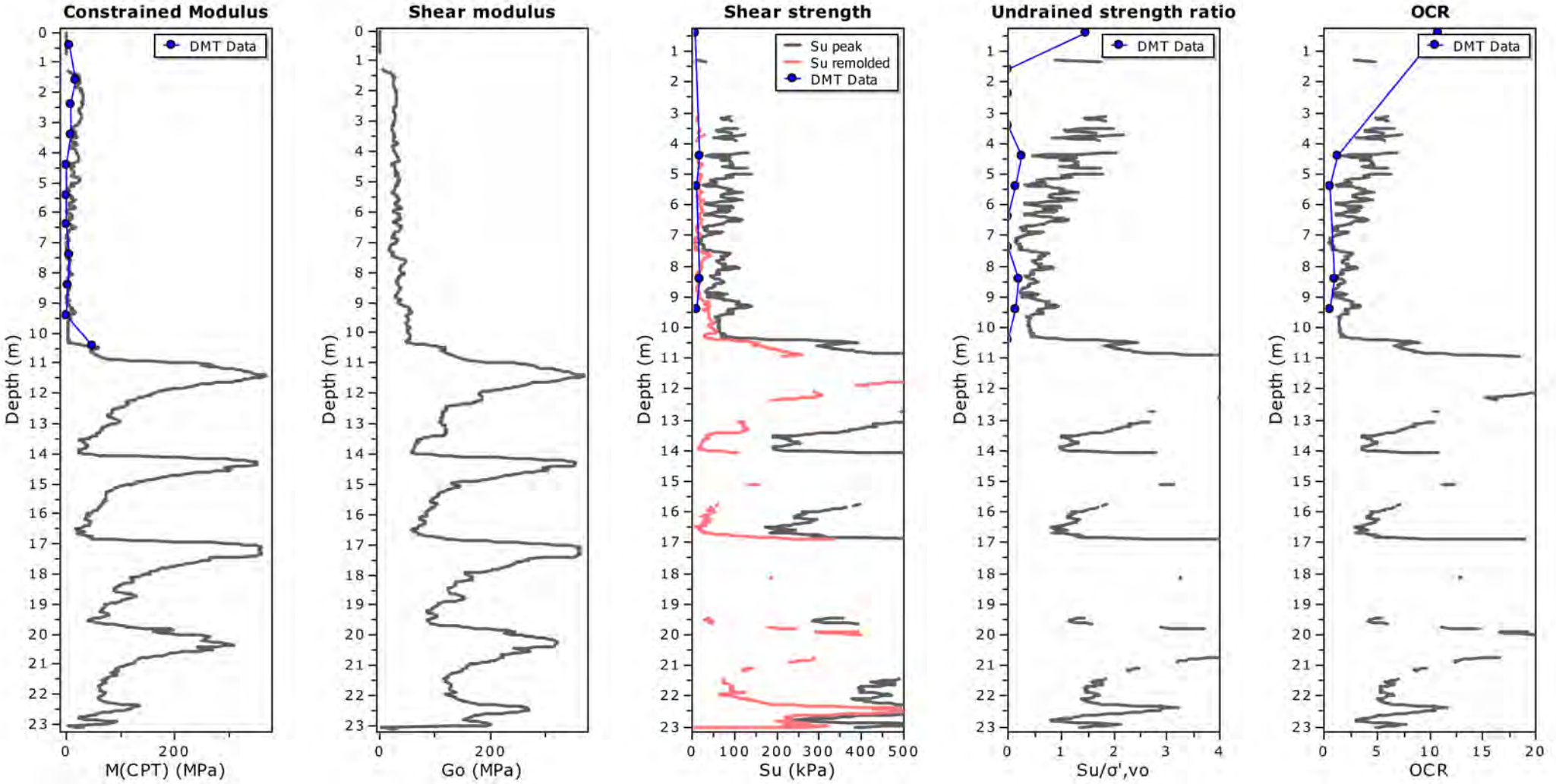
Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 11
OCR factor for clays, N_{kt}: 0.33
Flat Dilatometer Test data

Red Earth Engineering Pty Ltd
108 Bowen Street
Spring Hill: Q4000
Telephone: (07) 3173 1714

CPT: TL-03
Total depth: 23.10 m, Date: 29/06/2021
Surface Elevation: 213.68 m
Coords: X:630324.70, Y:7524755.80
Cone Type:
Cone Operator:

Project: **J20100 BMA Saraji Ramp 2 and 3 TSF Assessment**
Location:



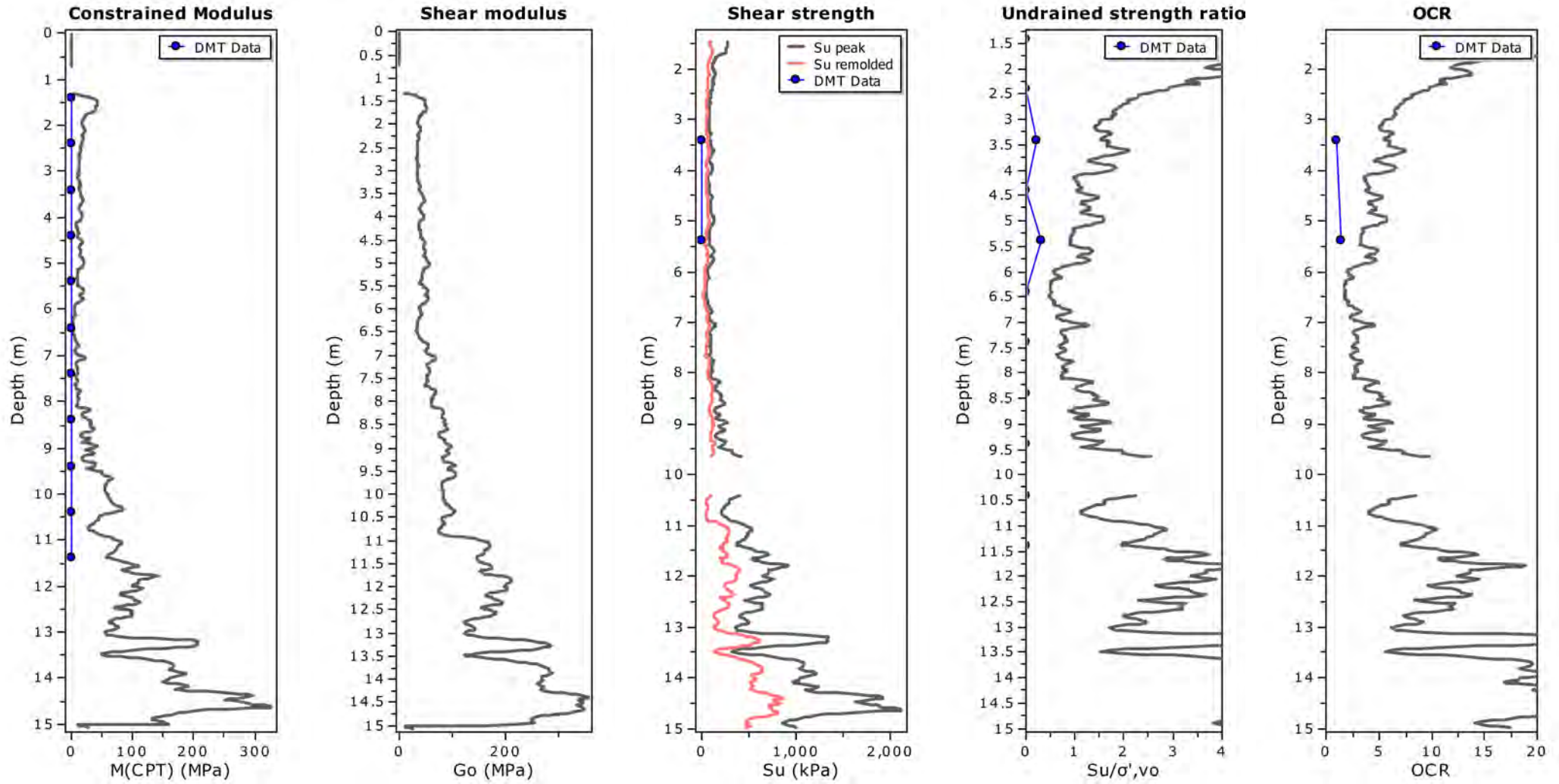
Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 11
OCR factor for clays, N_{kt}: 0.33
Flat Dilatometer Test data

Red Earth Engineering Pty Ltd
108 Bowen Street
Spring Hill: Q4000
Telephone: (07) 3173 1714

CPT: TL-05
Total depth: 15.08 m, Date: 29/06/2021
Surface Elevation: 212.33 m
Coords: X:630441.60, Y:7524568.10
Cone Type:
Cone Operator:

Project: **J20100 BMA Saraji Ramp 2 and 3 TSF Assessment**
Location:



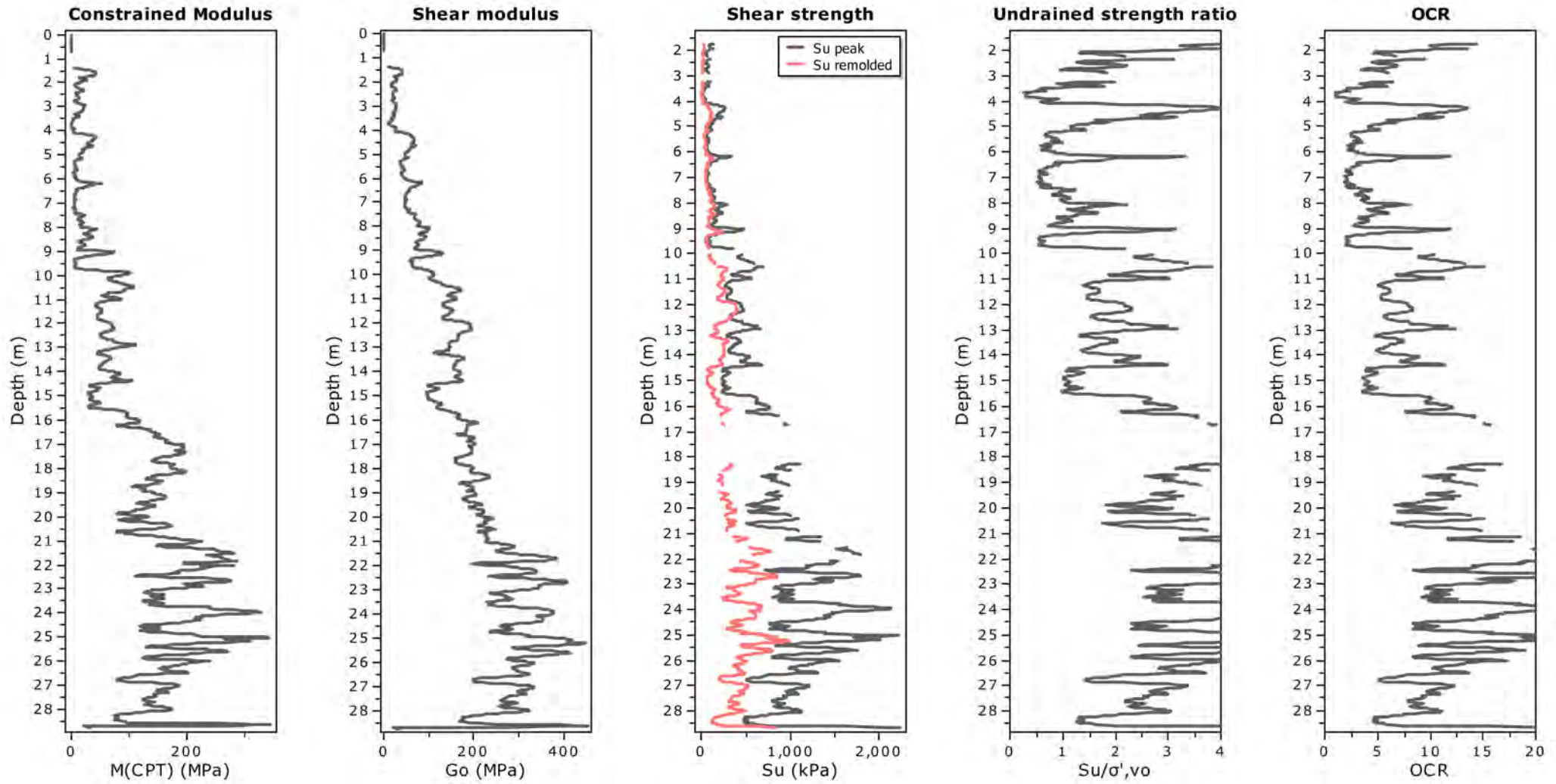
Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 11
OCR factor for clays, N_{kt}: 0.33
Flat Dilatometer Test data

Red Earth Engineering Pty Ltd
108 Bowen Street
Spring Hill: Q4000
Telephone: (07) 3173 1714

CPT: TL-07
Total depth: 28.76 m, Date: 29/06/2021
Surface Elevation: 212.20 m
Coords: X:630542.62, Y:7524386.27
Cone Type:
Cone Operator:

Project: **J20100 BMA Saraji Ramp 2 and 3 TSF Assessment**
Location:



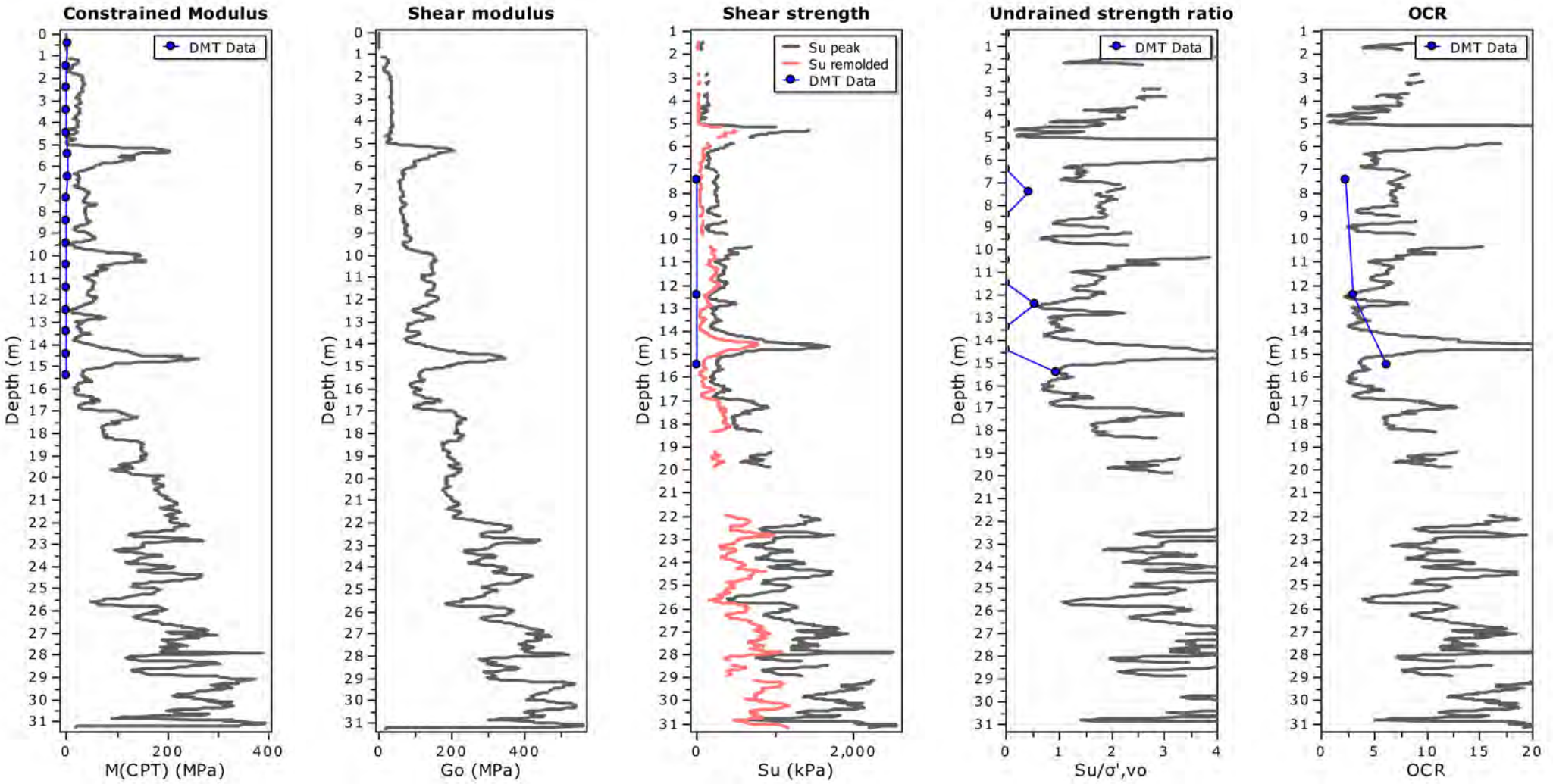
Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 11
OCR factor for clays, N_{kt}: 0.33
Flat Dilatometer Test data

Red Earth Engineering Pty Ltd
108 Bowen Street
Spring Hill: Q4000
Telephone: (07) 3173 1714

CPT: TL-09
Total depth: 31.26 m, Date: 29/06/2021
Surface Elevation: 212.25 m
Coords: X:630595.76, Y:7524291.32
Cone Type:
Cone Operator:

Project: **J20100 BMA Saraji Ramp 2 and 3 TSF Assessment**
Location:



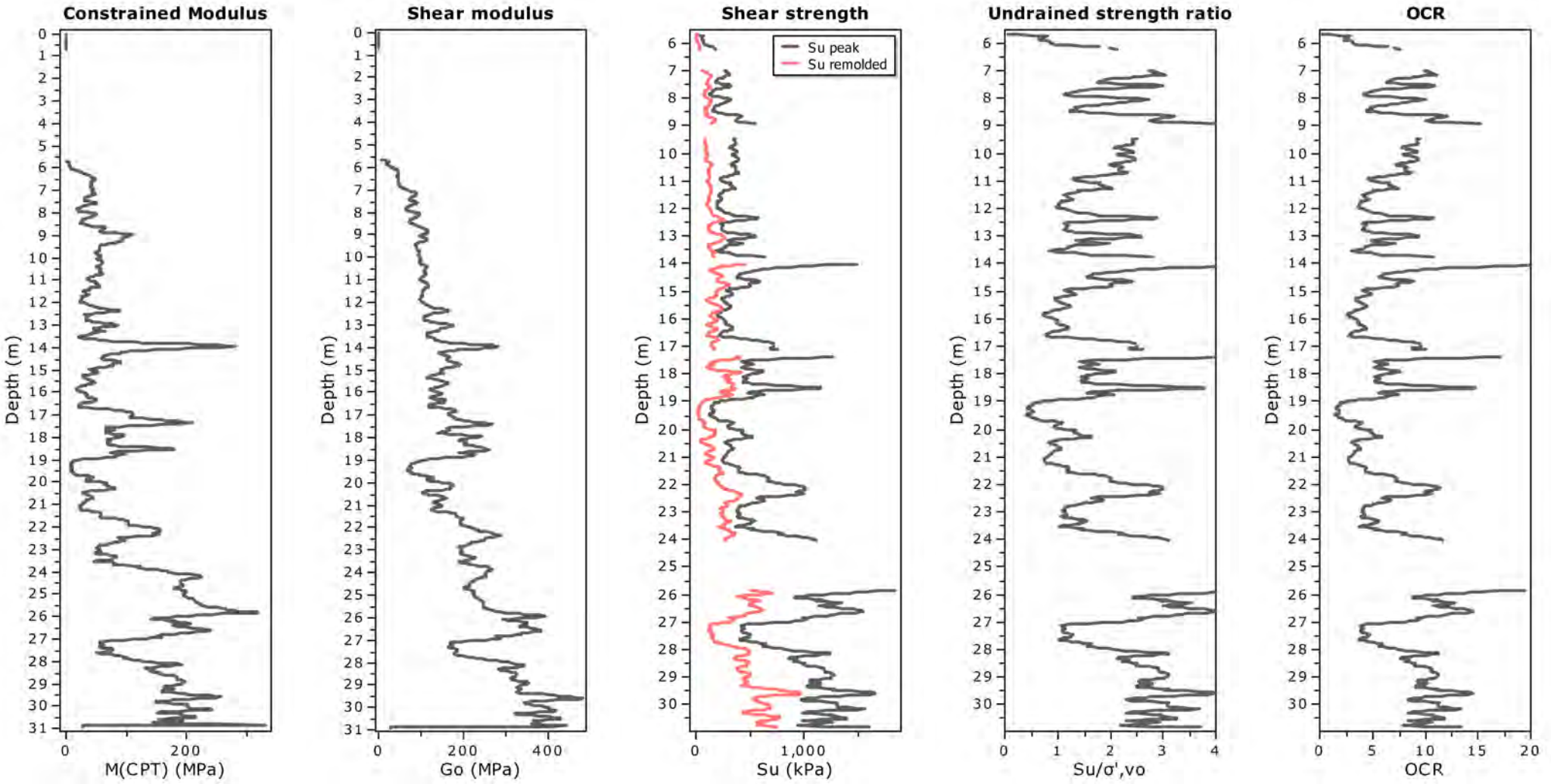
Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 11
OCR factor for clays, N_{kt}: 0.33
Flat Dilatometer Test data

Red Earth Engineering Pty Ltd
108 Bowen Street
Spring Hill: Q4000
Telephone: (07) 3173 1714

CPT: TL-10
Total depth: 30.92 m, Date: 29/06/2021
Surface Elevation: 215.71 m
Coords: X:630570.88, Y:7524279.20
Cone Type:
Cone Operator:

Project: **J20100 BMA Saraji Ramp 2 and 3 TSF Assessment**
Location:



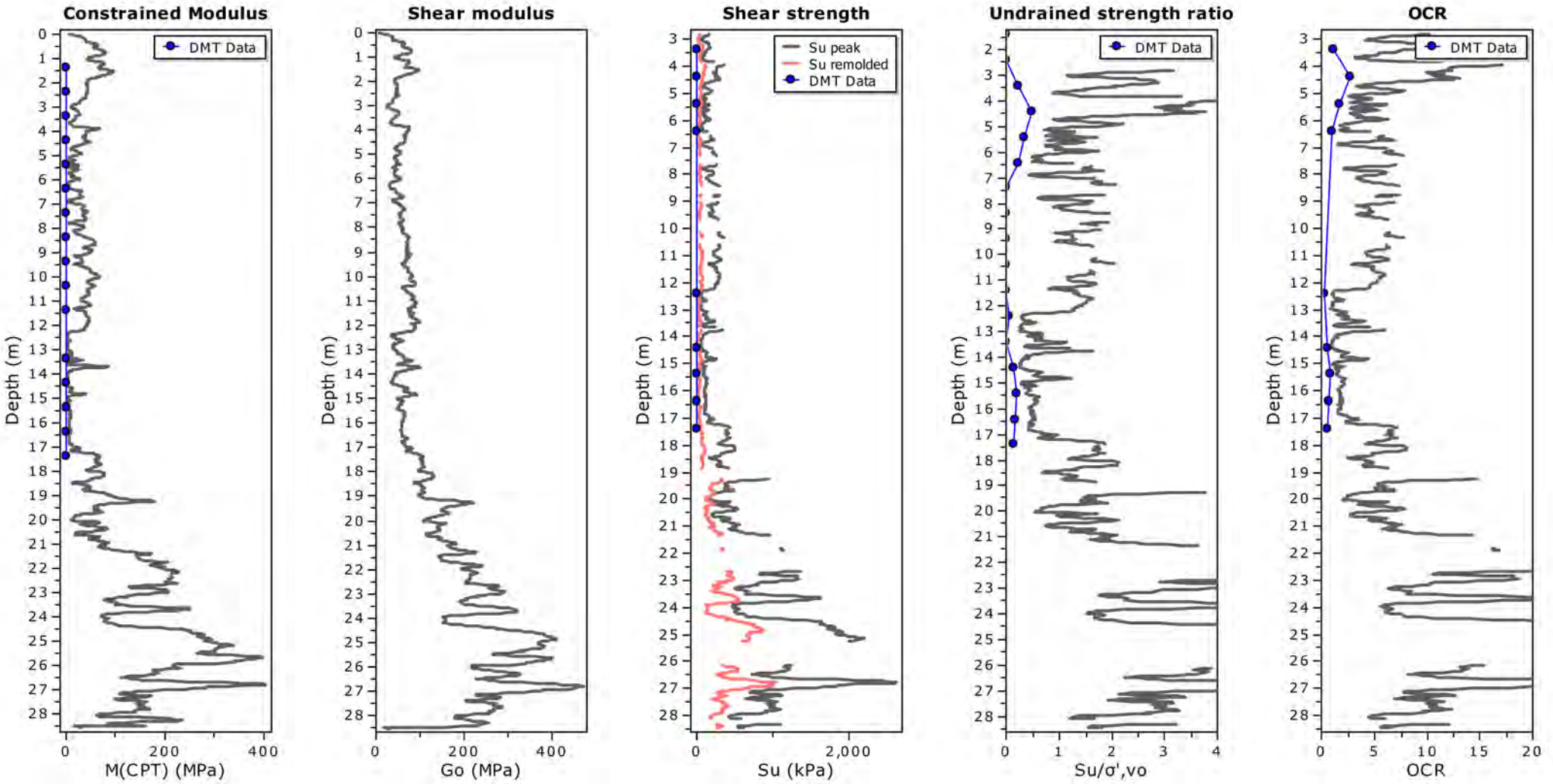
Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 11
OCR factor for clays, N_{kt}: 0.33
Flat Dilatometer Test data

Red Earth Engineering Pty Ltd
108 Bowen Street
Spring Hill: Q4000
Telephone: (07) 3173 1714

CPT: TL-11
Total depth: 28.54 m, Date: 29/06/2021
Surface Elevation: 210.88 m
Coords: X:630687.16, Y:7524010.54
Cone Type:
Cone Operator:

Project: **J20100 BMA Saraji Ramp 2 and 3 TSF Assessment**
Location:



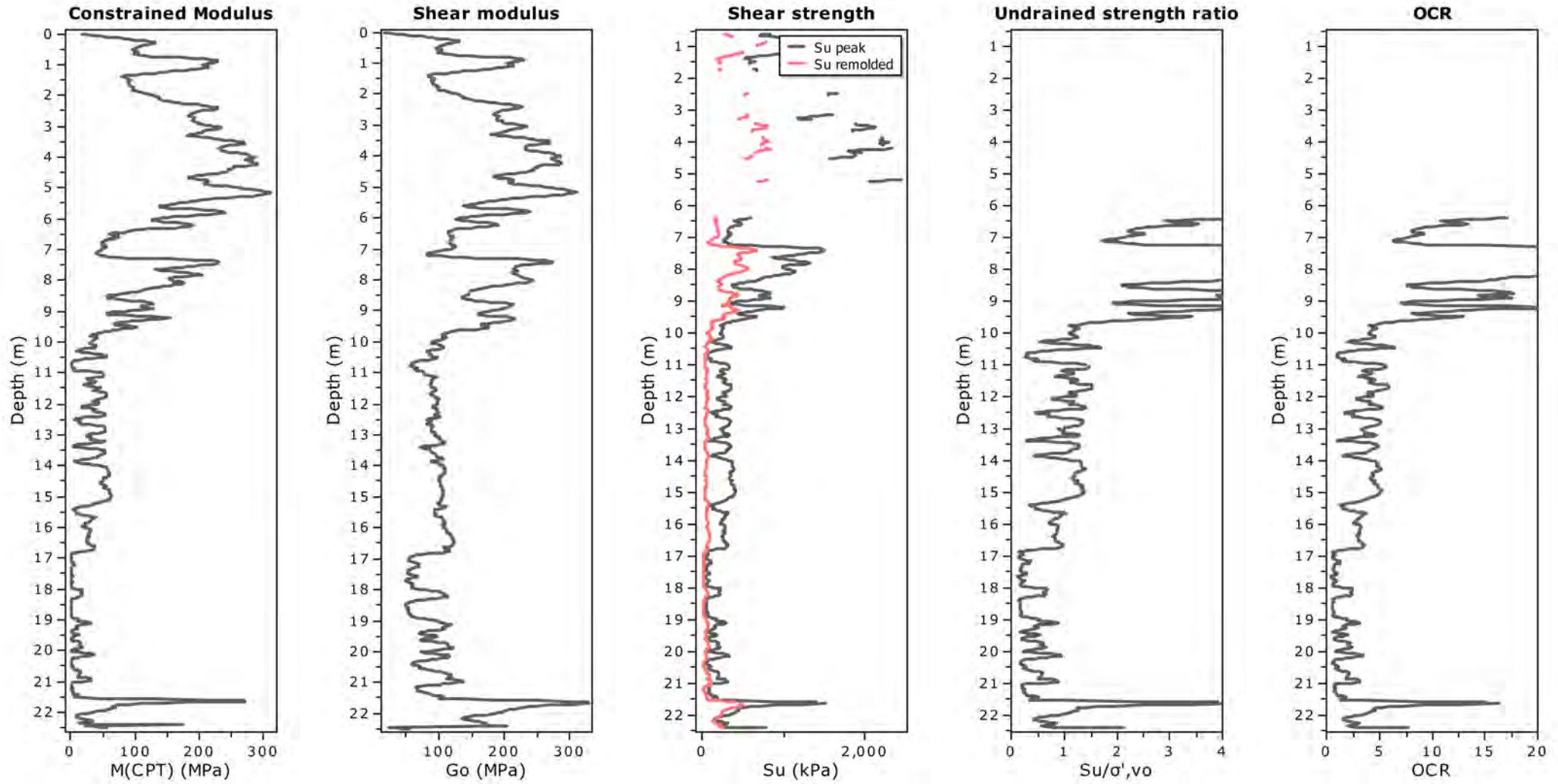
Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 11
OCR factor for clays, N_{kt}: 0.33
Flat Dilatometer Test data

Red Earth Engineering Pty Ltd
108 Bowen Street
Spring Hill: Q4000
Telephone: (07) 3173 1714

CPT: TL-13
Total depth: 22.50 m, Date: 29/06/2021
Surface Elevation: 215.96 m
Coords: X:630660.28, Y:7523996.00
Cone Type:
Cone Operator:

Project: **J20100 BMA Saraji Ramp 2 and 3 TSF Assessment**
Location:



Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: 11
OCR factor for clays, N_{kt}: 0.33
Flat Dilatometer Test data

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DIRECT SIMPLE SHEAR TEST REPORT

Test Method: ASTM D6528

Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Fine Grain Soils

Client	Red Earth Engineering Pty Ltd	**Report No.**	21050440- MDSS
		Workorder No	0008657
Address	108 Bowen Street, Spring Hill, QLD 4000	**Test Date**	2/06/2021
		Report Date	9/06/2021
Project	J20100 - Saraji Mine Ramp 2-3		
Client ID	TL-07	**Depth (m)**	3.70-4.26
Description	TAILINGS-black		
Sample Type	Single individual soil specimen - Undisturbed.		

SAMPLE DETAILS

Specimen Condition	Inundated	Initial Dry Density (t/m^3)	1.18
Initial Diameter (mm)	70.01	Initial Wet Density (t/m^3)	1.52
Initial Height (mm)	17.46	Initial Void Ratio	0.63
Initial Moisture Content (%)	28.9	Initial % Saturation	88.6
Specific Gravity	1.92	After Test Moisture Content (%)	41.7

CONSOLIDATION STAGES

Consolidation Stress (kPa)	15	25								
Total Height Change (mm)	1.406	1.596								
Consolidated Height (mm)	16.048	15.857								
Axial Strain (%)	8.06	9.15								
Duration (min)	60	191								

MONOTONIC SHEAR

Test Condition	Sheared under Constant Volume		
Strain Rate (mm/min)	0.01	Initial Vertical Effective Stress (kPa)	25.0
Pre-Shear Void Ratio	0.48	Initial Shear Stress (kPa)	-4.9
Pre-Shear Moisture Content	21.19	Max. Excess Pore Pressure (kPa)	6.3
Maximum Shear Stress (kPa)	12.50	Ratio of Peak τ/σ'_v	0.7
Normal Stress at Max Shear Stress (kPa)	18.66		
Shear Strain at Max Shear Stress (%)	24.82		

Notes/Remarks:

Sample/s supplied by the client

Tested at Trilab Brisbane Laboratory

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

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DIRECT SIMPLE SHEAR TEST REPORT

Test Method: ASTM D6528

Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Fine Grain Soils

Client	Red Earth Engineering Pty Ltd	**Report No.**	21050441- MDSS
		Workorder No	0008657
Address	108 Bowen Street, Spring Hill, QLD 4000	**Test Date**	26/05/2021
		Report Date	9/06/2021
Project	J20100 - Saraji Mine Ramp 2-3		
Client ID	TL-09	**Depth (m)**	4.60-5.25
Description	TAILINGS- black		
Sample Type	Single individual soil specimen - Undisturbed.		

SAMPLE DETAILS

Specimen Condition	Inundated	Initial Dry Density (t/m^3)	1.05
Initial Diameter (mm)	70.01	Initial Wet Density (t/m^3)	1.53
Initial Height (mm)	17.01	Initial Void Ratio	0.90
Initial Moisture Content (%)	46.7	Initial % Saturation	100.0
Specific Gravity	1.99	After Test Moisture Content (%)	42.1

CONSOLIDATION STAGES

Consolidation Stress (kPa)	15	30								
Total Height Change (mm)	0.568	0.836								
Consolidated Height (mm)	16.439	16.172								
Axial Strain (%)	3.34	4.92								
Duration (min)	60	252								

MONOTONIC SHEAR

Test Condition	Sheared under Constant Volume		
Strain Rate (mm/min)	0.01	Initial Vertical Effective Stress (kPa)	30.0
Pre-Shear Void Ratio	0.81	Initial Shear Stress (kPa)	-0.5
Pre-Shear Moisture Content	42.00	Max. Excess Pore Pressure (kPa)	22.2
Maximum Shear Stress (kPa)	16.47	Ratio of Peak τ/σ'_v	2.1
Normal Stress at Max Shear Stress (kPa)	7.80		
Shear Strain at Max Shear Stress (%)	24.55		

Notes/Remarks:

Sample/s supplied by the client

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DIRECT SIMPLE SHEAR TEST REPORT

Test Method: ASTM D6528

Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Fine Grain Soils

Client	Red Earth Engineering Pty Ltd	**Report No.**	21050442- MDSS
		Workorder No	0008657
Address	108 Bowen Street, Spring Hill, QLD 4000	**Test Date**	27/05/2021
		Report Date	9/06/2021
Project	J20100 - Saraji Mine Ramp 2-3		
Client ID	TL-11	**Depth (m)**	5.50-6.15
Description	TAILINGS-black		
Sample Type	Single individual soil specimen - Undisturbed.		

SAMPLE DETAILS

Specimen Condition	Inundated	Initial Dry Density (t/m^3)	1.21
Initial Diameter (mm)	70.01	Initial Wet Density (t/m^3)	1.59
Initial Height (mm)	17.28	Initial Void Ratio	0.61
Initial Moisture Content (%)	30.9	Initial % Saturation	98.5
Specific Gravity	1.96	After Test Moisture Content (%)	26.4

CONSOLIDATION STAGES

Consolidation Stress (kPa)	15	25	40							
Total Height Change (mm)	0.297	0.398	0.504							
Consolidated Height (mm)	16.984	16.884	16.777							
Axial Strain (%)	1.72	2.31	2.92							
Duration (min)	32	240	613							

MONOTONIC SHEAR

Test Condition	Sheared under Constant Volume		
Strain Rate (mm/min)	0.01	Initial Vertical Effective Stress (kPa)	40.0
Pre-Shear Void Ratio	0.57	Initial Shear Stress (kPa)	2.2
Pre-Shear Moisture Content	28.48	Max. Excess Pore Pressure (kPa)	23.4
Maximum Shear Stress (kPa)	28.32	Ratio of Peak τ/σ'_v	1.7
Normal Stress at Max Shear Stress (kPa)	16.58		
Shear Strain at Max Shear Stress (%)	23.78		

Notes/Remarks:

Sample/s supplied by the client

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DIRECT SIMPLE SHEAR TEST REPORT

Test Method: ASTM D6528

Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Fine Grain Soils

Client	Red Earth Engineering Pty Ltd	**Report No.**	21050670- MDSS
		Workorder No	0008657
Address	108 Bowen Street, Spring Hill, QLD 4000	**Test Date**	3/06/2021
		Report Date	10/06/2021
Project	J20100 - Saraji Mine Ramp 2-3		
Client ID	TL-07	**Depth (m)**	3.70-4.26
Description	TAILINGS- black		
Sample Type	Single individual soil specimen - Undisturbed.		

SAMPLE DETAILS

Specimen Condition	Inundated	Initial Dry Density (t/m^3)	1.20
Initial Diameter (mm)	70.01	Initial Wet Density (t/m^3)	1.56
Initial Height (mm)	16.98	Initial Void Ratio	0.60
Initial Moisture Content (%)	29.9	Initial % Saturation	96.3
Specific Gravity	1.92	After Test Moisture Content (%)	32.2

CONSOLIDATION STAGES

Consolidation Stress (kPa)	15	25	50							
Total Height Change (mm)	0.477	0.599	0.828							
Consolidated Height (mm)	16.503	16.381	16.152							
Axial Strain (%)	2.81	3.53	4.87							
Duration (min)	60	60	80							

MONOTONIC SHEAR

Test Condition	Sheared under Constant Volume		
Strain Rate (mm/min)	0.010	Initial Vertical Effective Stress (kPa)	50.0
Pre-Shear Void Ratio	0.52	Initial Shear Stress (kPa)	-2.5
Pre-Shear Moisture Content	25.91	Max. Excess Pore Pressure (kPa)	32.8
Maximum Shear Stress (kPa)	24.17	Ratio of Peak τ/σ'_v	1.4
Normal Stress at Max Shear Stress (kPa)	17.28		
Shear Strain at Max Shear Stress (%)	24.53		

Notes/Remarks:

Sample/s supplied by the client

Tested at Trilab Brisbane Laboratory

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DIRECT SIMPLE SHEAR TEST REPORT

Test Method: ASTM D6528

Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Fine Grain Soils

Client	Red Earth Engineering Pty Ltd	**Report No.**	21050671- MDSS
		Workorder No	0008657
Address	108 Bowen Street, Spring Hill, QLD 4000	**Test Date**	31/05/2021
		Report Date	9/06/2021
Project	J20100 - Saraji Mine Ramp 2-3		
Client ID	TL-09	**Depth (m)**	4.60-5.25
Description	TAILINGS- black		
Sample Type	Single individual soil specimen - Undisturbed.		

SAMPLE DETAILS

Specimen Condition	Inundated	Initial Dry Density (t/m^3)	1.06
Initial Diameter (mm)	70.01	Initial Wet Density (t/m^3)	1.52
Initial Height (mm)	17.26	Initial Void Ratio	0.87
Initial Moisture Content (%)	43.4	Initial % Saturation	99.1
Specific Gravity	1.99	After Test Moisture Content (%)	41.7

CONSOLIDATION STAGES

Consolidation Stress (kPa)	15	30	60							
Total Height Change (mm)	0.918	1.149	1.509							
Consolidated Height (mm)	16.344	16.113	15.753							
Axial Strain (%)	5.32	6.66	8.74							
Duration (min)	60	60	180							

MONOTONIC SHEAR

Test Condition	Sheared under Constant Volume		
Strain Rate (mm/min)	0.01	Initial Vertical Effective Stress (kPa)	60.1
Pre-Shear Void Ratio	0.71	Initial Shear Stress (kPa)	-5.3
Pre-Shear Moisture Content	35.24	Max. Excess Pore Pressure (kPa)	42.4
Maximum Shear Stress (kPa)	22.71	Ratio of Peak τ/σ'_v	1.3
Normal Stress at Max Shear Stress (kPa)	17.70		
Shear Strain at Max Shear Stress (%)	24.54		

Notes/Remarks:

Sample/s supplied by the client

Tested at Trilab Brisbane Laboratory

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DIRECT SIMPLE SHEAR TEST REPORT

Test Method: ASTM D6528

Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Fine Grain Soils

Client	Red Earth Engineering Pty Ltd	**Report No.**	21050672- MDSS
		Workorder No	0008657
Address	108 Bowen Street, Spring Hill, QLD 4000	**Test Date**	31/05/2021
		Report Date	9/06/2021
Project	J20100 - Saraji Mine Ramp 2-3		
Client ID	TL-11	**Depth (m)**	5.50-6.15
Description	TAILINGS- black		
Sample Type	Single individual soil specimen - Undisturbed.		

SAMPLE DETAILS

Specimen Condition	Inundated	Initial Dry Density (t/m^3)	1.24
Initial Diameter (mm)	70.01	Initial Wet Density (t/m^3)	1.58
Initial Height (mm)	17.12	Initial Void Ratio	0.58
Initial Moisture Content (%)	27.4	Initial % Saturation	92.9
Specific Gravity	1.96	After Test Moisture Content (%)	29.1

CONSOLIDATION STAGES

Consolidation Stress (kPa)	15	30	70							
Total Height Change (mm)	0.311	0.422	0.660							
Consolidated Height (mm)	16.811	16.701	16.463							
Axial Strain (%)	1.82	2.47	3.85							
Duration (min)	60	60	197							

MONOTONIC SHEAR

Test Condition	Sheared under Constant Volume		
Strain Rate (mm/min)	0.01	Initial Vertical Effective Stress (kPa)	70.0
Pre-Shear Void Ratio	0.52	Initial Shear Stress (kPa)	0.9
Pre-Shear Moisture Content	24.32	Max. Excess Pore Pressure (kPa)	18.2
Maximum Shear Stress (kPa)	37.26	Ratio of Peak τ/σ'_v	0.7
Normal Stress at Max Shear Stress (kPa)	51.79		
Shear Strain at Max Shear Stress (%)	23.82		

Notes/Remarks:

Sample/s supplied by the client

Tested at Trilab Brisbane Laboratory

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

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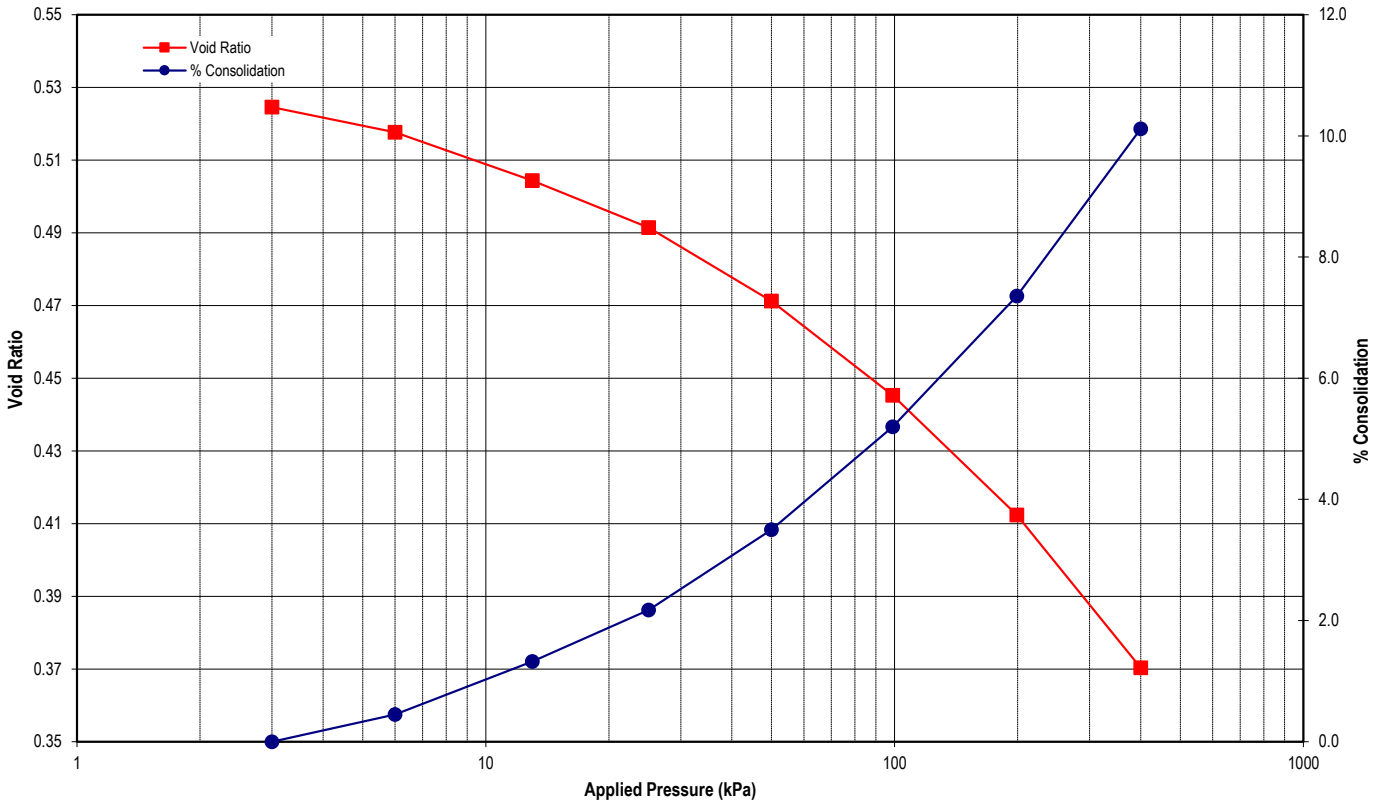
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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	Red Earth Engineering Pty Ltd	**Report No.:**	21080558-OED
		Workorder No.	9023
Address:	108 Bowen Street, Spring Hill, QLD 4000	**Test Date:**	1/09/2021
		Report Date:	16/09/2021
Project:	J20100 - Saraji Mine Ramp 2-3		
Client Id.:	TL-03	**Depth (m):**	5.00-5.65
Description:	SANDY SILT - black		



Initial Wet Density (t/m^3):	1.49	Initial Moisture (%):	33.6	Initial Height (mm):	19.82
Initial Dry Density (t/m^3):	1.12	Final Moisture (%):	26.3	Final Height (mm):	17.81
Initial Mass (g):	88.44	Initial Voids Ratio:	0.525	Test Condition:	Inundated on load
Particle Density (t/m^3):	1.70	Initial Degree of Saturation (%):	100.0	Undisturbed sample supplied by the client	

Remarks: Tested as Received

REP03103

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Channon

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory Number 9926

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ABN 25 065 630 506

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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	Red Earth Engineering Pty Ltd	**Report No.:**	21080558-OED
		Workorder No.	9023
Address:	108 Bowen Street, Spring Hill, QLD 4000	**Test Date:**	1/09/2021
		Report Date:	16/09/2021
Project:	J20100 - Saraji Mine Ramp 2-3		
Client Id.:	TL-03	**Depth (m):**	5.00-5.65
Description:	SANDY SILT - black		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	3-6	0.023	1.1E-08	17.17	23.05	1.502	0.41	0.5
2	6-13	0.040	9.6E-09	31.06	24.70	1.255	0.80	1.3
3	13-25	0.045	7.4E-09	41.63	33.31	0.715	0.95	2.2
4	25-50	0.067	6.6E-09	50.88	39.03	0.542	1.20	3.5
5	50-99	0.087	4.4E-09	51.44	39.09	0.360	1.40	5.2
6	99-199	0.109	3.5E-09	58.98	49.13	0.228	1.67	7.4
7	199-400	0.139	2.1E-09	62.10	46.00	0.148	1.93	10.1

Remarks: Tested as Received

REP03103

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Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Channon

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory Number 9926

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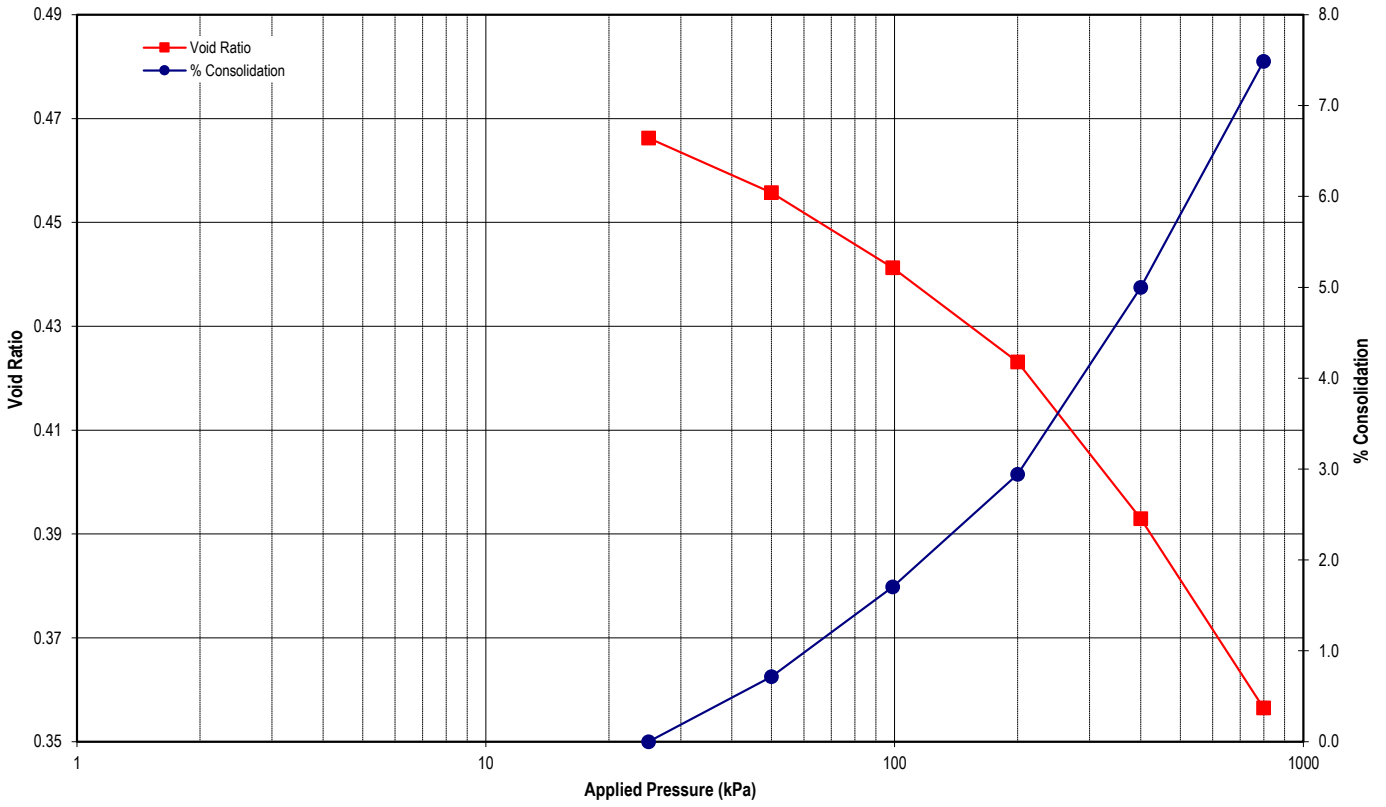
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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	Red Earth Engineering Pty Ltd	**Report No.:**	21080559-OED
		Workorder No.	9023
Address:	108 Bowen Street, Spring Hill, QLD 4000	**Test Date:**	1/09/2021
		Report Date:	16/09/2021
Project:	J20100 - Saraji Mine Ramp 2-3		
Client Id.:	TL-05	**Depth (m):**	6.00-6.60
Description:	SANDY SILTY CLAY - mottled black/brown/grey		



Initial Wet Density (t/m^3):	1.96	Initial Moisture (%):	17.9	Initial Height (mm):	19.94
Initial Dry Density (t/m^3):	1.66	Final Moisture (%):	20.2	Final Height (mm):	18.46
Initial Mass (g):	117.61	Initial Voids Ratio:	0.465	Test Condition:	Inundated on load
Particle Density (t/m^3):	2.43	Initial Degree of Saturation (%):	94.4	Undisturbed sample supplied by the client	

Remarks: Tested as Received

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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	Red Earth Engineering Pty Ltd	**Report No.:**	21080559-OED
		Workorder No.	9023
Address:	108 Bowen Street, Spring Hill, QLD 4000	**Test Date:**	1/09/2021
		Report Date:	16/09/2021
Project:	J20100 - Saraji Mine Ramp 2-3		
Client Id.:	TL-05	**Depth (m):**	6.00-6.60
Description:	SANDY SILTY CLAY - mottled black/brown/grey		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	25-50	0.035	1.4E-09	155.36	15.39	0.287	0.50	0.7
2	50-99	0.049	1.5E-09	242.19	24.14	0.203	0.63	1.7
3	99-200	0.059	8.9E-10	10.81	23.05	0.125	0.79	2.9
4	200-400	0.100	6.3E-10	9.43	19.29	0.106	1.28	5.0
5	400-799	0.121	3.6E-10	8.36	17.84	0.066	1.38	7.5

Remarks: Tested as Received

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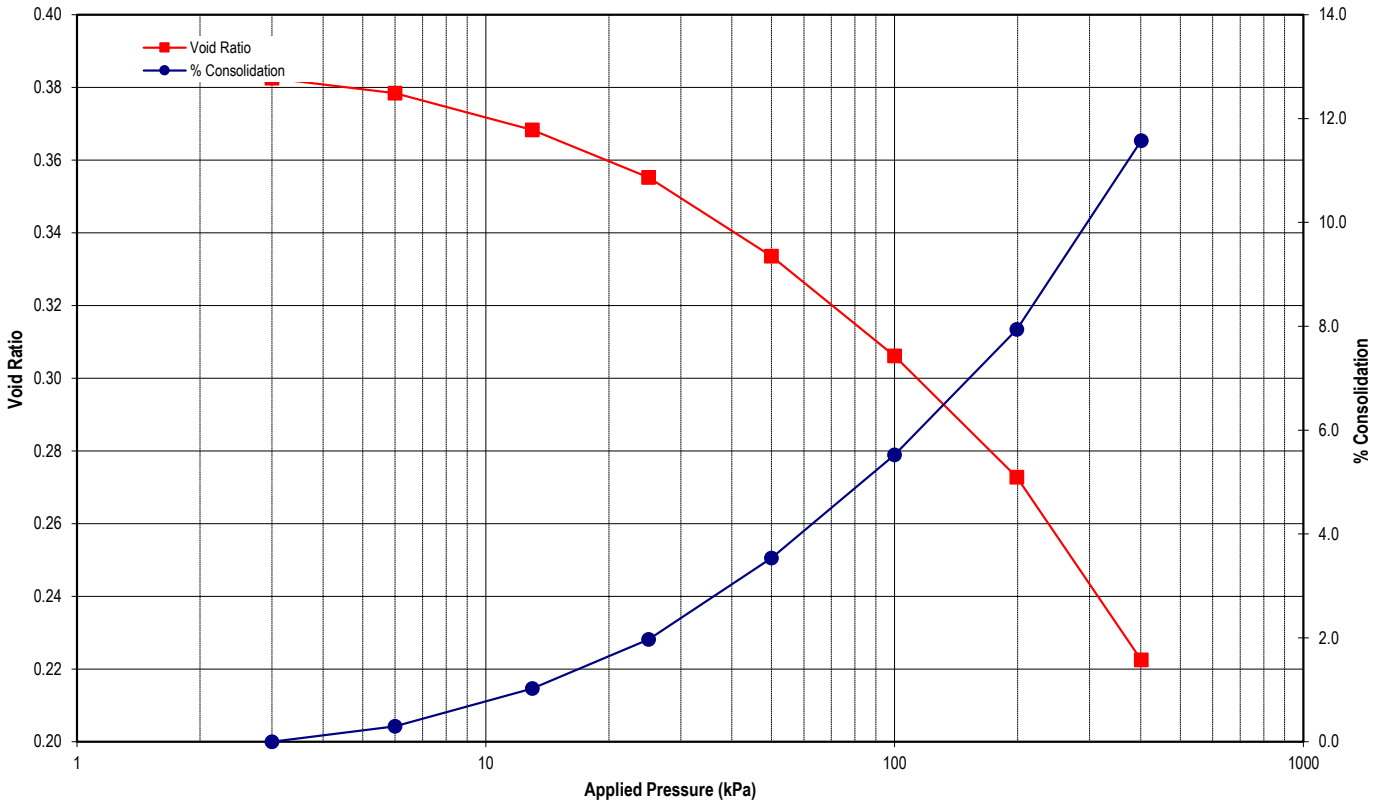
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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	Red Earth Engineering Pty Ltd	**Report No.:**	21080560-OED
		Workorder No.	9023
Address:	108 Bowen Street, Spring Hill, QLD 4000	**Test Date:**	1/09/2021
		Report Date:	16/09/2021
Project:	J20100 - Saraji Mine Ramp 2-3		
Client Id.:	TL-11	**Depth (m):**	12.50-13.15
Description:	SANDY SILT - black		



Initial Wet Density (t/m^3):	1.63	Initial Moisture (%):	32.9	Initial Height (mm):	19.96
Initial Dry Density (t/m^3):	1.23	Final Moisture (%):	26.7	Final Height (mm):	17.65
Initial Mass (g):	97.66	Initial Voids Ratio:	0.383	Test Condition:	Inundated on load
Particle Density (t/m^3):	1.70	Initial Degree of Saturation (%):	100.0	Undisturbed sample supplied by the client	

Remarks: Tested as Received

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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	Red Earth Engineering Pty Ltd	**Report No.:**	21080560-OED
		Workorder No.	9023
Address:	108 Bowen Street, Spring Hill, QLD 4000	**Test Date:**	1/09/2021
		Report Date:	16/09/2021
Project:	J20100 - Saraji Mine Ramp 2-3		
Client Id.:	TL-11	**Depth (m):**	12.50-13.15
Description:	SANDY SILT - black		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	3-6	0.014	6.4E-09	3.96	20.80	0.991	0.17	0.3
2	6-13	0.030	4.7E-09	9.72	14.54	1.043	0.74	1.0
3	13-25	0.046	3.6E-09	10.36	14.73	0.796	1.02	2.0
4	25-50	0.072	2.7E-09	11.56	13.61	0.640	1.28	3.5
5	50-100	0.091	1.7E-09	10.84	13.60	0.411	1.48	5.5
6	100-199	0.112	1.3E-09	14.94	16.50	0.258	2.36	7.9
7	199-401	0.165	8.7E-10	12.97	14.28	0.196	3.78	11.6

Remarks: Tested as Received

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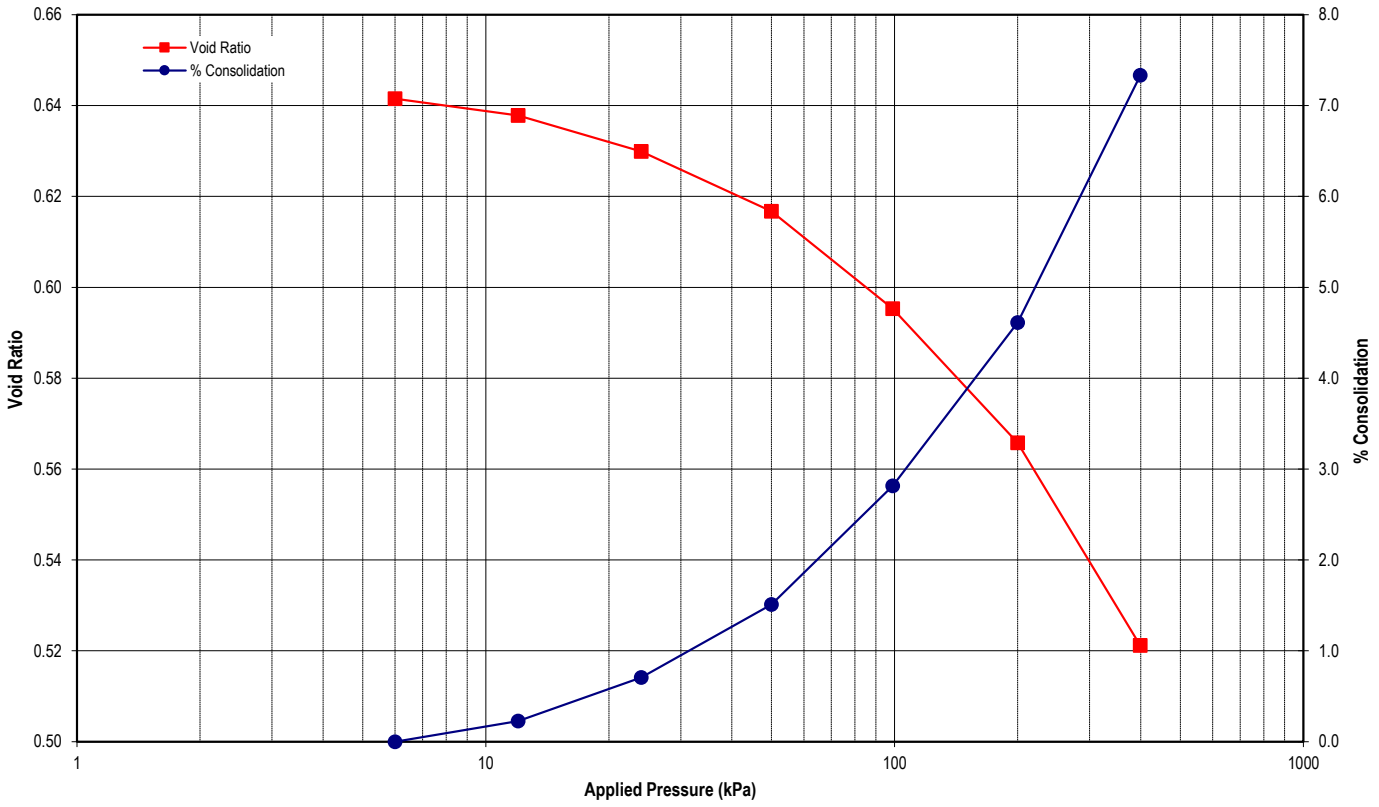
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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	Red Earth Engineering Pty Ltd	**Report No.:**	21080561-OED
		Workorder No.	9023
Address:	108 Bowen Street, Spring Hill, QLD 4000	**Test Date:**	1/09/2021
		Report Date:	16/09/2021
Project:	J20100 - Saraji Mine Ramp 2-3		
Client Id.:	TL-11	**Depth (m):**	15.00-15.65
Description:	SANDY SILTY CLAY-mottled grey/red-brown-orange		



Initial Wet Density (t/m^3):	1.62	Initial Moisture (%):	28.2	Initial Height (mm):	20.01
Initial Dry Density (t/m^3):	1.27	Final Moisture (%):	25.2	Final Height (mm):	18.54
Initial Mass (g):	97.61	Initial Voids Ratio:	0.642	Test Condition:	Inundated on load
Particle Density (t/m^3):	2.08	Initial Degree of Saturation (%):	91.8	Undisturbed sample supplied by the client	
Remarks:	Tested as Received				Page 1 of 2

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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	Red Earth Engineering Pty Ltd	**Report No.:**	21080561-OED
		Workorder No.	9023
Address:	108 Bowen Street, Spring Hill, QLD 4000	**Test Date:**	1/09/2021
		Report Date:	16/09/2021
Project:	J20100 - Saraji Mine Ramp 2-3		
Client Id.:	TL-11	**Depth (m):**	15.00-15.65
Description:	SANDY SILTY CLAY-mottled grey/red-brown-orange		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-12	0.012	2.7E-09	17.89	23.38	0.376	0.16	0.2
2	12-24	0.026	3.1E-09	13.34	24.65	0.400	0.27	0.7
3	24-50	0.041	2.0E-09	17.14	21.13	0.312	0.67	1.5
4	50-99	0.072	1.6E-09	15.80	19.40	0.270	0.84	2.8
5	99-200	0.097	1.1E-09	17.15	19.79	0.183	1.28	4.6
6	200-399	0.149	7.9E-10	15.16	17.82	0.143	1.94	7.3

Remarks: Tested as Received

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SOIL WATER ANALYSIS (SWA)

soilwater GROUP
45 Gladstone St
East Perth WA 6006
(08) 9228 3060
(08) 9228 3210
admin@soilwatergroup.com
www.soilwatergroup.com

TEST REPORT

Client: Red Earth Engineering
Client Contact: Michael Deacon
Client Job Title: Saraji Mine Ramp 2 & 3
Client Reference: **J201000**

SWA Job No: JN0760

Date of Analysis: 1st - 27th September 2021
No. Samples Submitted: 3
Sample(s) Condition: Disturbed (loose) sample

METHODOLOGY

- Gravimetric moisture content determined in accordance with AS 1289.2.1.1-2005.
- Atterberg limits determined in accordance with AS1289.3.1.1; AS 1289 3.2.1 & AS 1289.3.3.1.
- Specific gravity (ρ_p) determined in accordance with AS 1289.3.5.1-1995.
- Particle size distribution determined in accordance with AS 4816.1-2002 & AS 1289.3.6.1-1995

TEST RESULTS

SWA ID	**760-1**	**760-2**	**760-3**
Client ID	**TP01, 0.4-0.6m**	**TP02, 0.3-0.5m**	**TP03, 0.3-0.5m**
Grav. Moisture Content (%)	NR	NR	NR
Specific Gravity (g/cm^3)	1.76	2.00	1.72
Particle Size Distribution:			
% Sand (2 - 0.02mm)	68.16	72.06	66.27
% Silt (0.02 - 0.002mm)	19.54	18.27	17.84
% Clay (<0.002mm)	12.30	9.67	15.89
Texture	Loam	Loamy Sand	Loam
Wet Screening:	% Passing		
2mm	100	100	100
1.18mm	99.10	99.42	97.40
0.6mm	92.59	94.20	89.53
0.425mm	87.88	90.08	84.73
0.3mm	82.74	82.10	80.23
0.212mm	77.67	74.04	76.14
0.15mm	73.10	69.18	71.98
0.075mm	66.87	64.00	65.63
Atterberg Limits:			
• Liquid Limit (%, g/g)	35.84	34.22	34.61
• Plastic Limit (%, g/g)	26.35	23.58	23.90
• Plasticity Index	9.49	10.64	10.71

SOIL WATER ANALYSIS (SWA)

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TEST REPORT - SWCC

Client: Red Earth Engineering
Client Contact: Michael Deacon
Client Job Title: Saraji Mine Ramp 2 & 3
Client Reference: **J20100**
SWA Job No: JN0760

Date of Analysis: 1st - 27th September 2021
No. Samples Submitted: 3
Sample(s) Condition: Disturbed (loose) sample

METHODOLOGY

- SWCC determined in accordance with ASTM D6836 (Methods A, B & D)
- Cores repacked to a bulk density of 1.3 g/cm^3

TEST RESULTS

SWA-ID	Client ID	Volumetric Water Content (cm^3/cm^3)				
		0kPa	10kPa	33kPa	100kPa	1,500kPa
760-1	TP01, 0.4-0.6m	0.51	0.39	0.30	0.26	0.16
760-2	TP02, 0.3-0.5m	0.48	0.38	0.30	0.26	0.18
760-3	TP03, 0.3-0.5m	0.56	0.41	0.34	0.29	0.20

APPROVED SIGNATURE FOR

Adam Pratt
Operations Manager

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Red Earth Engineering Pty Ltd	**Report No.:**	21050443 - CU
		Workorder No.	0008657
Address	108 Bowen Street, Spring Hill, QLD 4000	**Test Date:**	28/05/2021
		Report Date:	7/06/2021
Project:	J20100 - Saraji Mine Ramp 2-3		
Client Id.:	TL-11	**Depth (m):**	12.50-13.15
Description:	CLAYEY SILTY SAND - black		

SAMPLE & TEST DETAILS

Initial Height:	153.8	mm	Initial Moisture Content:	29.6	%	Rate of Strain:	0.003	%/min
Initial Diameter:	72.3	mm	Final Moisture Content:	21.7	%	B Response:	98	%
L/D Ratio:	2.1 : 1		Wet Density:	1.55	t/m^3			
			Dry Density:	1.20	t/m^3			

Sample Type: Single Individual Undisturbed Specimen.

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses*			*Deviator Stress*	*Strain*
					σ'_1	σ'_3	σ'_1 / σ'_3		
97 kPa	600 kPa	503 kPa	503 kPa	551 kPa	197 kPa	49 kPa	4.015	148 kPa	1.81 %
153 kPa	652 kPa	499 kPa	499 kPa	580 kPa	288 kPa	72 kPa	4.005	216 kPa	4.10 %
301 kPa	652 kPa	351 kPa	351 kPa	524 kPa	492 kPa	128 kPa	3.840	364 kPa	6.99 %

FAILURE ENVELOPES

Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**0.4**	**7.1**	**4.5**
Angle of Shear Resistance Φ' (Degrees) :	**36.8**	**34.6**	**35.1**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received.
Sample/s supplied by the client

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TRIAXIAL TEST REPORT

Test Method: ASTM D7181

Client:	Red Earth Engineering Pty Ltd	**Report No.:**	21050444 - CD
		Workorder No.	0008657
Address	108 Bowen Street, Spring Hill, QLD 4000	**Test Date:**	28/05/2021
		Report Date:	9/06/2021
Project:	J20100 - Saraji Mine Ramp 2-3		
Client Id.:	TL-11	**Depth (m):**	15.00-15.65
Description:	SILTY CLAY-mottled grey/red-brown-orange		

SAMPLE & TEST DETAILS

Sample 1

Initial Height:	151.3	mm
Initial Diameter:	72.2	mm
L/D Ratio:	2.1 : 1	
Initial Moisture Content:	16.6	%
Final Moisture Content:	14.7	%
Wet Density:	2.18	t/m^3
Dry Density:	1.87	t/m^3
Rate of Strain:	0.003	%/min
B Response:	98	%

Failure Criteria: Peak Principal Stress Ratio

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses*			*Deviator Stress*	*Strain*
					σ'_1	σ'_3	σ'_1 / σ'_3		
158 kPa	660 kPa	502 kPa	502 kPa	501 kPa	631 kPa	159 kPa	3.968	472 kPa	8.92 %

Sample Type: Single Individual Undisturbed Specimen
Remarks: Tested as Received

Sample/s supplied by the client
Note: Graph not to scale

REP16401

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	Red Earth Engineering Pty Ltd	**Report No.:**	21050437 - CU
		Workorder No.	0008657
Address	108 Bowen Street, Spring Hill, QLD 4000	**Test Date:**	26/05/2021
		Report Date:	4/06/2021
Project:	J20100 - Saraji Mine Ramp 2-3		
Client Id.:	TL-03	**Depth (m):**	5.00-5.65
Description:	CLAYEY SILTY SAND - black		

SAMPLE & TEST DETAILS

Initial Height:	151.5	mm	Initial Moisture Content:	26.5	%	Rate of Strain:	0.005	%/min
Initial Diameter:	71.5	mm	Final Moisture Content:	24.6	%	B Response:	98	%
L/D Ratio:	2.1 : 1		Wet Density:	1.58	t/m^3			
			Dry Density:	1.25	t/m^3			

Sample Type: Single Individual Undisturbed Specimen.

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses*			*Deviator Stress*	*Strain*
					σ'_1	σ'_3	σ'_1 / σ'_3		
50 kPa	550 kPa	500 kPa	500 kPa	530 kPa	125 kPa	20 kPa	6.228	105 kPa	1.54 %
101 kPa	602 kPa	501 kPa	501 kPa	558 kPa	245 kPa	44 kPa	5.558	201 kPa	3.57 %
202 kPa	701 kPa	499 kPa	499 kPa	620 kPa	400 kPa	81 kPa	4.940	319 kPa	6.33 %

FAILURE ENVELOPES

Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**5.5**	**14.5**	**9.2**
Angle of Shear Resistance Φ' (Degrees) :	**41.8**	**38.0**	**39.5**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received.
Sample/s supplied by the client

REP03001

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TRIAXIAL TEST REPORT

Test Method: ASTM D7181

Client:	Red Earth Engineering Pty Ltd	**Report No.:**	21050438 - CD
		Workorder No.	0008657
Address	108 Bowen Street, Spring Hill, QLD 4000	**Test Date:**	3/06/2021
		Report Date:	14/06/2021
Project:	J20100 - Saraji Mine Ramp 2-3		
Client Id.:	TL-03	**Depth (m):**	7.00-7.33
Description:	SILTY CLAY-mottled grey/red-brown-orange		

SAMPLE & TEST DETAILS

Sample 1

Initial Height:	153.3	mm
Initial Diameter:	72.3	mm
L/D Ratio:	2.1 : 1	
Initial Moisture Content:	36.7	%
Final Moisture Content:	25.5	%
Wet Density:	1.52	t/m^3
Dry Density:	1.11	t/m^3
Rate of Strain:	0.003	%/min
B Response:	98	%

Failure Criteria: Peak Principal Stress Ratio

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses*			*Deviator Stress*	*Strain*
					σ'_1	σ'_3	σ'_1 / σ'_3		
65 kPa	567 kPa	502 kPa	502 kPa	503 kPa	271 kPa	64 kPa	4.232	207 kPa	16.47 %

Sample Type: Single Individual Undisturbed Specimen

Remarks: Tested as Received

Sample/s supplied by the client

Note: Graph not to scale

REP16401

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Channon

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory Number 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.
Trilab Pty Ltd
ABN 25 065 630 506

ELECTRIC FIELD VANE SHEAR TEST RESULTS

Sounding ID	File Name	Date	Load Cell Serial Number	Load Cell Location	Casing/Drillout Depth (m)	Test Depth[1] (m)	Vane Diameter D (mm)	Vane Height H (mm)	Top Taper Angle i_T (deg)	Bottom Taper Angle i_B (deg)	Vane Factor (kPa/Nm)	Peak Torque (Nm)	Remolded Torque (Nm)	Peak Stress (kPa)	Remolded Stress (kPa)	Peak Frictional Stress (kPa)	Remolded Frictional Stress (kPa)	Su Peak (kPa)	Su Remolded (kPa)	Sensitivity	Refer to Notation Number
VST21-01	21-18-21942_VST01	17-May-2021	AVLC055	Downhole	5.50	6.10	40	80	45	45	4.0249	20.13	9.55	81.03	38.42			81.03	38.42	2.11	
VST21-01	21-18-21942_VST01	17-May-2021	AVLC055	Downhole	5.50	6.60	40	80	45	45	4.0249	43.70	10.47	175.90	42.13			175.90	42.13	4.17	
VST21-02	21-18-21942_VST02	20-May-2021	AVLC013	Surface	0.50	1.10	60	120	45	45	1.1926	22.87	7.77	27.27	9.26	3.93	0.74	23.34	8.53	2.74	
VST21-02	21-18-21942_VST02	20-May-2021	AVLC013	Surface	5.40	6.00	60	120	45	45	1.1926	43.38	12.04	51.74	14.36	4.29	2.25	47.45	12.11	3.92	
VST21-02	21-18-21942_VST02	20-May-2021	AVLC013	Surface	7.40	8.00	60	120	45	45	1.1926	39.84	12.05	47.51	14.36	3.71	1.66	43.80	12.70	3.45	
VST21-03	21-18-21942_VST03	11-May-2021	AVLC013	Surface	6.40	5.20	50	100	45	45	2.0608	40.19	8.53	82.82	17.58	9.17	4.34	73.64	13.24	5.56	
VST21-03	21-18-21942_VST03	11-May-2021	AVLC013	Surface	6.40	7.20	50	100	45	45	2.0608	53.91	9.77	111.09	20.13	8.73	5.57	102.36	14.56	7.03	
VST21-05	21-18-21942_VST05	12-May-2021	AVLC013	Surface	2.40	3.00	50	100	45	45	2.0608	57.97	11.55	119.45	23.81	12.74	3.92	106.71	19.88	5.37	
VST21-05	21-18-21942_VST05	12-May-2021	AVLC013	Surface	5.90	6.50	50	100	45	45	2.0608	79.31	19.59	163.45	40.37	11.35	6.08	152.10	34.30	4.43	
VST21-07	21-18-21942_VST07	13-May-2021	AVLC013	Surface	3.20	3.80	50	100	45	45	2.0608	15.62	5.02	32.20	10.35	2.94	1.07	29.26	9.28	3.15	
VST21-07	21-18-21942_VST07	13-May-2021	AVLC013	Surface	6.40	7.00	50	100	45	45	2.0608	73.05	20.35	150.53	41.94	16.05	5.99	134.48	35.95	3.74	
VST21-08	21-18-21942_VST08	24-May-2021	AVLC013	Downhole	6.20	6.50	50	100	45	45	2.0608	62.44	28.05	128.68	57.80			128.68	57.80	2.23	
VST21-09	21-18-21942_VST09	14-May-2021	AVLC013	Surface	4.30	4.90	50	100	45	45	2.0608	32.95	8.81	67.90	18.15	6.30	1.63	61.60	16.52	3.73	
VST21-09	21-18-21942_VST09	14-May-2021	AVLC013	Surface	5.70	6.20	40	80	45	45	4.0249	>99.72		>401.4		28.54		>372.86			2
VST21-10	21-18-21942_VST10	24-May-2021	AVLC013	Downhole	5.50	5.85	50	100	45	45	2.0608	50.01	17.67	103.06	36.42			103.06	36.42	2.83	
VST21-11	21-18-21942_VST11	18-May-2021	AVLC013	Surface	3.20	3.80	50	100	45	45	2.0608	67.31	19.76	138.71	40.72	7.40	3.74	131.31	36.98	3.55	
VST21-11	21-18-21942_VST11	19-May-2021	AVLC013	Surface	4.60	5.20	50	100	45	45	2.0608	93.00	32.57	191.65	67.12	25.98	10.95	165.66	56.17	2.95	
VST21-11	21-18-21942_VST11	19-May-2021	AVLC013	Surface	14.40	15.00	40	80	45	45	4.0249	58.40	21.58	235.06	86.85	33.21	18.52	201.85	68.33	2.95	
VST21-12	21-18-21942_VST12	25-May-2021	AVLC013	Downhole	6.30	6.60	50	100	45	45	2.0608	65.55	25.22	135.07	51.96			135.07	51.96	2.60	
VST21-12	21-18-21942_VST12	25-May-2021	AVLC013	Downhole	8.80	9.10	40	80	45	45	4.0249	34.47	14.45	138.73	58.15			138.73	58.15	2.39	
VST21-13	21-18-21942_VST13	29-Apr-2021	AVLC013	Surface	11.40	12.00	40	80	45	45	4.0249	65.99	17.79	265.58	71.60	26.10	12.73	239.49	58.87	4.07	
VST21-13B	21-18-21942_VST13B	30-Apr-2021	AVLC013	Surface	10.90	17.00	40	80	45	45	4.0249	58.77	13.46	236.53	54.17	69.02	34.37	167.51	19.80	8.46	
VST21-13B	21-18-21942_VST13B	03-May-2021	AVLC013	Surface	17.90	18.50	40	80	45	45	4.0249	58.87	25.19	236.94	101.40	59.25	39.16	177.69	62.24	2.85	
VST21-19	21-18-21942_VST19	09-Apr-2021	AVLC004	Surface	4.90	5.50	40	80	45	45	4.0249	54.47	13.81	219.23	55.60	37.90	29.91	181.33	25.69	7.06	
VST21-19	21-18-21942_VST19	12-Apr-2021	AVLC004	Surface	4.90	6.00	40	80	45	45	4.0249	37.09	11.01	149.26	44.30	38.63	25.43	110.63	18.87	5.86	
VST21-19	21-18-21942_VST19	12-Apr-2021	AVLC004	Surface	4.90	7.00	40	80	45	45	4.0249	30.90	12.58	124.38	50.65	25.36	25.91	99.02	24.74	4.00	
VST21-19	21-18-21942_VST19	13-Apr-2021	AVLC004	Surface	4.90	9.00	40	80	45	45	4.0249	34.69	11.05	139.63	44.49	26.55	19.70	113.08	24.78	4.56	
VST21-22	21-18-21942_VST22	14-Apr-2021	AVLC004	Surface	8.55	9.30	40	80	45	45	4.0249	48.38	11.08	194.74	44.59	34.38	16.98	160.37	27.62	5.81	
VST21-22	21-18-21942_VST22	15-Apr-2021	AVLC004	Surface	15.40	16.00	40	80	45	45	4.0249	56.11	18.06	225.82	72.69	42.74	18.11	183.08	54.59	3.35	
VST21-24	21-18-21942_VST24	19-Apr-2021	AVLC004	Surface	10.40	11.00	40	80	45	45	4.0249	57.70	24.80	232.25	99.81	41.03	19.68	191.22	80.13	2.39	
VST21-24	21-18-21942_VST24	19-Apr-2021	AVLC004	Surface	13.60	14.20	40	80	45	45	4.0249	76.98	19.04	309.84	76.64	31.15	31.15	278.69	45.49	6.13	3
VST21-27	21-18-21942_VST27	06-Apr-2021	AVLC004	Downhole	7.60	8.00	50	100	45	45	2.0608	>97.72		>201.4				>201.4			2
VST21-27C	21-18-21942_VST27C	07-Apr-2021	AVLC004	Surface	8.40	9.50	40	80	45	45	4.0249	53.97	10.86	217.23	43.72	34.68	18.27	182.55	25.46	7.17	
VST21-27C	21-18-21942_VST27C	07-Apr-2021	AVLC004	Surface	8.40	10.50	40	80	45	45	4.0249	67.67	11.41	272.37	45.93	38.26	23.73	234.12	22.20	10.55	4

1. Test depths are referenced to the middle of the vane.
2. VST capacity maxed-out.
3. The peak frictional stress was assumed to be the same as the remolded frictional stress
4. The remold test was completed on 08-April-2021.

APPENDIX C

Sample Locations TSF 2



CLIENT
BMA

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-09-14
DESIGNED	
PREPARED	DAB
REVIEWED	
APPROVED	

PROJECT
SARAJI MINE - TAILINGS PRCP
TSF 2

TITLE
TSF 2 - COVER SHEET

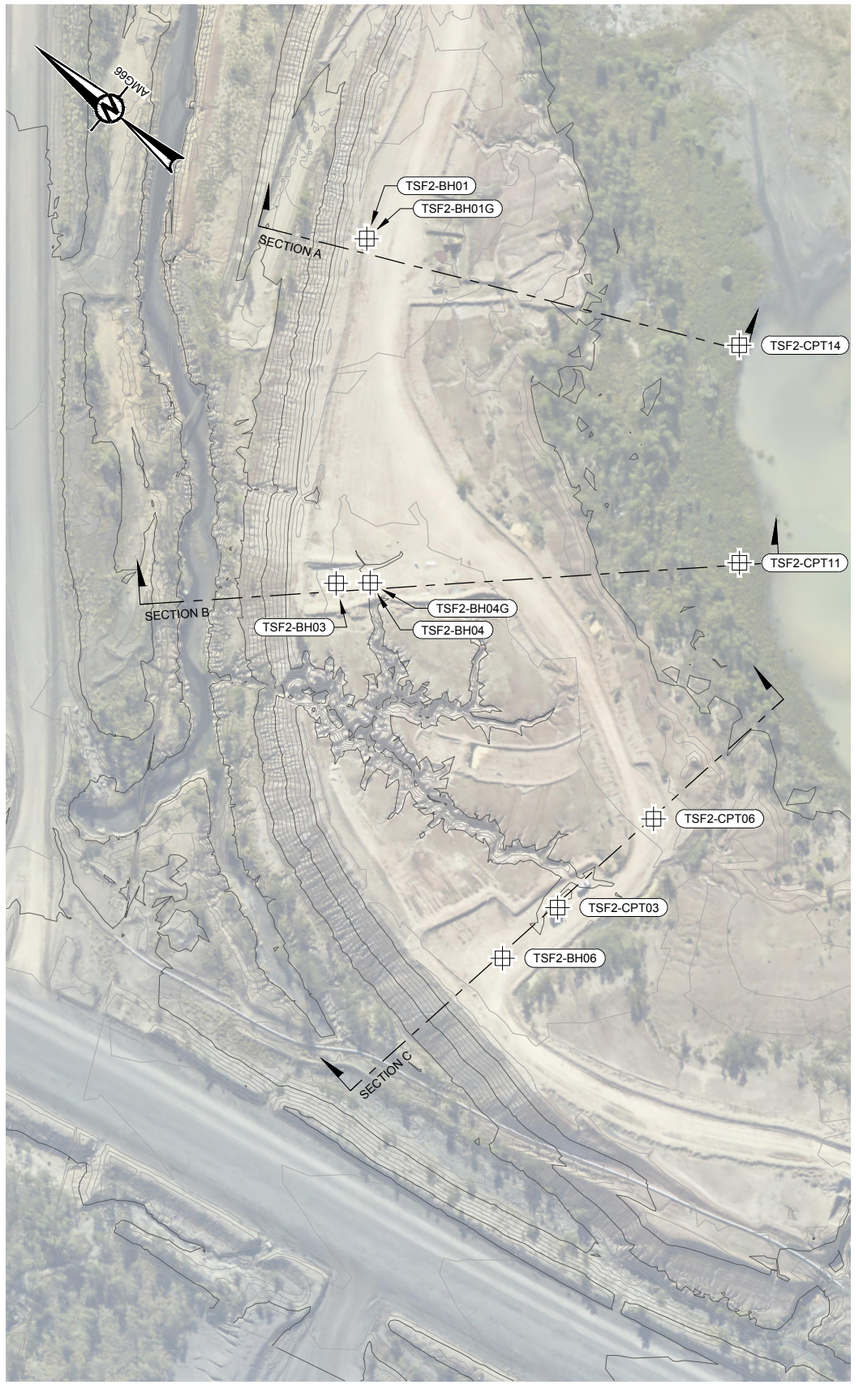
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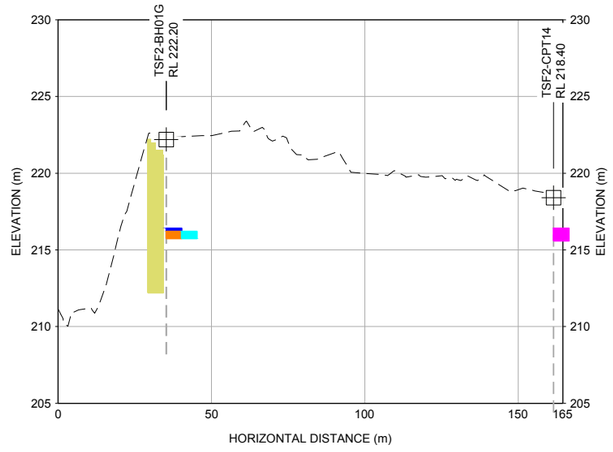
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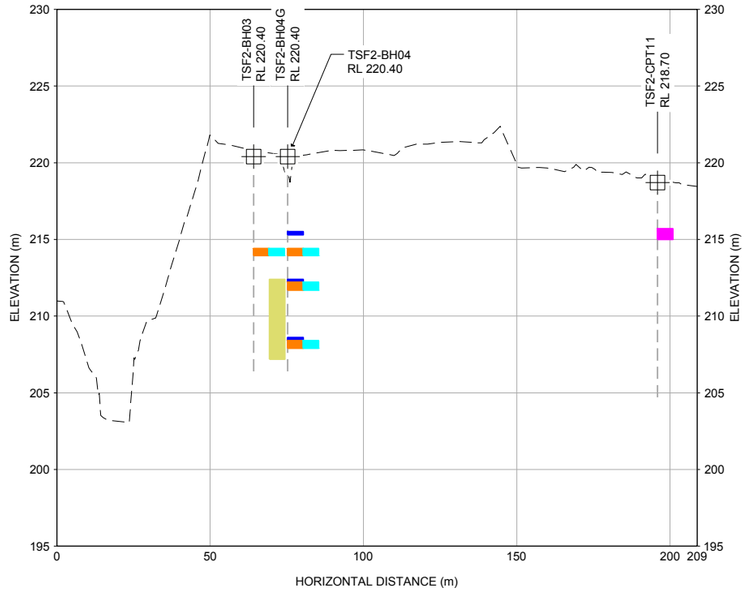
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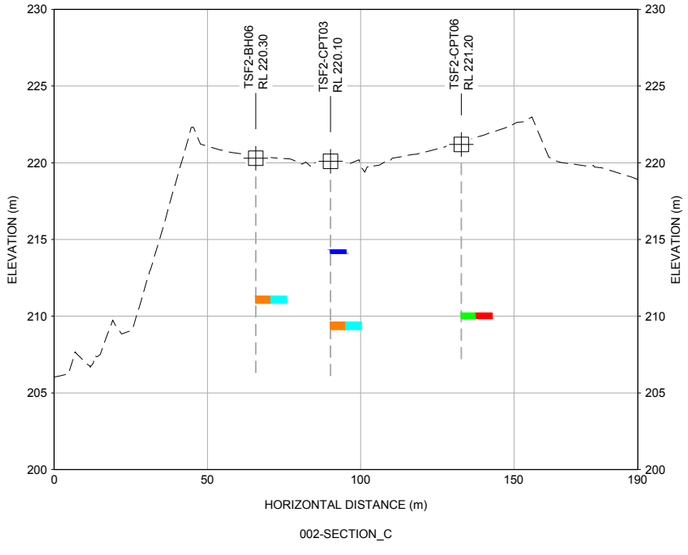
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TSF 2 LAYOUT PLAN
SCALE 1:2000







0 50 100
1:2,000 METRES

LEGEND

- EXISTING SURVEY CONTOURS
- EXISTING GROUND PROFILE
- RHEOLOGY TESTING LOCATION
- PSD TESTING LOCATION
- GEOCHEMICAL TESTING LOCATION
- SPECIFIC GRAVITY TESTING LOCATION
- ATTERBERG TESTING LOCATION
- MOISTURE CONTENT AND DRY DENSITY TESTING LOCATION
- SOIL WATER CHARACTERISTIC CURVE LOCATION

CLIENT
BMA

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-09-14
DESIGNED	
PREPARED	DAB
REVIEWED	
APPROVED	

PROJECT
SARAJI MINE - TAILINGS PRCP
TSF 2

TITLE
SAMPLING LOCATIONS PLAN AND SECTION A

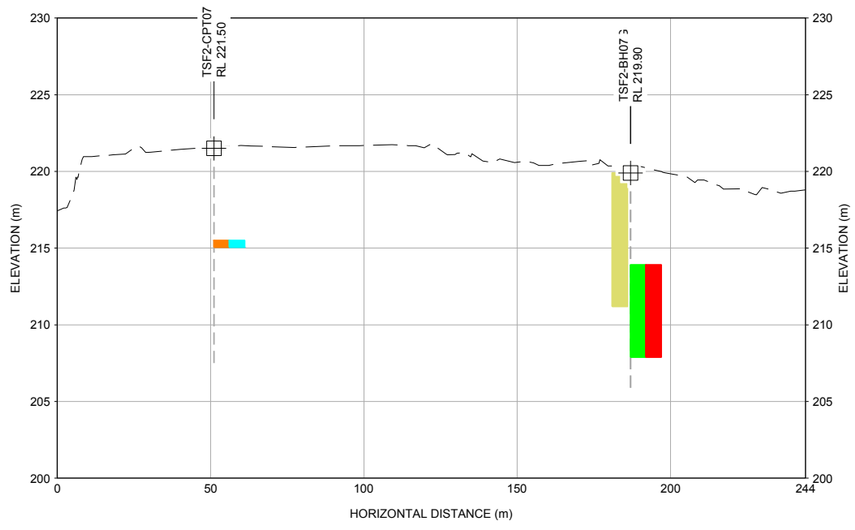
PROJECT NO.	CONTROL	REV.	FIGURE
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ISO A3
25 mm
0

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TSF 2 LAYOUT PLAN
SCALE 1:2000



002-SECTION_D

0 50 100
1:2,000 METRES

LEGEND

- EXISTING SURVEY CONTOURS
- EXISTING GROUND PROFILE
- RHEOLOGY TESTING LOCATION
- PSD TESTING LOCATION
- GEOCHEMICAL TESTING LOCATION
- SPECIFIC GRAVITY TESTING LOCATION
- ATTERBERG TESTING LOCATION
- MOISTURE CONTENT AND DRY DENSITY TESTING LOCATION
- SOIL WATER CHARACTERISTIC CURVE LOCATION

CLIENT
BMA

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-09-14
DESIGNED	
PREPARED	DAB
REVIEWED	
APPROVED	

PROJECT
SARAJI MINE - TAILINGS PRCP
TSF 2

TITLE
SAMPLING LOCATIONS PLAN AND SECTION B

PROJECT NO.	CONTROL	REV.	FIGURE
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APPENDIX D

Laboratory Certificates TSF 2

Rheology Testwork for Failure Impact Assessments for Saraji Mine TSFs – revision A

A Report submitted to:

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3rd June April 2021

Report Reference: BHP141-01A
Issue Date: 03/06/2021
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SUMMARY

BHP has committed to reducing the inherent risk of all tailings storage facilities (TSFs) across the BMA portfolio. Several internal risk reviews of each of the TSFs have been conducted across BMA. The Saraji Mine tailings storage facilities (SRM TSFs) require investigation and assessment works to better understand the geological setting, historical design, construction, and operation, to understand and mitigate any risk.

As part of these assessments, rheology testing was undertaken by RCS. Samples from three tailings storage facilities (TSFs) were provided for determination of the tailings physical and rheological properties including the as-received solids content, solids density and tailings in-situ dry density. Measurement of the shear yield stress profile and viscous properties of each of the tailings samples over the concentration range of interest to FIA was also conducted.

Saraji Mine samples were received at concentrations ranging from approximately 73wt% up to 98wt%.

Solids SGs ranged from 1.60 to 1.82, with up to 0.13 difference between two composite samples from the one TSF. The SG was lower at shallow depths for TSF 2 and TSF 4, but higher at shallow depth for TSF 3.

The shear yield stress of all tailings samples tested increased exponentially with solids concentration across the range of solids concentrations investigated and model parameters are provided. The yield stress behaviour for the two samples from TSF 3 and TSF 4 were similar to each other, however the two samples from TSF 2 differed from each other significantly, with the TSF2 sample from smaller depth showing a lower yield stress for a given solids concentration than any other sample. The TSF 2-BH07: 6-12 sample also had the lowest SG, and the ranking of yield stress curves was generally seen to follow SG for the Saraji mine samples. At a solids concentration of 55wt% the yield stress ranged from 10Pa (TSF 2-BH07: 6-12) to 80Pa (TSF4-CPT05: 10-13) for the samples tested.

In shear flow, all samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates investigated. For all but one sample, no shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due the sample collection, subsequent sub-sampling and sample preparation methods. The one notable exception was TSF2 BH07 at 71wt%. This sample showed a decrease in the shear stress as the shear rate increased from zero until approximately $100s^{-1}$ before increasing at higher shear rates. The behaviour was reproducible when the same sample was sheared then retested, possibly indicating a localised (but reversible) structuring of the material – possibly due to the presence of asymmetrical particles aligning in the direction of flow. The origin of the behaviour was not investigated.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected and the shear stress versus shear rate data was modelled using a Herschel-Bulkley model. The viscosity stress versus shear rate data was well described using a Power Law.

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1 INTRODUCTION

BHP Billiton Mitsubishi Alliance owns and operates several coal mines in the Bowen Basin, in Central Queensland, which produces semi-hard coking and hard coking coal products, including the Saraji Mine (SRM).

BHP has committed to reducing the inherent risk of all tailings storage facilities (TSFs) across the BMA portfolio. Several internal risk reviews of each of the TSFs have been conducted across BMA. The Saraji Mine tailings storage facilities (SRM TSFs) require further investigation and assessment works (failure impact analysis, FIA) to better understand the geological setting, historical design, construction, and operation, to understand risk levels. If required, preventative and/or mitigative measures to reduce the TSDs' risk profiles can then be implemented.

Rheology testing was required to inform parts of the FIA and to this end, samples from three tailings storage facilities (TSFs) were provided for determination of the tailings physical and rheological properties including the as-received solids content, solids density and tailings in-situ dry density. Measurement of the shear yield stress profile and viscous properties of each of the tailings samples over the concentration range of interest to FIA was also conducted.

2 SAMPLE Receipt and PREPARATION

Six samples listed in Table 1 were provided to RCS. Locations are provided in Table 2 and a sample map is shown in Figure 1.

Table 1 Samples received and prepared by RCS

Site	RCS ITEM #	ID	Depth	Type	Sample No.	RCS Sample Name
SRM TSF2,3,4	1	TSF2-CPT06	11.00	Steel Tube	1	**TSF2-CPT06: 11-13.5**
	2	TSF2-CPT06	12.00	Steel Tube		
	3	TSF2-CPT06	13.50	Steel Tube		
	4	TSF2-BH07	6.00	Steel Tube	2	**TSF2-BH07: 6-12**
	5	TSF2-BH07	7.00	Steel Tube		
	6	TSF2-BH07	9.00	Steel Tube		
	7	TSF2-BH07	12.00	Steel Tube		
	8	TSF3-CPT07	15.00	Steel Tube	1	**TSF3-CPT07: 15-17**
	9	TSF3-CPT07	17.00	Steel Tube		
	10	TSF3-CPT09	13.00	Steel Tube	2	**TSF3-CPT09: 13-16**
	11	TSF3-CPT09	16.00	Steel Tube		
	12	TSF4-CPT05	10.00	Steel Tube	1	**TSF4-CPT05: 10-13**
	13	TSF4-CPT05	13.00	Steel Tube		
	19	TSF4-CPT09G	9-10.5	Bucket	2	**TSF4-CPT09G: 9-10.5**

Table 2 SRM Sample location data

SRM TSF 2,3,4			
Location	**Easting**	**Northing**	**Elevation**
TSF2-CPT06	631846.5	7521453.8	221.2
TSF2-BH07	631832.5	7521147.0	219.9
TSF3-CPT07	631215.4	7522101.3	217.1
TSF3-CPT09	631092.6	7522451.9	215.8
TSF4-CPT05	631544.1	7522431.8	217.3
TSF4-CPT09G	631764.1	7522496.5	217.0

Upon receipt, samples were removed from core sample tubes or buckets and well sheared prior to combining and mixing well as per the bold boxes above to create composite two samples from each TSF.

Prior to yield stress and viscosity testing, samples were concentrated via centrifugation, if required, to a high solids concentration for initial yield stress testing. Dilution as required was undertaken using process water provided. All solids concentrations were determined by gravimetric analysis, drying at 90degC to constant mass.

3 GRAVIMETRIC ANALYSES

3.1 As received solids concentration

The solids concentration of the prepared samples (generated by combining 'as received' samples from each TSF) was determined by oven drying samples to constant dry mass.

Table 3 lists the measured solids concentrations.

Table 3. Prepared sample solids concentrations based on combining TSF samples as received.

Sample name	Solids concentration (wt%)
TSF2-BH07: 6-12	75.38
TSF2-CPT06: 11-13.5	75.96
TSF3-CPT09: 13-16	73.49
TSF3-CPT07: 15-17	72.92
TSF4-CPT09G: 9-10.5	98.62
TSF4-CPT05: 10-13	73.85

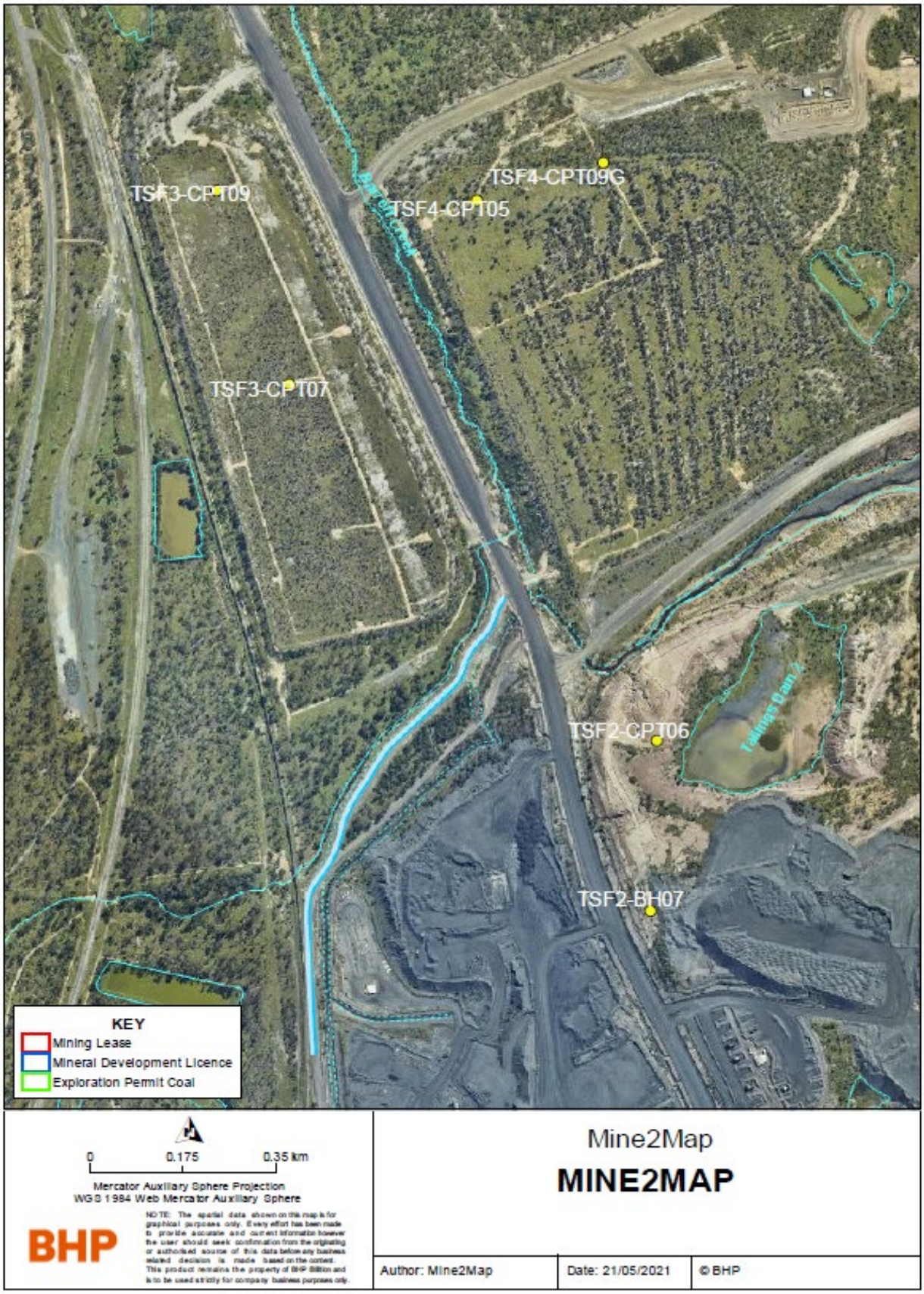


Figure 1 SSM sample location map

3.2 Specific Gravity

The solids specific gravity of the tailings was determined by measuring the density of a known volume (~100 cm^3) of slurried sample, and subsequently measuring the solids concentration of the slurry via oven drying to constant mass. By separately measuring the density for the water present in the sample under the same conditions, the density of the solid phase may be calculated using Equation 1 and the solids specific gravity subsequently determined. Results for the samples tested are shown in Table 4.

$$\rho_P = \frac{x\rho_s}{\left(1 - \frac{\rho_s}{\rho_L}(1-x)\right)}$$

Equation 1

Where: ρ_P is the particle (solids) density (kgm^{-3})
ρ_s is the slurry density (kgm^{-3})
ρ_L is the liquor density (kgm^{-3})
x is the solids mass fraction (-)

Solids SGs ranged from 1.60 to 1.82, with up to 0.13 difference between two composite samples from the one TSF. The SG was lower at shallow depths for TSF 2 and TSF4, but higher at shallow depth for TSF 3.

Table 4. BMC Saraji Mine tailings gravimetric analysis results

Sample name	Specific gravity
TSF2-BH07: 6-12	1.60
TSF2-CPT06: 11-13.5	1.66
TSF3-CPT09: 13-16	1.78
TSF3-CPT07: 15-17	1.68
TSF4-CPT09G: 9-10.5	1.69
TSF4-CPT05: 10-13	1.82

4 YIELD STRESS MEASUREMENTS

Yield stress measurements were conducted using the vane-shear method [1-4]. Many workers worldwide have adopted the vane-shear method and confirmed its applicability for numerous types of yield stress materials [5-9].

4.1 Experimental Procedure

Samples to be tested are placed in a plastic container and tapped on the laboratory bench to remove entrained air bubbles. A vane of suitable dimensions for the yield stress range under consideration is selected and attached to the rheometer. The container is placed on a stand under the vane and raised using a manual scissor lift to immerse the vane in the centre of the

sample. The vane is then rotated at a rate of 0.2 rpm and the maximum torque response of the sample is recorded. The yield stress is calculated using the maximum torque reading and Equation 1. All yield stress measurements are taken in triplicate to ensure reproducibility of results.

$$\tau_y = \frac{T_m}{\pi D_v^2\left(\frac{L_v}{2}+\frac{D_v}{6}\right)} \qquad \textbf{Equation 2}$$

Where τ_y is the calculated yield stress, T_m is the maximum torque experienced by the vane, D_v is the vane diameter and L_v is the vane length.

To ensure that wall and end effects are absent, vanes of varying dimensions are used for each material. Nguyen and Boger [3] suggest that the diameter and depth of the container should be at least twice as large as the diameter and length of the vane to minimise any effects caused by the rigid boundaries.

4.2 Results and Discussion

The shear yield stress profiles of the Saraji Mine tailings are given in Figure 2. The shear yield stress of all tailings samples increased exponentially with solids concentration across the range of solids concentrations investigated.

The yield stress versus solids concentration (mass fraction) curves for the Saraji Mine coal tailings were modelled using an exponential trendline (shown as a dashed line in Figure 2). Model parameters are given in Table 5 below.

Figure 2 shows that the yield stress behaviour for the two samples from TSF 3 and TSF 4 were similar to each other, however the two samples from TSF 2 differed from each other significantly, with the TSF2 sample from smaller depth showing a lower yield stress for a given solids concentration than any other sample. The TSF 2-BH07: 6-12 sample also had the lowest SG, and the ranking of yield stress curves was generally seen to follow SG for the Saraji mine samples.

For reference, Table 5 lists the yield stress of each sample at a solids concentration of 55wt%, showing that the yield stress ranged from 10Pa (TSF 2-BH07: 6-12) to 80Pa (TSF4-CPT05: 10-13) for the samples tested.

Table 5. Yield stress profile model parameters

Sample	Exponential Variables ($\tau_y=ae^{bx}$)		Yield stress @ 55wt%
	a	*b*	*(Pa) from* $\tau_y=ae^{bx}$
TSF2-BH07: 6-12	1.1095E-05	24.89	10
TSF2-CPT06: 11-13.5	3.2483E-04	21.37	41
TSF3-CPT09: 13-16	1.3536E-04	22.72	36
TSF3-CPT07: 15-17	3.5827E-04	21.47	48
TSF4-CPT09G: 9-10.5	7.7914E-04	20.55	63
TSF4-CPT05: 10-13	2.4982E-03	18.85	80

Where τ_y is the yield stress (*Pa*) and x is the solids mass fraction.

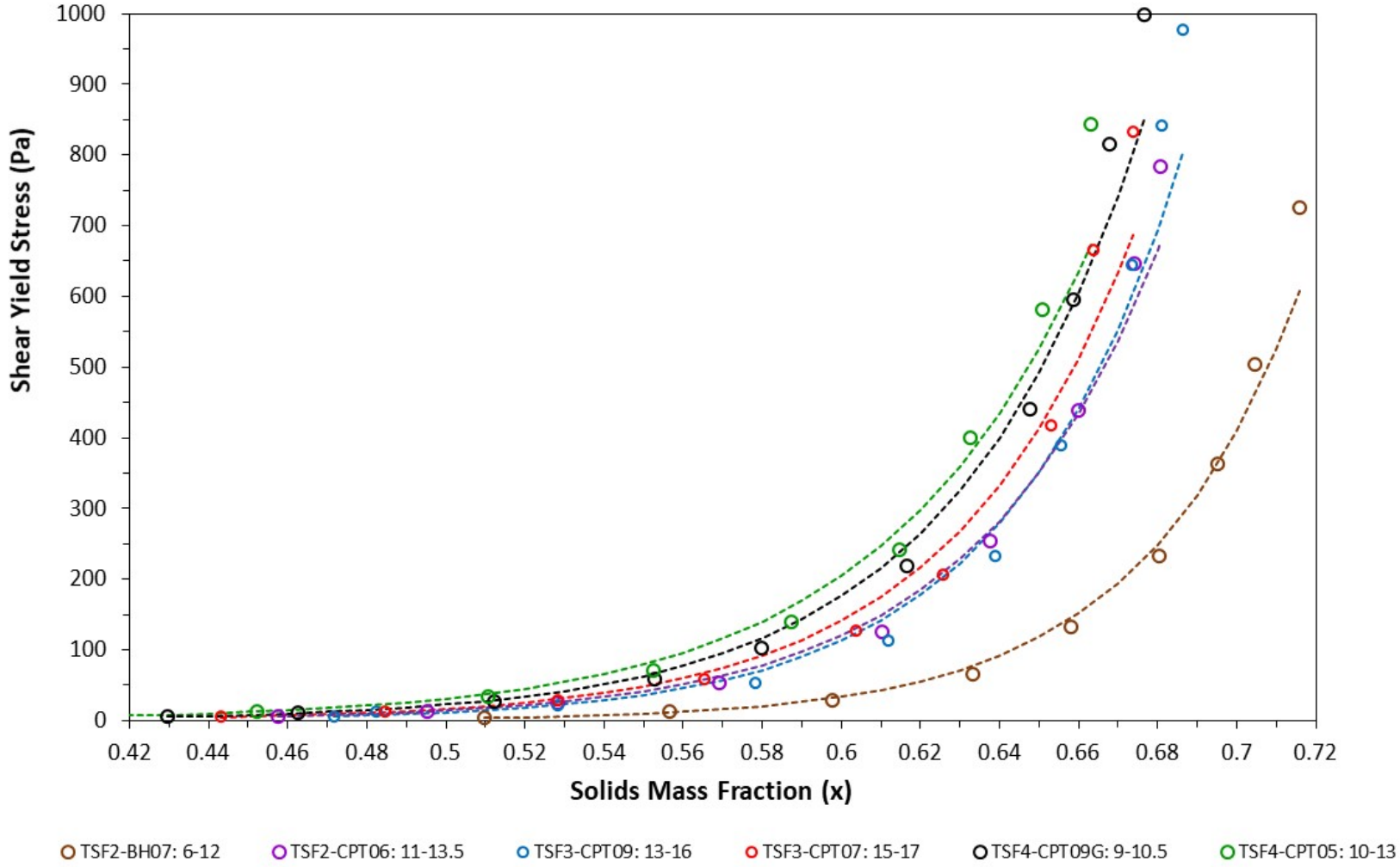


Figure 2 Shear yield stress (τ_y) vs. solids mass fraction (x) for Saraji Mine Tailings. See Table A 1 for tabulated data

5 SHEAR STRESS VS SHEAR RATE MEASUREMENTS

The shear stress (hence viscosity) of each of the coal tailings samples was measured as a function of shear rate at five solids concentrations per sample. These solids concentrations were specified by BHP and Klohn Crippen Berger (consulting on this study) personnel based on yield stress profile results and are shown in Table 6.

Measurements were conducted on fully sheared samples at ambient temperature with a Haake VT550 controlled strain rheometer using either vane (for high yield stress) or bob in cup geometry (low yield stress) as appropriate.

Table 6 Measured solids concentrations for flow behaviour testing

	Sample wt%				
	Min	**2**	**3**	**4**	**Max***
TSF2-BH07	0.55	0.583	0.635	0.673	0.71
TSF2-CPT06	0.555	0.583	0.613	0.651	0.676
TSF3-CPT07	0.567	0.595	0.617	0.645	0.665
TSF3-CPT09	0.575	0.588	0.618	0.642	0.667
TSF4-CPT05	0.55	0.588	0.607	0.625	65
TSF4-CPT09G	0.555	0.583	0.613	0.629	0.659

5.1 Experimental Procedure

Samples to be tested were either centrifuged and process water decanted or diluted to achieve the desired solids concentration for the test. Samples were placed in the test vessel and tapped on the laboratory bench to remove entrained air bubbles. The vessel was then placed on a stand under the bob or vane fixture and raised, using a manual scissor lift, to immerse the fixture in the centre of the sample. The fixture was then rotated at a constant rate, N *(rpm)*, and the torque experienced by the fixture was recorded, T *(μNm)*. This process was then repeated at successively increasing rotational rates with the sample homogenised via hand mixing between each measurement. The shear stress was measured at each successive rotational rate and the shear stress vs shear rate relationship (hence viscosity vs shear rate relationship) was determined as per [10] and [11].

5.2 Results and Discussion

The shear stress of the Saraji Mine tailings samples is given as a function of shear rate in Figure 3 to Figure 5, and the shear viscosity is given as a function of shear rate in Figure 6 to Figure 8. All samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates

investigated. For all but one sample, no shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due the sample collection, subsequent sub-sampling and sample preparation methods. The one notable exception was TSF2 BH07 at 71wt%. This sample showed a decrease in the shear stress as the shear rate increased from zero until approximately 100s^{-1}. This behaviour would normally be attributed to a breakup of the interparticle network structure, but in this case the behaviour was reproducible when the same sample was sheared then retested. The reproducibility may indicate a localised (but reversible) structuring of the material – possibly due to the presence of asymmetrical particles aligning in the direction of flow, however the origin of the behaviour was not investigated.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected.

The shear stress versus shear rate data was modelled using a Herschel-Bulkley model:

$\tau = \tau_y + K\dot{\gamma}^n$, where τ is the shear stress (*Pa*) and $\dot{\gamma}$ is the shear rate (s^{-1}) (shown as dashed lines in Figure 3 to Figure 5). The parameters for these curves are given in Table A2 in the Appendix. Note that model parameters are only valid over the shear rate range measured.

The viscosity stress versus shear rate data was curve fitted using a Power Law model:

$\eta = a\dot{\gamma}^b$, where η is the shear viscosity (*Pa.s*) and $\dot{\gamma}$ is the shear rate (s^{-1}), (shown as a dashed line in Figure 6 to Figure 8). The parameters for these curves are given in Table A3 in the Appendix. Note that model parameters are only valid over the shear rate range measured.

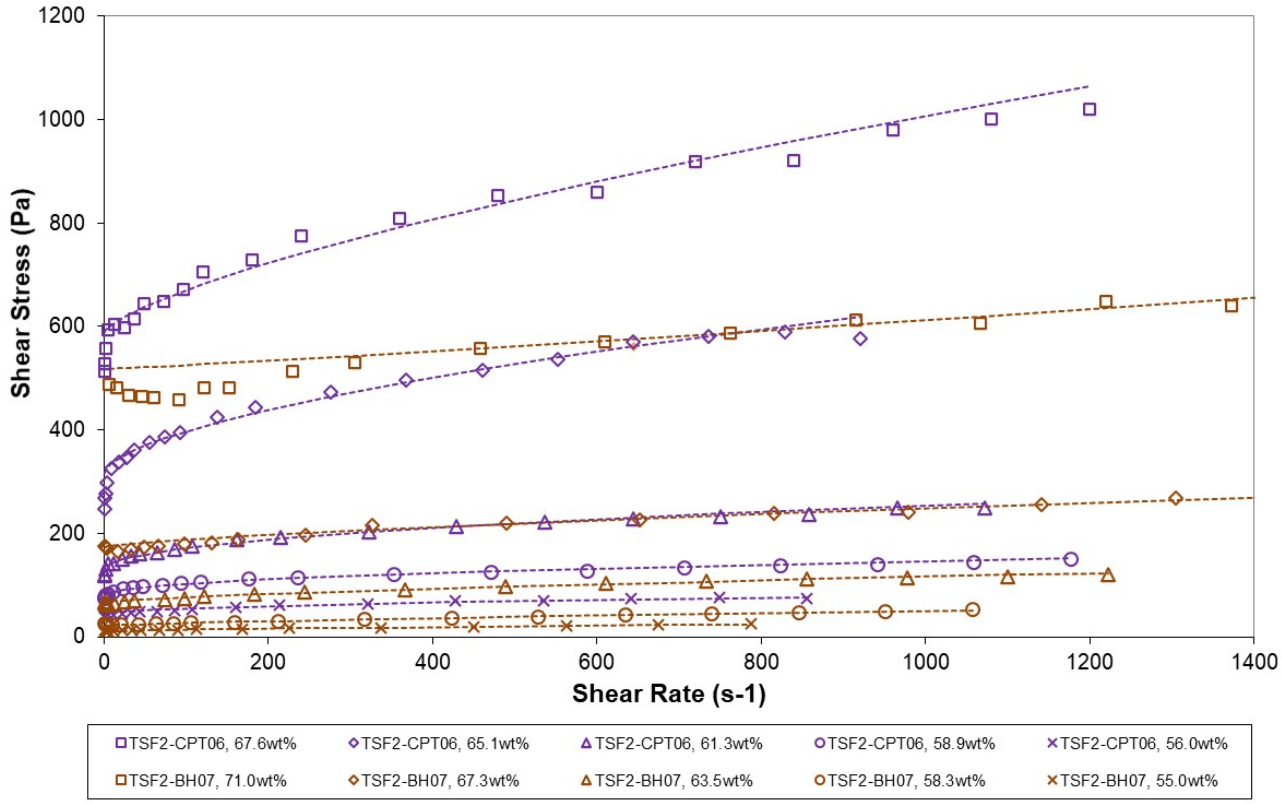


Figure 3 – Shear stress vs. shear rate for Saraji Mine TSF 2 samples.

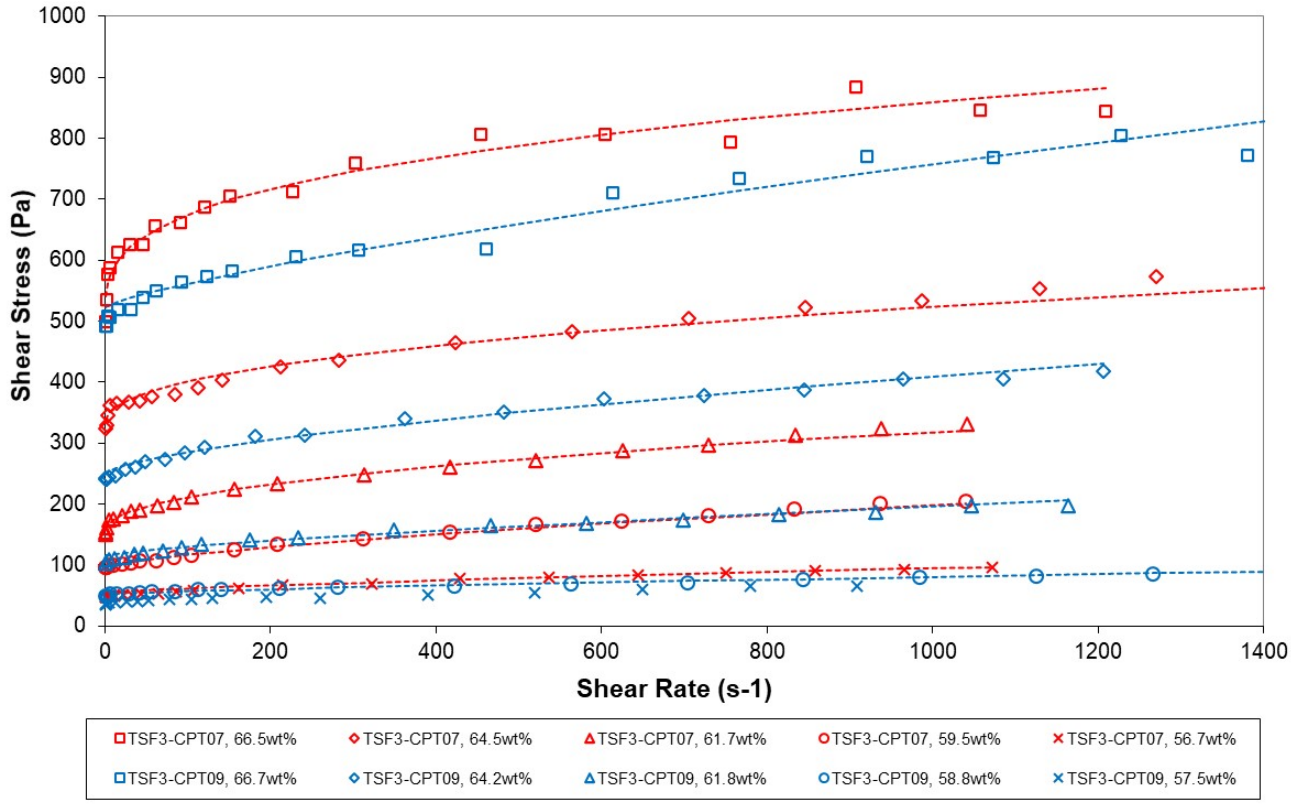


Figure 4 – Shear stress vs. shear rate for Saraji Mine TSF 3 samples.

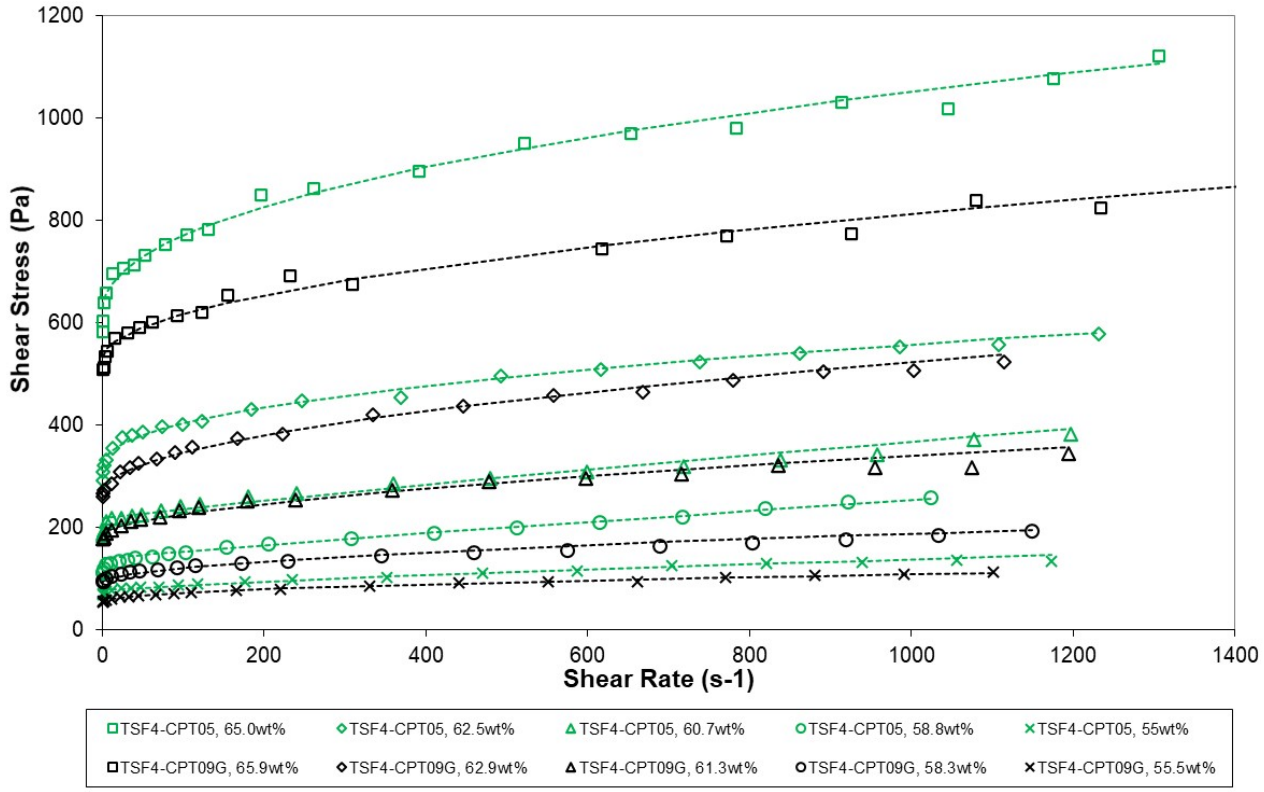


Figure 5 – Shear stress vs. shear rate for Saraji Mine TSF 4 samples.

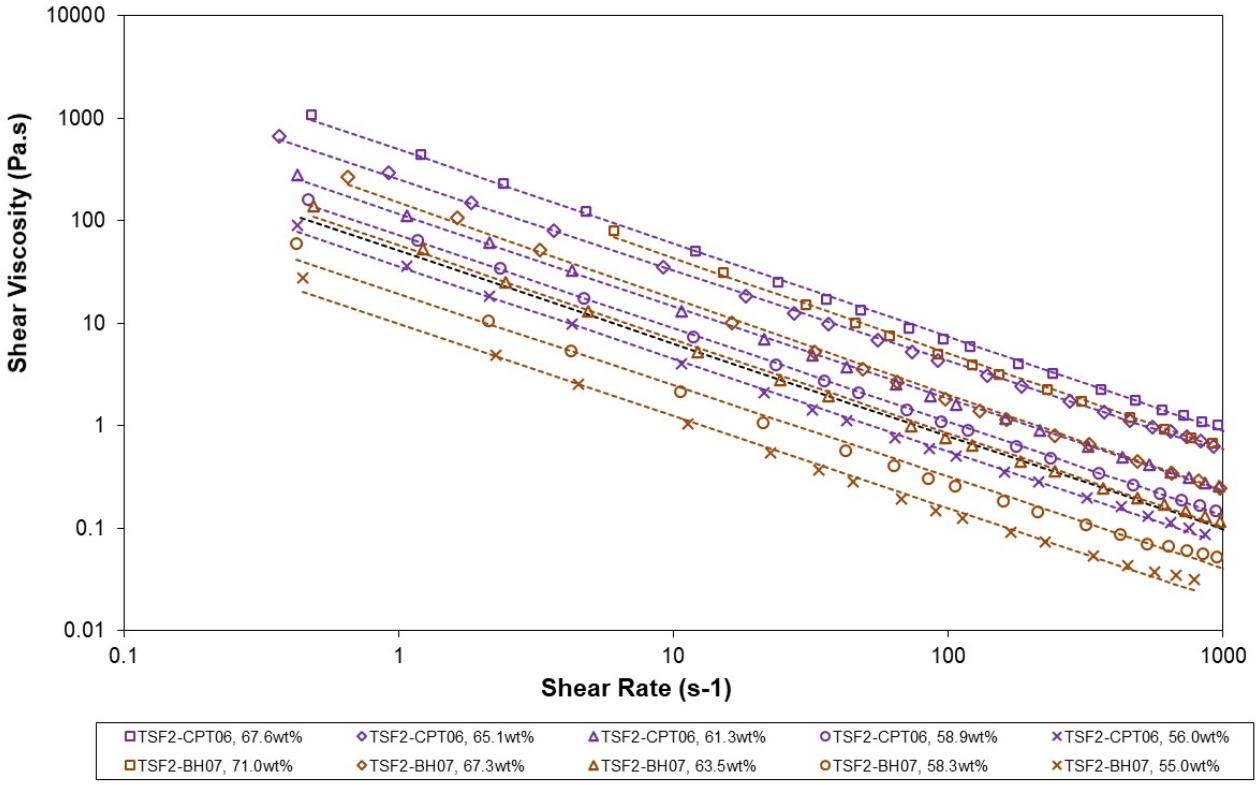


Figure 6 Shear viscosity vs. shear rate for Saraji Mine TSF 2 samples.

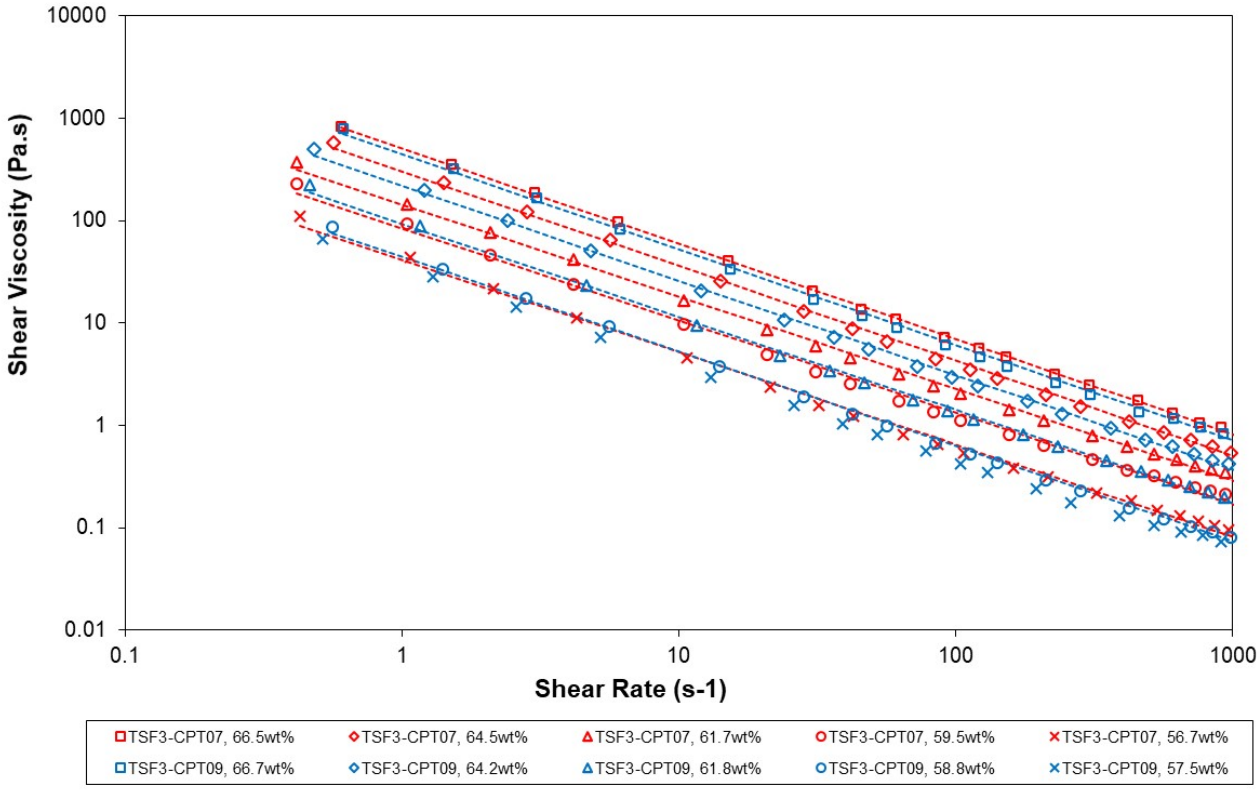


Figure 7 - Shear viscosity vs. shear rate for Saraji Mine TSF 3 samples.

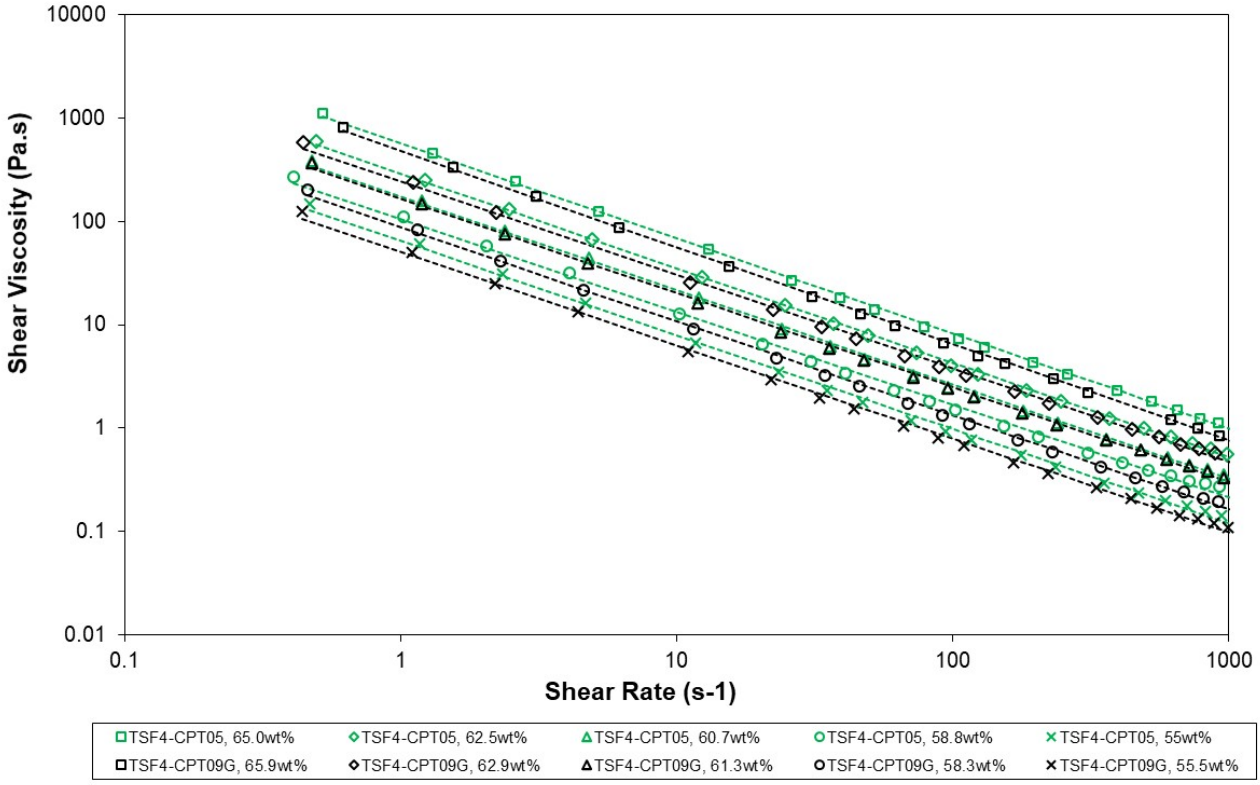


Figure 8 - Shear viscosity vs. shear rate for Saraji Mine TSF 4 samples.

6 CONCLUSION

Saraji Mine samples were received at concentrations ranging from approximately 73wt% up to 98wt%.

Solids SGs ranged from 1.60 to 1.82, with up to 0.13 difference between two composite samples from the one TSF. The SG was lower at shallow depths for TSF 2 and TSF 4, but higher at shallow depth for TSF 3.

The shear yield stress of all tailings samples tested increased exponentially with solids concentration across the range of solids concentrations investigated and model parameters are provided. The yield stress behaviour for the two samples from TSF 3 and TSF 4 were similar to each other, however the two samples from TSF 2 differed from each other significantly, with the TSF2 sample from smaller depth showing a lower yield stress for a given solids concentration than any other sample. The TSF 2-BH07: 6-12 sample also had the lowest SG, and the ranking of yield stress curves was generally seen to follow SG for the Saraji mine samples. At a solids concentration of 55wt% the yield stress ranged from 10Pa (TSF 2-BH07: 6-12) to 80Pa (TSF4-CPT05: 10-13) for the samples tested.

In shear flow, all samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates investigated. For all but one sample, no shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due the sample collection, subsequent sub-sampling and sample preparation methods. The one notable exception was TSF2 BH07 at 71wt%. This sample showed a decrease in the shear stress as the shear rate increased from zero until approximately $100s^{-1}$ before increasing at higher shear rates. The behaviour was reproducible when the same sample was sheared then retested, possibly indicating a localised (but reversible) structuring of the material – possibly due to the presence of asymmetrical particles aligning in the direction of flow. The origin of the behaviour was not investigated.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected and the shear stress versus shear rate data was modelled using a Herschel-Bulkley model. The viscosity stress versus shear rate data was well described using a Power Law.

A APPENDIX

A1 Shear Yield Stress Data

Table A 1 - Solids mass fraction (x) versus yield stress (τ_y) data for Saraji Mine Tailings Samples

TSF2-CPT06: 11-13.5			TSF2-BH07: 6-12	
Slurry Average Solids Fraction (total)	Yield Stress		Slurry Average Solids Fraction (total)	Yield Stress
0.4574	6.4305		0.5098	4.1160
0.4954	13.6350		0.5566	12.0900
0.5284	25.0800		0.5979	28.2950
0.5690	53.2450		0.6333	66.2350
0.6104	126.2000		0.6581	132.4500
0.6378	253.1000		0.6804	232.2500
0.6600	438.6500		0.6950	362.6000
0.6742	645.7500		0.7046	504.4000
0.6808	783.6000		0.7159	725.2000
0.6884	1003.2500		0.7241	1010.0000

TSF3-CPT07: 15-17			TSF3-CPT09: 13-16	
Slurry Average Solids Fraction (total)	Yield Stress		Slurry Average Solids Fraction (total)	Yield Stress
0.4430	5.4015		0.4719	5.1445
0.4846	12.6050		0.4823	12.3500
0.5282	29.3200		0.5284	21.6050
0.5653	59.2500		0.5781	54.0150
0.6036	127.4500		0.6120	112.4000
0.6258	206.3000		0.6390	232.0000
0.6529	417.2500		0.6556	388.8000
0.6636	665.2000		0.6734	644.1000
0.6737	832.8000		0.6811	842.1000
0.6820	1075.0000		0.6864	976.5000

Table A 1 - continued

TSF4-CPT05: 10-13			TSF4-CPT09G: 9-10.5	
Slurry Average Solids Fraction (total)	Yield Stress		Slurry Average Solids Fraction (total)	Yield Stress
0.3819	4.1160		0.4296	5.9160
0.4523	12.0900		0.4626	11.5750
0.5106	33.6950		0.5122	27.0100
0.5526	71.5050		0.5527	58.3900
0.5875	138.8000		0.5798	101.8500
0.6147	242.3000		0.6165	218.1500
0.6327	400.5000		0.6478	440.1000
0.6509	582.0000		0.6587	594.8000
0.6632	843.7500		0.6677	814.6000
0.6710	1061.5000		0.6767	997.5000

The shear stress versus shear rate data was curve fitted using a Herschel-Bulkley model :

$\tau = \tau_y + K\dot{\gamma}^n$, where τ is the shear stress (*Pa*) and $\dot{\gamma}$ is the shear rate (s^{-1}) (shown as a dashed line in Figure 3 to Figure 5). The parameters for these curves are given in Table A2 below. Note that model parameters are only valid over the shear rate range measured.

Table A2 Herschel Bulkley model parameters for Saraji Mine Tailings rheology testing.

Shear Stress Table:	***Herschel Bulkley Model: $\tau=\tau_y+Ky^n$***				
sample	τ_y	***K***	***n***	**min shear rate**	**max shear rate**
TSF3-CPT07, 66.5wt%	508.3	37.57	0.3235	0.60	1208.89
TSF3-CPT07, 64.5wt%	331.0	9.18	0.4406	0.56	1410.56
TSF3-CPT07, 61.7wt%	153.8	7.08	0.4550	0.42	1041.78
TSF3-CPT07, 59.5wt%	95.4	0.89	0.6859	0.42	1040.43
TSF3-CPT07, 56.7wt%	54.6	0.21	0.7628	0.43	1072.18
TSF3-CPT09, 66.7wt%	522.1	1.13	0.7723	0.61	1533.46
TSF3-CPT09, 64.2wt%	249.2	1.79	0.6505	0.48	1205.75
TSF3-CPT09, 61.8wt%	115.4	0.46	0.7482	0.47	1163.04
TSF3-CPT09, 58.8wt%	52.6	0.11	0.8045	0.56	1406.20
TSF3-CPT09, 57.5wt%	36.2	0.53	0.5789	0.52	908.80
TSF4-CPT05, 65.0wt%	617.3	19.06	0.4527	0.52	1305.73
TSF4-CPT05, 62.5wt%	317.5	11.11	0.4451	0.49	1231.27
TSF4-CPT05, 60.7wt%	217.2	0.33	0.8886	0.48	1197.07
TSF4-CPT05, 58.8wt%	139.4	0.23	0.8994	0.41	1024.15
TSF4-CPT05, 55wt%	77.0	0.28	0.7793	0.47	1173.20
TSF4-CPT09G, 65.9wt%	529.1	8.41	0.5096	0.62	1542.49
TSF4-CPT09G, 62.9wt%	267.1	7.67	0.5081	0.45	1114.04
TSF4-CPT09G, 61.3wt%	184.6	2.94	0.5752	0.48	1193.66
TSF4-CPT09G, 58.3wt%	93.1	2.43	0.5311	0.46	1148.37
TSF4-CPT09G, 55.5wt%	54.8	2.05	0.4726	0.44	1101.15
TSF2-CPT06, 67.6wt%	588.0	3.21	0.7050	0.48	1199.40
TSF2-CPT06, 65.1wt%	314.3	5.69	0.5829	0.37	920.05
TSF2-CPT06, 61.3wt%	130.1	4.55	0.4781	0.43	1072.29
TSF2-CPT06, 58.9wt%	79.1	2.79	0.4603	0.47	1176.36
TSF2-CPT06, 56.0wt%	40.9	1.77	0.4482	0.43	855.73
TSF2-BH07, 71.0wt%	518.2	0.04	1.1177	6.10	1524.08
TSF2-BH07, 67.3wt%	173.4	0.58	0.7041	0.65	1630.39
TSF2-BH07, 63.5wt%	66.6	0.43	0.6886	0.49	1222.36
TSF2-BH07, 58.3wt%	22.0	0.14	0.7681	0.42	1056.86
TSF2-BH07, 55.0wt%	9.8	0.24	0.6147	0.45	787.53

The viscosity stress versus shear rate data was curve fitted using a Power Law model: $\eta = a\dot{\gamma}^b$, where η is the shear viscosity (*Pa.s*) and $\dot{\gamma}$ is the shear rate (s^{-1}), (shown as a dashed line in Figure 6 to Figure 8Figure 8 - Shear viscosity vs. shear rate for Saraji Mine TSF 4 samples.). The parameters for these curves are given in Table A3 below. Note that model parameters are only valid over the shear rate range measured.

Table A3. Power law model parameters for Saraji Mine Tailings **rheology testing.**

Viscosity Table:	***Power Law Model $\eta=K\dot{\gamma}^n$***			
sample	***K***	***n***	**min shear rate**	**max shear rate**
TSF3-CPT07, 66.5wt%	509.1	-0.9307	0.60	1208.89
TSF3-CPT07, 64.5wt%	303.8	-0.9258	0.56	1410.56
TSF3-CPT07, 61.7wt%	143.9	-0.8995	0.42	1041.78
TSF3-CPT07, 59.5wt%	84.2	-0.8994	0.42	1040.43
TSF3-CPT07, 56.7wt%	41.5	-0.9023	0.43	1072.18
TSF3-CPT09, 66.7wt%	446.8	-0.9317	0.61	1533.46
TSF3-CPT09, 64.2wt%	218.3	-0.9236	0.48	1205.75
TSF3-CPT09, 61.8wt%	93.5	-0.9100	0.47	1163.04
TSF3-CPT09, 58.8wt%	44.4	-0.9255	0.56	1406.20
TSF3-CPT09, 57.5wt%	33.1	-0.9227	0.52	908.80
TSF4-CPT05, 65.0wt%	568.7	-0.9198	0.52	1305.73
TSF4-CPT05, 62.5wt%	290.5	-0.9150	0.49	1231.27
TSF4-CPT05, 60.7wt%	176.2	-0.9125	0.48	1197.07
TSF4-CPT05, 58.8wt%	105.5	-0.8978	0.41	1024.15
TSF4-CPT05, 55wt%	64.8	-0.9107	0.47	1173.20
TSF4-CPT09G, 65.9wt%	481.6	-0.9321	0.62	1542.49
TSF4-CPT09G, 62.9wt%	245.2	-0.9060	0.45	1114.04
TSF4-CPT09G, 61.3wt%	165.7	-0.9123	0.48	1193.66
TSF4-CPT09G, 58.3wt%	87.5	-0.9088	0.46	1148.37
TSF4-CPT09G, 55.5wt%	51.0	-0.9049	0.44	1101.15
TSF2-CPT06, 67.6wt%	493.7	-0.9127	0.48	1199.40
TSF2-CPT06, 65.1wt%	254.0	-0.8862	0.37	920.05
TSF2-CPT06, 61.3wt%	117.6	-0.9023	0.43	1072.29
TSF2-CPT06, 58.9wt%	72.8	-0.9110	0.47	1176.36
TSF2-CPT06, 56.0wt%	36.1	-0.9021	0.43	855.73
TSF2-BH07, 71.0wt%	371.6	-0.9358	6.10	1524.08
TSF2-BH07, 67.3wt%	150.3	-0.9358	0.65	1630.39
TSF2-BH07, 63.5wt%	57.5	-0.9143	0.08	1222.36
TSF2-BH07, 58.3wt%	19.3	-0.8914	0.42	1056.86
TSF2-BH07, 55.0wt%	9.9	-0.8997	0.45	787.53

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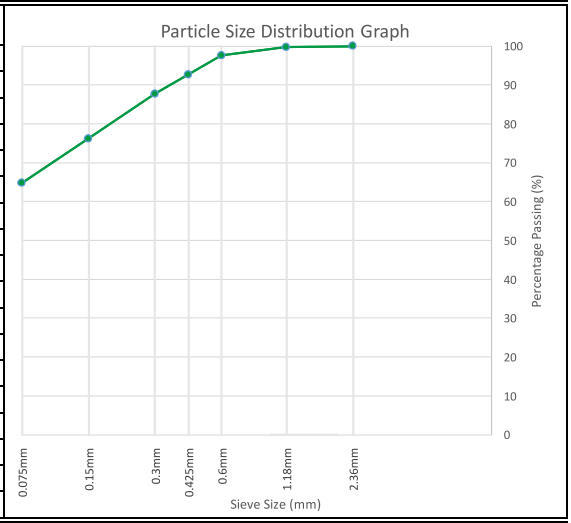
Material Quality Report

Client :	**EDG Consulting**	Report Number :	**SR/PTP/05417 - 4/1**
Client Address :	**Level 1, 18 Wandoo Street, Fortitude Valley, 4006, QLD**	Report Date :	**8/09/2020**
Project Name :	**EDG Consulting testing SRM**	Test Request :	-
Project Number :	**PTP/05417**	**Page 6 of 6**	
Location :	**Dysart**		

Test Methods :	**AS1289.3.6.1, AS1289.2.1.1**
Material Description	**Sandy SILT with Clay - Black**

Sample Number :	**S/077798**	Sampling Method :	**As Received**
Date Tested :	**31/08/2020**	Time :	**00:00**
Material Source :	**Insitu**	Location 1 :	**CPT03**
Material Type :	-	Location 2 :	**10.50 - 10.95**
Lot Number :	**TSF2-4**	Location 3 :	-
PSD Specification Number :	**N/A**	Location 4 :	-
ATT Specification Number :	**N/A**		

AS Sieve Size (mm) :	Percent Passing (%) :	Specification Limits :
75.0		
63.0		
53.0		
37.5		
26.5		
19.0		
16		
13.2		
9.5		
6.7		
4.75		
2.36	**100**	
1.18	**100**	
0.600	**98**	
0.425	**93**	
0.300	**88**	
0.150	**76**	
0.075	**65**	



Atterberg Limits :	Test Methods:	Test Results :	Specification Limits :		Test Results :	Specifications Limits :
Liquid Limit (%) :	**AS1289.3.1.1**	**25**		Weighted PI (PI x $P_{0.425}$) :	**722**	
Plastic Limit (%) :	**AS1289.3.2.1**	**17**		Weighted LS (LS x $P_{0.425}$) :	**1029**	
Plasticity Index (%) :	**AS1289.3.3.1**	**8**		Fines Ratio ($P_{0.075}$ / $P_{0.425}$) :	**0.70**	
Linear Shrinkage (%) :	**AS1289.3.4.1**	**11**				
Notes :	**History of Sample: Oven Dried, Method of Preparation: Dry Sieved, Linear Shrinkage: Curling Occurred**					

Remarks :	-

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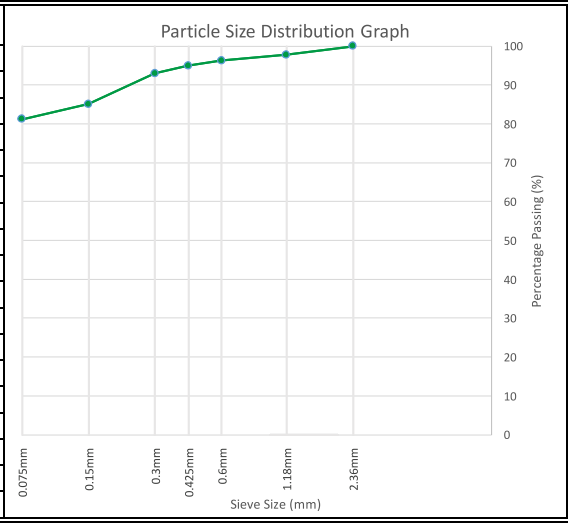
Material Quality Report

Client :	**EDG Consulting**	Report Number :	**SR/PTP/05417 - 4/1**
Client Address :	**Level 1, 18 Wandoo Street, Fortitude Valley, 4006, QLD**	Report Date :	**8/09/2020**
Project Name :	**EDG Consulting testing SRM**	Test Request :	-
Project Number :	**PTP/05417**	**Page 1 of 6**	
Location :	**Dysart**		

Test Methods :	**AS1289.3.6.1, AS1289.2.1.1**
Material Description	**Silty CLAY - Black / Red Brown mottled white and yellow**

Sample Number :	**S/077778**	Sampling Method :	**As Received**
Date Tested :	**31/08/2020**	Time :	**00:00**
Material Source :	**Insitu**	Location 1 :	**BH01**
Material Type :	-	Location 2 :	**6.00 - 6.45**
Lot Number :	**TSF2-4**	Location 3 :	-
PSD Specification Number :	**N/A**	Location 4 :	-
ATT Specification Number :	**N/A**		

AS Sieve Size (mm) :	Percent Passing (%) :	Specification Limits :
75.0		
63.0		
53.0		
37.5		
26.5		
19.0		
16		
13.2		
9.5		
6.7		
4.75		
2.36	**100**	
1.18	**98**	
0.600	**96**	
0.425	**95**	
0.300	**93**	
0.150	**85**	
0.075	**81**	



Atterberg Limits :	Test Methods:	Test Results :	Specification Limits :		Test Results :	Specifications Limits :
Liquid Limit (%) :	**AS1289.3.1.1**	**45**		Weighted PI (PI x $P_{0.425}$) :	**2232**	
Plastic Limit (%) :	**AS1289.3.2.1**	**22**		Weighted LS (LS x $P_{0.425}$) :	**862**	
Plasticity Index (%) :	**AS1289.3.3.1**	**23**		Fines Ratio ($P_{0.075}$ / $P_{0.425}$) :	**0.86**	
Linear Shrinkage (%) :	**AS1289.3.4.1**	**9**				
Notes :	**History of Sample: Oven Dried, Method of Preparation: Dry Sieved, Linear Shrinkage: Curling Occurred**					

Remarks :	-

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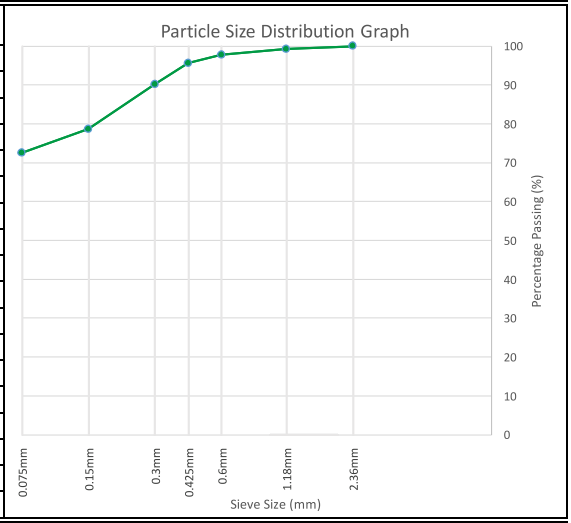
Material Quality Report

Client :	**EDG Consulting**	Report Number :	**SR/PTP/05417 - 4/1**
Client Address :	**Level 1, 18 Wandoo Street, Fortitude Valley, 4006, QLD**	Report Date :	**8/09/2020**
Project Name :	**EDG Consulting testing SRM**	Test Request :	-
Project Number :	**PTP/05417**		
Location :	**Dysart**		

Test Methods :	**AS1289.3.6.1, AS1289.2.1.1**
Material Description	**Silty CLAY with Sand - Red/Brown mottled White & Black**

Sample Number :	**S/077785**	Sampling Method :	**As Received**
Date Tested :	**31/08/2020**	Time :	**00:00**
Material Source :	**Insitu**	Location 1 :	**BH04**
Material Type :	-	Location 2 :	**6.00 - 6.45**
Lot Number :	**TSF2-4**	Location 3 :	-
PSD Specification Number :	**N/A**	Location 4 :	-
ATT Specification Number :	**N/A**		

AS Sieve Size (mm) :	Percent Passing (%) :	Specification Limits :
75.0		
63.0		
53.0		
37.5		
26.5		
19.0		
16		
13.2		
9.5		
6.7		
4.75		
2.36	**100**	
1.18	**99**	
0.600	**98**	
0.425	**96**	
0.300	**90**	
0.150	**79**	
0.075	**73**	



Atterberg Limits :	Test Methods:	Test Results :	Specification Limits :		Test Results :	Specifications Limits :
Liquid Limit (%) :	**AS1289.3.1.1**	**53**		Weighted PI (PI x $P_{0.425}$) :	**3419**	
Plastic Limit (%) :	**AS1289.3.2.1**	**17**		Weighted LS (LS x $P_{0.425}$) :	**1119**	
Plasticity Index (%) :	**AS1289.3.3.1**	**36**		Fines Ratio ($P_{0.075}$ / $P_{0.425}$) :	**0.76**	
Linear Shrinkage (%) :	**AS1289.3.4.1**	**11.5**				
Notes :	**History of Sample: Oven Dried, Method of Preparation: Dry Sieved, Linear Shrinkage: Curling Occurred**					

Remarks :	-

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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	EDG Consulting	**Report No.**	20090634-G
		Workorder No.	7833
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Report Date**	28/10/2020
Project	B01229-4 - TSF2-4 - Saraji Mine		

Sample No.	20090634	20090635	20090636	20090637	20090638	20090639	20090640
Test Date	22/10/2020	2/10/2020	2/10/2020	22/10/2020	30/09/2020	2/10/2020	22/10/2020
Client ID	TSF2-BH04	TSF2-BH04	TSF2-BH0I	TSF2-BH0I	TSF2-BH0I	TSF2-BH0I	TSF2-CPT03
Depth (m)	5.10	12.00	6.00	8.00	11.00	14.00	6.00
Moisture (%)	17.1	37.7	12.8	18.8	14.0	12.9	15.3
AS SIEVE SIZE (mm)	**PERCENT PASSING**						
150							
75							
63							
53							
37.5							
26.5							
19							
13.2							
9.5							
6.7							
4.75			100	100			
2.36	100		99	97	100	100	100
1.18	99		98	94	98	98	97
0.600	98		93	91	93	95	93
0.425	95		88	88	85	90	90
0.300	85		81	84	72	84	86
0.150	72		67	75	67	71	75
0.075	66	100	58	66	56	60	69

NOTES/REMARKS:

Sample/s supplied by the client

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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	EDG Consulting	**Report No.**	20090641-G
		Workorder No.	7833
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Report Date**	28/10/2020
Project	B01229-4 - TSF2-4 - Saraji Mine		

Sample No.	20090641						
Test Date	30/09/2020						
Client ID	TSF2-BH04						
Depth (m)	8.2						
Moisture (%)	15.6						
AS SIEVE SIZE (mm)	**PERCENT PASSING**						
150							
75							
63							
53							
37.5							
26.5							
19							
13.2							
9.5							
6.7							
4.75	100						
2.36	99						
1.18	96						
0.600	91						
0.425	85						
0.300	77						
0.150	63						
0.075	54						

NOTES/REMARKS:

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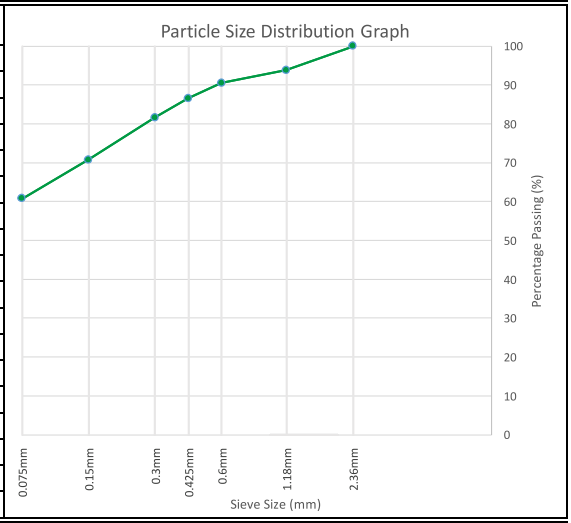
Material Quality Report

Client :	**EDG Consulting**	Report Number :	**SR/PTP/05417 - 4/1**
Client Address :	**Level 1, 18 Wandoo Street, Fortitude Valley, 4006, QLD**	Report Date :	**8/09/2020**
Project Name :	**EDG Consulting testing SRM**	Test Request :	-
Project Number :	**PTP/05417**		
Location :	**Dysart**		

Test Methods :	**AS1289.3.6.1, AS1289.2.1.1**
Material Description	**Silty CLAY with Sand - Black mottled Red/Brown**

Sample Number :	**S/077790**	Sampling Method :	**As Received**
Date Tested :	**31/08/2020**	Time :	**00:00**
Material Source :	**Insitu**	Location 1 :	**BH06**
Material Type :	-	Location 2 :	**9.00 - 9.45**
Lot Number :	**TSF2-4**	Location 3 :	-
PSD Specification Number :	**N/A**	Location 4 :	-
ATT Specification Number :	**N/A**		

AS Sieve Size (mm) :	Percent Passing (%) :	Specification Limits :
75.0		
63.0		
53.0		
37.5		
26.5		
19.0		
16		
13.2		
9.5		
6.7		
4.75		
2.36	**100**	
1.18	**94**	
0.600	**91**	
0.425	**87**	
0.300	**82**	
0.150	**71**	
0.075	**61**	



Atterberg Limits :	Test Methods:	Test Results :	Specification Limits :		Test Results :	Specifications Limits :
Liquid Limit (%) :	**AS1289.3.1.1**	**45**		Weighted PI (PI x $P_{0.425}$) :	**2016**	
Plastic Limit (%) :	**AS1289.3.2.1**	**22**		Weighted LS (LS x $P_{0.425}$) :	**743**	
Plasticity Index (%) :	**AS1289.3.3.1**	**23**		Fines Ratio ($P_{0.075}$ / $P_{0.425}$) :	**0.70**	
Linear Shrinkage (%) :	**AS1289.3.4.1**	**8.5**				
Notes :	**History of Sample: Oven Dried, Method of Preparation: Dry Sieved, Linear Shrinkage: Nil Occurred**					

Remarks :	-

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Atterberg Limits Report

Client :	**EDG Consulting**	Report Number :	**SR/PTP/05417 - 3/1**
Client Address :	**Level 1, 18 Wandoo Street, Fortitude Valley, 4006, QLD**	Report Date :	**8/09/2020**
Project Name :	**EDG Consulting testing SRM**	Test Request :	**-**
Project Number :	**PTP/05417**	**Page 3 of 12**	
Location :	**Dysart**		

Test Methods :	**AS1289.3.1.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.3.3.1, AS1289.2.1.1**
Material Description :	**Sandy CLAY - Black/Red/Brown mottled White**

Sample Number :	**S/077783**	Sampling Method :	**As Received**
Date Tested :	**5/09/2020**	Time :	**00:00**
Material Source :	**Insitu**	Location 1 :	**BH03**
Material Type :	**-**	Location 2 :	**6.00 - 6.45**
Lot Number :	**TSF2-4**	Location 3 :	**-**
ATT Specification Number :	**N/A**	Location 4 :	**-**

History of Sample :	**Oven Dried**
Method of Preparation :	**Dry Sieved**
Linear Shrinkage :	**Nil Occurred**

Atterberg Limits Test Results	*Liquid Limit (%) :*	*Plastic Limit (%) :*	*Plasticity Index (%) :*	*Linear Shrinkage (%) :*
Results :	**45**	**23**	**22**	**9.0**
Specifications :				

Remarks :	-

Note: The results contained in this report relate only to the item/s that were tested/sampled

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ATTERBERG LIMITS TEST REPORT

Test Method: AS 1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1

Client	EDG Consulting	**Report No.**	20090637-AL
		Workorder No.	0007833
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Report Date**	28/10/2020
Project	B01229-4 - TSF2-4 - Saraji Mine		

Sample No.	20090637	20090638	20090639	20090640	20090641	
Test Date	12/10/2020	12/10/2020	19/10/2020	21/10/2020	12/10/2020	
Client ID	TSF2-BH0I	TSF2-BH0I	TSF2-BH0I	TSF2-CPT03	TSF2-BH04	
Depth (m)	8.00	11.00	14.00	6.00	8.2	
Liquid Limit (%)	36	35	33	49	26	
Plastic Limit (%)	16	13	12	16	13	
Plasticity Index (%)	20	22	21	33	13	
Linear Shrinkage (%)	11.0	11.5	10.5	13.0	8.5	
Moisture Content (%)	18.9	14.0	12.9	13.0	15.6	

Sample No.						
Test Date						
Client ID						
Depth (m)						
Liquid Limit (%)						
Plastic Limit (%)						
Plasticity Index (%)						
Linear Shrinkage (%)						
Moisture Content (%)						

NOTES/REMARKS: The samples were tested oven dried, dry sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred

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ATTERBERG LIMITS TEST REPORT

Test Method: AS 1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1

Client	EDG Consulting	**Report No.**	20090641-AL
		Workorder No.	0007833
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Report Date**	20/10/2020
Project	B01229-4 - TSF2-4 - Saraji Mine		

Sample No.	20090641
Test Date	12/10/2020
Client ID	TSF2-BH04
Depth (m)	8.2
Liquid Limit (%)	26
Plastic Limit (%)	13
Plasticity Index (%)	13
Linear Shrinkage (%)	8.5
Moisture Content (%)	15.6

NOTES/REMARKS: The samples were tested oven dried, dry sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred

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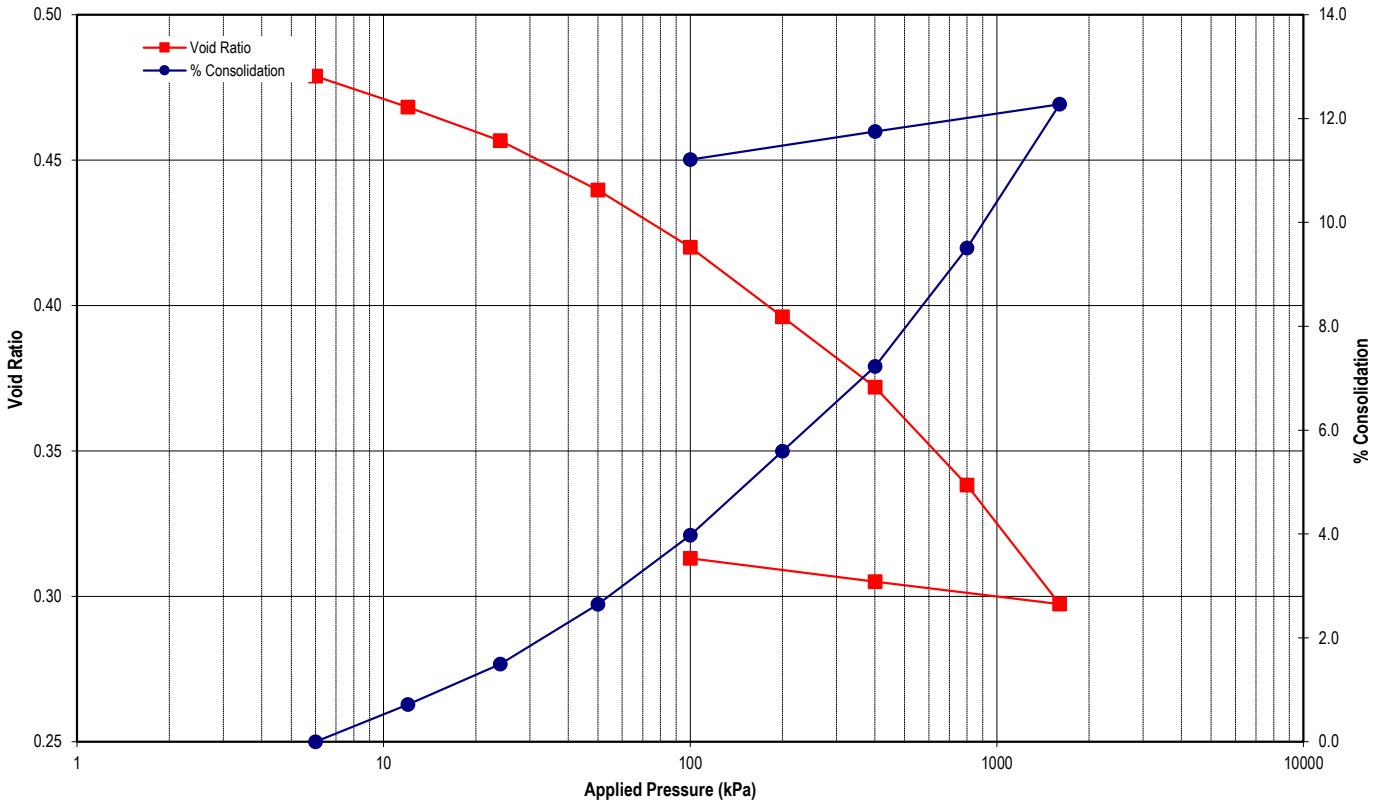
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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050065-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	6/05/2021
		Report Date:	25/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF2-CPT11	**Depth (m):**	5.00-5.80
Description:	SILTY CLAY- black		



Initial Wet Density (t/m^3):	1.37	Initial Moisture (%):	34.7	Initial Height (mm):	25.00
Initial Dry Density (t/m^3):	1.01	Final Moisture (%):	21.2	Final Height (mm):	22.20
Initial Mass (g):	59.42	Initial Voids Ratio:	0.479	Test Condition:	Inundated on load
Particle Density (t/m^3):	1.50	Initial Degree of Saturation (%):	100.0	Undisturbed sample supplied by the client	

Remarks: Tested as Received

REP03103

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Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Channon

NATA
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Laboratory Number 9926

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Soil Rock Calibration

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2 Kimmer Place,
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WA 6107
Ph: +61 8 9258 8323

OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050065-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	6/05/2021
		Report Date:	25/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF2-CPT11	**Depth (m):**	5.00-5.80
Description:	SILTY CLAY- black		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-12	0.035	1.6E-08	59.92	43.50	1.195	0.33	0.7
2	12-24	0.038	1.3E-08	56.08	65.36	0.654	0.31	1.5
3	24-50	0.053	1.0E-08	57.87	72.77	0.450	0.42	2.6
4	50-100	0.065	9.1E-09	107.42	107.44	0.273	0.49	4.0
5	100-200	0.080	6.1E-09	120.78	116.87	0.169	0.51	5.6
6	200-401	0.080	2.5E-09	115.57	95.03	0.086	0.86	7.2
7	401-799	0.113	2.4E-09	102.17	123.55	0.062	1.09	9.5
8	799-1603	0.135	1.2E-09	122.23	104.50	0.038	1.30	12.3
9	1603-401	0.013	3.4E-10	238.97	223.96	0.005	0.15	11.8
10	401-100	0.013	6.0E-10	95.64	95.32	0.020	0.23	11.2

Remarks: Tested as Received

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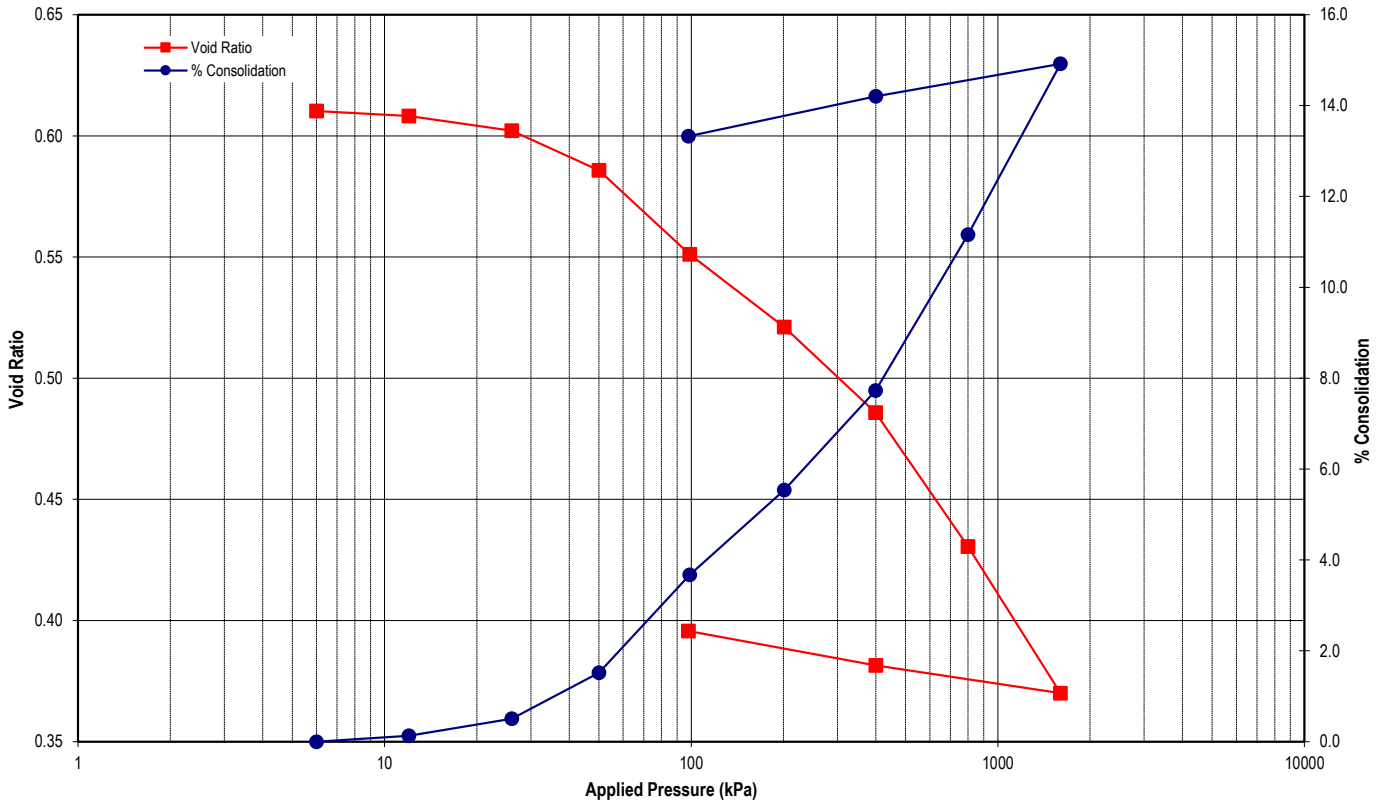
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Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050066-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	6/05/2021
		Report Date:	26/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF2-CPT14	**Depth (m):**	7.00-7.80
Description:	SILTY CLAY- black		



