Appendix D

Jacinth-Ambrosia Change in Operations Application

Jacinth-Ambrosia Mineral Sands Mine

Change in Operations Application

Final | Version 1.0

February 2023

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DOCUMENT CONTROL

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TERMS AND ABBREVIATIONS

Abbreviation	Definition
Amp	Ampere
ANCOLD	Australian National Committee on Large Dams
Bcm	Bank cubic metre
CD	Collection Deposit
DC	Direct Current
DEM	Department for Mining and Energy
DN	Diameter nominal
EC	Electrical Conductivity
ELA	Eco Logical Australia
FWC	Far West Coast
GL	Gigalitre
Ha	Hectares
HDPE	High Density Polyethylene
HM	Heavy Mineral
HMC	Heavy Mineral Concentrate
IBRA	Interim Biogeographical Regionalisation of Australia
J-A	Jacinth Ambrosia
kL	Kilolitre
Km	Kilometre
Ktpa	Kiloton per annum
kV	Kilovolt
kVA	Kilovolt-amp
kW	Kilowatt
L/s	Litres per second
LEM	Landform Evolution Modelling
LIMS	Low Intensity Magnetic Separator
LOM	Life of Mine
LV	Low Voltage
m	Metre
ML	Mining Lease or Megalitre
MLA	Mining Lease Application
MLP	Mining Lease Proposal

Abbreviation	Definition
ML/d	Megalitres per day
mm	Millimetre
ModCoD	Modified Co-disposal
MPL	Miscellaneous Purpose License
MUP	Mining Unit Plant
MW	Megawatt
MWh	Megawatt hours
Non-Mags	Non-Magnetics
NORM	Naturally Occurring Radioactive Material
NVAP	Native Vegetation Assessment Panel
NVC	Native Vegetation Council
OMC	Outcome Measurement Criteria
PAF	Potentially Acid Forming
PEPR	Program for Environment Protection and Rehabilitation
PFS	Pre-Feasibility Study
PIRSA	Department of Primary Industries and Resources of South Australia
RHF	Rotary Hearth Furnace
RL	Relative Level
RO	Reverse Osmosis
ROM	Run of Mine
SA	South Australia
SEB	Significant Environmental Benefit
TDS	Total Dissolved Solids
TMP	Tailings Management Plan
TOR	Terms of Reference
tph	Tailing per hour
TSF	Tailing Storage Facility
V	Volts
WA	Western Australia
WCP	Wet Concentrator Plant
WHIMS	Wet High Intensity Separation
WWTP	Wastewater Treatment Plant

1 INTRODUCTION

Iluka (Eucla Basin) Pty Ltd (Iluka), a wholly owned subsidiary of Iluka Resources Limited, own and operate the Jacinth-Ambrosia (J-A) open pit mineral sands mining operation in South Australia. The existing J-A Mine site operates on Mining Lease (ML) 6315 and was approved for operations by the then Department of Primary Industries and Resources of South Australia (PIRSA) (now referred to as the Department for Energy and Mining (DEM)), with operations commencing in 2009. Iluka is currently preparing a Mining Lease Application (MLA) for the development of the adjacent Atacama deposit. Atacama is located approximately 5 km north-east of the existing J-A mine and is approximately 290 km north-west of Ceduna on the Eyre Peninsula of South Australia (SA).

As required under Part 8B Division 7 of the *Mining Act 1971* this document has been prepared to outline the changes that will occur at J-A should the MLA for the Atacama Project be approved.

J-A currently operates two main pits; Jacinth to the south and Ambrosia to the north, both contained within ML 6315. The combined J-A deposits contain an estimated 4.6 million in situ tonnes of heavy mineral (HM) sands with an average grade of 4%, and a valuable heavy mineral assemblage of 50% zircon, 27% ilmenite and 4% rutile (Iluka, 2021). The life of mine (LOM) for both pits is expected to be completed at or before 2029, at which point it is anticipated new, already identified resources in the area will be approved for mining, including but not limited to Atacama. Atacama will be operated as a satellite deposit to J-A.

As with J-A, Atacama will be mined as an open pit operation and will be mined from four discrete open cut pits (central, western, eastern and southern, refer to Atacama Mining Lease Proposal (MLP) Section 4 for location details). Approximately 185 Mt of overburden and 25 Mt of ore will be mined, providing approximately 4.1 Mt of Heavy Mineral Concentrate (HMC). At Atacama, mineral sand ore will be transported via truck to a run of mine (ROM) stockpile adjacent to the associated pit(s) on the proposed Atacama ML after which it will undergo primary screening through a new Mining Unit Plant (MUP). The product will be slurry pumped via pipeline to J-A and processed at the J-A plant, and then through a new Wet High Intensity Magnetic Separation (WHIMS) plant to produce two stockpiles of HMC (one magnetic and one non-magnetic). HMC will be transported by truck to the Port of Thevenard near Ceduna and shipped for final processing at Iluka’s processing Capel/ Narngulu facilities in Western Australia (WA).

To allow for maximum flexibility between the tenements (once the Atacama ML is granted) the J-A and Atacama Projects will be managed as one operation and as such Iluka may use secondary oversize and/ or extractives from the J-A related ML/ Extractive Mineral Leases (EMLs) on the Atacama ML and at times may use secondary oversize from the Atacama ML on the J-A related tenements.

The submission of the MLP for the Atacama Project is expected to occur in early 2023, with Iluka currently also completing the Pre-Feasibility Study (PFS) for Atacama. As part of the approval process a self-assessment of the proposed changes that will occur at J-A as a result of the Atacama Project to determine the correct regulatory pathway has been undertaken by Eco Logical Australia Pty Ltd (ELA) and Tetra Tech Coffey (Coffey) in accordance with the Government of South Australia (DEM’s) Terms of Reference 025 (TOR 025) *Change in operations applications* dated 18 March 2021 and *Change Process for Quarries and Mines* final draft dated September 2022. The self-assessment has determined that from a total of nine proposed changes, seven are considered to be a significance level 2 or 3 and should be approved via either a Program Notification or a Program for Environment Protection and Rehabilitation (PEPR) review respectively, with two of the changes falling within the criteria of a Change in Operations Application (this document).

However, in order to be transparent all changes will be described to some level within this document. It is recommended that this document is read in conjunction with the Atacama Project MLP as together they provide detail on all aspects of the Atacama Project (i.e., or activities occurring on the Atacama ML and those being changed at J-A).

Please refer to Appendix A for a checklist of the content of this document against information required in TOR 025.

1.1 Project proponent

Proponent details are summarised in Table 1-1.

Table 1-1: Proponent details

Mine name	Jacinth-Ambrosia Mineral Sands Mine		
Operations	Various pits at Jacinth and Ambrosia		
Lease holder	Iluka (Eucla Basin) Pty Ltd		
Australian company number	008 675 018		
Operator	Iluka (Eucla Basin) Pty Ltd		
Tenement number	ML 6315, EML 6316, MPL 110, MPL 161 and MPL 111	**Approval Date**	2 July 2008
Site location	Ceduna is the closest population centre to the J-A Project area, located approximately 290 km southeast. The region has also been determined native lands of the FWC Aboriginal Traditional Owners.		
Site contact	Matthew Harding	**Position**	Principal – Approvals SA
Address	Level 17, 240 St. Georges Terrace, Perth, WA	**City (Postcode)**	6000
Email	Matthew.Harding@iluka.com	**Telephone**	0437 146 220
Registered Mine Managers	Nick Bartsch – Operations Manager Tom Liubinas – Production Manager		

1.2 Project location

The J-A mine is approximately 290 km northwest of the township of Ceduna on the Eyre Peninsula of South Australia, and approximately 800 km northwest of Adelaide. Atacama lies approximately 5 km to the northeast of J-A. Both tenements sit within the Great Victoria Desert according to the Interim Biogeographical

Regionalisation for Australia (IBRA), and in the Yellabinna IBRA subregion (Figure 1-1). The area comprises parallel dune systems which predominantly run in a northwest-southeast direction.

It is anticipated approximately 2,187 ha of native vegetation will be cleared for the Atacama Project (approximately 2,057 ha within the Atacama Project Area and 130 ha within ML 6315 and Miscellaneous Purposes Licence (MLP) 111), and mining is expected to occur via several open pits (western, central, eastern and south). Mining will occur over a seven-year period, including overburden stripping.

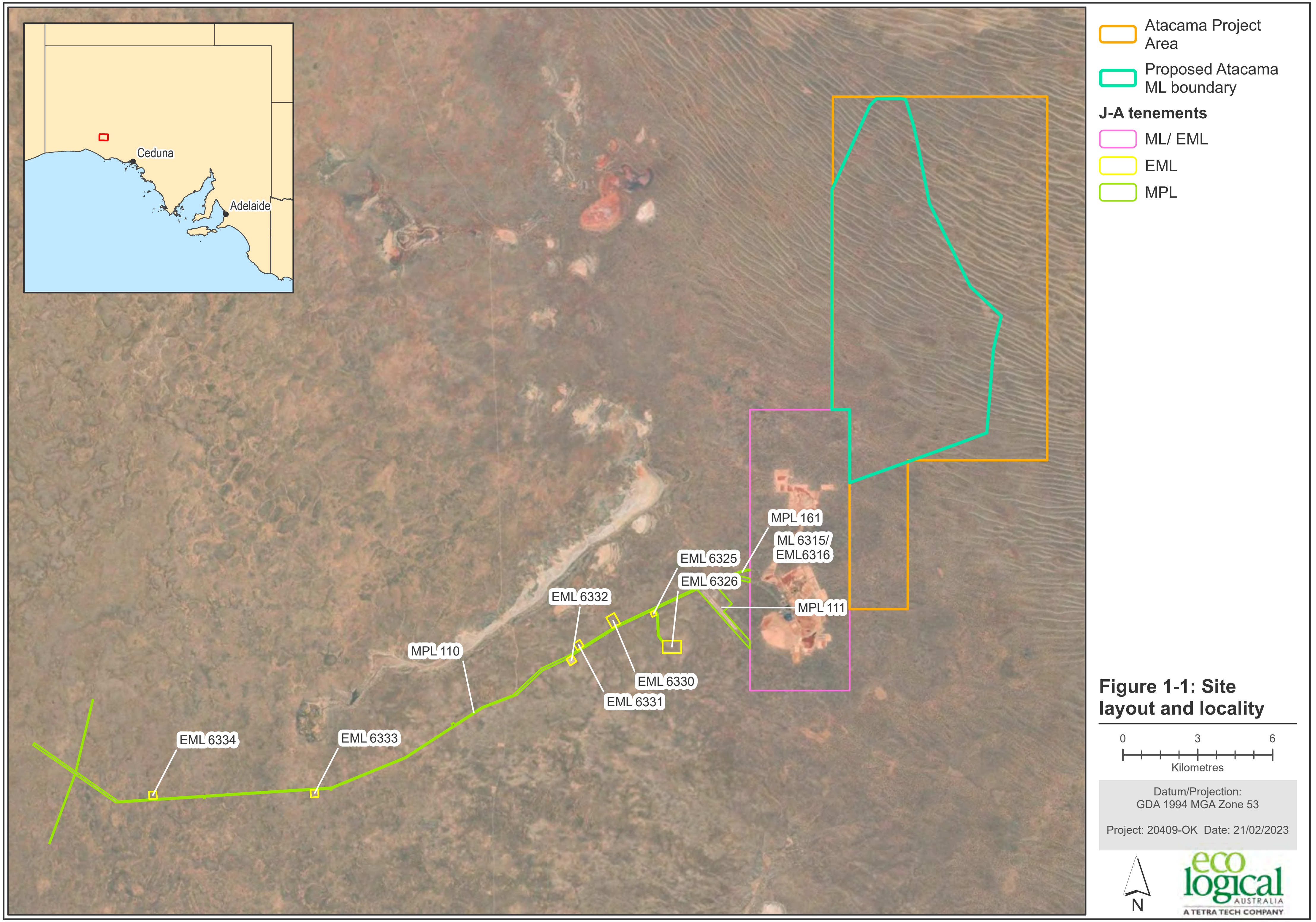

Figure 1-1: Site layout and locality

Datum/Projection:
GDA 1994 MGA Zone 53

Project: 20409-OK Date: 21/02/2023

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2 PURPOSE AND REASON FOR THE CHANGE

This Change in Operations (CiO) Application relates a change to the authorized operation to be carried out under the tenement. Namely upgrades and changes required at the current J-A mine to accommodate the transport, storage and processing of mineral sands from Atacama, should it be approved.

The feasibility of mining operations at Atacama is based upon an assumption that the current plant and infrastructure at J-A will be used, where possible, for mineral processing of Atacama ore.

In total, there are nine key project elements that are proposed to be changed at the J-A mine. All nine key project elements are discussed in further detail in Section 3. However, only two elements have been determined to be a significance level 1 (the remaining are level 2 or 3 and will be managed through an updated PEPR and/ or Program Notification) and are subject to further discussion within this CiO Application (Section 5).

These two elements are:

- increased extraction of groundwater from the borefield
- sand tailings stacking pad located at Jacinth & in-pit disposal of slimes/ tailings at Ambrosia.

3 CHANGE TO AUTHORISED OPERATIONS

All nine project elements, including those that require a Program Notification or PEPR update and the two elements that are addressed within this CiO application for J-A and, are:

- wet concentrator plant (WCP) (PC-12) upgrades
- new WHIMS circuit
- expansion of RO water supply system
- expansion of power generation facilities
- upgrade to HMC stacker pad and HMC stockpile area
- camp expansion
- traffic management
- increased extraction of groundwater from the borefield
- sand tailings stacking pad located at Jacinth & in-pit disposal of slimes/ tailings at Ambrosia.

Details of each CiO are provided in Chapter 3 below, with justification for the methods and approval pathways associated with the changes provided in the screening self-assessment in Table 4-1.

Figure 3-1 highlights the locations of each change within ML 6315 (or associated tenements).

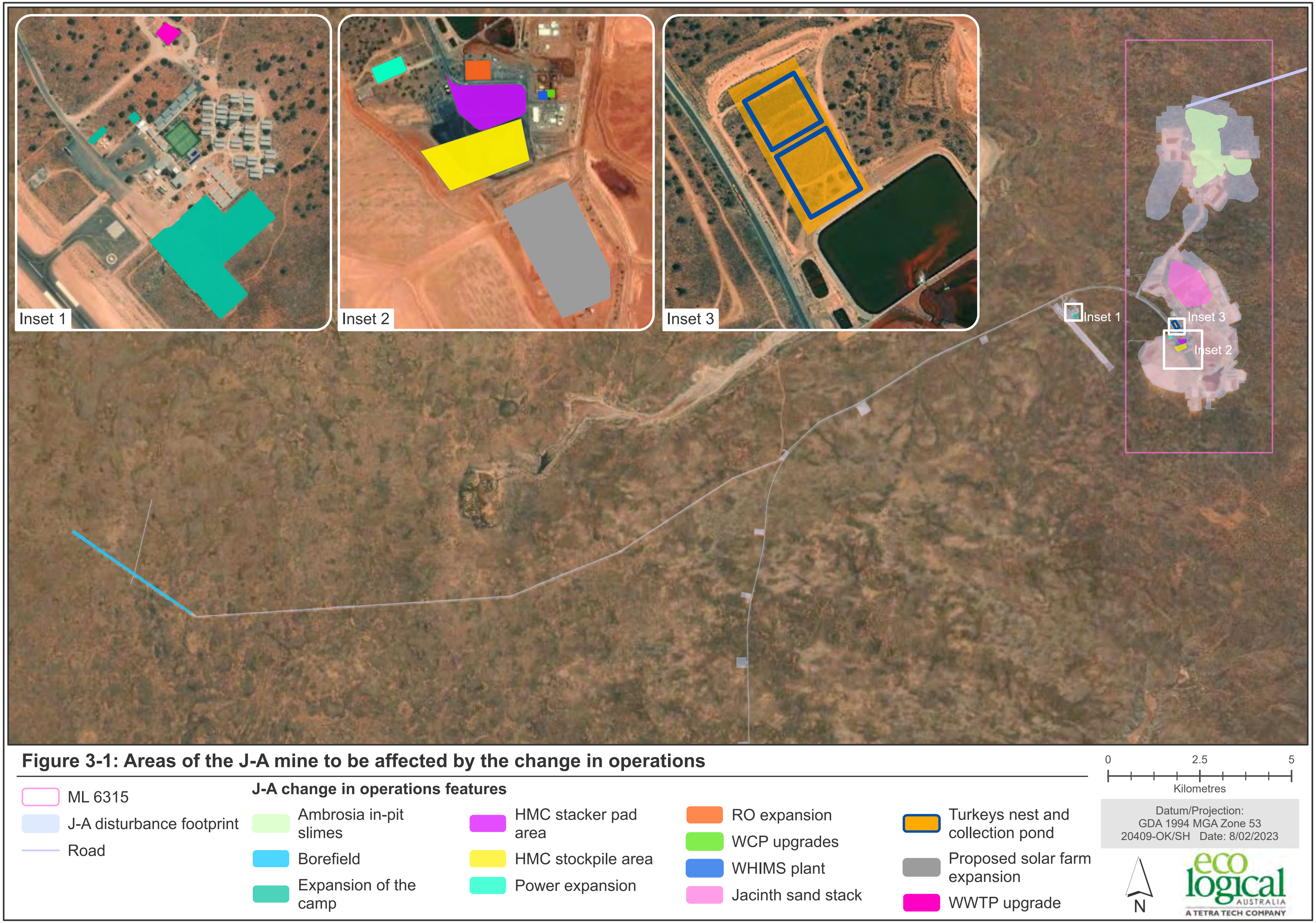

Figure 3-1: Areas of the J-A mine to be affected by the change in operations

3.1 WCP (PC-12) upgrades

Upgrades are required to the existing concentrator at J-A to accommodate and process the Atacama mineral sands. These include upgrades to the existing WCP equipment and machinery, electrical infrastructure and concentrator stacking area, and site development for a turkey's nest dam and lined collection pond.

All activities associated with the concentrator upgrades will occur on previously disturbed land within the existing plant footprint at J-A, and as such require no new clearance of native vegetation. Please refer to Figure 3-1 and Figure 3-4 for locations.

3.1.1 Upgrade to the existing WCP equipment and machinery

The WCP at J-A separates clay and quartz from higher specific gravity minerals in the ore to produce HMC. To accommodate the increased HMC grades associated with Atacama ore, upgrades are required to the existing WCP, this includes:

- Upgrade PC-12-C01-PU007 Cleaner Spiral Feed Pump, two separate pumps and associated lines.
- Upgrade PC-12-C01-PU008 Recleaner Spiral Feed Pump, two separate lines and associated pumps.
- The twin start Recleaner Spirals will be replaced with 6 x 9 HG10i triple start spirals, and the distributor will be replaced with the 9-way distributor.
- The recleaner cons will be redirected to feed the new WHIMS circuit, and the WHIMS non-magnetic will be returned to the HMC screen.

3.1.2 WCP electrical infrastructure

A new substation, transformer and switch room is required to accommodate the WHIMS expansion (Section 3.2). This new infrastructure will be located adjacent to the WCP and fed from the extension (Section 3.4) to the concentrator area main switchboard using an 11 kV underground cable. For this reason, this activity has been incorporated into this element of change.

The new substation will require a 11/0.433 kV 2000 kVVA transformer (PC12-E01-TF122). The new switch room will be equipped with a 415 V Motor Control Centre (MCC) (PC12-E01-MCC122).

3.1.3 Site development for water storages

A 9 Mega Litre (ML) turkey's nest dam and 10 ML HDPE lined collection pond will be constructed to the northwest of the existing process water pond as shown in Figure 3-2. These water storages will be used for aeration and pH pre-treatment to reduce the level of iron and manganese which is found naturally in the raw groundwater. The area where these water storages will be constructed have been previously used for soil and timber rehabilitation stockpiles, these stockpiles will be used for rehabilitation prior to the area being repurposed.

Figure 3-2: Turkey's nest and collector pond location

J-A change in operations features

Turkeys nest and collection pond

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3.2 New WHIMS circuit

A new, two-stage WHIMS circuit will be required for removal of the Atacama magnetic fraction from the HMC through separation of the magnetic (ilmenite) material from the non-magnetic (zircon) material (Figure 3-3).

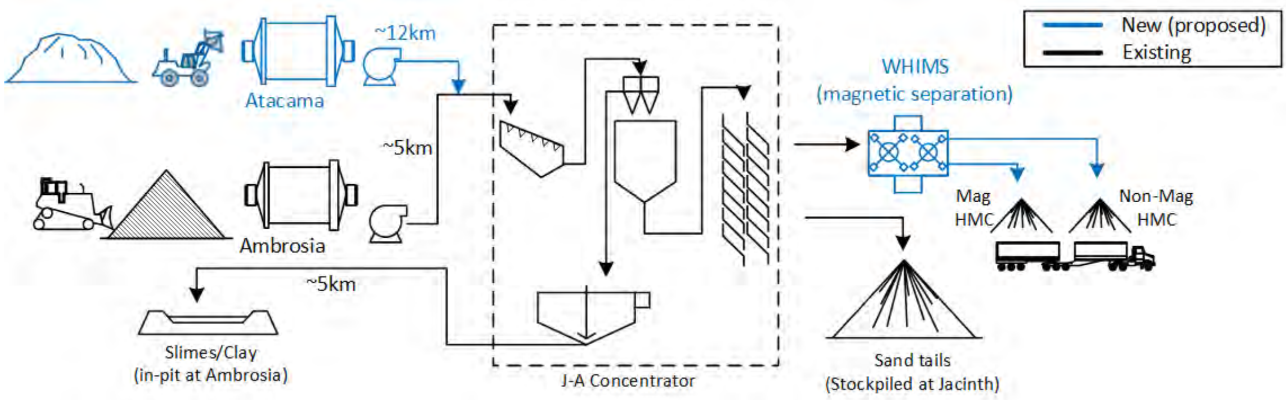

Figure 3-3: Flowsheet of proposed tailings management for combined J-A/Atacama operations

The WHIMS circuit will be fed by a steel collection deposit (CD) tank. The WHIMS building will be constructed using modular steel construction with concrete footings and will comprise:

- Screening stage (850µm).
- LIMS feed pump.
- Low Intensity Magnetic Separator "LIMS" stage.
- Primary WHIMS Magnetic hopper.
- Primary WHIMS Mags stacker pump.
- Primary WHIMS Non-Magnetic hopper.
- Primary WHIMS Non-Magnetic pump.
- Secondary WHIMS Magnetic hopper.
- Secondary WHIMS Mags transfer pump.
- Secondary WHIMS Non-Magnetic hopper.
- Secondary WHIMS Non-Magnetic transfer pump.

The rates of the primary and secondary WHIMS units and the volume of the CD tank remains unconfirmed. Two options are being considered:

- For Option E, where ore feeds are blended between Atacama and Ambrosia, the WHIMS circuit will be fed by a CD tank. The WHIMS building will comprise:
  - 3 x 40t/h primary WHIMS units
  - 2 x 40t/h secondary WHIMS units.
- For Option F, where the Atacama and Ambrosia feeds are campaigned through the concentrator, the WHIMS circuit will be fed by a CD tank with residence time of ~20 minutes. The WHIMS building will comprise:
  - 5 x 40t/h primary WHIMS units

- 4 x 40t/h secondary WHIMS units.

A fresh water washing circuit will be installed to remove process water salinity from the magnetic HMC. This will be integrated into the WHIMS building, with all saline runoff being integrated into the existing process water pond such that there is no net impact on discharge from the circuit.

The location of the new WHIMS building will be immediately to the west of the existing WCP building within the existing J-A plant footprint (Figure 3-4). All activities associated with the WHIMS plant will therefore occur on previously disturbed land and require no new native vegetation clearance.

In addition, a new switch room and LV MCC will be provided for all new drives within the WHIMS building. The substation will be supplied with 11kV power via a new feeder in the existing 11kV switch room (JACI-E01-HV001). The new MCC will be supplied with a new 11/0.43kV transformer located adjacent to it in a transformer bay, similar to existing PC-12 substations.

Figure 3-4: Areas of the WHIMS building location

J-A change in operations features

- CD Tank
- Substation
- WHIMS Building

0 30 60
Metres

Datum/Projection:
GDA 1994 MGA Zone 53
Project: 20409-SH Date: 12/19/2022

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3.3 Expansion of RO water supply system

To process the additional water requirements, a 1 ML/day RO plant will be installed to complement the existing RO plant. The new RO plant will be located at J-A and will be equipped with all necessary ancillaries, including:

- Two 174 m^3/h bore water pumps (duty/ standby).
- NaOH dosing and aeration blower for Fe/ Mn removal.
- Two 174 m^3/h bore water transfer pumps (duty/ standby).
- 1 ML/day RO plant (complete package).
- 200 kL RO water tank.
- RO water transfer pump and RO water booster pump (42 m^3/h) to pump the water to Atacama in the diameter nominal (DN) 140 pipe.

The RO plant will be fed by saline groundwater from the existing J-A borefield. The new turkey's nest and collection pond as per Figure 3-5 will be used for pre-treatment holding areas of extracted groundwater and will assist in the removal of impurities.

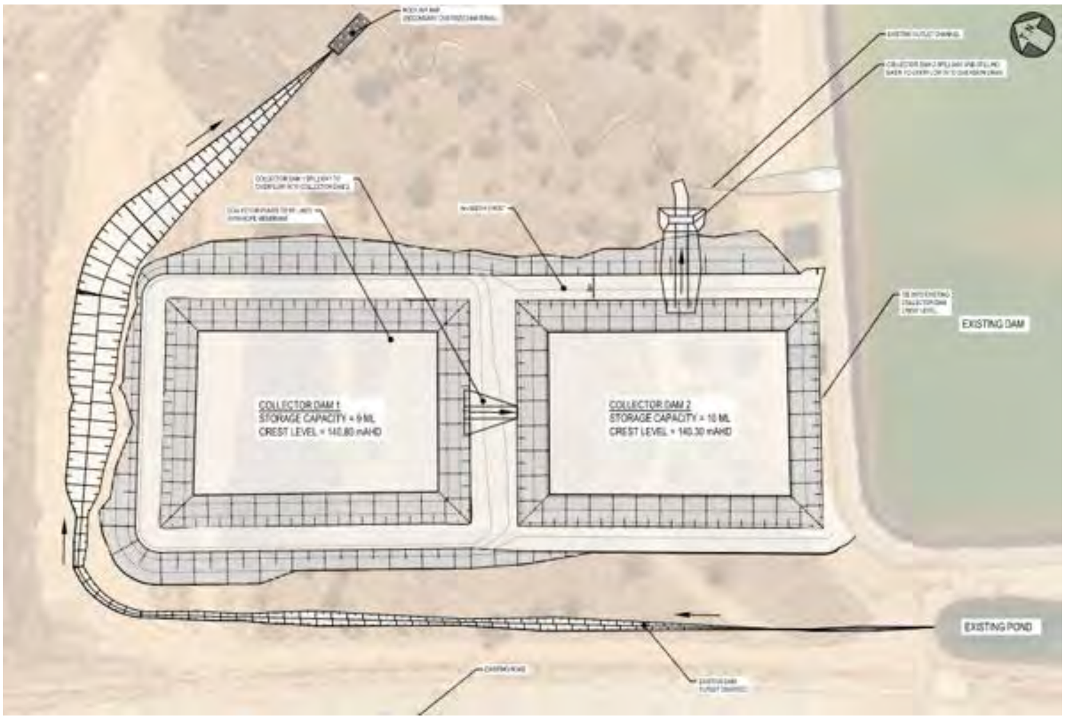

Figure 3-5: Proposed RO plant and Pre-treatment pond locations

The installed electrical load for the new RO Plant is expected to be 500 kilowatts (kW). All activities associated with the Proposed RO plant and Pre-treatment ponds will occur on previously disturbed land and require no new native vegetation clearance.

3.4 Expansion of power generation facilities

The main powerline from the J-A powerhouse to the mining pits currently operates at 11 kV with power generated by 12 diesel generators. The site also has a solar farm onsite used to supply electricity to J- A operations.

Power demand, should Atacama commence operations, will increase to approximately 4 MW greater than the current J-A peak demand supply ability. To supply the required electricity to Atacama the J-A power generation system and network will require expansion and upgrade, and a transmission line constructed between Atacama and J-A (Figure 3-6).

The existing powerhouse has two (2) unused bays available for the expansion. With the additional load the recommended number of operating generating sets is 13. There will be no additional land disturbance required to install additional diesel generators within the powerhouse.

Due to the transmission line length to Atacama, the main power line at J-A will require upgrade to 33kV and extend approximately 12 km to Atacama adjacent to the Atacama Haul Road to the proposed MUP locations at Atacama (refer Figure 3-6). This activity will require land disturbance and the clearance of new native vegetation. This includes 80 ha on ML 6315 for the transmission line, haul road and pipelines to Atacama.

The main 11 kV switch room at the WCP will be extended with an additional two tiers including 630 Amp circuit breakers, protection relays and control wiring to provide the two additional 11 kV feeders for the new RO and WHIMS plant substations.

During construction, temporary diesel generators will be used to provide power to the site.

3.4.1 Solar farm expansion

The additional power demand for Atacama is planned to be complemented by an expansion of the existing solar farm. The increase in power generation will be approximately 5 MW) bringing the total instantaneous solar supply to approximately 8.5 MW. Penetration of the solar farm will be constrained by daily weather and solar cycles.

The solar farm expansion will include the addition of energy storage. The proposed solar farm expansion will cover between 6-8 ha and is likely to be located on existing disturbed land (Figure 3-7). The solar farm expansion will connect to the J-A powerhouse via cable on already disturbed land, thereby not requiring additional clearance of native vegetation.

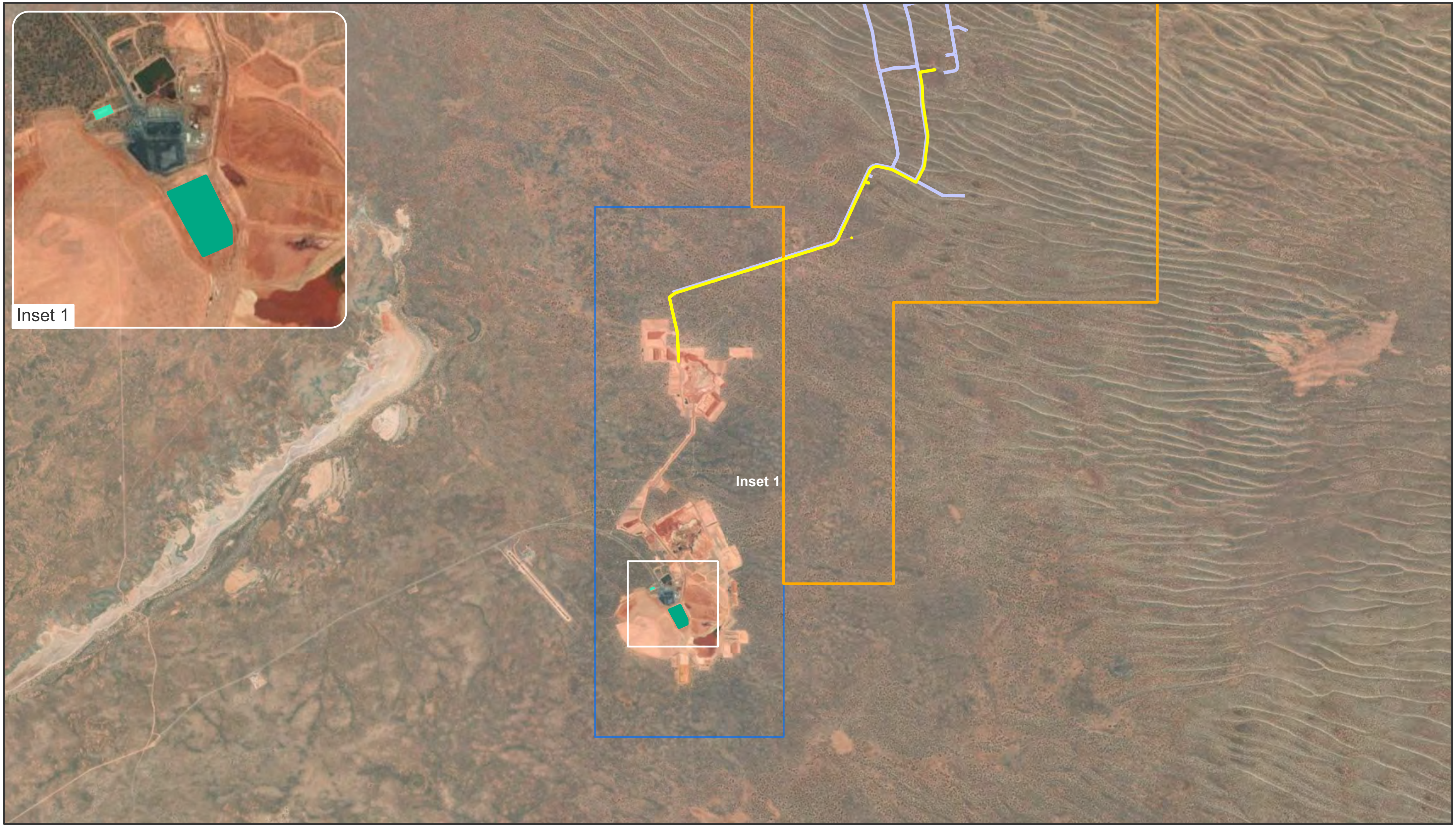

Figure 3-6: Transmission line from J-A to Atacama / Site energy infrastructure

ML 6315
Atacama Project Area
Road
Transmission line

J-A change in operations features
Power expansion
Proposed solar farm expansion

0 2 4
Kilometres

Datum/Projection:
GDA 1994 MGA Zone 53
Project: 20409-SH Date: 21/02/2023

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Figure 3-7: Proposed area for solar farm expansion

J-A change in operations features

Power expansion

Proposed solar farm expansion

0 150 300
Metres

Datum/Projection:
GDA 1994 MGA Zone 53
Project: 20409-SH Date: 8/02/2023

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3.5 Upgrade to HMC stacker pad and HMC stockpile area

A new HMC stockpile will be required for storage of Atacama magnetic material (ilmenite), separate from the non-magnetic material (zircon). The footprint of the new stockpile will extend the southern boundary of the existing stockpile area to the south into the current footprint of the HMC stockpile area/ long term storage bunker. To accommodate this extension, the concrete loading road around the existing J-A stacker pad will be relocated further south around the new (fourth) stockpile (refer to Figure 3-8 for preliminary layout noting this may change slightly). Existing lighting infrastructure will be relocated to an existing, alternative disturbed area.

Further to the additional stacker pad stockpile, a new, long-term storage bunker with a capacity of 400,000 bank cubic metre (bcm) will be required to store the additional magnetic HMC produced from Atacama (Figure 3-8). HMC produced from Atacama will be stockpiled in two stockpiles; a magnetic stockpile and non-magnetic stockpile located within the long-term storage bunker. During dry months a water spray system on the HMC stockpile pads will be utilized to maintain moisture content of the stockpiles and /or the application of dust suppressants will be used to reduce wind erosion and windblown HMC migrating from the stockpile pads.

There will be no new native vegetation clearance associated with this activity.

Figure 3-8: HMC stacker pad stockpiles including additional fourth stockpile and long-term storage bunker (yellow)

3.6 Camp expansion

Mining of Atacama will require an increase the workforce required for operations, consequently increasing the beds required at the J-A camp. The J-A camp currently provides accommodation for 200 personnel. It is expected a total of 175 additional beds will be required in association with mining Atacama, bringing the total occupancy of the site to 375 personnel at any given time.

All accommodation requirements for Atacama personnel will be met within the existing village on the J-A MPL 111, i.e., there will not be any accommodation within the proposed Atacama ML.

Additional upgrades required for the camp expansion include:

- The current camp car park will be expanded onto both existing disturbed land and an area of currently undisturbed land.
- The existing wastewater treatment plant at the camp will also be upgraded to accommodate the increased capacity which will be captured within the existing disturbance footprint of the camp area and will be approved as per current SA Health requirements.
- The recreational facilities such as the camp gymnasium will be enhanced.

Expansions to the camp will require approximately 2 ha of native vegetation clearance as shown in Figure 3-9.

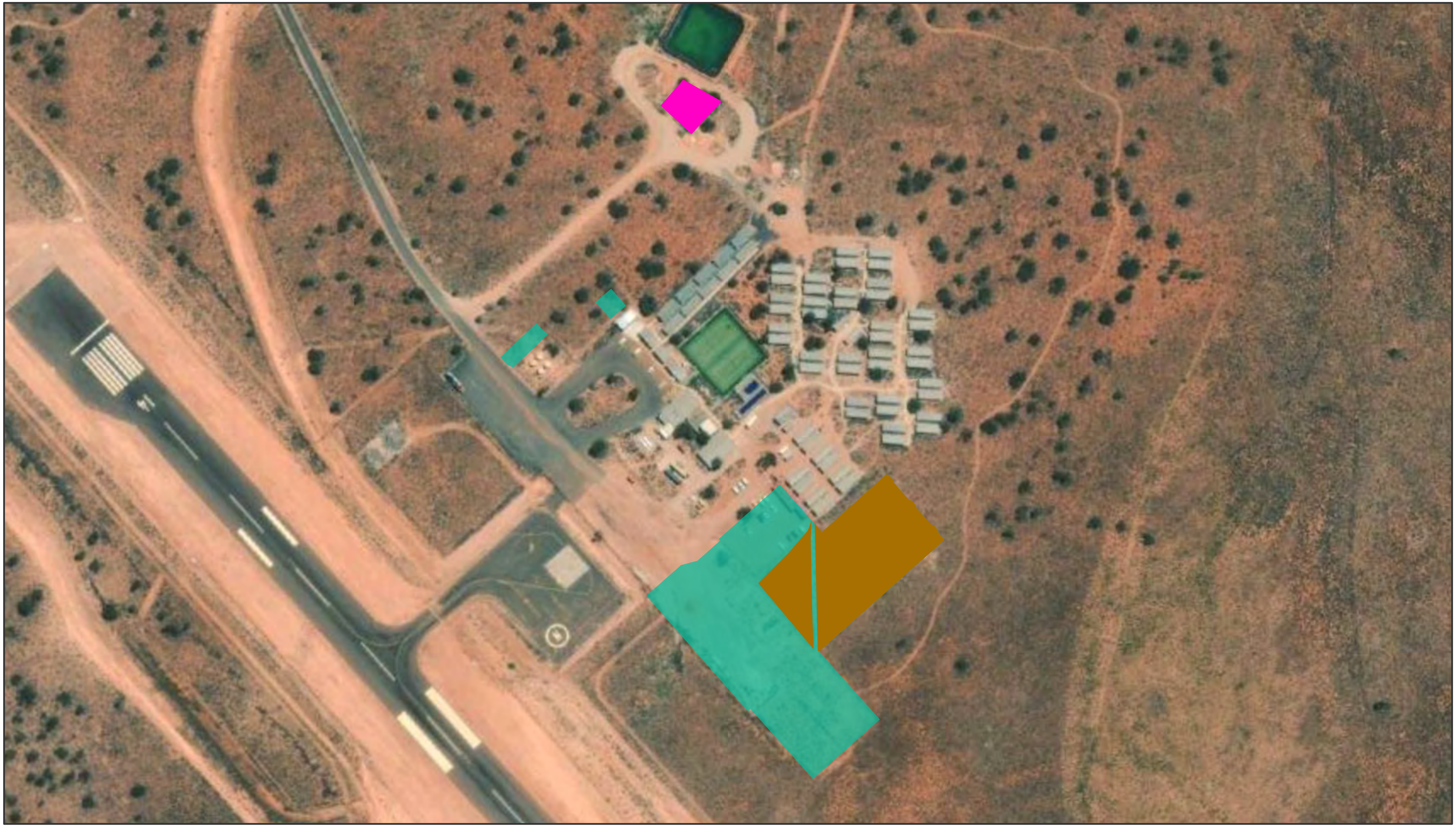

Figure 3-9: J-A camp expansion

J-A change in operations features

- Expansion of the camp (Existing disturb land)
- Expansion of the camp (Existing undisturb land)
- WWTP upgrade

0 50 100
Metres

Datum/Projection:
GDA 1994 MGA Zone 53
Project: 20409-SH Date: 8/02/2023

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3.7 Traffic management

The Atacama operation will work as a satellite mine separate to J-A. To connect the two tenements, a new Atacama Haul Road will join the existing haul road at the north-west corner of the J-A ML and will follow the alignment of the existing exploration track to Atacama. The haul road will be built from material won during construction and production activities, secondary oversize material from J-A and possibly calcrete from adjacent Iluka EML's. Haulage of Atacama product will use the same haulage road that currently transports HMC to Port Thevenard for shipping (Figure 3-10). No modifications are expected to be made to public roads as part of this project.

Similar to current J-A operations, as the volume of Ambrosia products begin to decline towards the end of Ambrosia's LOM, bringing Atacama online will not increase annual truck movements between J-A and Port Thevenard. Production at Atacama will supplement production at J-A and form a continuation of these operations, with haulage 14 loads per day (two return trips per day per truck, seven trucks) until 2031.

Following depletion of the Atacama deposit (indicatively in 2032), a further 3-4 years of stockpile haulage is likely to occur, with road train operations scaled back to six return trips per day.

There will be clearance of new native vegetation associated with the haul road (as well as the transmission line and pipelines) that will join Ambrosia to Atacama this is approximately 80 ha on ML 6315.

A Traffic Impact Assessment Study (Hatch, 2022) was undertaken as part of the Atacama MLP and found that the traffic generated from Atacama is expected to have a negligible additional impact in terms of the public roads network performance. For further information refer to Appendix C6 in the Atacama MLP.

Figure 3-10: Proposed haulage route between Ceduna and Atacama (Source Hatch, 2022)

3.8 Increased extraction of groundwater from the borefield

Detailed description and impact assessment associated with this element of change is provided in Section 5.

With the potential approval of operations at Atacama, the duration of groundwater extraction would increase, and it has been assumed that there will be an increase in the volume of groundwater extraction to support processing activities and potable water supply at J-A. This will result in:

- An extended period of pumping from the paleochannel wellfield for operations and processing (~5 y).
- An extended period of tailings deposition and seepage at J-A (~5 y).
- An extended period of pumping from the paleochannel wellfield for re-seeding and rehabilitation activities at a reduced rate (~ 20 years).

Water will be sourced from the existing borefield associated with J-A on MPL 110, located approximately 32 km from the J-A mine site. No new bores are proposed to be drilled or constructed as the existing borefield can meet the water demands for both J-A and Atacama operations, estimated to be in the range of 13.2 ML per day for operations and processing, after which it would reduce to approximately 2 ML/d.

The borefield has the capacity to supply up to 28.8 ML/d, in excess of the design demand for the combined J-A and Atacama Projects.

A new take-off from the existing borefield pipeline will supply two new booster pumps (duty/ standby) which will transfer water into the new 9 ML turkey's nest (Section 3.1). From the turkey's nest the bore water overflows into the new 10 ML collection pond, and from the collection pond two transfer pumps (duty/ standby) send the pre-treated bore water to the bore water feed tank in the plant. There will be no new native vegetation clearance associated with this activity.