Initial Wet Density (t/m^3):	1.52	Initial Moisture (%):	40.2	Initial Height (mm):	20.06
Initial Dry Density (t/m^3):	1.09	Final Moisture (%):	26.7	Final Height (mm):	17.39
Initial Mass (g):	51.84	Initial Voids Ratio:	0.610	Test Condition:	Inundated on load
Particle Density (t/m^3):	1.75	Initial Degree of Saturation (%):	100.0	Undisturbed sample supplied by the client	

Remarks: Tested as Received

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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050066-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	6/05/2021
		Report Date:	26/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF2-CPT14	**Depth (m):**	7.00-7.80
Description:	SILTY CLAY- black		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-12	0.007	1.4E-09	138.03	21.09	0.214	0.03	0.1
2	12-26	0.018	3.3E-09	42.99	39.10	0.268	0.27	0.5
3	26-50	0.058	5.4E-09	70.46	41.13	0.425	0.64	1.5
4	50-99	0.117	4.8E-09	40.10	35.02	0.446	1.09	3.7
5	99-201	0.098	2.6E-09	66.02	43.49	0.190	0.78	5.5
6	201-399	0.119	1.4E-09	42.18	38.56	0.117	1.45	7.7
7	399-799	0.183	1.4E-09	58.76	47.81	0.093	1.98	11.2
8	799-1601	0.200	5.7E-10	59.04	35.06	0.053	2.35	14.9
9	1601-400	0.019	9.8E-11	133.30	45.25	0.007	0.34	14.2
10	400-98	0.023	5.9E-10	54.96	56.43	0.034	0.72	13.3

Remarks: Tested as Received

REP03103

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C. Channon

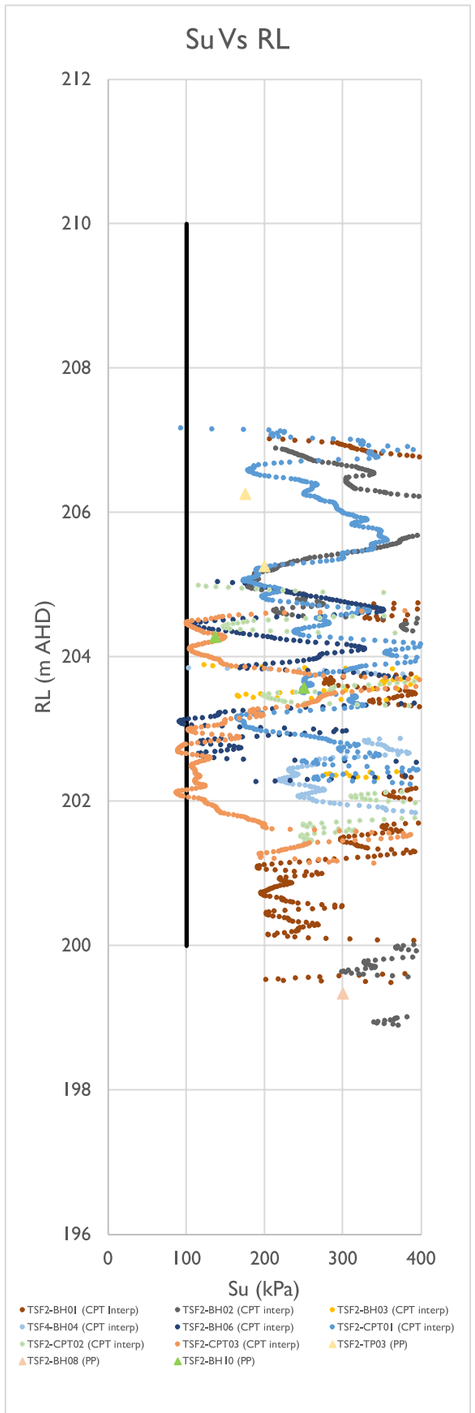
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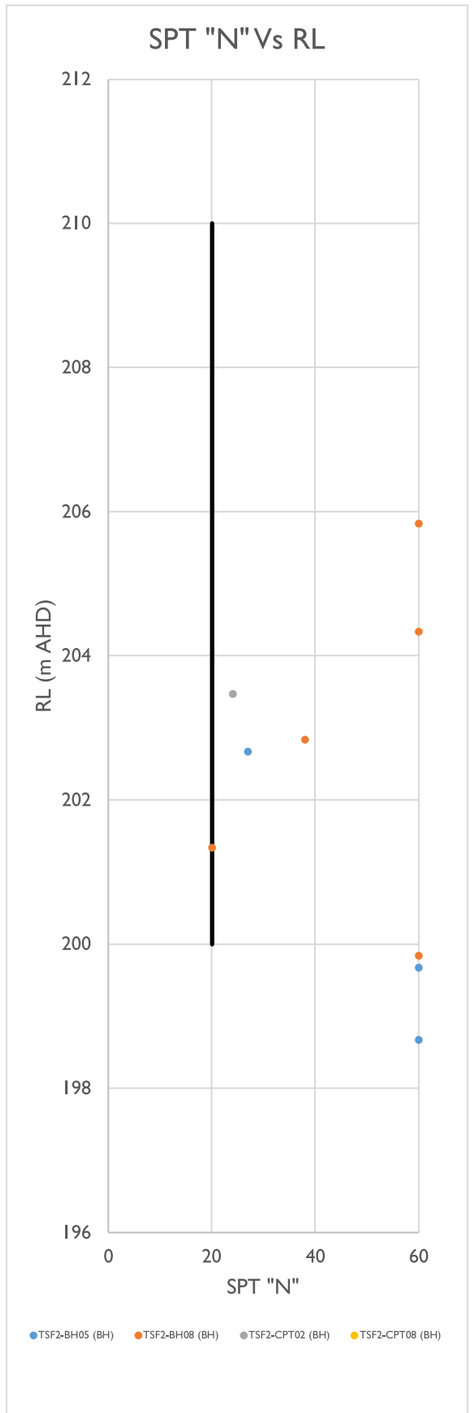
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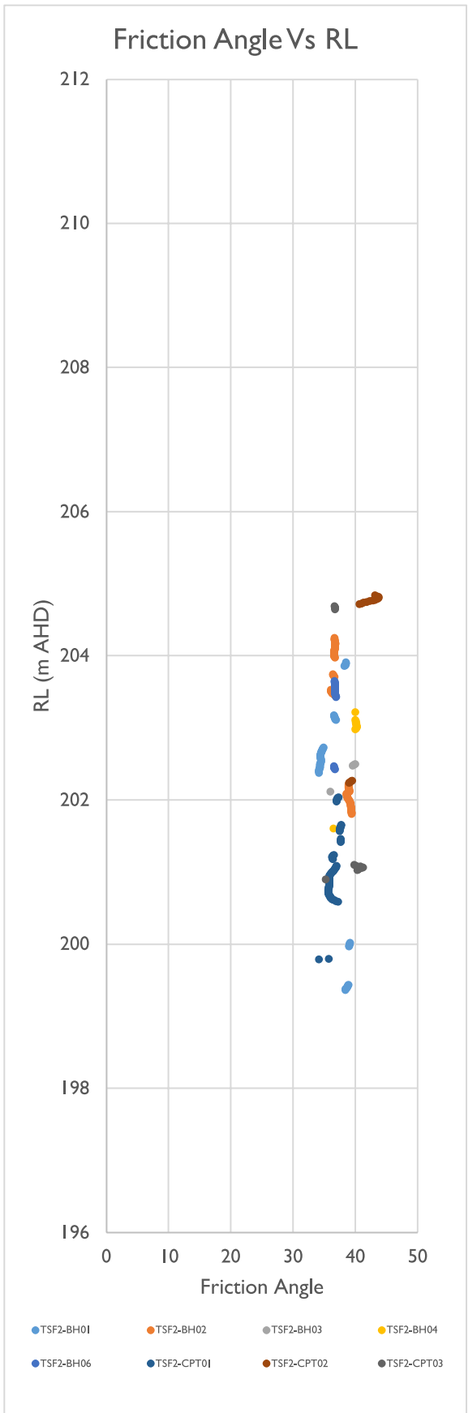
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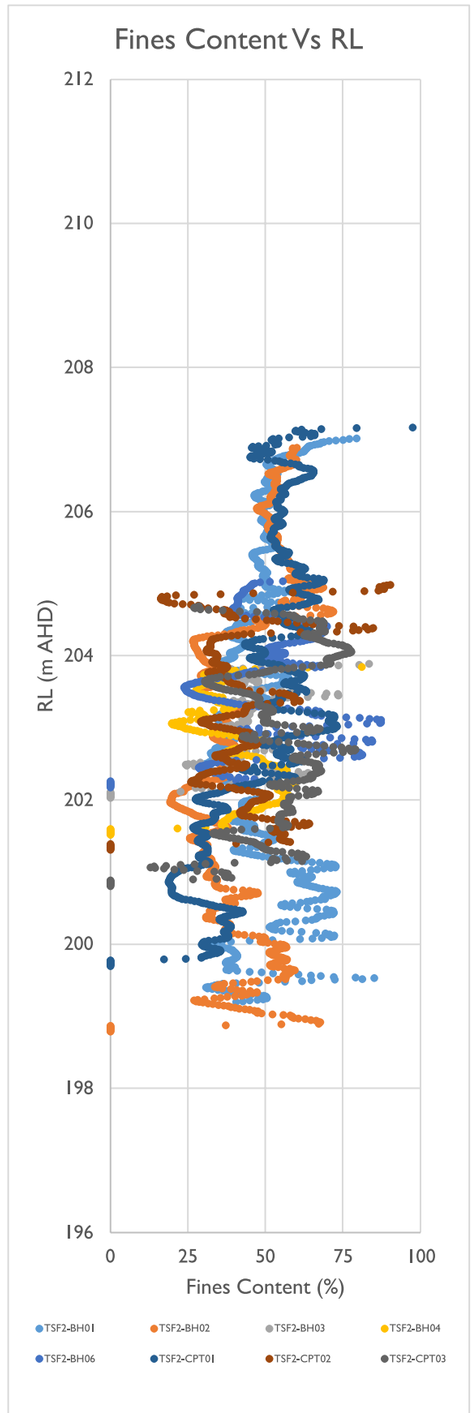
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project:	SRM TSF2-4	*date:*	11/06/2021
location:	TSF2	*by:*	DL
title:	*Material Characterisation Summary - Residual Soil (Near Embankment)*		

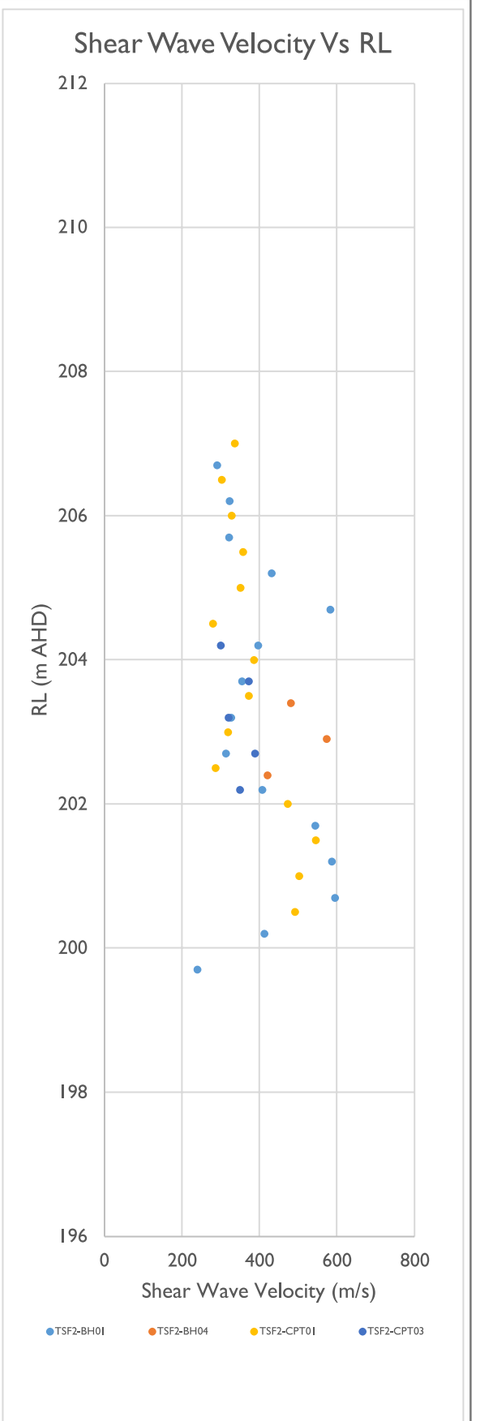
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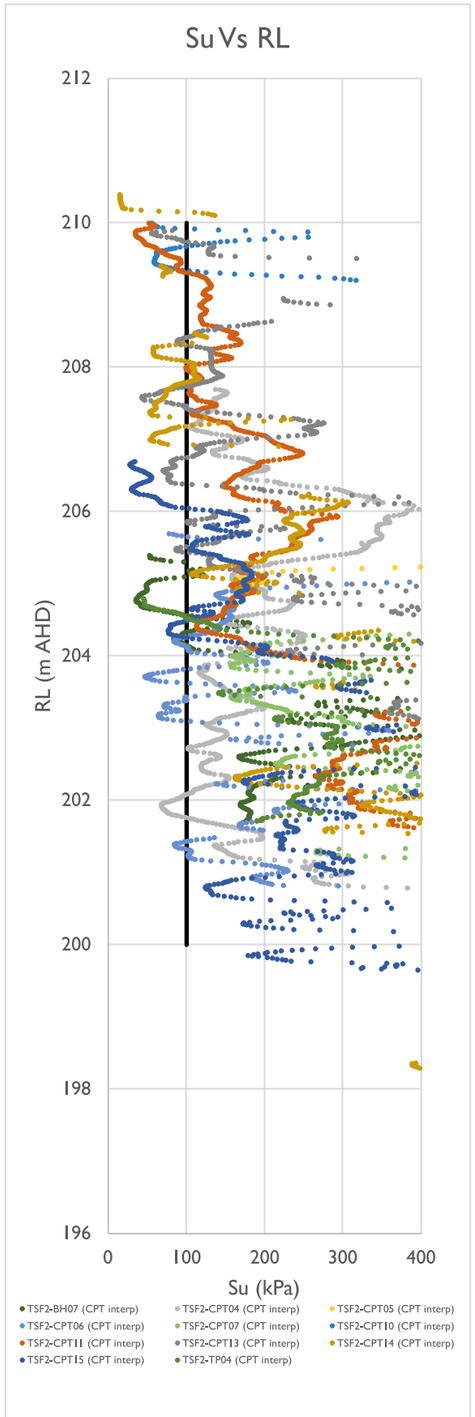


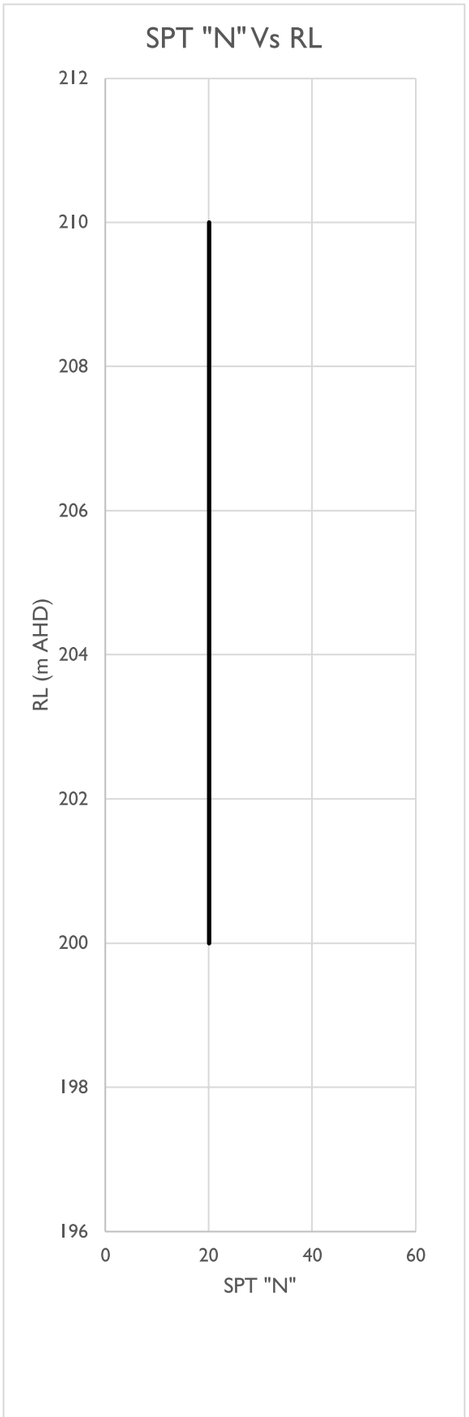


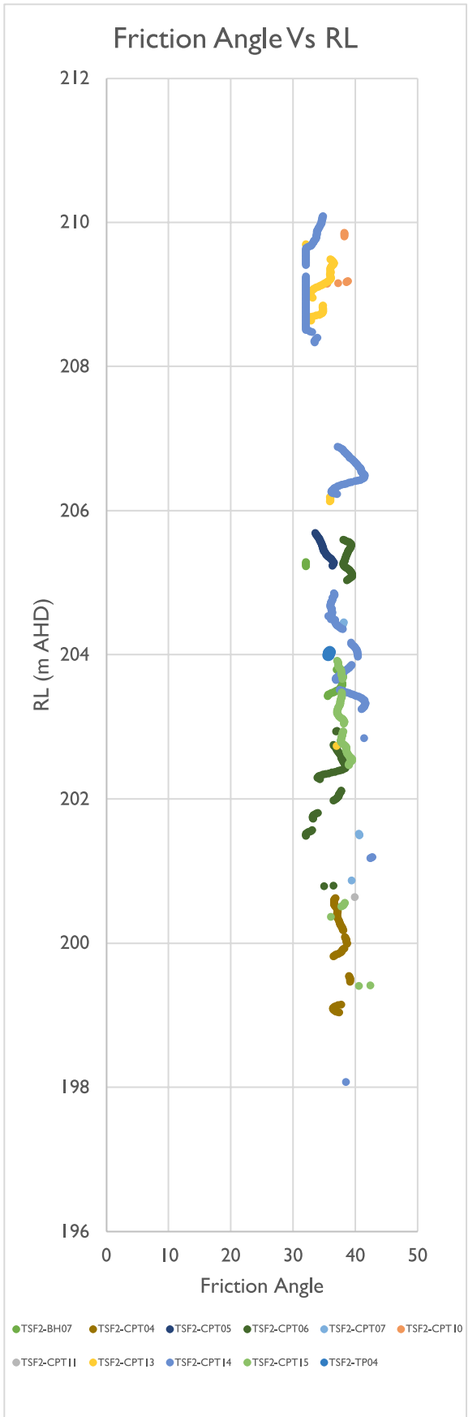


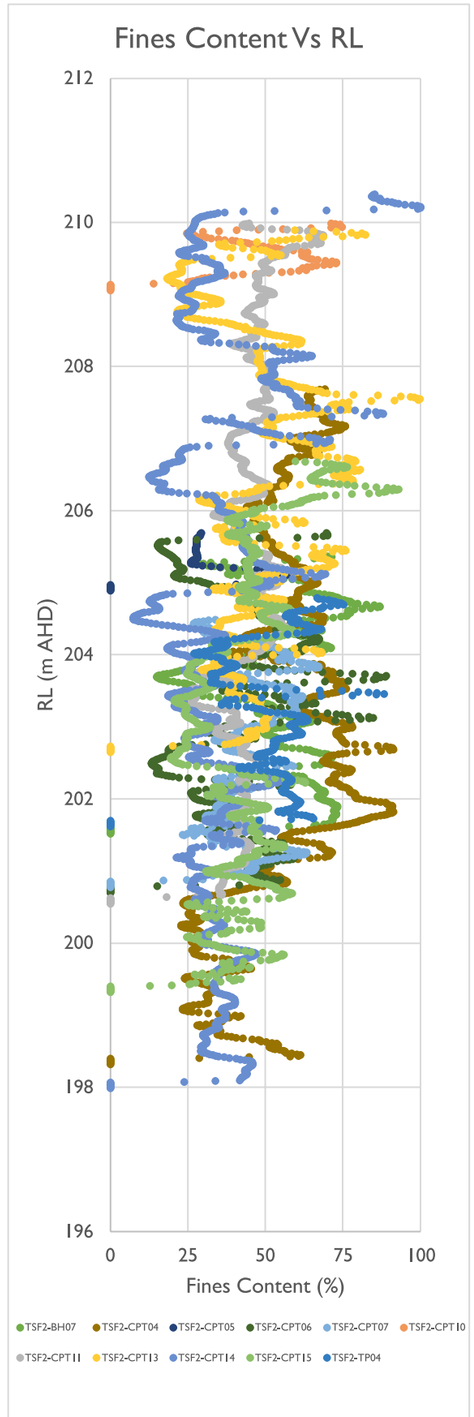
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project:	SRM TSF2-4	*date:*	11/06/2021
location:	TSF2	*by:*	DL
title:	*Material Characterisation Summary - Residual Soil (Near Decant Pond)*		

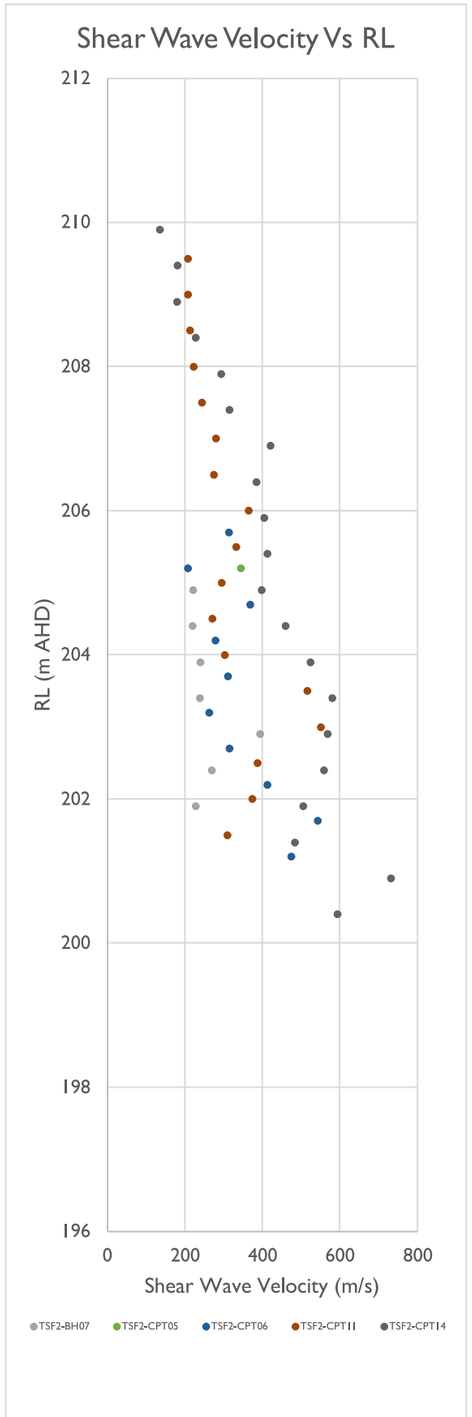
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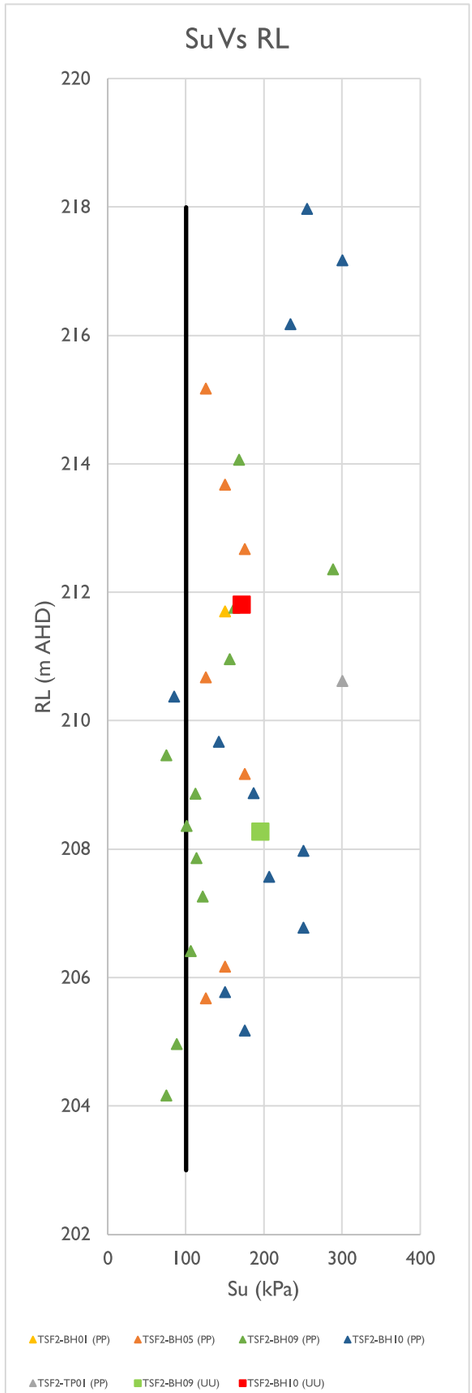


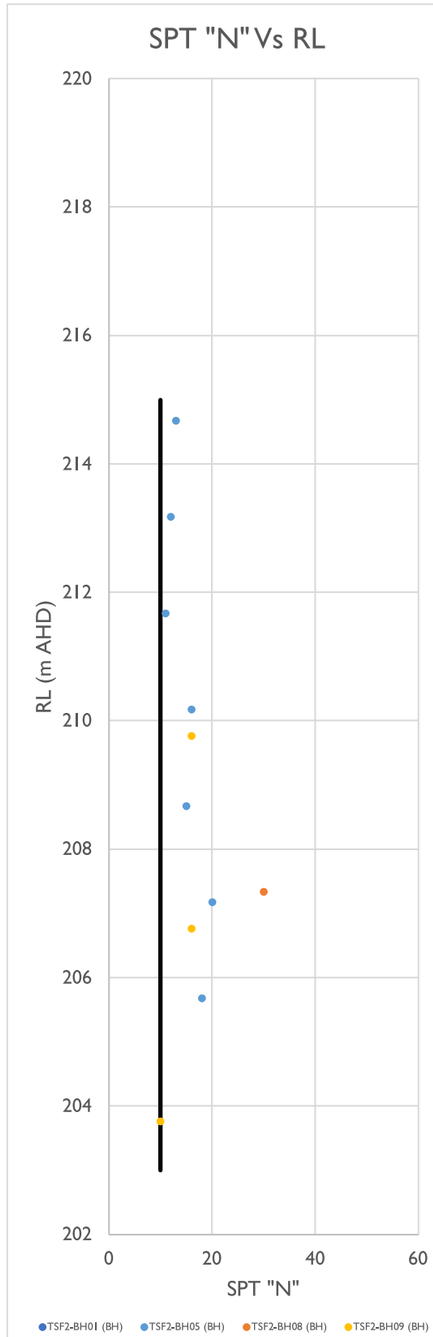


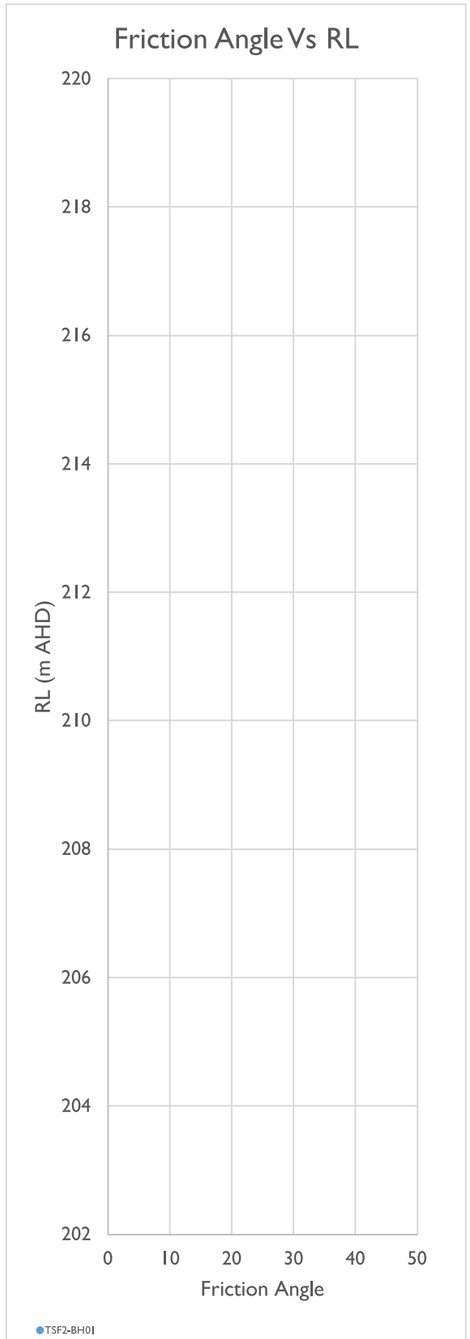


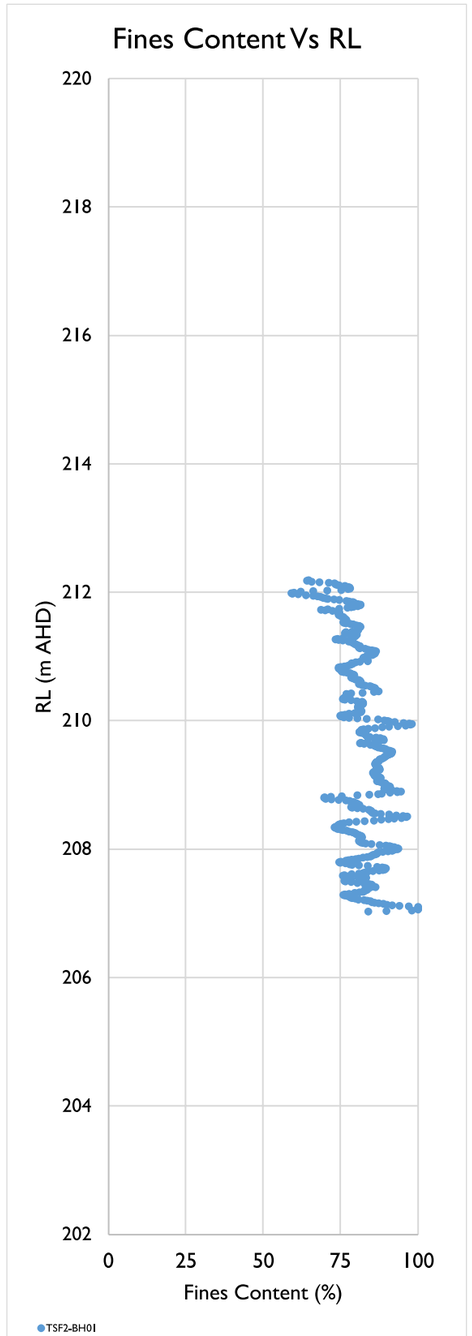
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location:	TSF2	*by:*	DL
title:	*Material Characterisation Summary - Embankment Fill*		

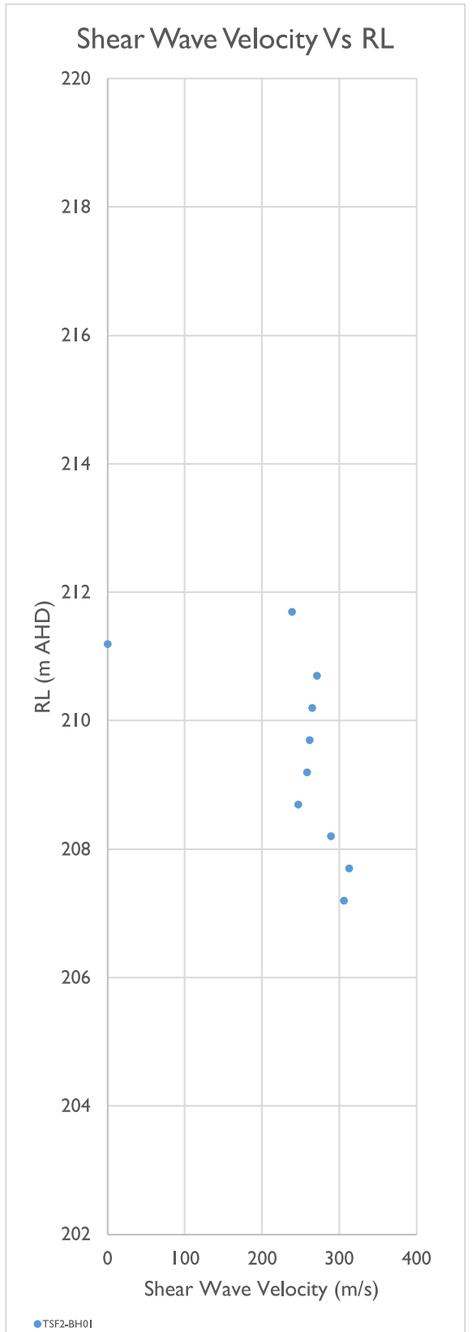
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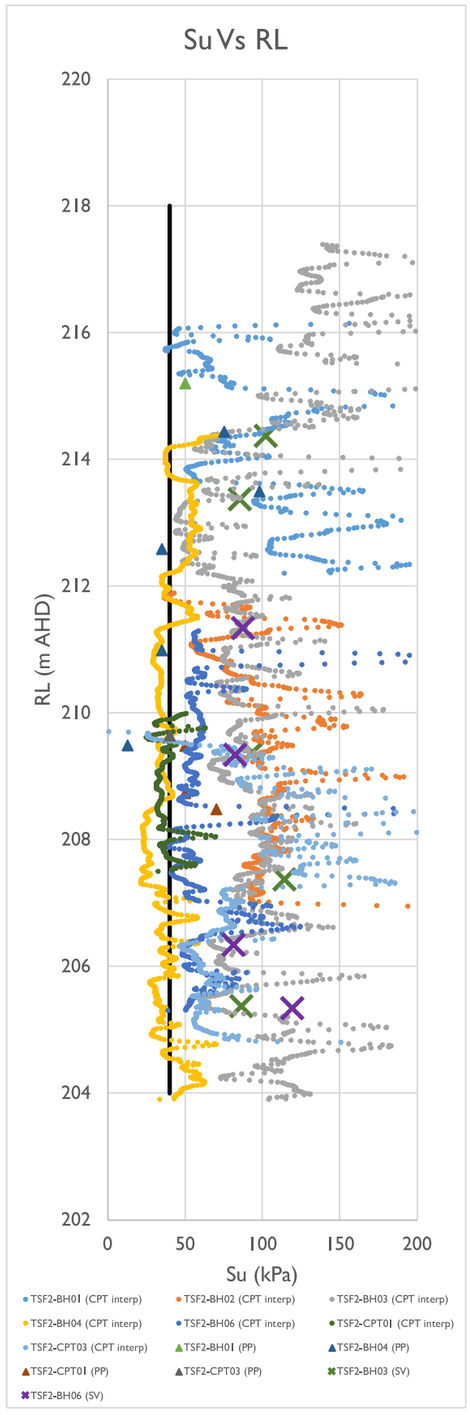


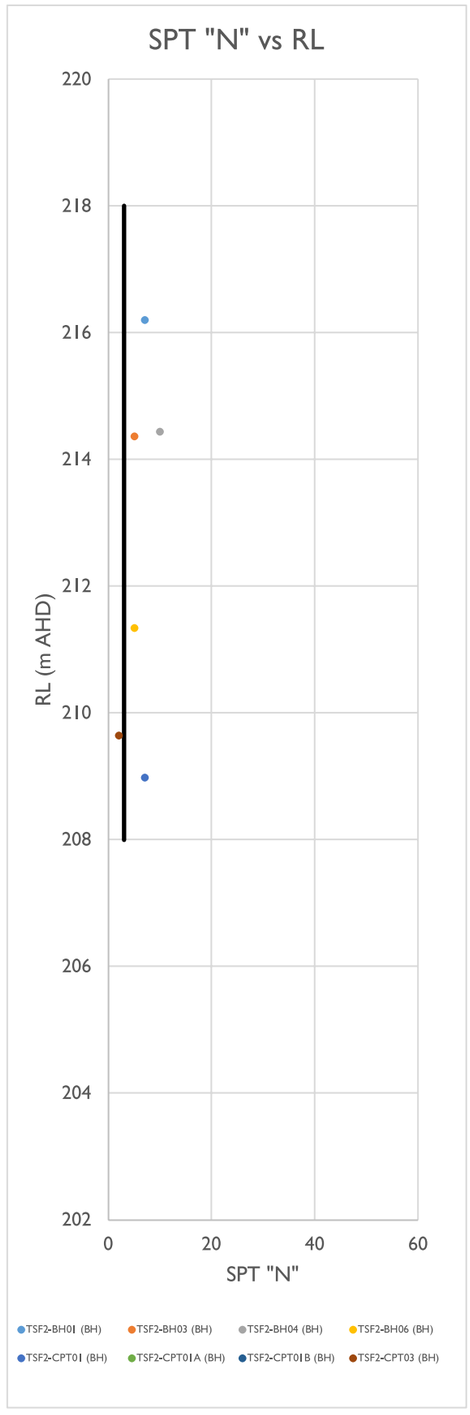


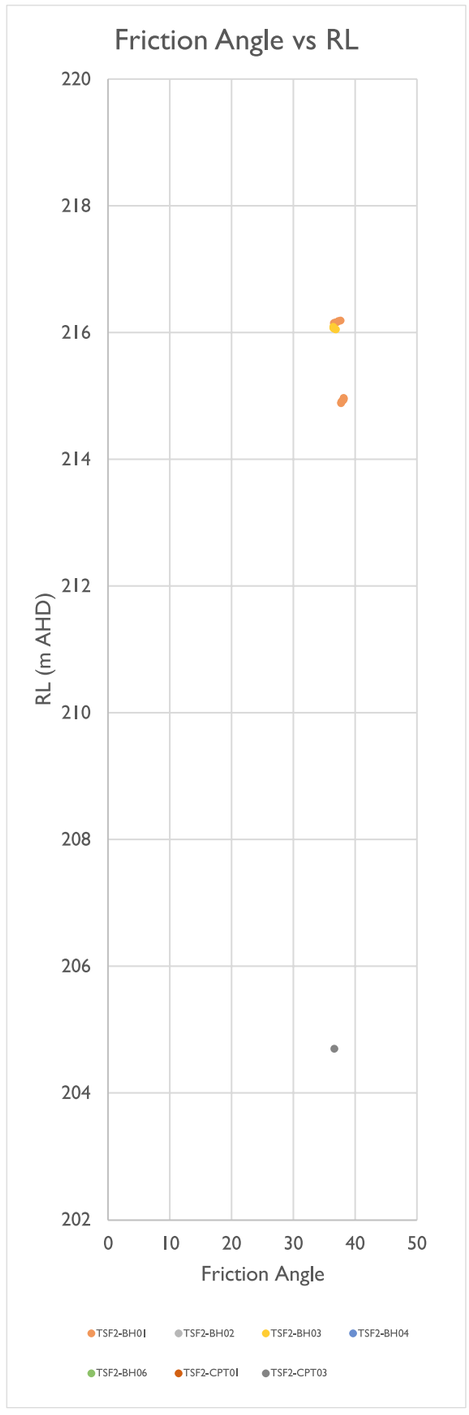


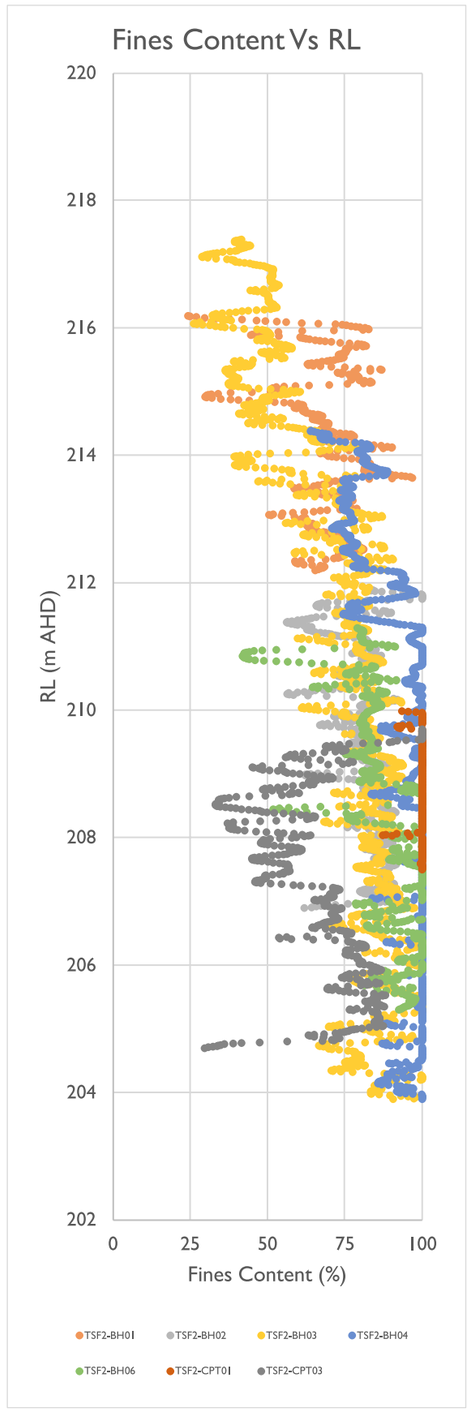
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project:	SRM TSF2-4	*date:*	11/06/2021
location:	TSF2	*by:*	DL
title:	*Material Characterisation Summary - Tailings (Near Embankment)*		

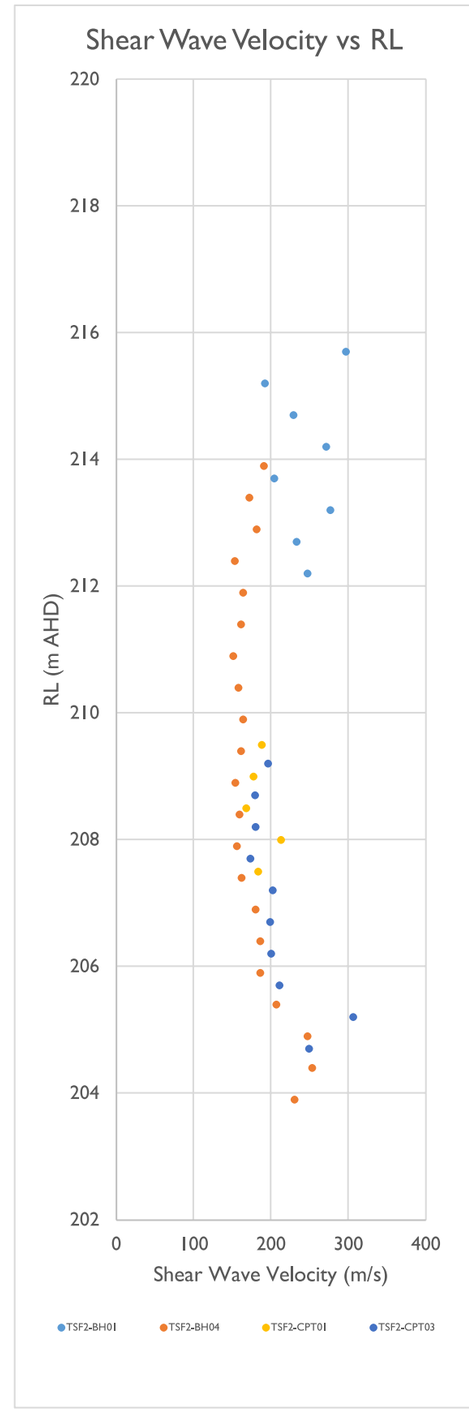
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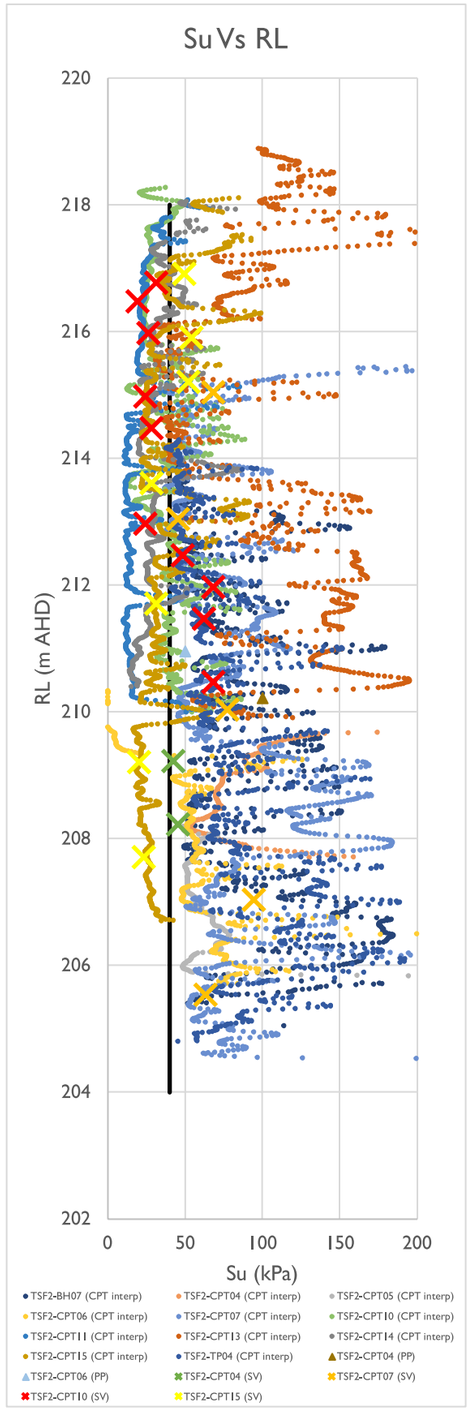


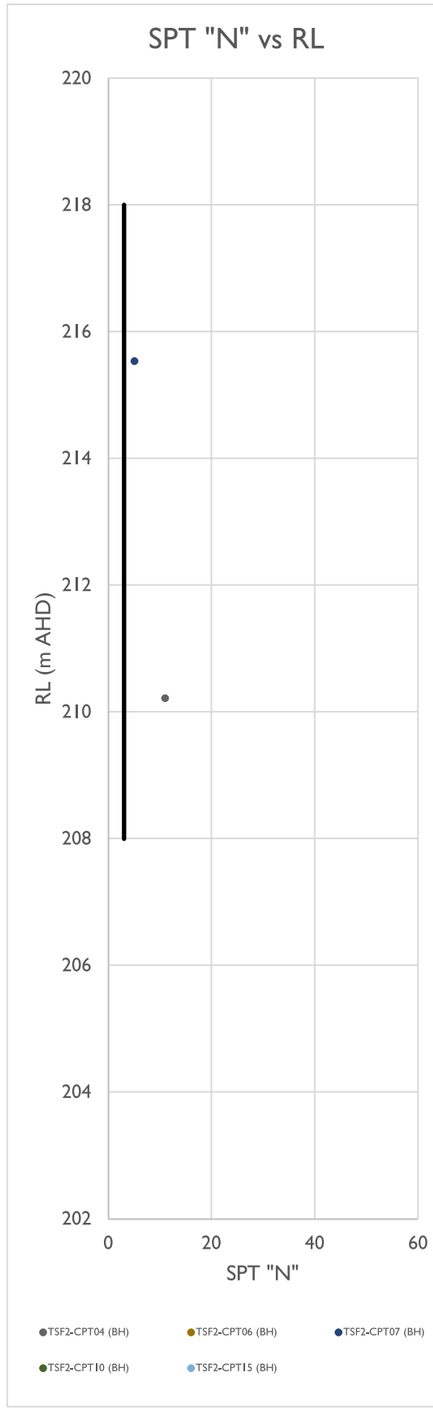


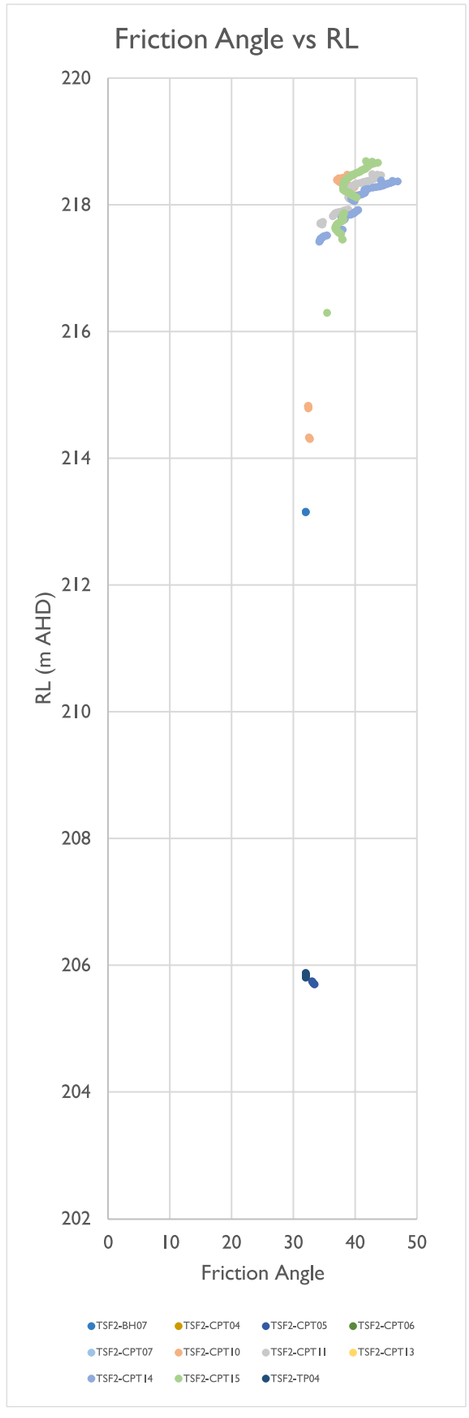


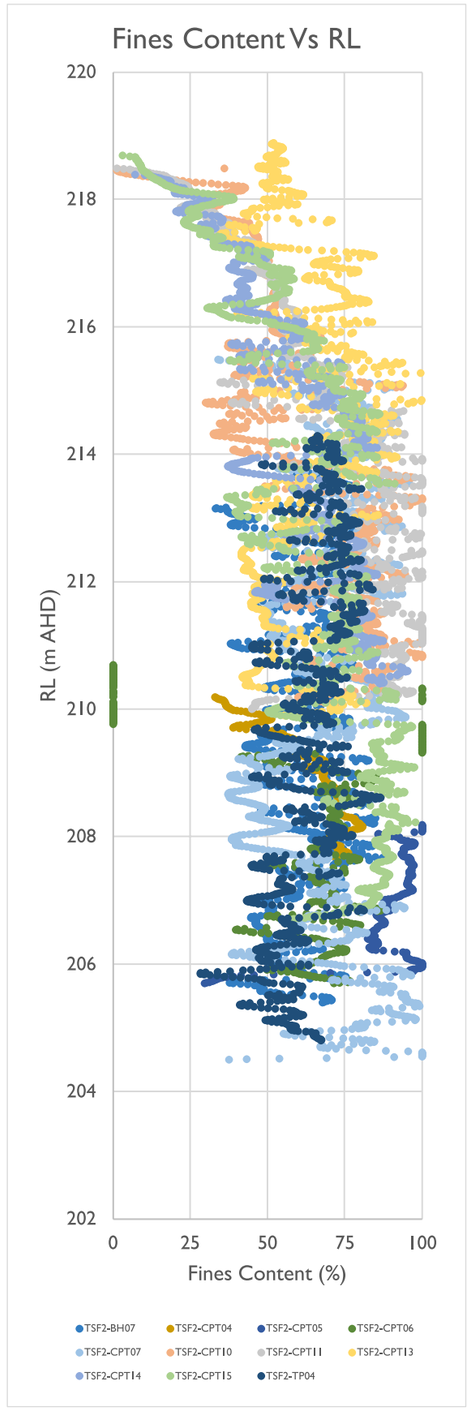
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project:	SRM TSF2-4	*date:*	11/06/2021
location:	TSF2	*by:*	DL
title:	*Material Characterisation Summary - Tailings (Near Decant Pond)*		

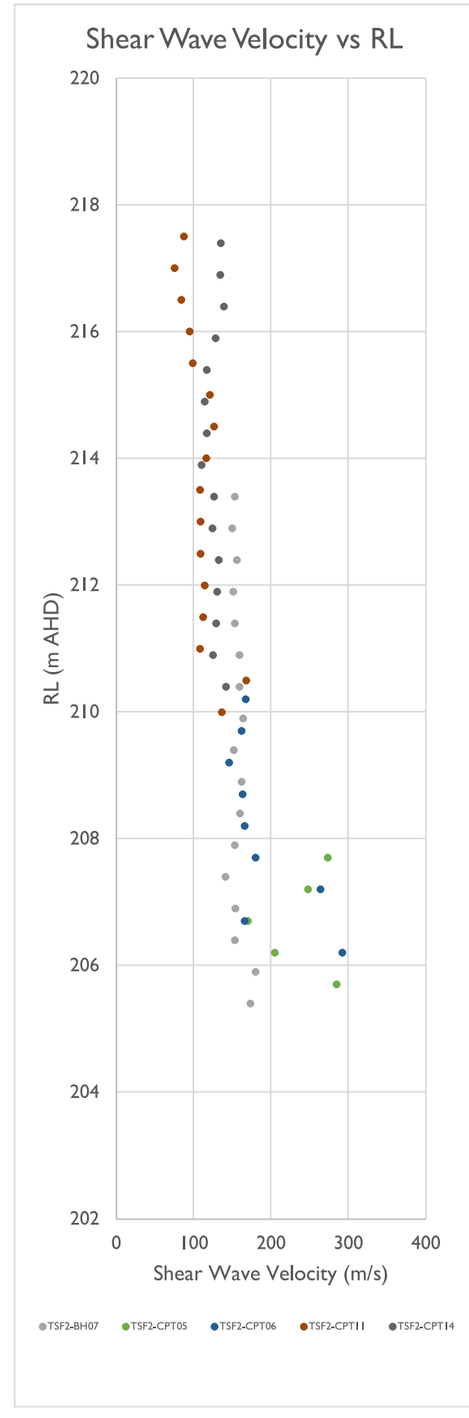
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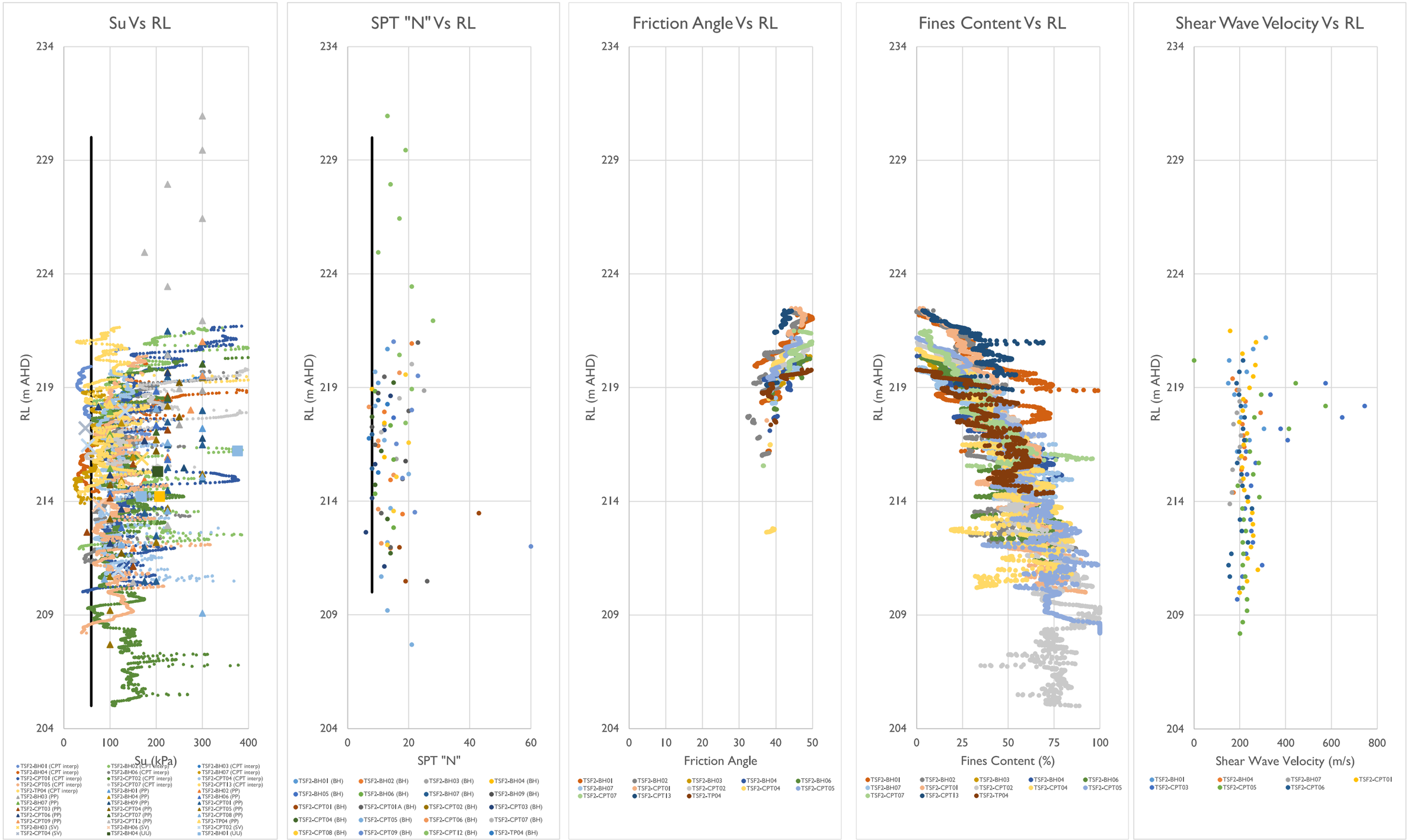






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project:	SRM TSF2-4	*date:*	11/06/2021
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title:	*Material Characterisation Summary - Uncontrolled Fill*		

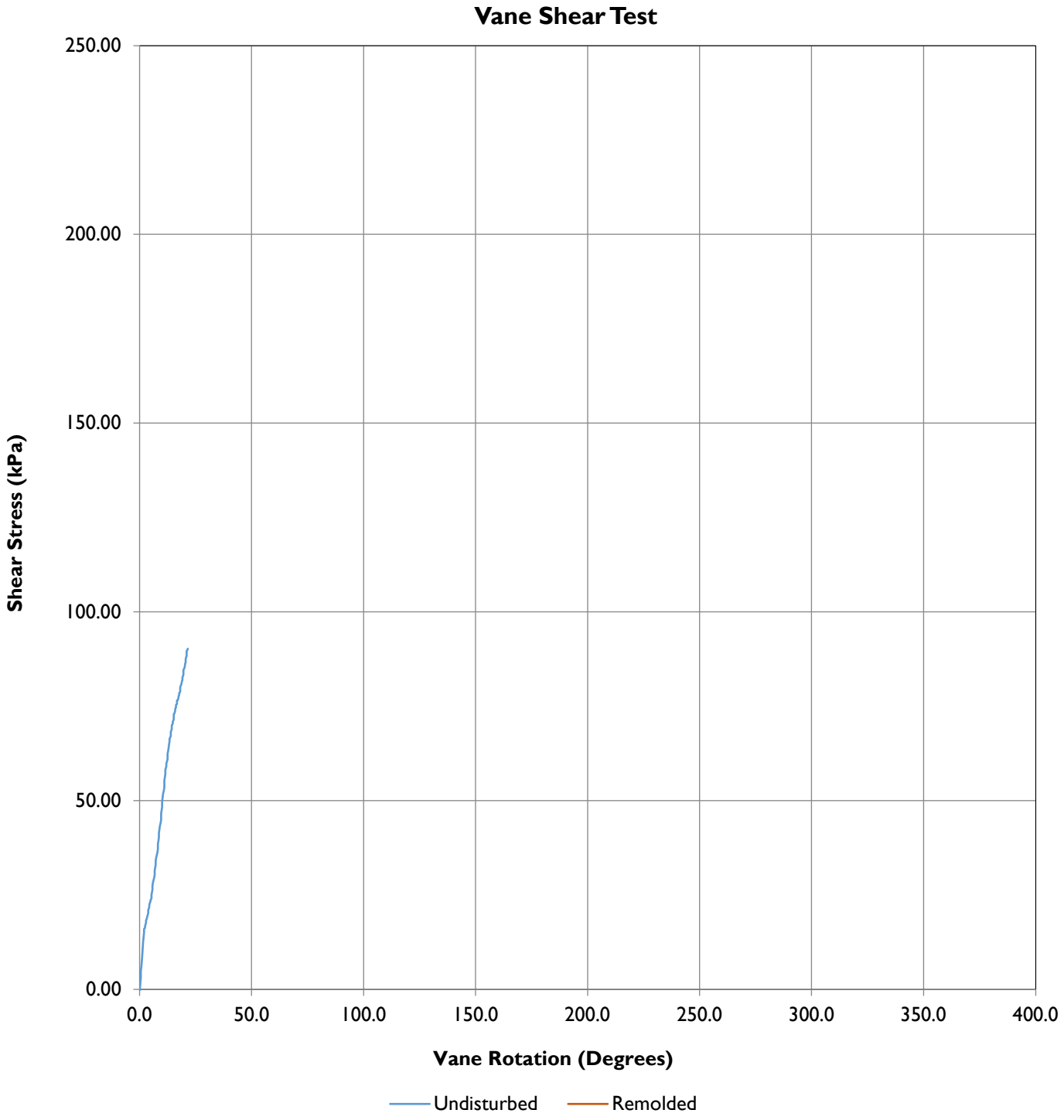
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Vane Shear Test

Test Location:	**TSF2-BH02**		
Test Depth:	**3.1m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**14/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631936.7*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521639.1*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	222.4m (AHD)

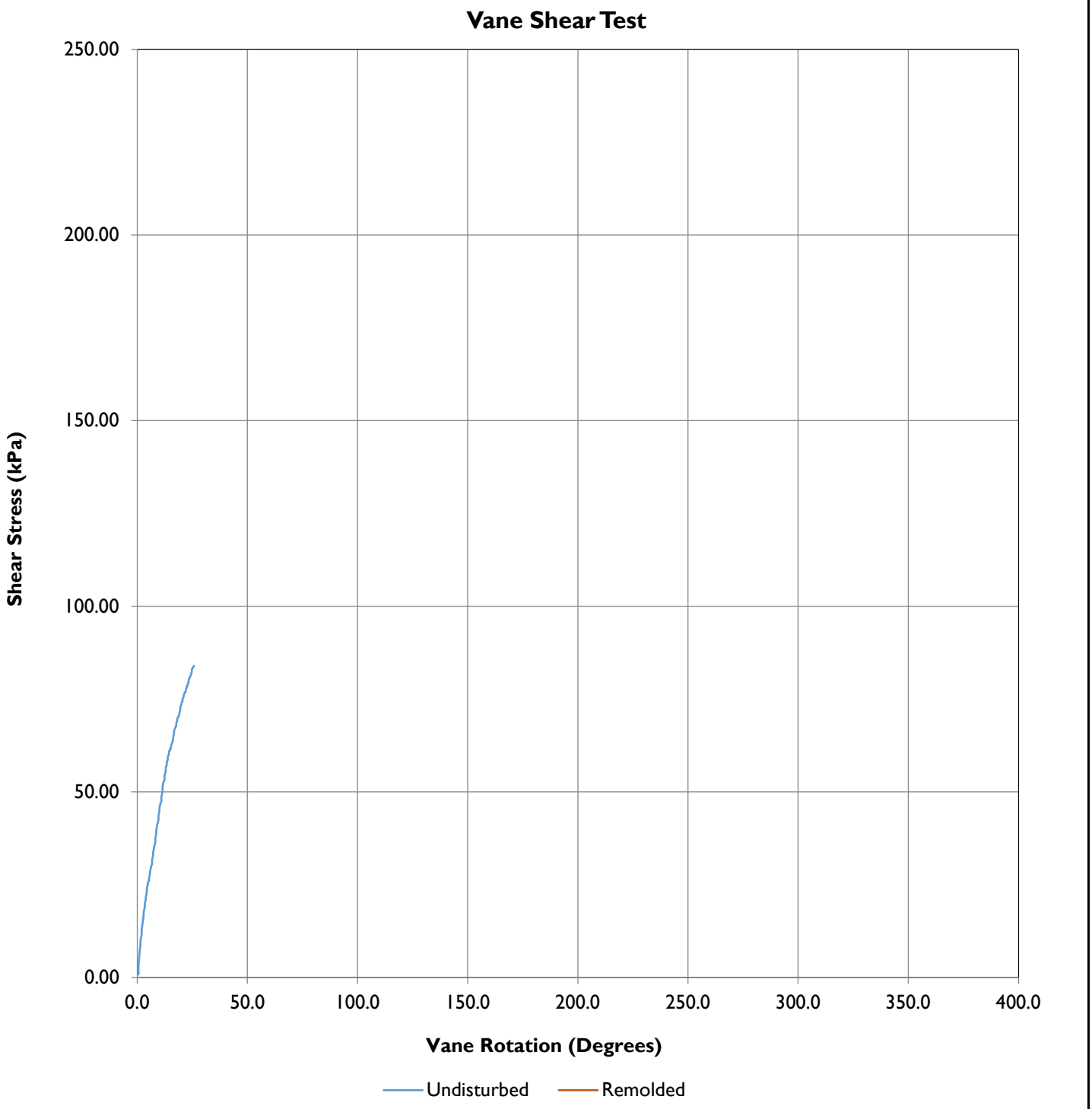


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Vane Shear Test

Test Location:	**TSF2-BH02**		
Test Depth:	**4m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**14/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631936.7*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521639.1*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	222.4m (AHD)

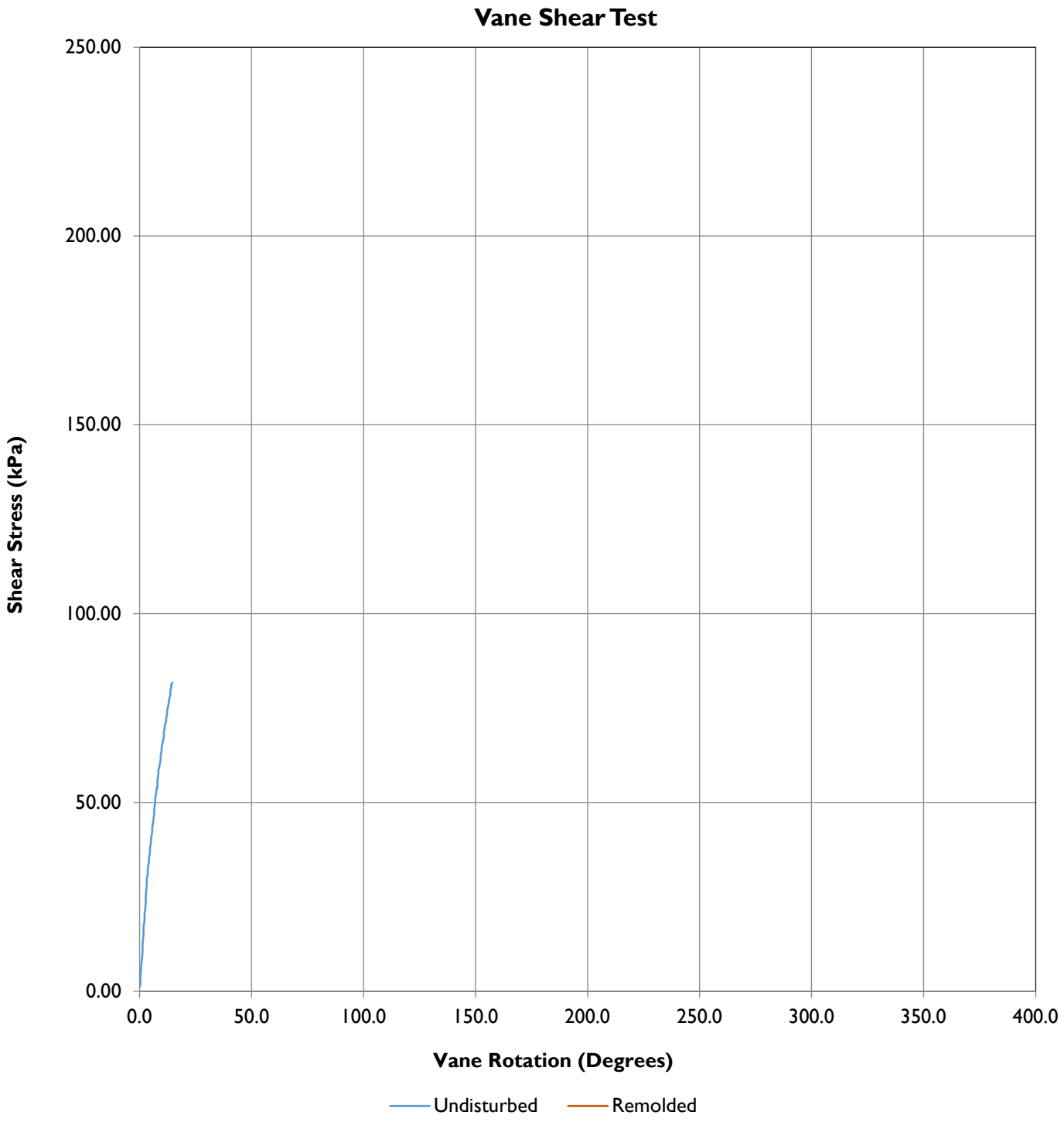


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Vane Shear Test

Test Location:	**TSF2-BH02**		
Test Depth:	**5.25m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**14/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

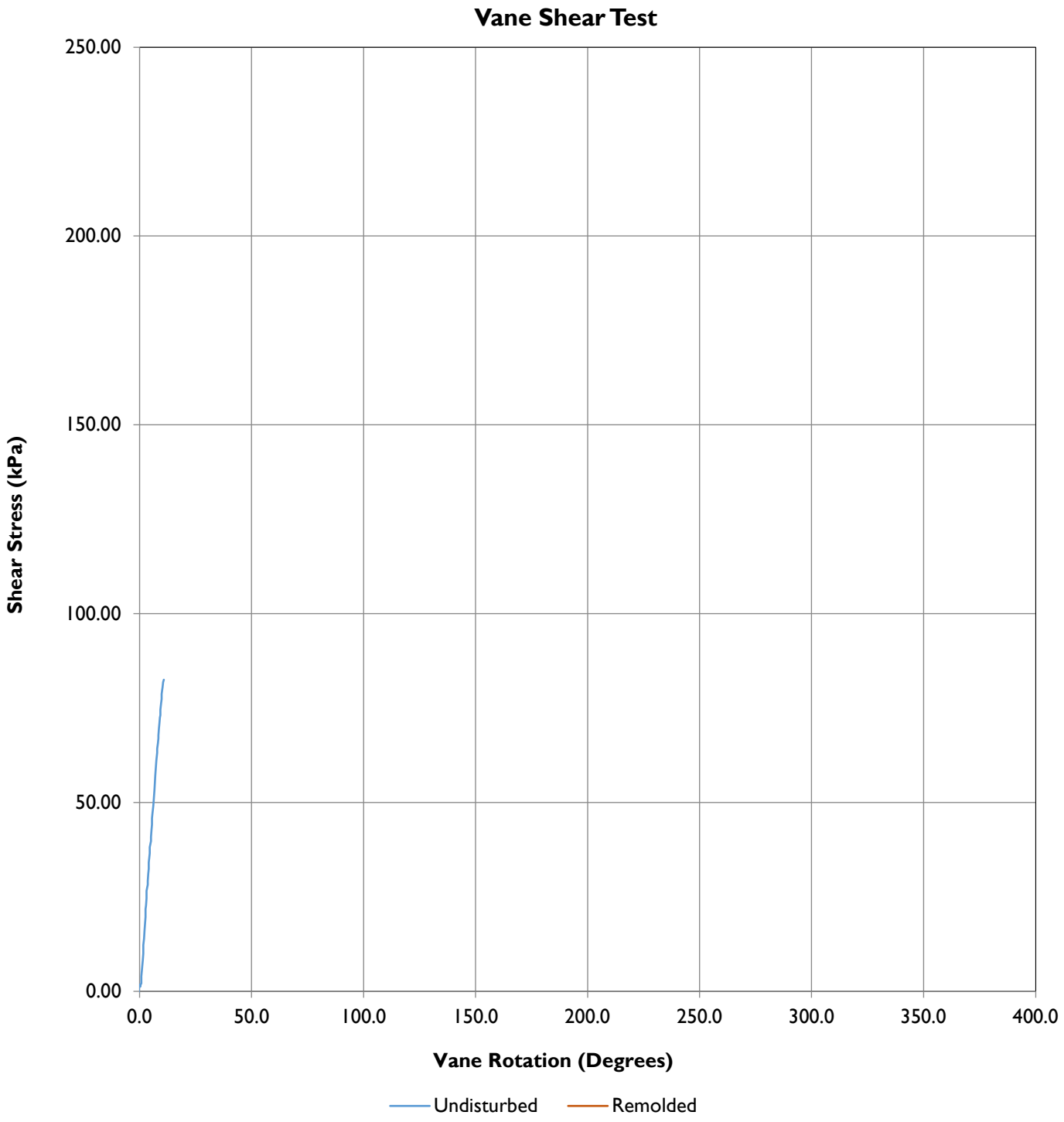
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631936.7*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521639.1*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	222.4m (AHD)



Vane Shear Test

Test Location:	**TSF2-BH02**		
Test Depth:	**6.8m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**14/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

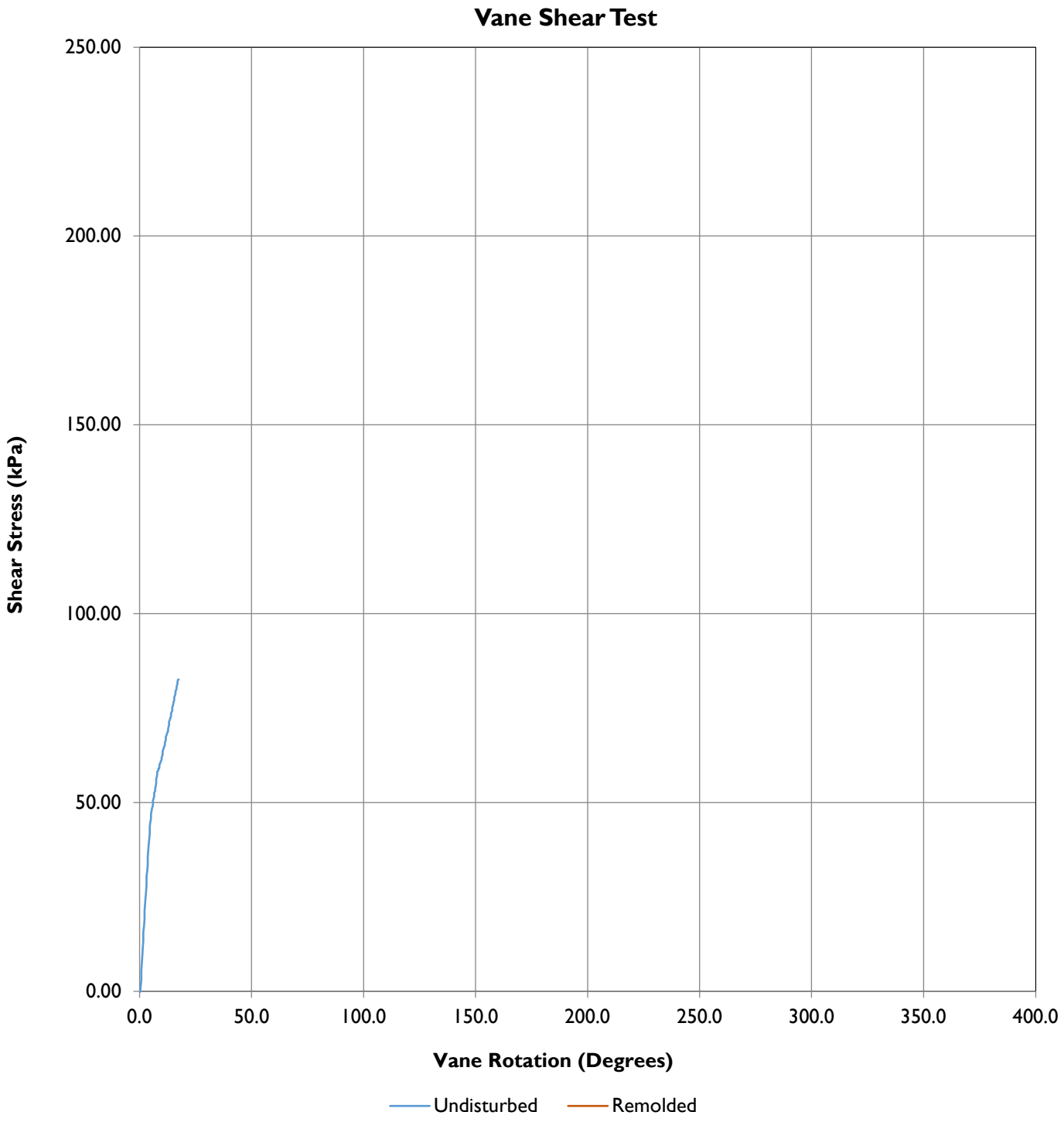
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631936.7*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521639.1*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	222.4m (AHD)



Vane Shear Test

Test Location:	**TSF2-BH02**		
Test Depth:	**10.5m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**14/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631936.7*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521639.1*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	222.4m (AHD)

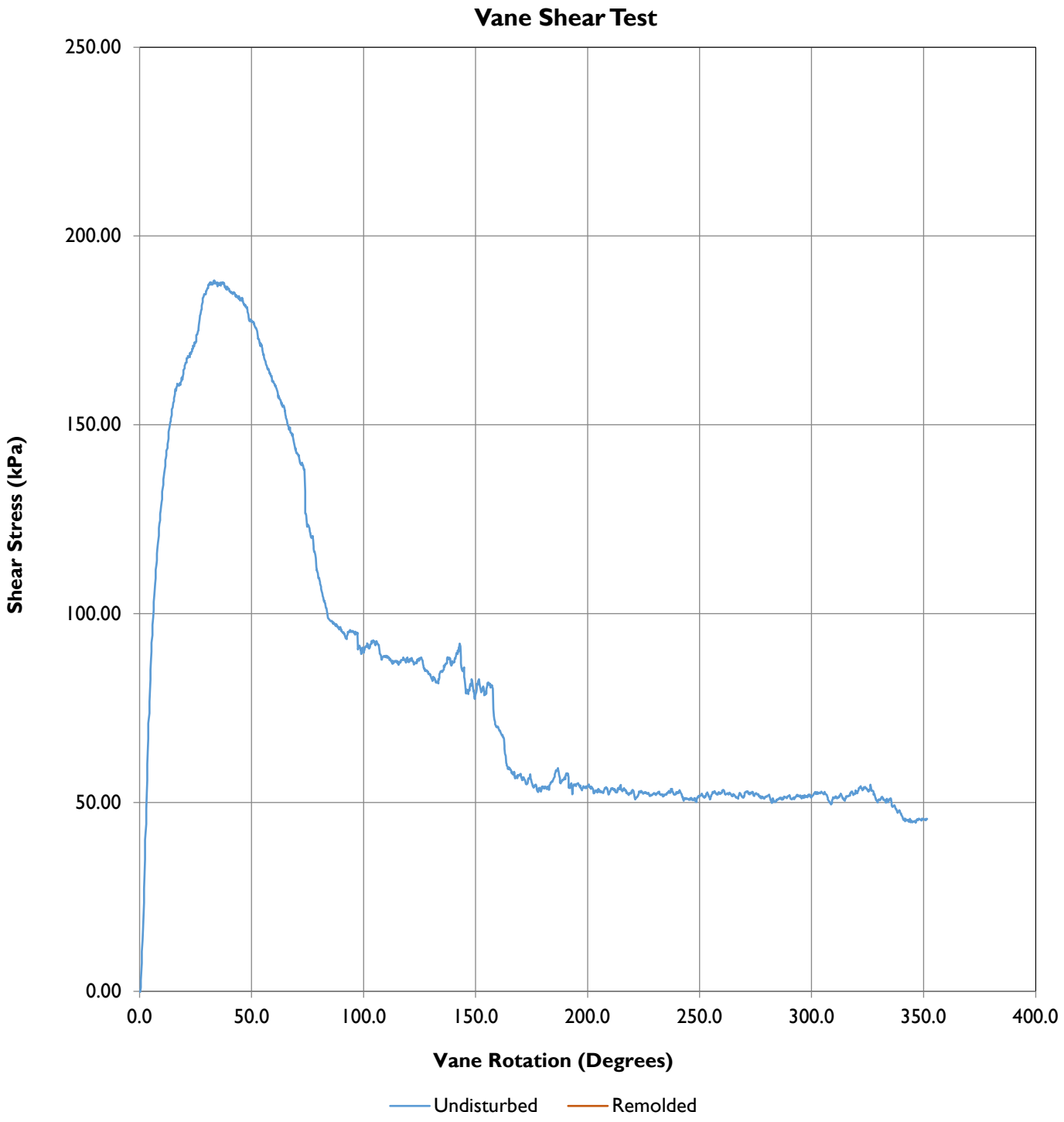


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Vane Shear Test

Test Location:	**TSF2-BH03**		
Test Depth:	**4.5m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**12/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

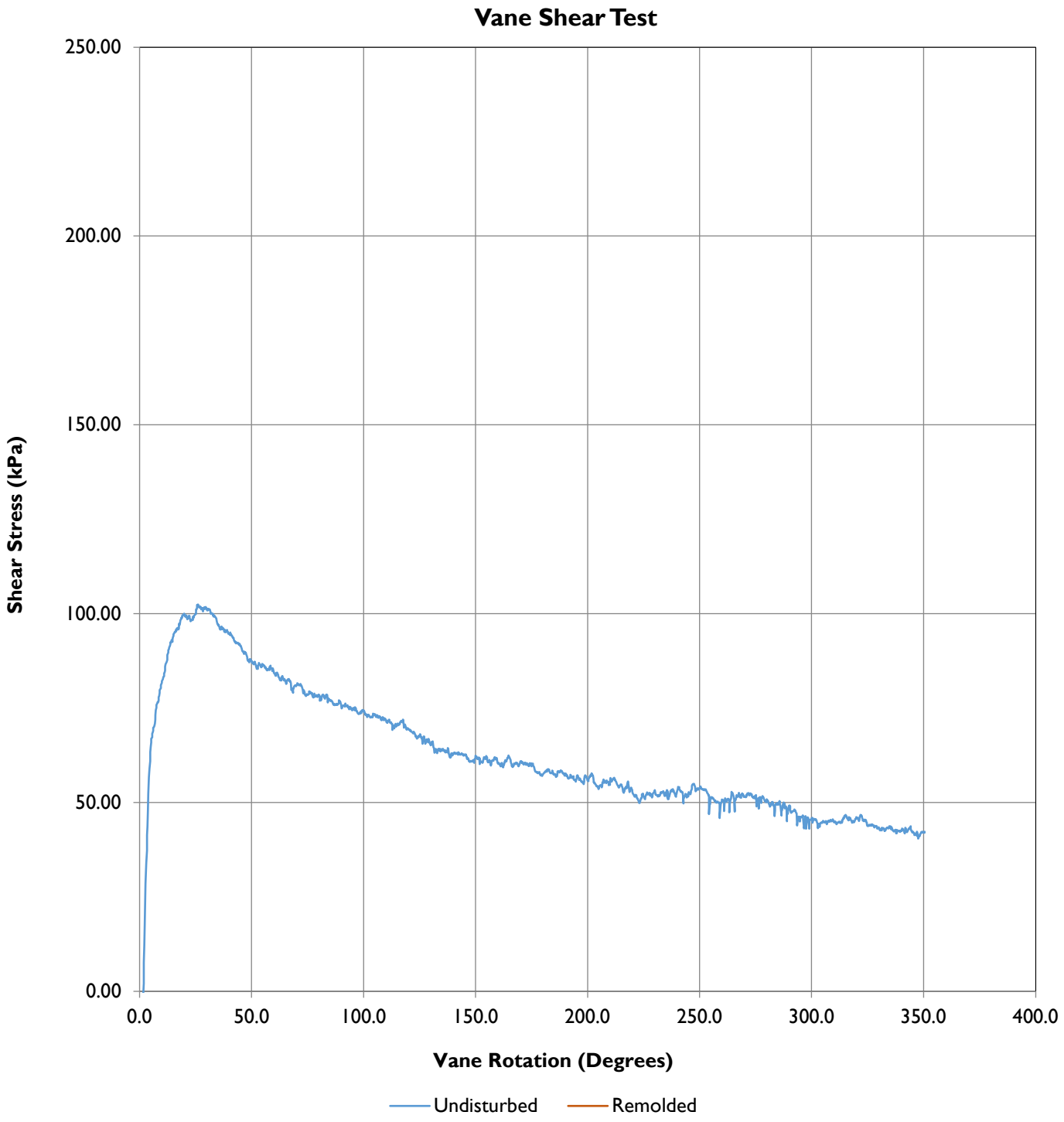
Vane Type:	*N/A*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631838.7*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521582.5*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	220.4m (AHD)



Vane Shear Test

Test Location:	**TSF2-BH03**		
Test Depth:	**6m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**12/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

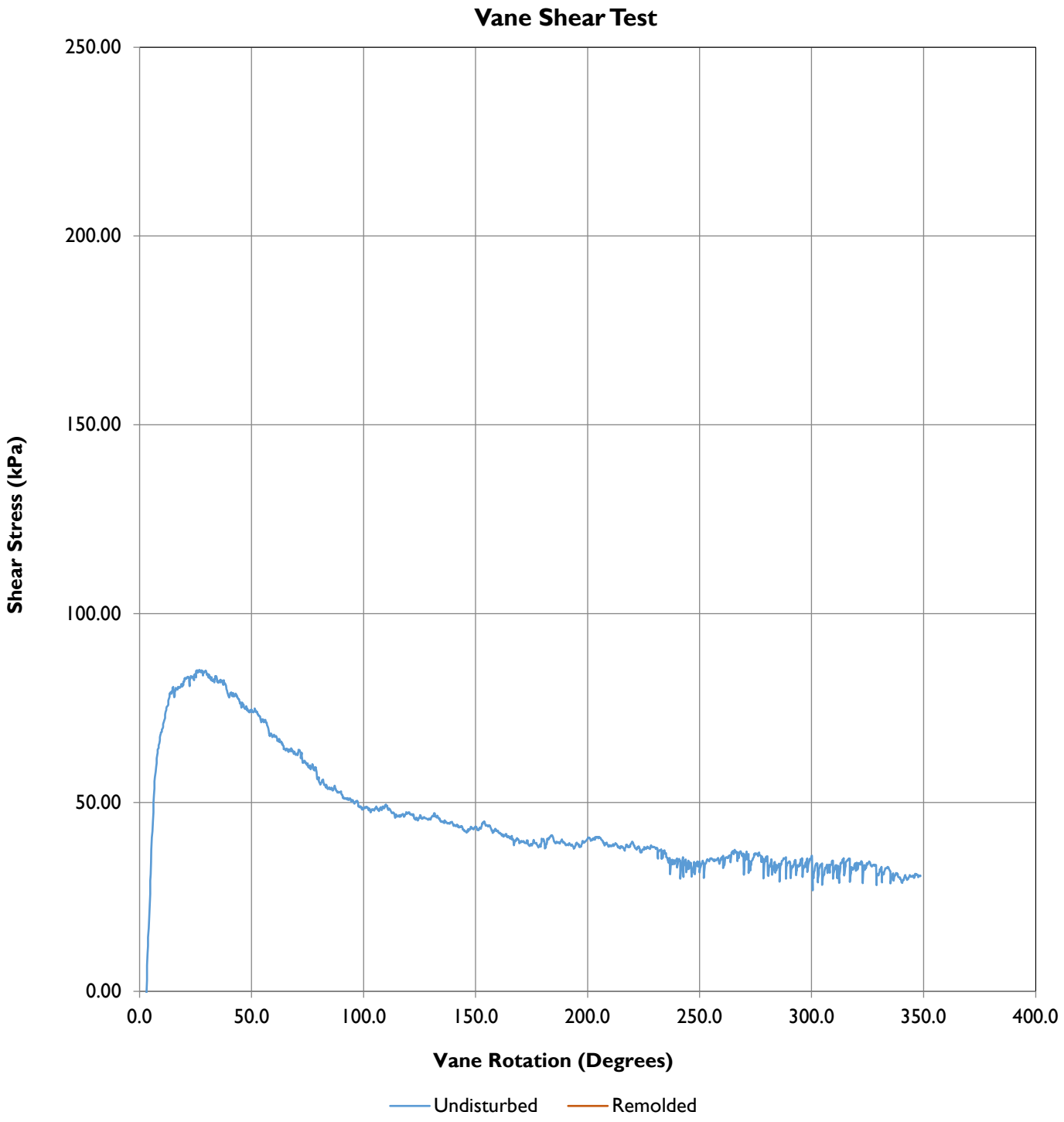
Vane Type:	*N/A*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631838.7*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521582.5*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	220.4m (AHD)



Vane Shear Test

Test Location:	**TSF2-BH03**		
Test Depth:	**7m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**13/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

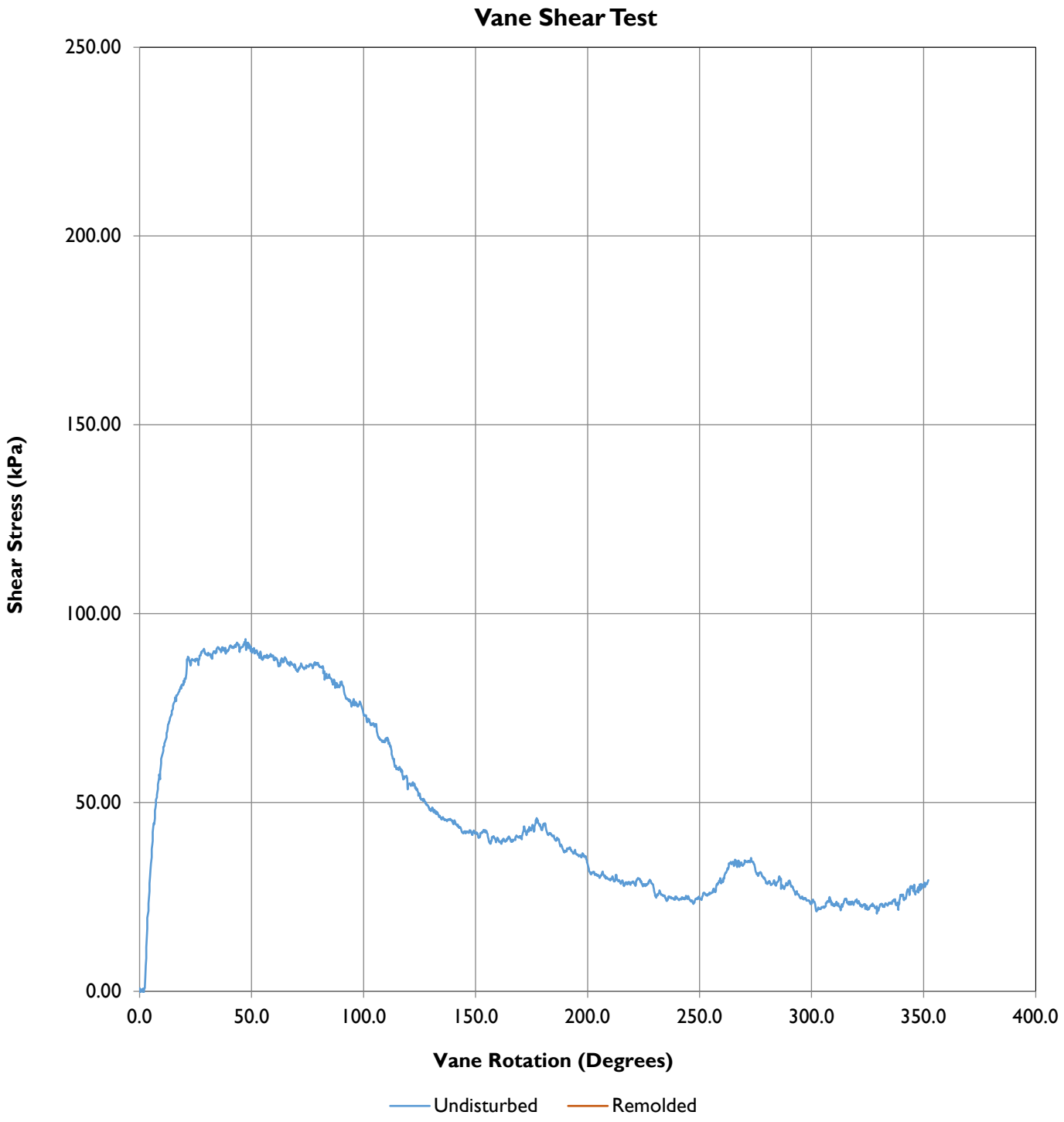
Vane Type:	*N/A*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631838.7*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521582.5*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	220.4m (AHD)



Vane Shear Test

Test Location:	**TSF2-BH03**		
Test Depth:	**11m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**13/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

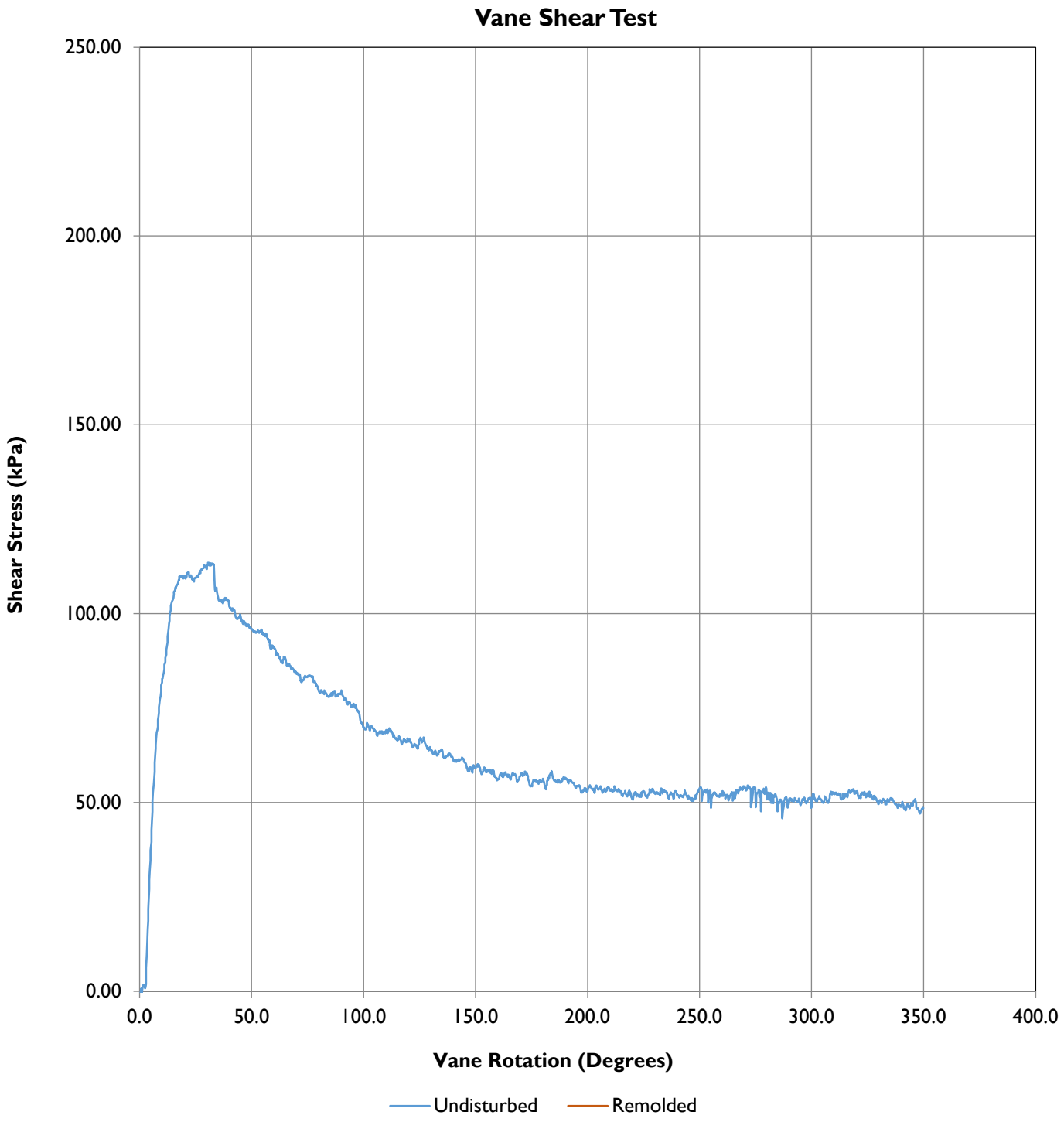
Vane Type:	*N/A*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631838.7*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521582.5*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	220.4m (AHD)



Vane Shear Test

Test Location:	**TSF2-BH03**		
Test Depth:	**13m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**13/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

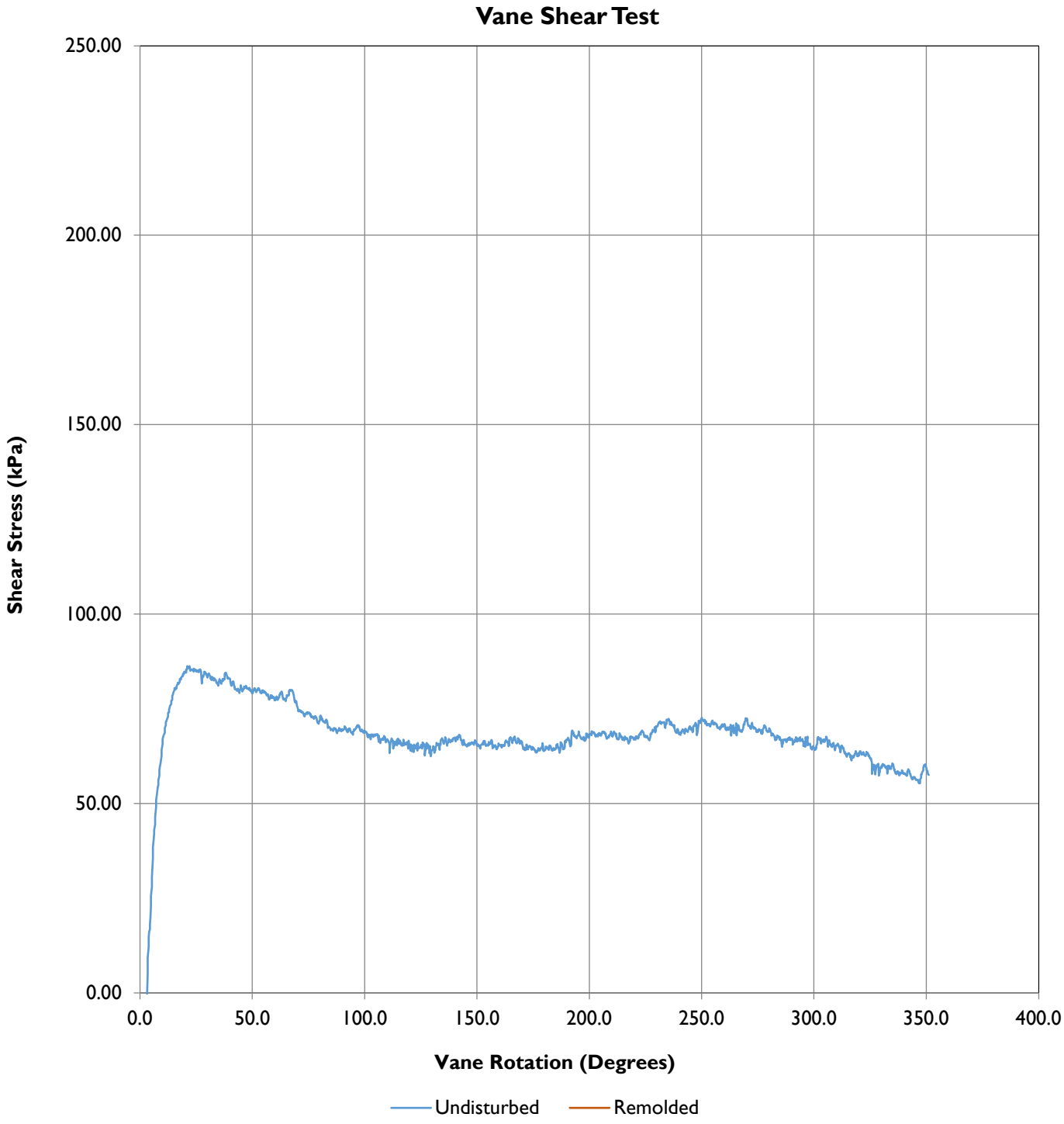
Vane Type:	*N/A*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631838.7*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521582.5*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	220.4m (AHD)



Vane Shear Test

Test Location:	**TSF2-BH03**		
Test Depth:	**15m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**14/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

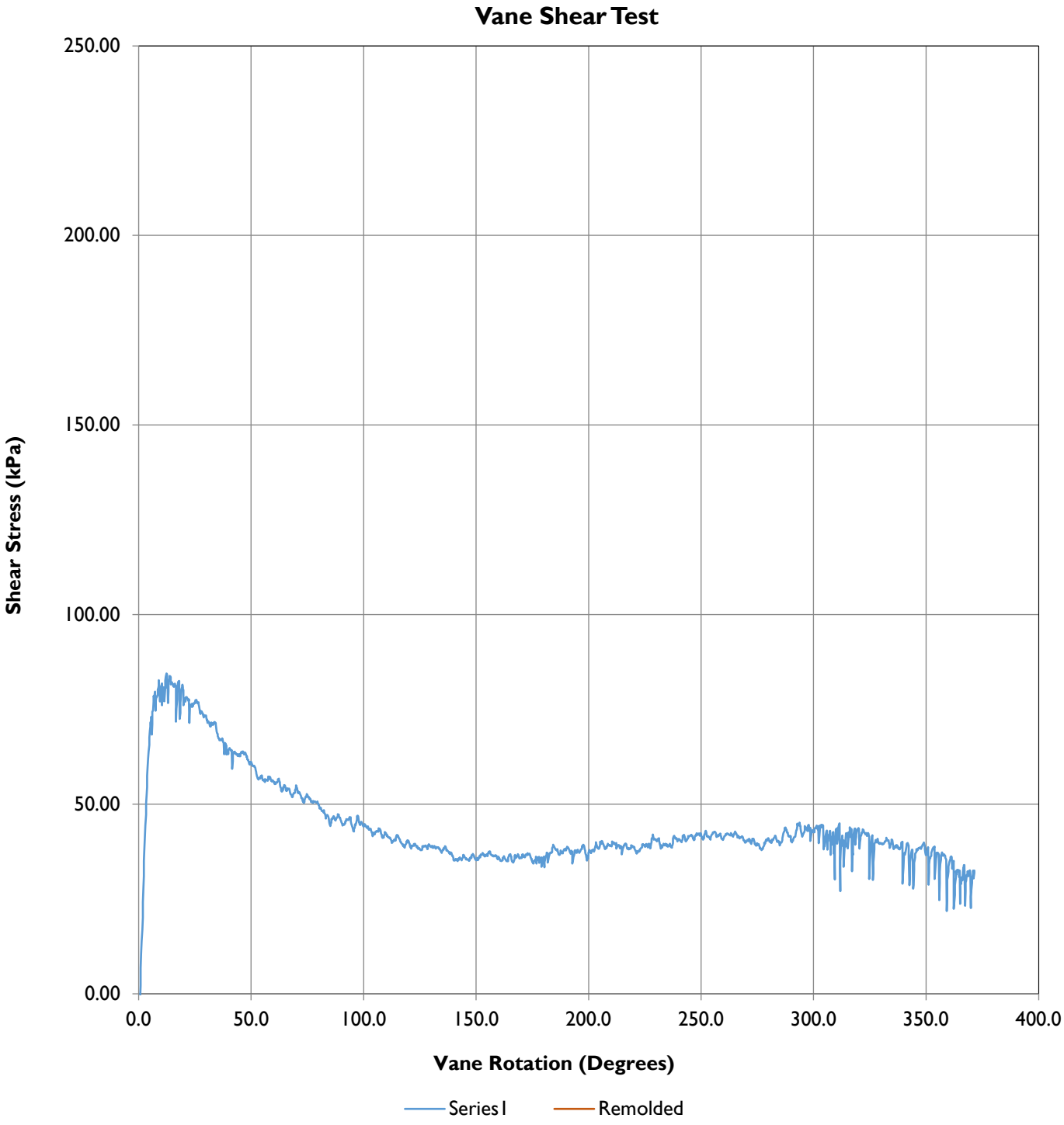
Vane Type:	*N/A*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631838.7*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521582.5*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	220.4m (AHD)



Vane Shear Test

Test Location:	**TSF2-BH06**		
Test Depth:	**6.5m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**14/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

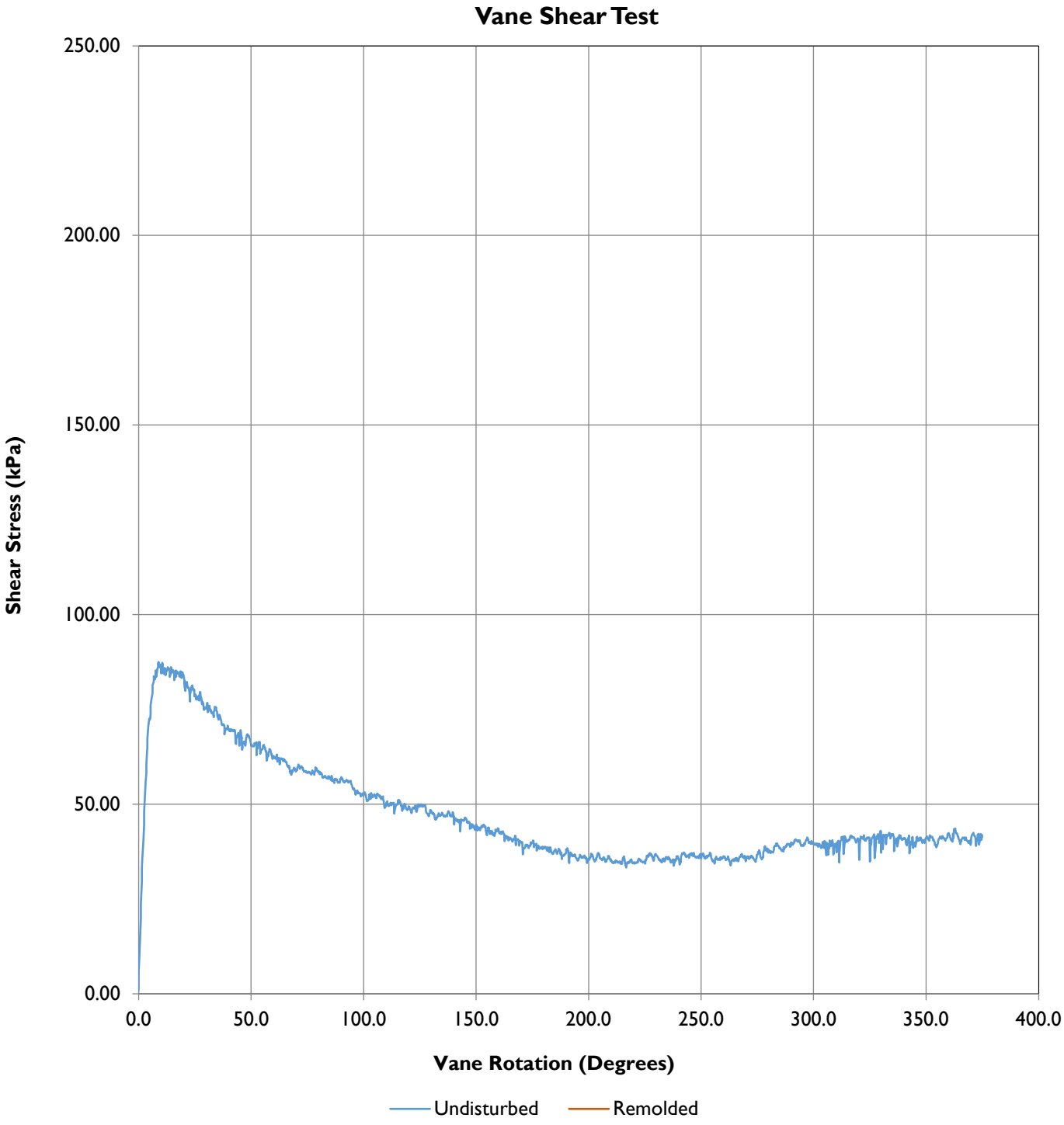
Vane Type:	*N/A*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631780.0*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521462.3*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	220.3m (AHD)



Vane Shear Test

Test Location:	**TSF2-BH06**		
Test Depth:	**9m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**14/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*N/A*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631780.0*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521462.3*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	220.3m (AHD)



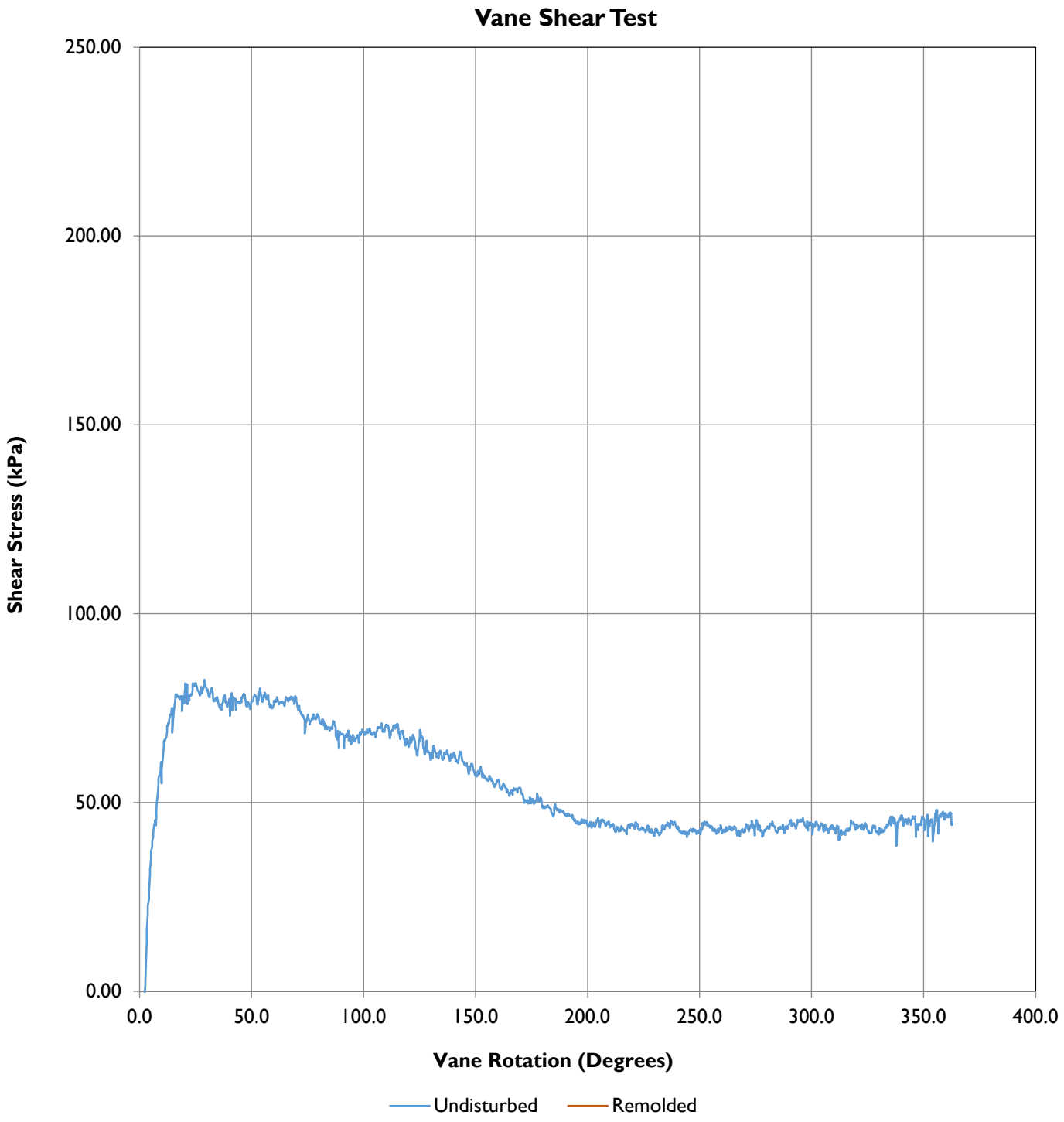
Vane Shear Test

Test Location:	**TSF2-BH06**
Test Depth:	**11m**
Job No:	**B01229-4**

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Client:	**BMA**	Date Tested:	**14/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

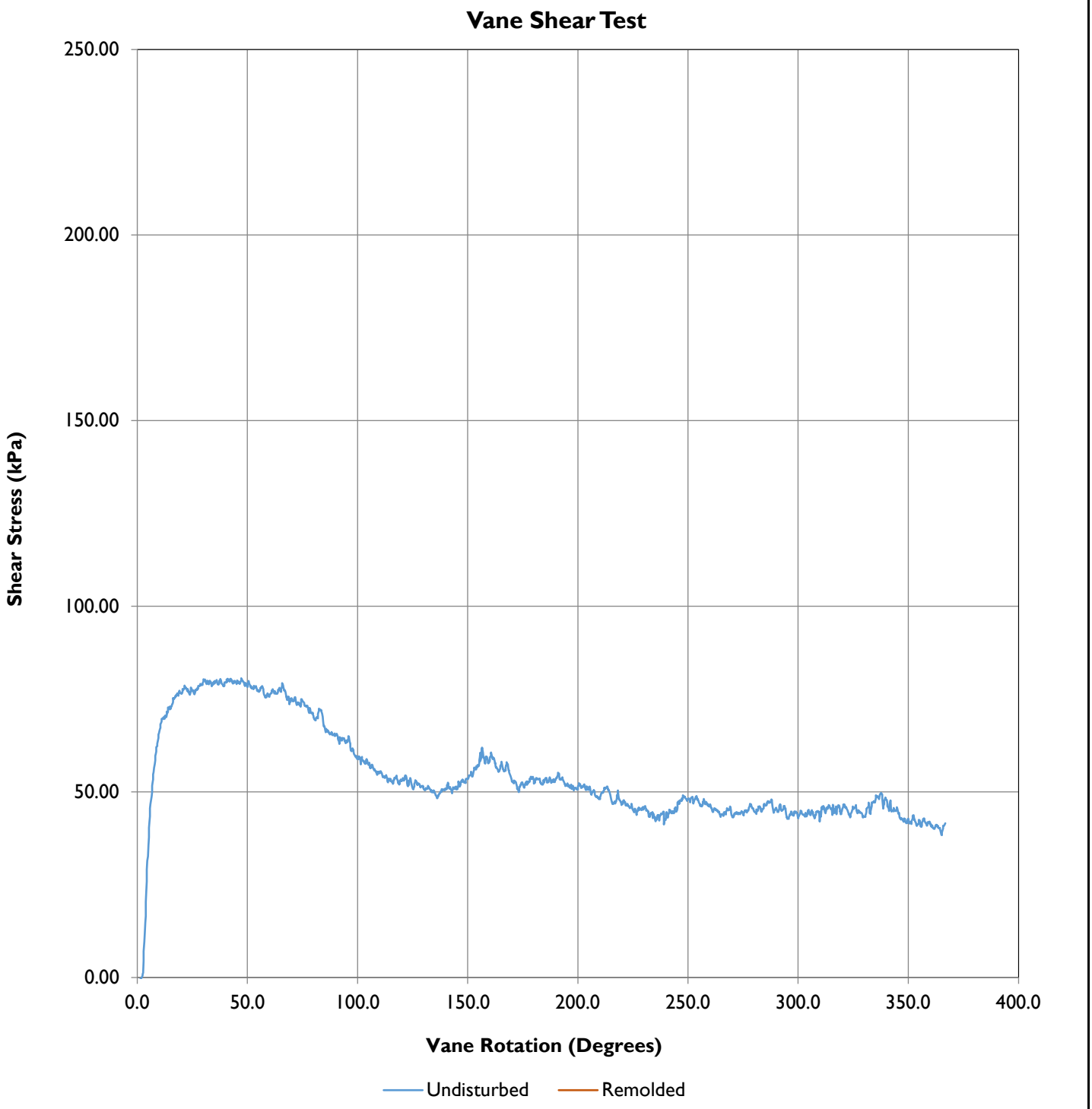
Vane Type:	*N/A*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631780.0*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521462.3*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	220.3m (AHD)



Vane Shear Test

Test Location:	**TSF2-BH06**		
Test Depth:	**14m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**15/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

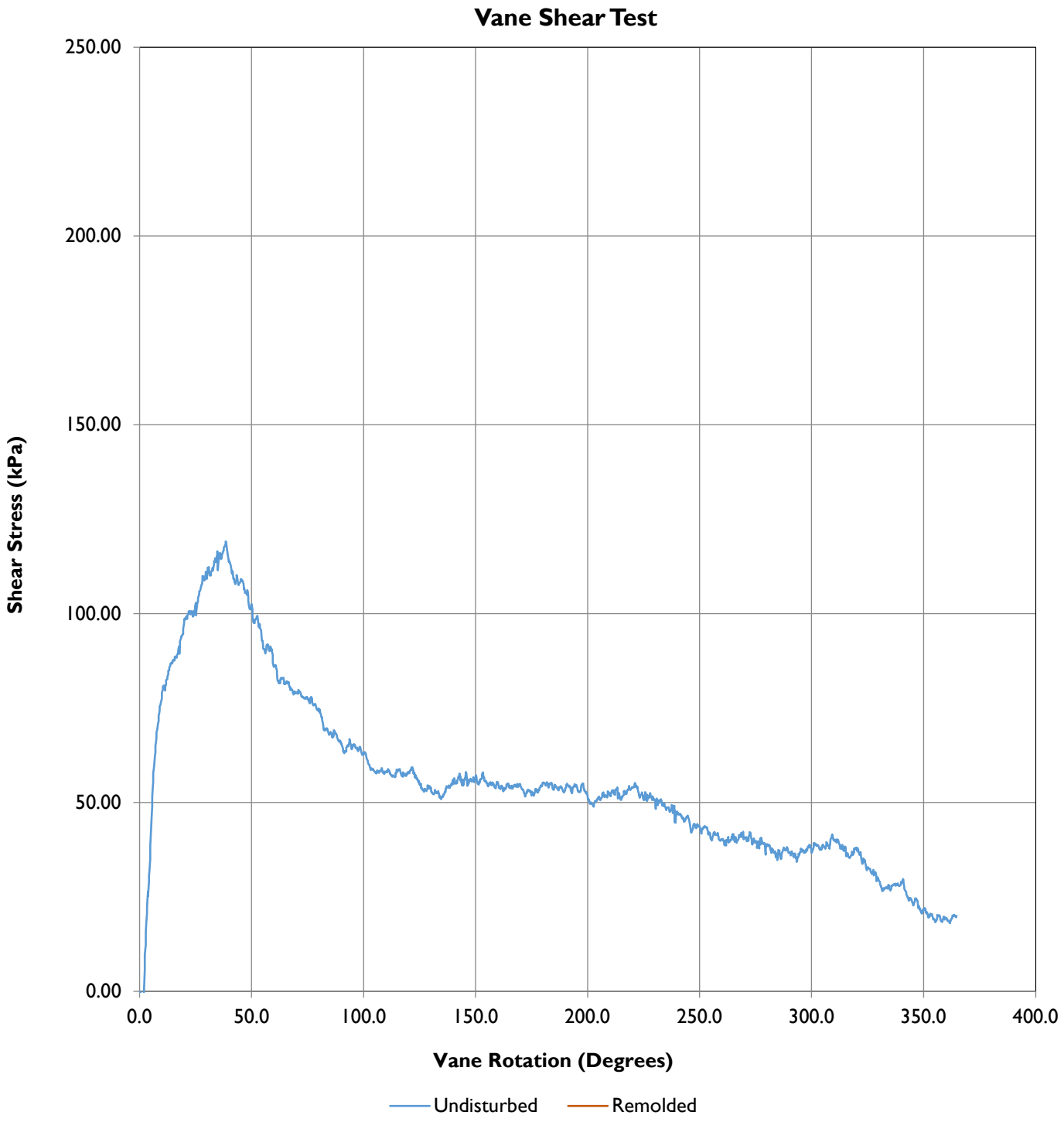
Vane Type:	*N/A*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631780.0*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521462.3*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	220.3m (AHD)



Vane Shear Test

Test Location:	**TSF2-BH06**		
Test Depth:	**15m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**15/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*N/A*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631780.0*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521462.3*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	220.3m (AHD)



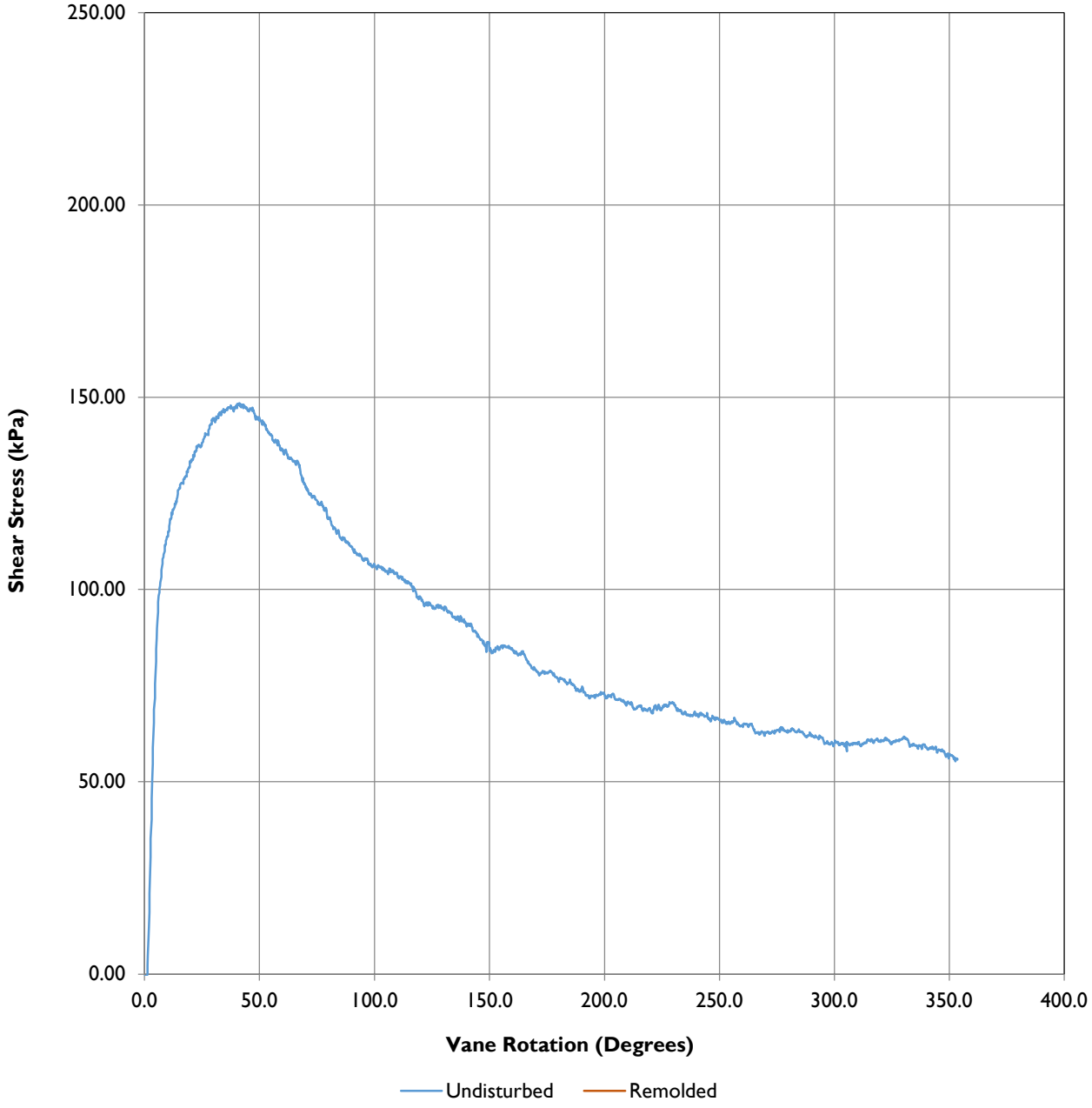
Vane Shear Test

Test Location:	**TSF2-CPT02**
Test Depth:	**3.5m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**11/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631864.6*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521554.4*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	221.5m (AHD)



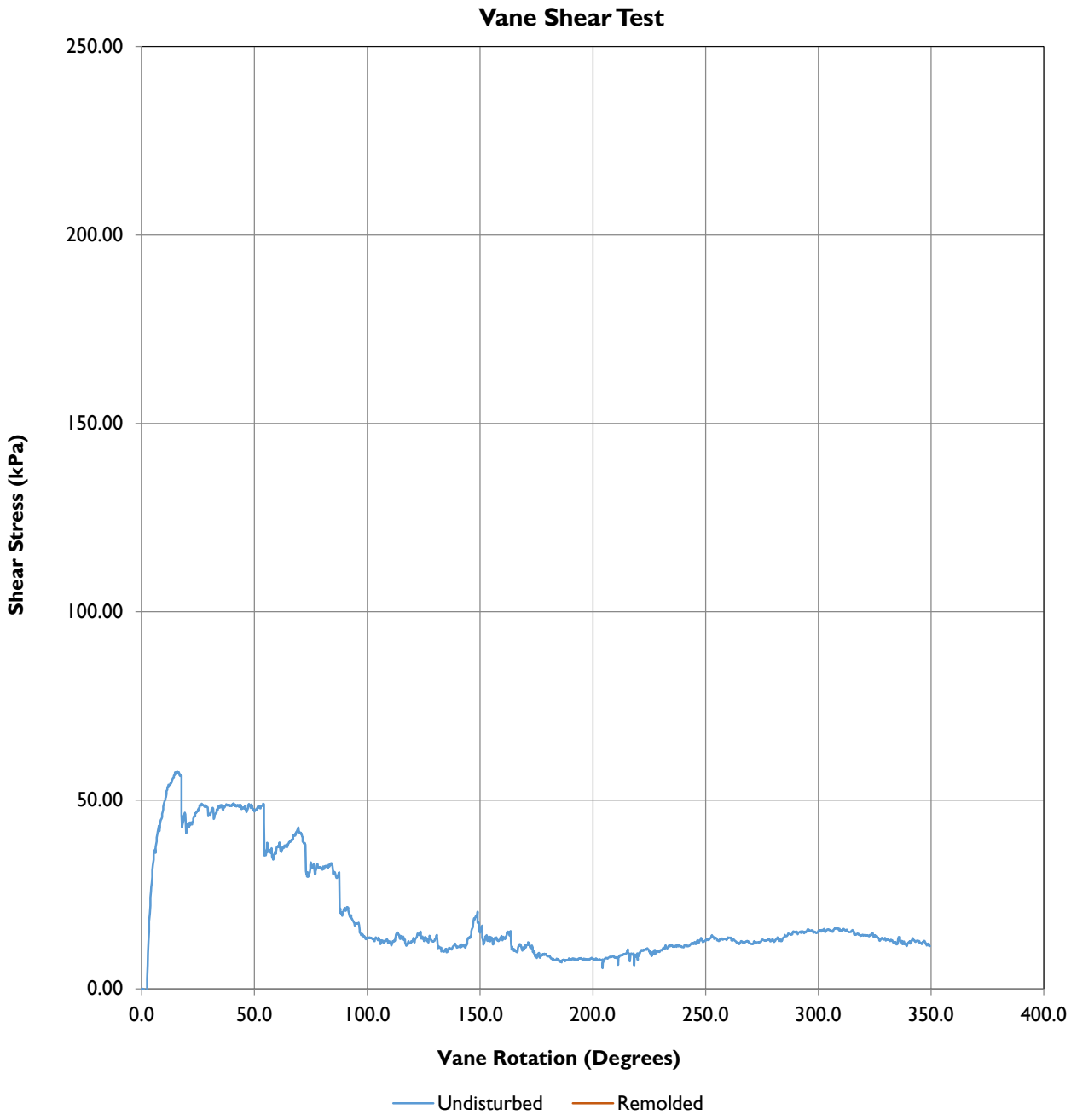
Vane Shear Test

Test Location:	**TSF2-CPT02**
Test Depth:	**5m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**12/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631864.6*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521554.4*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	221.5m (AHD)



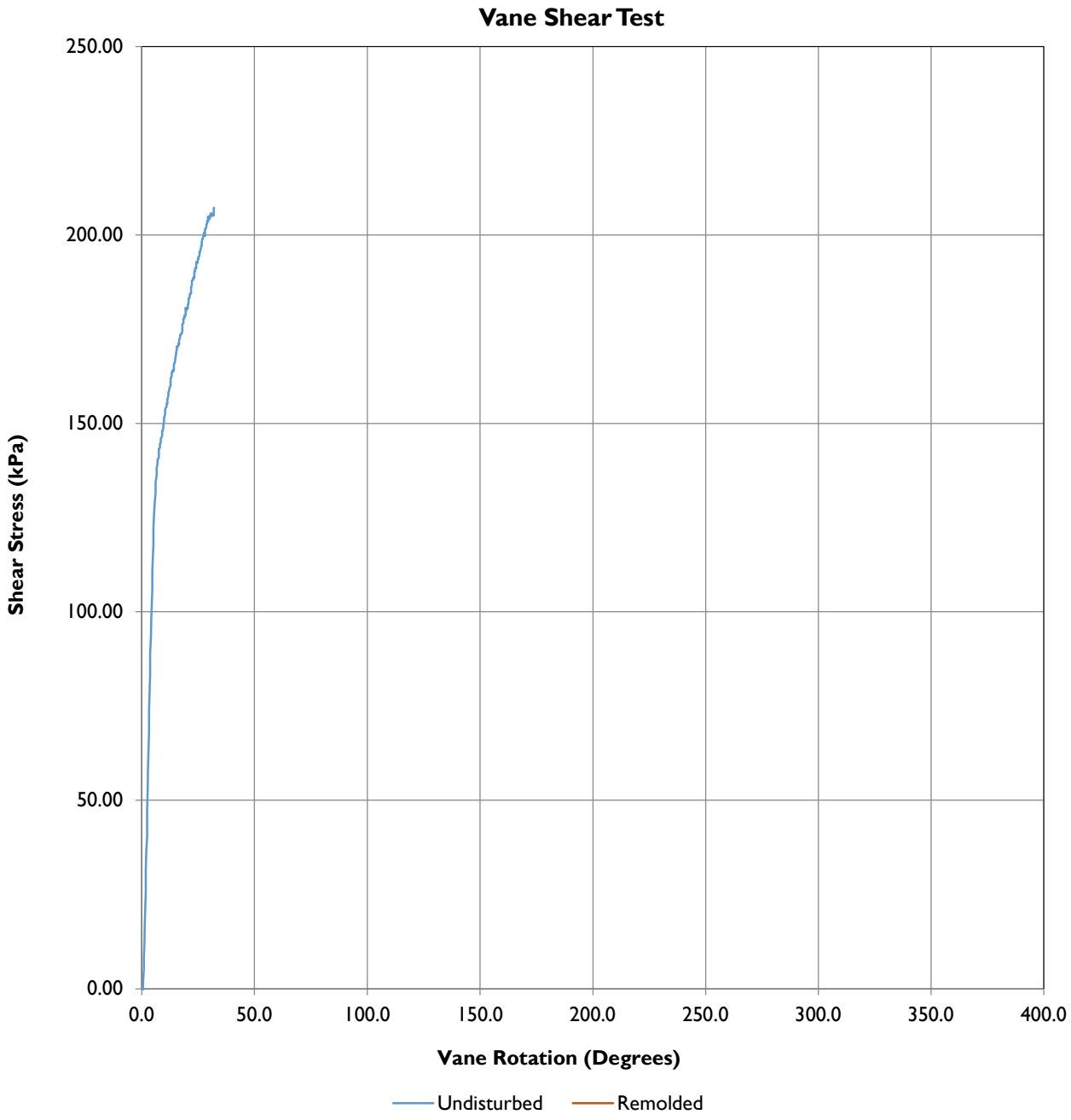
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Vane Shear Test

Test Location:	**TSF2-CPT02**
Test Depth:	**8.5m**
Job No:	**B01229-4**

Client:	**BMA**	Date Tested:	**12/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631864.6*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521554.4*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	221.5m (AHD)



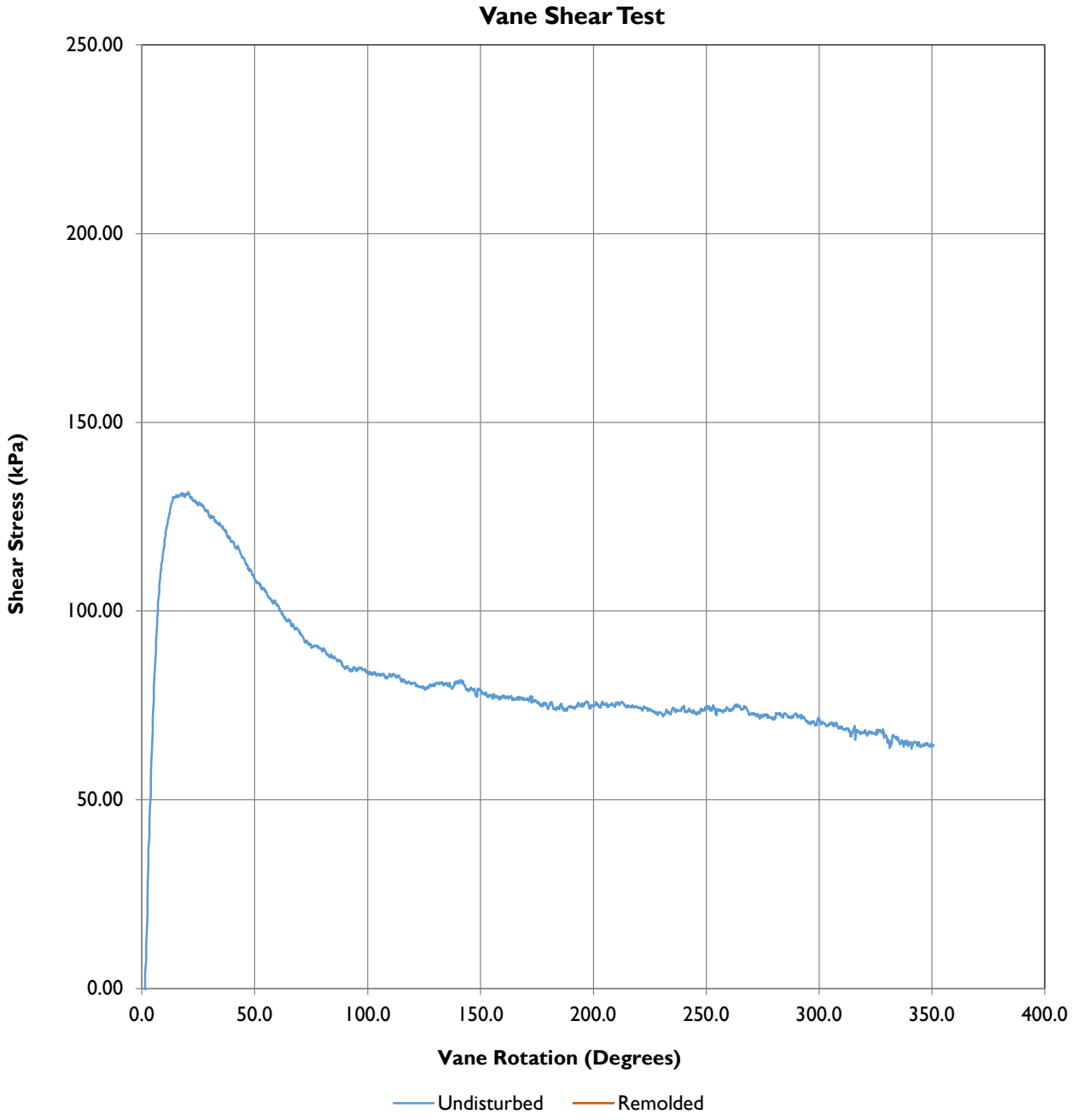
Vane Shear Test

Test Location:	**TSF2-CPT02**
Test Depth:	**10.5m**
Job No:	**B01229-4**

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Client:	**BMA**	Date Tested:	**12/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631864.6*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521554.4*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	221.5m (AHD)



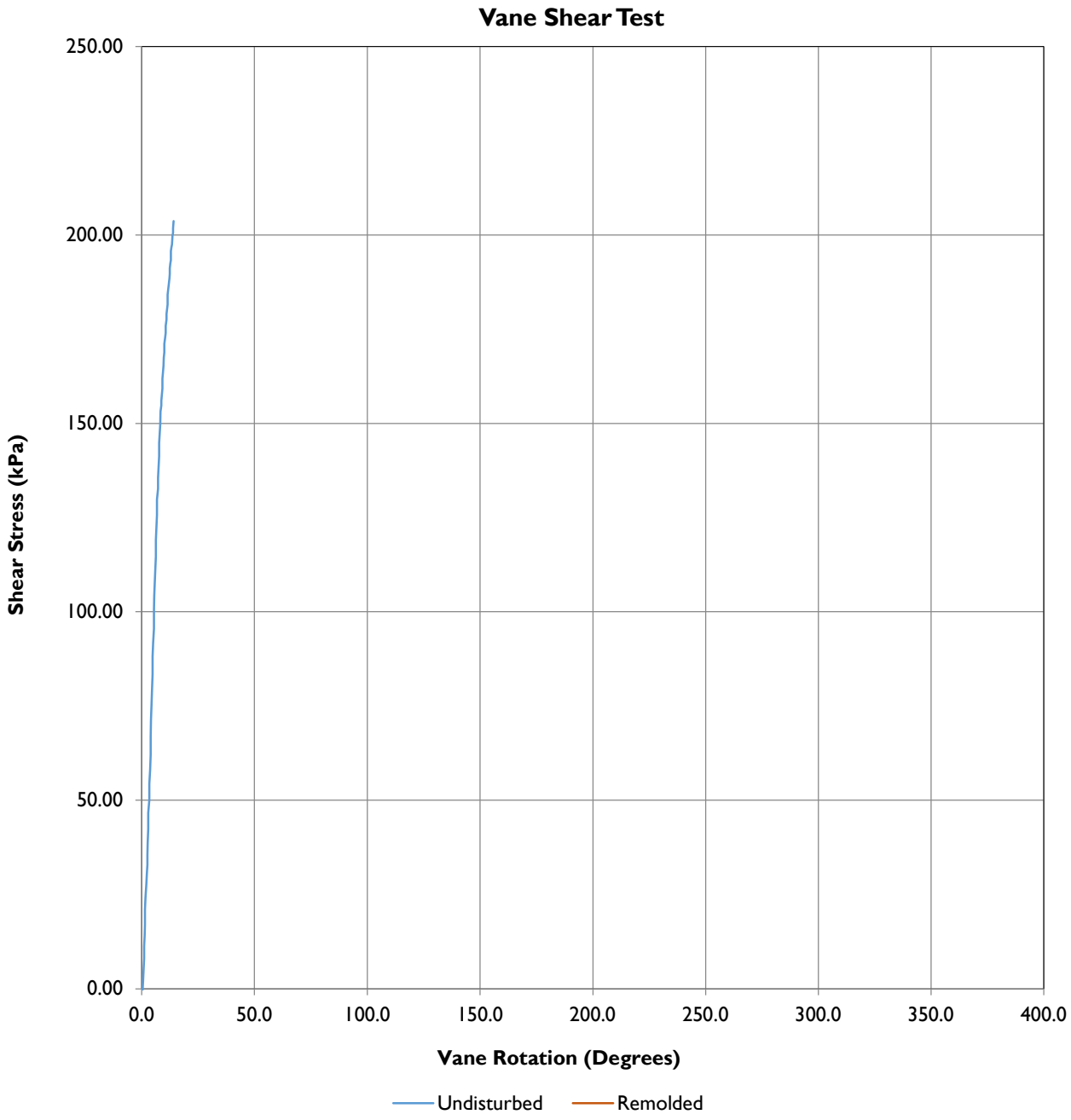
Vane Shear Test

Test Location:	**TSF2-CPT02**
Test Depth:	**11.8m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**12/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631864.6*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521554.4*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	221.5m (AHD)



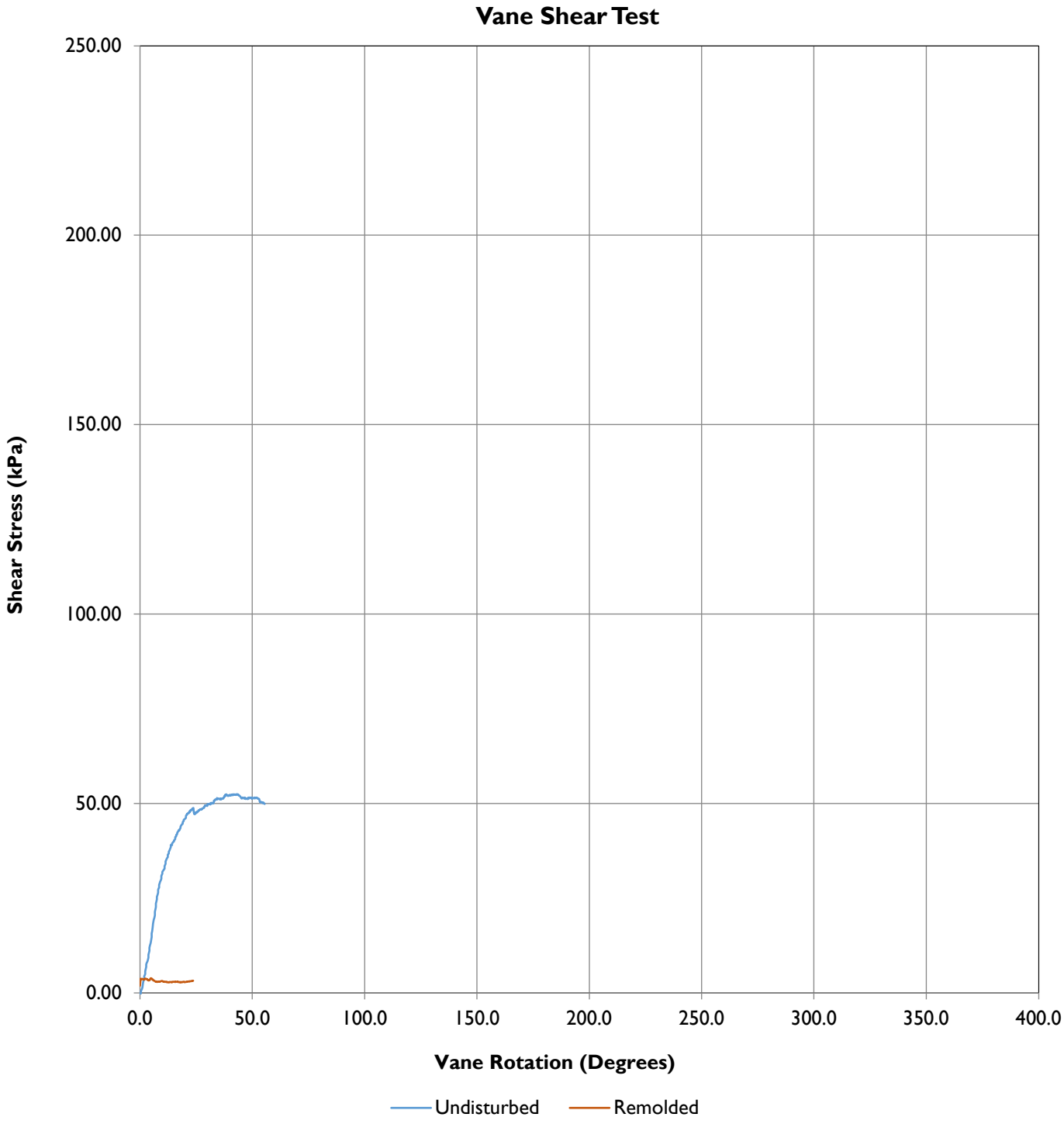
Vane Shear Test

Test Location:	**TSF2-CPT04**
Test Depth:	**3.5m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**15/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

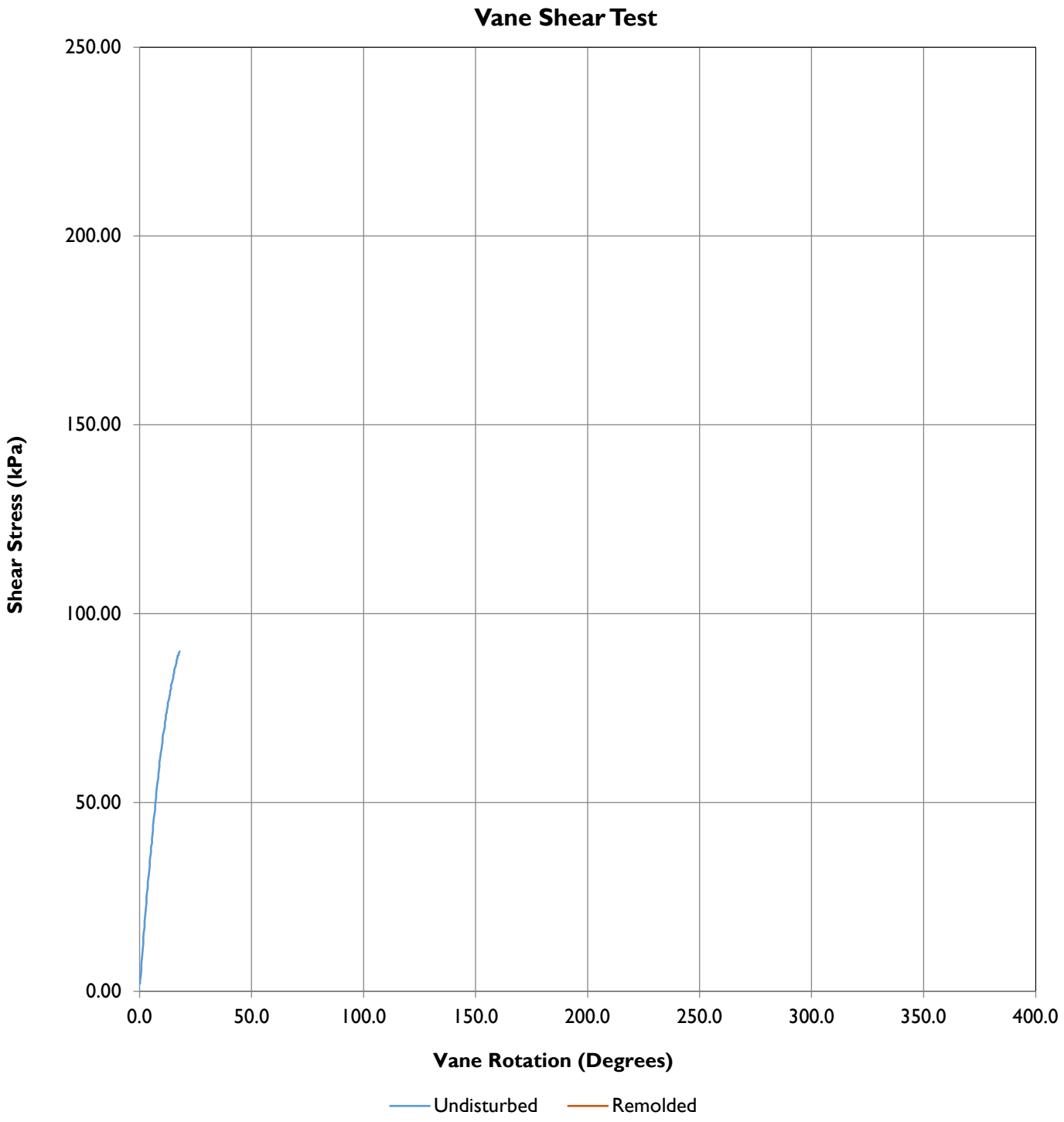
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631953.8*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521592.2*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	220.7m (AHD)



Vane Shear Test

Test Location:	**TSF2-CPT04**		
Test Depth:	**7m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**15/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

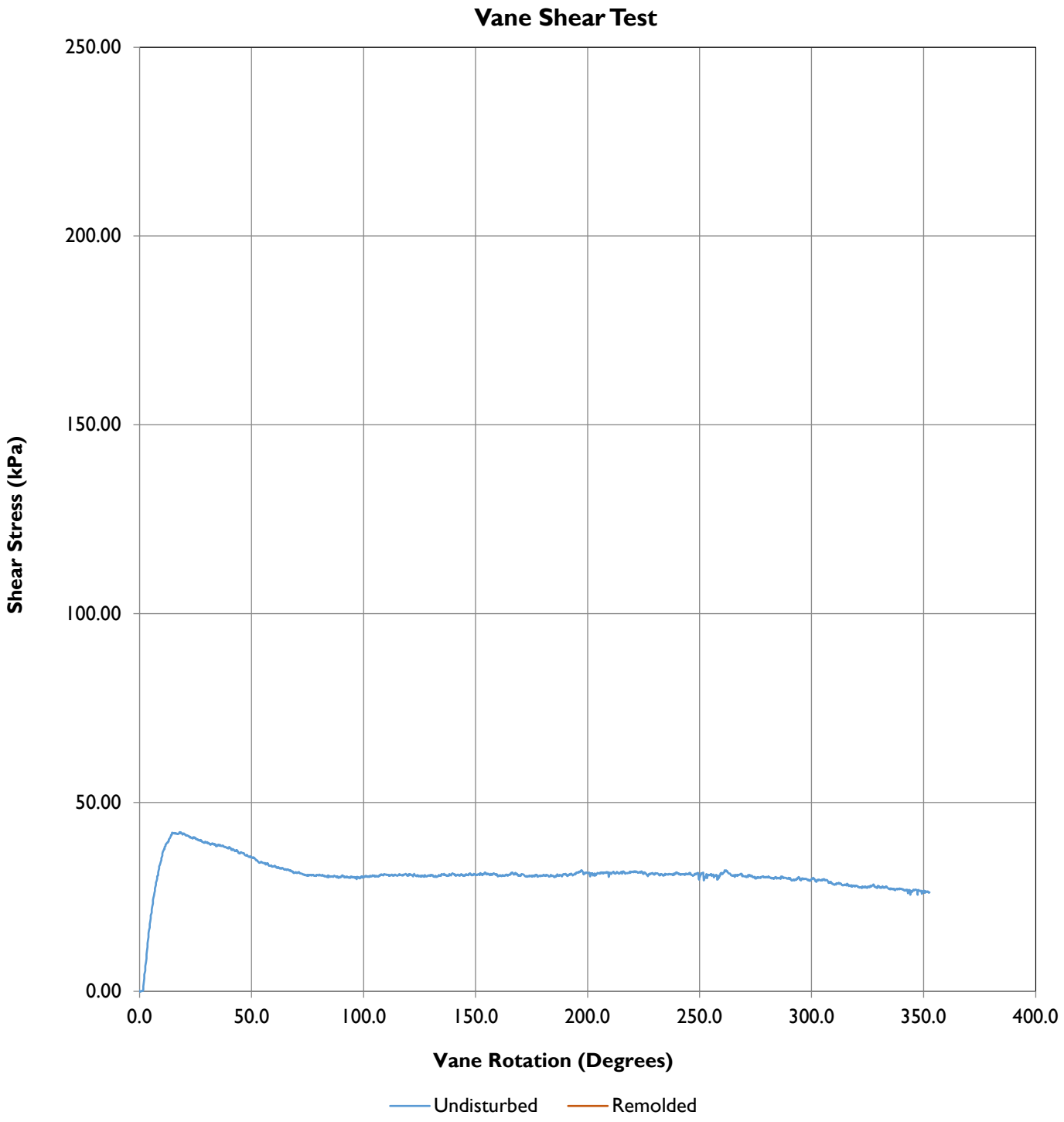
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631953.8*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521592.2*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	220.7m (AHD)



Vane Shear Test

Test Location:	**TSF2-CPT04**		
Test Depth:	**11.5m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**16/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

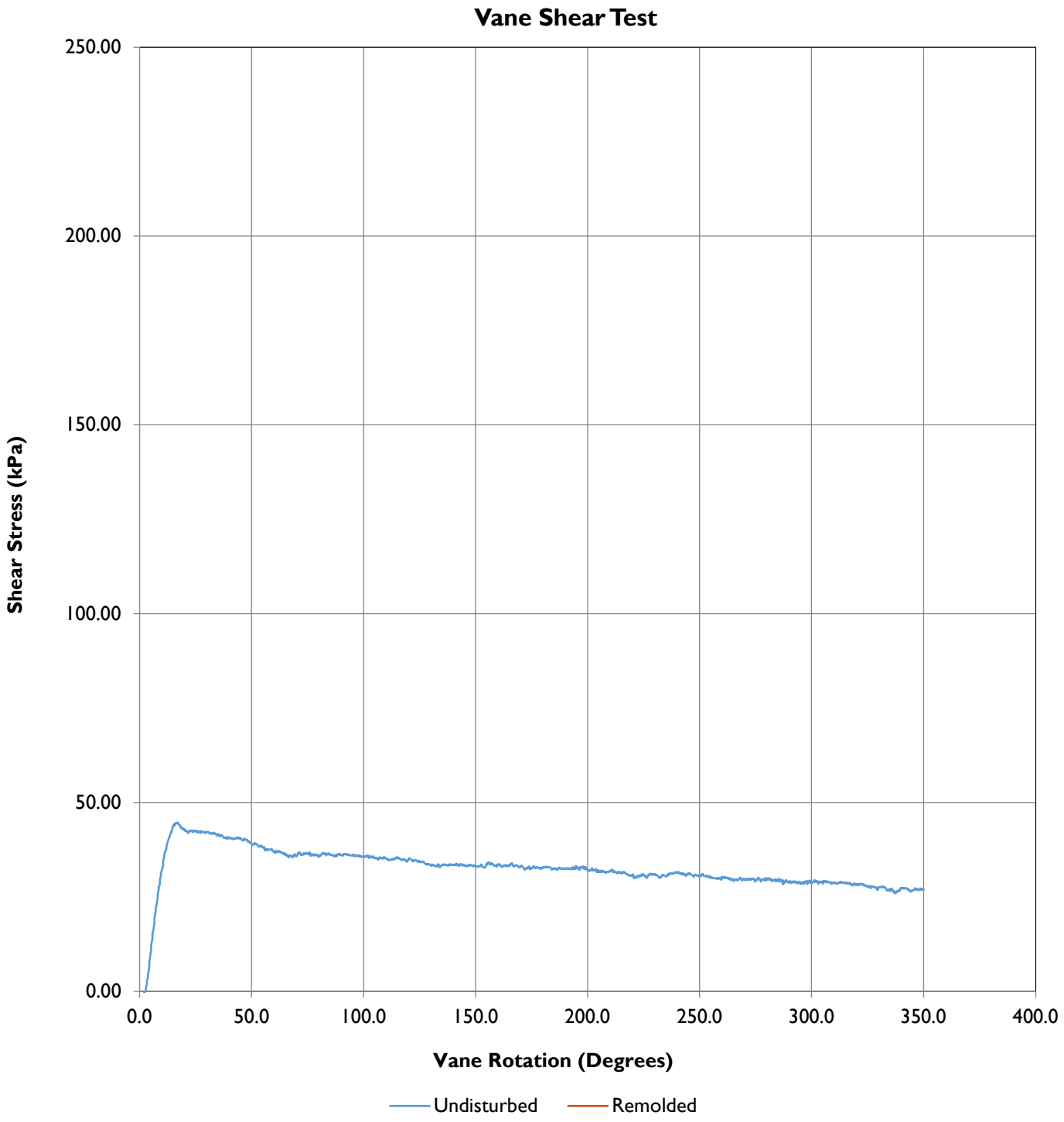
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631953.8*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521592.2*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	220.7m (AHD)



Vane Shear Test

Test Location:	**TSF2-CPT04**		
Test Depth:	**12.5m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**16/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

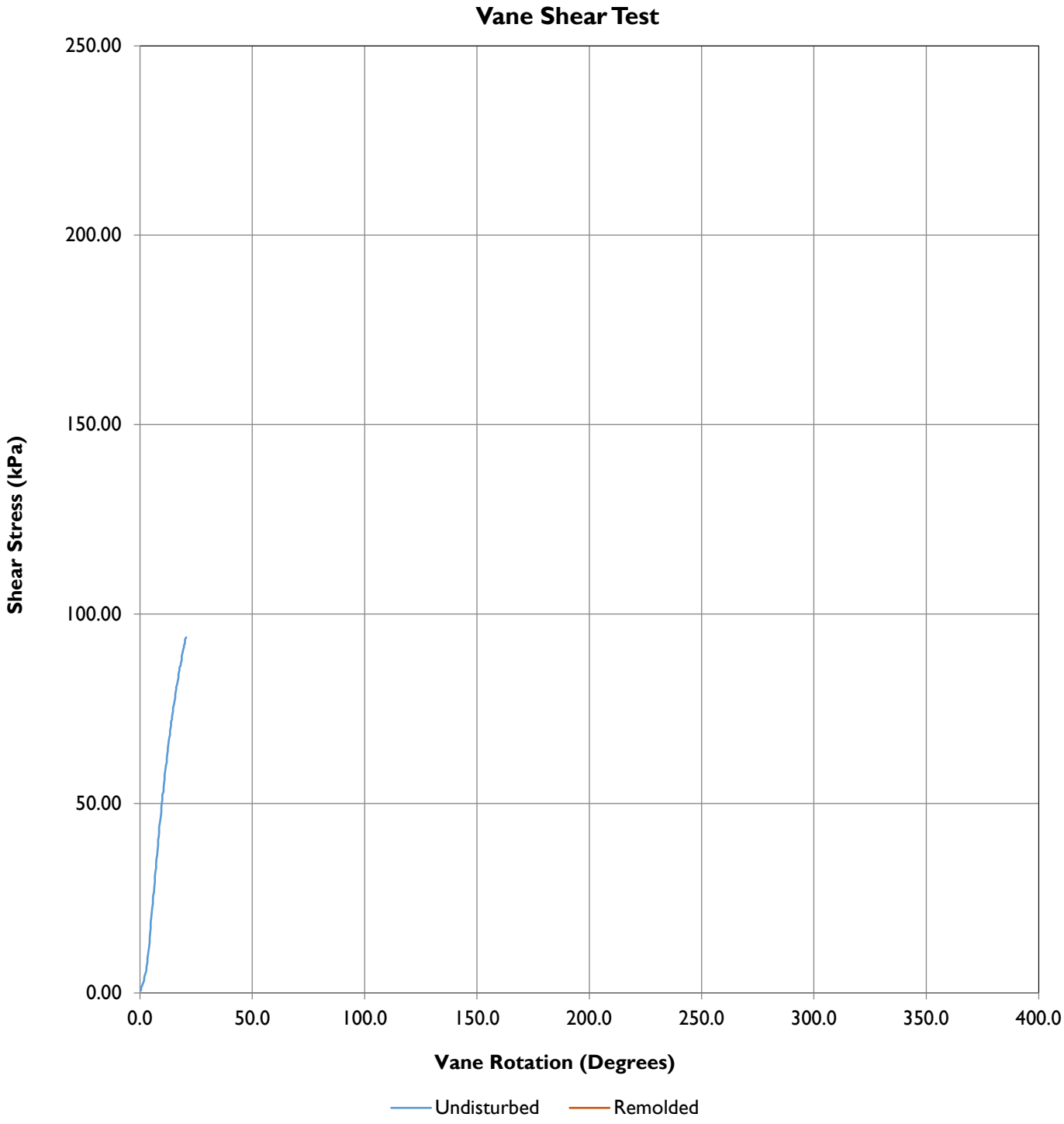
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631953.8*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521592.2*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	220.7m (AHD)



Vane Shear Test

Test Location:	**TSF2-CPT04**		
Test Depth:	**13.5m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**16/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631953.8*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521592.2*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	220.7m (AHD)



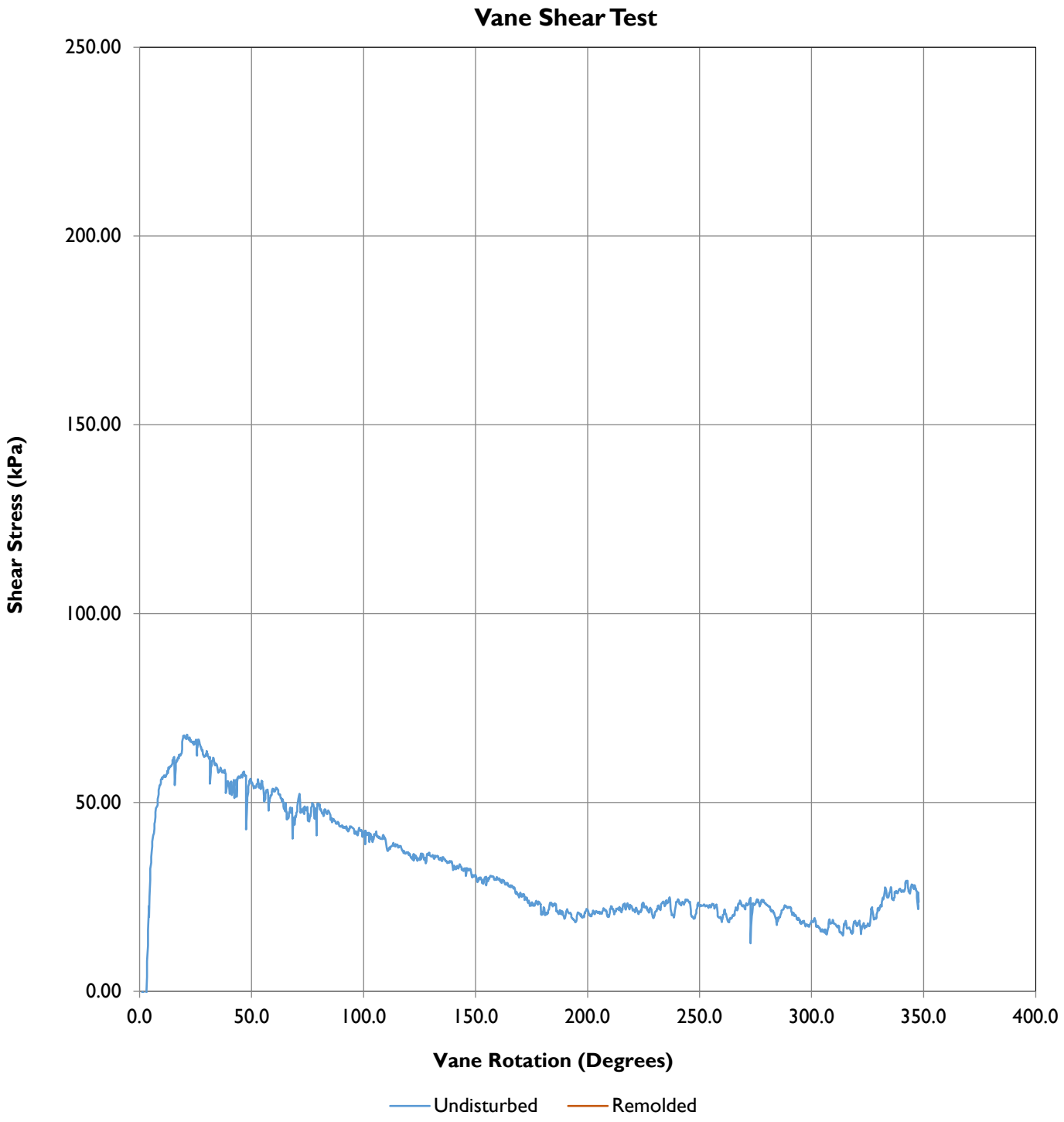
Vane Shear Test

Test Location:	**TSF2-CPT07**
Test Depth:	**6.5m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**
Project:	**TSF2-4**
Location:	**Saraji**
Date Tested:	**15/08/2020**
Tested By:	**IGS**

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631819.2*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521282.2*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	221.5m (AHD)

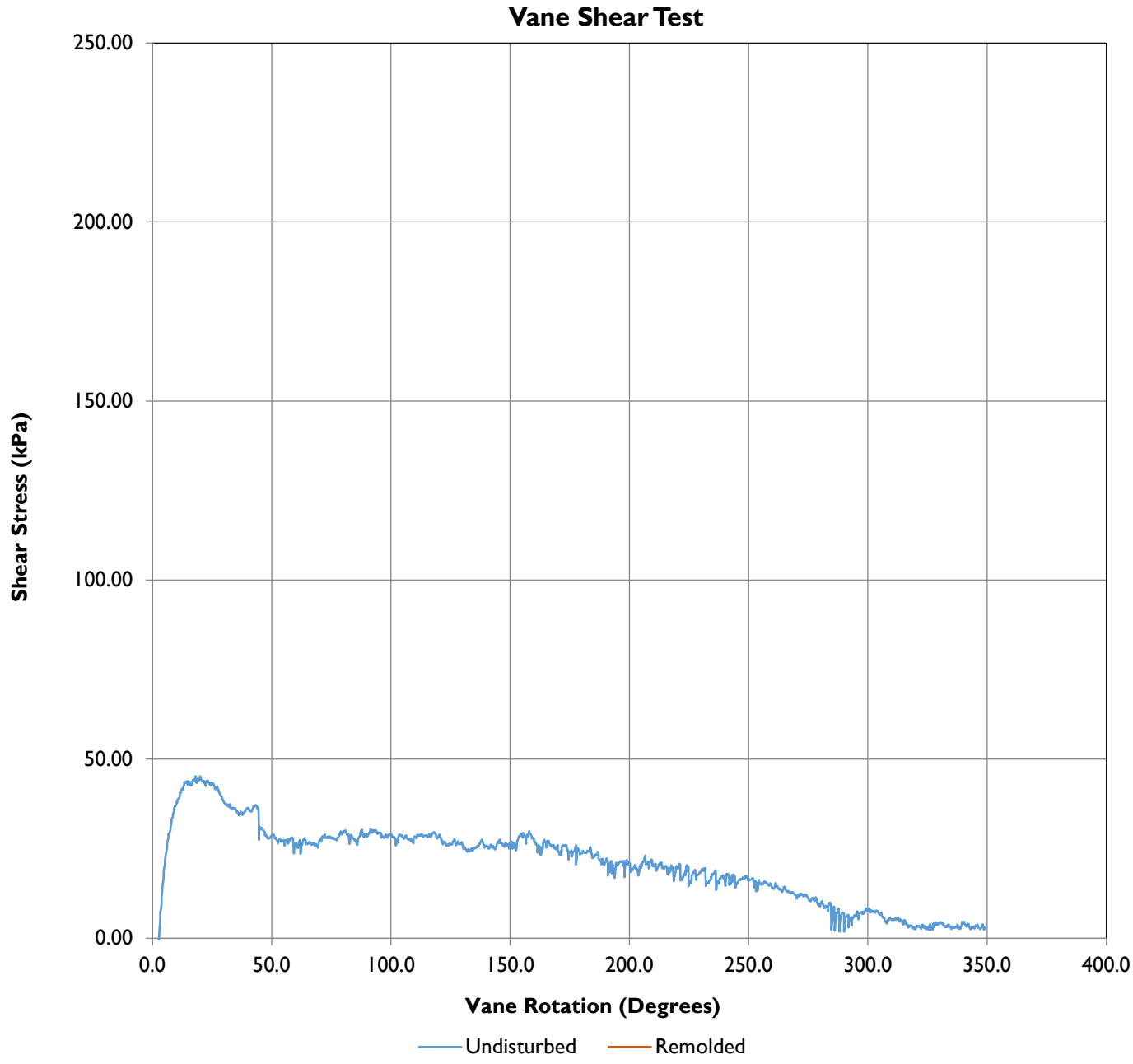


Vane Shear Test

Test Location:	**TSF2-CPT07**
Test Depth:	**8.5m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**			Date Tested:	**16/08/2020**
Project:	**TSF2-4**			Tested By:	**IGS**
Location:	**Saraji**				
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631819.2*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521282.2*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	221.5m (AHD)



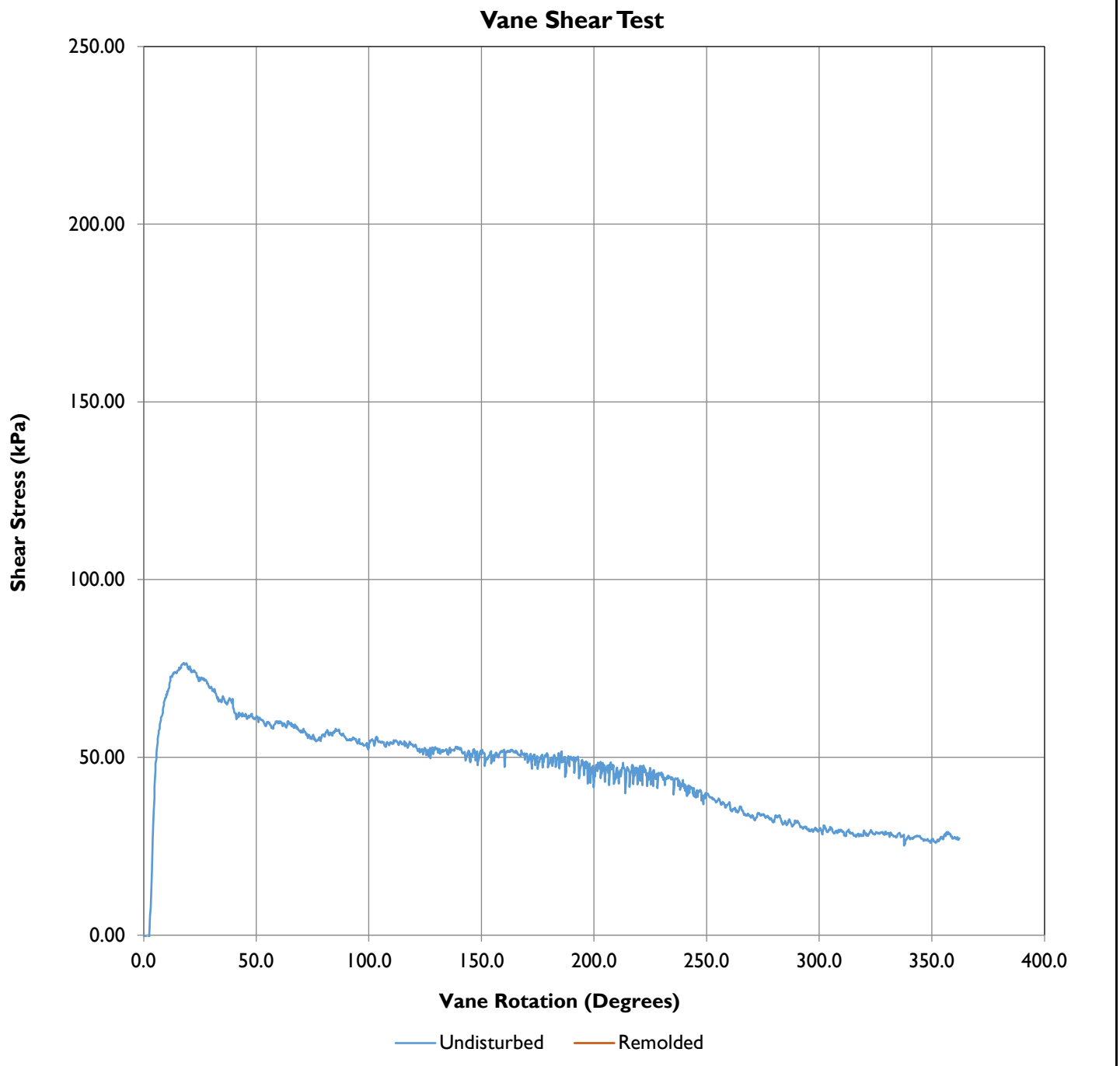
Vane Shear Test

Test Location:	**TSF2-CPT07**
Test Depth:	**11.5m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**16/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631819.2*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521282.2*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	221.5m (AHD)