Detailed description and impact assessment associated with this element of change is provided in Section 5.

3.9 Sand tailings stack located at Jacinth & in-pit disposal of slimes/ tailings at Ambrosia

All tailings produced during the processing of Atacama will be retained and stored within the J-A mine footprint on ML 6315 (i.e., it will not be returned to the Atacama ML). With the approval of Atacama, the tailings will be managed via the existing dual stream tailings management method. The coarse sand fraction of the Atacama/ J-A tailings will be disposed in a self-supported sand tailings stockpile area and the slimes/ modified co-disposal (ModCoD) (a mixture of quartz sands and clay fines) will be disposed of in-pit within the Ambrosia void.

No waste rock produced during the mining of Atacama will be processed on ML 6315. Pockets of Actual Acid Sulphate Soils (AASS) may occur within the ore zone and below the ore which will be assessed further.

3.9.1 Sand tailings stack (Jacinth)

The sand tailings stack will be located over the completed hydraulically placed ModCoD (from J-A operations) within the existing in-pit Jacinth Tailings Storage Facility (TSF) footprint (Figure 3-11 and Figure 3-12). The sand stack will largely be constructed within the existing disturbance footprint of Jacinth and will alter the reduced level (RL) of the final landform to a maximum of 178 m, dependent upon the capping option used at closure (either a 1.5 m cap or 6 m cap). Dependent upon the design chosen, the impact to undisturbed ground/ native vegetation ranges from 15 ha (for 1.5 m capping option) up to 65 ha (for 6 m capping option) on the eastern edge of the sand stack (Figure 3-11 and Figure 3-12).

In addition to the conceptual TSF design undertaken by Iluka, an updated conceptual TSF design has been undertaken by ATC Williams Pty Ltd (ATCW, 2022) and can be found in Appendix C. The TSF design will continue to be refined during DFS and operations.

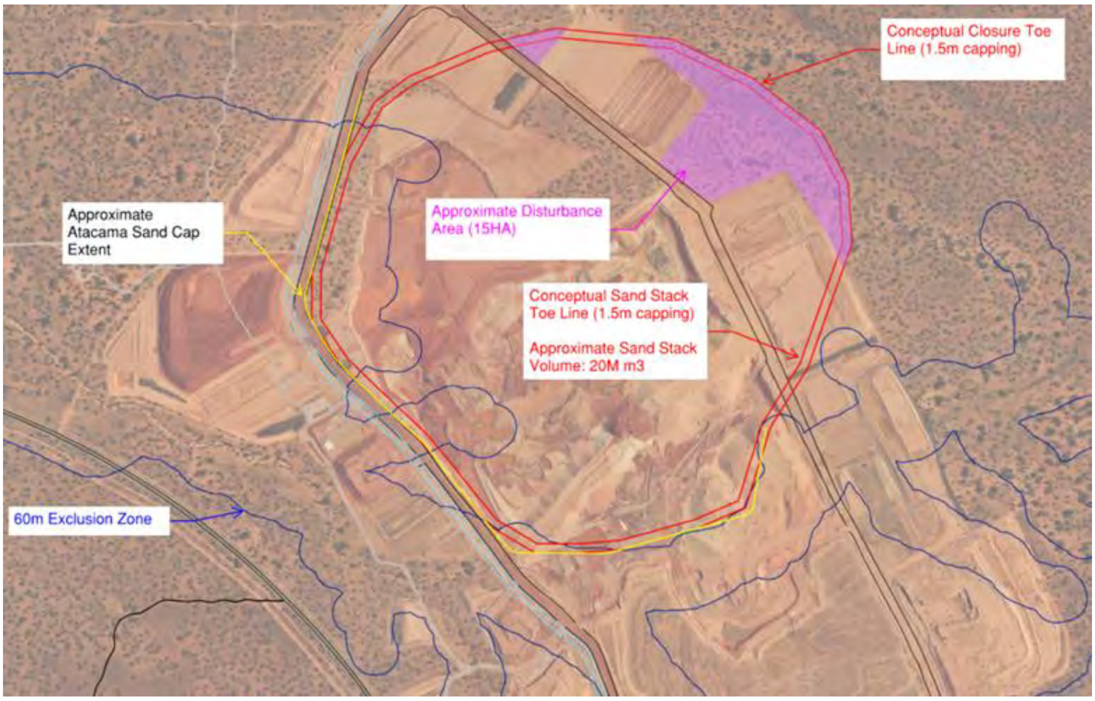

Figure 3-11: Location and footprint of sand stacker at Jacinth (1.5 m capping)

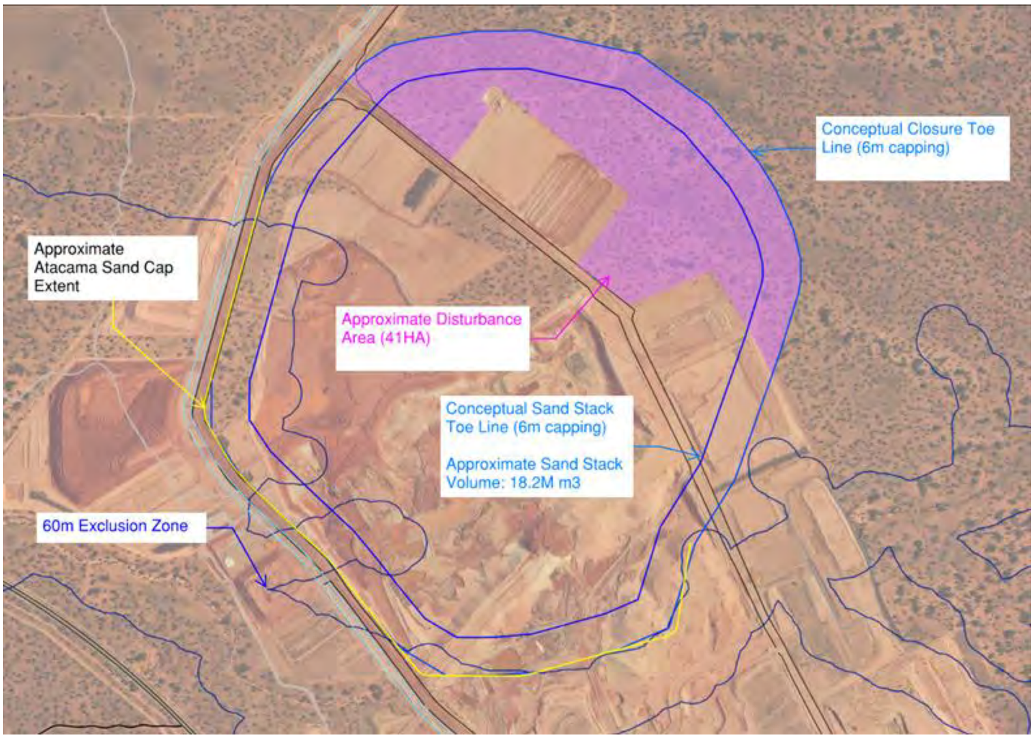

Figure 3-12: Location and footprint of sand stacker at Jacinth (6 m capping)

3.9.2 In-pit disposal of slimes/ tailings (Ambrosia)

The slime/ ModCoD component of Atacama tailings will be deposited in the Ambrosia void, with any remaining process water continuing to be returned to the process water circuit for reuse. Modelling has predicted the Atacama tailings component is expected to increase the Ambrosia final surface profile by approximately 1-3 m.

The total tonnage of slime/ ModCoD tailings from the WCP expected to be deposited into the Ambrosia pit and the sand tails stack can be seen in Table 3-1 (Iluka, Atacama tailings memo, 2022).

Table 3-1: Tailings tonnage from WCP

	Sand Stackers	Total	ModCoD	Slurry	Sand	Fines	Fines
	tph	tph	tph	% (wt)	tph	tph	% (wt)
Atacama	194	430	600	50	494	106	18
Ambrosia	237						
TOTAL	**430**		**600**				

The Iluka Environment, Health and Safety Group Procedure – Tailings, will apply. This procedure covers design, construction, and rehabilitation and closure requirements, and will be updated to reflect J-A site-specific considerations within the Tailings Management Plan (TMP), to be approved by the J-A Site Operations Manager. The TMP will be prepared in accordance with ANCOLD Guidelines.

There will be no new native vegetation clearance associated with ModCoD tailings management.

3.9.3 Altered hydrology from sand tails stacking (Jacinth)

All tailings produced during the processing of Atacama will be retained and stored within the J-A mine footprint on ML 6315 (i.e., not returned to the Atacama ML).

The sand stack landform at Jacinth will be constructed to be similar to the existing off-path TSF in the landscape and will comprise of sands with a loam capping. Studies have assessed the risks associated with the proximity of the sand stack to an existing nearby creek line (Figure 3-13), and an assessment has shown the proposed location will not impact surface water movement (Alluvium, 2022) on the provision that setback widths are met and the pre-mining watercourse be reinstated.

Setback requirements (the distance between the top of the bank of the reinstated watercourse to the south of the tailings sand stack, and the toe of the proposed tailings stack) to reinstate the watercourse have been informed by hydraulic modelling. The recommended initial setback distance of 60 m, measured as a distance from the 0.1% Annual Exceedance Probability extent, will be adopted and will provide a conservative guideline that will be wide enough to mitigate any potential future channel change, including widening or meander migration (Alluvium, 2022). The recommended setback reference point and the setback are conservative and can be refined (potentially reducing the setback distance) on further detailed assessments of the watercourse to the south of the proposed tailings sand stack.

The current PEPR RL outcome measurement criteria for final landforms will still be met, and landform evolution modelling (LEM) modelling has been undertaken. Small amounts of land clearance may be required; this will be confirmed once the final design is confirmed (these land clearances have been discussed within Section 3.9.1). Further information regarding the hydraulic modelling results is in Appendix D.

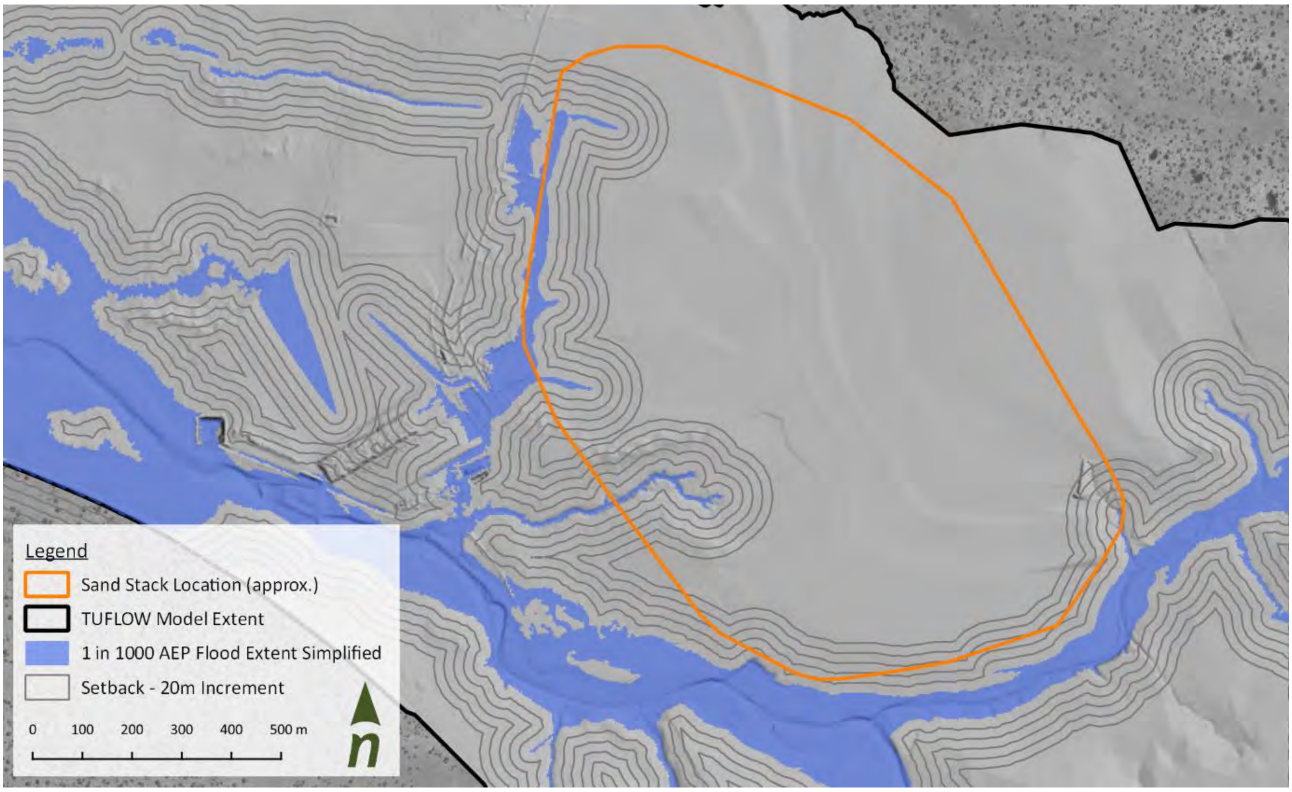

Figure 3-13: Watercourse modelling 0.1% AEP flood extent with setback increments(Source Alluvium, 2022)

4 SCOPE OF PROPOSED CHANGE TO AUTHORISED OPERATIONS

As described earlier in the document, the majority of the proposed changes will require either a Program Notification or PEPR review, with two key components necessitating a CiO Application. These are discussed in Section 5.

The regulatory pathway associated with each change proposed is analysed and justified within Table 4-1 in accordance with the *Change Process for Quarries and Mines* final draft dated September 2022 and TOR 25.

4.1 Assessment of alternatives

An assessment of alternatives, in terms of approaches and options relating to proposed changes to the authorised J-A operations has been considered at length based upon both environmental and economic outcomes.

Refer to Chapter 4 of the Atacama MLP for further information.

Table 4-1: Screening/ self-assessment of regulatory pathways

Scenario	Analysis criteria Change in Operations (Mining Act s56Q)			Analysis criteria PEPR review (Mining Act s70C)					Analysis criteria Program Notification		Regulatory pathway	Regulatory pathway justification
	Is inconsistent with, or outside the scope of the authorised operations that were approved as part of the original tenement grant?	Will result in a non-compliance with existing lease or licence terms and conditions?	Requires an environmental impact assessment to authorise the change?	Is inconsistent with the current approved PEPR?	Requires alterations to approved outcomes and criteria?	Relates to significant alterations to the description of mining operations or control strategies (but does not affect the achievement of outcomes)?	Relates to a new or changed strategy that is an essential control necessary to achieve existing environmental outcomes?	Requires new or changed native vegetation clearance and/ or SEB?	Is a significance level 1 or 2?	Has not already been sufficiently addressed in the approved PEPR		
WCP (PC-12) upgrades (including cleaner/ recleaner upgrades for increased HMC grade), including 9 ML turkey's nest and 10 ML lined collection pond.	N	N	N	N	N	N	N	N	N	N	Program Notification	Does not require any new native vegetation clearance as turkeys' nest and collection pond will occur on previously disturbed land and all plant upgrades will occur within the concentrator. Processing is a considered activity in the PEPR, and the changes are considered minor. Therefore, a Program Notification is considered appropriate, however the information may subsequently form part of the larger PEPR review.
New WHIMS circuit (including wash plant)	N	N	N	N	N	N	N	N	N	N	Program Notification	Does not require any new native vegetation clearance, the WHIMs and wash plant is a module which will sit next to the existing WCP, on land already disturbed within the existing J-A plant area. Processing is a considered activity in the PEPR, and the changes are considered minor. Therefore, a Program Notification is considered appropriate, however the information may subsequently form part of the larger PEPR review.
Expansion of RO water supply system	N	N	N	N	N	N	N	N	N	N	Program Notification	It is estimated that an additional 1 ML/d of RO water will be required for dust suppression and domestic uses, and this will occur through upgrades to the existing J-A RO plant. This will occur on existing disturbed and as such will not result in the clearance of native vegetation. An RO Plant is a considered activity in the PEPR and only minor modifications to that description are required. Therefore, a Program Notification is considered appropriate, however the information may subsequently form part of the larger PEPR review.
Expansion of power generation facilities (including expansion of solar farm)	N	N	N	N	N	N	N	Y	Y	N	PEPR review	Power to Atacama is proposed to be supplied by modifying the existing J-A power network. The power station located in the J-A ML will be upgraded as part of the Project, increasing the number of 1 MW generators from twelve to fourteen, bringing the total potential capacity to 14 MW. A 33 kV overhead power line is installed from the power station to the Ambrosia operation and is currently operated at 11 kV. It is intended to upgrade the power line to 33 kV and extend it from Ambrosia to Atacama. The new overhead line will run for approximately 12 km adjacent to the haul road up to both proposed MUP locations at Atacama.

Scenario	Analysis criteria Change in Operations (Mining Act s56Q)			Analysis criteria PEPR review (Mining Act s70C)					Analysis criteria Program Notification		Regulatory pathway	Regulatory pathway justification
	Is inconsistent with, or outside the scope of the authorised operations that were approved as part of the original tenement grant?	Will result in a non-compliance with existing lease or licence terms and conditions?	Requires an environmental impact assessment to authorise the change?	Is inconsistent with the current approved PEPR?	Requires alterations to approved outcomes and criteria?	Relates to significant alterations to the description of mining operations or control strategies (but does not affect the achievement of outcomes)?	Relates to a new or changed strategy that is an essential control necessary to achieve existing environmental outcomes?	Requires new or changed native vegetation clearance and/ or SEB?	Is a significance level 1 or 2?	Has not already been sufficiently addressed in the approved PEPR		
												Land clearance will be required for the power line adjacent to the haulage road from Ambrosia to Atacama. The PEPR describes these activities though the number of generators needs to be updated in the PEPR. It is therefore considered that a PEPR review is required. Additionally, a solar farm expansion has been planned, this will occur within the footprint of previously disturbed land on J-A thereby not requiring any new vegetation clearance. This aspect on its own would be considered as a Program Notification.
Upgrade to HMC stacker pad and HMC stockpile area	N	N	N	N	N	N	N	N	N	N	Program Notification	The WHIMS process will produce two HMC streams which will need to be stockpiled separately. The storage of HMC will continue to be on the existing stacker pad and stockpile area, though minor modifications will occur these areas. No new land clearance will be required as all modifications will occur on disturbed land. HMC storage is a considered activity in the PEPR, and the changes are considered minor. Therefore, a Program Notification is considered appropriate, however the information may subsequently form part of the larger PEPR review.
Camp expansion	N	N	N	N	N	N	N	Y	Y	N	PEPR review	The camp will be upgraded from the approximate 200 beds currently available to up to 375. Having a camp as an activity was described in both the MLP and is described in the PEPR, however the size of the camp will increase. The wastewater treatment plant (WWTP) will also require upgrades. Native vegetation clearance will be required as part of the expansion of the camp facilities (approximately 2 ha). This clearance however is associated with an activity which is already described within the PEPR. Discussions with the Native Vegetation Council (NVC) Native Vegetation Assessment Panel (NVAP) have suggested that the is clearance for new activities may trigger this threshold and this should be confirmed. If the clearance for the activity is deemed already approved under the current SEB then a Program Notification may be more appropriate then a PEPR Review.

Scenario	Analysis criteria Change in Operations (Mining Act s56Q)			Analysis criteria PEPR review (Mining Act s70C)					Analysis criteria Program Notification		Regulatory pathway	Regulatory pathway justification
	Is inconsistent with, or outside the scope of the authorised operations that were approved as part of the original tenement grant?	Will result in a non-compliance with existing lease or licence terms and conditions?	Requires an environmental impact assessment to authorise the change?	Is inconsistent with the current approved PEPR?	Requires alterations to approved outcomes and criteria?	Relates to significant alterations to the description of mining operations or control strategies (but does not affect the achievement of outcomes)?	Relates to a new or changed strategy that is an essential control necessary to achieve existing environmental outcomes?	Requires new or changed native vegetation clearance and/ or SEB?	Is a significance level 1 or 2?	Has not already been sufficiently addressed in the approved PEPR		
Traffic management	N	N	N	N	N	N	N	N	N	N	Program Notification	Atacama will generate traffic beyond the anticipated LOM for J-A and add an additional six years to the total mining operations. A new Atacama Haul Road will join the existing haul road at the north-west corner of the J-A ML and will follow the alignment of the existing exploration track to Atacama. The haul road will require widening of the existing exploration track and will require approximately 80 ha of vegetation clearance. Haulage of Atacama product will use the same haulage road that currently transports HCM to Port Thevenard. The use of J-A's plant and haulage road by Atacama will generate traffic beyond the anticipated LOM for J-A and add an additional six years to the total mining operations in the Eucla Basin. Production at Atacama will supplement production at J-A and form a continuation of these operations, with haulage 14 loads per day (two return trips per day per truck, seven trucks) until 2031. No modifications are expected to be made to public roads. There will be no annual increase in truck movements between J-A and Port Thevenard though there will be an increase in duration. Transport is a considered activity in the PEPR, and the changes are considered minor. Therefore, a Program Notification is considered appropriate, however the information may subsequently form part of the larger PEPR review.
Increased extraction of groundwater from the borefield	N	N	Y	N	Unknown	N	N	N	Y	N	Change in Operations	Water will be sourced from the existing borefield used for the J-A mine site. The borefield has the capacity to supply up to 28.8 ML/d Modelling undertaken was based upon an assumed demand of 10.3 to 12.4 ML/d, with expected water demand for the combined operations of J-A and Atacama now understood to be 13.2 ML/d till 2032 and then approximately 2 ML/d for a further 20 years. The increase in volume and duration of pumping requires numerical modelling to be undertaken to consider if the impact profile of the J-A project would change. A Change in Operations is therefore required.

Scenario	Analysis criteria Change in Operations (Mining Act s56Q)			Analysis criteria PEPR review (Mining Act s70C)					Analysis criteria Program Notification		Regulatory pathway	Regulatory pathway justification
	Is inconsistent with, or outside the scope of the authorised operations that were approved as part of the original tenement grant?	Will result in a non-compliance with existing lease or licence terms and conditions?	Requires an environmental impact assessment to authorise the change?	Is inconsistent with the current approved PEPR?	Requires alterations to approved outcomes and criteria?	Relates to significant alterations to the description of mining operations or control strategies (but does not affect the achievement of outcomes)?	Relates to a new or changed strategy that is an essential control necessary to achieve existing environmental outcomes?	Requires new or changed native vegetation clearance and/ or SEB?	Is a significance level 1 or 2?	Has not already been sufficiently addressed in the approved PEPR		
Sand tailings stacking pad located at Jacinth & in-pit disposal of slimes/ tailings at Ambrosia	N	Y	Y	N	Unknown	N	N	N	Y	N	Change in Operations	The J-A operation having multiple tailings streams is already in scope of the current PEPR. The MLP described co-disposal, but this was amended later to two streams. A self-supported Sand Tailings stockpile will be constructed at Jacinth for the storage of tailings material from J-A and Atacama blended feed. It will be constructed on the existing disturbance footprint of Jacinth. This will change the RL of the final landform. Fine tailings (<53 micron) will be blended with similar material from Ambrosia and placed in Ambrosia voids consistent with the current approved J-A backfill plan. This will change the final landform RL (though will not impact upon Iluka's ability to meet RL closure criteria) and will all be on disturbed land. The sand tailings stack at Jacinth will be constructed to be similar to the existing off-path TSF in the landscape. Studies have assessed the risks associated with the proximity of the sand stack to a creek line, and an assessment has shown the location will not impact surface water movements. The RL outcomes for final landforms will still be met, and LEM modelling is occurring to ensure the long-term functionality of the landform. Small amounts of land clearance may be required pending the final capping design and will range from either 15 ha to a maximum of 60 ha on the eastern side of the TSF. The impact of further tailings seepage into the fractured rock aquifer/ sands layer and its potential for impacts to the downstream receptor Lake Ifould, from both locations will require numerical modelling and an impact assessment. A Change in Operations is therefore required for this aspect of the change. However, it is considered that for the actual construction of the TSF that a PEPR review is considered appropriate to manage this aspect of the change.

5 ASSESSMENT OF CHANGES TO ENVIRONMENTAL IMPACTS

5.1 Changes to environmental impacts of the authorised operations

No significant changes (i.e., level 1 in accordance with *Change Process for Quarries and Mines* final draft dated September 2022 and TOR 25) are expected outside of the current approved J-A PEPR, except for two key areas:

- increased extraction of groundwater from the borefield
- seepage from sand tailings stacking pad located at Jacinth & in-pit disposal of slimes/ tailings at Ambrosia.

5.1.1 Increased extraction of groundwater from the borefield

In order to facilitate the processing and tailings management of ore mined from Atacama at J-A, additional groundwater abstraction will be required. Groundwater is currently abstracted from a borefield established in a paleochannel aquifer located 30 km to the west of the site (CDM Smith, 2022).

CDM Smith (2022) have undertaken a Groundwater Impact Assessment which examines the cumulative impacts associated with this increased abstraction of groundwater to support Atacama. The current understanding of groundwater impacts is based upon a significant body of work that has been undertaken by Iluka and its consultants since mine feasibility studies were initiated for J-A and draws on data obtained from a well-established groundwater monitoring and sampling program (CDM Smith, 2022).

The existing borefield is used to supply J-A operations with water for potable supply, operations and processing activities. There is no recorded use or users of this groundwater source other than for road construction and maintenance within a 50 km radius from the borefield and mine operations, and a 10 km radius from the Haul Road. The borefield has the capacity to supply up to 28.8 ML/d currently.

CDM Smith (2022) undertook two assessments:

- Scenario 1 at 10.3 ML/d until 2032
- Scenario 2 at 12.4 ML/d till 2028.

Since modelling was undertaken it has been confirmed that the combined J-A and Atacama operation will require an average demand of 13.2 ML/d until 2032, followed by a demand of approximately 2 ML/d during rehabilitation activities (up to 20 years).

It is acknowledged that there a small discrepancy in the volume modelled compared to the expected required demand and the number of years simulated in both the modelled scenarios. However, it is considered that based on the simulated ranges of predicted drawdowns that are presented (Figure 5-1 and **Figure 5-2**) the discrepancy between total volume and number of years modelled is unlikely to incur significantly different drawdown predictions or change the recovery timeframe of groundwater levels.

5.1.2 Seepage from sand tailings stacking pad located at Jacinth & in-pit disposal of slimes/ tailings at Ambrosia

Current operations and mine plans at J-A incorporate a dual stream tailings (DST) deposition method in which sand tails and fine tails (slimes) are deposited separately. Iluka is considering shifting to a single stream tailings (SST) method in which all tails are deposited together at J-A. However, should Atacama be approved, it is proposed that DST deposition will recommence at J-A. Wet tailings placement at the Atacama site is less attractive due to the high drainage characteristics of the overburden with its associated water losses, potential geochemical impacts underlying aquifers, higher pumping costs, and greater carbon footprint (Iluka, 2022).

Sand tailings from Atacama will be stockpiled over the completed, hydraulically placed ModCoD within the in-pit TSF (Figure 3-11). The sand stack will be constructed within the existing disturbance footprint of Jacinth and will alter the reduced level (RL) of the final landform to a maximum of 178 m dependent upon the capping option used.

As the area is sited within a surface water catchment area, designs include mitigations to manage excess water within the footprint during operations (i.e., by use of decant drains), and subsequently at the completion of the sand stack during rehabilitation and closure. The final landform has been designed to ensure that it integrates with the surrounding undisturbed topography.

ATC Williams (ATCW) were engaged to design the sand stack at Jacinth North accommodating the Atacama/ Ambrosia sand blend (Appendix C). The original sand stack design was based on a conceptual 3D model supplied by Iluka (Iluka, 2022). The conceptual design assumed the following:

- The sand stack slope is nominally 10°, with a closure design slope of 3.5° (this is in line with the slopes of the rehabilitated off path TSF).
- Height limit of RL 172.3m for the sand stack, which excludes a 5.7m capping to an ultimate profile limit of RL178m.
- Sand stack to avoid any water courses required during closure.
- Sand stack volume around 18Mm^3 (a ratio of Atacama and Ambrosia sand).
- Iluka advised the machinery to be used to spread the pioneer layers would either be a Caterpillar D8T LGP or D10T. A D10t was considered for the stability assessments undertaken by ATCW.

Additional studies to assess the risks associated with potential surface water movement along the southern margin of the rehabilitated sand stack (Alluvium, 2022), erosion at the interface between the batters of the stand stack and the existing landscape, and risks related to the discharge of runoff from upslope areas onto the sand stack (i.e. the positioning of the landform) are available within the Appendix D. Erosion studies undertaken by Landloch (2022, Appendix E) indicate that the top surface of the current design is erosionally stable on the proviso that batters will be constructed to be less than 5°. At this stage it is proposed to achieve a final batter degree of 3.5°. The sands will be chemically stable in the stack formation.

Capping options for the Jacinth North pit may remain as per the current approved standard for Jacinth, being capped with 1.5 m of material as per Figure 3-11. Alternatively, the Jacinth North pit may be capped to 6 m which would allow for woodlands vegetation rehabilitation over the sand stack, however, this will require a larger total footprint and will require clearance of native vegetation that is currently undisturbed (Figure 3-12). The capping is subject to further assessment including a material balance.

Refer to Appendix C for engineering specifications associated with these two options.

Groundwater quality beneath and down hydraulic gradient of J-A has been previously characterised by elevated concentrations of certain metals (aluminium and manganese in particular), which appear to be aligned with acidic groundwater and correlate to areas of tailings seepage and associated groundwater mounding (CDM Smith, 2022). A geochemical assessment undertaken by CDM Smith (2022) found that the causation of acidity and elevated metals at J-A is most likely a function of naturally occurring aluminium (and other metal) hydrolysis i.e., metal hydrolysis drives the pH change as opposed to the acidic environment developing first and driving a change in metal concentration.

The disposal of wet mine tails at J-A within the free-draining cover sequence has led to rates of seepage much higher than background recharge rates at a local scale. The groundwater system has responded through the development of a groundwater mound underneath J-A with groundwater levels rising by up to 40 m in places. Wet tails from the processing of blended Atacama and Ambrosia ore will continue to be disposed of at J-A, with seepage expected to continue associated with this additional disposal.

5.1.3 Groundwater impacts and mitigation

Development of the Atacama Project would result in (CDM Smith, 2022):

- An extended period of pumping from the paleochannel wellfield.
- An extended period of tailings deposition and seepage at J-A effectively increasing the cumulative groundwater recharge.

Known, existing groundwater-related impacts arising from the J-A mine, as described in the PEPR (Iluka, 2021) are summarised as:

- GW1: Long-term reduction in groundwater levels and associated impacts to the paleochannel aquifer due to groundwater abstraction – Moderate inherent (unmitigated) risk level.
- GW2: Impacts to groundwater quality impacting beneficial use of the system due to tailings water seepage - Moderate inherent (unmitigated) risk level.
- GW3: Hyper saline groundwater rise (salinity) impacting soils and vegetation within the extent of mine workings – Very High inherent (unmitigated) risk level.
- GW4: Hyper saline groundwater rise (salinity) impacting soils and vegetation beyond the extent of mine workings due to groundwater mound migration - Moderate inherent (unmitigated) risk level.

With the introduction of operations at Atacama, an additional impact was identified (CDM Smith, 2022).

- GW-A: Cumulative effects for each of the above impacts (GW1-GW4).

The long-term recovery of water levels within the aquifer will be delayed should Atacama operations commence due to the extended period of pumping required for Atacama, but it is expected this difference would contract with time. For instance, post 2060 the water levels at the wellfield are at ~19 mAHD in Scenario 1 (with Atacama, Figure 5-1) compared to ~19.5 mAHD in Scenario 2 (no Atacama, **Figure 5-2**). Importantly, both with and without the development of Atacama, complete recovery of the groundwater levels is not predicted to occur for many years given the very low recharge rates to the aquifer (CDM Smith, 2022). Predicted drawdown in the paleochannel aquifer at the wellfield is shown in Figure 5-1 (Scenario 1) and **Figure 5-2** (Scenario 2).

With the re-introduction of DST should Atacama be approved, and the variation to tailings management deposition methods for J-A, CDM Smith (2022) modelled a number of scenarios to analyse the effect of the Atacama on cumulative groundwater recharge and associated mounding. These scenarios were:

- Scenario 4. J-A tailings only. DST for 2022 operations then SST.
- Scenario 5. J-A tailings only. DST to 2023 then SST.
- Scenario 6. J-A and Atacama tailings. DST to 2022, SST 2023-2024. Atacama and DST from 2025.
- Scenario 7. J-A and Atacama tailings. DST throughout LoM

Figure 5-3 and Figure 5-4 show hydrographs showing the simulated groundwater levels under each of the scenarios above. The hydrographs show groundwater levels rising in response to tailings seepage and then gradually receding (CDM Smith, 2022). Increases in groundwater level at Lake Ifould are likely to be negligible, a consequence of continuing evaporation, albeit it at higher rates.

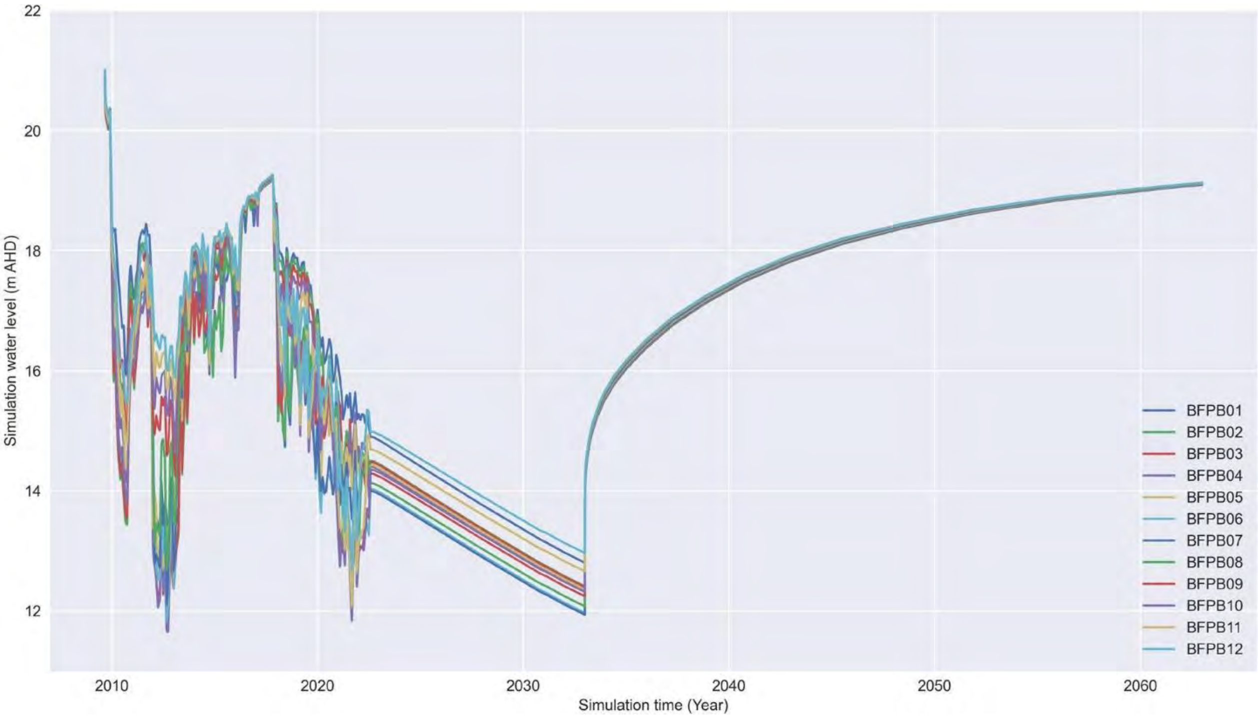

Figure 5-1: Scenario 1 (with Atacama) predicted drawdown (CDM Smith, 2022)

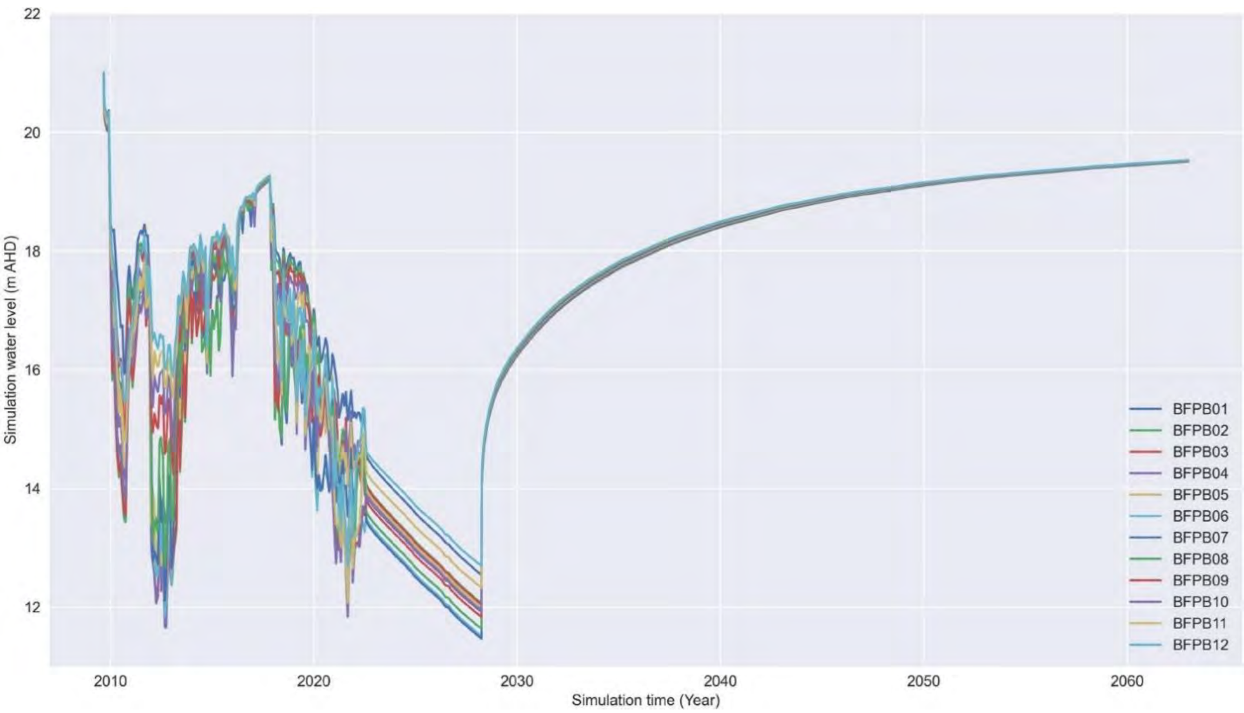

Figure 5-2: Scenario 2 (no Atacama) predicted drawdown (CDM Smith, 2022)

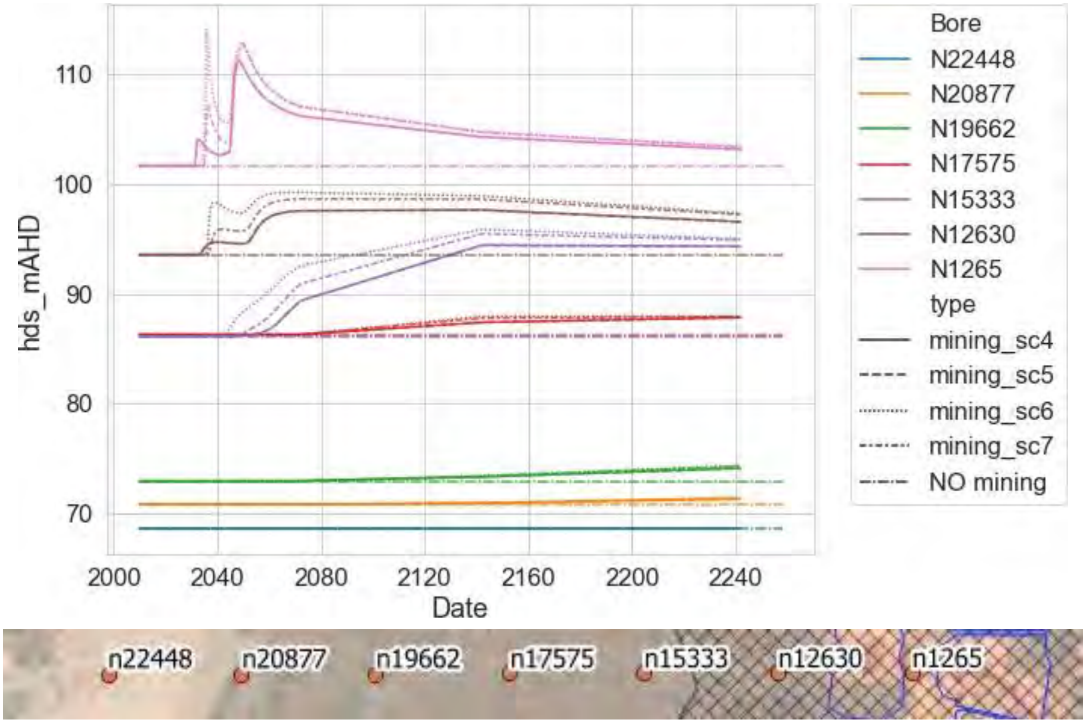

Figure 5-3: Hydrographs along the northern transect between Ambrosia and Lake Ifould for Scenarios 4, 5, 6 and 7 (CDM Smith, 2022)

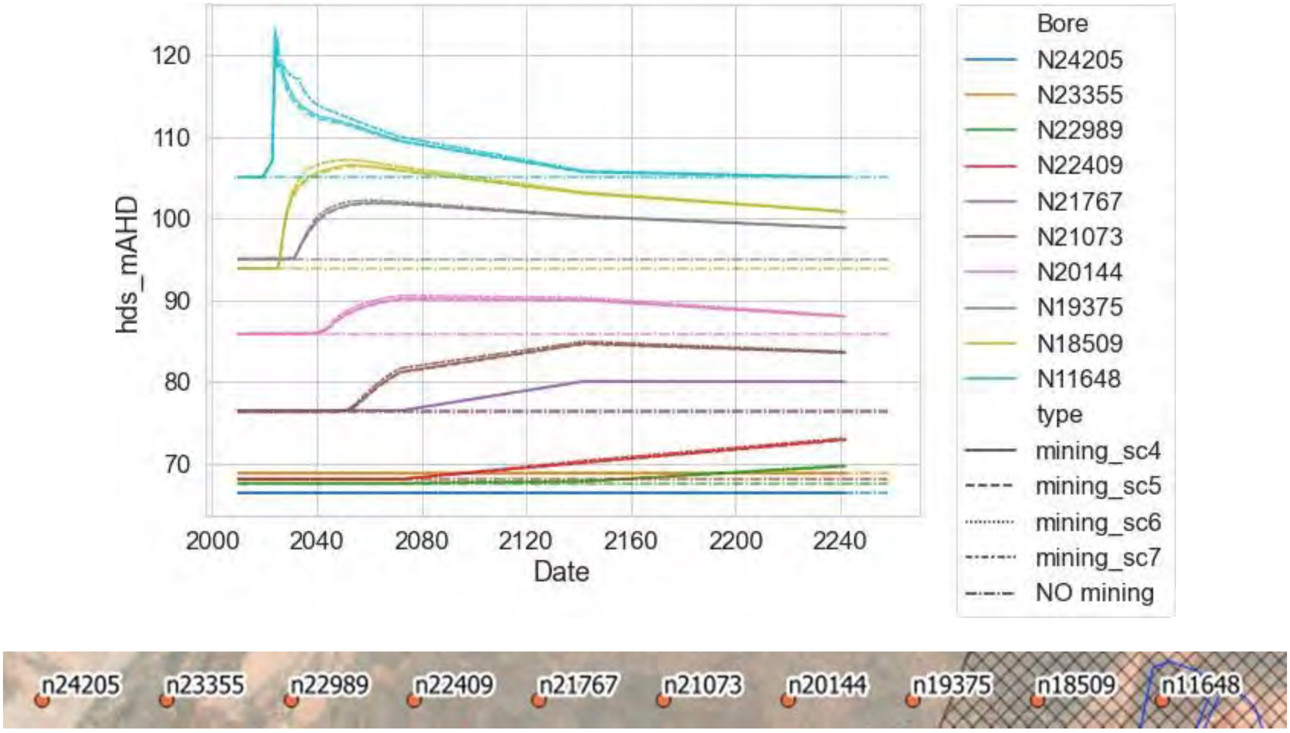

Figure 5-4: Hydrographs along the southern transect between Jacinth and Lake Ifould for Scenarios 4, 5, 6 and 7 (CDM Smith, 2022)

As assessed through the groundwater modelling undertaken (CDM Smith, 2022), the groundwater mound will most likely spread out towards Lake Ifould over time and at some stage manifest as an increase in groundwater levels and discharge at the lake via evaporation (Figure 5-5). Such a process may take many years (decades or even longer), with the greatest increase in groundwater level occurring in the area between the mine and the eastern side of the lake. Such increases could lead to saline groundwater intercepting the rootzones of vegetation. However, this assessment has demonstrated that the cumulative risk associated with this change (GW-A) remained consistent with existing profiles (GW4). Therefore, no cumulative groundwater impacts above those already approved are likely to occur with the approval from Atacama.