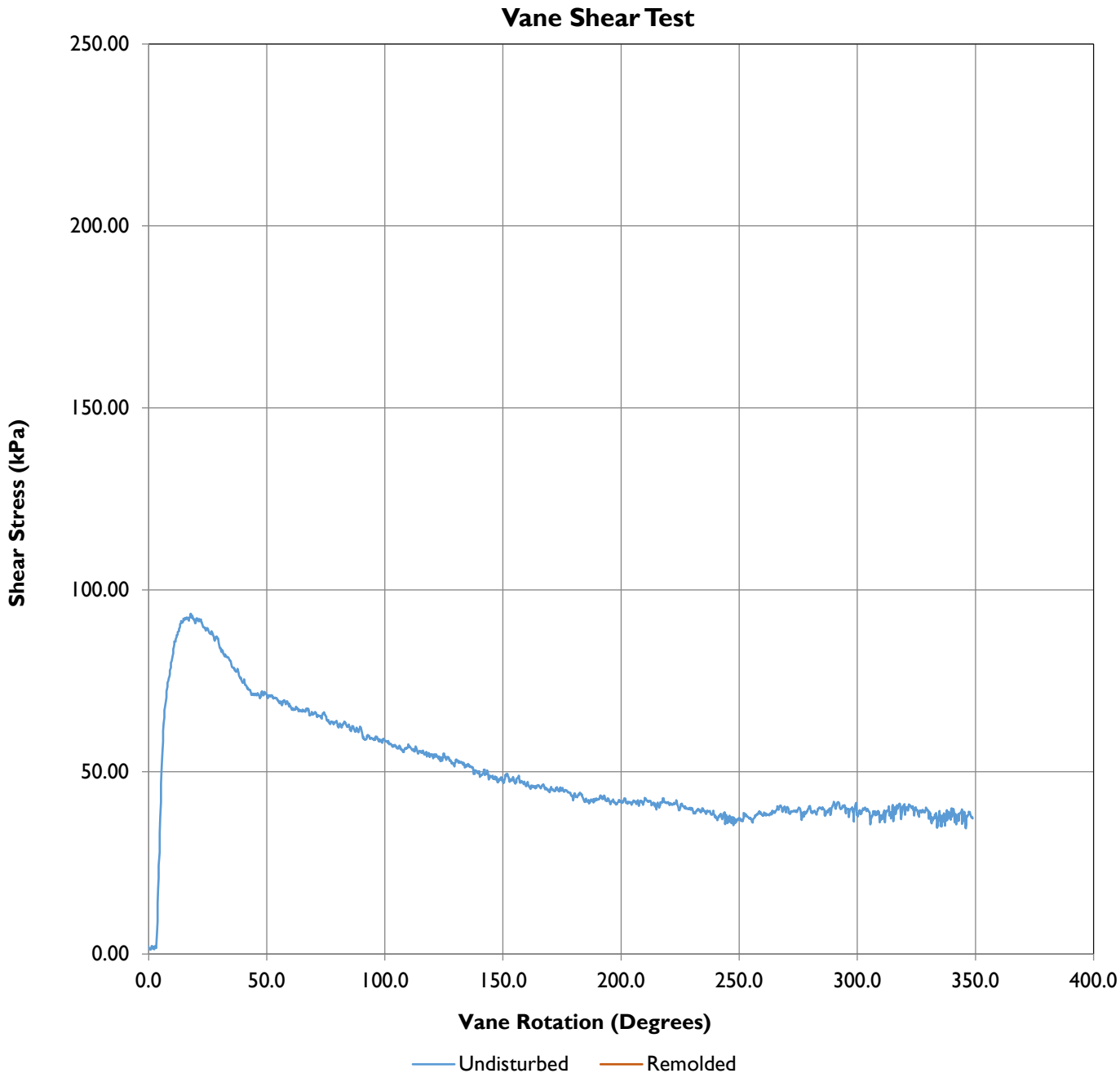


Vane Shear Test

Test Location:	**TSF2-CPT07**
Test Depth:	**14.5m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**			Date Tested:	**16/08/2020**
Project:	**TSF2-4**			Tested By:	**IGS**
Location:	**Saraji**				
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631819.2*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521282.2*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	221.5m (AHD)



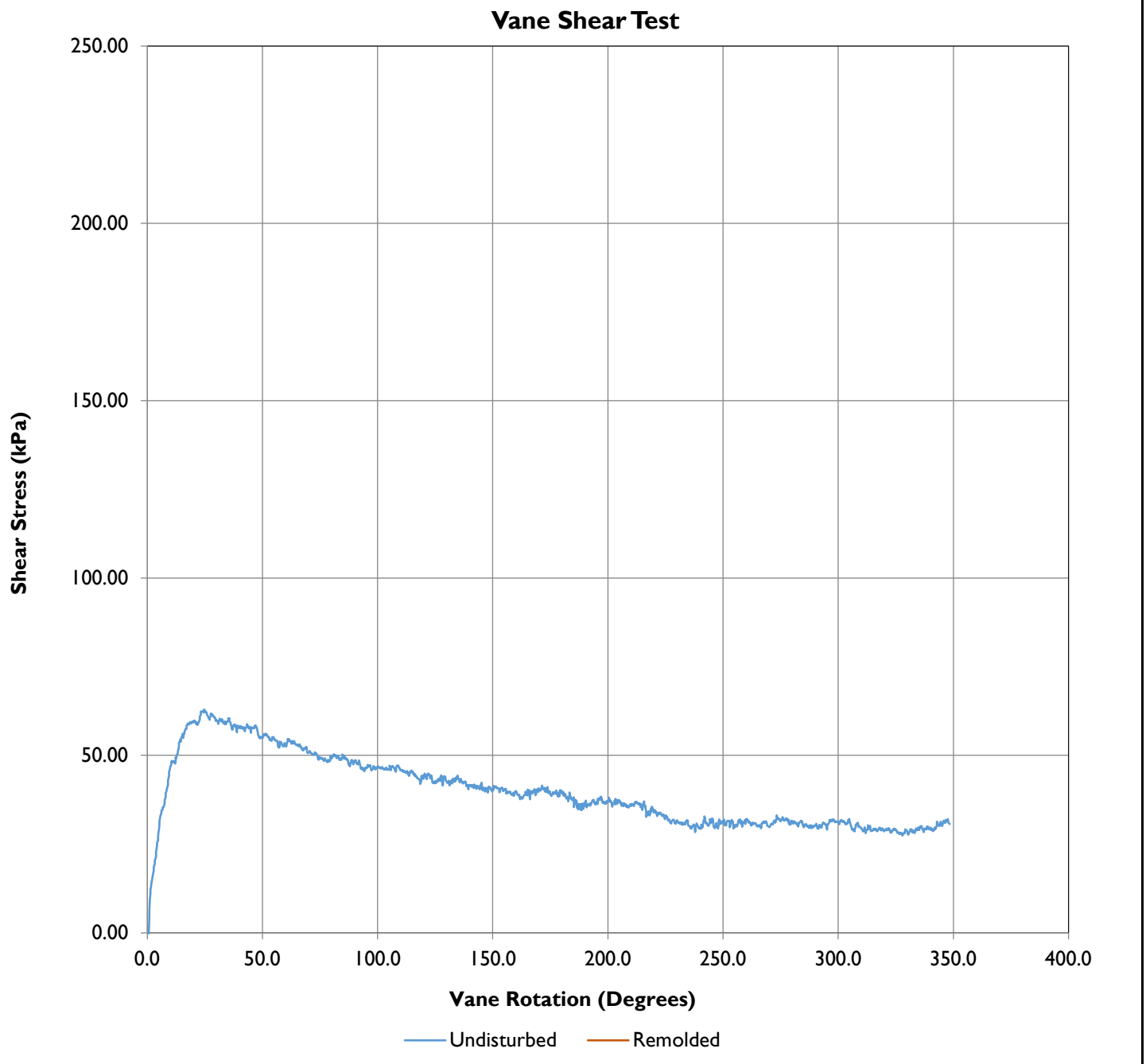
Vane Shear Test

Test Location:	**TSF2-CPT07**
Test Depth:	**16m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**16/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

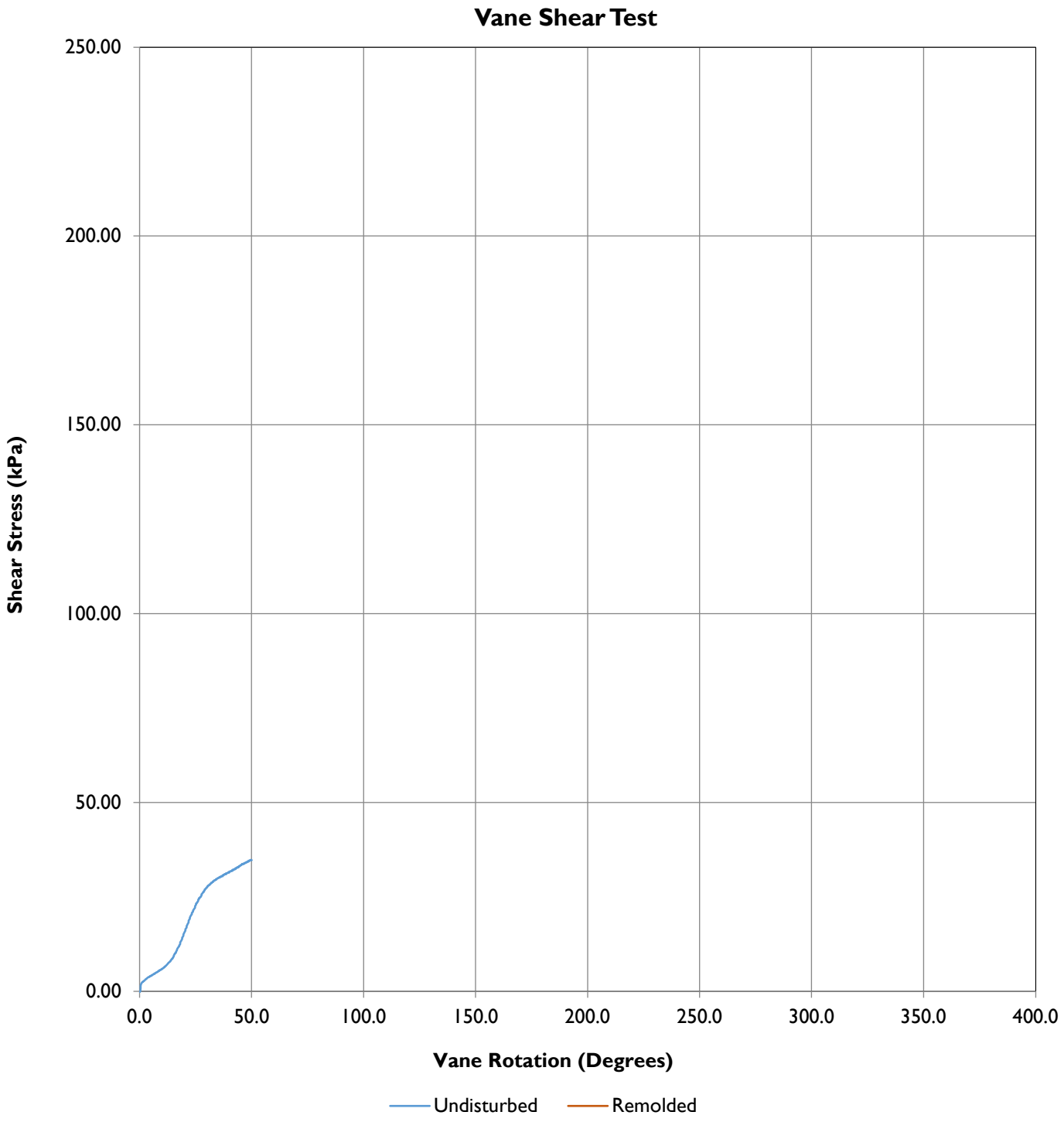
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631819.2*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521282.2*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	221.5m (AHD)



Vane Shear Test

Test Location:	**TSF2-CPT10**		
Test Depth:	**0.5m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**21/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

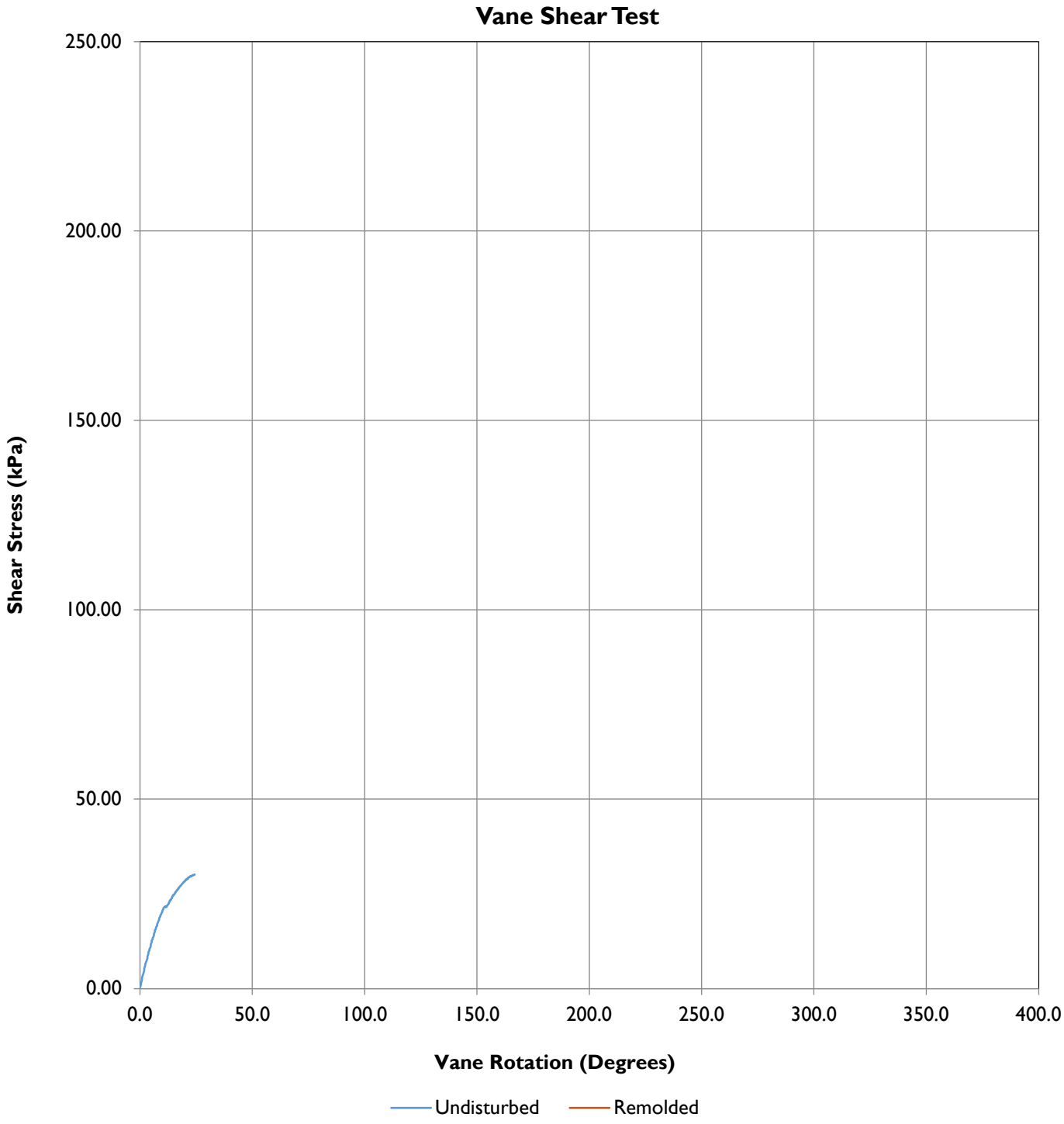
Vane Type:	*V2*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*75mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*150mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*0.595*	R.L. Surface:	218.5m (AHD)



Vane Shear Test

Test Location:	**TSF2-CPT10**		
Test Depth:	**1.5m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**21/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

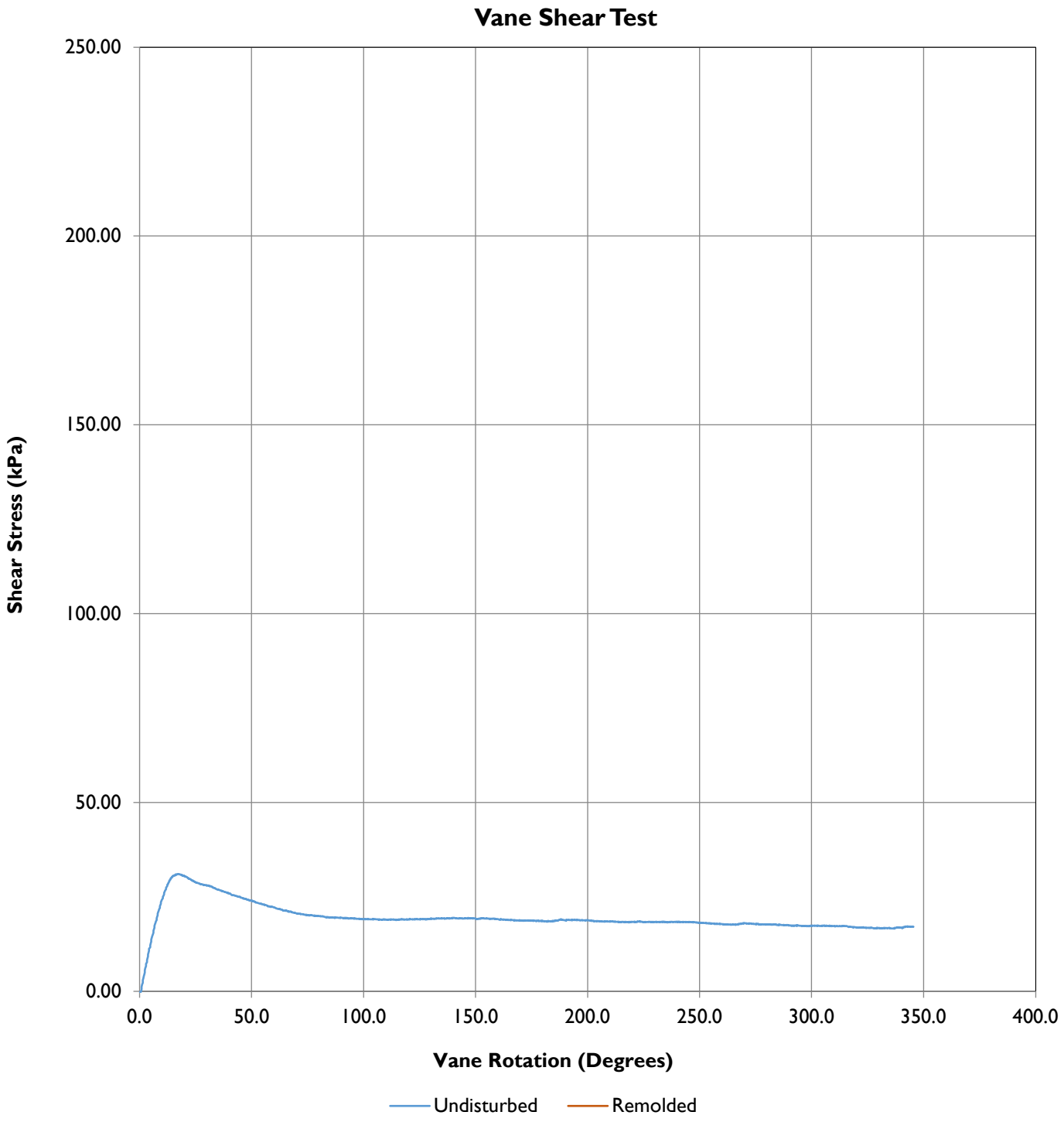
Vane Type:	*V2*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*75mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*150mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*0.595*	R.L. Surface:	218.5m (AHD)



Vane Shear Test

Test Location:	**TSF2-CPT10**		
Test Depth:	**1.7m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**21/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V2*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*75mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*150mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*0.595*	R.L. Surface:	218.5m (AHD)

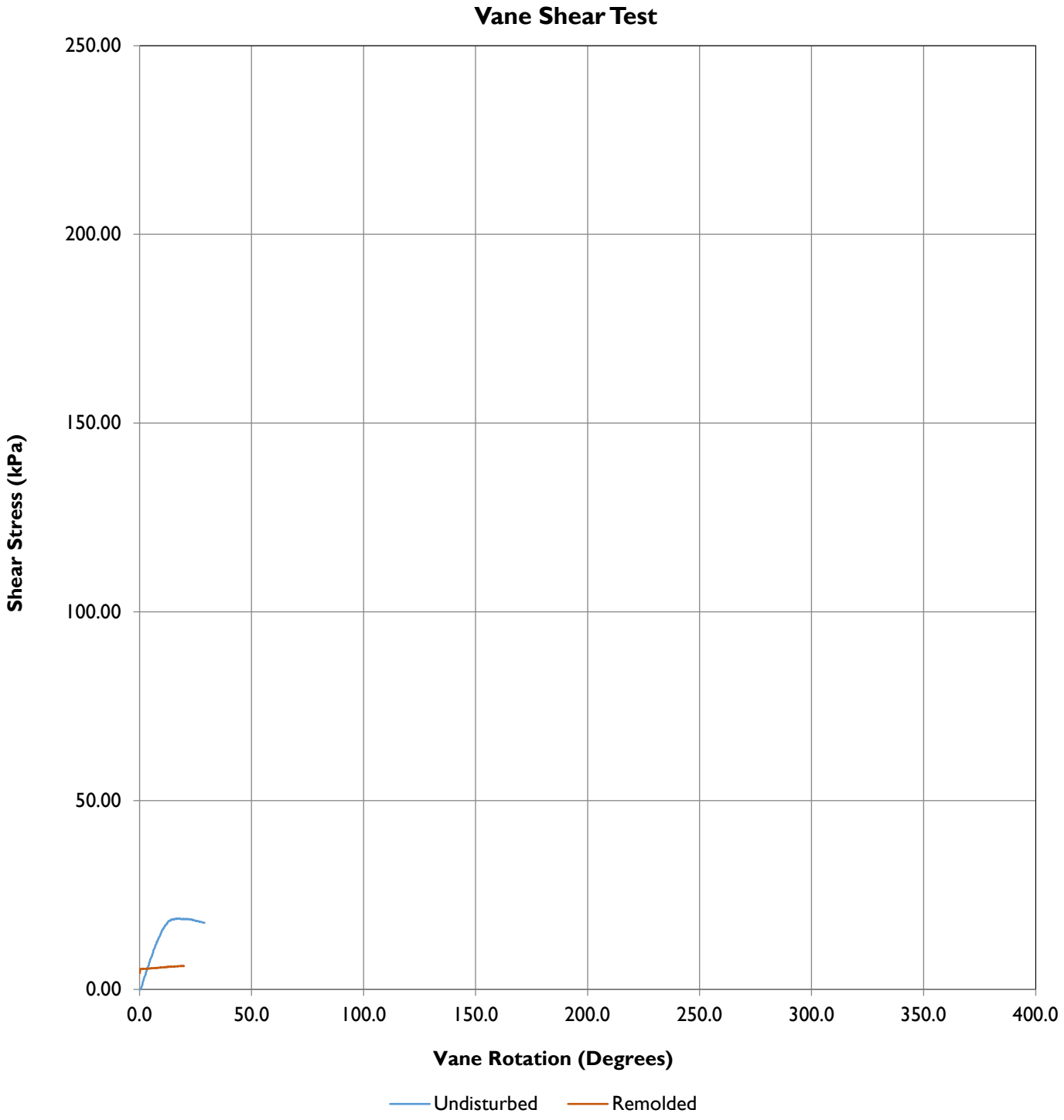


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Vane Shear Test

Test Location:	**TSF2-CPT10**		
Test Depth:	**2m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**28/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

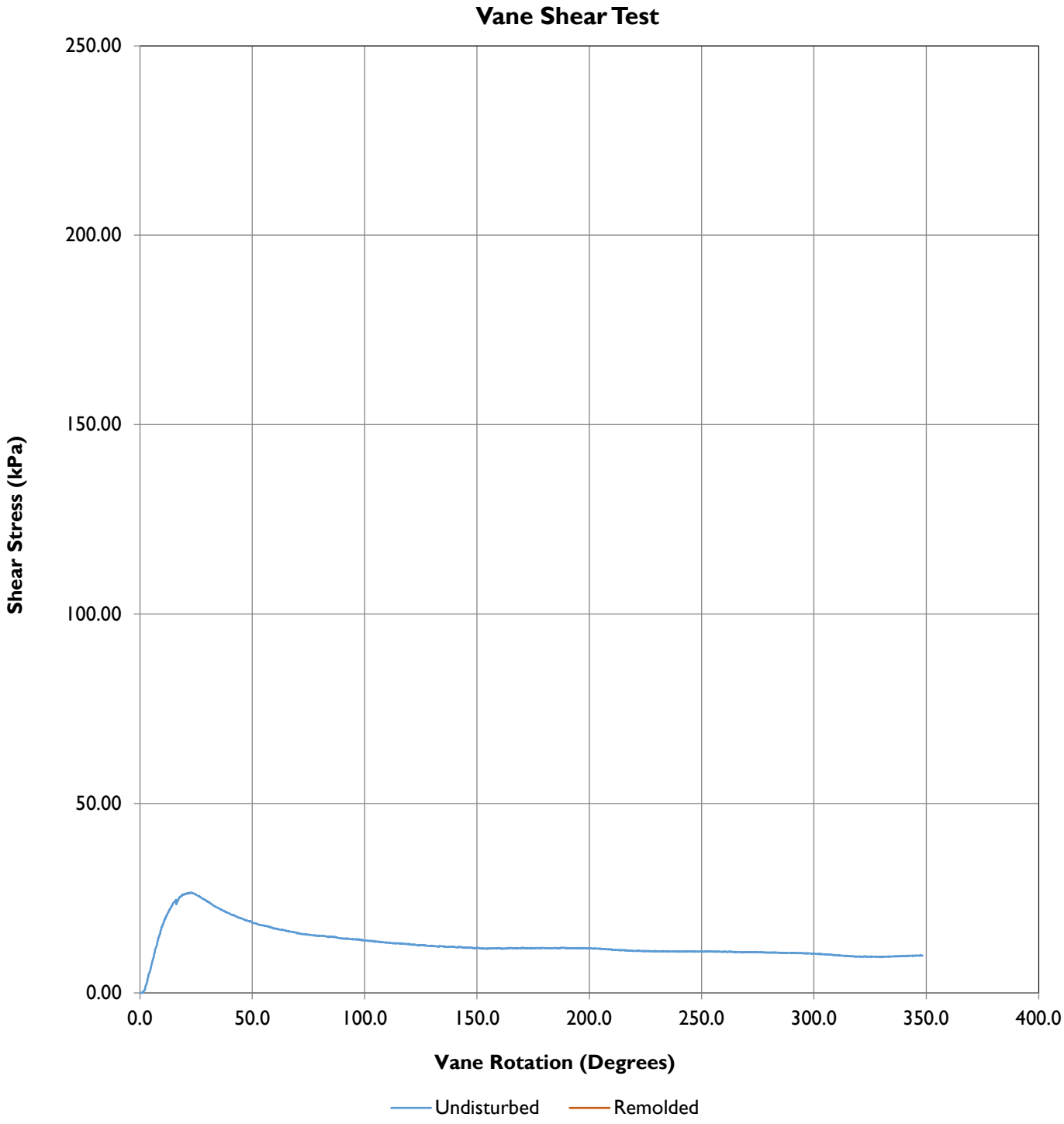
Vane Type:	*V2*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*75mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*150mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*0.595*	R.L. Surface:	218.5m (AHD)



Vane Shear Test

Test Location:	**TSF2-CPT10**		
Test Depth:	**2.5m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**28/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V2*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*75mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*150mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*0.595*	R.L. Surface:	218.5m (AHD)

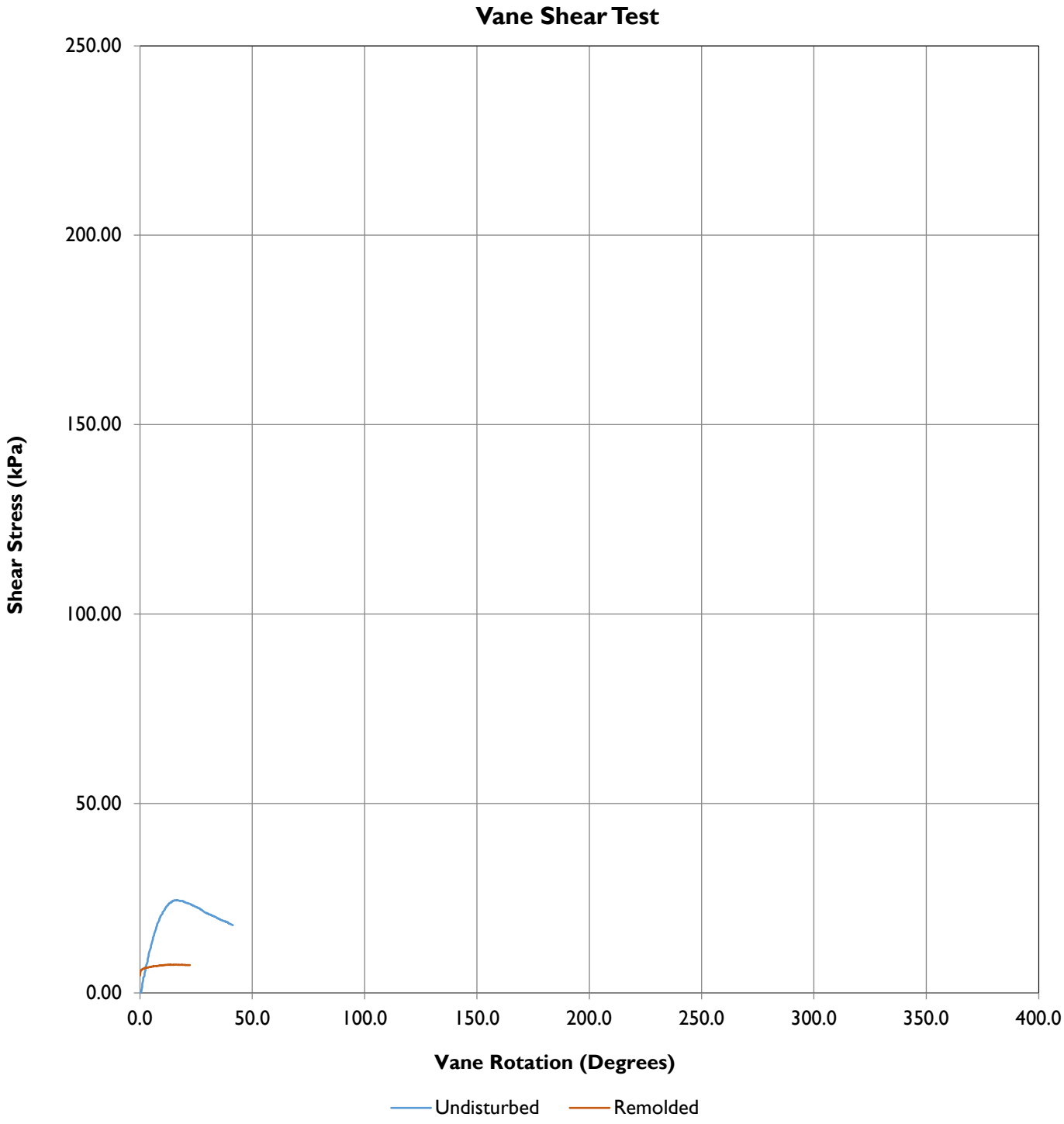


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Vane Shear Test

Test Location:	**TSF2-CPT10**		
Test Depth:	**3.5m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**28/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

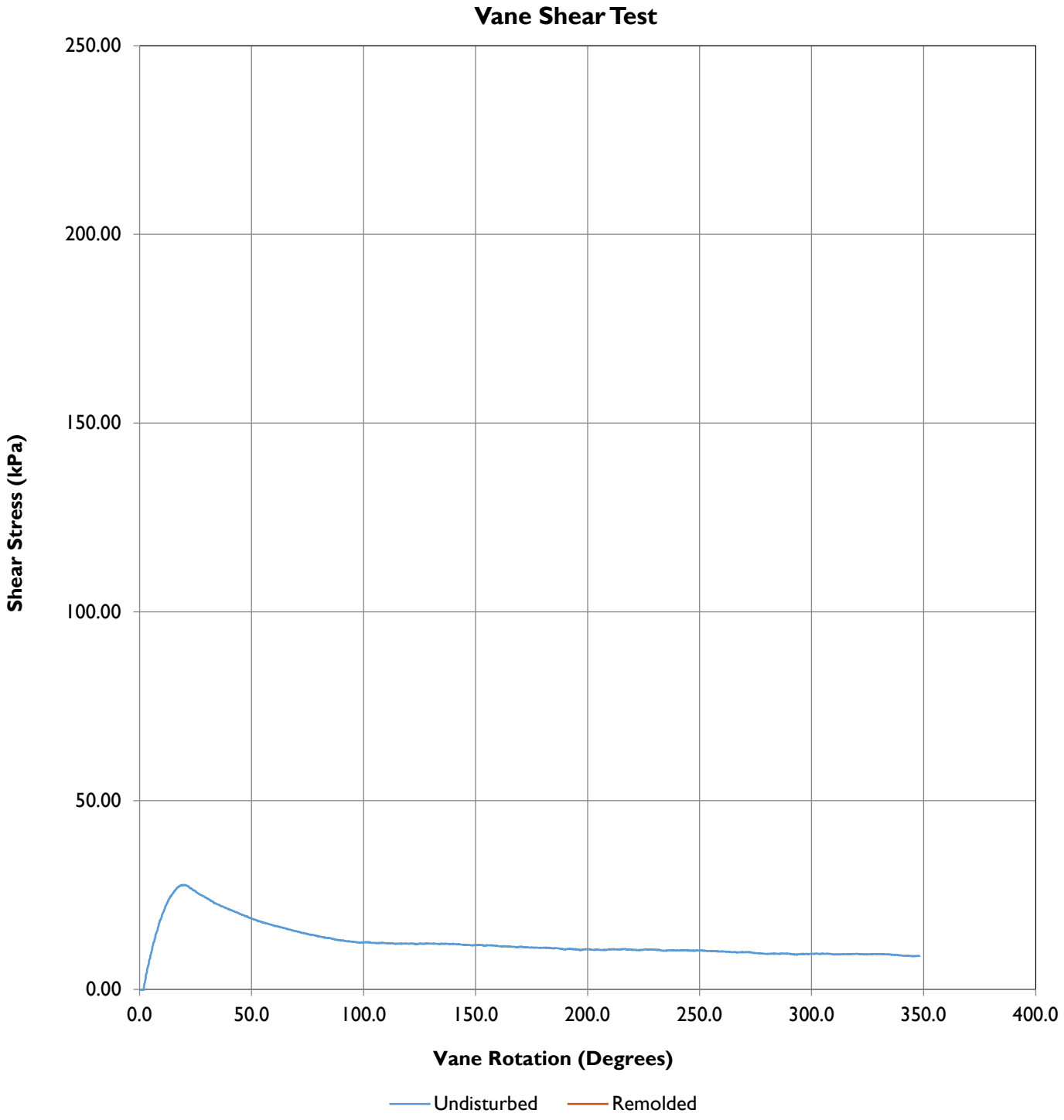
Vane Type:	*V2*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*75mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*150mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*0.595*	R.L. Surface:	218.5m (AHD)



Vane Shear Test

Test Location:	**TSF2-CPT10**		
Test Depth:	**4m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**28/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

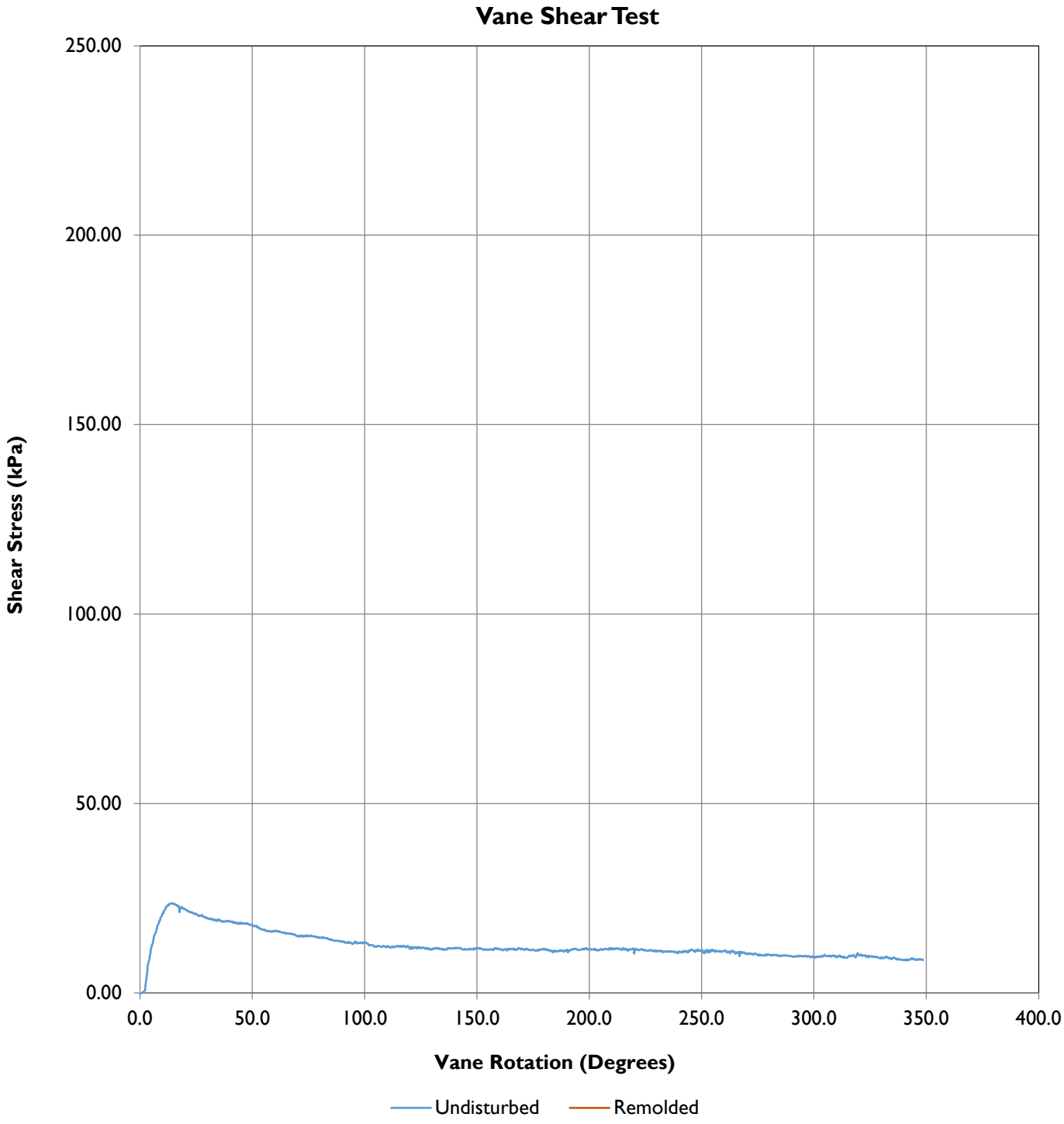
Vane Type:	*V2*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*75mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*150mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*0.595*	R.L. Surface:	218.5m (AHD)



Vane Shear Test

Test Location:	**TSF2-CPT10**		
Test Depth:	**5.5m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.5m (AHD)

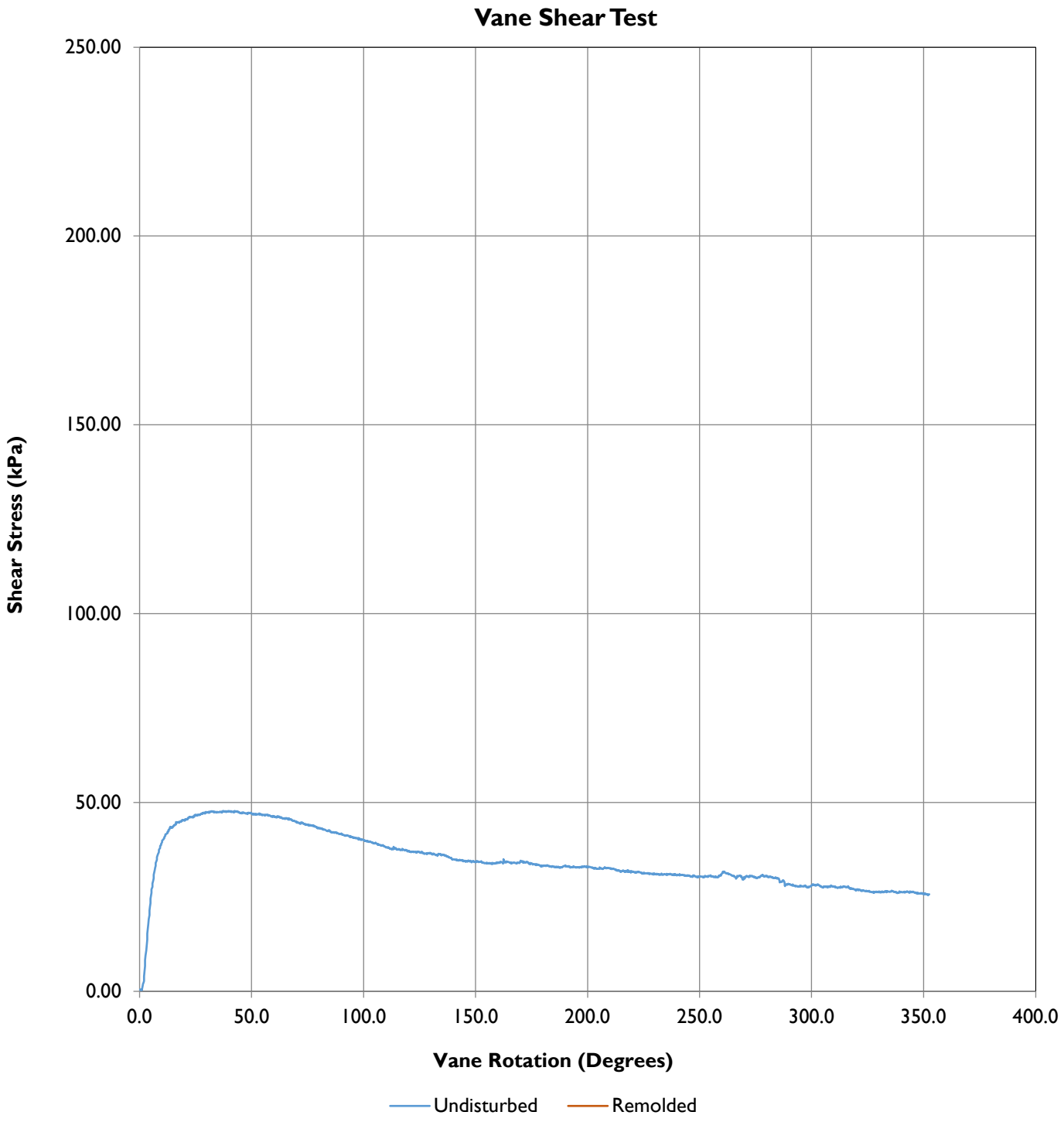


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Vane Shear Test

Test Location:	**TSF2-CPT10**		
Test Depth:	**6m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.5m (AHD)

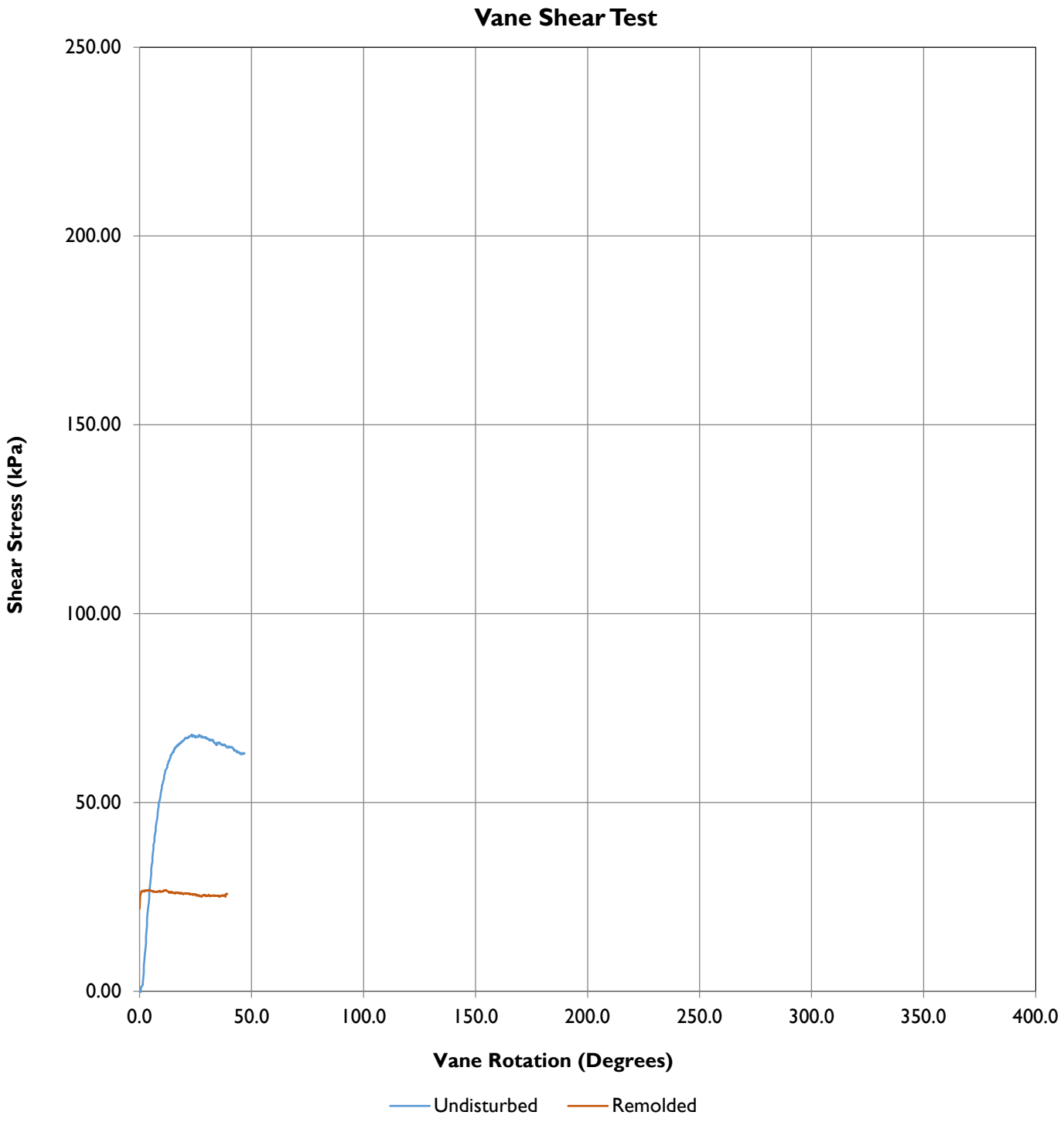


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Vane Shear Test

Test Location:	**TSF2-CPT10**		
Test Depth:	**6.5m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.5m (AHD)



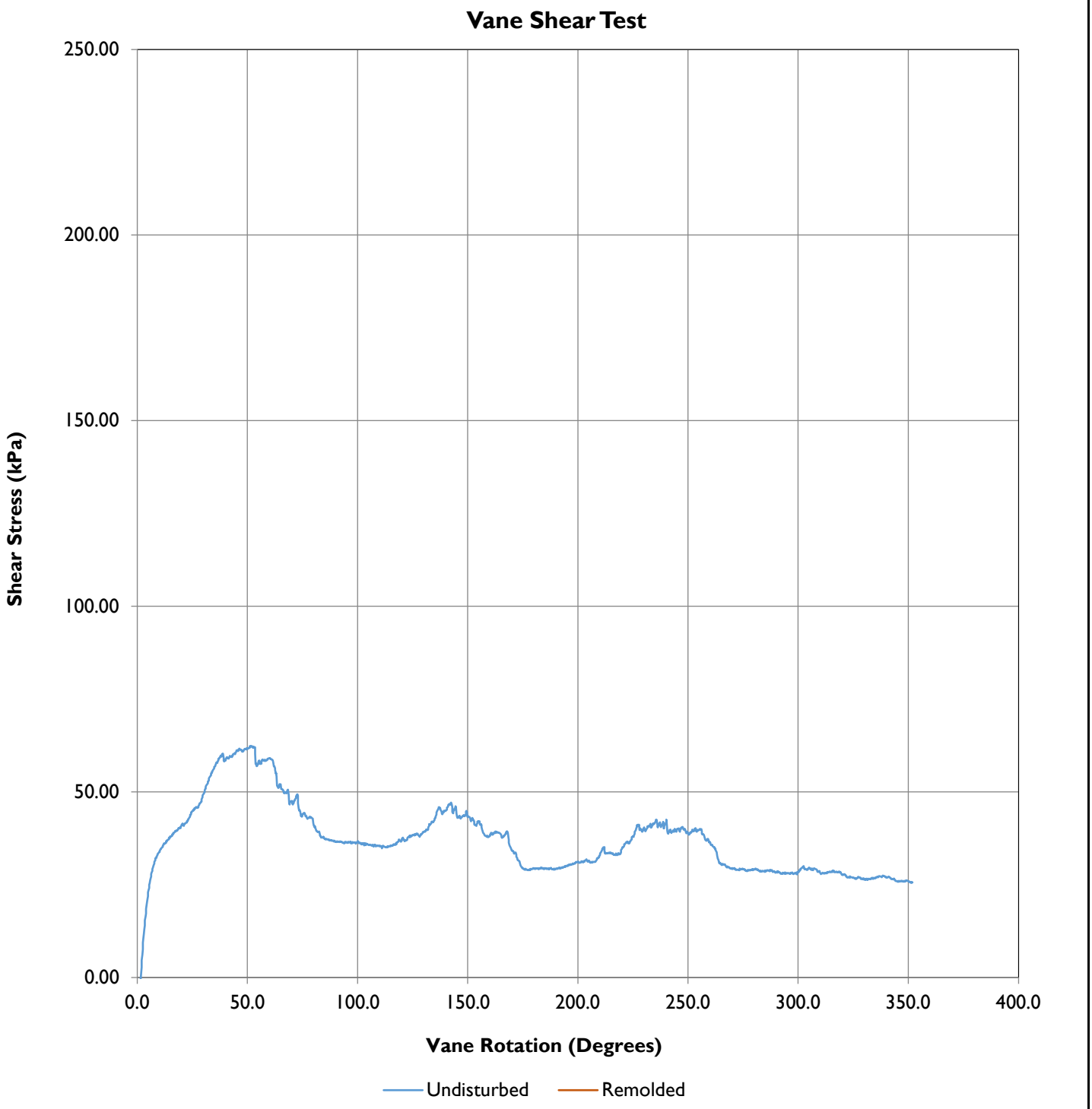
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Vane Shear Test

Test Location:	**TSF2-CPT10**
Test Depth:	**7m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**			Date Tested:	**29/05/2020**
Project:	**TSF2-4**			Tested By:	**IGS**
Location:	**Saraji**				
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.5m (AHD)

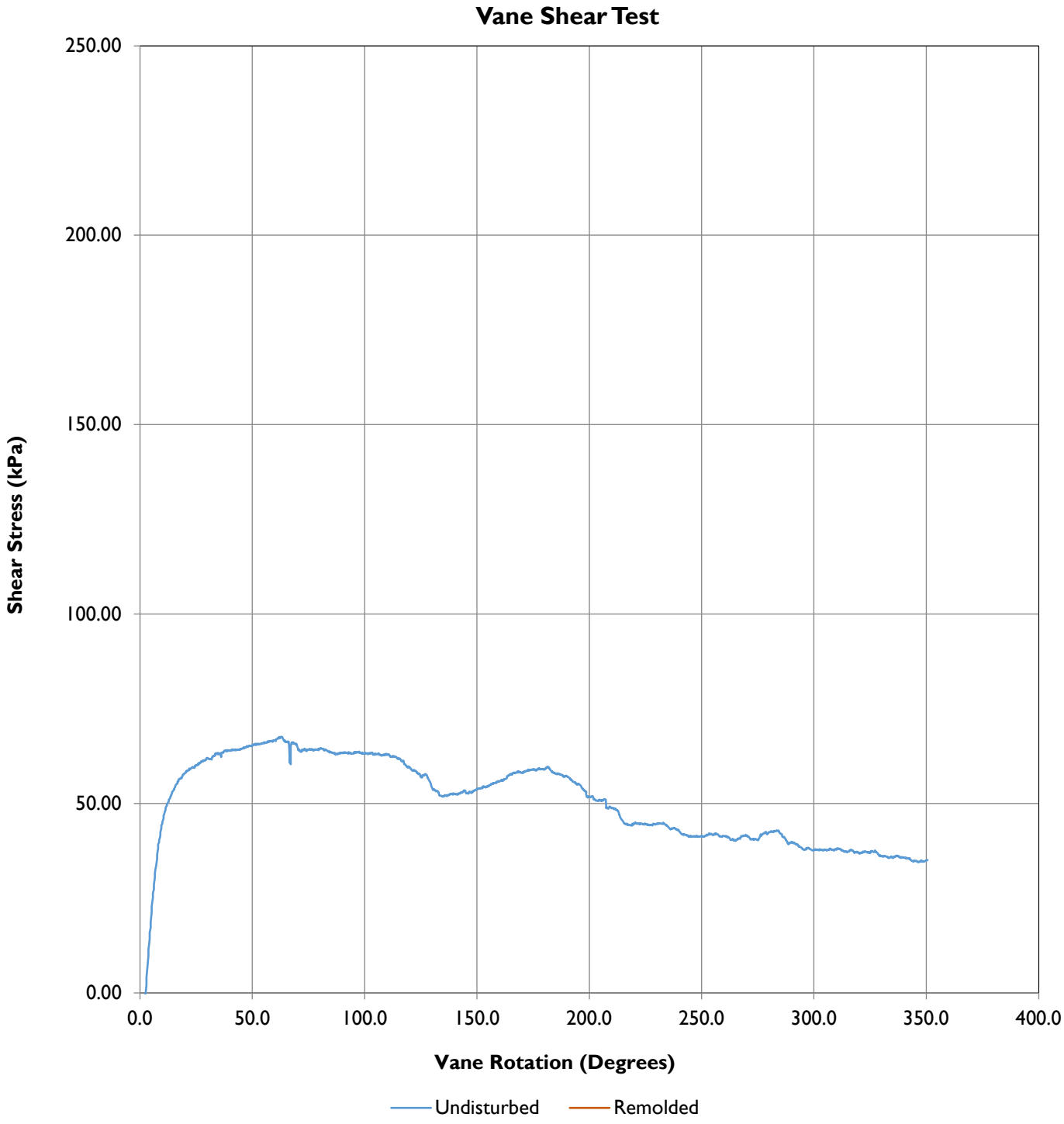


T:\04 BRIS\B01229-4 BMA, TSF2 to 4, Saraji\06 Site Investigation\05 CPT Results\01 TSF2\01 EDG Template\02 EDG VS Template\[TSF2-CPT10_VS.xlsm]

Vane Shear Test

Test Location:	**TSF2-CPT10**		
Test Depth:	**8m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.5m (AHD)

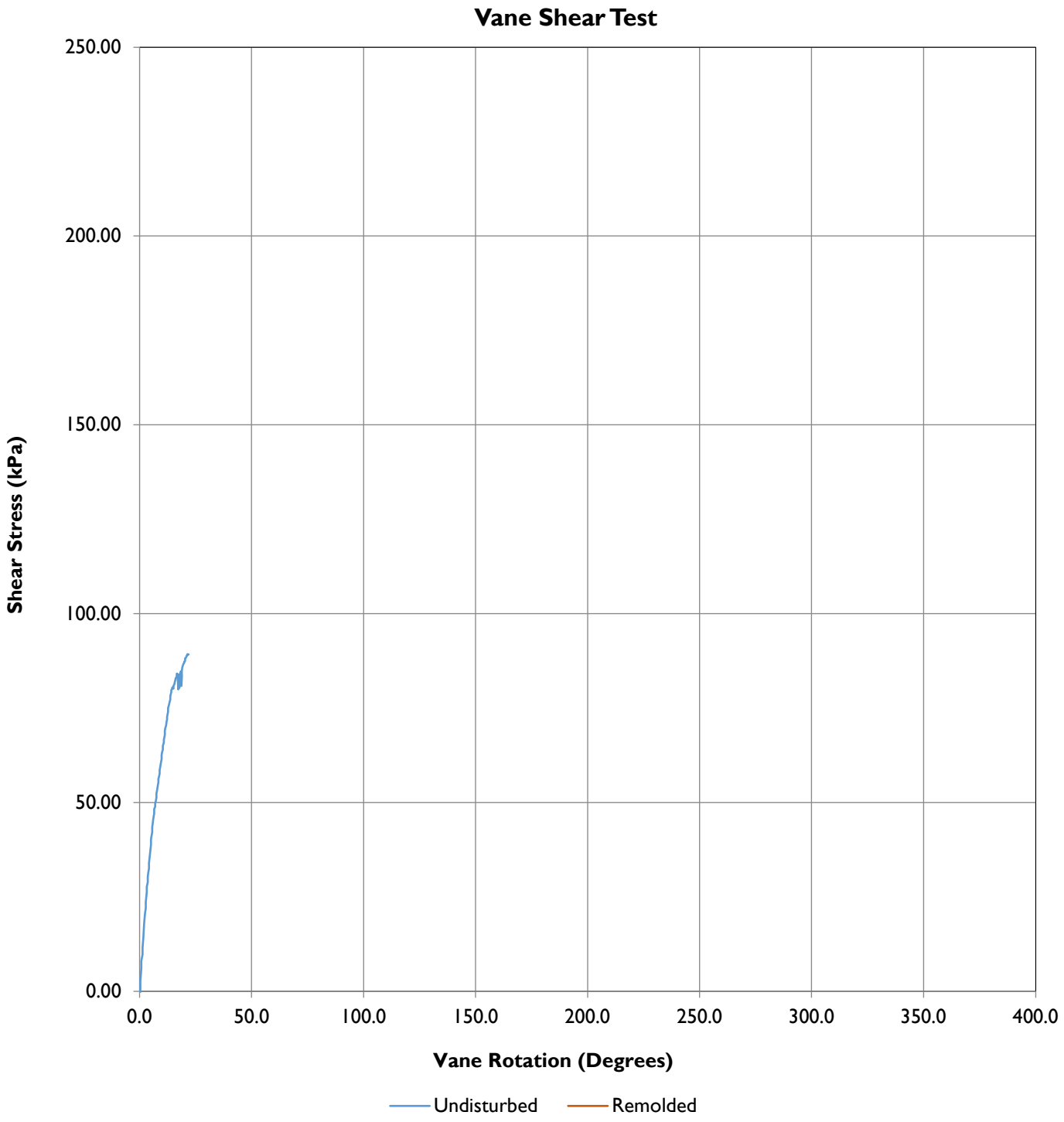


T:\04 BRIS\B01229-4 BMA, TSF2 to 4, Saraji\06 Site Investigation\05 CPT Results\01 TSF2\01 EDG Template\02 EDG VS Template\[TSF2-CPT10_VS.xlsm]

Vane Shear Test

Test Location:	**TSF2-CPT10**		
Test Depth:	**8.9m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*632141.9*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521514.6*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.5m (AHD)



T:\04 BRIS\B01229-4 BMA, TSF2 to 4, Saraji\06 Site Investigation\05 CPT Results\01 TSF2\01 EDG Template\02 EDG VS Template\[TSF2-CPT10_VS.xlsm]

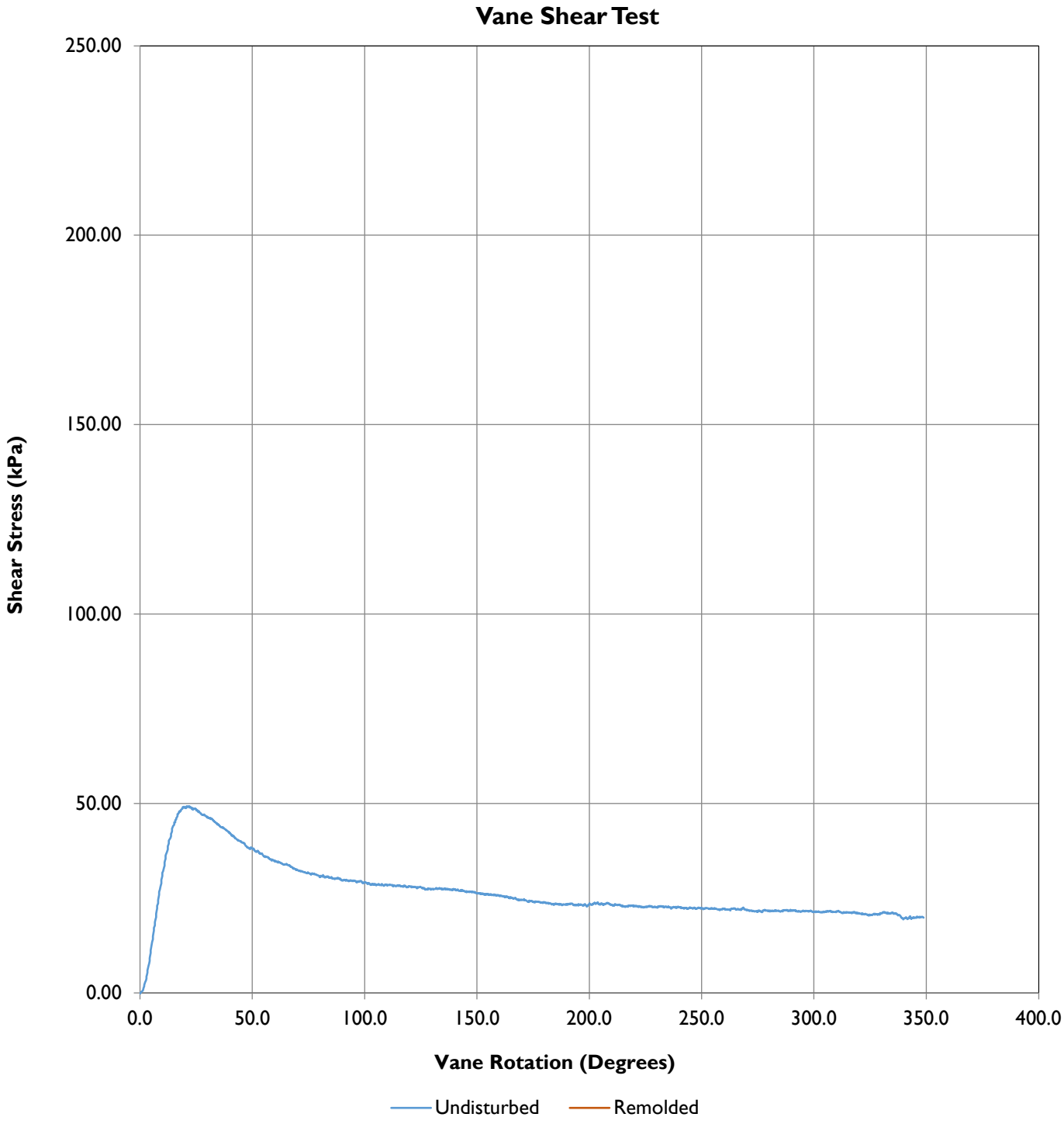
Vane Shear Test

Test Location:	**TSF2-CPT15**
Test Depth:	**1.8m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**15/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631928.4*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521486.0*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.7m (AHD)



T:\04 BRIS\B01229-4 BMA, TSF2 to 4, Saraji\06 Site Investigation\05 CPT Results\01 TSF2\01 EDG Template\02 EDG VS Template\[TSF2-CPT15_VS.xlsm]

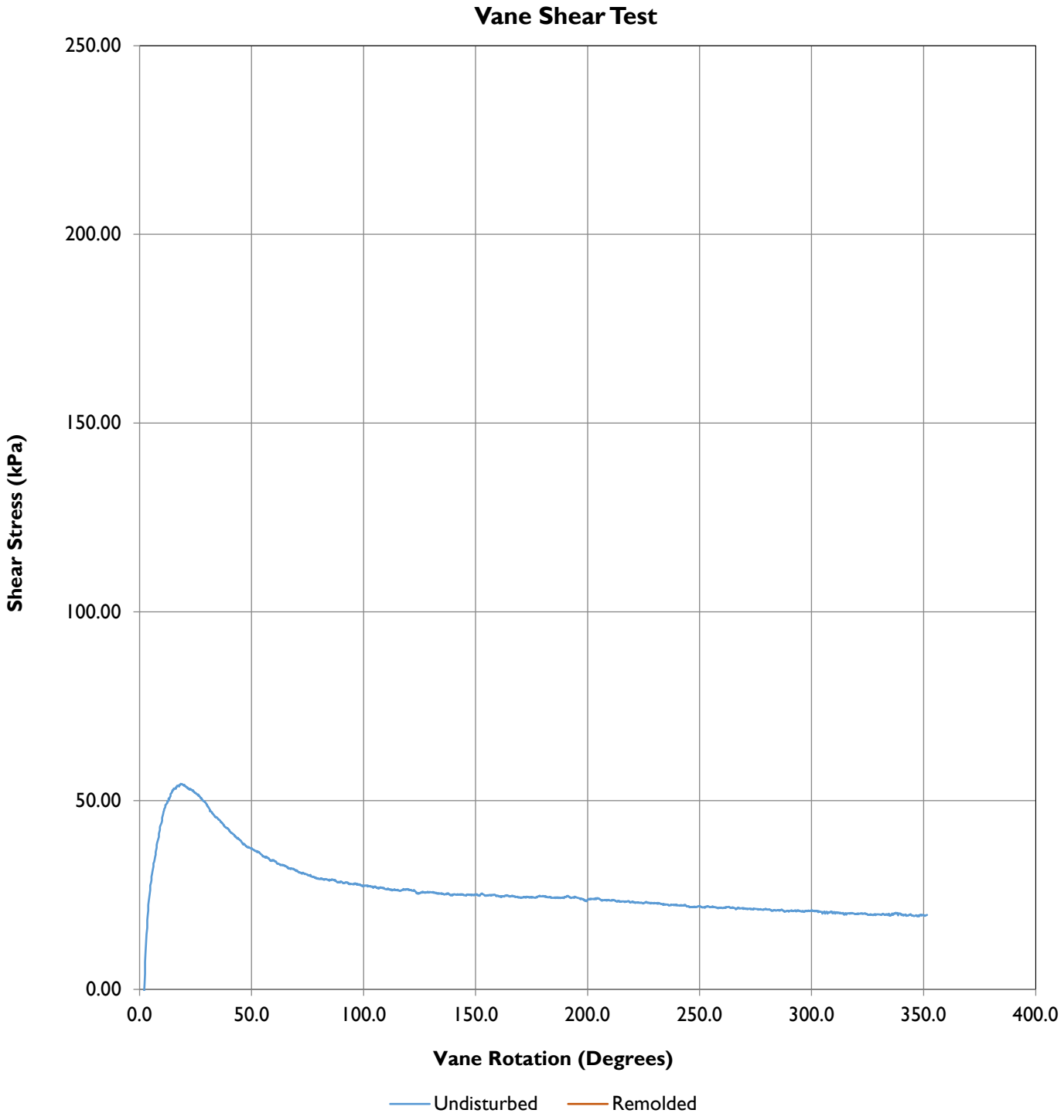
Vane Shear Test

Test Location:	**TSF2-CPT15**
Test Depth:	**2.8m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**
Project:	**TSF2-4**
Location:	**Saraji**
Date Tested:	**15/07/2020**
Tested By:	**IGS**

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631928.4*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521486.0*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.7m (AHD)



T:\04 BRIS\B01229-4 BMA, TSF2 to 4, Saraji\06 Site Investigation\05 CPT Results\01 TSF2\01 EDG Template\02 EDG VS Template\[TSF2-CPT15_VS.xlsm]

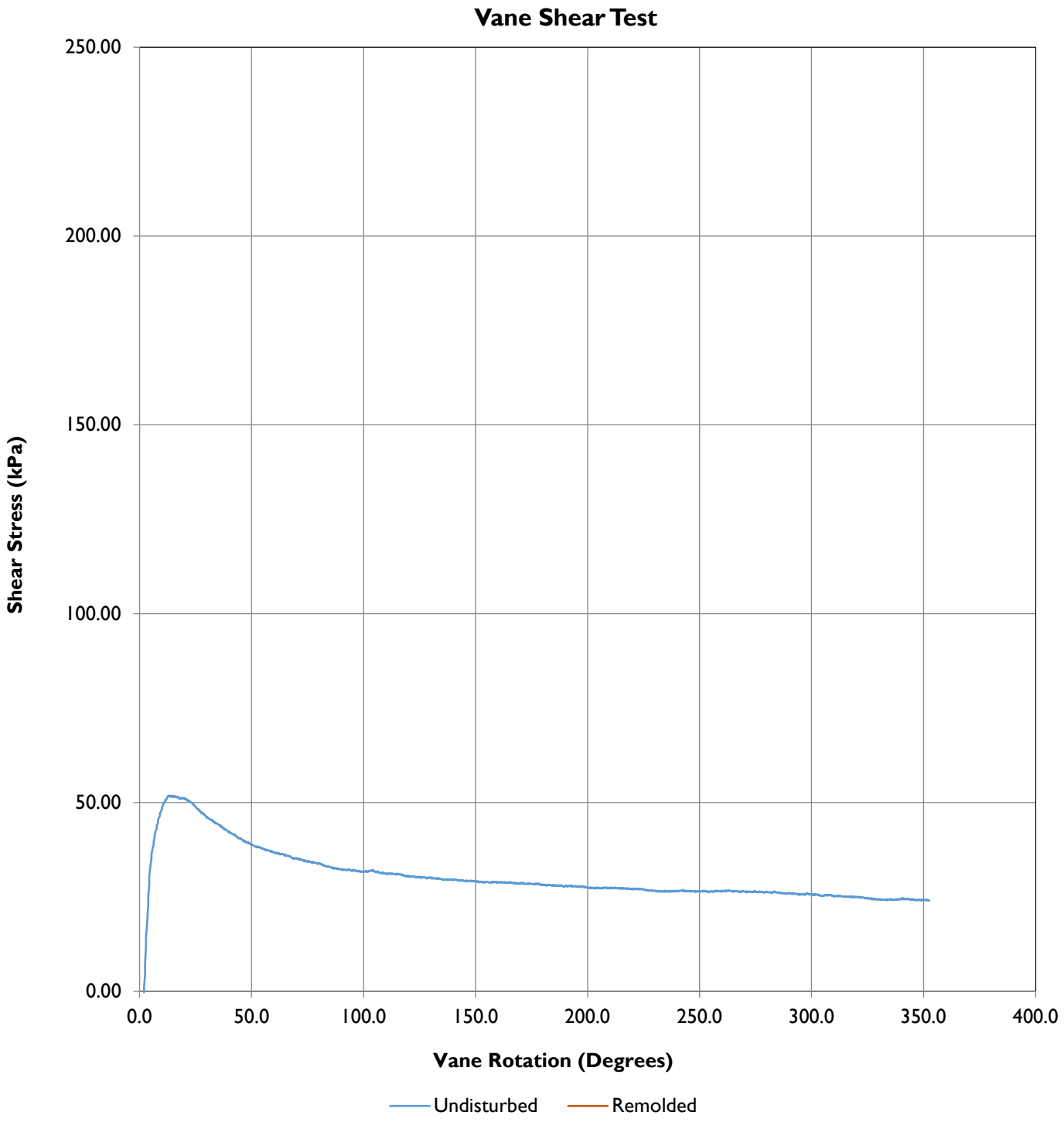
Vane Shear Test

Test Location:	**TSF2-CPT15**
Test Depth:	**3.5m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**
Project:	**TSF2-4**
Location:	**Saraji**
Date Tested:	**15/07/2020**
Tested By:	**IGS**

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631928.4*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521486.0*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.7m (AHD)



T:\04 BRIS\B01229-4 BMA, TSF2 to 4, Saraji\06 Site Investigation\05 CPT Results\01 TSF2\01 EDG Template\02 EDG VS Template\[TSF2-CPT15_VS.xlsm]

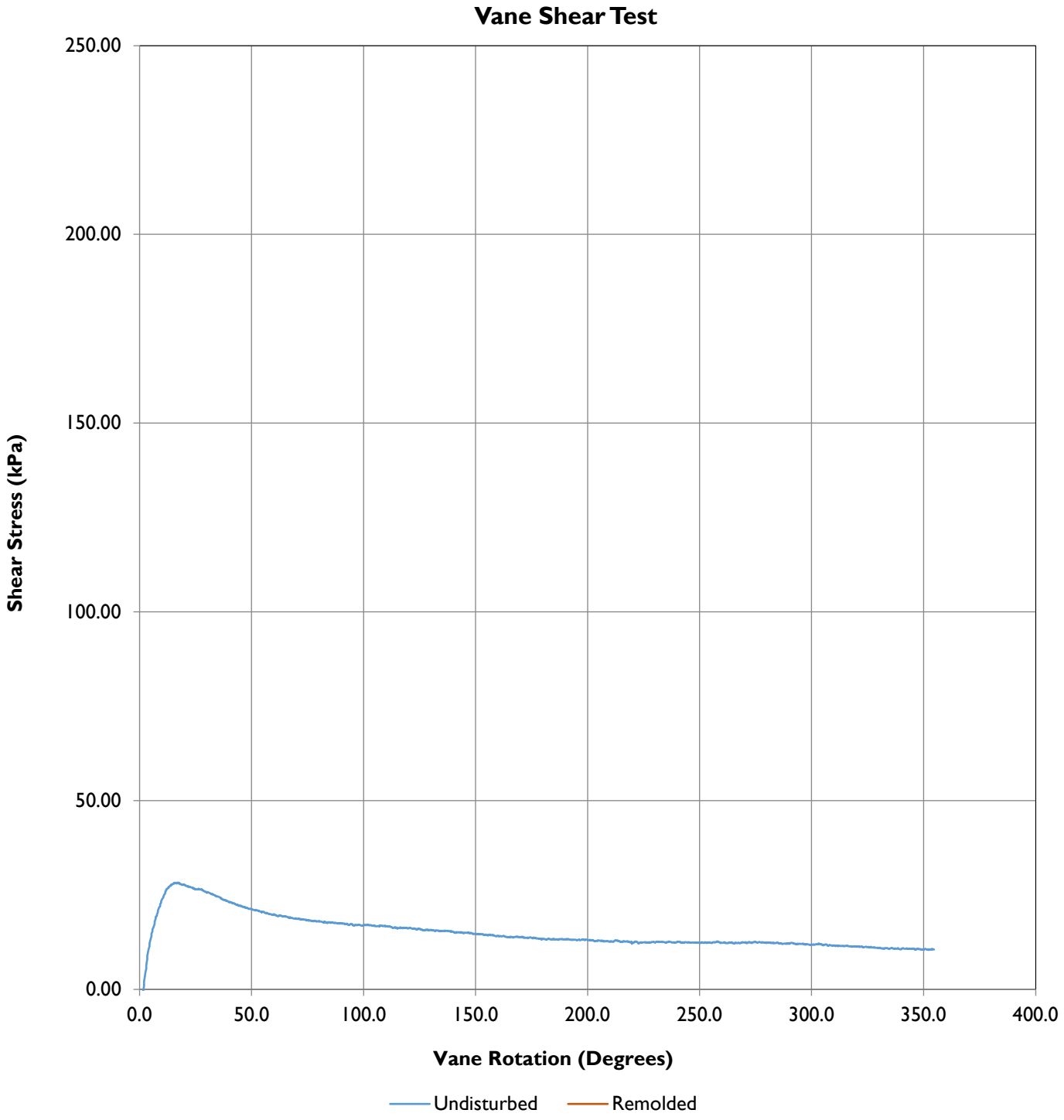
Vane Shear Test

Test Location:	**TSF2-CPT15**
Test Depth:	**5.1m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**
Project:	**TSF2-4**
Location:	**Saraji**
Date Tested:	**15/07/2020**
Tested By:	**IGS**

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631928.4*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521486.0*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.7m (AHD)

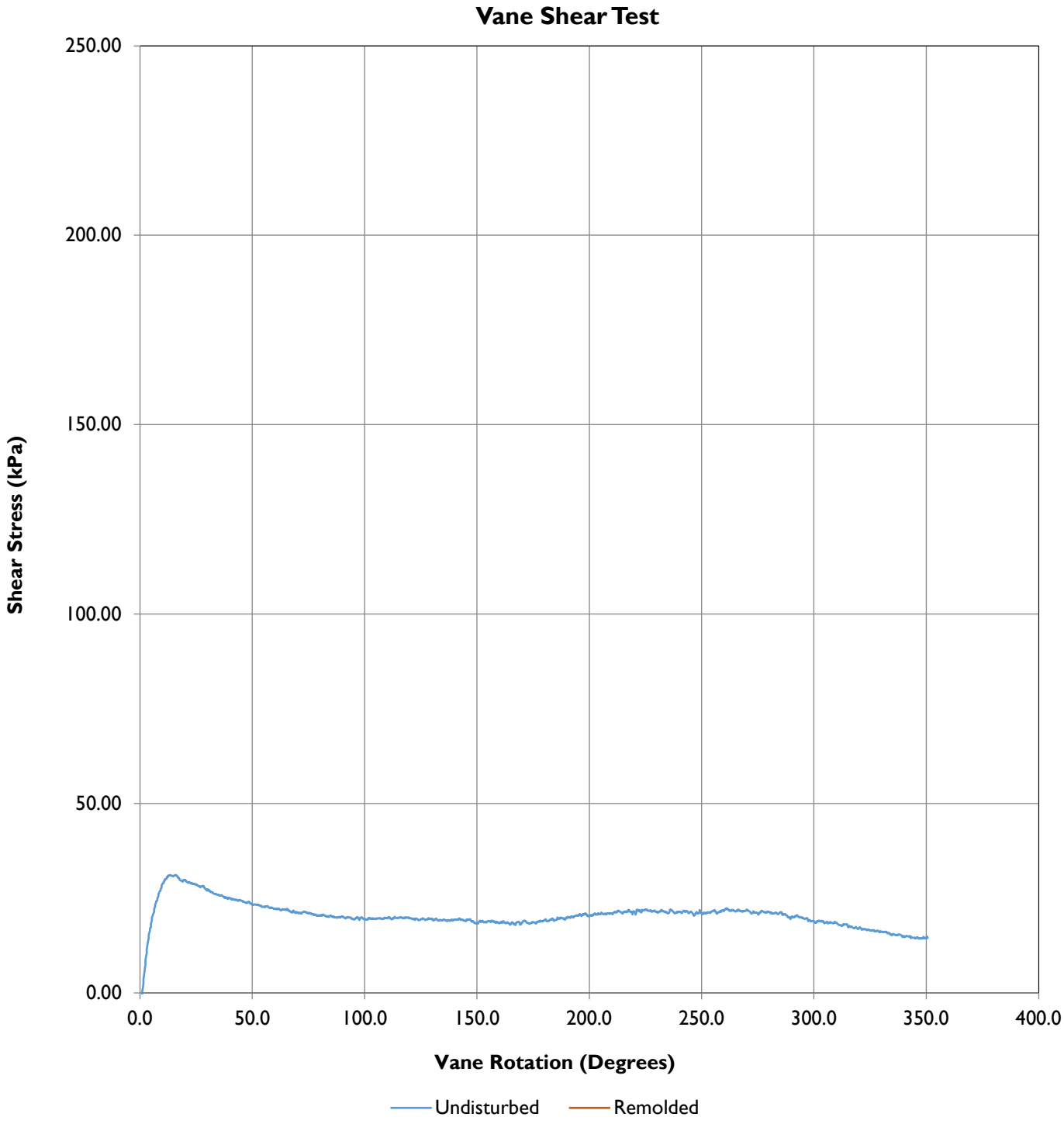


T:\04 BRIS\B01229-4 BMA, TSF2 to 4, Saraji\06 Site Investigation\05 CPT Results\01 TSF2\01 EDG Template\02 EDG VS Template\[TSF2-CPT15_VS.xlsm]

Vane Shear Test

Test Location:	**TSF2-CPT15**		
Test Depth:	**7m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**25/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631928.4*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521486.0*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.7m (AHD)



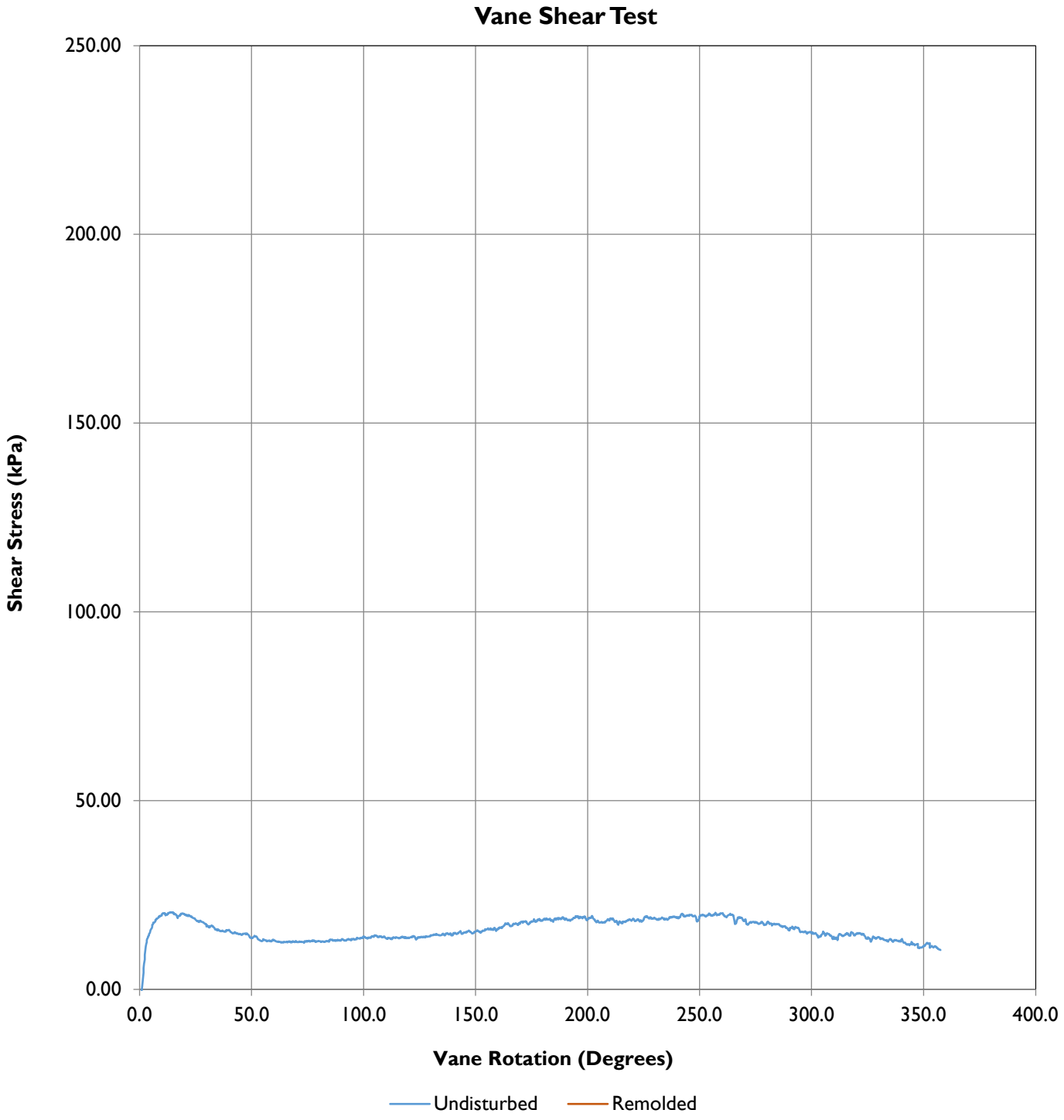
Vane Shear Test

Test Location:	**TSF2-CPT15**
Test Depth:	**9.5m**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**
Project:	**TSF2-4**
Location:	**Saraji**
Date Tested:	**25/07/2020**
Tested By:	**IGS**

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631928.4*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521486.0*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.7m (AHD)

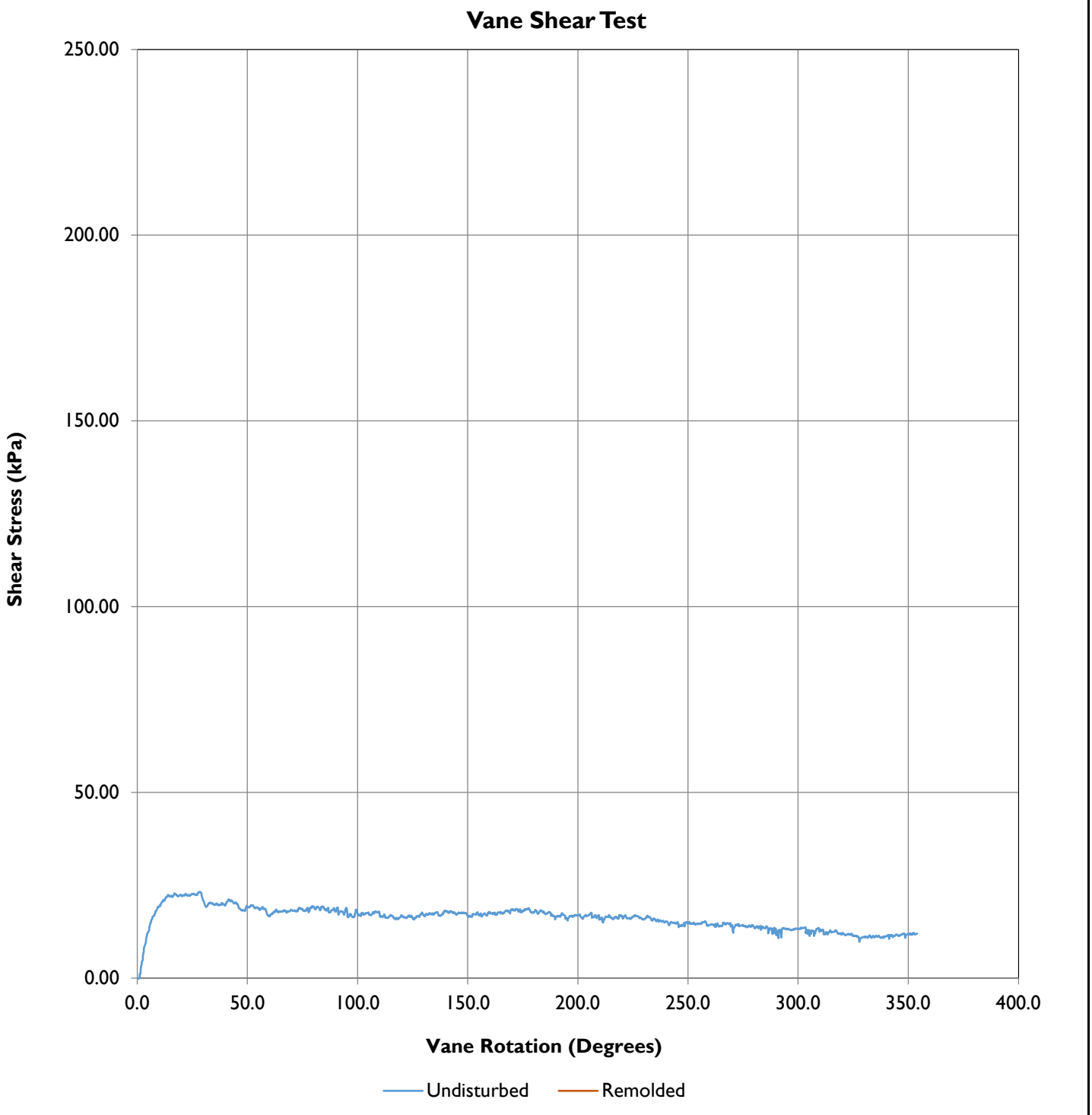


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Vane Shear Test

Test Location:	**TSF2-CPT15**		
Test Depth:	**11m**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**25/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631928.4*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521486.0*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.7m (AHD)



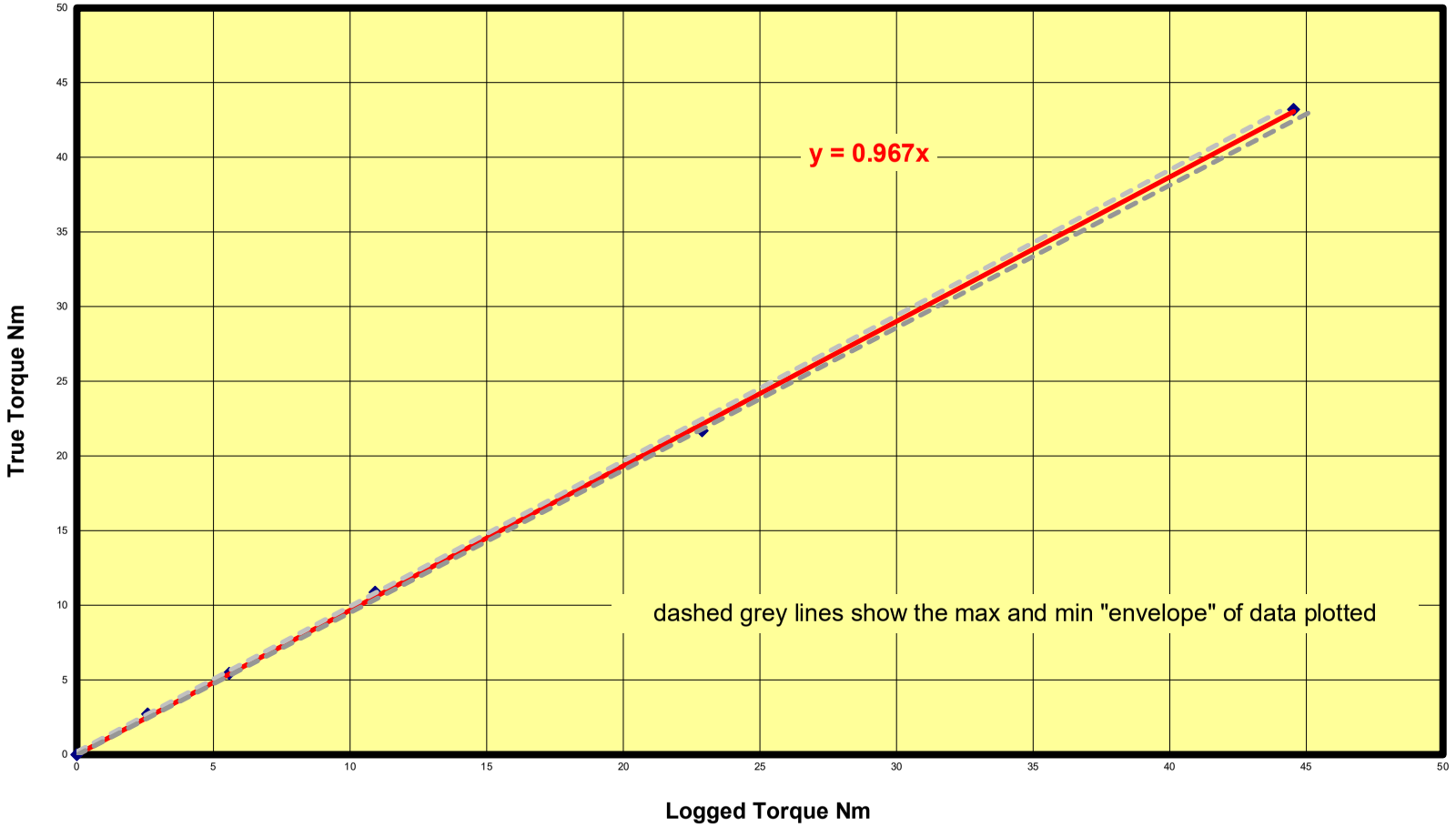
T:\04 BRIS\B01229-4 BMA, TSF2 to 4, Saraji\06 Site Investigation\05 CPT Results\01 TSF2\01 EDG Template\02 EDG VS Template\[TSF2-CPT15_VS.xlsm]

Vane Shear Data Acquisition System Calibration
Insitu Geotech Services Pty Ltd (IGS)

Type: Geomil
Number: 0002
Date: 15-Jun-2018

To adjust for this calibration use the adjusted vane constants below in the IGS Importer sheet
Set max Su in data acquisition software (on "Parameters" page) at blue value shown below
(refer to IGS web site www.insitu.com.au for additional information)

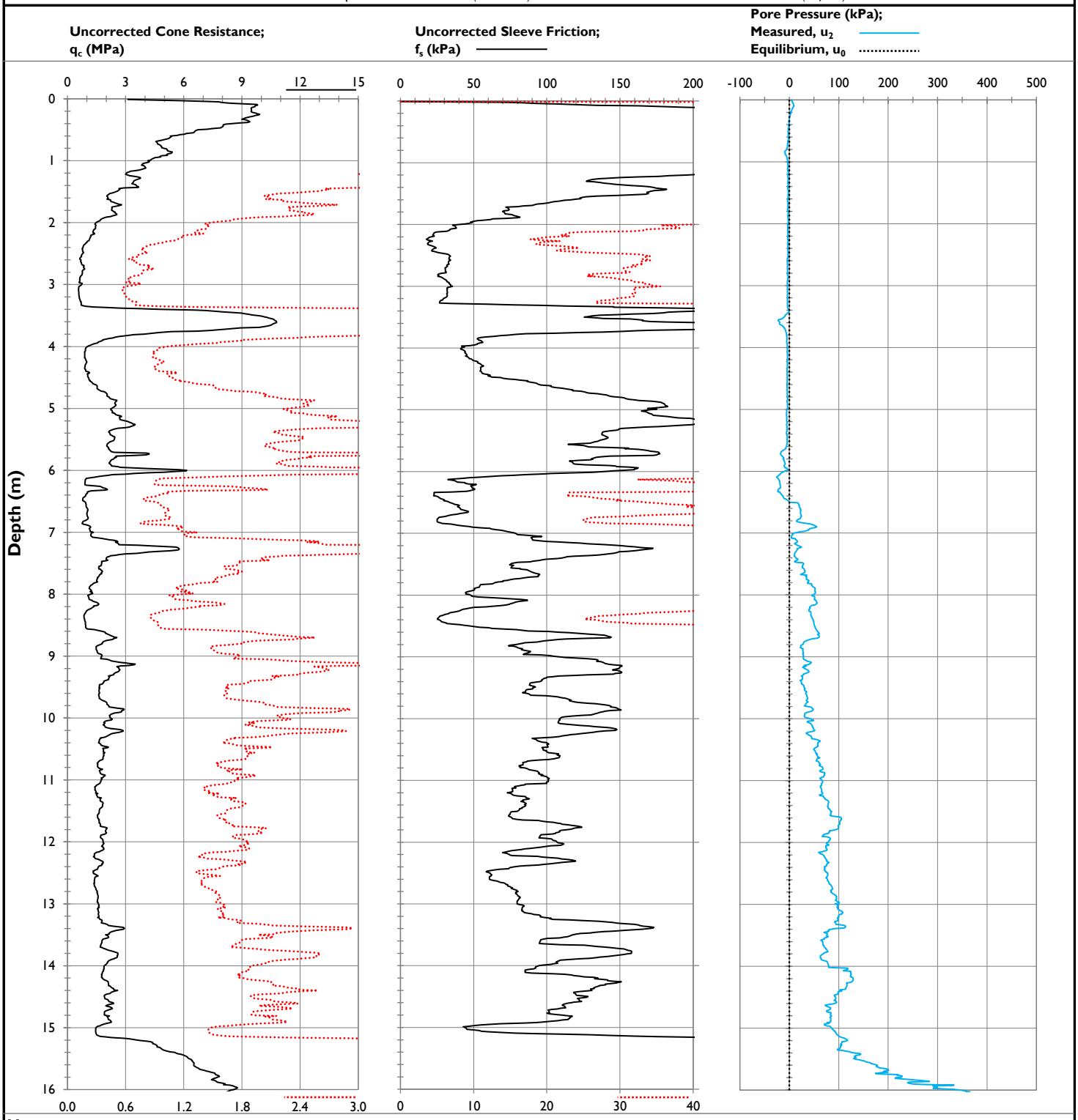
50 x 100 vane	75 x 150 vane	100 x 200 vane
1.796	0.595	0.258
108	36	15



Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH01**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631931.2 (AGD66 /*	R.L. Surface:	*222.2m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521647.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.81*	Depth to GW:	*16.0m (Estimated)*	Termination:	*23.38m (Refusal)*		

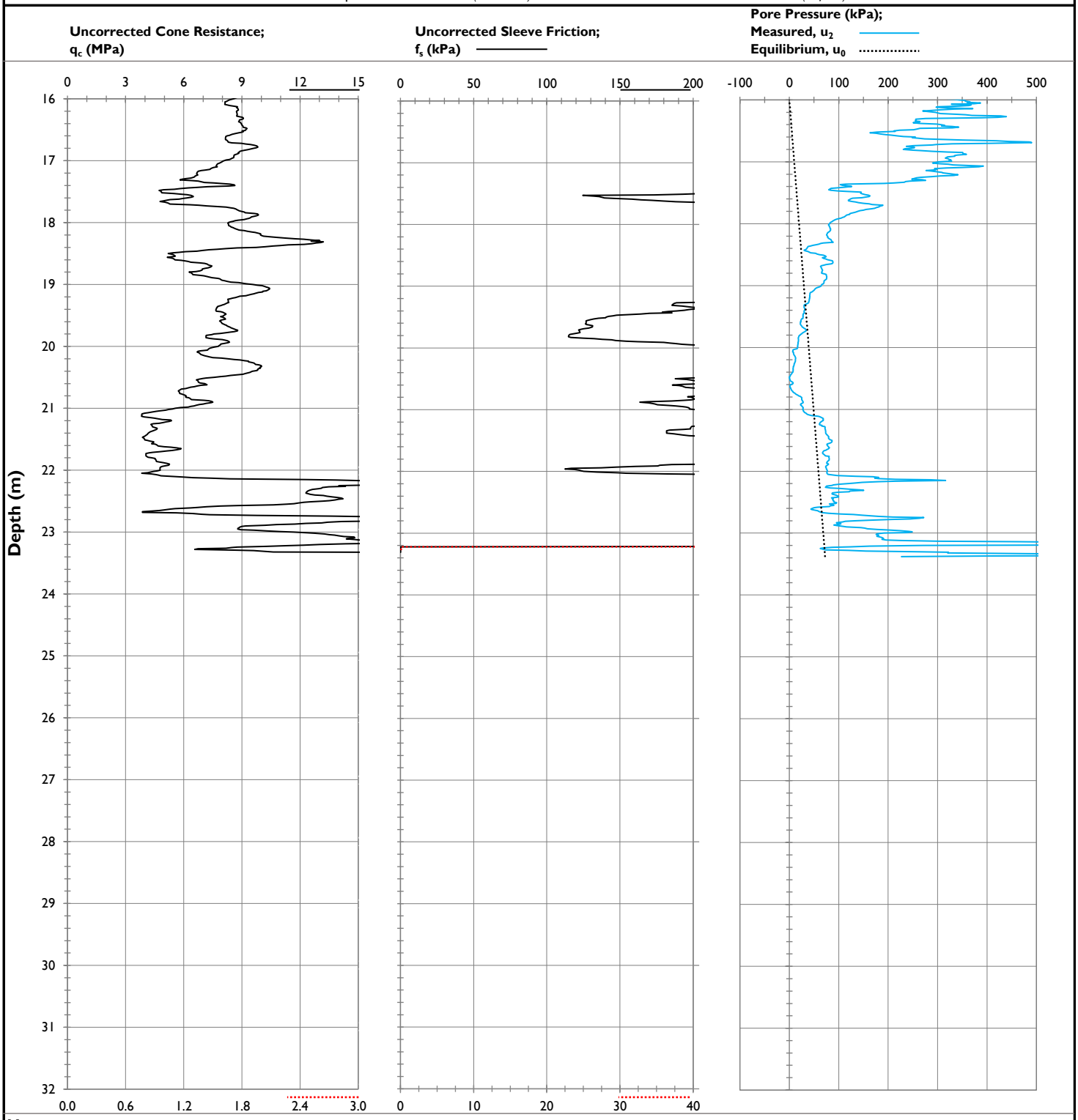


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH01**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631931.2 (AGD66 /*	R.L. Surface:	*222.2m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521647.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.81*	Depth to GW:	*16.0m (Estimated)*	Termination:	*23.38m (Refusal)*		

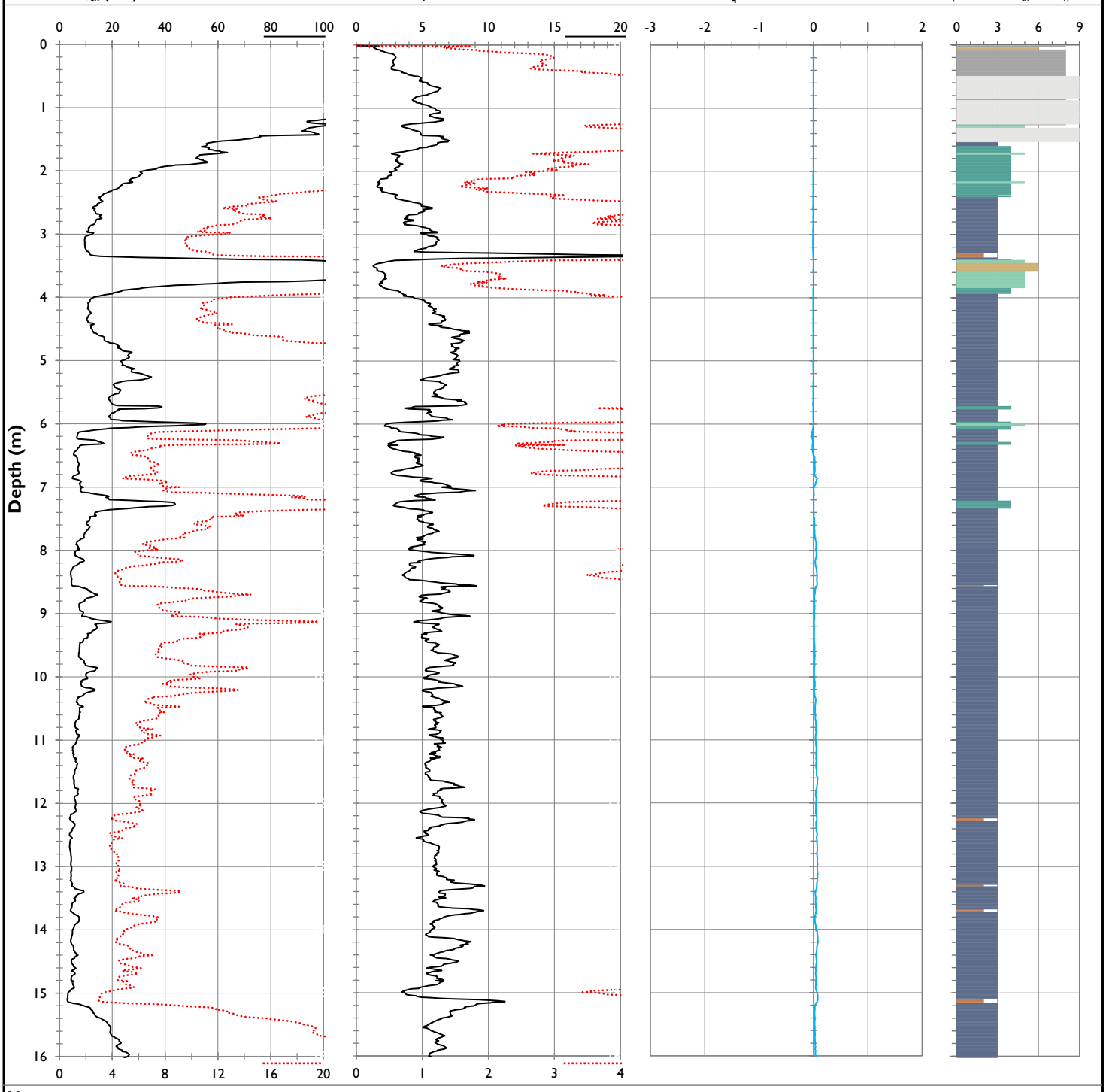


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH01**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631931.2 (AGD66 /*	R.L. Surface:	*222.2m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521647.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.81*	Depth to GW:	*16.0m (Estimated)*	Termination:	*23.38m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

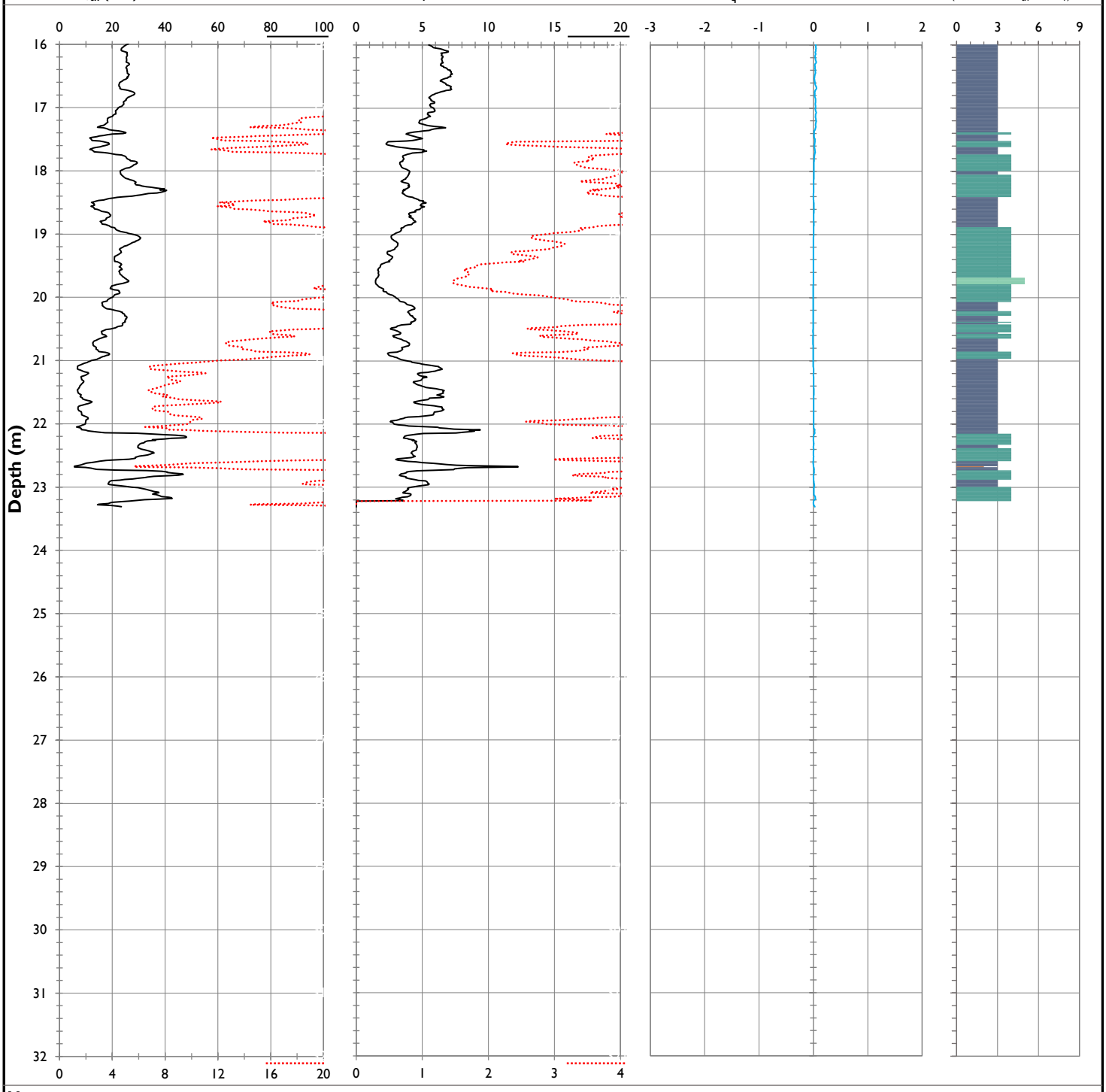
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH01**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631931.2 (AGD66 /* R.L. Surface: *222.2m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521647.1 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.81*	Depth to GW:	*16.0m (Estimated)*	Termination:	*23.38m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

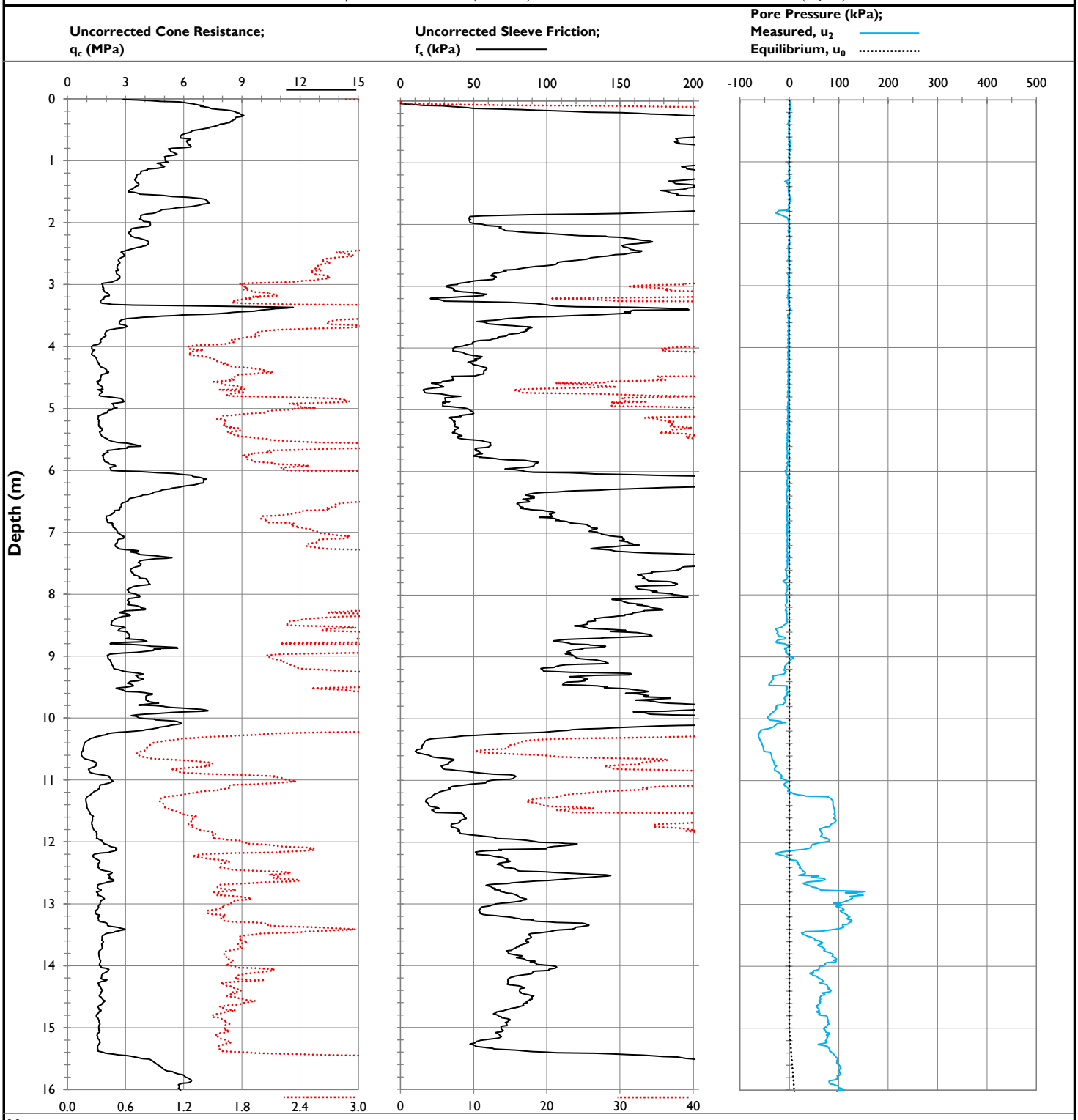
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH02**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631936.7 (AGD66 /*	R.L. Surface:	*222.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521639.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.81*	Depth to GW:	*15.0m (Estimated)*	Termination:	*23.68m (Refusal)*		

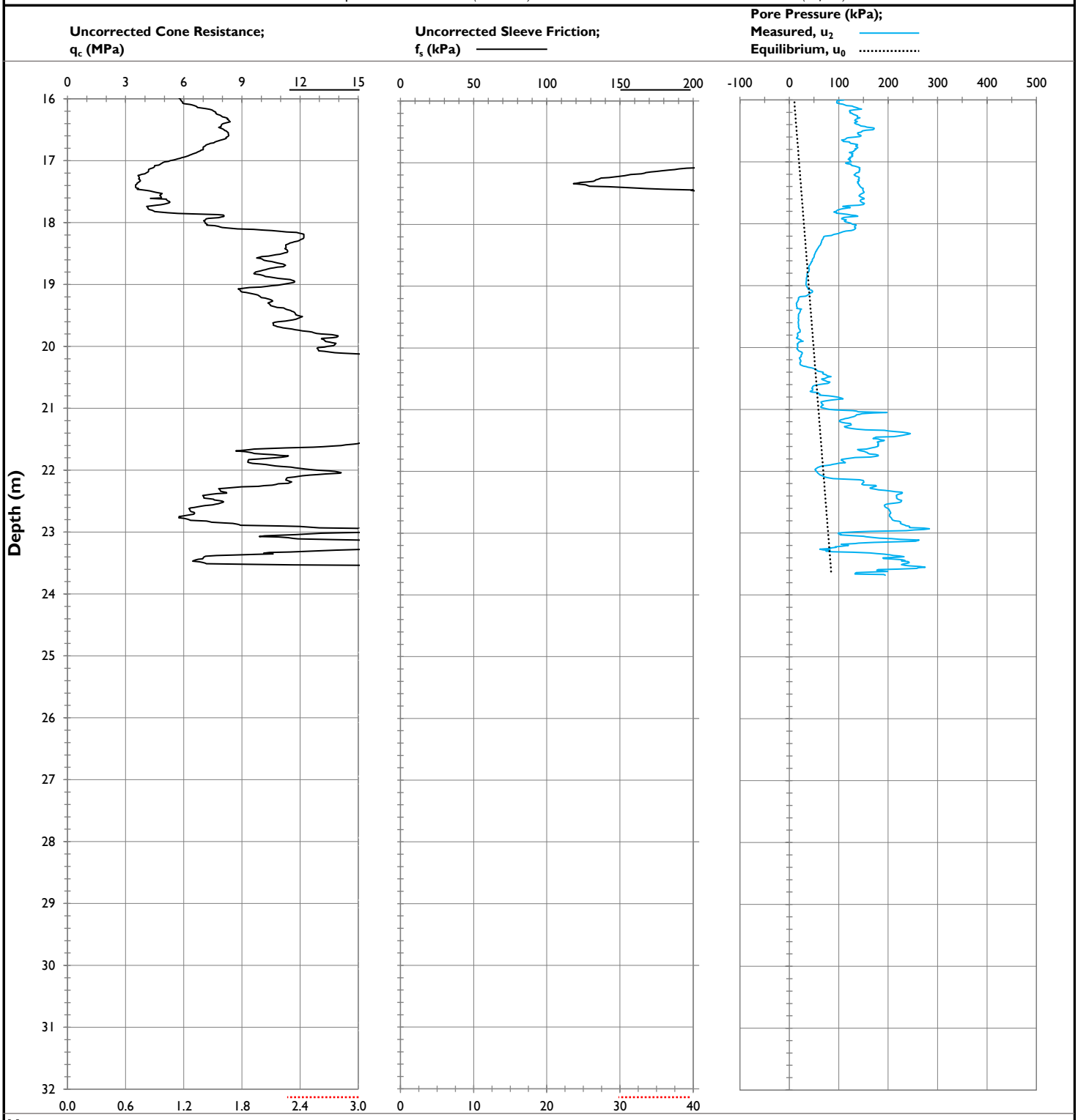


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH02**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631936.7 (AGD66 /*	R.L. Surface:	*222.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521639.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.81*	Depth to GW:	*15.0m (Estimated)*	Termination:	*23.68m (Refusal)*		

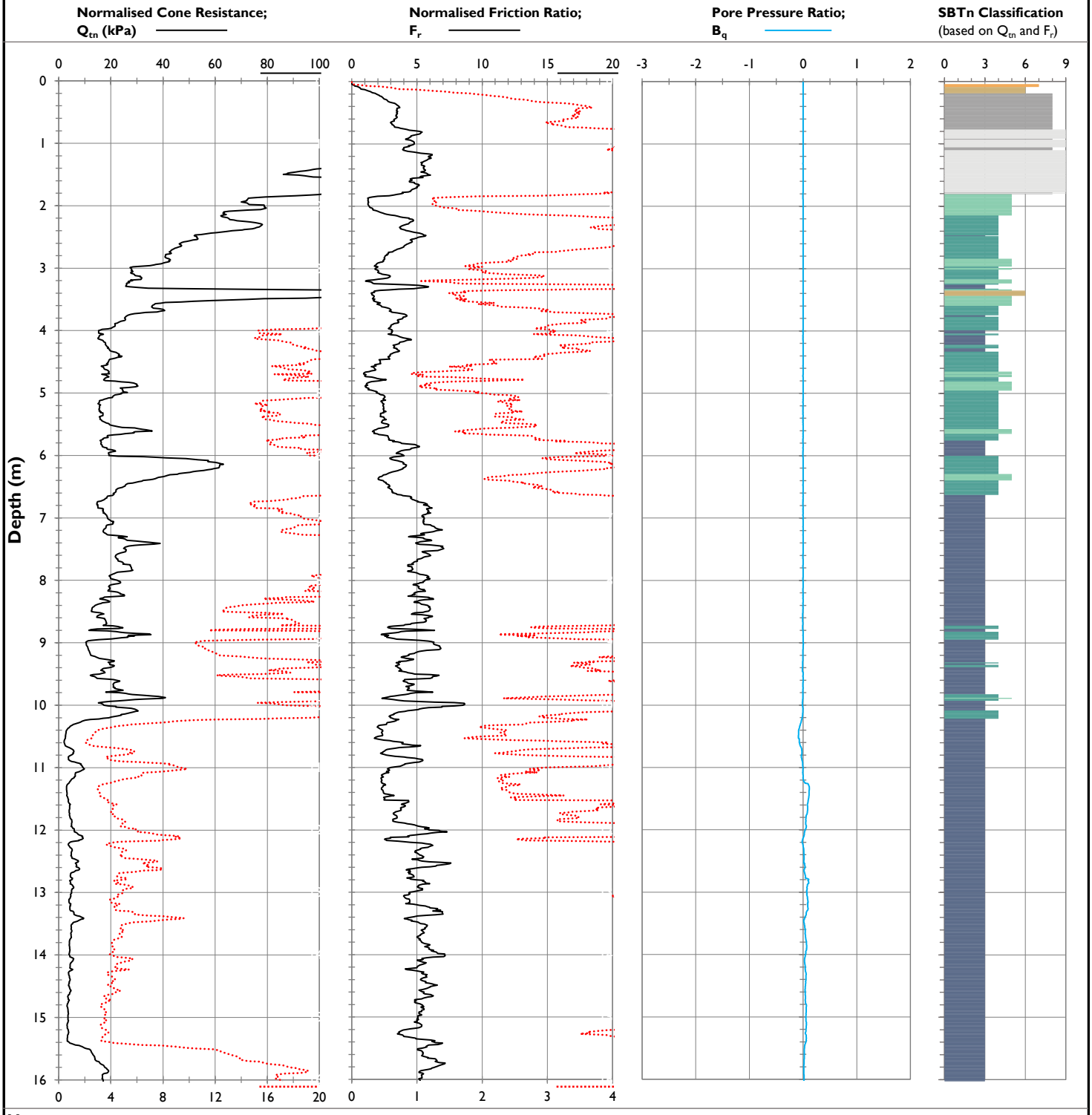


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH02**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631936.7 (AGD66 /*	R.L. Surface:	*222.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521639.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.81*	Depth to GW:	*15.0m (Estimated)*	Termination:	*23.68m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

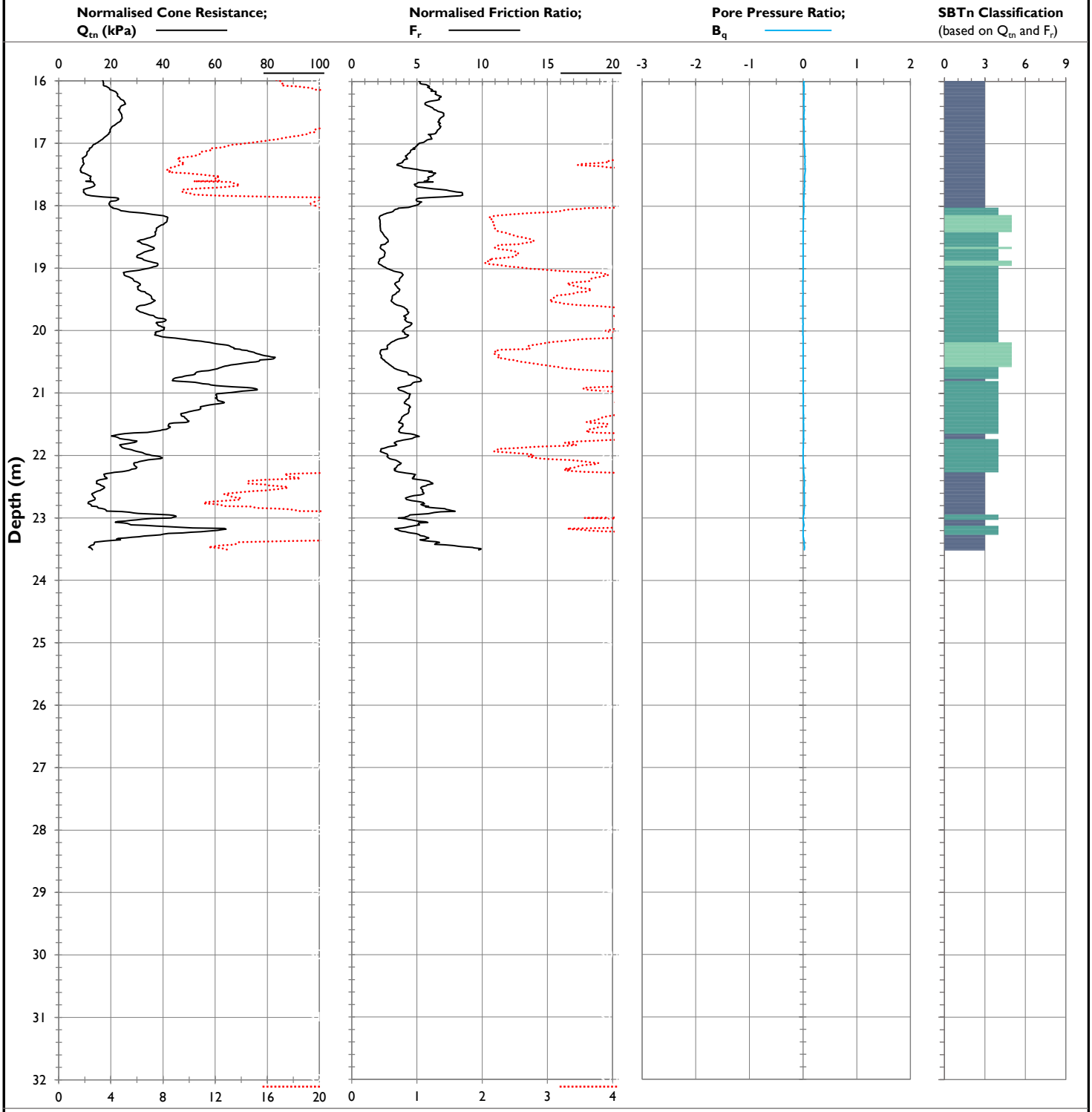
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH02**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631936.7 (AGD66 /* R.L. Surface: *222.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521639.1 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.81*	Depth to GW:	*15.0m (Estimated)*	Termination:	*23.68m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

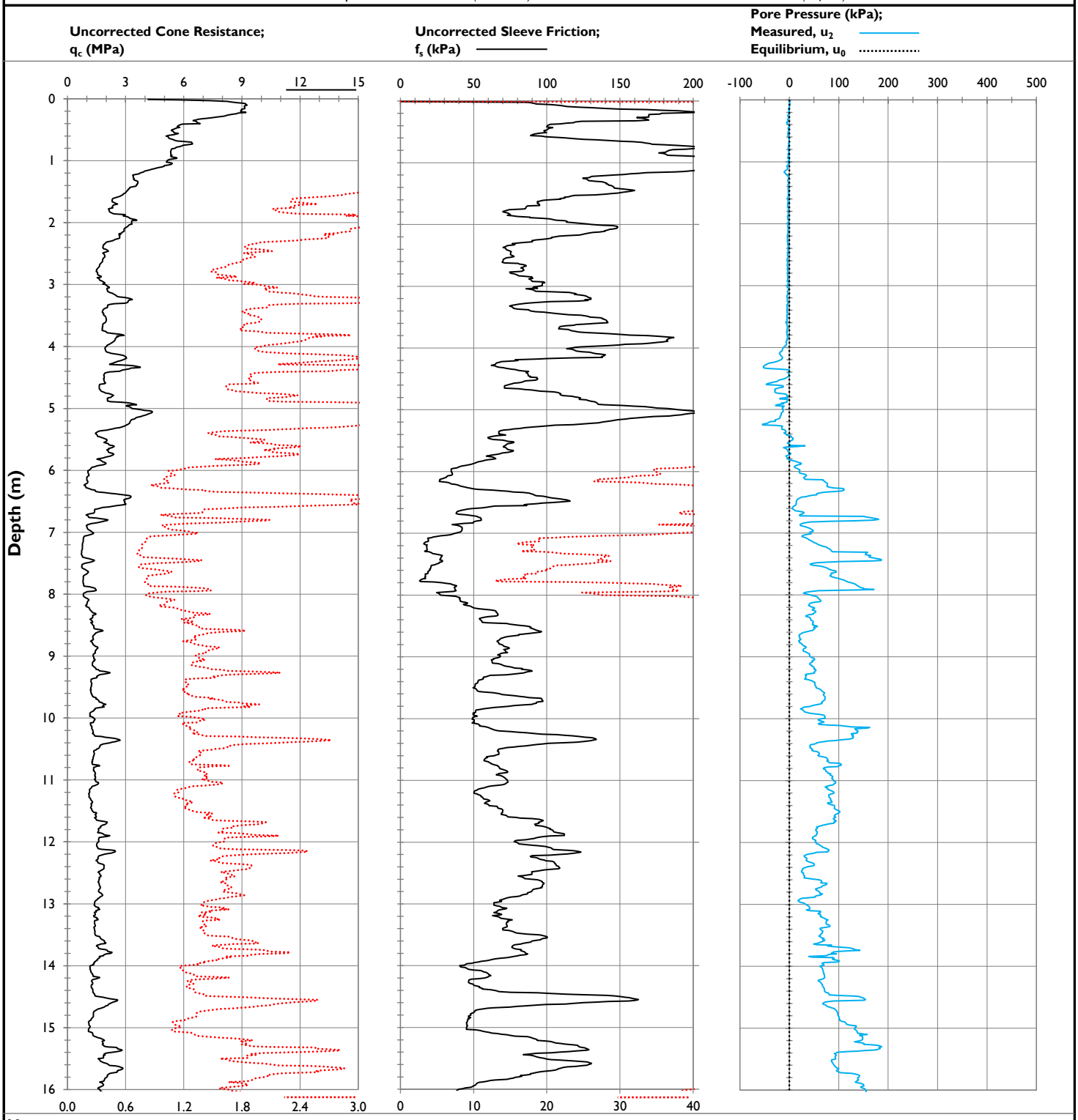
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH03**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**28/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631838.69 (AGD66* R.L. Surface: *220.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521582.462 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*18.44m (Refusal)*

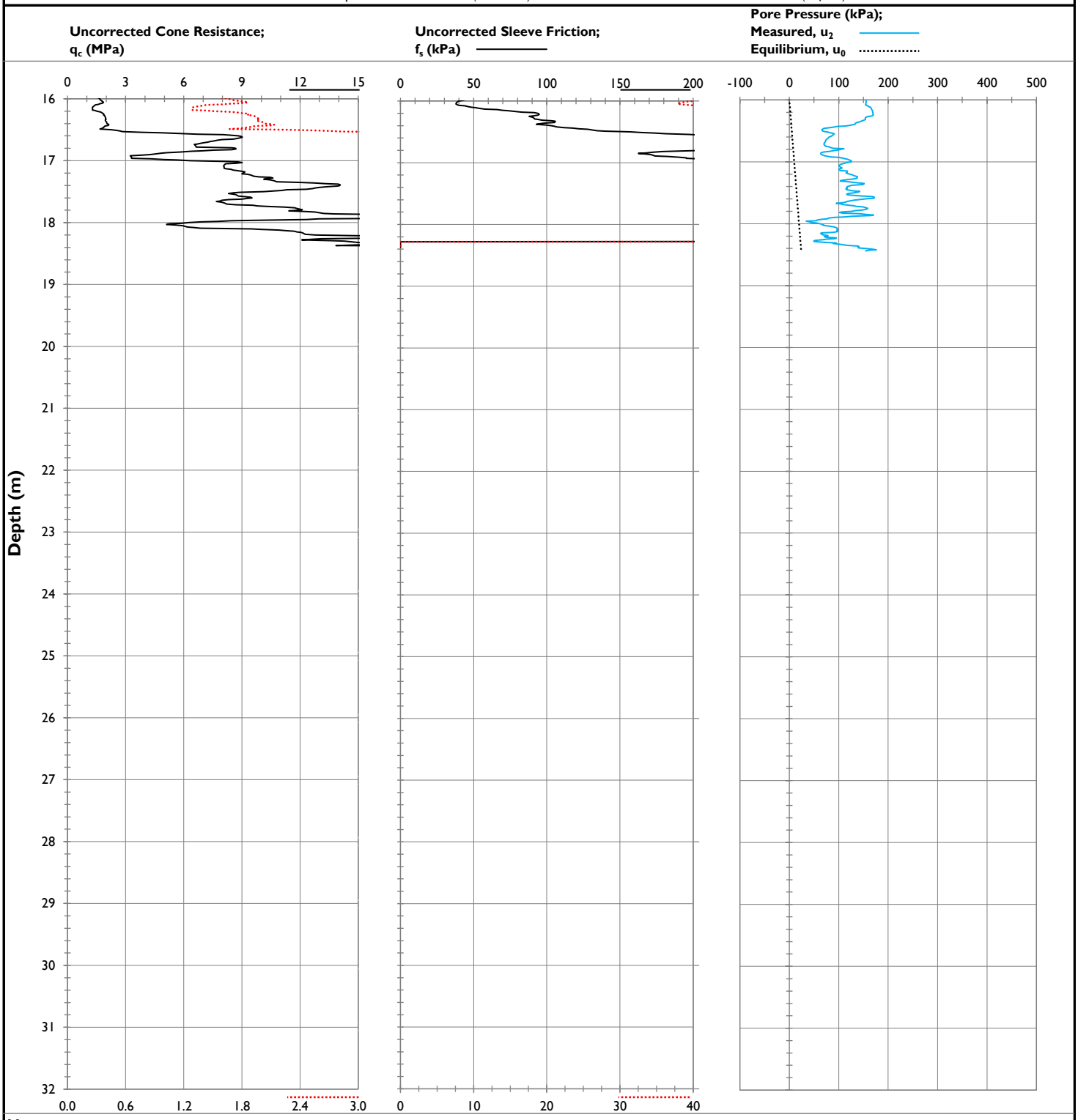


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH03**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**28/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631838.69 (AGD66* R.L. Surface: *220.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521582.462 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*18.44m (Refusal)*

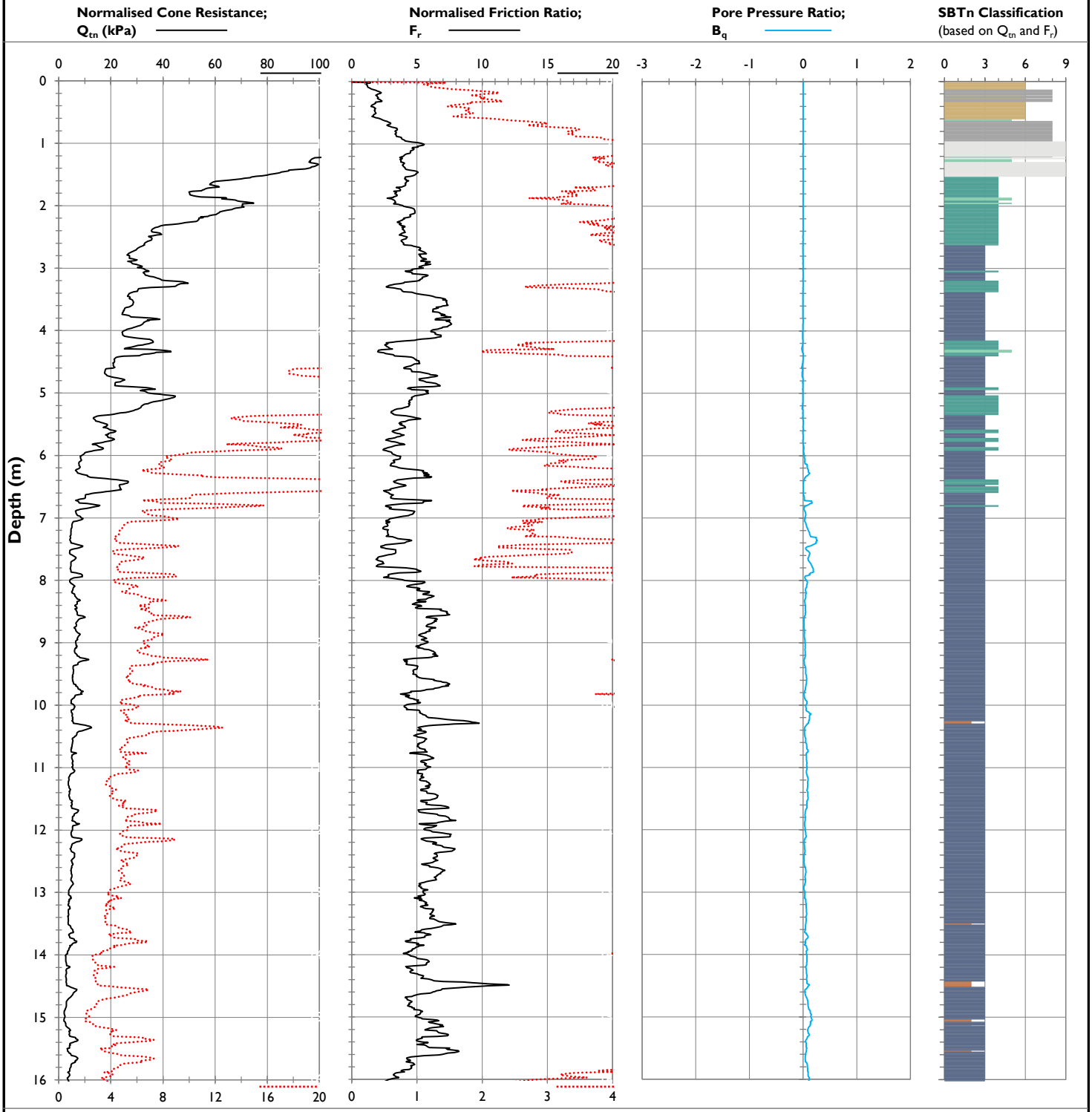


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH03**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**28/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631838.69 (AGD66* R.L. Surface: *220.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521582.462 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*18.44m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

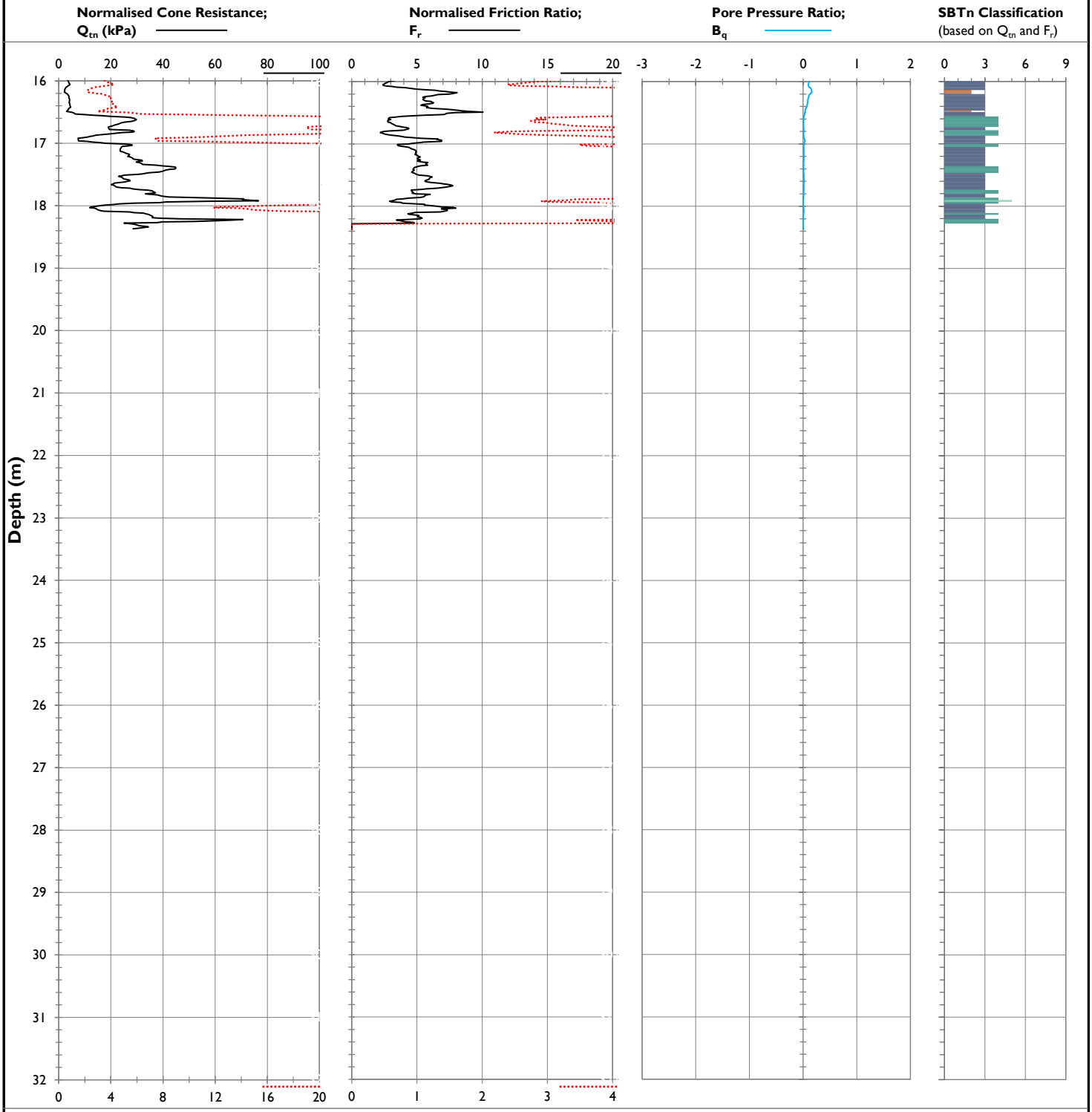
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH03**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**28/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631838.69 (AGD66* R.L. Surface: *220.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521582.462 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*18.44m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

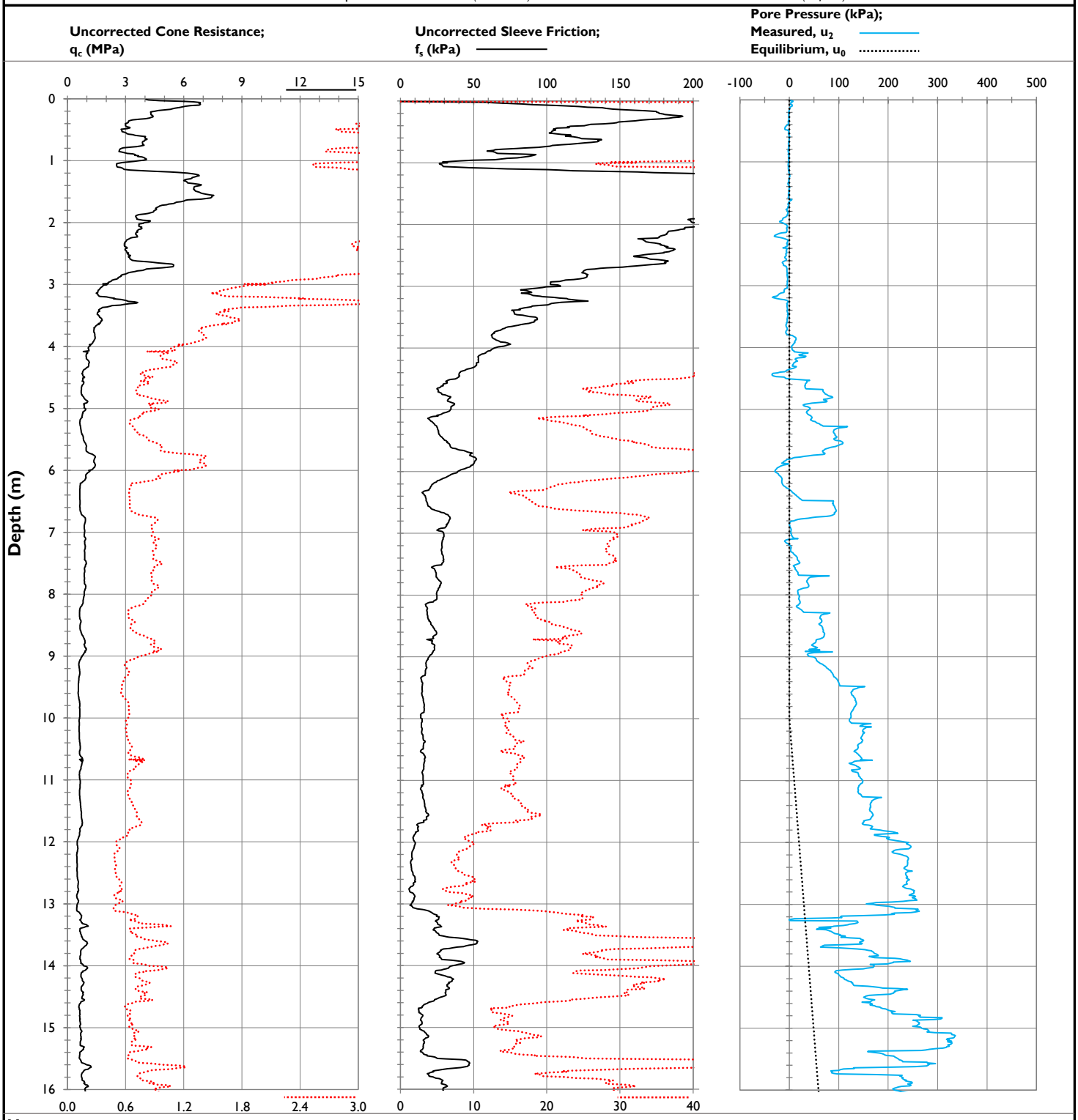
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH04**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**28/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631846 (AGD66 / A*	R.L. Surface:	*220.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521574.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*10.0m (Estimated)*	Termination:	*18.95m (Refusal)*		

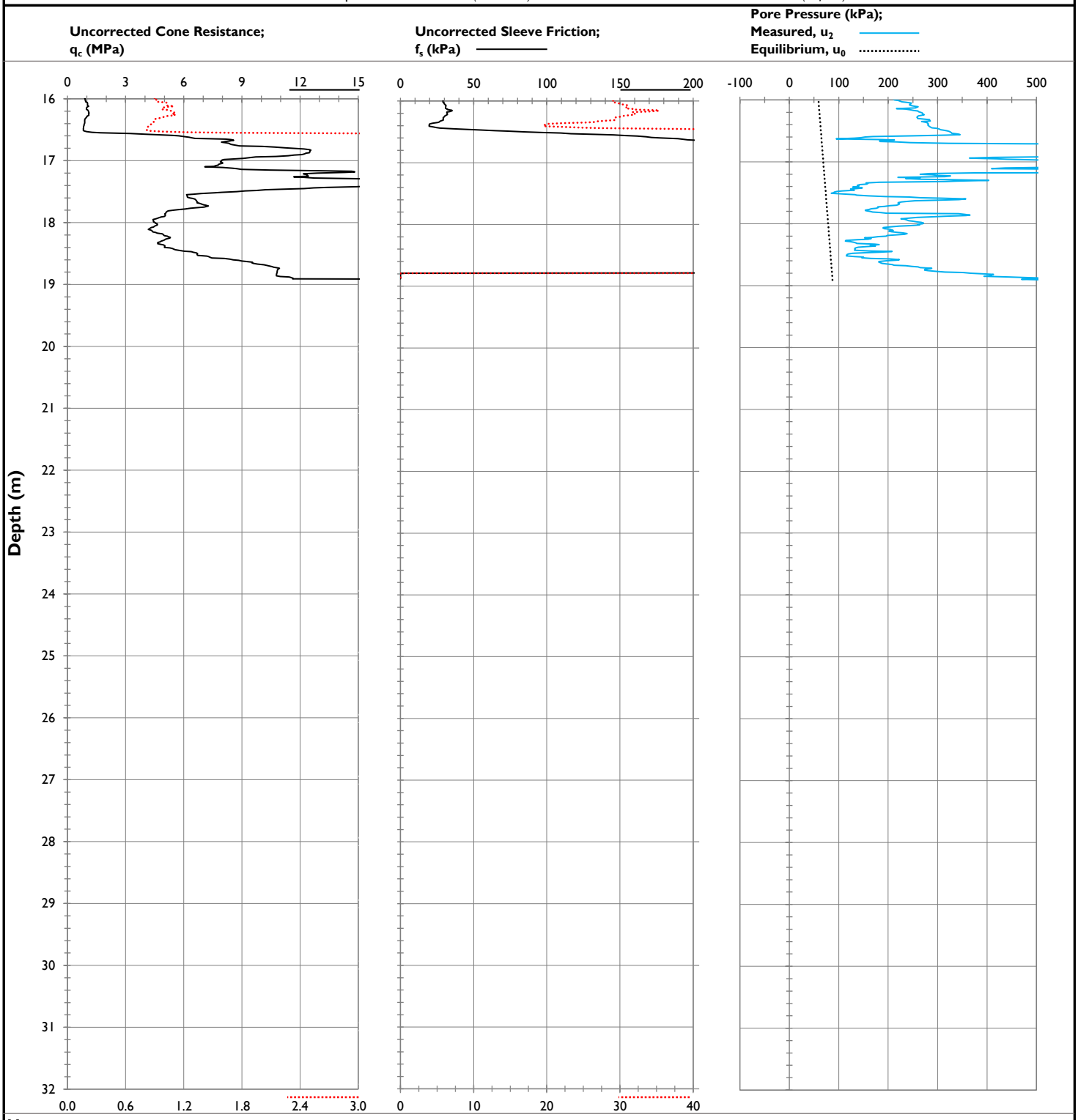


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH04**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**28/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631846 (AGD66 / A* R.L. Surface: *220.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521574.1 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*10.0m (Estimated)*	Termination:	*18.95m (Refusal)*

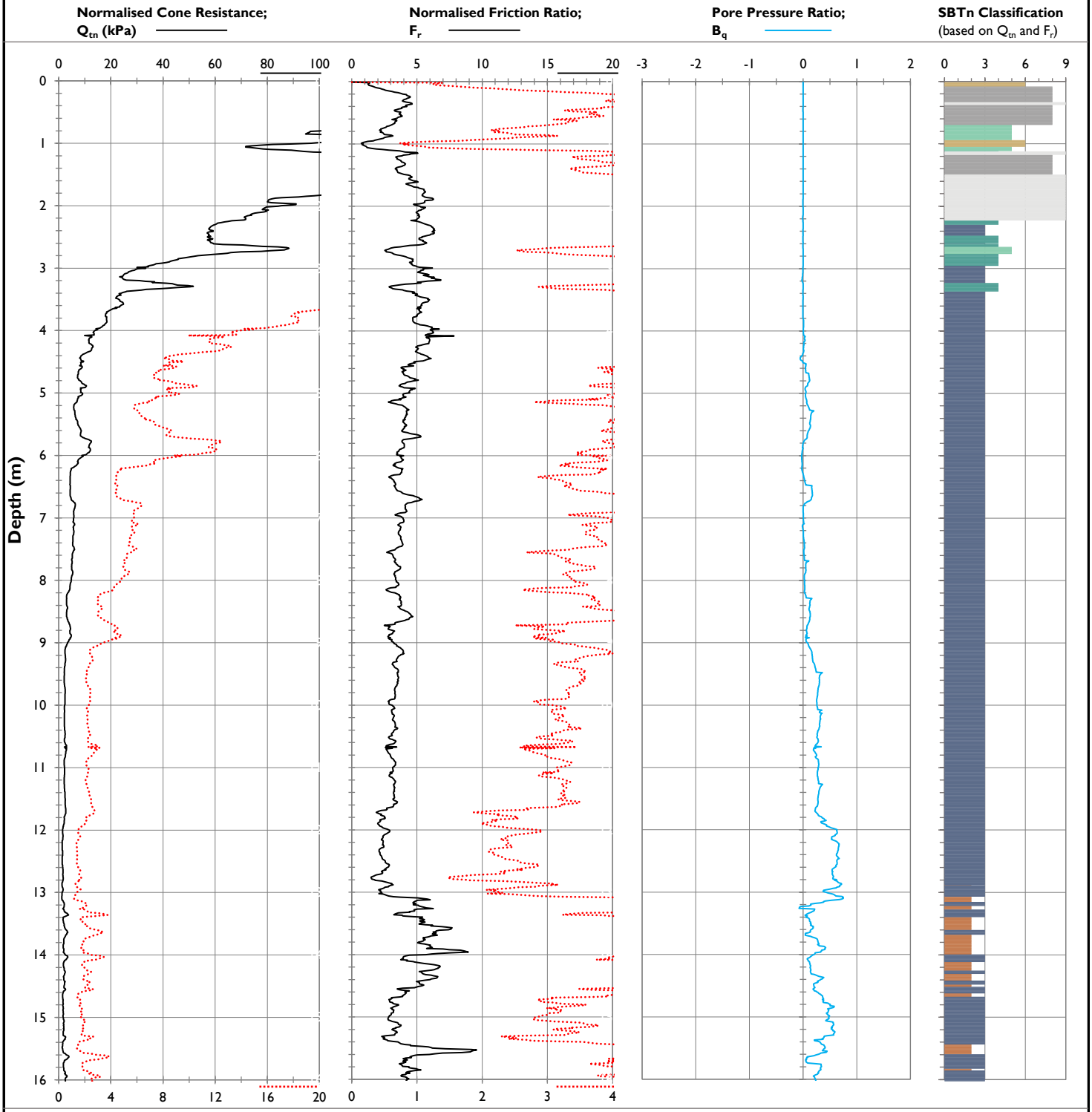


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH04**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**28/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631846 (AGD66 / A*	R.L. Surface:	*220.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521574.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*10.0m (Estimated)*	Termination:	*18.95m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

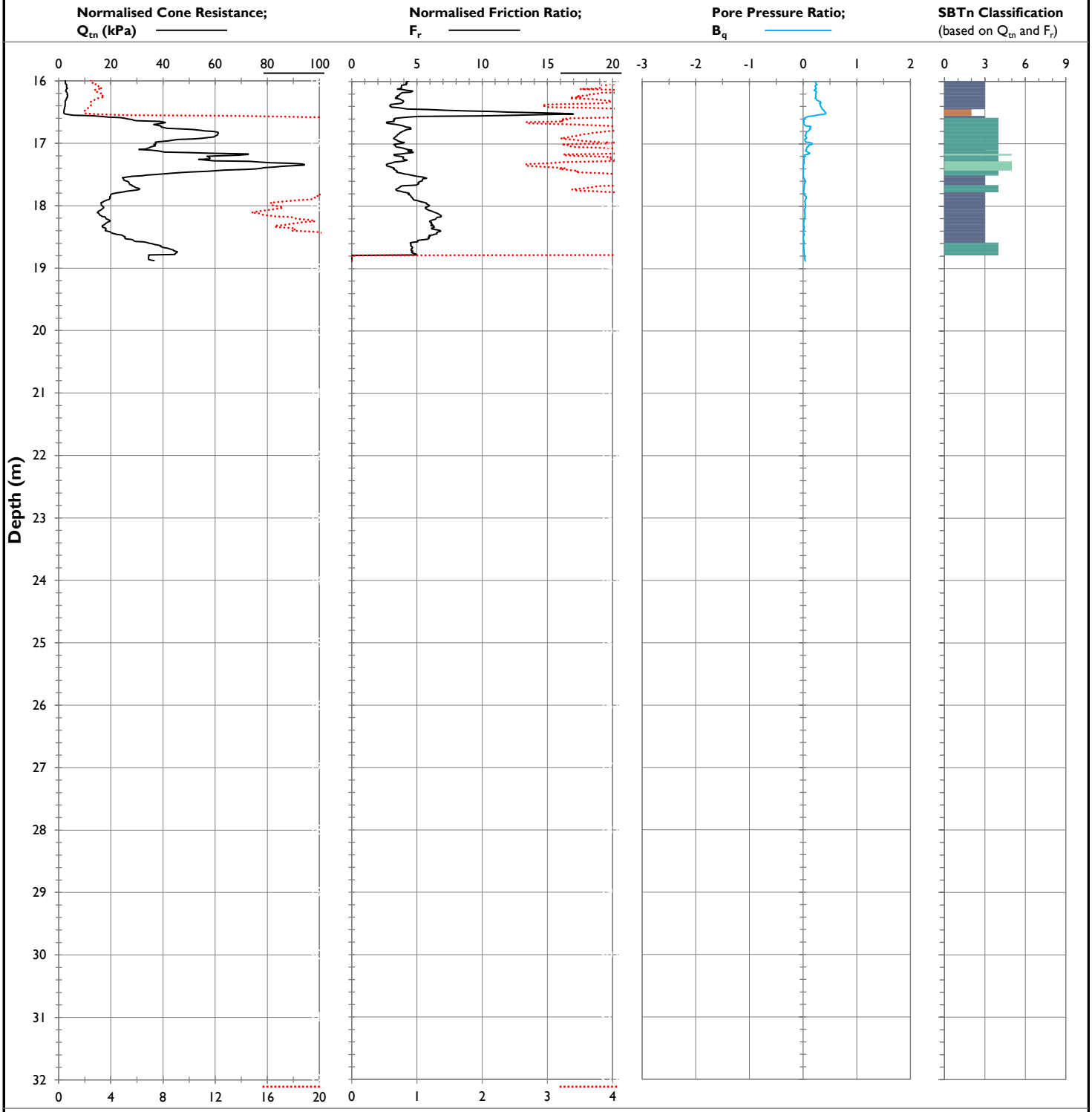
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH04**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**28/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631846 (AGD66 / A* R.L. Surface: *220.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521574.1 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*10.0m (Estimated)*	Termination:	*18.95m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

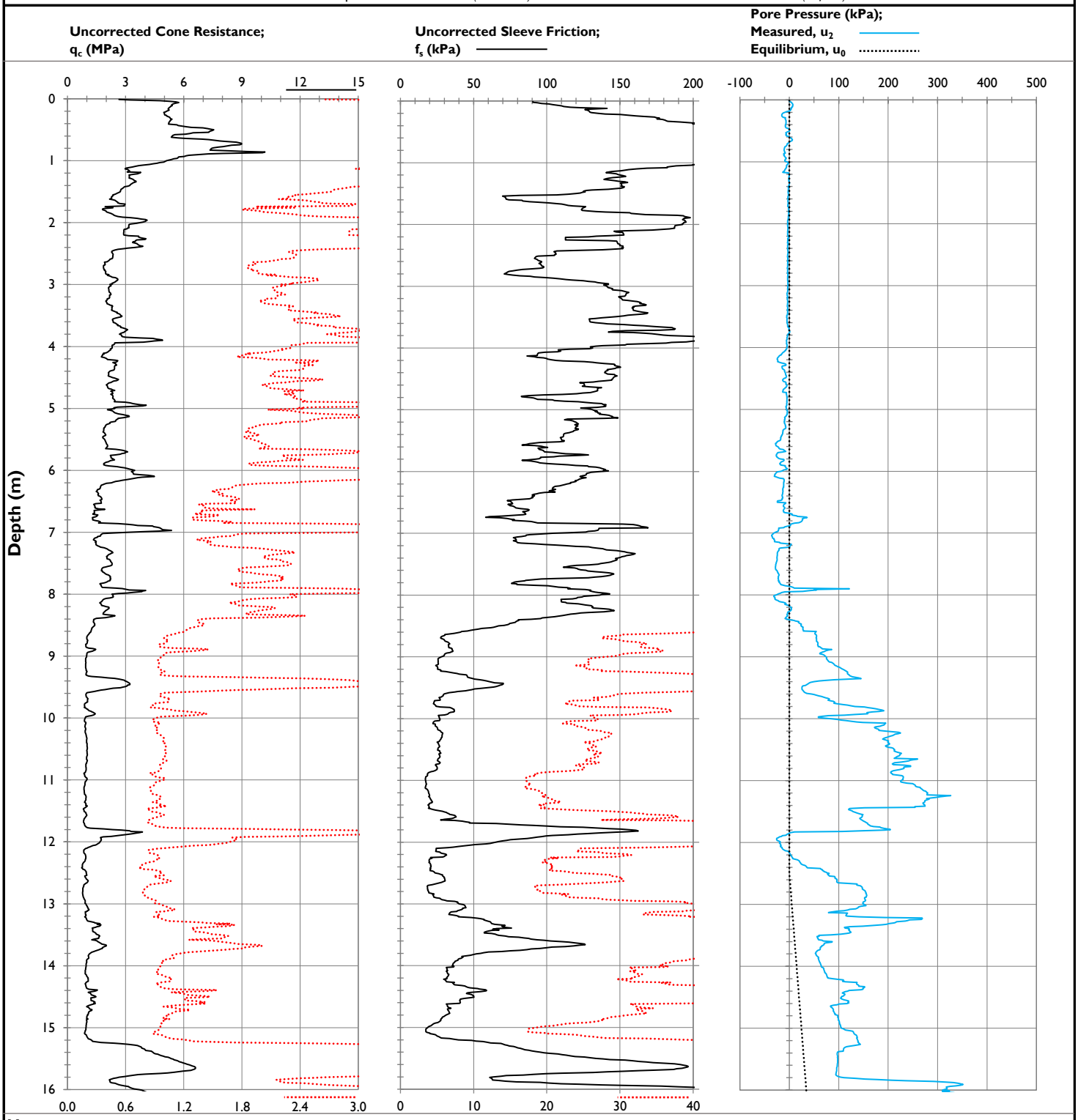
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH06**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631780 (AGD66 / A* R.L. Surface: *220.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521462.3 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.81*	Depth to GW:	*12.5m (Estimated)*	Termination:	*18.19m (Refusal)*

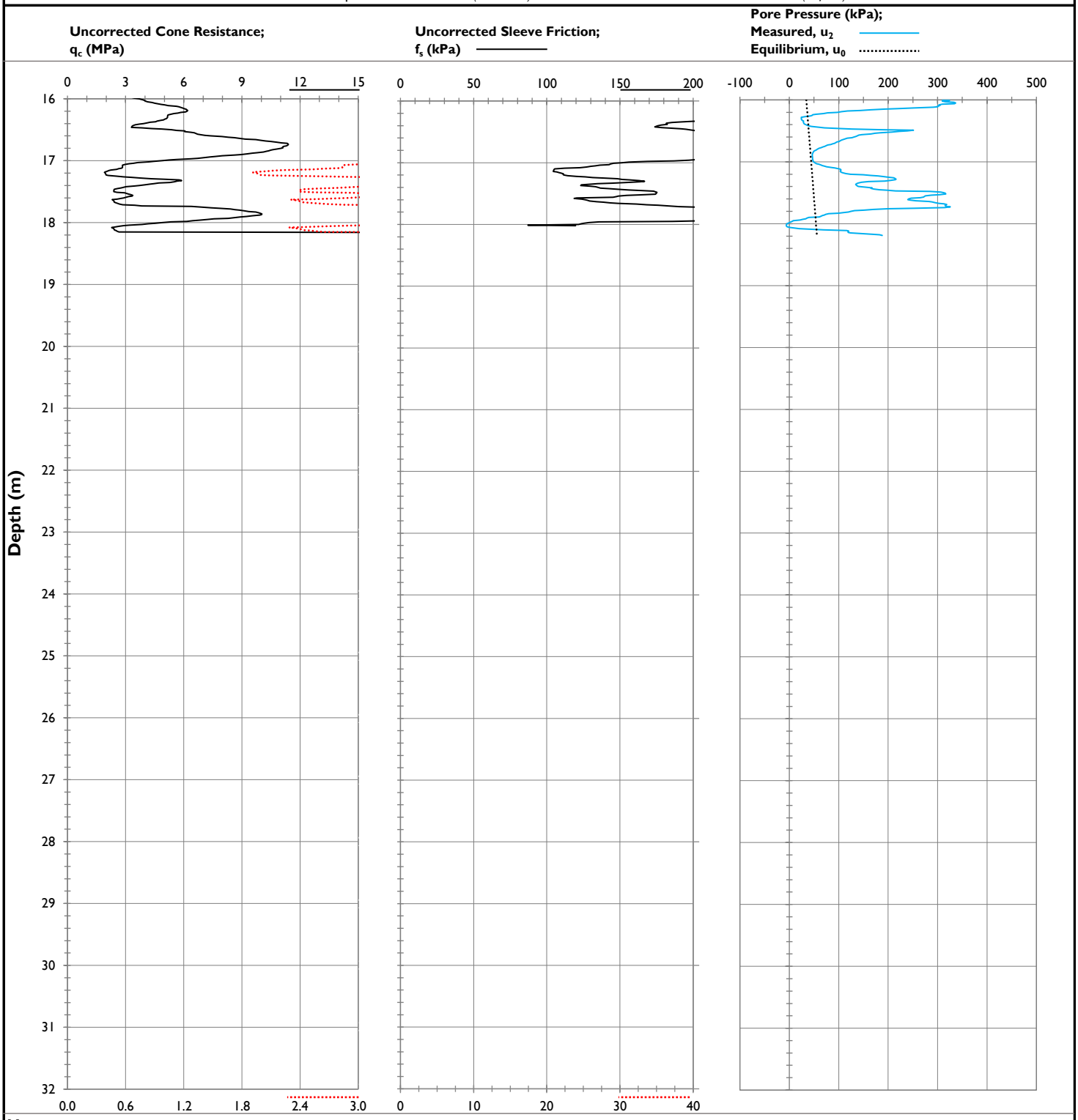


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH06**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631780 (AGD66 / A*	R.L. Surface:	*220.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521462.3 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.81*	Depth to GW:	*12.5m (Estimated)*	Termination:	*18.19m (Refusal)*		

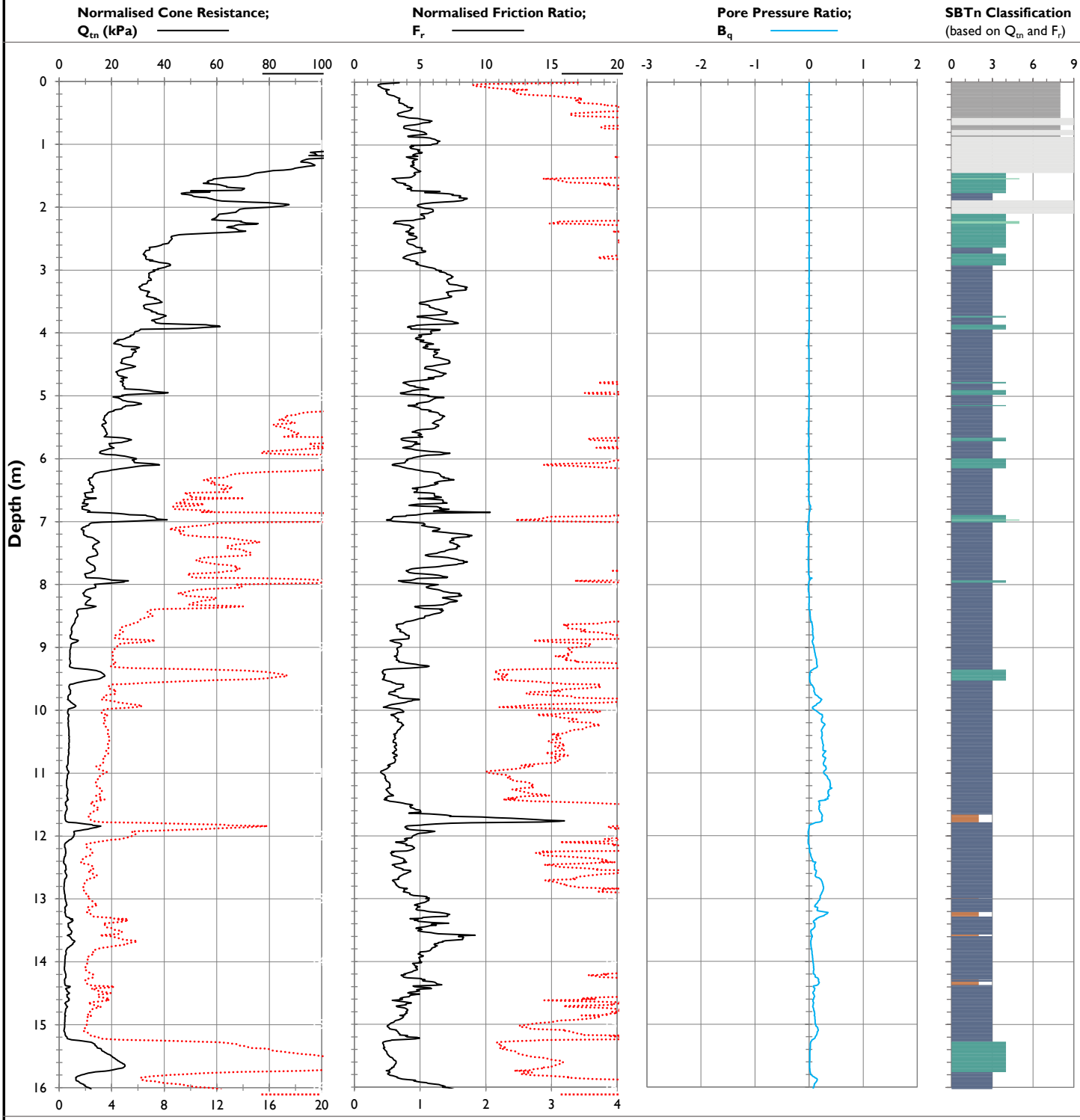


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH06**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631780 (AGD66 / A* R.L. Surface: *220.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521462.3 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.81*	Depth to GW:	*12.5m (Estimated)*	Termination:	*18.19m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

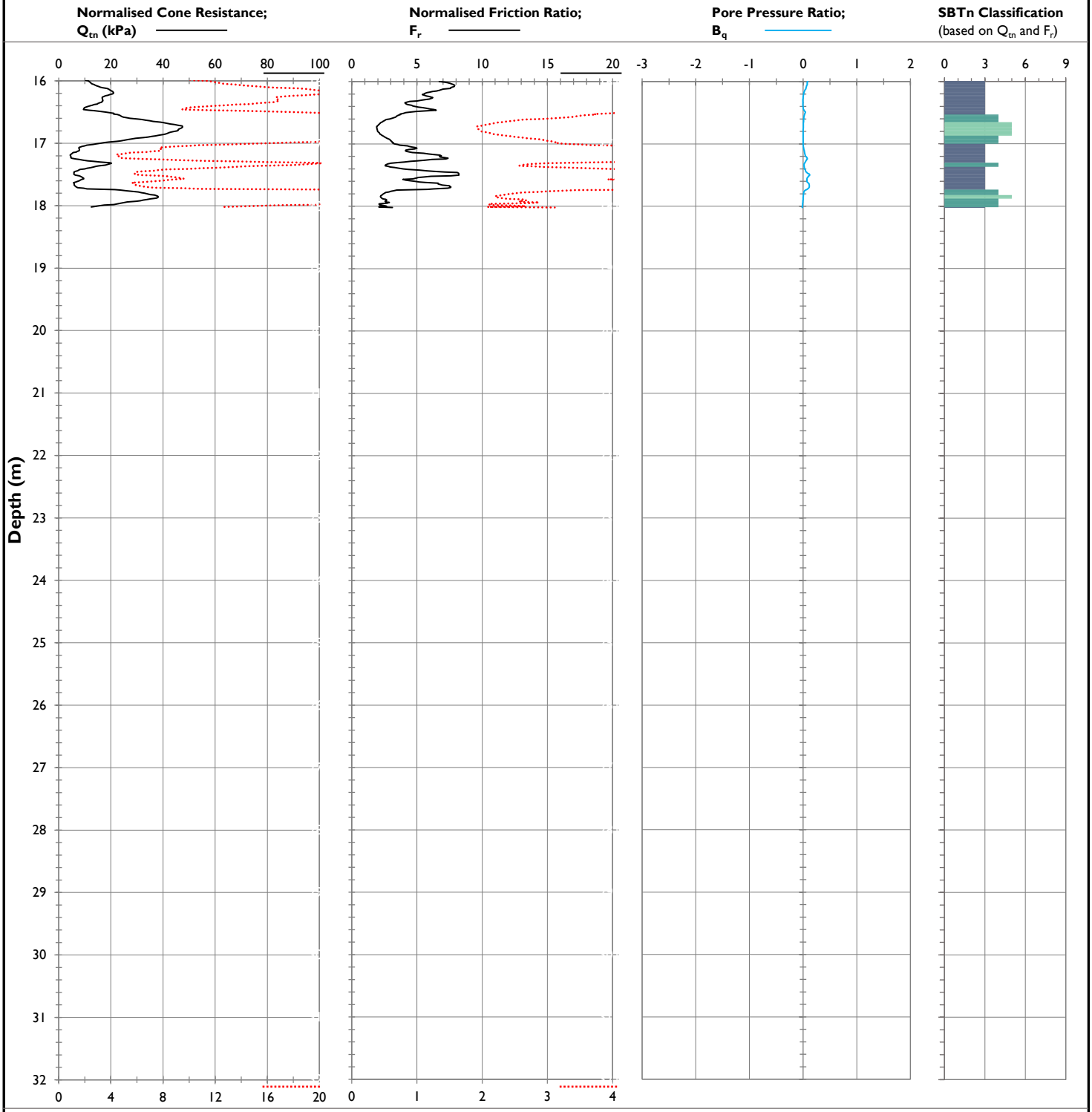
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH06**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631780 (AGD66 / A*	R.L. Surface:	*220.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521462.3 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.81*	Depth to GW:	*12.5m (Estimated)*	Termination:	*18.19m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

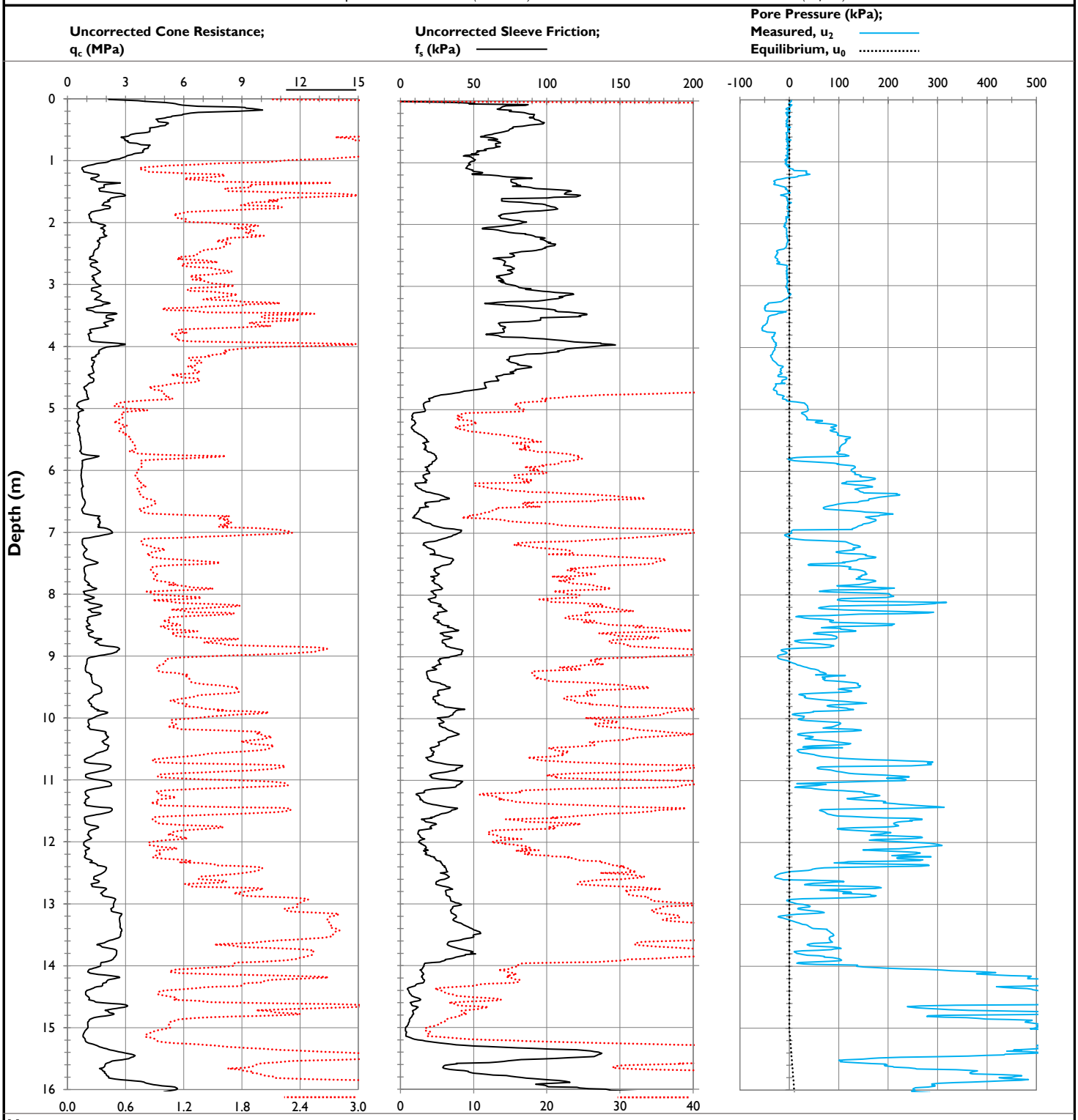
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH07**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**2/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631832.5 (AGD66 /* R.L. Surface: *219.9m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521146.995 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*18.45m (Refusal)*

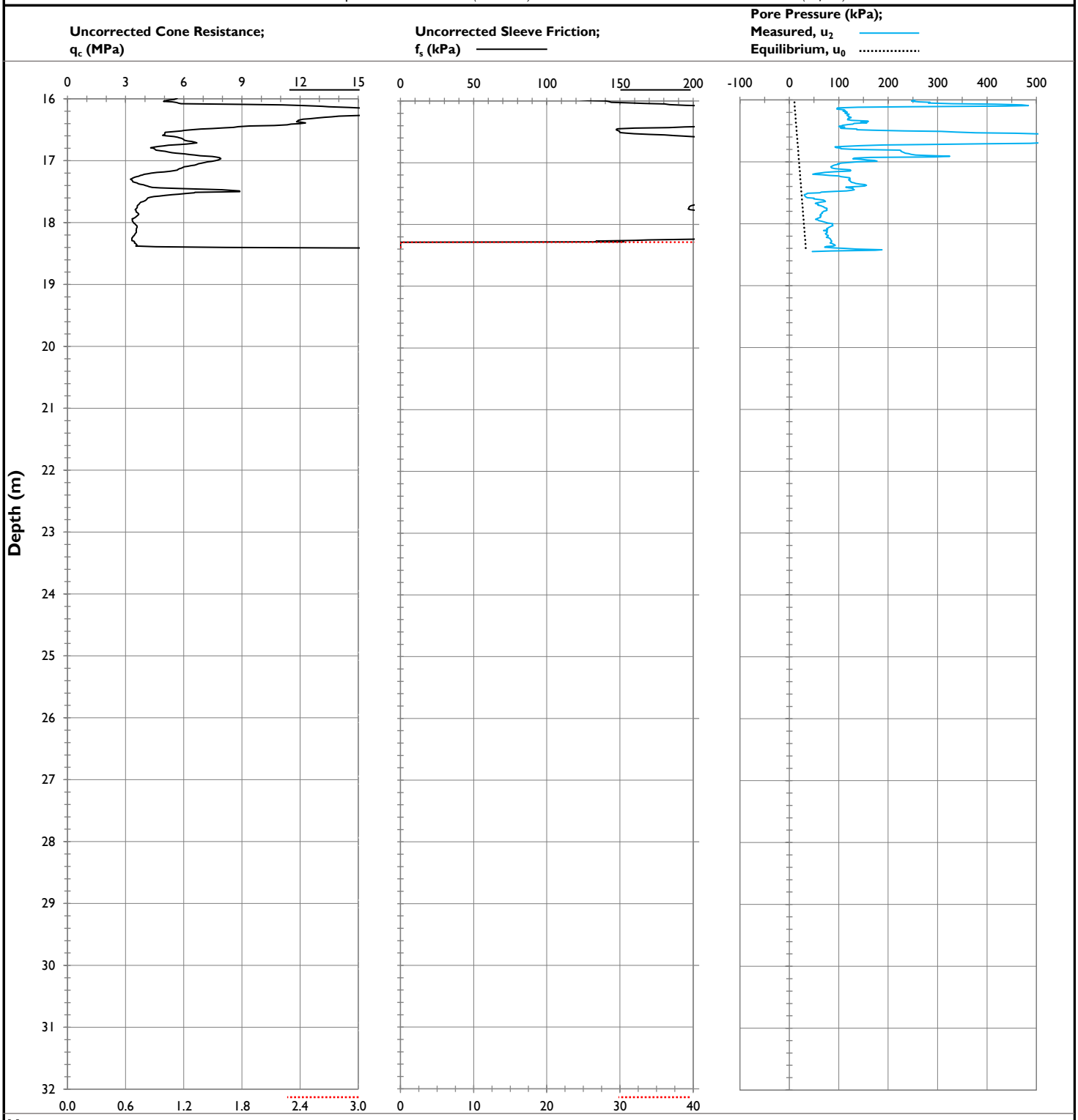


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH07**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**2/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631832.5 (AGD66 /* R.L. Surface: *219.9m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521146.995 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*18.45m (Refusal)*

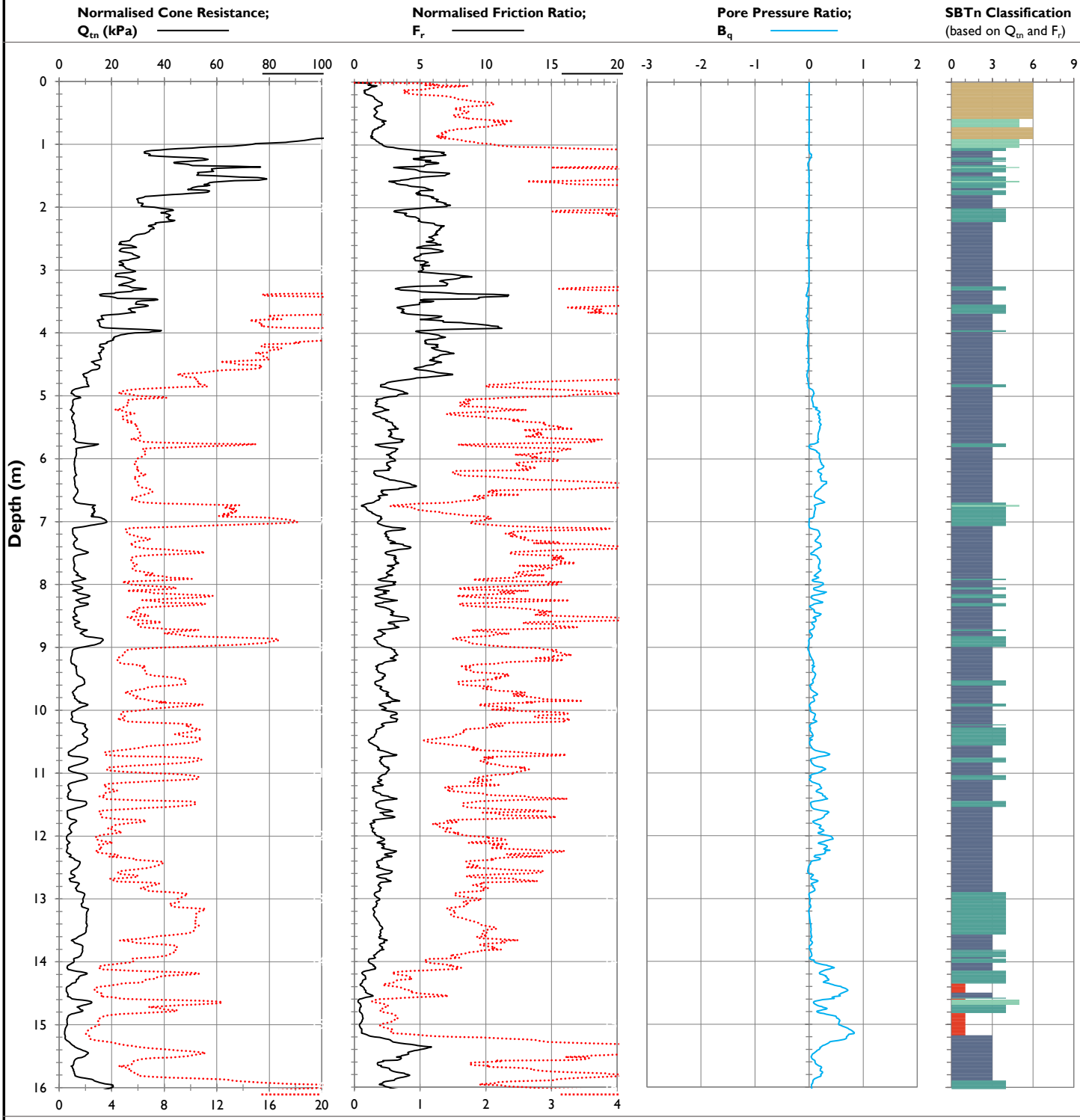


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH07**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**2/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631832.5 (AGD66 /* R.L. Surface: *219.9m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521146.995 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*18.45m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

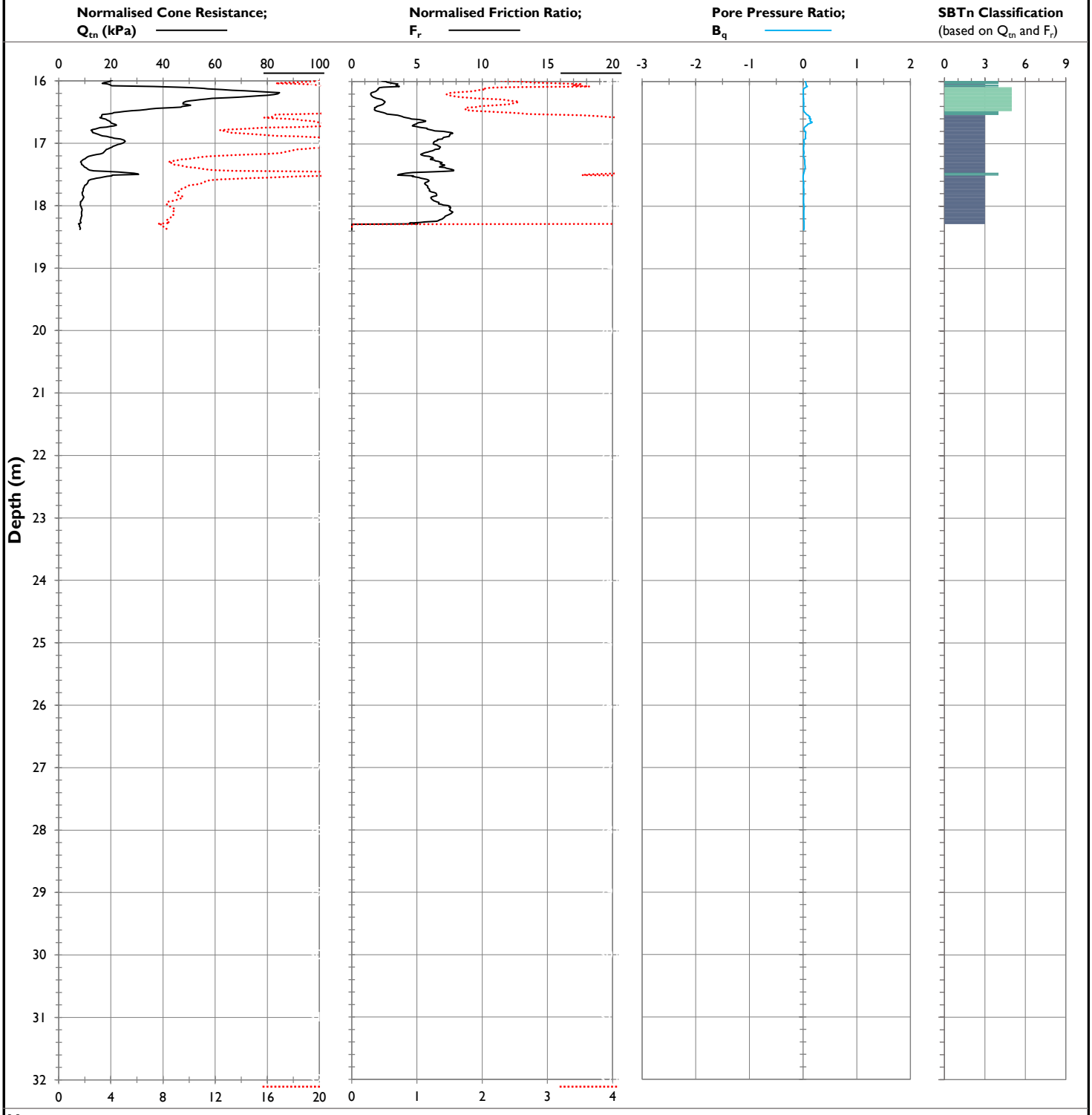
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-BH07**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**2/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631832.5 (AGD66 /* R.L. Surface: *219.9m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521146.995 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*18.45m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

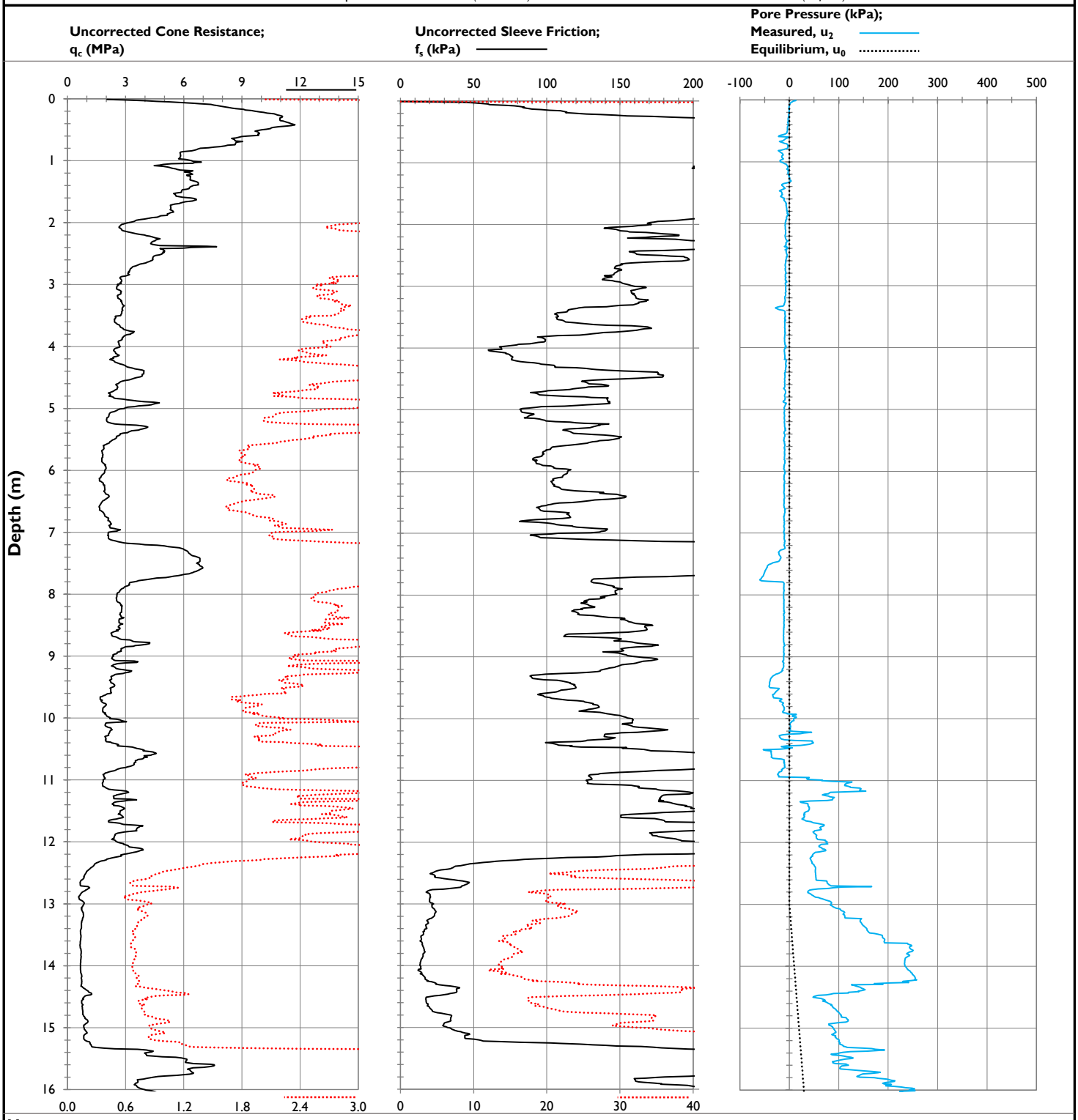
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT01**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631941.2 (AGD66 /* R.L. Surface: *222.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521621.4 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*13.0m (Estimated)*	Termination:	*22.87m (Refusal)*

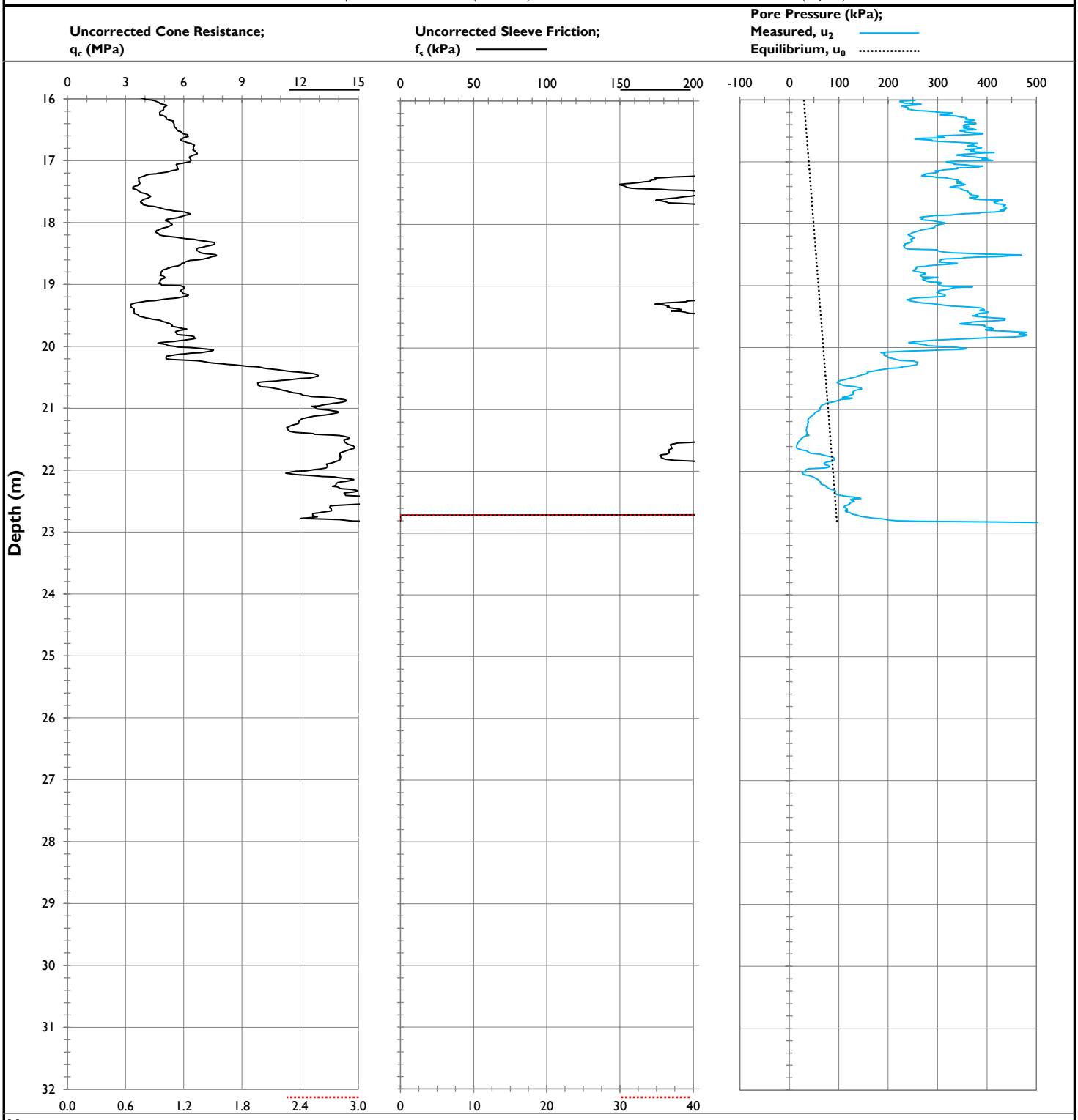


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT01**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631941.2 (AGD66 /*	R.L. Surface:	*222.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521621.4 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*13.0m (Estimated)*	Termination:	*22.87m (Refusal)*		

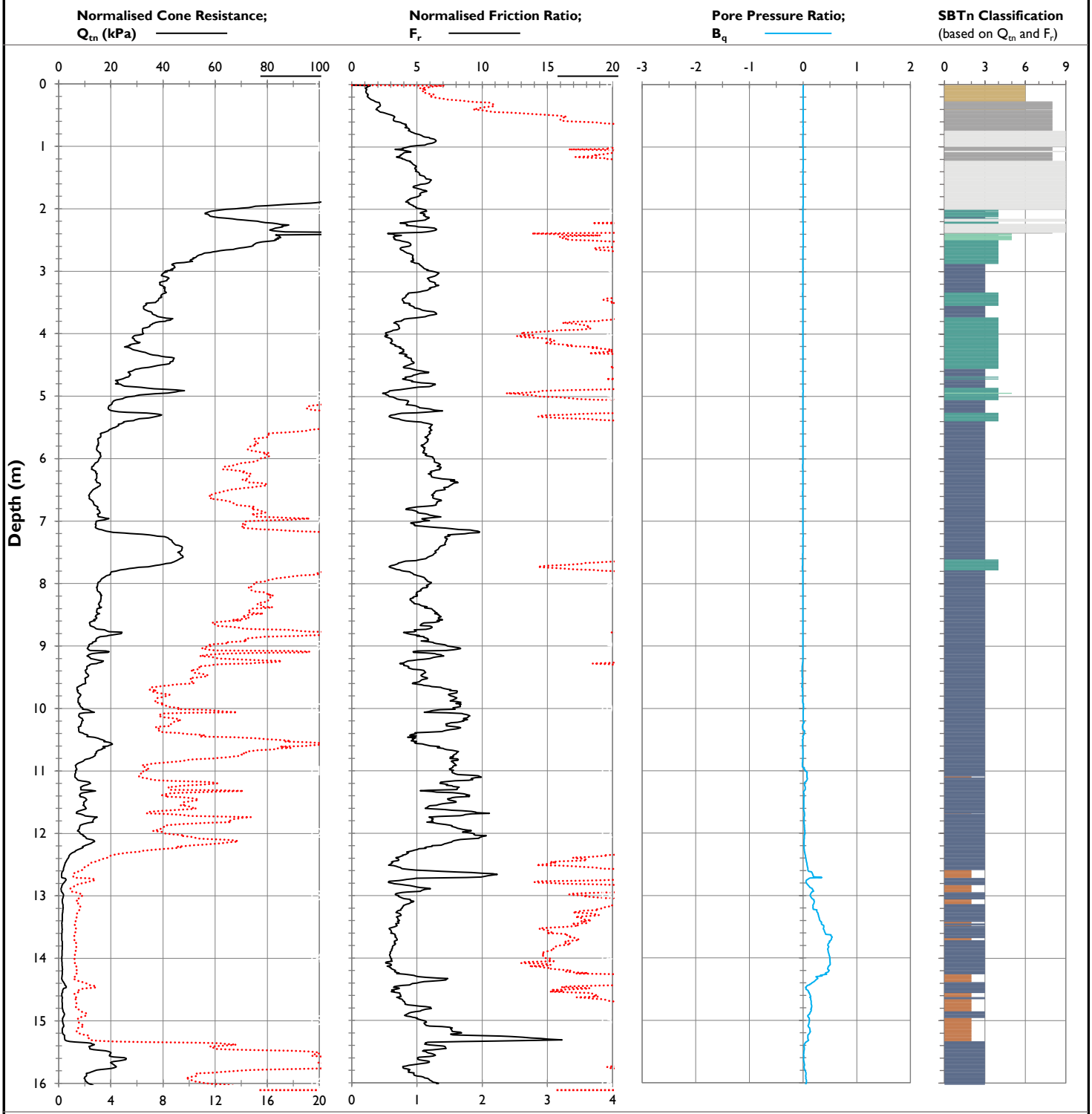


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT01**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631941.2 (AGD66 /* R.L. Surface: *222.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521621.4 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*13.0m (Estimated)*	Termination:	*22.87m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

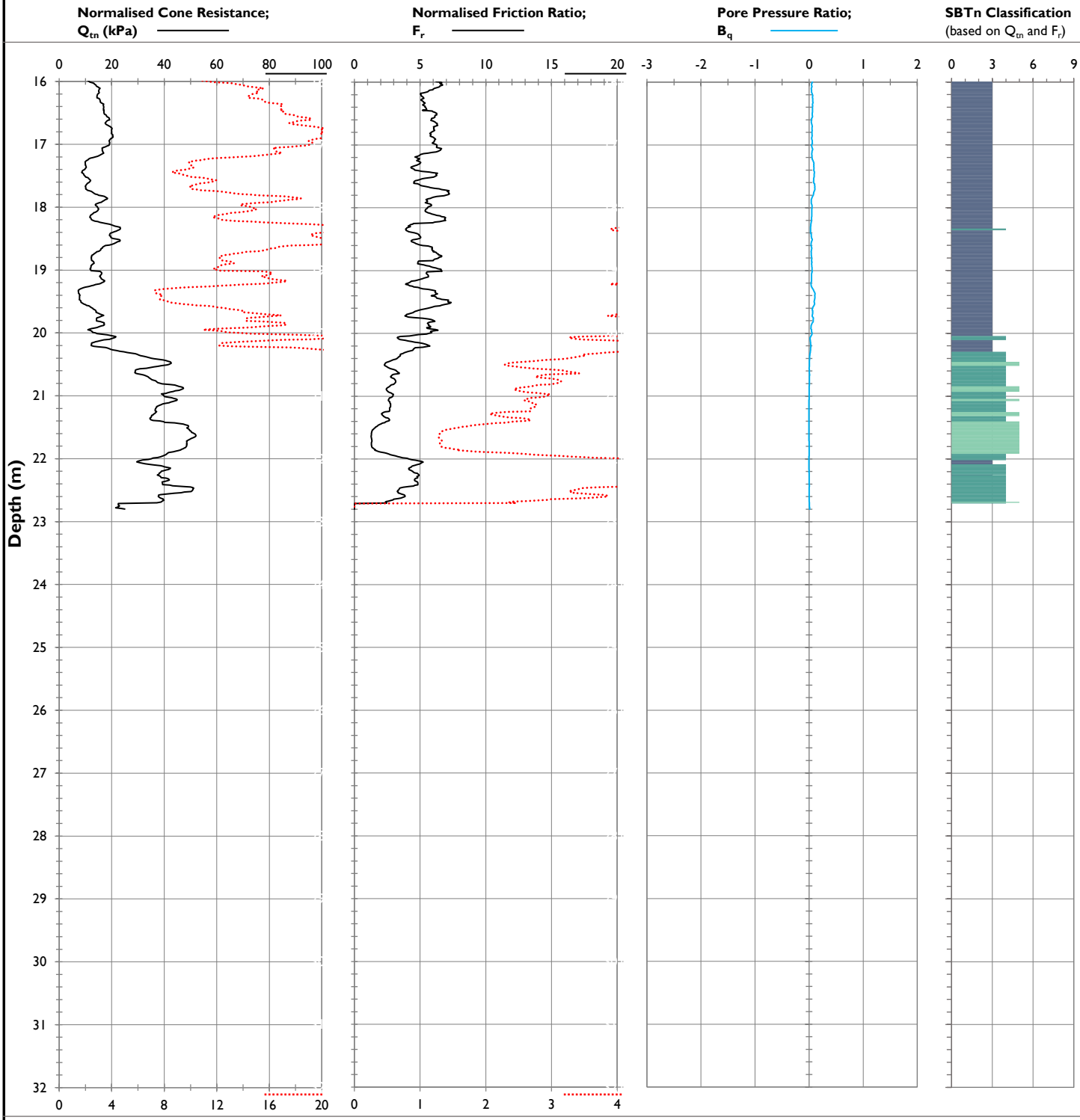
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT01**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631941.2 (AGD66 /*	R.L. Surface:	*222.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521621.4 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*13.0m (Estimated)*	Termination:	*22.87m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

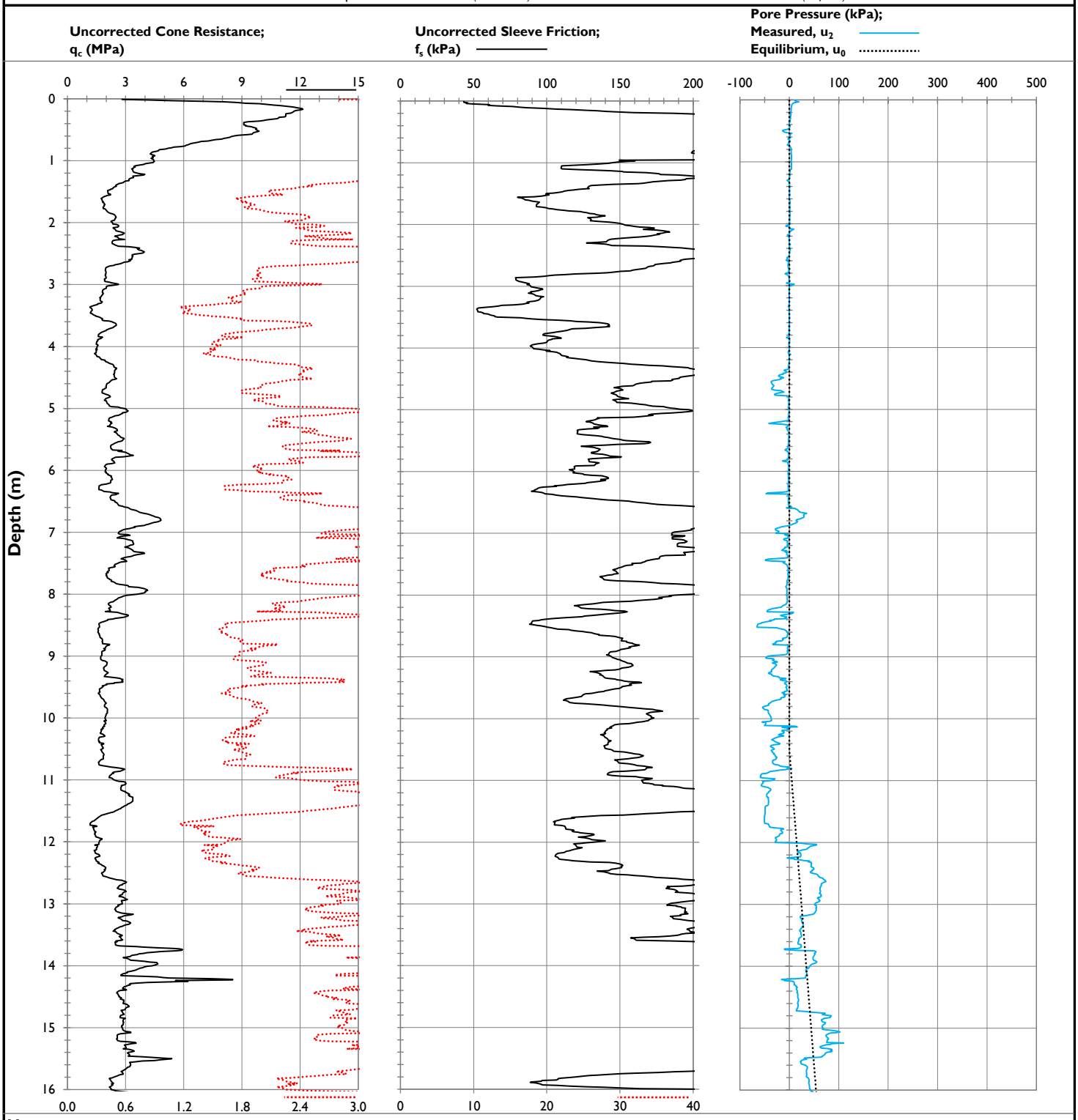
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT02**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**7/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631864.6 (AGD66 /* R.L. Surface: *221.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521554.4 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.80*	Depth to GW:	*10.5m (Estimated)*	Termination:	*19.76m (Refusal)*

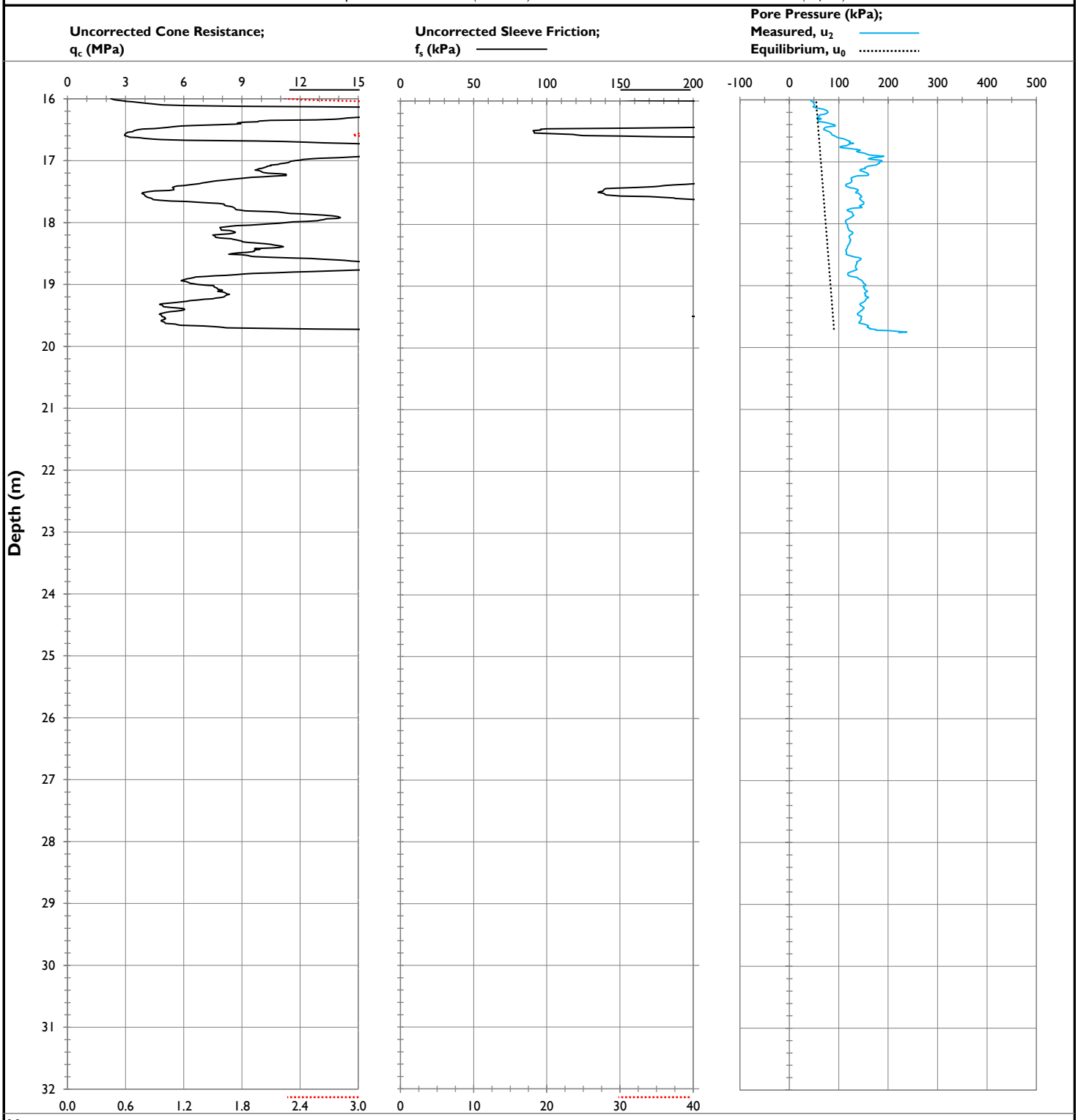


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT02**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**7/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631864.6 (AGD66 /* R.L. Surface: *221.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521554.4 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.80*	Depth to GW:	*10.5m (Estimated)*	Termination:	*19.76m (Refusal)*

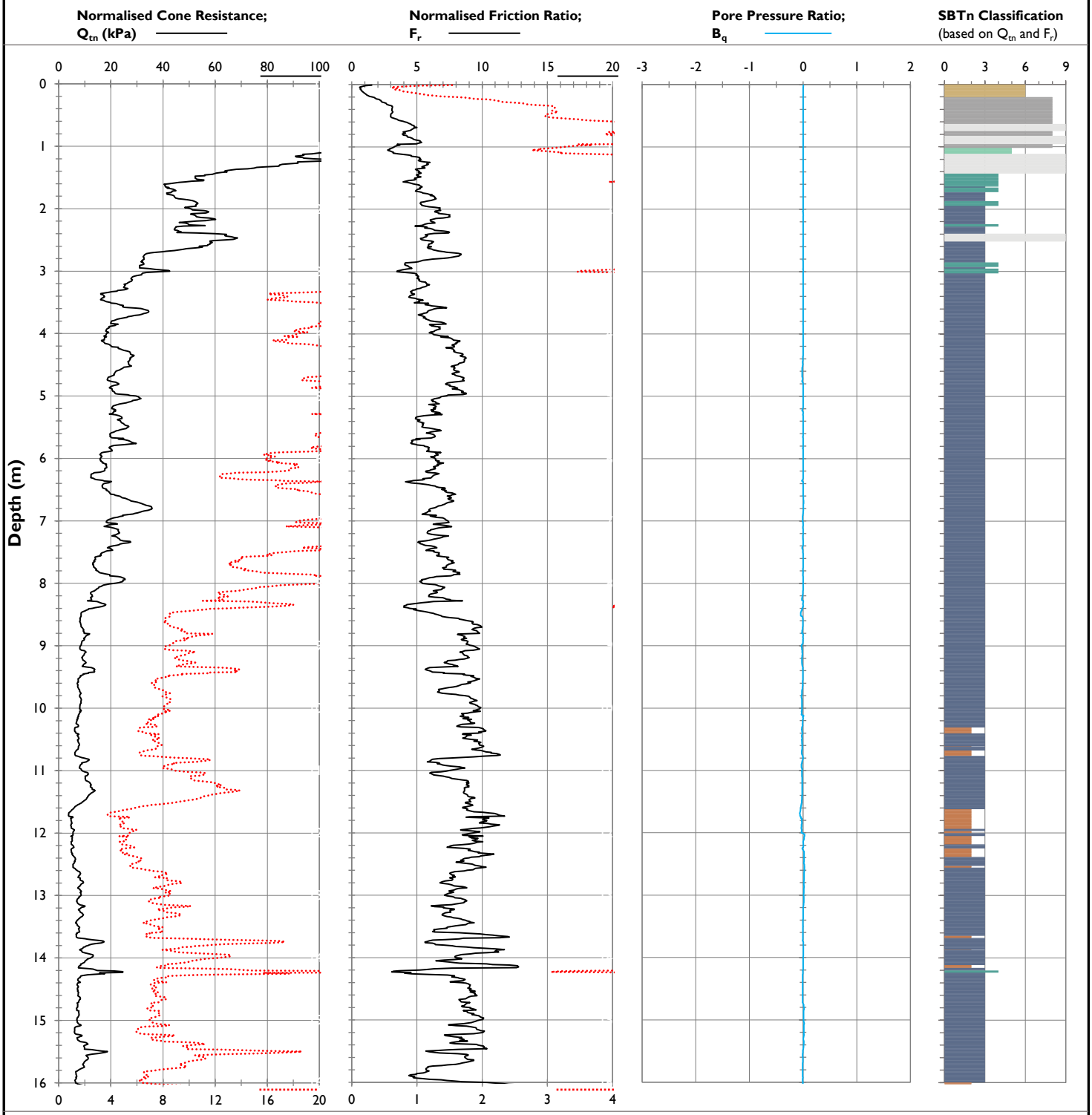


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT02**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**7/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631864.6 (AGD66 /*	R.L. Surface:	*221.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521554.4 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.80*	Depth to GW:	*10.5m (Estimated)*	Termination:	*19.76m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

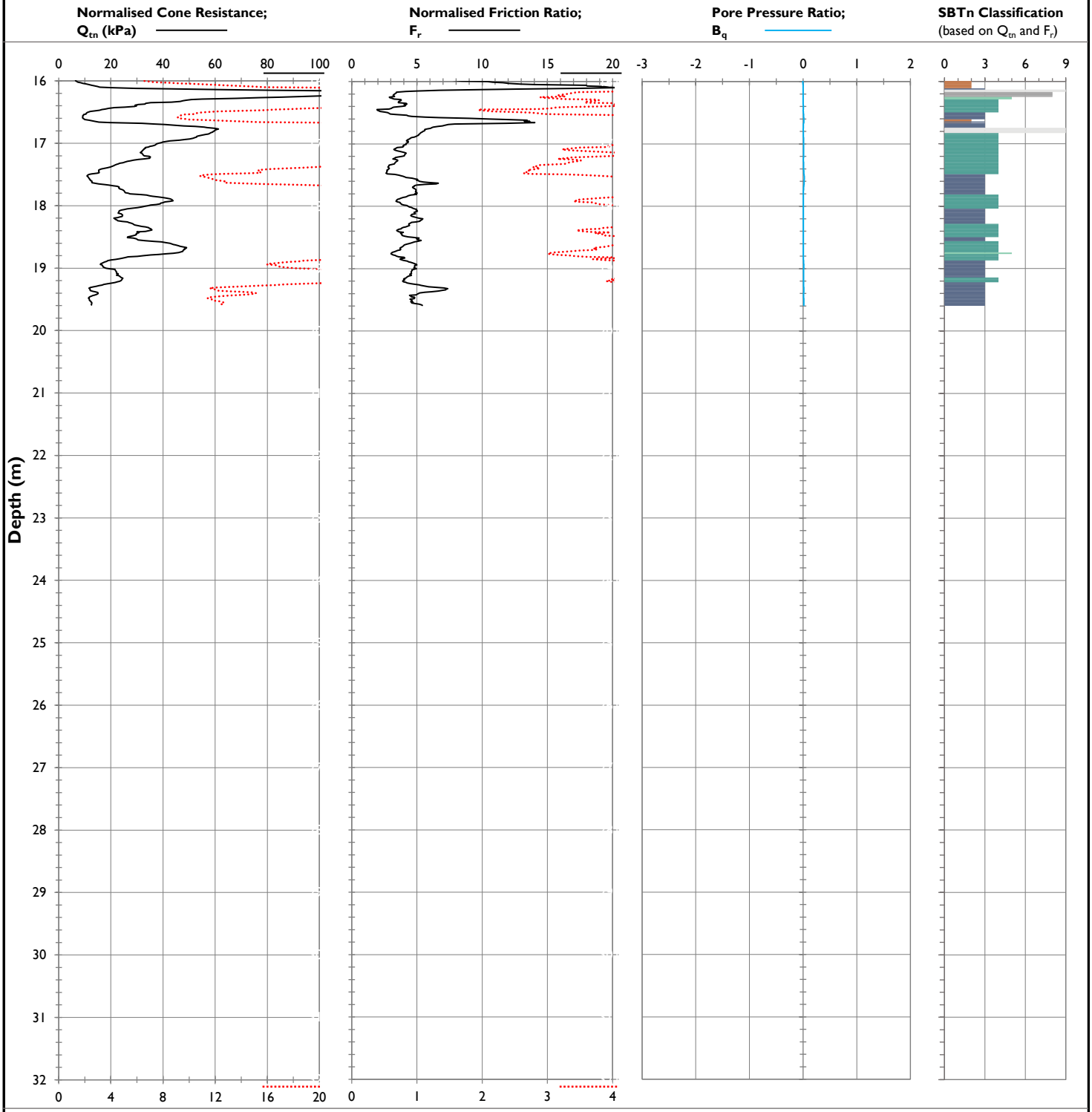
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT02**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**7/08/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631864.6 (AGD66 /*	R.L. Surface:	*221.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521554.4 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.80*	Depth to GW:	*10.5m (Estimated)*	Termination:	*19.76m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

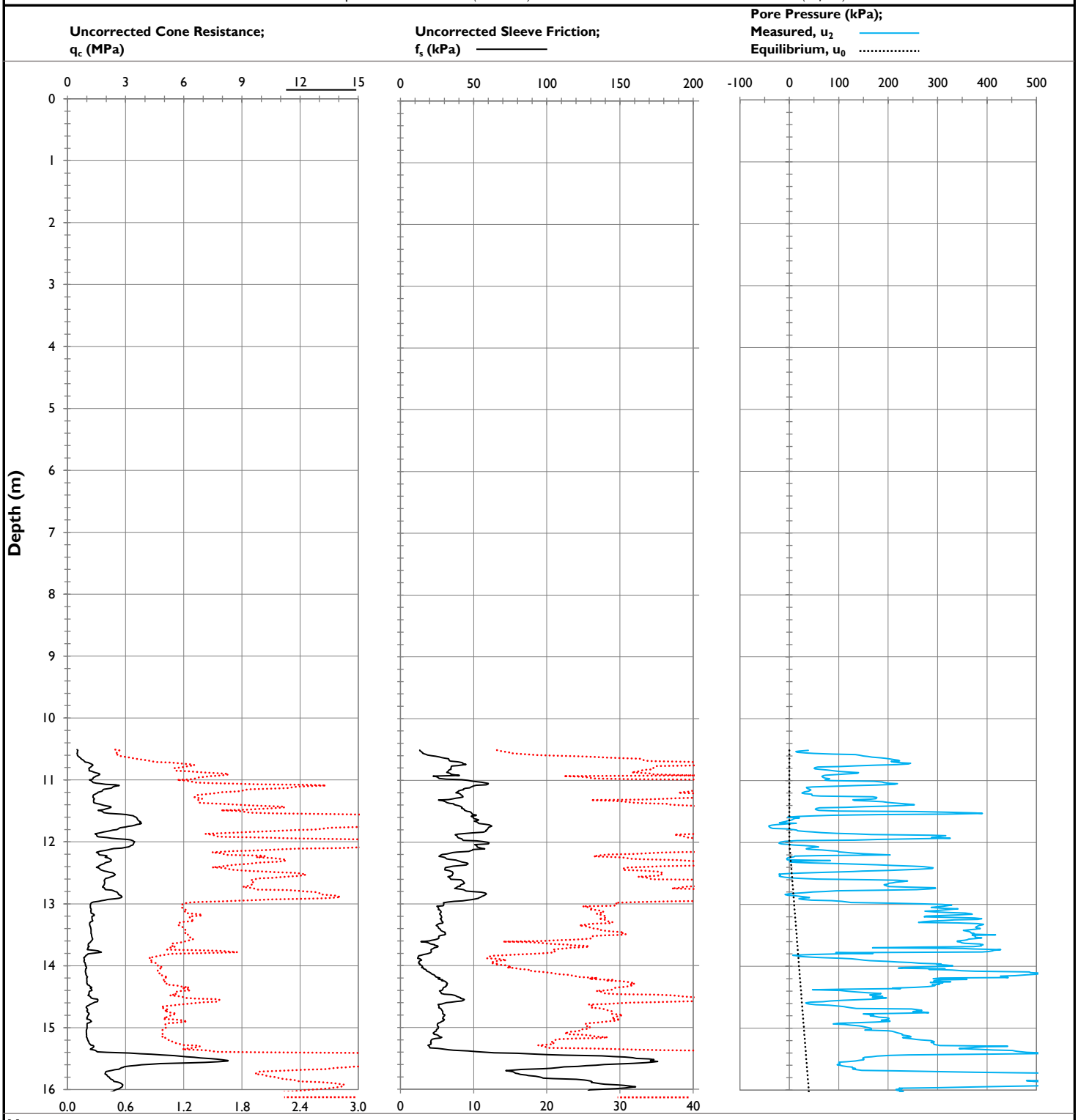
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT03**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631804.2 (AGD66 /* R.L. Surface: *220.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*10.5m (Auger)*	Northing:	*7521459.2 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*12.0m (Estimated)*	Termination:	*19.46m (Refusal)*

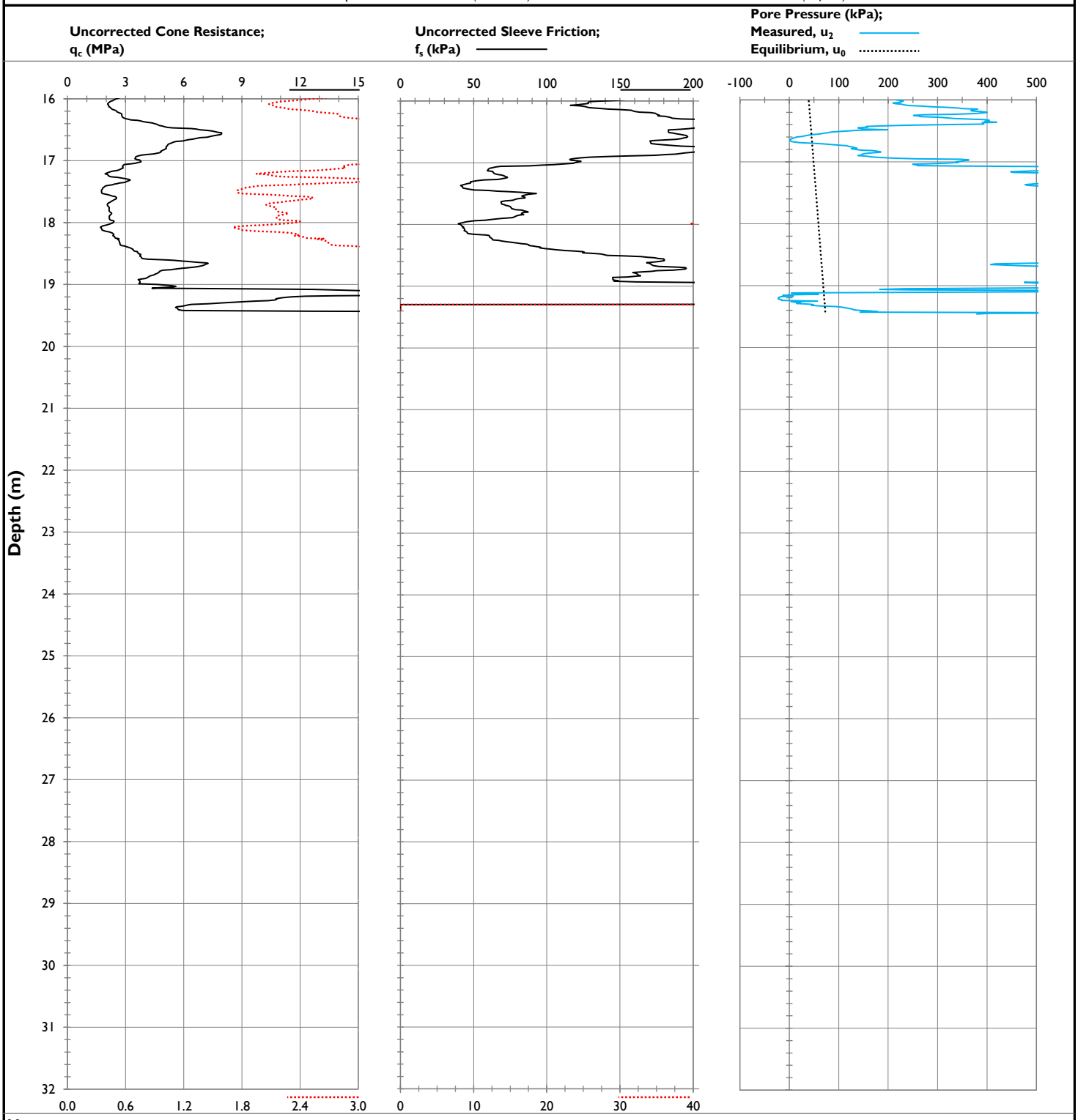


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT03**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631804.2 (AGD66 /* R.L. Surface: *220.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*10.5m (Auger)*	Northing:	*7521459.2 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*12.0m (Estimated)*	Termination:	*19.46m (Refusal)*

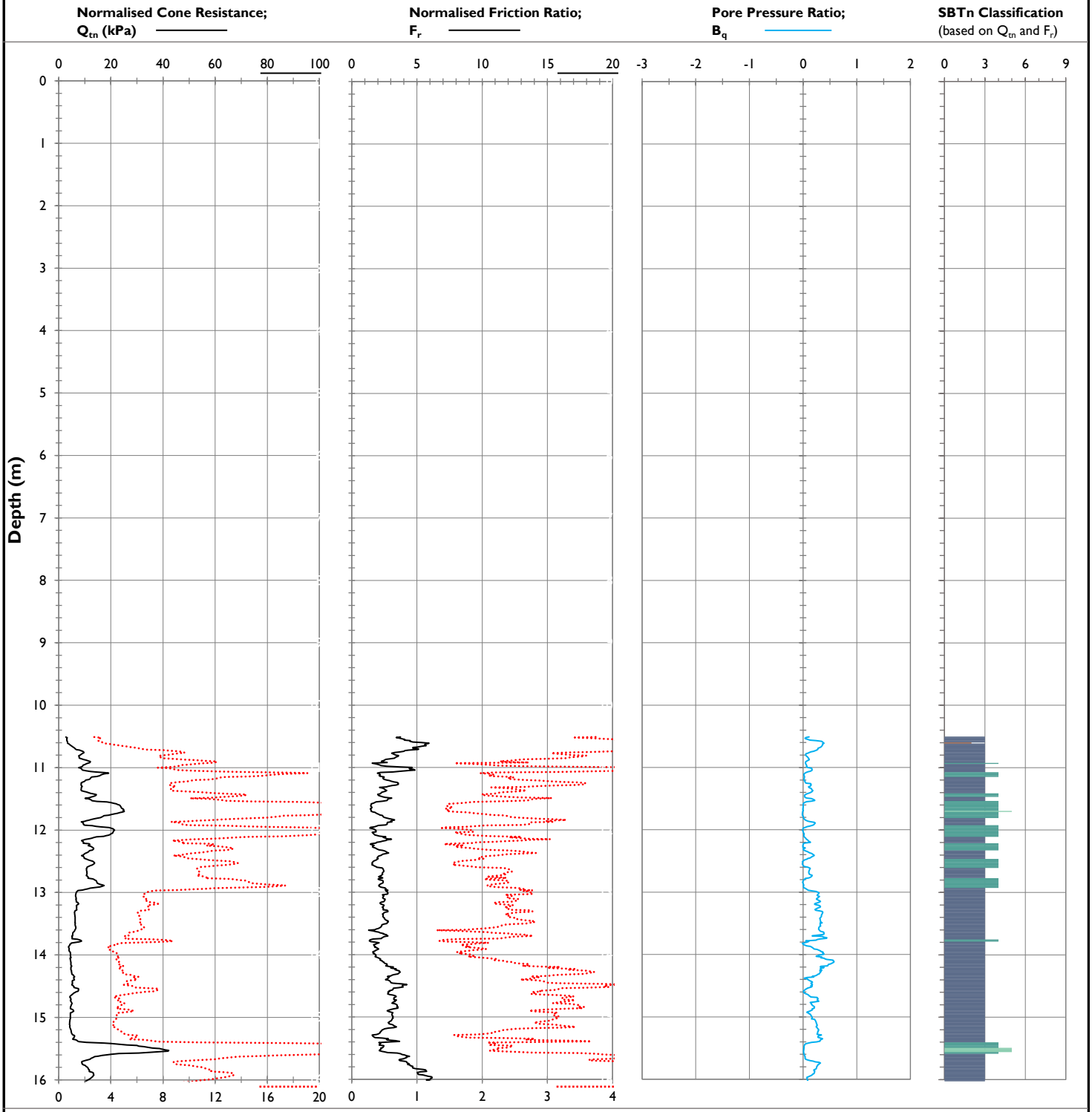


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT03**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631804.2 (AGD66 /*	R.L. Surface:	*220.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*10.5m (Auger)*	Northing:	*7521459.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*12.0m (Estimated)*	Termination:	*19.46m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

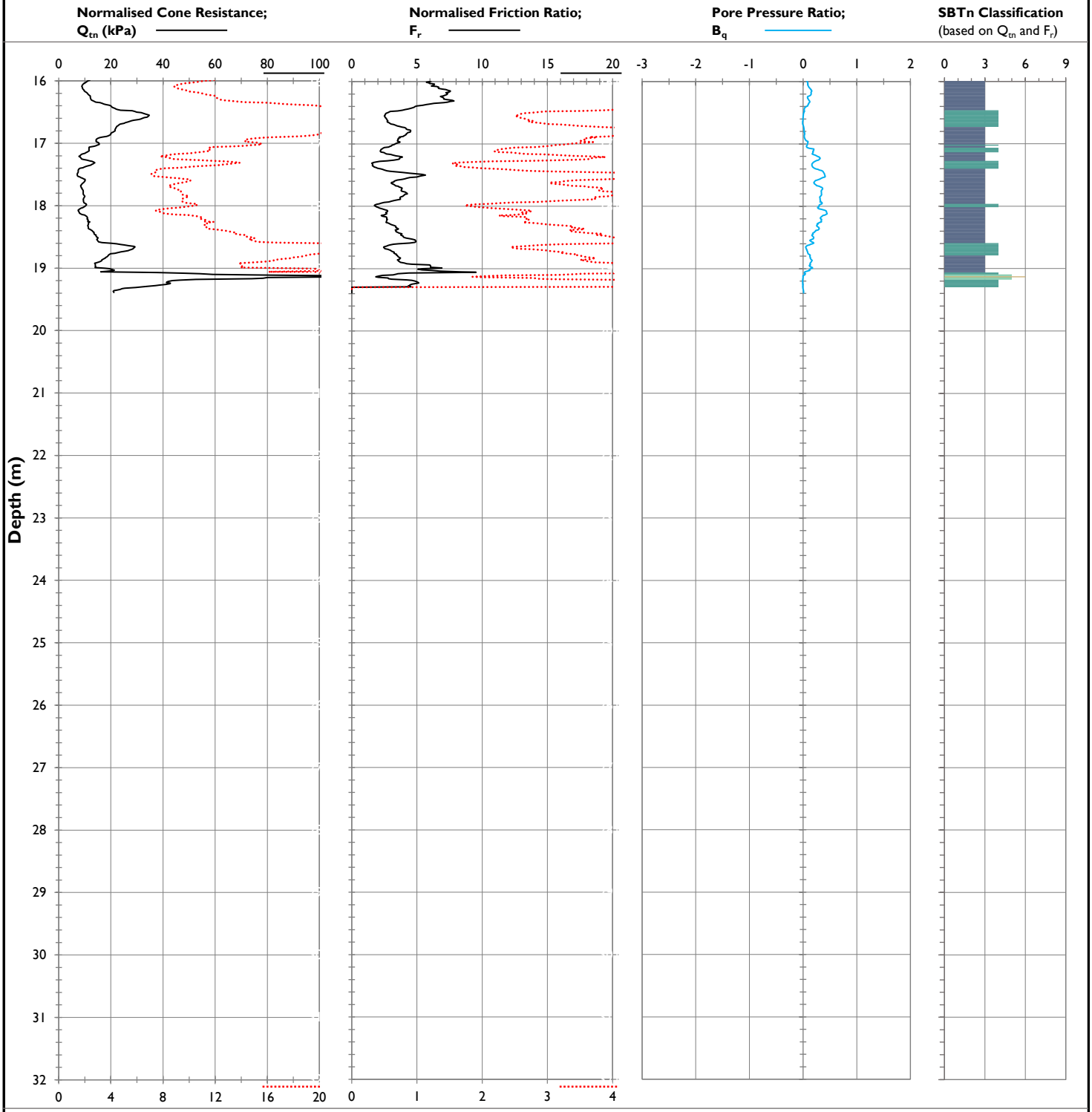
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT03**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631804.2 (AGD66 /*	R.L. Surface:	*220.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*10.5m (Auger)*	Northing:	*7521459.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*12.0m (Estimated)*	Termination:	*19.46m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

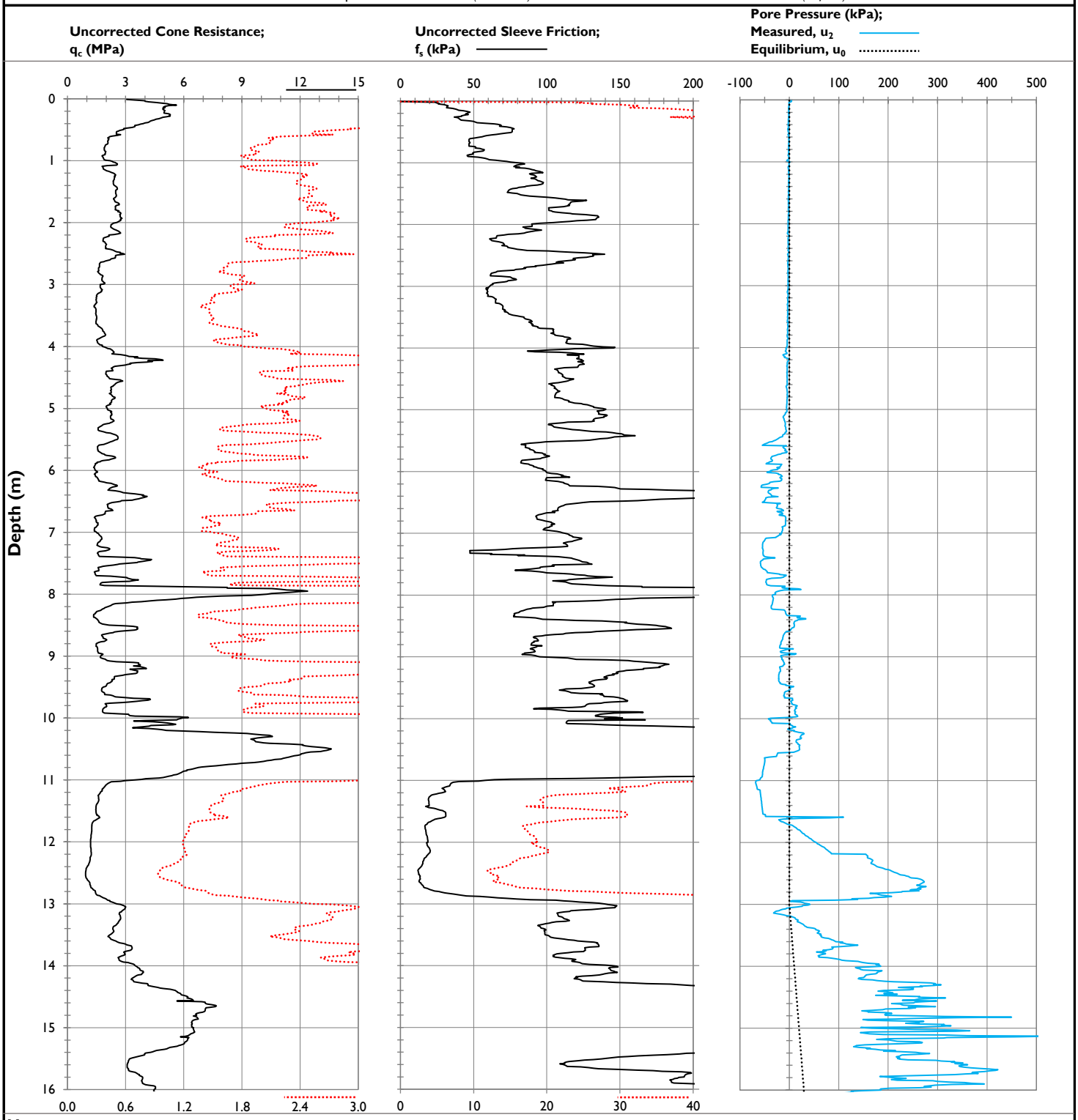
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT04**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**11/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631953.8 (AGD66 /*	R.L. Surface:	*220.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521592.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*13.0m (Estimated)*	Termination:	*22.45m (Refusal)*		

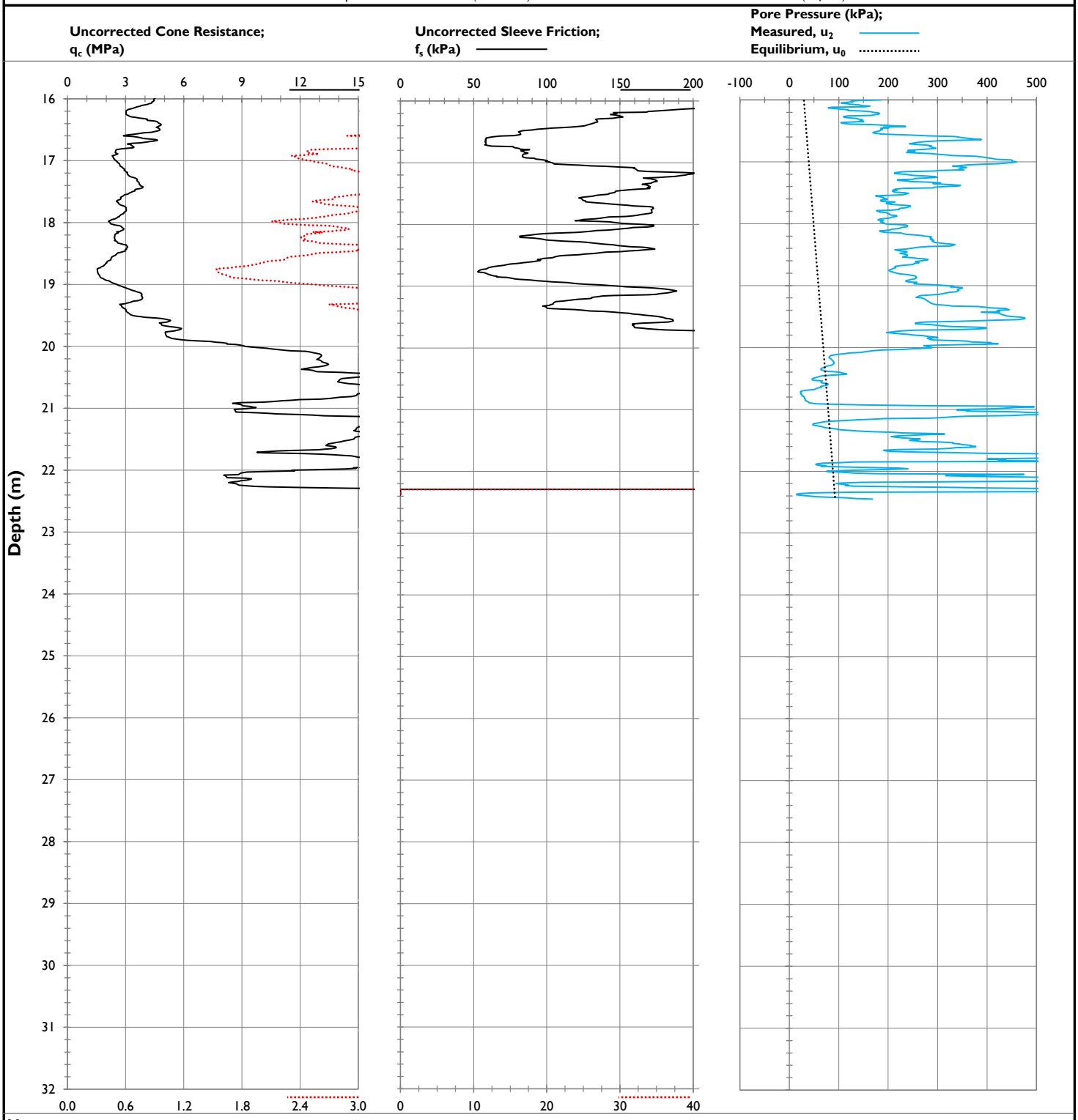


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT04**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**11/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631953.8 (AGD66 /*	R.L. Surface:	*220.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521592.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*13.0m (Estimated)*	Termination:	*22.45m (Refusal)*		

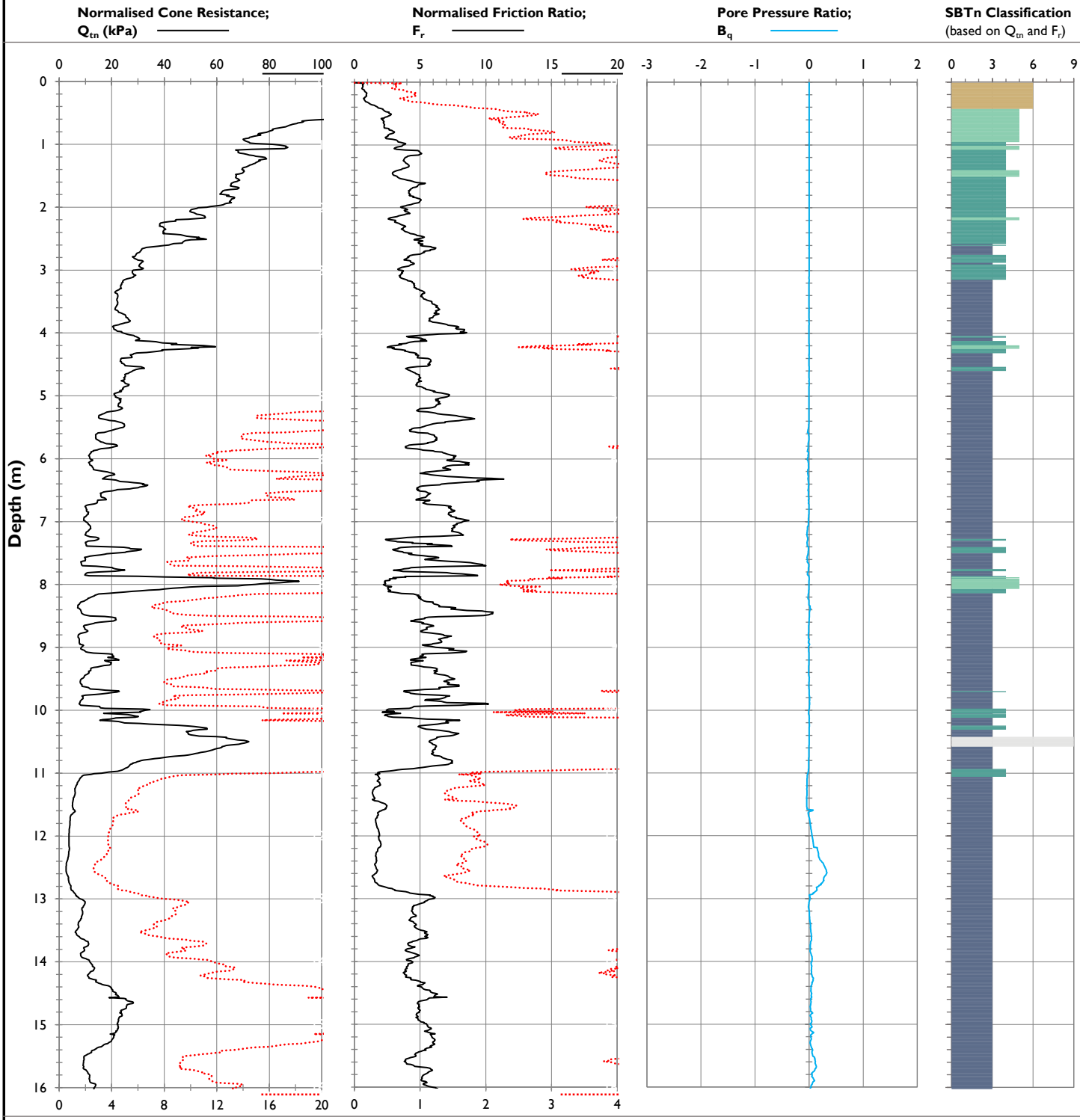


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT04**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**11/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631953.8 (AGD66 /* R.L. Surface: *220.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521592.2 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.79*	Depth to GW:	*13.0m (Estimated)*	Termination:	*22.45m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

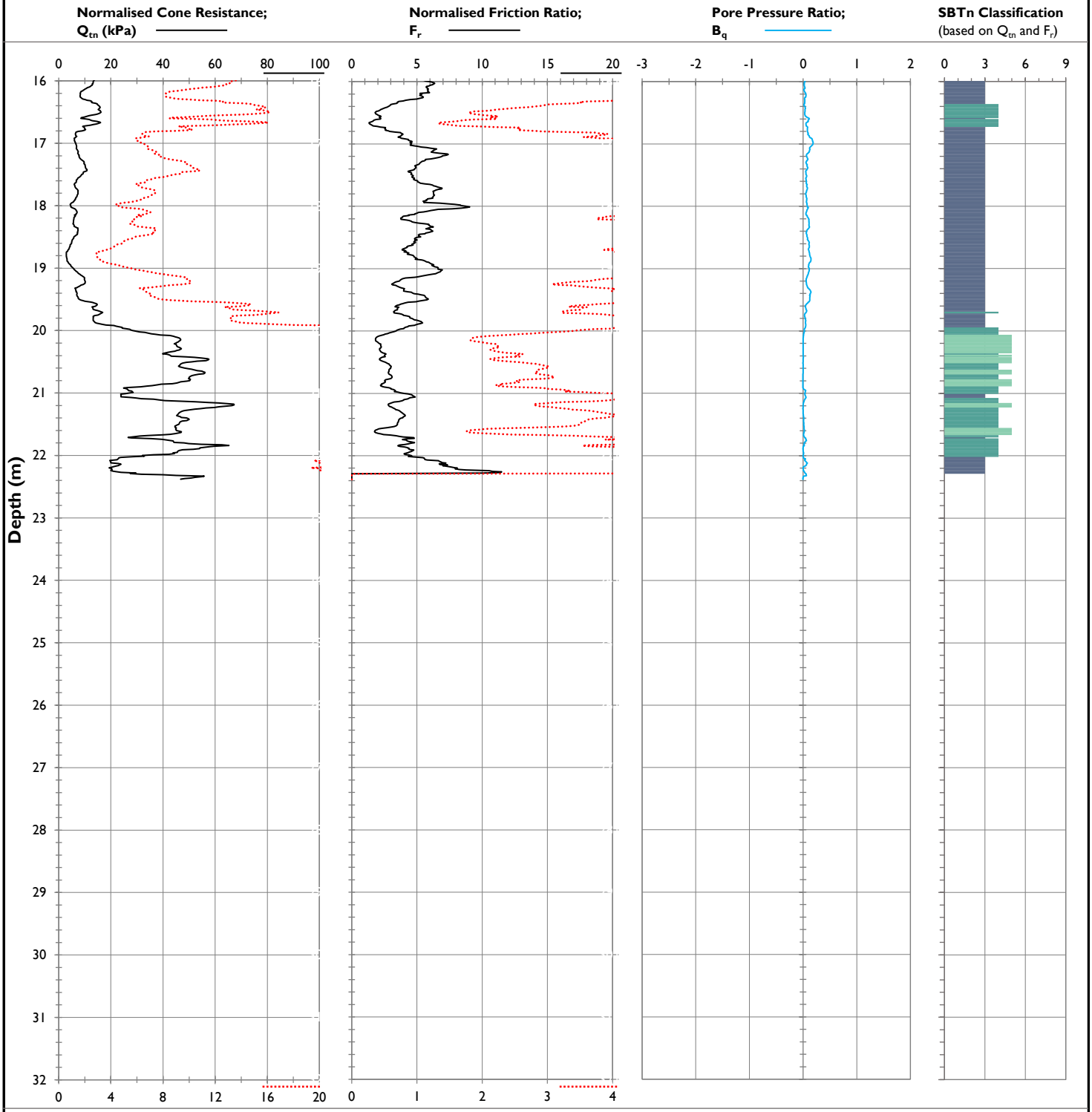
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT04**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**11/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631953.8 (AGD66 /* R.L. Surface: *220.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521592.2 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.79*	Depth to GW:	*13.0m (Estimated)*	Termination:	*22.45m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

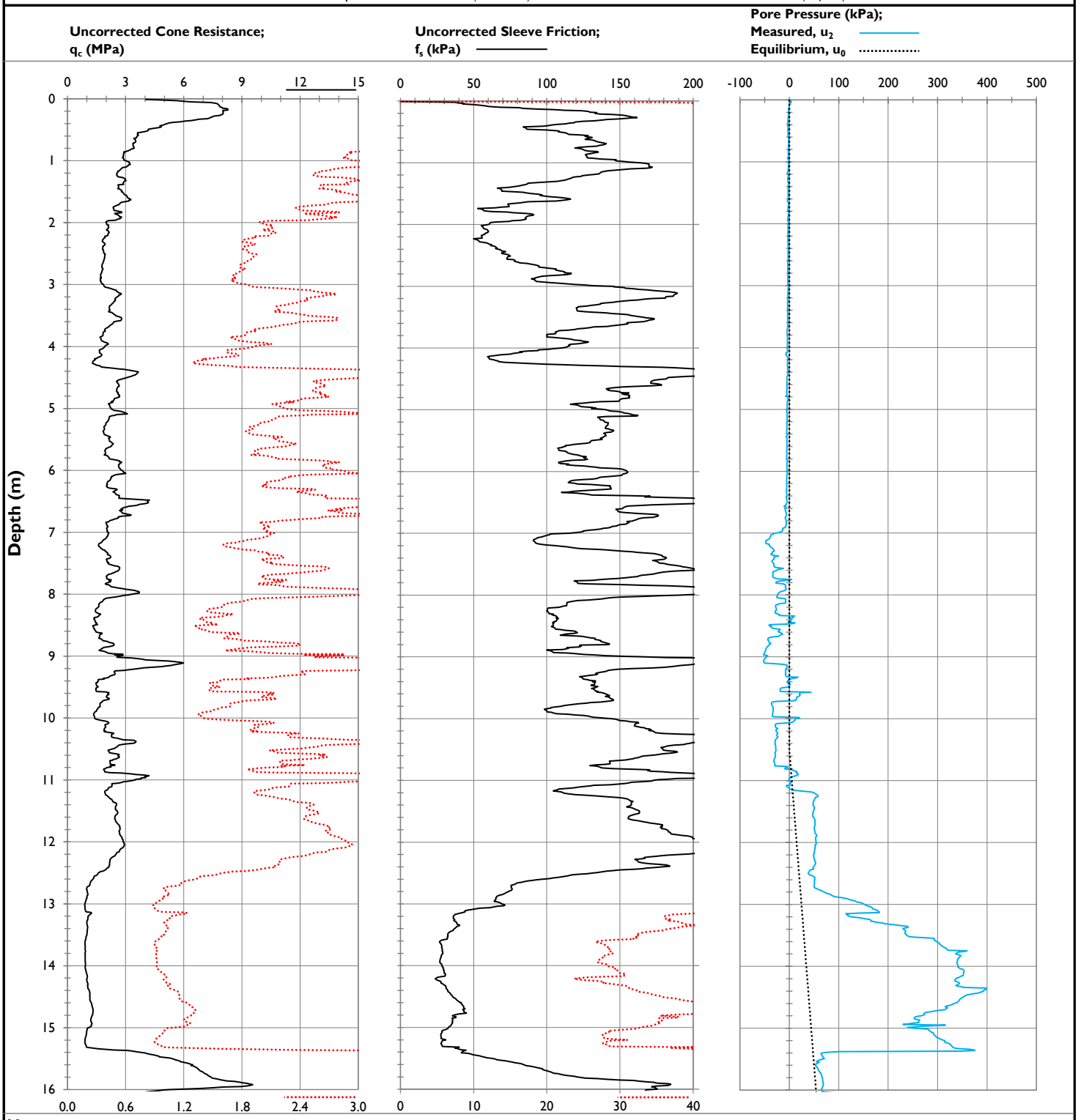
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT05**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**11/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631880.1 (AGD66 /*	R.L. Surface:	*221.2m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521533.3 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*10.5m (Estimated)*	Termination:	*16.38m (Refusal)*		

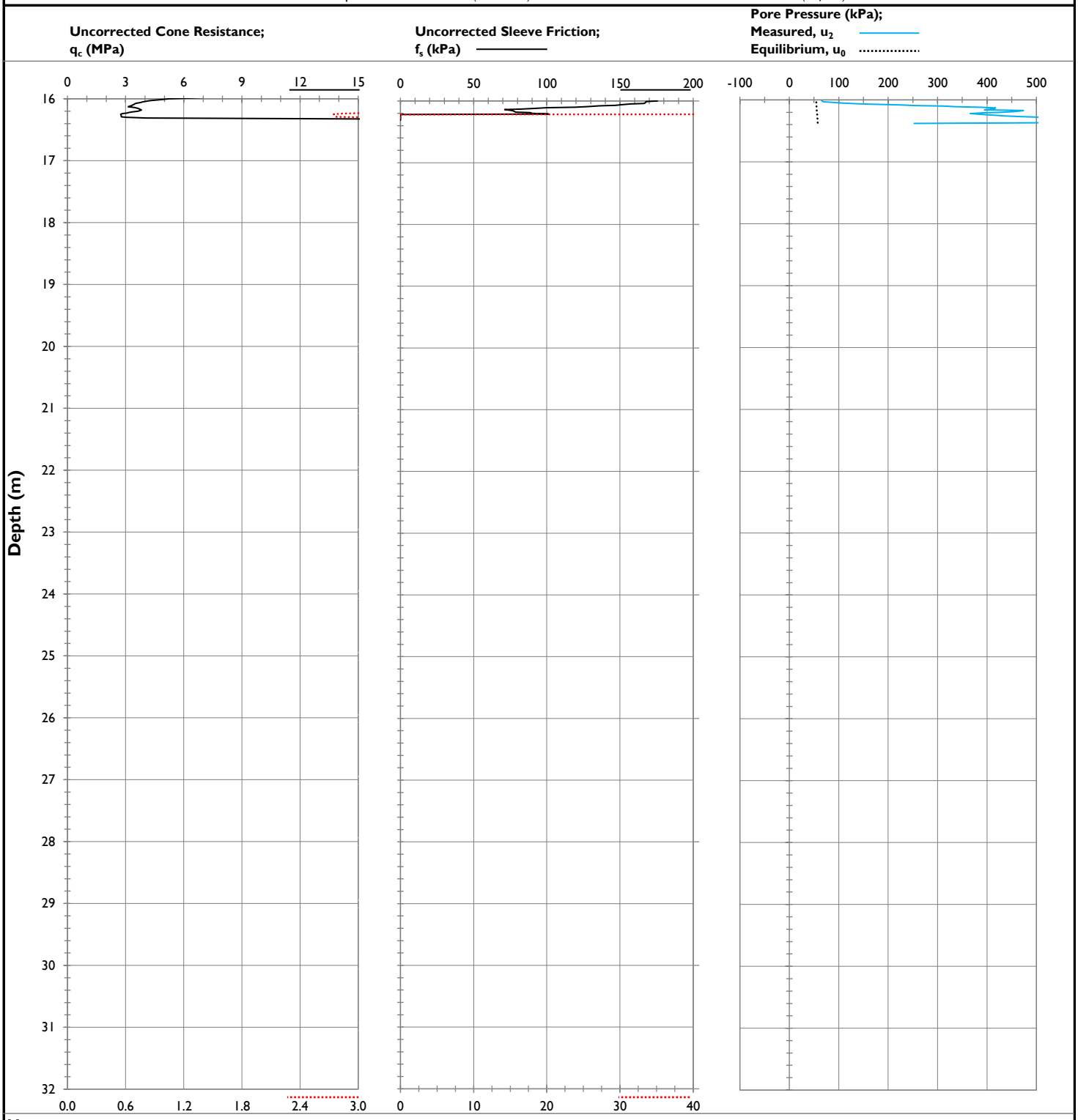


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT05**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**11/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631880.1 (AGD66 /* R.L. Surface: *221.2m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521533.3 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.79*	Depth to GW:	*10.5m (Estimated)*	Termination:	*16.38m (Refusal)*

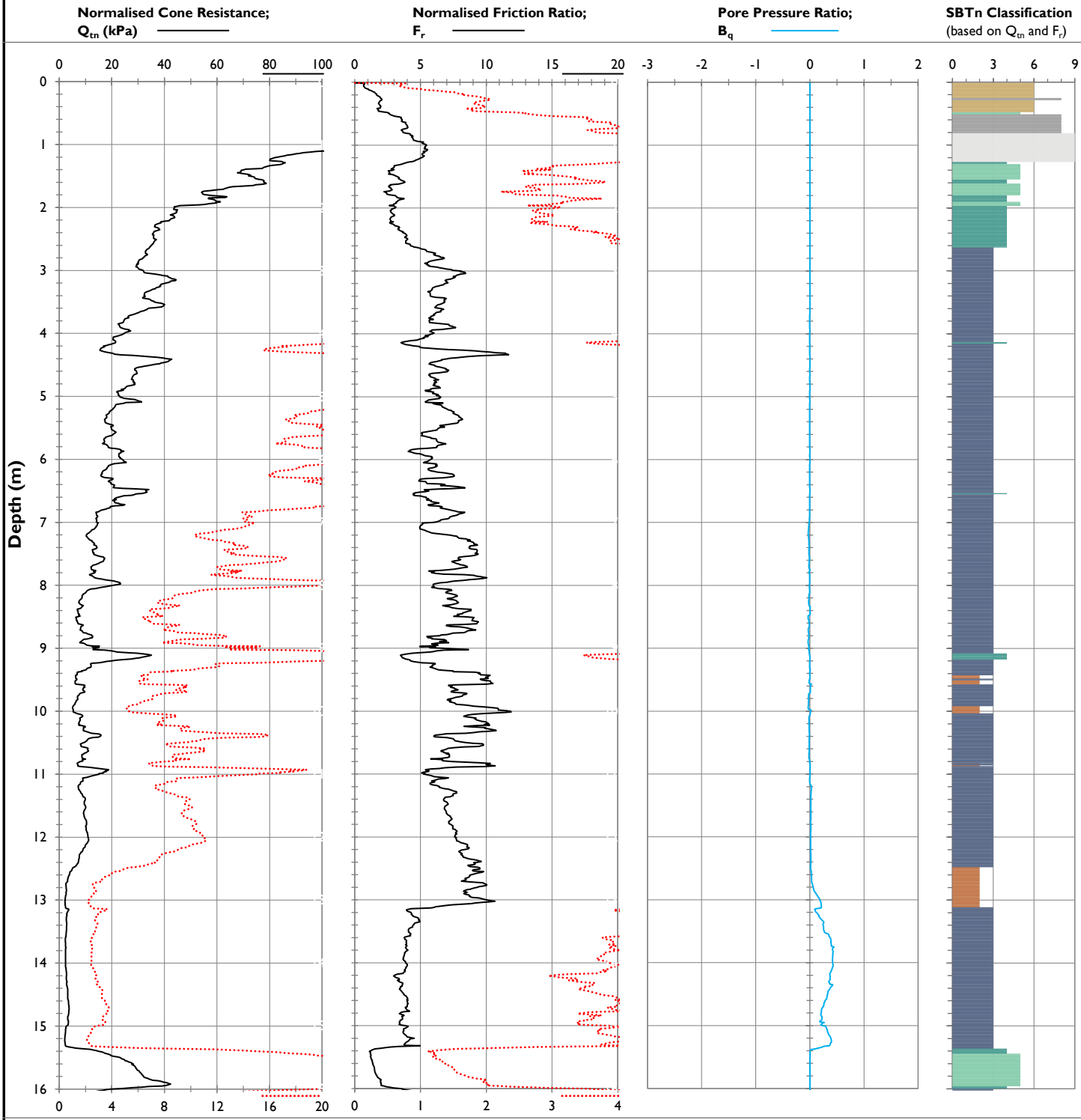


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT05**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**11/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631880.1 (AGD66 /* R.L. Surface: *221.2m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521533.3 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.79*	Depth to GW:	*10.5m (Estimated)*	Termination:	*16.38m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

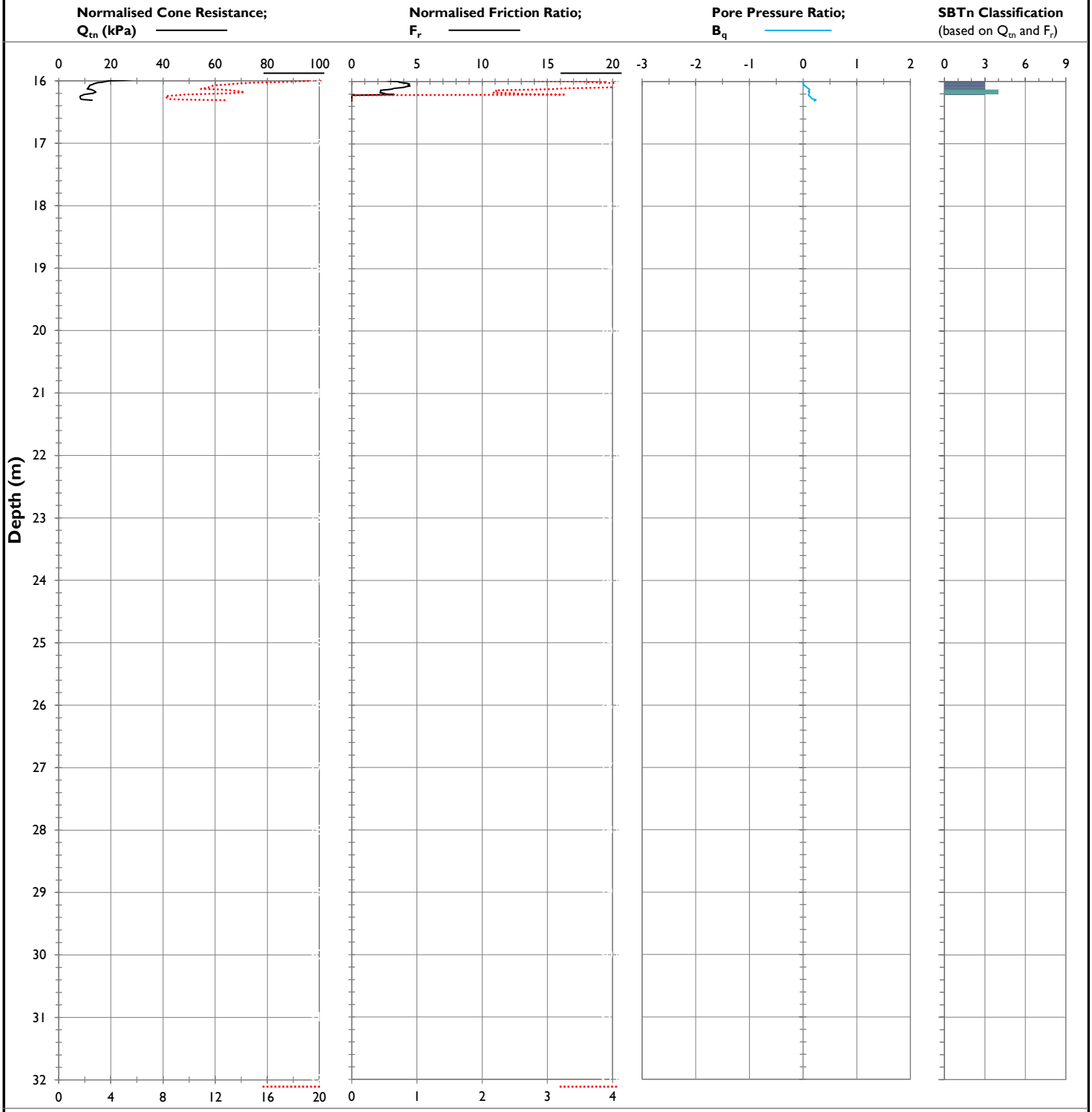
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT05**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**11/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631880.1 (AGD66 /*	R.L. Surface:	*221.2m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521533.3 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*10.5m (Estimated)*	Termination:	*16.38m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

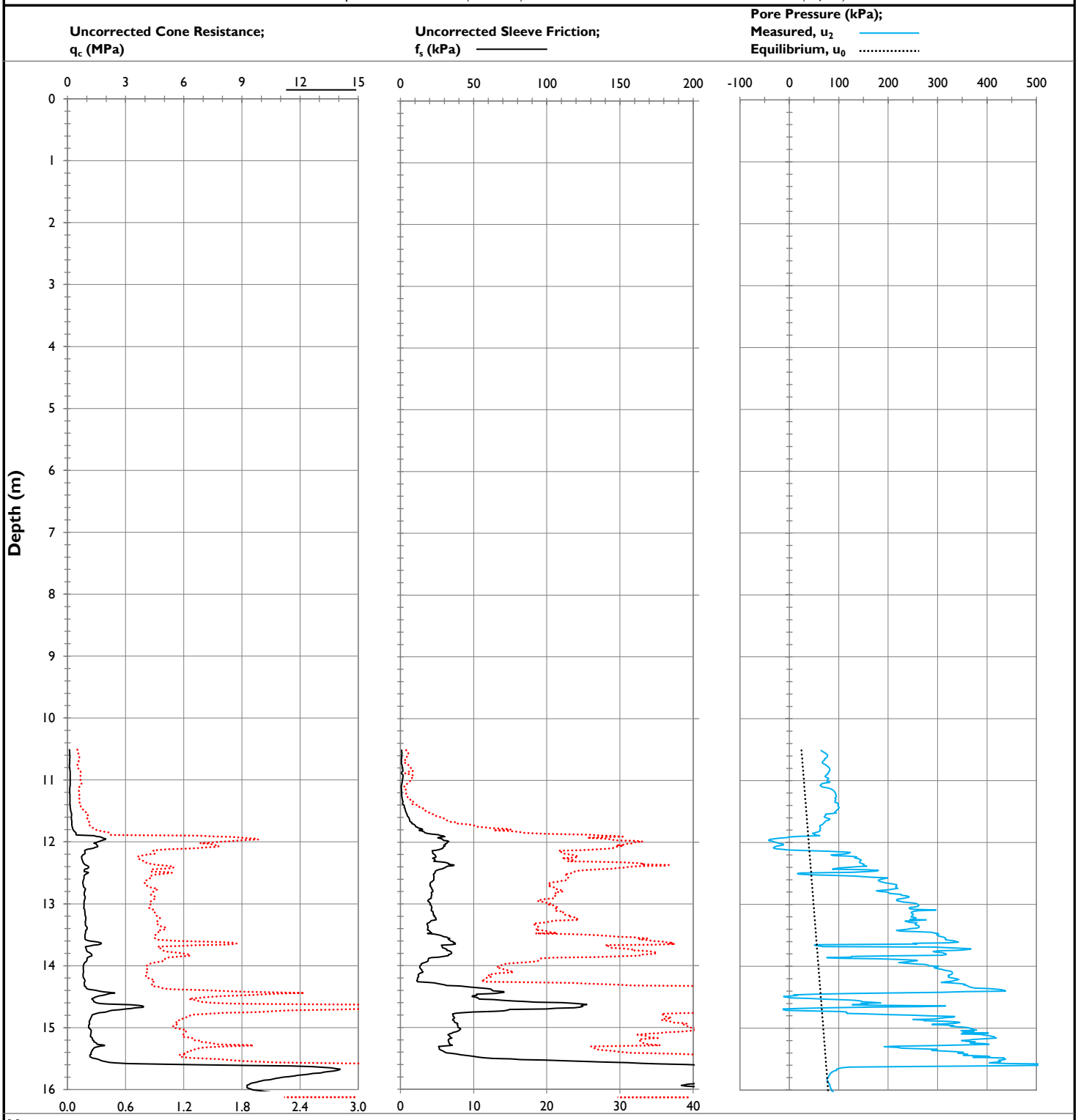
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT06**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631846.5 (AGD66 /*	R.L. Surface:	*221.2m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*10.5m (Auger)*	Northing:	*7521453.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*8.0m (Estimated)*	Termination:	*20.57m (Refusal)*		

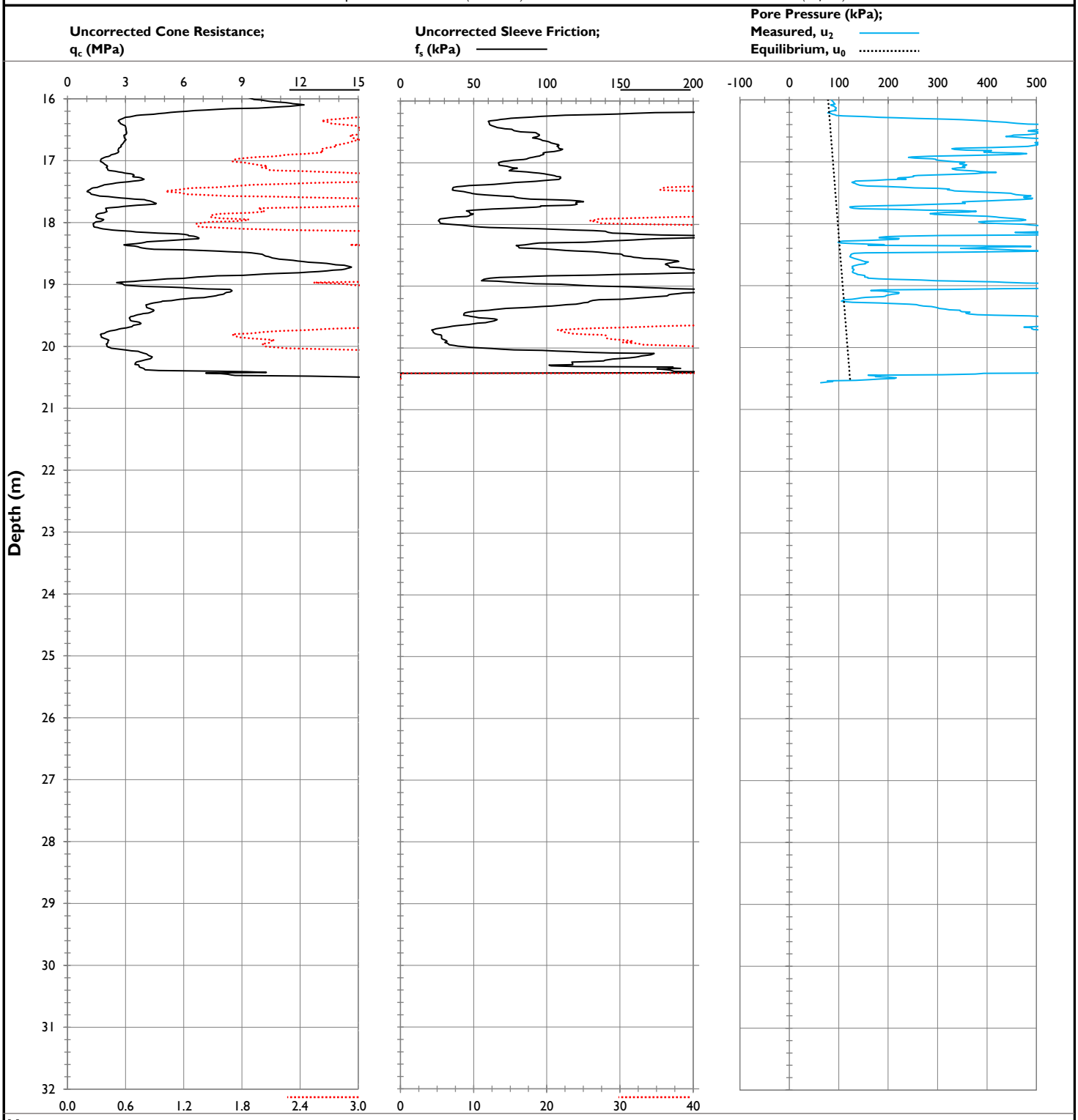


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT06**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631846.5 (AGD66 /*	R.L. Surface:	*221.2m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*10.5m (Auger)*	Northing:	*7521453.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*8.0m (Estimated)*	Termination:	*20.57m (Refusal)*		

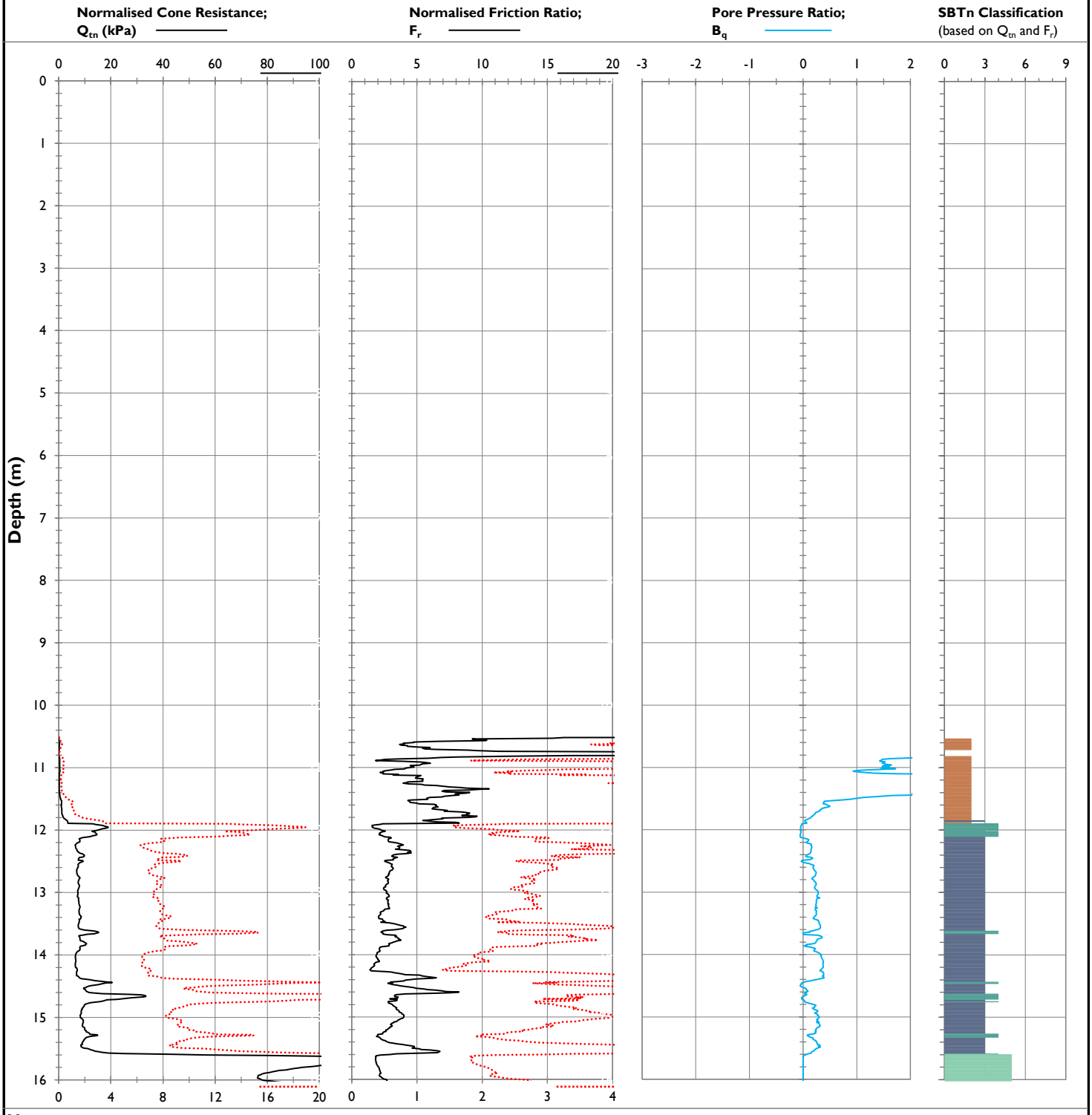


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT06**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631846.5 (AGD66 /* R.L. Surface: *221.2m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*10.5m (Auger)*	Northing:	*7521453.8 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*8.0m (Estimated)*	Termination:	*20.57m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

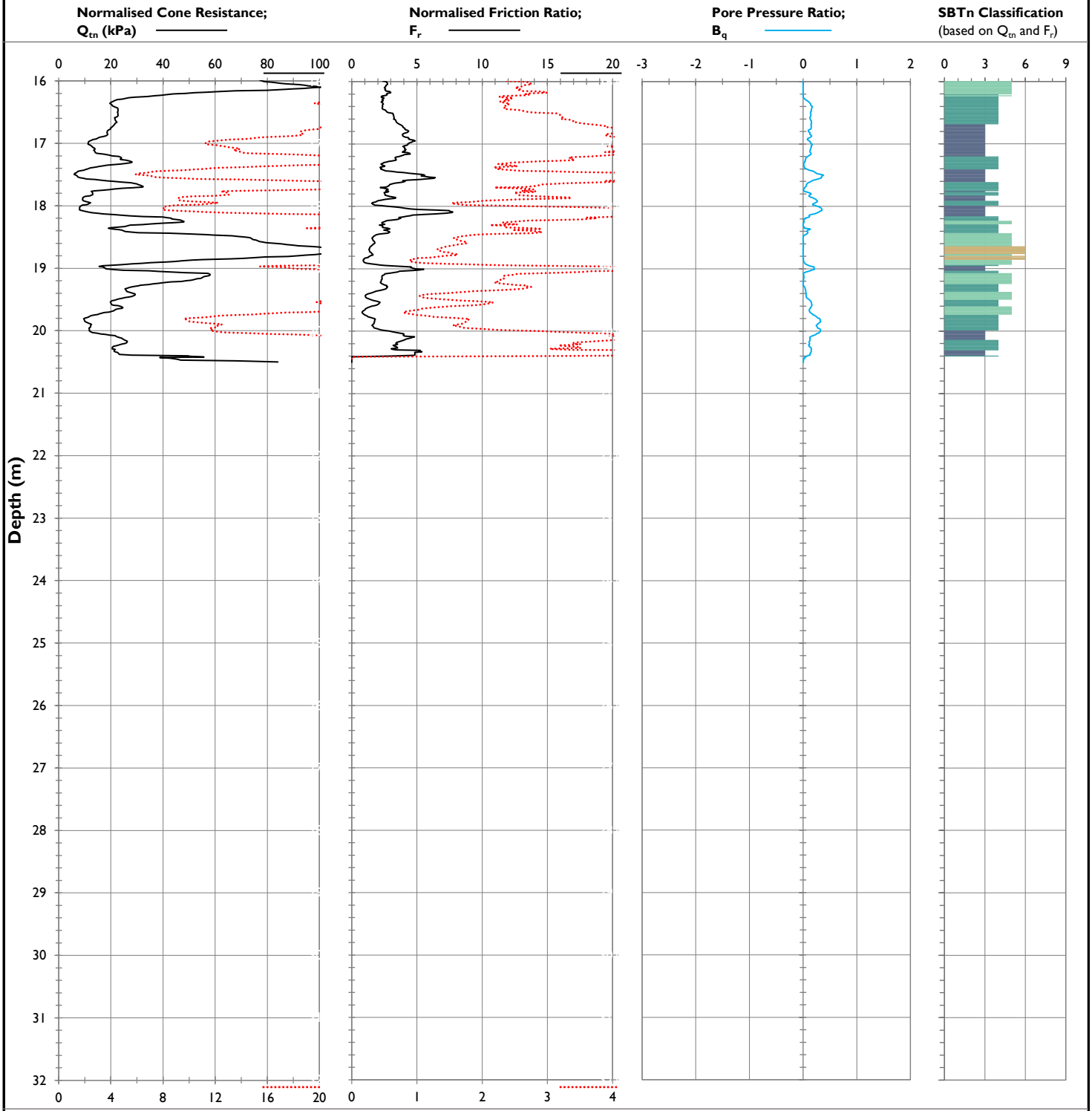
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT06**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631846.5 (AGD66 /* R.L. Surface: *221.2m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*10.5m (Auger)*	Northing:	*7521453.8 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*8.0m (Estimated)*	Termination:	*20.57m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

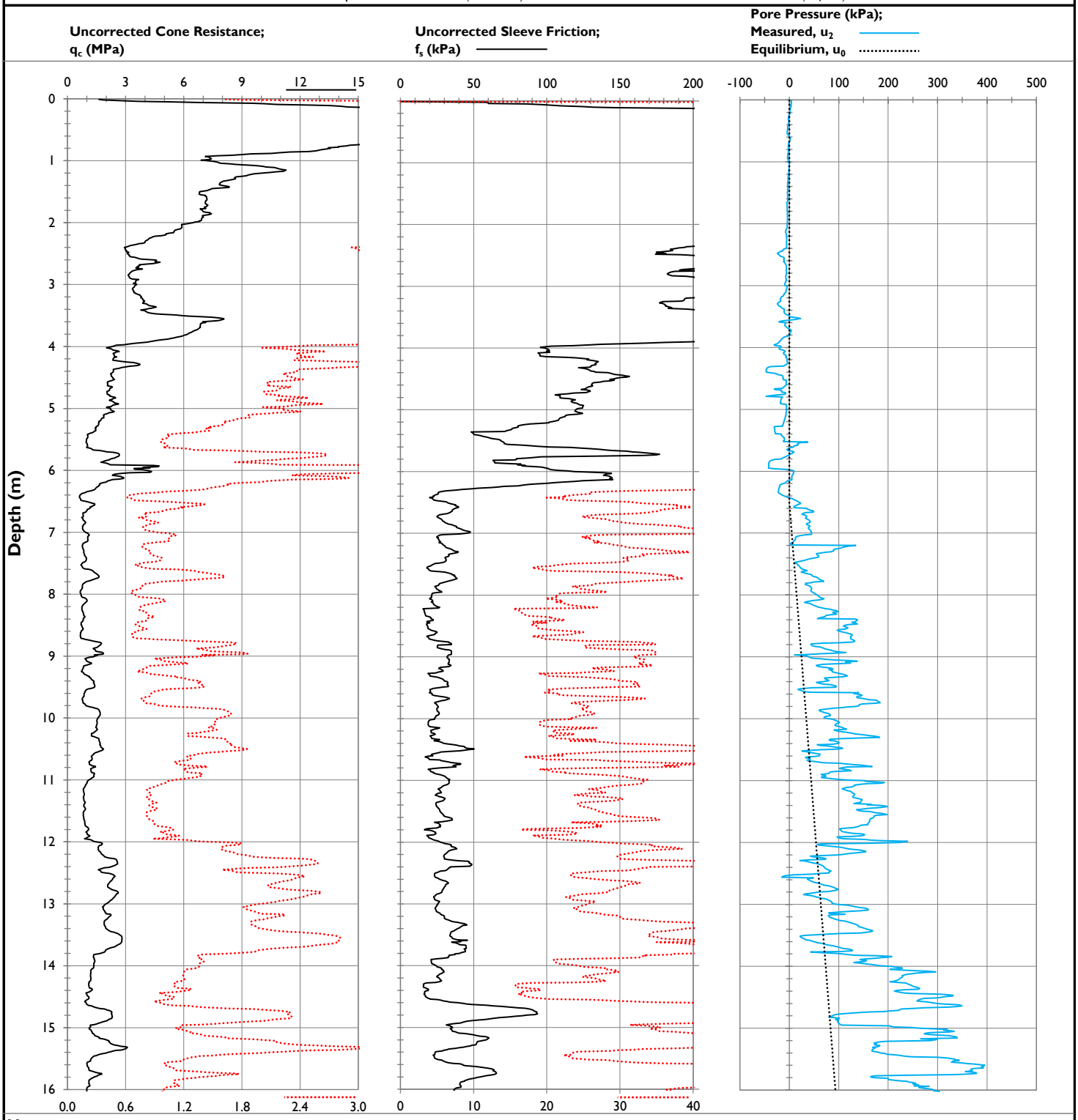
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT07**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**11/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631819.2 (AGD66 /*	R.L. Surface:	*221.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521282.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*6.5m (Estimated)*	Termination:	*20.79m (Refusal)*		

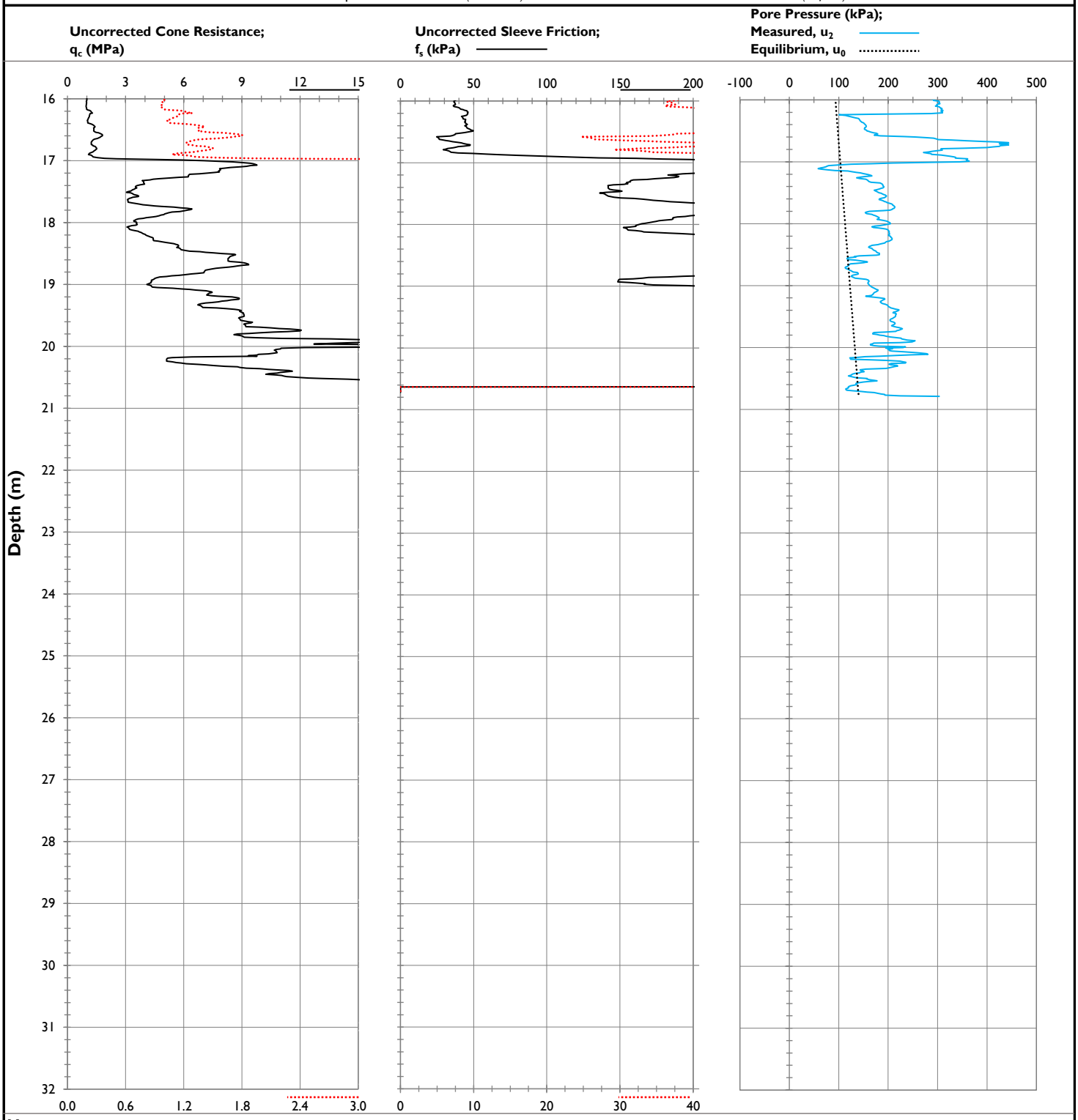


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT07**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**11/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631819.2 (AGD66 /* R.L. Surface: *221.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521282.2 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.79*	Depth to GW:	*6.5m (Estimated)*	Termination:	*20.79m (Refusal)*

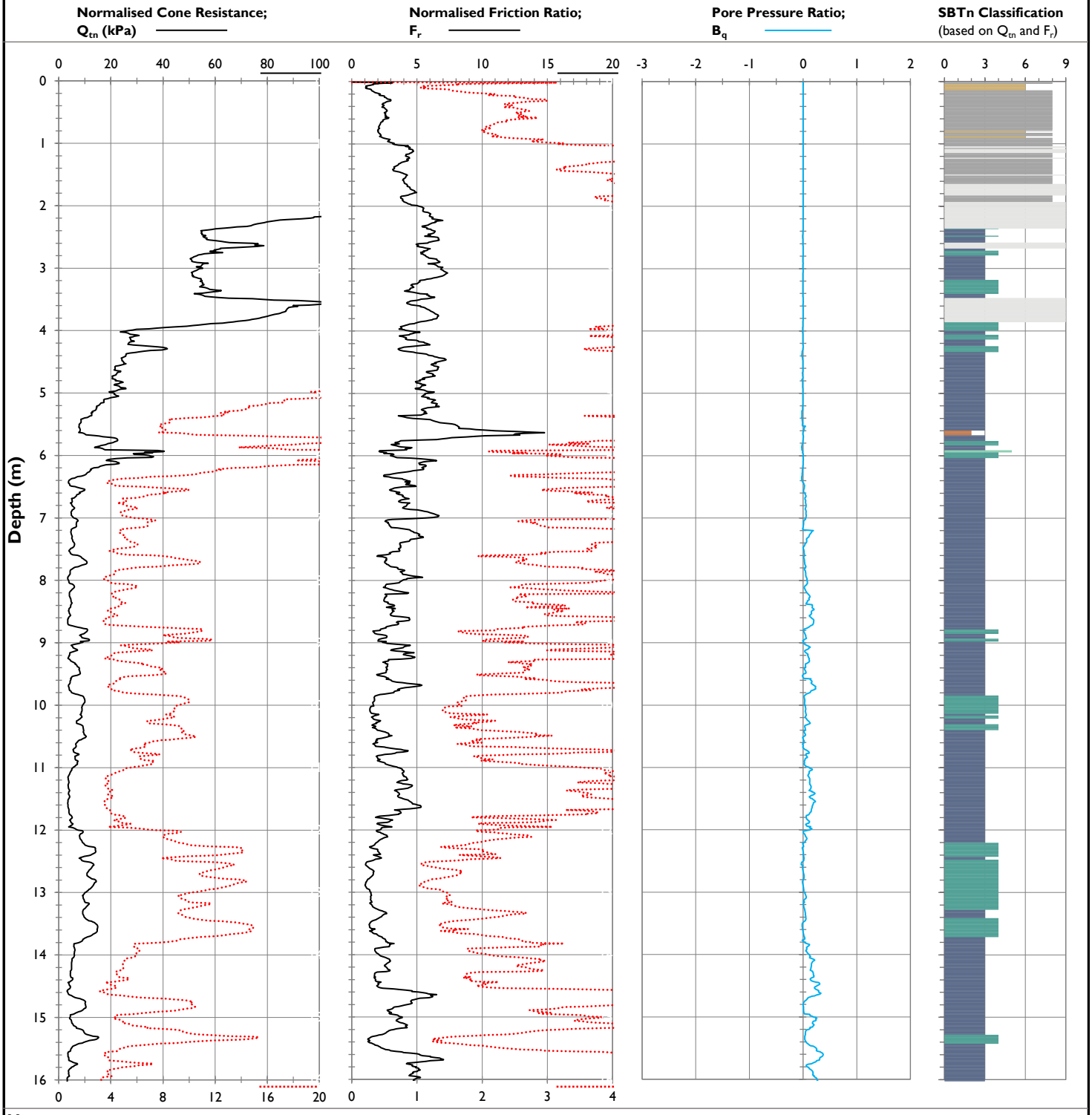


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT07**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**11/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631819.2 (AGD66 /*	R.L. Surface:	*221.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521282.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*6.5m (Estimated)*	Termination:	*20.79m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

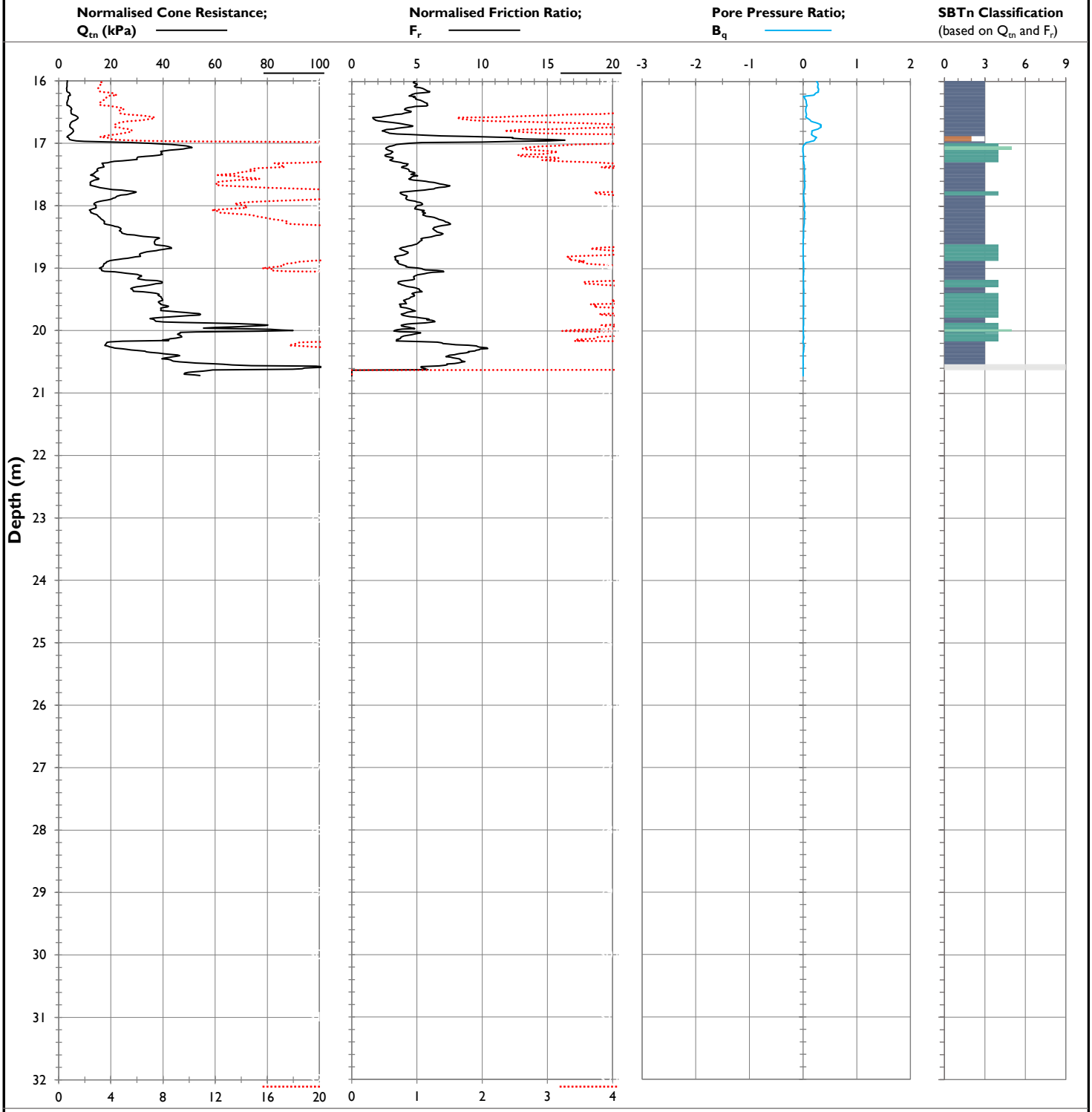
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT07**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**11/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631819.2 (AGD66 /* R.L. Surface: *221.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521282.2 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.79*	Depth to GW:	*6.5m (Estimated)*	Termination:	*20.79m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

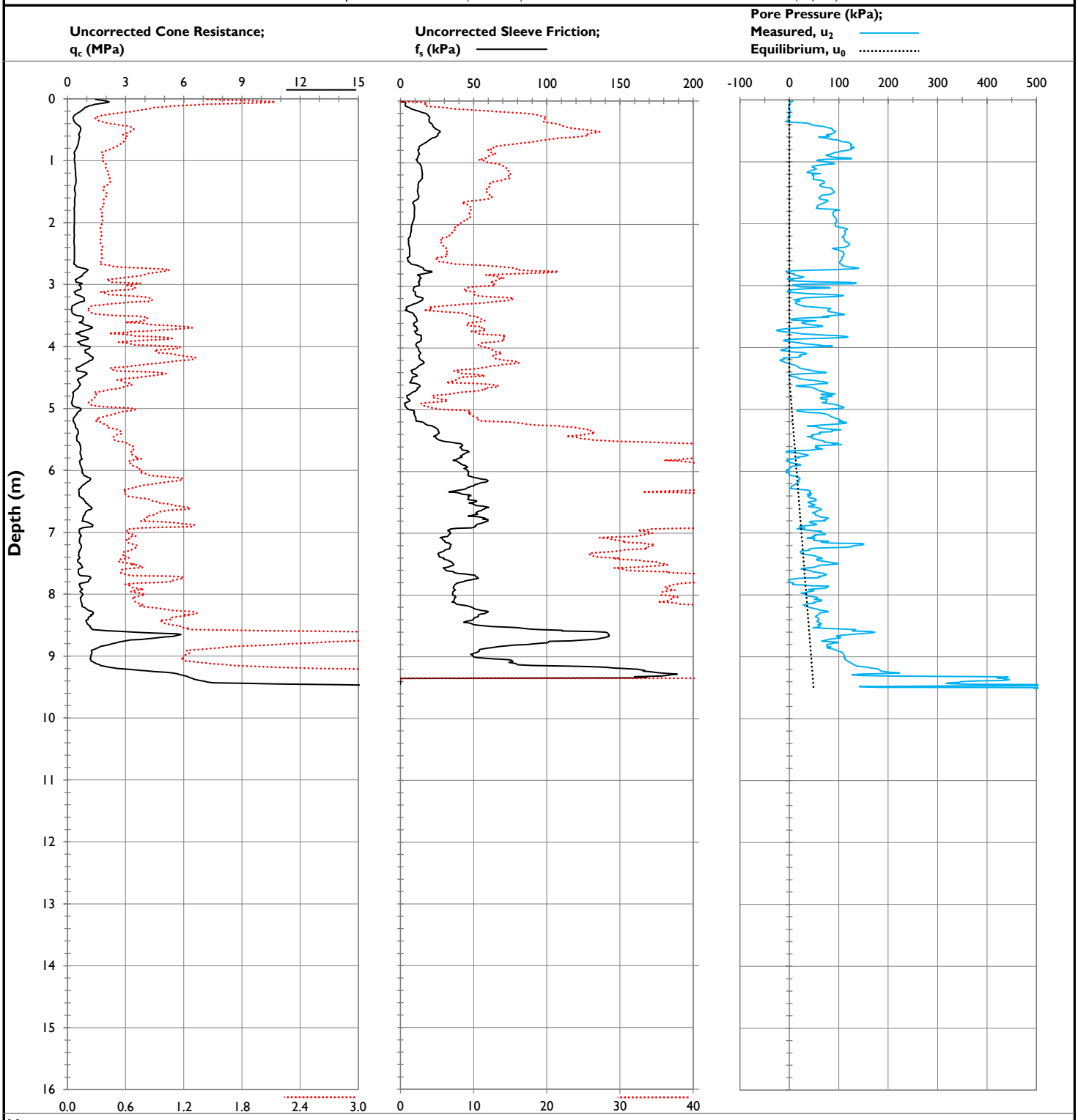
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT10**		
Sheet:	1 of 2		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**16/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*632141.9 (AGD66 /*	R.L. Surface:	*218.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521514.6 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*9.51m (Refusal)*		

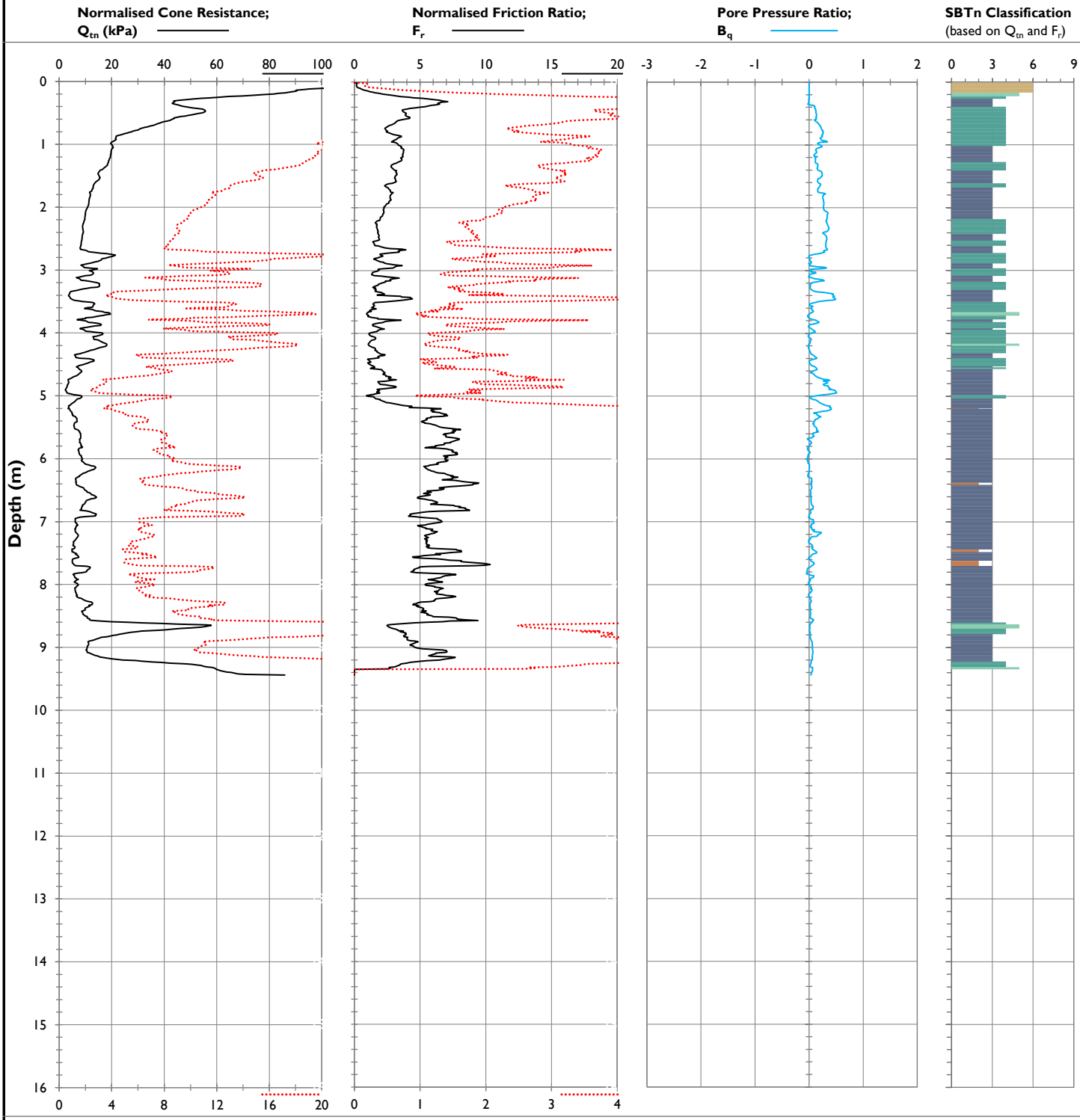


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT10**		
Sheet:	2 of 2		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**16/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*632141.9 (AGD66 /* R.L. Surface: *218.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521514.6 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*9.51m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

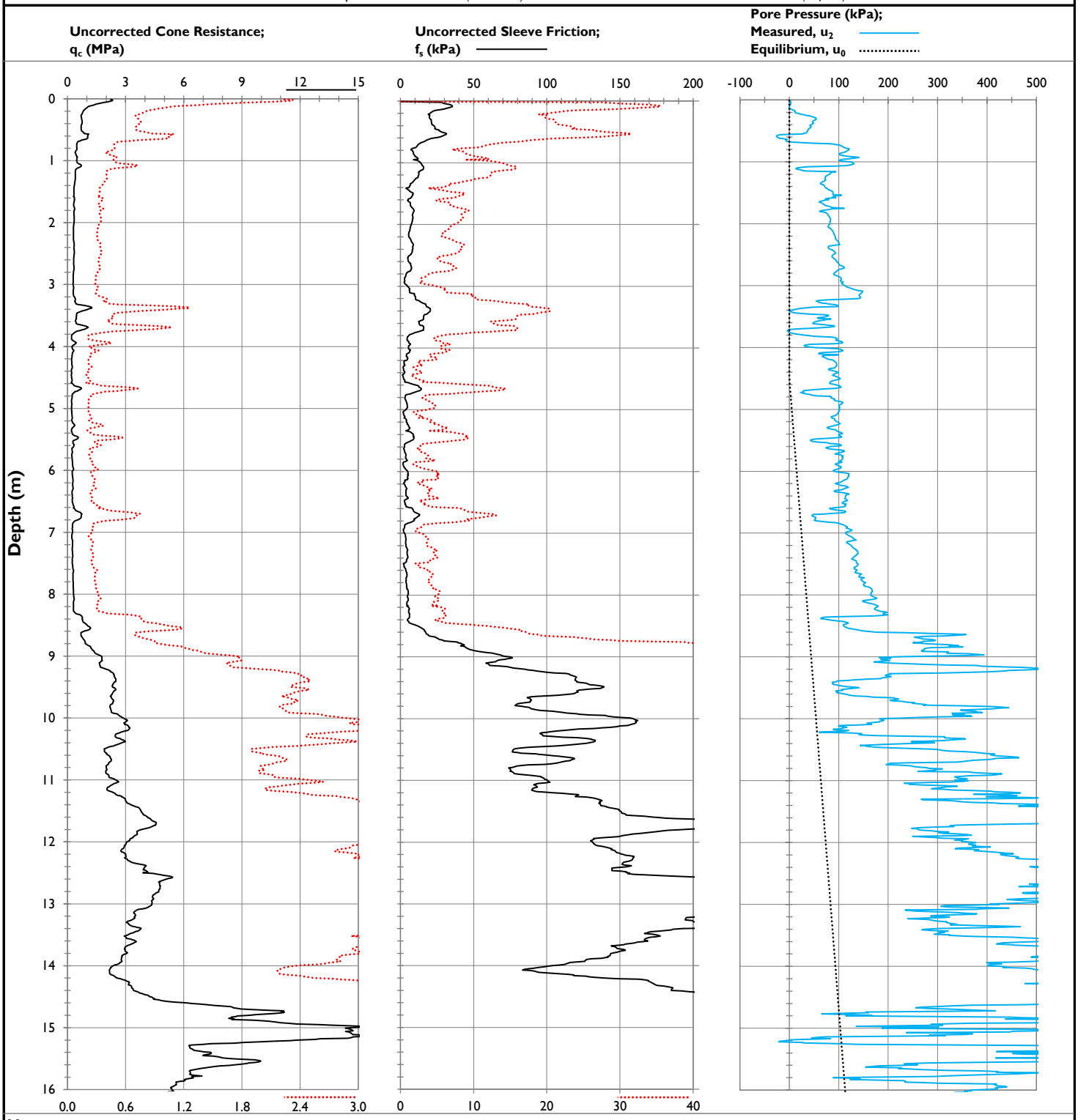
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT11**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**16/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*632099.2 (AGD66 /*	R.L. Surface:	*218.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521554.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*18.02m (Refusal)*		

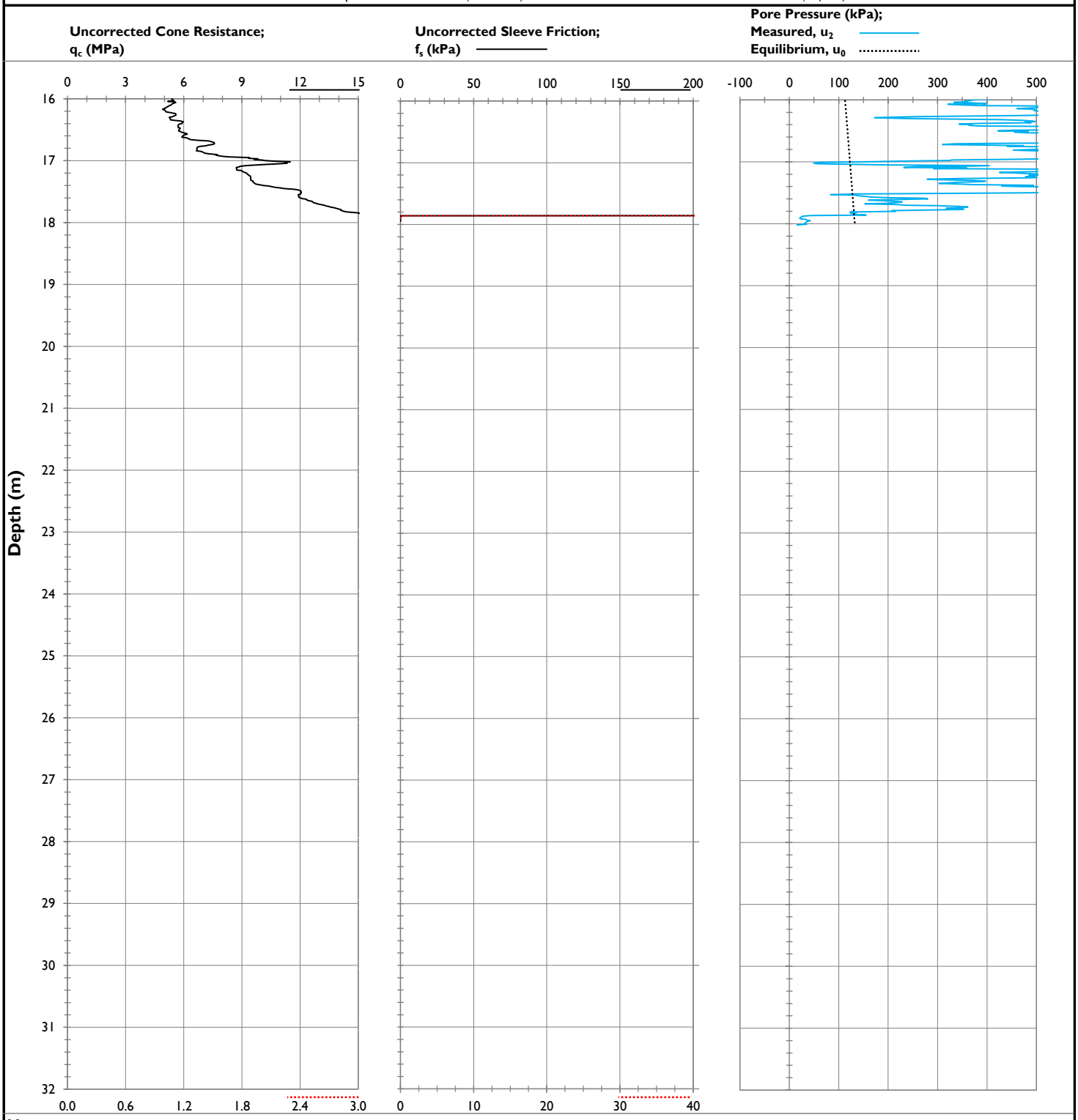


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT11**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**16/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*632099.2 (AGD66 /* R.L. Surface: *218.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521554.8 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*18.02m (Refusal)*

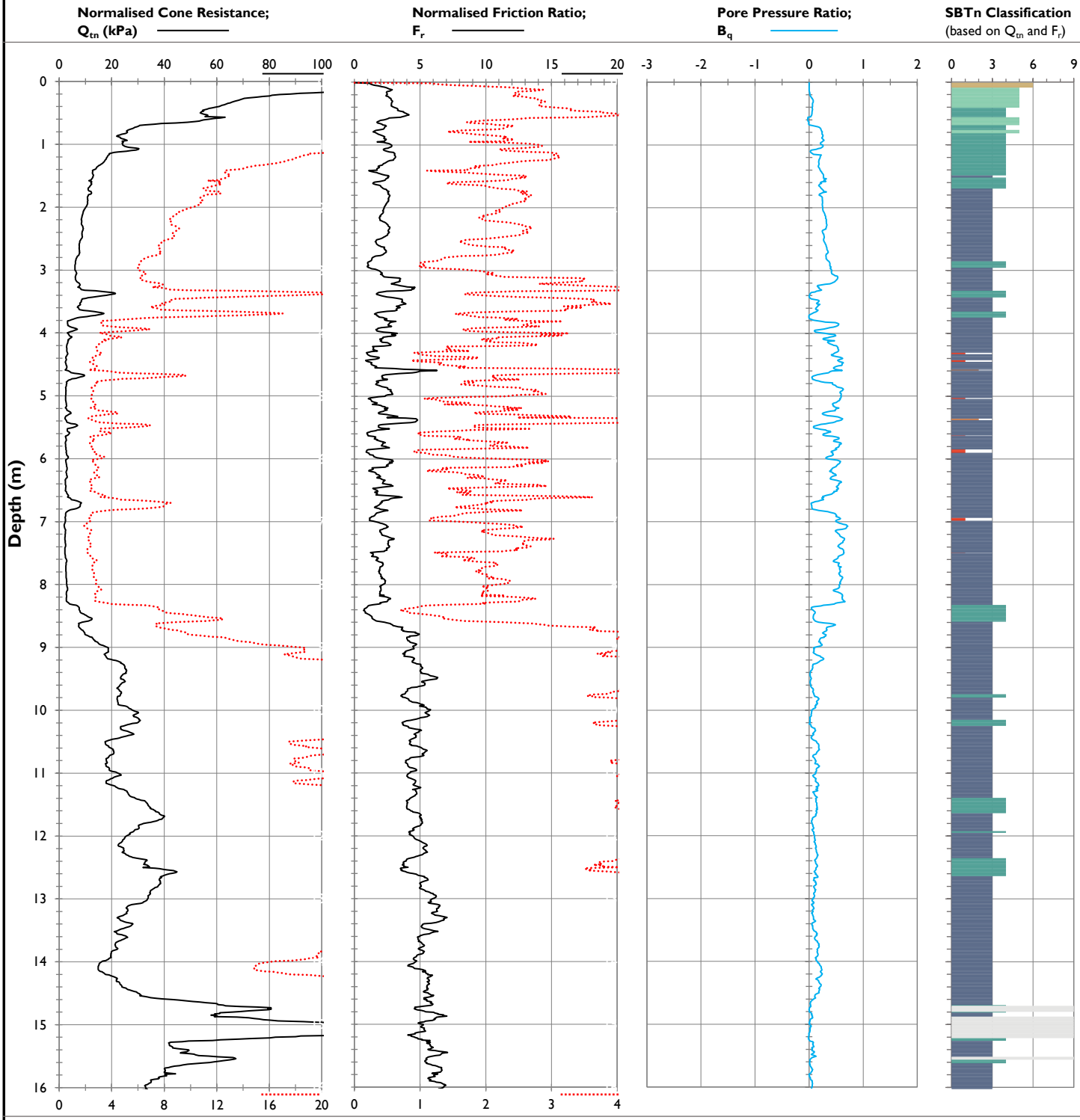


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT11**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**16/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*632099.2 (AGD66 /*	R.L. Surface:	*218.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521554.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*18.02m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

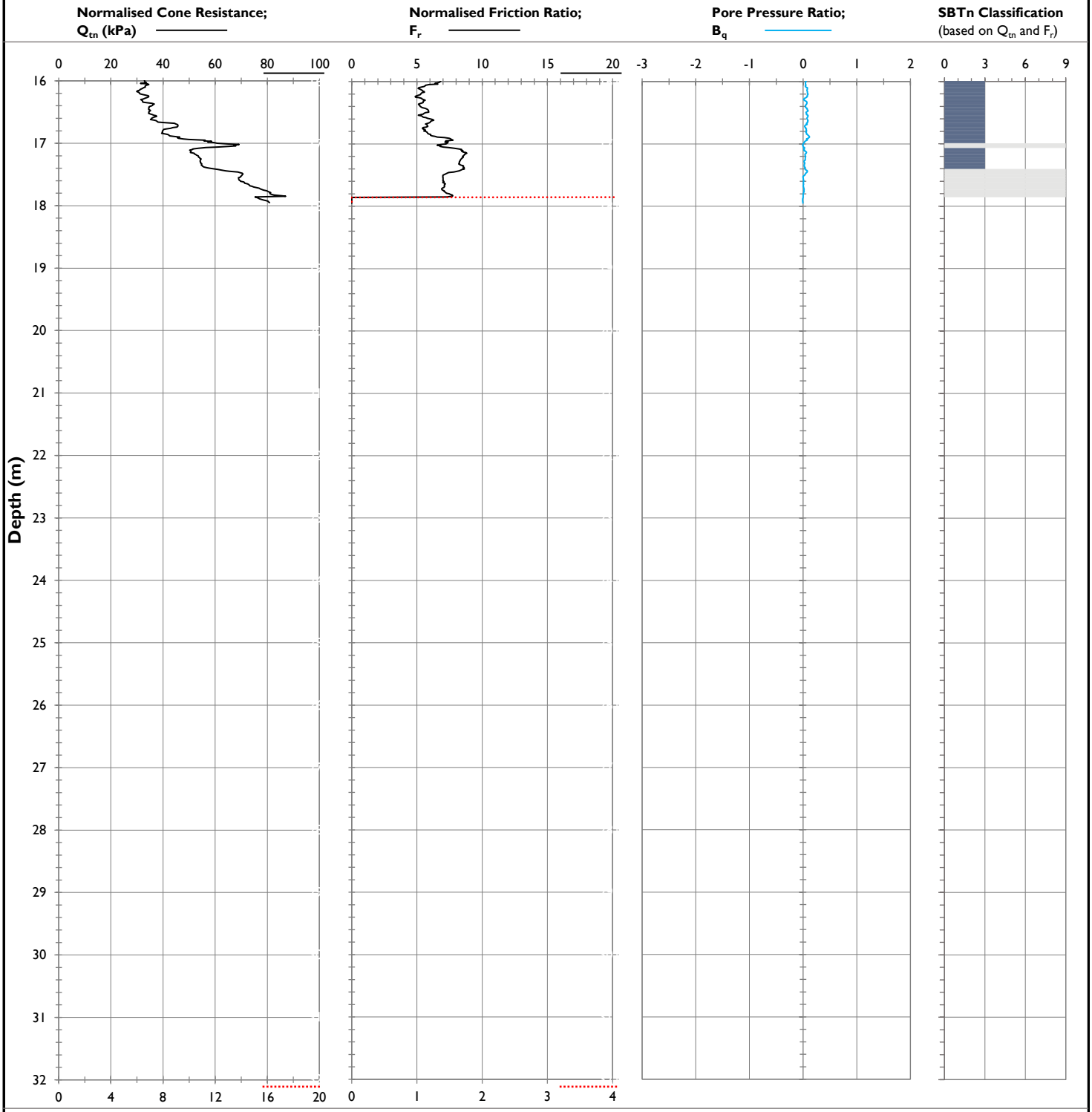
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT11**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**16/05/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*632099.2 (AGD66 /*	R.L. Surface:	*218.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521554.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*18.02m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

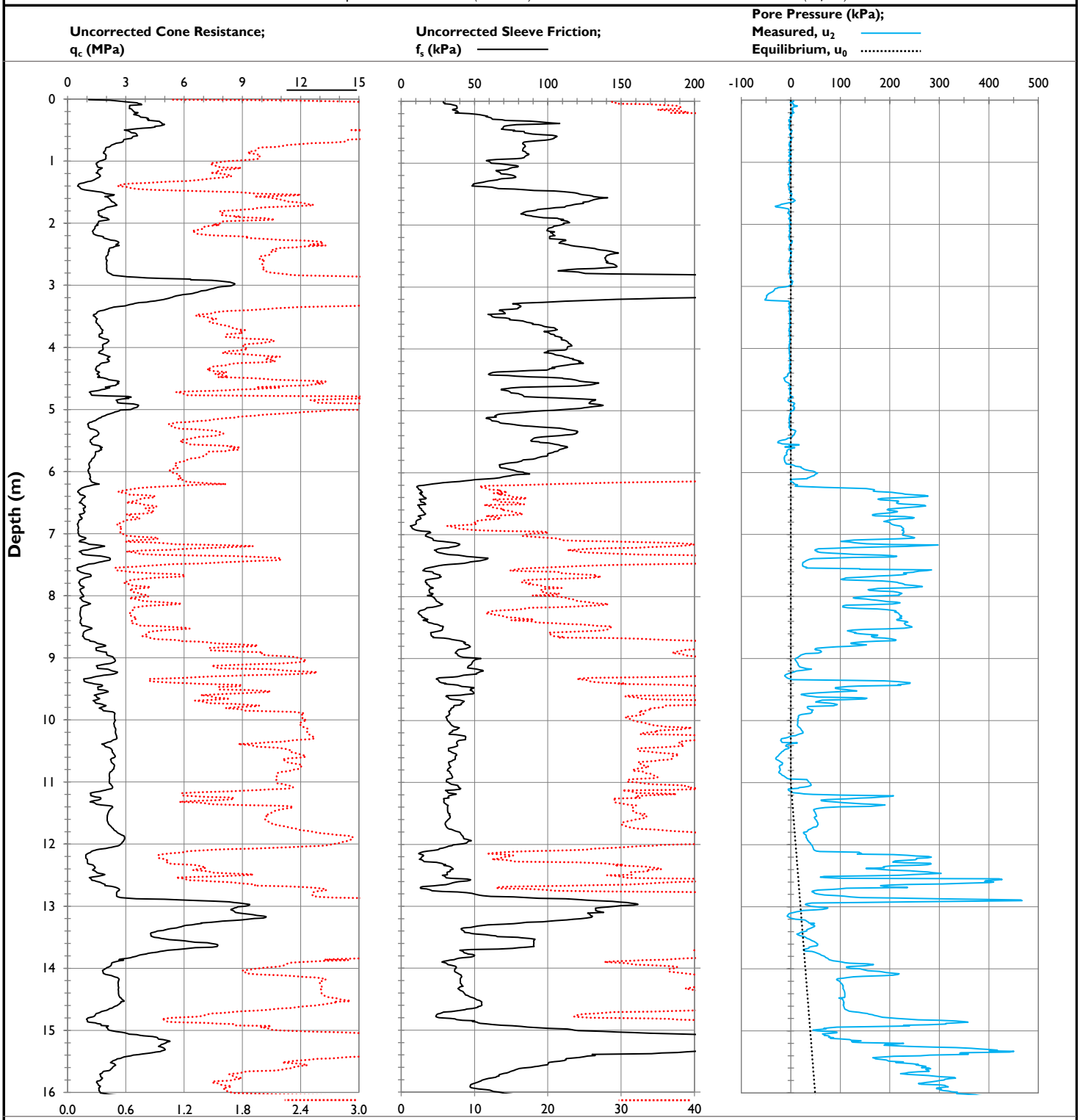
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT13**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**1/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*632025.1 (AGD66 /*	R.L. Surface:	*222.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521356.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*11.0m (Estimated)*	Termination:	*19.82m (Refusal)*		

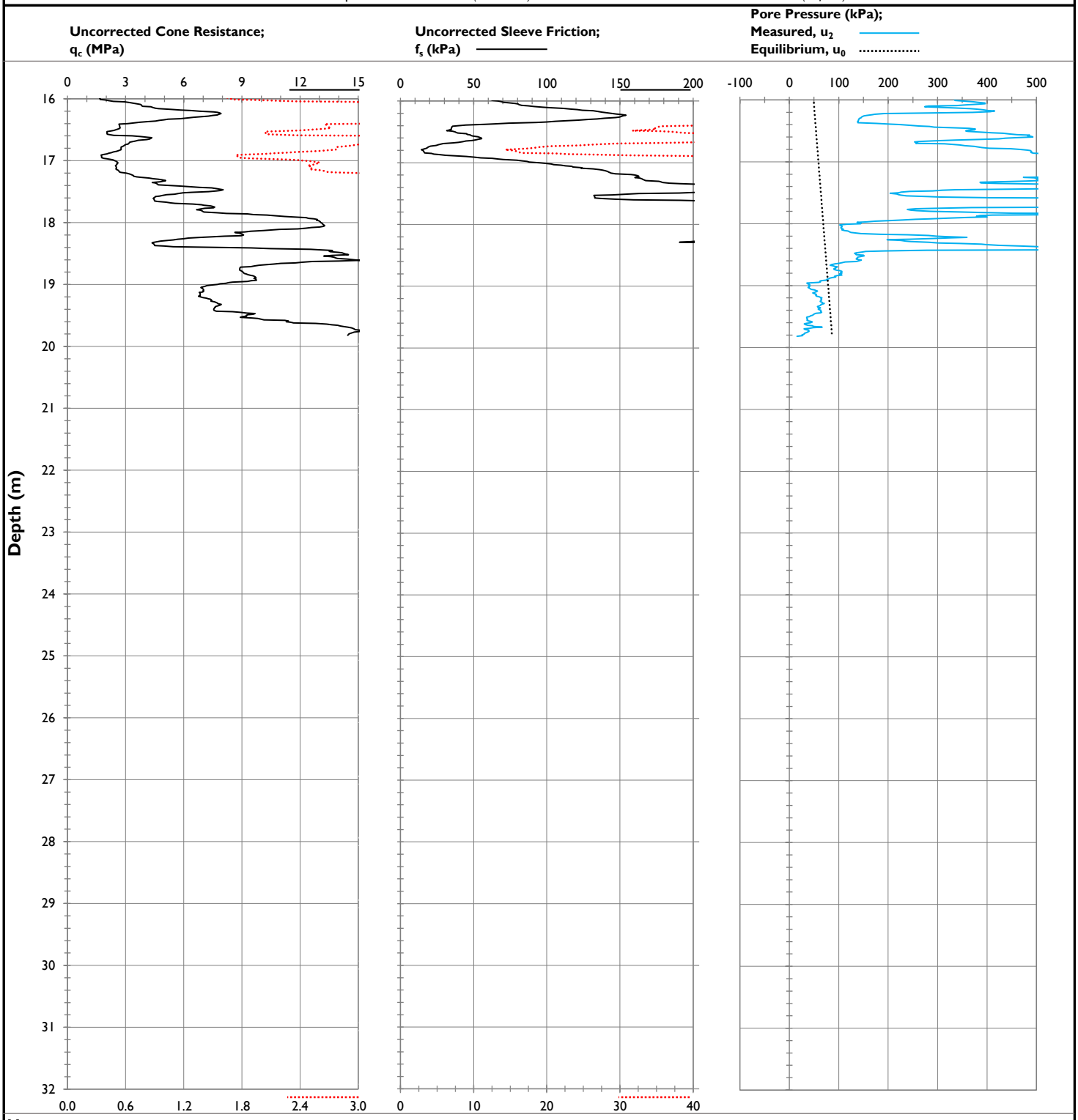


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT13**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**1/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*632025.1 (AGD66 /* R.L. Surface: *222.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521356.2 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*11.0m (Estimated)*	Termination:	*19.82m (Refusal)*

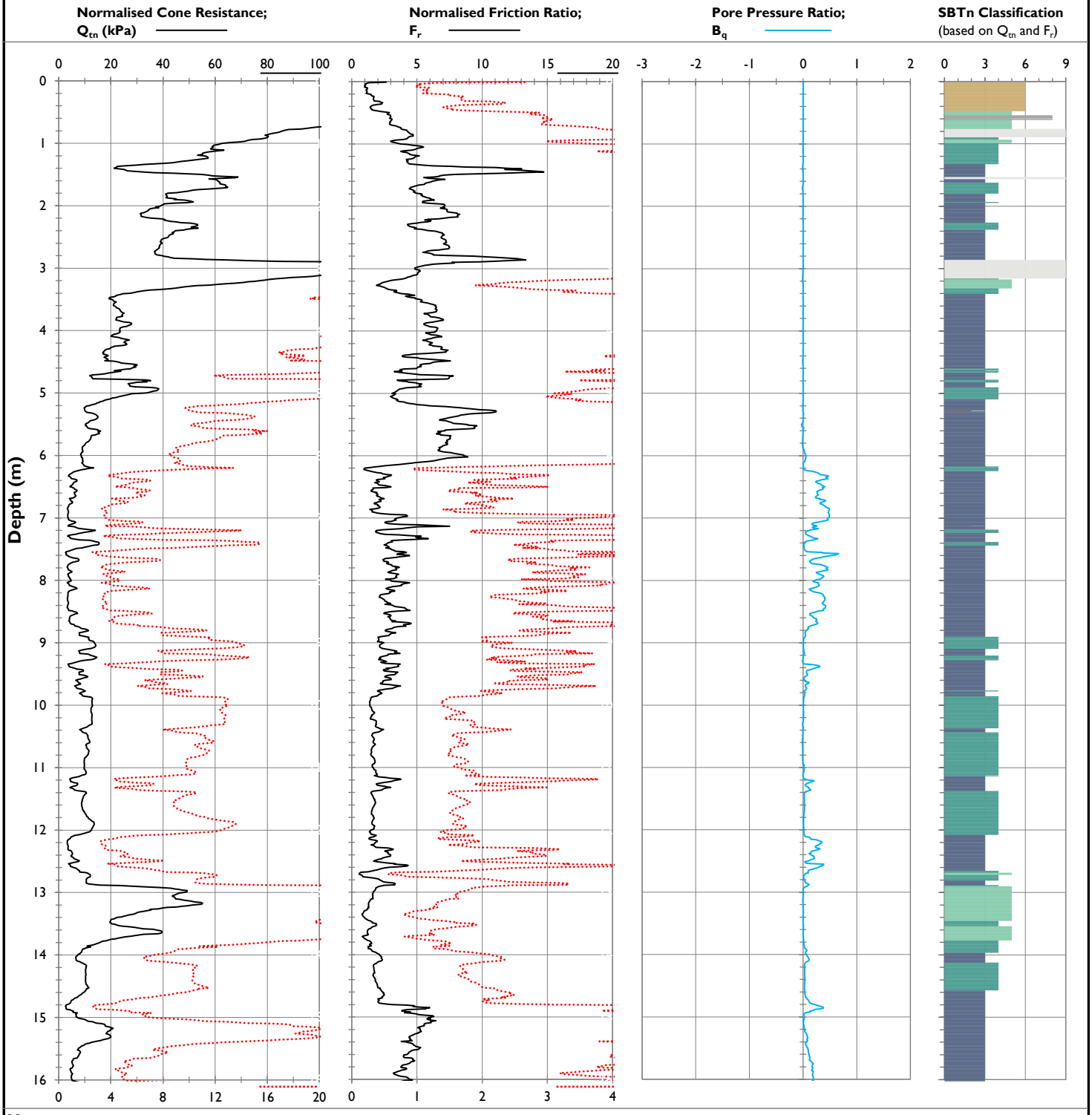


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT13**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**1/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*632025.1 (AGD66 /* R.L. Surface: *222.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521356.2 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*11.0m (Estimated)*	Termination:	*19.82m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

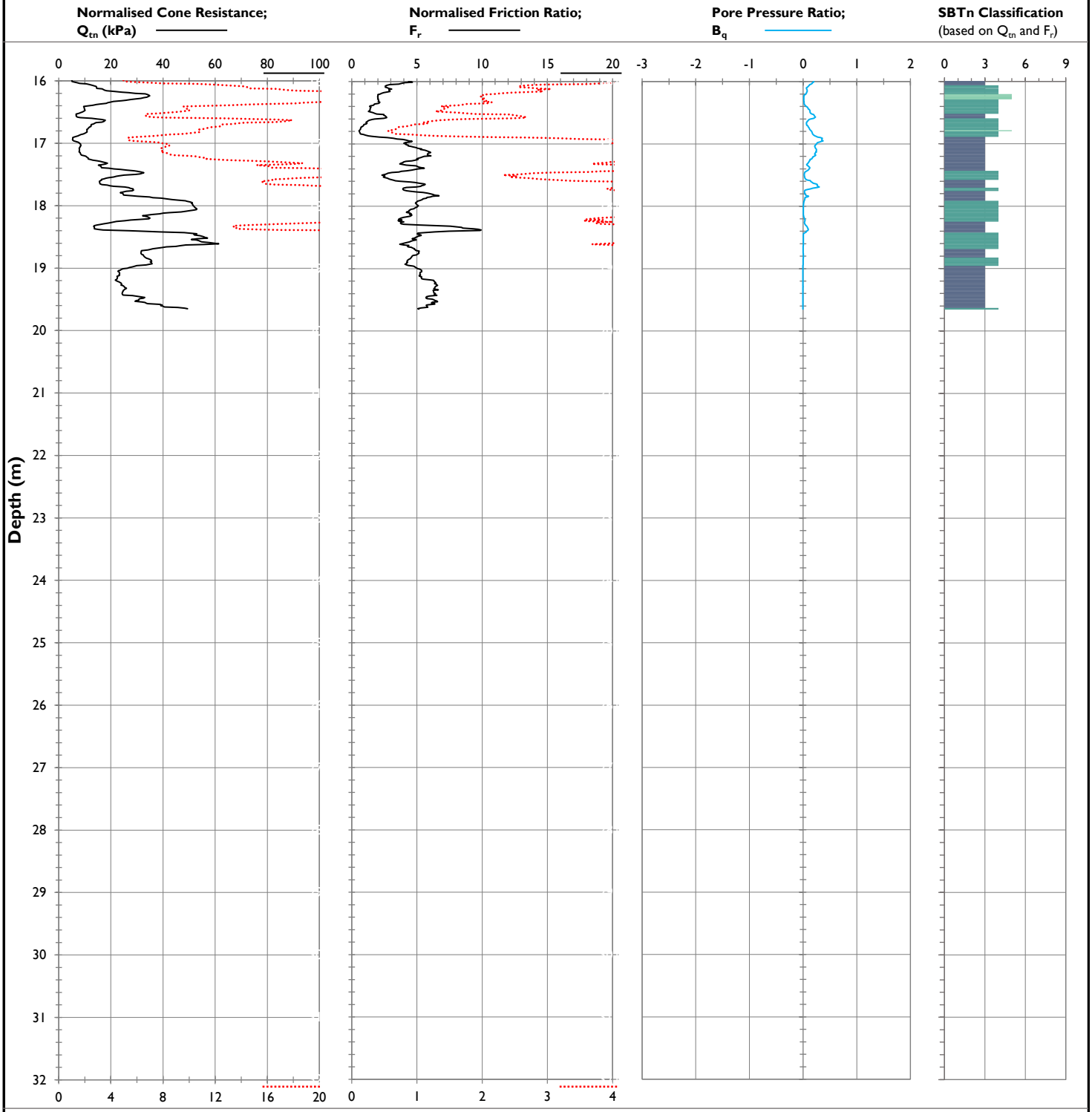
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT13**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**1/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*632025.1 (AGD66 /*	R.L. Surface:	*222.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521356.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*11.0m (Estimated)*	Termination:	*19.82m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

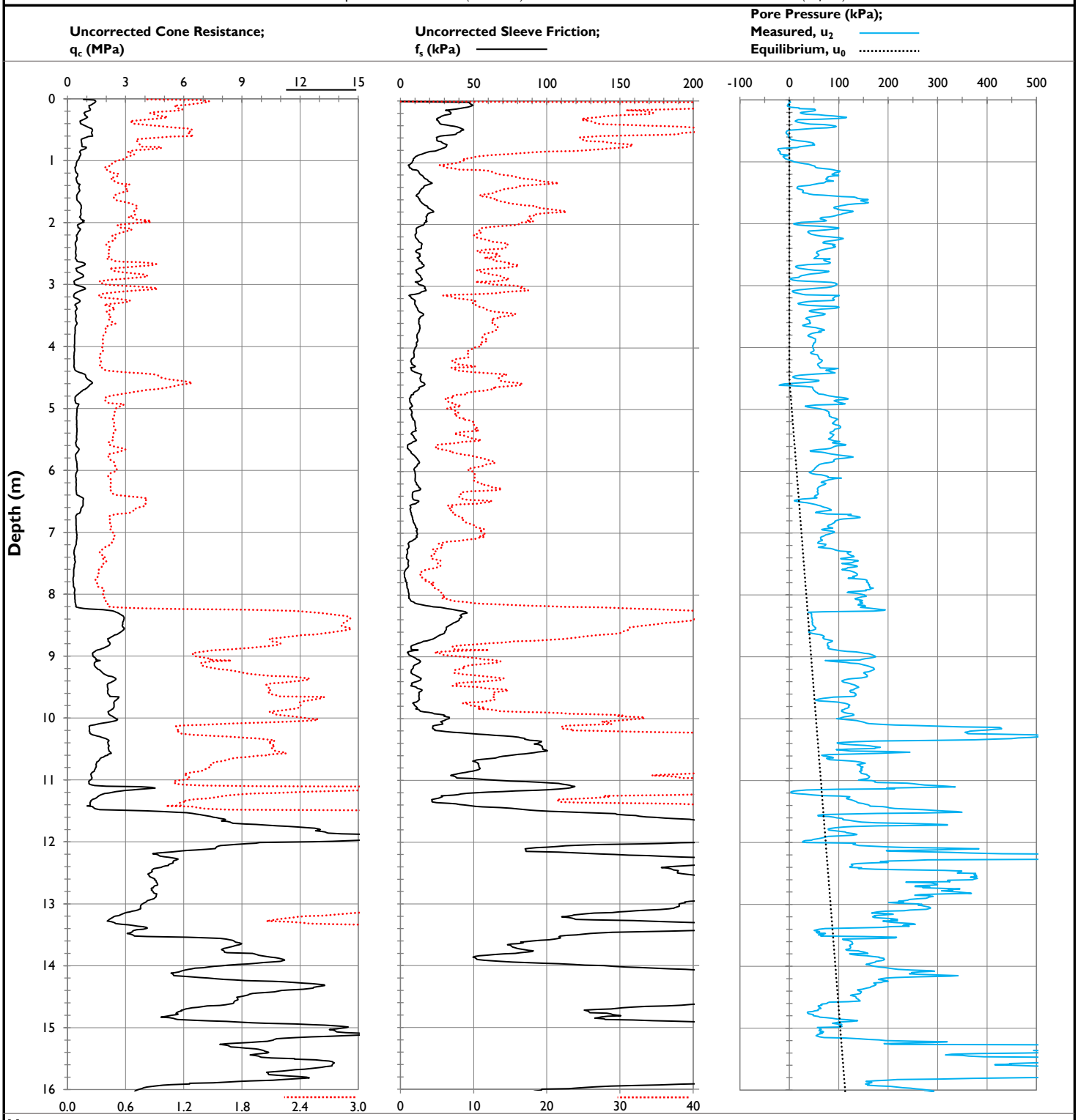
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT14**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**1/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631982.7 (AGD66 /*	R.L. Surface:	*218.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521531.7 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*20.48m (Refusal)*		