The cumulative effects of groundwater-related impacts resulting from the commencement of operations at Atacama were compared with those described in the PEPR (Iluka, 2021).

Design Control and Management Measures are also provided in Table 5-1.

5.2 Changes to criteria

Changes to outcomes, outcome measurement criteria and leading indicators are not applicable for the scenarios associated with this CiO Application

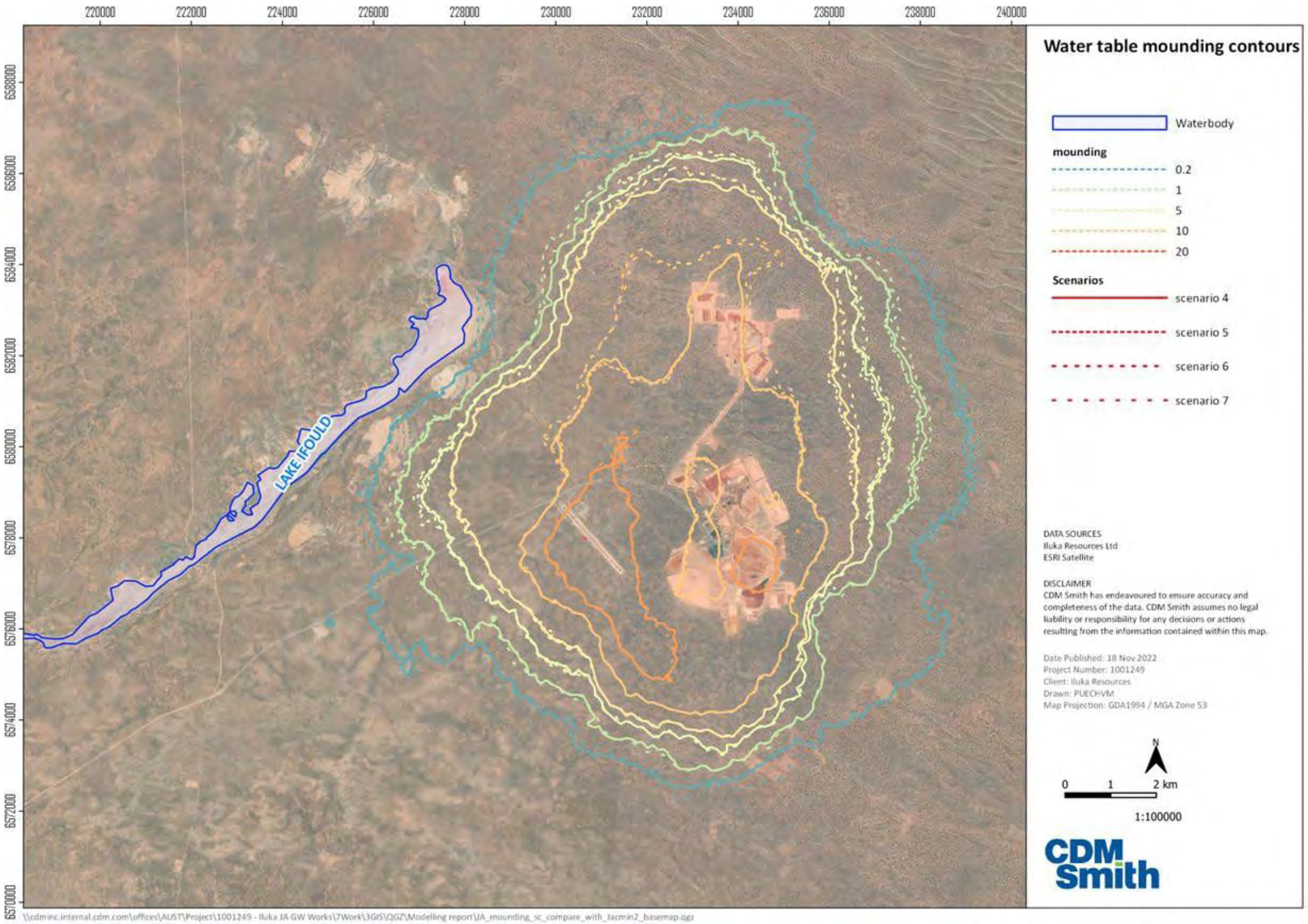

Figure 5-5: Projected groundwater level mounding (metres above pre-mining levels) based on median model realisations at 110 years post mining for Scenarios 4 to 7 (CDM Smith, 2022)

Table 5-1: Significance of cumulative impacts and proposed design control and management measures (CDM Smith, 2022)

Impact	Possible impact	Significance of cumulative effect	Design Control and Management measures	Uncertainties and assumptions	Sensitivity to change in assumptions	Existing Controls and management strategies as per 2021 PEPR
GW01	Long-term reduction in groundwater levels and associated aquifer impact(s) impacting or preventing beneficial use of the paleochannel aquifer by other parties	No significant change in groundwater level drawdown in the paleochannel aquifer are projected to occur with the development of Atacama. This is based on the results from Scenario 2 of the updated paleochannel wellfield model, which showed groundwater level drawdown remaining within the historical bounds observed in the paleochannel aquifer. Because pumping extends for a period of 5 years with the development of Atacama, the recovery of water levels in the aquifer (after pumping ceases) will be offset by a period of 5 years (i.e., it will occur 5 years later). By 2060, the difference in the recovering groundwater levels is only ~0.5 m lower under the Atacama scenario compared to the current mine plan, and this difference will continue contract with time. Given these minor changes in drawdown projections and the absence of other beneficial users of the aquifer, **no changes to the risk rating/ impact assessment for GW01 are warranted** should the Atacama Project be developed.	The controls and management strategies used to manage the impact are as follows: Groundwater Management and Monitoring Plan. Monitoring of groundwater abstraction rates and groundwater levels to ensure they are in line with model predictions and historical ranges. Drawdown below the historical range or significant deviations below the model predictions to be investigated to determine if risk rating and management practices require revision. Water return efficiency measures within mine processing to minimise paleochannel aquifer demand. J-A paleochannel abstraction predictive model. Annual aquifer review and biennial update of groundwater predictive model with operational abstraction and groundwater level data, plus tailings schedule.	Future paleochannel aquifer demand associated with mine operations.	Low. Sensitivity tested over historical period of operation	• Groundwater Management and Monitoring Plan. • Monitoring of groundwater abstraction rates and groundwater levels. • Increased water return efficiency within mine processing reducing paleochannel aquifer demand. • J-A borefield paleochannel abstraction predictive model. • Annual aquifer review and biennial update of groundwater predictive model with operational abstraction and groundwater level data, plus tailings schedule.
GW02	Impacts to groundwater quality	No significant change in impacts to groundwater quality are projected to occur with the development of the Atacama Project, because: 1) the geochemical processes are linked to mounding behaviour with the source of acidity inherent in geological strata at J-A (i.e., it is not introduced by tailings seepage), and 2) insignificant changes to the magnitude and extent of groundwater mounding are projected under the Atacama model. Therefore, **no changes to the risk rating/ impact assessment for GW02 are warranted** should the Atacama project be developed. A caveat to this risk rating is the requirement to continue to the monitor and sample the processing circuit with the introduction of ore from Atacama as part of ongoing tailings management practice to ensure tailings seepage quality remains within acceptable parameters.	The management controls for this potential impact are as follows: Groundwater Management and Monitoring Plan. Inclusion of the eight recently installed wells within the monitoring network and sampling procedure. Ongoing monitoring, assessment and evaluation of mine site groundwater chemistry against criteria to be established in the updated 2023 PEPR. Sampling and analysis of process circuit (sediment and water) and management (e.g., inclusion of Brown loam in process circuit) to maintain its circumneutral status. Application of water return efficiency measures to reduce tailings seepage.	Long term impact of tailing water seepage on groundwater chemistry and geochemistry.	Medium. Geochemical changes sensitive to the Distribution of soluble forms of aluminium minerals, neutralising capacity of native groundwater	• Groundwater Management and Monitoring Plan. • Monitoring of mine site groundwater chemistry. • Detailed assessment of mine site groundwater quality. • Sampling and analysis of process water. • Reduction of the use of flocculant in operations, where feasible.
GW03	Hyper saline groundwater rise (salinity) impacting soils and	No significant change in impacts to soils and vegetation within the mine working zone are projected to occur from the development of the Atacama Project due	The management controls for this potential impact are as follows:	Volume of water disposed in tails, end fate and associated mounding impacts.	Low.	**Groundwater** • Groundwater Management and Monitoring Plan.

Impact	Possible impact	Significance of cumulative effect	Design Control and Management measures	Uncertainties and assumptions	Sensitivity to change in assumptions	Existing Controls and management strategies as per 2021 PEPR
	vegetation within the extent of mine workings	to there being insignificant changes to the magnitude and extent of groundwater mounding under the Atacama model scenarios. Therefore, **no changes to the risk rating/ impact assessment for GW03 are warranted** should the Atacama Project be developed.	Groundwater Management and Monitoring Plan (including an updated trigger response framework, which is proposed for the next update of the PEPR in 2023). Monitoring of groundwater levels (tailings cell Vibrating Wire Piezometer networks, monitoring wells) and assessing trends relative to those predicted by the regional groundwater model (JACMIN 4.0). Ongoing use and update of the J-A regional groundwater model. Tailings Monitoring Management Plan to monitor tailings seepage and use control measures and water recovery infrastructure (e.g. under drainage) to minimise tailings seepage. Vegetation condition monitoring, particularly in areas where water table reference points are predicted to be exceeded.	Plant response to saline water stress.	Sensitivity explored by stochastic modelling undertaken in JACMIN4.0	• J-A mine regional Groundwater Predictive Model. • Management trigger levels (depth from surface, mBGL). • Tailings Management Plan. • Tailings water recovery infrastructure (sub-surface drainage and extraction systems). • Monitoring of groundwater levels (tailings cell Vibrating Wire Piezometer networks, monitoring wells). • Monitoring volume of water being disposed as tails. • Active return of water from tails stream. • Use of water efficient tails methods to reduce volume of water disposed in tailings plant standard operating procedures. **Soils** • Soil water and salt movement modelling in reconstructed soil profiles. • Texture analysis and soil water characteristic curves. • Draining of tailings to residual water content (3% gravimetric water content expressed as a dry weight basis). • Confirm phreatic surface within tails profile is within acceptable limits i.e., > 2.1 m below tails surface in myall/mallee and myall woodland associations and > 4.5 m in chenopod associations, prior to reinstatement of clean overburden (i.e., red loam, brown loam). • Capillary break installation if residual moisture content is not achieved at the time of rehabilitation earthworks commencement. **Native Vegetation** • Comparison of annual aerial photography to ensure vegetation clearance is within approved internal permit limits. • Monitoring of vegetation health in impact zones.
GW04	Hyper saline groundwater rise (salinity) impacting soils and vegetation beyond the extent of mine workings due to groundwater mound migration	No significant change in impacts to soils and vegetation outside the mine working zone are projected to occur from the development of the Atacama Project due to there being insignificant changes to the magnitude and extent of groundwater mounding under the Atacama model scenarios. Therefore, **no changes to the risk rating/ impact assessment for GW04 are warranted** should the Atacama Project be developed.	The management controls for this potential impact are as follows: Groundwater Management and Monitoring Plan (including an updated trigger response framework, which is proposed for the next update of the PEPR in 2023). Inclusion of the 8 recently installed wells within the monitoring network. Monitoring of groundwater levels (tailings cell Vibrating Wire Piezometer networks, monitoring wells) and assessing trends relative to those predicted by the regional groundwater model (JACMIN 4.0).	As above.	Low. Sensitivity explored by stochastic modelling undertaken	• All controls and management strategies per above for GW3

Impact	Possible impact	Significance of cumulative effect	Design Control and Management measures	Uncertainties and assumptions	Sensitivity to change in assumptions	Existing Controls and management strategies as per 2021 PEPR
			Ongoing use and update of the J-A regional groundwater model. Tailings Monitoring Management Plan to monitor tailings seepage and use control measures and water recovery infrastructure (e.g., under drainage) to minimise tailings seepage. Vegetation condition monitoring, particularly in areas where water table reference points are predicted to be exceeded.			

The assessment by CDM Smith (2022) demonstrated no changes to the risk profile or control measures for each of the above potential impacts (GW1-GW4), other than the process circuit monitoring (sediment and water) which will require intensive focus (additional monitoring rounds) when ore from Atacama is introduced to ensure tailings seepage quality remains within acceptable parameters (CDM Smith, 2022).

For a more detailed assessment please refer to Appendix B.

6 EFFECTIVE AND EFFICENT MINING

6.1 Reserve or resources (or both)

Mined materials will comprise zircon, ilmenite and rutile bearing mineralised sands and non-mineralised waste. The waste generated will be a mixture of non-mineralised waste from the pit and mineral depleted tailings from the J-A processing plant. A summary of the Mineral Resource Estimate for J-A at the end of 2022 is shown in Table 6-1, for information relating to the Atacama Project resource estimate please refer to Section 4 of the Atacama MLP

Table 6-1: J-A mineral resource estimate (as at 31 December 2016)

Mineral Resource category[1]	Material tonnes (Mt)	In-situ HM tonnes (Mt)	HM grade (%)	Clay grade (%)	HM assemblage[2]			
					Ilmenite grade (%)	Zircon grade (%)	Rutile grade (%)	Monazite & Xenotime grade (%)
Ambrosia								
Measured	101,558	2,683	2.6	14.9	24.5	50	4.7	
Indicated	19,602	300	1.5	13.8	21	48	4.5	
Inferred	28,002	405	1.4	13.3	19.3	49.6	2.1	
Jacinth								
Measured	48,050	1,957	4.1	11.3	31	47.2	4.3	
Indicated	3,150	113	3.6	10.5	20.6	54.9	4.1	
Inferred	8,170	228	2.8	5	32.4	41.3	4.6	

6.2 Reasonable prospect of access to land

Access to land is already in place, and the changes to authorised operations largely occurring within the existing disturbed footprint of the J-A ML 6315 and MPL 110 and 111. The proposed changes do not affect current native title mining agreements with the registered Far West Coast (FWC) Native Title Group.

Refer to the Atacama MLP for further information regarding access to land in relation to Atacama Project.

[1] Mineral resources are inclusive of ore reserves

[2] The mineral assemblage is reported as a percentage of the in-situ HM content

7 ASSESSMENT OF LEASE AND/ OR LICENCE TERMS/ CONDITIONS AND THE ACT

The proposed changes in operation will be compliant with the terms and conditions of the J-A ML.

8 REFERENCES

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Iluka, 2017. *Updated Mineral Resource and Ore Reserve Statement*. ASX release date 20 February 2017 [https://www.asx.com.au/asxpdf/20170220/pdf/43g4fffv5vb43z.pdf] accessed 16 January 2020.

Landloch. 2022. *Erosion potential of the proposed landform design for the sand stack at Jacinth North*. Report prepared for Iluka Resources Ltd.

Appendix A – TOR 025 Checklist

Form	Relevant Section or Comment
Applicant name(s) (company and / or individual)	Table 1-1
Applicant contact details including postal address	Table 1-1
Email	Table 1-1
Phone number	Table 1-1
Primary tenement the change applies to	Table 1-1
Statement of whether the application relates to a change in the following: Authorised operations; and/or	Section 1
Mineral intended to be recovered; and/or	Section 6
Ability of the tenement holder to achieve a particular outcome of change in criteria to be adopted; and/or Terms and/or conditions of the tenement.	Section 5
PROPOSAL	
PURPOSE AND REASON FOR CHANGE	
Provide a statement specifying whether the proposed change is: 1.1 a change to the authorised operations to be carried out under the tenement, and/or; 1.2 a change in the mineral that is intended to be recovered; and/or 1.3 a change that may reduce the ability of the tenement holder to achieve a particular outcome, including an environmental outcome, and/or; 1.4 a change to the criteria to be adopted to measure a particular outcome; and/or 1.5 a change to the terms or conditions of the tenement	Section 2
CHANGE TO AUTHORISED OPERATIONS	
Description of change to authorized operations	
Describe all elements of the proposed change in operations.	Section 3
Maps, plans and cross-sections	Section 3
Scope of proposed change to authorised operations	Section 3
Assessment of alternatives	Section 4
Assessment of Changes to Environmental Impacts	
Changes to environmental impacts of the authorised operations	Section 5

Form	Relevant Section or Comment
Control strategies	Section 5
Description of uncertainty	Section 5
Assessment of environmental outcomes	Section 5
Changes to criteria	Section 5
EFFECTIVE AND EFFICIENT MINING (MINING LEASES ONLY)	
Reserves or resources or both	
If the change involves the extraction of minerals that are not currently authorised, for those minerals provide: a JORC-compliant reserve or resource estimate (or both)	N/A
If the change involves the extraction of minerals that are not currently authorised, for those minerals provide: the accompanying JORC Public Report and competent person statement.	N/A
If a JORC-compliant reserve or resource (or both) has not been reported provide: a detailed estimate of the resource to be mined, the basis of this estimate, and evidence that demonstrates that the resource can be economically mined at current market prices.	Section 6
Reasonable prospect of access to land	
A statement that demonstrates that any waivers of exemption under Section 9AA of the Mining Act 1971 required for the proposed changes have been obtained, or there is a reasonable prospect that they can be and	Section 6
A statement that demonstrates how the proposed changes relate to any native title mining agreements obtained under the Mining Act 1971 or Indigenous Land Use Agreements (ILUA) under the Native Title Act 1993 (Cth).	Section 6
ASSESSMENT OF LEASE AND/OR LICENCE TERMS/CONDITIONS AND THE ACT: With the exception of any proposed changes to lease and/or licence terms and conditions (as per clause 1.3), provide an assessment that demonstrates the proposed change in operations would be compliant with the terms and conditions of the lease/licence.	Section 7

Appendix B – Jacinth Ambrosia Groundwater Impact Assessment (CDM Smith)

Iluka Resources Limited

Jacinth-Ambrosia Groundwater Impact Assessment

8 December 2022

CDM Smith

listen. think. deliver.

Table of Contents

Figures

Tables

Appendices

No table of contents entries found.

Document history & status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
V0	14/10/2022	J. Fox	D. Currie	14/10/2022	Draft
V1	23/11/2022	Iluka	D. Currie	23/11/2022	Draft
V2	5/12/2022	Iluka	D. Currie	5/12/2022	Final

Distribution of copies

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V2	5/12/2022	1	1	B. Ryan

Last Saved:	8 December 2022
File Name:	1001249-RPT-J-A Groundwater Impact Assessment-v2
Author:	Dougal Currie
Project Manager:	Dougal Currie
Client:	Iluka Resources Limited
Document Title:	**Jacinth-Ambrosia Groundwater Impact Assessment**
Document Version:	V2
Project Number:	1001249

Section 1 Introduction

1.1 Background

Iluka Resources Limited (Iluka) has been mining and processing heavy mineral (HM) sands at the Jacinth-Ambrosia mine (J-A) in the Eucla Basin since operations commenced in 2009. Operations have consisted of:

- Dry mining of HM ore at two contiguous deposits (Jacinth and Ambrosia)
- Water supply and pipeline transfer from a wellfield established in a paleochannel aquifer located 30 km to the west of site.
- On-site processing and concentration of HM via gravity separation.
- Deposition of wet tailings in an off-path tailings storage facility (TSF) and then in mined out voids.
- Progressive rehabilitation of disturbed areas.

Iluka is also considering the development of the Atacama deposit (a satellite deposit to the north of J-A, see Figure 1-1) to augment its HM production from existing processing facilities at J-A. The proposed operations at Atacama are:

- Dry mining of HM ore.
- Off-site processing and tailings deposition using existing facilities at J-A.
- Progressive rehabilitation of disturbed areas.

Atacama is currently the subject of pre-feasibility studies being undertaken by Iluka, as well as the development of a Mining Lease Proposal (MLP) which is planned to be submitted to the South Australian Government in late 2022. As part of the approvals process, Iluka must submit a Change in Operations (CiO) Application. The CiO will assess changes that will occur on the J-A Mining Lease (ML) due to the Atacama Project. An impact assessment is required to assess the cumulative changes to impacts.

To satisfy South Australian regulatory approvals and its own commitment to environmental stewardship, Iluka has prepared a Program for Environmental Protection and Rehabilitation (PEPR) for J-A which outlines its responsibilities and approaches to avoid unacceptable impacts from mining and rehabilitation activities, both during mining and post-closure. The PEPR includes a groundwater monitoring and management framework to manage groundwater-related risks and potential impacts.

The latest iteration of the PEPR (Iluka 2021), lists the following potential groundwater-related impacts (and associated risk ratings) arising from the J-A mine:

- GW1: Long-term reduction in groundwater levels and associated impacts to the paleochannel aquifer due to groundwater abstraction – Moderate inherent (unmitigated) risk level.
- GW2: Impacts to groundwater quality impacting beneficial use of the system due to tailings water seepage - Moderate inherent (unmitigated) risk level.
- GW3: Hyper saline groundwater rise (salinity) impacting soils and vegetation within the extent of mine workings – Very High inherent (unmitigated) risk level.
- GW4: Hyper saline groundwater rise (salinity) impacting soils and vegetation beyond the extent of mine workings due to groundwater mound migration - Moderate inherent (unmitigated) risk level.

The current understanding of these potential impacts is based on a significant body of work that has been undertaken by Iluka and its consultants since mine feasibility studies were initiated and draws on an established groundwater monitoring and sampling program. These works are summarised in the PEPR, which also lists key remaining knowledge gaps and commitments from Iluka to address these gaps via additional investigation and monitoring.

No potential groundwater-related impacts are expected at the Atacama site itself, given the dry mining operations (i.e. all mining will occur above the water table) and lack of tailings deposition (which is to occur at J-A). However, the Atacama project would result in an extension of processing and tailings deposition at J-A with associated extended demand on groundwater abstraction from the paleochannel aquifer and extended tailings seepage at J-A. Thus, it would have a cumulative effect on the existing potential impacts which concern groundwater at J-A (GW1–4).

1.2 Objectives and scope of works

Iluka engaged CDM Smith in partnership with Land and Water Consulting (LWC) to undertake a program of works to address knowledge gaps listed in the PEPR (2021) to gain an improved understanding of the potential groundwater-related impacts arising from continued operations at the J-A mine and from the development of the Atacama project. The scope of work has involved:

- Drilling supervision, logging, sampling and geochemical testing at four new drillholes within the mine working zone.
- Drilling supervision, logging, sampling, and geochemical and groundwater testing at eight new monitoring wells established outside of the mine working zone between J-A and Lake Ifould.
- Recalibration of the existing paleochannel aquifer model.
- Development of a robust and defensible groundwater flow model for J-A Mine and surrounds, including the area between the mine and Lake Ifould.
- Geochemical assessment to understand if changes to groundwater chemistry at the mine are due to tailings activities and to identify the mechanism of change.
- Predicting, with more certainty, changes to groundwater levels and water quality at Lake Ifould as a result of mine activities, if any.
- Identifying any deleterious impacts to sensitive receptors and groundwater-dependent ecosystems (GDE) due to changes in groundwater chemistry, if identified.
- Assessment of cumulative impacts resulting from the future development of the Atacama Deposit.

The outcomes being sought by Iluka, include:

- A knowledge base to revise the groundwater management framework through an improved understanding of hydrogeology and geochemistry, and updating of existing conceptual and quantitative models, giving particular attention to the area between the mine and Lake Ifould to the northwest.
- A more holistic understanding the hydrogeochemical processes that draws together the hydrogeology and geochemistry.
- An improved understanding of potential impacts and strategies to mitigate them.
- An augmented monitoring network.
- Information to support a review and update of the site-specific risk trigger levels (SSTLs) that are a key element of the groundwater management framework.
- Clear communication products for engagement with stakeholders and regulators.

1.3 This report

This report summarises the works undertaken and presents a reassessment of the groundwater-related impacts at J-A, with and without the Atacama development, based on the new information acquired. It draws on the detailed technical reports that cover the various elements of the groundwater assessment program as follows:

- Jacinth-Ambrosia drilling, construction and testing completion report (CDM Smith 2022a).
- Groundwater flow modelling assessment, Jacinth-Ambrosia mine (CDM Smith 2022b).
- Jacinth-Ambrosia wellfield groundwater modelling update (CDM Smith 2022c).
- Jacinth-Ambrosia Environmental Geochemical Assessment (LWC 2022).

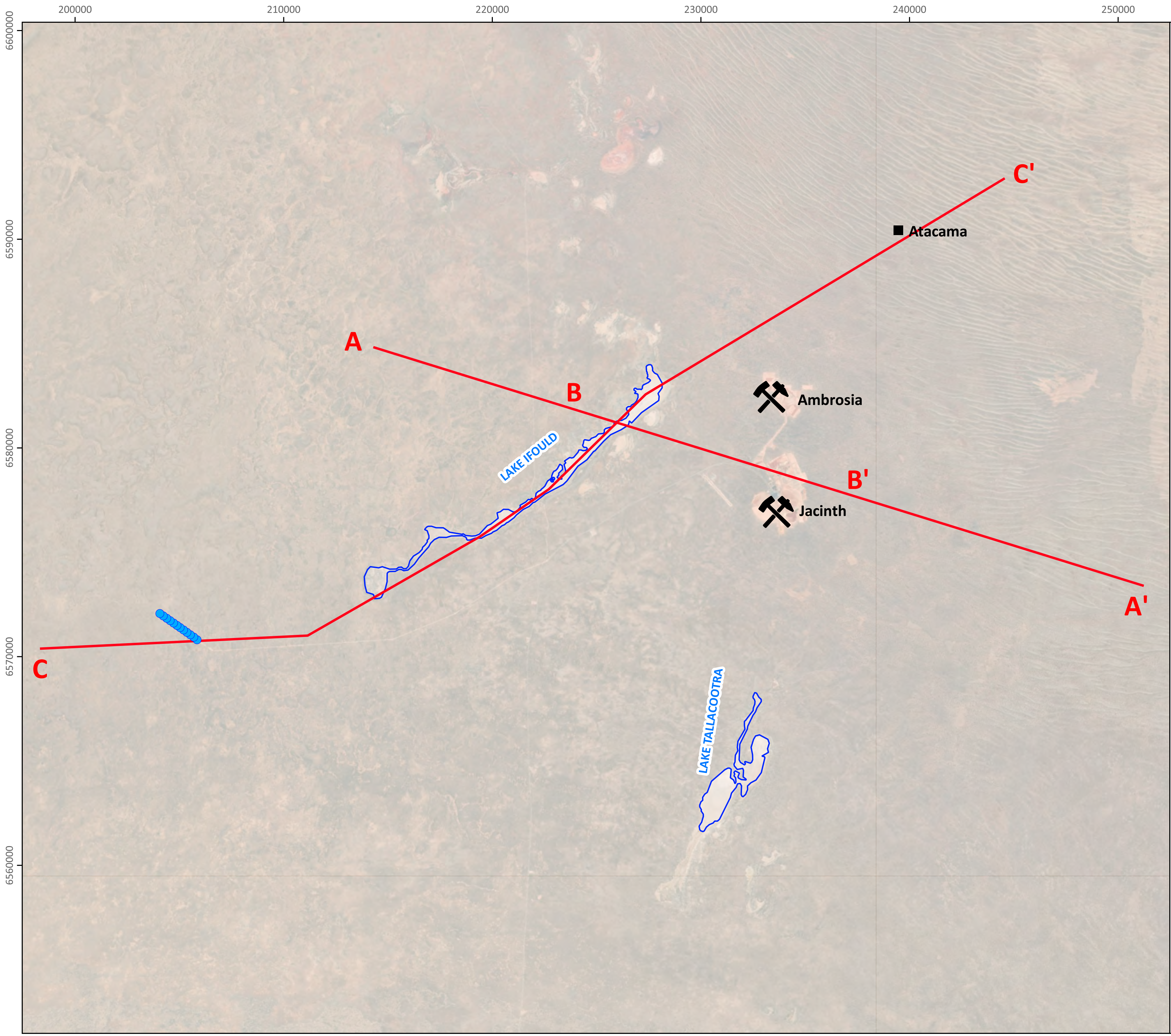

Figure 1-1

Site locations

- Mine
- Developing project
- Waterbody
- Borefield - production well
- Cross section transect

DATA SOURCES
Iluka Resources, ESRI Satellite

DISCLAIMER
CDM Smith has endeavoured to ensure accuracy and completeness of the data. CDM Smith assumes no legal liability or responsibility for any decisions or actions resulting from the information contained within this map.

Date Published: 21 Nov 2022
Project Number: 1001249
Client: Iluka Resources
Drawn: ETEROVICZ
Map Projection: GDA1994 / MGA Zone 53

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Section 2 Summary of works undertaken and key findings

The following sections summarise the groundwater assessment works undertaken at J-A by CDM Smith and LWC in 2022 and the key findings of relevance to the groundwater impact assessment.

2.1 Hydrogeological conceptualisation

At the outset of the program, the conceptualisation of the regional hydrogeology was reviewed using the latest data from Iluka, public sources and the fieldworks carried out as part of this work program. This review found:

1. The regional hydrogeology can be compartmentalised into the groundwater flow systems associated with the Ooldea Range and the groundwater flow systems associated with the paleochannels of the Nullarbor Plain. These groundwater flow systems are hydraulically distinct due to the presence of basement highs along the foot of the Ooldea Range (see Figure 2-1). This conceptualisation supports the use of two separate groundwater models to: i) evaluate the influence of mining and tailings seepage on groundwater near J-A; and ii) evaluate the influence of pumping from the paleochannel aquifer.
2. The hydro-stratigraphy implemented in previous groundwater flow models for the Ooldea Range required revision to capture the key contrasts in permeability and porosity evident in the geology with three hydr-stratigraphic units (HSUs) defined as follows (in order of depth from the land surface): Unit 1) Cenozoic sediments, which are mostly unsaturated yet permeable; Unit 2) Saprolite / weathered basement, which is clayey and of very low permeability and; Unit 3) Fresh basement, which is very impermeable aside from fracture networks which can host localised groundwater systems.
3. Groundwater chloride concentrations point to very low recharge rates with previous estimates of rainfall recharge being an order of magnitude too high.
4. Paleovalleys exert key controls on regional groundwater flow direction in the Ooldea Range, with flow directed towards and along these features. Groundwater moves very gradually along these flow paths before discharging at Lake Ifould, Lake Tallacootra or other such playa lakes via evaporation, without being expressed at the surface. Given the low rates of recharge this is a very slow, gradual process and groundwater salinity is very high.
5. Aside from the groundwater discharge via evaporation at Lake Ifould, there is negligible interaction between groundwater and surface environments with the high groundwater salinity preventing the use of groundwater by vegetation. The low yields and high salinity also restrict any groundwater use by third-party users. In summary, there are no direct groundwater receptors, and groundwater-related risks are linked to mounding occurring to an extent whereby it would intercept surface environments (vegetation and soils).
6. The basement morphology exerts considerable control over the groundwater mounding behaviour at J-A due to the permeability contrast between the Cenozoic sediments and the weathered basement. Thus, the basement surface layer (top of the weathered basement) is a critical input to an assessment of mounding from mining activities at J-A. This layer surface was refined as part this work using data from SARIG and Iluka mineral exploration activity.
7. The Cenozoic sediments are quite variable in terms of thickness and composition, as evident in the drilling undertaken between J-A and Lake Ifould (see Section 2.2). Representing such heterogeneity in the groundwater flow model was therefore implemented.
8. The disposal of wet mine tails at J-A within the free-draining cover sequence has led to rates of seepage much higher than background recharge rates at a local scale. The groundwater system has responded through the development of a groundwater mound underneath J-A with groundwater levels rising by up to 40 m in places The size and shape of the groundwater mound over time is controlled by the following primary factors:
    a. The mine schedule, which shifts the location of tailings disposal over time.

b. Operational responses which have sought to reduce tailings seepage.

c. The dedicated groundwater interception pumping from 2013 to 2016.

d. The basement morphology, which governs the thickness of the overlying sediments and the slope of the low permeability basement surface.

e. The hydraulic conductivity and storage properties of the Cenozoic sediments that overlie the basement.

9. The groundwater mound will most likely spread out towards Lake Ifould over time and at some stage manifest as an increase in groundwater levels and discharge at the lake via evaporation. Such a process may take many years (decades or even longer) and the change in groundwater level may be relatively imperceptible. However, it could also lead to saline groundwater becoming unacceptably shallow and intercepting the rootzones of vegetation. The groundwater modelling undertaken was designed to assess these potential impacts.

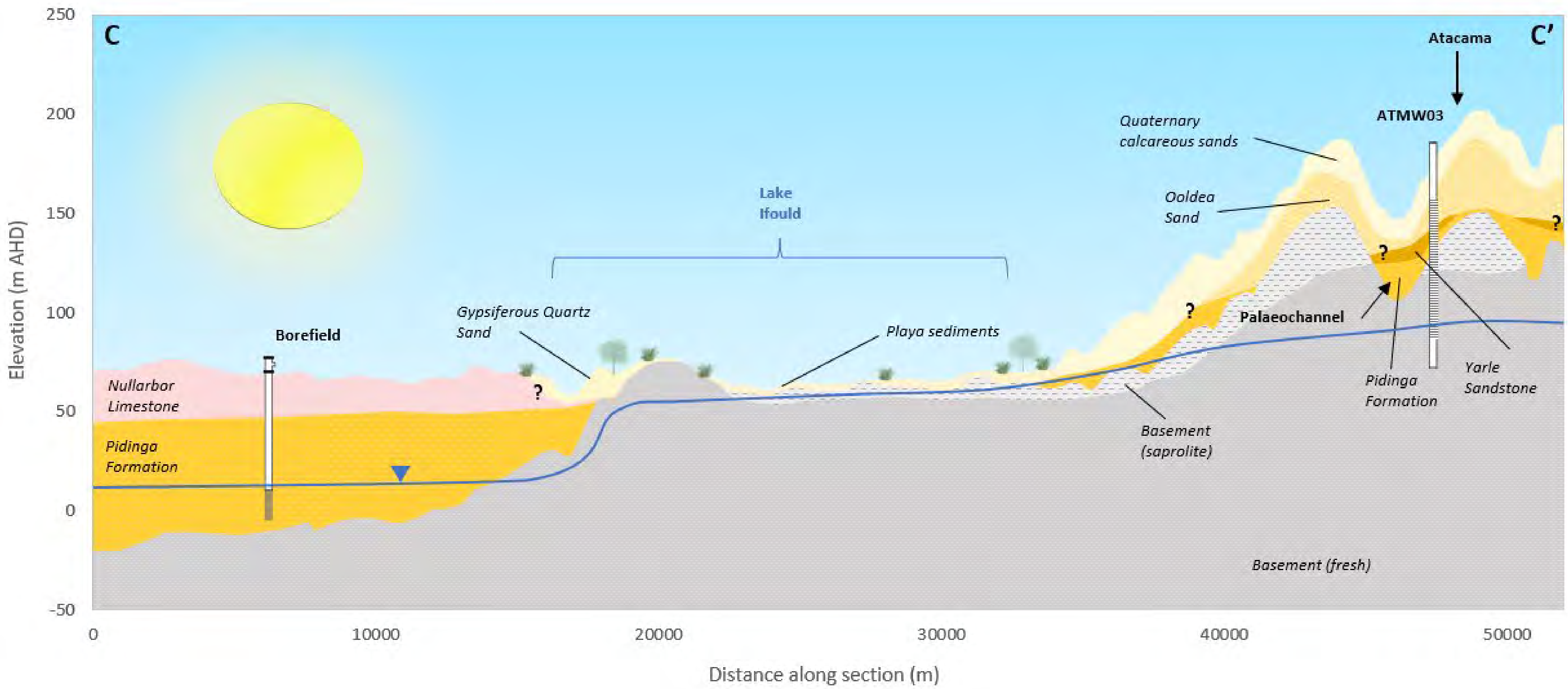

Figure 2-1 Regional stratigraphic cross-section C-C'. The water table shown indicates a pre-mining and pre-pumping condition. See Figure 1-1 for section location.

2.2 Fieldworks

Fieldworks were undertaken in May and June 2022 and consisted of the following activities:

- Drilling supervision, logging, geochemical testing and core sampling from boreholes drilled using a sonic method at four sites located near the mine working zone (Figure 2-2).
- Drilling supervision, logging, geochemical testing, core sampling and well installation using a diamond drilling method to establish eight new monitoring wells between J-A and Lake Ifould (Figure 2-2). Four of these wells were installed at shallow depths (~20-30 m) and screened across the water table that was hosted in the heavily weathered zone (saprolite) of the basement. The four other wells were installed at greater depths (~40-60 m) and screened to intersect water-bearing fractures of the fresh, unweathered basement.
- Groundwater sampling and slug testing in the newly installed monitoring wells.
- Sampling and analysis of sediment and water from the mine process circuit.

The key findings of the fieldworks were as follows:

1. The lithology at the boreholes in the mine working zone (GC01-04) was consistent with the existing understanding at J-A.
2. The lithology outside of the mine working zone showed (in order of increasing depth),
   a. Quaternary sediments covering the surface (referred to as Brown Loam).
   b. A thin layer (2-5 m) of reworked Ooldea sands.
   c. A fine-to-coarse grained sandstone (Yarle Sandstone), 2-9 m thick.
   d. An absence of the marine Ooldea sands unit.
   e. A saprolite layer of variable thickness (5-30 m) and composition but generally containing low plasticity clay and heavily decomposed granite/gneiss.
   f. In places (mostly towards Lake Ifould), a zone of altered granitic gneiss between the saprolite and the basement.
   g. Fresh basement, comprising very high strength graodiorite and orthogneiss with variable fracturing.
3. Outside of the mine working zone, the water table was hosted in the saprolite layer and the overlying sedimentary units were unsaturated.
4. The estimated hydraulic conductivity of the deeper wells, as determined by hydraulic (slug) testing, ranged from 1.0 x 10^{-3} m/day to 1.5 x 10^{-1} m/day. The hydraulic conductivity estimated from the shallow wells (installed in the saprolite unit) ranged from 1.0 x 10^{-3} m/day to 3.0 x 10^{-2} m/day and was notably lower due to the clayey nature of the saprolite material.
5. Field geochemical testing was undertaken during drilling by measuring the electrical conductivity (EC), pH (pHF) and oxidised pH (pHFOX) of core sub-samples. The testing found pH decreased with depth with no significant lowering of pH by forced oxidation (i.e. an absence of potential acid forming (PAF) material), except for at MB20 where a sample of saprolite just beneath the water table returned a pHFOX of 1.8 compared to a pHF of 7.9. High EC (salinity) was found throughout the strata at all sites.
6. The results of the logging and geochemical field testing were used to select samples for laboratory testing as part of the geochemical assessment.

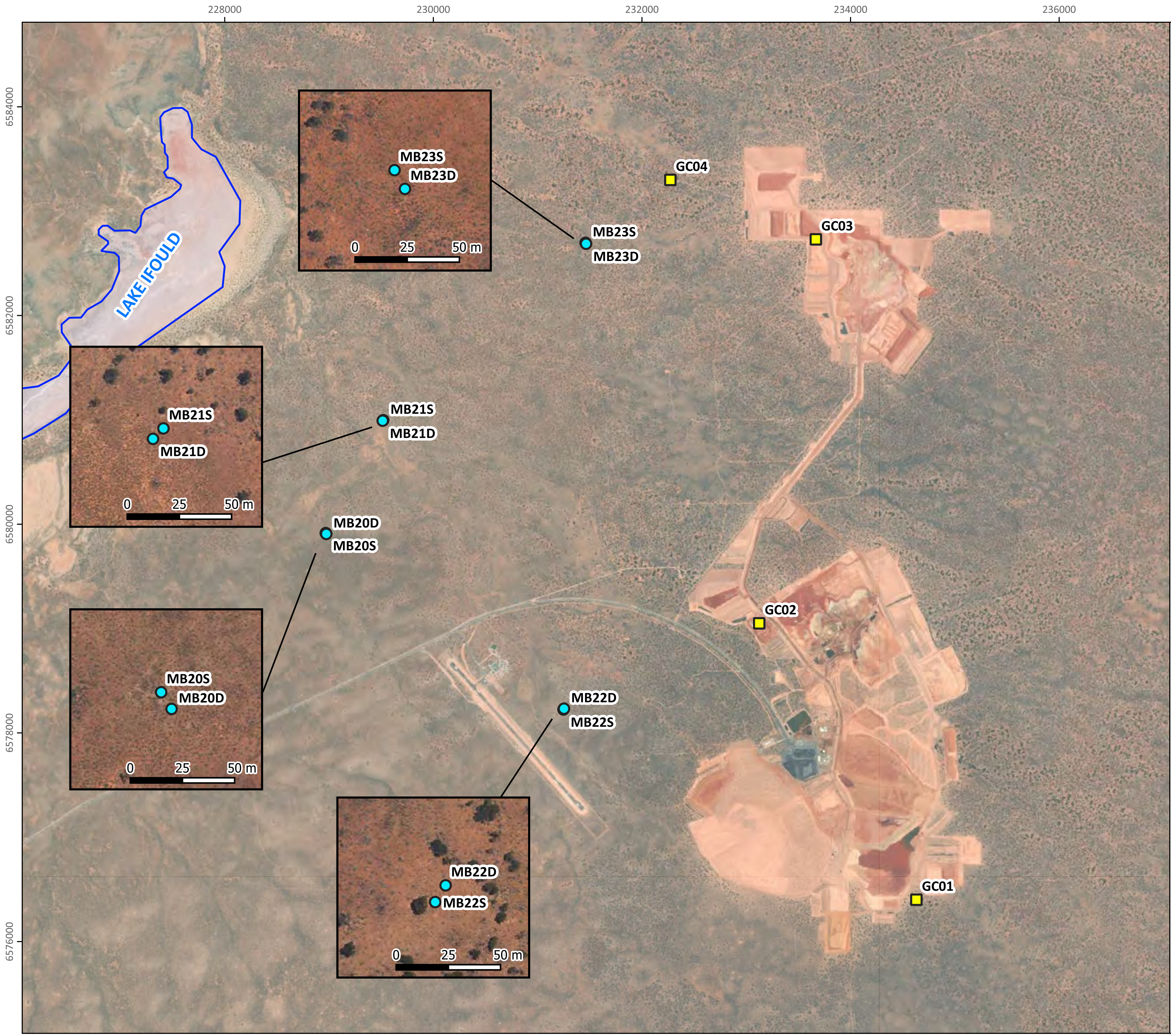

Figure 2-2

Drilling locations

DATA SOURCES
Iluka Resources Ltd
ESRI Satellite

DISCLAIMER
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Date Published: 12 Aug 2022
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Client: Iluka Resources
Drawn: ETEROVICZ
Map Projection: GDA1994 / MGA Zone 53

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2.3 Groundwater modelling of J-A mine and surrounds

2.3.1 Model refinements and recalibration

A refined groundwater modelling platform has been developed, JACMIN4.0, to model groundwater flow processes at J-A. The model focussed on simulating the response of groundwater levels to tailings deposition at J-A (i.e. groundwater mounding), the propagation of the groundwater mound over time, and whether it could interact with environmental receptors (Lake Ifould, soils and vegetation). The modelling was conducted at a regional scale and over long timeframes to assist in the development of management and monitoring strategies that aim to avoid unacceptable impacts from mining and rehabilitation activities, both during mining and post-closure. The area of interest is depicted in the hydrogeological cross-section shown in Figure 2-3.