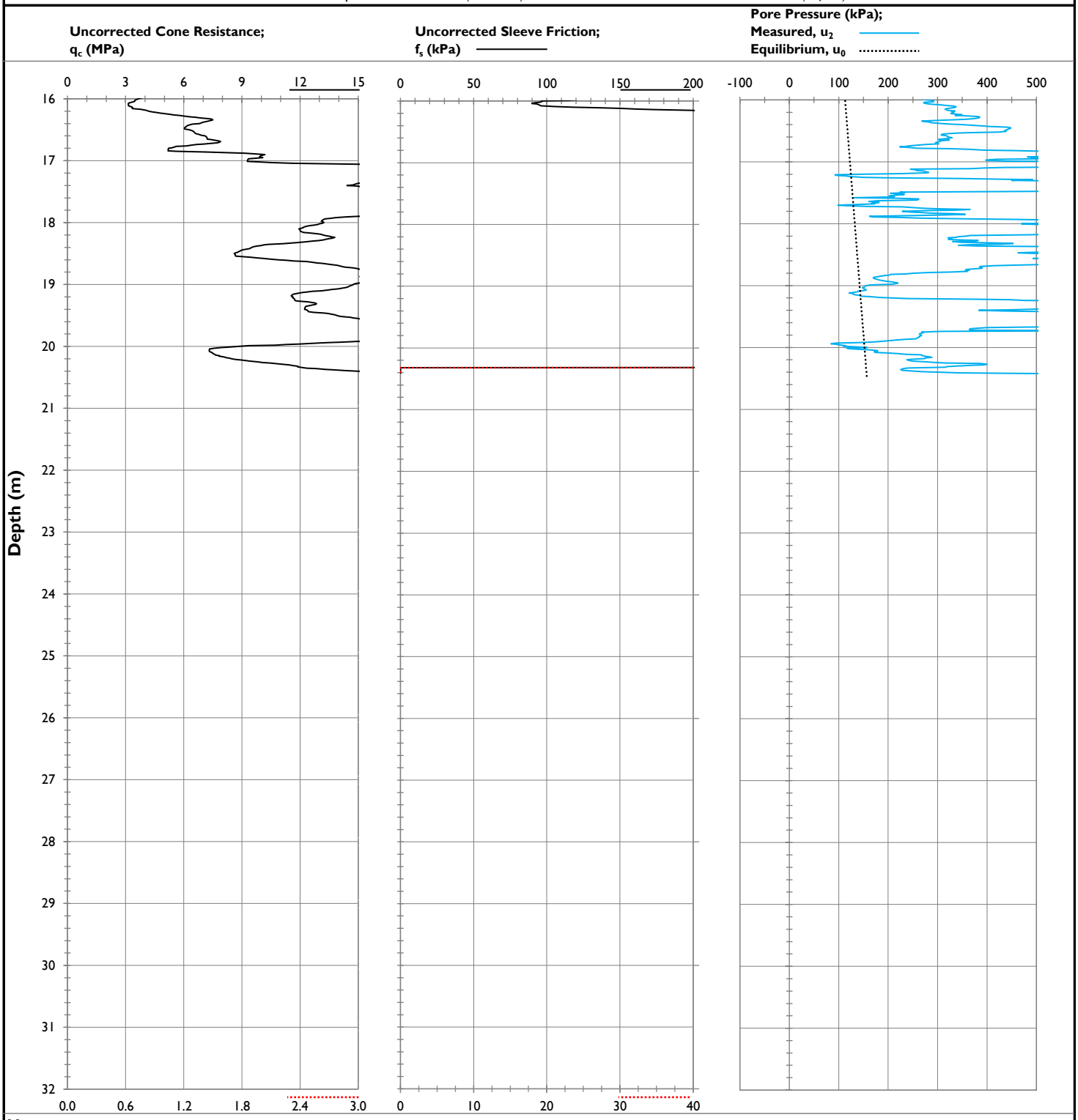


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT14**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**1/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631982.7 (AGD66 /* R.L. Surface: *218.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521531.7 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*20.48m (Refusal)*

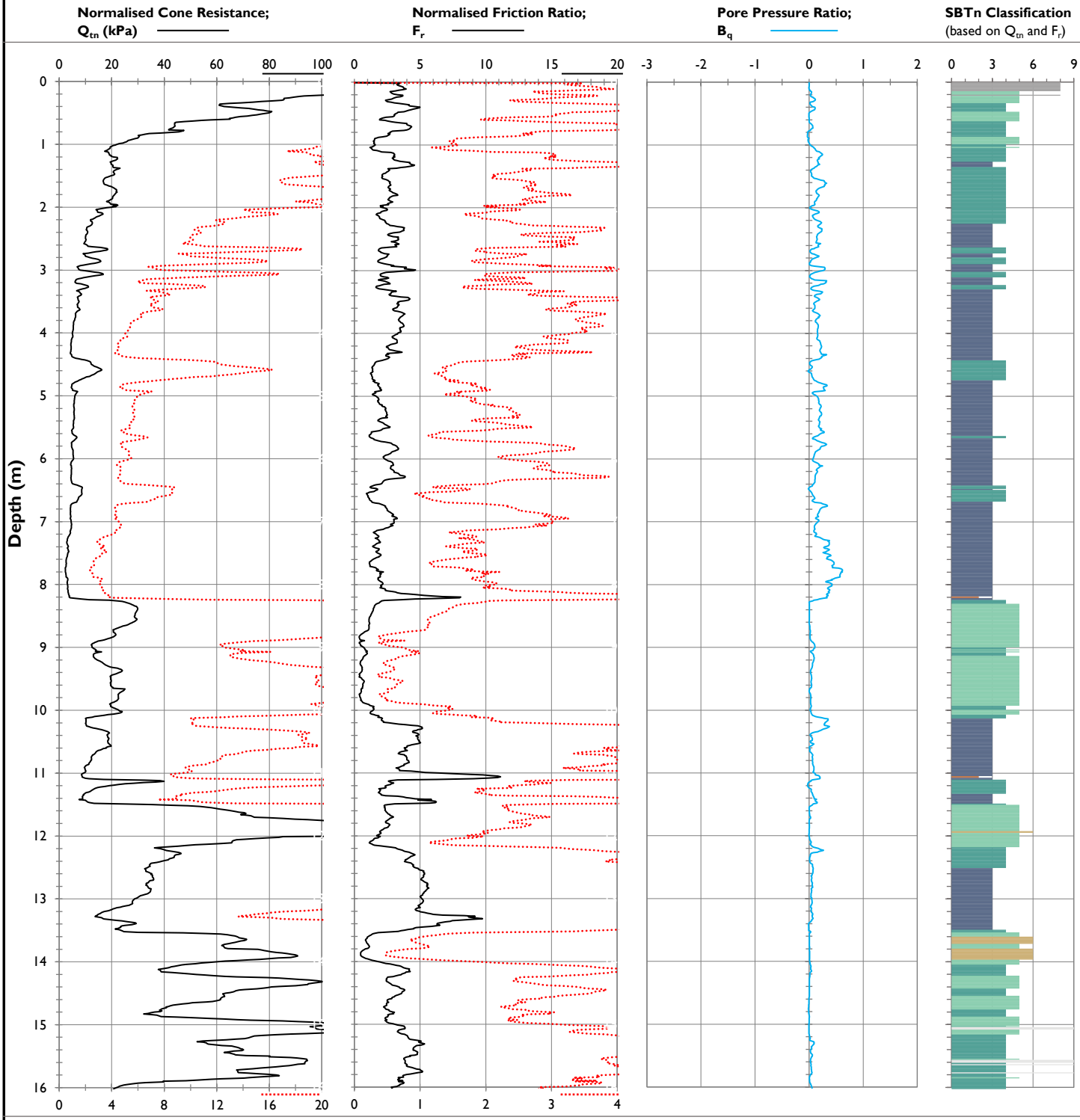


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT14**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**1/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631982.7 (AGD66 /*	R.L. Surface:	*218.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521531.7 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*20.48m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

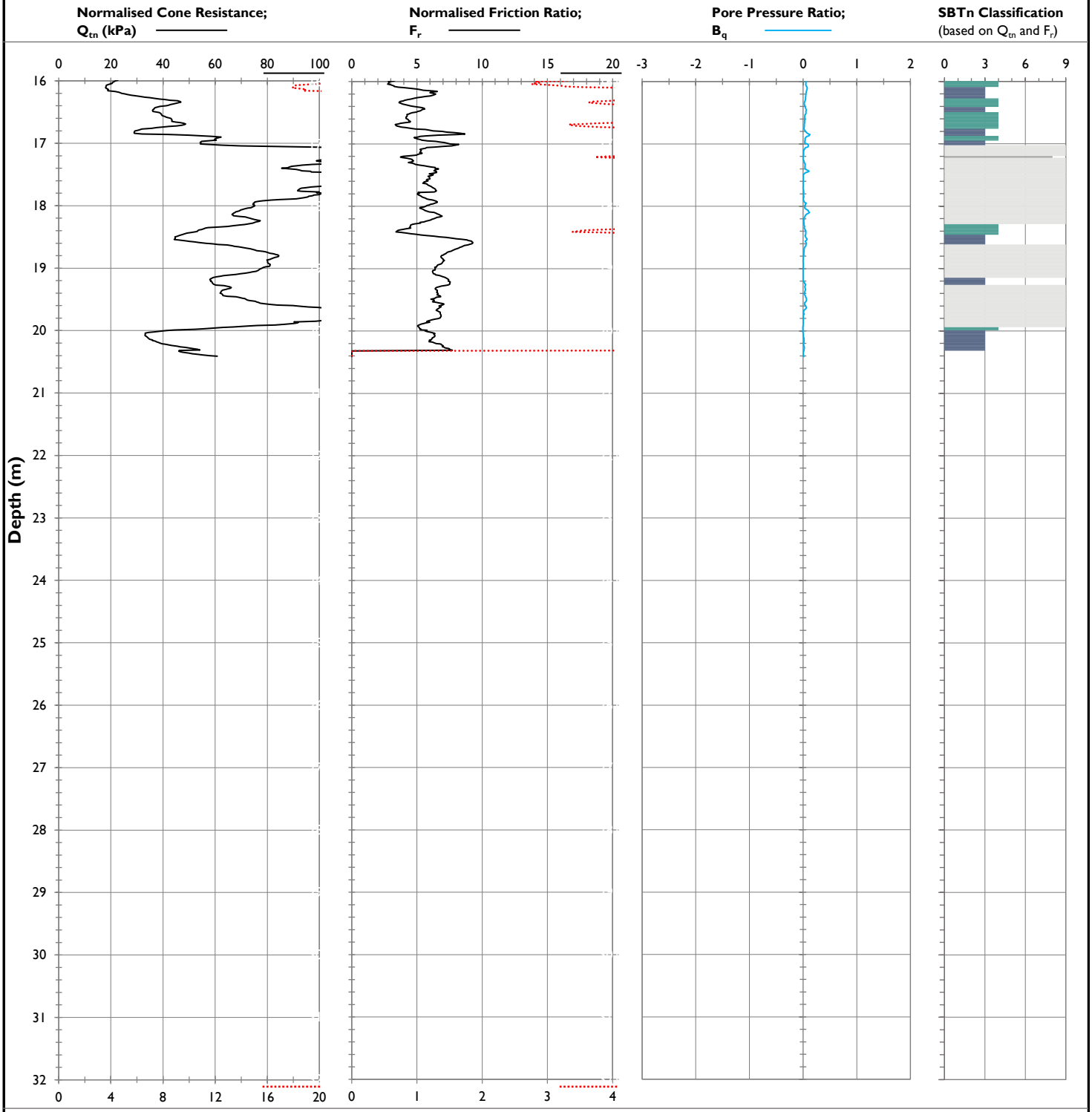
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT14**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**1/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631982.7 (AGD66 /*	R.L. Surface:	*218.4m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521531.7 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*20.48m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

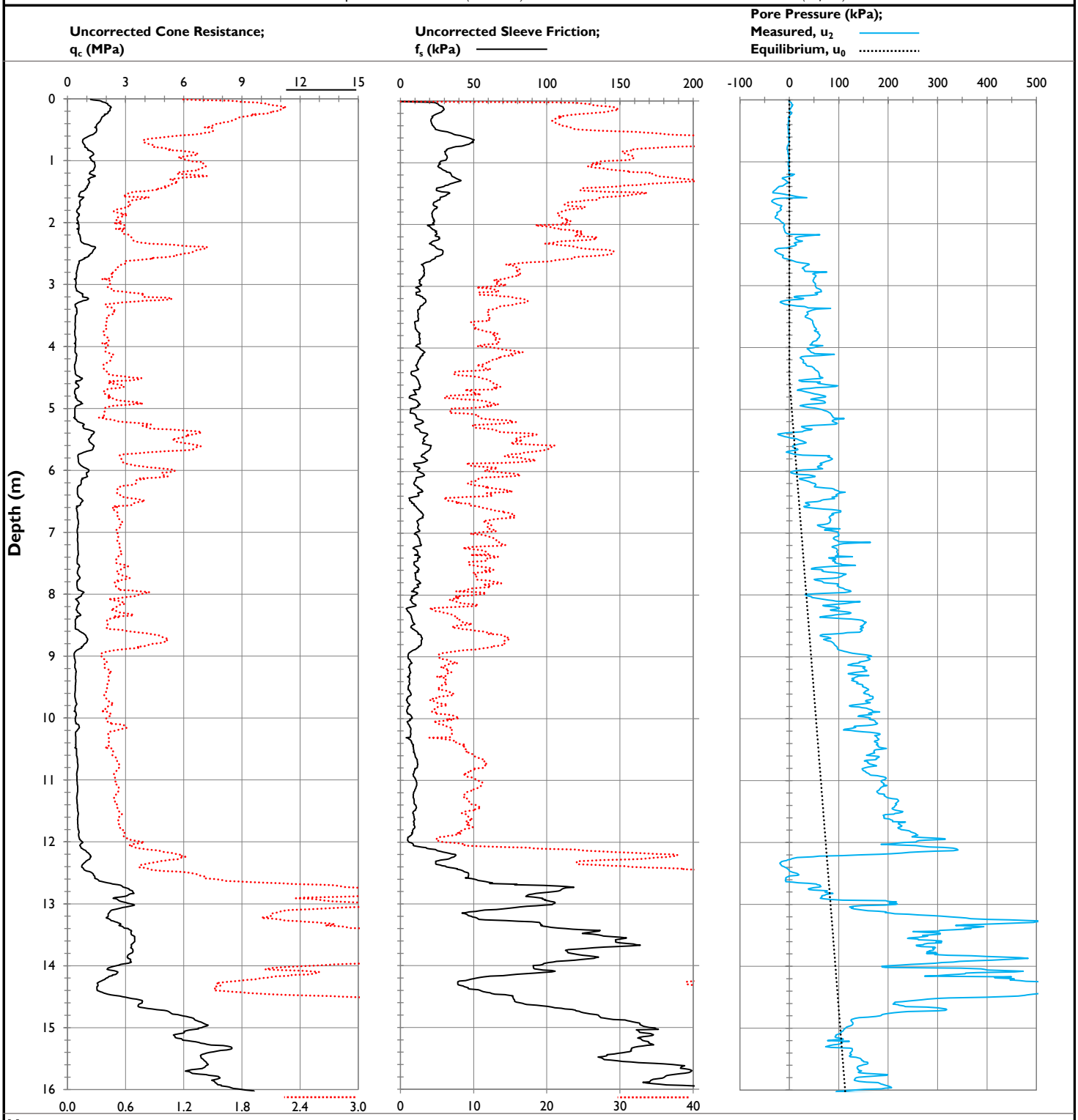
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT15**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**2/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631928.4 (AGD66 /*	R.L. Surface:	*218.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521486 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*19.45m (Refusal)*		

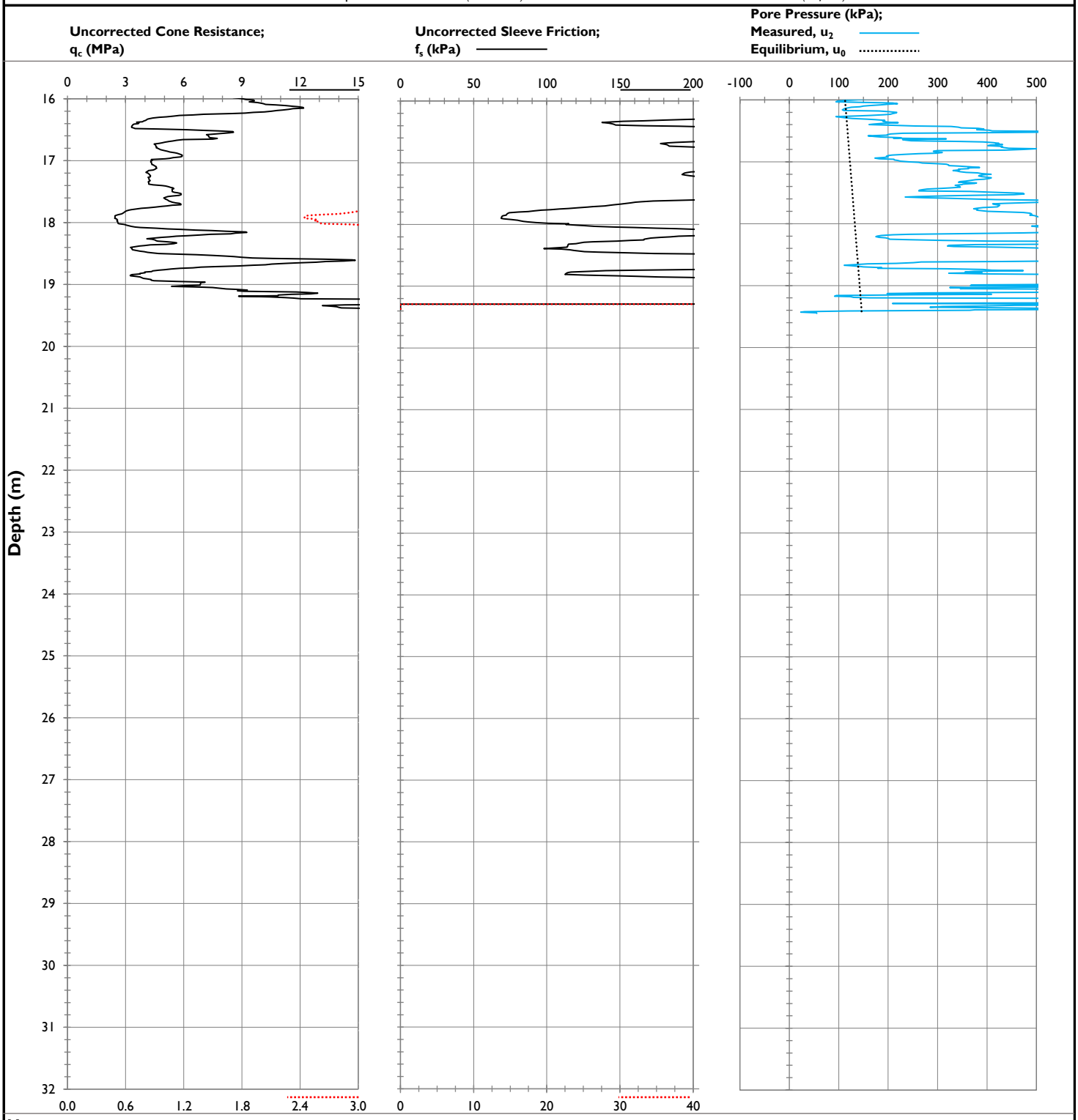


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT15**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**2/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631928.4 (AGD66 /* R.L. Surface: *218.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521486 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*19.45m (Refusal)*

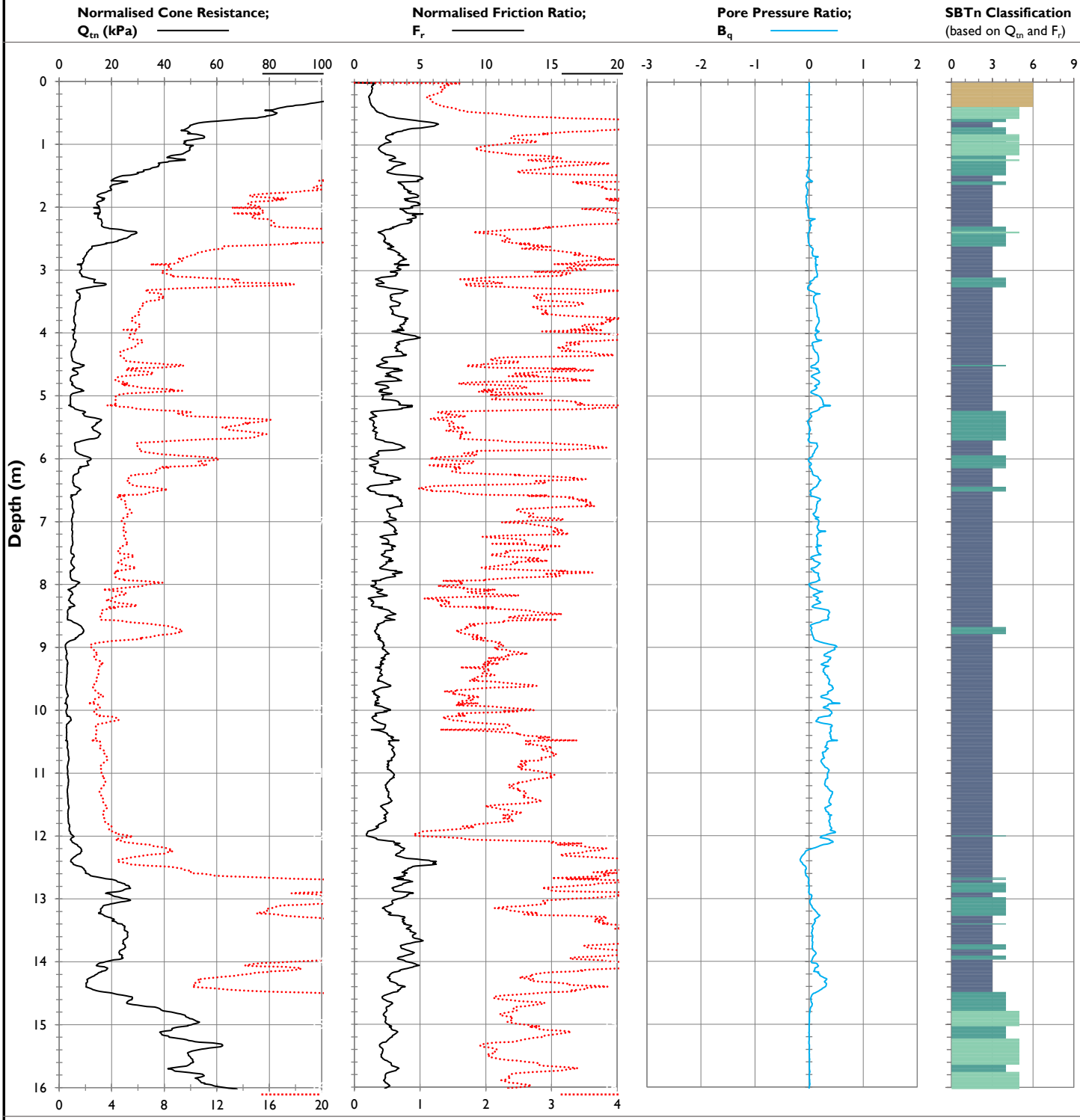


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT15**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**2/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631928.4 (AGD66 /* R.L. Surface: *218.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521486 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*19.45m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

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$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

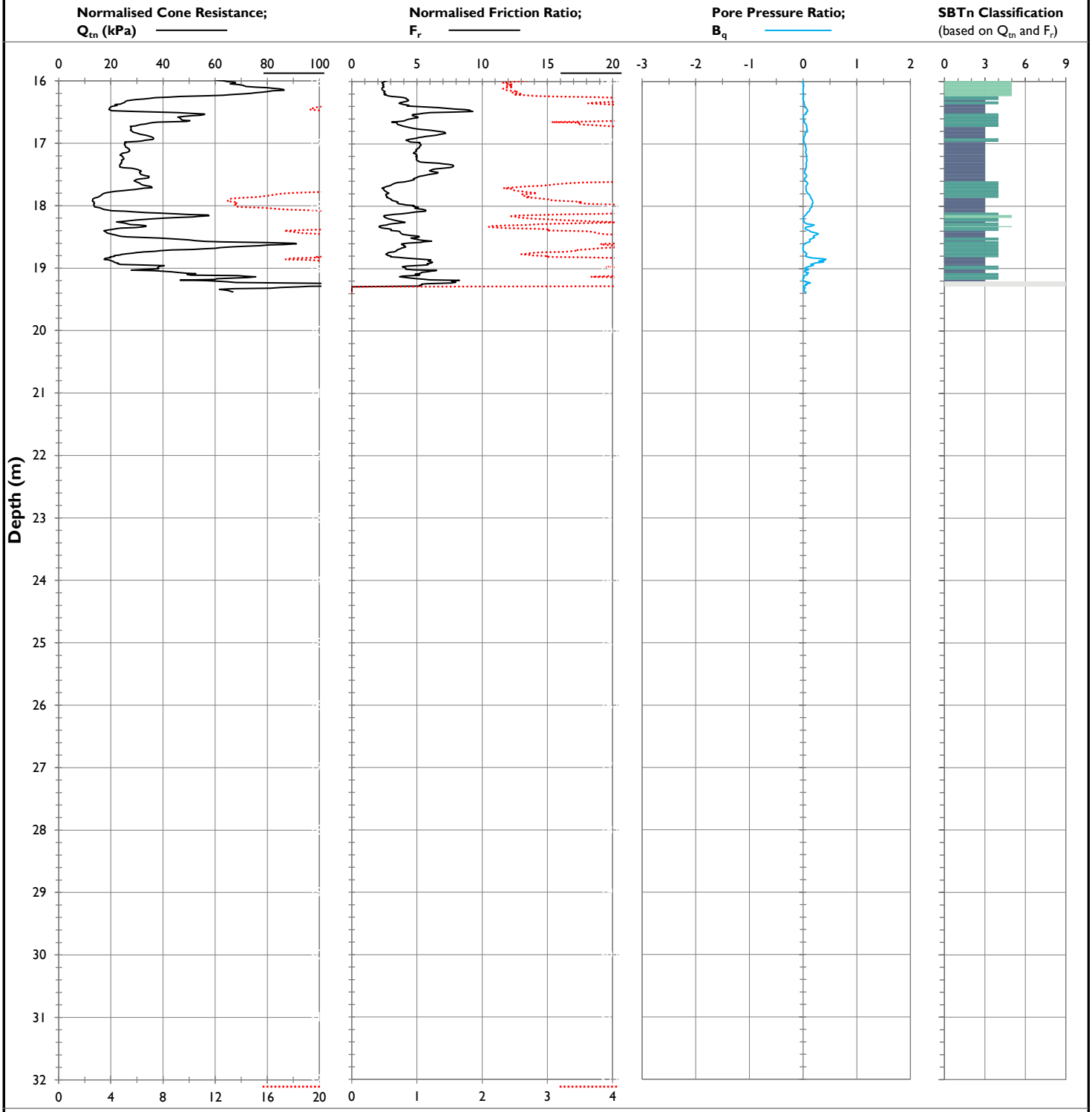
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-CPT15**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**2/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631928.4 (AGD66 /* R.L. Surface: *218.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521486 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*4.5m (Estimated)*	Termination:	*19.45m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

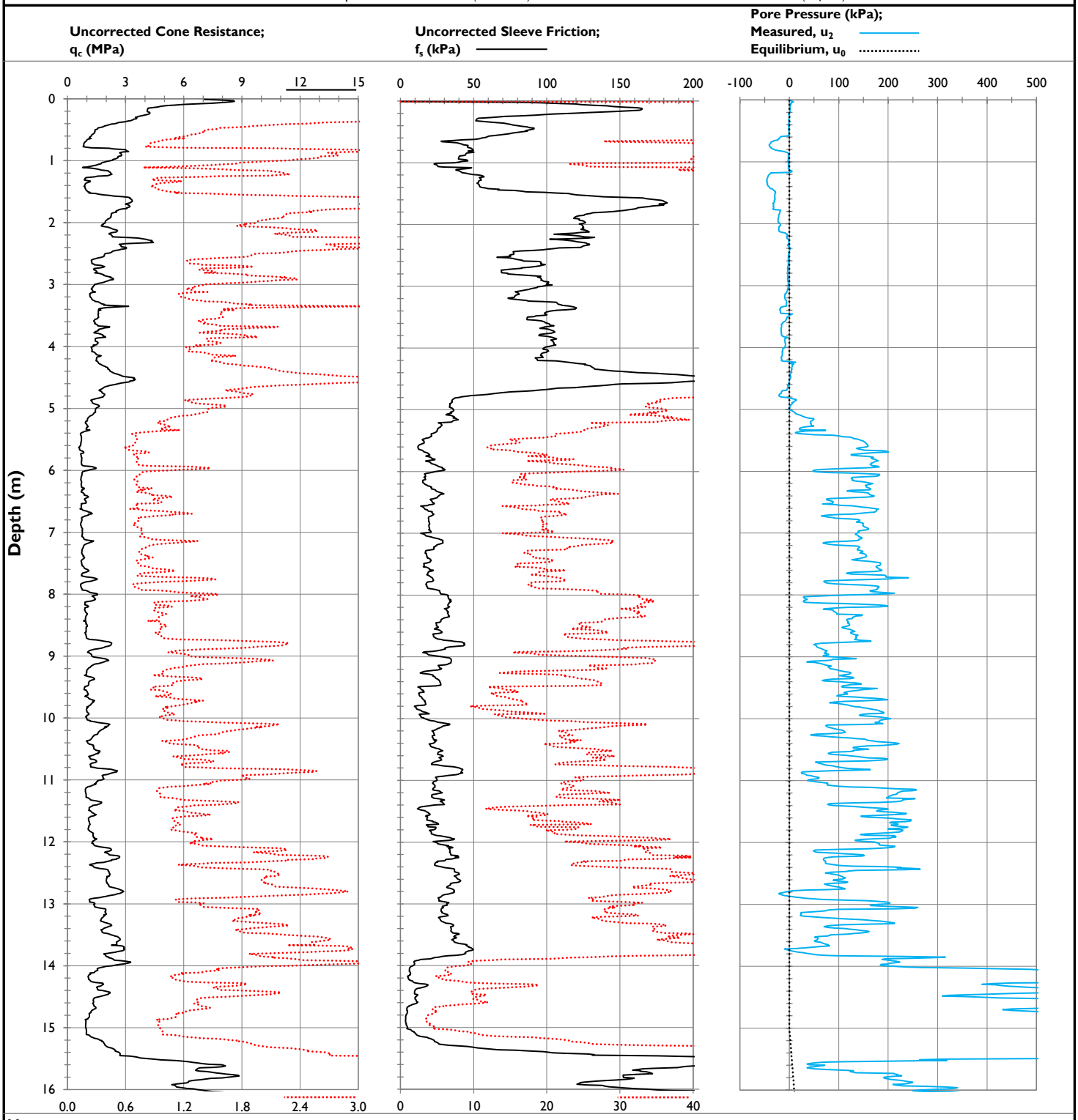
1 - Sensitive, fine grained
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5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-TP04**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631824.4 (AGD66 /*	R.L. Surface:	*219.8m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521145.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.81*	Depth to GW:	*15.0m (Estimated)*	Termination:	*18.25m (Refusal)*		

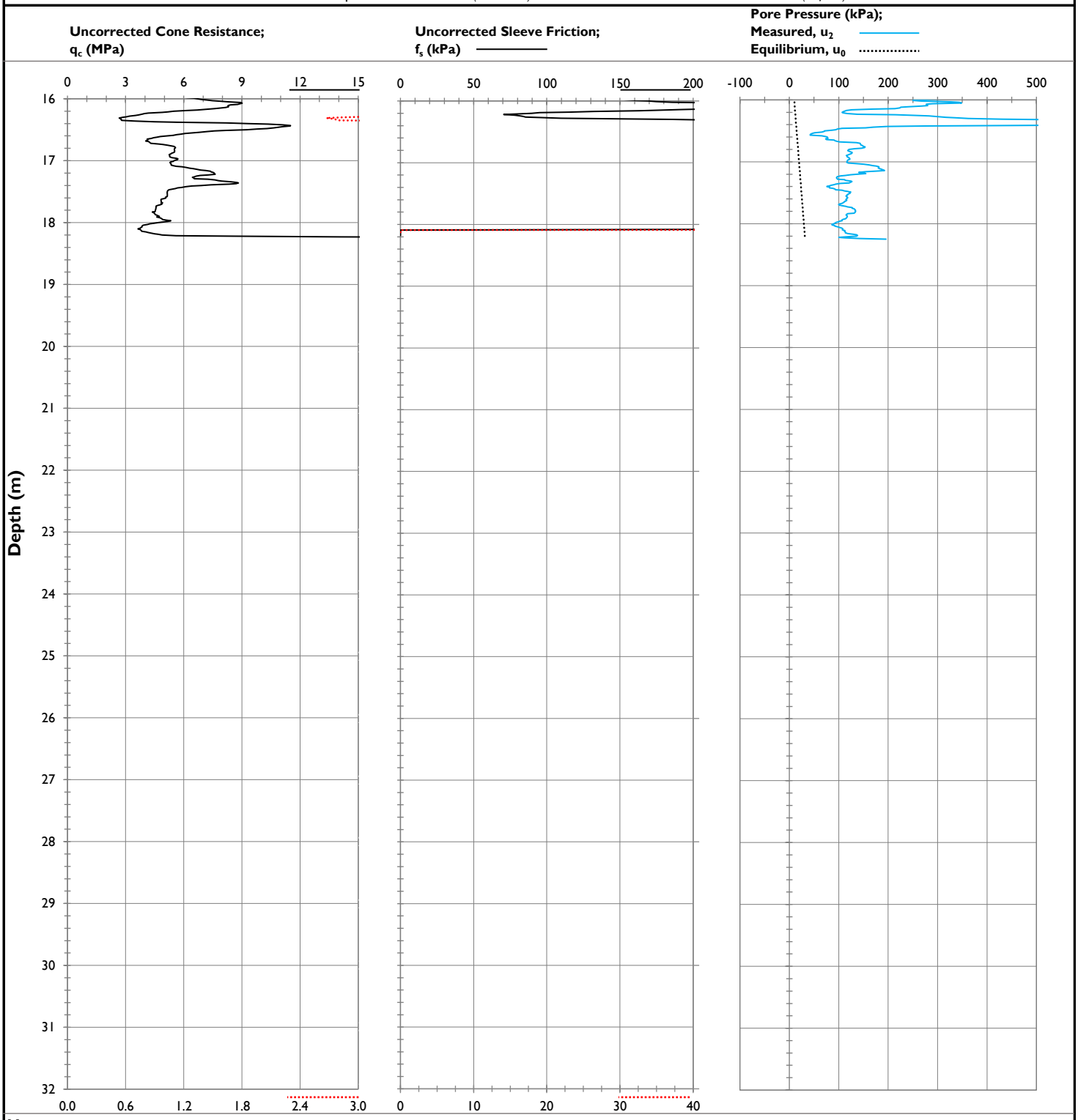


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-TP04**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631824.4 (AGD66 /* R.L. Surface: *219.8m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521145.1 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.81*	Depth to GW:	*15.0m (Estimated)*	Termination:	*18.25m (Refusal)*

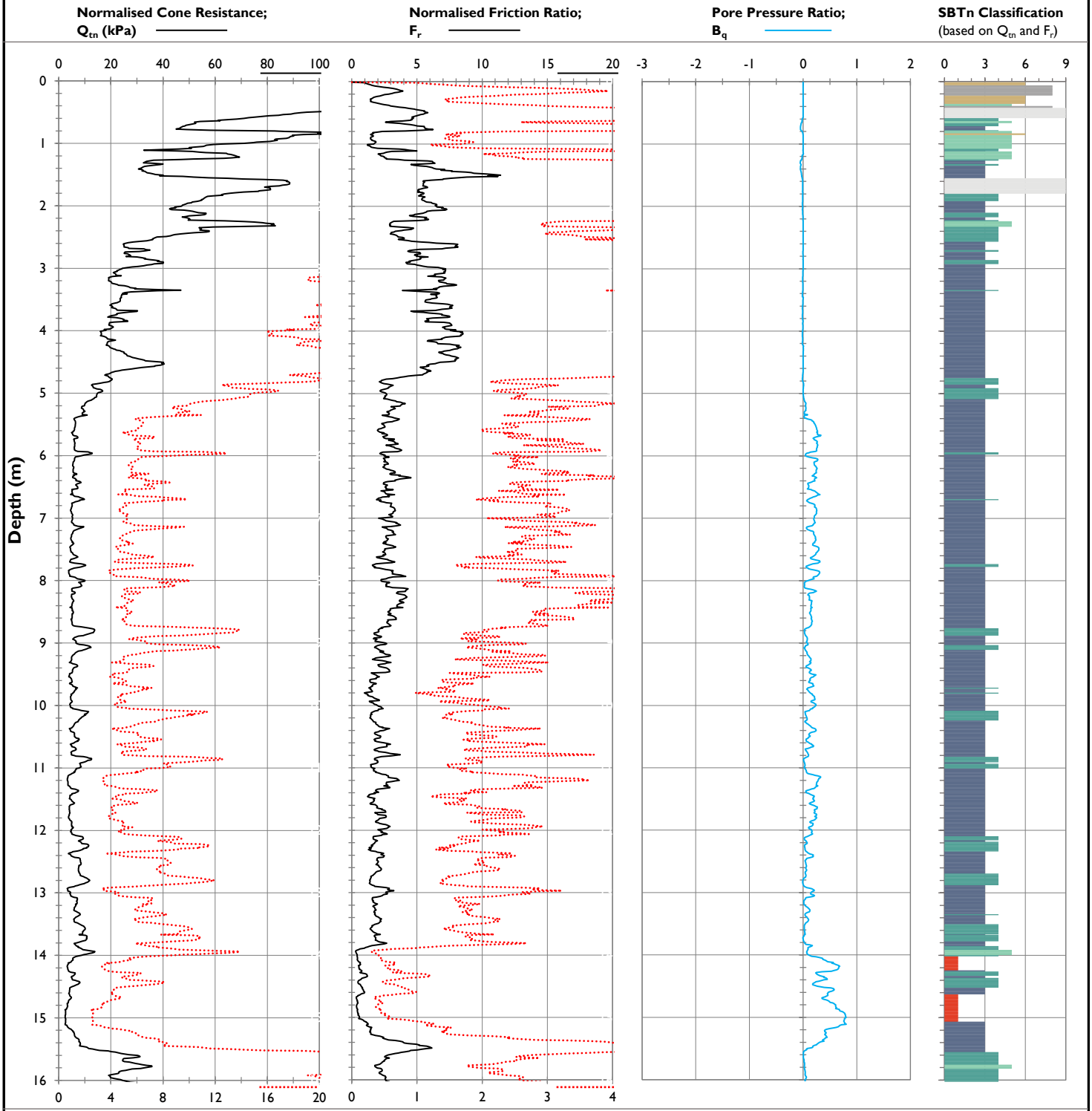


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-TP04**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631824.4 (AGD66 /* R.L. Surface: *219.8m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521145.1 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.81*	Depth to GW:	*15.0m (Estimated)*	Termination:	*18.25m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

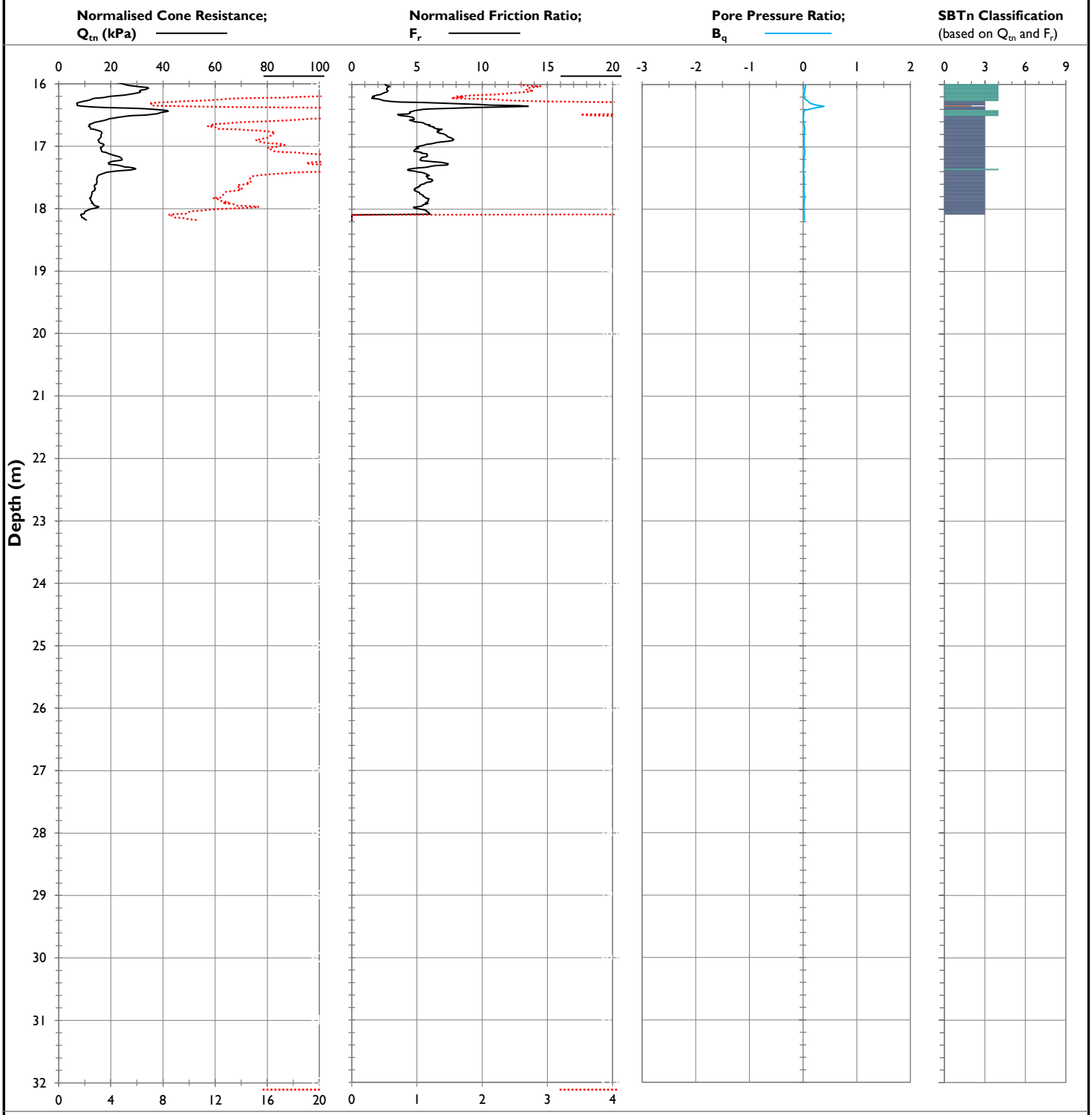
1 - Sensitive, fine grained
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4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF2-TP04**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631824.4 (AGD66 /* R.L. Surface: *219.8m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*0.0m*	Northing:	*7521145.1 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.81*	Depth to GW:	*15.0m (Estimated)*	Termination:	*18.25m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
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** Heavily overconsolidated or cemented*

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050065-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	6/05/2021
		Report Date:	25/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF2-CPT11	**Depth (m):**	5.00-5.80
Description:	SILTY CLAY- black		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-12	0.035	1.6E-08	59.92	43.50	1.195	0.33	0.7
2	12-24	0.038	1.3E-08	56.08	65.36	0.654	0.31	1.5
3	24-50	0.053	1.0E-08	57.87	72.77	0.450	0.42	2.6
4	50-100	0.065	9.1E-09	107.42	107.44	0.273	0.49	4.0
5	100-200	0.080	6.1E-09	120.78	116.87	0.169	0.51	5.6
6	200-401	0.080	2.5E-09	115.57	95.03	0.086	0.86	7.2
7	401-799	0.113	2.4E-09	102.17	123.55	0.062	1.09	9.5
8	799-1603	0.135	1.2E-09	122.23	104.50	0.038	1.30	12.3
9	1603-401	0.013	3.4E-10	238.97	223.96	0.005	0.15	11.8
10	401-100	0.013	6.0E-10	95.64	95.32	0.020	0.23	11.2

Remarks: Tested as Received

REP03103

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Channon

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory Number 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.
Trilab Pty Ltd
ABN 25 065 630 506

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050066-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	6/05/2021
		Report Date:	26/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF2-CPT14	**Depth (m):**	7.00-7.80
Description:	SILTY CLAY- black		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-12	0.007	1.4E-09	138.03	21.09	0.214	0.03	0.1
2	12-26	0.018	3.3E-09	42.99	39.10	0.268	0.27	0.5
3	26-50	0.058	5.4E-09	70.46	41.13	0.425	0.64	1.5
4	50-99	0.117	4.8E-09	40.10	35.02	0.446	1.09	3.7
5	99-201	0.098	2.6E-09	66.02	43.49	0.190	0.78	5.5
6	201-399	0.119	1.4E-09	42.18	38.56	0.117	1.45	7.7
7	399-799	0.183	1.4E-09	58.76	47.81	0.093	1.98	11.2
8	799-1601	0.200	5.7E-10	59.04	35.06	0.053	2.35	14.9
9	1601-400	0.019	9.8E-11	133.30	45.25	0.007	0.34	14.2
10	400-98	0.023	5.9E-10	54.96	56.43	0.034	0.72	13.3

Remarks: Tested as Received

REP03103

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Trilab Pty Ltd
ABN 25 065 630 506

SOIL WATER ANALYSIS (SWA)

soilwater GROUP
45 Gladstone St
East Perth WA 6006
(08) 9228 3060
(08) 9228 3210
admin@soilwatergroup.com
www.soilwatergroup.com

TEST REPORT

Client: EDG Consulting
Client Contact: Darron Lee; Jo Perrett
Client Job Title: Saraji Mine
Client Reference: **B01229-4**

SWA Job No: JN0739

Date of Analysis: 28 June - 22 July 2021
No. Samples Submitted: 7
Sample(s) Condition: Intact Core

METHODOLOGY

- Gravimetric moisture content determined in accordance with AS 1289.2.1.1-2005.
- Atterberg limits determined in accordance with AS1289.3.1.1; AS 1289 3.2.1 & AS 1289.3.3.1.
- Bulk density (ρ_b) determined in accordance with AS 1289.1.3.1-1999.
- Particle density (ρ_p) determined in accordance with AS 1289.3.5.1-1995.
- Total porosity (T_p) determined by calculation: Tp = 1-(ρ_b/ρ_p)

TEST RESULTS

SWA ID	739-02	739-03	739-04
Client ID	TSF4-CPT06 8.0 - 8.8m	TSF3-CPT09 7.0 - 7.8m	TSF3-CPT07 5.0 - 5.5m
Grav. Moisture Content (%)	32.45	32.25	33.62
Atterberg Limits:			
• Liquid Limit	34.91	36.94	39.93
• Plastic Limit	27.94	27.97	28.59
• Plasticity Index	6.97	8.97	11.34

SWA ID	Client ID	Bulk Density (g/cm3)	Particle Density (g/cm3)	Total Porosity (%)
739-01	TSF2-CPT14 2.0-2.8m	1.02	1.49	31.39
739-02	TSF4-CPT06 8.0-8.8m	1.09	1.61	32.27
739-03	TSF3-CPT09 7.0-7.8m	1.11	1.54	27.89
739-04	TSF3-CPT07 5.0-5.5m	1.14	1.55	26.24
739-05	TSF4-CPT06 11.0 - 11.8m	1.12	1.60	30.13
739-06	TSF4-CPT07 7.5 - 8.0m	1.18	1.69	30.46
739-07	TSF2-CPT11 3.0-3.7m	0.96	1.56	38.56

SOIL WATER ANALYSIS (SWA)

soilwater GROUP
45 Gladstone St
East Perth WA 6006
(08) 9228 3060
(08) 9228 3210
admin@soilwatergroup.com
www.soilwatergroup.com

TEST REPORT - SWCC

Client: EDG Consulting
Client Contact: Darron Lee; Jo Perrett
Client Job Title: Saraji Mine
Client Reference: **B01229-4**
SWA Job No: JN0739

Date of Analysis: 28 June - 22 July 2021
No. Samples Submitted: 7
Sample(s) Condition: Intact Core

METHODOLOGY

• SWCC determined in accordance with ASTM D6836 (Methods A, B & D)

TEST RESULTS

SWA-ID	Client ID	Volumetric Water Content (cm^3/cm^3)										
		0kPa	2.5kPa	5kPa	7.5kPa	10kPa	33kPa	100kPa	1,500kPa	39MPa	98MPa	300MPa
739-01	TSF2-CPT14 2.0-2.8m	0.3139	0.2680	0.2508	0.2406	0.2314	0.2058	0.1829	0.1311	0.0918	0.0825	0.0729
739-02	TSF4-CPT06 8.0-8.8m	0.3537	0.2949	0.2559	0.2325	0.2166	0.1578	0.1388	0.0965	0.0870	0.0859	0.0850
739-03	TSF3-CPT09 7.0-7.8m	0.3578	0.3149	0.2731	0.2466	0.2286	0.1759	0.1509	0.1326	0.1293	0.1291	0.1290
739-04	TSF3-CPT07 5.0-5.5m	0.3833	0.3032	0.2563	0.2308	0.2146	0.1628	0.1392	0.1120	0.1058	0.1053	0.1049
739-05	TSF4-CPT06 11.0 - 11.8m	0.3624	0.3308	0.3009	0.2803	0.2638	0.2189	0.1789	0.1547	0.1447	0.144	0.1434
739-06	TSF4-CPT07 7.5 - 8.0m	0.3806	0.3241	0.298	0.2827	0.2710	0.2359	0.2017	0.1592	0.1315	0.1269	0.1226
739-07	TSF2-CPT11 3.0-3.7m	0.3856	0.3193	0.2943	0.2800	0.2689	0.2359	0.2018	0.1548	0.1201	0.1135	0.1071

APPENDIX E

Sample Locations TSF 3



CLIENT
BMA

CONSULTANT
WSP GOLDER

PROJECT
SARAJI MINE - TAILINGS PRCP
TSF 3

TITLE
TSF 3 - COVER SHEET

YYYY-MM-DD	2022-09-14
DESIGNED	
PREPARED	DAB
REVIEWED	
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
21470654	003	A	F000

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

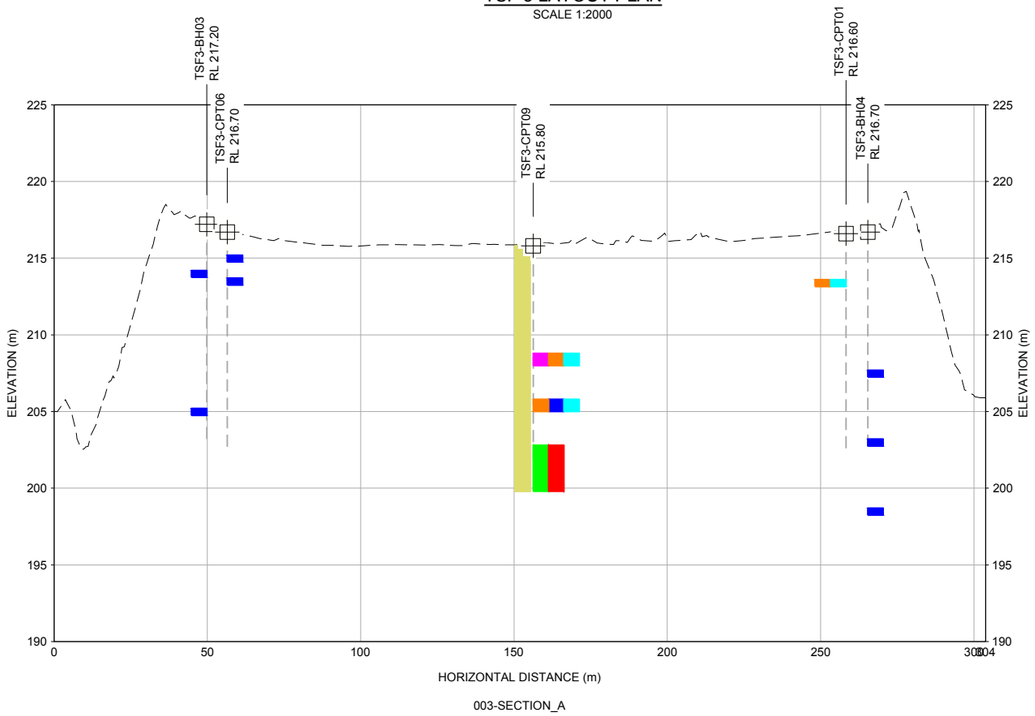
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TSF 3 LAYOUT PLAN

SCALE 1:2000



0 50 100
1:2,000 METRES

LEGEND

- EXISTING SURVEY CONTOURS
- EXISTING GROUND PROFILE
- RHEOLOGY TESTING LOCATION
- PSD TESTING LOCATION
- GEOCHEMICAL TESTING LOCATION
- SPECIFIC GRAVITY TESTING LOCATION
- ATTERBERG TESTING LOCATION
- MOISTURE CONTENT AND DRY DENSITY TESTING LOCATION
- SOIL WATER CHARACTERISTIC CURVE LOCATION

CLIENT
BMA

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-09-14
DESIGNED	
PREPARED	DAB
REVIEWED	
APPROVED	

PROJECT
SARAJI MINE - TAILINGS PRCP
TSF 3

TITLE
SAMPLING LOCATIONS PLAN AND SECTION A

PROJECT NO.	CONTROL	REV.	FIGURE
21470654	003	A	F001

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

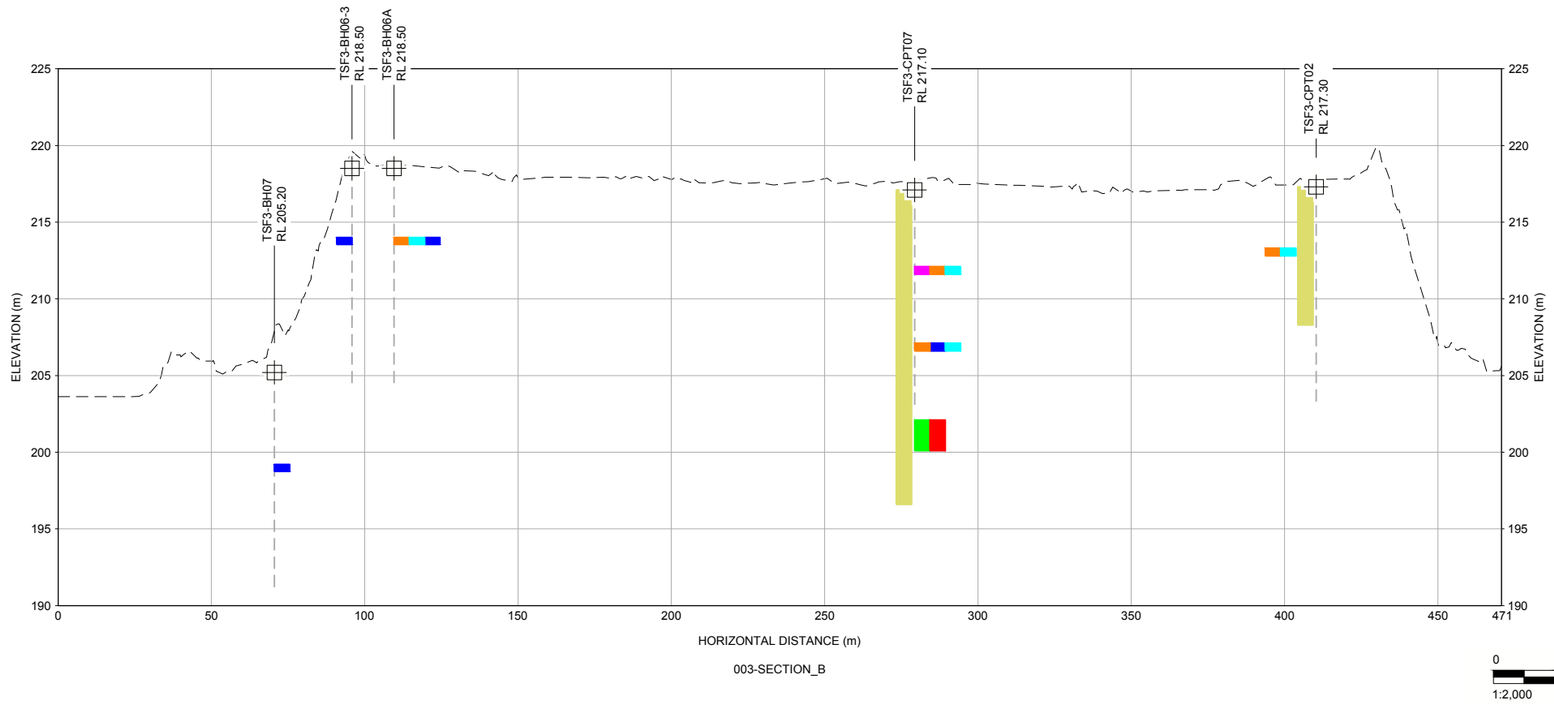
25 mm 0

Path: \\golder.gds\gap\Brisbane\Geomatics\BMA\SARAJI_MINE\99_PROJECTS\21470654_SARAJI MINE - TAILINGS PRCP\000_TAILINGS PRCP_SAMPLING LOCATIONS\02_PRODUCTION\DWG\ | File Name: 21470654-001-004.dwg | Last Edited By: awtb5096996 Date: 2022-10-21 Time:11:19:01 AM | Printed By: AUDB5096996 Date: 2022-10-21 Time:11:20:10 AM



TSF 3 LAYOUT PLAN

SCALE 1:2000



0 50 100
1:2,000 METRES

LEGEND

- EXISTING SURVEY CONTOURS
- EXISTING GROUND PROFILE
- RHEOLOGY TESTING LOCATION
- PSD TESTING LOCATION
- GEOCHEMICAL TESTING LOCATION
- SPECIFIC GRAVITY TESTING LOCATION
- ATTERBERG TESTING LOCATION
- MOISTURE CONTENT AND DRY DENSITY TESTING LOCATION
- SOIL WATER CHARACTERISTIC CURVE LOCATION

CLIENT
BMA

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-09-14
DESIGNED	
PREPARED	DAB
REVIEWED	
APPROVED	

PROJECT
SARAJI MINE - TAILINGS PRCP
TSF 3

TITLE
SAMPLING LOCATIONS PLAN AND SECTION B

PROJECT NO.	CONTROL	REV.	FIGURE
21470654	003	A	F002

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
0

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APPENDIX F

Laboratory Certificates TSF 3

Rheology Testwork for Failure Impact Assessments for Saraji Mine TSFs – revision A

A Report submitted to:

Robert James, RRR Project Engineer – Dams, Brisbane Queensland Australia

Submitted by:

Fiona Sofra
Rheological Consulting Services Pty Ltd
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3rd June April 2021

Report Reference: BHP141-01A
Issue Date: 03/06/2021
Prepared by: Fiona Sofra (fsofra@rheological-consulting.com)
Checked by: Raul Cavalida (rcavalida@rheological-consuloting.com)

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SUMMARY

BHP has committed to reducing the inherent risk of all tailings storage facilities (TSFs) across the BMA portfolio. Several internal risk reviews of each of the TSFs have been conducted across BMA. The Saraji Mine tailings storage facilities (SRM TSFs) require investigation and assessment works to better understand the geological setting, historical design, construction, and operation, to understand and mitigate any risk.

As part of these assessments, rheology testing was undertaken by RCS. Samples from three tailings storage facilities (TSFs) were provided for determination of the tailings physical and rheological properties including the as-received solids content, solids density and tailings in-situ dry density. Measurement of the shear yield stress profile and viscous properties of each of the tailings samples over the concentration range of interest to FIA was also conducted.

Saraji Mine samples were received at concentrations ranging from approximately 73wt% up to 98wt%.

Solids SGs ranged from 1.60 to 1.82, with up to 0.13 difference between two composite samples from the one TSF. The SG was lower at shallow depths for TSF 2 and TSF 4, but higher at shallow depth for TSF 3.

The shear yield stress of all tailings samples tested increased exponentially with solids concentration across the range of solids concentrations investigated and model parameters are provided. The yield stress behaviour for the two samples from TSF 3 and TSF 4 were similar to each other, however the two samples from TSF 2 differed from each other significantly, with the TSF2 sample from smaller depth showing a lower yield stress for a given solids concentration than any other sample. The TSF 2-BH07: 6-12 sample also had the lowest SG, and the ranking of yield stress curves was generally seen to follow SG for the Saraji mine samples. At a solids concentration of 55wt% the yield stress ranged from 10Pa (TSF 2-BH07: 6-12) to 80Pa (TSF4-CPT05: 10-13) for the samples tested.

In shear flow, all samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates investigated. For all but one sample, no shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due the sample collection, subsequent sub-sampling and sample preparation methods. The one notable exception was TSF2 BH07 at 71wt%. This sample showed a decrease in the shear stress as the shear rate increased from zero until approximately $100s^{-1}$ before increasing at higher shear rates. The behaviour was reproducible when the same sample was sheared then retested, possibly indicating a localised (but reversible) structuring of the material – possibly due to the presence of asymmetrical particles aligning in the direction of flow. The origin of the behaviour was not investigated.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected and the shear stress versus shear rate data was modelled using a Herschel-Bulkley model. The viscosity stress versus shear rate data was well described using a Power Law.

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1 INTRODUCTION

BHP Billiton Mitsubishi Alliance owns and operates several coal mines in the Bowen Basin, in Central Queensland, which produces semi-hard coking and hard coking coal products, including the Saraji Mine (SRM).

BHP has committed to reducing the inherent risk of all tailings storage facilities (TSFs) across the BMA portfolio. Several internal risk reviews of each of the TSFs have been conducted across BMA. The Saraji Mine tailings storage facilities (SRM TSFs) require further investigation and assessment works (failure impact analysis, FIA) to better understand the geological setting, historical design, construction, and operation, to understand risk levels. If required, preventative and/or mitigative measures to reduce the TSDs' risk profiles can then be implemented.

Rheology testing was required to inform parts of the FIA and to this end, samples from three tailings storage facilities (TSFs) were provided for determination of the tailings physical and rheological properties including the as-received solids content, solids density and tailings in-situ dry density. Measurement of the shear yield stress profile and viscous properties of each of the tailings samples over the concentration range of interest to FIA was also conducted.

2 SAMPLE Receipt and PREPARATION

Six samples listed in Table 1 were provided to RCS. Locations are provided in Table 2 and a sample map is shown in Figure 1.

Table 1 Samples received and prepared by RCS

Site	RCS ITEM #	ID	Depth	Type	Sample No.	RCS Sample Name
SRM TSF2,3,4	1	TSF2-CPT06	11.00	Steel Tube	1	**TSF2-CPT06: 11-13.5**
	2	TSF2-CPT06	12.00	Steel Tube		
	3	TSF2-CPT06	13.50	Steel Tube		
	4	TSF2-BH07	6.00	Steel Tube	2	**TSF2-BH07: 6-12**
	5	TSF2-BH07	7.00	Steel Tube		
	6	TSF2-BH07	9.00	Steel Tube		
	7	TSF2-BH07	12.00	Steel Tube		
	8	TSF3-CPT07	15.00	Steel Tube	1	**TSF3-CPT07: 15-17**
	9	TSF3-CPT07	17.00	Steel Tube		
	10	TSF3-CPT09	13.00	Steel Tube	2	**TSF3-CPT09: 13-16**
	11	TSF3-CPT09	16.00	Steel Tube		
	12	TSF4-CPT05	10.00	Steel Tube	1	**TSF4-CPT05: 10-13**
	13	TSF4-CPT05	13.00	Steel Tube		
	19	TSF4-CPT09G	9-10.5	Bucket	2	**TSF4-CPT09G: 9-10.5**

Table 2 SRM Sample location data

SRM TSF 2,3,4			
Location	**Easting**	**Northing**	**Elevation**
TSF2-CPT06	631846.5	7521453.8	221.2
TSF2-BH07	631832.5	7521147.0	219.9
TSF3-CPT07	631215.4	7522101.3	217.1
TSF3-CPT09	631092.6	7522451.9	215.8
TSF4-CPT05	631544.1	7522431.8	217.3
TSF4-CPT09G	631764.1	7522496.5	217.0

Upon receipt, samples were removed from core sample tubes or buckets and well sheared prior to combining and mixing well as per the bold boxes above to create composite two samples from each TSF.

Prior to yield stress and viscosity testing, samples were concentrated via centrifugation, if required, to a high solids concentration for initial yield stress testing. Dilution as required was undertaken using process water provided. All solids concentrations were determined by gravimetric analysis, drying at 90degC to constant mass.

3 GRAVIMETRIC ANALYSES

3.1 As received solids concentration

The solids concentration of the prepared samples (generated by combining 'as received' samples from each TSF) was determined by oven drying samples to constant dry mass.

Table 3 lists the measured solids concentrations.

Table 3. Prepared sample solids concentrations based on combining TSF samples as received.

Sample name	Solids concentration (wt%)
TSF2-BH07: 6-12	75.38
TSF2-CPT06: 11-13.5	75.96
TSF3-CPT09: 13-16	73.49
TSF3-CPT07: 15-17	72.92
TSF4-CPT09G: 9-10.5	98.62
TSF4-CPT05: 10-13	73.85

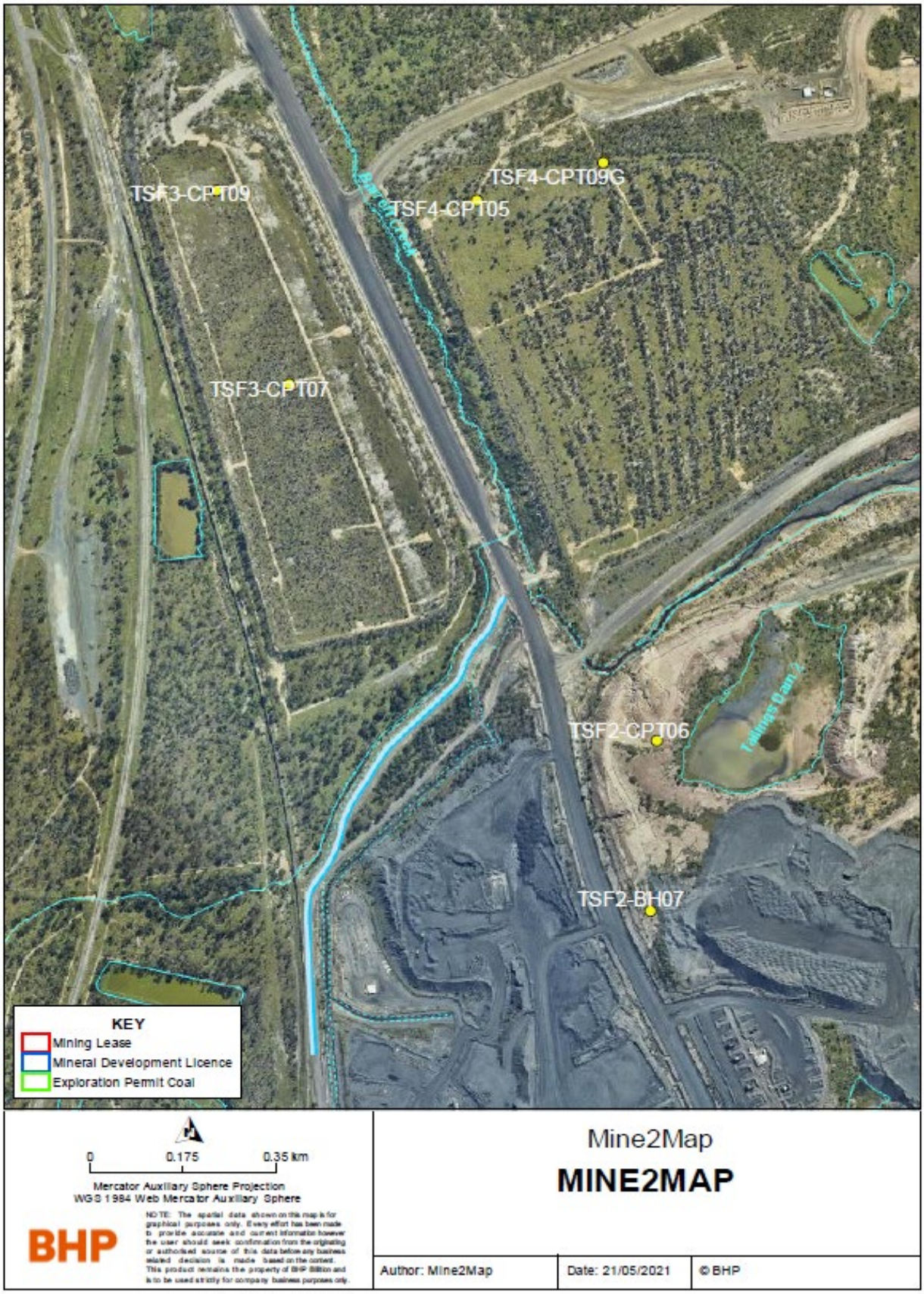


Figure 1 SSM sample location map

3.2 Specific Gravity

The solids specific gravity of the tailings was determined by measuring the density of a known volume (~100 cm^3) of slurried sample, and subsequently measuring the solids concentration of the slurry via oven drying to constant mass. By separately measuring the density for the water present in the sample under the same conditions, the density of the solid phase may be calculated using Equation 1 and the solids specific gravity subsequently determined. Results for the samples tested are shown in Table 4.

$$\rho_P = \frac{x\rho_s}{\left(1 - \frac{\rho_s}{\rho_L}(1-x)\right)}$$

Equation 1

Where: ρ_P is the particle (solids) density (kgm^{-3})
ρ_s is the slurry density (kgm^{-3})
ρ_L is the liquor density (kgm^{-3})
x is the solids mass fraction (-)

Solids SGs ranged from 1.60 to 1.82, with up to 0.13 difference between two composite samples from the one TSF. The SG was lower at shallow depths for TSF 2 and TSF4, but higher at shallow depth for TSF 3.

Table 4. BMC Saraji Mine tailings gravimetric analysis results

Sample name	Specific gravity
TSF2-BH07: 6-12	1.60
TSF2-CPT06: 11-13.5	1.66
TSF3-CPT09: 13-16	1.78
TSF3-CPT07: 15-17	1.68
TSF4-CPT09G: 9-10.5	1.69
TSF4-CPT05: 10-13	1.82

4 YIELD STRESS MEASUREMENTS

Yield stress measurements were conducted using the vane-shear method [1-4]. Many workers worldwide have adopted the vane-shear method and confirmed its applicability for numerous types of yield stress materials [5-9].

4.1 Experimental Procedure

Samples to be tested are placed in a plastic container and tapped on the laboratory bench to remove entrained air bubbles. A vane of suitable dimensions for the yield stress range under consideration is selected and attached to the rheometer. The container is placed on a stand under the vane and raised using a manual scissor lift to immerse the vane in the centre of the

sample. The vane is then rotated at a rate of 0.2 rpm and the maximum torque response of the sample is recorded. The yield stress is calculated using the maximum torque reading and Equation 1. All yield stress measurements are taken in triplicate to ensure reproducibility of results.

$$\tau_y = \frac{T_m}{\pi D_v^2\left(\frac{L_v}{2}+\frac{D_v}{6}\right)} \qquad \textbf{Equation 2}$$

Where τ_y is the calculated yield stress, T_m is the maximum torque experienced by the vane, D_v is the vane diameter and L_v is the vane length.

To ensure that wall and end effects are absent, vanes of varying dimensions are used for each material. Nguyen and Boger [3] suggest that the diameter and depth of the container should be at least twice as large as the diameter and length of the vane to minimise any effects caused by the rigid boundaries.

4.2 Results and Discussion

The shear yield stress profiles of the Saraji Mine tailings are given in Figure 2. The shear yield stress of all tailings samples increased exponentially with solids concentration across the range of solids concentrations investigated.

The yield stress versus solids concentration (mass fraction) curves for the Saraji Mine coal tailings were modelled using an exponential trendline (shown as a dashed line in Figure 2). Model parameters are given in Table 5 below.

Figure 2 shows that the yield stress behaviour for the two samples from TSF 3 and TSF 4 were similar to each other, however the two samples from TSF 2 differed from each other significantly, with the TSF2 sample from smaller depth showing a lower yield stress for a given solids concentration than any other sample. The TSF 2-BH07: 6-12 sample also had the lowest SG, and the ranking of yield stress curves was generally seen to follow SG for the Saraji mine samples.

For reference, Table 5 lists the yield stress of each sample at a solids concentration of 55wt%, showing that the yield stress ranged from 10Pa (TSF 2-BH07: 6-12) to 80Pa (TSF4-CPT05: 10-13) for the samples tested.

Table 5. Yield stress profile model parameters

Sample	Exponential Variables ($\tau_y=ae^{bx}$)		Yield stress @ 55wt%
	a	*b*	*(Pa) from* $\tau_y=ae^{bx}$
TSF2-BH07: 6-12	1.1095E-05	24.89	10
TSF2-CPT06: 11-13.5	3.2483E-04	21.37	41
TSF3-CPT09: 13-16	1.3536E-04	22.72	36
TSF3-CPT07: 15-17	3.5827E-04	21.47	48
TSF4-CPT09G: 9-10.5	7.7914E-04	20.55	63
TSF4-CPT05: 10-13	2.4982E-03	18.85	80

Where τ_y is the yield stress (*Pa*) and x is the solids mass fraction.

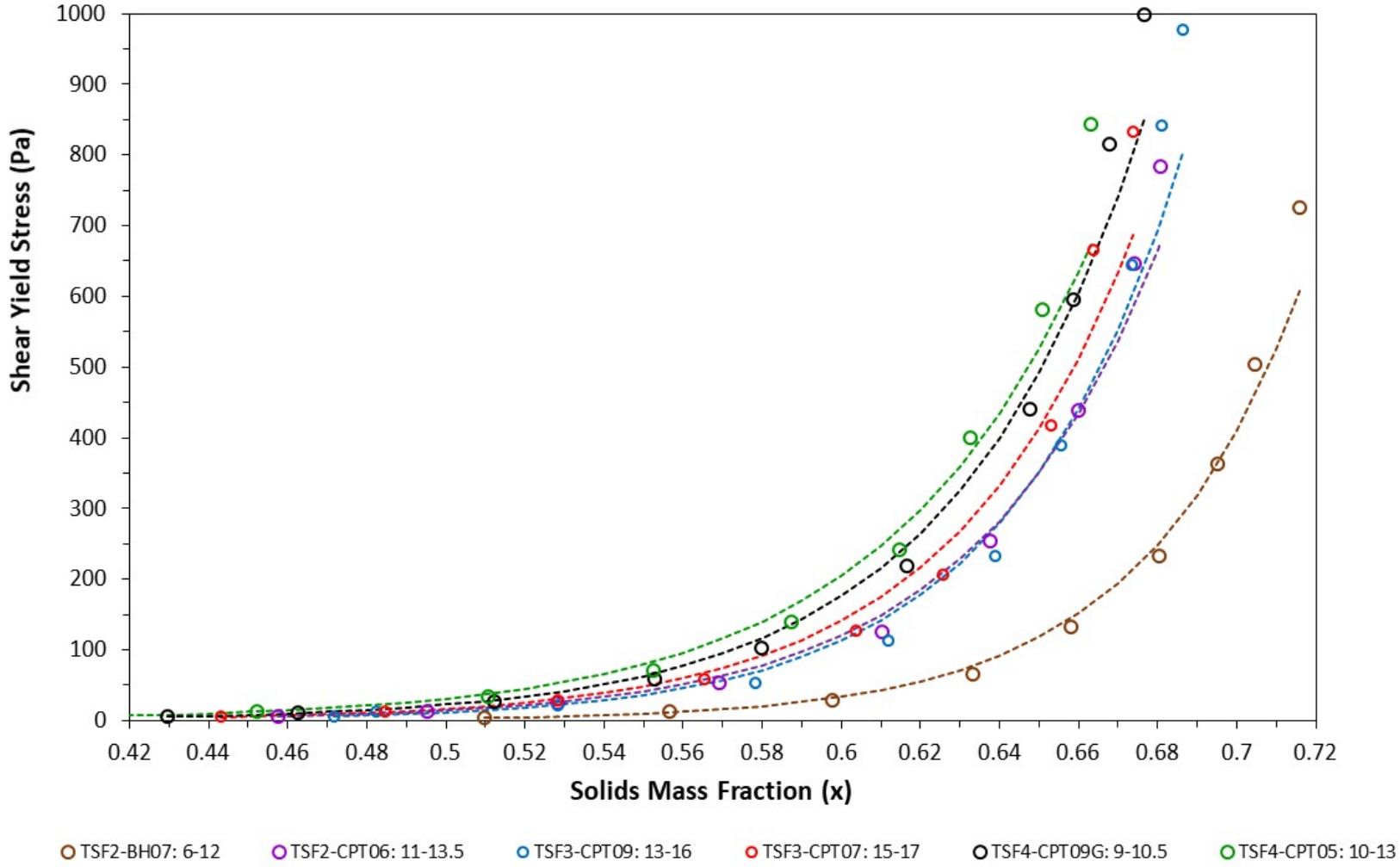


Figure 2 Shear yield stress (τ_y) vs. solids mass fraction (x) for Saraji Mine Tailings. See Table A 1 for tabulated data

5 SHEAR STRESS VS SHEAR RATE MEASUREMENTS

The shear stress (hence viscosity) of each of the coal tailings samples was measured as a function of shear rate at five solids concentrations per sample. These solids concentrations were specified by BHP and Klohn Crippen Berger (consulting on this study) personnel based on yield stress profile results and are shown in Table 6.

Measurements were conducted on fully sheared samples at ambient temperature with a Haake VT550 controlled strain rheometer using either vane (for high yield stress) or bob in cup geometry (low yield stress) as appropriate.

Table 6 Measured solids concentrations for flow behaviour testing

	Sample wt%				
	Min	**2**	**3**	**4**	**Max***
TSF2-BH07	0.55	0.583	0.635	0.673	0.71
TSF2-CPT06	0.555	0.583	0.613	0.651	0.676
TSF3-CPT07	0.567	0.595	0.617	0.645	0.665
TSF3-CPT09	0.575	0.588	0.618	0.642	0.667
TSF4-CPT05	0.55	0.588	0.607	0.625	65
TSF4-CPT09G	0.555	0.583	0.613	0.629	0.659

5.1 Experimental Procedure

Samples to be tested were either centrifuged and process water decanted or diluted to achieve the desired solids concentration for the test. Samples were placed in the test vessel and tapped on the laboratory bench to remove entrained air bubbles. The vessel was then placed on a stand under the bob or vane fixture and raised, using a manual scissor lift, to immerse the fixture in the centre of the sample. The fixture was then rotated at a constant rate, N *(rpm)*, and the torque experienced by the fixture was recorded, T *(μNm)*. This process was then repeated at successively increasing rotational rates with the sample homogenised via hand mixing between each measurement. The shear stress was measured at each successive rotational rate and the shear stress vs shear rate relationship (hence viscosity vs shear rate relationship) was determined as per [10] and [11].

5.2 Results and Discussion

The shear stress of the Saraji Mine tailings samples is given as a function of shear rate in Figure 3 to Figure 5, and the shear viscosity is given as a function of shear rate in Figure 6 to Figure 8. All samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates

investigated. For all but one sample, no shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due the sample collection, subsequent sub-sampling and sample preparation methods. The one notable exception was TSF2 BH07 at 71wt%. This sample showed a decrease in the shear stress as the shear rate increased from zero until approximately 100s^{-1}. This behaviour would normally be attributed to a breakup of the interparticle network structure, but in this case the behaviour was reproducible when the same sample was sheared then retested. The reproducibility may indicate a localised (but reversible) structuring of the material – possibly due to the presence of asymmetrical particles aligning in the direction of flow, however the origin of the behaviour was not investigated.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected.

The shear stress versus shear rate data was modelled using a Herschel-Bulkley model:

$\tau = \tau_y + K\dot{\gamma}^n$, where τ is the shear stress (*Pa*) and $\dot{\gamma}$ is the shear rate (s^{-1}) (shown as dashed lines in Figure 3 to Figure 5). The parameters for these curves are given in Table A2 in the Appendix. Note that model parameters are only valid over the shear rate range measured.

The viscosity stress versus shear rate data was curve fitted using a Power Law model:

$\eta = a\dot{\gamma}^b$, where η is the shear viscosity (*Pa.s*) and $\dot{\gamma}$ is the shear rate (s^{-1}), (shown as a dashed line in Figure 6 to Figure 8). The parameters for these curves are given in Table A3 in the Appendix. Note that model parameters are only valid over the shear rate range measured.

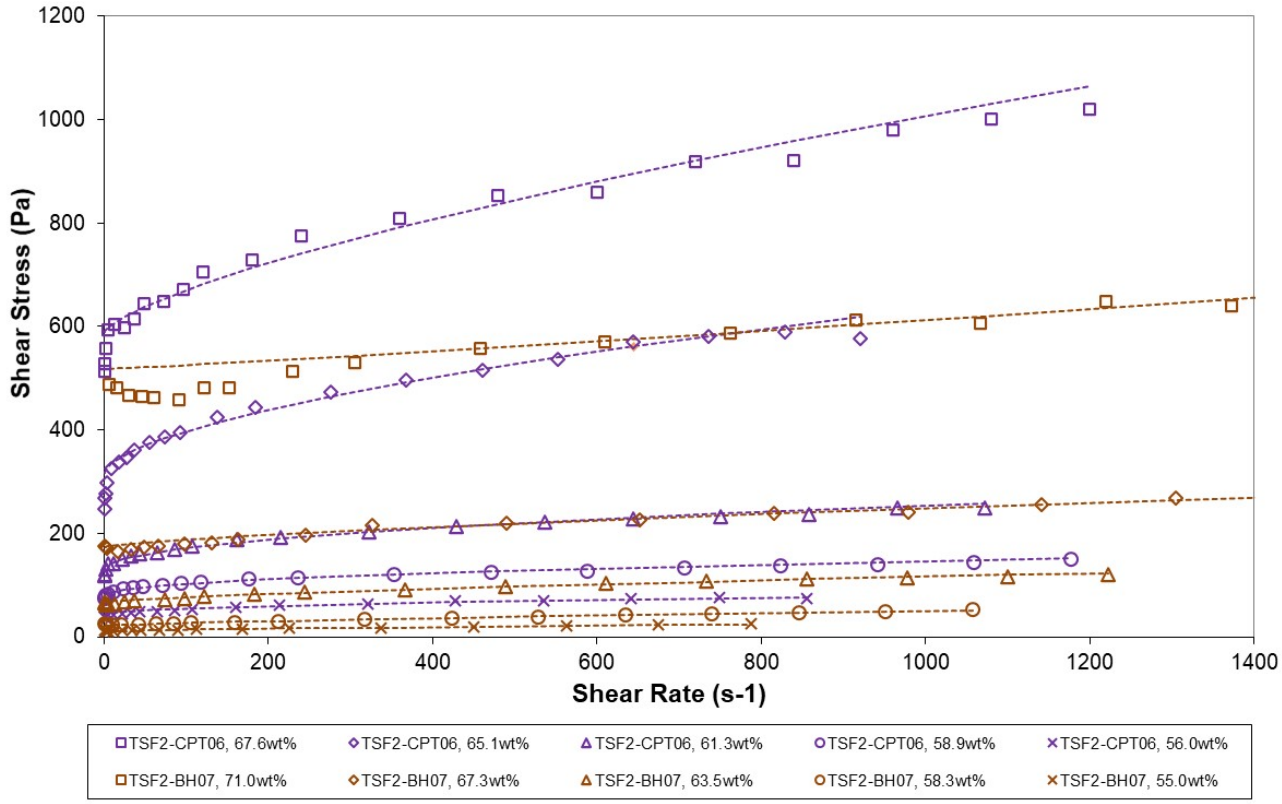


Figure 3 – Shear stress vs. shear rate for Saraji Mine TSF 2 samples.

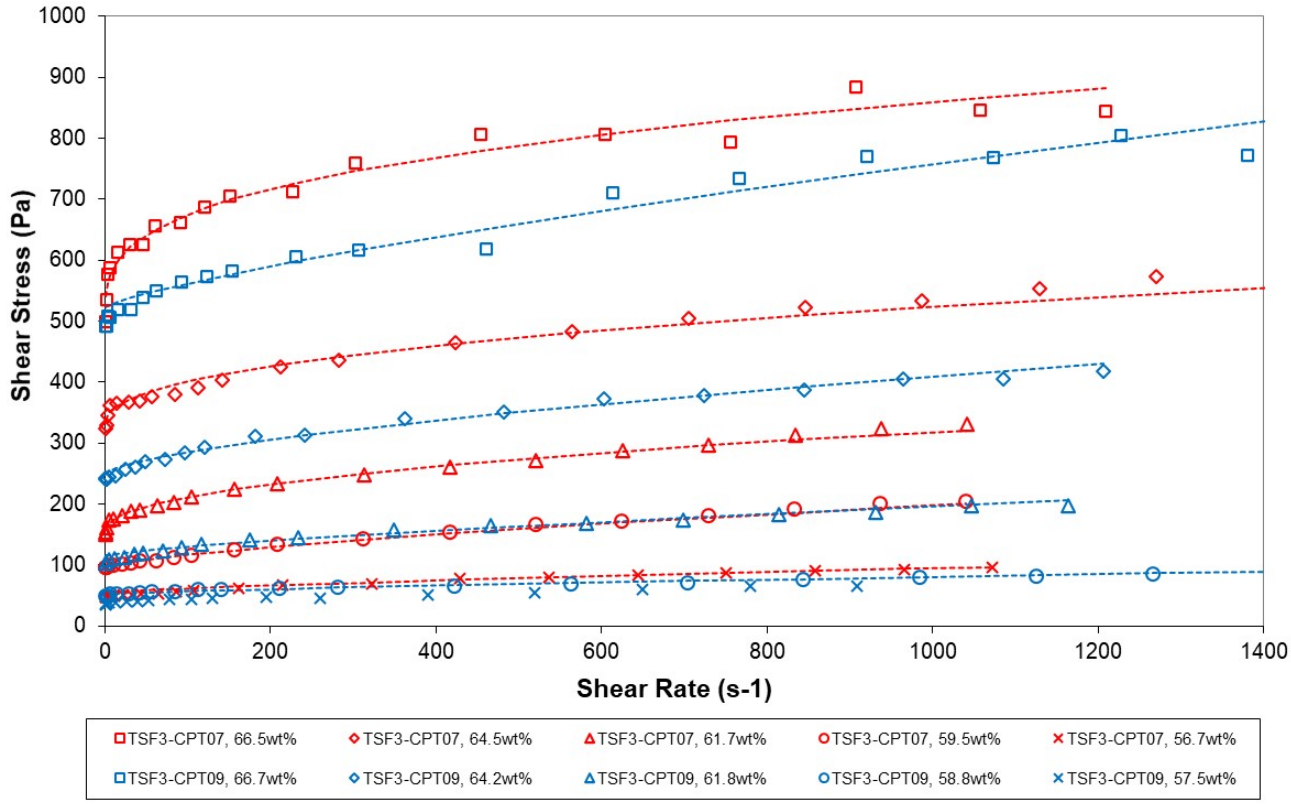


Figure 4 – Shear stress vs. shear rate for Saraji Mine TSF 3 samples.

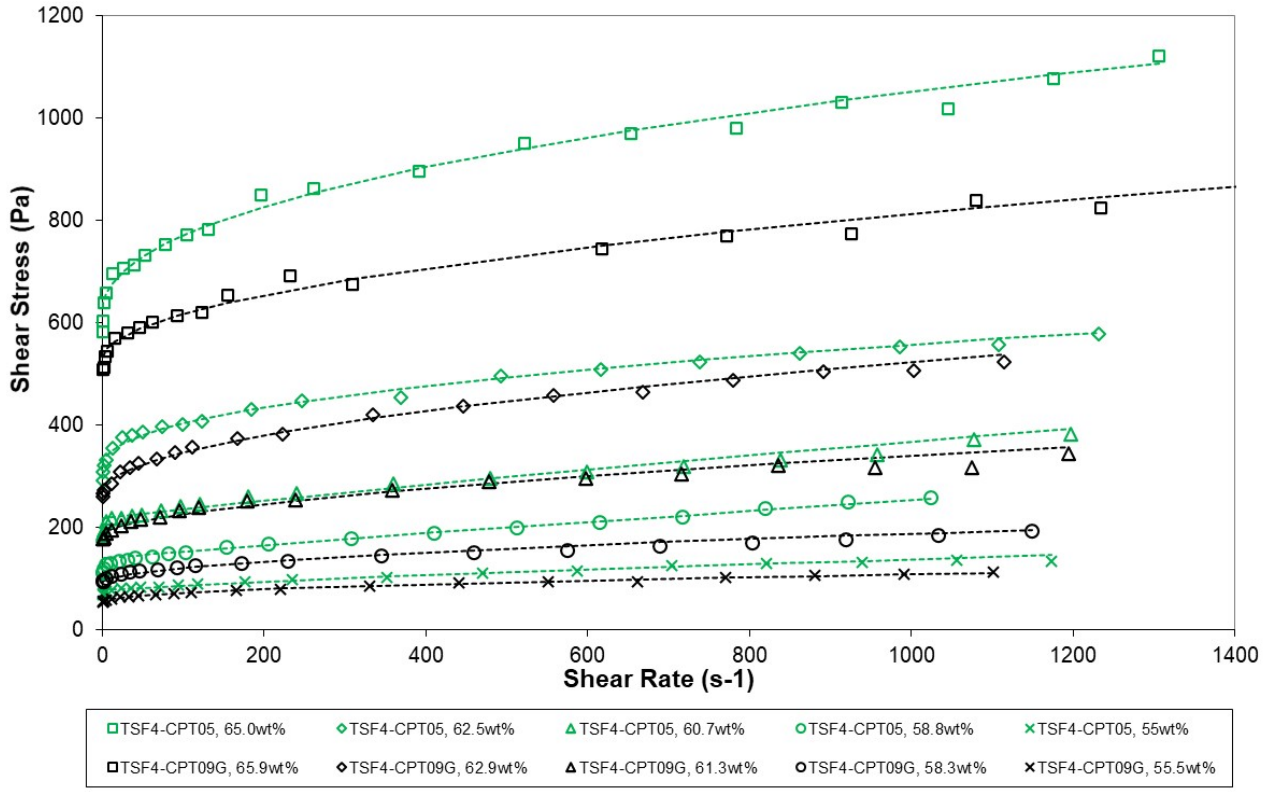


Figure 5 – Shear stress vs. shear rate for Saraji Mine TSF 4 samples.

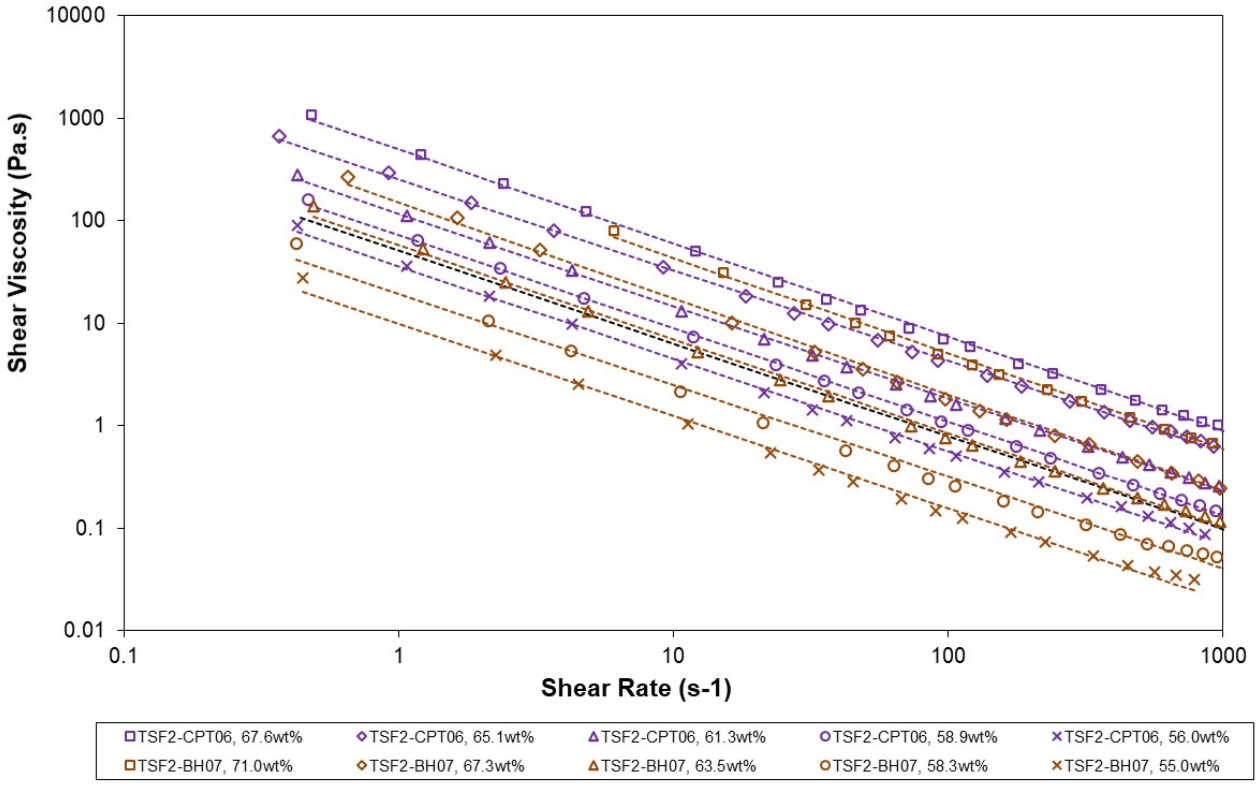


Figure 6 Shear viscosity vs. shear rate for Saraji Mine TSF 2 samples.

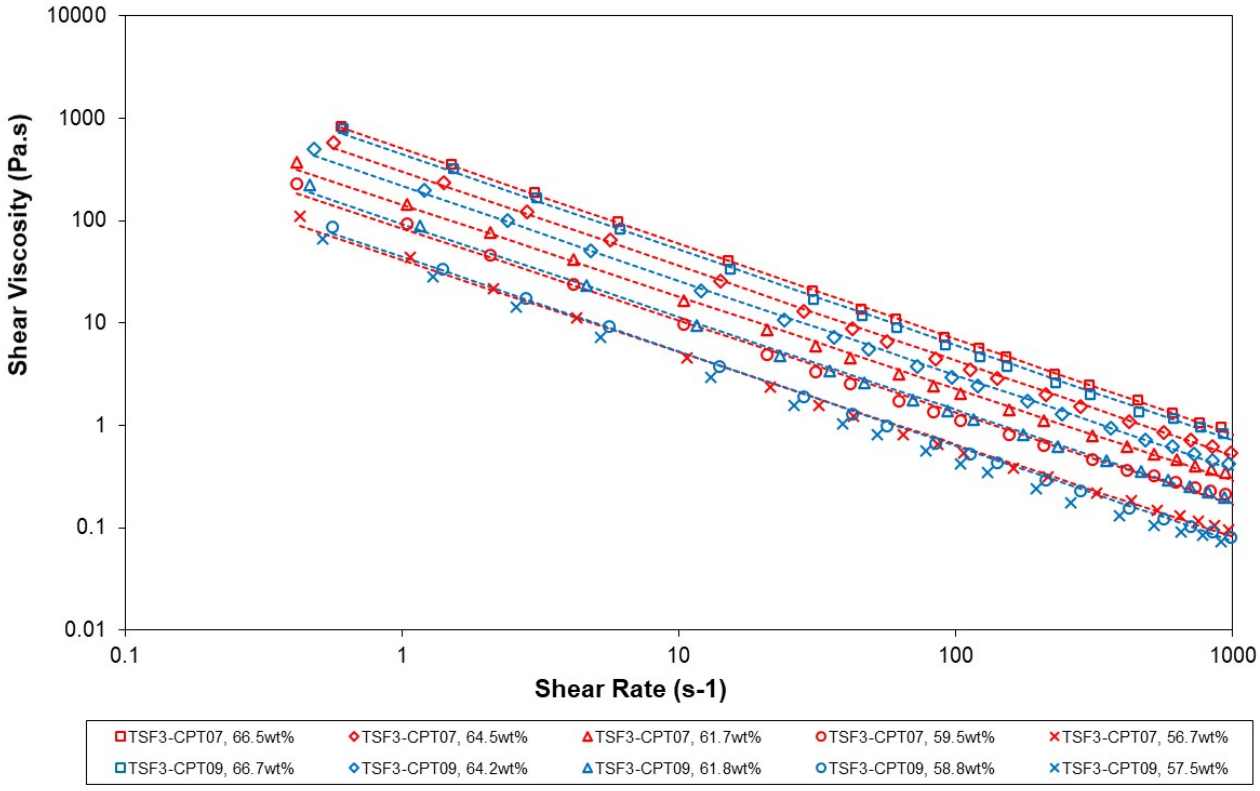


Figure 7 - Shear viscosity vs. shear rate for Saraji Mine TSF 3 samples.

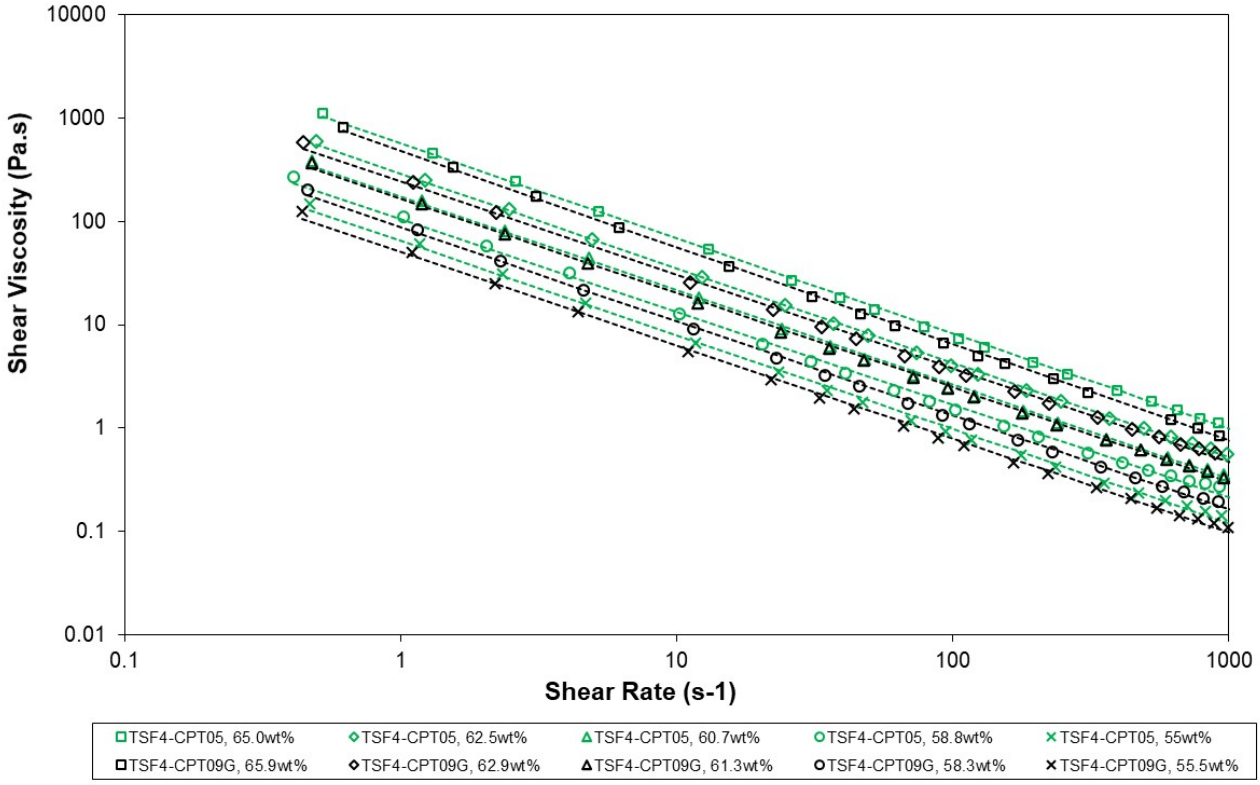


Figure 8 - Shear viscosity vs. shear rate for Saraji Mine TSF 4 samples.

6 CONCLUSION

Saraji Mine samples were received at concentrations ranging from approximately 73wt% up to 98wt%.

Solids SGs ranged from 1.60 to 1.82, with up to 0.13 difference between two composite samples from the one TSF. The SG was lower at shallow depths for TSF 2 and TSF 4, but higher at shallow depth for TSF 3.

The shear yield stress of all tailings samples tested increased exponentially with solids concentration across the range of solids concentrations investigated and model parameters are provided. The yield stress behaviour for the two samples from TSF 3 and TSF 4 were similar to each other, however the two samples from TSF 2 differed from each other significantly, with the TSF2 sample from smaller depth showing a lower yield stress for a given solids concentration than any other sample. The TSF 2-BH07: 6-12 sample also had the lowest SG, and the ranking of yield stress curves was generally seen to follow SG for the Saraji mine samples. At a solids concentration of 55wt% the yield stress ranged from 10Pa (TSF 2-BH07: 6-12) to 80Pa (TSF4-CPT05: 10-13) for the samples tested.

In shear flow, all samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates investigated. For all but one sample, no shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due the sample collection, subsequent sub-sampling and sample preparation methods. The one notable exception was TSF2 BH07 at 71wt%. This sample showed a decrease in the shear stress as the shear rate increased from zero until approximately $100s^{-1}$ before increasing at higher shear rates. The behaviour was reproducible when the same sample was sheared then retested, possibly indicating a localised (but reversible) structuring of the material – possibly due to the presence of asymmetrical particles aligning in the direction of flow. The origin of the behaviour was not investigated.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected and the shear stress versus shear rate data was modelled using a Herschel-Bulkley model. The viscosity stress versus shear rate data was well described using a Power Law.

A APPENDIX

A1 Shear Yield Stress Data

Table A 1 - Solids mass fraction (x) versus yield stress (τ_y) data for Saraji Mine Tailings Samples

TSF2-CPT06: 11-13.5			TSF2-BH07: 6-12	
Slurry Average Solids Fraction (total)	Yield Stress		Slurry Average Solids Fraction (total)	Yield Stress
0.4574	6.4305		0.5098	4.1160
0.4954	13.6350		0.5566	12.0900
0.5284	25.0800		0.5979	28.2950
0.5690	53.2450		0.6333	66.2350
0.6104	126.2000		0.6581	132.4500
0.6378	253.1000		0.6804	232.2500
0.6600	438.6500		0.6950	362.6000
0.6742	645.7500		0.7046	504.4000
0.6808	783.6000		0.7159	725.2000
0.6884	1003.2500		0.7241	1010.0000

TSF3-CPT07: 15-17			TSF3-CPT09: 13-16	
Slurry Average Solids Fraction (total)	Yield Stress		Slurry Average Solids Fraction (total)	Yield Stress
0.4430	5.4015		0.4719	5.1445
0.4846	12.6050		0.4823	12.3500
0.5282	29.3200		0.5284	21.6050
0.5653	59.2500		0.5781	54.0150
0.6036	127.4500		0.6120	112.4000
0.6258	206.3000		0.6390	232.0000
0.6529	417.2500		0.6556	388.8000
0.6636	665.2000		0.6734	644.1000
0.6737	832.8000		0.6811	842.1000
0.6820	1075.0000		0.6864	976.5000

Table A 1 - continued

TSF4-CPT05: 10-13			TSF4-CPT09G: 9-10.5	
Slurry Average Solids Fraction (total)	Yield Stress		Slurry Average Solids Fraction (total)	Yield Stress
0.3819	4.1160		0.4296	5.9160
0.4523	12.0900		0.4626	11.5750
0.5106	33.6950		0.5122	27.0100
0.5526	71.5050		0.5527	58.3900
0.5875	138.8000		0.5798	101.8500
0.6147	242.3000		0.6165	218.1500
0.6327	400.5000		0.6478	440.1000
0.6509	582.0000		0.6587	594.8000
0.6632	843.7500		0.6677	814.6000
0.6710	1061.5000		0.6767	997.5000

The shear stress versus shear rate data was curve fitted using a Herschel-Bulkley model :

$\tau = \tau_y + K\dot{\gamma}^n$, where τ is the shear stress (*Pa*) and $\dot{\gamma}$ is the shear rate (s^{-1}) (shown as a dashed line in Figure 3 to Figure 5). The parameters for these curves are given in Table A2 below. Note that model parameters are only valid over the shear rate range measured.

Table A2 Herschel Bulkley model parameters for Saraji Mine Tailings rheology testing.

Shear Stress Table:	***Herschel Bulkley Model: $\tau=\tau_y+Ky^n$***				
sample	τ_y	***K***	***n***	**min shear rate**	**max shear rate**
TSF3-CPT07, 66.5wt%	508.3	37.57	0.3235	0.60	1208.89
TSF3-CPT07, 64.5wt%	331.0	9.18	0.4406	0.56	1410.56
TSF3-CPT07, 61.7wt%	153.8	7.08	0.4550	0.42	1041.78
TSF3-CPT07, 59.5wt%	95.4	0.89	0.6859	0.42	1040.43
TSF3-CPT07, 56.7wt%	54.6	0.21	0.7628	0.43	1072.18
TSF3-CPT09, 66.7wt%	522.1	1.13	0.7723	0.61	1533.46
TSF3-CPT09, 64.2wt%	249.2	1.79	0.6505	0.48	1205.75
TSF3-CPT09, 61.8wt%	115.4	0.46	0.7482	0.47	1163.04
TSF3-CPT09, 58.8wt%	52.6	0.11	0.8045	0.56	1406.20
TSF3-CPT09, 57.5wt%	36.2	0.53	0.5789	0.52	908.80
TSF4-CPT05, 65.0wt%	617.3	19.06	0.4527	0.52	1305.73
TSF4-CPT05, 62.5wt%	317.5	11.11	0.4451	0.49	1231.27
TSF4-CPT05, 60.7wt%	217.2	0.33	0.8886	0.48	1197.07
TSF4-CPT05, 58.8wt%	139.4	0.23	0.8994	0.41	1024.15
TSF4-CPT05, 55wt%	77.0	0.28	0.7793	0.47	1173.20
TSF4-CPT09G, 65.9wt%	529.1	8.41	0.5096	0.62	1542.49
TSF4-CPT09G, 62.9wt%	267.1	7.67	0.5081	0.45	1114.04
TSF4-CPT09G, 61.3wt%	184.6	2.94	0.5752	0.48	1193.66
TSF4-CPT09G, 58.3wt%	93.1	2.43	0.5311	0.46	1148.37
TSF4-CPT09G, 55.5wt%	54.8	2.05	0.4726	0.44	1101.15
TSF2-CPT06, 67.6wt%	588.0	3.21	0.7050	0.48	1199.40
TSF2-CPT06, 65.1wt%	314.3	5.69	0.5829	0.37	920.05
TSF2-CPT06, 61.3wt%	130.1	4.55	0.4781	0.43	1072.29
TSF2-CPT06, 58.9wt%	79.1	2.79	0.4603	0.47	1176.36
TSF2-CPT06, 56.0wt%	40.9	1.77	0.4482	0.43	855.73
TSF2-BH07, 71.0wt%	518.2	0.04	1.1177	6.10	1524.08
TSF2-BH07, 67.3wt%	173.4	0.58	0.7041	0.65	1630.39
TSF2-BH07, 63.5wt%	66.6	0.43	0.6886	0.49	1222.36
TSF2-BH07, 58.3wt%	22.0	0.14	0.7681	0.42	1056.86
TSF2-BH07, 55.0wt%	9.8	0.24	0.6147	0.45	787.53

The viscosity stress versus shear rate data was curve fitted using a Power Law model: $\eta = a\dot{\gamma}^b$, where η is the shear viscosity (*Pa.s*) and $\dot{\gamma}$ is the shear rate (s^{-1}), (shown as a dashed line in Figure 6 to Figure 8Figure 8 - Shear viscosity vs. shear rate for Saraji Mine TSF 4 samples.). The parameters for these curves are given in Table A3 below. Note that model parameters are only valid over the shear rate range measured.

Table A3. Power law model parameters for Saraji Mine Tailings **rheology testing.**

Viscosity Table:	***Power Law Model $\eta=K\dot{\gamma}^n$***			
sample	***K***	***n***	**min shear rate**	**max shear rate**
TSF3-CPT07, 66.5wt%	509.1	-0.9307	0.60	1208.89
TSF3-CPT07, 64.5wt%	303.8	-0.9258	0.56	1410.56
TSF3-CPT07, 61.7wt%	143.9	-0.8995	0.42	1041.78
TSF3-CPT07, 59.5wt%	84.2	-0.8994	0.42	1040.43
TSF3-CPT07, 56.7wt%	41.5	-0.9023	0.43	1072.18
TSF3-CPT09, 66.7wt%	446.8	-0.9317	0.61	1533.46
TSF3-CPT09, 64.2wt%	218.3	-0.9236	0.48	1205.75
TSF3-CPT09, 61.8wt%	93.5	-0.9100	0.47	1163.04
TSF3-CPT09, 58.8wt%	44.4	-0.9255	0.56	1406.20
TSF3-CPT09, 57.5wt%	33.1	-0.9227	0.52	908.80
TSF4-CPT05, 65.0wt%	568.7	-0.9198	0.52	1305.73
TSF4-CPT05, 62.5wt%	290.5	-0.9150	0.49	1231.27
TSF4-CPT05, 60.7wt%	176.2	-0.9125	0.48	1197.07
TSF4-CPT05, 58.8wt%	105.5	-0.8978	0.41	1024.15
TSF4-CPT05, 55wt%	64.8	-0.9107	0.47	1173.20
TSF4-CPT09G, 65.9wt%	481.6	-0.9321	0.62	1542.49
TSF4-CPT09G, 62.9wt%	245.2	-0.9060	0.45	1114.04
TSF4-CPT09G, 61.3wt%	165.7	-0.9123	0.48	1193.66
TSF4-CPT09G, 58.3wt%	87.5	-0.9088	0.46	1148.37
TSF4-CPT09G, 55.5wt%	51.0	-0.9049	0.44	1101.15
TSF2-CPT06, 67.6wt%	493.7	-0.9127	0.48	1199.40
TSF2-CPT06, 65.1wt%	254.0	-0.8862	0.37	920.05
TSF2-CPT06, 61.3wt%	117.6	-0.9023	0.43	1072.29
TSF2-CPT06, 58.9wt%	72.8	-0.9110	0.47	1176.36
TSF2-CPT06, 56.0wt%	36.1	-0.9021	0.43	855.73
TSF2-BH07, 71.0wt%	371.6	-0.9358	6.10	1524.08
TSF2-BH07, 67.3wt%	150.3	-0.9358	0.65	1630.39
TSF2-BH07, 63.5wt%	57.5	-0.9143	0.08	1222.36
TSF2-BH07, 58.3wt%	19.3	-0.8914	0.42	1056.86
TSF2-BH07, 55.0wt%	9.9	-0.8997	0.45	787.53

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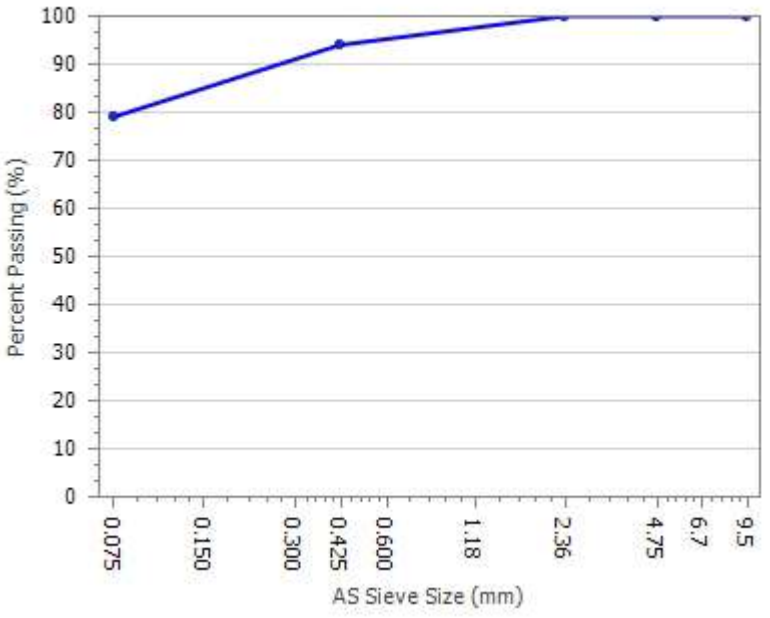
QUALITY OF MATERIALS REPORT

Client:	EDG Consulting PTY LTD	Report Number:	14892/R/28614-1
Client Address:	Level 1, 18 Wandoo st, Fortitude Valley	Project Number:	14892/P/907
Project:	Saraji Mine Laboratory Testing	Lot Number:	TFS3
Location:	Saraji Mine	Internal Test Request:	14892/T/16651
Supplied To:	n/a	Client Reference/s:	22-04-2021 - TSF2-4 - Job No: B012
Area Description:	Saraji Mine	Report Date / Page:	4/05/2021 Page 4 of 5

Test Procedures	AS1289.3.6.1, AS1289.3.1.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1			
Sample Number	14892/S/76231	Test Pit #		BH-06-1
Sampling Method	Tested As Received	Starting Depth	M	4.50
Date Sampled	22/04/2021	Finished Depth	M	4.95
Sampled By	Client Sampled			U75
Date Tested	29/04/2021	Material Source	ONSITE	
Att. Drying Method	Oven Dried	Material Type	EXISTING	
Atterberg Preparation	Dry Sieved	Material Description	-	

AS Sieve (mm)	Specification Minimum (%)	**Percent Passing (%)**	Specification Maximum (%)
9.5		**100**	
4.75		**100**	
2.36		**100**	
0.425		**94**	
0.075		**79**	

PARTICLE SIZE DISTRIBUTION GRAPH



Test Result	Specification Minimum (%)	**Result**	Specification Maximum (%)
Liquid Limit (%)		**45**	
Plastic Limit (%)		**24**	
Plastic Index (%)		**21**	
Linear Shrinkage (%)		**5.0**	

Test Result	Specification Minimum (%)	**Result (%)**	Specification Maximum (%)
0.075/0.425 Fines Ratio		**0.84**	
PI x 0.425 Ratio (%)		**1980.0**	
LS x 0.425 Ratio (%)		**471.4**	
Linear Shrinkage Defects	-		

Remarks: Results apply to the sample/s as received.

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Accreditation Number: 1986
Corporate Site Number: 14892

Approved Signatory: Zachery Zarb
Form ID: W85Rep Rev 2

Construction Sciences

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QUALITY OF MATERIALS REPORT

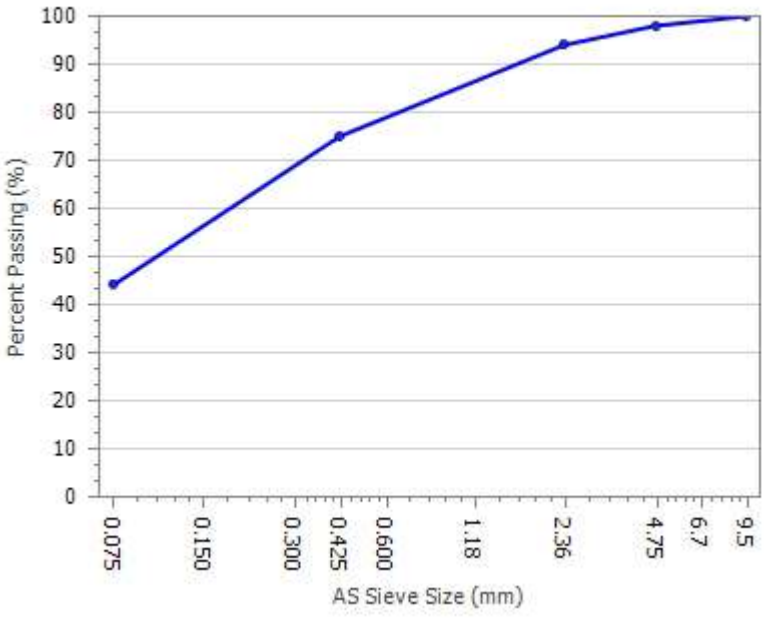
Client:	EDG Consulting PTY LTD	Report Number:	14892/R/28614-1
Client Address:	Level 1, 18 Wandoo st, Fortitude Valley	Project Number:	14892/P/907
Project:	Saraji Mine Laboratory Testing	Lot Number:	TFS3
Location:	Saraji Mine	Internal Test Request:	14892/T/16651
Supplied To:	n/a	Client Reference/s:	22-04-2021 - TSF2-4 - Job No: B012
Area Description:	Saraji Mine	Report Date / Page:	4/05/2021 Page 5 of 5

Test Procedures	AS1289.3.6.1, AS1289.3.1.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1

Sample Number	14892/S/76232	Test Pit #		CPT01
Sampling Method	Tested As Received	Starting Depth	M	3.00
Date Sampled	22/04/2021	Finished Depth	M	3.45
Sampled By	Client Sampled			SPT
Date Tested	29/04/2021	Material Source	ONSITE	
Att. Drying Method	Oven Dried	Material Type	EXISTING	
Atterberg Preparation	Dry Sieved	Material Description	-	

AS Sieve (mm)	Specification Minimum (%)	**Percent Passing (%)**	Specification Maximum (%)
9.5		**100**	
4.75		**98**	
2.36		**94**	
0.425		**75**	
0.075		**44**	

PARTICLE SIZE DISTRIBUTION GRAPH



Test Result	Specification Minimum (%)	**Result**	Specification Maximum (%)
Liquid Limit (%)		**26**	
Plastic Limit (%)		**18**	
Plastic Index (%)		**8**	
Linear Shrinkage (%)		**5.0**	

Test Result	Specification Minimum (%)	**Result (%)**	Specification Maximum (%)
0.075/0.425 Fines Ratio		**0.59**	
PI x 0.425 Ratio (%)		**602.8**	
LS x 0.425 Ratio (%)		**376.8**	
Linear Shrinkage Defects	-		

Remarks: Results apply to the sample/s as received.

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Accreditation Number: 1986
Corporate Site Number: 14892

Approved Signatory: Zachery Zarb
Form ID: W85Rep Rev 2

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	EDG Consulting	**Report No.:**	20100569 - CU
		Workorder No.	0007942
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	3/11/2020
		Report Date:	20/11/2020
Project:	B01229-4 - TSF2-4 - TSF3, Saraji Mine		
Client Id.:	TSF3-CPT02	**Depth (m):**	4.00
Description:	SILT - black		

SAMPLE & TEST DETAILS

Initial Height:	98.5	mm	Initial Moisture Content:	23.7	%	Rate of Strain:	0.009	%/min
Initial Diameter:	47.4	mm	Final Moisture Content:	24.8	%	B Response:	97	%
L/D Ratio:	2.1 : 1		Wet Density:	1.48	t/m^3			
			Dry Density:	1.19	t/m^3			

Sample Type: Single Individual Specimen

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses* σ'_1	σ'_3	σ'_1 / σ'_3	*Deviator Stress*	*Strain*
71 kPa	570 kPa	499 kPa	499 kPa	511 kPa	245 kPa	59 kPa	4.162	186 kPa	2.13 %
143 kPa	640 kPa	497 kPa	497 kPa	537 kPa	398 kPa	103 kPa	3.860	295 kPa	5.06 %
282 kPa	779 kPa	497 kPa	497 kPa	612 kPa	622 kPa	167 kPa	3.737	456 kPa	8.49 %

FAILURE ENVELOPES

	1 to 2	2 to 3	1 to 3
Interpretation between stages :			
Cohesion C' (kPa) :	11.2	8.9	10.1
Angle of Shear Resistance Φ' (Degrees) :	33.5	34.0	33.8

Failure Criteria: Peak Principal Stress Ratio

Remarks: Specimen remoulded to a target density of 100% of Field Dry Density at Field Moisture Content.
Sample/s supplied by the client

REP03001

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Authorised Signatory

C. Channon

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	EDG Consulting	**Report No.:**	20100567 - CU
		Workorder No.	0007942
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	6/11/2020
		Report Date:	16/11/2020
Project:	B01229-4 - TSF2-4 - TSF3, Saraji Mine		
Client Id.:	TSF3-BH01	**Depth (m):**	13.50-13.95
Description:	CLAYEY SILTY SAND - orange/brown		

SAMPLE & TEST DETAILS

Initial Height:	151.5	mm	Initial Moisture Content:	8.3	%	Rate of Strain:	0.004	%/min
Initial Diameter:	73.2	mm	Final Moisture Content:	7.9	%	B Response:	97	%
L/D Ratio:	2.1 : 1		Wet Density:	2.21	t/m^3			
			Dry Density:	2.04	t/m^3			

Sample Type: Single Individual Undisturbed Specimen.

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses*			*Deviator Stress*	*Strain*
					σ'_1	σ'_3	σ'_1 / σ'_3		
259 kPa	558 kPa	299 kPa	299 kPa	389 kPa	579 kPa	169 kPa	3.428	410 kPa	2.60 %
420 kPa	720 kPa	300 kPa	300 kPa	345 kPa	1270 kPa	375 kPa	3.386	895 kPa	6.65 %
842 kPa	1145 kPa	303 kPa	303 kPa	406 kPa	2404 kPa	739 kPa	3.253	1665 kPa	9.20 %

FAILURE ENVELOPES

Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**3.5**	**28.7**	**14.7**
Angle of Shear Resistance Φ' (Degrees) :	**32.7**	**30.9**	**31.5**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received.
Sample/s supplied by the client

REP03001

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ATTERBERG LIMITS TEST REPORT

Test Methods: AS 1289 2.1.1, 3.2.1, 3.3.1, 3.4.1

Client	EDG Consulting	**Report No.**	21050067-AL
		Workorder No.	0008593
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Report Date**	19/05/2021
Project	B01229-4 - TSF2-4 - Saraji Mine		

Sample No.	21050067	21050068	21050069	21050070		
Liquid Limit Determination	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2		
Test Date	14/05/2021	14/05/2021	14/05/2021	14/05/2021		
Client ID	TSF3-CPT07	TSF3-CPT09	TSF4-CPT06	TSF4-CPT07		
Depth (m)	10.00-10.50	10.00-10.80	11.00-11.80	7.50-8.00		
Liquid Limit (%)	42	44	40	41		
Plastic Limit (%)	22	23	22	24		
Plasticity Index (%)	20	21	18	17		
Linear Shrinkage (%)	5.5	6.5	4.5	6.0		
Moisture Content (%)	31.7	40.4	33.2	33.3		

Sample No.						
Liquid Limit Determination						
Test Date						
Client ID						
Depth (m)						
Liquid Limit (%)						
Plastic Limit (%)						
Plasticity Index (%)						
Linear Shrinkage (%)						
Moisture Content (%)						

NOTES/REMARKS: The samples were tested oven dried, dry sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

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ATTERBERG LIMITS TEST REPORT

Test Method: AS 1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1

Client	EDG Consulting	**Report No.**	20100569-AL
		Workorder No.	0007942
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Report Date**	12/11/2020
Project	B01229-4 - TSF2-4 - TSF3, Saraji Mine		

Sample No.	20100569
Test Date	3/11/2020
Client ID	TSF3-CPT02
Depth (m)	4.00
Liquid Limit (%)	42
Plastic Limit (%)	23
Plasticity Index (%)	19
Linear Shrinkage (%)	6.5
Moisture Content (%)	23.7

NOTES/REMARKS: The samples were tested oven dried, dry sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred

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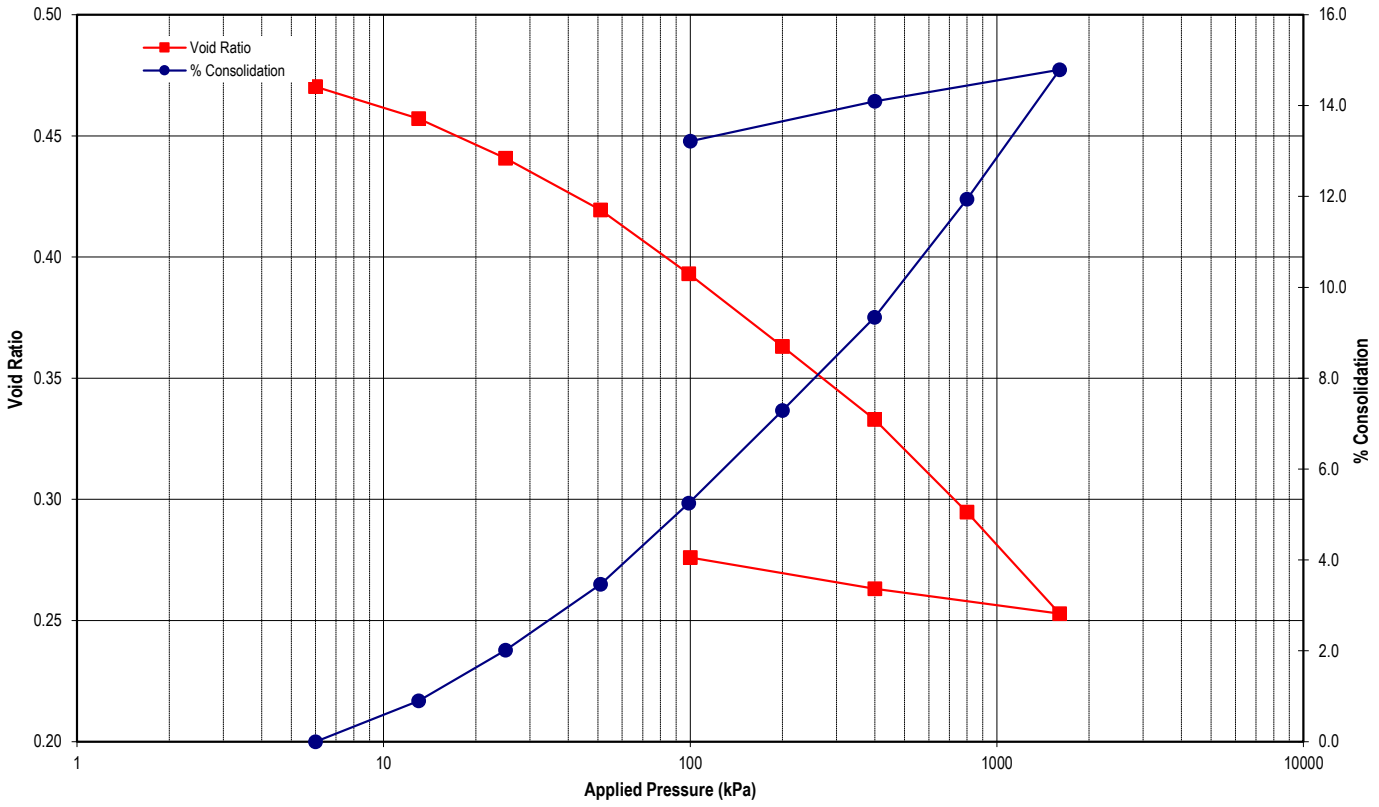
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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050067-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	7/05/2021
		Report Date:	26/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF3-CPT07	**Depth (m):**	10.00-10.50
Description:	SILTY CLAY- black		



Initial Wet Density (t/m^3):	1.49	Initial Moisture (%):	31.7	Initial Height (mm):	20.00
Initial Dry Density (t/m^3):	1.13	Final Moisture (%):	21.5	Final Height (mm):	17.36
Initial Mass (g):	89.18	Initial Voids Ratio:	0.470	Test Condition:	Inundated on load
Particle Density (t/m^3):	1.66	Initial Degree of Saturation (%):	100.0	Undisturbed sample supplied by the client	

Remarks: Tested as Received

REP03103

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Tested at Trilab Brisbane Laboratory

Authorised Signatory

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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050067-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	7/05/2021
		Report Date:	26/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF3-CPT07	**Depth (m):**	10.00-10.50
Description:	SILTY CLAY- black		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-13	0.039	1.7E-09	3.23	4.27	1.283	0.61	0.9
2	13-25	0.058	2.0E-09	5.61	6.85	0.936	0.89	2.0
3	25-51	0.069	1.9E-09	8.90	10.51	0.570	1.01	3.5
4	51-99	0.091	1.1E-09	9.11	9.31	0.386	0.87	5.3
5	99-200	0.098	8.7E-10	14.49	13.16	0.213	1.14	7.3
6	200-399	0.100	5.8E-10	13.60	16.92	0.111	1.08	9.3
7	399-800	0.127	3.8E-10	20.02	17.24	0.072	1.27	11.9
8	800-1603	0.139	2.4E-10	19.96	19.05	0.040	1.64	14.8
9	1603-400	0.017	5.4E-11	67.09	25.62	0.007	0.25	14.1
10	400-100	0.021	1.9E-10	17.33	18.33	0.034	0.57	13.2

Remarks: Tested as Received

REP03103

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Channon

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory Number 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
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Trilab
Soil Rock Calibration

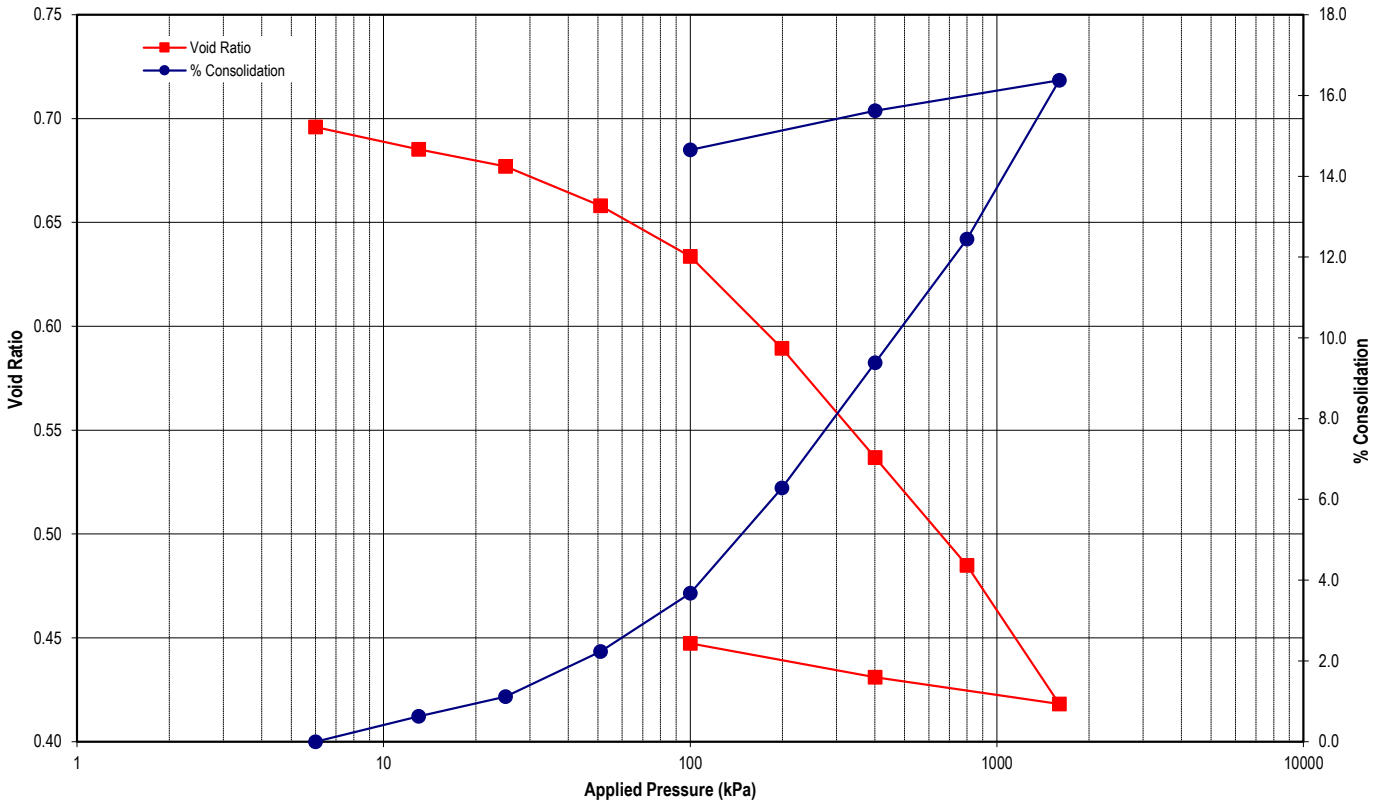
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346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
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Ph: +61 8 9258 8323

OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050068-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	6/05/2021
		Report Date:	27/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF3-CPT09	**Depth (m):**	10.00-10.80
Description:	SILTY CLAY- black		



Initial Wet Density (t/m^3):	1.39	Initial Moisture (%):	41.5	Initial Height (mm):	19.95
Initial Dry Density (t/m^3):	0.98	Final Moisture (%):	28.4	Final Height (mm):	17.03
Initial Mass (g):	48.13	Initial Voids Ratio:	0.696	Test Condition:	Inundated on load
Particle Density (t/m^3):	1.67	Initial Degree of Saturation (%):	100.3	Undisturbed sample supplied by the client	

Remarks: Tested as Received

REP03103

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Trilab
Soil Rock Calibration

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Ph: +61 8 9258 8323

OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050068-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	6/05/2021
		Report Date:	27/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF3-CPT09	**Depth (m):**	10.00-10.80
Description:	SILTY CLAY- black		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-13	0.032	6.9E-09	15.27	24.89	0.900	0.34	0.6
2	13-25	0.029	4.1E-09	25.52	32.36	0.407	0.48	1.1
3	25-51	0.061	5.0E-09	40.93	36.90	0.434	0.72	2.2
4	51-100	0.084	3.6E-09	46.47	38.77	0.302	0.92	3.7
5	100-199	0.148	2.9E-09	32.24	34.02	0.273	0.91	6.3
6	199-401	0.173	2.3E-09	48.69	44.36	0.164	1.72	9.4
7	401-799	0.173	9.5E-10	47.43	36.03	0.085	1.69	12.4
8	799-1599	0.221	6.1E-10	48.30	34.87	0.056	1.65	16.4
9	1599-401	0.021	2.0E-10	117.55	84.01	0.008	0.33	15.6
10	401-100	0.027	3.2E-10	47.93	26.88	0.038	0.58	14.7

Remarks: Tested as Received

REP03103

Accredited for compliance with ISO/IEC 17025 - Testing.
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Authorised Signatory

C. Channon

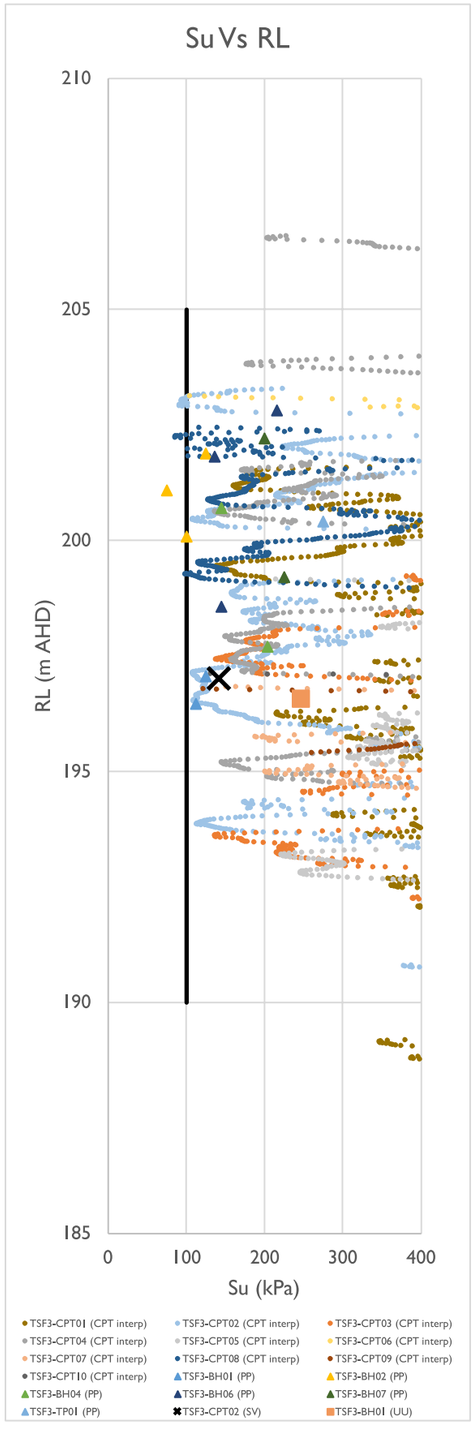
NATA
ACCREDITED FOR TECHNICAL COMPETENCE

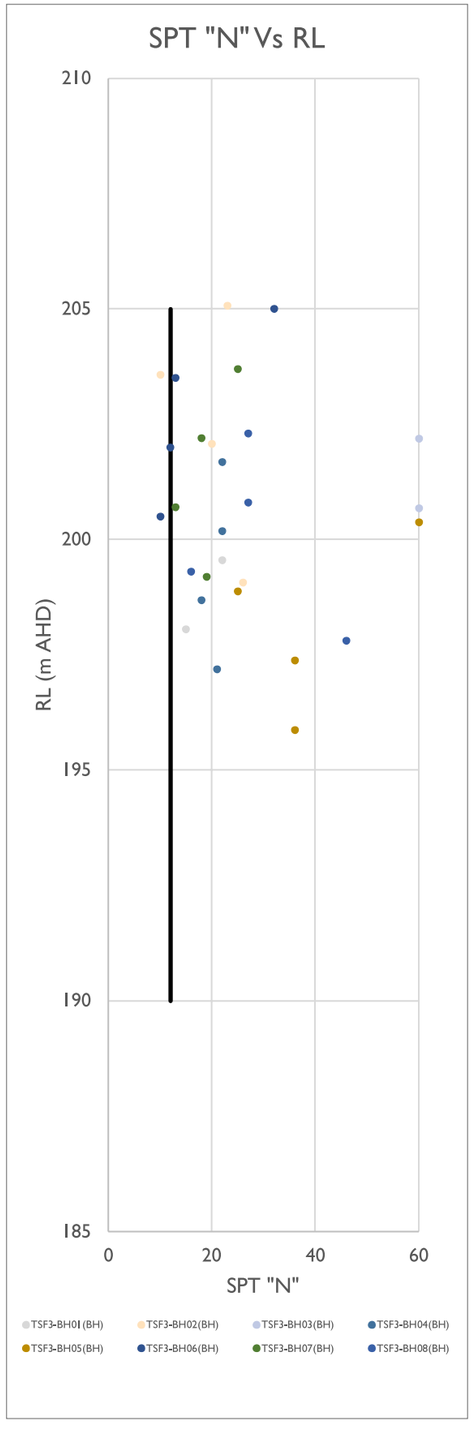
Laboratory Number 9926

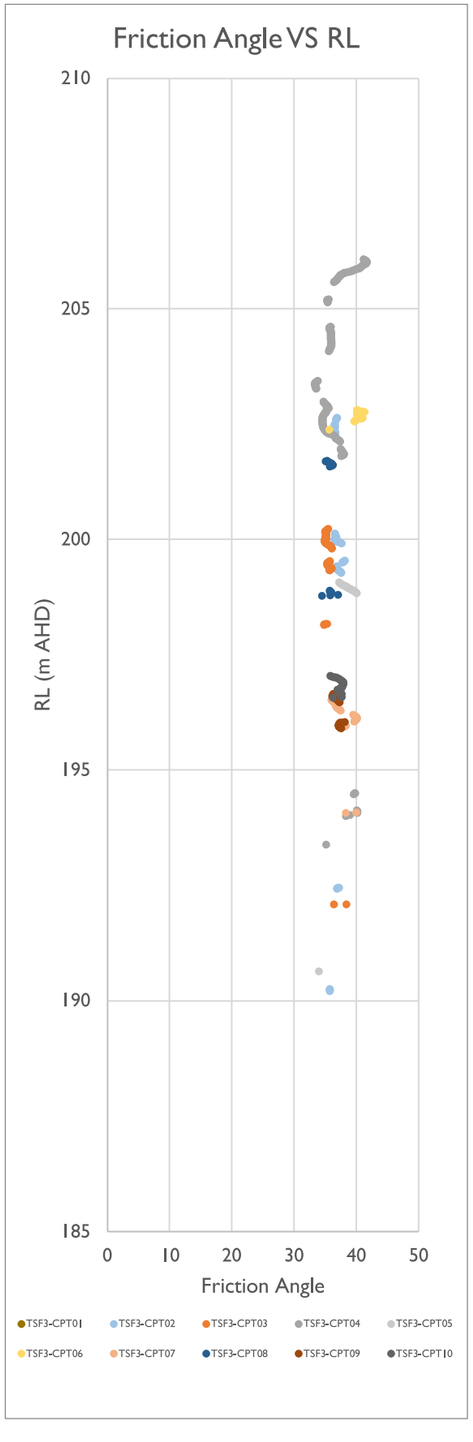
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ABN 25 065 630 506

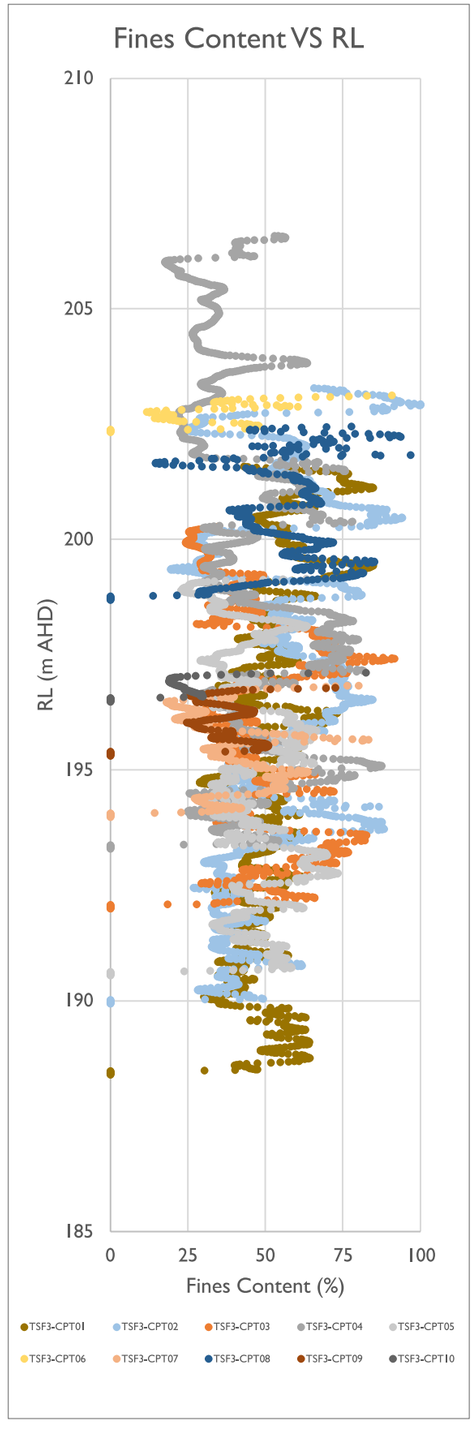
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project:	SRM TSF2-4	*date:*	19/08/2021
location:	TSF3	*by:*	DL
title:	*Material Characterisation Summary - Alluvial Soil*		

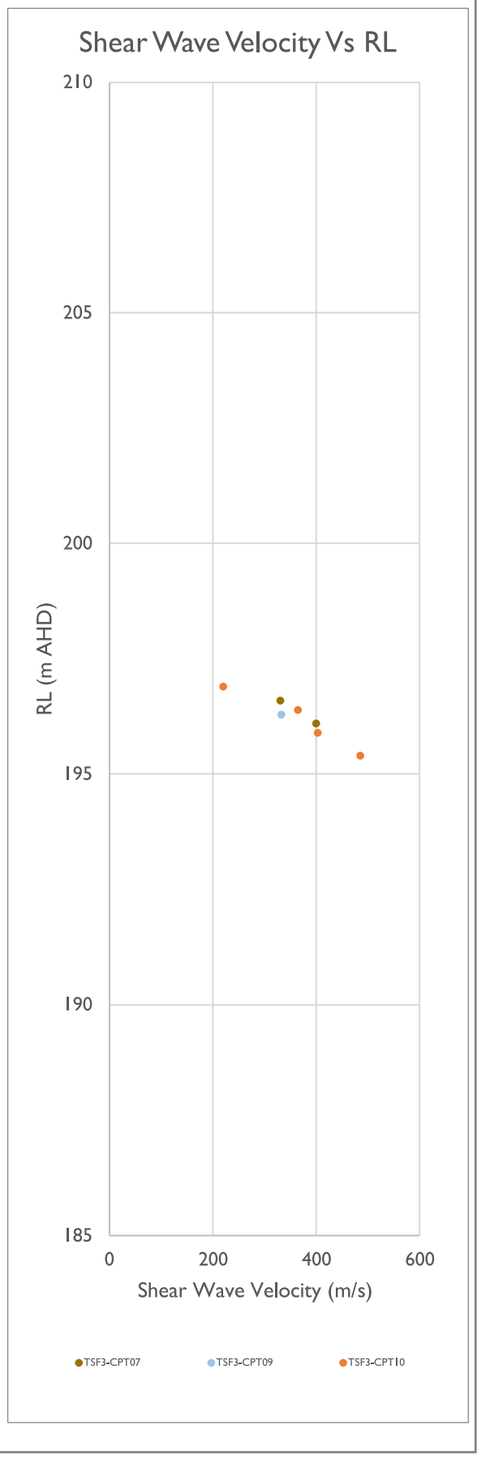
EDG consulting
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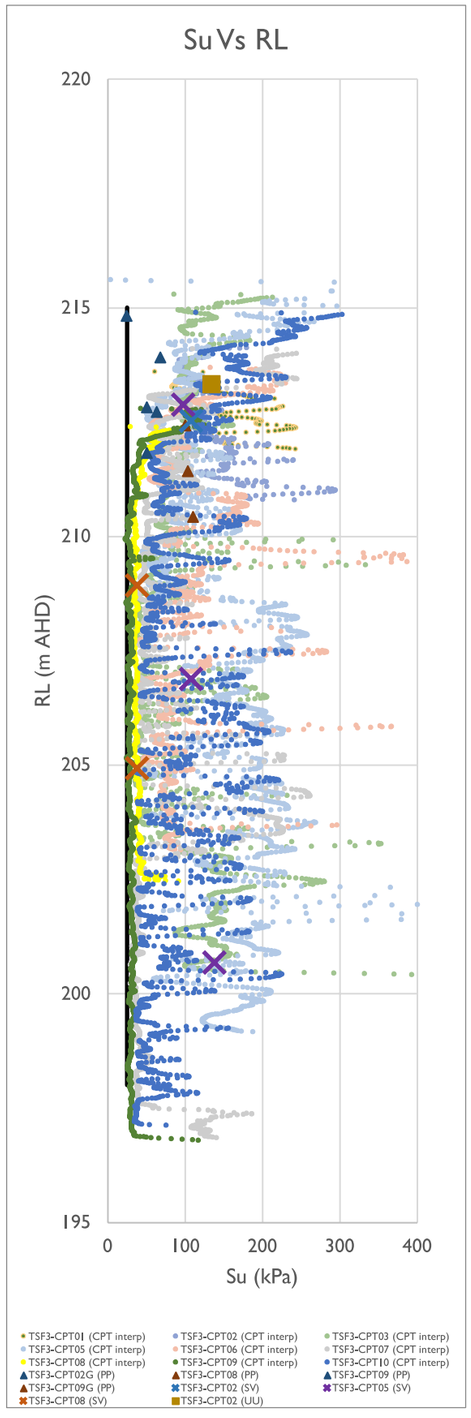


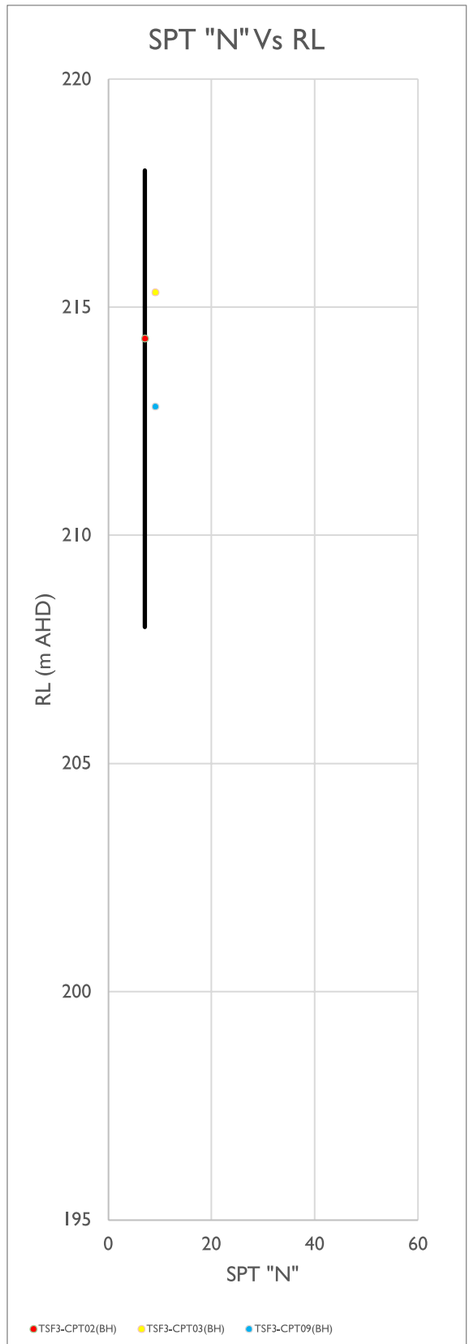


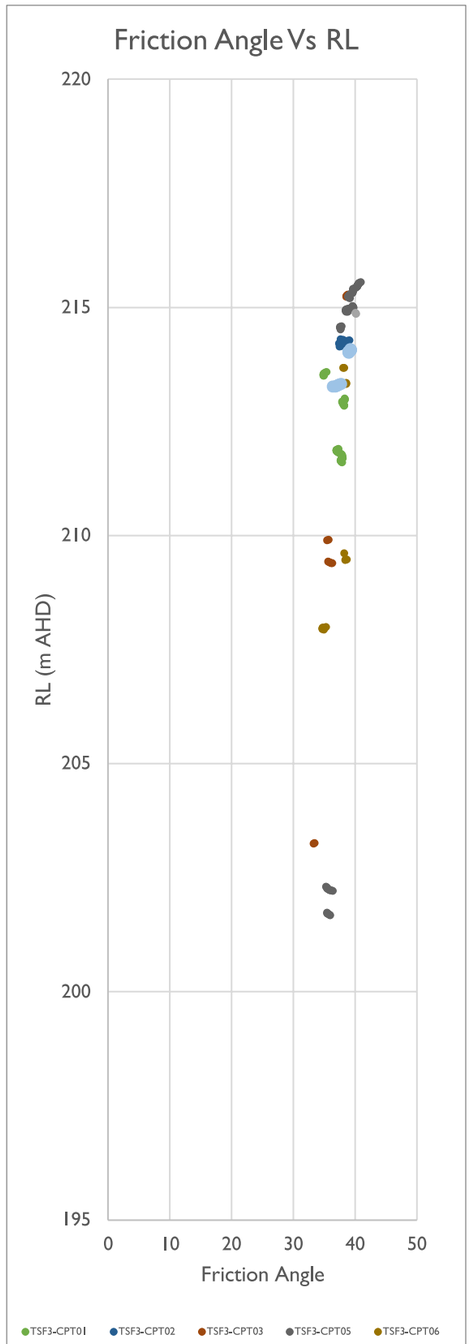
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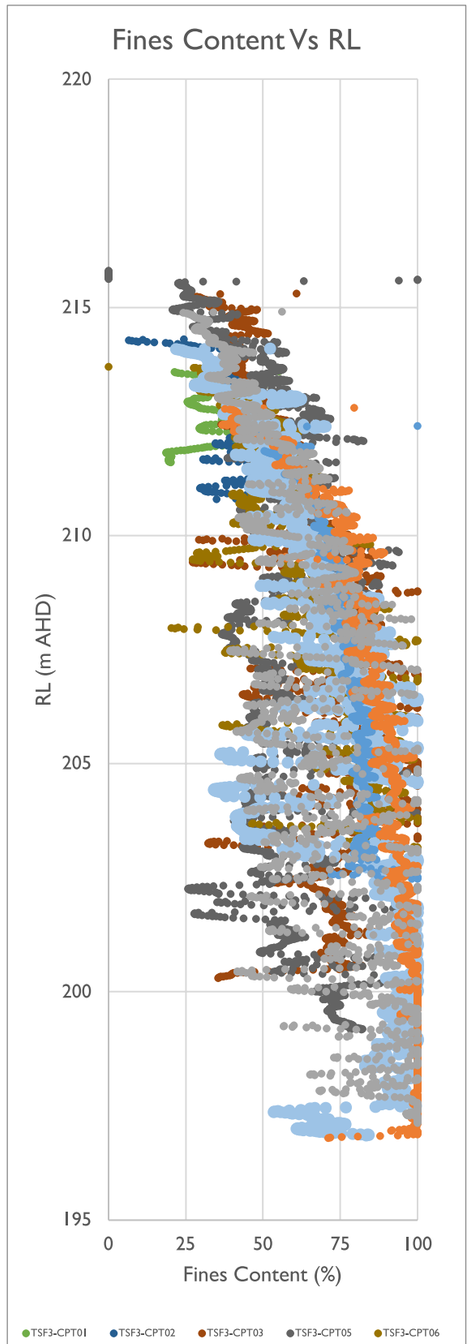
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project:	SRM TSF2-4	*date:*	19/08/2021
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title:	*Material Characterisation Summary - Tailings*		

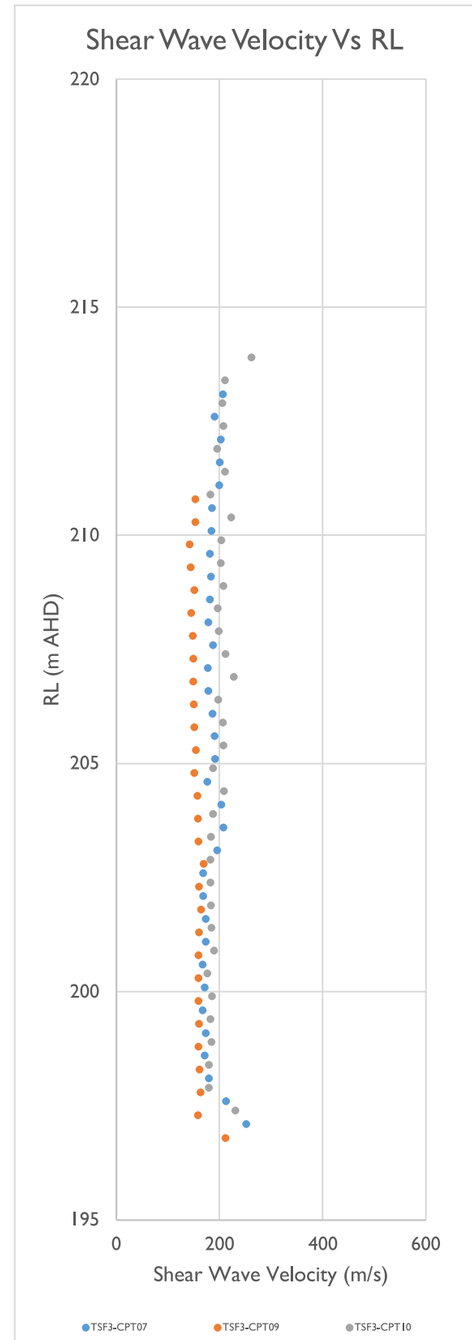
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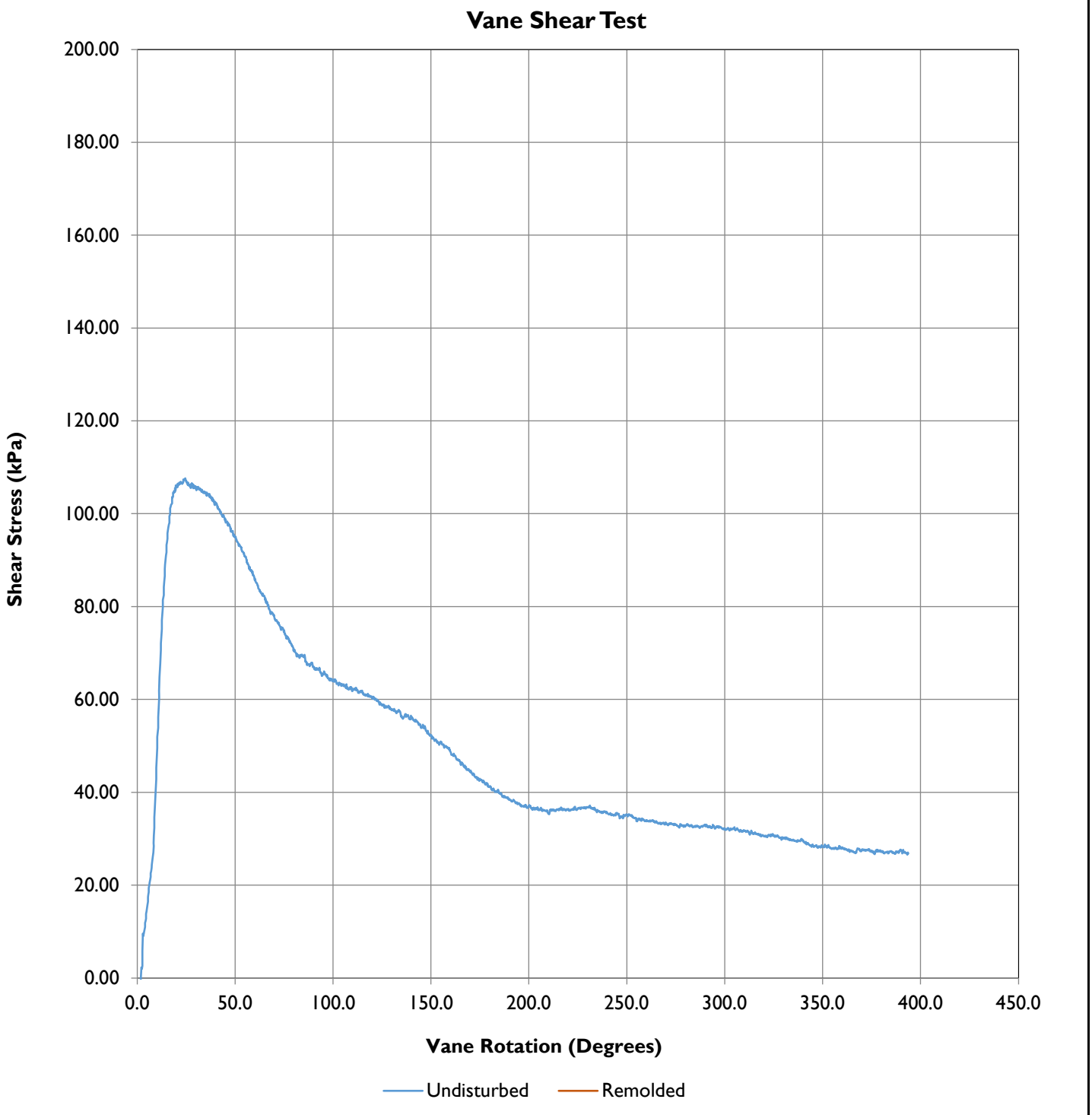




Vane Shear Test

Test Location:	**TSF3-CPT02**		
Test Depth:	**4.80**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**7/09/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

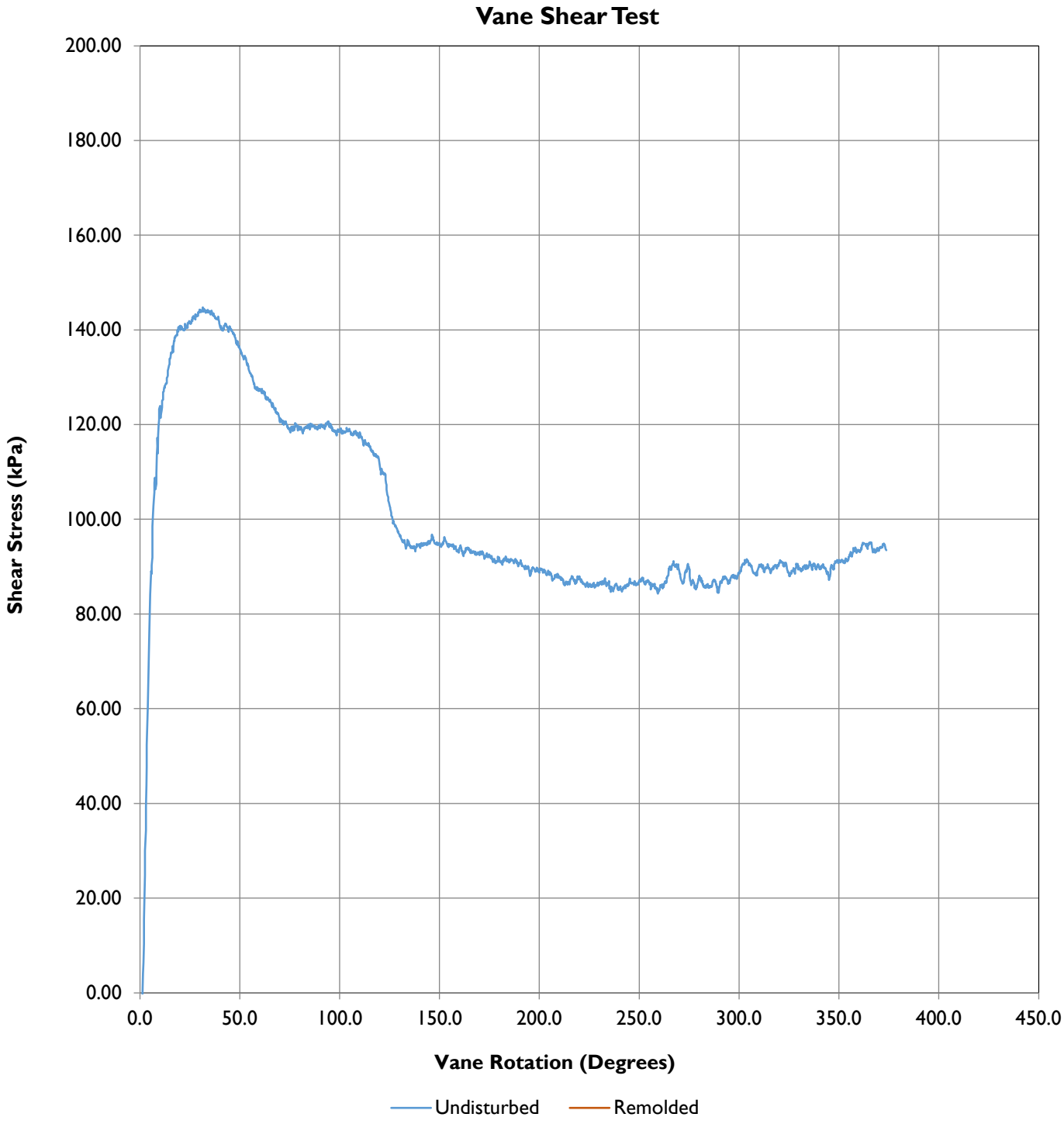
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631303.9*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522197.8*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	217.3m (AHD)



Vane Shear Test

Test Location:	**TSF3-CPT02**
Test Depth:	**13.00**
Job No:	**B01229-4**
Date Tested:	**7/09/2020**
Tested By:	**IGS**

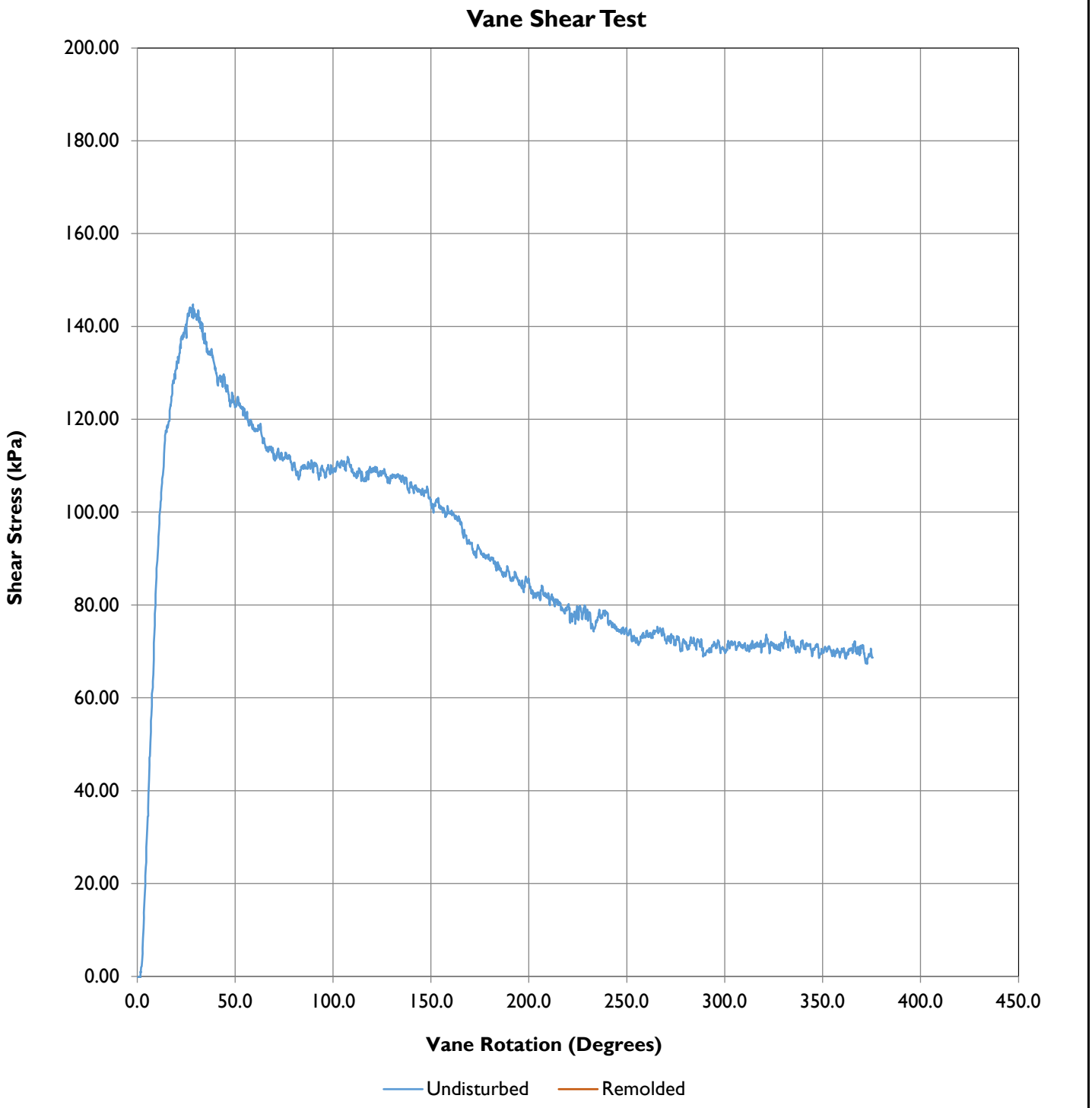
Client:	**BMA**				
Project:	**SRM TSF2-4**				
Location:	**TSF3**				
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631303.9*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522197.8*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	217.3m (AHD)



Vane Shear Test

Test Location:	**TSF3-CPT02**		
Test Depth:	**20.30**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**8/09/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631303.9*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522197.8*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	217.3m (AHD)



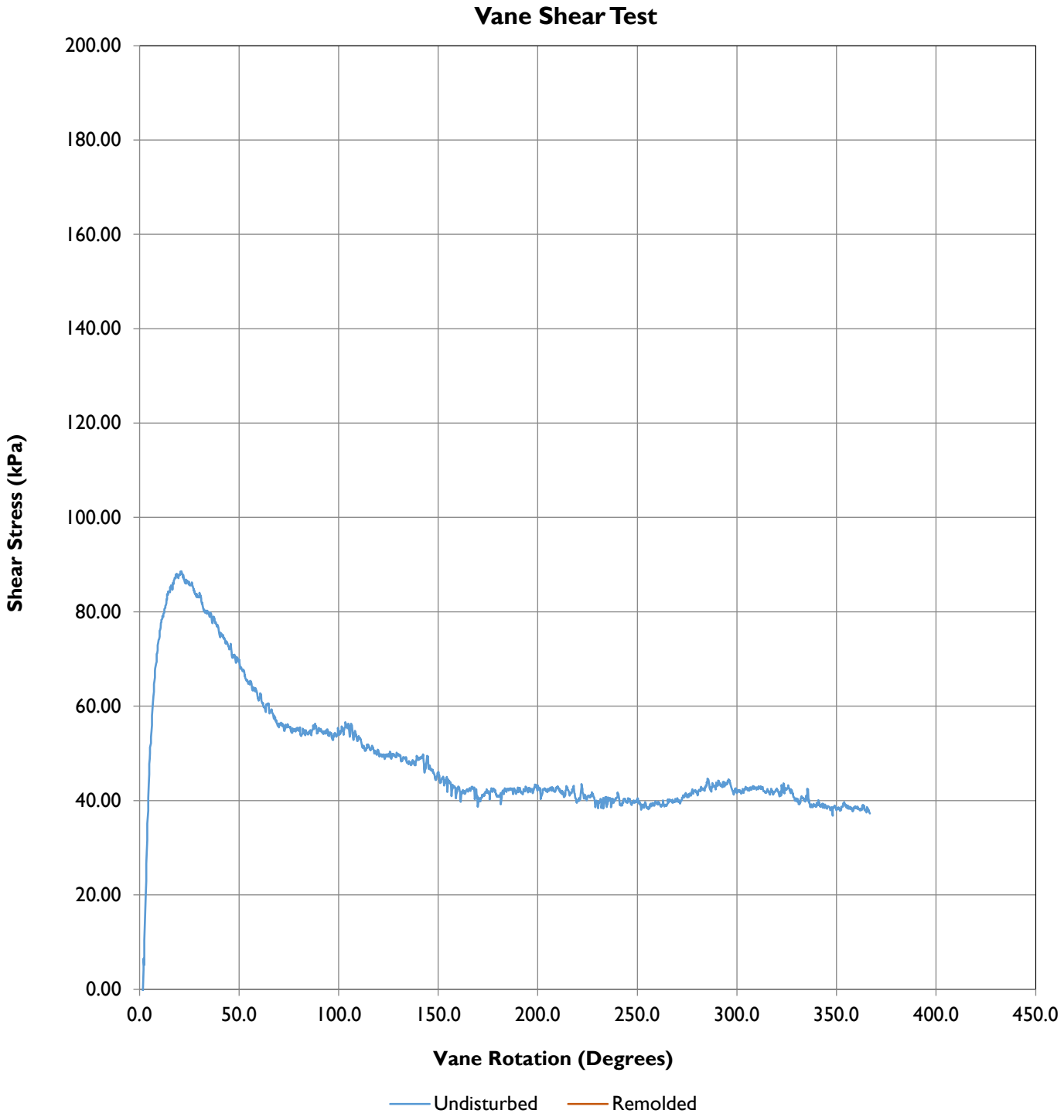
Vane Shear Test

Test Location:	**TSF3-CPT04**
Test Depth:	**10.00**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**8/09/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

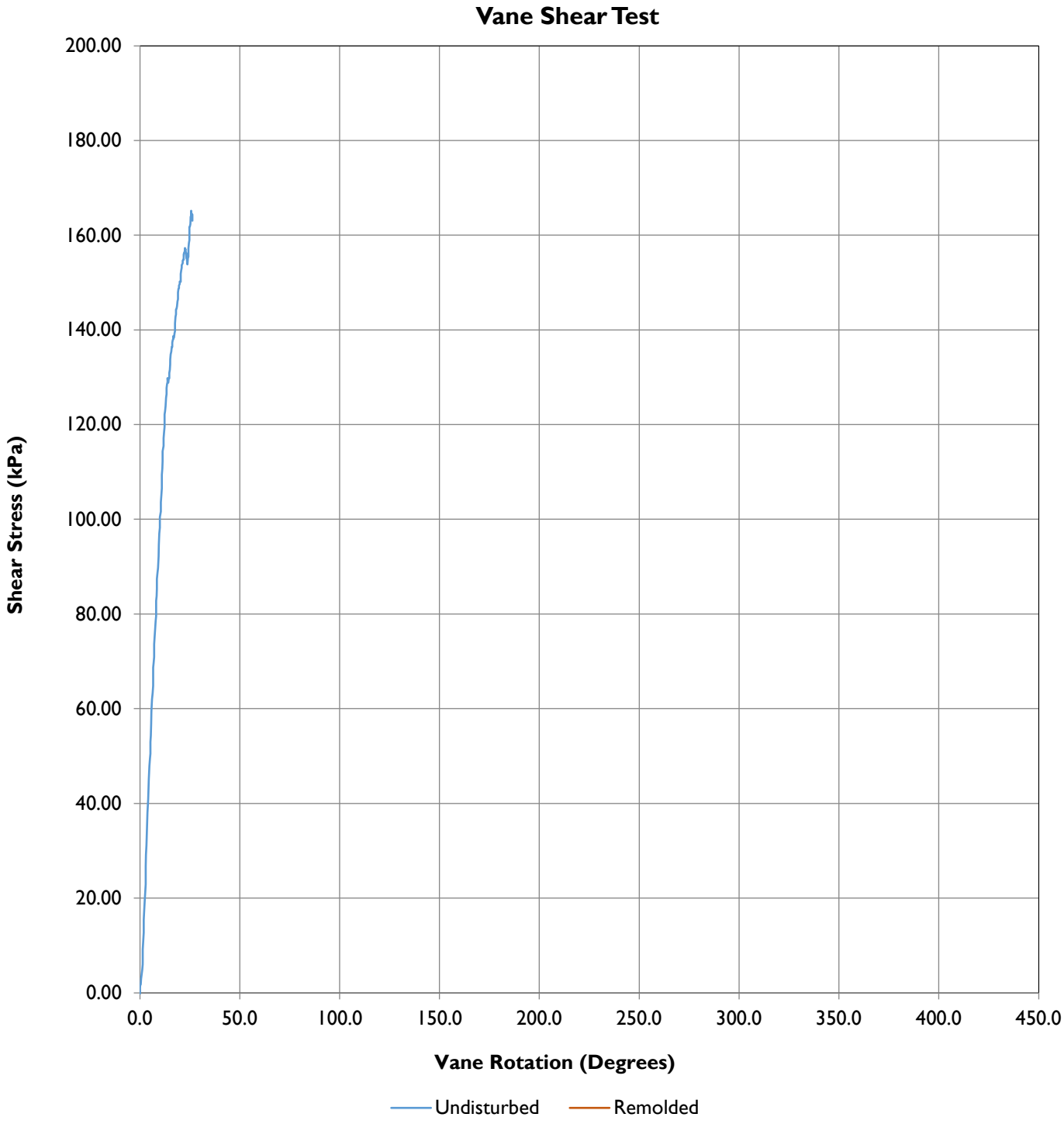
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631334.4*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521669.0*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	219.7m (AHD)



Vane Shear Test

Test Location:	**TSF3-CPT04**		
Test Depth:	**18.50**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/09/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

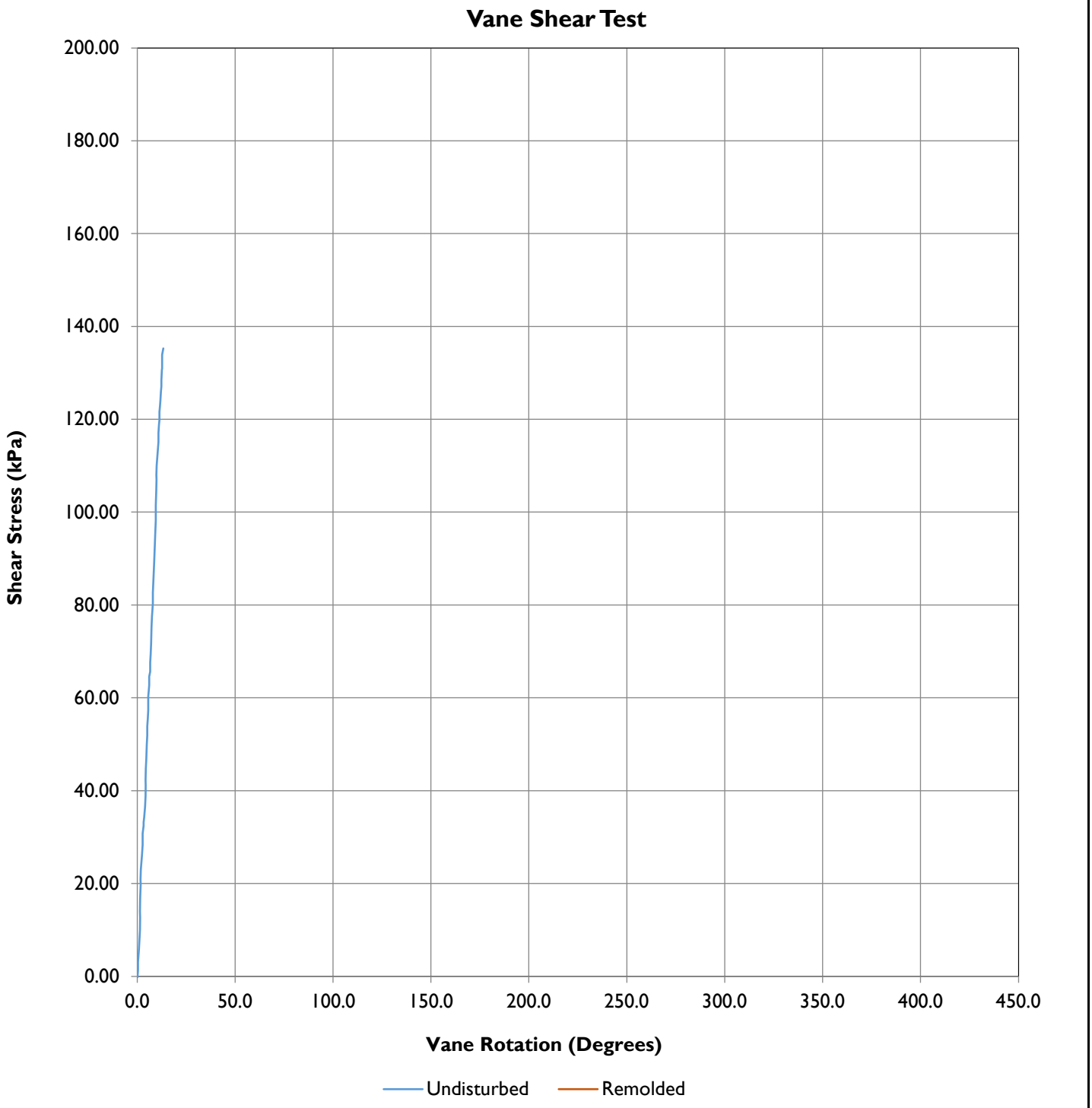
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Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631334.4*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521669.0*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	219.7m (AHD)



Vane Shear Test

Test Location:	**TSF3-CPT04**		
Test Depth:	**21.70**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/09/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

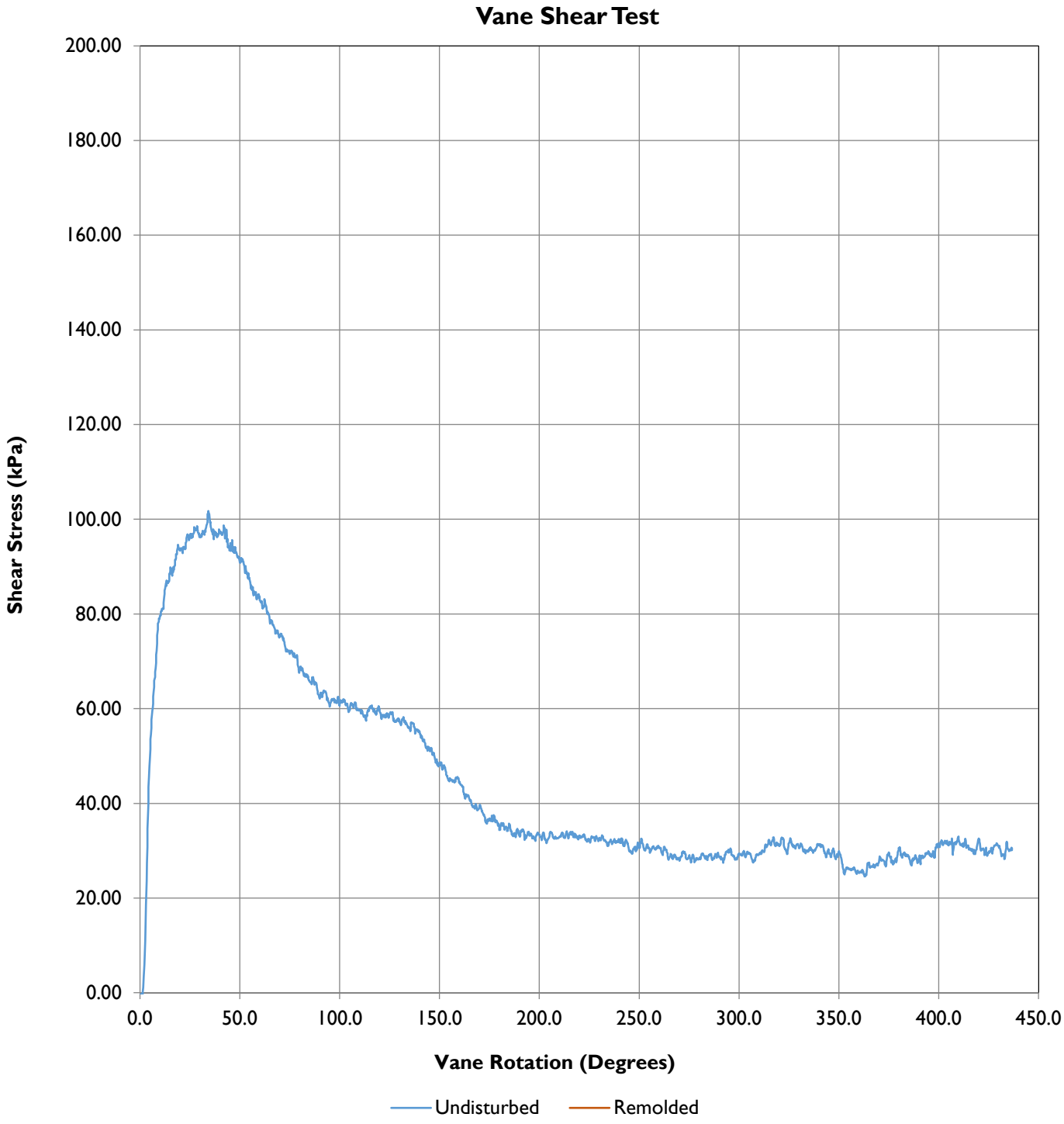
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Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631334.4*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521669.0*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	219.7m (AHD)



Vane Shear Test

Test Location:	**TSF3-CPT05**		
Test Depth:	**6.00**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/09/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

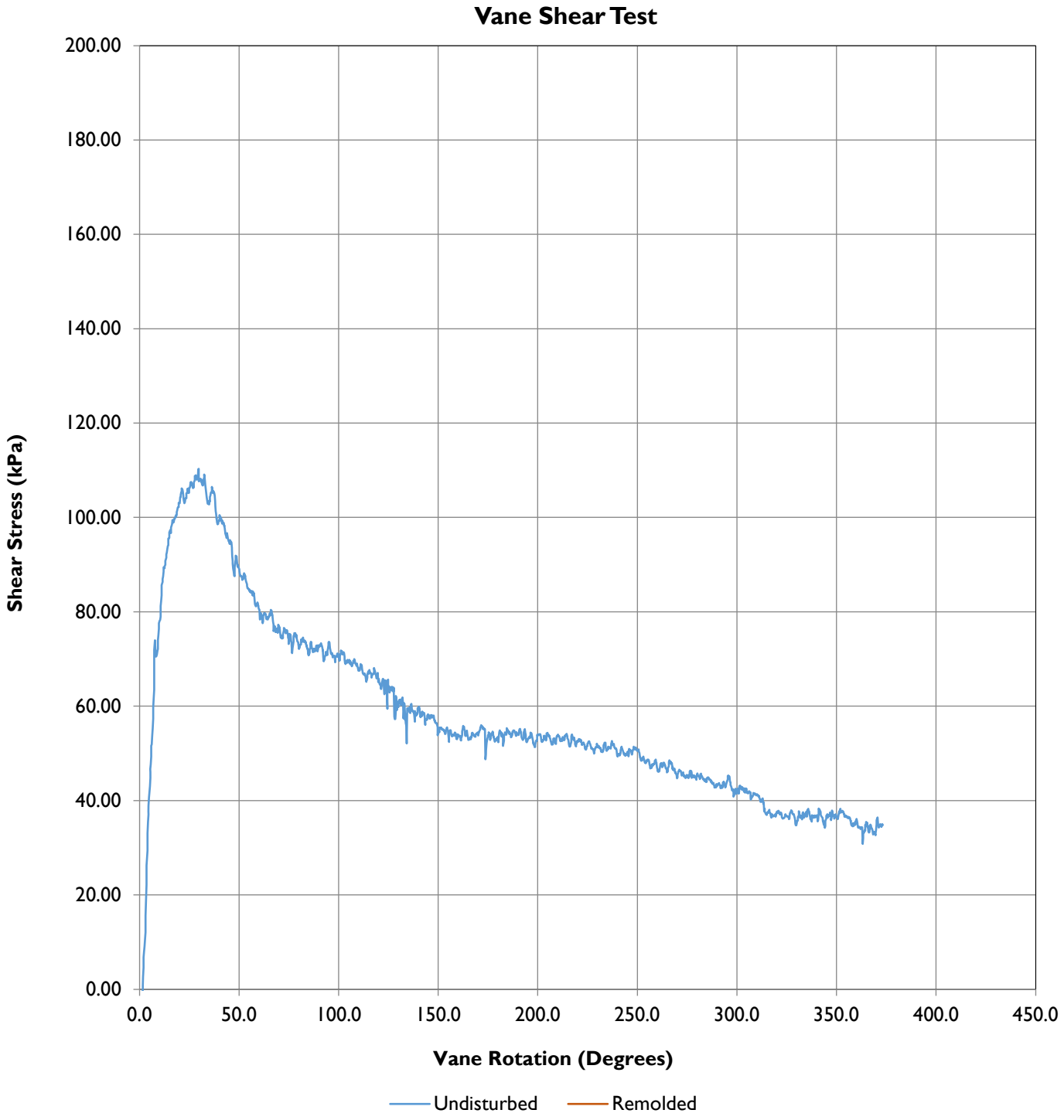
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631194.2*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521751.3*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	218.9m (AHD)



Vane Shear Test

Test Location:	**TSF3-CPT05**		
Test Depth:	**12.00**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**9/09/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

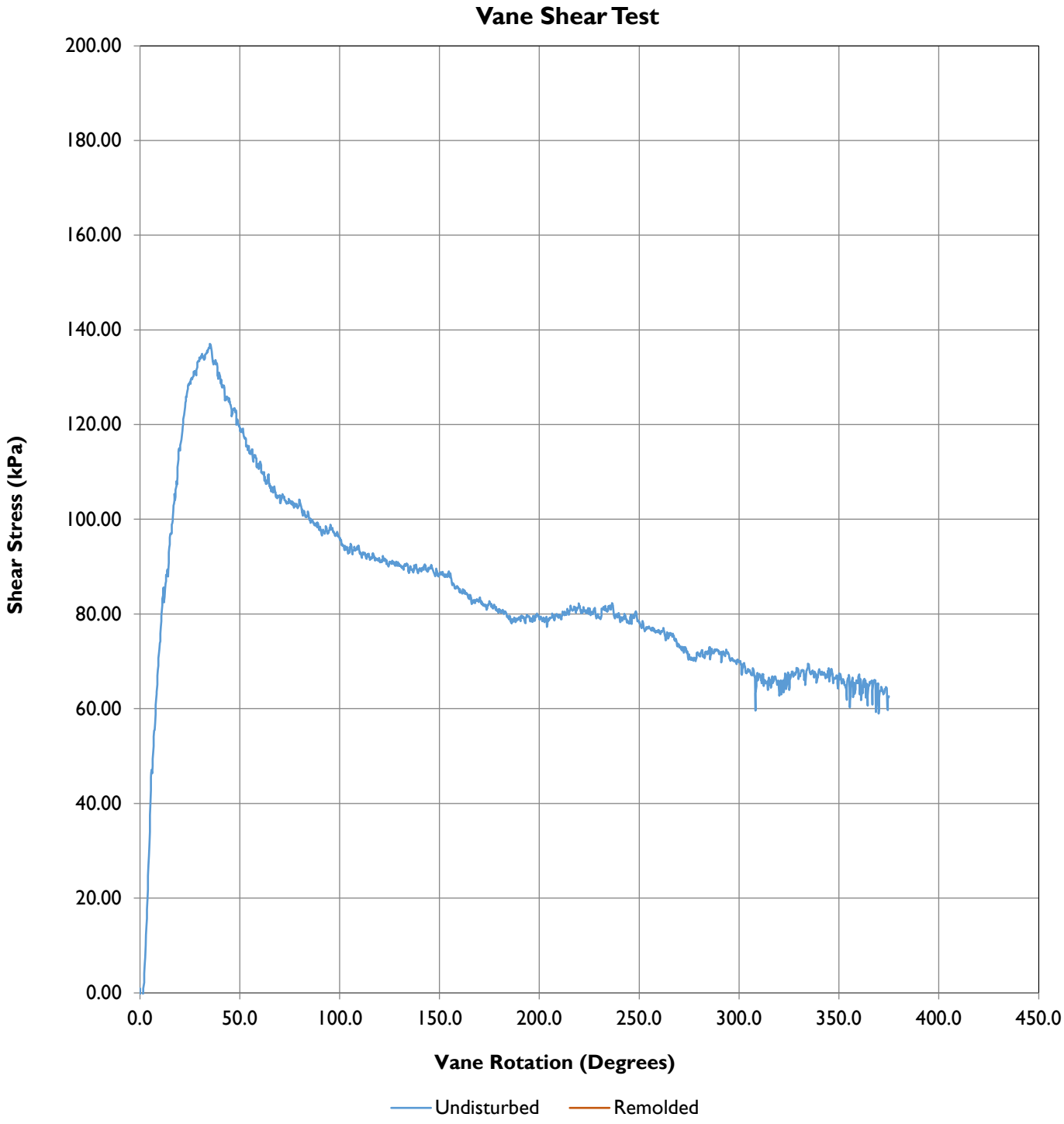
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Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631194.2*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521751.3*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	218.9m (AHD)



Vane Shear Test

Test Location:	**TSF3-CPT05**		
Test Depth:	**18.20**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**21/09/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

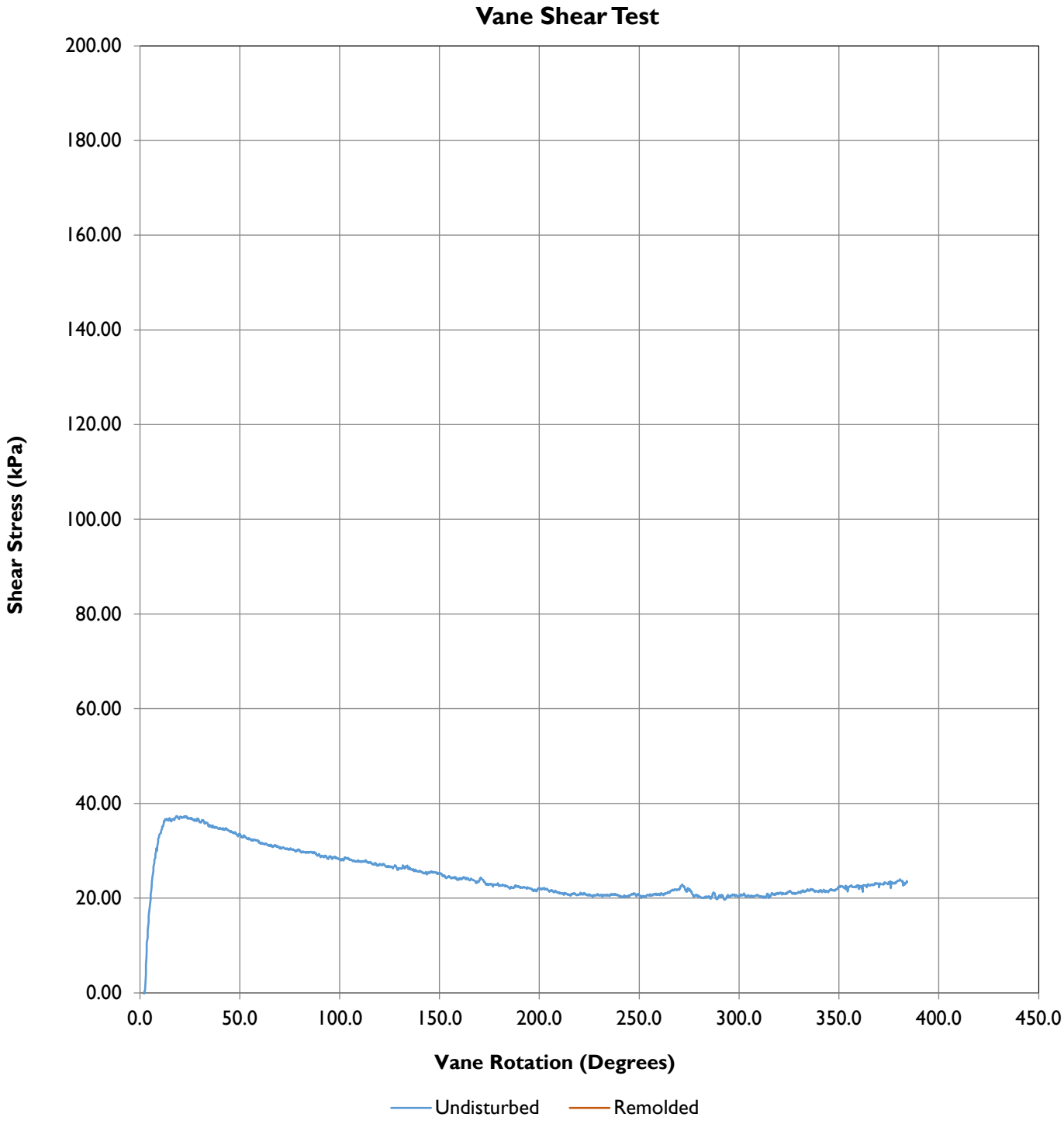
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631194.2*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521751.3*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	218.9m (AHD)



Vane Shear Test

Test Location:	**TSF3-CPT08**		
Test Depth:	**8.00**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**6/09/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

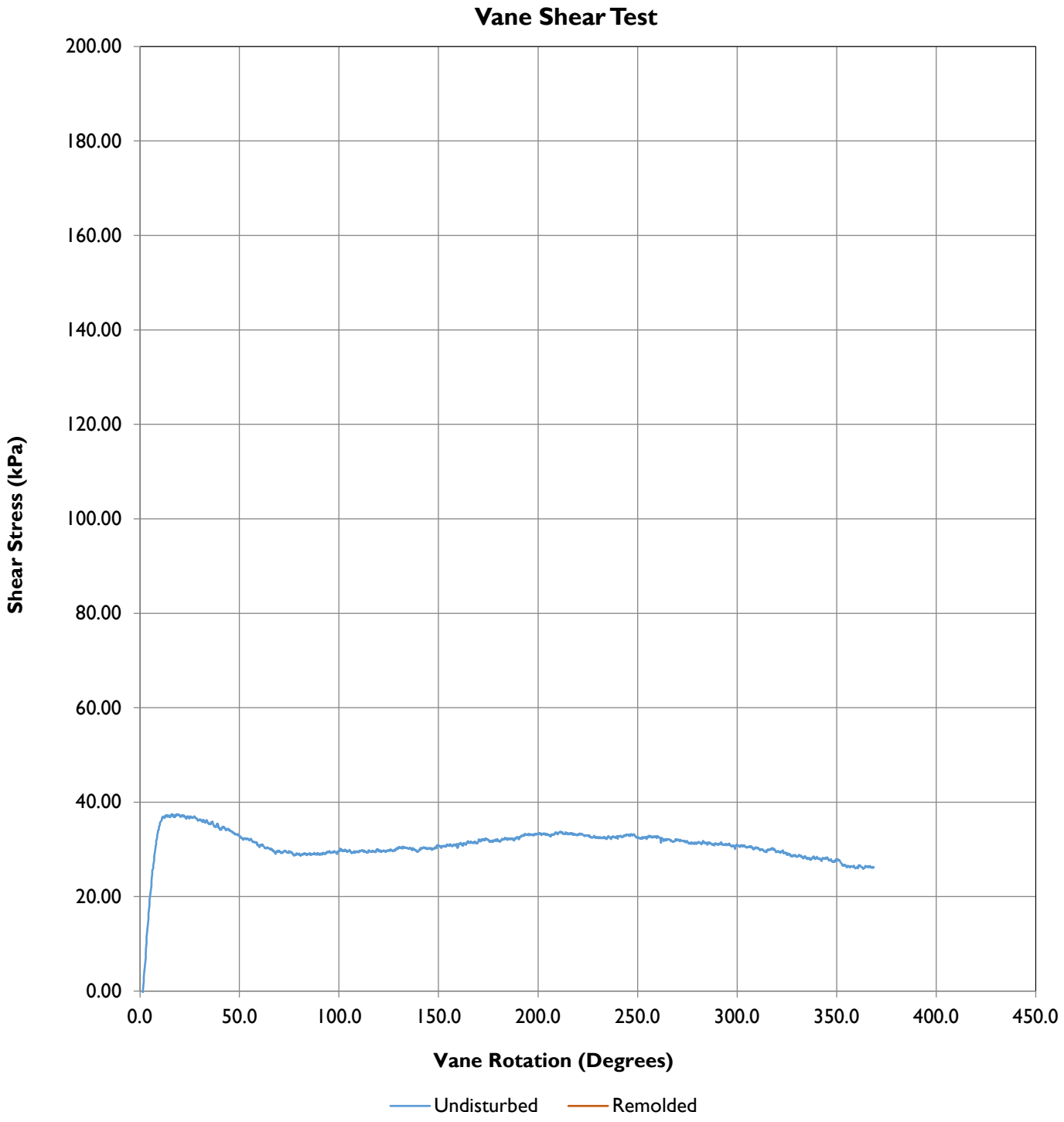
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631070.0*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522538.1*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	216.9m (AHD)



Vane Shear Test

Test Location:	**TSF3-CPT08**		
Test Depth:	**12.00**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**7/09/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

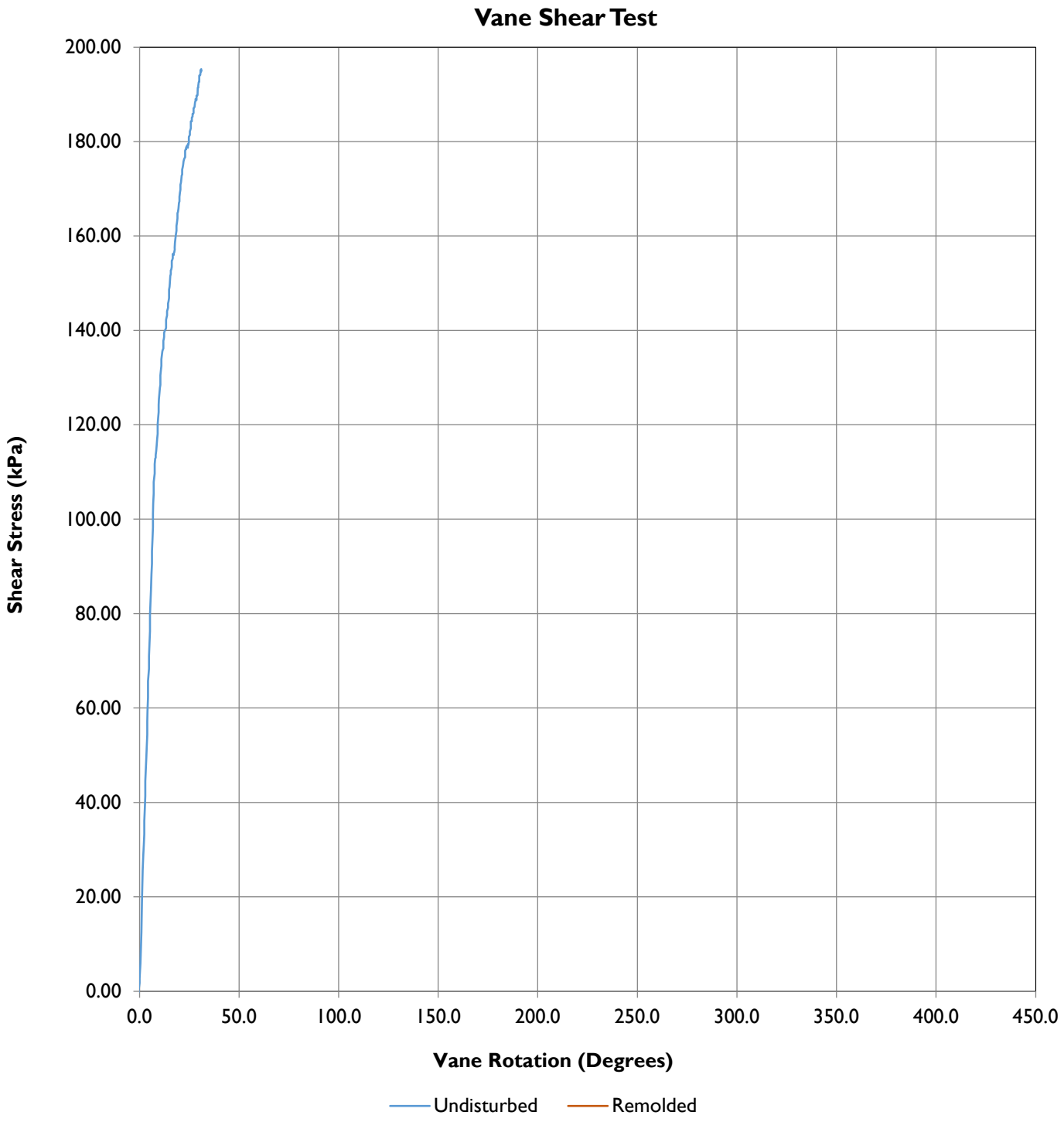
Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631070.0*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522538.1*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	216.9m (AHD)



Vane Shear Test

Test Location:	**TSF3-CPT08**		
Test Depth:	**17.50**		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**7/09/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*35mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631070.0*
Vane Height:	*70mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522538.1*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*4.07*	R.L. Surface:	216.9m (AHD)

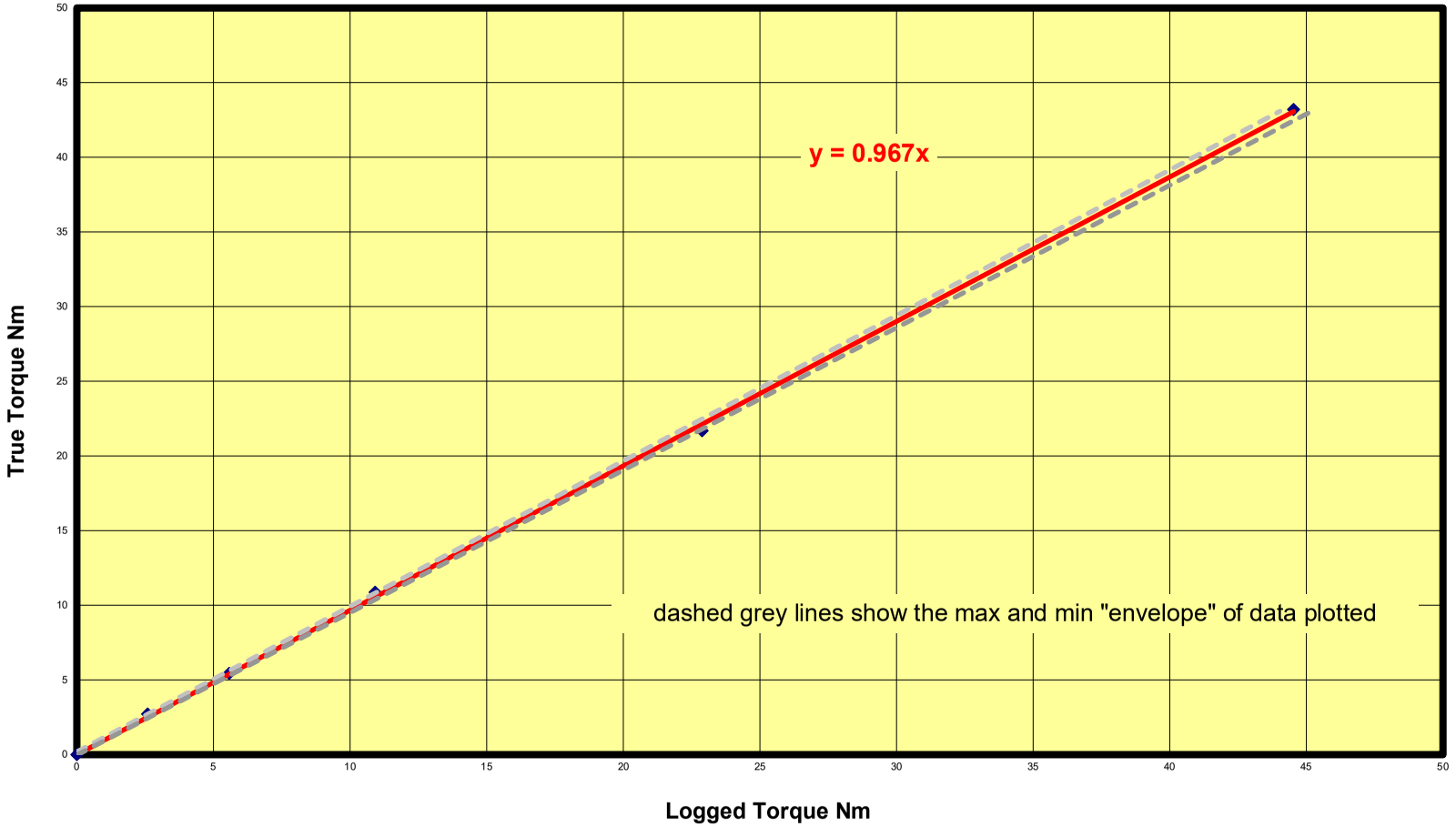


Vane Shear Data Acquisition System Calibration
Insitu Geotech Services Pty Ltd (IGS)

Type: Geomil
Number: 0002
Date: 15-Jun-2018

To adjust for this calibration use the adjusted vane constants below in the IGS Importer sheet
Set max Su in data acquisition software (on "Parameters" page) at blue value shown below
(refer to IGS web site www.insitu.com.au for additional information)

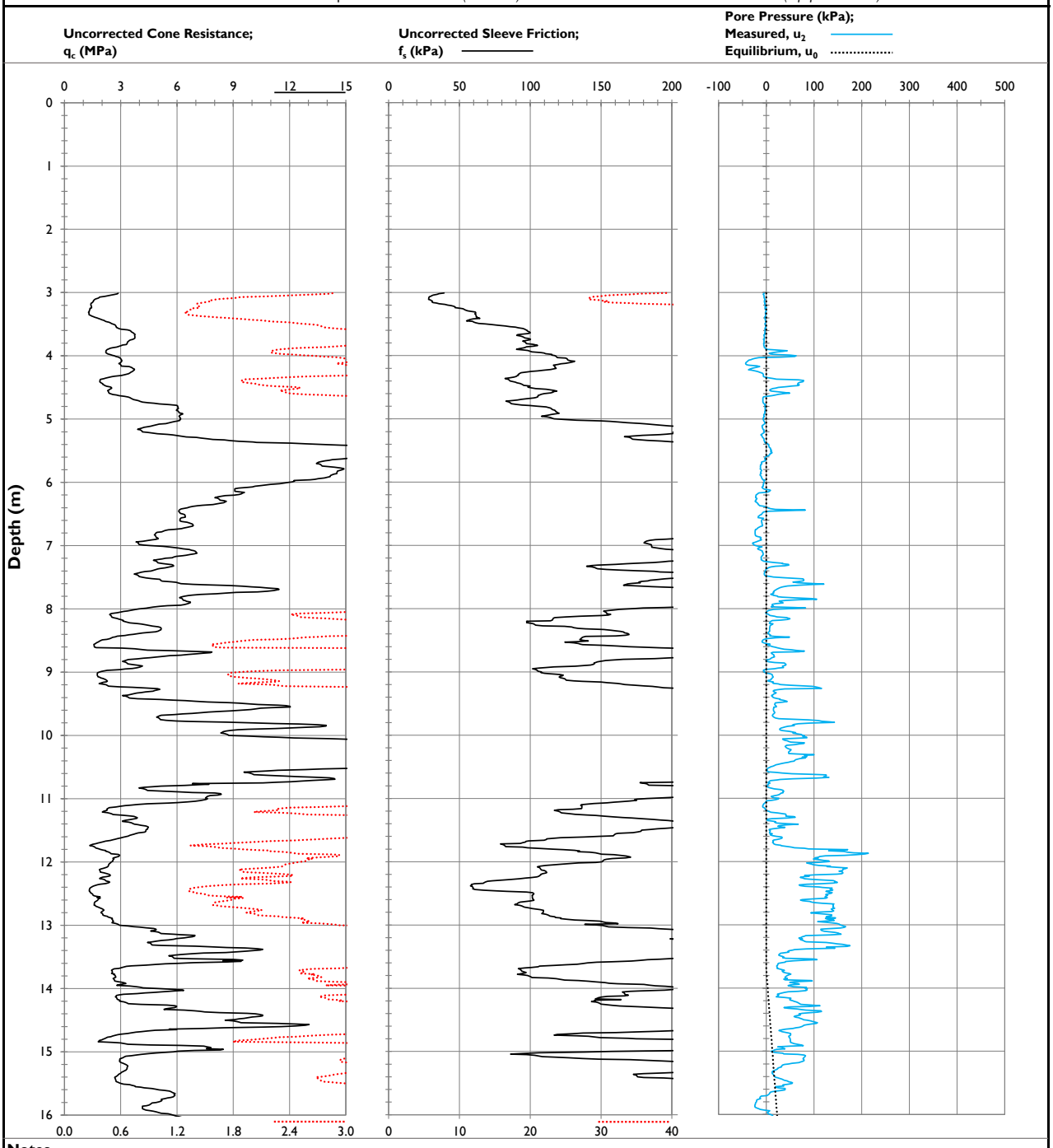
50 x 100 vane	75 x 150 vane	100 x 200 vane
1.796	0.595	0.258
108	36	15



Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT01**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**18/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631159.4 (AGD66*	R.L. Surface:	*216.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522529 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*13.7m (Estimated)*	Termination:	*28.27m (Equipment at risk)*		

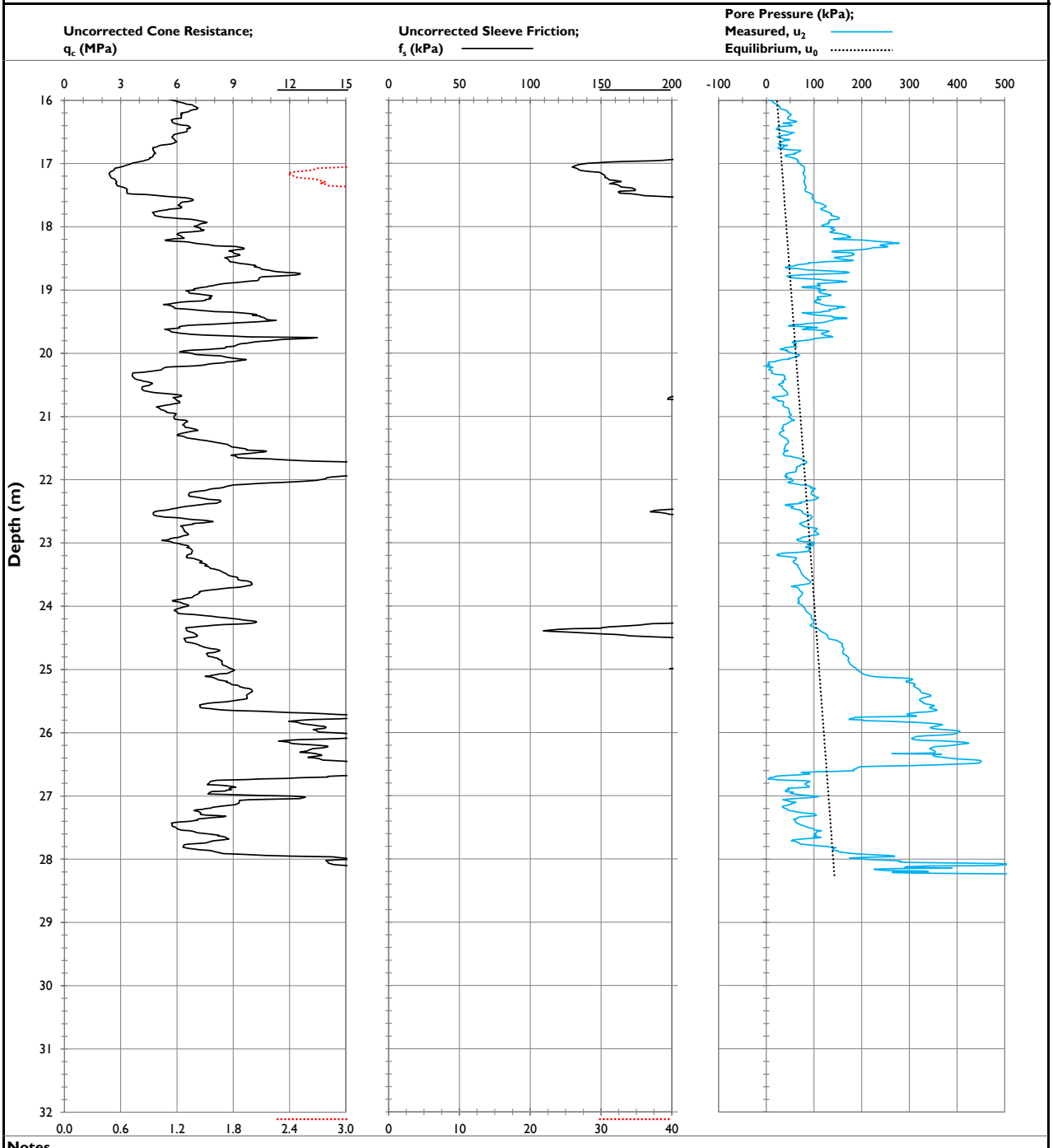


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT01**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**18/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631159.4 (AGD66*	R.L. Surface:	*216.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522529 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*13.7m (Estimated)*	Termination:	*28.27m (Equipment at risk)*		

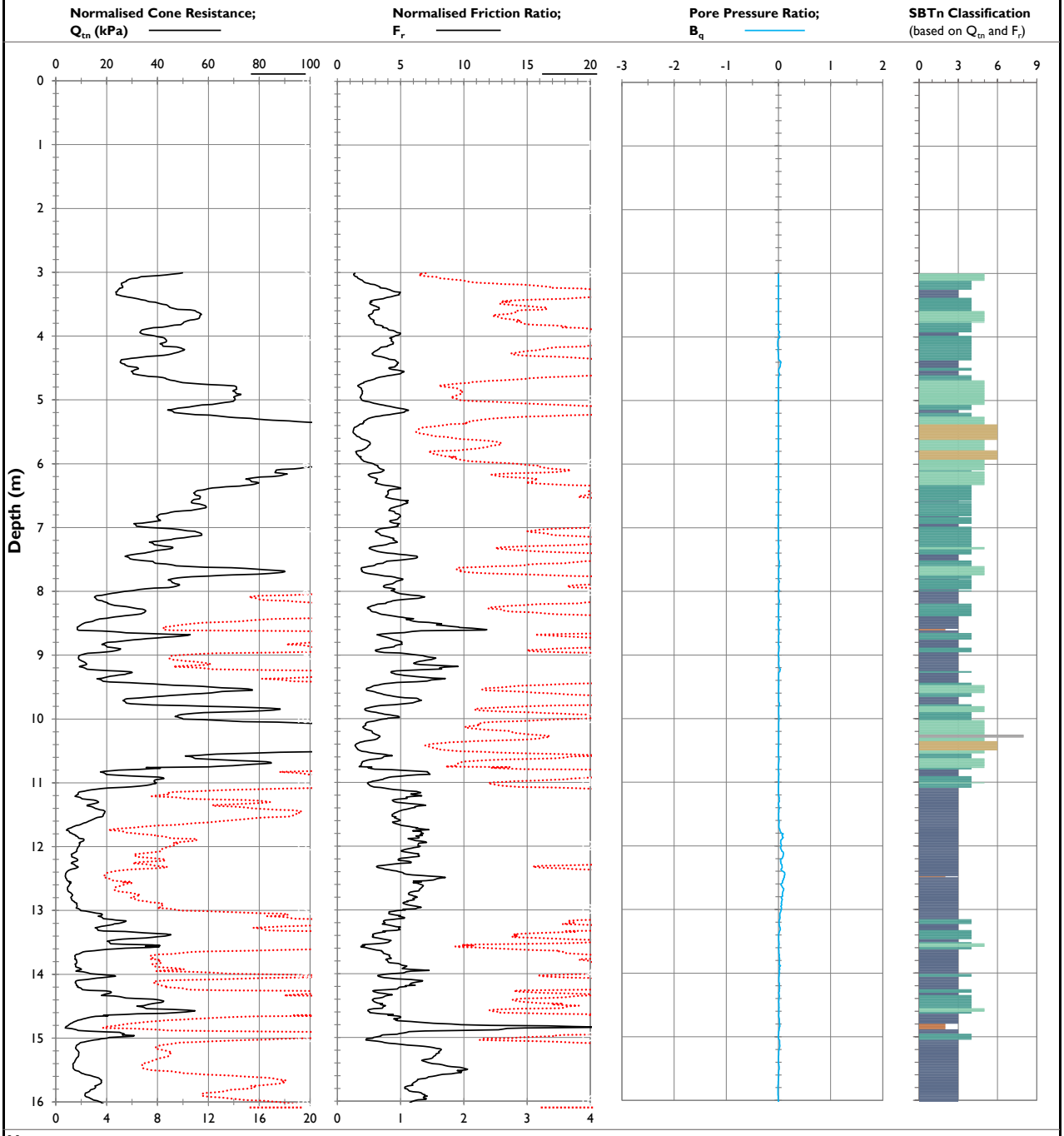


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT01**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**18/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631159.4 (AGD66*	R.L. Surface:	*216.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522529 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*13.7m (Estimated)*	Termination:	*28.27m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

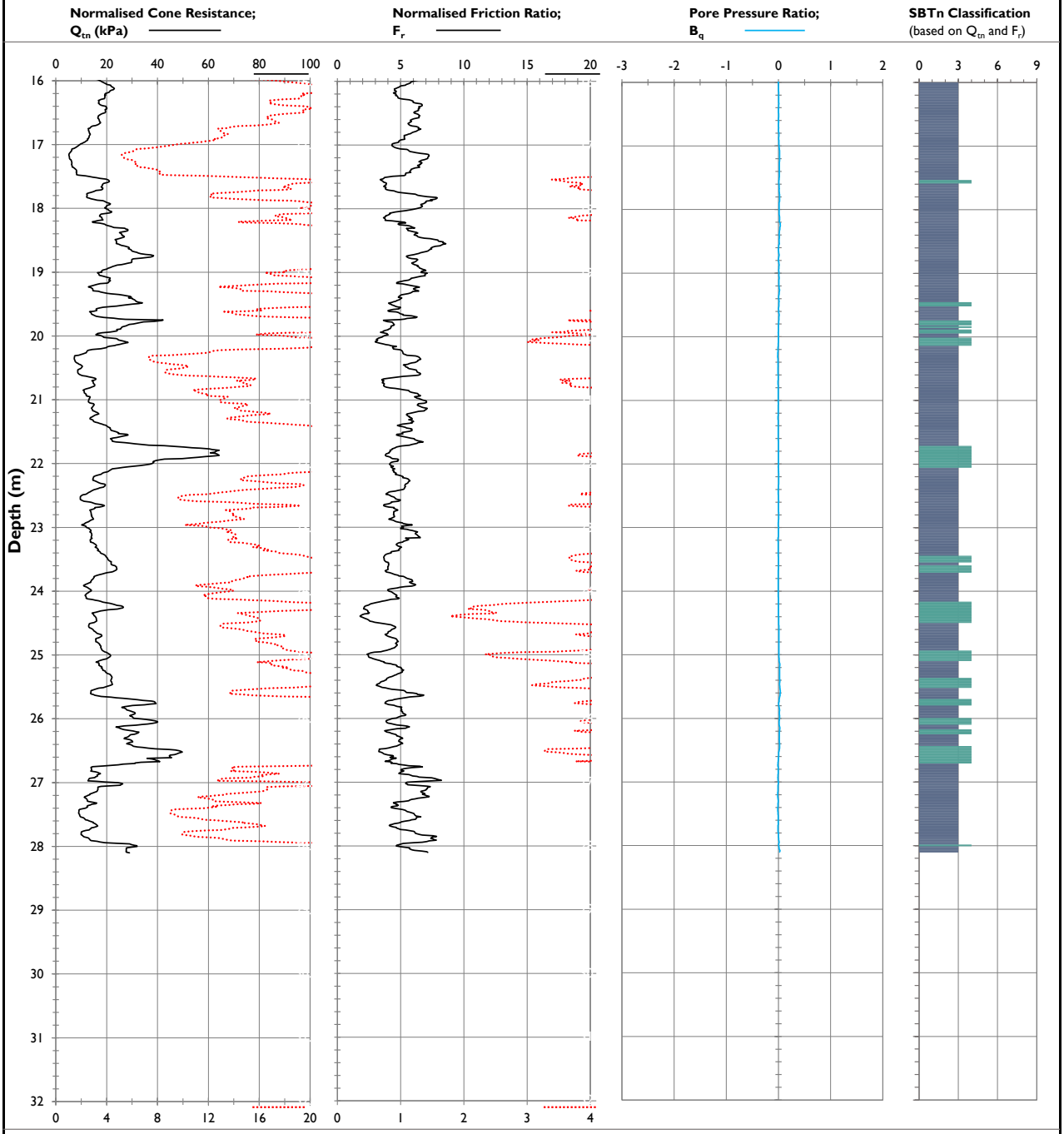
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT01**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**18/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631159.4 (AGD66*	R.L. Surface:	*216.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522529 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*13.7m (Estimated)*	Termination:	*28.27m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

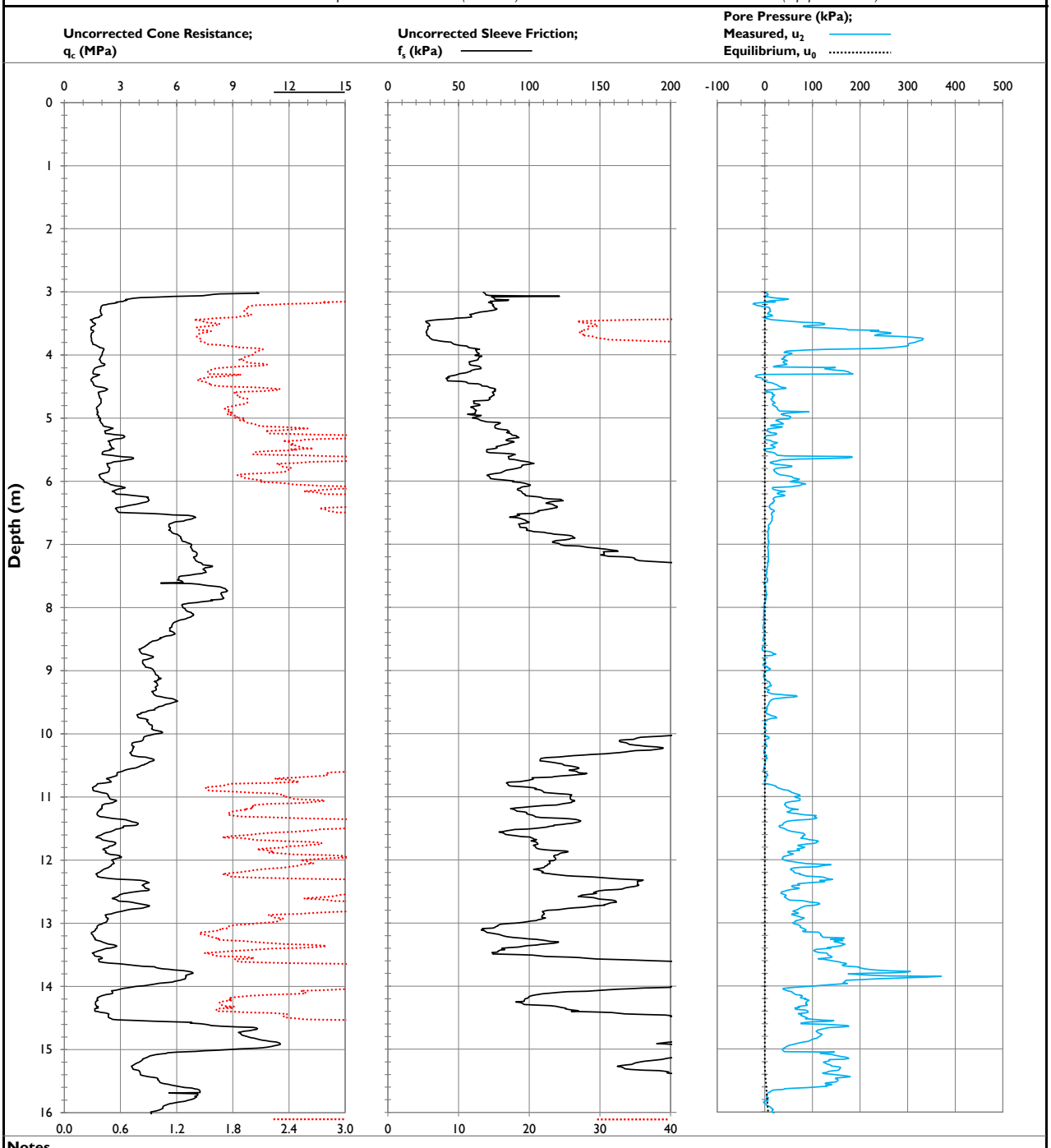
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT02**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**26/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631303.9 (AGD66*	R.L. Surface:	*217.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522197.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*15.3m (Estimated)*	Termination:	*27.43m (Equipment at risk)*		

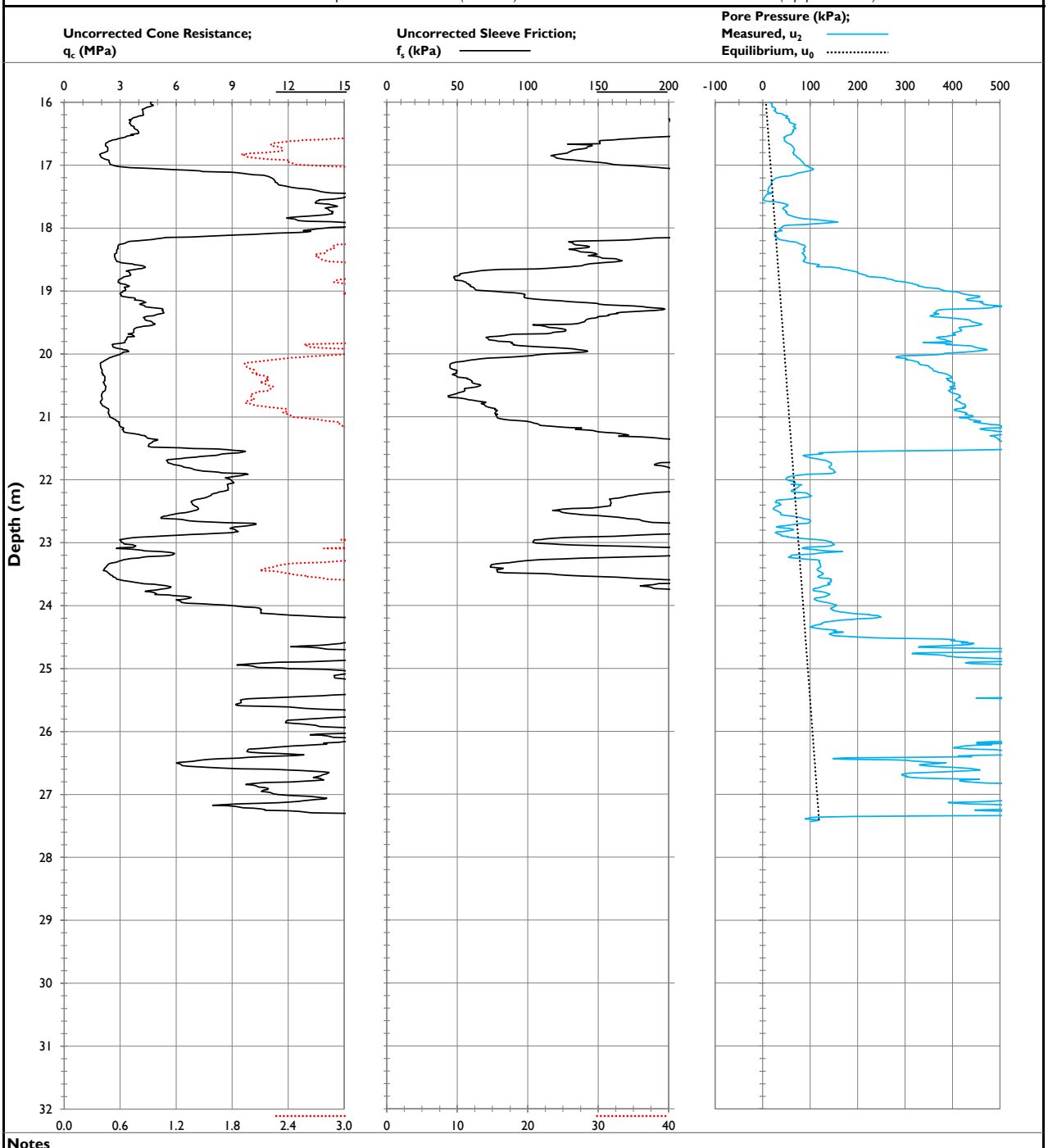


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT02**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**26/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631303.9 (AGD66*	R.L. Surface:	*217.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522197.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*15.3m (Estimated)*	Termination:	*27.43m (Equipment at risk)*		

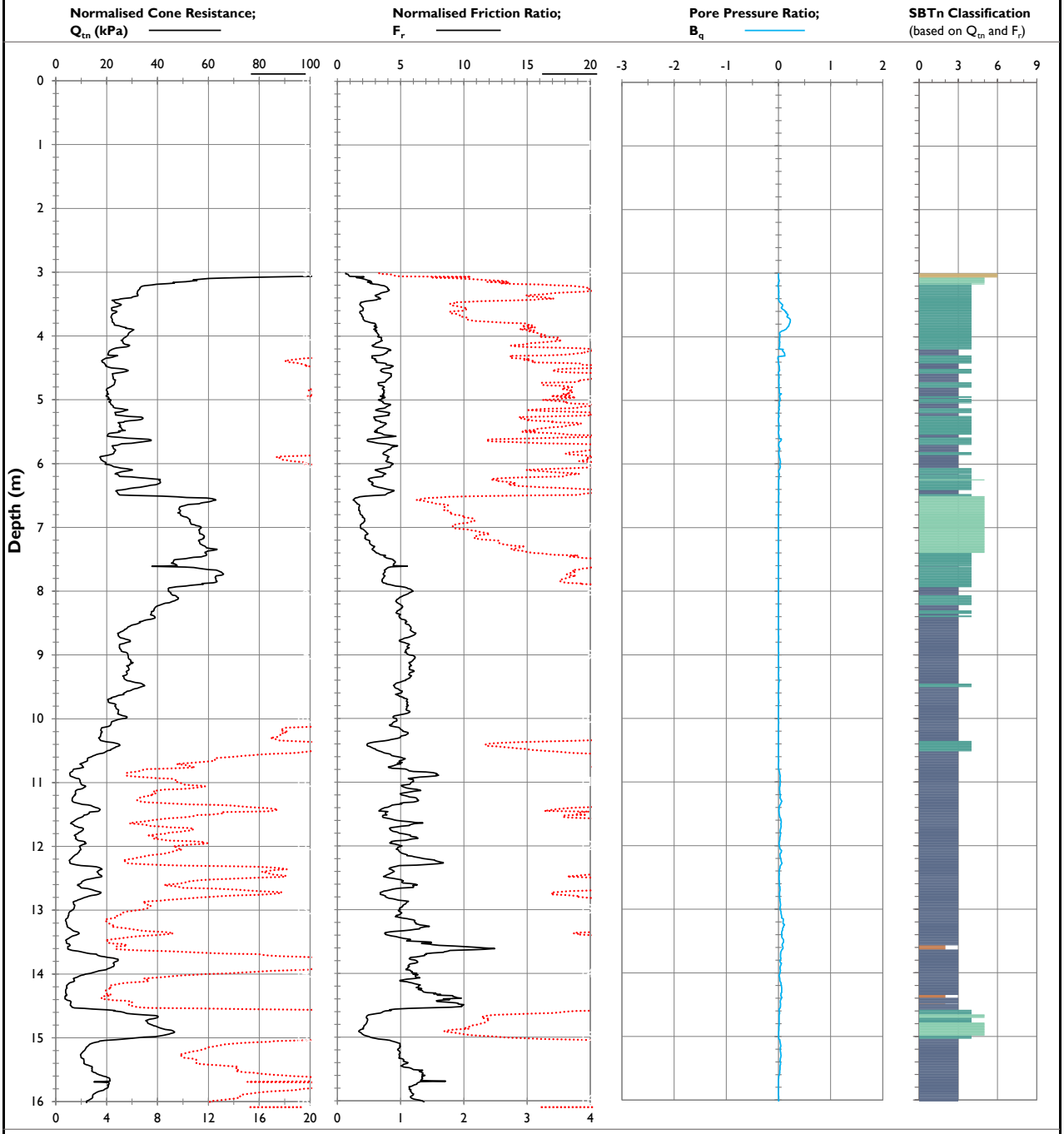


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT02**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**26/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631303.9 (AGD66*	R.L. Surface:	*217.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522197.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*15.3m (Estimated)*	Termination:	*27.43m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

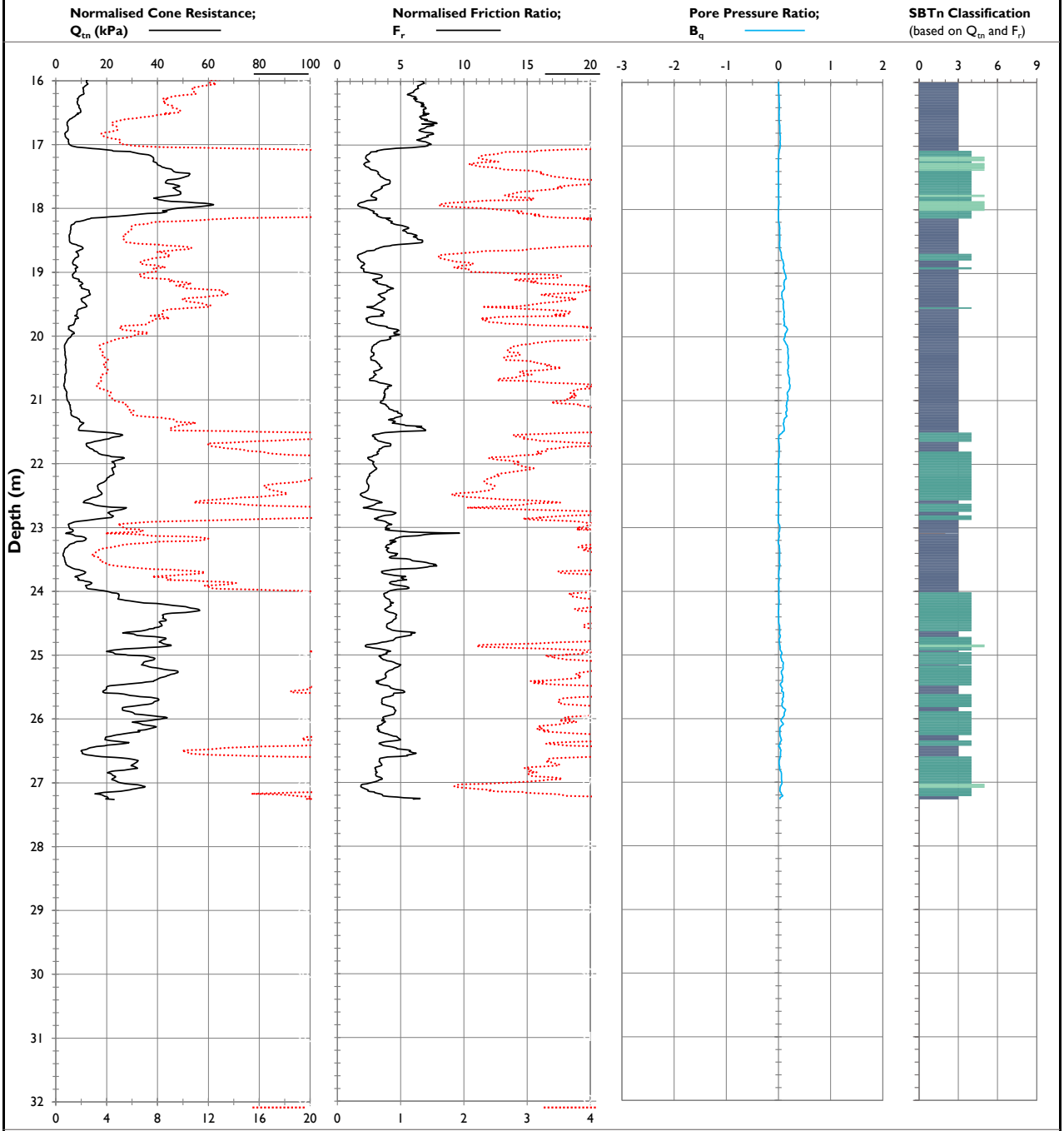
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT02**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**26/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631303.9 (AGD66*	R.L. Surface:	*217.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522197.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*15.3m (Estimated)*	Termination:	*27.43m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

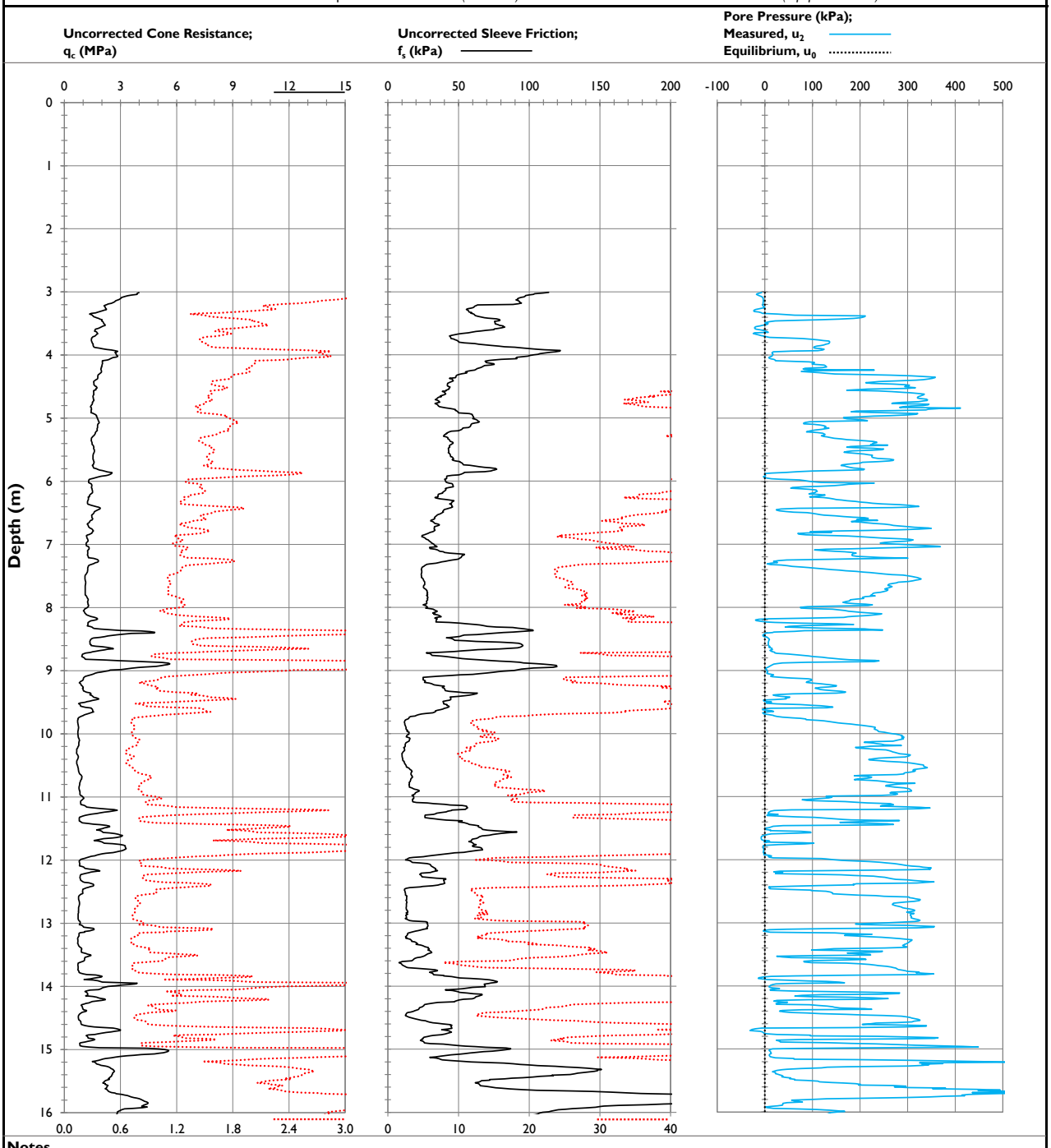
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT03**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**26/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631446.6 (AGD66*	R.L. Surface:	*218.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521825.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*26.37m (Equipment at risk)*		

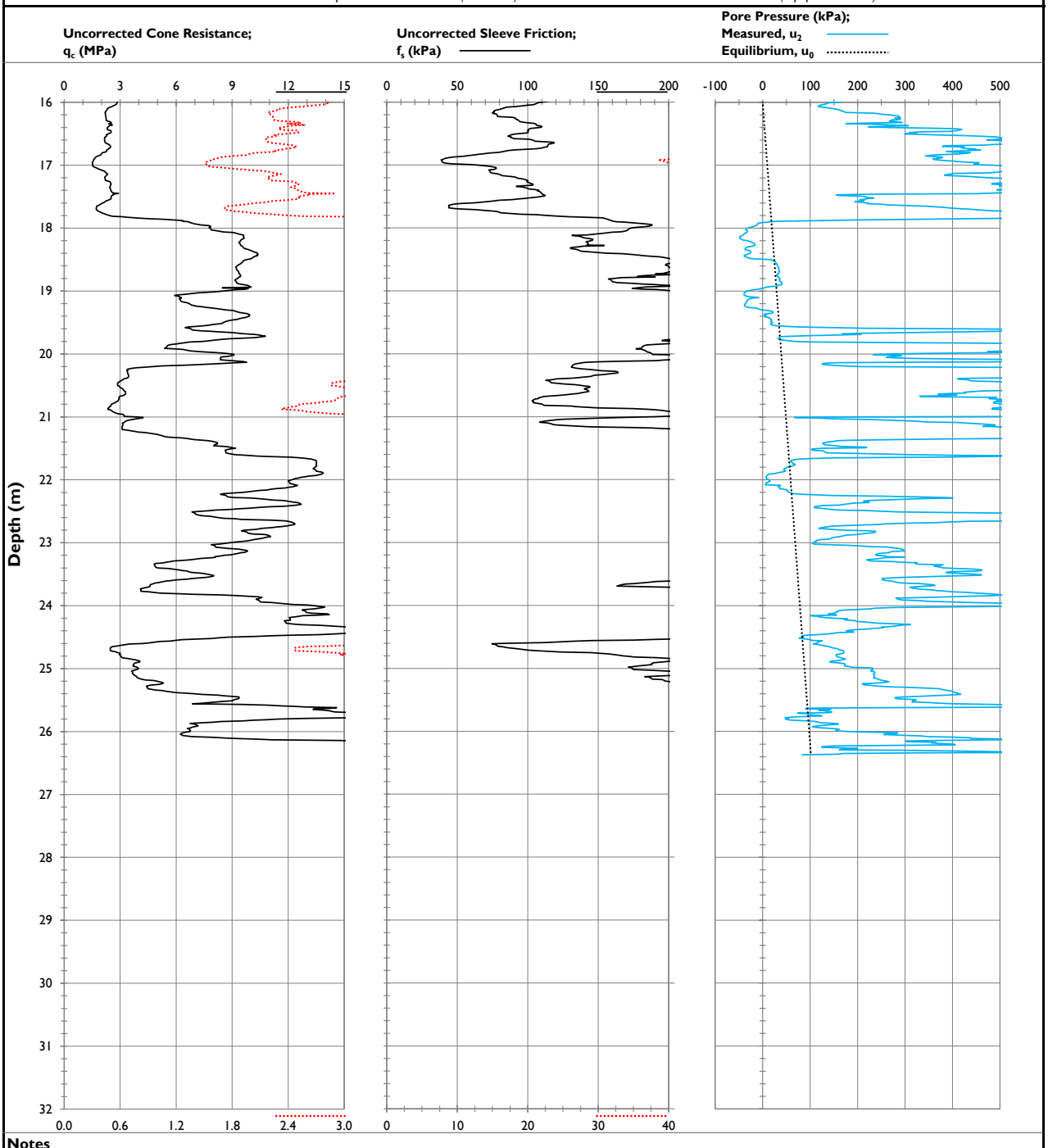


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT03**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**26/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631446.6 (AGD66*	R.L. Surface:	*218.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521825.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*26.37m (Equipment at risk)*		

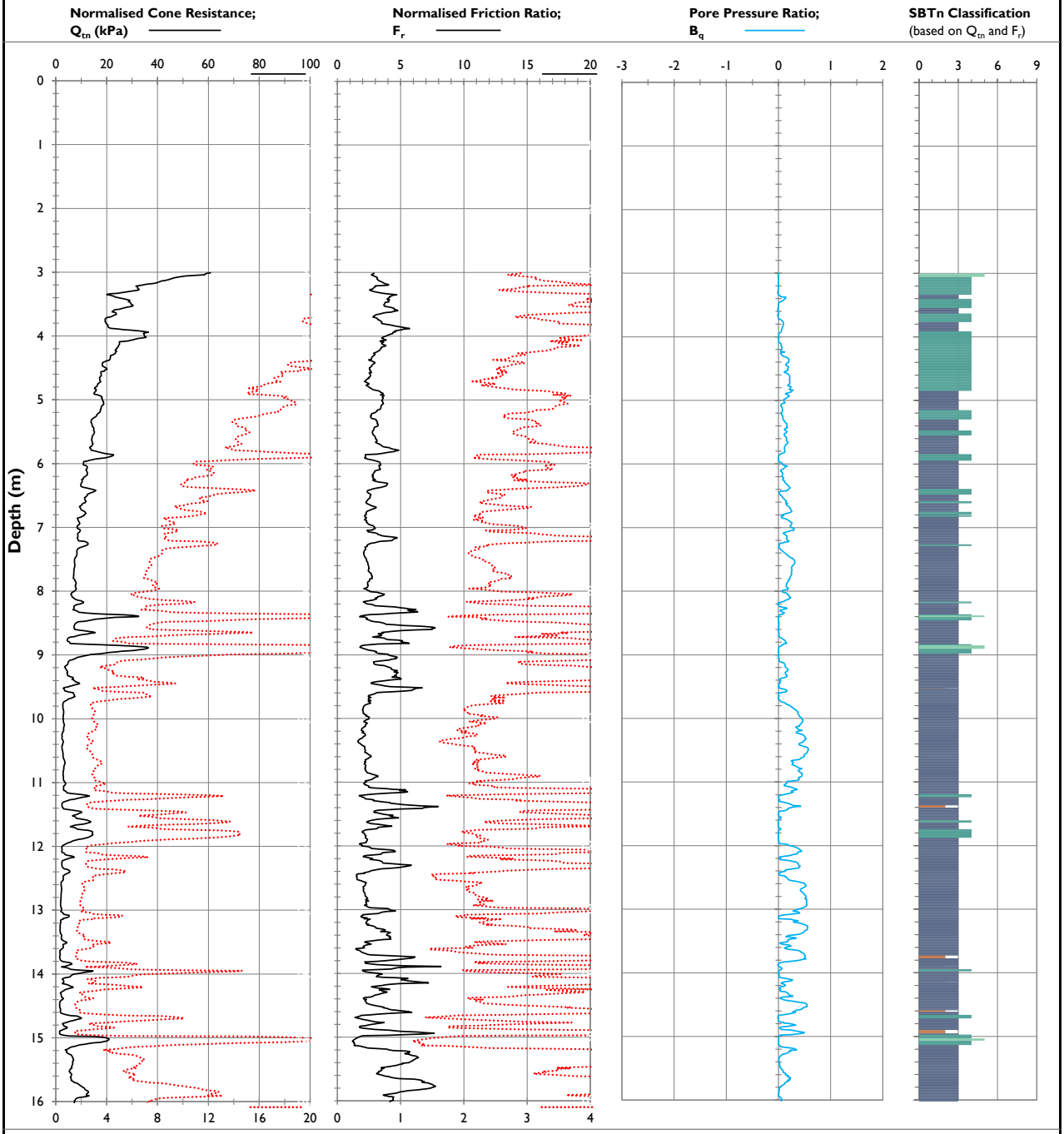


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT03**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**26/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631446.6 (AGD66*	R.L. Surface:	*218.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521825.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*26.37m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

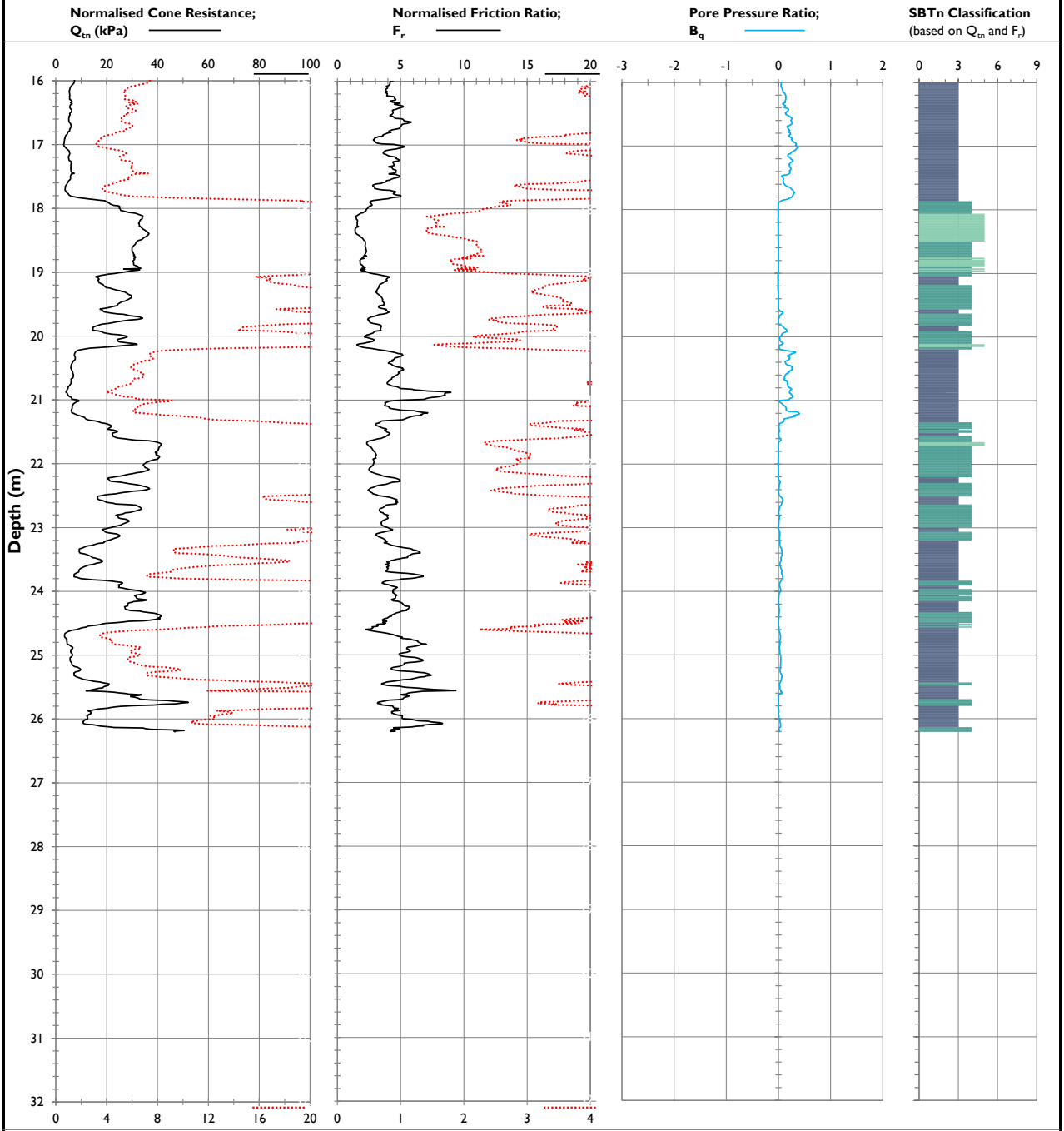
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT03**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**26/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631446.6 (AGD66*	R.L. Surface:	*218.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521825.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*26.37m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

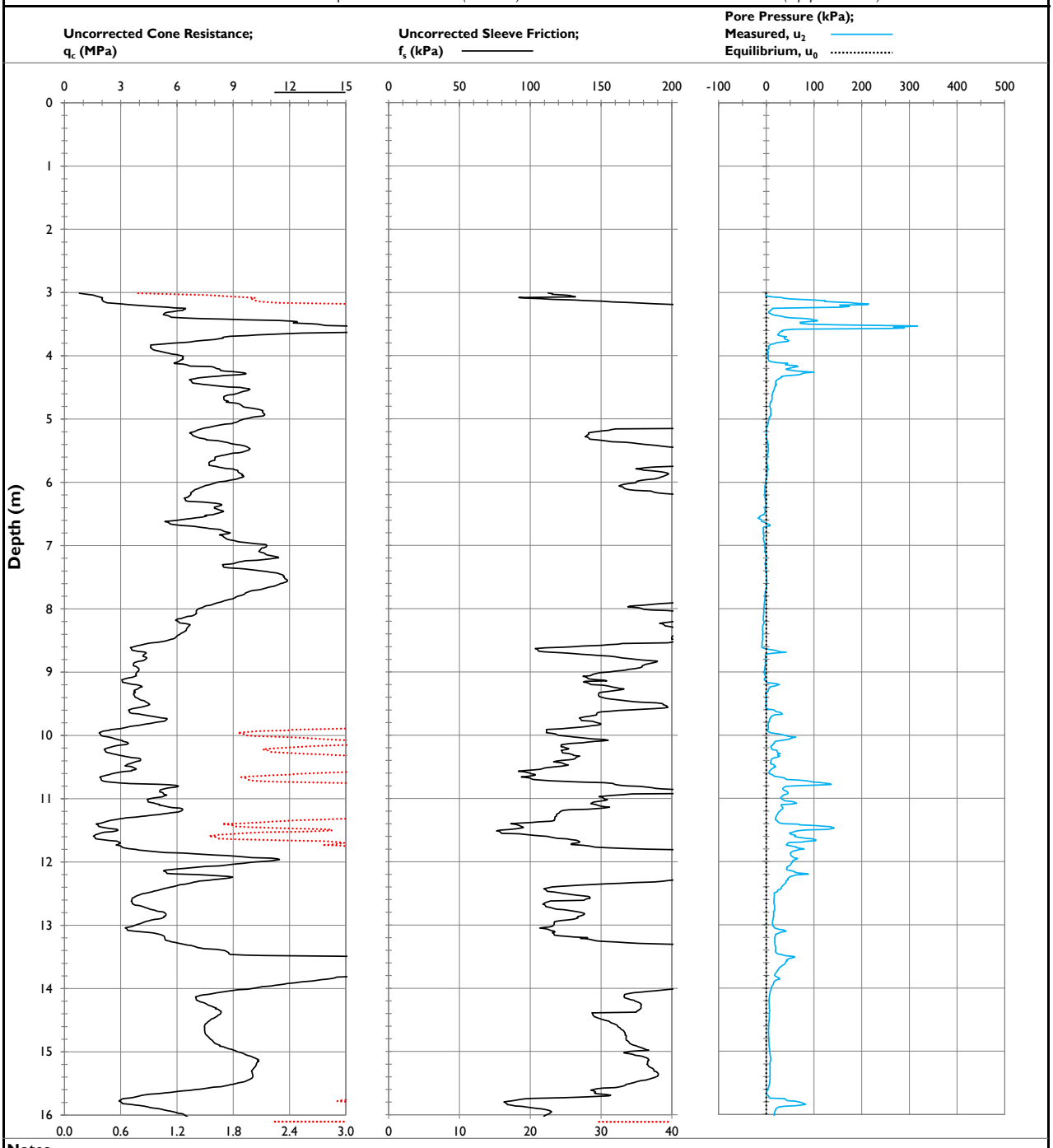
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT04**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631334.4 (AGD66*	R.L. Surface:	*219.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521669 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*18.0m (Estimated)*	Termination:	*26.37m (Equipment at risk)*		



Notes

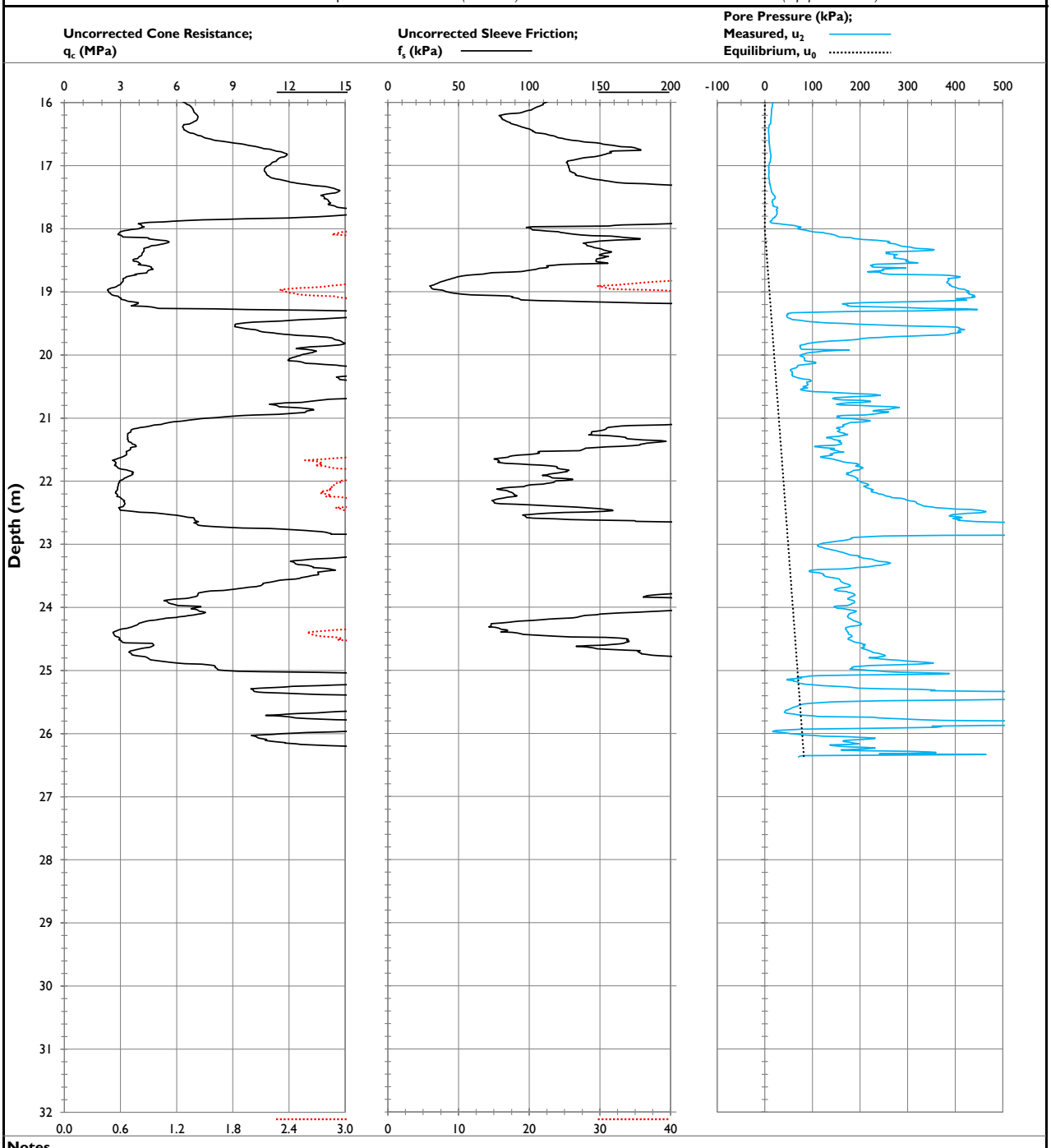
Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT04**
Sheet:	2 of 4
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631334.4 (AGD66*	R.L. Surface:	*219.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521669 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*18.0m (Estimated)*	Termination:	*26.37m (Equipment at risk)*		

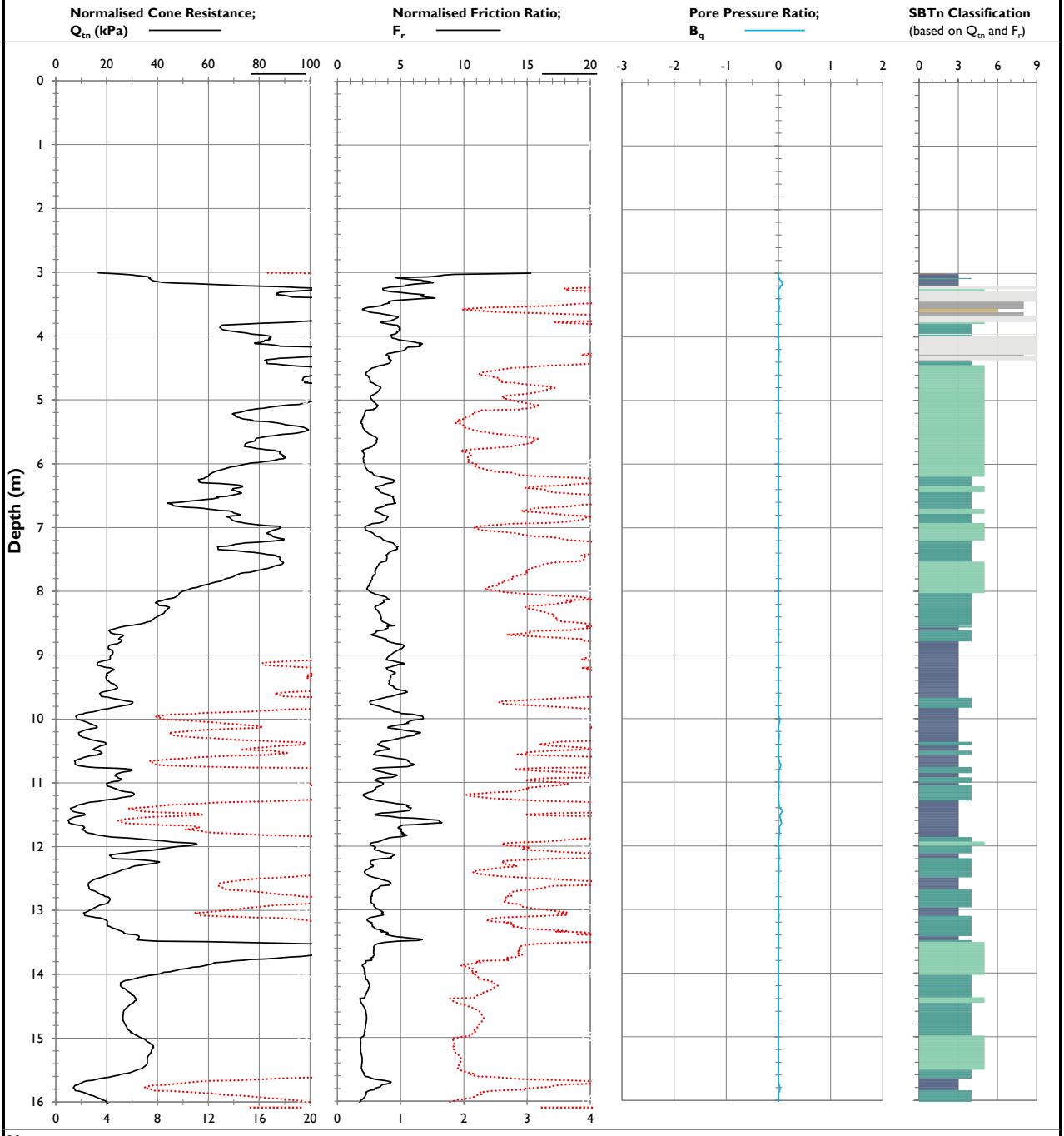


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT04**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631334.4 (AGD66*	R.L. Surface:	*219.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521669 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*18.0m (Estimated)*	Termination:	*26.37m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

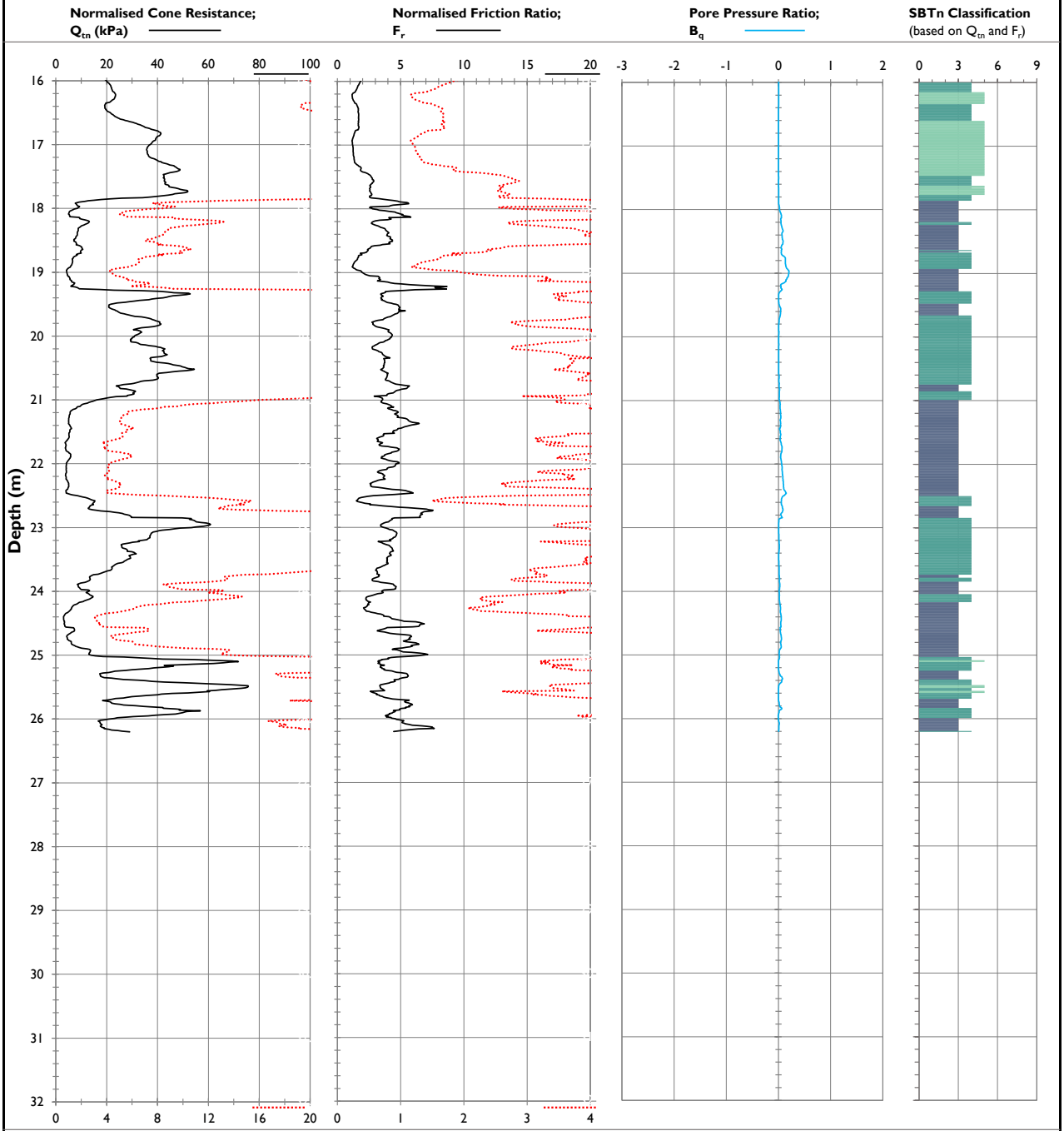
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT04**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631334.4 (AGD66*	R.L. Surface:	*219.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521669 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*18.0m (Estimated)*	Termination:	*26.37m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

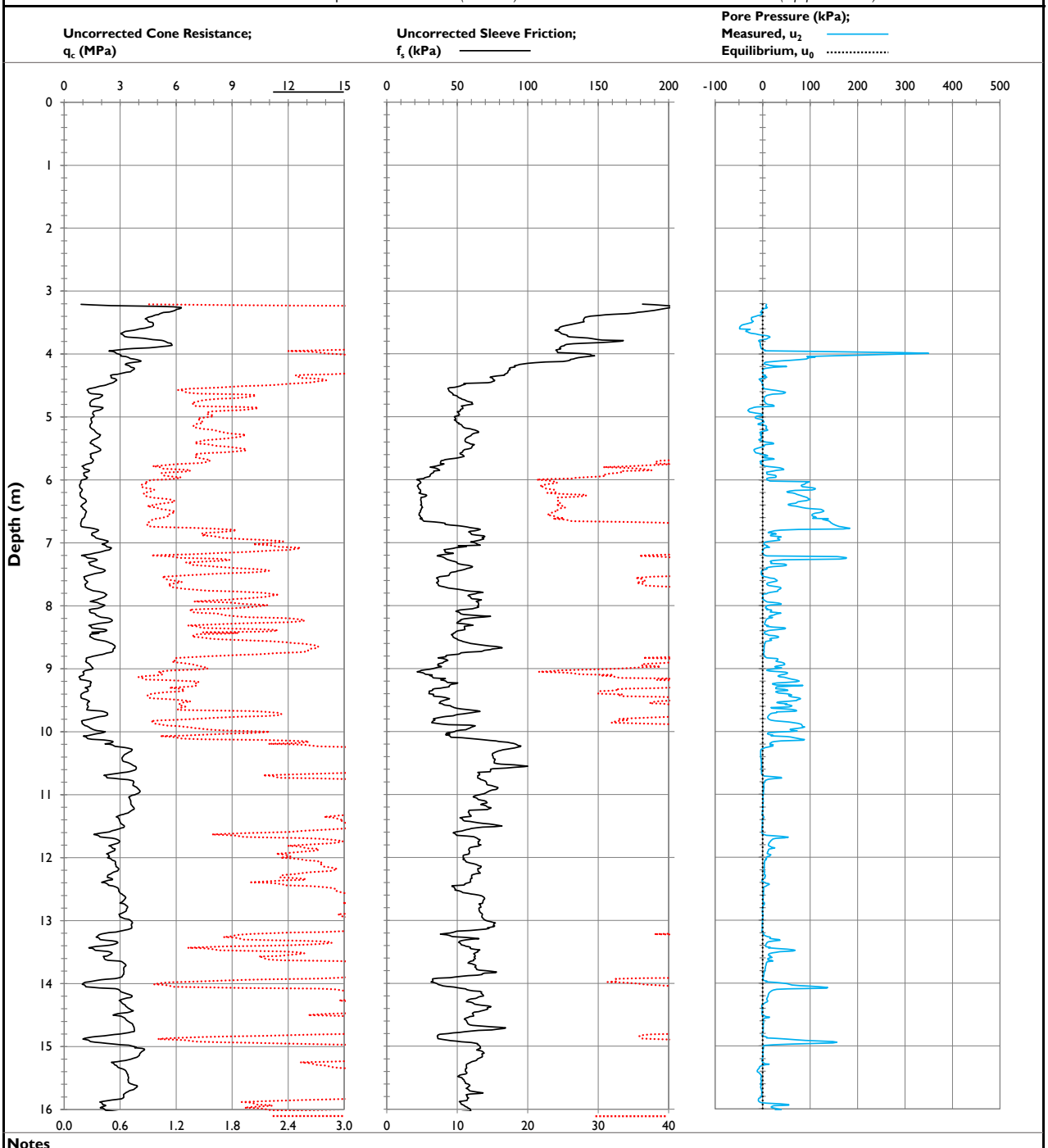
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT05**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631194.2 (AGD66*	R.L. Surface:	*218.9m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521751.3 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*28.32m (Equipment at risk)*		

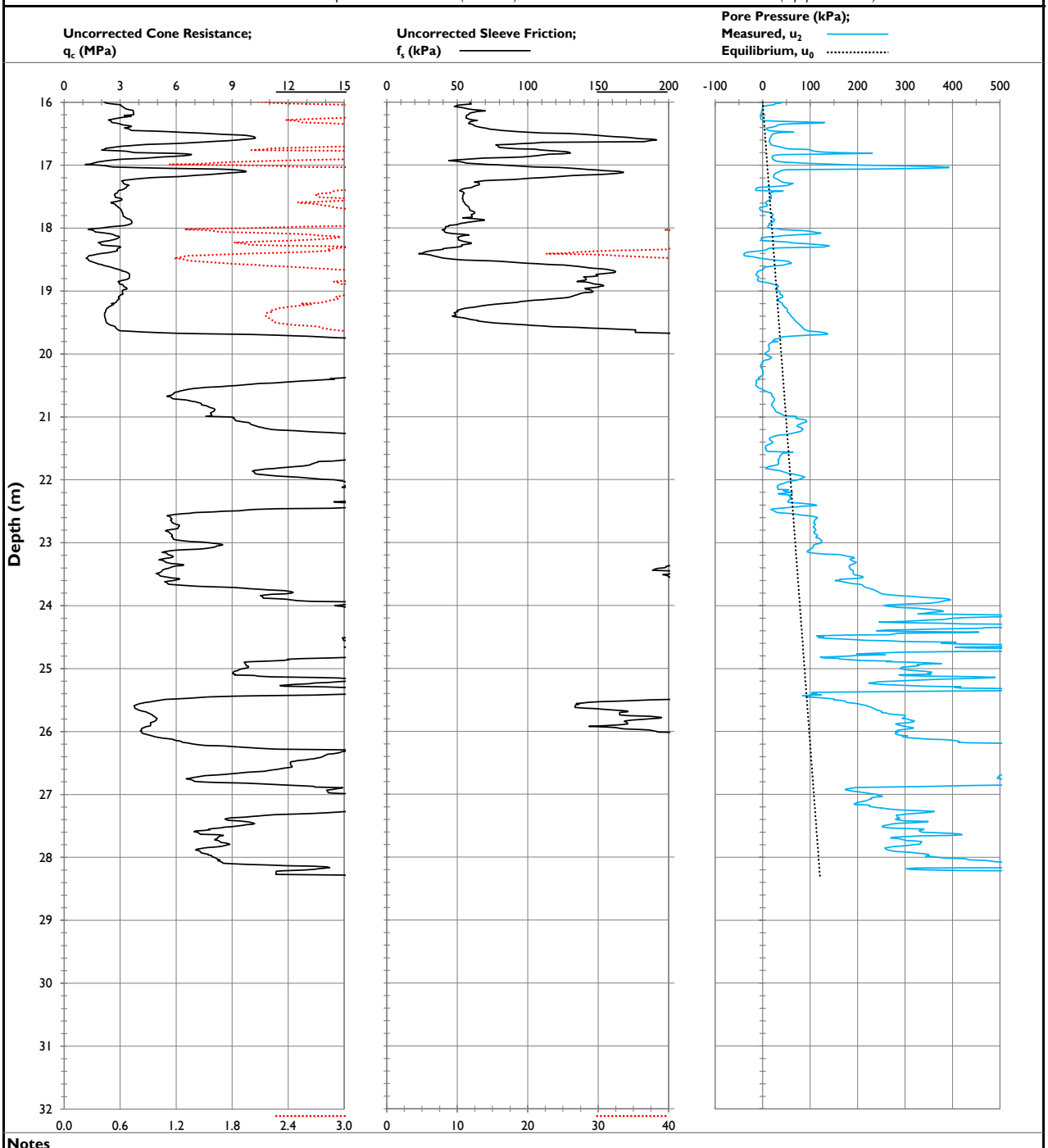


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT05**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631194.2 (AGD66*	R.L. Surface:	*218.9m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521751.3 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*28.32m (Equipment at risk)*		

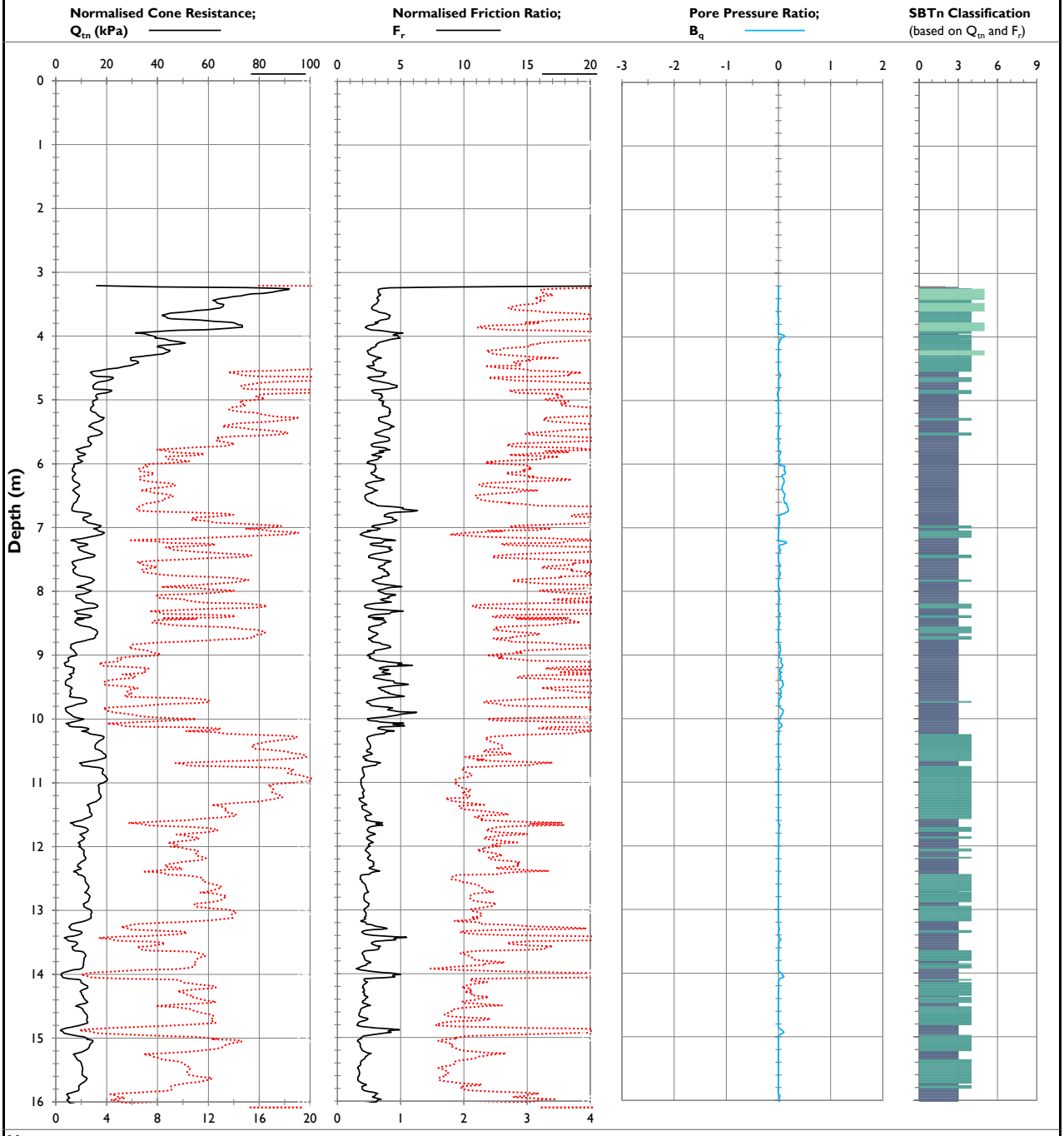


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT05**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631194.2 (AGD66*	R.L. Surface:	*218.9m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521751.3 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*28.32m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

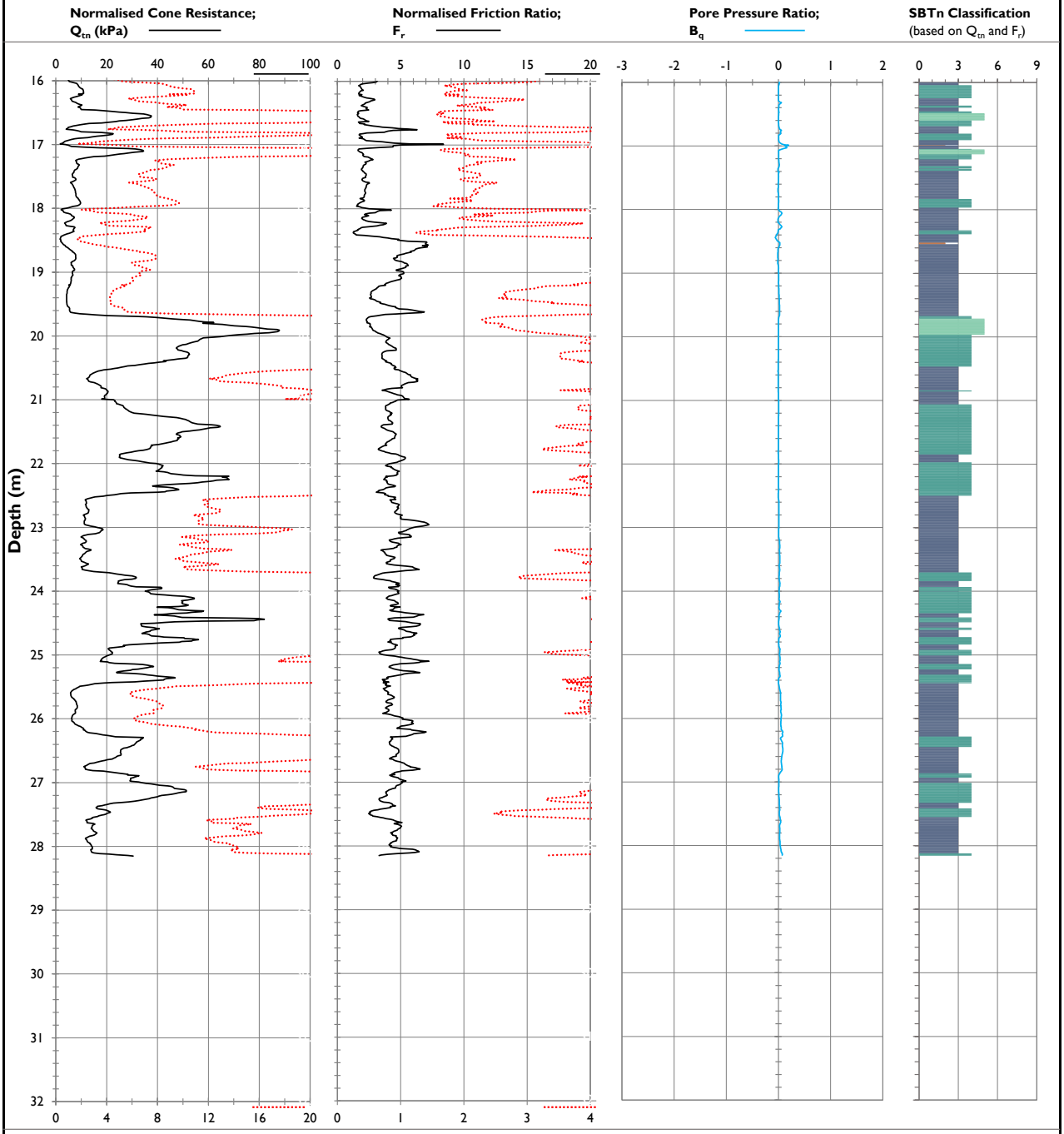
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT05**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631194.2 (AGD66*	R.L. Surface:	*218.9m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521751.3 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*28.32m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

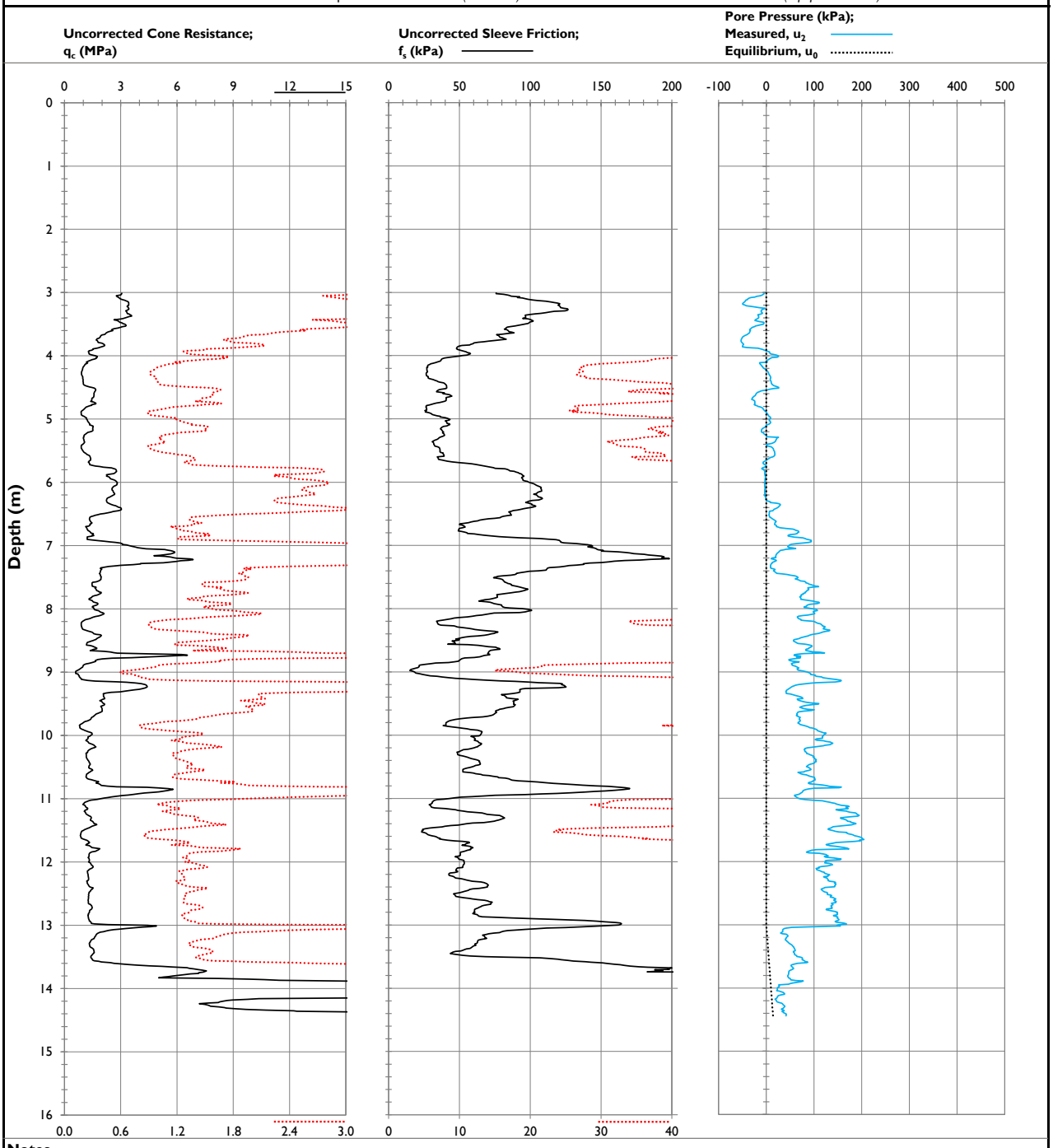
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT06**		
Sheet:	1 of 2		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*630992.6 (AGD66*	R.L. Surface:	*216.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522446.9 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*13.0m (Estimated)*	Termination:	*14.44m (Equipment at risk)*		

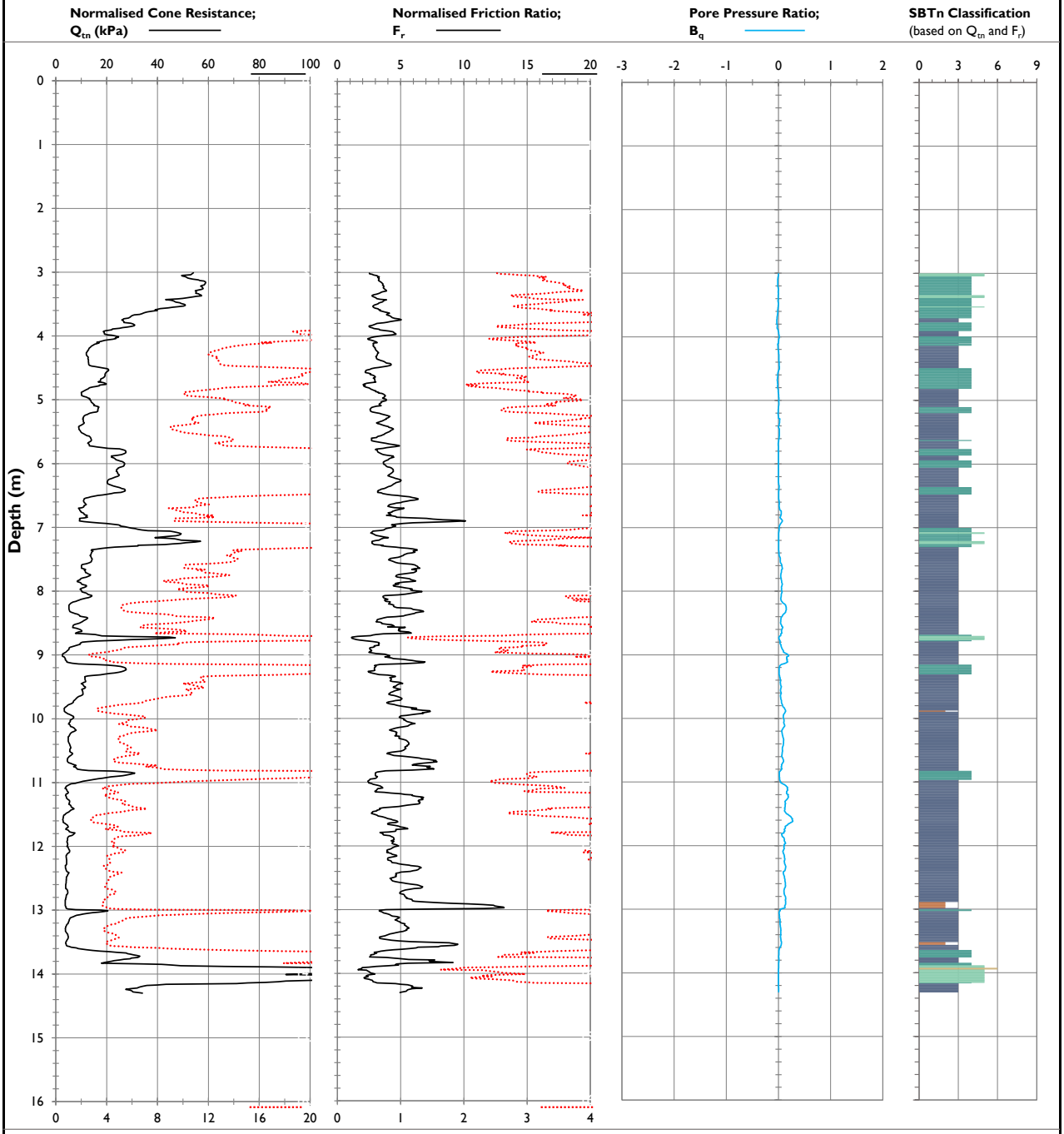


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT06**		
Sheet:	2 of 2		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*630992.6 (AGD66*	R.L. Surface:	*216.7m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522446.9 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*13.0m (Estimated)*	Termination:	*14.44m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

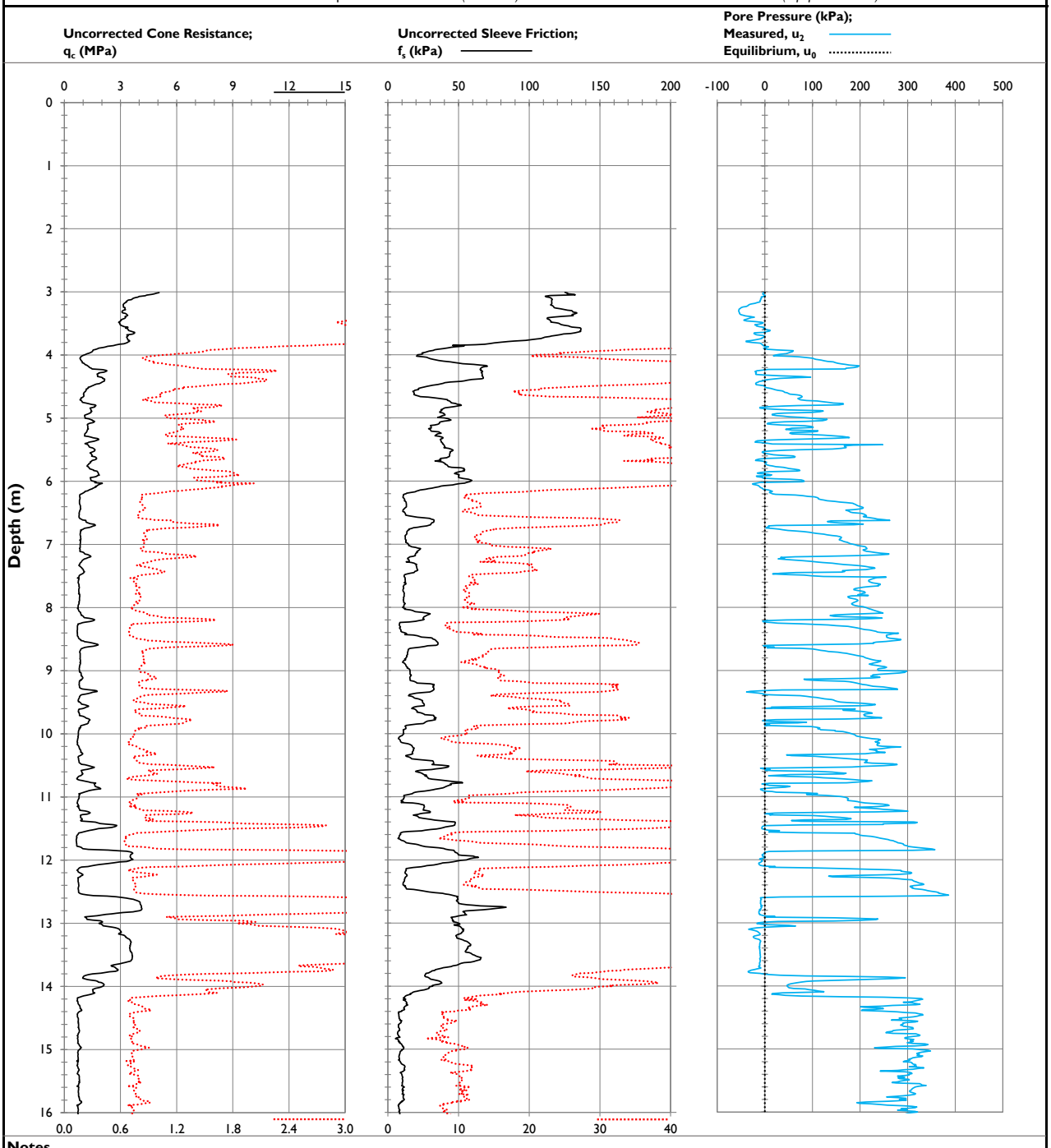
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT07**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**26/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631215.4 (AGD66*	R.L. Surface:	*217.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522101.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*23.18m (Equipment at risk)*		

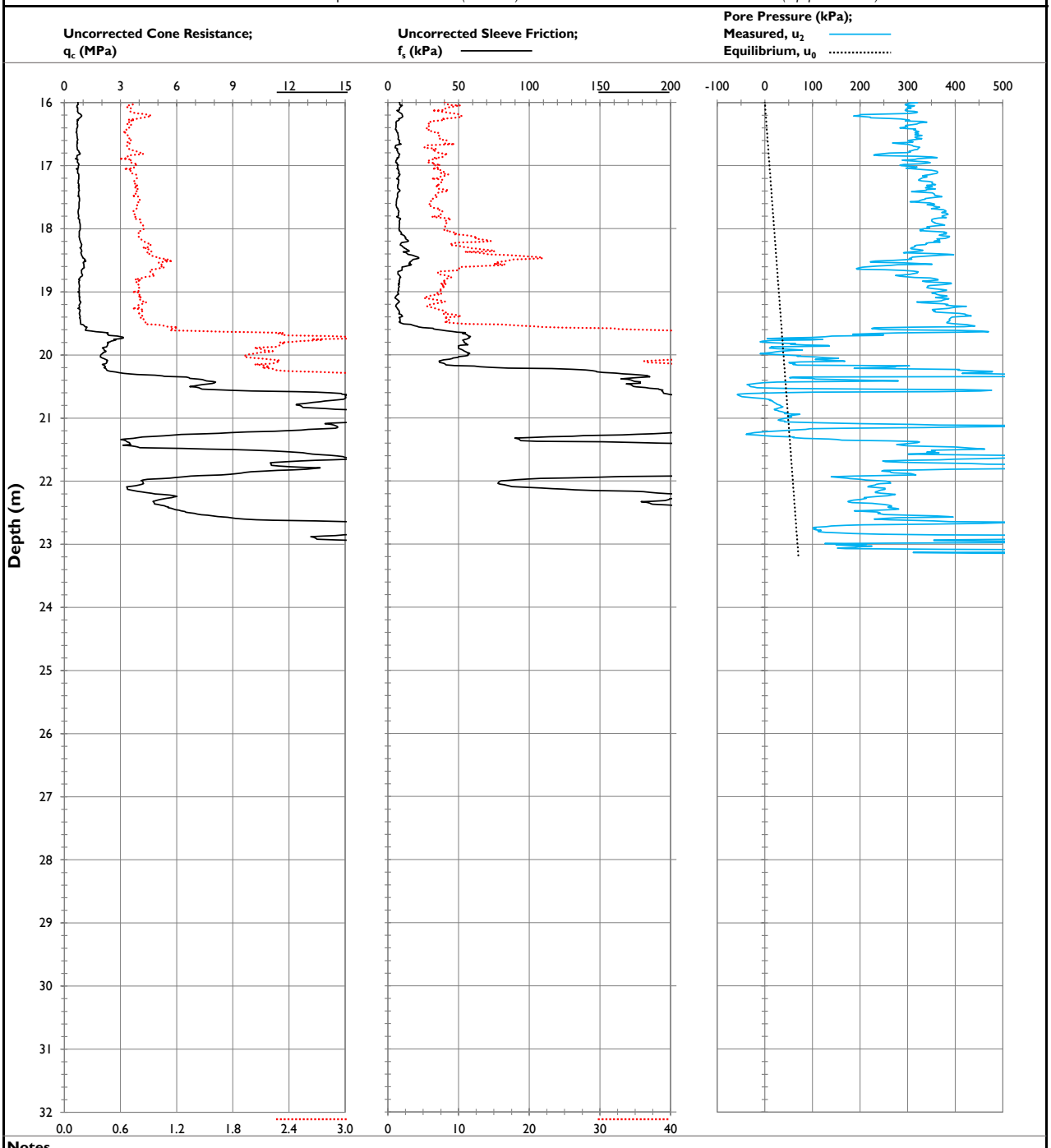


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT07**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**26/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631215.4 (AGD66*	R.L. Surface:	*217.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522101.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*23.18m (Equipment at risk)*		

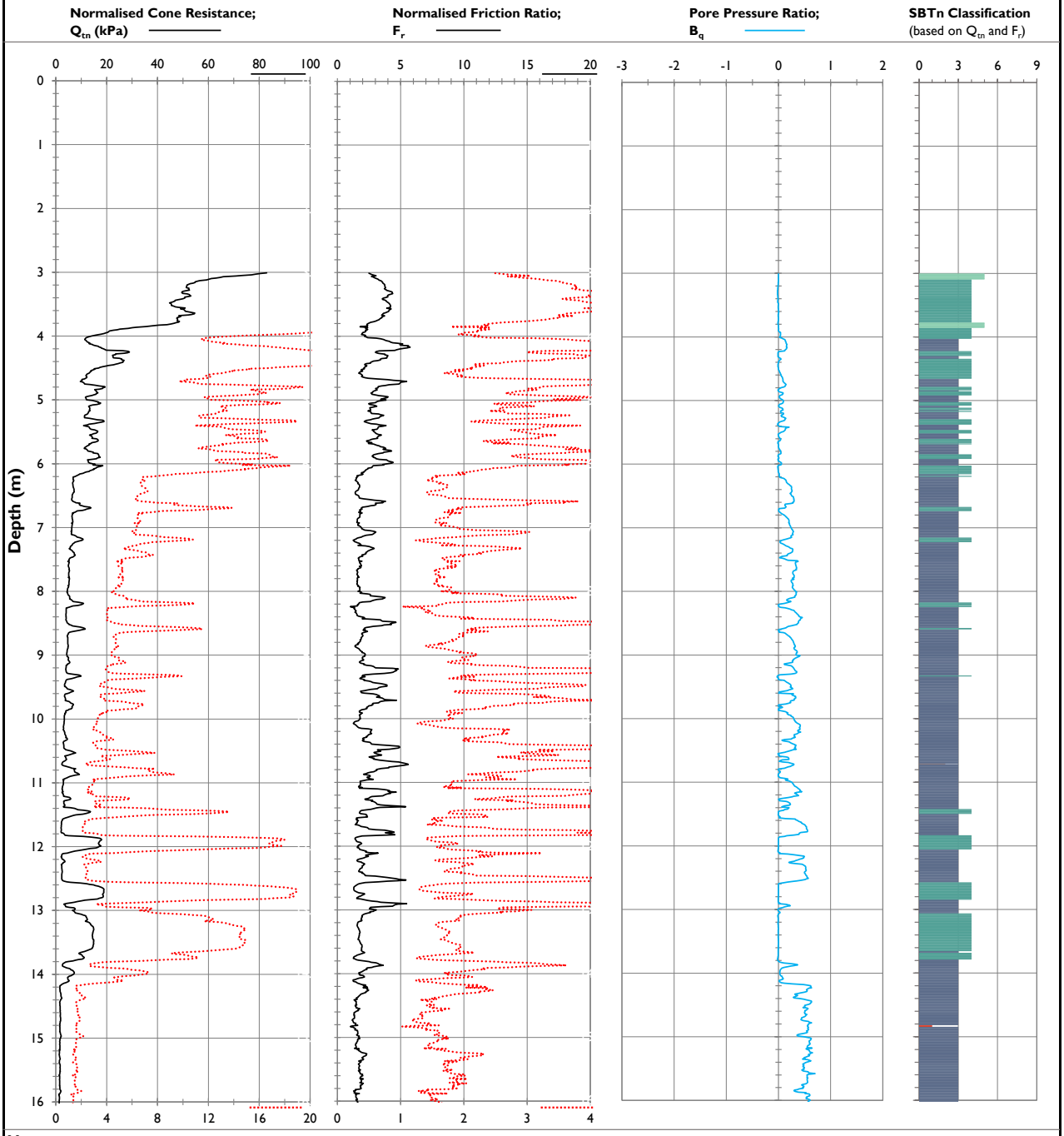


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT07**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**26/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631215.4 (AGD66*	R.L. Surface:	*217.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522101.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*23.18m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

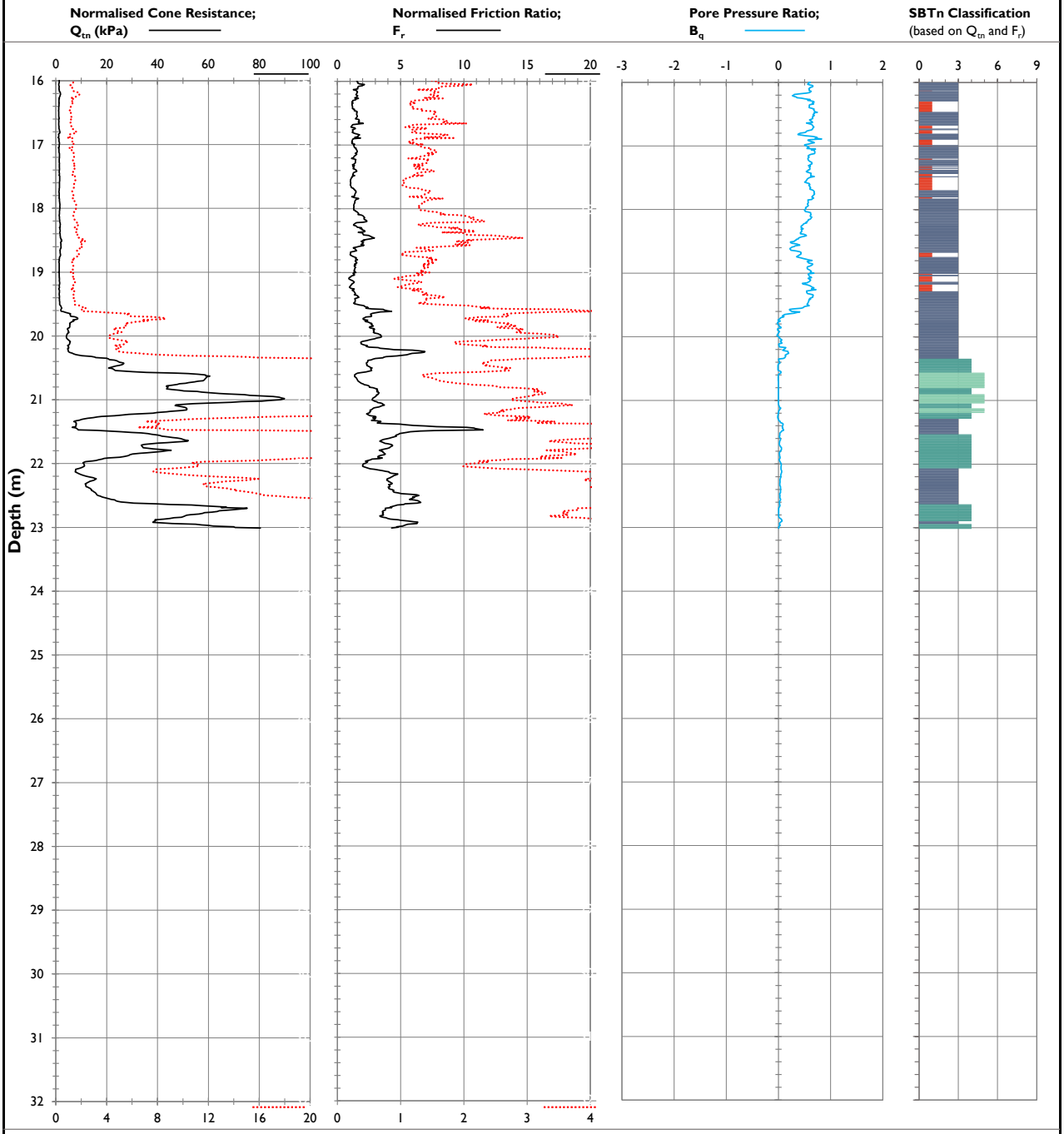
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT07**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**26/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631215.4 (AGD66*	R.L. Surface:	*217.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522101.2 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*23.18m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

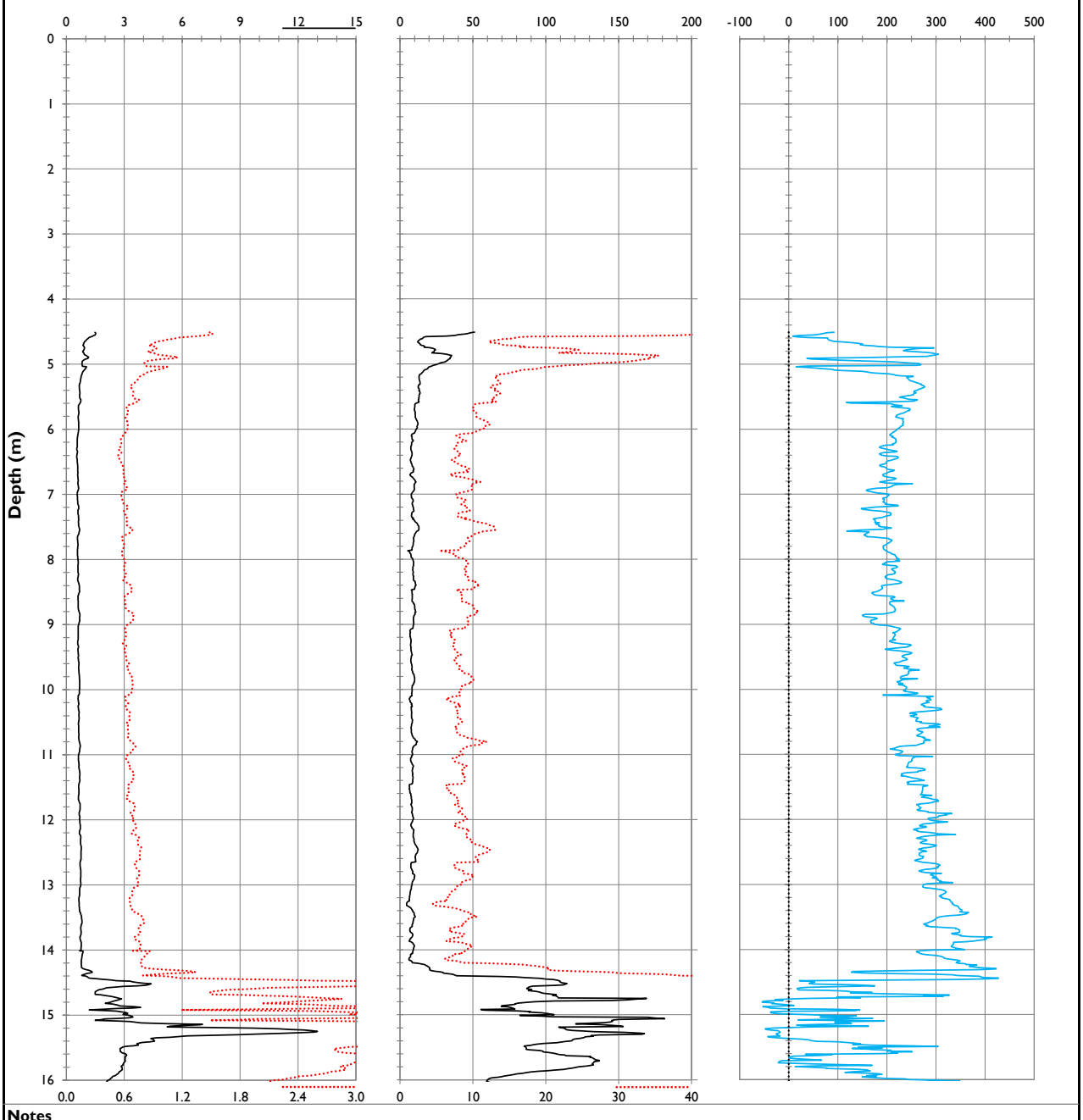
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT08**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**17/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631070 (AGD66 /*	R.L. Surface:	*216.9m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*4.5m (Auger)*	Northing:	*7522538.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*16.0m (Estimated)*	Termination:	*18.28m (Equipment at risk)*		

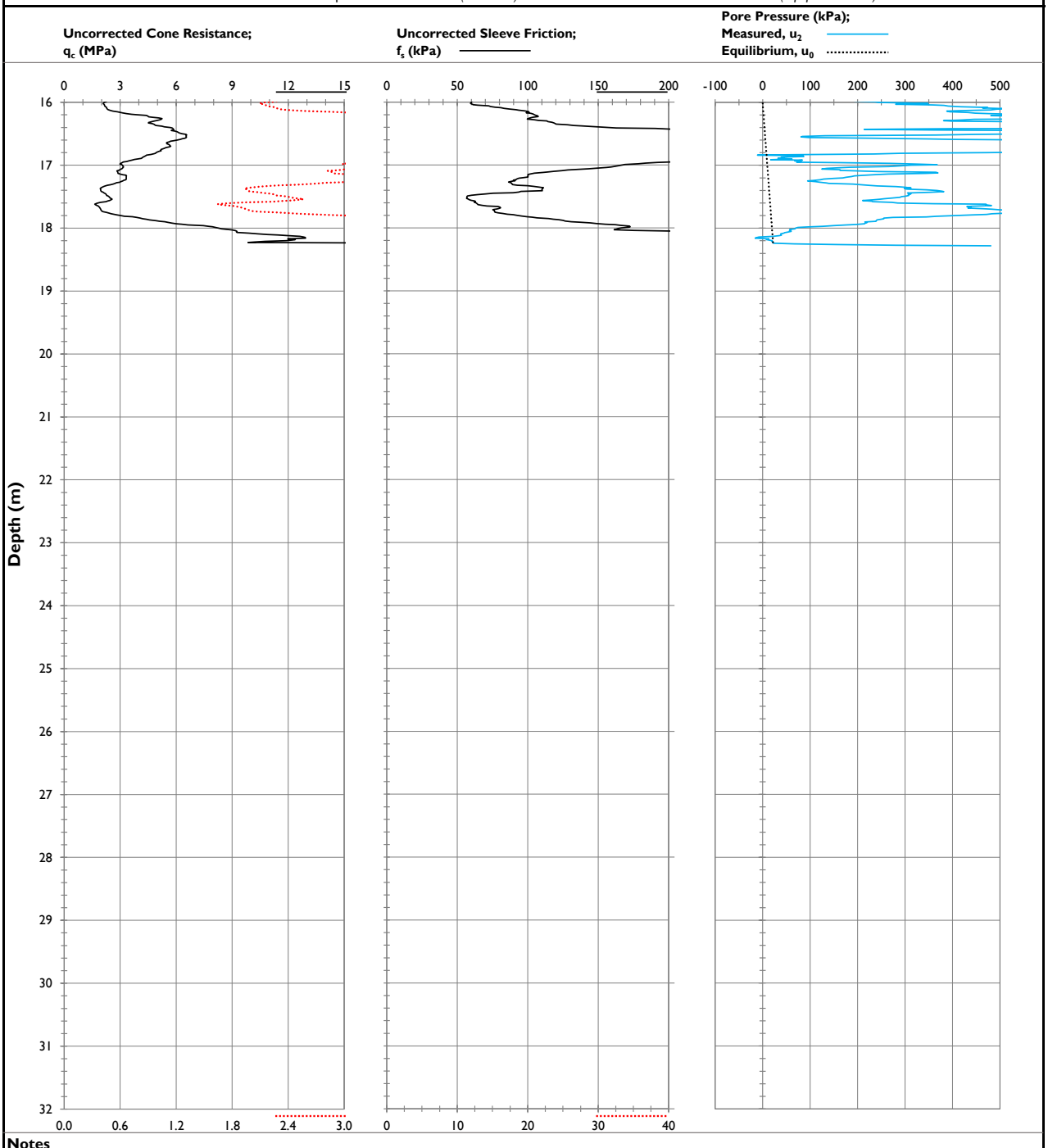


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT08**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**17/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631070 (AGD66 /*	R.L. Surface:	*216.9m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*4.5m (Auger)*	Northing:	*7522538.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*16.0m (Estimated)*	Termination:	*18.28m (Equipment at risk)*		

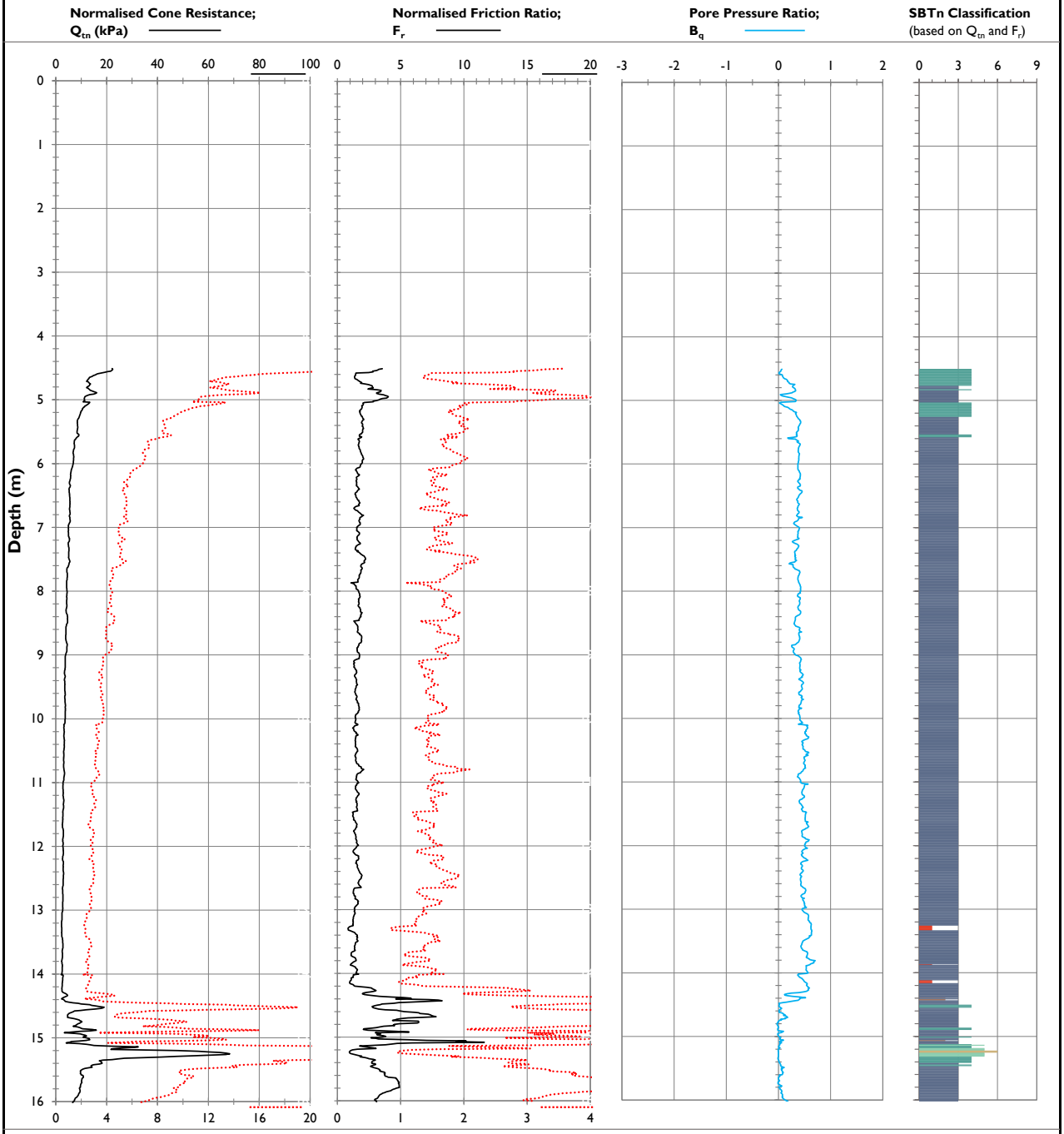


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT08**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**17/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631070 (AGD66 /*	R.L. Surface:	*216.9m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*4.5m (Auger)*	Northing:	*7522538.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*16.0m (Estimated)*	Termination:	*18.28m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

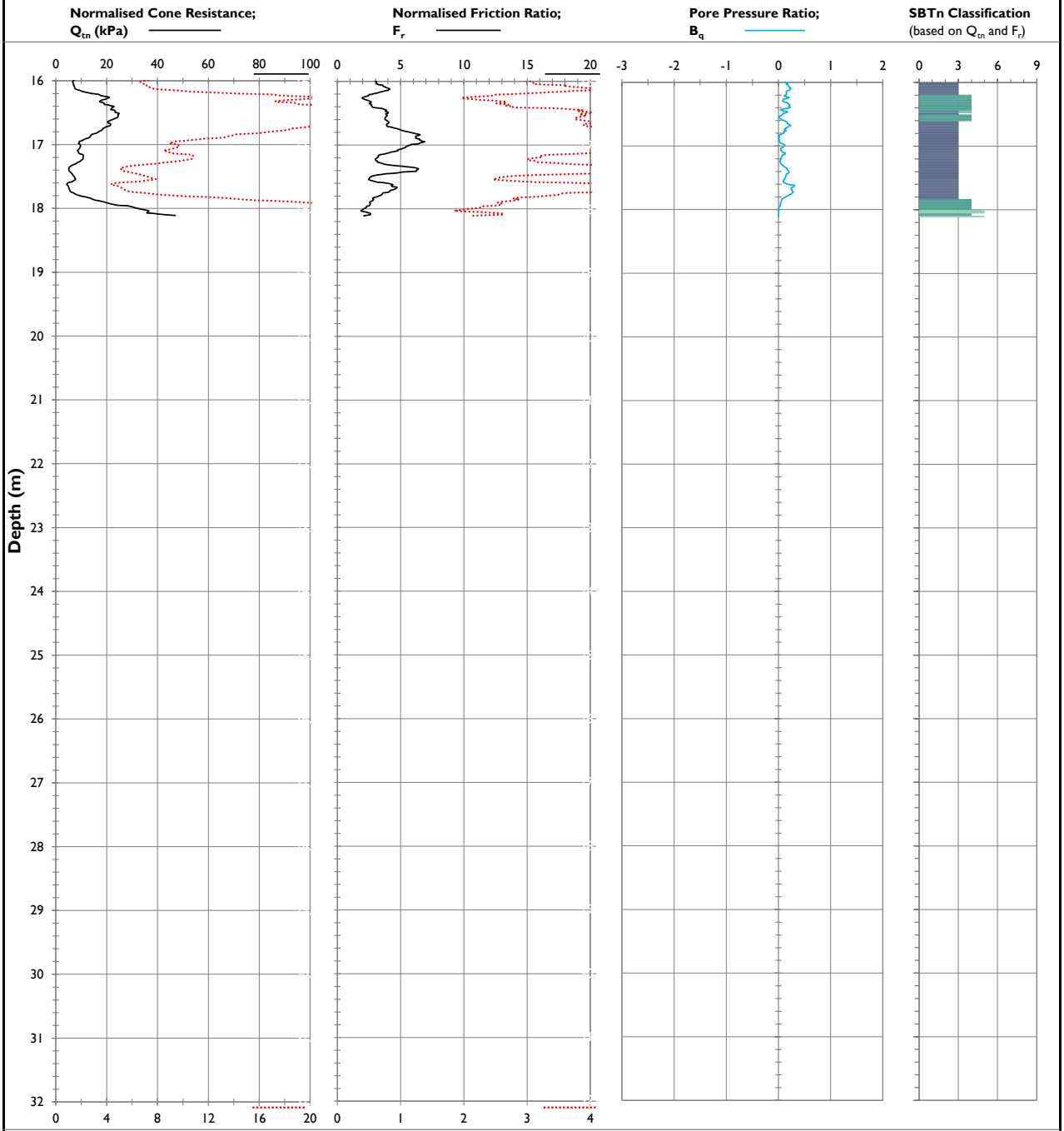
1 - Sensitive, fine grained
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5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT08**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**17/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15252*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631070 (AGD66 /*	R.L. Surface:	*216.9m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*4.5m (Auger)*	Northing:	*7522538.1 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.79*	Depth to GW:	*16.0m (Estimated)*	Termination:	*18.28m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

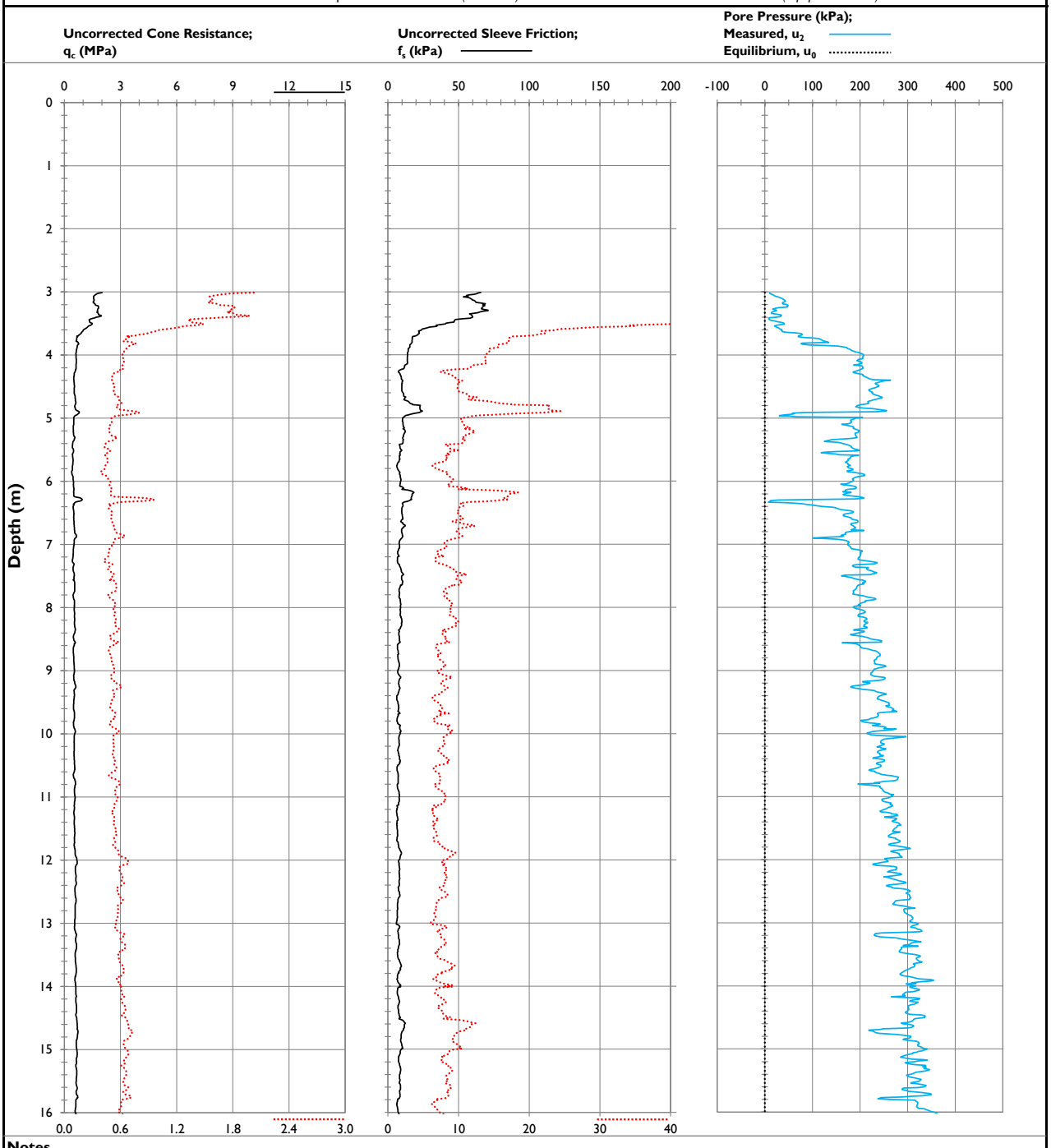
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5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT09**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**25/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631092.5 (AGD66*	R.L. Surface:	*215.8m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522451.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*20.55m (Equipment at risk)*		

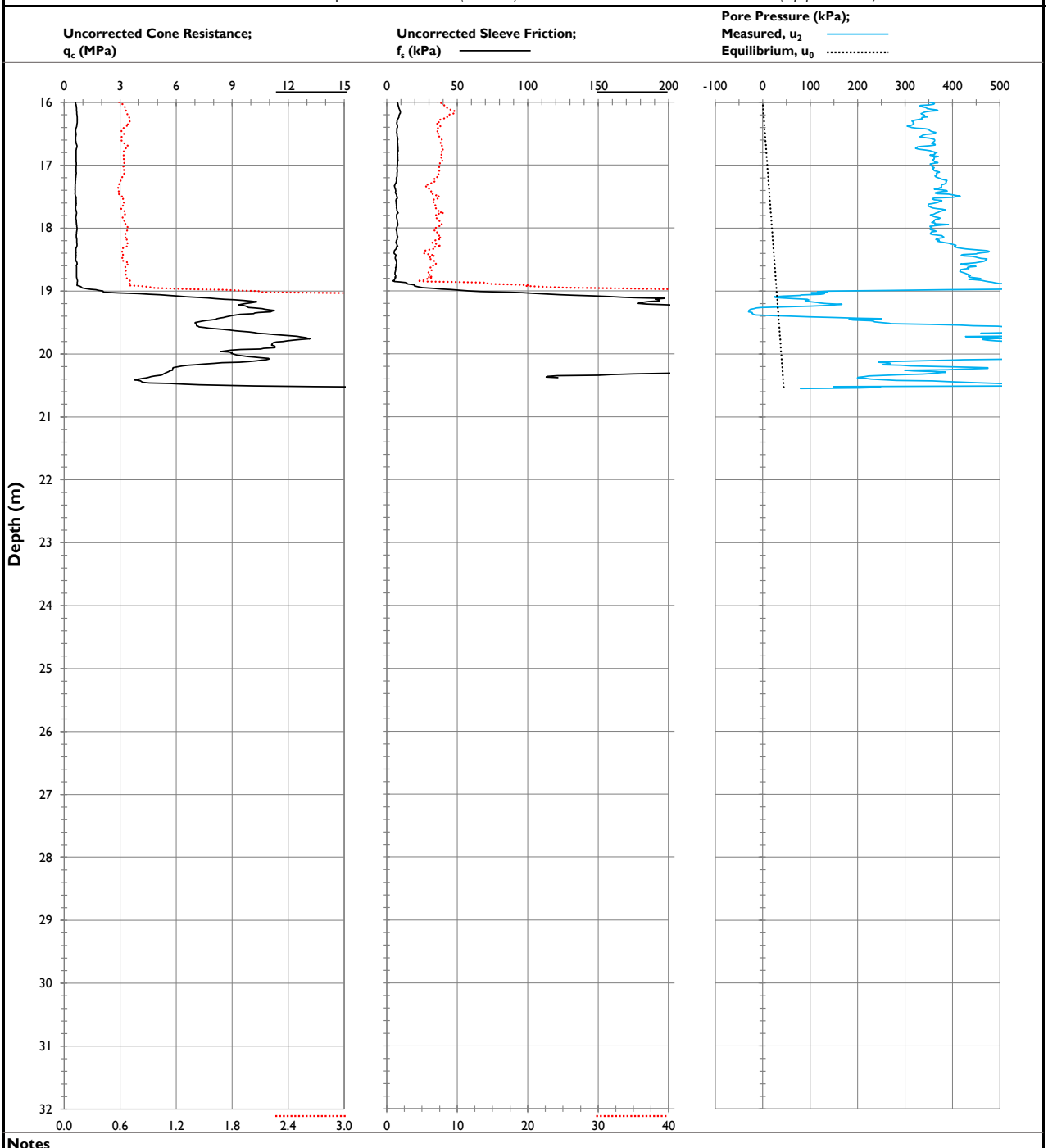


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT09**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**25/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631092.5 (AGD66*	R.L. Surface:	*215.8m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522451.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*20.55m (Equipment at risk)*		

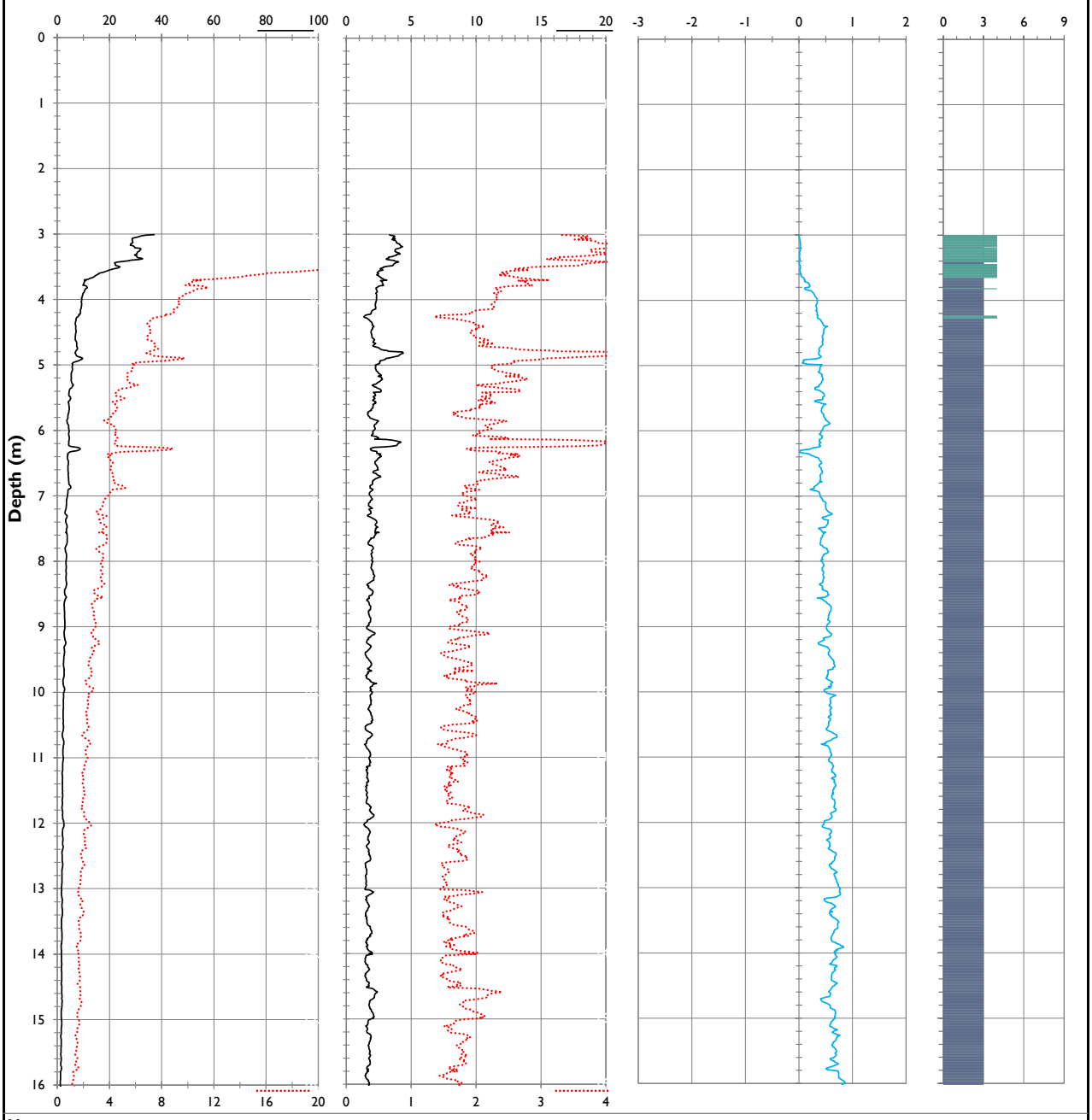


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT09**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**25/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631092.5 (AGD66*	R.L. Surface:	*215.8m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522451.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*20.55m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

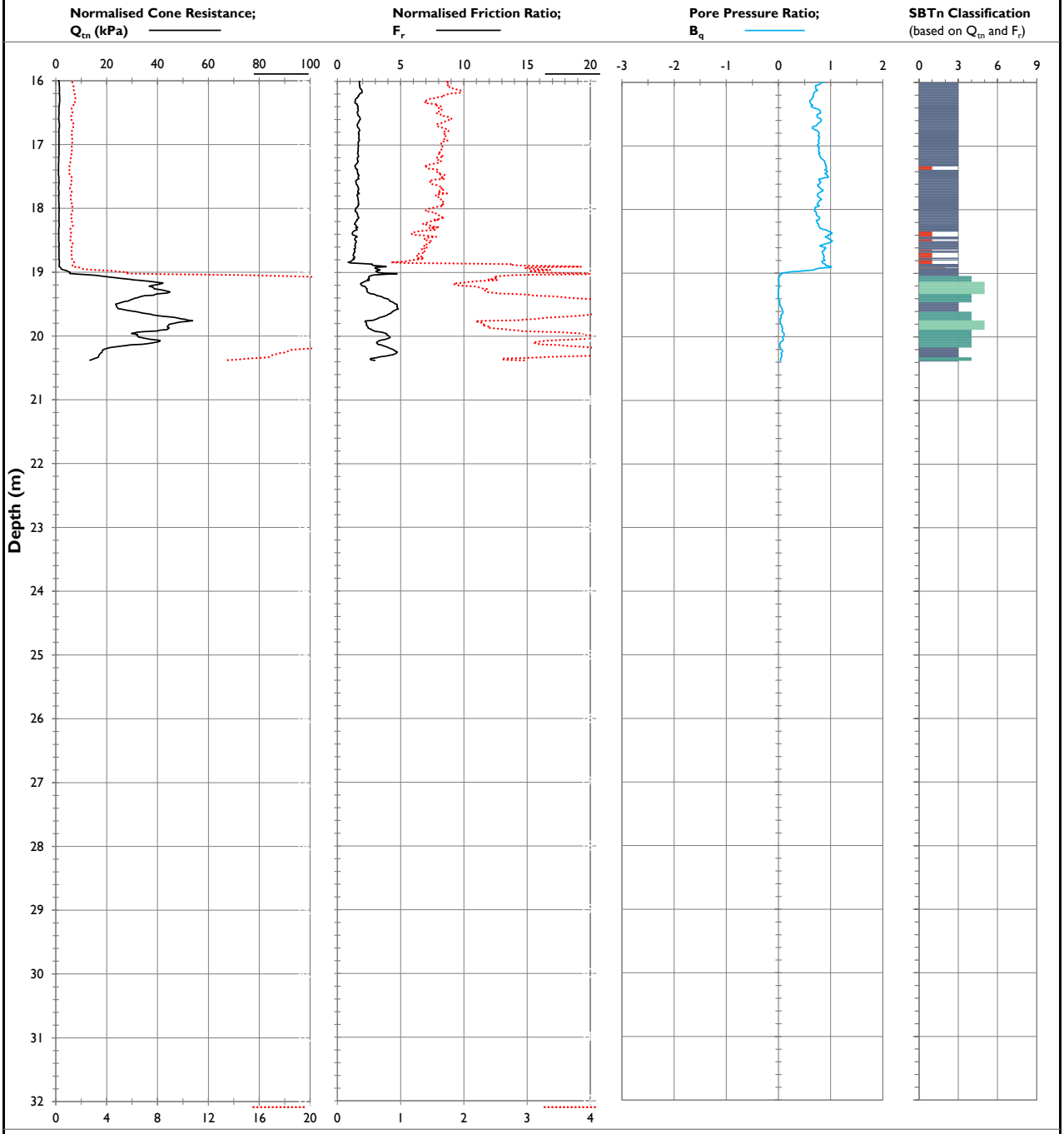
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5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT09**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**25/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631092.5 (AGD66*	R.L. Surface:	*215.8m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7522451.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*20.55m (Equipment at risk)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

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Soil Behaviour Type Description

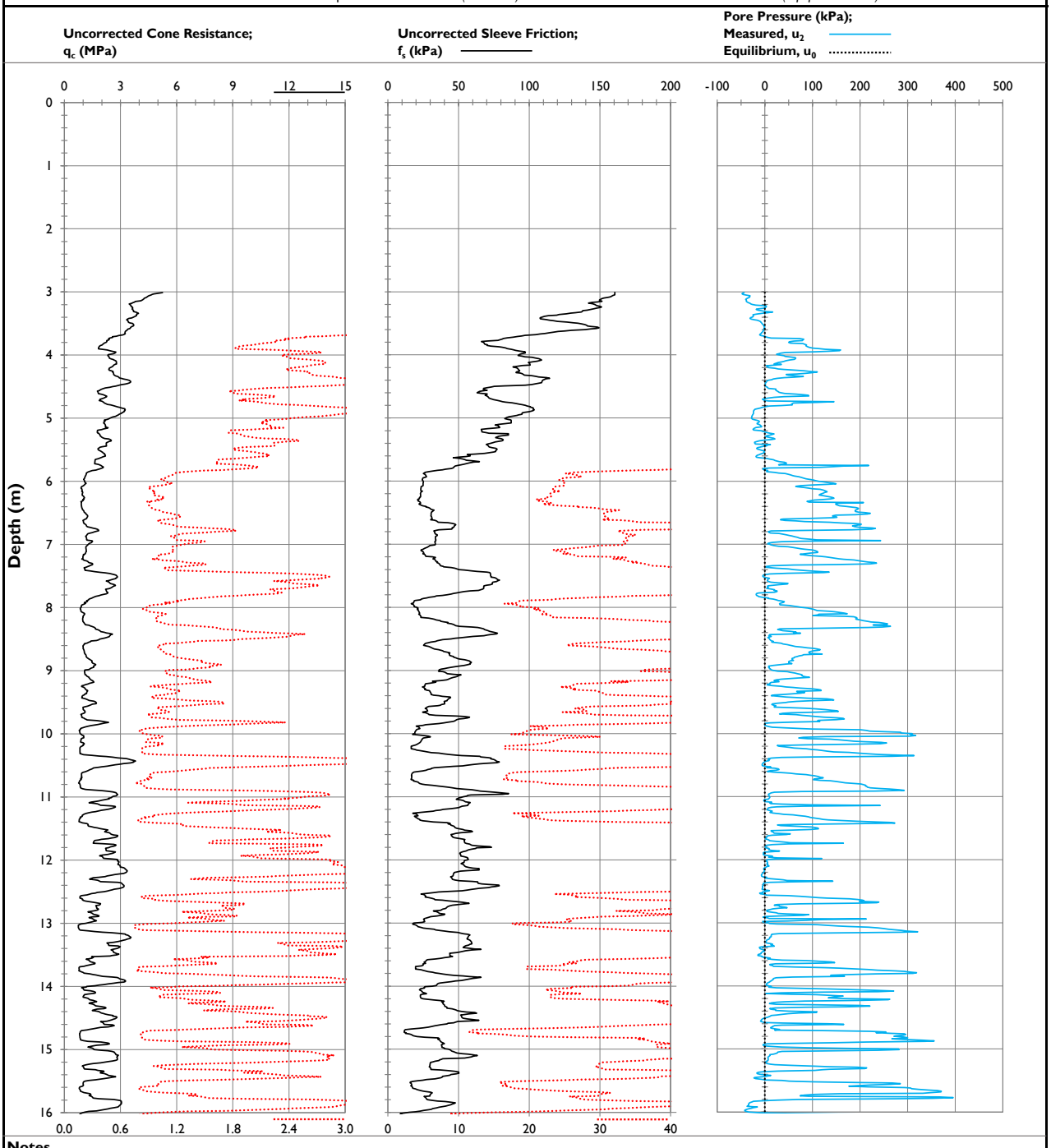
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6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT10**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631297.1 (AGD66*	R.L. Surface:	*218.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521834.9 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*21.48m (Equipment at risk)*		

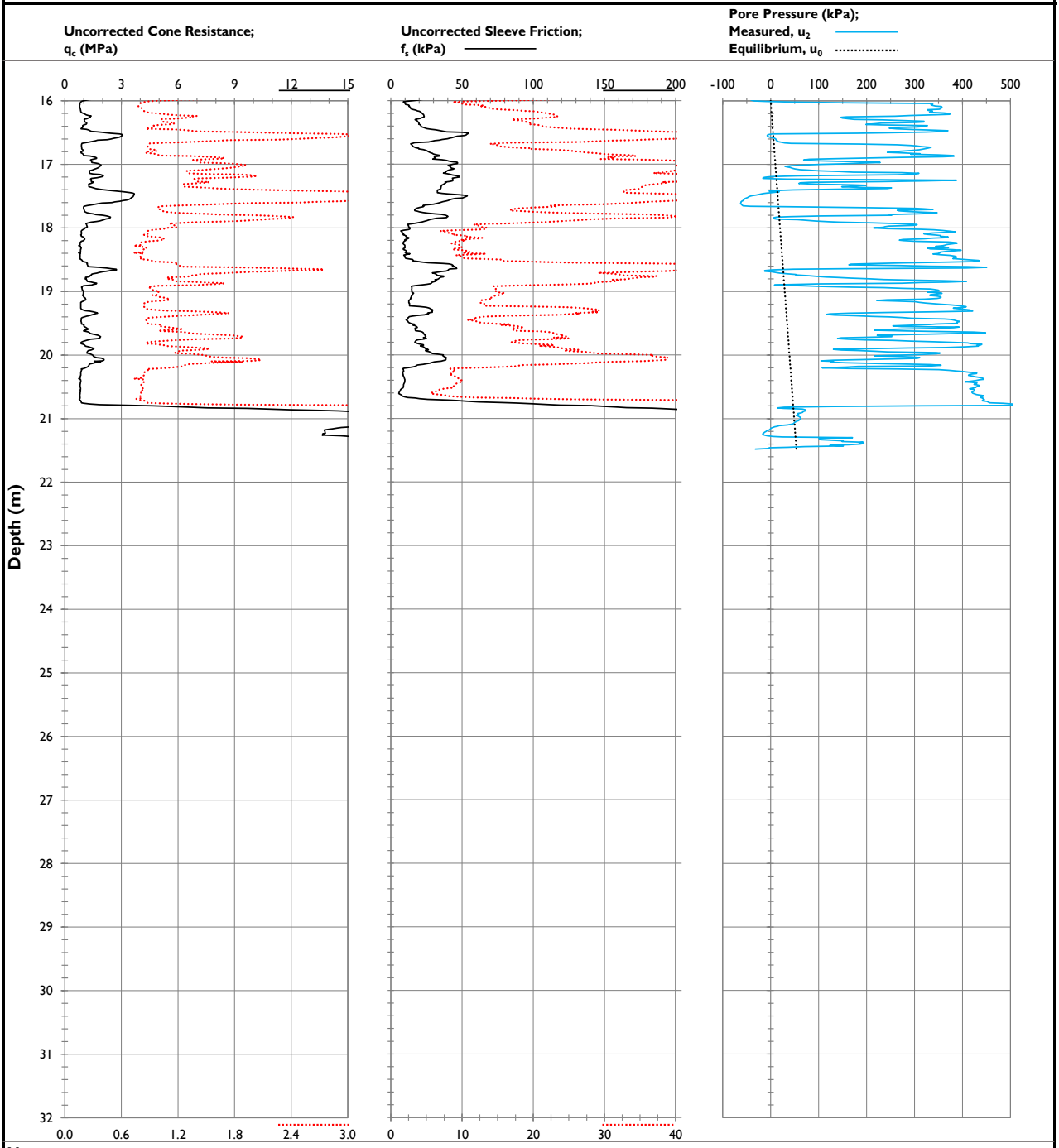


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT10**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631297.1 (AGD66*	R.L. Surface:	*218.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521834.9 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*21.48m (Equipment at risk)*		

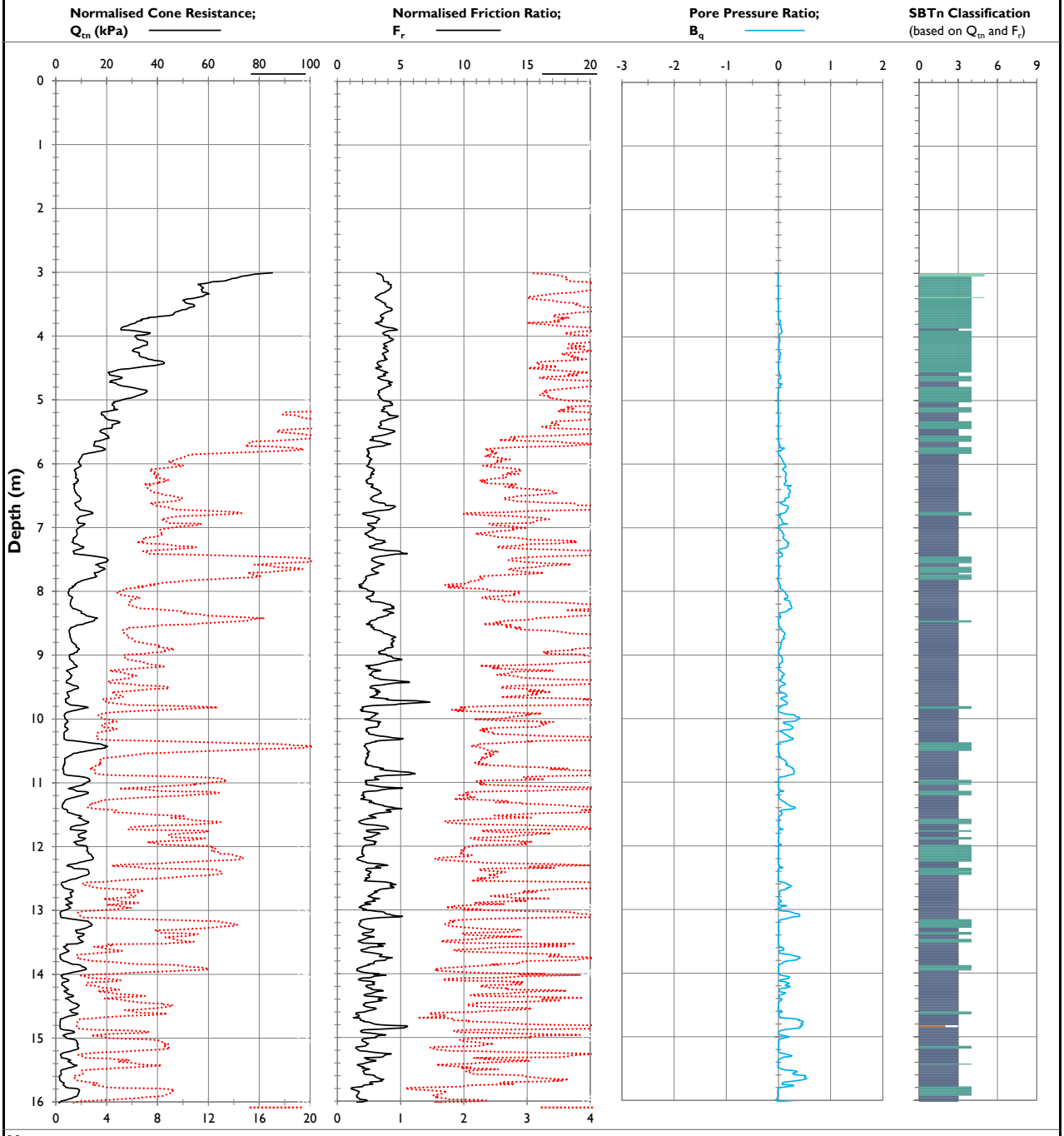


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT10**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631297.1 (AGD66*	R.L. Surface:	*218.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521834.9 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*21.48m (Equipment at risk)*		



Notes

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n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

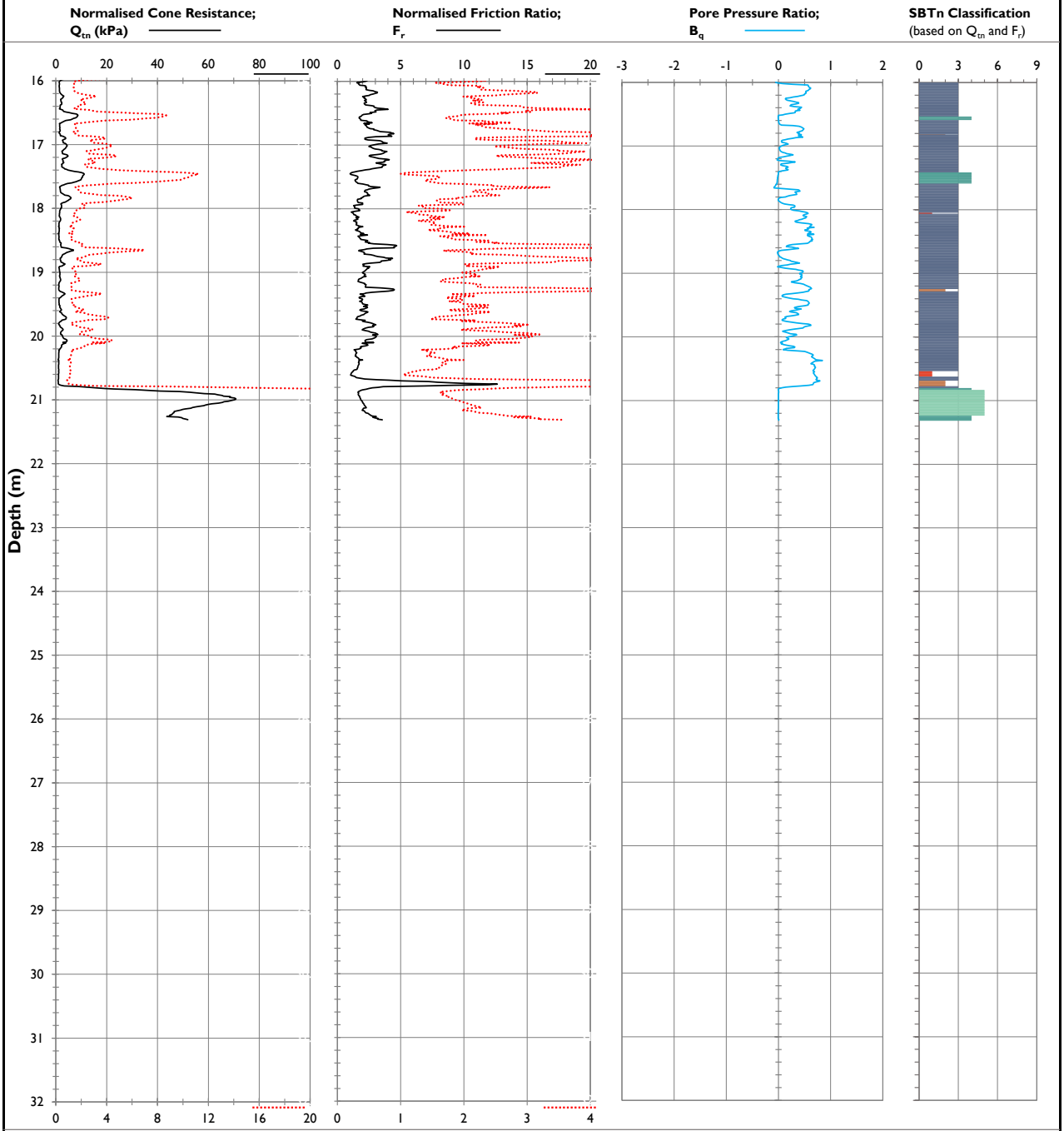
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** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF3-CPT10**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**27/06/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF3**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631297.1 (AGD66*	R.L. Surface:	*218.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m (Auger)*	Northing:	*7521834.9 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*16.0m (Estimated)*	Termination:	*21.48m (Equipment at risk)*		



Notes

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Soil Behaviour Type Description

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Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050067-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	7/05/2021
		Report Date:	26/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF3-CPT07	**Depth (m):**	10.00-10.50
Description:	SILTY CLAY- black		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-13	0.039	1.7E-09	3.23	4.27	1.283	0.61	0.9
2	13-25	0.058	2.0E-09	5.61	6.85	0.936	0.89	2.0
3	25-51	0.069	1.9E-09	8.90	10.51	0.570	1.01	3.5
4	51-99	0.091	1.1E-09	9.11	9.31	0.386	0.87	5.3
5	99-200	0.098	8.7E-10	14.49	13.16	0.213	1.14	7.3
6	200-399	0.100	5.8E-10	13.60	16.92	0.111	1.08	9.3
7	399-800	0.127	3.8E-10	20.02	17.24	0.072	1.27	11.9
8	800-1603	0.139	2.4E-10	19.96	19.05	0.040	1.64	14.8
9	1603-400	0.017	5.4E-11	67.09	25.62	0.007	0.25	14.1
10	400-100	0.021	1.9E-10	17.33	18.33	0.034	0.57	13.2

Remarks: Tested as Received

REP03103

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Channon

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory Number 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.
Trilab Pty Ltd
ABN 25 065 630 506

Trilab
Soil Rock Calibration

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346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050068-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	6/05/2021
		Report Date:	27/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF3-CPT09	**Depth (m):**	10.00-10.80
Description:	SILTY CLAY- black		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-13	0.032	6.9E-09	15.27	24.89	0.900	0.34	0.6
2	13-25	0.029	4.1E-09	25.52	32.36	0.407	0.48	1.1
3	25-51	0.061	5.0E-09	40.93	36.90	0.434	0.72	2.2
4	51-100	0.084	3.6E-09	46.47	38.77	0.302	0.92	3.7
5	100-199	0.148	2.9E-09	32.24	34.02	0.273	0.91	6.3
6	199-401	0.173	2.3E-09	48.69	44.36	0.164	1.72	9.4
7	401-799	0.173	9.5E-10	47.43	36.03	0.085	1.69	12.4
8	799-1599	0.221	6.1E-10	48.30	34.87	0.056	1.65	16.4
9	1599-401	0.021	2.0E-10	117.55	84.01	0.008	0.33	15.6
10	401-100	0.027	3.2E-10	47.93	26.88	0.038	0.58	14.7

Remarks: Tested as Received

REP03103

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Trilab Pty Ltd
ABN 25 065 630 506

SOIL WATER ANALYSIS (SWA)

soilwater GROUP
45 Gladstone St
East Perth WA 6006
(08) 9228 3060
(08) 9228 3210
admin@soilwatergroup.com
www.soilwatergroup.com

TEST REPORT - PSD (Wet Sieve)

Client: EDG Consulting
Client Contact: Darron Lee; Jo Perrett
Client Job Title: Saraji Mine
Client Reference: **B01229-4**

SWA Job No: JN0739

Date of Analysis: 28 June - 22 July 2021
No. Samples Submitted: 3
Sample(s) Condition: Intact Core

METHODOLOGY

- PSD (Wet Sieve) determined in accordance with AS 1289.3.6.1-1995.