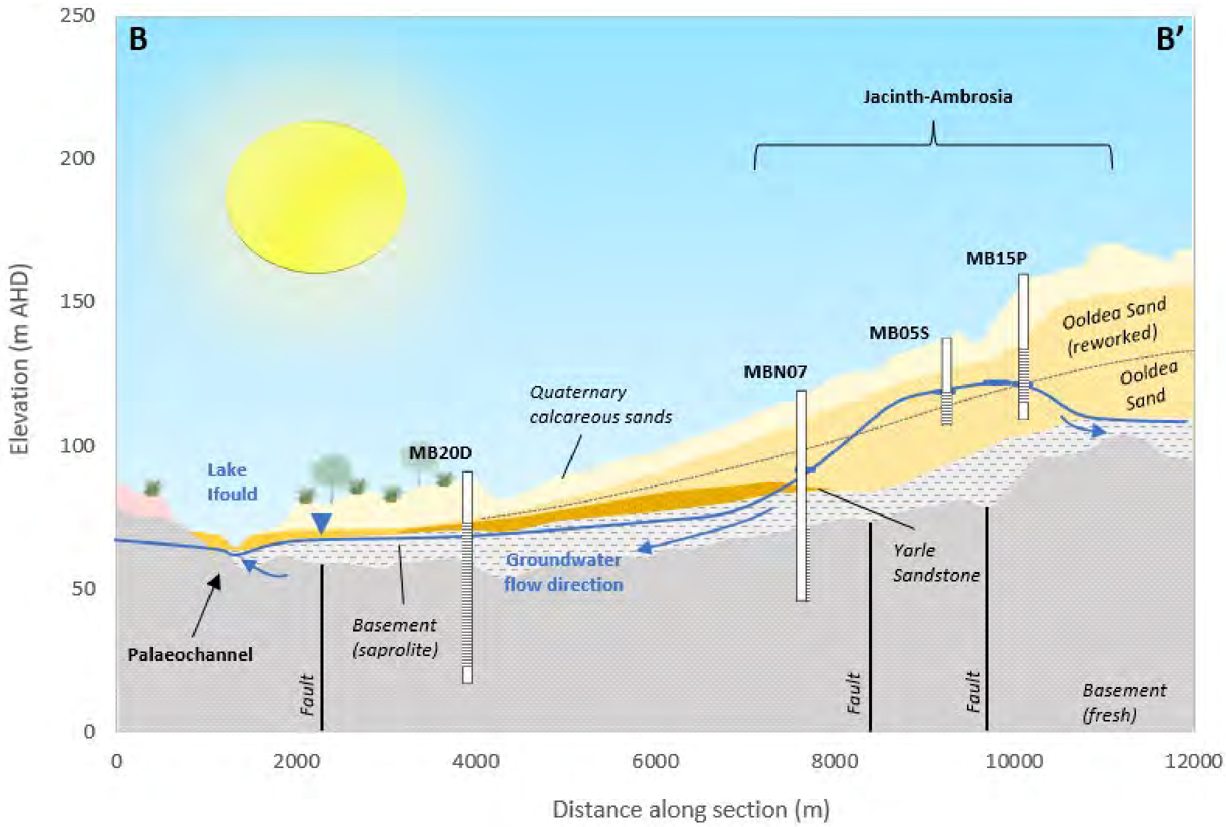

Figure 2-3 Hydrogeological cross-section between J-A and Lake Ifould depicting groundwater mounding in response to tailings deposition

JACMIN4.0 supersedes the previous groundwater modelling platforms at J-A (JACMIN2.0), with the following refinements made:

- The model domain has been extended to cover a larger area of Lake Ifould and include Lake Tallacootra.
- A Voronoi gridding system to refine the model in and around the mine and for numerical efficiency.
- New model layering to align with revised hydrostratigraphy.
- A highly parameterised approach to model calibration using pilot points.
- A much lower background rainfall recharge rate (0.1 mm/y).
- Representation of recharge from tailings seepage incorporates a time delay and a reduction factor to account for unsaturated zone processes (such as perching behaviour) which can influence groundwater response times.

- A stochastic modelling method in which 110, equally plausible, model realisations have been developed and calibrated to allow for a probabilistic assessment in the scenario analysis undertaken.

Model calibration was performed using PESTPP-IES (White et al. 2020) and the calibration statistics have improved markedly from pre-existing model. JACMIN 4.0 has a Scaled Root-Mean Square (SRMS) groundwater level residual of 4.2% (see Figure 2-4)compared to 10.1% in JACMIN2.0. The simulated groundwater level hydrographs also provide a closer match to the groundwater responses observed in the monitoring wells.

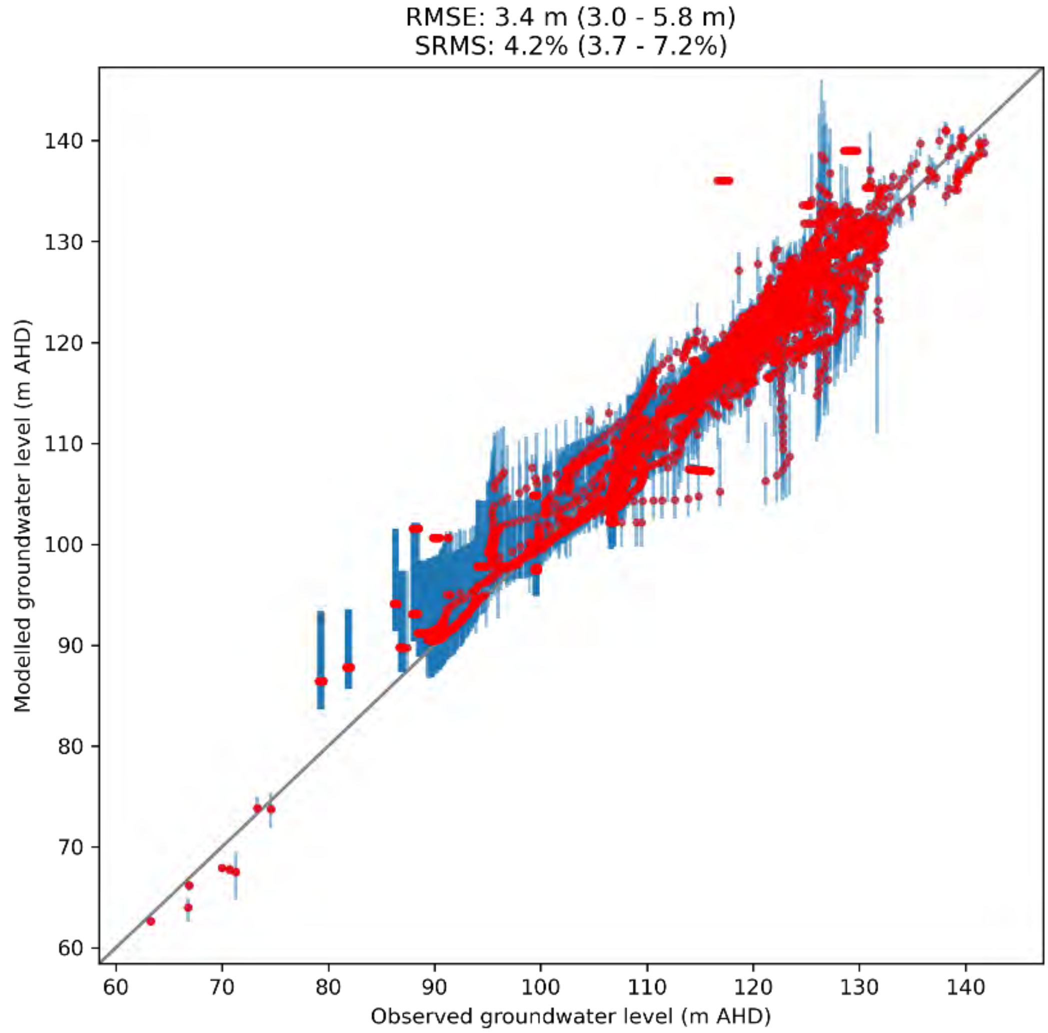

Figure 2-4 Comparison of observed and simulated groundwater levels. Blue bars mark simulated ranged over all 100 model simulations.

While every effort was made to refine model layering, structural uncertainty remains within the model (particularly in areas where there are few boreholes) and the interpretation of the results must acknowledge this limitation. A basement high, indicated in the layer surface on the eastern side of Jacinth South, appears to be somewhat anomalous; however, its inclusion in the model has the effect of forcing additional water towards Lake Ifould and therefore adds to conservatism in the assessment of mounding.

2.3.2 Scenario analysis to assess single stream vs dual stream tailings deposition

Current operations and mine plans at J-A incorporate a dual stream tailings (DST) method in which sand tails and fine tails (slimes) are deposited separately. Iluka is considering shifting J-A operations to a single stream tailings (SST) method in which all tails are deposited together. Scenario analysis was performed using JACMIN4.0 to assess the effect of shifting from DST to SST on groundwater mounding at J-A, with the following scenarios developed:

- Scenario 1. DST deposition during the life of mine (LoM) (to April 2028), representing the current mine plan.
- Scenario 2. DST to February 2023, then changing to SST for the remaining LoM (March 2023 to April 2028).

The scenarios were implemented in all 110 model realisations and run for 5,000 years post-mining to simulate the long-term effect on groundwater mounding. A third scenario (Scenario 3) was run with very high seepage rates applied (deemed to be unrealistic) and the results are not presented here (see CDM Smith 2022b for detail).

Figure 2-5 shows the cumulative recharge to groundwater implemented by Scenarios 1 and 2. In both cases, a range of recharge projections is simulated by the ensemble of models (110 realisations). Higher recharge occurs under Scenario 2 due to the greater seepage rates associated with SST. The period of tailings-related recharge is longer than the period of tailings deposition due to the use of time delays in the model to account for unsaturated zone transmission.

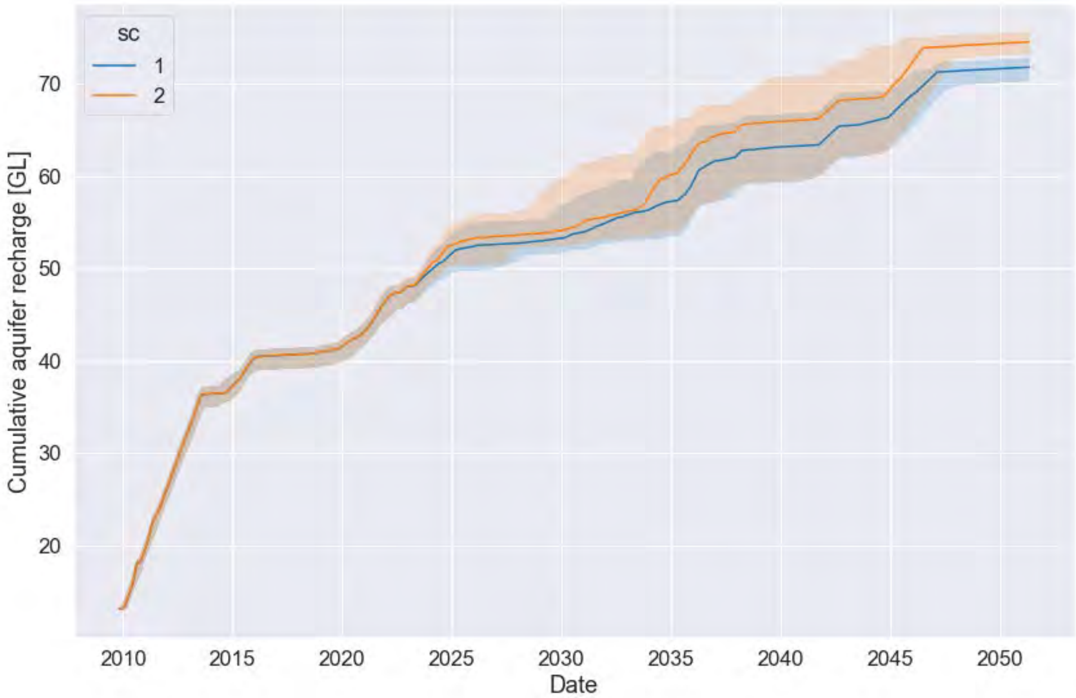

Figure 2-5 Cumulative recharge to groundwater simulated under Scenarios 1 (DST) and 2 (SST). The shaded area represents the range covered by all 110 model realisations. The solid lines represent the median simulation.

Figure 2-6 and Figure 2-7 show the simulated groundwater level hydrographs under Scenarios 1 and 2 at various locations between J-A and Lake Ifould. The hydrographs show groundwater levels rising in response to tailings seepage and then gradually receding. At the north of Jacinth (see n11648 in Figure 2-6) a rise of 20 m is projected, with the peak in groundwater mounding being lower and occurring later with increasing distance toward Lake Ifould. Similar trends are observed at between Ambrosia and Lake Ifould (Figure 2-7). At most locations there is negligible difference in projected groundwater levels under Scenarios 1 and 2. While some differences are apparent within the mine working zone at Ambrosia during mining operations (see n1265 in Figure 2-7), any increases outside of the mine working zone are very minor (~0.1 m at n17575 in Figure 2-7). Projected increases in groundwater level at Lake Ifould are also very minor (~0.05 m at n22448 in Figure 2-7), are unrelated to tailings deposition method, and the water level remains below the surface.

The shape of the projected groundwater mound is shown at 20 years post-mining in Figure 2-8 and at 110 years post-mining in Figure 2-9. In both cases, there is minimal difference in the extent of mounding between the scenarios. At 110 years post-mining, the 0.1 m mounding contour has extended up to ~500 m further from the mine site to the north of Ambrosia under the SST scenario, but otherwise the extent of mounding is broadly similar and there is no difference near Lake Ifould.

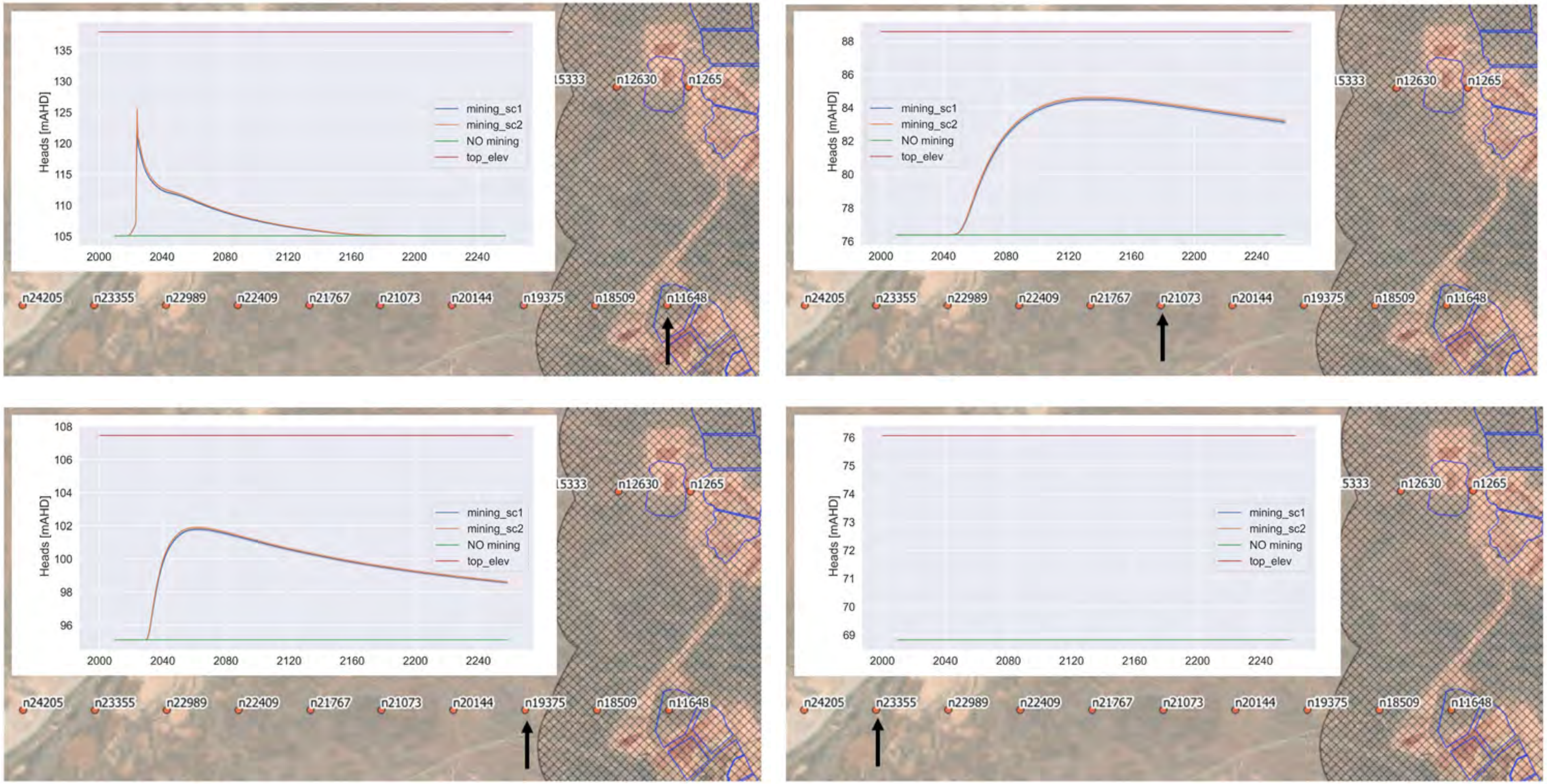

Figure 2-6 **Simulated groundwater level hydrographs along a section between the Jacinth Mine and Lake Ifould. The red line is the ground surface. The green line is the pre-mining groundwater level. The blue line is the simulated groundwater level under Scenario 1 (DST). The orange line is the simulated groundwater level under Scenario 2 (SST).**

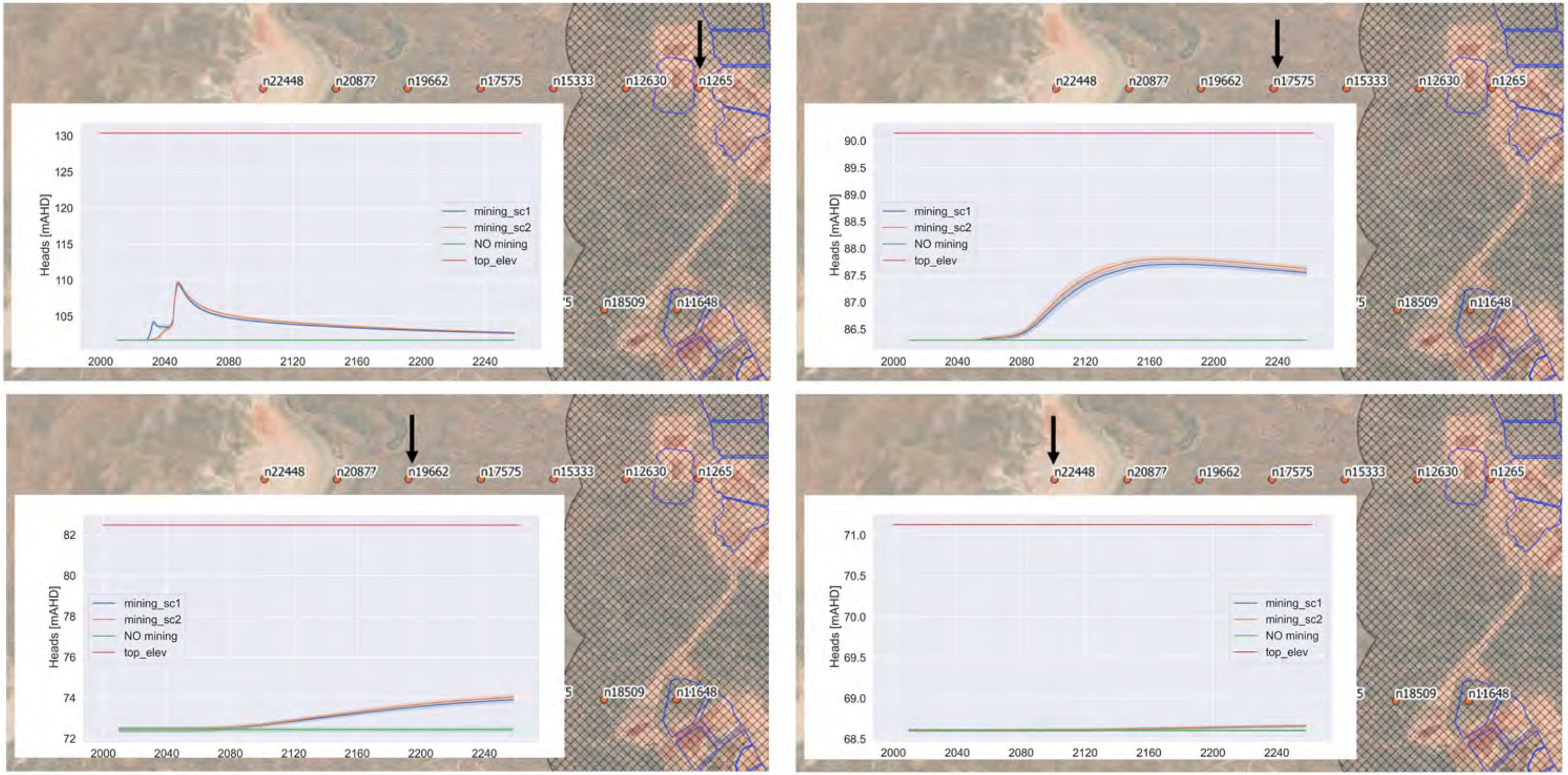

Figure 2-7 **Simulated groundwater level hydrographs along a section between the Ambrosia Mine and Lake Ifould. The red line is the ground surface. The green line is the pre-mining groundwater level. The blue line is the simulated groundwater level under Scenario 1 (DST). The orange line is the simulated groundwater level under Scenario 2 (SST).**

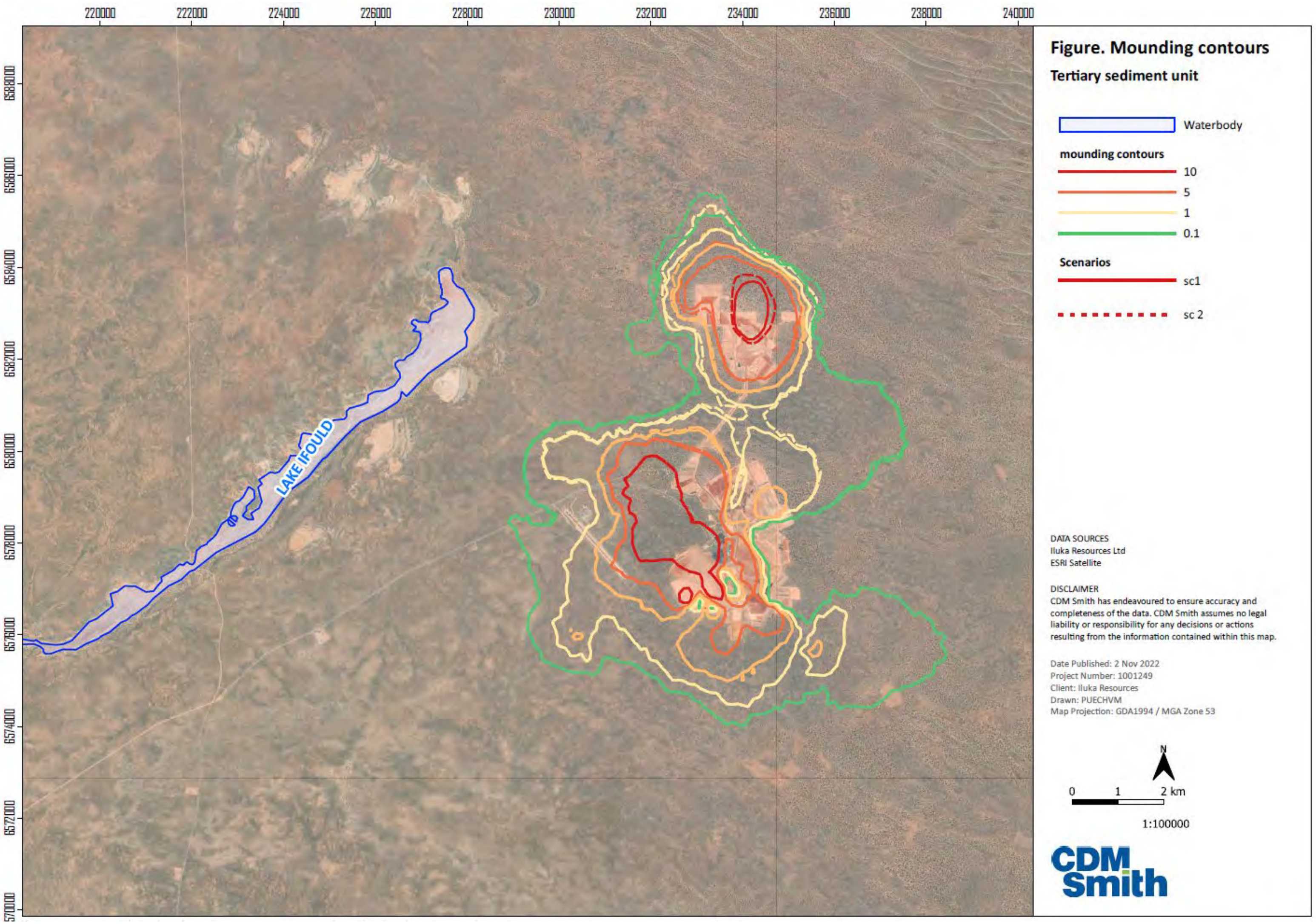

Figure 2-8 **Projected groundwater level mounding (metres above pre-mining level) based on median model realisations within the Cenozoic sediments at 20 years post-mining for Scenarios 1 (DST) and 2 (SST)**

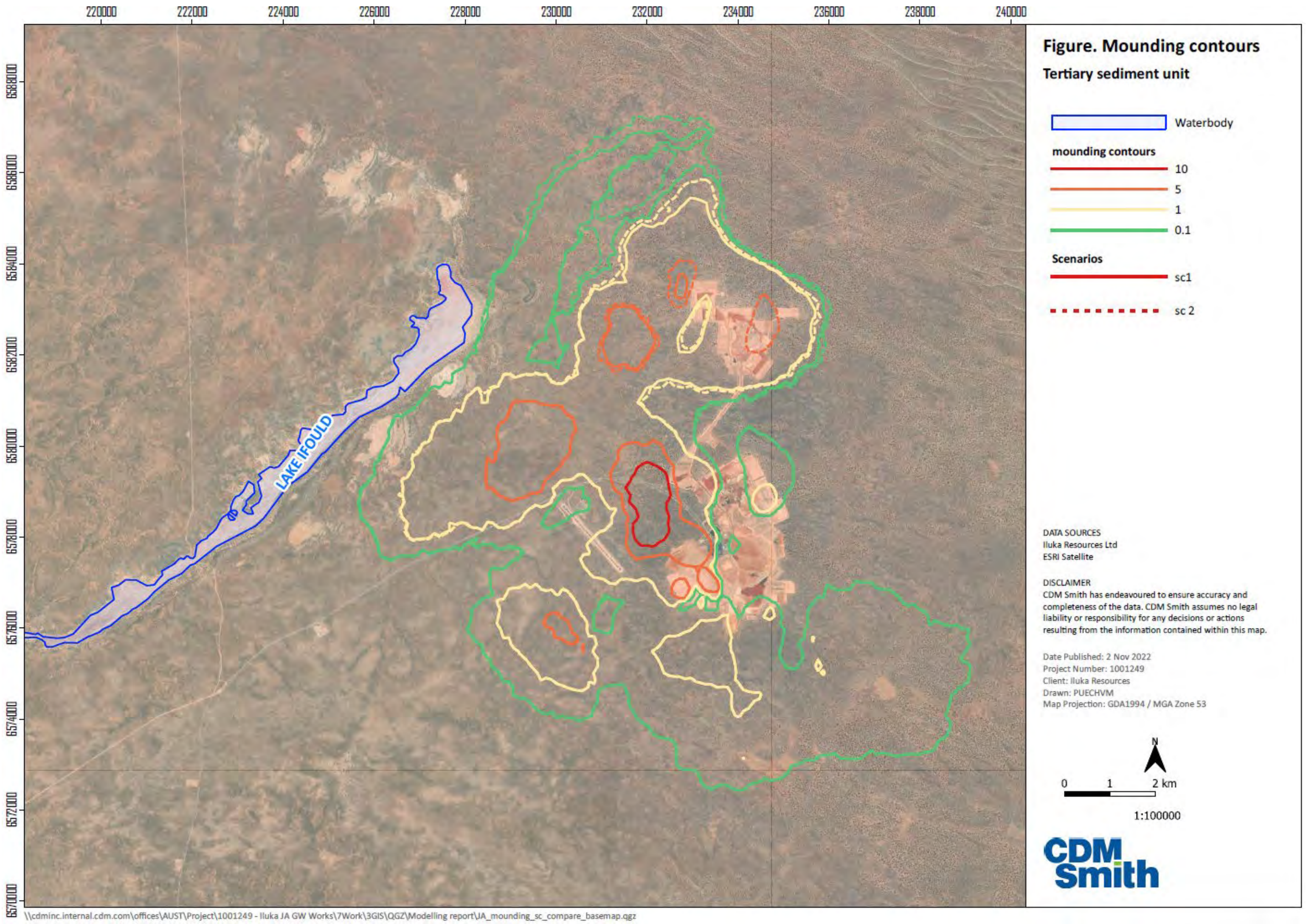

Figure 2-9 Projected groundwater level mounding (metres above pre-mining level) based on median model realisations within the Cenozoic sediments at 110 years post-mining for Scenarios 1 (dual-stream tailings) and 2 (single stream tailings)

The potential for groundwater mounding to cause the water table to rise and affect soils and vegetation is explored in Figure 2-10 and Figure 2-11. These figures show the probability that the water table will exceed a certain level (6 metres below ground level (mbgl) in Figure 2-10, and 3 mbgl and 1 mbgl in Figure 2-11) at any point in time during the model run. A comparison between Scenarios 1 and 2 is shown in Figure 2-10 and the two outputs are virtually identical, indicating no increased probability of water table rise affecting soils and vegetation due to the implementation of SST.

Figure 2-11 shows the probability of water table becoming shallower than 3 mbgl and 1 mbgl under the current mine plan (Scenario 1). It shows that in some areas between J-A and Lake Ifould, the water table is predicted to rise to within 3 m of the land surface, but it will remain deeper than 1 m below the land surface at all locations outside of the mine working zone. Results for the SST scenario are shown in Figure 2-12 with no significant differences to results of the current mine plan apparent.

An example of water table level rise to within 3 m of the land surface is shown in the hydrograph for n17575 in Figure 2-7. At this site, the pre-mining groundwater level is ~4 mbgl and it rises to ~2.5 mbgl in 2160. The 1.5 m rise in the water table takes ~100 y to occur, indicating very gradual change of ~1.5 cm/y.

Figure 2-11 also shows that groundwater is not projected to rise to the land surface at Lake Ifould as a result of mining activities at any stage over the 5,000 y model runtime, and it will remain deeper than 1 m from the surface.

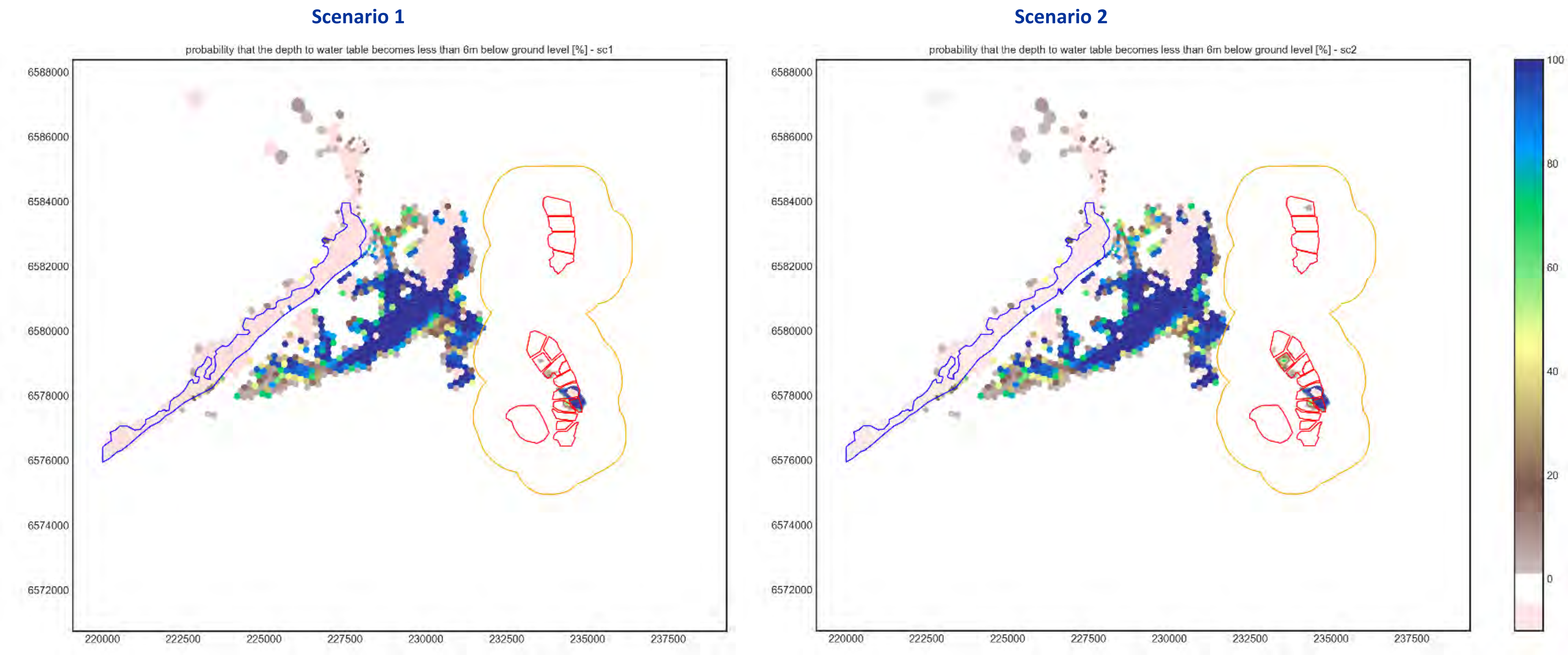

Figure 2-10 Probability (%) of the water table becoming shallower than 6 m below ground level at any point in time under Scenario 1 (DST) and Scenario 2 (SST) over the 5,000-year model run. The probability is based on the outputs of 110 model realisations, which were run for 5,000 years. Pink shades represent areas where the pre-mining water table was already shallower than 6 mbgl. The mine working zone is defined by the orange line and the outline of Lake Ifould is defined by the blue line.

< 3 mbgl **< 1 mbgl**

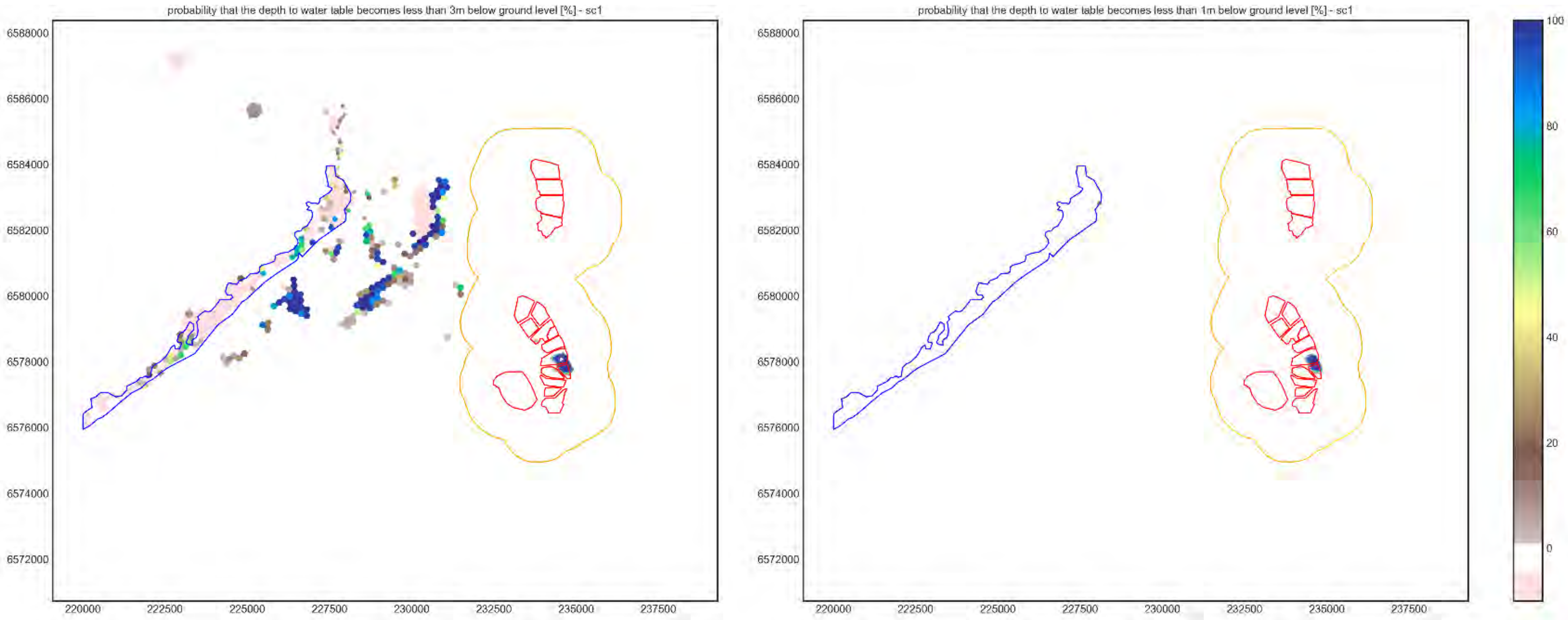

Figure 2-11 Probability (%) of the water table becoming shallower than 3 m and 1 m below ground level (bgl) at any point in time under Scenario 1 (DST) over the 5,000-year model run. The probability is based on the outputs of 110 model realisations, which were run for 5,000 years. Pink shades represent areas where the pre-mining water table was already shallower than 3 mbgl or 1 mbgl. The mine working zone is defined by the orange line and the outline of Lake Ifould is defined by the blue line.

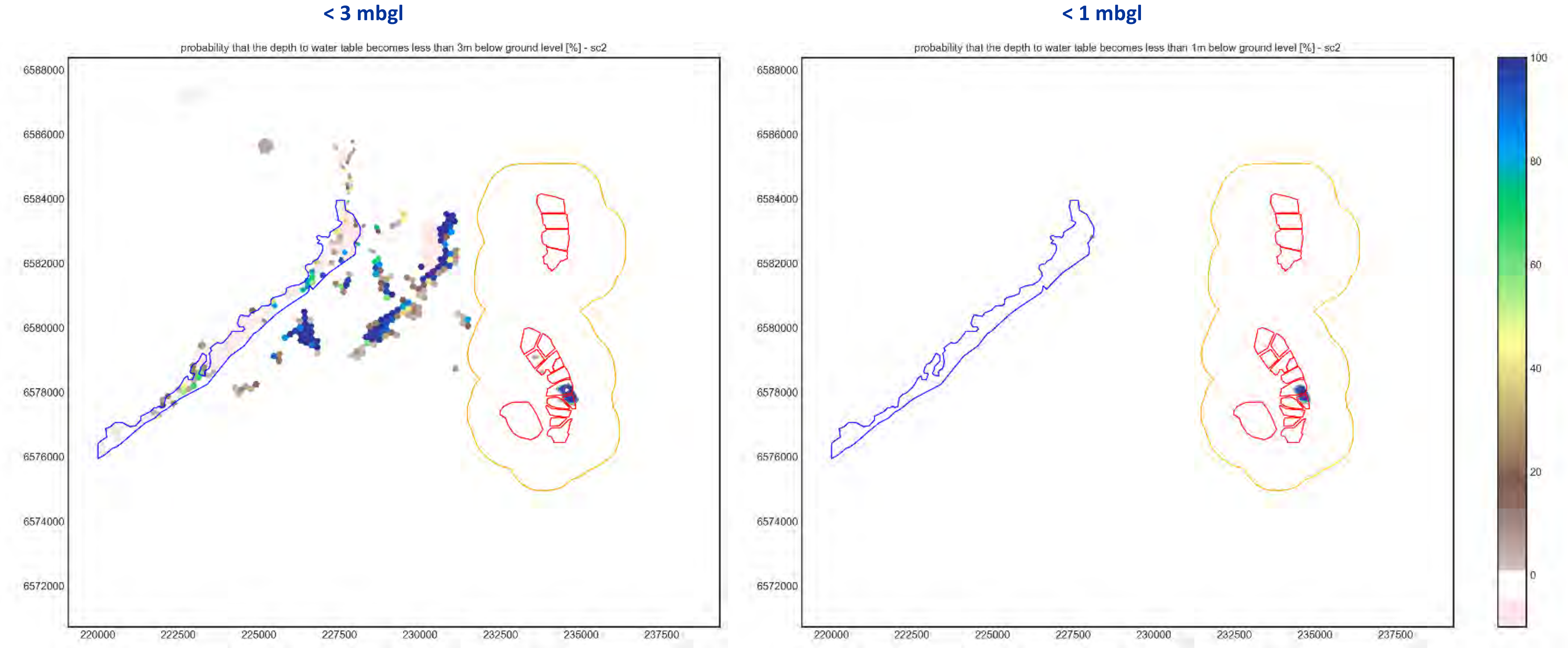

Figure 2-12 Probability (%) of the water table becoming shallower than 3 m and 1 m below ground level (bgl) at any point in time under Scenario 2 (SST) over the 5,000-year model run. The probability is based on the outputs of 110 model realisations, which were run for 5,000 years. Pink shades represent areas where the pre-mining water table was already shallower than 3 mbgl or 1 mbgl. The mine working zone is defined by the orange line and the outline of Lake Ifould is defined by the blue line.

2.3.3 Scenario analysis to assess effect of Atacama project

The development of the Atacama project would result in tailings deposition at J-A extending for a longer period, effectively increasing the cumulative groundwater recharge. The proposed Atacama processing period is from 2025 to 2031 (i.e. a 7-year period) and will overlap slightly with the remaining processing of ore from J-A (during 2025 to 2027). Effectively, this will extend the period of tailings deposition by ~4 years, with the tailings to deposited at Ambrosia over this period. Scenario analysis was performed using JACMIN4.0 to examine the effect this may have on groundwater mounding at J-A. The following scenarios were developed:

- Scenario 4. J-A tailings only. DST for 2022, SST from 2023 to 2027. Note this is very similar to Scenario 2 with minor changes to the tailings schedule (switch to SST is two months earlier and operations conclude four months earlier).
- Scenario 5. J-A tailings only. DST for 2022 to 2023, SST from 2024 to 2027.
- Scenario 6. J-A and Atacama tailings. DST for 2022, SST 2023-2024. Atacama and DST from 2025 to 2031.
- Scenario 7. J-A and Atacama tailings. DST for 2022 to 2031.

The scenarios were implemented in all 110 model realisations and run for 5,000 years post-mining to simulate the long-term effect on groundwater mounding. The period of tailings-related recharge is longer than the period of tailings deposition due to the use of time delays in the model to account for unsaturated zone transmission.

Figure 2-13 shows the cumulative recharge to groundwater implemented by Scenarios 4 to 7. In all cases, a range of recharge projections is simulated by the ensemble of models (110 realisations). More recharge occurs under Scenarios 6 and 7 due to the protracted period of tailings deposition linked to the processing of ore from Atacama. Thus, comparing the outputs of Scenarios 6 and 7 to those of Scenarios 4 and 5 allows for an assessment of the effects of the Atacama project.

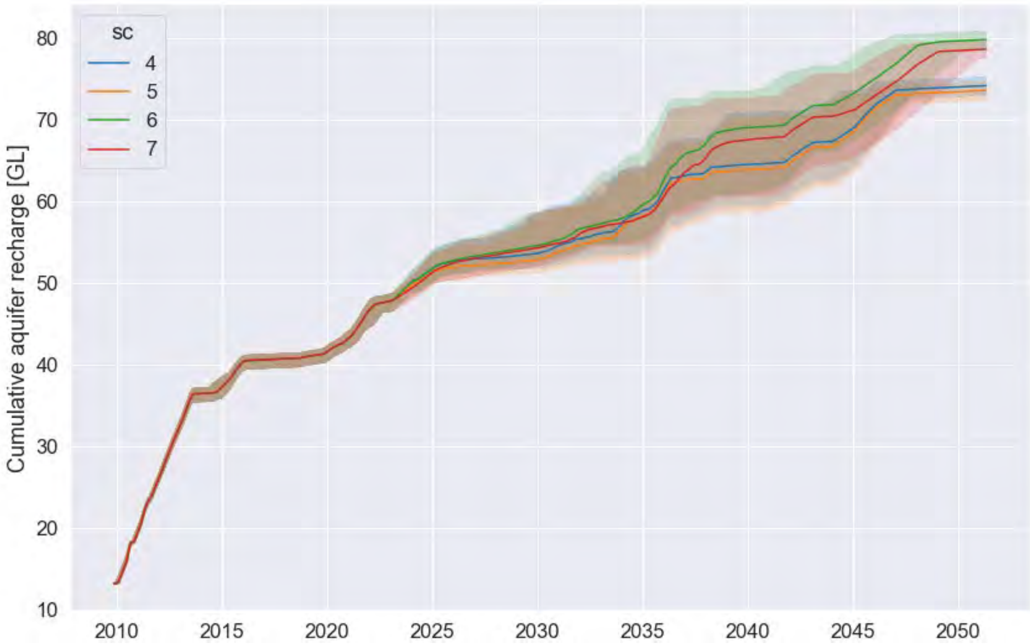

Figure 2-13 Cumulative recharge to groundwater simulated under Scenario 4 (J-A only, SST from 2023), Scenario 5 (J-A only, SST from 2024), Scenario 6 (J-A + Atacama with SST 2023-2024), Scenario 7 (J-A + Atacama, DST throughout). The shaded area represents the range covered by all 110 model realisations. The solid lines represent the median simulations.

Figure 2-14 and Figure 2-15 show the simulated groundwater level hydrographs under Scenarios 4–7 at various locations between J-A and Lake Ifould. The hydrographs show groundwater levels rising in response to tailings seepage and then gradually receding. At the north of Jacinth (see n11648 in Figure 2-15) a rise of 20 m is projected, with the peak in groundwater mounding being lower and occurring later with increasing distance to Lake Ifould. Similar trends are observed at between Ambrosia and Lake Ifould (Figure 2-14). At most locations there is minimal difference in projected groundwater levels between the scenarios. While some differences are apparent within the mine working zone at Ambrosia during mining operations (see n1265 in Figure 2-14), any increases outside of the mine working zone are minor at the peak of mounding (~1.5 m at n1533 in Figure 2-14). Projected increases in groundwater level at Lake Ifould are negligible.

The shape of the projected groundwater mound is shown at 20 years post-mining in Figure 2-16 and at 110 years post-mining in Figure 2-17. In both cases, there is minimal difference in the extent of mounding between the scenarios. At 110 years post-mining, the 10 m mounding contour has extended further to the west of Ambrosia under the Atacama scenarios, but otherwise the overall extent of mounding marked by the 0.2 m contour is similar under all scenarios indicating no appreciable increase in groundwater mounding due to the Atacama project development.

Further discussion of the groundwater modelling results in relation to an assessment of potential impacts is provided in Section 3.

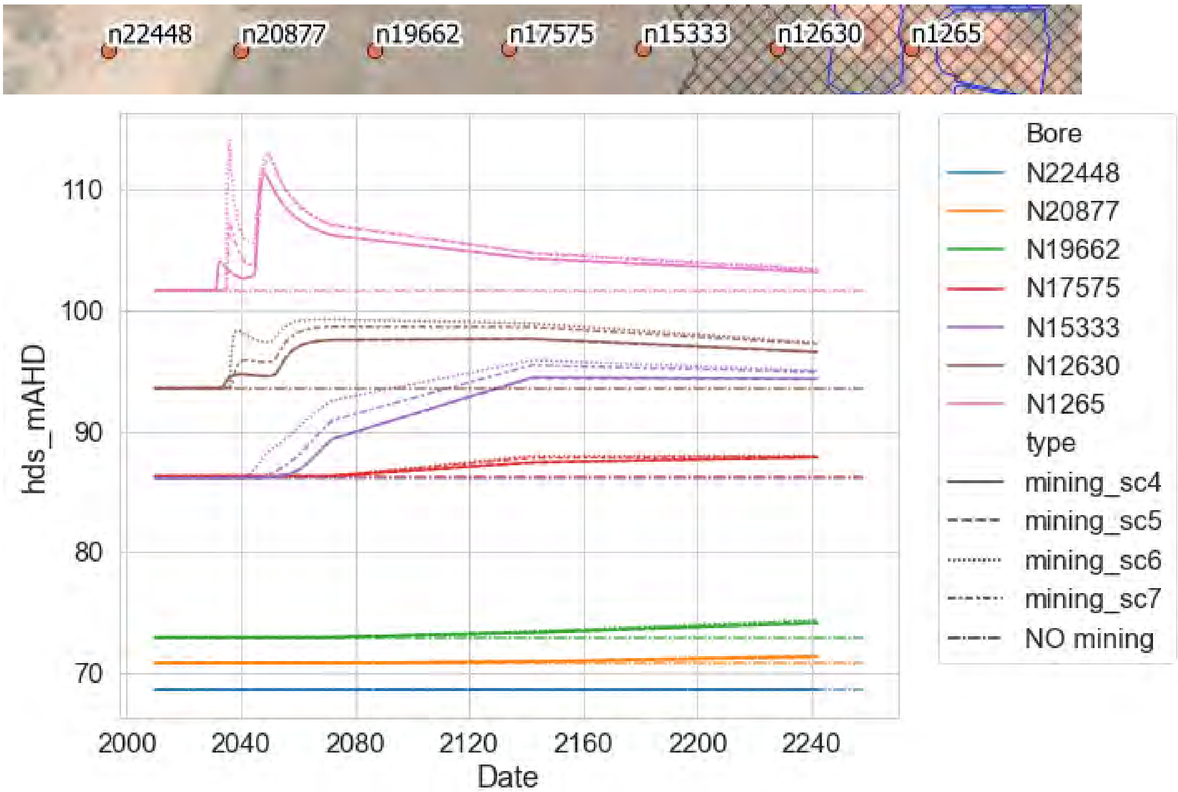

Figure 2-14 Hydrographs along the northern transect between Ambrosia and Lake Ifould for Scenarios 4, 5, 6 & 7

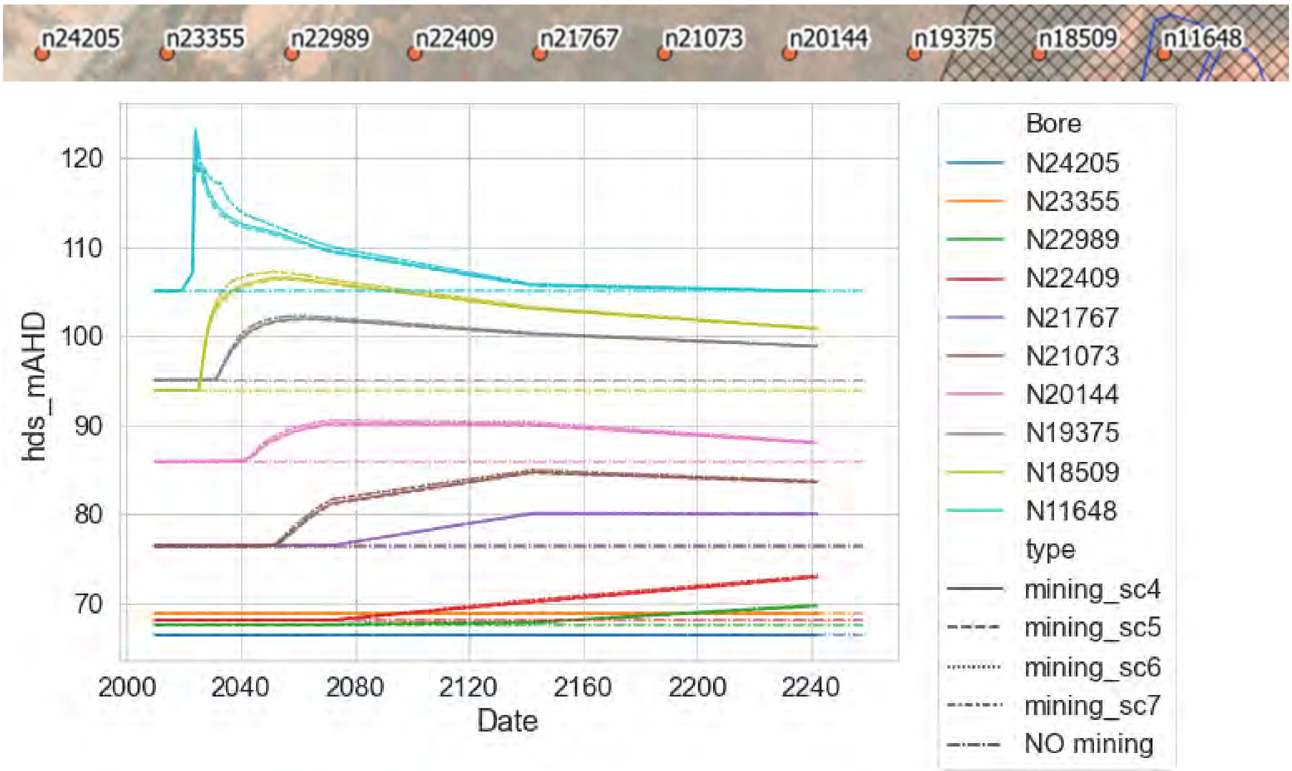

Figure 2-15 Hydrographs along the southern transect between Jacinth and Lake Ifould for Scenarios 4, 5, 6 & 7

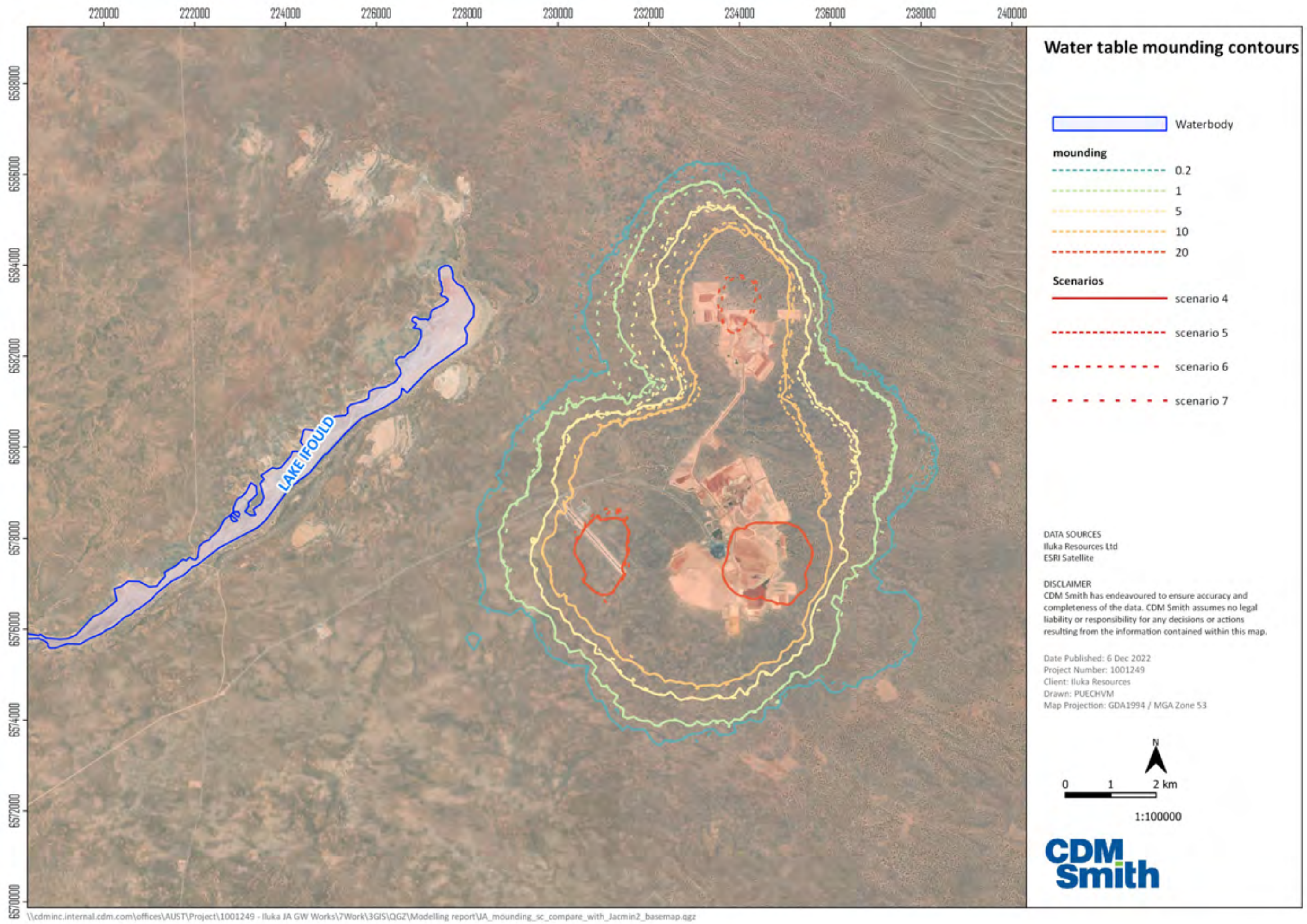

Figure 2-16 **Projected groundwater level mounding (metres above pre-mining level) based on median model realisations at 20 years post-mining for Scenario 4 (J-A only, SST from 2023), Scenario 5 (J-A only, SST from 2024), Scenario 6 (J-A + Atacama with SST 2023-2024), Scenario 7 (J-A + Atacama, DST throughout)**

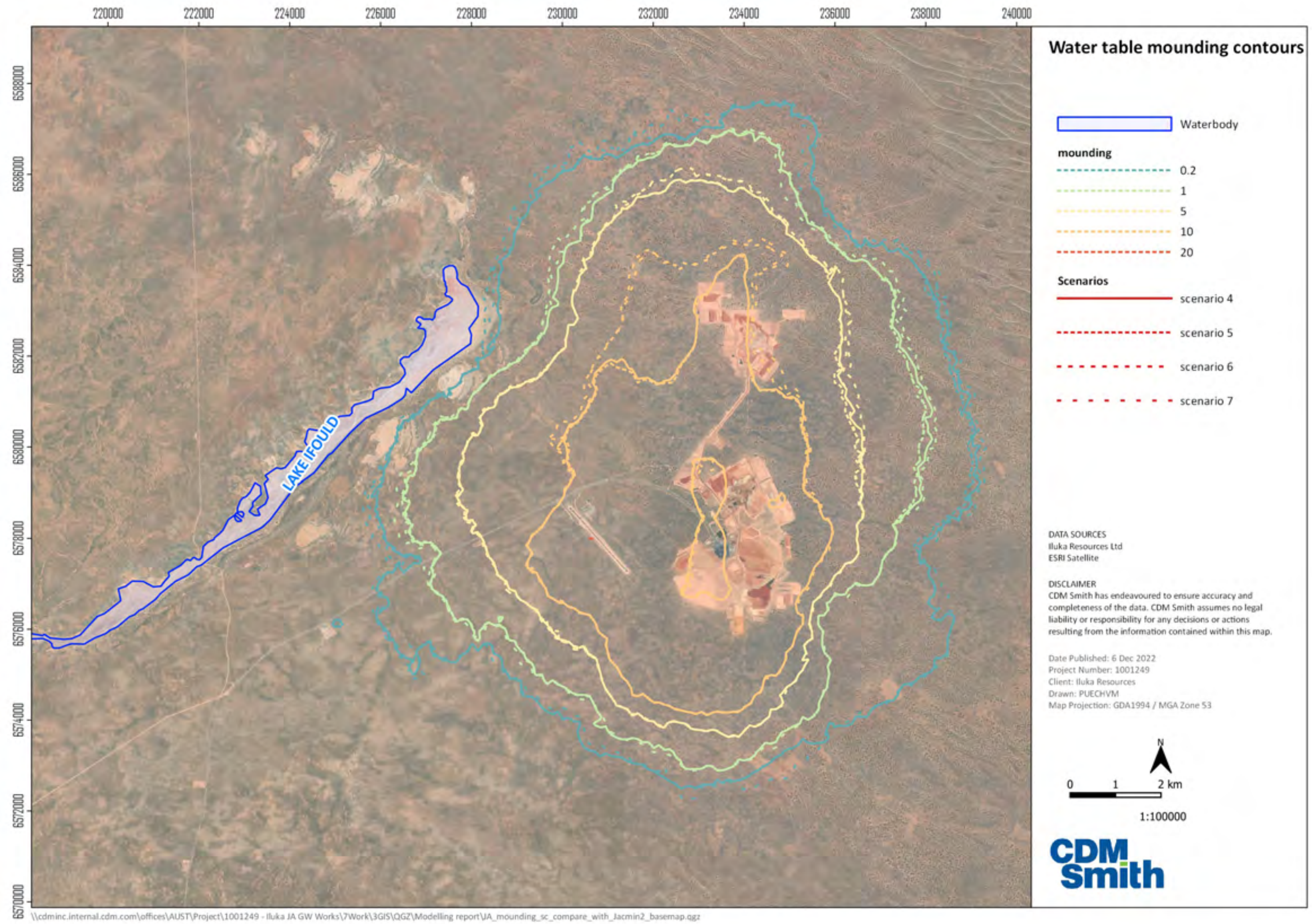

Figure 2-17 Projected groundwater level mounding (metres above pre-mining level) based on median model realisations at 110 years post-mining for Scenario 4 (J-A only, SST from 2023), Scenario 5 (J-A only, SST from 2024), Scenario 6 (J-A + Atacama with SST 2023-2024), Scenario 7 (J-A + Atacama, DST throughout)

2.4 Groundwater modelling of the paleochannel aquifer

The groundwater model for the Jacinth-Ambrosia paleochannel wellfield has been updated using the latest observation data from 2013 to 2022, recalibrated, and used to model the effects of groundwater abstraction on groundwater levels in the paleochannel aquifer into the future.

The extended data set and the use of a calibration method incorporating both pilot points and zones for parameter estimation resulted in improved calibration statistics and returned more realistic estimates of aquifer storage parameters in comparison to the previous model. Thus, there is improved confidence in using the model to assess the effects of future groundwater extraction regimes that may be contemplated by Iluka.

Future groundwater extraction regimes were simulated to represent possible mining plans as follows:

- Scenario 1. DST deposition during the LoM, with mining of Atacama leading to an extended period of pumping. Pumping rate of 119 L/s (10.3 ML/d) (equivalent to the average historical rate) applied for 10.4 years to December 2032.
- Scenario 2. Changing to SST deposition for the remaining LoM at J-A. No mining of Atacama. Pumping rate of 144 L/s (12.4 ML/d) (higher than the historical average due to SST having a higher water demand) applied for 5.1 years to April 2028.

It is acknowledged that the period of pumping simulated in the Atacama model scenario (Scenario 1) may differ from what is listed in the Mining Lease Proposal (MLP), which includes some ongoing pumping for a period of ~15 years to support rehabilitation activities. However, these ongoing pumping rates are expected to be much lower than the historical average after mineral processing ceases in 2031 and are not expected to have a material effect on the long-term recovery of groundwater levels in the aquifer.

Predicted drawdown in the paleochannel aquifer at the wellfield is shown in Figure 2-18 (Scenario 1) and Figure 2-19 (Scenario 2).

Despite the different periods and rates of pumping, there are minimal differences in peak drawdowns at the wellfield between Scenarios 1 and 2, with predicted pumping and observation well water levels generally remaining within or close to the historical bounds.

The long-term recovery of water levels within the aquifer is slightly more protracted under the Atacama development scenario due to the extended period of pumping. For instance, in 2060 the water levels at the wellfield are at ~19 mAHD in Scenario 1 (with Atacama) compared to ~19.5 mAHD in Scenario 2 (no Atacama), but it is expected this difference would contract with time. With or without the Atacama development, complete recovery of the groundwater levels is not predicted to occur for many years (>100 years) given the very low recharge rates to the aquifer.

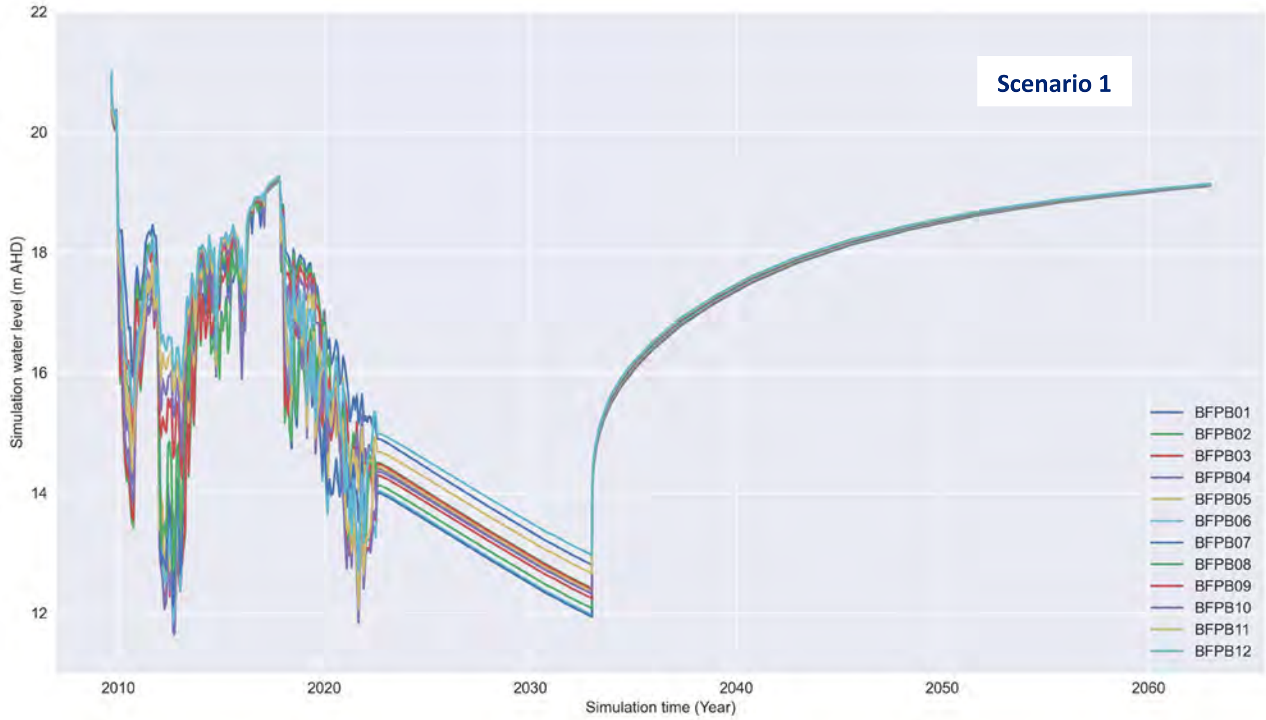

Figure 2-18 Modelled groundwater levels across the twelve production wells, shallowest pump elevation of -5 m AHD not shown, for Scenario 1.

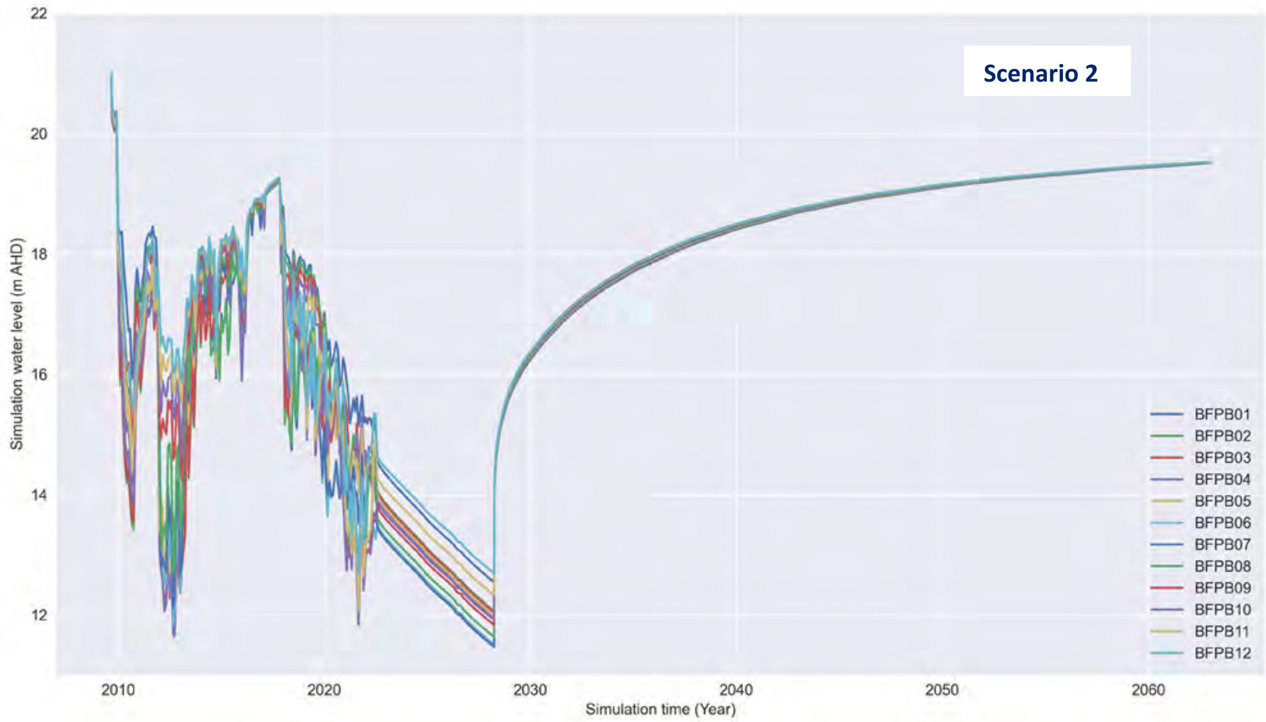

Figure 2-19 Modelled groundwater levels across the twelve production wells, shallowest pump elevation of -5 m AHD not shown, for Scenario 2.

2.5 Geochemical assessment

Groundwater beneath and down hydraulic gradient of J-A has been previously characterised by elevated concentrations of certain metals (aluminium and manganese in particular), which appear to be aligned with acidic groundwater[1] and correlate to areas of tailings seepage and associated groundwater mounding. Prior to this study, the specific causation of acidic groundwater (and associated elevated dissolved metals) was theorised to be associated with three potential sources as follows:

- Potential Source 1: Low pH water from the paleochannel wellfield contributing to low pH tailings seepage.
- Potential Source 2: The presence of acid sulfate soils (ASS) and/or Potential Acid Forming (PAF) rock.
- Potential Source 3: Hydrolysis of aluminium, iron and manganese.

This study aimed to identify if one or more of these causations was relevant with respect to groundwater composition. The key question is whether the acidic environment develops first and thus solubilises metals, or hydrolysis of metals partitioning to dissolved phase under circumneutral pH occurs first, creating acidic conditions. Results from the study indicates it is the latter (i.e. Potential Source 3 is the major source of acidic groundwater).

Sampling and analysis of the mine processing circuit indicated that Potential Source 1 was unlikely to be the major driver of acidic groundwater. While water from the paleochannel wellfield is of low pH, the tailings seepage is neutralised by the inclusion of alkaline material (Brown Loam) in processing operations resulting in tailings seepage that is circumneutral with some inherent buffering capacity.

Field and laboratory testing of the core samples collected by the field program indicated that ASS and PAF rock (Potential Source 2) to be mostly absent. Consolidated rock samples (i.e. from the fresh basement) were non-acid forming (NAF). Of the 33 unconsolidated samples analysed, pyrite (iron sulfide, an indicator of ASS) was found in only one of the samples (at MB20S at the water table) with minor concentrations of jarosite (an indicator of some partially oxidised ASS) occurring at the same location. The results suggest that while some minor contribution to acidity via oxidation of sulfides cannot be ruled out, this is likely to be sporadic and not a significant lode/ source of acidity. The limited pyrite that was found is beneath the water table and only presents a risk if oxidation occurs. This is considered unlikely to occur in response to tailings seepage which causes the water table to rise, not fall.

Laboratory testing showed the lithology to be rich in aluminium, particularly in the saprolite, and the aluminium was found to be highly leachable regardless of pH. This finding indicated that the causation of acidity and elevated metals at J-A is most likely a function of naturally occurring aluminium (and other metal) hydrolysis (Potential Source 3); i.e. the metal hydrolysis drives the pH change as opposed to the acidic environment developing first and driving a change in metal concentration.

The hydrogeochemical process can be summarised as follows,

1. There is a natural latent source of acidity related to aluminium hydrolysis within the weathered Gawler Range Volcanics (saprolite) between 15 and 27 m below ground level (approximately), commensurate with the water table.
2. The saprolite is widespread but the heterogeneity of the various mineralised forms of aluminium, the concentration of aluminium in such phases, and their different solubilities are spatially variable – amorphous phases have around 40 time more solubility than crystalline phases, and so the weathered Gawler Range Volcanics has an increased propensity for aluminium phase solubility.
3. The tailings seepage and associated mounding is not a source of acidity itself, but the increased leaching can initiate aluminium hydrolysis, leading to increased acidity and increased concentration of certain metals.

[1] Acidity will generally liberate (solubilise) metals and metalloids from lithological strata, depending on the specific chemical composition of such strata. In general groundwater has a circumneutral pH.

4. Aluminium hydrolysis is a natural process; however the tailings seepage and associated mounding can accelerate the process and make the acid and metal generation more acute.
5. The extent of hydrolysis is a function of the neutralising capacity in water flowing through such strata whether this be mounding related or natural background groundwater. Thus, the occurrence of low pH / acidity and elevated metals is a function of various factors such as the presence / extent of amorphous mineralogy, the inherent elemental composition of such mineralogy, the buffering capacity of through-flow water and the velocity of through flow water. Given the heterogeneity of these factors, the magnitude and extent of hydrolysis is highly variable spatially and difficult to model/predict with confidence. However, given that it is correlated with groundwater velocity, throughflow and the magnitude of mounding, its influence (i.e. changes in groundwater composition) will diminish with increasing distance from the mine site.

Discussion of the potential impacts related to these geochemical changes is provided in Section 3.1.2.

Groundwater beneath Atacama has not been considered in this assessment because there is no impacting source—tailings placement is not proposed as part of the development of the Atacama deposit. Atacama tailings will be deposited at J-A.

Section 3 Assessment of groundwater-related impacts

This section presents a reassessment of the groundwater-related impacts at J-A (as listed in the PEPR) and an impact assessment for the aspects of the Atacama project which will occur on J-A tenements based on the new information acquired by this program of works. The assessment methodology is consistent to that which is applied in the current PEPR and as recommended in the Minerals Regulatory Guideline MG2a - Preparation of a mining application for metallic and industrial minerals (referred hereafter as MG2a). Each potential impact is identified and described using a source-pathway-receptor model and the inherent and residual risks are assessed using the risk matrix applied in the PEPR.

3.1 Current mine plan

This section presents an assessment of the potential groundwater-related impacts under the current mine plan at J-A, which incorporates the continued use of dual-stream tailings deposition and no development of the Atacama project.

3.1.1 GW01: Reduction in groundwater levels in paleochannel aquifer

This potential impact, as listed in the PEPR, concerns the "long-term reduction in groundwater levels and associated aquifer impact(s) to the paleochannel aquifer due to groundwater abstraction". The source-pathway-receptor relationship is as follows:

- **Source:** groundwater abstraction
- **Pathway:** groundwater level drawdown in paleochannel aquifer
- **Receptor:** paleochannel aquifer and associated beneficial use by other parties and the environment

The modelling undertaken in this assessment (see Section 2.4 and CDM Smith 2022c) indicates that by 2060 groundwater levels in the paleochannel aquifer recover to within 2 m of pre-mining under Scenario 2, which does not include Atacama, noting this has a higher rate of groundwater abstraction compared to historical rates (144 L/s c.f. 120 L/s). Complete recovery does not occur over the modelling period of 40 years, as negligible groundwater recharge is assumed. These drawdown results are similar to those of the previous modelling assessment (Jacobs 2020), which have already been approved, and have been determined with a higher degree of confidence given the recalibration and improved calibration statistics.

Based on the high salinity of the groundwater, use of the groundwater resource is restricted to industrial applications. There are no existing groundwater users and no springs have been identified within a 50 km radius of the wellfield. Thus, any drawdown of the aquifer will not affect users of the aquifer, and the potential for mining operations to impact or prevent beneficial use by other parties (i.e. environmental, economic, social or cultural values) is considered to be extremely low.

Given the equivalence of the model results to previous modelling works, there is no basis to revise the existing risk ratings (inherent or residual) for this potential impact defined in the approved PEPR. The inherent risk is rated moderate (likelihood rating of unlikely x consequence rating of moderate) and the residual risk (taking into account the control and management strategies listed below) is rated as low (likelihood rating of rare x consequence rating of moderate) for this potential impact.

The controls and management strategies used to manage the risk are as follows:

- Groundwater Management and Monitoring Plan
- Monitoring of groundwater abstraction rates and groundwater levels to ensure they are in line with model predictions and historical ranges. Drawdown below the historical range or significant deviations below the model predictions to be investigated to determine if risk rating and management practices require revision.
- Water-return efficiency measures within mine processing to minimise paleochannel aquifer demand

- J-A paleochannel abstraction predictive model
- Annual aquifer review and biennial update of groundwater predictive model with operational abstraction and groundwater level data, plus tailings schedule.

3.1.2 GW02: Impacts to groundwater quality due to tailings seepage

This potential impact, as listed in the PEPR, concerns tailings seepage causing "impacts to groundwater quality impacting beneficial use of the system".

The geochemical assessment undertaken in this scope of works (see Section 2.5, LWC 2022) has resulted in a clearer understanding of the drivers of groundwater chemistry changes and the sporadic trends evident. Based on the new information obtained, the source-pathway-receptor relationship can be refined, as follows:

- **Source:** naturally occurring sources of acidity in geological strata (previously described as *process water seepage*)
- **Pathway:** seepage from tailings disposal and subsequent groundwater mounding interacting with geological strata leading to changes in groundwater chemistry (previously described as *mining operations – tailings*)
- **Receptor:** groundwater (previously described as *groundwater aquifer*)

The geochemical assessment has determined that the main source of acidity is the presence of soluble forms of aluminium in geological strata (particularly in the saprolite) as opposed to the process water seepage, which is generally circumneutral. The source description has been changed to reflect this.

The pathway description has also been revised to better describe how a mining activity (tailings disposal) may trigger geochemical changes.

The receptor description has been altered to remove the term 'aquifer'. The term 'aquifer' has a specific definition of "a (geological) formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs" (Lohman 1972). Given the low-yielding nature of groundwater in the mine working zone and its immediate vicinity, this definition is not met; i.e., it is incapable of supplying usable quantities of water.

The geochemical assessment (LWC 2022) identified a naturally occurring process (aluminium hydrolysis) that could be exacerbated by tailings seepage water (and associated mounding) leading to changes in groundwater chemistry (lower pH and increased concentration of certain metals). Such changes are evident in groundwater monitoring trends, but are spatially variable due to the heterogeneity of the mineralised forms of aluminium and their different solubilities. On this basis, the likelihood of adverse changes to groundwater quality without any management controls are considered likely. But given the low yields and high salinity of groundwater preventing its beneficial use, the consequence of these changes is considered negligible. As such, the inherent risk rating is moderate for this potential impact.

The management controls for this potential impact are as follows:

- Groundwater Management and Monitoring Plan
- Inclusion of the eight recently installed wells within the monitoring network and sampling procedure
- Ongoing monitoring, assessment and evaluation of mine site groundwater chemistry against criteria to be established in the updated 2023 PEPR.
- Sampling and analysis of process circuit (sediment and water) and management (e.g. inclusion of Brown loam in process circuit) to maintain its circumneutral status
- Application of water return efficiency measures to reduce tailings seepage

With management controls in place, the likelihood of adverse changes is possible, the consequence is low and the residual risk is low.

In assessing this potential impact, consideration was given to including soils and vegetation as receptors related to this potential impact. However, while soil and vegetation are receptors with a linkage to potential impacts associated with groundwater rise (see GW03 and GW04) the linkage to groundwater quality changes (specifically acidification) is not apparent due to the widespread presence of carbonates in the subsoils (i.e. they are alkaline with a very high acid neutralising capacity). Furthermore, it has been assumed that chemistry of the groundwater is already hostile to soils and vegetation due to its inherently high salinity and this is addressed in the assessment of GW03 and GW04.

3.1.3 GW03: Groundwater rise within the mine working zone

This potential impact concerns tailings seepage causing the naturally hypersaline groundwater to rise and adversely affect soils and vegetation within the mine working zone (defined in the PEPR as the life-of-mine disturbance footprint plus a 150 m offset). The source-pathway-receptor relationship is as follows:

- **Source:** tailings disposal
- **Pathway:** tailings seepage to groundwater and subsequent groundwater level rise
- **Receptor:** soil and native vegetation

Such an impact would arise if the groundwater level were to rise (mounding) to such as extent that it intersects the rootzone of the vegetation, increasing the soil salinity and restricting the ability of the vegetation to transpire due to its very high salinity.

The likelihood of impact is therefore governed by the depth to which groundwater rises into the rootzone and the sensitivity of the soils and vegetation to salinisation. The consequence of the impact is related to the effects to soils and vegetation (e.g. temporary or long-term changes to soil salinity, increased stress to vegetation, reduced function or dieback) and the extent of these effects.

Context to an assessment of this potential impact is provided in the baseline soil studies undertaken at J-A (SWC 2009). The soils are characterised as having shallow non-saline topsoils (< 20 cm), above calcareous B horizons (Brown Loam) of variable thicknesses (up to 7 m, but generally less than 4 m) and textures (sand to sandy loam), above a hard calcrete layer, above clayey sands of the reworked Ooldea unit (Red Loam). The deeper soils occur under dunes and the shallower soils occur in swales and depressions. Vegetation is correlated with soil thickness and tree roots are heavily concentrated in the topsoils but sinker roots have been found at significant depths (7m or more).

Soil salinities are generally very high (except for topsoils) and increase with depth, being particularly high in the calcrete layer and in the underlying Red Loam. Thus, there is a clear relationship between rooting density and salinity. Based on the rooting density and soil salinity distribution it appears that most of the soil moisture and nutrition for plants is sourced from very shallow layers (upper 20 cm) but it has been speculated that the deeper sinker roots may access deeper moisture reserves as a supplementary water source as well as providing structural support to the vegetation.

The groundwater modelling undertaken (see Section 2.3 and CDM Smith 2022) addresses the likelihood component of rating the risk of this potential impact with some uncertainty around the magnitude of water table rise that would pose a threat to soils and vegetation. Based on the description of the soils and vegetation rootzones provided above, thresholds of 1 m, 3 m and 6 m below ground level (bgl) were selected as nominal reference points to assess the likelihood of impact. A water table rise to within 6 m would indicate some potential exposure of deep sinker roots to saline groundwater, noting the subsoil salinity is already very high at depth (i.e. a possible likelihood of impact). A water rise to within 3 m of the surface would indicate an incursion into the subsoil (i.e. a likely impact). A water table rise to within 1 m of the surface would indicate an incursion into the topsoil and the development of significant capillary rise (to salinise the topsoil) and waterlogging effects (i.e. an almost certain impact). Consequence can be judged by the spatial extent of water table rise. Using these reference points, the JACMIN4.0 groundwater modelling under Scenario 1 (representing the current mine plan) indicates:

- Outside of the mine pits themselves where active tailings deposition occurs, the 6 m reference point is exceeded to a very minor extent (a single model cell along the western boundary of the mine working zone).