TEST RESULTS

SWA ID	739-02	739-03	739-04
Client ID	TSF4-CPT06 8.0 - 8.8m	TSF3-CPT09 7.0 - 7.8m	TSF3-CPT07 5.0 - 5.5m
Sieve Size (mm)	% Passing		
2	100.00	100.00	100.00
1.18	99.36	99.97	99.81
0.6	96.68	99.75	98.08
0.425	90.72	99.08	75.59
0.3	81.01	97.80	53.88
0.212	77.10	94.87	41.91
0.15	72.94	36.75	35.34
0.075	59.54	27.27	29.77

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TEST REPORT

Client: EDG Consulting
Client Contact: Darron Lee; Jo Perrett
Client Job Title: Saraji Mine
Client Reference: **B01229-4**

SWA Job No: JN0739

Date of Analysis: 28 June - 22 July 2021
No. Samples Submitted: 7
Sample(s) Condition: Intact Core

METHODOLOGY

- Gravimetric moisture content determined in accordance with AS 1289.2.1.1-2005.
- Atterberg limits determined in accordance with AS1289.3.1.1; AS 1289 3.2.1 & AS 1289.3.3.1.
- Bulk density (ρ_b) determined in accordance with AS 1289.1.3.1-1999.
- Particle density (ρ_p) determined in accordance with AS 1289.3.5.1-1995.
- Total porosity (T_p) determined by calculation: Tp = 1-(ρ_b/ρ_p)

TEST RESULTS

SWA ID	739-02	739-03	739-04
Client ID	TSF4-CPT06 8.0 - 8.8m	TSF3-CPT09 7.0 - 7.8m	TSF3-CPT07 5.0 - 5.5m
Grav. Moisture Content (%)	32.45	32.25	33.62
Atterberg Limits:			
• Liquid Limit	34.91	36.94	39.93
• Plastic Limit	27.94	27.97	28.59
• Plasticity Index	6.97	8.97	11.34

SWA ID	Client ID	Bulk Density (g/cm3)	Particle Density (g/cm3)	Total Porosity (%)
739-01	TSF2-CPT14 2.0-2.8m	1.02	1.49	31.39
739-02	TSF4-CPT06 8.0-8.8m	1.09	1.61	32.27
739-03	TSF3-CPT09 7.0-7.8m	1.11	1.54	27.89
739-04	TSF3-CPT07 5.0-5.5m	1.14	1.55	26.24
739-05	TSF4-CPT06 11.0 - 11.8m	1.12	1.60	30.13
739-06	TSF4-CPT07 7.5 - 8.0m	1.18	1.69	30.46
739-07	TSF2-CPT11 3.0-3.7m	0.96	1.56	38.56

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TEST REPORT - SWCC

Client: EDG Consulting
Client Contact: Darron Lee; Jo Perrett
Client Job Title: Saraji Mine
Client Reference: **B01229-4**
SWA Job No: JN0739

Date of Analysis: 28 June - 22 July 2021
No. Samples Submitted: 7
Sample(s) Condition: Intact Core

METHODOLOGY

• SWCC determined in accordance with ASTM D6836 (Methods A, B & D)

TEST RESULTS

SWA-ID	Client ID	Volumetric Water Content (cm^3/cm^3)										
		0kPa	2.5kPa	5kPa	7.5kPa	10kPa	33kPa	100kPa	1,500kPa	39MPa	98MPa	300MPa
739-01	TSF2-CPT14 2.0-2.8m	0.3139	0.2680	0.2508	0.2406	0.2314	0.2058	0.1829	0.1311	0.0918	0.0825	0.0729
739-02	TSF4-CPT06 8.0-8.8m	0.3537	0.2949	0.2559	0.2325	0.2166	0.1578	0.1388	0.0965	0.0870	0.0859	0.0850
739-03	TSF3-CPT09 7.0-7.8m	0.3578	0.3149	0.2731	0.2466	0.2286	0.1759	0.1509	0.1326	0.1293	0.1291	0.1290
739-04	TSF3-CPT07 5.0-5.5m	0.3833	0.3032	0.2563	0.2308	0.2146	0.1628	0.1392	0.1120	0.1058	0.1053	0.1049
739-05	TSF4-CPT06 11.0 - 11.8m	0.3624	0.3308	0.3009	0.2803	0.2638	0.2189	0.1789	0.1547	0.1447	0.144	0.1434
739-06	TSF4-CPT07 7.5 - 8.0m	0.3806	0.3241	0.298	0.2827	0.2710	0.2359	0.2017	0.1592	0.1315	0.1269	0.1226
739-07	TSF2-CPT11 3.0-3.7m	0.3856	0.3193	0.2943	0.2800	0.2689	0.2359	0.2018	0.1548	0.1201	0.1135	0.1071

APPENDIX G

Sample Locations TSF 4



CLIENT
BMA

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-09-14
DESIGNED	
PREPARED	DAB
REVIEWED	
APPROVED	

PROJECT
SARAJI MINE - TAILINGS PRCP
TSF 4

TITLE
TSF 4 - COVER SHEET

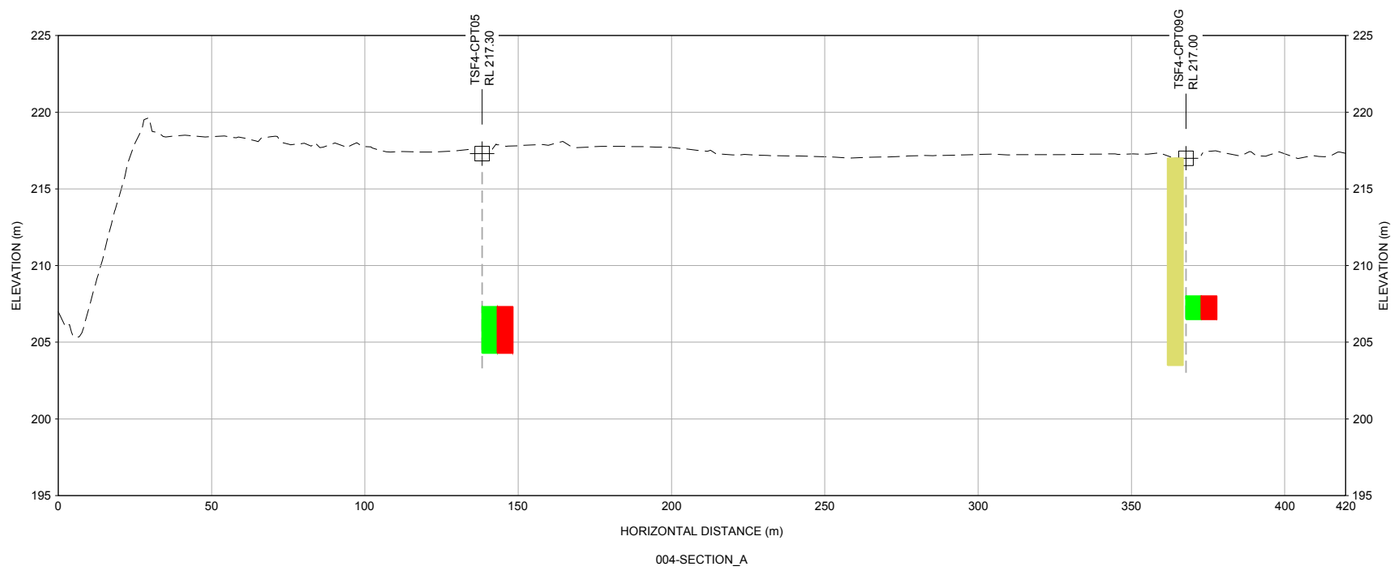
PROJECT NO.	CONTROL	REV.	FIGURE
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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm
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TSF 4 LAYOUT PLAN
SCALE 1:2000



004-SECTION_A

0 50 100
1:2,000 METRES

LEGEND

- EXISTING SURVEY CONTOURS
- EXISTING GROUND PROFILE
- RHEOLOGY TESTING LOCATION
- PSD TESTING LOCATION
- GEOCHEMICAL TESTING LOCATION
- SPECIFIC GRAVITY TESTING LOCATION
- ATTERBERG TESTING LOCATION
- MOISTURE CONTENT AND DRY DENSITY TESTING LOCATION
- SOIL WATER CHARACTERISTIC CURVE LOCATION

CLIENT
BMA

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-09-14
DESIGNED	
PREPARED	DAB
REVIEWED	
APPROVED	

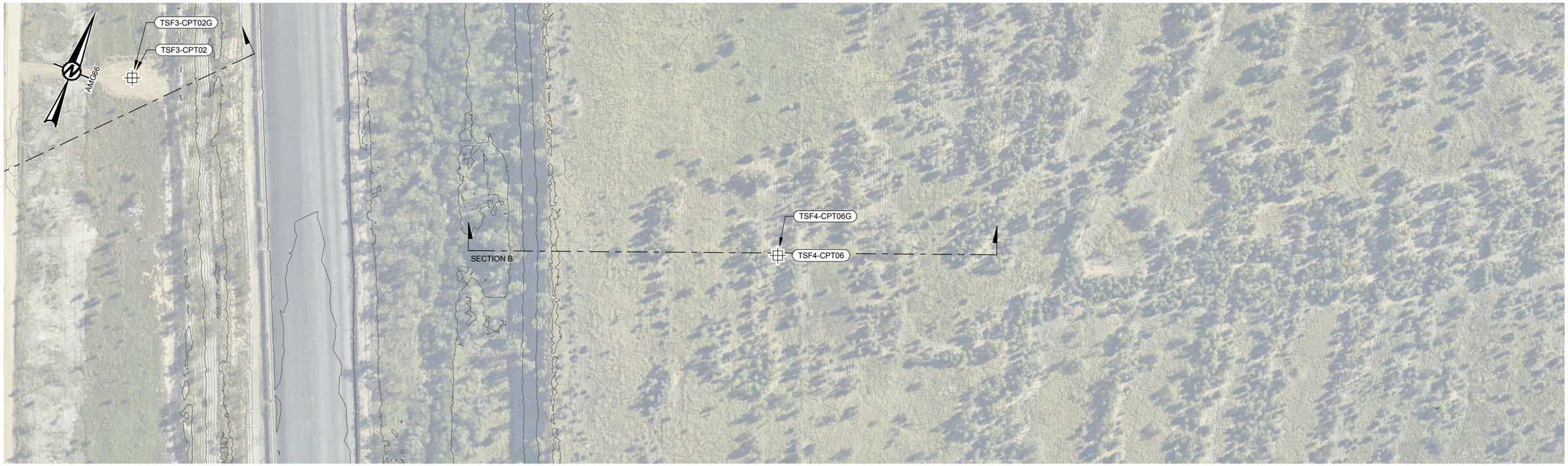
PROJECT
SARAJI MINE - TAILINGS PRCP
TSF 4

TITLE
SAMPLING LOCATIONS PLAN AND SECTION A

PROJECT NO.	CONTROL	REV.	FIGURE
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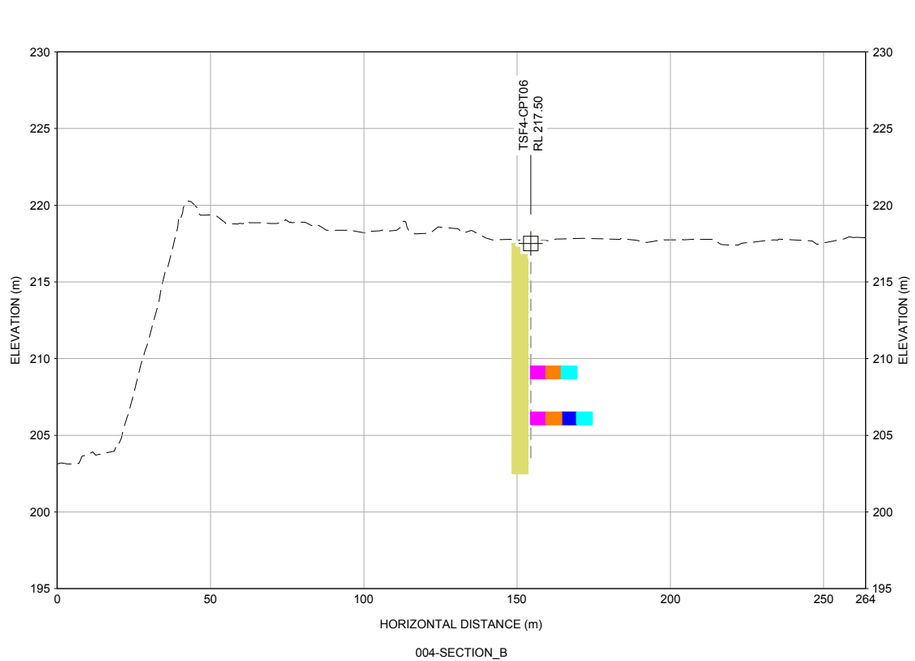
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TSF 4 LAYOUT PLAN

SCALE 1:2000



004-SECTION_B

0 50 100
1:2,000 METRES

LEGEND

- EXISTING SURVEY CONTOURS
- EXISTING GROUND PROFILE
- RHEOLOGY TESTING LOCATION
- PSD TESTING LOCATION
- GEOCHEMICAL TESTING LOCATION
- SPECIFIC GRAVITY TESTING LOCATION
- ATTERBERG TESTING LOCATION
- MOISTURE CONTENT AND DRY DENSITY TESTING LOCATION
- SOIL WATER CHARACTERISTIC CURVE LOCATION

CLIENT
BMA

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-09-14
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PREPARED	DAB
REVIEWED	
APPROVED	

PROJECT
SARAJI MINE - TAILINGS PRCP
TSF 4

TITLE
SAMPLING LOCATIONS PLAN AND SECTION B

PROJECT NO.	CONTROL	REV.	FIGURE
21470654	004	A	F002

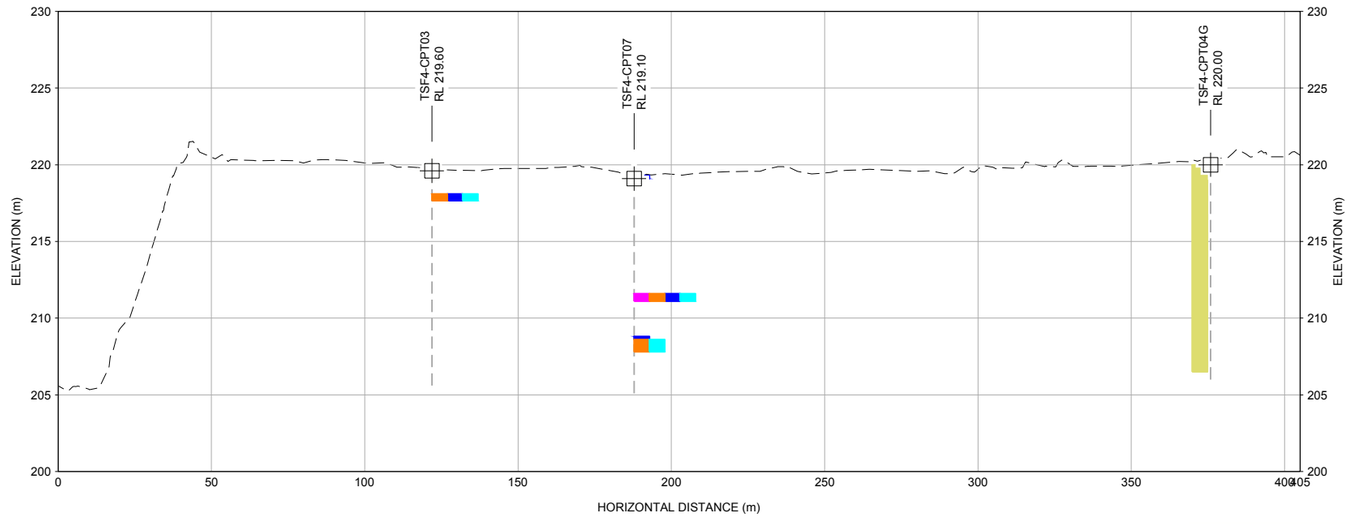
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TSF 4 LAYOUT PLAN
SCALE 1:2000



004-SECTION_C

0 50 100
1:2,000 METRES

LEGEND

- EXISTING SURVEY CONTOURS
- EXISTING GROUND PROFILE
- RHEOLOGY TESTING LOCATION
- PSD TESTING LOCATION
- GEOCHEMICAL TESTING LOCATION
- SPECIFIC GRAVITY TESTING LOCATION
- ATTERBERG TESTING LOCATION
- MOISTURE CONTENT AND DRY DENSITY TESTING LOCATION
- SOIL WATER CHARACTERISTIC CURVE LOCATION

CLIENT
BMA

CONSULTANT
WSP GOLDER

YYYY-MM-DD	2022-09-14
DESIGNED	
PREPARED	DAB
REVIEWED	
APPROVED	

PROJECT
SARAJI MINE - TAILINGS PRCP
TSF 4

TITLE
SAMPLING LOCATIONS PLAN AND SECTION C

PROJECT NO.	CONTROL	REV.	FIGURE
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APPENDIX H

Laboratory Certificates TSF 4

Rheology Testwork for Failure Impact Assessments for Saraji Mine TSFs – revision A

A Report submitted to:

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3rd June April 2021

Report Reference: BHP141-01A
Issue Date: 03/06/2021
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SUMMARY

BHP has committed to reducing the inherent risk of all tailings storage facilities (TSFs) across the BMA portfolio. Several internal risk reviews of each of the TSFs have been conducted across BMA. The Saraji Mine tailings storage facilities (SRM TSFs) require investigation and assessment works to better understand the geological setting, historical design, construction, and operation, to understand and mitigate any risk.

As part of these assessments, rheology testing was undertaken by RCS. Samples from three tailings storage facilities (TSFs) were provided for determination of the tailings physical and rheological properties including the as-received solids content, solids density and tailings in-situ dry density. Measurement of the shear yield stress profile and viscous properties of each of the tailings samples over the concentration range of interest to FIA was also conducted.

Saraji Mine samples were received at concentrations ranging from approximately 73wt% up to 98wt%.

Solids SGs ranged from 1.60 to 1.82, with up to 0.13 difference between two composite samples from the one TSF. The SG was lower at shallow depths for TSF 2 and TSF 4, but higher at shallow depth for TSF 3.

The shear yield stress of all tailings samples tested increased exponentially with solids concentration across the range of solids concentrations investigated and model parameters are provided. The yield stress behaviour for the two samples from TSF 3 and TSF 4 were similar to each other, however the two samples from TSF 2 differed from each other significantly, with the TSF2 sample from smaller depth showing a lower yield stress for a given solids concentration than any other sample. The TSF 2-BH07: 6-12 sample also had the lowest SG, and the ranking of yield stress curves was generally seen to follow SG for the Saraji mine samples. At a solids concentration of 55wt% the yield stress ranged from 10Pa (TSF 2-BH07: 6-12) to 80Pa (TSF4-CPT05: 10-13) for the samples tested.

In shear flow, all samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates investigated. For all but one sample, no shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due the sample collection, subsequent sub-sampling and sample preparation methods. The one notable exception was TSF2 BH07 at 71wt%. This sample showed a decrease in the shear stress as the shear rate increased from zero until approximately $100s^{-1}$ before increasing at higher shear rates. The behaviour was reproducible when the same sample was sheared then retested, possibly indicating a localised (but reversible) structuring of the material – possibly due to the presence of asymmetrical particles aligning in the direction of flow. The origin of the behaviour was not investigated.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected and the shear stress versus shear rate data was modelled using a Herschel-Bulkley model. The viscosity stress versus shear rate data was well described using a Power Law.

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1 INTRODUCTION

BHP Billiton Mitsubishi Alliance owns and operates several coal mines in the Bowen Basin, in Central Queensland, which produces semi-hard coking and hard coking coal products, including the Saraji Mine (SRM).

BHP has committed to reducing the inherent risk of all tailings storage facilities (TSFs) across the BMA portfolio. Several internal risk reviews of each of the TSFs have been conducted across BMA. The Saraji Mine tailings storage facilities (SRM TSFs) require further investigation and assessment works (failure impact analysis, FIA) to better understand the geological setting, historical design, construction, and operation, to understand risk levels. If required, preventative and/or mitigative measures to reduce the TSDs' risk profiles can then be implemented.

Rheology testing was required to inform parts of the FIA and to this end, samples from three tailings storage facilities (TSFs) were provided for determination of the tailings physical and rheological properties including the as-received solids content, solids density and tailings in-situ dry density. Measurement of the shear yield stress profile and viscous properties of each of the tailings samples over the concentration range of interest to FIA was also conducted.

2 SAMPLE Receipt and PREPARATION

Six samples listed in Table 1 were provided to RCS. Locations are provided in Table 2 and a sample map is shown in Figure 1.

Table 1 Samples received and prepared by RCS

Site	RCS ITEM #	ID	Depth	Type	Sample No.	RCS Sample Name
SRM TSF2,3,4	1	TSF2-CPT06	11.00	Steel Tube	1	**TSF2-CPT06: 11-13.5**
	2	TSF2-CPT06	12.00	Steel Tube		
	3	TSF2-CPT06	13.50	Steel Tube		
	4	TSF2-BH07	6.00	Steel Tube	2	**TSF2-BH07: 6-12**
	5	TSF2-BH07	7.00	Steel Tube		
	6	TSF2-BH07	9.00	Steel Tube		
	7	TSF2-BH07	12.00	Steel Tube		
	8	TSF3-CPT07	15.00	Steel Tube	1	**TSF3-CPT07: 15-17**
	9	TSF3-CPT07	17.00	Steel Tube		
	10	TSF3-CPT09	13.00	Steel Tube	2	**TSF3-CPT09: 13-16**
	11	TSF3-CPT09	16.00	Steel Tube		
	12	TSF4-CPT05	10.00	Steel Tube	1	**TSF4-CPT05: 10-13**
	13	TSF4-CPT05	13.00	Steel Tube		
	19	TSF4-CPT09G	9-10.5	Bucket	2	**TSF4-CPT09G: 9-10.5**

Table 2 SRM Sample location data

SRM TSF 2,3,4			
Location	**Easting**	**Northing**	**Elevation**
TSF2-CPT06	631846.5	7521453.8	221.2
TSF2-BH07	631832.5	7521147.0	219.9
TSF3-CPT07	631215.4	7522101.3	217.1
TSF3-CPT09	631092.6	7522451.9	215.8
TSF4-CPT05	631544.1	7522431.8	217.3
TSF4-CPT09G	631764.1	7522496.5	217.0

Upon receipt, samples were removed from core sample tubes or buckets and well sheared prior to combining and mixing well as per the bold boxes above to create composite two samples from each TSF.

Prior to yield stress and viscosity testing, samples were concentrated via centrifugation, if required, to a high solids concentration for initial yield stress testing. Dilution as required was undertaken using process water provided. All solids concentrations were determined by gravimetric analysis, drying at 90degC to constant mass.

3 GRAVIMETRIC ANALYSES

3.1 As received solids concentration

The solids concentration of the prepared samples (generated by combining 'as received' samples from each TSF) was determined by oven drying samples to constant dry mass.

Table 3 lists the measured solids concentrations.

Table 3. Prepared sample solids concentrations based on combining TSF samples as received.

Sample name	Solids concentration (wt%)
TSF2-BH07: 6-12	75.38
TSF2-CPT06: 11-13.5	75.96
TSF3-CPT09: 13-16	73.49
TSF3-CPT07: 15-17	72.92
TSF4-CPT09G: 9-10.5	98.62
TSF4-CPT05: 10-13	73.85

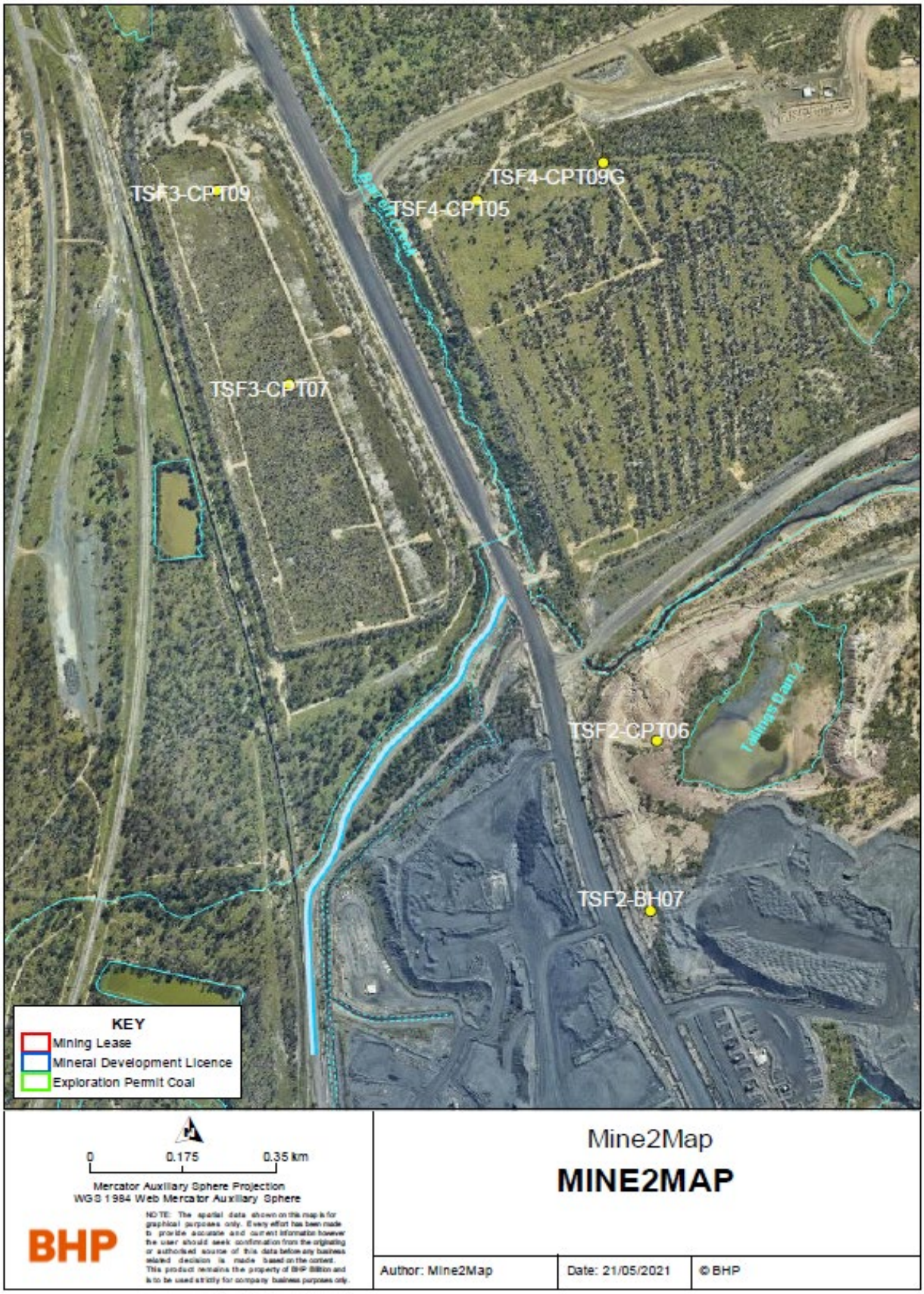


Figure 1 SSM sample location map

3.2 Specific Gravity

The solids specific gravity of the tailings was determined by measuring the density of a known volume (~100 cm^3) of slurried sample, and subsequently measuring the solids concentration of the slurry via oven drying to constant mass. By separately measuring the density for the water present in the sample under the same conditions, the density of the solid phase may be calculated using Equation 1 and the solids specific gravity subsequently determined. Results for the samples tested are shown in Table 4.

$$\rho_P = \frac{x\rho_s}{\left(1 - \frac{\rho_s}{\rho_L}(1-x)\right)}$$

Equation 1

Where: ρ_P is the particle (solids) density (kgm^{-3})
ρ_s is the slurry density (kgm^{-3})
ρ_L is the liquor density (kgm^{-3})
x is the solids mass fraction (-)

Solids SGs ranged from 1.60 to 1.82, with up to 0.13 difference between two composite samples from the one TSF. The SG was lower at shallow depths for TSF 2 and TSF4, but higher at shallow depth for TSF 3.

Table 4. BMC Saraji Mine tailings gravimetric analysis results

Sample name	Specific gravity
TSF2-BH07: 6-12	1.60
TSF2-CPT06: 11-13.5	1.66
TSF3-CPT09: 13-16	1.78
TSF3-CPT07: 15-17	1.68
TSF4-CPT09G: 9-10.5	1.69
TSF4-CPT05: 10-13	1.82

4 YIELD STRESS MEASUREMENTS

Yield stress measurements were conducted using the vane-shear method [1-4]. Many workers worldwide have adopted the vane-shear method and confirmed its applicability for numerous types of yield stress materials [5-9].

4.1 Experimental Procedure

Samples to be tested are placed in a plastic container and tapped on the laboratory bench to remove entrained air bubbles. A vane of suitable dimensions for the yield stress range under consideration is selected and attached to the rheometer. The container is placed on a stand under the vane and raised using a manual scissor lift to immerse the vane in the centre of the

sample. The vane is then rotated at a rate of 0.2 rpm and the maximum torque response of the sample is recorded. The yield stress is calculated using the maximum torque reading and Equation 1. All yield stress measurements are taken in triplicate to ensure reproducibility of results.

$$\tau_y = \frac{T_m}{\pi D_v^2\left(\frac{L_v}{2}+\frac{D_v}{6}\right)} \qquad \textbf{Equation 2}$$

Where τ_y is the calculated yield stress, T_m is the maximum torque experienced by the vane, D_v is the vane diameter and L_v is the vane length.

To ensure that wall and end effects are absent, vanes of varying dimensions are used for each material. Nguyen and Boger [3] suggest that the diameter and depth of the container should be at least twice as large as the diameter and length of the vane to minimise any effects caused by the rigid boundaries.

4.2 Results and Discussion

The shear yield stress profiles of the Saraji Mine tailings are given in Figure 2. The shear yield stress of all tailings samples increased exponentially with solids concentration across the range of solids concentrations investigated.

The yield stress versus solids concentration (mass fraction) curves for the Saraji Mine coal tailings were modelled using an exponential trendline (shown as a dashed line in Figure 2). Model parameters are given in Table 5 below.

Figure 2 shows that the yield stress behaviour for the two samples from TSF 3 and TSF 4 were similar to each other, however the two samples from TSF 2 differed from each other significantly, with the TSF2 sample from smaller depth showing a lower yield stress for a given solids concentration than any other sample. The TSF 2-BH07: 6-12 sample also had the lowest SG, and the ranking of yield stress curves was generally seen to follow SG for the Saraji mine samples.

For reference, Table 5 lists the yield stress of each sample at a solids concentration of 55wt%, showing that the yield stress ranged from 10Pa (TSF 2-BH07: 6-12) to 80Pa (TSF4-CPT05: 10-13) for the samples tested.

Table 5. Yield stress profile model parameters

Sample	Exponential Variables ($\tau_y=ae^{bx}$)		Yield stress @ 55wt%
	a	*b*	*(Pa) from* $\tau_y=ae^{bx}$
TSF2-BH07: 6-12	1.1095E-05	24.89	10
TSF2-CPT06: 11-13.5	3.2483E-04	21.37	41
TSF3-CPT09: 13-16	1.3536E-04	22.72	36
TSF3-CPT07: 15-17	3.5827E-04	21.47	48
TSF4-CPT09G: 9-10.5	7.7914E-04	20.55	63
TSF4-CPT05: 10-13	2.4982E-03	18.85	80

Where τ_y is the yield stress (*Pa*) and x is the solids mass fraction.

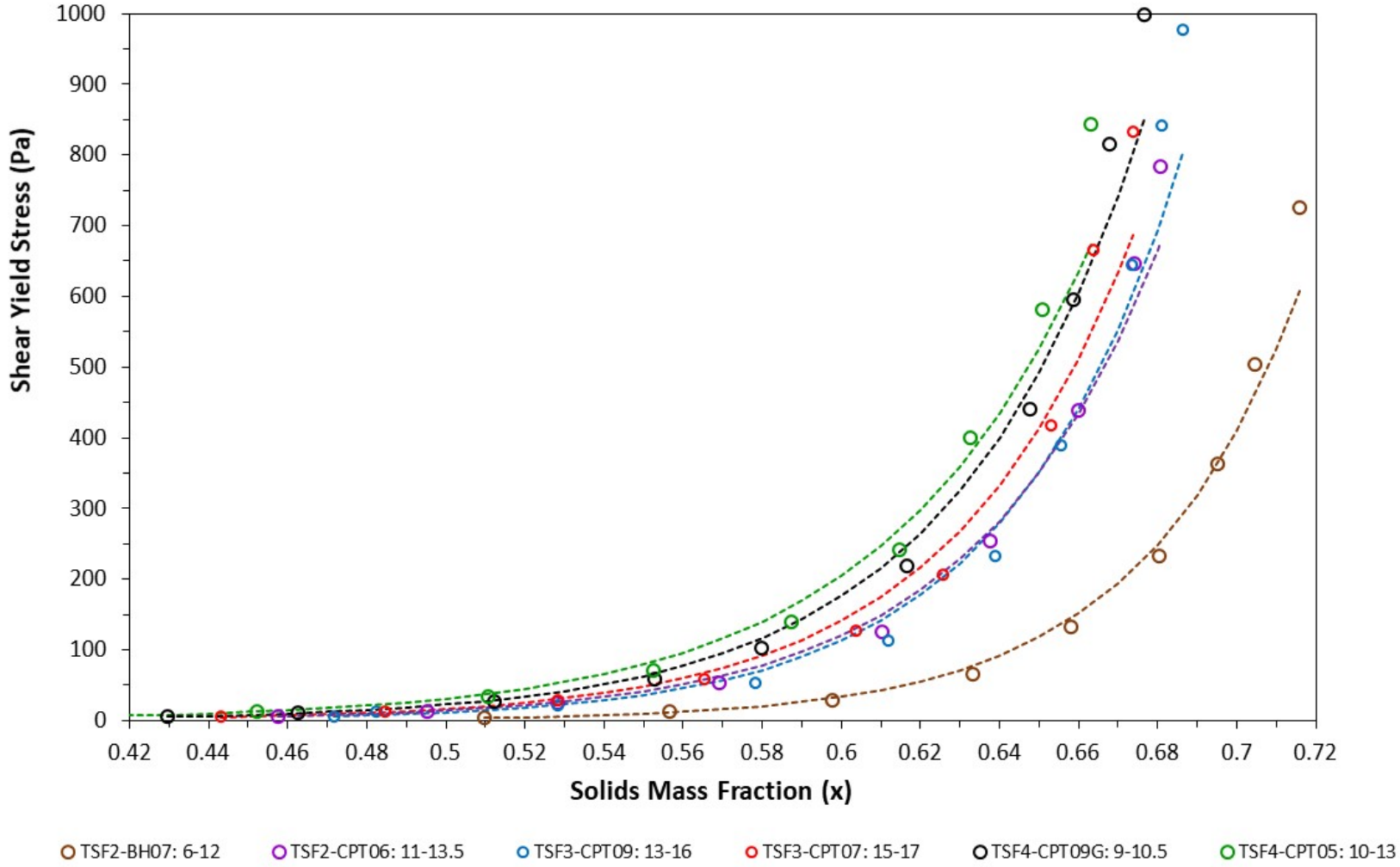


Figure 2 Shear yield stress (τ_y) vs. solids mass fraction (x) for Saraji Mine Tailings. See Table A 1 for tabulated data

5 SHEAR STRESS VS SHEAR RATE MEASUREMENTS

The shear stress (hence viscosity) of each of the coal tailings samples was measured as a function of shear rate at five solids concentrations per sample. These solids concentrations were specified by BHP and Klohn Crippen Berger (consulting on this study) personnel based on yield stress profile results and are shown in Table 6.

Measurements were conducted on fully sheared samples at ambient temperature with a Haake VT550 controlled strain rheometer using either vane (for high yield stress) or bob in cup geometry (low yield stress) as appropriate.

Table 6 Measured solids concentrations for flow behaviour testing

	Sample wt%				
	Min	**2**	**3**	**4**	**Max***
TSF2-BH07	0.55	0.583	0.635	0.673	0.71
TSF2-CPT06	0.555	0.583	0.613	0.651	0.676
TSF3-CPT07	0.567	0.595	0.617	0.645	0.665
TSF3-CPT09	0.575	0.588	0.618	0.642	0.667
TSF4-CPT05	0.55	0.588	0.607	0.625	65
TSF4-CPT09G	0.555	0.583	0.613	0.629	0.659

5.1 Experimental Procedure

Samples to be tested were either centrifuged and process water decanted or diluted to achieve the desired solids concentration for the test. Samples were placed in the test vessel and tapped on the laboratory bench to remove entrained air bubbles. The vessel was then placed on a stand under the bob or vane fixture and raised, using a manual scissor lift, to immerse the fixture in the centre of the sample. The fixture was then rotated at a constant rate, N *(rpm)*, and the torque experienced by the fixture was recorded, T *(μNm)*. This process was then repeated at successively increasing rotational rates with the sample homogenised via hand mixing between each measurement. The shear stress was measured at each successive rotational rate and the shear stress vs shear rate relationship (hence viscosity vs shear rate relationship) was determined as per [10] and [11].

5.2 Results and Discussion

The shear stress of the Saraji Mine tailings samples is given as a function of shear rate in Figure 3 to Figure 5, and the shear viscosity is given as a function of shear rate in Figure 6 to Figure 8. All samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates

investigated. For all but one sample, no shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due the sample collection, subsequent sub-sampling and sample preparation methods. The one notable exception was TSF2 BH07 at 71wt%. This sample showed a decrease in the shear stress as the shear rate increased from zero until approximately 100s^{-1}. This behaviour would normally be attributed to a breakup of the interparticle network structure, but in this case the behaviour was reproducible when the same sample was sheared then retested. The reproducibility may indicate a localised (but reversible) structuring of the material – possibly due to the presence of asymmetrical particles aligning in the direction of flow, however the origin of the behaviour was not investigated.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected.

The shear stress versus shear rate data was modelled using a Herschel-Bulkley model:

$\tau = \tau_y + K\dot{\gamma}^n$, where τ is the shear stress (*Pa*) and $\dot{\gamma}$ is the shear rate (s^{-1}) (shown as dashed lines in Figure 3 to Figure 5). The parameters for these curves are given in Table A2 in the Appendix. Note that model parameters are only valid over the shear rate range measured.

The viscosity stress versus shear rate data was curve fitted using a Power Law model:

$\eta = a\dot{\gamma}^b$, where η is the shear viscosity (*Pa.s*) and $\dot{\gamma}$ is the shear rate (s^{-1}), (shown as a dashed line in Figure 6 to Figure 8). The parameters for these curves are given in Table A3 in the Appendix. Note that model parameters are only valid over the shear rate range measured.

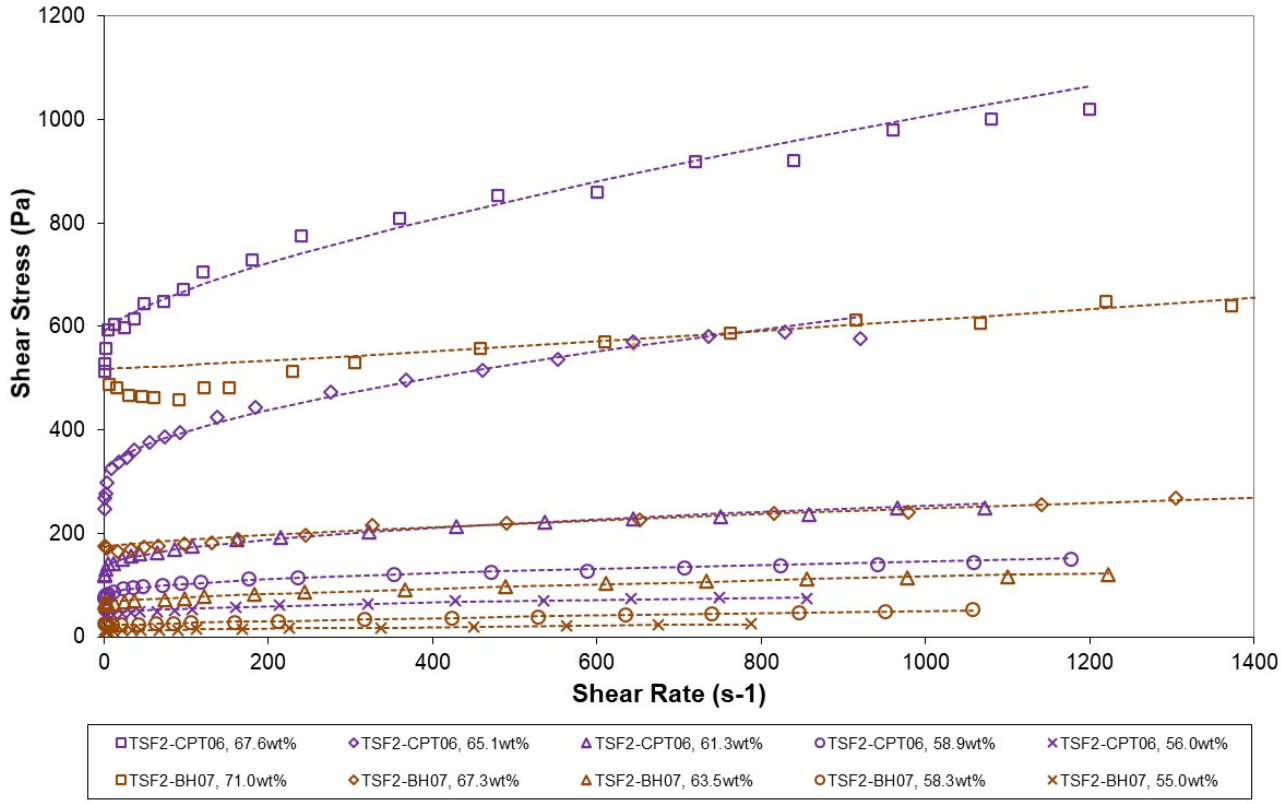


Figure 3 – Shear stress vs. shear rate for Saraji Mine TSF 2 samples.

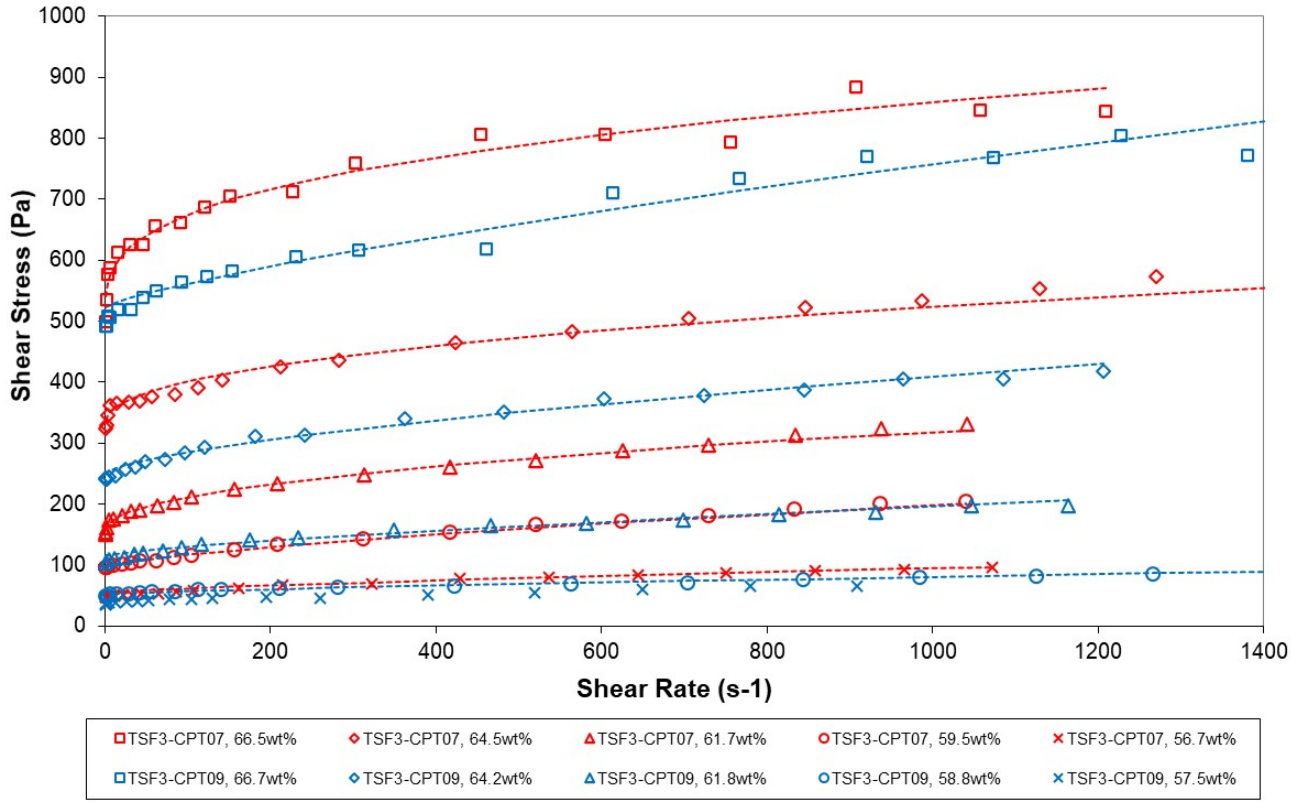


Figure 4 – Shear stress vs. shear rate for Saraji Mine TSF 3 samples.

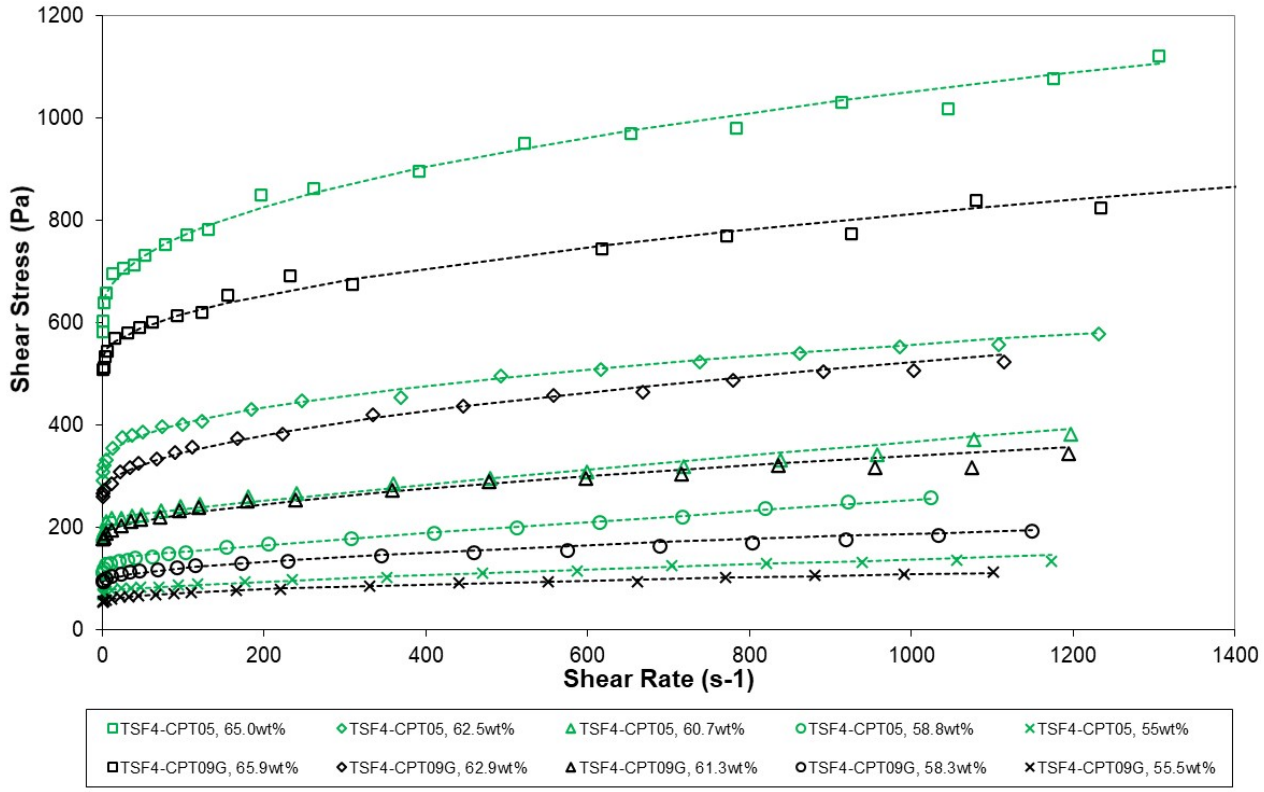


Figure 5 – Shear stress vs. shear rate for Saraji Mine TSF 4 samples.

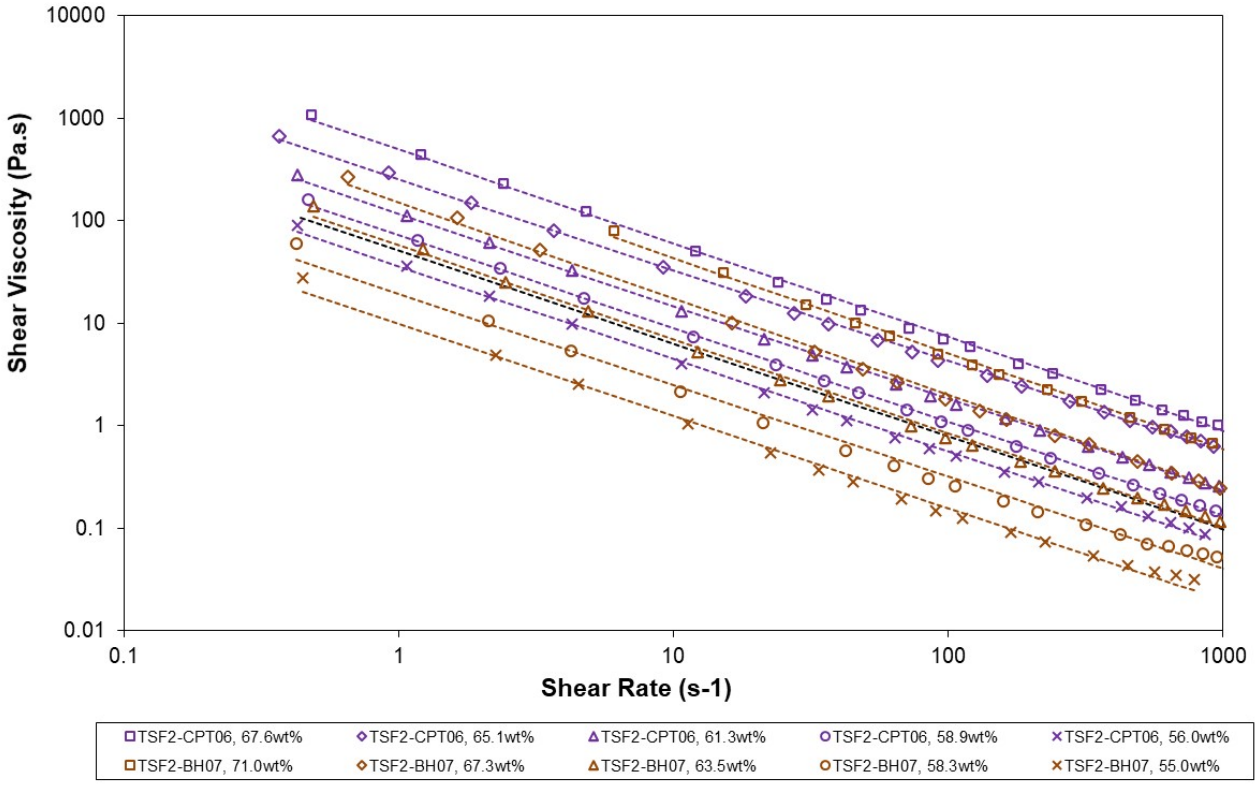


Figure 6 Shear viscosity vs. shear rate for Saraji Mine TSF 2 samples.

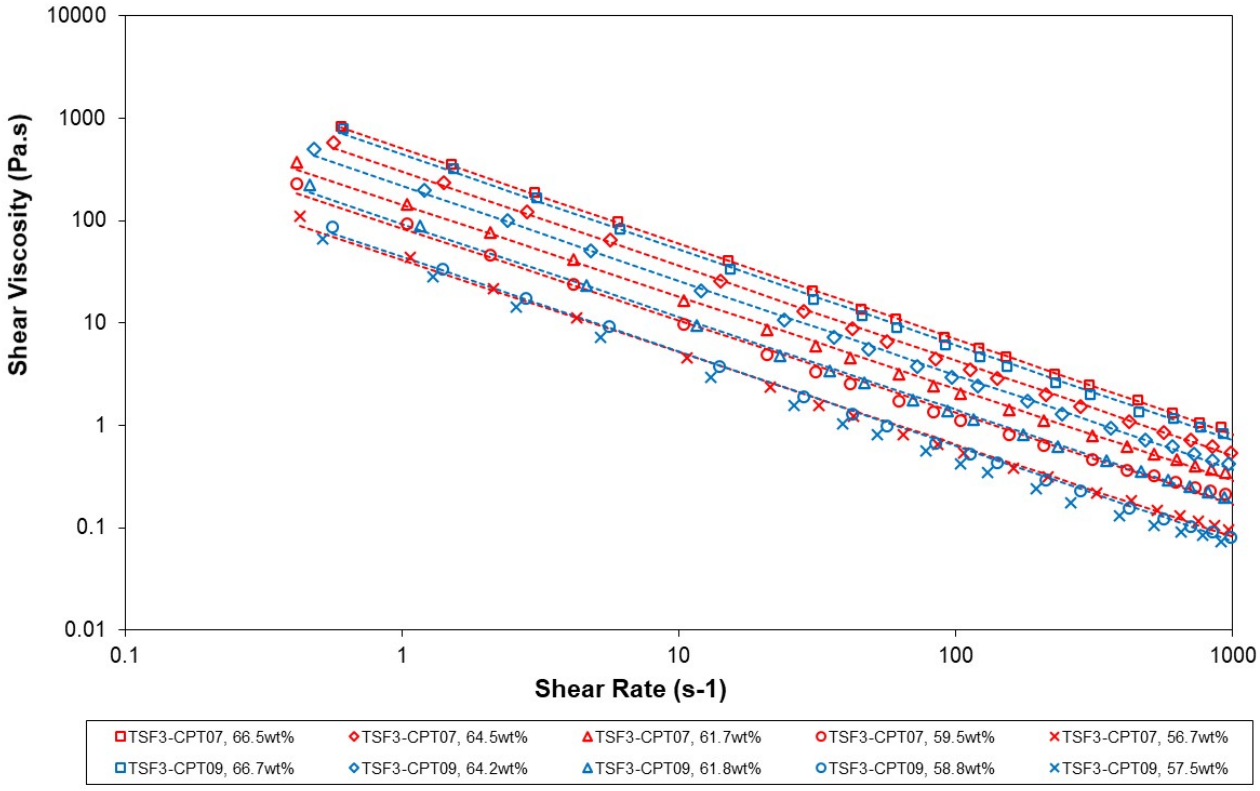


Figure 7 - Shear viscosity vs. shear rate for Saraji Mine TSF 3 samples.

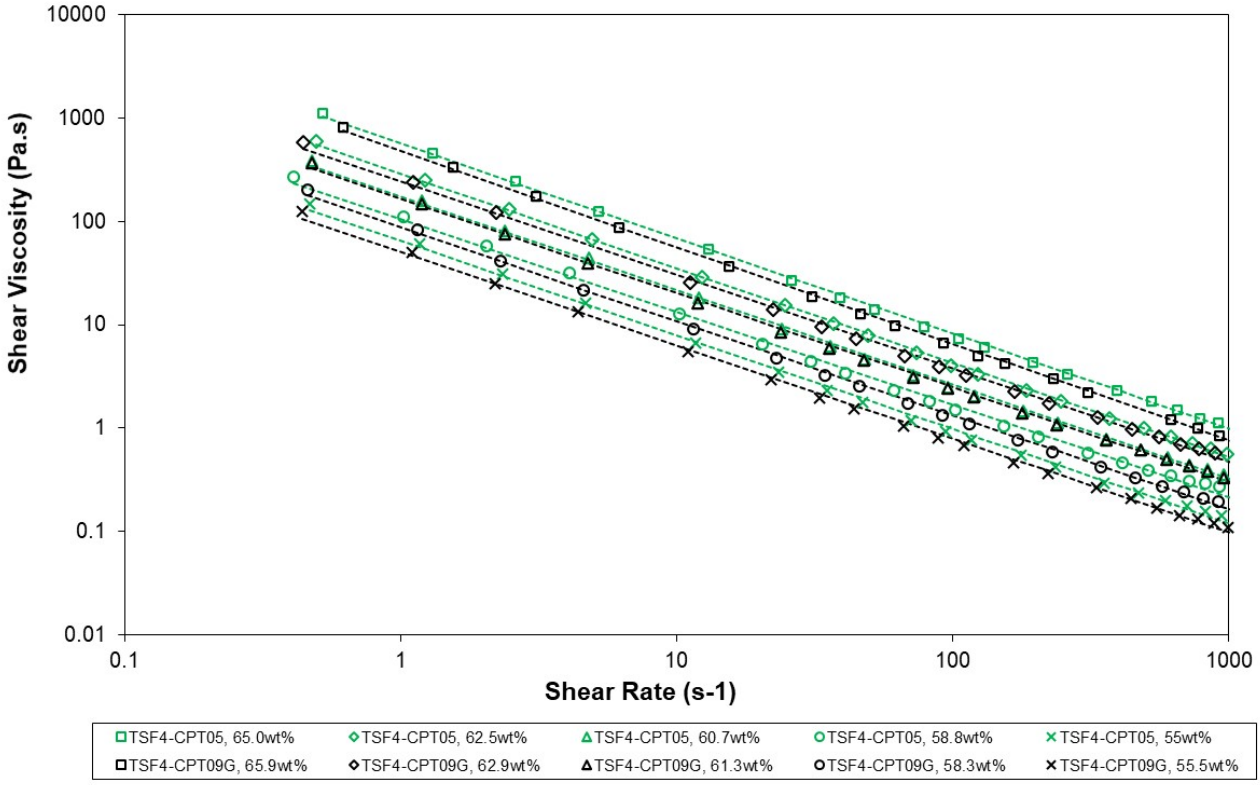


Figure 8 - Shear viscosity vs. shear rate for Saraji Mine TSF 4 samples.

6 CONCLUSION

Saraji Mine samples were received at concentrations ranging from approximately 73wt% up to 98wt%.

Solids SGs ranged from 1.60 to 1.82, with up to 0.13 difference between two composite samples from the one TSF. The SG was lower at shallow depths for TSF 2 and TSF 4, but higher at shallow depth for TSF 3.

The shear yield stress of all tailings samples tested increased exponentially with solids concentration across the range of solids concentrations investigated and model parameters are provided. The yield stress behaviour for the two samples from TSF 3 and TSF 4 were similar to each other, however the two samples from TSF 2 differed from each other significantly, with the TSF2 sample from smaller depth showing a lower yield stress for a given solids concentration than any other sample. The TSF 2-BH07: 6-12 sample also had the lowest SG, and the ranking of yield stress curves was generally seen to follow SG for the Saraji mine samples. At a solids concentration of 55wt% the yield stress ranged from 10Pa (TSF 2-BH07: 6-12) to 80Pa (TSF4-CPT05: 10-13) for the samples tested.

In shear flow, all samples displayed yield - shear thinning (or yield-pseudoplastic) behaviour across the range of solids concentrations and shear rates investigated, with the shear viscosity decreasing in the order of three orders of magnitude across the range of shear rates investigated. For all but one sample, no shear history or time dependence was observed on the time scale of testing, however it should be noted that all samples were fully sheared prior to testing due the sample collection, subsequent sub-sampling and sample preparation methods. The one notable exception was TSF2 BH07 at 71wt%. This sample showed a decrease in the shear stress as the shear rate increased from zero until approximately $100s^{-1}$ before increasing at higher shear rates. The behaviour was reproducible when the same sample was sheared then retested, possibly indicating a localised (but reversible) structuring of the material – possibly due to the presence of asymmetrical particles aligning in the direction of flow. The origin of the behaviour was not investigated.

The ranking of flow curves and viscosity results generally trended with yield stress and solids concentration values as would be expected and the shear stress versus shear rate data was modelled using a Herschel-Bulkley model. The viscosity stress versus shear rate data was well described using a Power Law.

A APPENDIX

A1 Shear Yield Stress Data

Table A 1 - Solids mass fraction (x) versus yield stress (τ_y) data for Saraji Mine Tailings Samples

TSF2-CPT06: 11-13.5			TSF2-BH07: 6-12	
Slurry Average Solids Fraction (total)	Yield Stress		Slurry Average Solids Fraction (total)	Yield Stress
0.4574	6.4305		0.5098	4.1160
0.4954	13.6350		0.5566	12.0900
0.5284	25.0800		0.5979	28.2950
0.5690	53.2450		0.6333	66.2350
0.6104	126.2000		0.6581	132.4500
0.6378	253.1000		0.6804	232.2500
0.6600	438.6500		0.6950	362.6000
0.6742	645.7500		0.7046	504.4000
0.6808	783.6000		0.7159	725.2000
0.6884	1003.2500		0.7241	1010.0000

TSF3-CPT07: 15-17			TSF3-CPT09: 13-16	
Slurry Average Solids Fraction (total)	Yield Stress		Slurry Average Solids Fraction (total)	Yield Stress
0.4430	5.4015		0.4719	5.1445
0.4846	12.6050		0.4823	12.3500
0.5282	29.3200		0.5284	21.6050
0.5653	59.2500		0.5781	54.0150
0.6036	127.4500		0.6120	112.4000
0.6258	206.3000		0.6390	232.0000
0.6529	417.2500		0.6556	388.8000
0.6636	665.2000		0.6734	644.1000
0.6737	832.8000		0.6811	842.1000
0.6820	1075.0000		0.6864	976.5000

Table A 1 - continued

TSF4-CPT05: 10-13			TSF4-CPT09G: 9-10.5	
Slurry Average Solids Fraction (total)	Yield Stress		Slurry Average Solids Fraction (total)	Yield Stress
0.3819	4.1160		0.4296	5.9160
0.4523	12.0900		0.4626	11.5750
0.5106	33.6950		0.5122	27.0100
0.5526	71.5050		0.5527	58.3900
0.5875	138.8000		0.5798	101.8500
0.6147	242.3000		0.6165	218.1500
0.6327	400.5000		0.6478	440.1000
0.6509	582.0000		0.6587	594.8000
0.6632	843.7500		0.6677	814.6000
0.6710	1061.5000		0.6767	997.5000

The shear stress versus shear rate data was curve fitted using a Herschel-Bulkley model :

$\tau = \tau_y + K\dot{\gamma}^n$, where τ is the shear stress (*Pa*) and $\dot{\gamma}$ is the shear rate (s^{-1}) (shown as a dashed line in Figure 3 to Figure 5). The parameters for these curves are given in Table A2 below. Note that model parameters are only valid over the shear rate range measured.

Table A2 Herschel Bulkley model parameters for Saraji Mine Tailings rheology testing.

Shear Stress Table:	***Herschel Bulkley Model: $\tau=\tau_y+Ky^n$***				
sample	τ_y	***K***	***n***	**min shear rate**	**max shear rate**
TSF3-CPT07, 66.5wt%	508.3	37.57	0.3235	0.60	1208.89
TSF3-CPT07, 64.5wt%	331.0	9.18	0.4406	0.56	1410.56
TSF3-CPT07, 61.7wt%	153.8	7.08	0.4550	0.42	1041.78
TSF3-CPT07, 59.5wt%	95.4	0.89	0.6859	0.42	1040.43
TSF3-CPT07, 56.7wt%	54.6	0.21	0.7628	0.43	1072.18
TSF3-CPT09, 66.7wt%	522.1	1.13	0.7723	0.61	1533.46
TSF3-CPT09, 64.2wt%	249.2	1.79	0.6505	0.48	1205.75
TSF3-CPT09, 61.8wt%	115.4	0.46	0.7482	0.47	1163.04
TSF3-CPT09, 58.8wt%	52.6	0.11	0.8045	0.56	1406.20
TSF3-CPT09, 57.5wt%	36.2	0.53	0.5789	0.52	908.80
TSF4-CPT05, 65.0wt%	617.3	19.06	0.4527	0.52	1305.73
TSF4-CPT05, 62.5wt%	317.5	11.11	0.4451	0.49	1231.27
TSF4-CPT05, 60.7wt%	217.2	0.33	0.8886	0.48	1197.07
TSF4-CPT05, 58.8wt%	139.4	0.23	0.8994	0.41	1024.15
TSF4-CPT05, 55wt%	77.0	0.28	0.7793	0.47	1173.20
TSF4-CPT09G, 65.9wt%	529.1	8.41	0.5096	0.62	1542.49
TSF4-CPT09G, 62.9wt%	267.1	7.67	0.5081	0.45	1114.04
TSF4-CPT09G, 61.3wt%	184.6	2.94	0.5752	0.48	1193.66
TSF4-CPT09G, 58.3wt%	93.1	2.43	0.5311	0.46	1148.37
TSF4-CPT09G, 55.5wt%	54.8	2.05	0.4726	0.44	1101.15
TSF2-CPT06, 67.6wt%	588.0	3.21	0.7050	0.48	1199.40
TSF2-CPT06, 65.1wt%	314.3	5.69	0.5829	0.37	920.05
TSF2-CPT06, 61.3wt%	130.1	4.55	0.4781	0.43	1072.29
TSF2-CPT06, 58.9wt%	79.1	2.79	0.4603	0.47	1176.36
TSF2-CPT06, 56.0wt%	40.9	1.77	0.4482	0.43	855.73
TSF2-BH07, 71.0wt%	518.2	0.04	1.1177	6.10	1524.08
TSF2-BH07, 67.3wt%	173.4	0.58	0.7041	0.65	1630.39
TSF2-BH07, 63.5wt%	66.6	0.43	0.6886	0.49	1222.36
TSF2-BH07, 58.3wt%	22.0	0.14	0.7681	0.42	1056.86
TSF2-BH07, 55.0wt%	9.8	0.24	0.6147	0.45	787.53

The viscosity stress versus shear rate data was curve fitted using a Power Law model: $\eta = a\dot{\gamma}^b$, where η is the shear viscosity (*Pa.s*) and $\dot{\gamma}$ is the shear rate (s^{-1}), (shown as a dashed line in Figure 6 to Figure 8Figure 8 - Shear viscosity vs. shear rate for Saraji Mine TSF 4 samples.). The parameters for these curves are given in Table A3 below. Note that model parameters are only valid over the shear rate range measured.

Table A3. Power law model parameters for Saraji Mine Tailings **rheology testing.**

Viscosity Table:	***Power Law Model $\eta=K\dot{\gamma}^n$***			
sample	***K***	***n***	**min shear rate**	**max shear rate**
TSF3-CPT07, 66.5wt%	509.1	-0.9307	0.60	1208.89
TSF3-CPT07, 64.5wt%	303.8	-0.9258	0.56	1410.56
TSF3-CPT07, 61.7wt%	143.9	-0.8995	0.42	1041.78
TSF3-CPT07, 59.5wt%	84.2	-0.8994	0.42	1040.43
TSF3-CPT07, 56.7wt%	41.5	-0.9023	0.43	1072.18
TSF3-CPT09, 66.7wt%	446.8	-0.9317	0.61	1533.46
TSF3-CPT09, 64.2wt%	218.3	-0.9236	0.48	1205.75
TSF3-CPT09, 61.8wt%	93.5	-0.9100	0.47	1163.04
TSF3-CPT09, 58.8wt%	44.4	-0.9255	0.56	1406.20
TSF3-CPT09, 57.5wt%	33.1	-0.9227	0.52	908.80
TSF4-CPT05, 65.0wt%	568.7	-0.9198	0.52	1305.73
TSF4-CPT05, 62.5wt%	290.5	-0.9150	0.49	1231.27
TSF4-CPT05, 60.7wt%	176.2	-0.9125	0.48	1197.07
TSF4-CPT05, 58.8wt%	105.5	-0.8978	0.41	1024.15
TSF4-CPT05, 55wt%	64.8	-0.9107	0.47	1173.20
TSF4-CPT09G, 65.9wt%	481.6	-0.9321	0.62	1542.49
TSF4-CPT09G, 62.9wt%	245.2	-0.9060	0.45	1114.04
TSF4-CPT09G, 61.3wt%	165.7	-0.9123	0.48	1193.66
TSF4-CPT09G, 58.3wt%	87.5	-0.9088	0.46	1148.37
TSF4-CPT09G, 55.5wt%	51.0	-0.9049	0.44	1101.15
TSF2-CPT06, 67.6wt%	493.7	-0.9127	0.48	1199.40
TSF2-CPT06, 65.1wt%	254.0	-0.8862	0.37	920.05
TSF2-CPT06, 61.3wt%	117.6	-0.9023	0.43	1072.29
TSF2-CPT06, 58.9wt%	72.8	-0.9110	0.47	1176.36
TSF2-CPT06, 56.0wt%	36.1	-0.9021	0.43	855.73
TSF2-BH07, 71.0wt%	371.6	-0.9358	6.10	1524.08
TSF2-BH07, 67.3wt%	150.3	-0.9358	0.65	1630.39
TSF2-BH07, 63.5wt%	57.5	-0.9143	0.08	1222.36
TSF2-BH07, 58.3wt%	19.3	-0.8914	0.42	1056.86
TSF2-BH07, 55.0wt%	9.9	-0.8997	0.45	787.53

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13. Nguyen, Q.D. and D.V. Boger, *Measuring the Flow Properties of Yield Stress Fluids.* Annual Review of Fluid Mechanics, 1992. **24**(1): p. 47-88.

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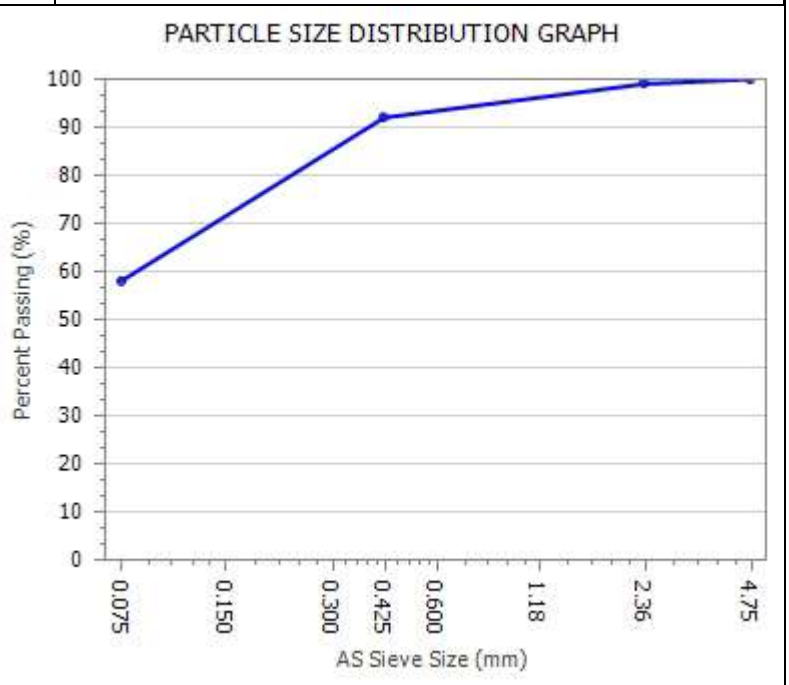
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QUALITY OF MATERIALS REPORT

Client:	EDG Consulting PTY LTD	Report Number:	14892/R/27161-1
Client Address:	Level 1, 18 Wandoo st, Fortitude Valley	Project Number:	14892/P/907
Project:	Saraji Mine Laboratory Testing	Lot Number:	
Location:	Saraji Mine	Internal Test Request:	14892/T/15685
Supplied To:	n/a	Client Reference/s:	TFS4 Testing
Area Description:		Report Date / Page:	26/10/2020 Page 24 of 25

Test Procedures	AS1289.3.6.1, AS1289.3.1.2, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1, AS 1289.3.3.1		
Sample Number	14892/S/70715	Location:	TFS4-CPT03
Sampling Method	Tested As Received		1.50-1.95
Date Sampled	14/10/2020		SPT
Sampled By	Client Sampled		
Date Tested	19/10/2020	Material Source	ONSITE
Att. Drying Method	Oven Dried	Material Type	EXISTING
Atterberg Preparation	Dry Sieved	Material Description	.

AS Sieve (mm)	Specification Minimum (%)	**Percent Passing (%)**	Specification Maximum (%)
4.75		**100**	
2.36		**99**	
0.425		**92**	
0.075		**58**	



Test Result	Specification Minimum (%)	**Result**	Specification Maximum (%)
Liquid Limit (%)		**26**	
Plastic Limit (%)		**20**	
Plastic Index (%)		**6**	
Linear Shrinkage (%)		**2.0**	

Test Result	Specification Minimum (%)	**Result (%)**	Specification Maximum (%)
0.075/0.425 Fines Ratio		**0.63**	
PI x 0.425 Ratio (%)		**553.6**	
LS x 0.425 Ratio (%)		**184.5**	
Linear Shrinkage Defects	-		

Remarks: Results apply to the sample/s as received.

Accredited for compliance with ISO/IEC 17025 – Testing

Accreditation Number: 1986
Corporate Site Number: 14892

Approved Signatory: Zachery Zarb
Form ID: W85Rep Rev 2

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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	EDG Consulting	**Report No.**	21050067-G
		Workorder No.	8593
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Report Date**	17/05/2021
Project	B01229-4 - TSF2-4 - Saraji Mine		

Sample No.	21050067	21050068	21050069	21050070			
Test Date	10/05/2021	10/05/2021	10/05/2021	10/05/2021			
Client ID	TSF3-CPT07	TSF3-CPT09	TSF4-CPT06	TSF4-CPT07			
Depth (m)	10.00-10.50	10.00-10.80	11.00-11.80	7.50-8.00			
Moisture (%)	31.7	40.4	33.2	33.3			
AS SIEVE SIZE (mm)	**PERCENT PASSING**						
150							
75							
63							
53							
37.5							
26.5							
19							
13.2							
9.5							
6.7							
4.75							
2.36							
1.18							
0.600							
0.425	100	100					
0.300	99	99	100	100			
0.212	97	99	99	100			
0.150	94	98	96	99			
0.075	86	93	84	92			

NOTES/REMARKS:

Sample/s supplied by the client

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The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Channon

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ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory No. 9926

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ACCURATE QUALITY RESULTS FOR TOMORROW'S ENGINEERING

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PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.1, 2.1.1

Client	EDG Consulting	**Report No.**	20100564-G
		Workorder No.	7941
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Report Date**	18/11/2020
Project	B01229-4 - TSF2-4 - TSF4, Saraji Mine		

Sample No.	20100564	20100565	20100566				
Test Date	4/11/2020	12/11/2020	12/11/2020				
Client ID	TSF4-BH01	TSF4-BH03	TSF4-CPT07				
Depth (m)	22.50-22.95	16.50-16.95	10.50				
Moisture (%)	17.2	13.2	28.7				
AS SIEVE SIZE (mm)	**PERCENT PASSING**						
150							
75							
63							
53							
37.5							
26.5							
19							
13.2							
9.5		100					
6.7		99					
4.75		99					
2.36		95					
1.18	100	90					
0.600	99	84	100				
0.425	96	79	96				
0.300	88	73	93				
0.150	67	57	85				
0.075	48	47	73				

NOTES/REMARKS:

Sample/s supplied by the client

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Tested at Trilab Brisbane Laboratory

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ATTERBERG LIMITS TEST REPORT

Test Methods: AS 1289 2.1.1, 3.2.1, 3.3.1, 3.4.1

Client	EDG Consulting	**Report No.**	21050067-AL
		Workorder No.	0008593
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Report Date**	19/05/2021
Project	B01229-4 - TSF2-4 - Saraji Mine		

Sample No.	21050067	21050068	21050069	21050070		
Liquid Limit Determination	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2	AS 1289.3.1.2		
Test Date	14/05/2021	14/05/2021	14/05/2021	14/05/2021		
Client ID	TSF3-CPT07	TSF3-CPT09	TSF4-CPT06	TSF4-CPT07		
Depth (m)	10.00-10.50	10.00-10.80	11.00-11.80	7.50-8.00		
Liquid Limit (%)	42	44	40	41		
Plastic Limit (%)	22	23	22	24		
Plasticity Index (%)	20	21	18	17		
Linear Shrinkage (%)	5.5	6.5	4.5	6.0		
Moisture Content (%)	31.7	40.4	33.2	33.3		

Sample No.						
Liquid Limit Determination						
Test Date						
Client ID						
Depth (m)						
Liquid Limit (%)						
Plastic Limit (%)						
Plasticity Index (%)						
Linear Shrinkage (%)						
Moisture Content (%)						

NOTES/REMARKS: The samples were tested oven dried, dry sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred

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ATTERBERG LIMITS TEST REPORT

Test Method: AS 1289 2.1.1, 3.1.1, 3.1.2, 3.2.1, 3.3.1, 3.4.1

Client	EDG Consulting	**Report No.**	20100566-AL
		Workorder No.	0007941
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Report Date**	13/11/2020
Project	B01229-4 - TSF2-4 - TSF4, Saraji Mine		

Sample No.	20100566
Test Date	10/11/2020
Client ID	TSF4-CPT07
Depth (m)	10.50
Liquid Limit (%)	35
Plastic Limit (%)	22
Plasticity Index (%)	13
Linear Shrinkage (%)	3.5 *
Moisture Content (%)	28.7

NOTES/REMARKS: The samples were tested oven dried, dry sieved and in a 125-250mm mould.

Sample/s supplied by the client * Cracking occurred + Curling occurred

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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.2

Client:	EDG Consulting	**Report No.:**	20100566 - CU
		Workorder No.	0007941
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	6/11/2020
		Report Date:	20/11/2020
Project:	B01229-4 - TSF2-4 - TSF4, Saraji Mine		
Client Id.:	TSF4-CPT07	**Depth (m):**	10.50
Description:	SILTY CLAY - black		

SAMPLE & TEST DETAILS

Initial Height:	129.7	mm	Initial Moisture Content:	28.7	%	Rate of Strain:	0.004	%/min
Initial Diameter:	59.2	mm	Final Moisture Content:	20.4	%	B Response:	97	%
L/D Ratio:	2.2 : 1		Wet Density:	1.51	t/m^3			
			Dry Density:	1.17	t/m^3			

Sample Type: Single Individual Undisturbed Specimen.

TEST RESULTS

FAILURE DETAILS

Effective Pressure	Confining Pressure	Back Pressure	Initial Pore	Failure Pore	*Principal Effective Stresses*			*Deviator Stress*	*Strain*
					σ'_1	σ'_3	σ'_1 / σ'_3		
180 kPa	677 kPa	497 kPa	497 kPa	570 kPa	291 kPa	107 kPa	2.721	184 kPa	2.48 %
362 kPa	660 kPa	298 kPa	298 kPa	464 kPa	575 kPa	196 kPa	2.939	379 kPa	5.22 %
719 kPa	1019 kPa	300 kPa	300 kPa	474 kPa	1691 kPa	544 kPa	3.109	1147 kPa	13.66 %

FAILURE ENVELOPES

Interpretation between stages :	**1 to 2**	**2 to 3**	**1 to 3**
Cohesion C' (kPa) :	**-14.4**	**-14.4**	**-14.4**
Angle of Shear Resistance Φ' (Degrees) :	**31.6**	**31.6**	**31.6**
Failure Criteria:	Peak Principal Stress Ratio		

Remarks: Tested as Received.
Sample/s supplied by the client

REP03001

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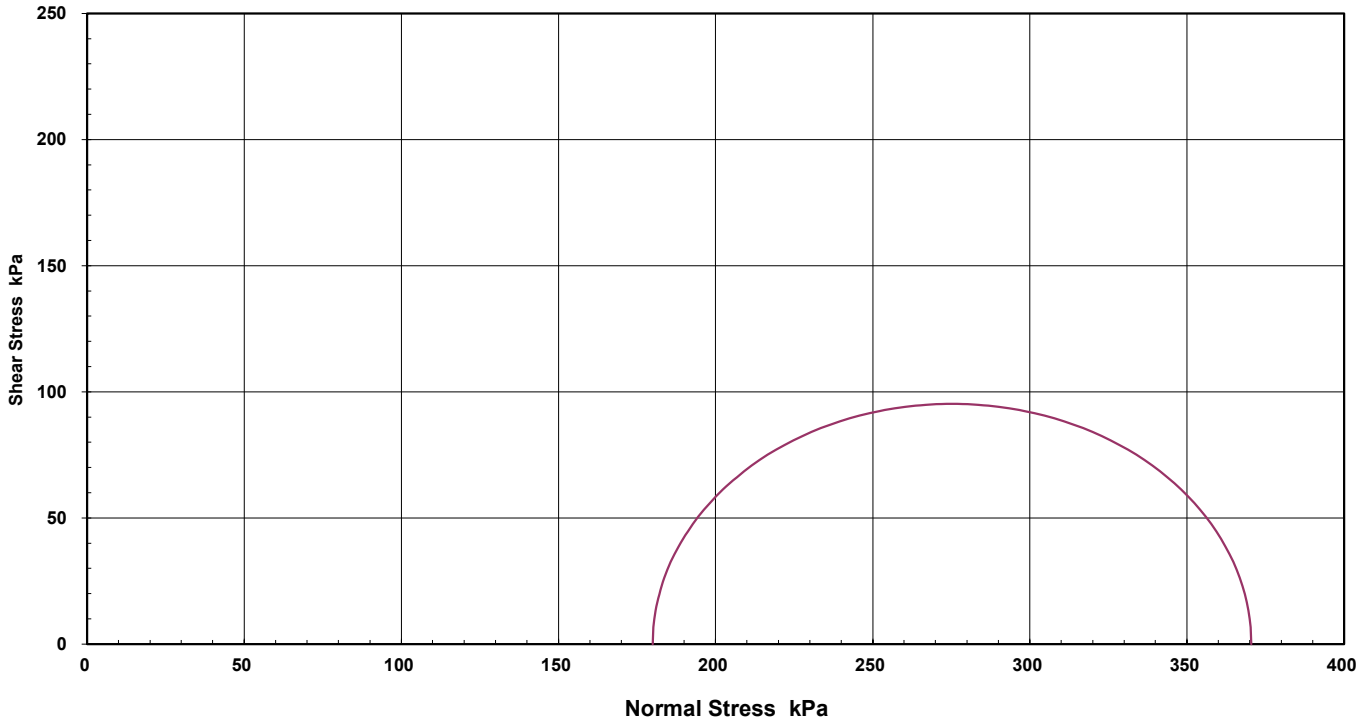
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TRIAXIAL TEST REPORT

Test Method: AS1289.6.4.1

Client	EDG Consulting	**Report No.**	20100566- UU
		Workorder No.	0007941
Address	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date**	6/11/2020
		Report Date	10/11/2020
Project	B01229-4 - TSF2-4 - TSF4, Saraji Mine		
Client ID	TSF4-CPT07	**Depth (m)**	10.50
Description	SILTY CLAY-black	**Sample Type**	Single Individual Undisturbed Specimen

Mohr Circle Diagram



Interpretation between stages

Cohesion C (kPa)

Angle of Shear Resistance Φ (^{0})

MOISTURE CONTENTS **Initial** 29.7 % **Final** 29.7 %

Failure Criteria Peak Shear Stress

SAMPLE & TEST DETAILS

Sample Details		
Initial Height	128.9	mm
Initial Diameter	59.2	mm
Wet Density	1.43	t/m^3
Dry Density	1.10	t/m^3
Rate of Strain	0.465	% / min

FAILURE DETAILS

Confining Pressure	Principal Stresses σ_1	Principal Stresses σ_3	Deviator Stress	Strain
180 kPa	370 kPa	180 kPa	190 kPa	13.05 %

Notes/Remarks:

Graph not to scale

Tested as received

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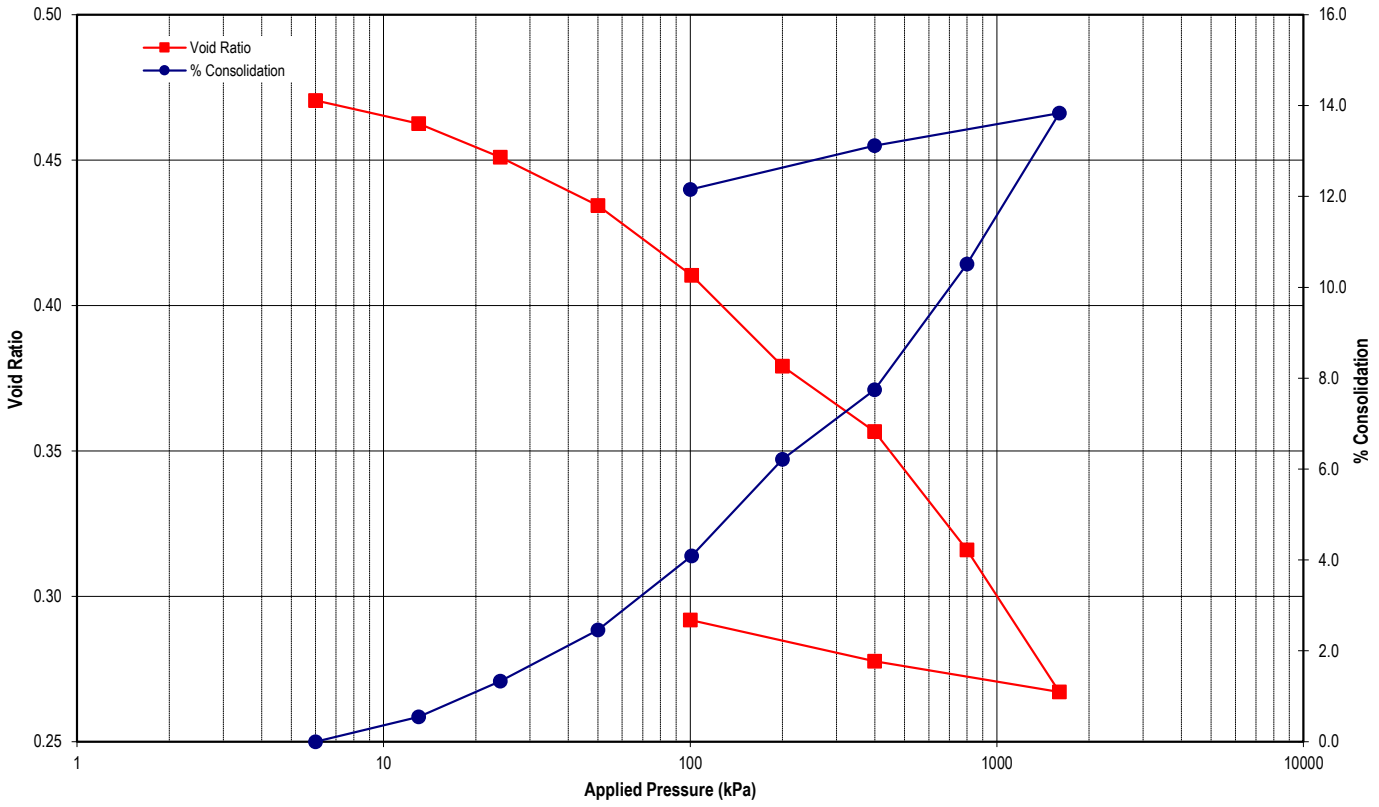
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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050069-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	7/05/2021
		Report Date:	26/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF4-CPT06	**Depth (m):**	11.00-11.80
Description:	SILTY CLAY- black		



Initial Wet Density (t/m^3):	1.48	Initial Moisture (%):	34.3	Initial Height (mm):	19.95
Initial Dry Density (t/m^3):	1.10	Final Moisture (%):	25.8	Final Height (mm):	17.50
Initial Mass (g):	51.44	Initial Voids Ratio:	0.473	Test Condition:	Inundated on load
Particle Density (t/m^3):	1.62	Initial Degree of Saturation (%):	100.0	Undisturbed sample supplied by the client	

Remarks: Tested as Received

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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050069-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	7/05/2021
		Report Date:	26/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF4-CPT06	**Depth (m):**	11.00-11.80
Description:	SILTY CLAY- black		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-13	0.024	5.1E-09	16.44	20.94	0.779	0.44	0.5
2	13-24	0.043	3.5E-09	12.82	15.91	0.718	0.60	1.3
3	24-50	0.052	3.0E-09	23.44	21.62	0.440	0.80	2.5
4	50-101	0.078	2.0E-09	22.41	19.81	0.328	0.87	4.1
5	101-200	0.105	1.7E-09	32.33	24.67	0.224	1.05	6.2
6	200-399	0.075	6.8E-10	33.76	26.59	0.082	0.92	7.7
7	399-800	0.135	6.1E-10	38.26	26.44	0.075	1.94	10.5
8	800-1600	0.162	3.1E-10	29.64	21.38	0.046	1.83	13.8
9	1600-399	0.017	7.5E-11	72.09	34.92	0.007	0.23	13.1
10	399-100	0.024	3.1E-10	40.05	26.98	0.037	0.61	12.2

Remarks: Tested as Received

REP03103

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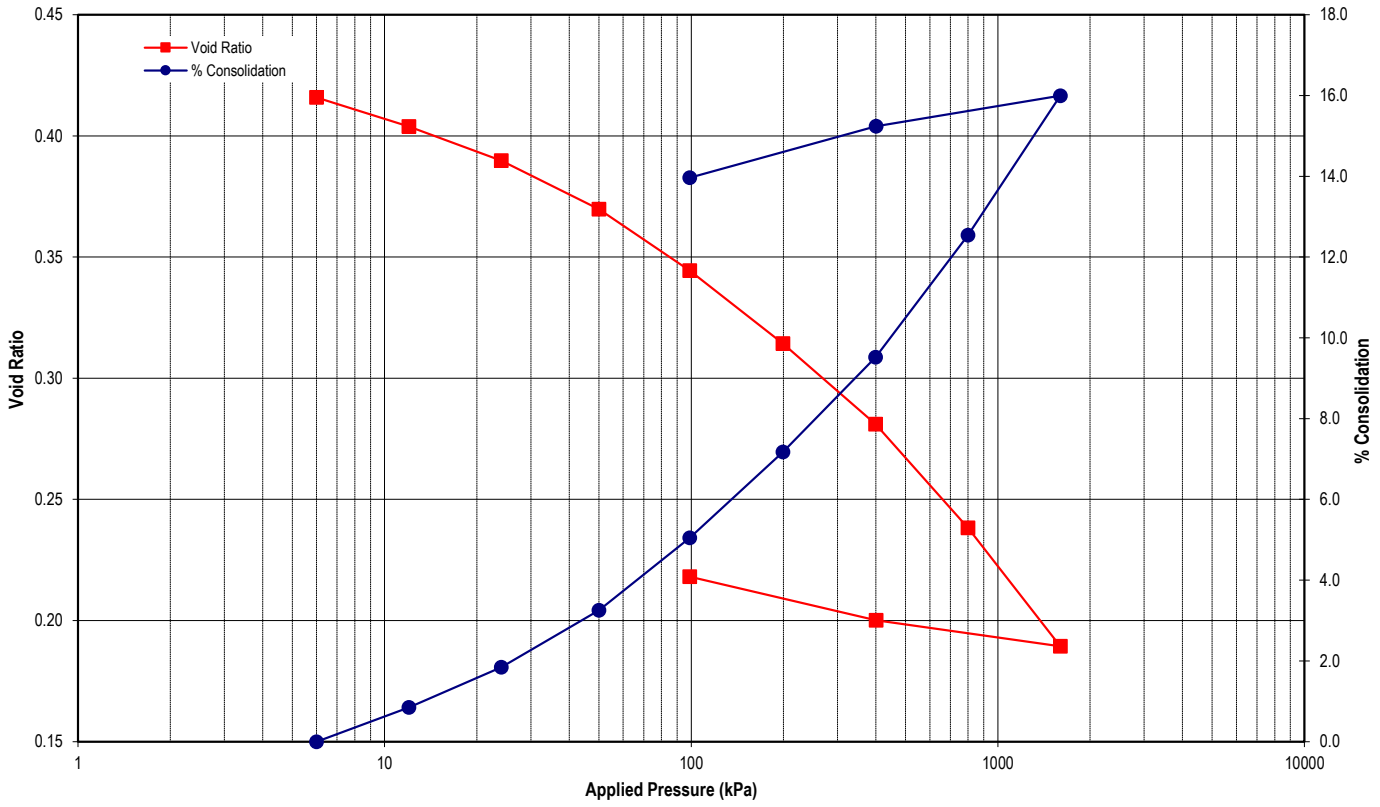
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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050070-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	7/05/2021
		Report Date:	26/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF4-CPT07	**Depth (m):**	7.50-8.00
Description:	-		



Initial Wet Density (t/m^3):	1.54	Initial Moisture (%):	33.7	Initial Height (mm):	20.10
Initial Dry Density (t/m^3):	1.15	Final Moisture (%):	23.5	Final Height (mm):	17.29
Initial Mass (g):	92.35	Initial Voids Ratio:	0.416	Test Condition:	Inundated on load
Particle Density (t/m^3):	1.63	Initial Degree of Saturation (%):	100.0	Undisturbed sample supplied by the client	

Remarks: Tested as Received

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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050070-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	7/05/2021
		Report Date:	26/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF4-CPT07	**Depth (m):**	7.50-8.00
Description:	-		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-12	0.040	4.1E-09	6.30	9.26	1.412	0.64	0.8
2	12-24	0.047	3.5E-09	9.01	13.51	0.836	0.87	1.8
3	24-50	0.063	2.7E-09	13.28	15.55	0.554	1.10	3.3
4	50-99	0.086	1.9E-09	13.82	16.08	0.378	1.16	5.0
5	99-199	0.099	1.2E-09	18.77	17.49	0.224	1.39	7.2
6	199-399	0.110	7.9E-10	22.82	20.22	0.126	1.59	9.5
7	399-799	0.142	5.8E-10	24.19	22.24	0.084	1.71	12.5
8	799-1599	0.162	3.1E-10	28.13	20.08	0.049	2.23	16.0
9	1599-401	0.018	9.9E-11	61.39	42.54	0.008	0.26	15.2
10	401-99	0.030	2.9E-10	22.81	18.73	0.050	0.73	14.0

Remarks: Tested as Received

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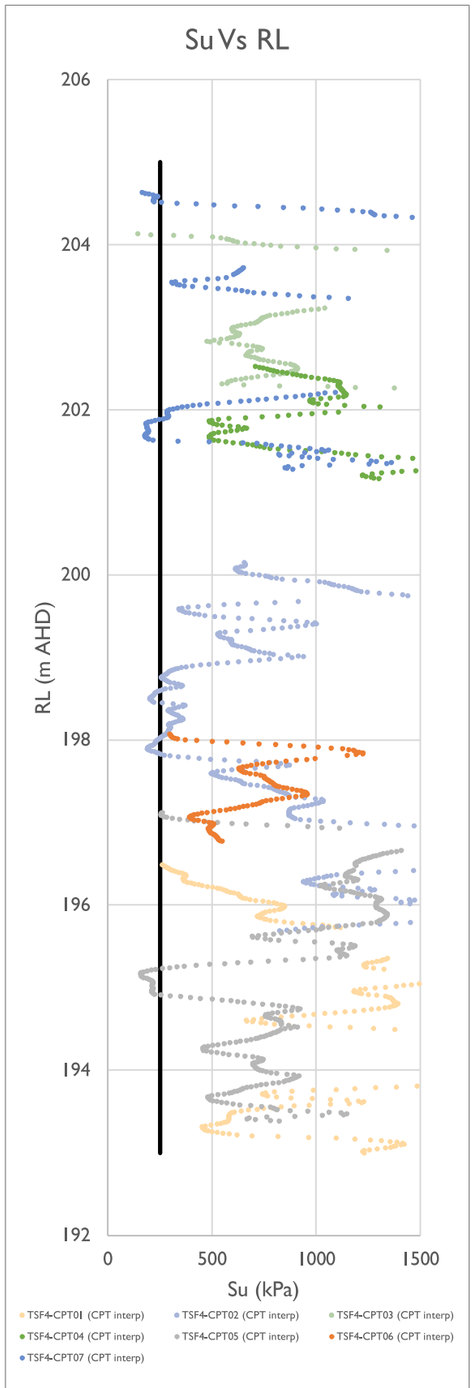
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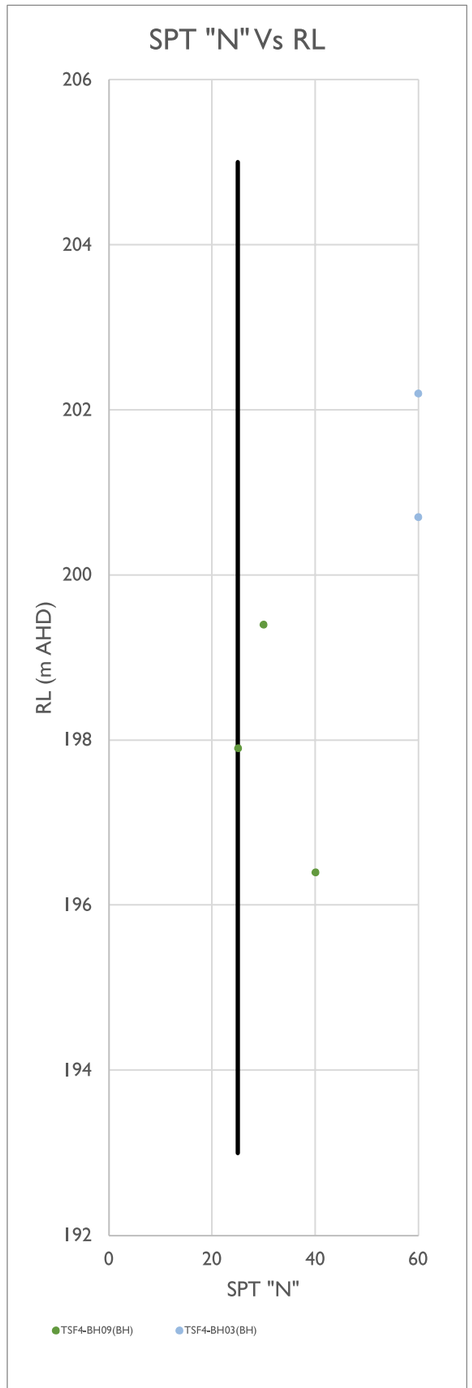
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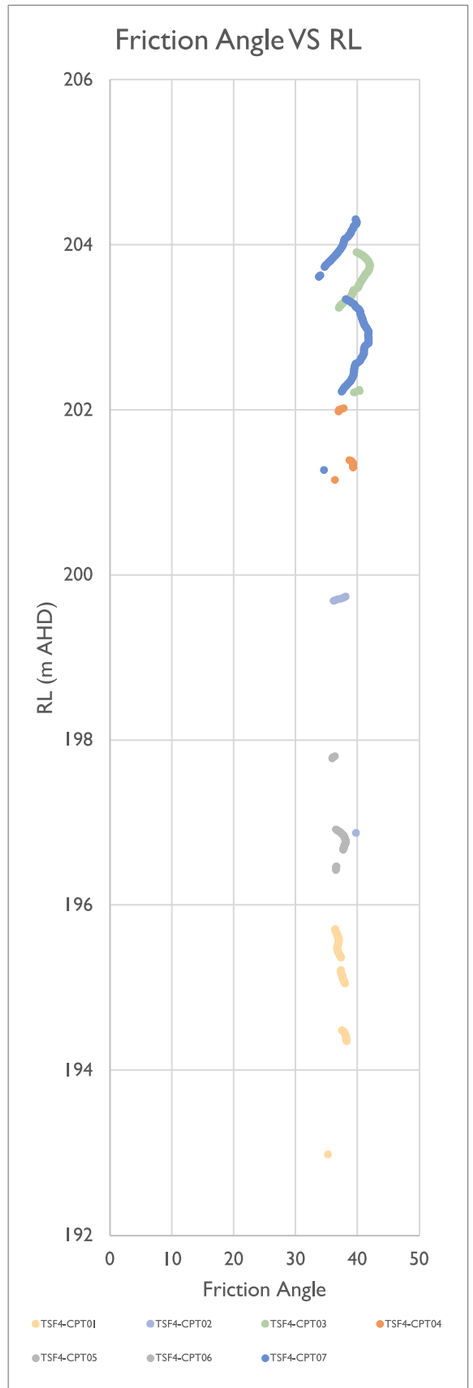
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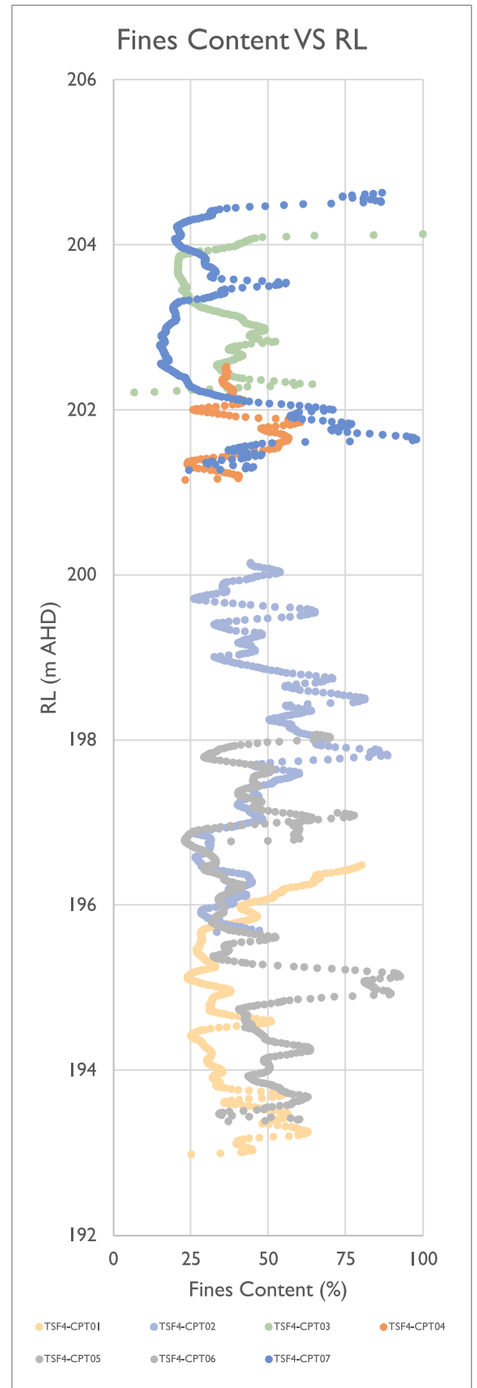
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location:	TSF4	*by:*	DL
title:	*Material Characterisation Summary - Residual Soil / Extremely Weathered Material*		

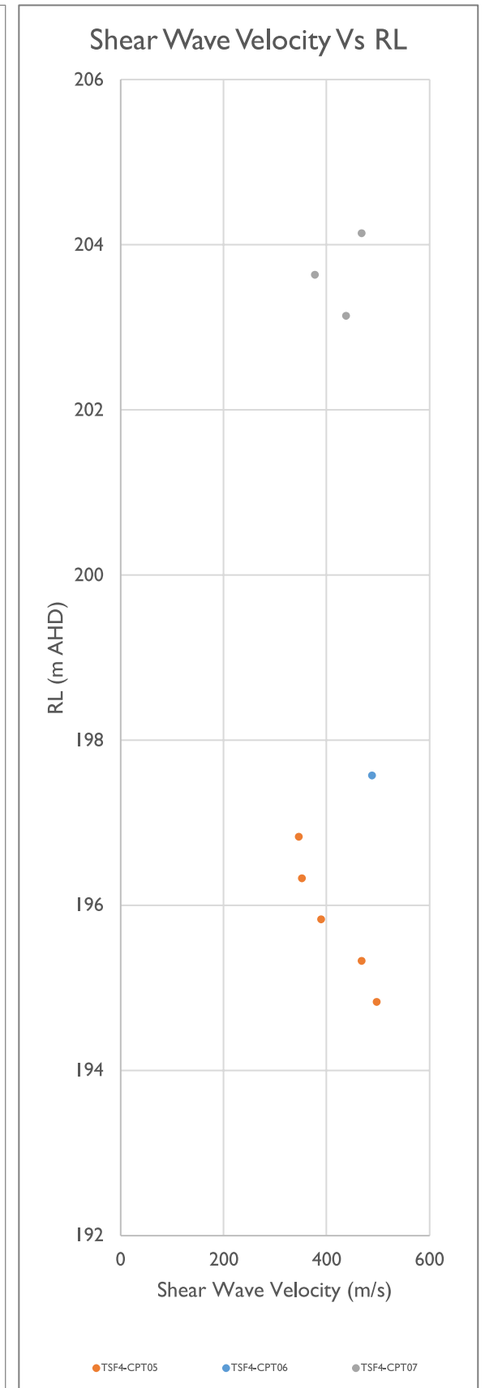
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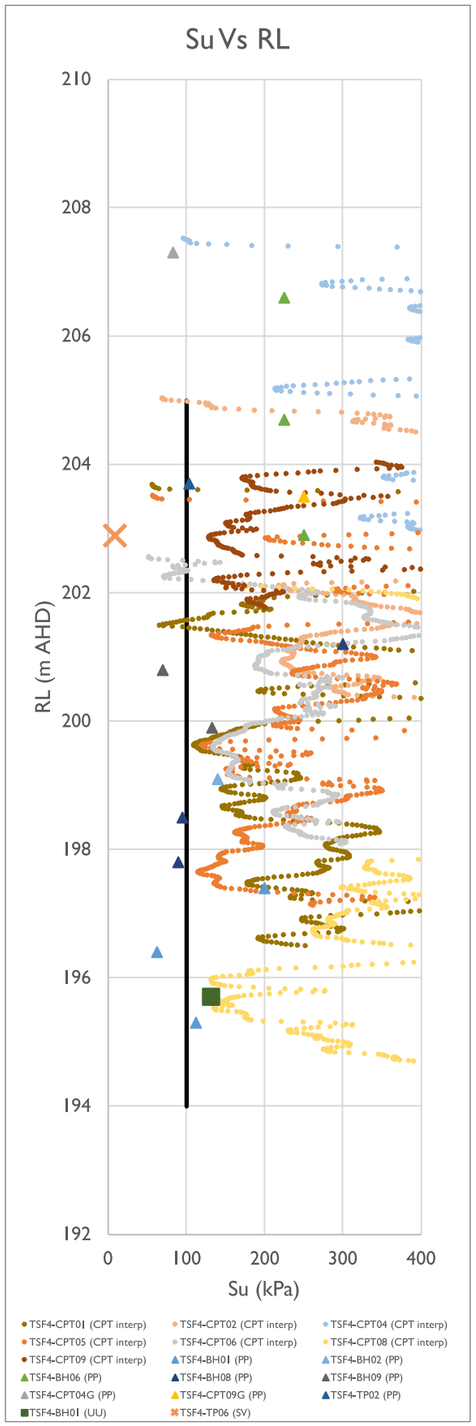


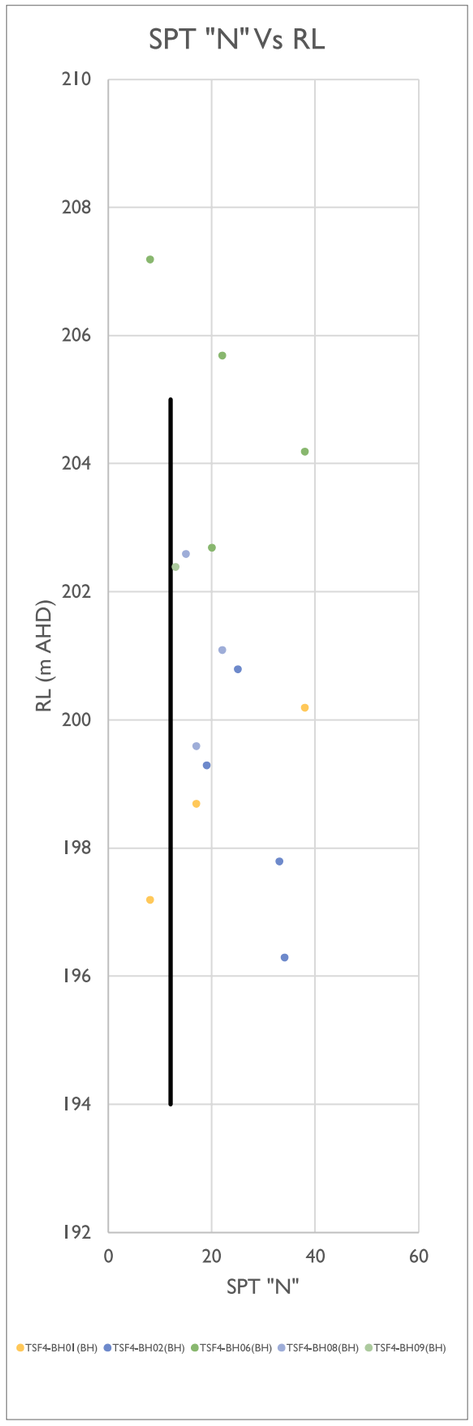


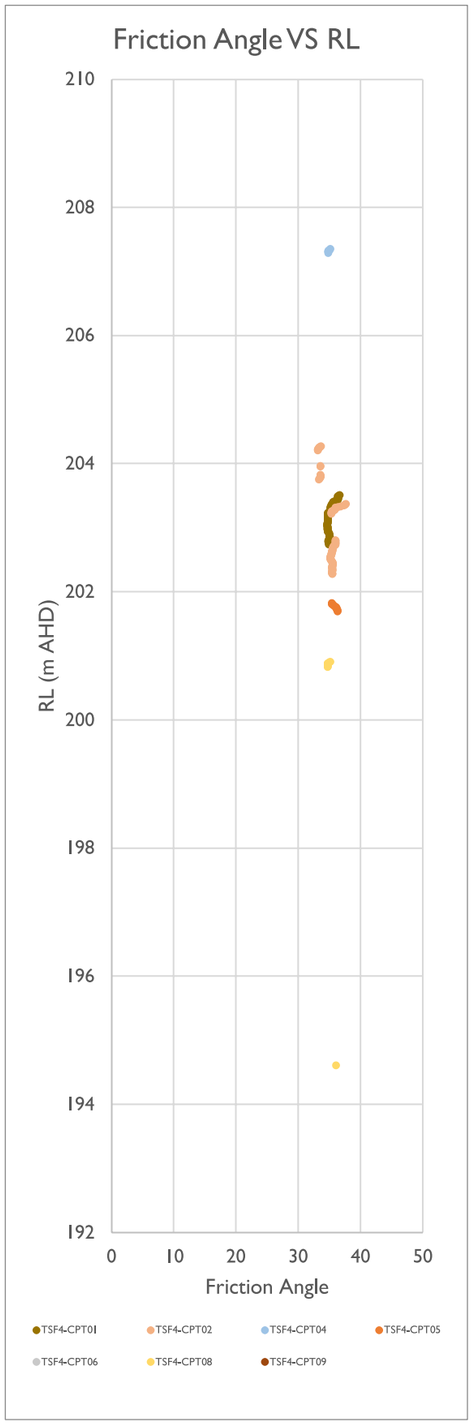
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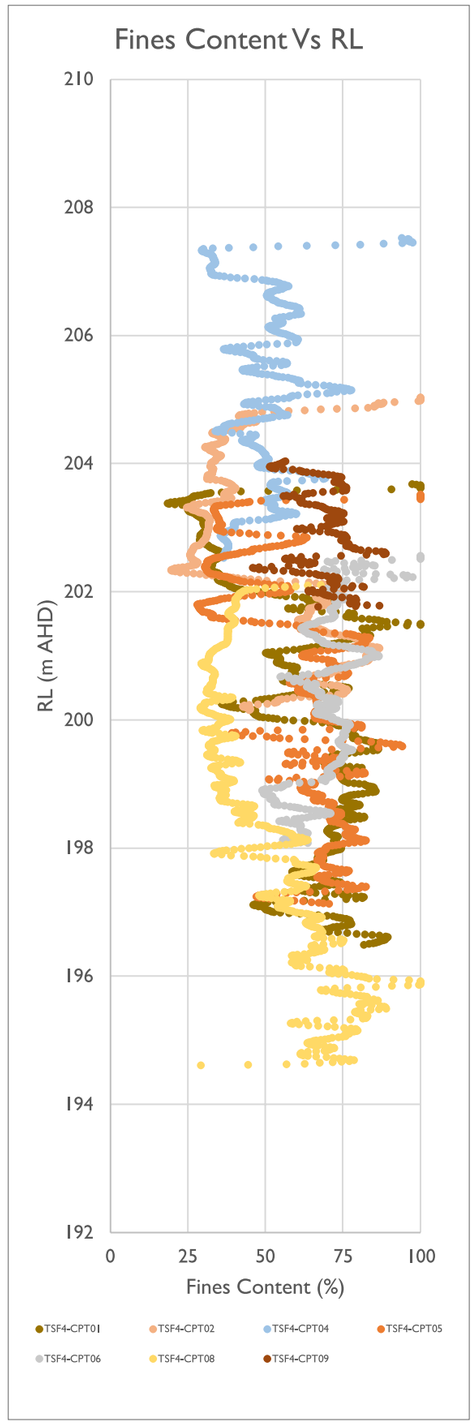
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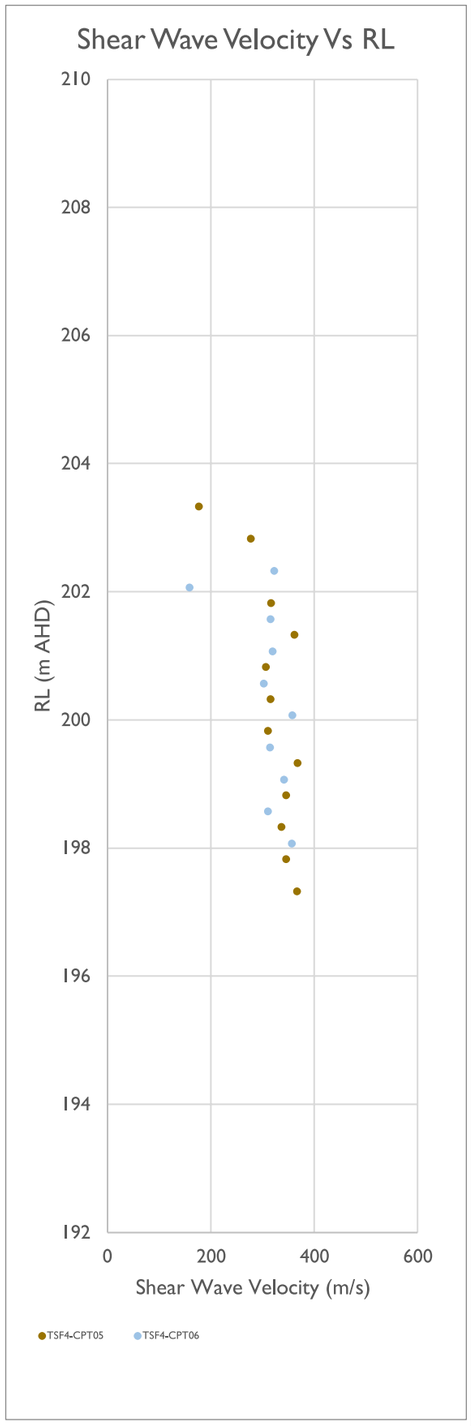
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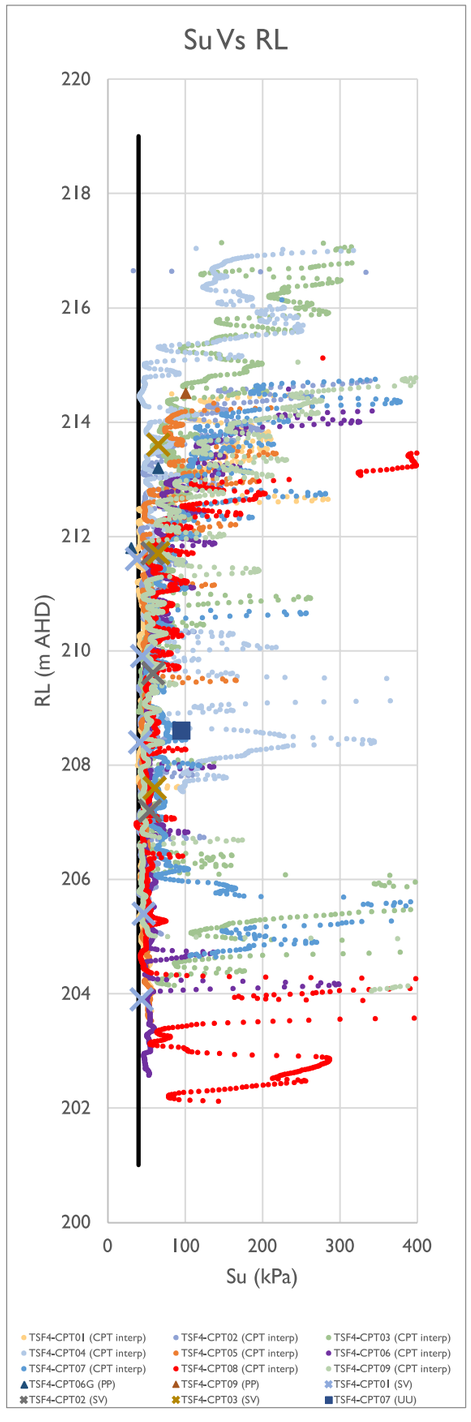


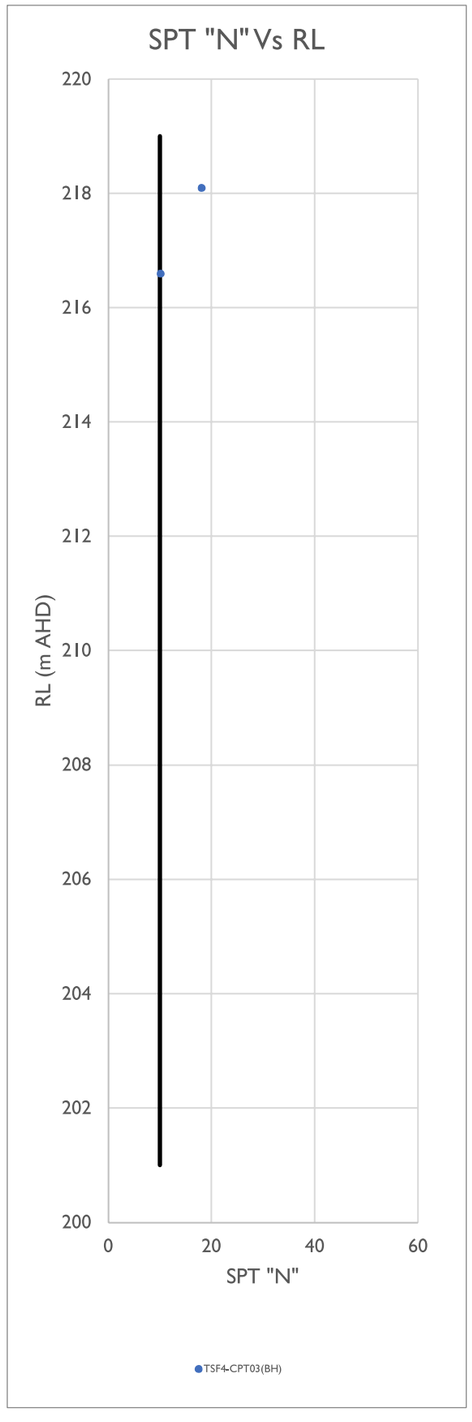


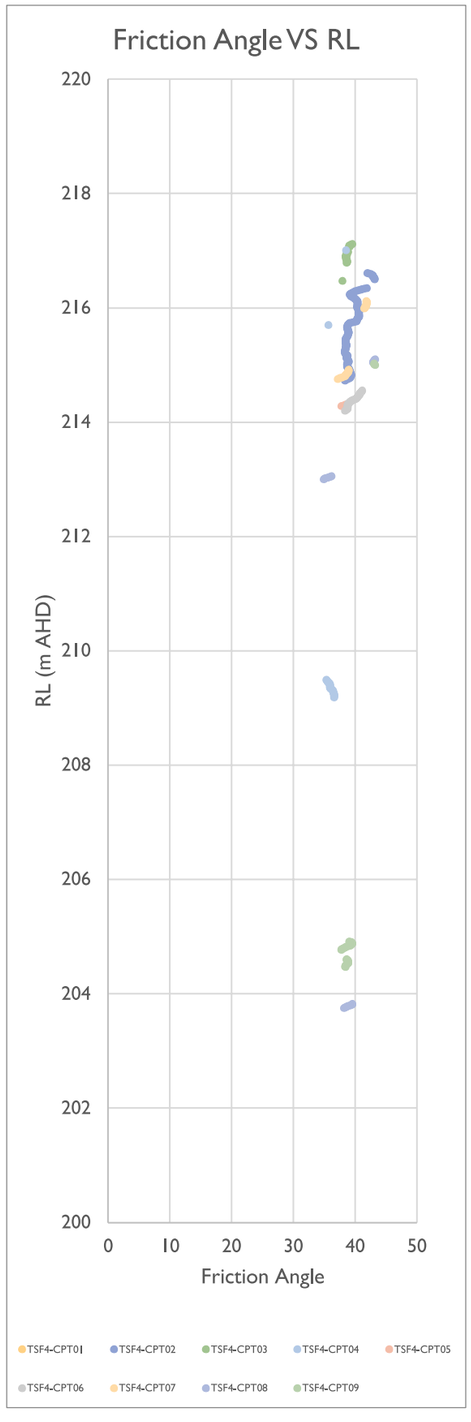
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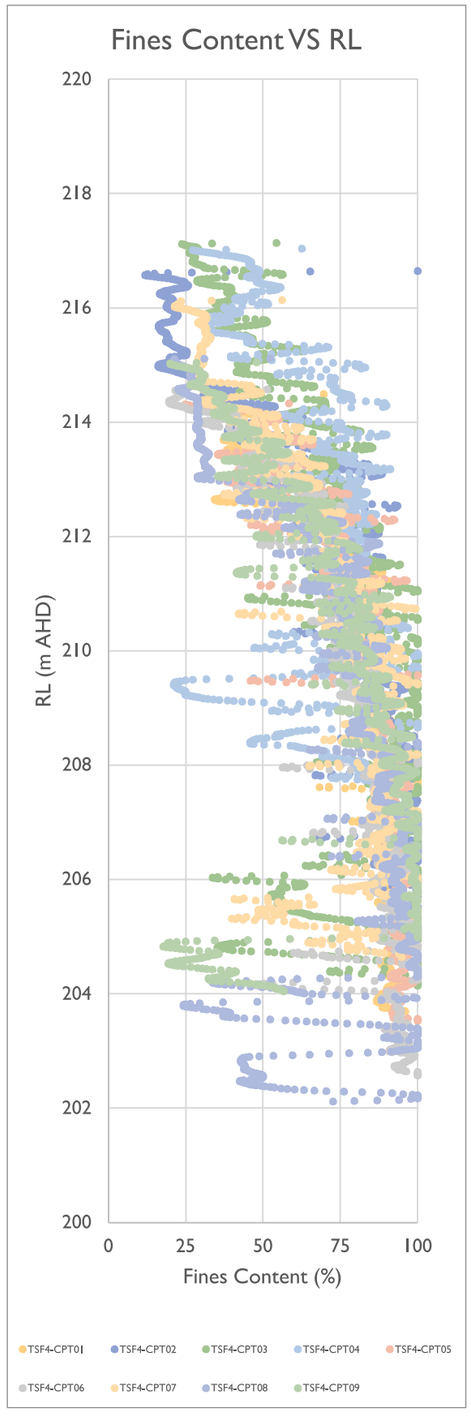
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project:	SRM TSF2-4	*date:*	20/08/2021
location:	TSF4	*by:*	DL
title:	*Material Characterisation Summary - Tailings*		

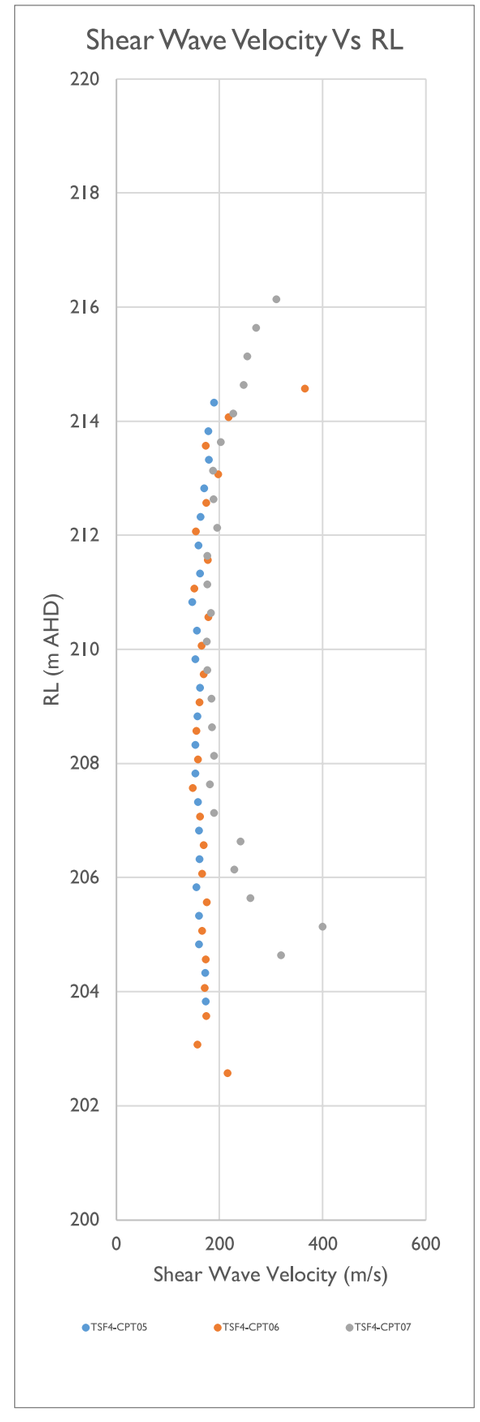
EDG consulting
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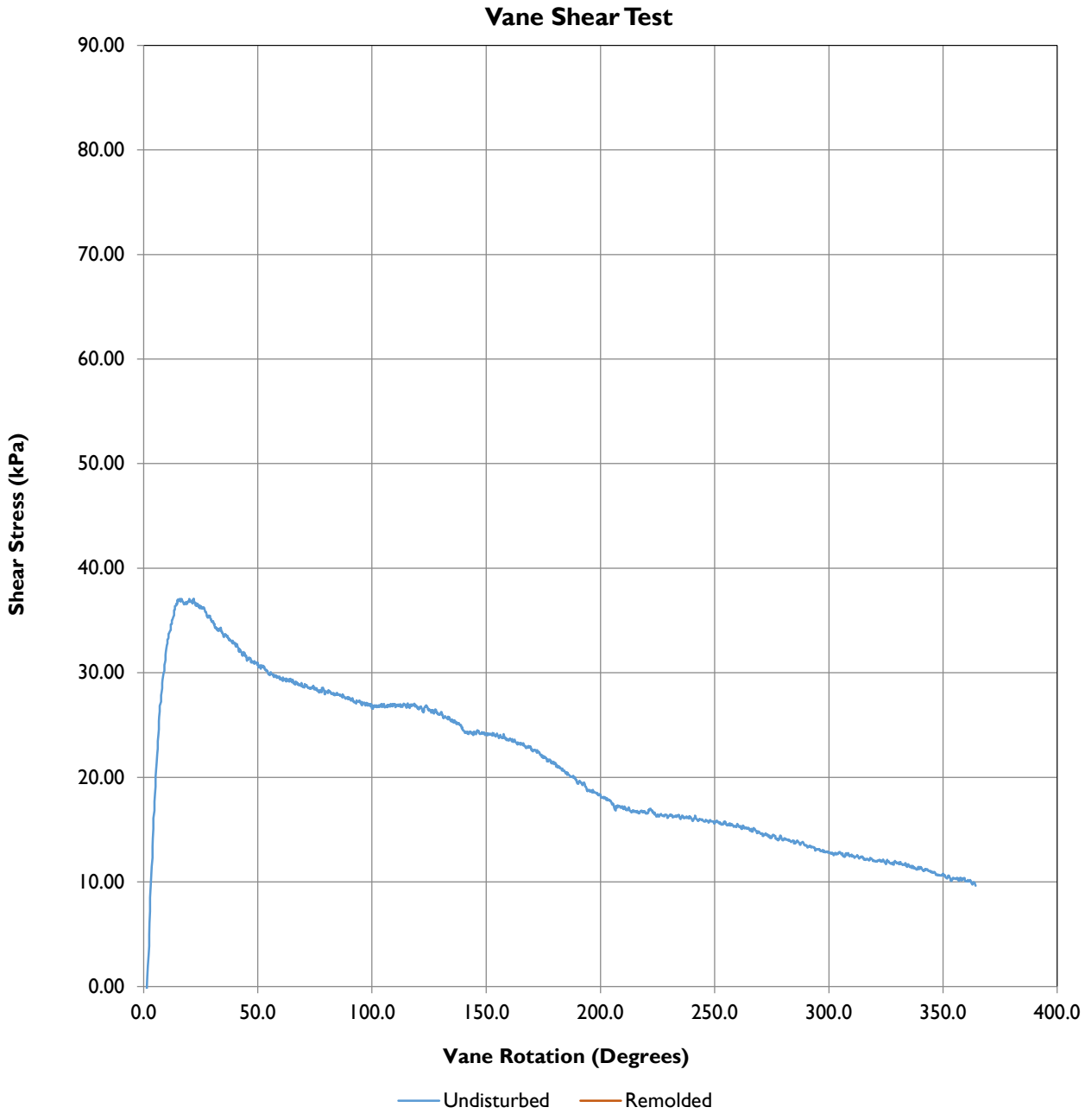
Vane Shear Test

Test Location:	**TSF4-CPT01**
Test Depth:	**5.80**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**5/10/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF4**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631502.5*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522411.9*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	217.5m (AHD)



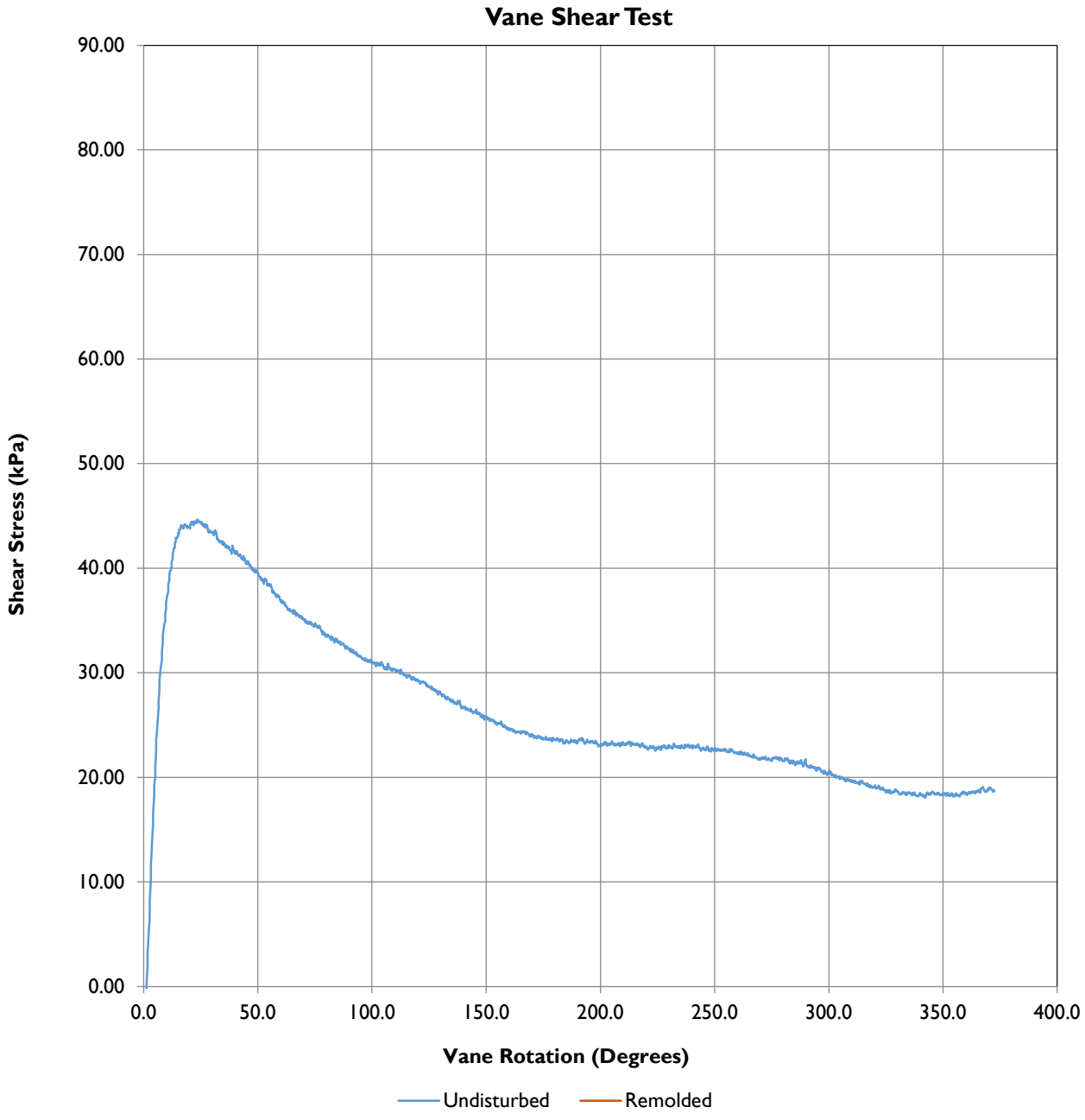
Vane Shear Test

Test Location:	**TSF4-CPT01**
Test Depth:	**7.50**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**5/10/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF4**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631502.5*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522411.9*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	217.5m (AHD)



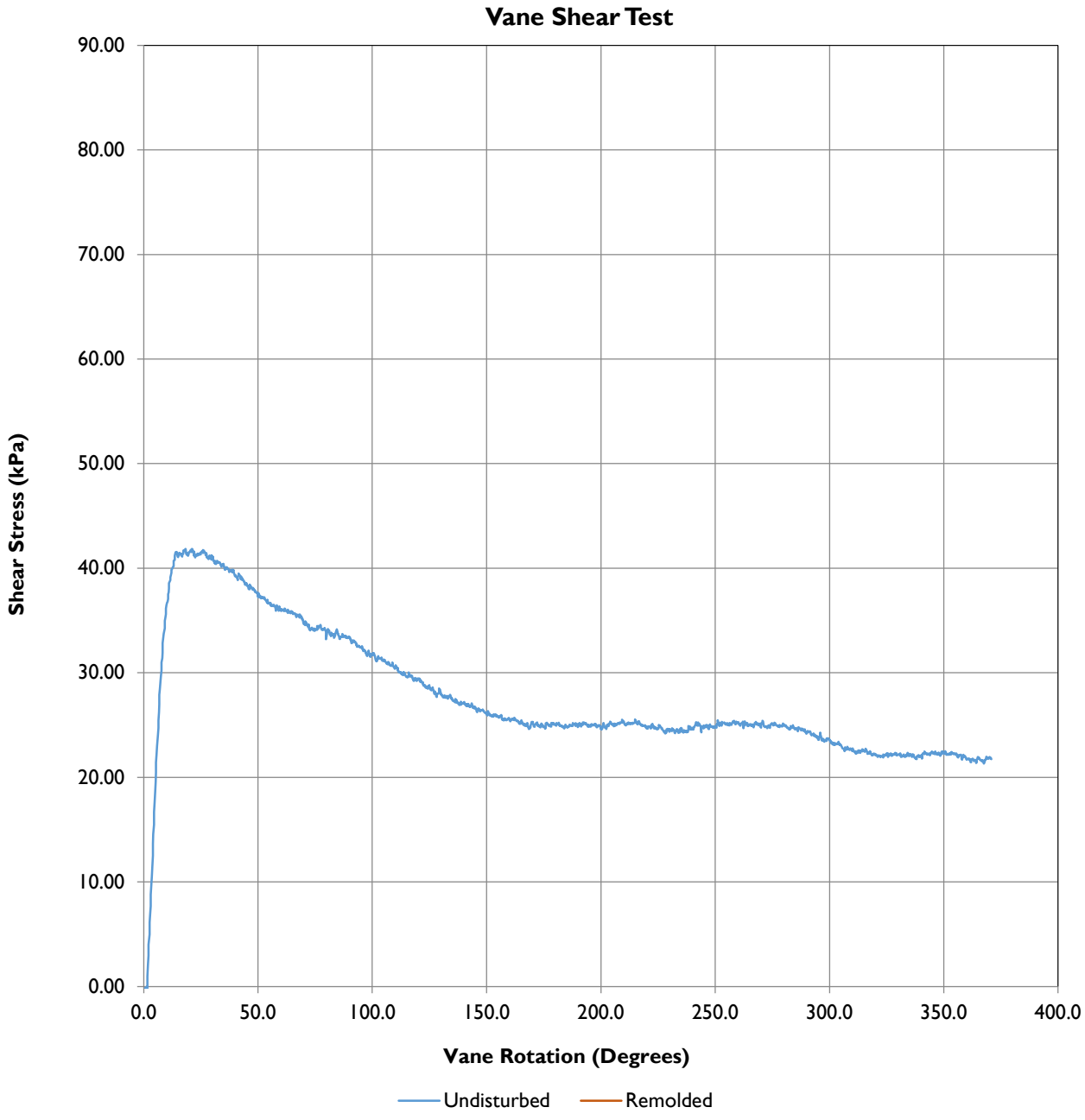
Vane Shear Test

Test Location:	**TSF4-CPT01**
Test Depth:	**9.00**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**5/10/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF4**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631502.5*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522411.9*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	217.5m (AHD)



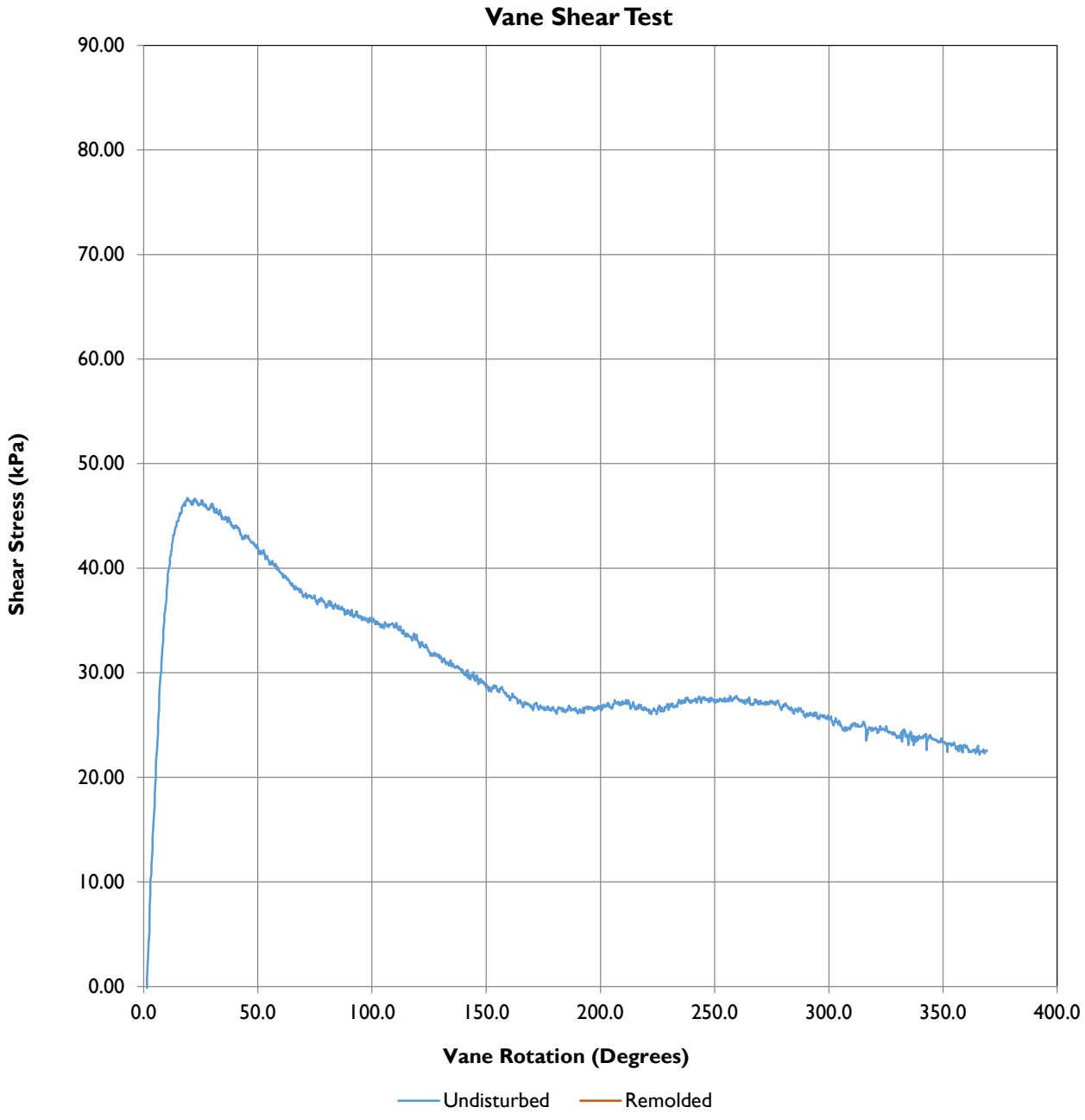
Vane Shear Test

Test Location:	**TSF4-CPT01**
Test Depth:	**12.00**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**
Project:	**SRM TSF2-4**
Location:	**TSF4**
Date Tested:	**5/10/2020**
Tested By:	**IGS**

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631502.5*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522411.9*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	217.5m (AHD)



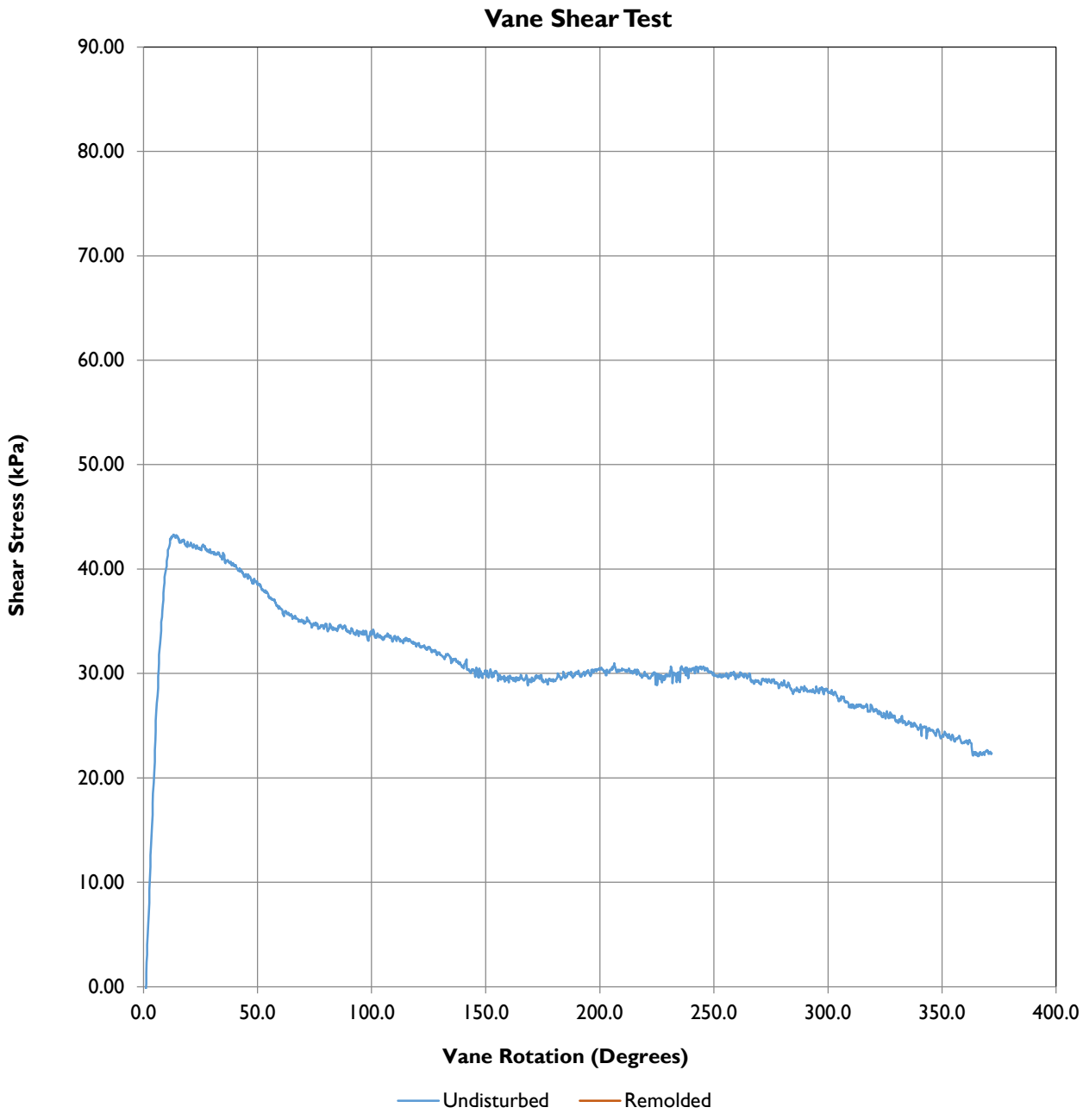
Vane Shear Test

Test Location:	**TSF4-CPT01**
Test Depth:	**13.50**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**5/10/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF4**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631502.5*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522411.9*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	217.5m (AHD)



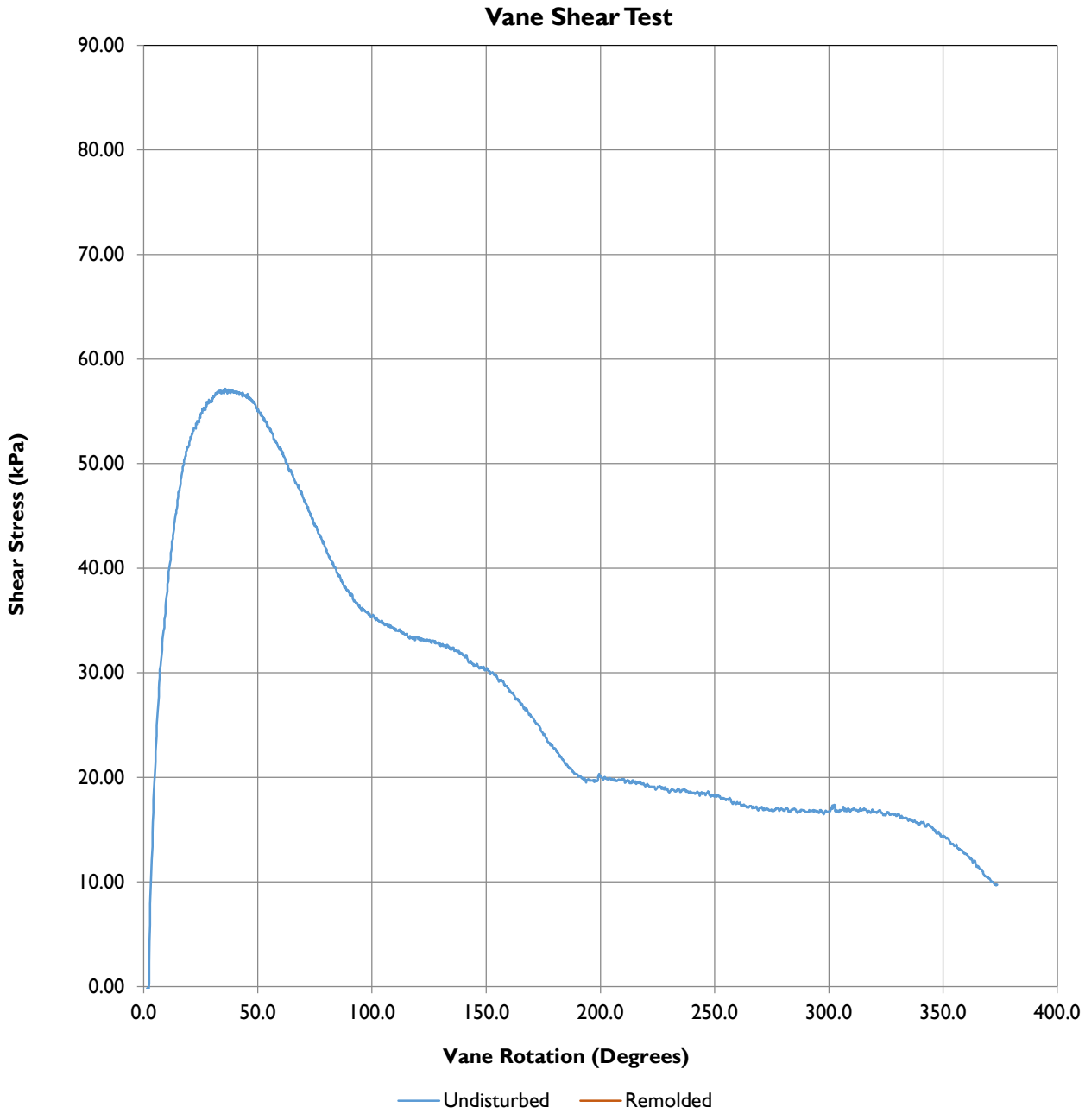
Vane Shear Test

Test Location:	**TSF4-CPT02**
Test Depth:	**6.40**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**6/10/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF4**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631580.6*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522211.9*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.1m (AHD)



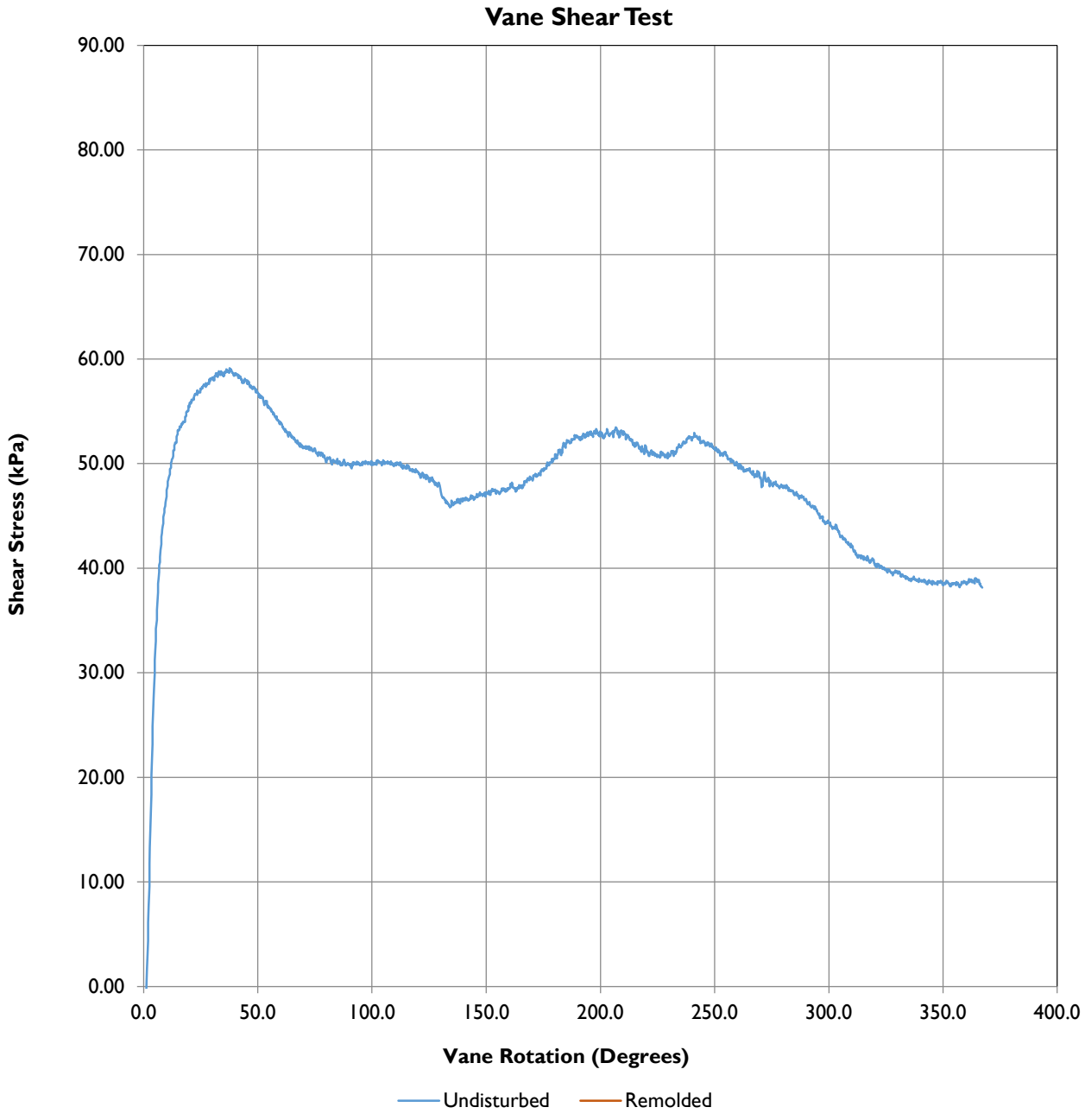
T:\04 BRIS\B01229-4 BMA, TSF2 to 4, Saraji\06 Site Investigation\05 CPT Results\03 TSF4\01 EDG Template\02 EDG VS Template\[TSF4-CPT02_VS.xlsm]