- Neither the 3 m or 1 m reference points are exceeded.

On this basis, the likelihood of this threat (i.e. water table rise to within 6 m, but less than 3 m of the ground surface within the mine working zone) being realised is possible and its consequence is moderate, resulting in a High inherent risk rating.

The management controls for this potential impact are as follows:

- Groundwater Management and Monitoring Plan (including an updated trigger response framework, which is proposed for the next update of the PEPR in 2023)
- Monitoring of groundwater levels (tailings cell Vibrating Wire Piezometer networks, monitoring wells) and assessing trends relative to those predicted by the regional groundwater model (JACMIN 4.0).
- Ongoing use and update of the J-A regional groundwater model
- Tailings Monitoring Management Plan to monitor tailings seepage and use control measures and water recovery infrastructure (e.g. under drainage) to minimise tailings seepage.
- Vegetation condition monitoring, particularly in areas where water table reference points are predicted to be exceeded.

With the above management controls in place, the likelihood rating is unlikely and the consequence rating is minor resulting in a residual risk rating of Moderate.

3.1.4 GW04: Groundwater rise outside of the mine working zone, including Lake Ifould

This potential impact concerns tailings seepage causing the naturally hypersaline groundwater to rise and adversely affect soils and vegetation outside the mine working zone including Lake Ifould and its surrounds. It is very similar to GW03, aside from the area of potential impact that is considered. The source-pathway-receptor relationship and the context to the assessment is identical to GW03 (see Section 3.1.3 for detail).

Applying the same method as GW03 for the area outside the mine working zone, the groundwater modelling under Scenario 1 (see Figure 2-6, Figure 2-7, Figure 2-10 and Figure 2-11) indicates:

- Widespread occurrence of the 6 m reference point being exceeded due to mining activities.
- A smaller area of the 3 m reference point being exceeded due to mining activities.
- No occurrence of the 1 m reference point being exceeded due to mining activities, which also indicates no surface expression of groundwater at Lake Ifould due to mining activities.

On this basis, the likelihood of this threat being realised is likely and its consequence is significant, resulting in a Very High inherent risk rating.

The management controls for this potential impact are as follows:

- Groundwater Management and Monitoring Plan (including an updated trigger response framework, which is proposed for the next update of the PEPR in 2023)
- Inclusion of the eight recently installed wells within the monitoring network
- Monitoring of groundwater levels (tailings cell Vibrating Wire Piezometer networks, monitoring wells) and assessing trends relative to those predicted by the regional groundwater model (JACMIN 4.0).
- Ongoing use and update of the J-A regional groundwater model
- Tailings Monitoring Management Plan to monitor tailings seepage and use control measures and water recovery infrastructure (e.g. under drainage) to minimise tailings seepage.
- Vegetation condition monitoring, particularly in areas where water table reference points are predicted to be exceeded.

- Additional soil and vegetation studies in the area of predicted water table rise above 3 m BGL and based on the findings of these studies investigating options to control water table rise outside of the mine working zone (e.g. drainage systems).

With the above management controls in place, the likelihood rating is possible and the consequence rating is minor resulting in a residual risk rating of Moderate.

3.2 Change in tailings management, SST

A change in tailings management at J-A to SST (no Atacama project) would result in:

- Higher pumping rates from the paleochannel wellfield.
- Higher rates of tailings seepage.

These changes may have a cumulative effect on the potential groundwater-related impacts at J-A. The significance of this cumulative effect is evaluated for each of the potential impacts as follows:

- GW01: No significant change in groundwater level drawdown in the paleochannel aquifer is projected to occur with the implementation of SST. This is based on the results from Scenario 1 of the updated paleochannel wellfield model, which showed groundwater level drawdown remaining within or close to the historical bounds observed in the paleochannel aquifer. Therefore, no changes to the risk rating for GW01 are warranted.
- GW02: No significant change in impacts to groundwater quality is projected to occur from the implementation of SST, because: 1) the geochemical processes are linked to mounding behaviour, and 2) insignificant changes to the magnitude and extent of groundwater mounding are projected under the SST model scenario (Scenario 2) compared to the DST model scenario (Scenario 1) (see Figure 2-6, Figure 2-7, Figure 2-8). Therefore, no changes to the risk rating for GW02 are warranted.
- GW03: No significant change in impacts to soils and vegetation within the mine working zone is projected to occur from the implementation of SST due to there being insignificant changes to the magnitude and extent of groundwater mounding under the SST model scenario (Scenario 2) compared to the DST model scenario (Scenario 1) (see Figure 2-6, Figure 2-7, Figure 2-8). Therefore, no changes to the risk rating for GW03 are warranted.
- GW04: No significant change in impacts to soils and vegetation outside the mine working zone is projected to occur from the implementation of SST due to there being insignificant changes to the magnitude and extent of groundwater mounding under the SST model scenario (Scenario 2) compared to the DST model scenario (Scenario 1) (see Figure 2 6, Figure 2 7, Figure 2 8). Therefore, no changes to the risk rating for GW04 are warranted.

3.3 Development of Atacama project

Development of the Atacama project would result in:

- An extended period of pumping from the paleochannel wellfield.
- An extended period of tailings deposition and seepage at J-A.

These changes may have a cumulative effect on the potential groundwater-related impacts at J-A and the paleochannel aquifer. The significance of this cumulative effect is evaluated for each of the potential impacts as follows:

- GW01: No significant change in groundwater level drawdown in the paleochannel aquifer is projected to occur with the development of Atacama. This is based on the results from Scenario 1 of the updated paleochannel wellfield model, which showed groundwater level drawdown remaining within the historical bounds observed in the paleochannel aquifer (see Figure 2-18). Because pumping extends for a period 5 y with the development of

Atacama, the recovery of water levels in the aquifer (after pumping ceases) will be offset (i.e. it will occur later) compared to the current mine plan at J-A). Modelling indicates that by 2060, the difference in the recovering groundwater levels is only ~0.5 m lower (i.e. less recovery) under the Atacama scenario compared to the current mine plan, and this difference will continue to contract with time. Given these minor changes in drawdown projections and the absence of other beneficial users of the aquifer, no changes to the risk rating for GW01 are warranted should the Atacama project be developed.

- GW02: No significant change in impacts to groundwater quality is projected to occur with the development of the Atacama project, because: 1) the geochemical processes are linked to mounding behaviour with the source of acidity inherent in geological strata at J-A (i.e. it is not introduced by tailings seepage), and 2) insignificant changes to the magnitude and extent of groundwater mounding are projected under the Atacama model scenarios (Scenarios 6 and 7) compared to the J-A-only scenarios (Scenarios 4 and 5) (see Figure 2-14 to Figure 2-17). Therefore, no changes to the risk rating for GW02 are warranted should the Atacama project be developed. A caveat to this risk rating is the requirement to continue to monitor and sample the processing circuit with the introduction of ore from Atacama as part of ongoing tailings management practice to ensure tailings seepage quality remains within acceptable parameters.
- GW03: No significant change in impacts to soils and vegetation within the existing J-A mine working zone is projected to occur from the development of the Atacama project due to there being insignificant changes to the magnitude and extent of groundwater mounding under the Atacama model scenarios (Scenarios 6 and 7) compared to the J-A-only model scenarios (Scenarios 4 and 5) (see Figure 2-14, Figure 2-15, Figure 2-16, Figure 2-17). Therefore, no changes to the risk rating for GW03 are warranted should the Atacama project be developed.
- GW04: No significant change in impacts to soils and vegetation outside the mine working zone are projected to occur from the development of the Atacama project due to there being insignificant changes to the magnitude and extent of groundwater mounding under the Atacama model scenarios (Scenarios 6 and 7) compared to the J-A-only model scenarios (Scenarios 4 and 5) (see Figure 2-14, Figure 2-15, Figure 2-16, Figure 2-17).Therefore, no changes to the risk rating for GW04 are warranted should the Atacama project be developed.

3.4 Summary of impacts assessed and risk ratings

Table 3-1 and Table 3-2 provide a summary of the impacts assessed, their risk ratings and identified management controls.

Table 3-1 Description of potential groundwater impacts at J-A using source-pathway-receptor model

Impact ID	Source	Pathway	Receptor	Potential Impact	Confirmation of S-P-R linkage?	Uncertainties and assumptions	Sensitivity to change in assumptions
GW01	Groundwater abstraction	Groundwater level drawdown in paleochannel aquifer	Paleochannel aquifer and associated beneficial use by other parties and environment	Long-term reduction in groundwater levels and associated aquifer impact(s) impacting or preventing beneficial use of the paleochannel aquifer by other parties	Yes	Aquifer geometry, lack of monitoring wells in areas at distance from wellfield, future pumping rates	Sensitivity tested over historical period of operation
GW02	Naturally occurring sources of acidity in geological strata	Seepage from tailings disposal and subsequent groundwater mounding interacting with geological strata leading to changes in groundwater chemistry	Groundwater	Impacts to groundwater quality	Yes	Distribution of soluble forms of aluminium minerals, neutralising capacity of native groundwater, no expected geochemical contribution from Atacama tailings themselves	Geochemical changes sensitive to these factors and variable
GW03	Tailings disposal	Tailings seepage to groundwater and subsequent rise of saline water table (mounding)	Soil Native vegetation	Hyper saline groundwater rise (salinity) impacting soils and vegetation within the extent of mine workings	Yes	Future seepage rates, hydrostratigraphic mapping, vegetation sensitivity	Sensitivity explored by stochastic modelling undertaken in JACMIN4.0
GW04	Tailings disposal	Tailings seepage to groundwater and subsequent rise of saline water table (mounding)	Soil Native vegetation Lake Ifould	Hyper saline groundwater rise (salinity) impacting soils and vegetation beyond the extent of mine workings due to groundwater mound migration	Yes	Future seepage rates, hydrostratigraphic mapping, vegetation sensitivity	Sensitivity explored by stochastic modelling undertaken
GW-SST	Change to SST	Contributions to all above	All above	Cumulative effects for each of the above impacts	Yes	As above	As above

Impact ID	Source	Pathway	Receptor	Potential Impact	Confirmation of S-P-R linkage?	Uncertainties and assumptions	Sensitivity to change in assumptions
GW-A	Atacama project	Contributions to all above	All above	Cumulative effects for each of the above impacts	Yes	As above	As above

Table 3-2 Summary of risk assessment for groundwater related impacts at J-A

Impact ID	Possible Impact	Inherent risk level			Management controls	Residual risk level		
		L	C	R		L	C	R
GW01	Long-term reduction in groundwater levels and associated aquifer impact(s) impacting or preventing beneficial use of the paleochannel aquifer by other parties	Unlikely	Moderate	Moderate	> Groundwater Management and Monitoring Plan > Monitoring of abstraction rates and groundwater levels with deviations from historical ranges or groundwater drawdown predictions investigated to determine if management practices requires revision. > Water return efficiency measures within mine processing to minimise paleochannel aquifer demand > J-A paleochannel abstraction predictive model > Annual aquifer review and biennial update of groundwater model with operational data plus tailings schedule.	Rare	Moderate	Low
GW02	Impacts to groundwater quality	Likely	Negligible	Moderate	> Groundwater Management and Monitoring Plan > Inclusion of 8 newly installed wells within monitoring network > Ongoing monitoring, assessment and evaluation of mine site groundwater chemistry against criteria to be revised in 2023 update of PEPR > Sampling and analysis of process circuit (sediment and water) and management (e.g. use of brown loam in processing) to maintain circumneutral status of seepage water. > Application of water return efficiency measures to reduce tailings seepage	Possible	Low	Low

Impact ID	Possible Impact	Inherent risk level			Management controls	Residual risk level		
		L	C	R		L	C	R
GW03	Hyper saline groundwater rise (salinity) impacting soils and vegetation within the extent of mine workings	Possible	Moderate	High	> Groundwater Management and Monitoring Plan (including an updated trigger response framework in 2023 PEPR) > Monitoring of groundwater levels (tailings cell Vibrating Wire Piezometer networks, monitoring wells) > Ongoing use and update of the J-A regional model > Tailings Monitoring Management Plan to monitor tailings seepage and use control measures and water recovery infrastructure to minimise seepage. > Vegetation condition monitoring	Unlikely	Minor	Moderate
GW04	Hyper saline groundwater rise (salinity) impacting soils and vegetation beyond the extent of mine workings due to groundwater mound migration	Likely	Significant	Very High	> As for GW03 with additional soil and vegetation studies in the area of predicted water table rise above 3 m BGL and (based on the findings of these studies) investigating options to control water table rises outside of the mine working zone (e.g. drainage systems) if supported by monitoring trends.	Possible	Minor	Moderate
GW-SST	Cumulative effects for each of the above impacts	No changes to risk profile or control measures for each of the above potential impacts						
GW-A	Cumulative effects for each of the above impacts	No changes to risk profile or control measures for each of the above potential impacts, other than the process circuit monitoring (sediment and water) will require intensive focus (additional monitoring rounds) when ore from Atacama is introduced to ensure tailings seepage quality remains within acceptable parameters.						

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Section 4 References

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Appendix C – Atacama Sand Stack Conceptual Tailings Storage Facility Design (ATC Williams)

ATC WILLIAMS

ILUKA ATACAMA SAND STACK

ILUKA RESOURCES
ABN: 34 008 675 018

Atacama Sand Stack
Conceptual Tailings Storage Facility Design

119085.06R01
December 2022

TAILINGS.WATER.WASTE.

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EXECUTIVE SUMMARY

ATC Williams Pty Ltd (ATCW) has been engaged by Iluka Resources (Iluka) to undertake a conceptual design of the Atacama tailings sand stack (Atacama sand stack). The proposed Atacama sand stack will be located at the Jacinth North (JN) in-pit tailings storage facility (TSF) and will be placed over the hydraulically placed ModCod within the in-pit tailings cell (i.e., tailings deposition already completed). The proposed works include the refinement of the conceptual closure design completed by Iluka to take into account additional constraints, the primary restriction being a 60 m offset allowance / setback from reinstated water ways post closure as defined through Alluvium's hydraulic modelling **[1]**.

The conceptual sand stack design included undertaking laboratory testing of two sand material types, namely:

- Blended material comprising a mix of Ambrosia (60%) and Atacama sand (40%); and
- Atacama sand only (i.e., 100% Atacama sands).

The key outcomes following the laboratory testing are summarised as follows:

- Particle Classification
  - Atacama Sand: Medium to Fine Sands
  - Blend: Fine Sands
- Specific Gravity
  - Atacama Sand: 2.66 g/mm^3
  - Blend: 2.65 g/mm^3
- Triaxial test work to establish internal Friction Angle
  - Atacama Sand: 27.8°
  - Blend: 28.6°

The preliminary configuration of the sand stack was conceptually developed by Iluka to assess the geometry and general layout necessary for the required capacity of 18 Mm^3 of tailings. Preliminary design assumptions include a nominal sand stack height of 25 m and side slopes of 10°.

As the sand stack will be located at the Jacinth North (JN) in-pit TSF, the likely foundation conditions for the sand stack include:

- Natural in-situ ground (including existing vegetation) around the edges of the Jacinth Ambrosia (JA) pit;
- In-pit cell sand stacked embankments (constructed using sand stackers); and
- Hydraulically placed ModCod tailings including:
  - Head of beach tailings containing coarse gained material with relatively high bearing capacity in comparison with the lower beach tailings;
  - Mid beach tailings with a higher fines content and with a reduced strength compared with the upper beach tailings, and
- Decant area where the decant pond historically formed and consists of fine-grained tailings that has had minimal opportunity to dry and desiccate and gain strength. Of all the likely foundation material types, the decant area will likely contain the lowest strength material and may still have a high-water content.

Based on the likely foundation conditions, the sand stack stability analysis considered the following:

- In-pit cell sand stacked embankments (constructed using sand stackers);
- Natural in-situ ground around the edges of the Jacinth Ambrosia (JA) pit;
- Hydraulically placed ModCod tailings including:
  - Head of beach tailings; and
  - Decant area tailings.

The stability analysis indicated that a stand stack height of 15 m can be safely placed over the in-pit embankments, natural in-situ ground and the ModCod head of beach. The ModCod decant area however required a lowered phreatic surface of 2 m below surface and 6 m thick pioneer layer, constructed in two 3 m lifts, to be placed prior to placement of the sand stack. The sand stacking operations can then be undertaken to full height of approximately 25 m.

Iluka provided a memo by Alluvium and a report by Landloch that outline some of the closure requirements, including a 60 m water way offset and 3.5° closure slopes respectively. In addition to the closure requirements outlined, Iluka asked that ATCW consider a closure cap thickness of 5.7 m and 1.5 m.

Key outcomes from the conceptual sand stack closure landform are summarised as follows:

- Initial Conceptual Closure Landform (Iluka)
  - Impact to undisturbed ground to the east of JN pit – minimal areas
  - Approximate Volume: 15 Mm^3
- Redesigned Closure Landform with nominal 5.7 m thick cap (ATCW)
  - Estimated capping volume: 12.5 Mm^3,
  - Approximate Volume: 20 Mm^3
  - Impact to undisturbed ground to the east of JN pit – estimated 65 Ha
- Redesigned Closure Landform with nominal 1.5 m thick cap (ATCW)
  - Estimated capping volume – 3 Mm^3
  - Approximate Volume: 20 Mm^3
  - Impact to undisturbed ground to the east of JN pit – estimated 15 ha

Based on the closure restrictions, the redesigned conceptual closure landform extended significantly to the north-east of the JN TSF. The north-east area is where the site was not identified as being restricted by either water way setbacks or existing infrastructure, however, there are existing stockpiles at that location that will be impacted and likely need to be moved.

It should also be noted that Iluka also indicated they may not have sufficient capping material for the 5.7m thick cap option.

CONTENTS

FIGURES

TABLES

APPENDICES

1 INTRODUCTION

ATC Williams Pty Ltd (ATCW) has been engaged by Iluka Resources (Iluka) to undertake a conceptual design of the Atacama tailings sand stack (Atacama sand stack). The proposed Atacama sand stack will be located at the Jacinth North (JN) in-pit tailings storage facility (TSF) and will be placed over the hydraulically placed ModCod within the in-pit tailings cell (i.e., tailings deposition already completed).

The proposed works include the refinement of the conceptual closure design completed by Iluka to take into account additional constraints, the primary restriction being a 60 m offset allowance / setback from reinstated water ways post closure as defined through Alluvium's hydraulic modelling **[1]** and the closure batters of 3.5° proposed by Iluka based on the Landloch study **[4].**

The conceptual sand stack design included undertaking laboratory testing of two sand material types, namely:

- Blended material comprising a mix of Ambrosia (60%) and Atacama sand (40%); and
- Atacama sand only (i.e., 100% Atacama sands).

The test work included Particle Size Distribution (PSD) and triaxial testing. The results of the testing aided in material parameter determination and was used in various design analyses.

2 PROJECT BACKGROUND

2.1 Location

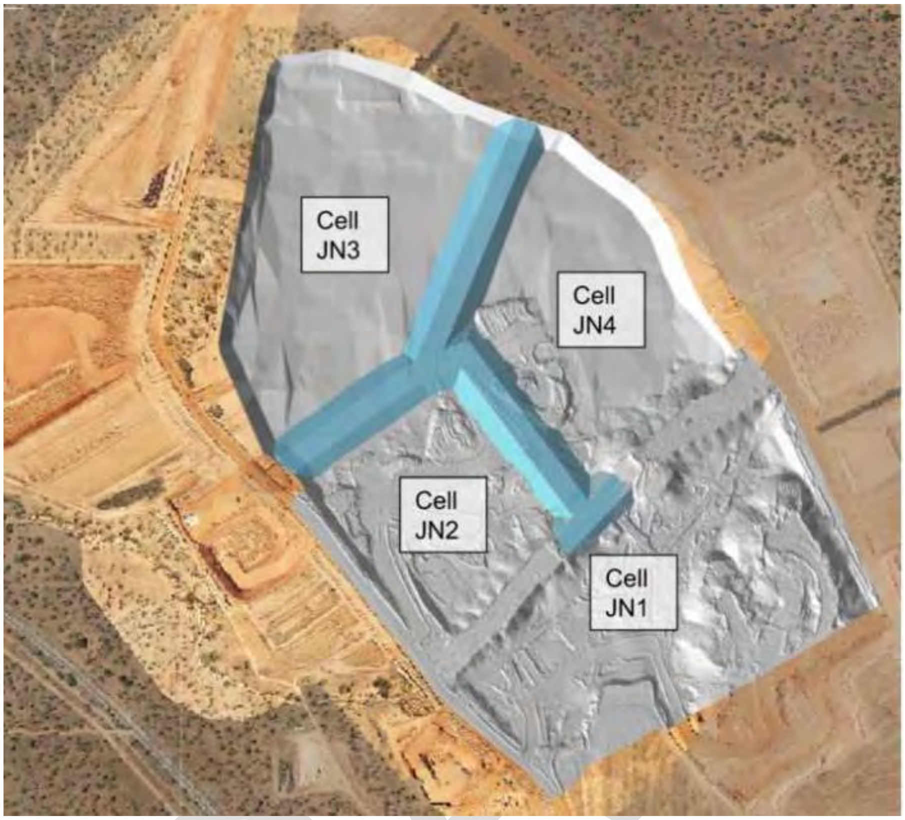
The Jacinth-Ambrosia (JA) mine site is located in mid-west South Australia, at Yellabinna, north of Coorabie and Yalata. The JA mine site is approximately 800 km from Adelaide and 270 km from the Port of Thevenard.

The mine site has an active sand mining operation where zircon, rutile and ilmenite are mined. The sand is dry mined, and concentration of the ore is by gravity separation. The heavy mineral concentrate is transported from the Port of Thevenard to Iluka's Narngulu mineral separation plant in Western Australia (WA). The final products are zircon, rutile and ilmenite.

The project area is the Jacinth-North (JN) in-pit TSF where tailings from the current mining activities is deposited in the in-pit TSF cells. In-pit embankments are constructed across the pit using sand stackers. These embankments are typically 20-30 m high with nominally 70 m wide crests.

A typical layout of the Jacinth-North in-pit cells is presented in Figure 2.1.

FIGURE 2.1 JACINTH NORTH IN-PIT TAILINGS CELL LAYOUT



2.2 Sand Stack Foundation Conditions

The Atacama sand stack will be constructed over hydraulically placed ModCod tailings in the JN in-pit TSF cells as presented in Figure 2.1.

The likely foundation conditions of the sand stack can be summarised as follows:

- Natural in-situ ground (including existing vegetation) around the edges of the Jacinth Ambrosia (JA) pit;
- In-pit cell sand stacked embankments (constructed using sand stackers); and
- Hydraulically placed ModCod tailings including:
  - Head of beach tailings containing coarse gained material with relatively high bearing capacity in comparison with the lower beach tailings;
  - Mid beach tailings with a higher fines content and with a reduced strength compared with the upper beach tailings, and
  - Decant area where the decant pond historically formed and consists of fine-grained tailings that has had minimal opportunity to dry and desiccate and gain strength. Of all the likely foundation material types, the decant area will likely contain the lowest strength material and may still have a high-water content.

Several historical geotechnical investigations and studies (completed by ATCW and others) have been made available by Iluka to provide background information on the natural ground, in-pit embankments and head of beach material. However, it should be noted that information for the tailings contained within the decant area is very limited.

Preliminary stability analyses undertaken for the concept design study in the decant area has utilised data previously obtained from Iluka's Gingin mine site located in Western Australia. This was discussed with the team (i.e., ATCW and Iluka) and it was agreed that the available CPTu data from Gingin would be suitable to assess the JN decant tailings area.

While it is understood that Iluka initially intended to undertake a site trial at one of the TSF cells (Cell 5) at the Jacinth South TSF where tailings deposition has ceased (i.e., facility has been dormant for approximately 2 years), however, Iluka have since advised this may not go ahead.

3 SEISMICITY

While a site-specific seismic assessment was not undertaken as part of the current works, ATCW undertook a Site-Specific Seismic Hazard Assessment for the Jacinth Ambrosia Mine in 2016 (ATCW ref. 110762.12R02 dated May 2016). The study reviewed the following:

- Australian Standard (AS 1170.4, 2007);
- Geoscience Australia (2012); and
- AMC's 2007 report.

For the 1 in 500 years return period, the AS1170 noted a Peak Ground Acceleration (PGA) of 0.03G while the Geoscience Australia report noted a range between 0.01G and 0.02G (for 1:500 return period). The AMC report indicated a PGA of 0.067G for the 1 in 10,000 years return period for the Maximum Credible Earthquake (MCE) case.

ATCW then conducted a probabilistic study which aimed to develop the ground-motion spectra for the in-pit storage facility at JA, the results of which are presented in Table 3.1**.**

TABLE 3.1 PROBABILISTIC SPECTRA FOR IDENTIFIED RETURN PERIODS

Period (seconds)	Return Period (years)					
	200	500	1,000	2,500	5,000	10,000
0.01 (PGA)	0.018	0.037	0.061	0.105	0.148	0.207

As the ATCW analyses considered the latest earthquake database and utilised the latest analytical methodologies, it is proposed, where necessary, that the data presented in Table 3.1 be adopted.

4 FOUNDATION STRENGTH

The estimated strength parameters of the foundation conditions, as indicated in **Section 2.2**, have been adopted from several historical investigations performed by ATCW and others because there were no deposited tailings available within the JN TSF at the time of analysis.

It is understood that deposition into Cell 1 is currently underway and ATCW recommends that the in-pit tailings be tested to inform future analyses. However, for this stage of works it was agreed with Iluka that the following geotechnical investigations be used to inform the foundation parameters used in for the stability analysis in this study:

- AMC Consultants Pty. Ltd. (AMC) Design Study (2008) Error! Reference source not found.
- Gingin CPTu Investigation (2012) Error! Reference source not found.
- Jacinth Ambrosia (JA) Stability Assessment (2019) Error! Reference source not found.
- Jacinth Ambrosia (JA) – Generic Design Report (2016) Error! Reference source not found.

These investigations are further discussed in the following sections.

4.1 Estimated Foundation Conditions

Several historical geotechnical investigations have informed the likely natural ground conditions that that sand stack is expected to interface with. The following three foundation condition was considered to be applicable foundation conditions, not inclusive of the ModCod tailings:

- Natural In-Situ Red and Brown Loam
  - Parameters defined by AMC in their JA Geotechnical Design Study Error! Reference source not found. and;
- Constructed Sand Stacked embankments,
  - Parameters defined by previous stability analyses Error! Reference source not found. conducted by ATCW for the detailed design of the JA Cell 7 sand stacked embankment.

The material parameters for these three materials have been adopted from the studies Error! Reference source not found. Error! Reference source not found. and are summarised in **Table 4.1**:

TABLE 4.1 ESTIMATED FOUNDATION CONDITION STRENGTH PARAMETERS

Foundation Condition	Cohesion, c' (kPa)	Friction Angle ϕ'(°)	Unit Weight (kN/m^3)	Source
Natural In-Situ Ground – Red Loam	7	31	16.8	AMC Design Study Error! Reference source not found.
Natural In-Situ Ground – Brown Loam	17	12.1	29	AMC Design Study Error! Reference source not found.
In-Pit Cell Sand Stacked Embankments	0	33	15.9	ATCW Stability analyses Error! Reference source not found.

4.2 Estimated Foundation Conditions – ModCod Tailings

As stated above, at the time of analysis there were no tailings within the JN pit. As a result, Iluka agreed that CPTu data obtained from historical CPTu investigations at the Gingin Mine site Error! Reference source not found. and at JA in 2015 Error! Reference source not found. and 2019 Error! Reference source not found. could be used estimate the likely strength parameters for both the HoB and decant ModCod tailings.

4.2.1 Head of Beach ModCod Tailings

The HoB ModCod tailings parameters were interpreted from data gathered in the 2015 Error! Reference source not found. and 2019 Error! Reference source not found. CPTu investigations at JA. Selected CPT data was analysed to estimate both the minimum strength (**Figure 4.1**) and the shear strength ratio as a function of vertical stress (**Figure 4.2**) to be used in the stability analysis.

The minimum shear strength was conservatively estimated to be 10 kPa by assessing the tailings shear strength near the surface (**Figure 4.1)**.

Estimation of the shear strength ratio was based on the 5th percentile of the selected CPT data that indicated a lower bound shear strength ratio of 0.6. For added conservatism, a shear strength ratio of 0.4 was adopted for a selected depth range (2.5 - 19m) to account for lower shear strength values observed in several CPT's within this region (**Figure 4.2**).

FIGURE 4.1 CPT DATA – HOB - SHEAR STRENGTH VS. DEPTH

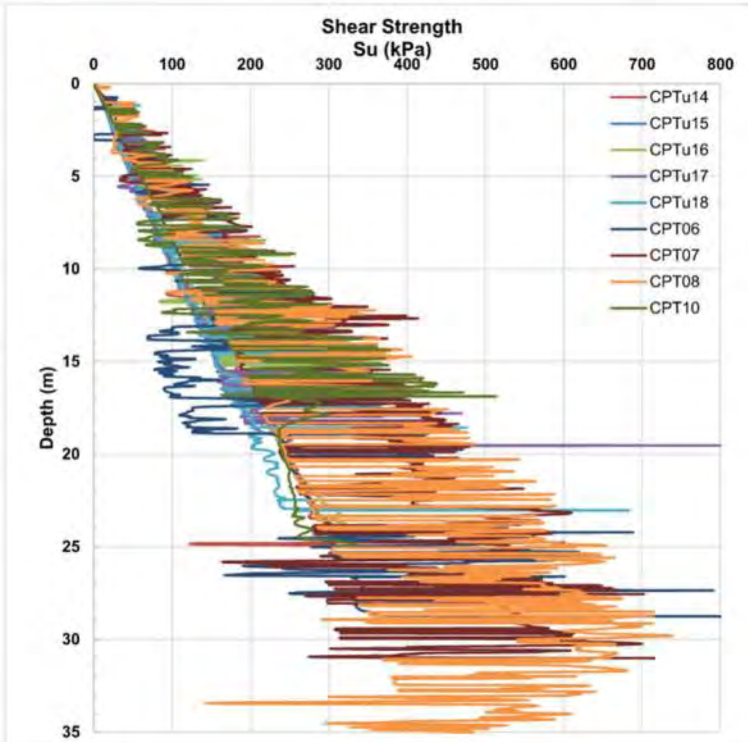
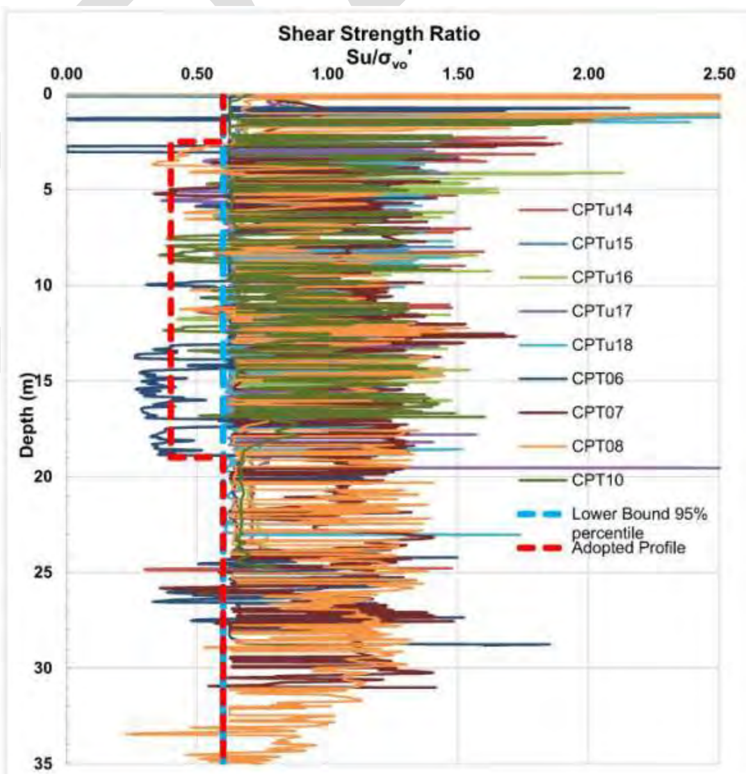


FIGURE 4.2 CPT DATA – HOB - SHEAR STRENGTH RATIO VS. DEPTH



4.2.2 Decant ModCod Tailings

The Decant ModCod tailings parameters were estimated from data gathered from the CPTu investigation at the Gingin mine site Error! Reference source not found.. These conditions were agreed by Iluka to be likely conditions in the decant area at the JN decant area.

The minimum strength was derived from CPT data shown in (**Figure 4.3)** and estimated by approximating the shear strength near the surface and was conservatively estimated to be 5 kPa.

The shear strength ratio as a function of vertical stress (**Figure 4.4**) was determined based on the 5th percentile from the CPT data to provide an estimated ratio of 0.3.

FIGURE 4.3 CPT DATA – DECANT - SHEAR STRENGTH VS. DEPTH

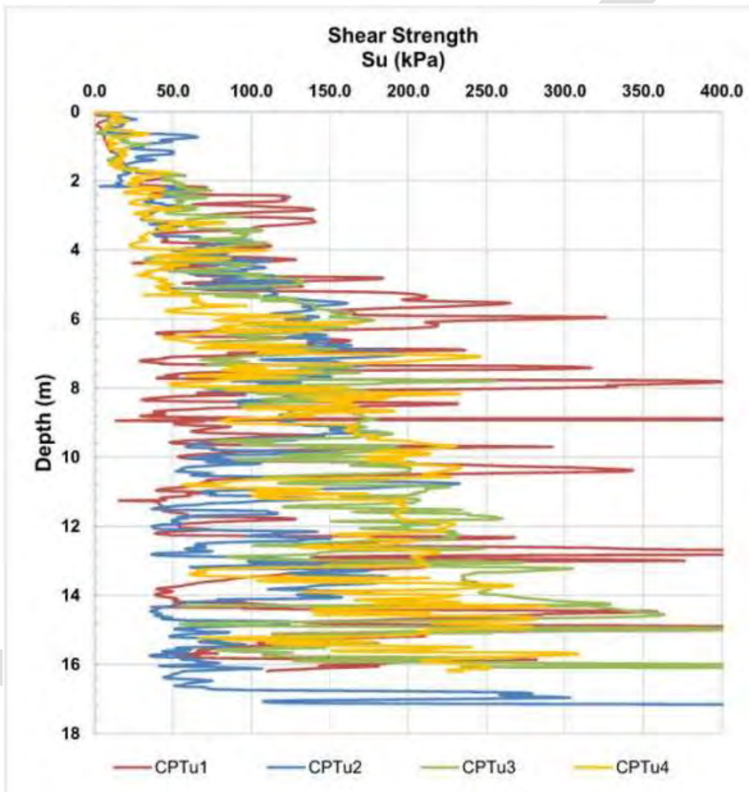
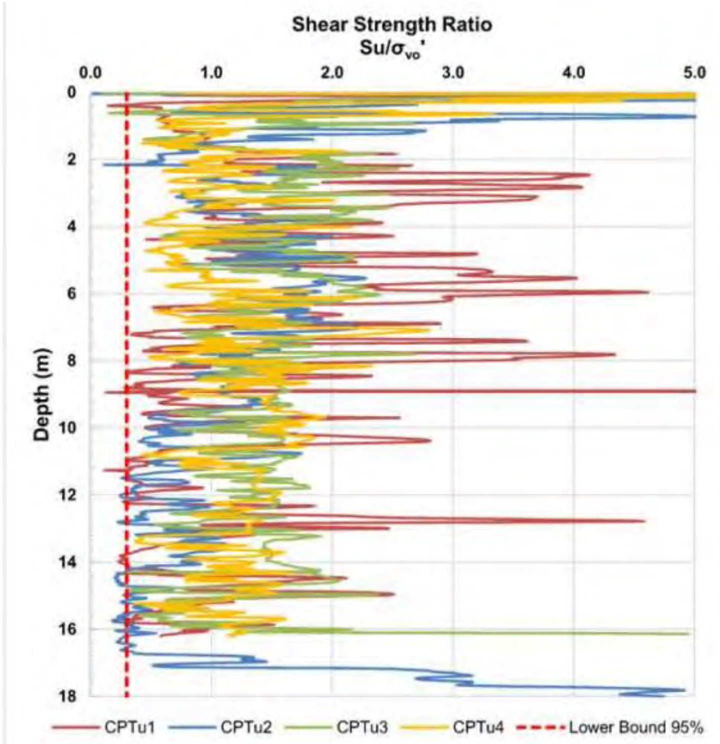


FIGURE 4.4 CPT DATA – DECANT - SHEAR STRENGTH RATIO VS. DEPTH



A summary of the derived parameters for the two ModCod tailings materials used in the analysis are shown in **Table 4.2**.

TABLE 4.2 ESTIMATED FOUNDATION CONDITION STRENGTH PARAMETERS - MODCOD TAILINGS

Founding Condition	Shear Strength ratio	Min. Strength (kPa)	Unit Weight (kN/m³)	Source
ModCod HoB Tailings	0.6 (depth <2.5m and >19m)	10	12	JA CPT data from 2015 Error! Reference source not found. and 2019 Error! Reference source not found.
	0.4 (depth 2.5 – 19m)			
ModCod Decant Tailings	0.3	5	12	Gingin CPT Data Error! Reference source not found.

All results tabulated in **Table 4.1** and **Table 4.2** were used to inform materials properties for the stability analyses. These material properties will need to be reviewed and updated for the next stage of study based additional CPT investigation to be undertaken on the Mod-Cod tailings present in the JN cells.

5 SAND PROPERTIES

5.1 General

As stated in **Section 1**, Iluka is considering developing the sand stack using either the Atacama sands or a blended sand comprising 60% Ambrosia sand with 40% Atacama sand.

5.2 Sand Stack Material Characterisation

ATCW have undertaken laboratory testing of the sand material to understand the likely behaviour once deposited. The test work undertaken at the ATC Williams Melbourne based laboratory can be summarised as follows:

- Particle Size Distribution (PSD) for sand component;
- Particle Specific Gravity;
- Minimum and maximum density; and
- Triaxial testing of the Blend and Atacama sands to assess material strengths.

Please see **Appendix A** for the relevant laboratory test certificates. The results of testing completed are summarised in Table 5.1.

TABLE 5.1 TAILINGS LABORATORY TEST RESULTS SUMMARY

Test Description		Blend	Atacama
Particle Size Distribution (PSD)			
% Passing	2.36 mm	100%	100%
	1.18 mm	100%	100%
	0.600 mm	99.9%	100%
	0.425 mm	97.9%	99.7%
	0.300 mm	88.5%	99.1%
	0.150 mm	44.6%	74.6%
	0.075 mm	1.6%	0.9%
	0.038 mm	0.8%	0%
Min / Max Density, (t/m^3)		1.43 – 1.75	1.36 – 1.69
Particle Density, (g/cm^3)		2.65	2.66
Triaxial testing		Refer discussion in **Section 5.4**	

Please refer to Chart 7.1 in **Section 7.3** for the PSD plots.

Both the Blend and Atacama Sand samples can be described as poorly graded, uniform sands (SP). The Blended sands contain a higher percentage of fines (passing 0.075 mm sieve)

5.3 Triaxial Testing

5.3.1 Overview

This section describes and details the testing and results obtained from the triaxial test work performed on two sand material types. Both sand samples were provided by Iluka.

As part of the testing program, three isotropically consolidated undrained and four isotropically consolidated drained monotonic triaxial tests were performed on both samples to establish the Critical State Line (CSL) of the materials.

The testing was undertaken utilising triaxial machines at the ATCW laboratory.

5.3.2 Sample Preparation

The as received samples were prepared for testing by either riffle splitting or quartering to obtain a homogenous sample prior to remoulding.

The remoulding procedure involved moist tamping each sample into a split mould that was positioned on the triaxial pedestal. The samples were compacted to predetermined densities (refer to Table 5.2).

The assigned laboratory register numbers for the samples are summarised as follows:

- Blended sample - #33122; and
- Atacama sample - #33022.

The target densities were varied, as required, for establishing the CSL and to assess the shear strength of the material.

To achieve a uniform density, the samples were developed in six even layers and compacted using moist tamping. Once placed, the split mould was removed, and the sample was sealed with an impermeable rubber membrane and readied for saturation.

All samples were remoulded within a 75 mm Diameter (D) split mould. The Height (H) of the remoulded samples were approximately 150 mm to ensure the required 2H:1D ratio was achieved.

5.3.3 Testing Schedule

Table 5.2 summarises the triaxial testing schedule for both material types, including the initial conditions at which each sample was placed onto the triaxial pedestal (i.e., prior to saturation), and conditions after saturation (i.e., prior to consolidation).

Prior to shearing, all samples initially underwent saturation. The saturation process first involved running de-aired Melbourne tap water through the sample, from the base to the top, until either the volume of water into the system matched the estimated volume of air in the sample, or a constant flow rate was recorded from the top of the sample.

The next phase of saturation involved ramping up the pore pressure and confining pressure simultaneously to 500 kPa and 520 kPa, respectively, over a period of 500 minutes (i.e., 1 kPa per minute). This procedure forces any air remaining in the system / sample to dissolve into the pore fluid.

Following saturation and prior to shearing, isotropic consolidation stages were undertaken as per Table 5.2 . Once the defined pressure was applied to a sample for each isotropic consolidation stage, the excess pore water pressure generated was allowed to dissipate.

The target pressures for the tests considered the range of pressures expected in the field. For both material types, three isotropic consolidation pressures of 100, 200 and 400 kPa were adopted. The range of pressures are chosen to represent expected site conditions with 100 and 200 kPa confining pressures being chosen to replicate the deposition of the sand stack up to 25 m.

The 400 kPa confining pressure was chosen to determine the location of the Critical State at a high mean effective pressure.

All tests were undertaken at different densities to assess respective behaviour during shearing (refer to Table 5.2). All the samples that underwent shearing were loaded at a rate no greater than 0.05mm/min, presented in Table 5.2 .

The associated laboratory test reports for the tailings have been provided in **Appendix A**.

5.3.4 Results

A tabulated summary of the triaxial test results is presented in Table 5.2 . The results were used to identify the critical state line in q-p’ and e-p’ spaces. The stress paths are presented in **Figures A1** and **A2** of **Appendix A**. The associated laboratory test reports are provided in **Appendix A**. The results are further discussed in **Section 5.4**.

TABLE 5.2 TRIAXIAL TEST RESULTS SUMMARY

Parameter		Unit	Test 1 (B)	Test 2 (B)	Test 3 (B)	Test 1 (S)	Test 2 (S)	Test 3 (S)	Test 4 (S)
			Appendix A, Figure A1 A2						
Sample Identification		-	Blended Sand (B)			Atacama Sand (S)			
ATCW Lab. Register Number		-	33122			33022			
Sampled Depth			Bulk sample			Bulk sample			
Material Type			Blended sand (Ambrosia and Atacama)			Atacama sand only			
Scheduled Test Type			CU	CD	CD	CU	CD	CD	CU
Particle Density, ρ_{st}		t/m^3	2.65			2.66			
Effective Confining Pressures prior to Shearing, σ'_3		kPa	100	400	200	100	400	200	200
Vertical Effective Stress prior to Shearing, σ'_1		kPa	100 (k_0 = 1)	400 (k_0 = 1)	200 (k_0 = 1)	100 (k_0 = 1)	400 (k_0 = 1)	200 (k_0 = 1)	200 (k_0 = 1)
Placed (Target Density)	Void Ratio, e	-	0.77	0.77	0.75	0.77	0.90	1.05	1.05
	Dry Density, ρ_d	t/m^3	1.50	1.50	1.51	1.50	1.40	1.30	1.30
Saturated	Void Ratio, e	-	0.73	0.66	0.70	0.68	0.64	0.81	0.75
	Dry Density, ρ_d	t/m^3	1.53	1.60	1.56	1.58	1.63	1.47	1.52

Parameter		Unit	Test 1 (B)	Test 2 (B)	Test 3 (B)	Test 1 (S)	Test 2 (S)	Test 3 (S)	Test 4 (S)
Monotonic Shear Rate, $\dot{\varepsilon}$		mm/min	0.05			0.05			
Prior to Shearing	Void Ratio, e	-	0.71	0.63	0.68	0.67	0.61	0.74	0.73
	Dry Density, ρ_d	t/m^3	1.55	1.63	1.58	1.59	1.65	1.53	1.54
Monotonic Failure Point*			Max q	Max q	Max q	QSS	Max q/p’	Max q/p’	QSS
Undrained Shear Strength, S_u		kPa	30	-	-	52	-	-	31
Shear Strength Ratio, S_u/σ'_v		-	0.29	-	-	0.48	-	-	0.15
Axial Strain at Failure, ε_a		%	0.5	8.8	8.6	0.4	10.3	13.1	3.7
Inferred CSL	Void Ratio, e_{cs}	-	0.71	0.61	068	-*	0.63	0.70	0.73
	Deviator stress, $q_{cs}$$^\$$	kPa	10	724	366	-*	710	312	62
	Mean Effective Stress, p'_{cs}	kPa	6	638	320	-	635	303	54
	State Parameter, Ψ	-	0.01	-0.03	-0.01	-0.05	-0.06	0.03	0.02
Internal Friction Angle, ϕ'_{cs} (Assumed c’=0)		°	28.6 (Approx. M_{tc} = 1.14)			27.8 (Approx. M_{tc} = 1.10)			

B: Blend sample
S: Atacama sample
CIU: Consolidated Isotropically Undrained
CD: Consolidated Drained
QSS: Transition point between contractive and dilative behaviour.
** Dilative sample, results were not used for CSL determination.*
$^\$$ End of test data

5.4 Establishing Critical State Line Parameters

5.4.1 General

The following sections describe the assessment undertaken to establish the CSL of the sands tested based on the results obtained from the monotonic triaxial testing.

5.4.2 CSL Parameters

5.4.2.1 Overview

The Critical State Line (CSL, or critical void ratio) is the locus of void ratio-effective stress conditions that is achieved after shearing a soil to large strains and there are no further changes to the net void ratio (specific volume) or effective stresses if shearing continues, i.e. **[2]**:

$$\frac{\partial p'}{\partial \varepsilon_q} = \frac{\partial q}{\partial \varepsilon_q} = \frac{\partial \nu}{\partial \varepsilon_q} = 0$$

The CSL can be used to predict the contractive or dilative behaviour of a material under shear. The critical state of a material can be represented by the CSL in the critical state framework, that is typically void ratio versus mean effective stress (i.e. e:p' space), and deviatoric stress versus mean effective stress (i.e. q:p' space).

In e:p' space, materials that exist above the CSL exhibit strain softening (or contractive) behaviour during shearing (i.e. loose state). Conversely, materials below the CSL exhibit strain hardening (or dilative behaviour) during shearing (i.e. dense state).

Defined by Jefferies and Been (2016) **[3]**, the state parameter (Ψ) of a material can be defined in relation to the CSL using the following expression:

$$\Psi = e - e_c$$

where, e is the void ratio at a given stress condition, and e_c is the critical void ratio at the same mean effective stress (Cambridge, p').

Furthermore, the CSL can be defined in the e:p' and q:p' spaces, respectively, using the following expressions **[2]**:

$$e_c = a - b \times \left(\frac{p'}{p_{ref}}\right)^c$$

$$q = M_{tc} p'$$

Where, a, b and c are coefficients and p_{ref} is the reference pressure, usually taken as 100 kPa, q is the deviatoric stress, and M_{tc} is the slope of the CSL in q:p' space.

A material which is predicted to exhibit strain softening (or contractive) behaviour during shearing would have a state parameter greater than -0.05. Conversely, a material which is predicted to exhibit strain hardening (or dilative) behaviour during shearing would have a state parameter less than -0.05.

Noted by Jefferies and Been (2016) **[3]**, -0.05 "*is the state parameter criterion that emerges from laboratory tests and appears to be the limiting situation for various flow slide case histories in sands and silts when assessed in a state parameter context*".

Therefore, a strain-softening, contractive material with a state parameter greater than -0.05 is said to have the potential to undergo flow liquefaction under static or cyclic loading.

5.4.2.2 Critical State Line (CSL)

The parameters required to express the CSL for the sand materials in the q:p' space and e:p' space were obtained by performing seven monotonic triaxial compression tests.

The tests were undertaken under Isotropically Consolidated Undrained (CU) and Drained (CD) conditions.

The triaxial compression tests provided sufficient information to determine the locus of the CSL in the q:p' and e:p' space.

Presented in Table 5.2 are the parameters obtained from the seven monotonic triaxial compression tests used to determine the locus of the CSL in the q:p' space and e:p' space. The state parameter (Ψ) of each sample (prior to shearing) has also been estimated.

A summary of the critical state parameters is provided in Table 5.3 . A graphical representation of the CSL in q:p' space and e:p' space is provided in **Figures A1** and **A2**, respectively.

As presented in Table 5.3 , the loci of the CSL in q:p' space indicates the critical friction angles for the blended sample and Atacama sand sample to be 28.6° (M_{tc} = 1.14) and 27.8° (M_{tc} = 1.10), respectively. The results from the triaxial tests indicate the CSL can be defined in the e:p' space using the following expressions:

Blend sample:

$$e_{cs} = 0.71 - 0.006 \times \left(\frac{p'}{100}\right)^{1.50}$$

Atacama Sand sample:

$$e_{cs} = 0.73 - 0.006 \times \left(\frac{p'}{100}\right)^{1.55}$$

In relation to the CSL in e:p' space, the collapse (or densification) of some samples during saturation and consolidation resulted in the samples remaining on the dilative side of the CSL prior to shearing (i.e. $\Psi < -0.05$).

TABLE 5.3 CSL PARAMETERS FOR TESTED SAMPLES

Parameter	Symbol	Value	
Sample Identification	-	Blend sand (Bulk)	Atacama sand (Bulk)
Void ratio intercept at zero mean effective stress	a	0.71	0.73
Slope of the CSL in e:p' space	b	0.006	0.006
Power of the CSL in e:p' space	c	1.50	1.55
Slope of the CSL in q:p' space	M_{tc}	M_{tc} = 1.14 (Approx. ϕ´=28.6º)	M_{tc} = 1.10 (Approx. ϕ´=27.8º)

5.4.3 Liquefaction Potential

The laboratory tests have established the CSL for the Blend and Atacama sand samples under specific laboratory test conditions. The results provide a baseline and reference point where a liquefaction potential assessment can be undertaken when compared to the material properties of the tailings collected from site. It should be noted that the triaxial laboratory tests themselves do not indicate if the material is liquefiable. However, high level assessments based on preliminary PSD's (presented in **Section 7.3 -** Chart 7.1) suggest that the sand materials are potentially liquifiable.

Once sand stacking commences, the placed material can be tested to compare it current state in the field to the identified CSL.

6 SAND STACK CONCEPT

6.1 Required Storage Capacity

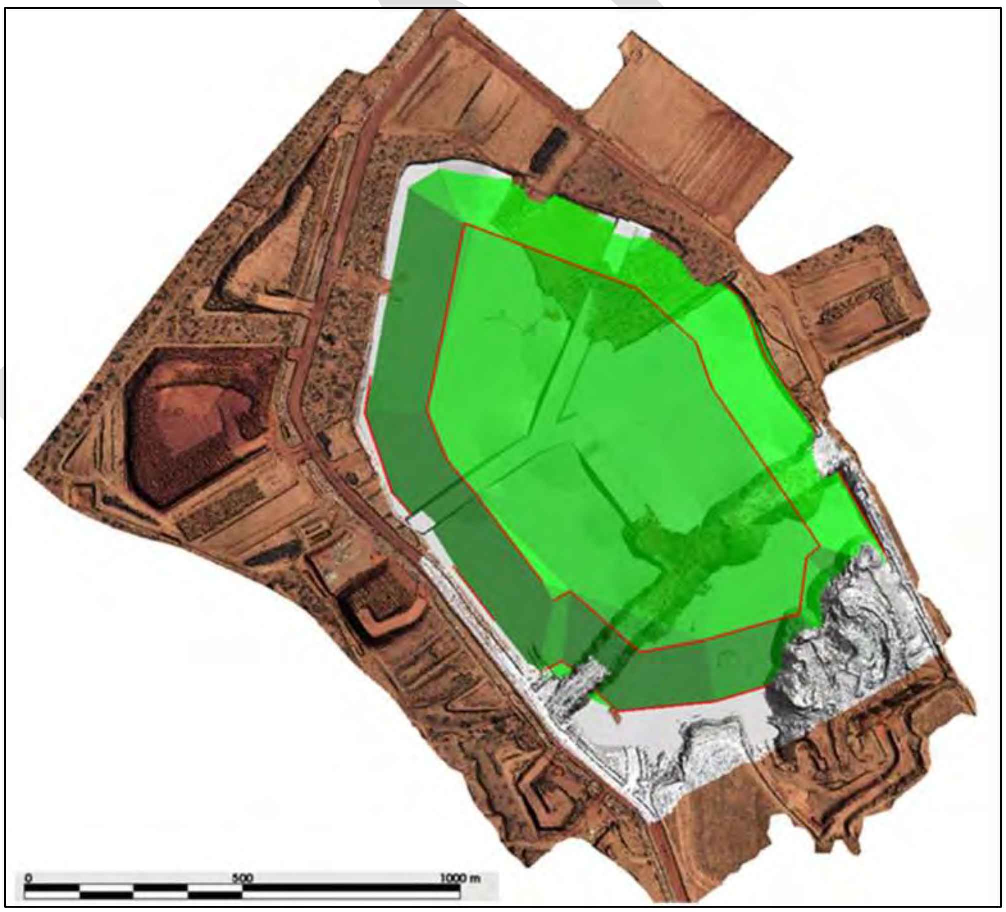
Iluka indicated that the storage capacity requirements for the sand stack is approximately 18 Mm^3. Ideally this material should be placed primarily within the mined pit extents of JN.

6.2 Conceptual Sand Stack Layout

The conceptual sand stack layout as modelled by Iluka is presented by the hatched green area presented in Figure 6.1. The configuration was conceptually developed by Iluka and the model was provided to ATCW. The conceptual sand stack was developed to assess the geometry required to allow for 18 Mm^3 of tailings from the Atacama mining operations. Iluka informed the assumptions used to develop the sand stack are:

- Sand stack height of 25 m, and
- Sand stack slopes of 10°.

FIGURE 6.1 ORIGINALLY PROPOSED SAND STACK LAYOUT



Additional restrictions, discussed in **Section 8,** have been imposed with respect to allowable offsets from the proposed final landform stream reinstatement and final batter slopes. ATCW has been engaged to refine the conceptual Iluka model taking into account any additional restrictions imposed by the regulator or further refinements identified by Iluka.

7 SAND STACK STABILITY ASSESSMENT

7.1 Overview

ATCW has undertaken several stability analyses for the foundation types identified in **Section 2.2** to inform the sand stack design refinement and material properties outlined in **Sections 4.1** and **4.2**.

The governing design principle with regards to stability analyses is that the sand stack is placed in a manner such that the integrity of the sand stack is preserved until it is rehabilitated.

Stability analyses have been conducted using results of laboratory testing and assumed parameters based on past experience on similar projects.

All analyses have been conducted considering long-term (Drained) conditions. ATCW propose to undertake undrained and post seismic assessments during the next stage of the study.

It should also be noted that the sand stack stability is dependent on the sand stackers performance, and it is therefore recommended that Iluka ensure the sand stackers have been optimized for the sand material to be stacked (i.e., Iluka to consider if the cyclones, sand feed rate and water addition has been optimized to minimise excessive water being imposed on the system).

7.2 Static Stability Criteria

Operationally, a minimum acceptable factor of safety has been defined at 1.3.

The minimum factors of safety that have been adopted for stability analyses for earth structures are presented in Table 7.1 and have been obtained from the ANCOLD guidelines.

TABLE 7.1 MINIMUM REQUIRED FACTORS OF SAFETY (ANCOLD)

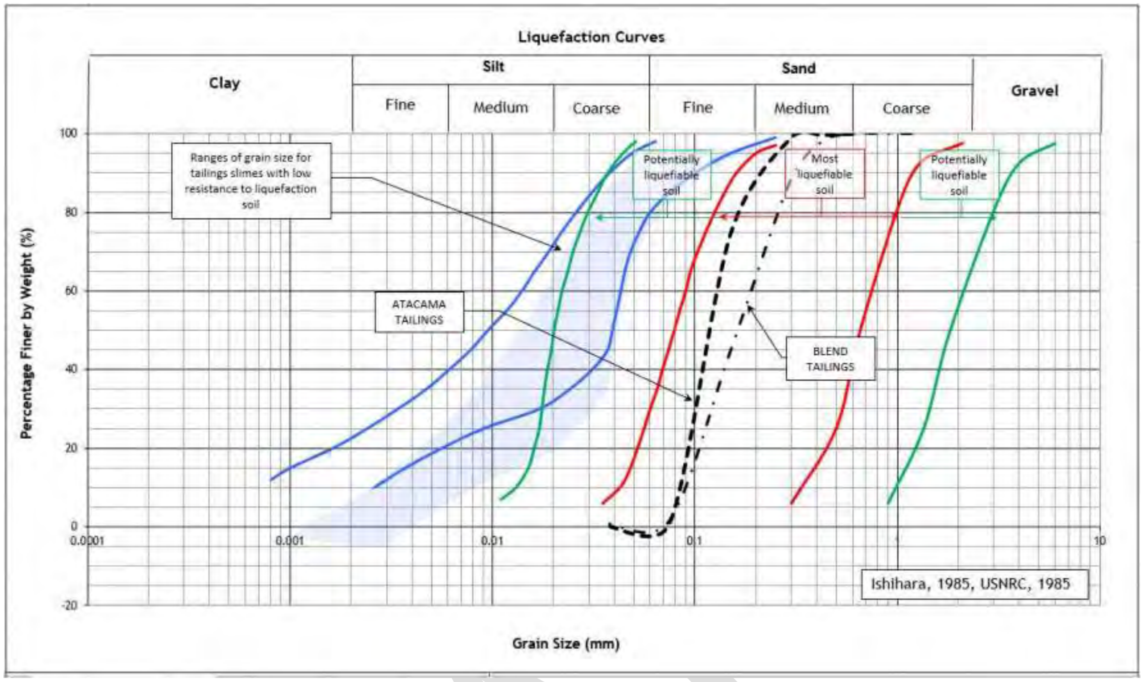
Analysis	Scenarios	Minimum Required Factor of Safety*
Long-Term Drained	Steady State Seepage	1.5
Short-Term Undrained (no potential loss of containment)	Construction Conditions	1.3
Short-Term Undrained (potential loss of containment)	Construction Conditions	1.5
Post-Seismic	Seismic Loading (pseudo-static) for non-liquefiable case	1.0 - 1.2

*The Factors of Safety (FoS) limits are obtained from the ANCOLD guidelines.

7.3 Liquefaction Potential

A high-level liquefaction potential assessment of the sand stack was undertaken based on the method developed by Ishihara (1985) using the Particle Size Distribution (PSD) of the sand materials. The results of this assessment are presented in Chart 7.1.

CHART 7.1 LIQUEFACTION POTENTIAL ASSESSMENT



Based on the data presented in Chart 7.1, both the Blend and Atacama sand samples are considered to be potentially liquefiable.

7.4 Adopted Material Parameters

The material parameters utilised in the stability analyses have been derived from laboratory test results, literature review and past experience with similar materials. Adopted material parameters are summarised in Table 7.2.

TABLE 7.2 MATERIAL PARAMETERS ADOPTED FOR STABILITY ANALYSES

Material	Model	Unit Weight	Minimum Strength (kPa)	Tau/Sigma Ratio	Cohesion, c' (kPa)	Phi, ϕ' (°)
Sand Stack Material	Mohr-Coulomb	14.7	-	-	0	25
ModCod Tailings	SHANSEP	12	5	0.3	-	-

It is important to note that the foundation strength profiles presented in **Section 4**, have been adopted in the stability analyses.

The results of the triaxial testing of both samples suggest a ϕ' (phi) angle of between 27.8° and 28.6° to be appropriate. During a meeting with Iluka on 5 October 2022, ATCW presented this finding and were informed to adopt the originally assumed value of 25° as it provided some conservatism in the stability assessment.

7.5 Phreatic Surface

The phreatic surface is the equilibrium level of groundwater where the pressure head tends to zero along a given profile, for a given boundary condition. It is important for stability analyses as it influences the strength of the materials in two significant ways, namely:

- Soil below the phreatic surface is saturated and therefore has a lower undrained shear strength than that applied to dry, unsaturated material; and
- The elevation of the phreatic surface has a direct influence on the factor of safety by influencing the effective stress and frictional strength. The higher the phreatic surface the lower the resulting factor of safety.

Various phreatic surface conditions in the JN decant area were considered to assess the viability of placing a pioneer layer to facilitate sand stack placement and if it is possible to place this pioneer layer and then to identify any potential limitations during the construction works.

The outcomes of the assessment are presented in **Section 7.6.5**.

7.6 Stability Cases Considered

7.6.1 General

As stated in **Section 2.2**, stability analyses have been completed considering the various foundation conditions that are likely to exist on site and are summarised again below:

- In-pit cell sand stacked embankments (constructed using sand stackers);
- Natural in-situ ground around the edges of the Jacinth Ambrosia (JA) pit;
- Hydraulically placed ModCod tailings including:
  - Head of beach tailings; and
  - Decant area tailings.

The following assumptions were maintained for all analyses undertaken

- Iluka prefer to complete the sand stack operation in a single pass to the final stack height;
- Deposited tailings (HoB) / in-situ foundation material is not saturated;
- Decant tailings strength parameters are based on the Gingin Mine CPTu data;
- The natural angle of repose of a water filled sand ranges between 15° – 30°. ATCW conservatively adopted a sand stack slope of 15° for all stability models;
- The adopted phreatic surface within the stacked mass will be similar to that of the sand stacked embankment construction completed a Jacinth Ambrosia during 2016;
- No additional weight imposed by the sand stackers has been accounted for (require additional information from Iluka);
- Foundation strata consists of Brown Loam and Red Loam only; and
- HoB tailings slope is estimated to be 8%.

Please note that all stability analyses results are graphically presented in **Appendix B**.

7.6.2 In-pit cell Sand Stacked Embankment

In this scenario the assessment considered the stability of the sand stack when placed over the in-pit sand stacked embankments. Results of this assessment are presented in Table 7.3.

TABLE 7.3 PREVIOUSLY SAND STACKED EMBANKMENT FOUNDATION STABILITY RESULTS SUMMARY

Sand Stack Height (m)	Equipment	FoS	Figure Number
15	D10T	2.1	B1

It can be seen that a 15 m high sand stack placed over the sand stacked embankment a FoS value well in excess of the minimum required 1.5 value, implying that there should be no adverse effects on the stacked sand mass (i.e. stacking can take place to full height in a single operation).

7.6.3 In-Situ Ground

In this scenario the assessment considered the stability of the sand stack when placed over the natural surface, comprising brown or red loam. Results of this assessment is presented in Table 7.4.

TABLE 7.4 IN-SITU FOUNDATION MATERIAL STABILITY RESULTS SUMMARY

Sand Stack Height (m)	Equipment	Foundation Material	FoS	Figure Number
15	D10T	Brown Loam	1.7	B2
		Red Loam	1.7	B3

It can be seen that the results presented in Table 7.4, exceed the minimum FoS requirement indicating that the in-situ foundation material is suitable for sand stacking operations (i.e. construction to full height in a single operation).

7.6.4 ModCod Head of Beach

In this scenario the assessment considered the stability of the sand stack when placed over the HoB ModCod Tailings. Results of this assessment are presented in Table 7.5.

TABLE 7.5 HEAD OF BEACH MODCOD TAILINGS STABILITY RESULTS SUMMARY

Sand Stack Height (m)	Equipment	FoS	Figure Number
3	D10T	1.6	B4
15	D10T	1.8	B5

The lower FoS value of 1.6 obtained for the 3m stacked layer is due to the effect of the distributed load of the equipment through a 3m thick layer compared to the lower distributed load through a 15 m thick layer of material. The results indicate that sand stacking over the HoB tailings can be carried out with minimal adverse effects on the sand stack and can be completed in a single operation.

7.6.5 ModCod Decant Area

In this scenario the assessment considered the stability of the sand stack when placed over the decant area of the ModCod tailings. This location was subsequently determined to be the critical case and identified the need for a pioneer layer to be placed and span the decant area tailings. The pioneer layer(s) are required to ensure sufficient foundation strength to allow sand stacking to take place.

Three scenario's were identified for the decant area and can be summarised as follows:

1. Pioneer Layer 1 - It was determined that a pioneer layer (comprised of sand stack material) will be required over the decant area ModCod to improve the foundation bearing capacity to allow sand stacking to take place. The results of this assessment are presented in Table 7.6
2. Pioneer Layer 2 – Assessment to consider the requirements of a second pioneer layer to allow sand stacking to take place in a single operation over the decant ModCod. The results of the analyses are presented in Table 7.7; and
3. Assess the foundation and sand stack stability with the aim to maximise the height of the stack. Iluka would prefer that the stacking operation be completed to full heigh in a single pass of the stackers. The results are presented in Table 7.8.

All stability analyses for the scenario's defined above considered:

- Varying phreatic levels; and
- Varying the construction equipment placed at the leading edge.

TABLE 7.6 ASSESSMENT OF INITIAL PIONEER LAYER THICKNESS

Pioneer Layer Thickness (m)	Phreatic Surface (mgbl. Tailings)	Equipment	FoS	Figure Number
1	0	D8T LGP	1.1	C1
		D10T	0.9	C2
	2	D8T LGP	1.2	C3
2	0	D8T LGP	1.1	C4
		D10T	1.1	C5
	2	D8T LGP	1.4	C6
		D10T	1.3	C7
3	0	-	1.2	C8
		D8T LGP	1.1	C9
		D10T	1.1	C10
	1	-	1.4	C11
		D8T LGP	1.3	C12
		D10T	1.3	C13
	2	-	1.6	C14
		D8T LGP	1.5	C15
		D10T	1.4	C16
4	0	D10T	1.1	C17
	1	D10T	1.2	C18

Pioneer Layer Thickness (m)	Phreatic Surface (mgbl. Tailings)	Equipment	FoS	Figure Number
	2	D10T	1.4	C19
5	0	-	1.1	C20
		D8T LGP	1.1	C21
		D10T	1.0	C22
	2	D10T	1.4	C23
10	0	D10T	1.0	C24
	2	D10T	1.2	C25
15	0	D10T	1.0	C26
	2	D10T	1.1	C27

The stability analysis results indicate that the initial pioneer layer should be constructed to 3 m. It is important to note that to achieve the minimum FoS, the phreatic surface does need to be at least 2 m below the tailings surface. High-level stability assessments were undertaken to assess if sand stacking could take place to the ultimate height in a single operation, however the results indicate that this is not possible while maintaining an acceptable FoS.

TABLE 7.7 PLACEMENT OF SECOND PIONEER LAYER

Second Pioneer Layer Thickness (m)	Phreatic Surface (mgbl. Tailings)	Equipment	FoS	Figure Number
3	0	D8T LGP	1.7	C28
		D10T	1.6	C29

To allow stacking to full height within the decant area, it is recommended that a second pioneer layer be constructed to a 3 m thickness. A pioneer layer of 6 m is required to allow sand stacking to take place in a single operation. It is important to note that the pioneer layer must be constructed in two 3 m thick layers.

TABLE 7.8 ASSESSMENT OF DEPTH OF SAND STACK PLACEMENT OVER PIONEER LAYER

Pioneer Layer Thickness (m)	Sand Stack Height (m)	Phreatic Surface (mgbl. Tailings)	Equipment	FoS	Figure Number
3m Pioneer Layer	10	0	D10T	1.3	C30
	15	0	D10T	1.2	C31
	20	0	D10T	1.2	C32
	25	0	D10T	1.1	C33

Pioneer Layer Thickness (m)	Sand Stack Height (m)	Phreatic Surface (mgbl. Tailings)	Equipment	FoS	Figure Number
	30	0	D10T	1.1	C34
4m Pioneer Layer	10	0	D10T	1.4	C35
	15	0	D10T	1.3	C36
	20	0	D10T	1.2	C37
	25	0	D10T	1.2	C38
	30	0	D10T	1.1	C39
6m Pioneer Layer	10	0	D10T	1.4	C40
	15	0	D10T	1.4	C41
	20	0	D10T	1.4	C42
	25	0	D10T	1.3	C43
	30	0	D10T	1.2	C44

The results presented in Table 7.8, indicate that with a 6 m pioneer layer will allow sand stacking to take place in a single operation up to 20 m to 25 m in height (i.e. achieving a FoS greater than 1.3).

7.6.6 Stability Result Summary

Key outcomes of the stability analyses can be summarised as follows:

- The existing sand stacked embankments located within the pit are suitable as foundation material to allow sand stacking to take place to full height in a single operation;
- The in-situ material located beyond the extents of the JN pit are considered suitable to allow sand stacking to take place to full height in a single operation;
- The hydraulically placed HoB ModCod are considered suitable to allow sand stacking to take place to full height in a single operation;
- **The decant area ModCod does require a pioneer layer of 6 m thick to be constructed in two 3 m layers. It is important to note that the phreatic surface does need to be maintained at least 2 m below the tailings surface**; and
- Sand stacking within the decant area can be undertaken to full height in a single pass, however the 6 m pioneer layer must be constructed in place first.

While Iluka initially indicated a plan to undertake a full-scale field trial, they have since advised this may not proceed. However, if this trial does proceed, data obtained from the field trial will feed back into the analyses to allow design refinements to be implemented in the next design stage.

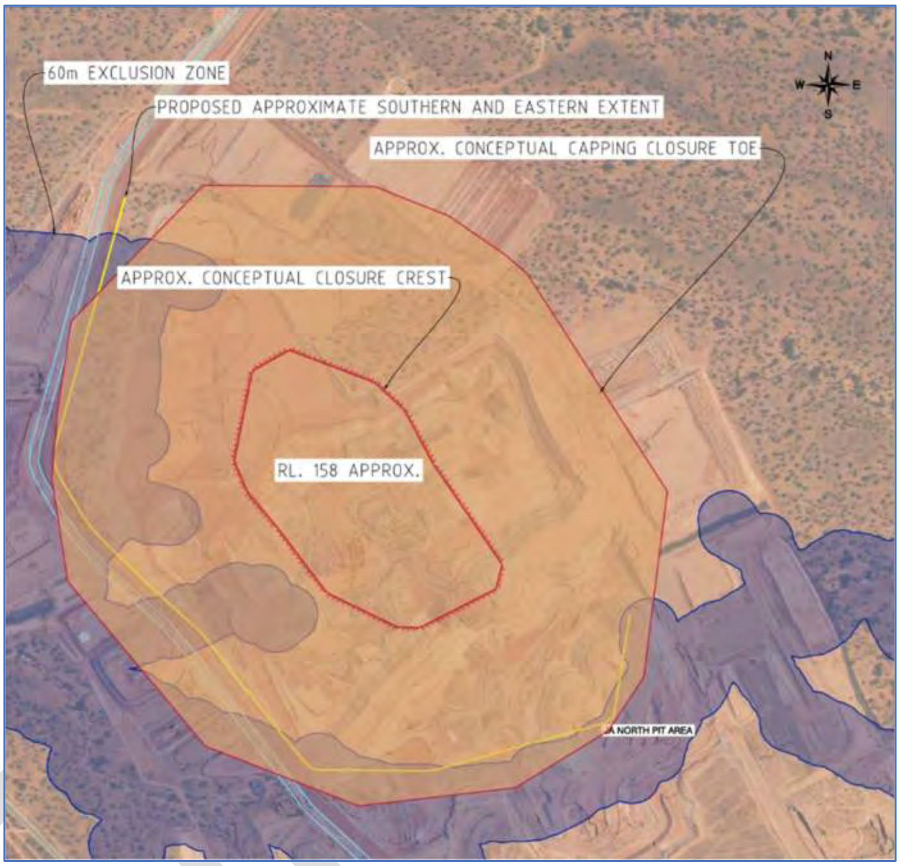
8 SAND STACK DESIGN REFINEMENTS

8.1 Restrictions Influencing the sand stack

Iluka provided ATCW with a memo compiled by Alluvium **[1]** regarding the requirements for reinstating the waterways and associated setback requirements post rehabilitation based on their hydraulic modelling works. ATCW was requested to review the memo and assess potential impacts of the setback on the sand stack closure profile.

The Alluvium memo and 3D models indicated the areas where waterway setbacks are required. Figure 8.1 graphically presents the setback requirements (hatched blue areas) in relation to the initial Iluka conceptual model. It can be seen that the waterway offsets impact the likely storage volume of the sand stack.

FIGURE 8.1 SAND STACK RESTRICTIONS



Several meetings and discussions were held with Iluka to discuss the opportunity of relaxing the offsets on the western and southern sides of the JN pit to allow additional area and hence additional sand stack storage. Based on internal discussions, Iluka informed ATCW that the offset boundary was altered and is graphically represented by the yellow line in Error! Reference source not found..

In addition to the waterway offset, Iluka commissioned Landloch **[4]** to assess the erosion potential of the proposed sand stack. The assessment indicated that the sand stack reshaped slope should be at approximately 3.5°.

Additionally, Iluka asked that ATCW consider a closure cap of 5.7 m thick and 1.5 m thick. It is noted that the current approved cap is 5.7 m and the 1.5 m thick cap was based on recent capping works undertaken by Iluka.

8.2 Sand Stack Model Refinements

8.2.1 Overview

Iluka confirmed the following for the design refinement:

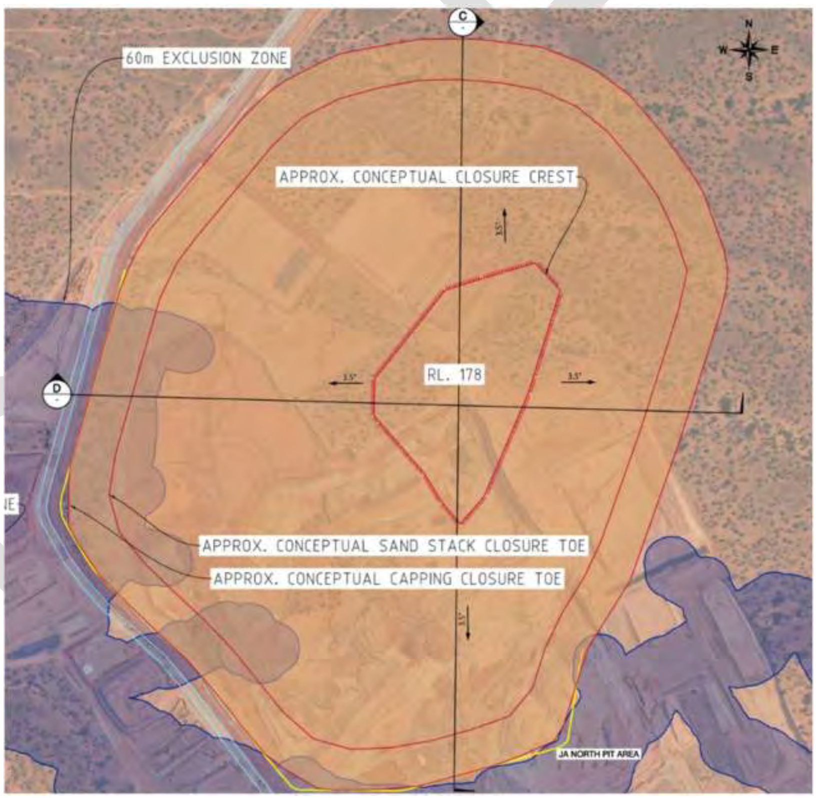
- The sand stack cap can extend to the yellow line presented in Error! Reference source not found.;
- The final sand stack height shall not exceed RL 172.3 m to allow for a sand stack cap thickness of 5.7 m and RL 176.5 m for the 1.5 m thick cap. Hence, the final closure landform has a maximum allowable height of RL 178 m based on current approvals,
- Develop models for a 1.5 m and 5.7 thick cap; and
- The sand stack batters are to be approximately 3.5° (or nominally 6.1%) at closure.

It is important to note that with the imposed restrictions and the storage volume requirement of 18 Mm^3, the sand stack will extend to the north east of the JN pit. Consideration of the alternate cap thicknesses aims to provide Iluka with additional information to allow discussions with the regulator agree on a cap thickness to progress to the next design phase.

8.2.2 Sand stack (5.7 m Cap)

Error! Reference source not found. presents the proposed sand stack considering a 5.7 m thick cap. The outermost red line represents the conceptual closure profile including the cap. The distance between the reshaped sand stack toe and the closure toe is estimated to be approximately 100 m.

FIGURE 8.2 CONCEPTUAL SAND STACK CLOSURE LANDFORM (5.7 M THICK CAP)

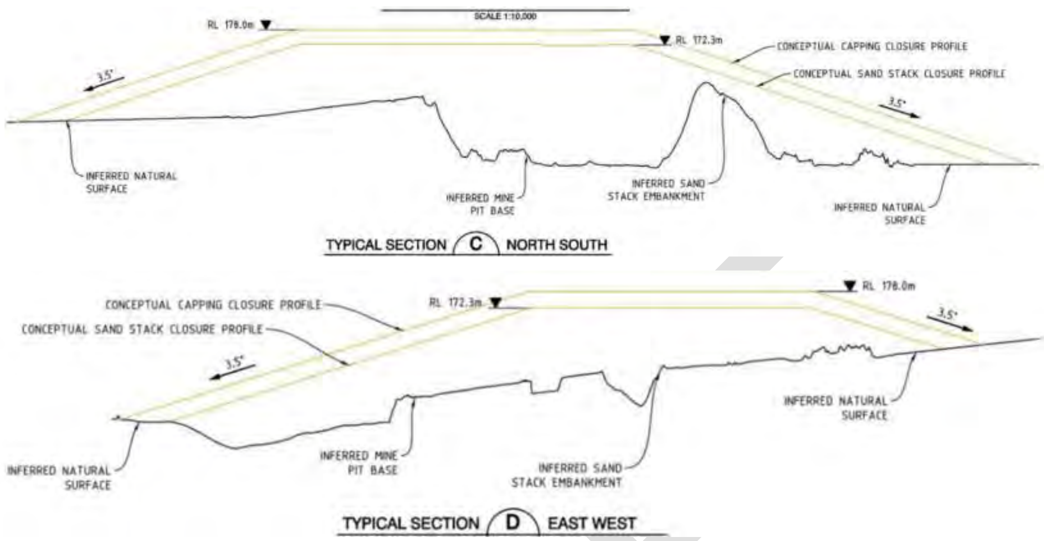


It is estimated that the design presented in Figure 8.2 allows for the following:

- Sand stack volume – 20 Mm^3;
- Estimated capping volume – 12.5 Mm^3; and
- Impact to undisturbed ground to the east of JN pit – estimated 65 ha.

Typical sections (Section C and D), as presented in Error! Reference source not found. provides context of the size, shape, and extent of the sand stack.

FIGURE 8.3 TYPICAL CONCEPTUAL CLOSURE CROSS SECTIONS (5.7 M THICK CAP)



8.2.3 Sand Stack (1.5 m Cap)

Error! Reference source not found. presents the conceptual sand stack closure landform and takes into account the 1.5 m thick closure cap. The outermost red line represents the conceptual closure profile including the cap. The distance between the reshaped sand stack toe and the closure toe is estimated to be approximately 25 m.

It is estimated that the design presented in Figure 8.4 allows for the following:

- Sand stack volume – 20 Mm^3;
- Estimated capping volume – 3 Mm^3; and
- Impact to undisturbed ground to the east of JN pit – estimated 15 ha.

Typical sections (Section E and F), as presented in Figure 8.5**,** provides context of the size, shape, and extent of the sand stack.

FIGURE 8.4 CONCEPTUAL SAND STACK CLOSURE LANDFORM (1.5 M THICK CAP)

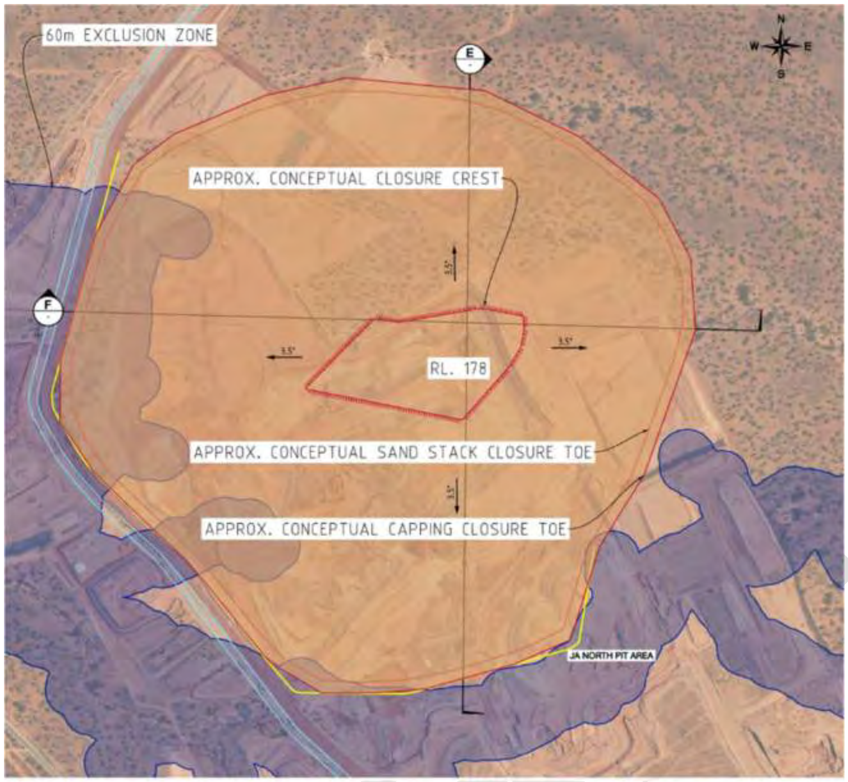
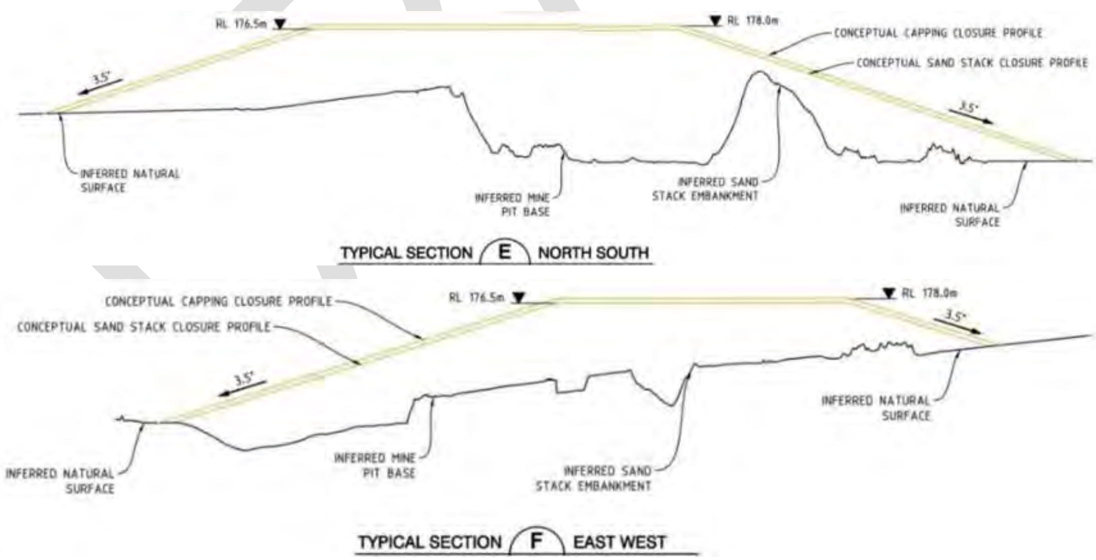


FIGURE 8.5 TYPICAL CONCEPTUAL CLOSURE CROSS SECTIONS (1.5M THICK CAP)



8.2.4 Summary of Capping Alternatives

A summary of the key differences between the 2 closure models is summarized in Table 8.1.

TABLE 8.1 SAND STACK CAPPING ALTERNATIVES

Cap Thickness	Estimated Sand Stack Volume	Estimated Capping Material Required	Estimated Area of Additional Disturbance
1.5 m	20 Mm^2	3.0 Mm^3	15 Ha
5.7 m	20 Mm^2	12.5 Mm^3	65 Ha

Iluka should further consider the impacts of the proposed designs to surrounding flora, fauna and cultural heritage sites (if applicable).

9 RECOMMENDATIONS AND FUTURE WORKS

The following is a summary of recommendations and proposed future works:

- Stability models should be updated as required based on outcomes of any field trials taken on site;
- In the next phase of works the sand stack design can be further refined;
- The foundation conditions (i.e., phreatic levels, foundation strength, etc.) will need to be assessed prior to the construction works being undertaken to confirm site conditions are consistent with the stability assessment parameters;
- Active dewatering will be required in the decant areas of all in-pit cells during filling of the cells and shall continue prior to commencement of sand stacking as this will significantly improve the decant area ModCod tailings strength prior to pioneer layer placement;
- One alternative method to managing the phreatic surface in the ModCod cells during operation is by varying the deposition locations where the sand is being deposited. This can be done by hydraulically placing sand within the decant area and then moving the deposition point to another location of the cell. This deposition method would minimise the concentration of water at a single location within the cell;
- Sand stack placement can commence in the following areas within the JN TSF without concerns of foundation instability. These areas include the following:
  - In-pit sand embankments;
  - In-situ foundations; and
  - ModCod Head of Beach.
- Sand stacking can take place over the decant taliings areas, however two 3 m thick pioneer layers will be required and the phreatic surface within the decant area must be at least 2 m below the tailings surface;
- Management of surface water from storm water runoff prior to and during the sand stacking operation should be undertaken to:
  - Divert stormwater run-off and/or bleed water run-off from the sand stack placement operations and away from the decant area; and
  - The phreatic surface at the decant area within the in-pit cells should be maintained to below surface or as low as practicable to allow tailings strength gain, to facilitate pioneer layer placement.
- Underdrainage may be required for the sand stack to minimise phreatic surface build up within the sand stack during sand stacking operations;

- Development of a work plan for sand stacking will be required and should, as a minimum, include the following:
  - Developing pioneer layer placement methodology;
  - Delineation of areas to be filled;
  - Staging of sand stacking placement based on Mod-Cod tailings strength and to avoid areas of low tailings strength; and
  - Establishment of exclusion areas, i.e., the decant areas at JN TSF if those areas to be filled last.