Vane Shear Test

Test Location:	**TSF4-CPT02**
Test Depth:	**8.50**
Job No:	**B01229-4**

Client:	**BMA**	Date Tested:	**6/10/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF4**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631580.6*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522211.9*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.1m (AHD)



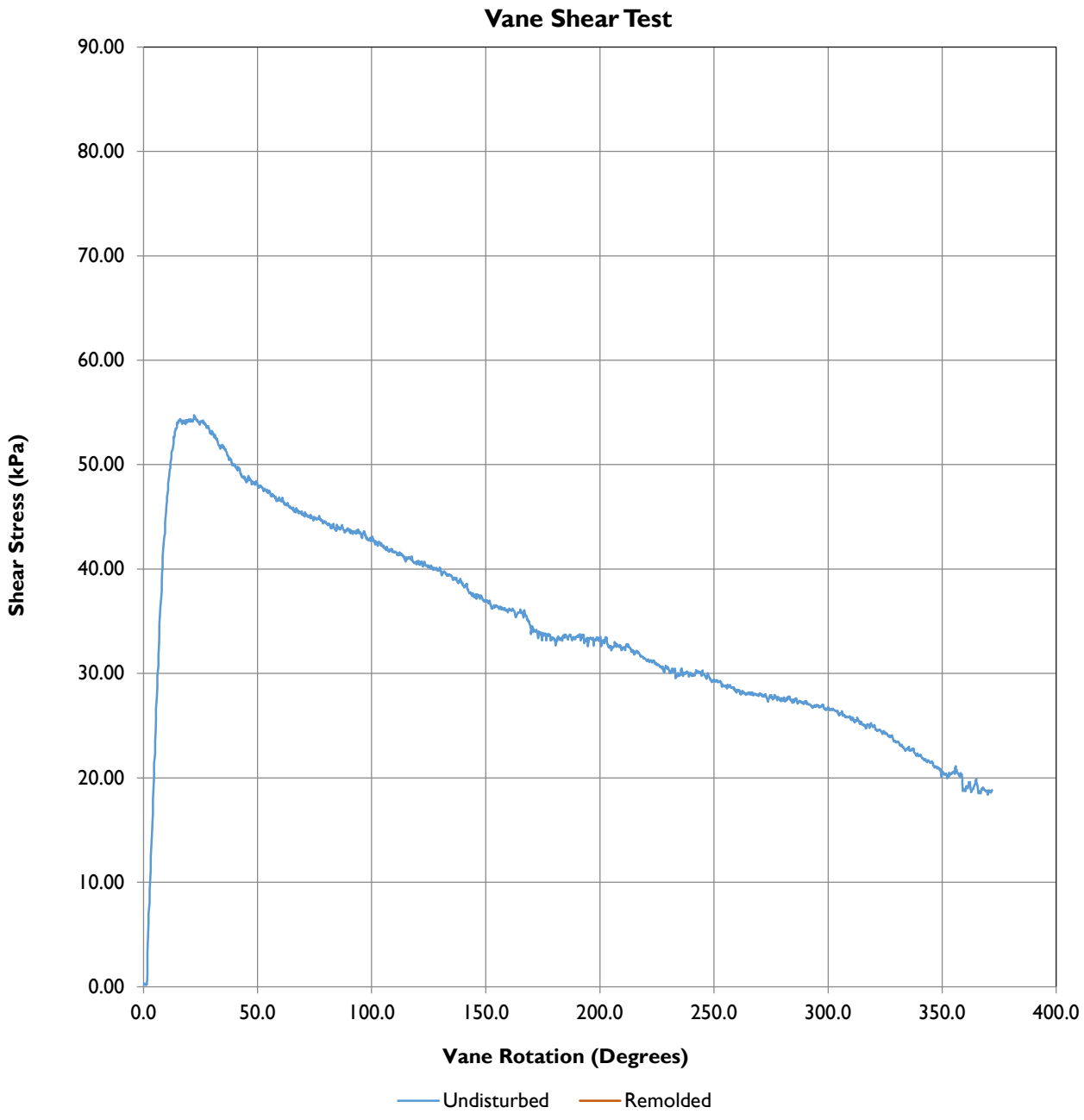
Vane Shear Test

Test Location:	**TSF4-CPT02**
Test Depth:	**10.90**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**6/10/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF4**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631580.6*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522211.9*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.1m (AHD)



T:\04 BRIS\B01229-4 BMA, TSF2 to 4, Saraji\06 Site Investigation\05 CPT Results\03 TSF4\01 EDG Template\02 EDG VS Template\[TSF4-CPT02_VS.xlsm]

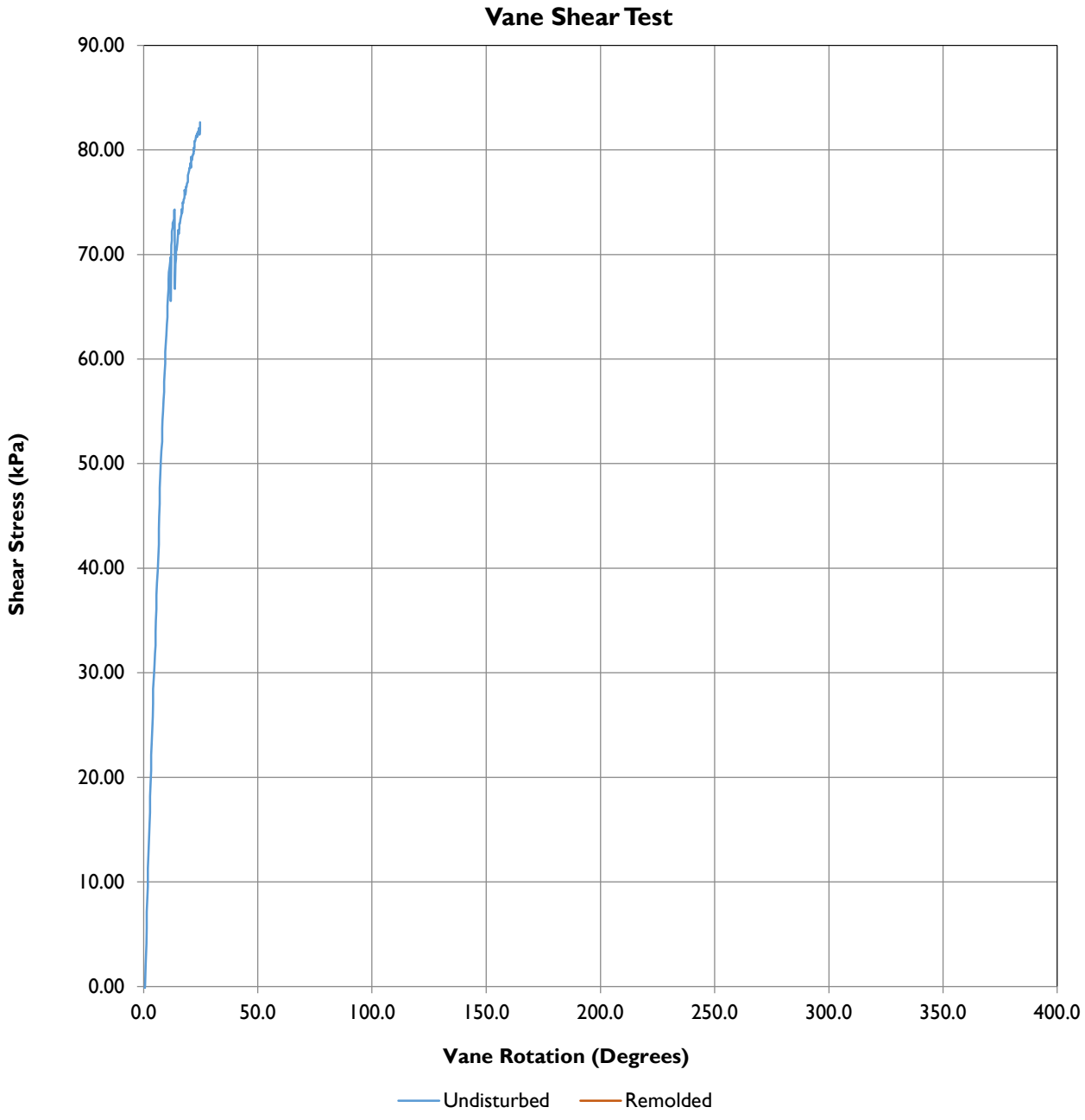
Vane Shear Test

Test Location:	**TSF4-CPT02**
Test Depth:	**12.70**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**6/10/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF4**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631580.6*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7522211.9*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	218.1m (AHD)



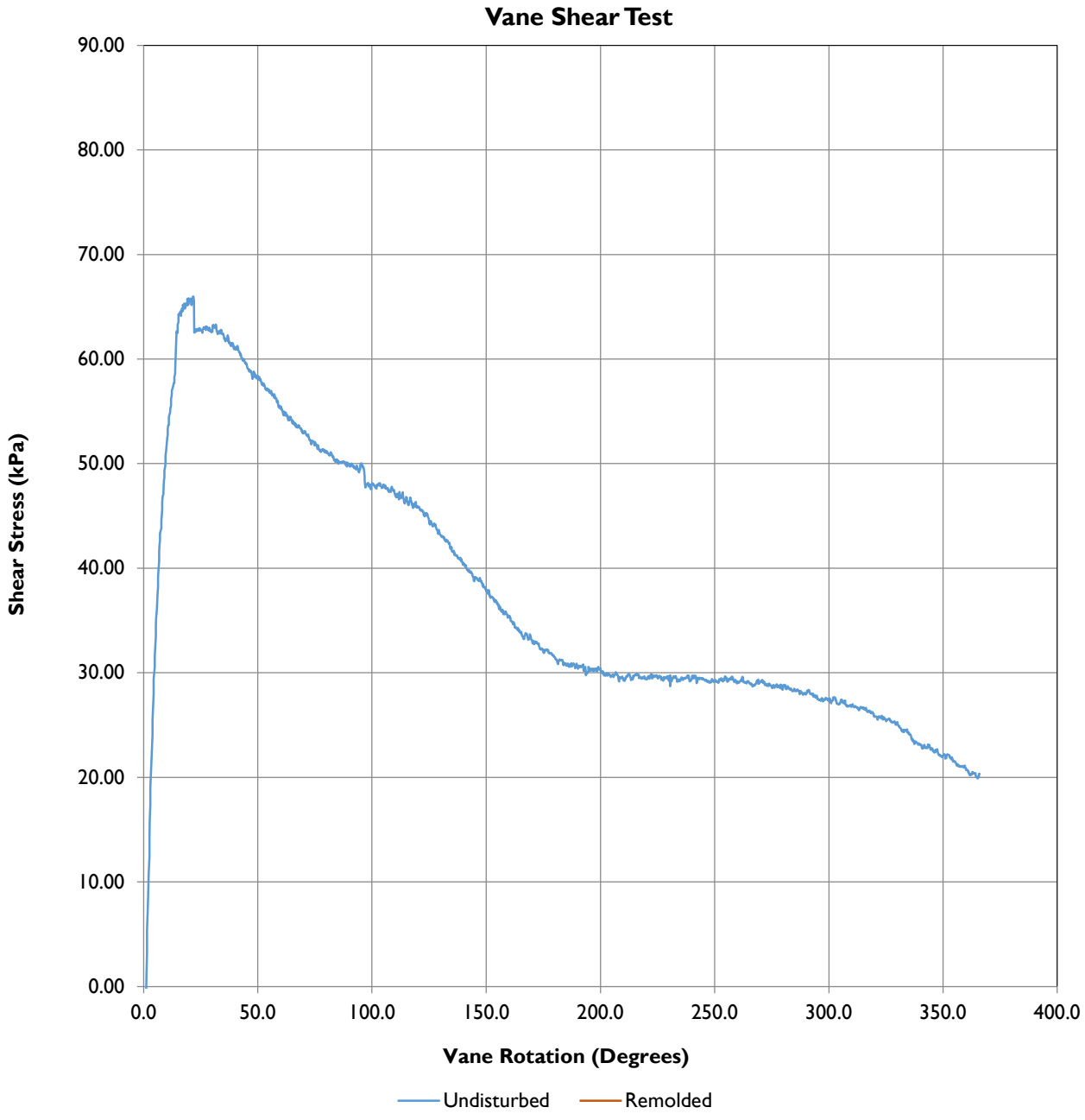
Vane Shear Test

Test Location:	**TSF4-CPT03**
Test Depth:	**6.00**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**7/10/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF4**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631764.1*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521840.5*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	219.6m (AHD)



T:\04 BRIS\B01229-4 BMA, TSF2 to 4, Saraji\06 Site Investigation\05 CPT Results\03 TSF4\01 EDG Template\02 EDG VS Template\[TSF4-CPT03_VS.xlsm]

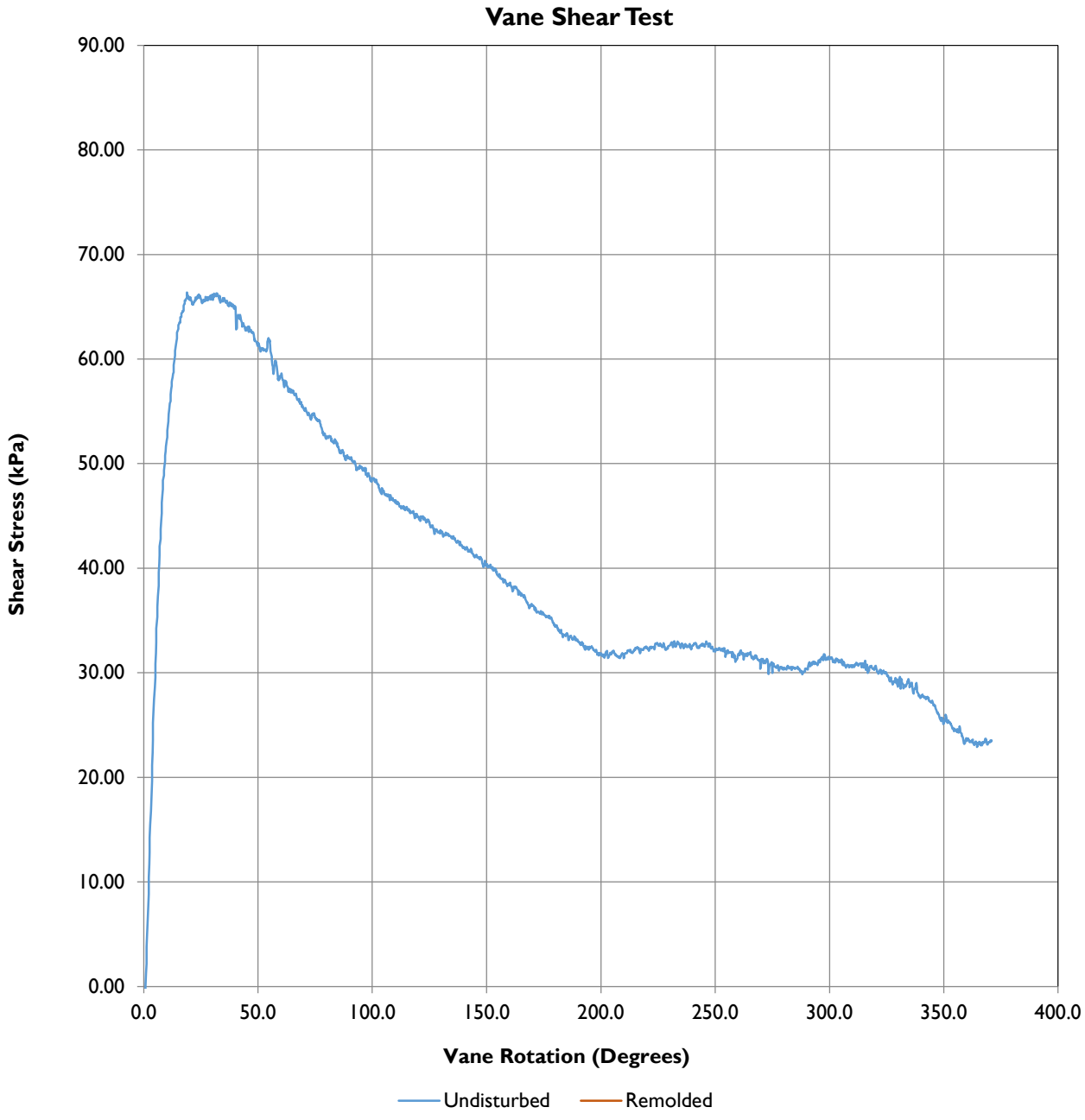
Vane Shear Test

Test Location:	**TSF4-CPT03**
Test Depth:	**7.90**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**7/10/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF4**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631764.1*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521840.5*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	219.6m (AHD)



T:\04 BRIS\B01229-4 BMA, TSF2 to 4, Saraji\06 Site Investigation\05 CPT Results\03 TSF4\01 EDG Template\02 EDG VS Template\[TSF4-CPT03_VS.xlsm]

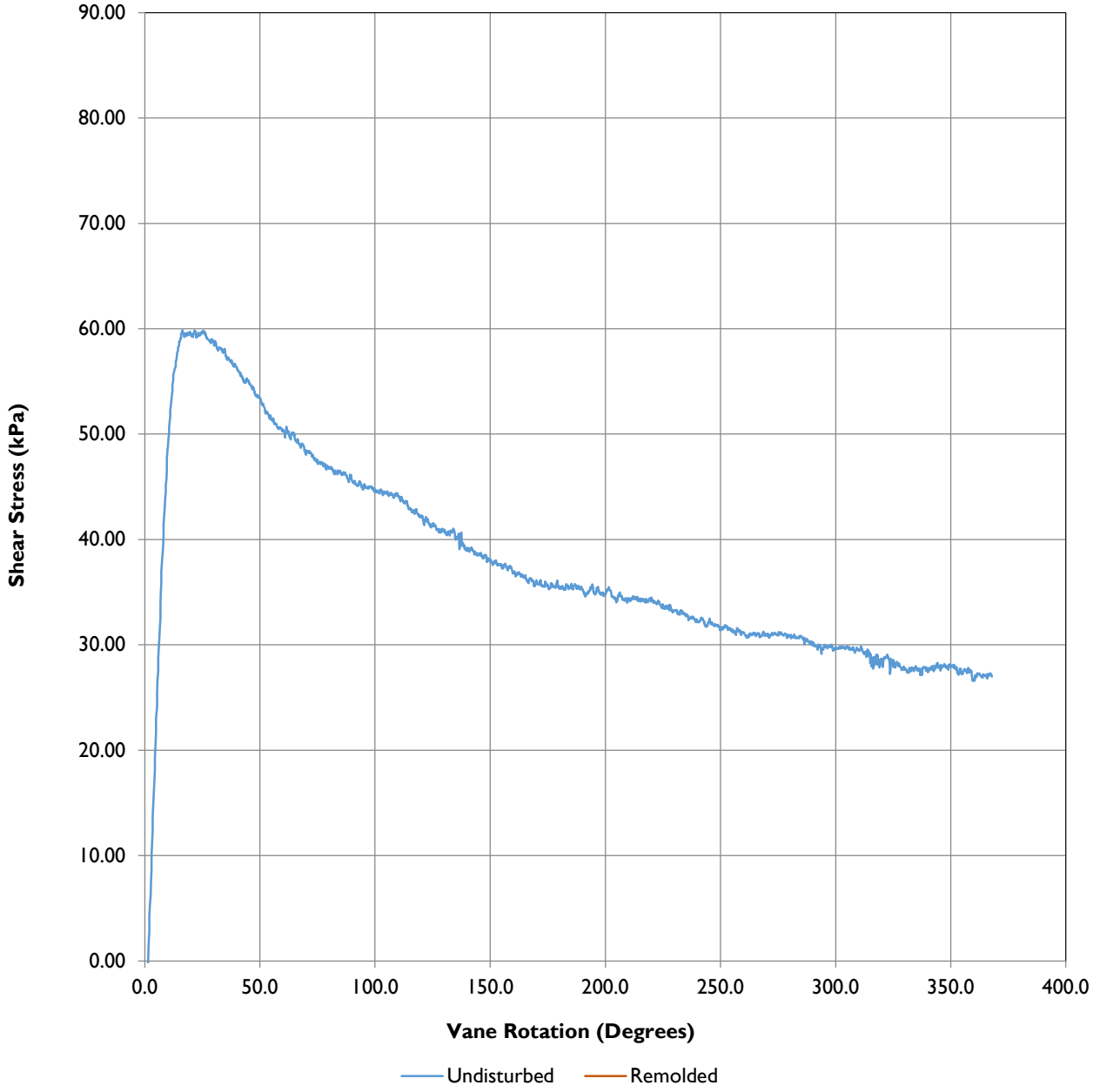
Vane Shear Test

Test Location:	**TSF4-CPT03**
Test Depth:	**12.00**
Job No:	**B01229-4**

EDG consulting

Client:	**BMA**	Date Tested:	**7/10/2020**
Project:	**SRM TSF2-4**	Tested By:	**IGS**
Location:	**TSF4**		

Vane Type:	*V1*	Equipment/Rig:	*Tommy, Track mounted*	Coordinate System:	*AGD66 / AMG Zone 55*
Vane Diameter:	*50mm*	Rotation Rate (deg/min):	*4.2*	Easting:	*631764.1*
Vane Height:	*100mm*	Load Cell Serial Number:	*N/A*	Northing:	*7521840.5*
Taper Angles:	*N/A*	Vane Factor (kPa/Nm):	*1.796*	R.L. Surface:	219.6m (AHD)

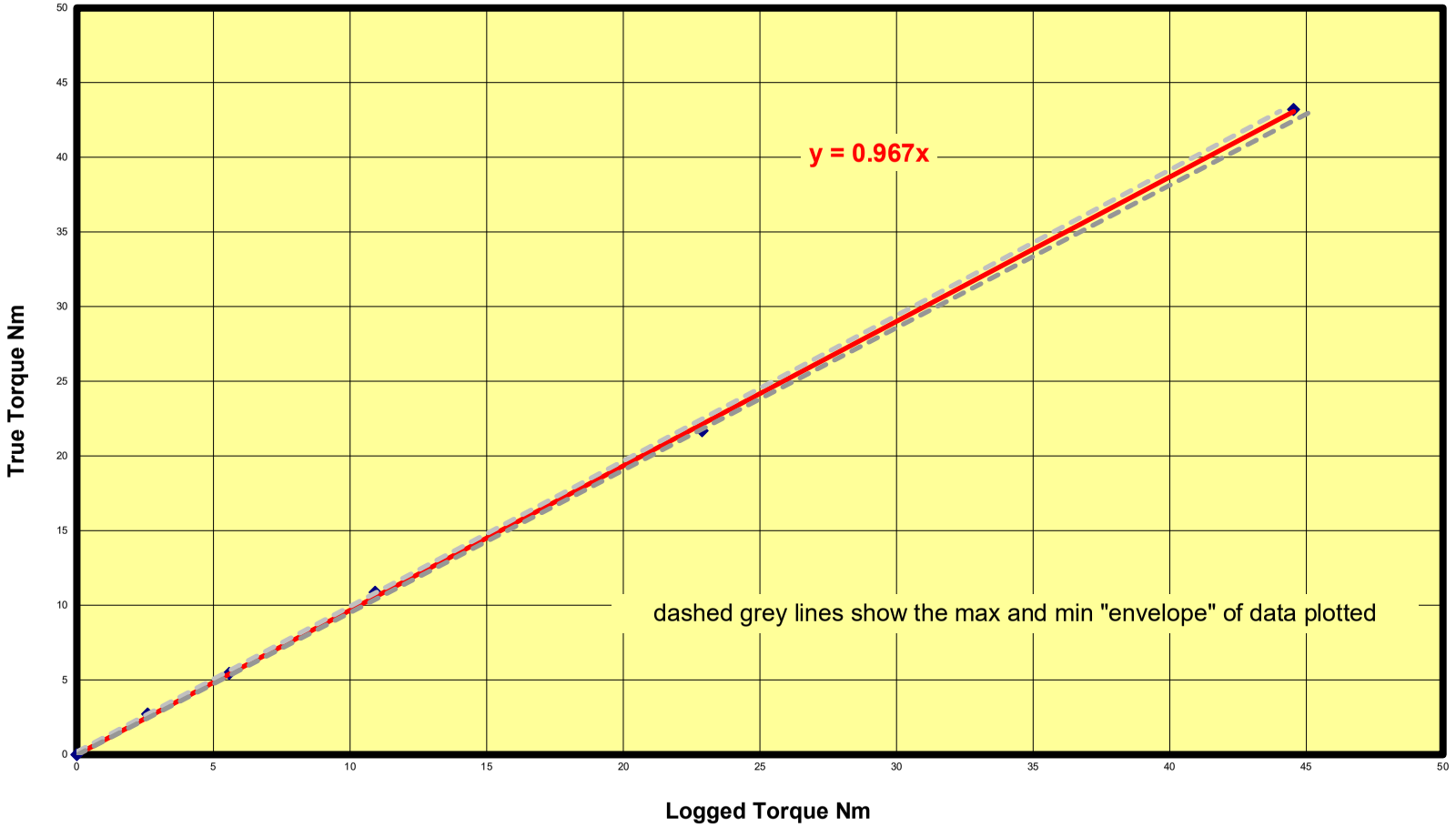


Vane Shear Data Acquisition System Calibration
Insitu Geotech Services Pty Ltd (IGS)

Type: Geomil
Number: 0002
Date: 15-Jun-2018

To adjust for this calibration use the adjusted vane constants below in the IGS Importer sheet
Set max Su in data acquisition software (on "Parameters" page) at blue value shown below
(refer to IGS web site www.insitu.com.au for additional information)

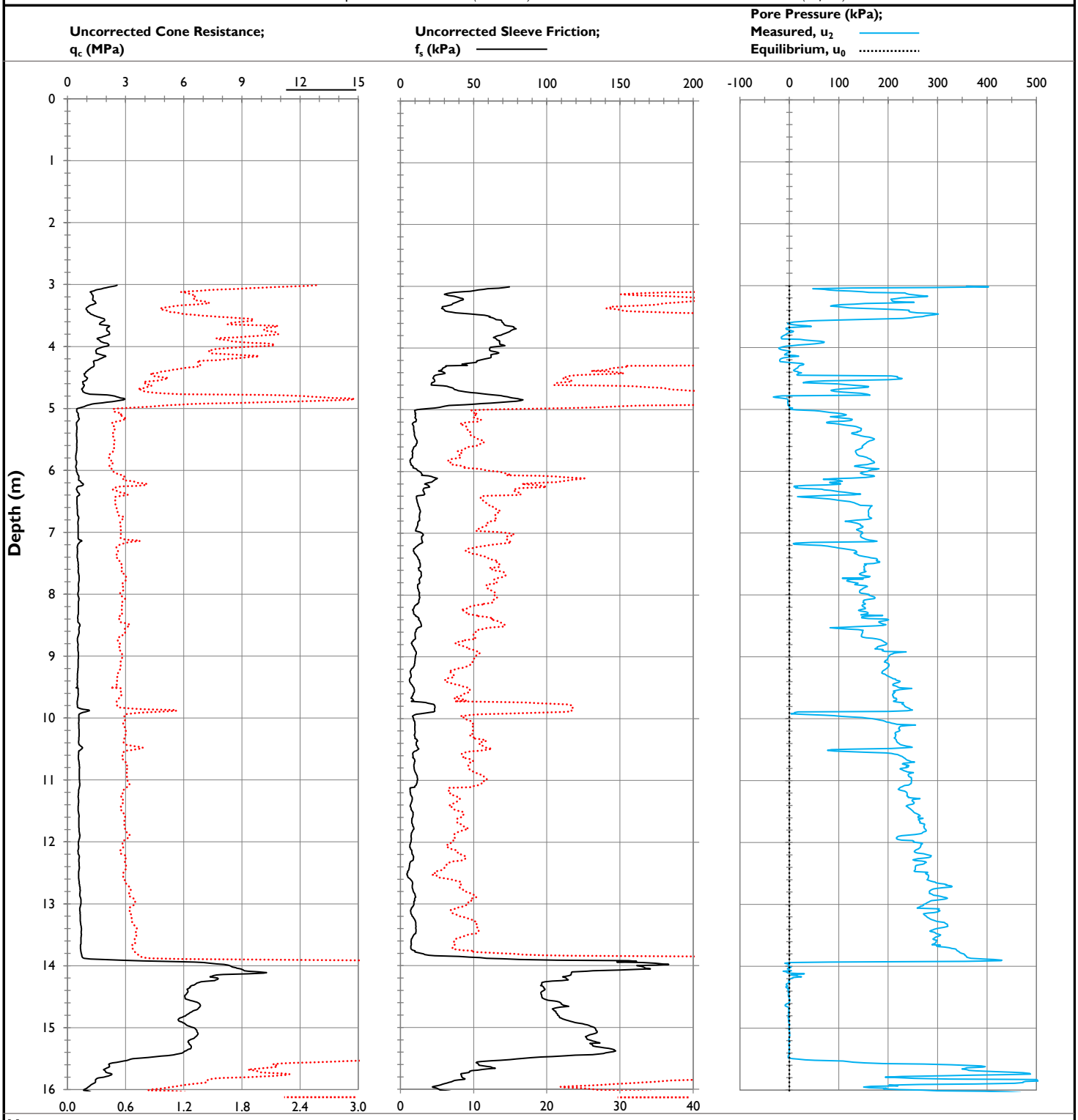
50 x 100 vane	75 x 150 vane	100 x 200 vane
1.796	0.595	0.258
108	36	15



Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT01**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631502.5 (AGD66 /* R.L. Surface: *217.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7522411.9 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*18.0m (Estimated)*	Termination:	*24.67m (Refusal)*

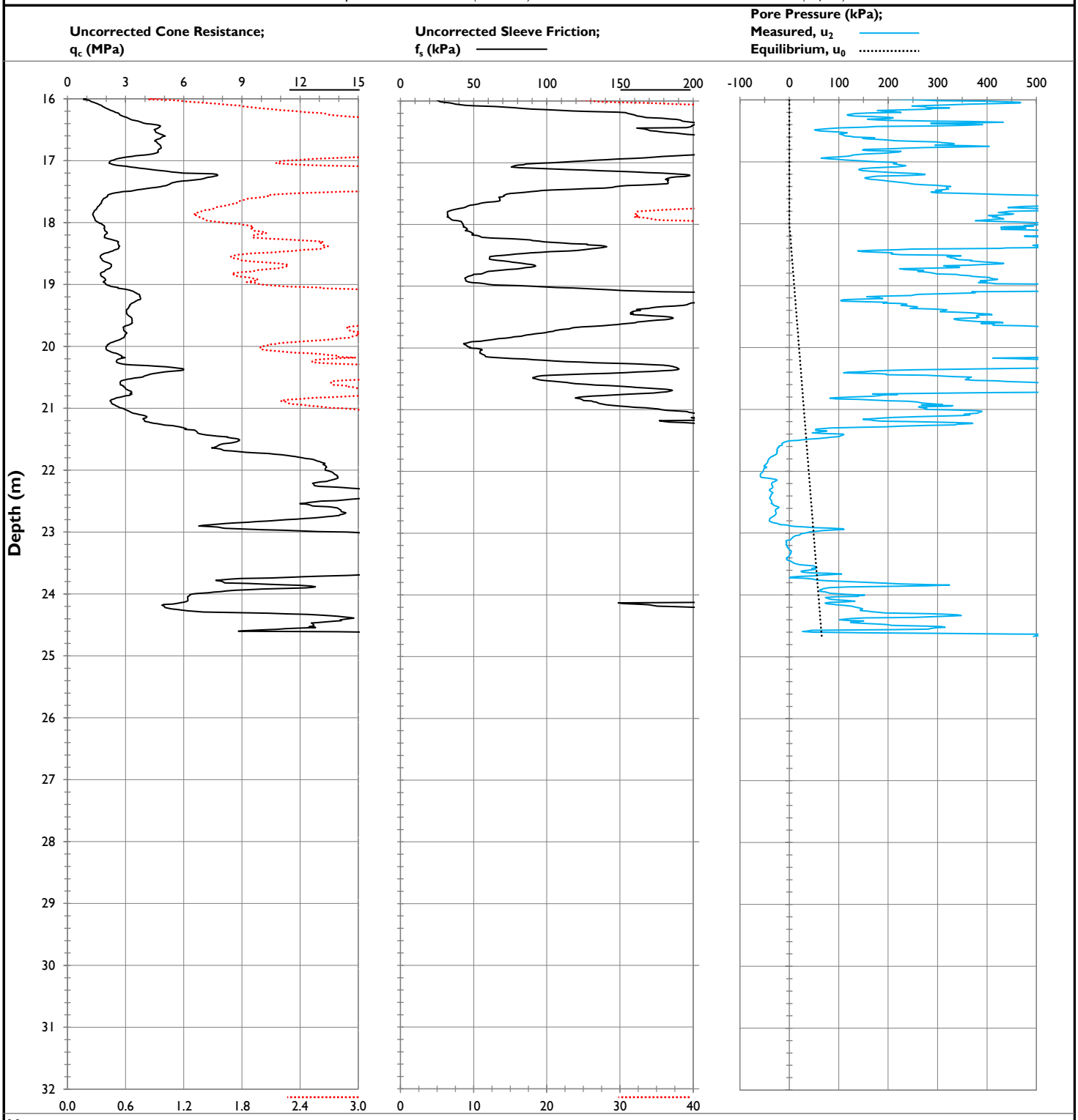


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT01**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631502.5 (AGD66 /* R.L. Surface: *217.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7522411.9 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*18.0m (Estimated)*	Termination:	*24.67m (Refusal)*

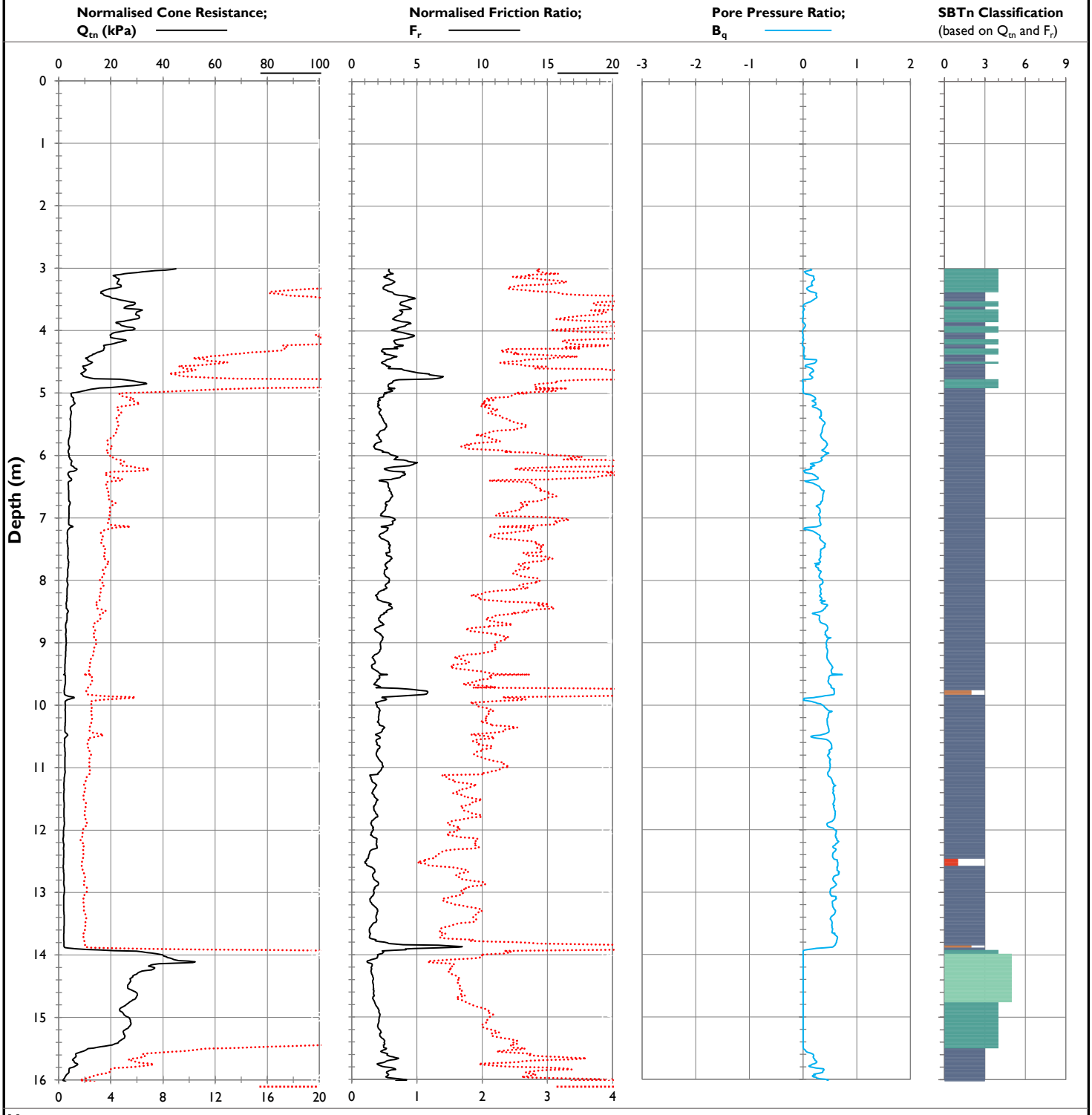


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT01**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631502.5 (AGD66 /*	R.L. Surface:	*217.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7522411.9 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*18.0m (Estimated)*	Termination:	*24.67m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

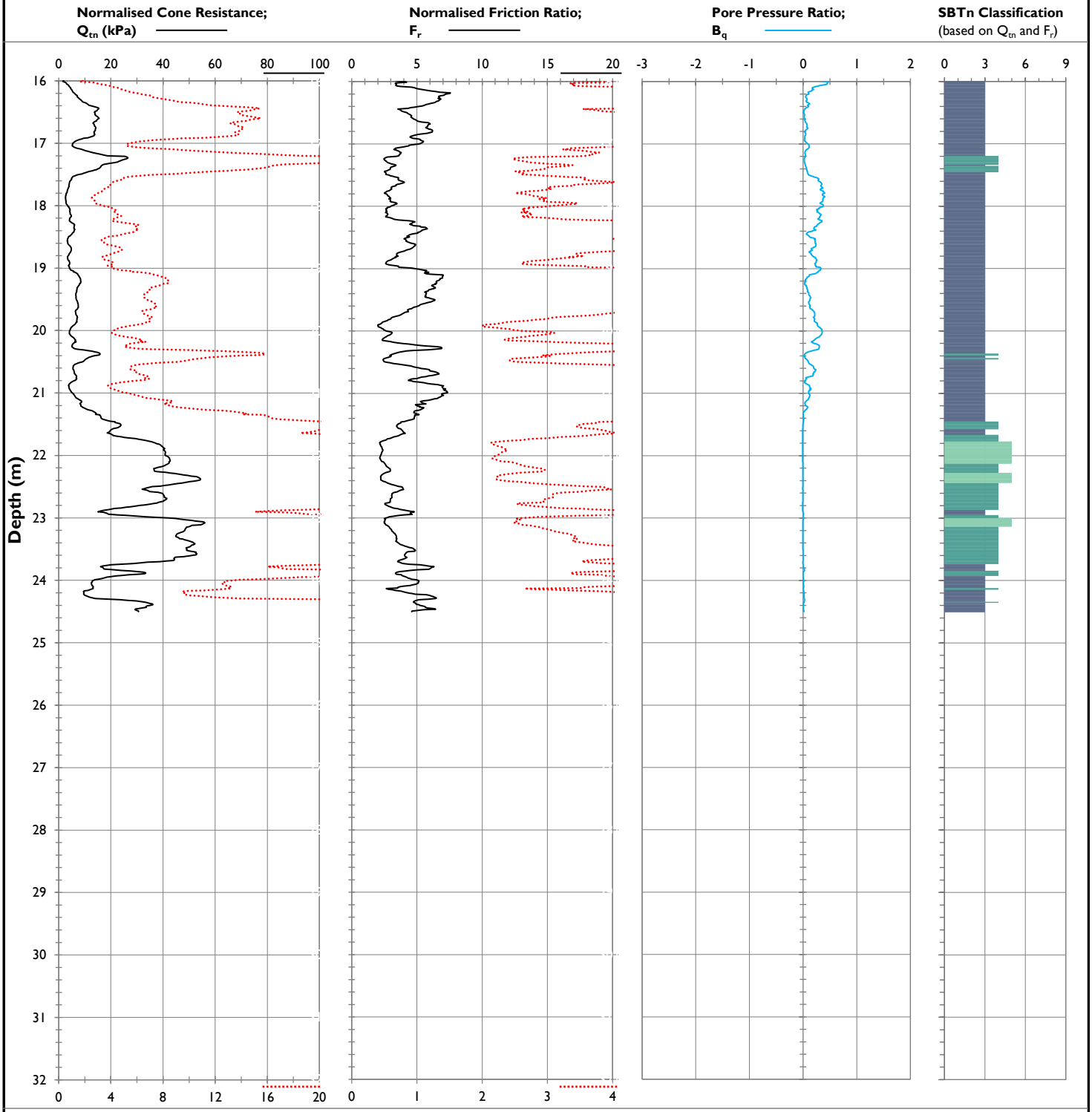
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT01**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631502.5 (AGD66 /* R.L. Surface: *217.5m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7522411.9 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*18.0m (Estimated)*	Termination:	*24.67m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

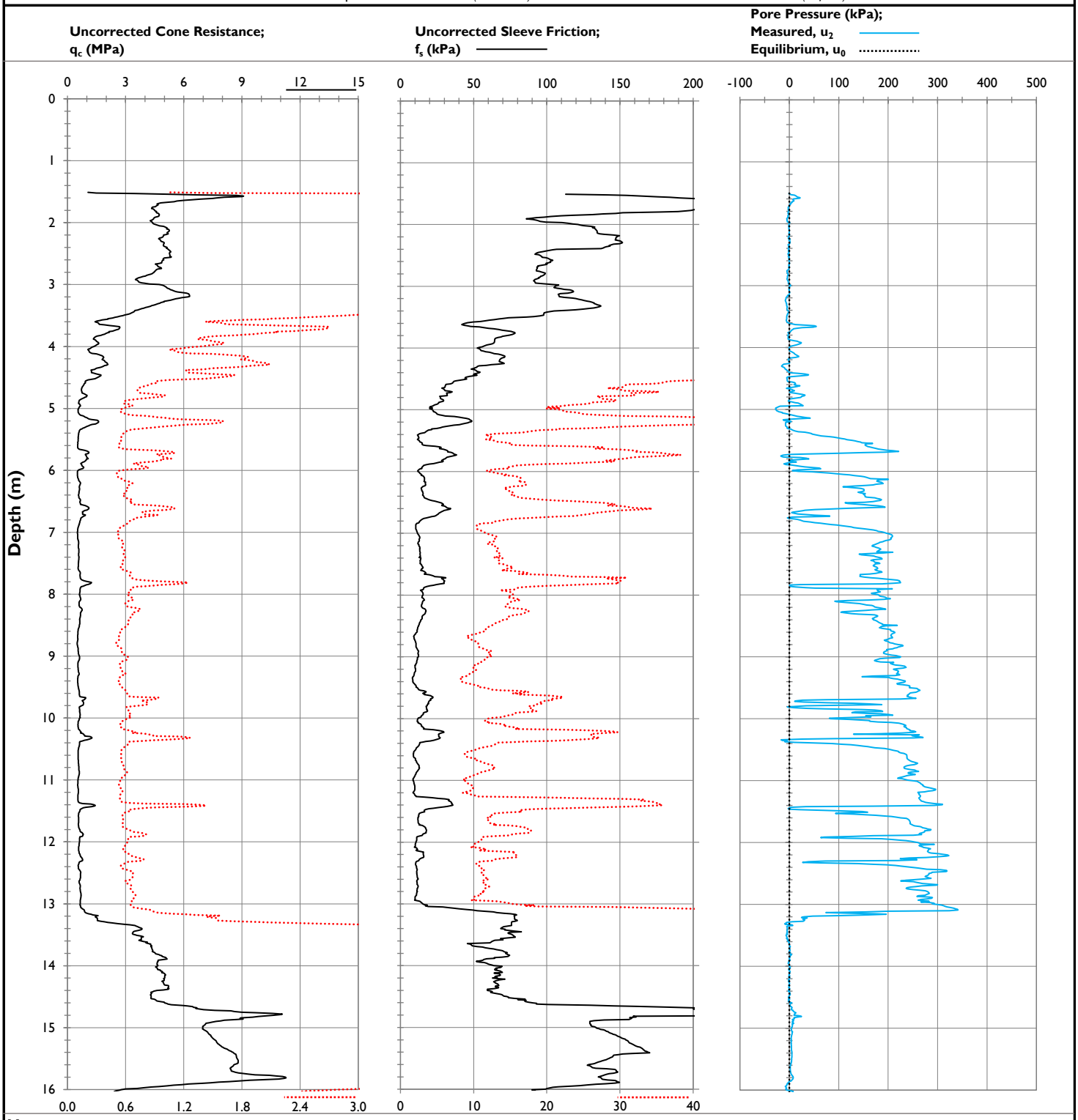
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT02**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631580.6 (AGD66 /* R.L. Surface: *218.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*1.5m*	Northing:	*7522211.9 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*19.0m (Estimated)*	Termination:	*22.63m (Refusal)*

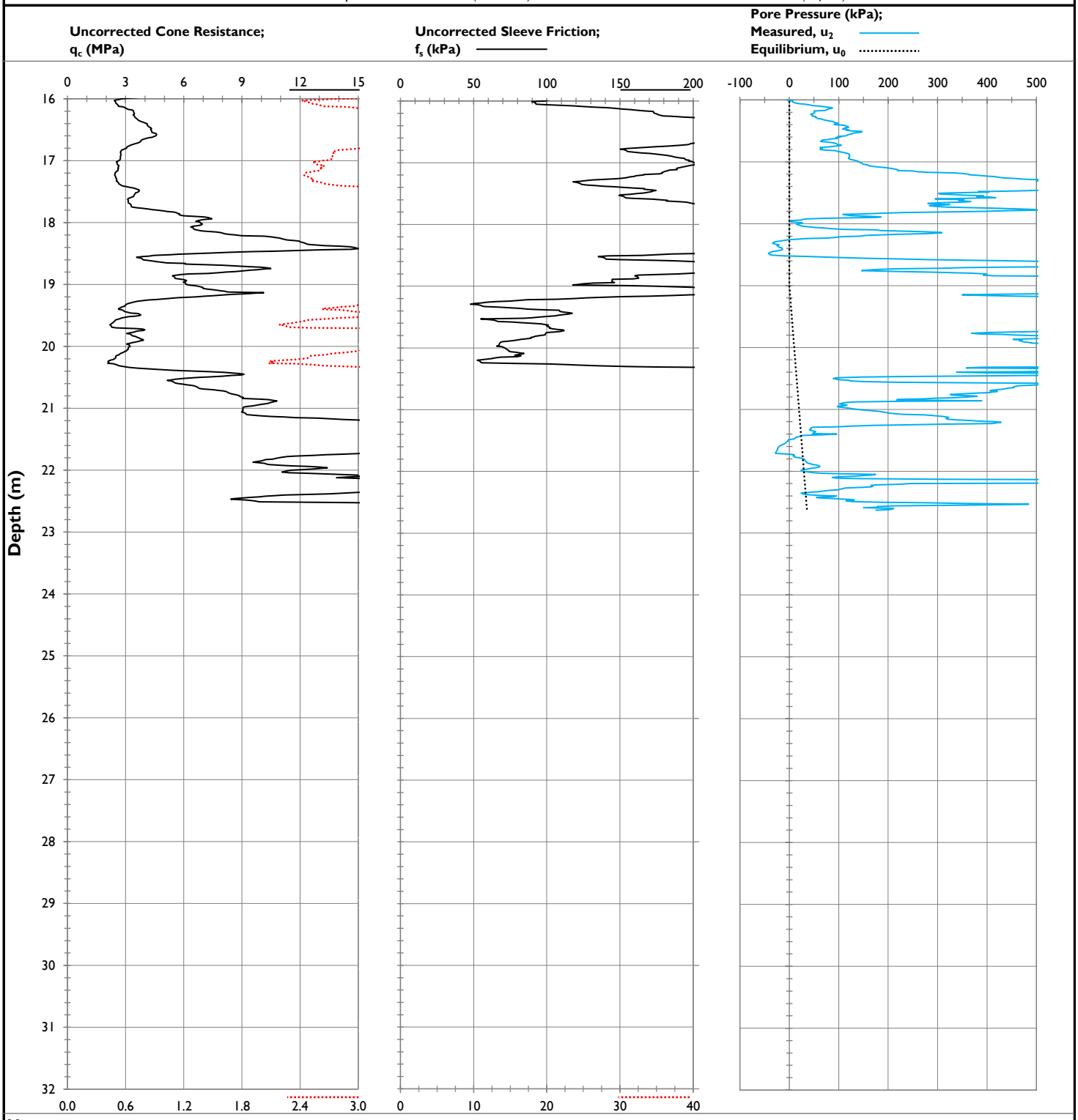


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT02**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631580.6 (AGD66 /* R.L. Surface: *218.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*1.5m*	Northing:	*7522211.9 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*19.0m (Estimated)*	Termination:	*22.63m (Refusal)*

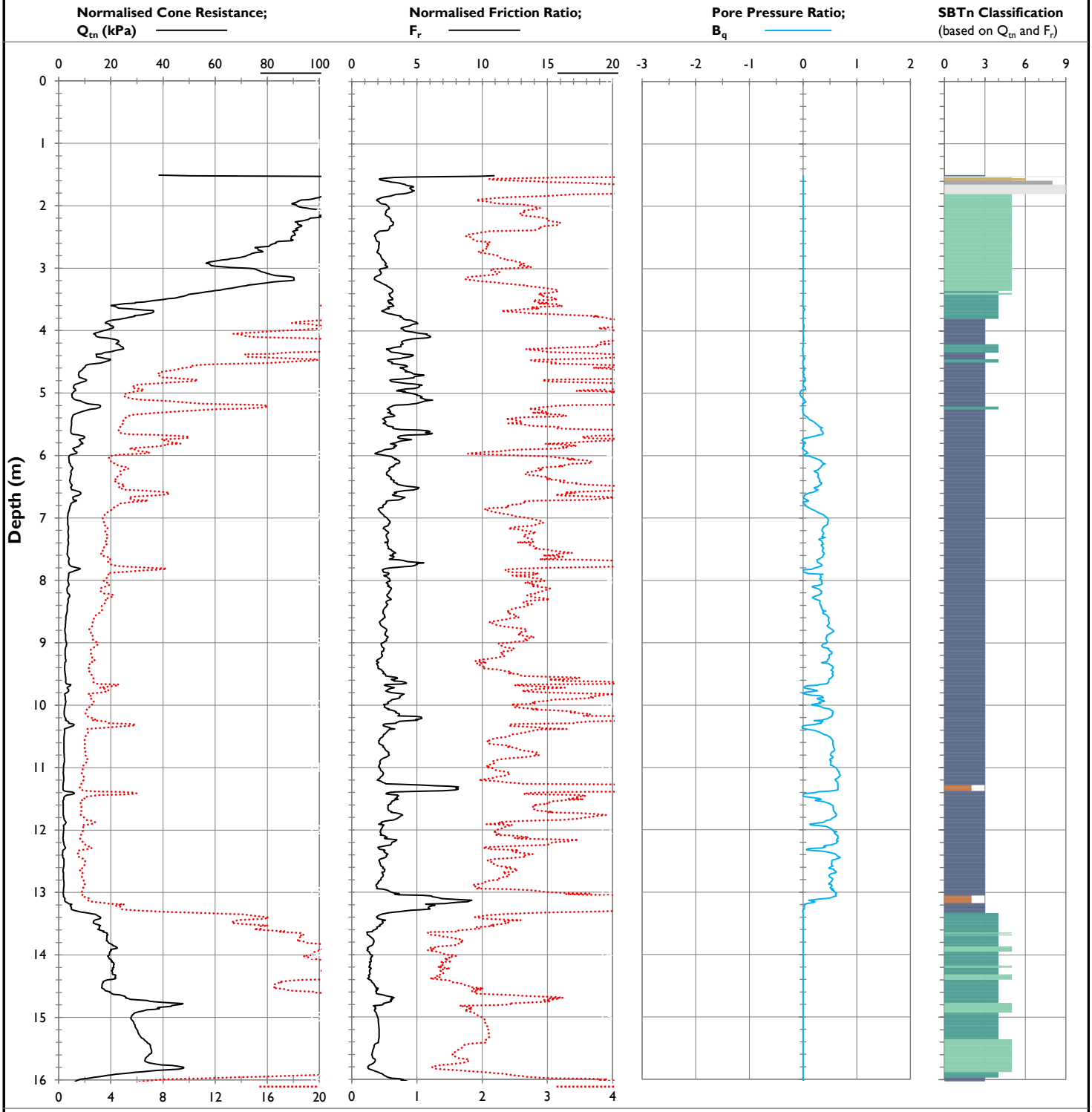


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT02**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631580.6 (AGD66 /*	R.L. Surface:	*218.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*1.5m*	Northing:	*7522211.9 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*19.0m (Estimated)*	Termination:	*22.63m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

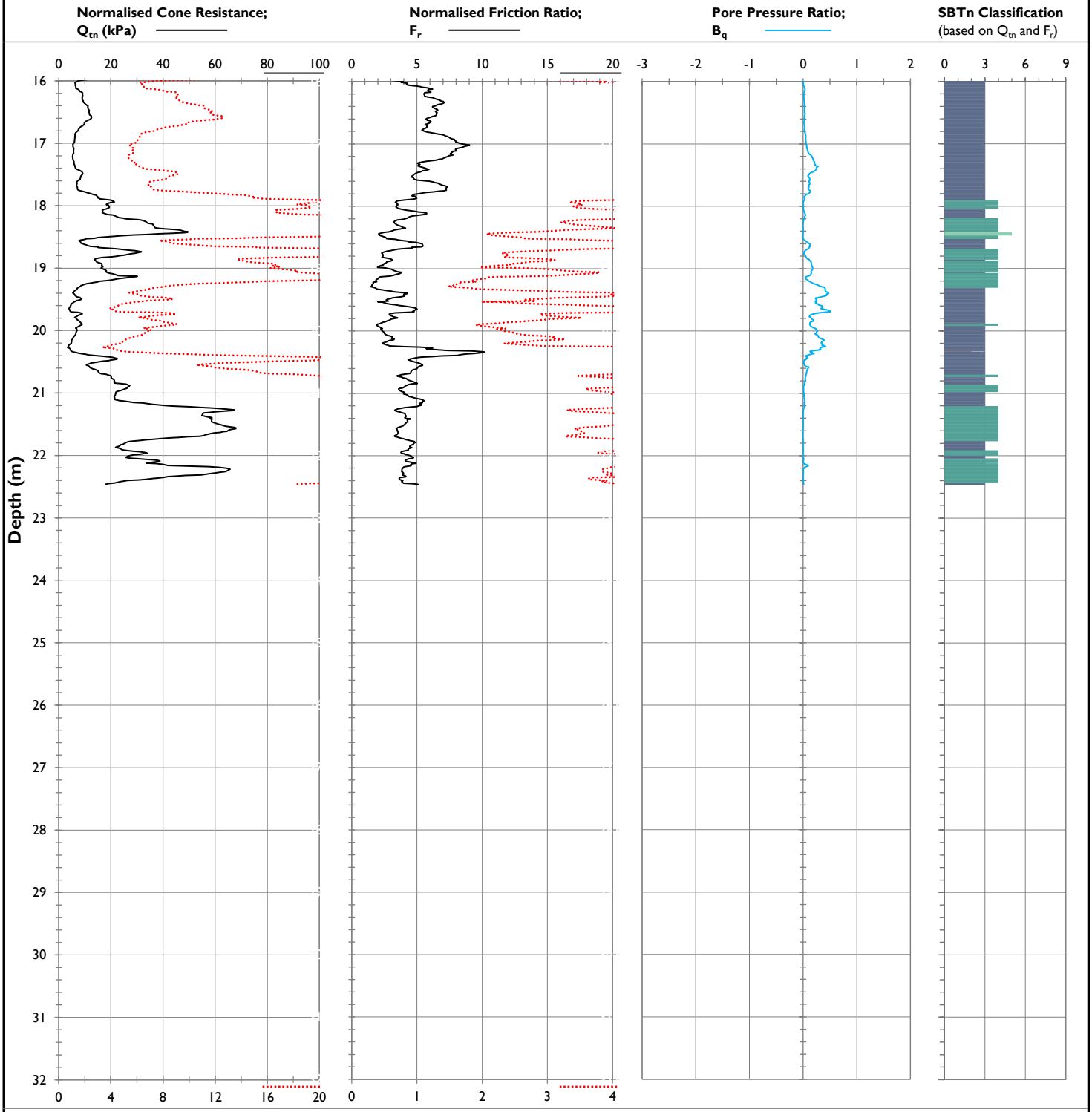
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT02**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631580.6 (AGD66 /*	R.L. Surface:	*218.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*1.5m*	Northing:	*7522211.9 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*19.0m (Estimated)*	Termination:	*22.63m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

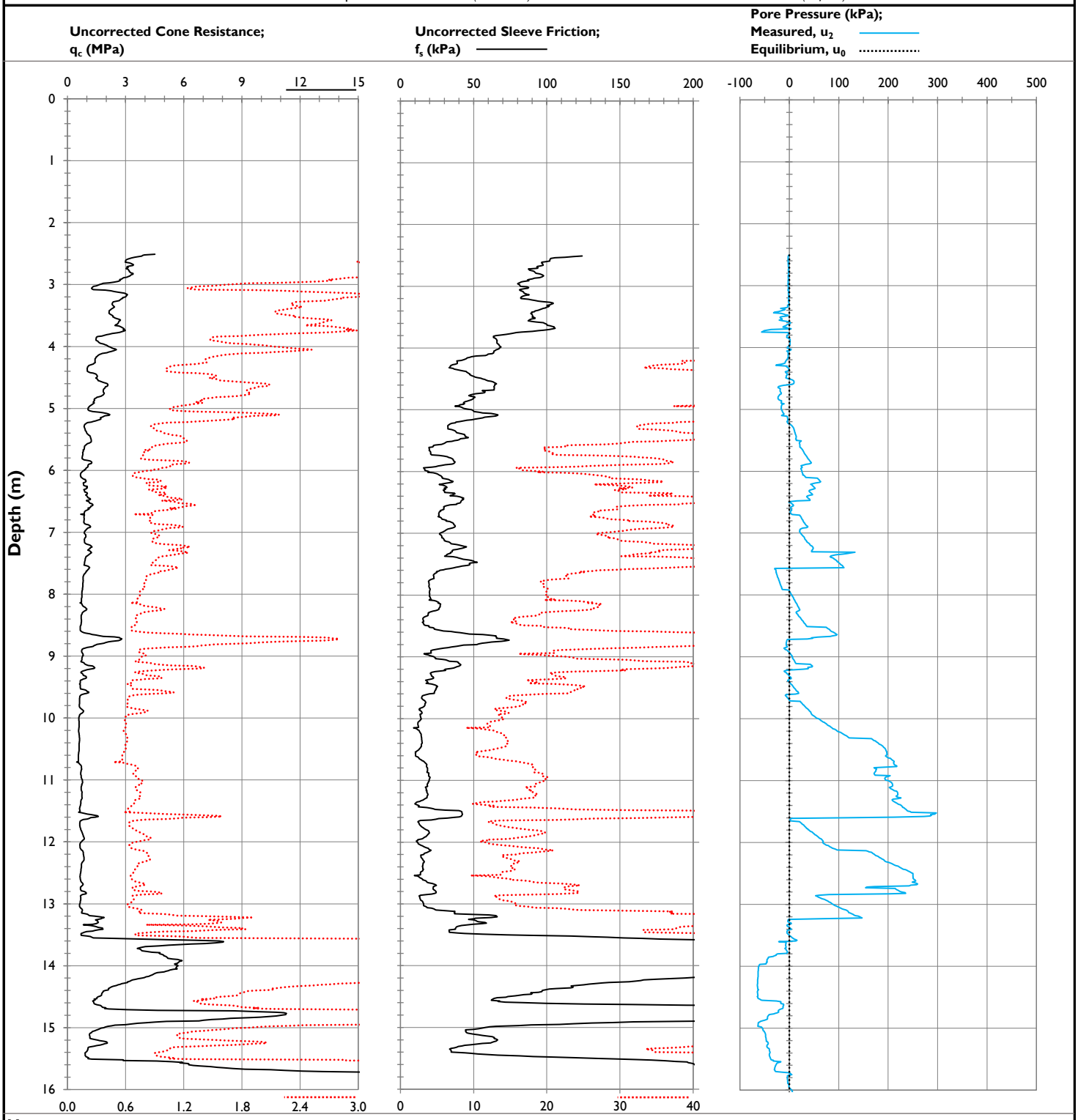
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT03**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**7/10/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631764.1 (AGD66 /* R.L. Surface: *219.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*2.5m*	Northing:	*7521840.5 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.81*	Depth to GW:	*16.7m (Estimated)*	Termination:	*17.59m (Refusal)*

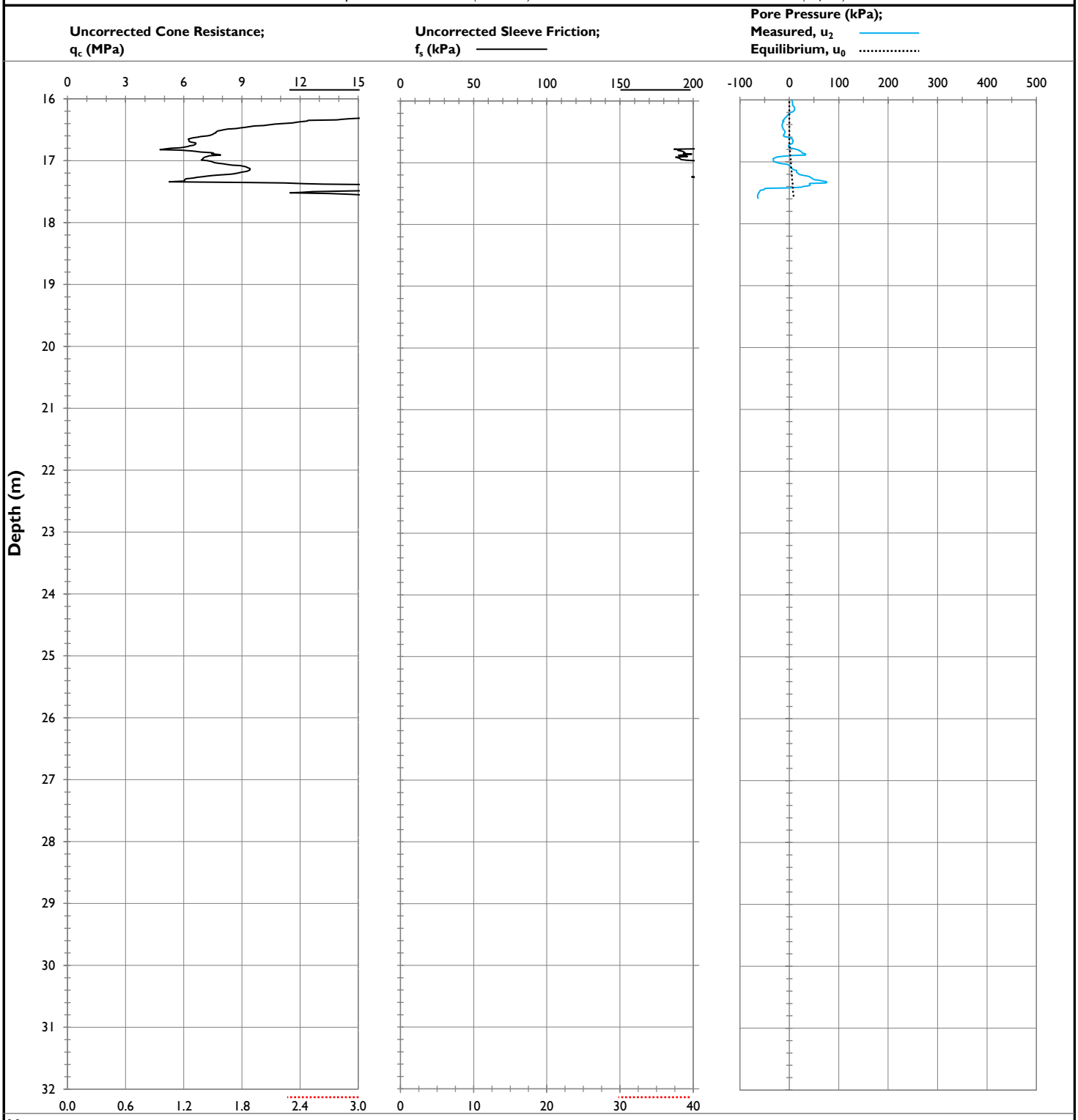


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT03**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**7/10/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631764.1 (AGD66 /* R.L. Surface: *219.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*2.5m*	Northing:	*7521840.5 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.81*	Depth to GW:	*16.7m (Estimated)*	Termination:	*17.59m (Refusal)*

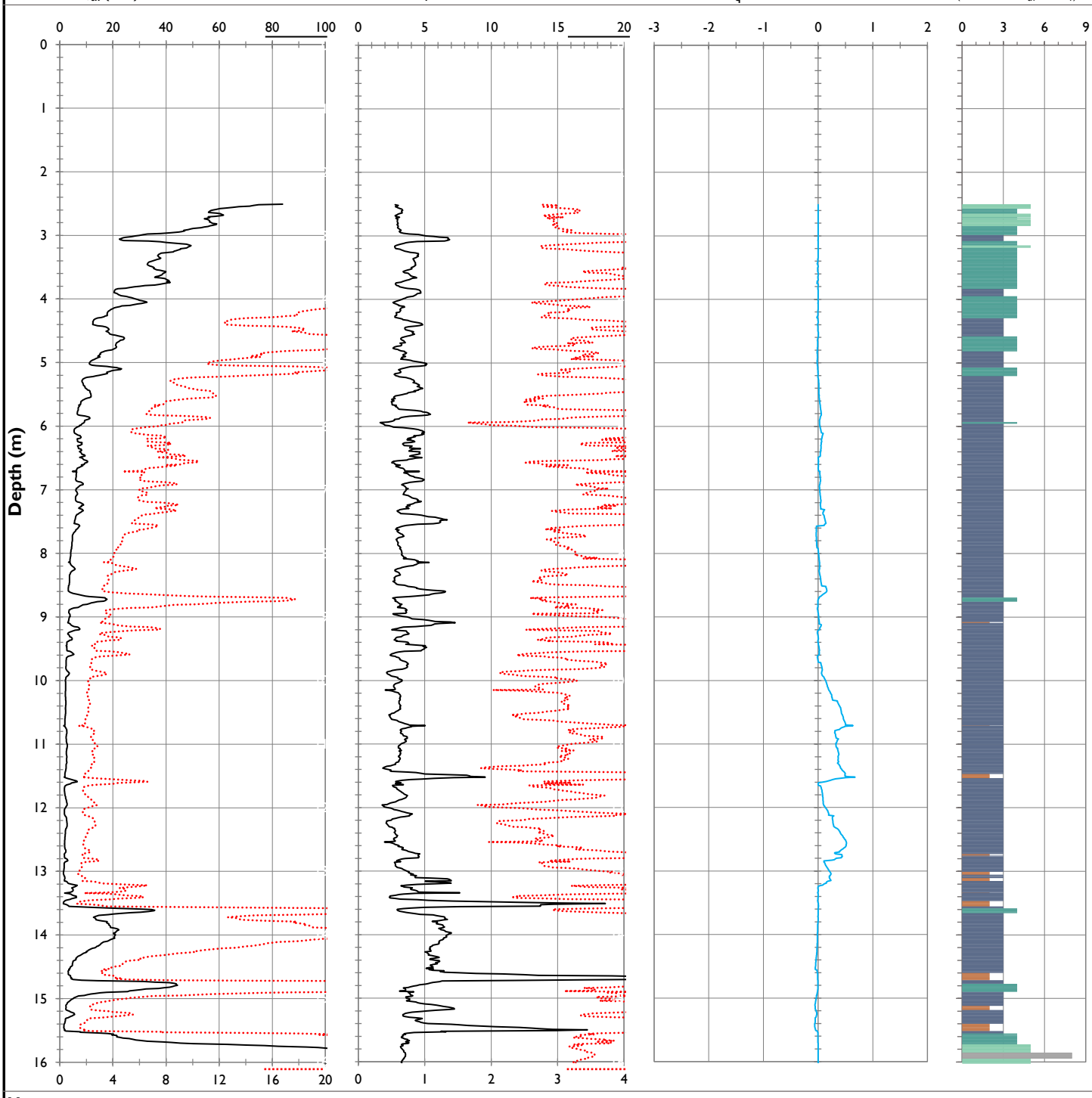


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT03**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**7/10/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631764.1 (AGD66 /*	R.L. Surface:	*219.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*2.5m*	Northing:	*7521840.5 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.81*	Depth to GW:	*16.7m (Estimated)*	Termination:	*17.59m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

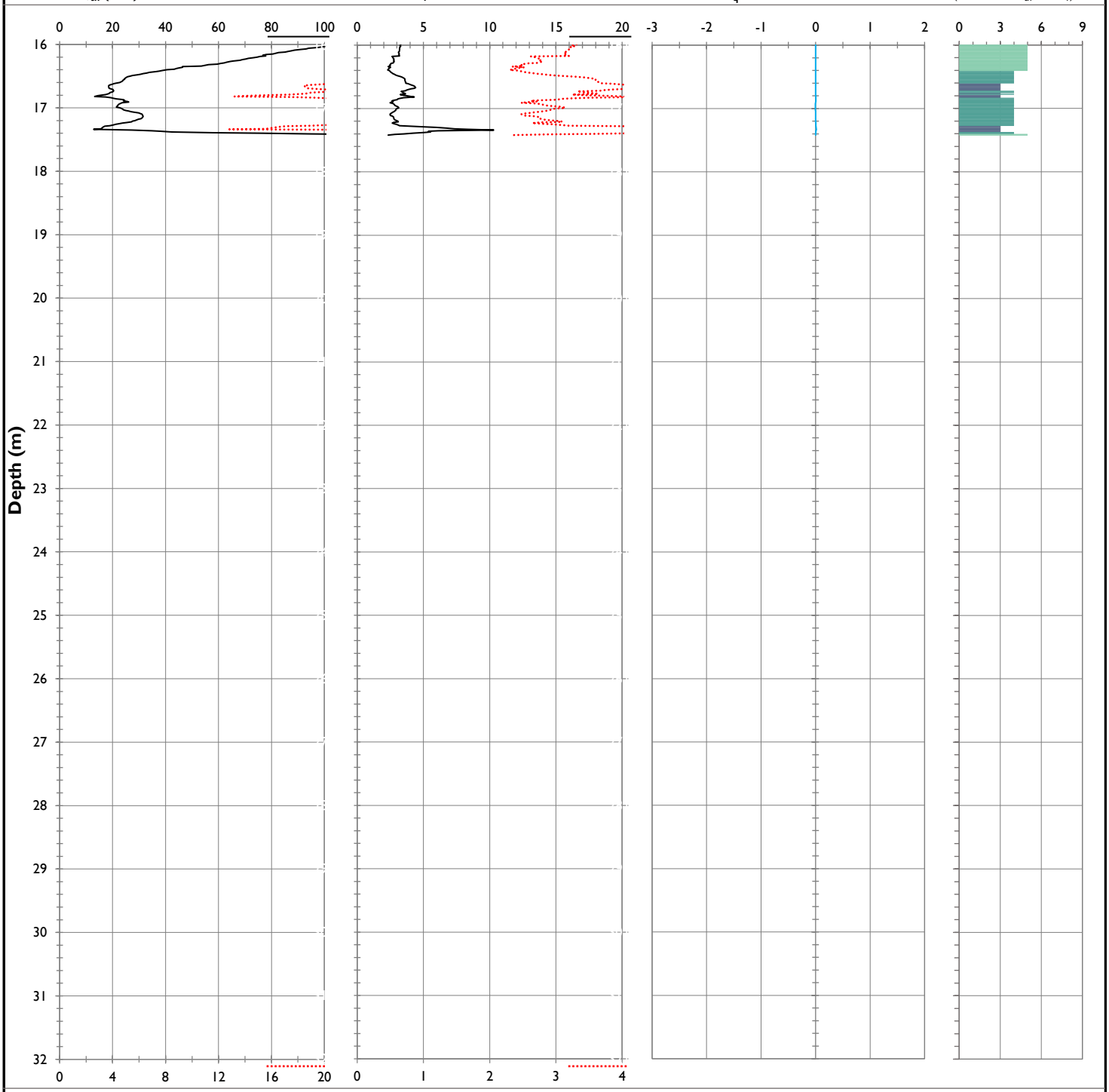
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT03**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**7/10/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631764.1 (AGD66 /*	R.L. Surface:	*219.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*2.5m*	Northing:	*7521840.5 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.81*	Depth to GW:	*16.7m (Estimated)*	Termination:	*17.59m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

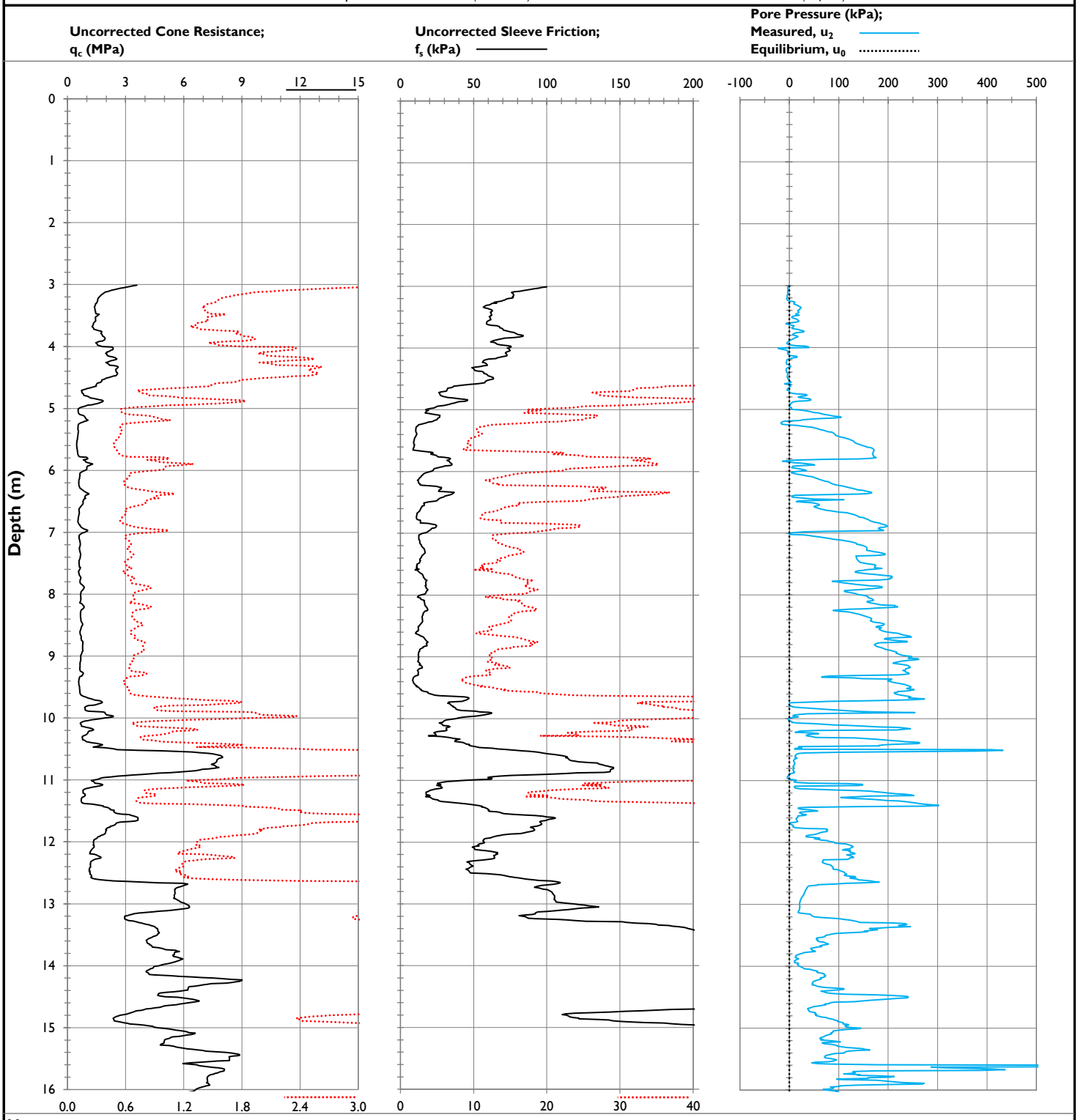
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT04**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631990.5 (AGD66 /*	R.L. Surface:	*220.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7521945.9 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*17.0m (Estimated)*	Termination:	*19.04m (Refusal)*		

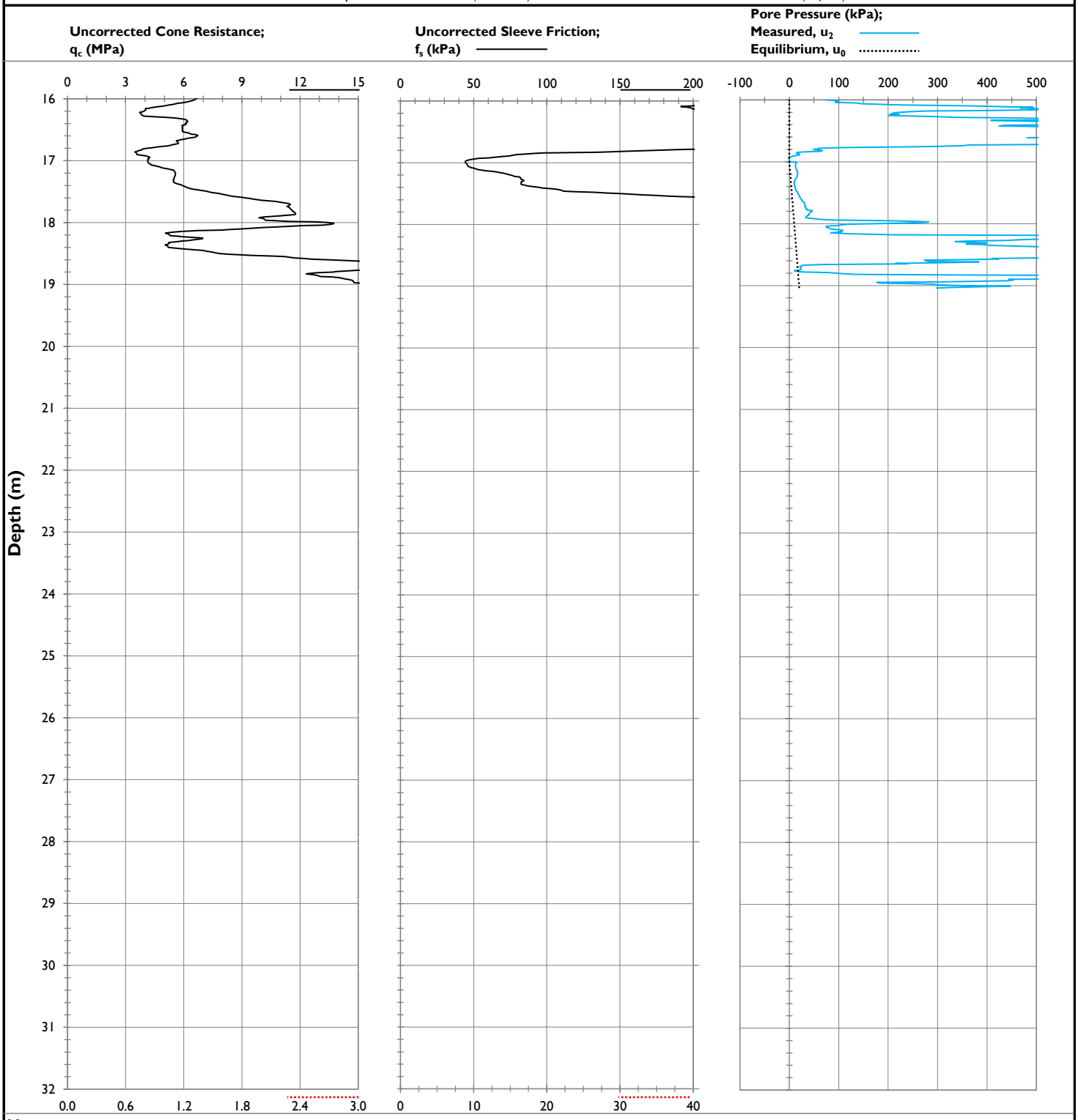


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT04**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631990.5 (AGD66 /* R.L. Surface: *220.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7521945.9 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*17.0m (Estimated)*	Termination:	*19.04m (Refusal)*

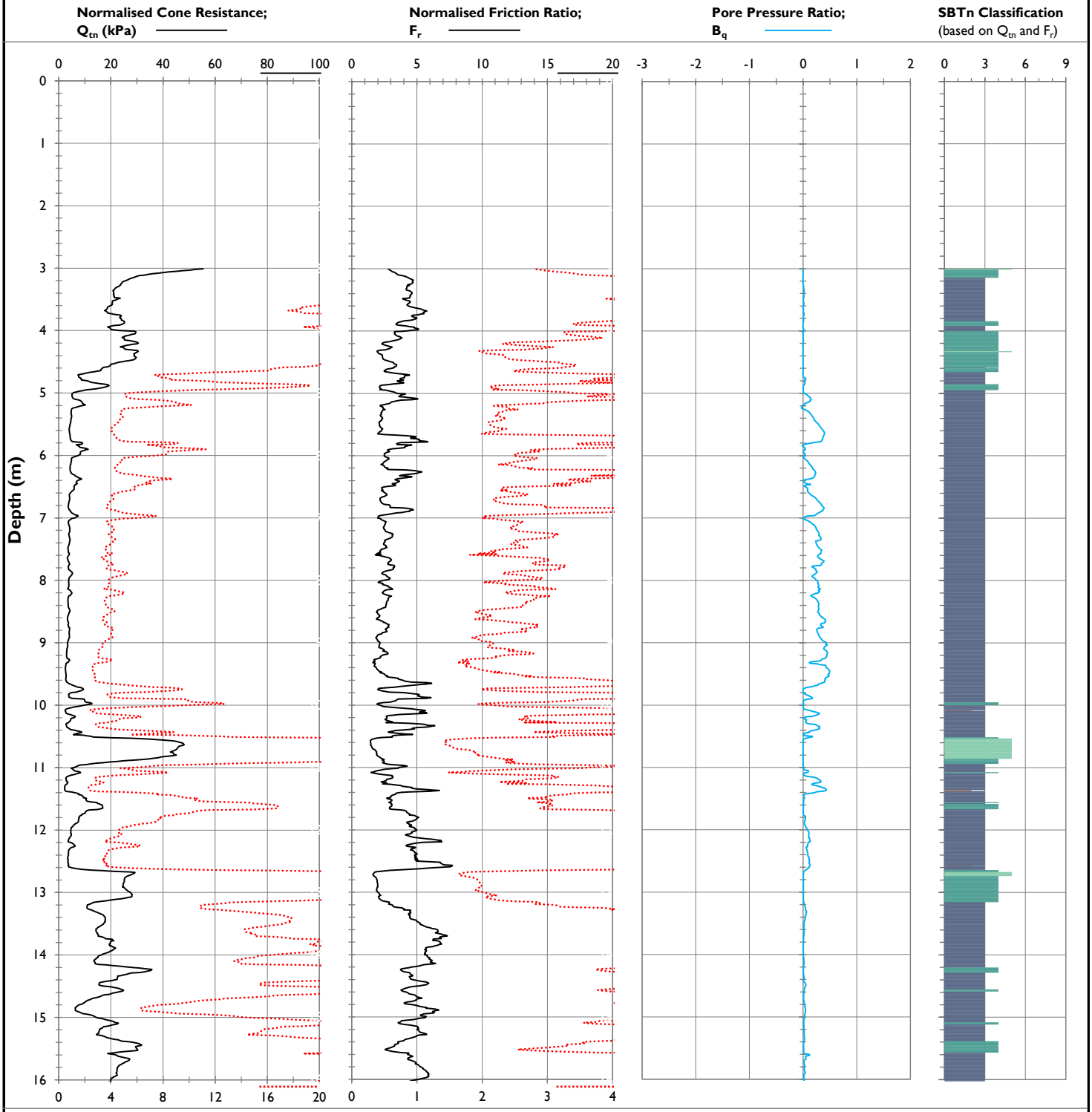


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT04**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631990.5 (AGD66 /* R.L. Surface: *220.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7521945.9 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*17.0m (Estimated)*	Termination:	*19.04m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

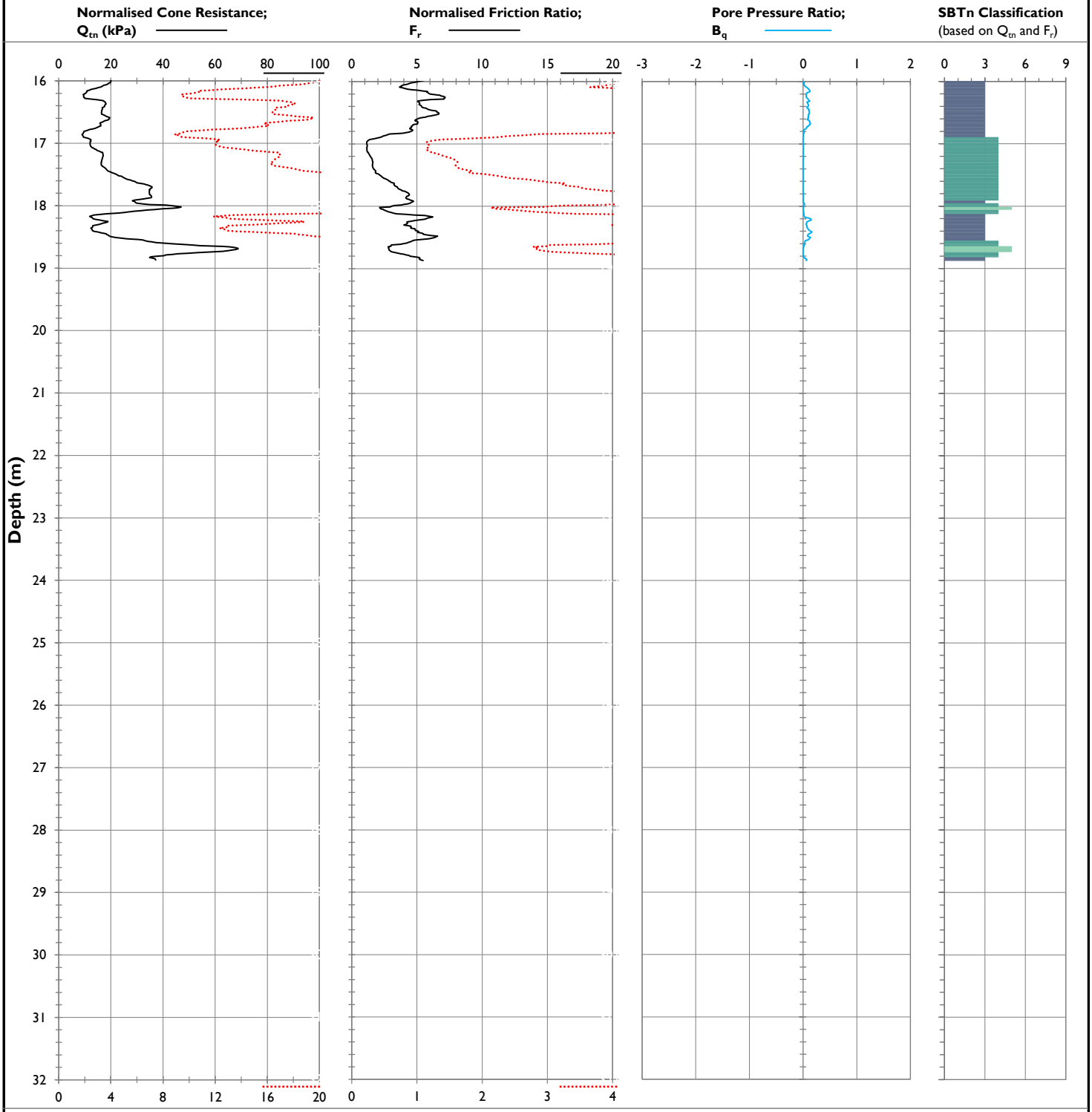
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT04**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631990.5 (AGD66 /* R.L. Surface: *220.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7521945.9 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*17.0m (Estimated)*	Termination:	*19.04m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

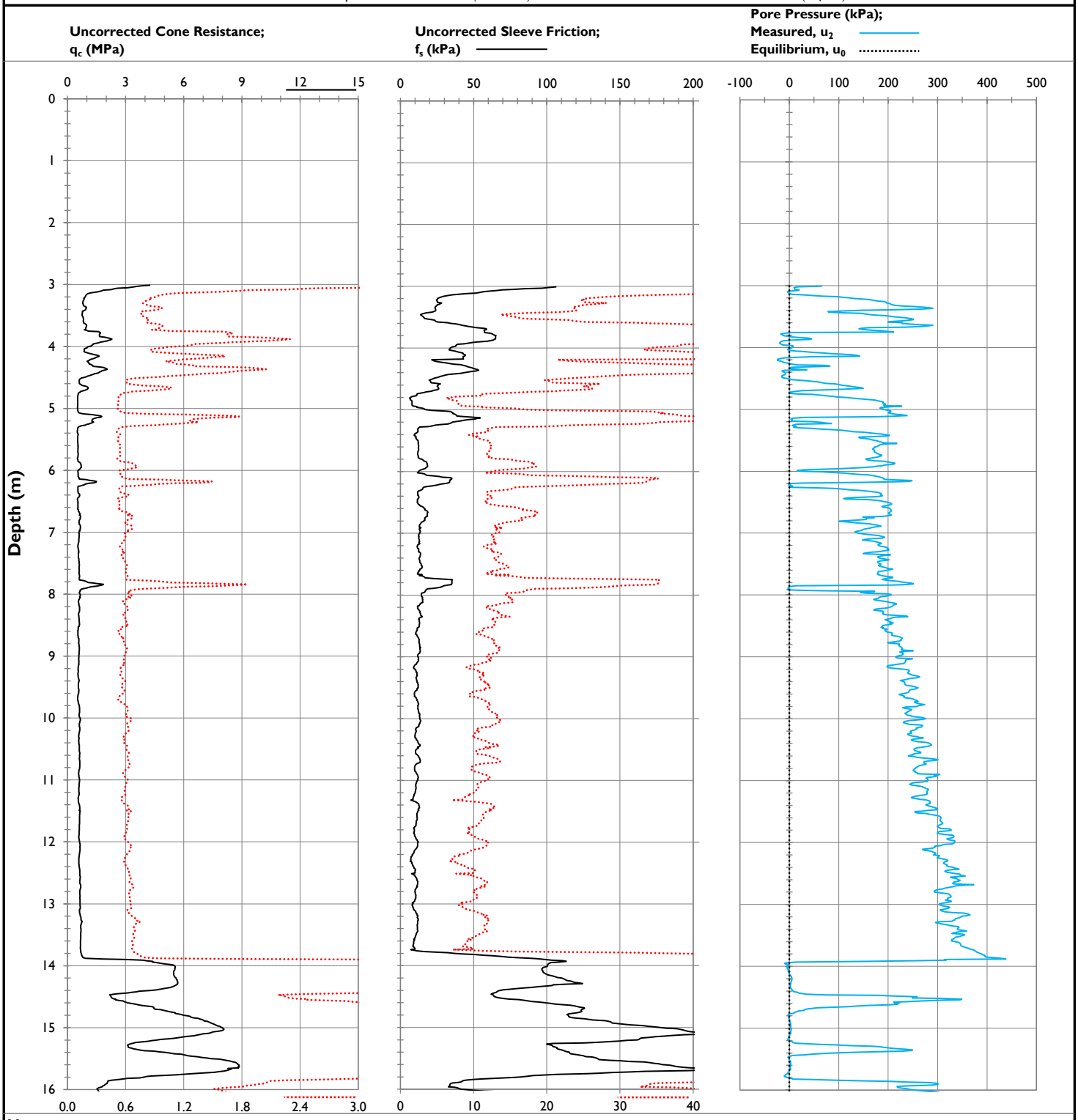
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT05**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631544.2 (AGD66 /*	R.L. Surface:	*217.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7522431.8 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*19.0m (Estimated)*	Termination:	*24.11m (Refusal)*		

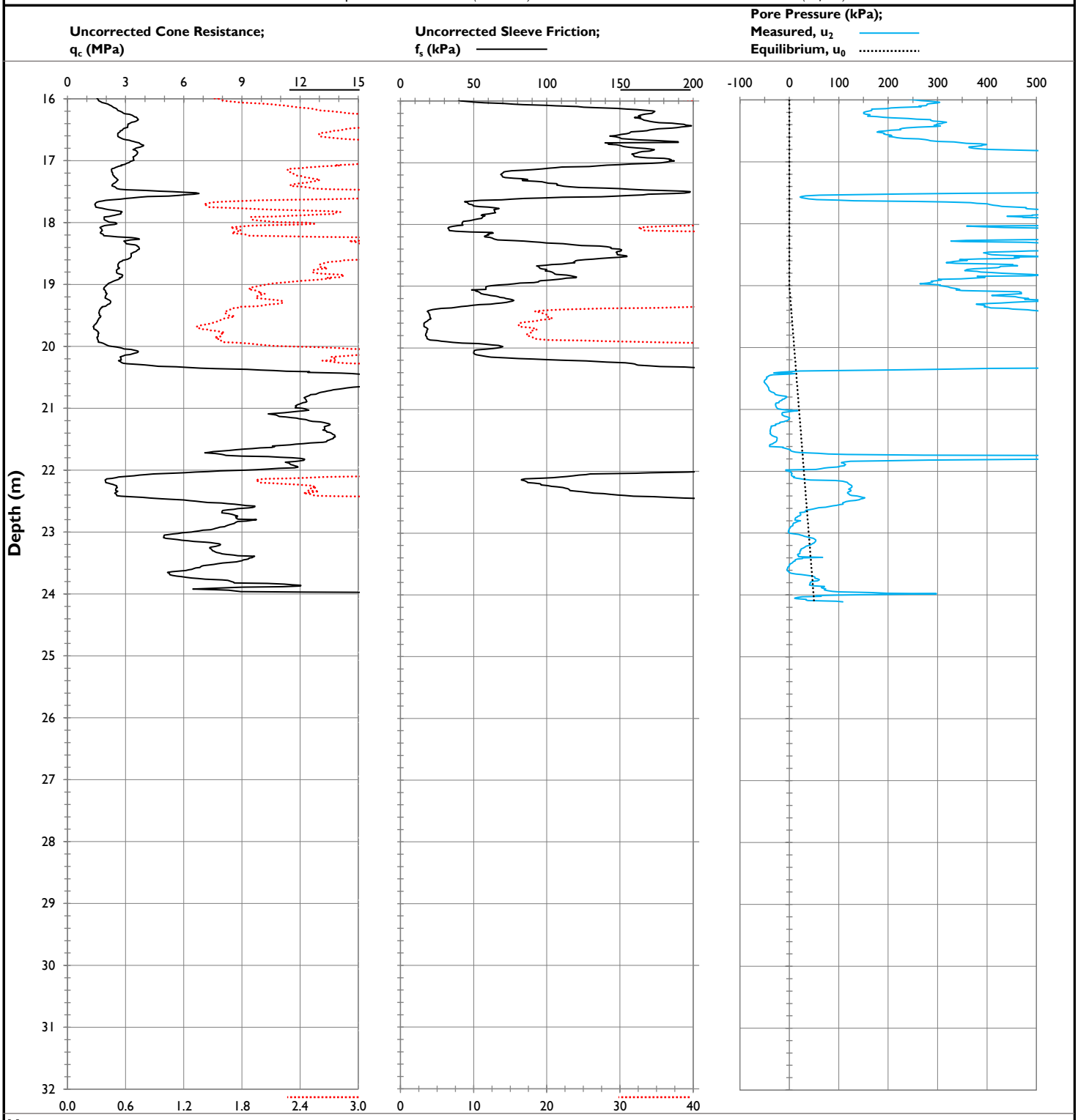


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT05**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631544.2 (AGD66 /* R.L. Surface: *217.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7522431.8 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*19.0m (Estimated)*	Termination:	*24.11m (Refusal)*

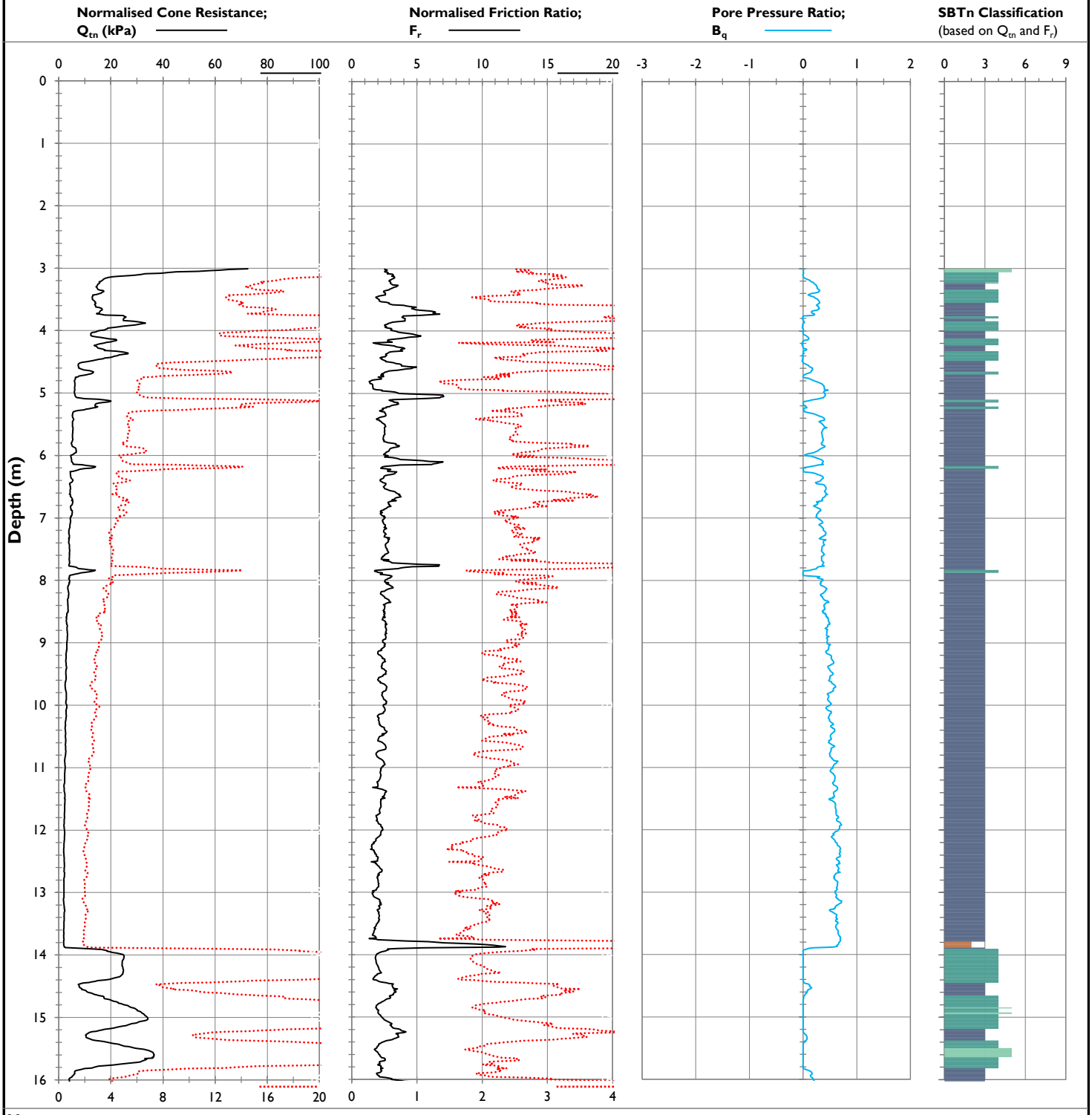


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT05**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631544.2 (AGD66 /* R.L. Surface: *217.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7522431.8 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*19.0m (Estimated)*	Termination:	*24.11m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

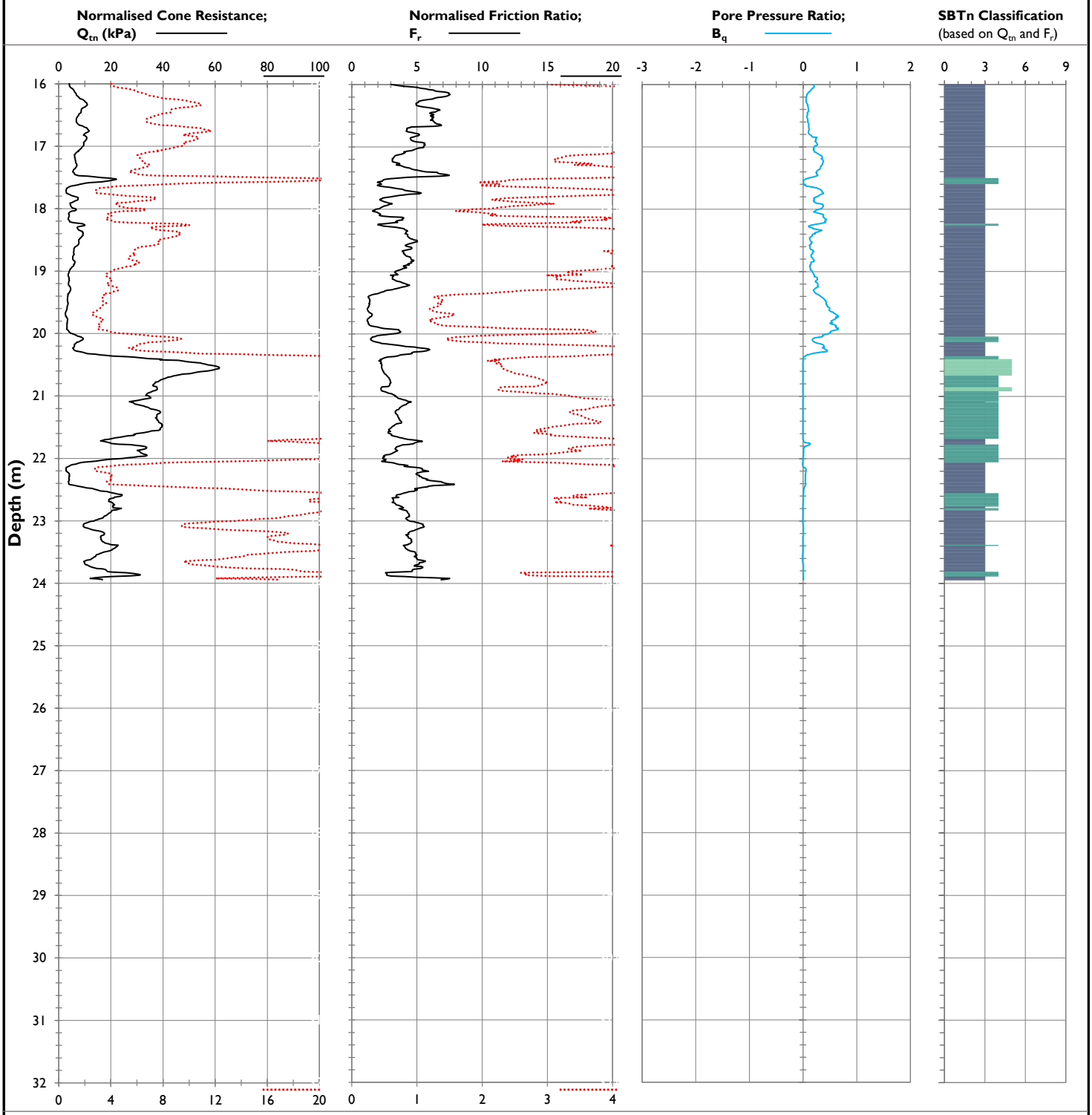
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT05**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631544.2 (AGD66 /* R.L. Surface: *217.3m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7522431.8 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*19.0m (Estimated)*	Termination:	*24.11m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

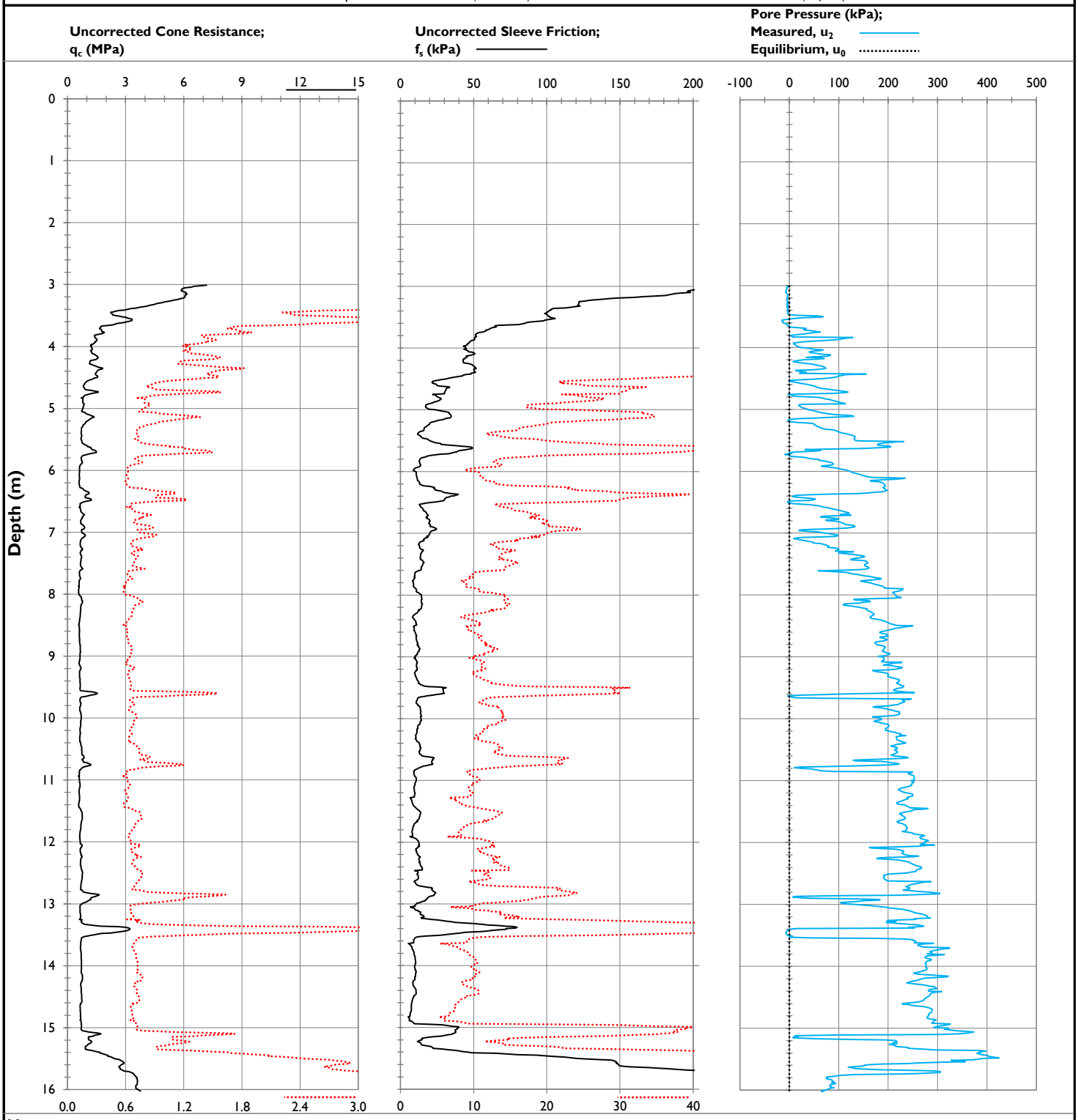
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT06**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631635.7 (AGD66 /* R.L. Surface: *217.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7522236.5 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*19.0m (Estimated)*	Termination:	*20.96m (Refusal)*

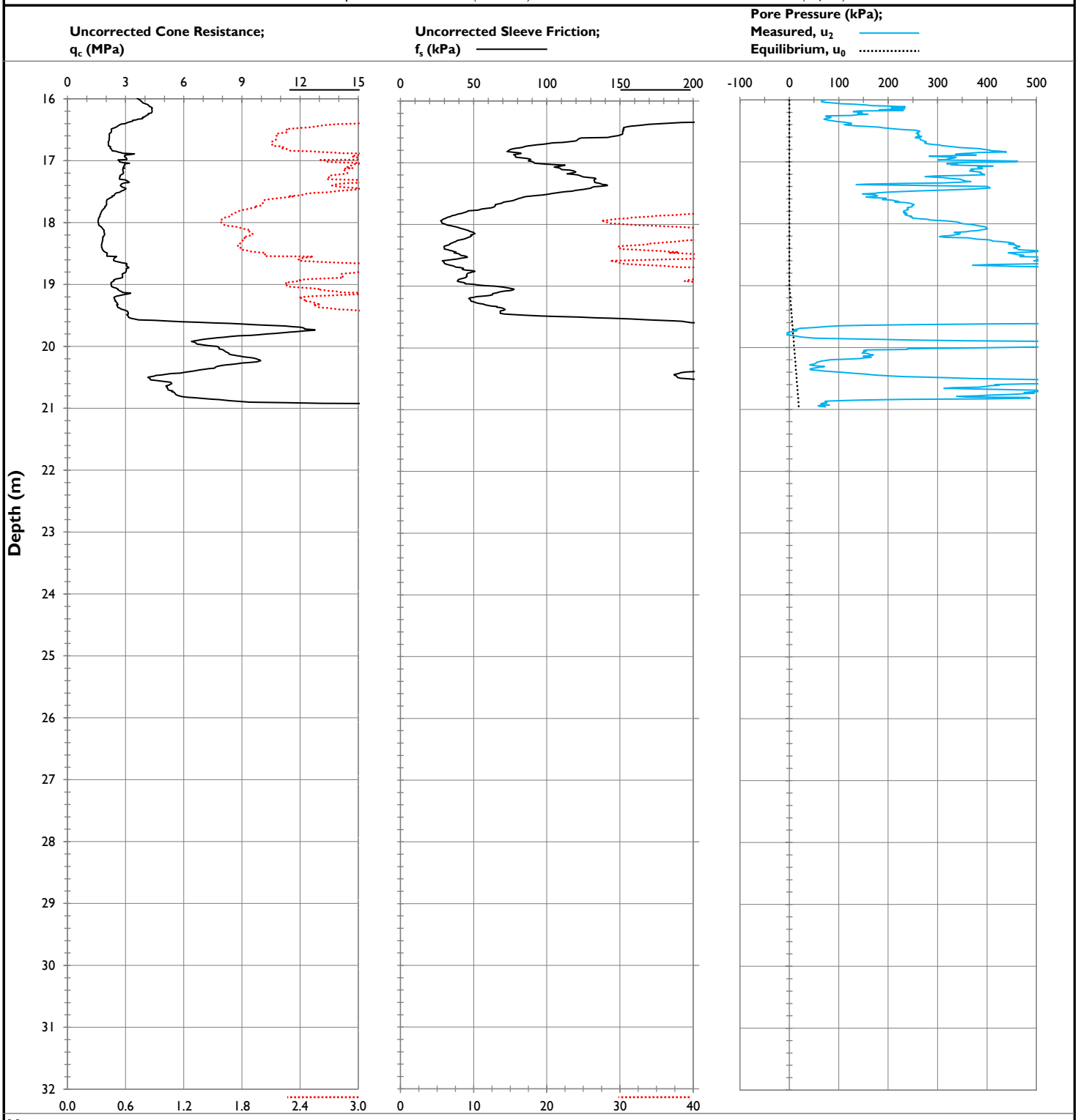


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT06**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631635.7 (AGD66 /* R.L. Surface: *217.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7522236.5 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*19.0m (Estimated)*	Termination:	*20.96m (Refusal)*

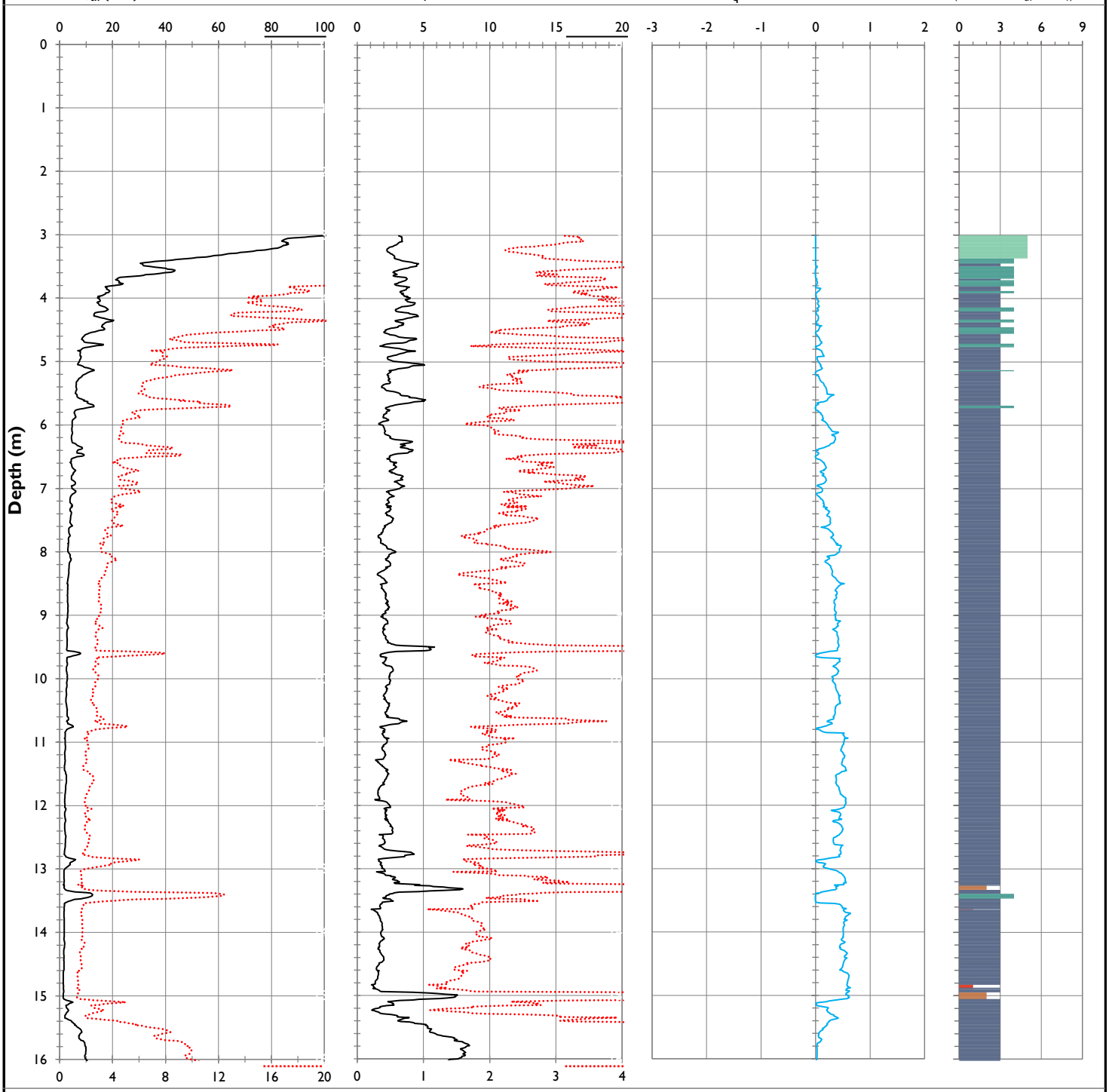


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT06**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631635.7 (AGD66 /*	R.L. Surface:	*217.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7522236.5 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*19.0m (Estimated)*	Termination:	*20.96m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

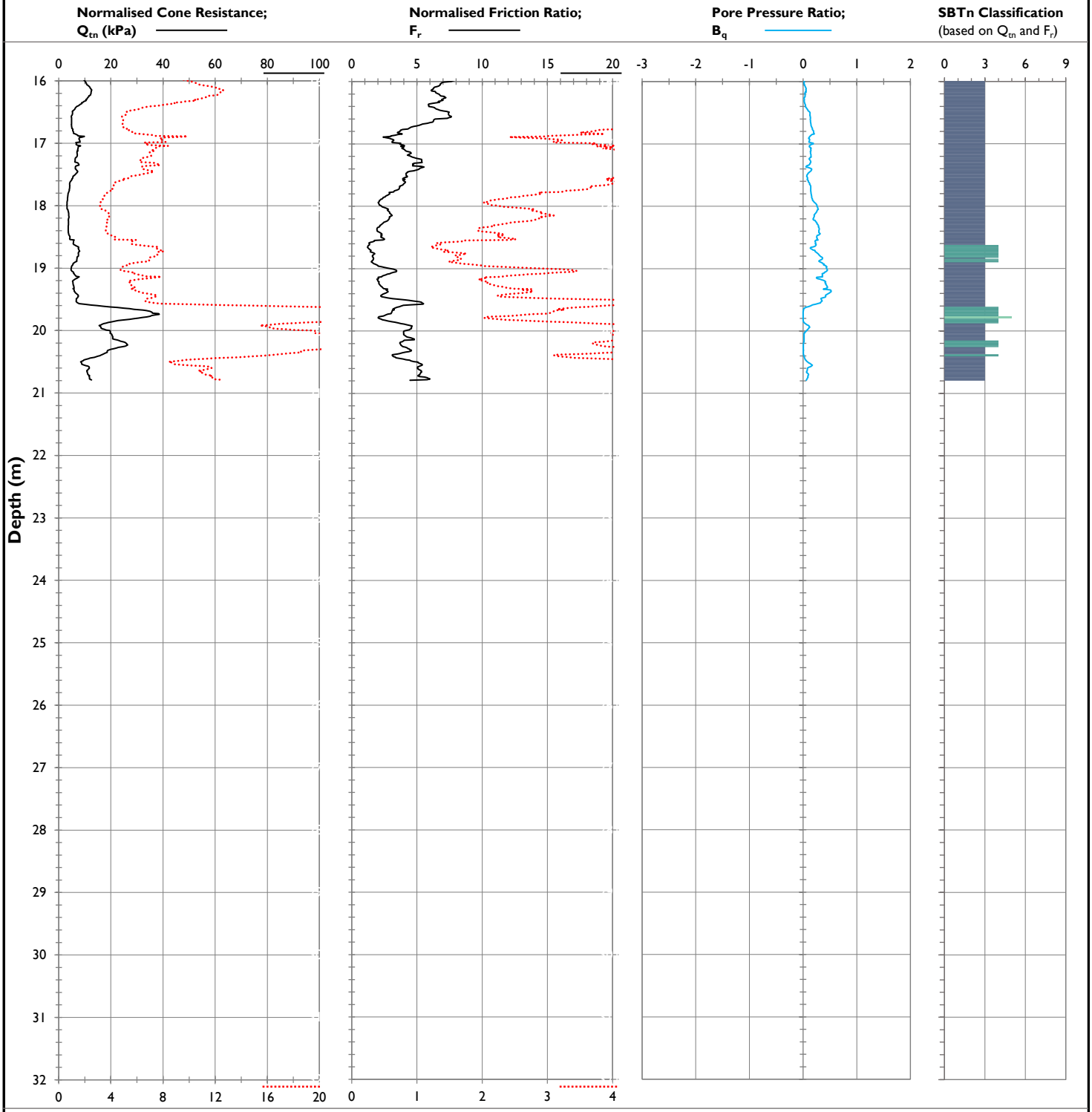
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT06**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**30/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631635.7 (AGD66 /* R.L. Surface: *217.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7522236.5 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*19.0m (Estimated)*	Termination:	*20.96m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

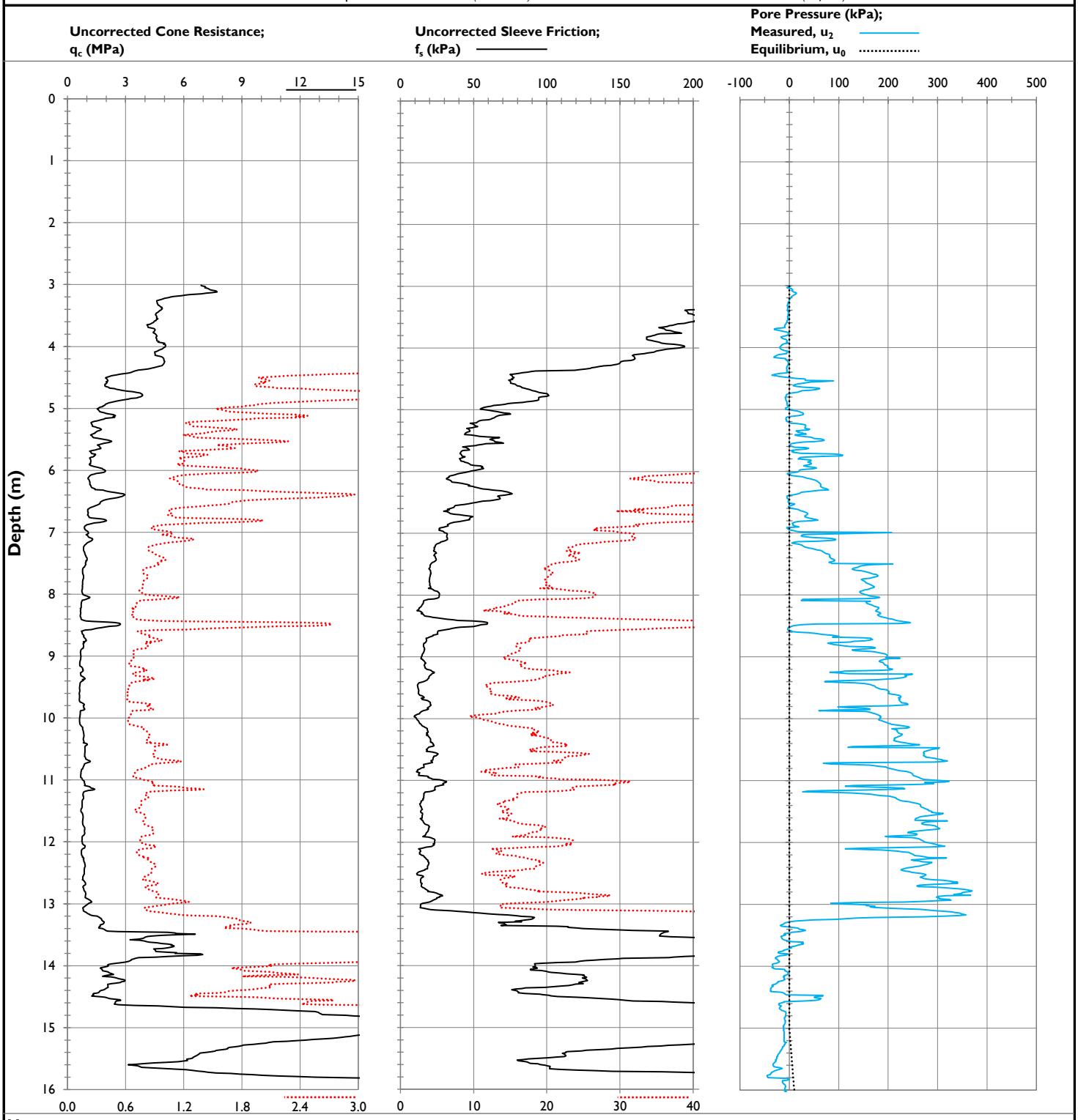
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT07**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**1/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631808.3 (AGD66 /*	R.L. Surface:	*219.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7521893.5 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*18.03m (Refusal)*		

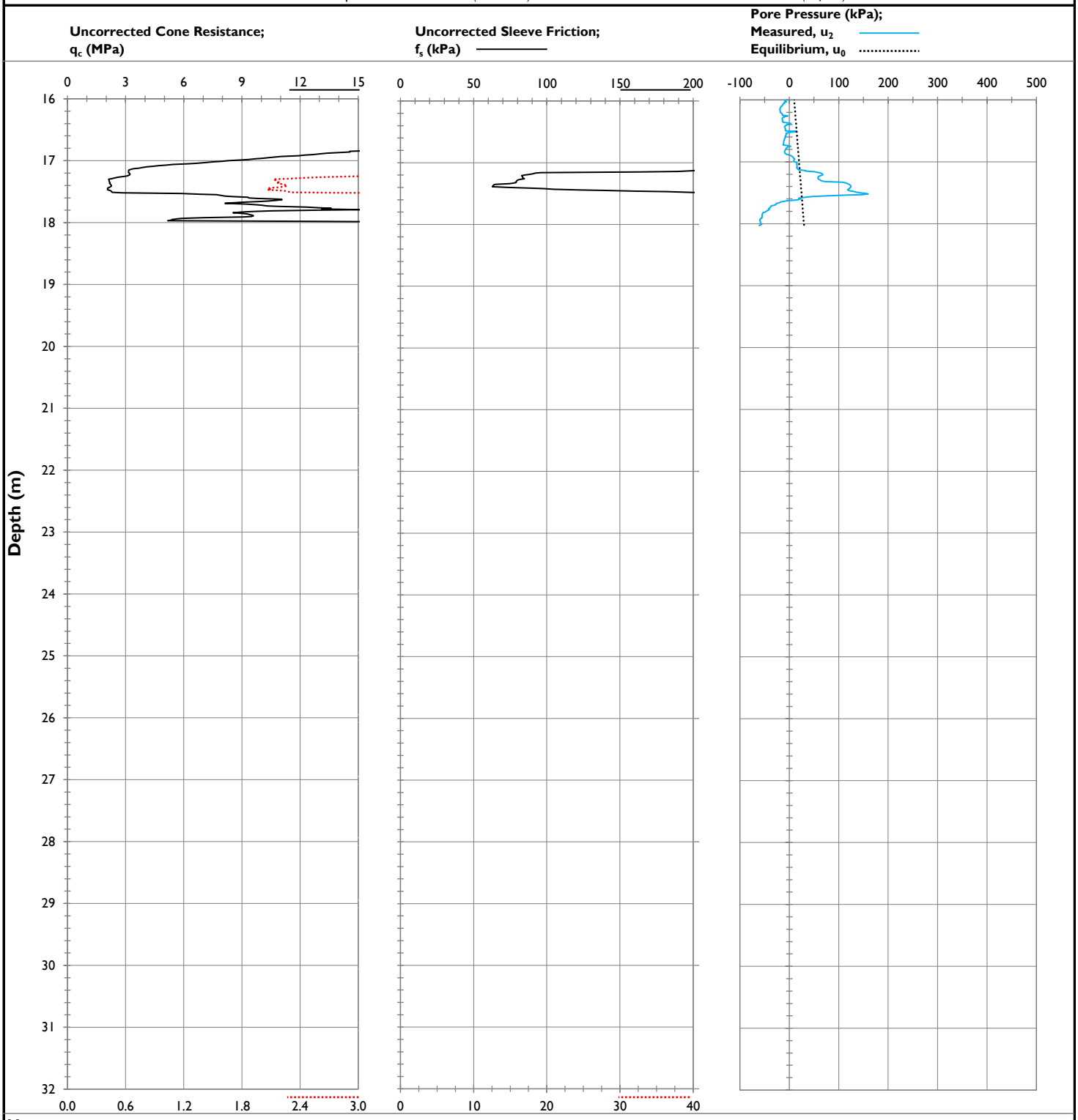


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT07**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**1/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631808.3 (AGD66 /* R.L. Surface: *219.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7521893.5 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*18.03m (Refusal)*

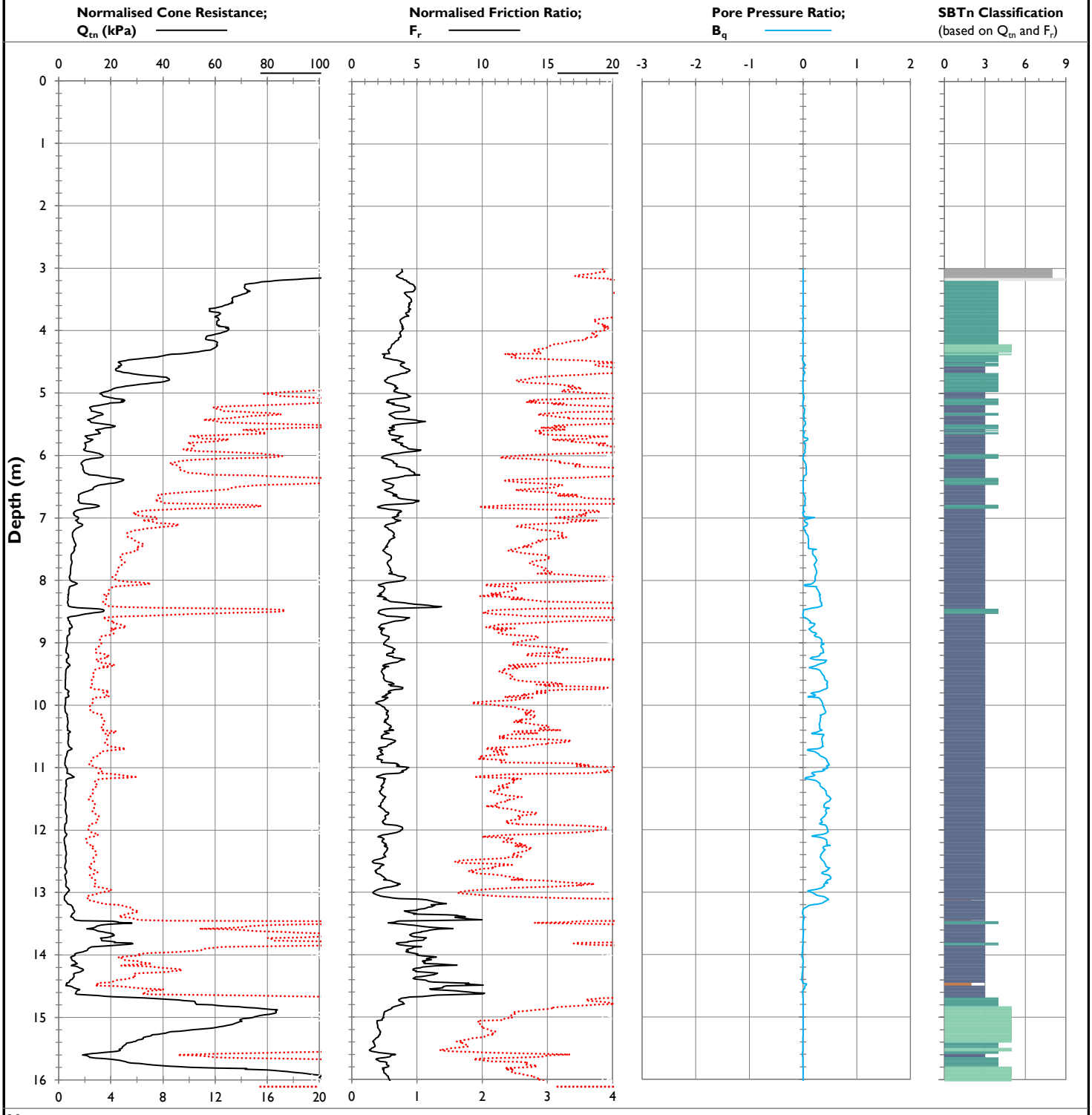


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT07**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**1/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631808.3 (AGD66 /*	R.L. Surface:	*219.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7521893.5 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*18.03m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

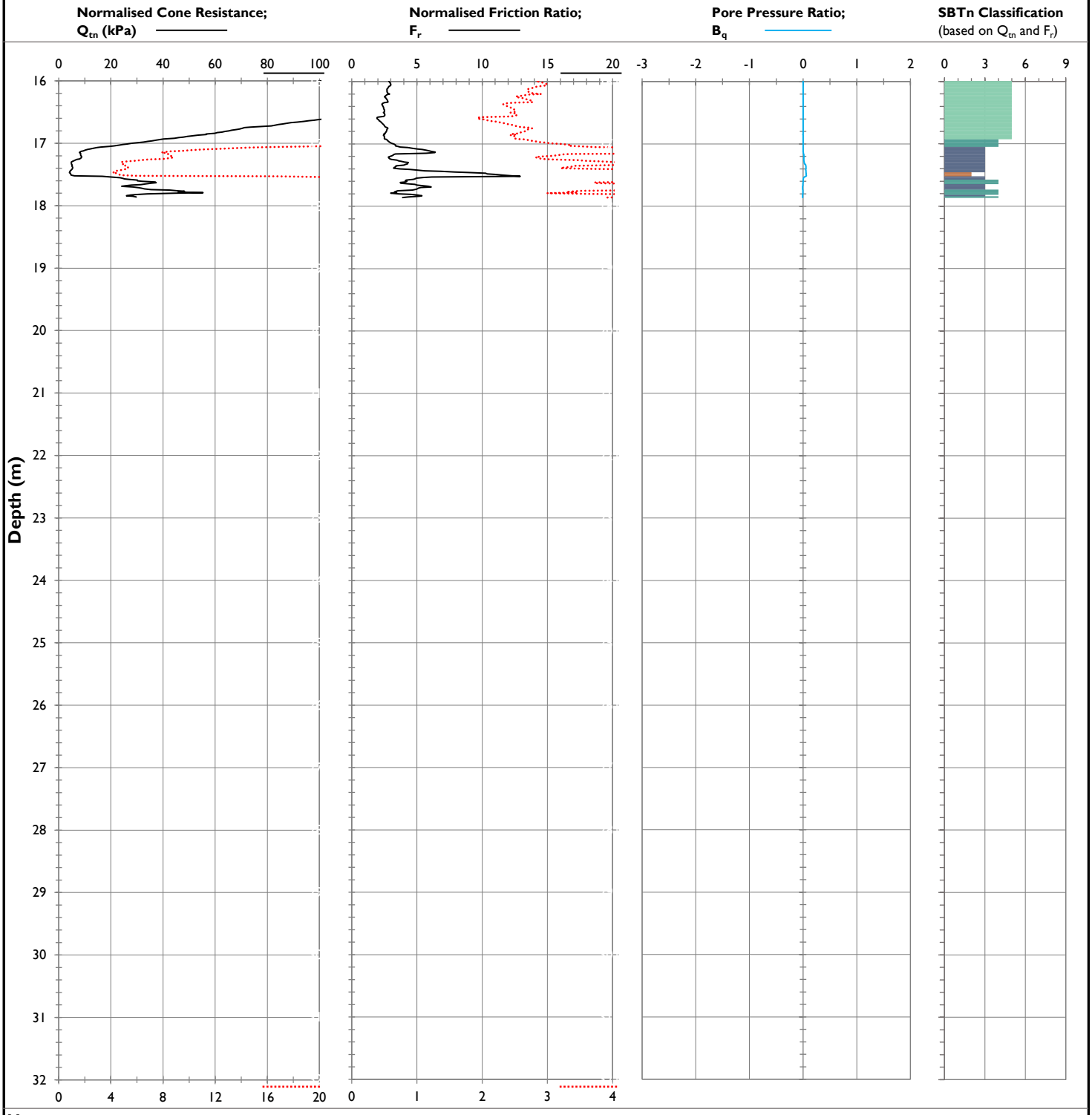
1 - Sensitive, fine grained
2 - Organic soils - clay
3 - Clays - silty clay to clay
4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

** Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT07**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**1/07/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631808.3 (AGD66 /* R.L. Surface: *219.1m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*3.0m*	Northing:	*7521893.5 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*18.03m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

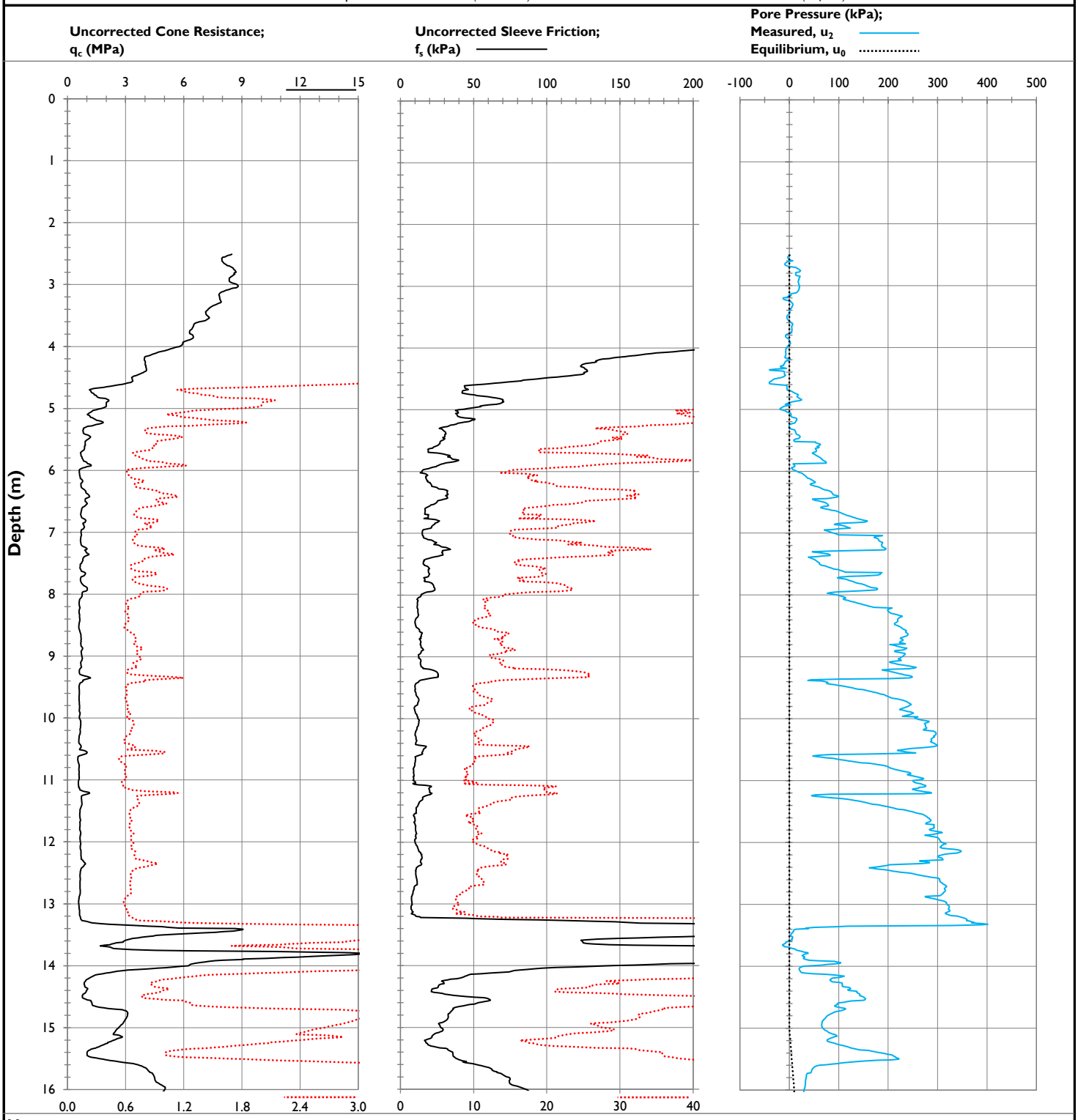
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4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT08**		
Sheet:	1 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631848 (AGD66 / A* R.L. Surface: *217.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*2.5m*	Northing:	*7522322.7 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*23.17m (Refusal)*

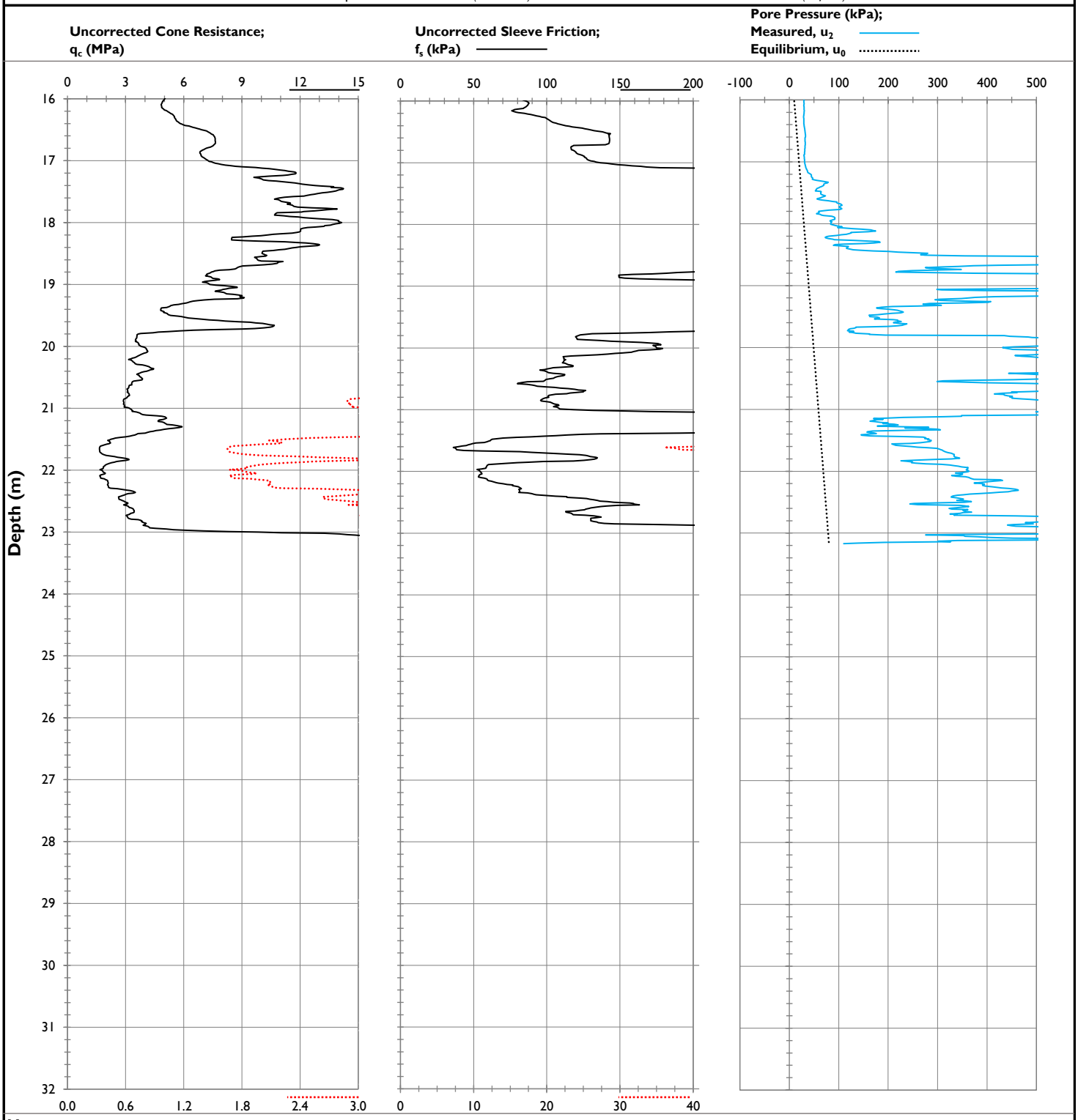


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT08**		
Sheet:	2 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631848 (AGD66 / A*	R.L. Surface:	*217.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*2.5m*	Northing:	*7522322.7 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*23.17m (Refusal)*		

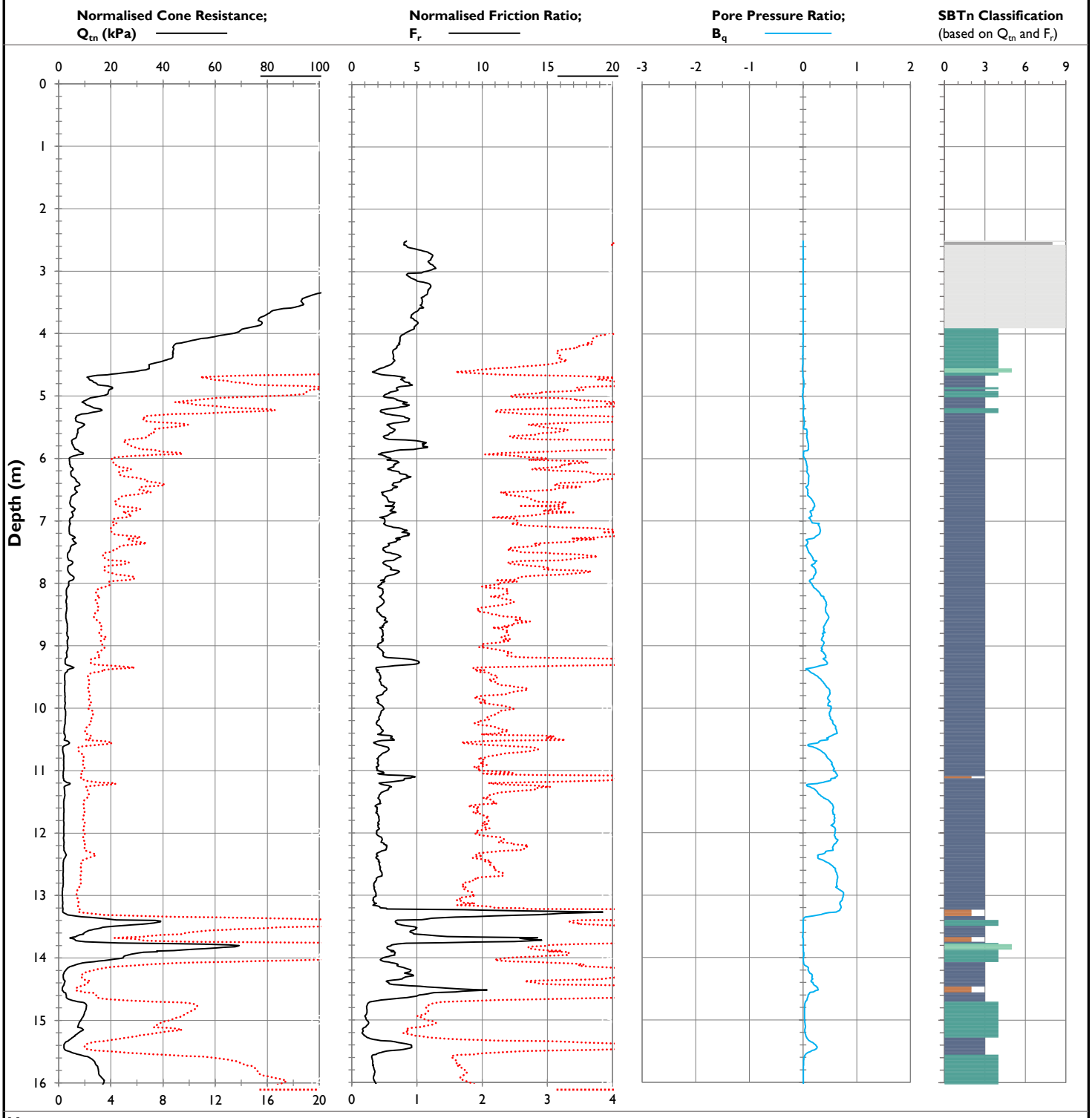


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT08**		
Sheet:	3 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631848 (AGD66 / A*	R.L. Surface:	*217.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*2.5m*	Northing:	*7522322.7 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*23.17m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

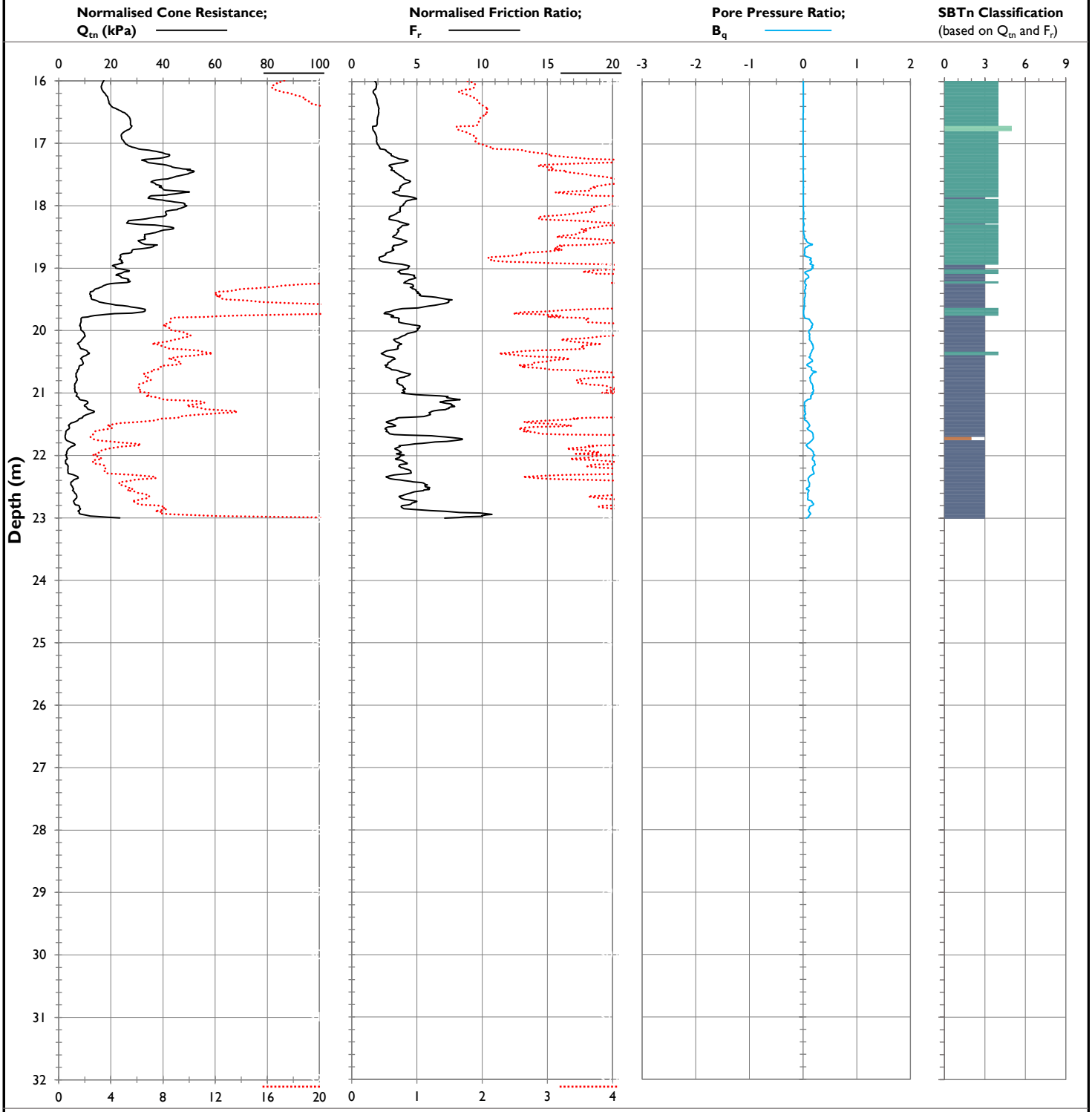
- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT08**		
Sheet:	4 of 4		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631848 (AGD66 / A* R.L. Surface: *217.6m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*2.5m*	Northing:	*7522322.7 (AGD66 / AMG Zone 55)*
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*23.17m (Refusal)*



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

$$F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

$$B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

Soil Behaviour Type Description

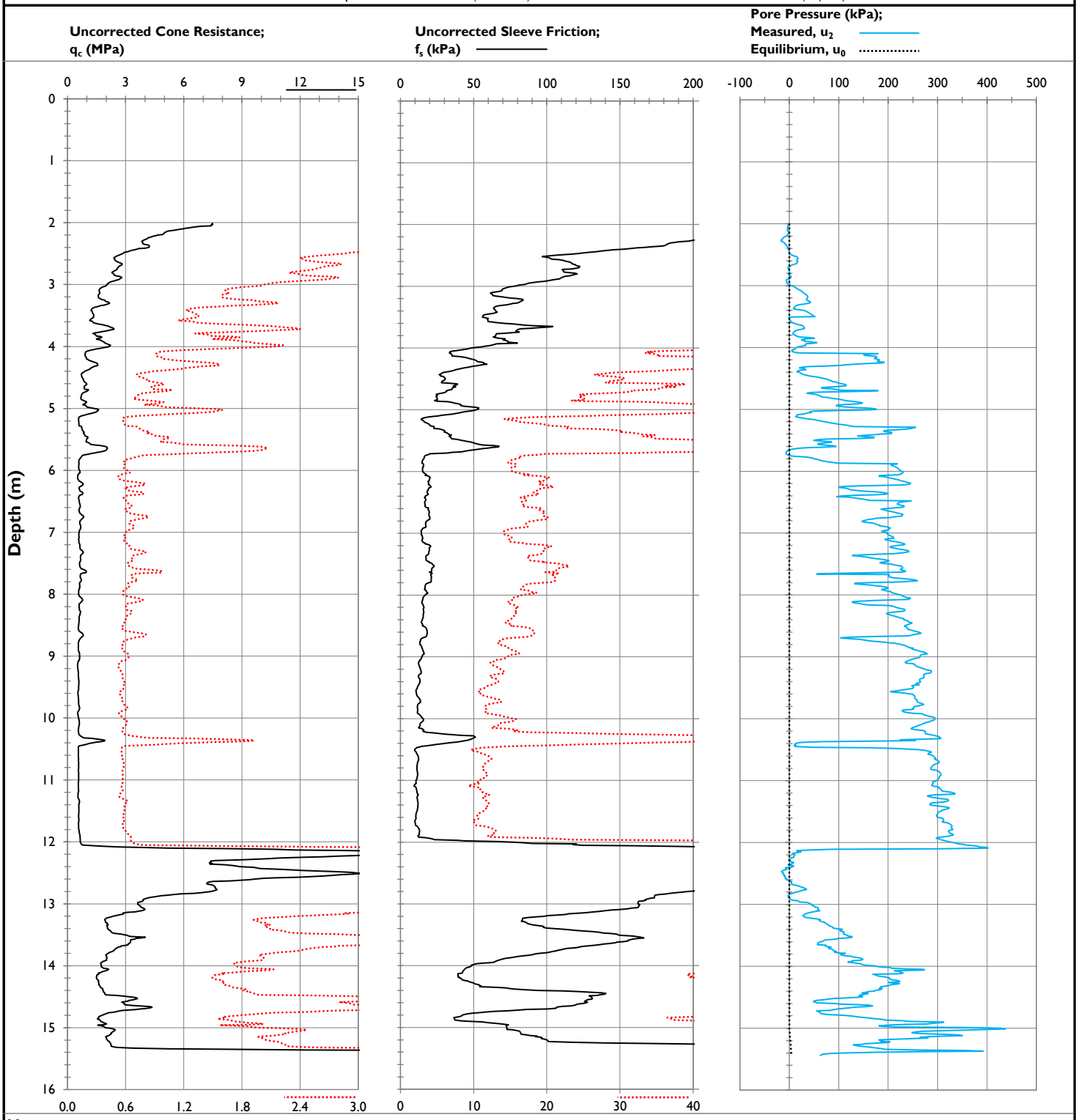
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4 - Silt mixtures - clayey silt to silty clay
5 - Sand mixtures - silty sand to sandy silt
6 - Sands - clean sand to silty sand
7 - Gravelly sand to dense sand
8 - Very stiff sand to clayey sand*
9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT09**		
Sheet:	1 of 2		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631764.1 (AGD66 /*	R.L. Surface:	*217.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*2.0m*	Northing:	*7522496.5 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*15.44m (Refusal)*		

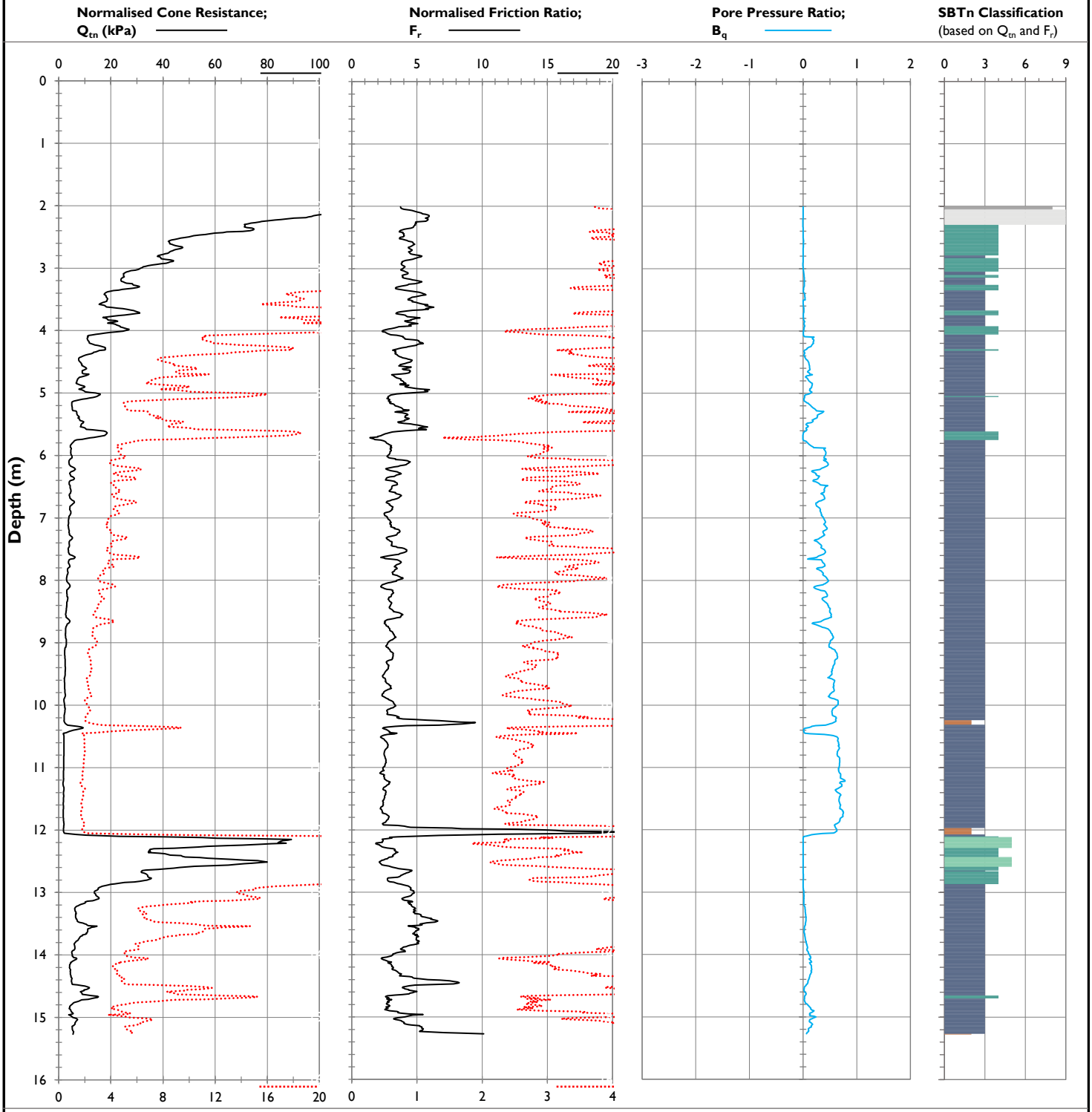


Notes

Piezocone Penetration Test (CPTu)

Test No:	**TSF4-CPT09**		
Sheet:	2 of 2		
Job No:	**B01229-4**		
Client:	**BMA**	Date Tested:	**29/06/2020**
Project:	**TSF2-4**	Tested By:	**IGS**
Location:	**Saraji**		

Cone ID:	*C15178*	Equipment/Rig:	*Tommy, Track mounted*	Easting:	*631764.1 (AGD66 /*	R.L. Surface:	*217.0m (AHD)*
Cone Type:	*C15CFIIP*	Predrill Depth:	*2.0m*	Northing:	*7522496.5 (AGD66 / AMG Zone 55)*		
Cone Area Ratio:	*0.78*	Depth to GW:	*15.0m (Estimated)*	Termination:	*15.44m (Refusal)*		



Notes

$$Q_{tn} = \left(\frac{q_t - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n \qquad F_r = \frac{f_s}{q_t - \sigma_{vo}} \times 100\% \qquad B_q = \frac{u_2 - u_0}{q_t - \sigma_{vo}}$$

n determined through iteration of Q_{tn}, I_c and n until change in n <0.01

Soil Behaviour Type Description

- 1 - Sensitive, fine grained
- 2 - Organic soils - clay
- 3 - Clays - silty clay to clay
- 4 - Silt mixtures - clayey silt to silty clay
- 5 - Sand mixtures - silty sand to sandy silt
- 6 - Sands - clean sand to silty sand
- 7 - Gravelly sand to dense sand
- 8 - Very stiff sand to clayey sand*
- 9 - Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

Trilab
Soil Rock Calibration

Brisbane
346A Bilsen Road,
Geebung
QLD 4034
Ph: +61 7 3265 5656

Perth
2 Kimmer Place,
Queens Park
WA 6107
Ph: +61 8 9258 8323

OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050069-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	7/05/2021
		Report Date:	26/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF4-CPT06	**Depth (m):**	11.00-11.80
Description:	SILTY CLAY- black		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-13	0.024	5.1E-09	16.44	20.94	0.779	0.44	0.5
2	13-24	0.043	3.5E-09	12.82	15.91	0.718	0.60	1.3
3	24-50	0.052	3.0E-09	23.44	21.62	0.440	0.80	2.5
4	50-101	0.078	2.0E-09	22.41	19.81	0.328	0.87	4.1
5	101-200	0.105	1.7E-09	32.33	24.67	0.224	1.05	6.2
6	200-399	0.075	6.8E-10	33.76	26.59	0.082	0.92	7.7
7	399-800	0.135	6.1E-10	38.26	26.44	0.075	1.94	10.5
8	800-1600	0.162	3.1E-10	29.64	21.38	0.046	1.83	13.8
9	1600-399	0.017	7.5E-11	72.09	34.92	0.007	0.23	13.1
10	399-100	0.024	3.1E-10	40.05	26.98	0.037	0.61	12.2

Remarks: Tested as Received

REP03103

Accredited for compliance with ISO/IEC 17025 - Testing.
The results of the tests, calibrations, and/or measurements included in this document are traceable to Australian/National Standards.

Tested at Trilab Brisbane Laboratory

Authorised Signatory

C. Channon

NATA
ACCREDITED FOR TECHNICAL COMPETENCE

Laboratory Number 9926

The results of calibrations and tests performed apply only to the specific instrument or sample at the time of test unless otherwise clearly stated.
Reference should be made to Trilab's "Standard Terms and Conditions of Business" for further details.
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OEDOMETER TEST REPORT

Test Method: AS1289.6.6.1, 3.5.1

Client:	EDG Consulting	**Report No.:**	21050070-OED
		Workorder No.	8593
Address:	Level 1, 18 Wandoo Street, Fortitude Valley QLD 4006	**Test Date:**	7/05/2021
		Report Date:	26/05/2021
Project:	B01229-4 - TSF2-4 - Saraji Mine		
Client Id.:	TSF4-CPT07	**Depth (m):**	7.50-8.00
Description:	-		

TEST RESULTS

Stage	Load (kPa)	Cc	k (m/s)	Cv (m^2/yr) t_{50}	Cv (m^2/yr) t_{90}	Mv ($kPa^{-1}x10^{-3}$)	C_a x 10^{-3}	% Consolidation
1	6-12	0.040	4.1E-09	6.30	9.26	1.412	0.64	0.8
2	12-24	0.047	3.5E-09	9.01	13.51	0.836	0.87	1.8
3	24-50	0.063	2.7E-09	13.28	15.55	0.554	1.10	3.3
4	50-99	0.086	1.9E-09	13.82	16.08	0.378	1.16	5.0
5	99-199	0.099	1.2E-09	18.77	17.49	0.224	1.39	7.2
6	199-399	0.110	7.9E-10	22.82	20.22	0.126	1.59	9.5
7	399-799	0.142	5.8E-10	24.19	22.24	0.084	1.71	12.5
8	799-1599	0.162	3.1E-10	28.13	20.08	0.049	2.23	16.0
9	1599-401	0.018	9.9E-11	61.39	42.54	0.008	0.26	15.2
10	401-99	0.030	2.9E-10	22.81	18.73	0.050	0.73	14.0

Remarks: Tested as Received

REP03103

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Tested at Trilab Brisbane Laboratory

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SOIL WATER ANALYSIS (SWA)

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TEST REPORT - PSD (Wet Sieve)

Client: EDG Consulting
Client Contact: Darron Lee; Jo Perrett
Client Job Title: Saraji Mine
Client Reference: **B01229-4**

SWA Job No: JN0739

Date of Analysis: 28 June - 22 July 2021
No. Samples Submitted: 3
Sample(s) Condition: Intact Core

METHODOLOGY

- PSD (Wet Sieve) determined in accordance with AS 1289.3.6.1-1995.

TEST RESULTS

SWA ID	739-02	739-03	739-04
Client ID	TSF4-CPT06 8.0 - 8.8m	TSF3-CPT09 7.0 - 7.8m	TSF3-CPT07 5.0 - 5.5m
Sieve Size (mm)	% Passing		
2	100.00	100.00	100.00
1.18	99.36	99.97	99.81
0.6	96.68	99.75	98.08
0.425	90.72	99.08	75.59
0.3	81.01	97.80	53.88
0.212	77.10	94.87	41.91
0.15	72.94	36.75	35.34
0.075	59.54	27.27	29.77

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TEST REPORT

Client: EDG Consulting
Client Contact: Darron Lee; Jo Perrett
Client Job Title: Saraji Mine
Client Reference: **B01229-4**

SWA Job No: JN0739

Date of Analysis: 28 June - 22 July 2021
No. Samples Submitted: 7
Sample(s) Condition: Intact Core

METHODOLOGY

- Gravimetric moisture content determined in accordance with AS 1289.2.1.1-2005.
- Atterberg limits determined in accordance with AS1289.3.1.1; AS 1289 3.2.1 & AS 1289.3.3.1.
- Bulk density (ρ_b) determined in accordance with AS 1289.1.3.1-1999.
- Particle density (ρ_p) determined in accordance with AS 1289.3.5.1-1995.
- Total porosity (T_p) determined by calculation: Tp = 1-(ρ_b/ρ_p)

TEST RESULTS

SWA ID	739-02	739-03	739-04
Client ID	TSF4-CPT06 8.0 - 8.8m	TSF3-CPT09 7.0 - 7.8m	TSF3-CPT07 5.0 - 5.5m
Grav. Moisture Content (%)	32.45	32.25	33.62
Atterberg Limits:			
• Liquid Limit	34.91	36.94	39.93
• Plastic Limit	27.94	27.97	28.59
• Plasticity Index	6.97	8.97	11.34

SWA ID	Client ID	Bulk Density (g/cm3)	Particle Density (g/cm3)	Total Porosity (%)
739-01	TSF2-CPT14 2.0-2.8m	1.02	1.49	31.39
739-02	TSF4-CPT06 8.0-8.8m	1.09	1.61	32.27
739-03	TSF3-CPT09 7.0-7.8m	1.11	1.54	27.89
739-04	TSF3-CPT07 5.0-5.5m	1.14	1.55	26.24
739-05	TSF4-CPT06 11.0 - 11.8m	1.12	1.60	30.13
739-06	TSF4-CPT07 7.5 - 8.0m	1.18	1.69	30.46
739-07	TSF2-CPT11 3.0-3.7m	0.96	1.56	38.56

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TEST REPORT - SWCC

Client: EDG Consulting
Client Contact: Darron Lee; Jo Perrett
Client Job Title: Saraji Mine
Client Reference: **B01229-4**
SWA Job No: JN0739

Date of Analysis: 28 June - 22 July 2021
No. Samples Submitted: 7
Sample(s) Condition: Intact Core

METHODOLOGY

• SWCC determined in accordance with ASTM D6836 (Methods A, B & D)

TEST RESULTS

SWA-ID	Client ID	Volumetric Water Content (cm^3/cm^3)										
		0kPa	2.5kPa	5kPa	7.5kPa	10kPa	33kPa	100kPa	1,500kPa	39MPa	98MPa	300MPa
739-01	TSF2-CPT14 2.0-2.8m	0.3139	0.2680	0.2508	0.2406	0.2314	0.2058	0.1829	0.1311	0.0918	0.0825	0.0729
739-02	TSF4-CPT06 8.0-8.8m	0.3537	0.2949	0.2559	0.2325	0.2166	0.1578	0.1388	0.0965	0.0870	0.0859	0.0850
739-03	TSF3-CPT09 7.0-7.8m	0.3578	0.3149	0.2731	0.2466	0.2286	0.1759	0.1509	0.1326	0.1293	0.1291	0.1290
739-04	TSF3-CPT07 5.0-5.5m	0.3833	0.3032	0.2563	0.2308	0.2146	0.1628	0.1392	0.1120	0.1058	0.1053	0.1049
739-05	TSF4-CPT06 11.0 - 11.8m	0.3624	0.3308	0.3009	0.2803	0.2638	0.2189	0.1789	0.1547	0.1447	0.144	0.1434
739-06	TSF4-CPT07 7.5 - 8.0m	0.3806	0.3241	0.298	0.2827	0.2710	0.2359	0.2017	0.1592	0.1315	0.1269	0.1226
739-07	TSF2-CPT11 3.0-3.7m	0.3856	0.3193	0.2943	0.2800	0.2689	0.2359	0.2018	0.1548	0.1201	0.1135	0.1071



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