It is important to note that the details provided above includes a conceptual closure cap for reference only. The capping design is to be undertaken, by others, separate from the current scope of works.

9.1 Proposed Future Works

Works required to be completed for future design phases can be summarized as follows:

- Review the sand stacker cyclones and that they are appropriately sized for both sand types;
- Site investigation (i.e., CPT test work) on the tailings aimed to assess actual tailings strength with the aim of updating stability models;
- Optimisation of sand stack design to minimize double handling;
- Assessing the option of hydraulically placing sand at different locations within the JN pit, i.e., varying the deposition locations so that the decant area is not located at one location;
- Assess if there are sensitive areas at the footprint of the sand stack. This includes:
  - Cultural heritage sites;
  - Flora and fauna, and
  - Stormwater drainage areas and/or stormwater runoff that needs to be managed.

REFERENCES

[1] Alluvium, "Atacama sand stack setback determination Stage 1 - Hydraulic modelling results and setback width literature review", document reference Memo dated 24 August 2022

[2] Wood, D.M., "Soil behaviour and critical State soil mechanics". 1990, New York: Cambridge University Press. 462.

[3] Jefferies, M. and K. Been, "*Soil Liquefaction - A Critical State Approach (Second Edition)*", Taylor & Francis Group, 2016: p. 712.

[4] Landloch, "Erosion Potential of the Proposed Landform Design for the Sand Stack at Jacinth North", draft report dated October 2022.

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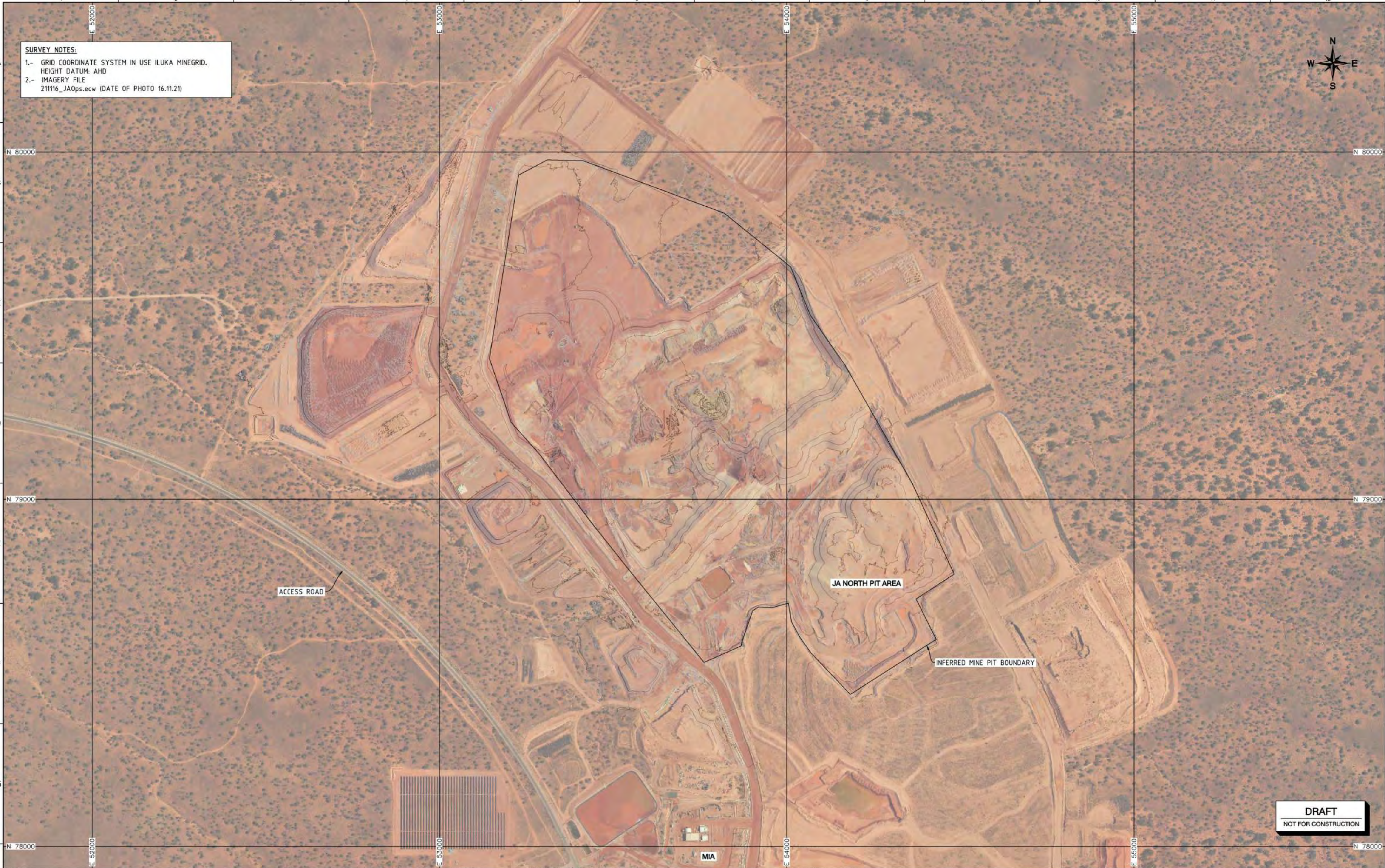
2. The scope of the work has been planned in the absence of any fore knowledge of the site other than that stated in the report. Unless otherwise stated we consider that the number of locations investigated and the depths to which they have been investigated are reasonable bearing in mind the scale and nature of the project, and the defined purpose for which the investigation was undertaken.
3. We do not accept any responsibility for any variance between the interpreted and extrapolated conditions and those that are revealed by any means subsequently. Specific warning is also given that many factors, either natural or artificial, may render ground conditions different from those which pertained at the time of the investigation. Should there be revealed during the construction or at any other time any apparent difference from subsurface conditions described or assessed in this report, it is strongly recommended that such differences be brought to our attention so that its significance may be assessed, and appropriate advice given.

FIGURES



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JACINTH NORTH PIT
EXISTING CONDITIONS

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FIGURE 1

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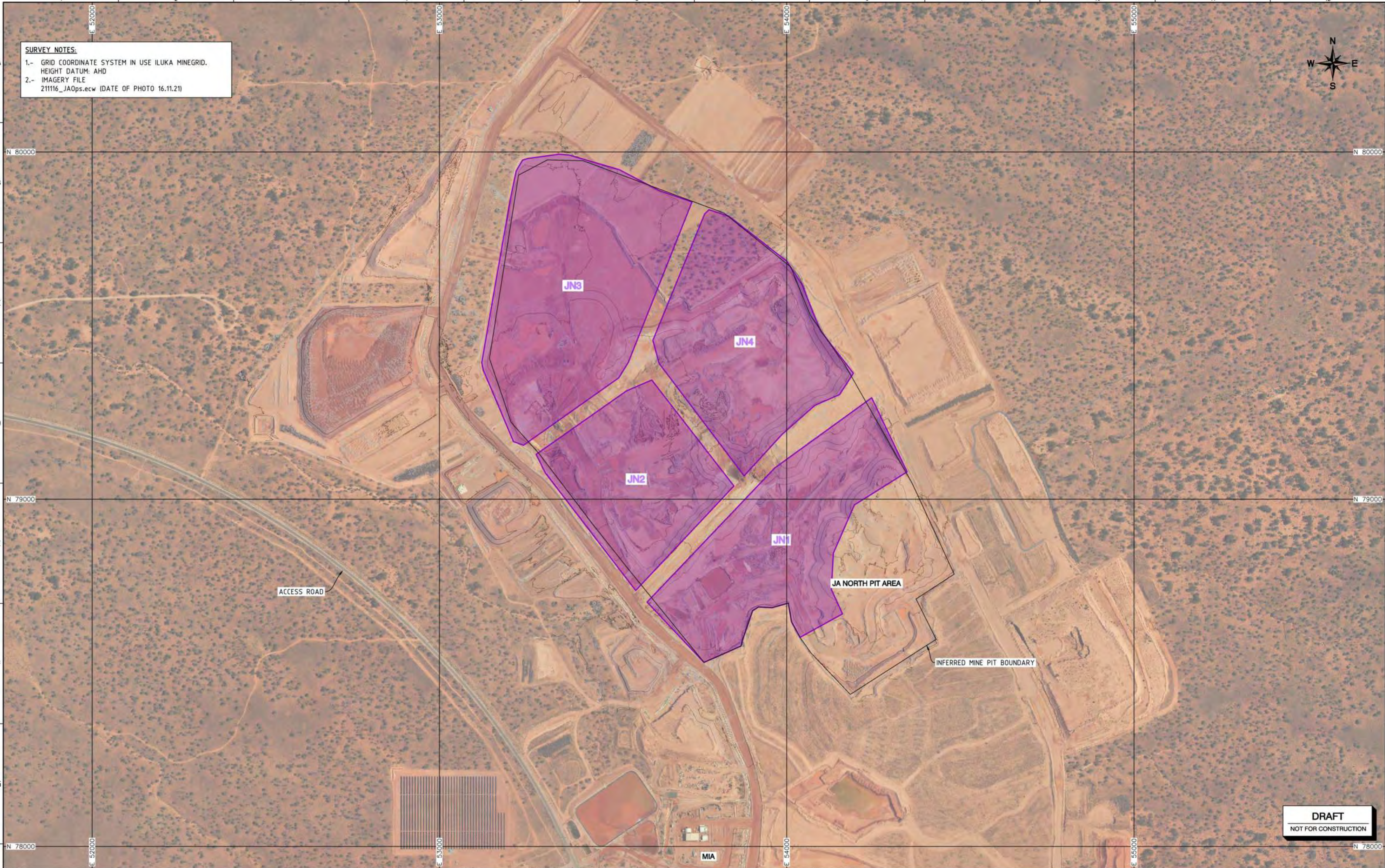

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CONCEPTUAL JACINTH NORTH IN-PIT CELLS

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FIGURE 2

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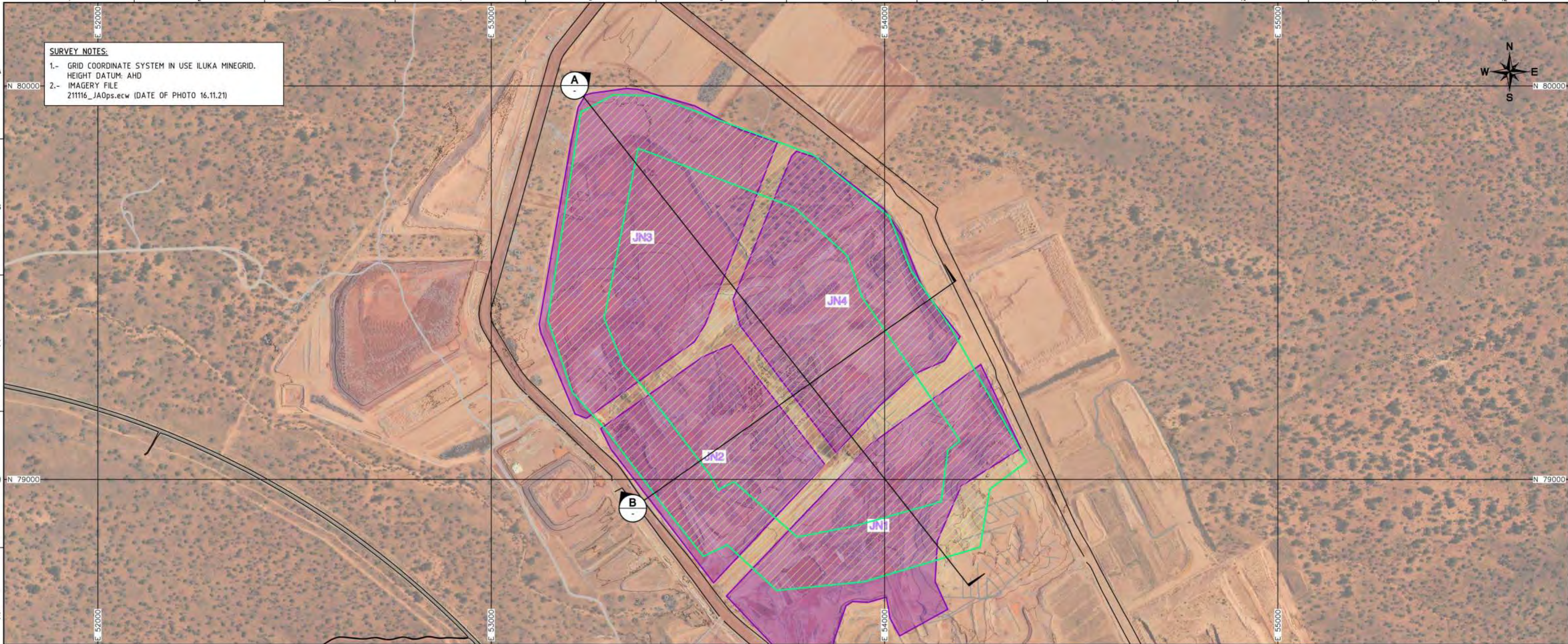

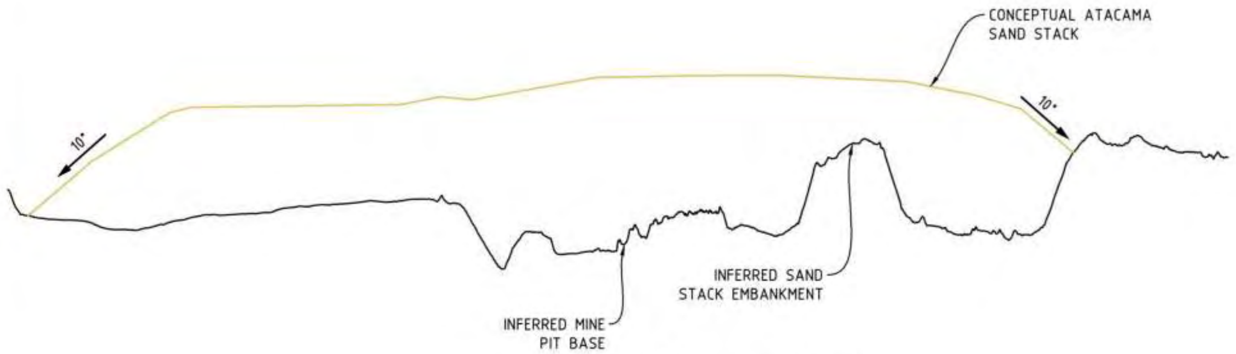

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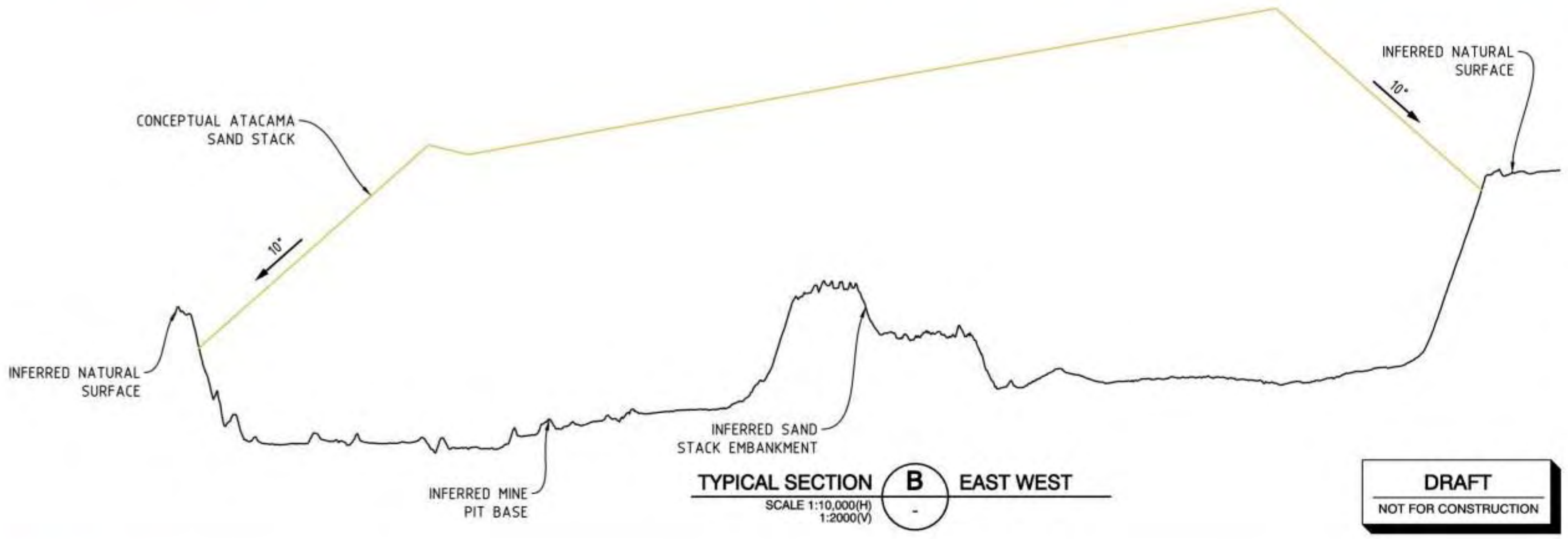

TYPICAL SECTION B EAST WEST
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CONCEPTUAL SAND STACK DESIGN

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FIGURE 3

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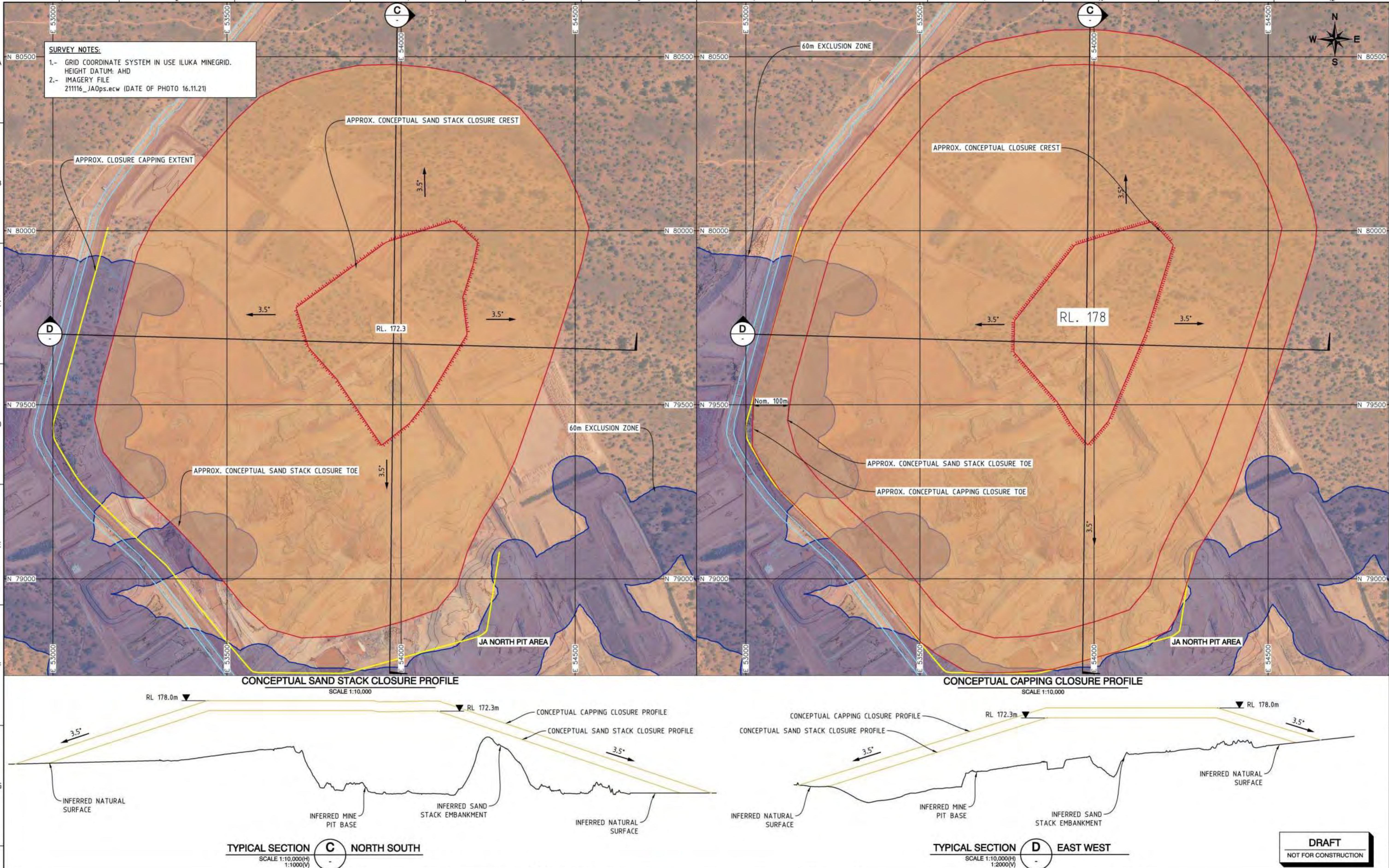

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CONCEPTUAL CLOSURE PROFILE (5.7m CAPPING)

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FIGURE 4

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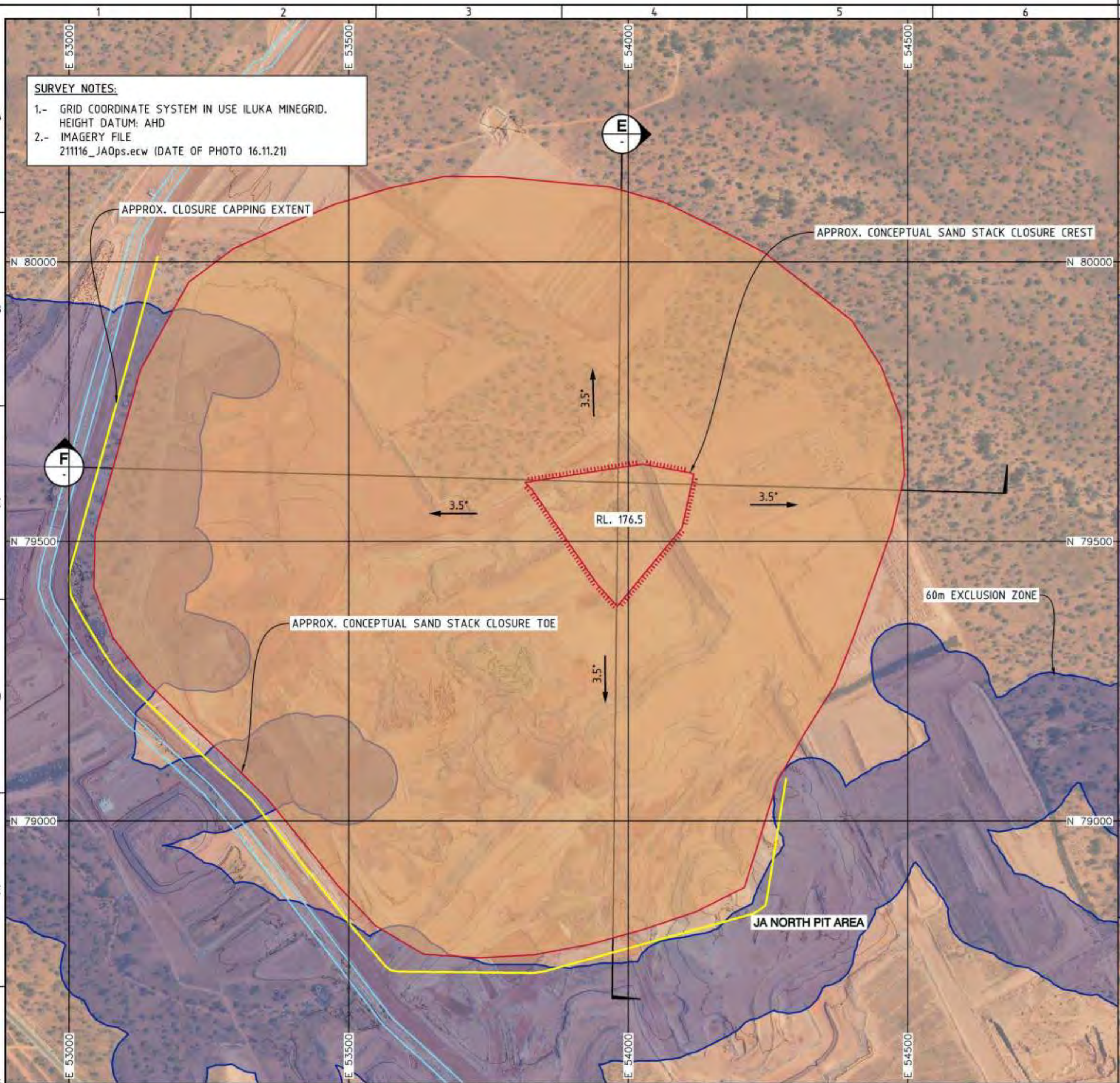

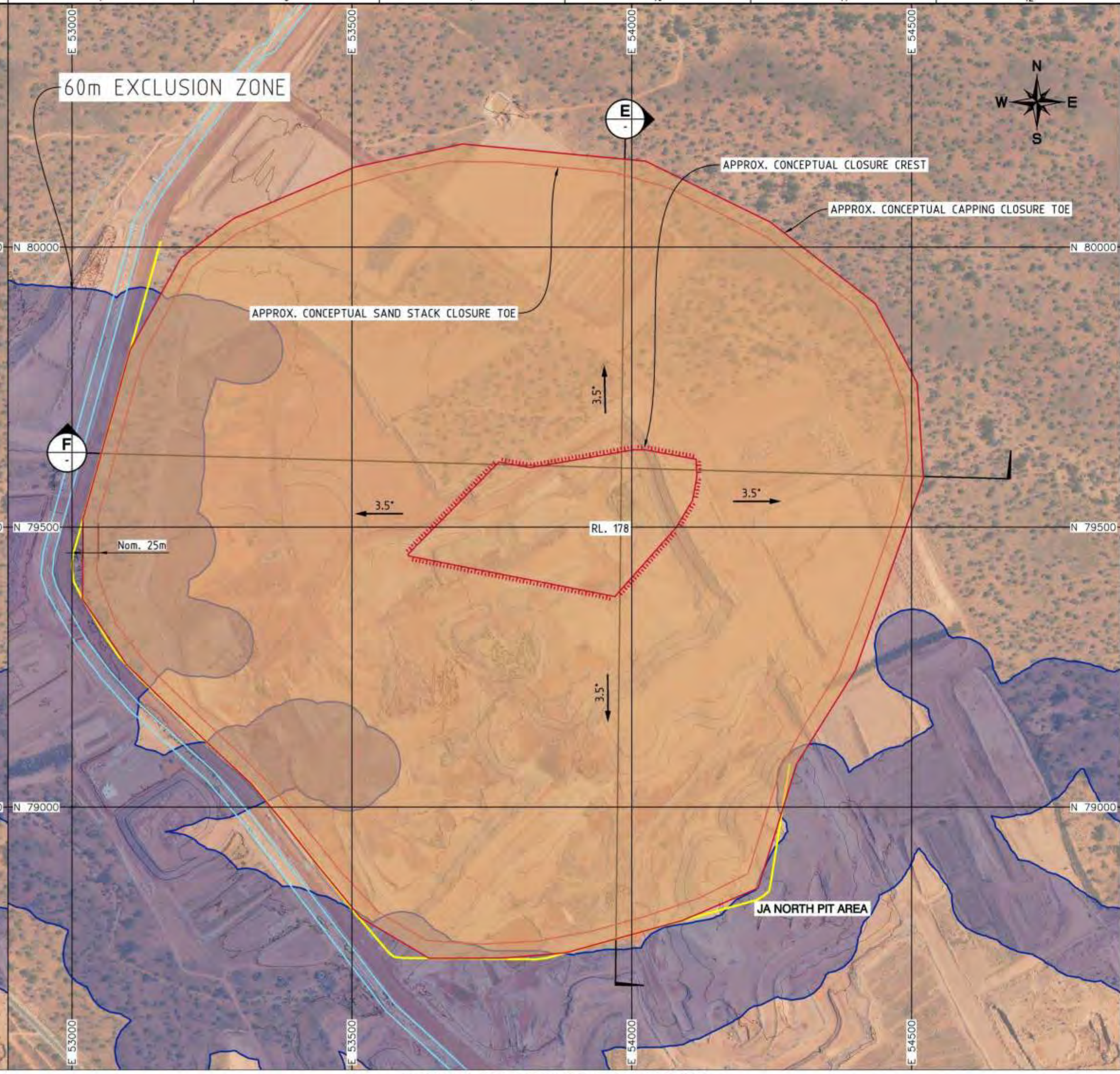

CONCEPTUAL SAND STACK CLOSURE PROFILE

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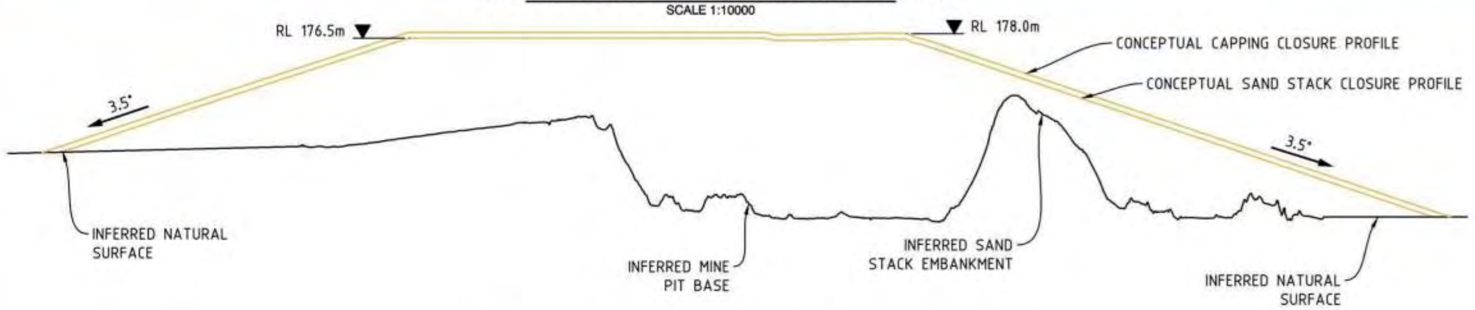

TYPICAL SECTION E NORTH SOUTH

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CONCEPTUAL CAPPING CLOSURE PROFILE

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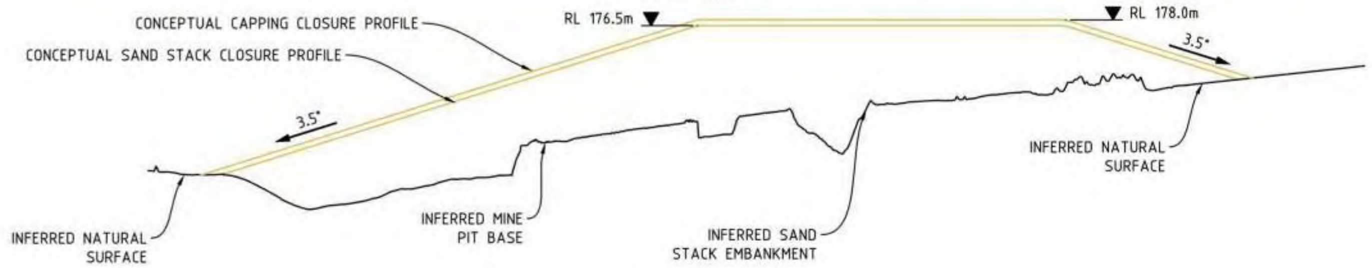

TYPICAL SECTION F EAST WEST

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ILUKA RESOURCES (SA) LTD
ATACAMA

CONCEPTUAL CLOSURE PROFILE (1.5m CAPPING)

DWG. No.

FIGURE 5

SHEET SIZE A3 Rev. A

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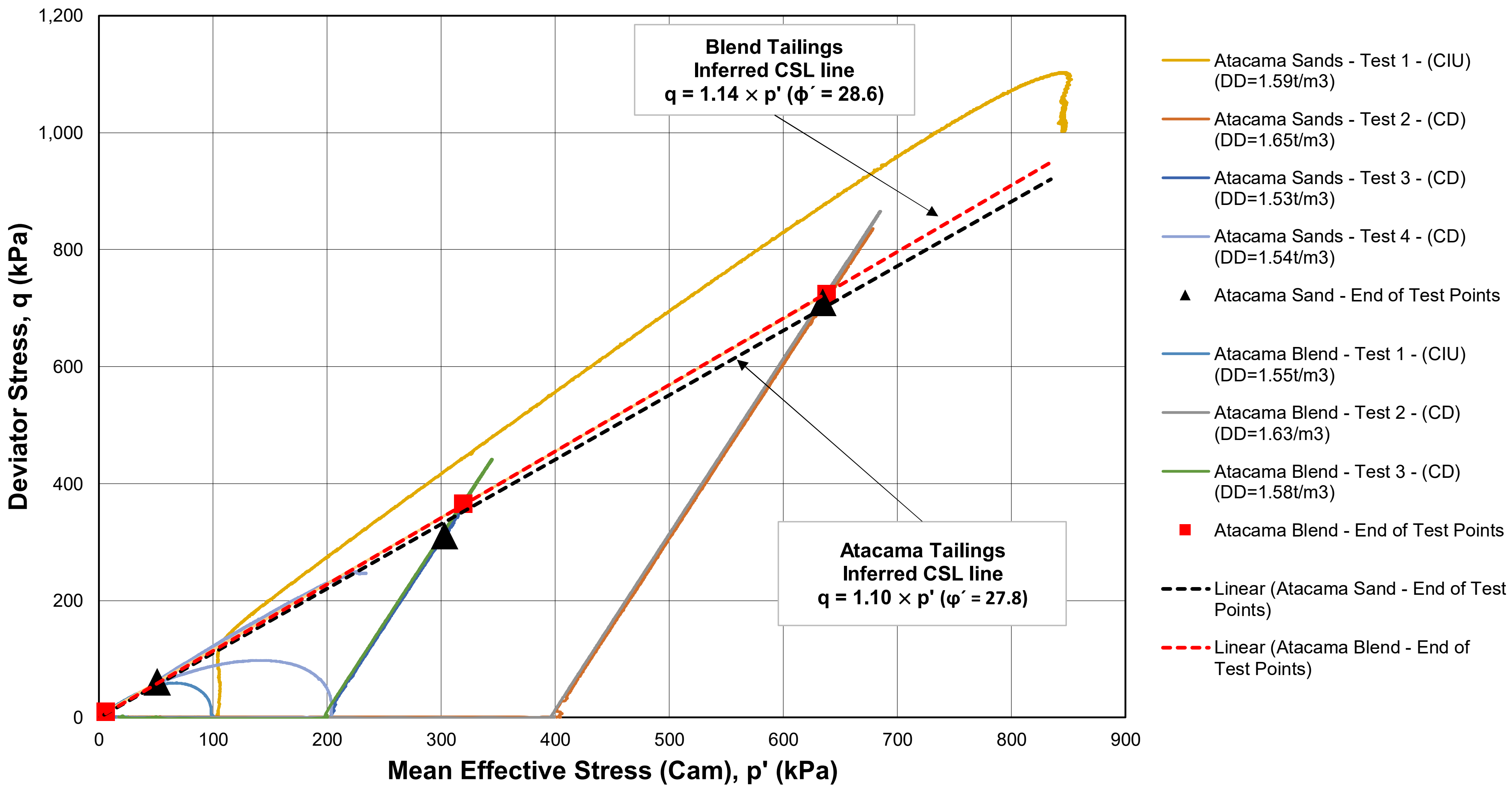
SHEET 1 OF 1

K:\Projects\119\119085 Atacama\02 Tails Placement\CADD\CAD\Figure 5 - Proposed Closure Landform (1.5m Capping).dwg

Printed on: Thursday, 24 November 2022 02:23:25 PM

APPENDICIES

APPENDIX A – TAILINGS LABORATORY TEST CERTIFICATES



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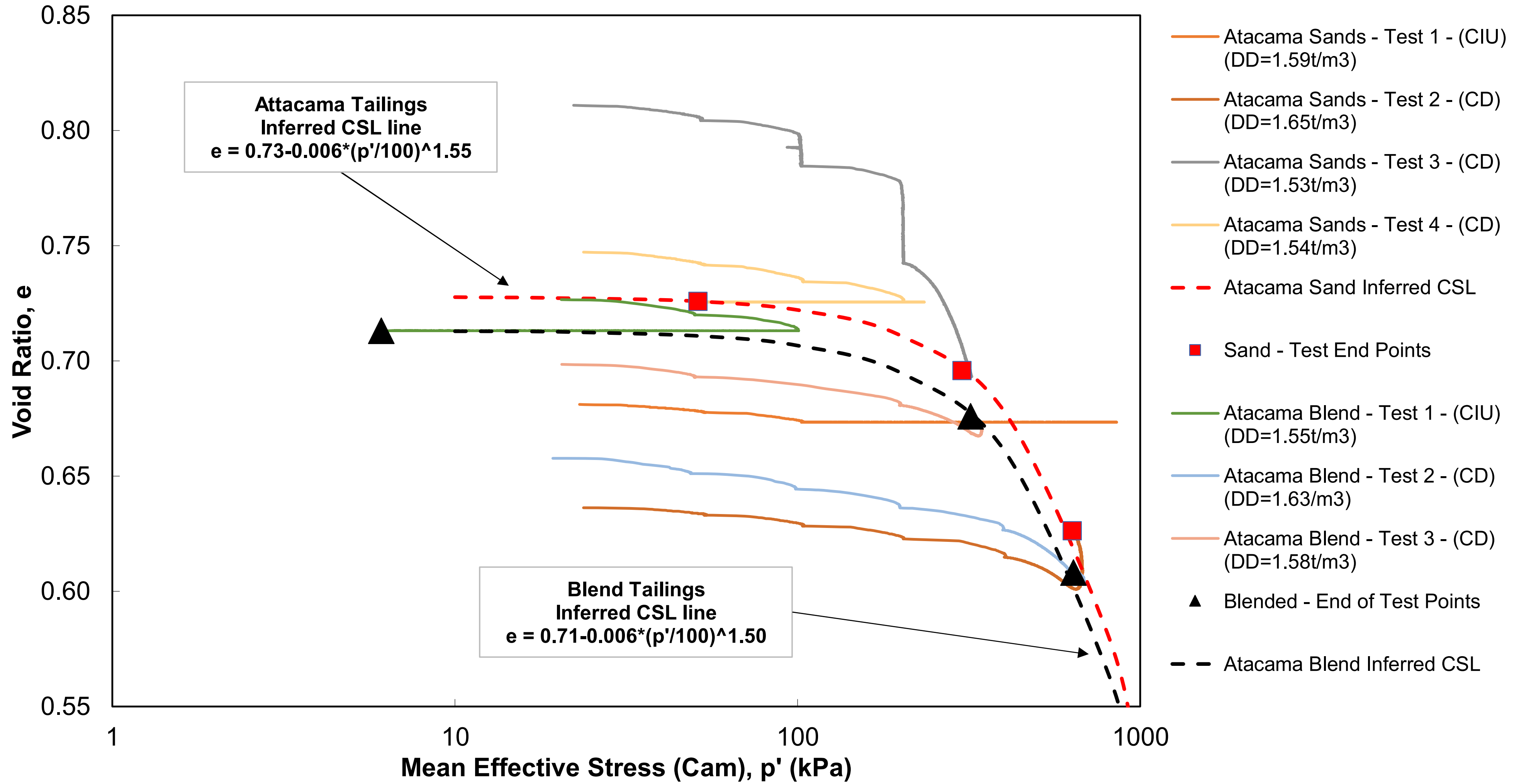
ATACAMA

Triaxial Laboratory Results

Triaxial Stress Paths - Coarse and fine Tailings - Deviator Stress vs Cambridge Mean Eff. Stress

Date:	7/11/2022	**Job No:**	119085.02	**FIGURE A1**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\Lab Test Results\Figure 1 and 2 Figure 1



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ILUKA RESOURCES PTY. LTD.

ATACAMA

Triaxial Laboratory Results

Triaxial Stress Paths - Coarse and fine Tailings - Void Ratio vs Cambridge Mean Eff. Stress

Date:	18/01/2021	**Job No:**	119085.02	**FIGURE A2**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\Lab Test Results\Figure 1 and 2 Figure 2

Determination of the Soil Particle Density of a Soil

TEST IN ACCORDANCE WITH AS 1289.3.5.1

ATC WILLIAMS

Client: Iluka Resources Limited

NATA Report No.: R48222

Address: Level 17, 240 St Georges Terrace, Perth WA 6000

Job No.: 119085.02

Project: Atacama Sands

Location: Australia

Register Number	Sample Description	Test Temperature (°C)	% of Sample >2.36 mm	Particle Density (g/cm³)
33022	Atacama Tailings	18.9	None	2.66 #
33122	Blend Tailings	19.0	None	2.65 #

Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☒ Sample provided by the client

* = apparent average soil particle density – particle size less than 2.36 mm

X = apparent average soil particle density – particle size greater than 2.36 mm

= soil particle density of the total sample

The test results relate only to the items tested.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory ....[signature]..........

Name of Signatory John Walker

Date Tested: 29/7 to 3/8/2022

Date Reported: 4/08/2022

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Form RSN 003.7
Date of Issue: July 2020

Minimum and Maximum Dry Density of a Cohesionless Material

TEST IN ACCORDANCE WITH AS 1289.5.5.1

ATC WILLIAMS

Client: Iluka Resources Limited

NATA Report No.: R48322

Address: Level 17, 240 St Georges Terrace, Perth WA 6000

Job No.: 119085.02

Project: Atacama Sands

Location: Australia

Register Number	Sample Description	Type of Material Size of Mould	Minimum Dry Density ρd min (t/m^3)	Maximum Dry Density ρd max (t/m^3)
33022	Atacama Tailings	Sand – Proctor	1.36	1.69
33122	Blend Tailings	Sand - Proctor	1.43	1.75

Notes:

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☒ Sample provided by the client

The test results relate only to the items tested.

NATA ACCREDITED FOR TECHNICAL COMPETENCE

NATA ACCREDITED LABORATORY NUMBER: 3372

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory .... [signature] ....

Name of Signatory John Walker

Date Tested: 29/7 to 3/8/2022

Date Reported: 4/8/2022

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Form RSN 015.3
Date of Issue: July 2020

Particle Size Distribution Results

TEST IN ACCORDANCE WITH AS 1289

☑ Method 3.6.1 ☐ Method 3.6.3

☑ Oven Drying Method 2.1.1

ATC WILLIAMS

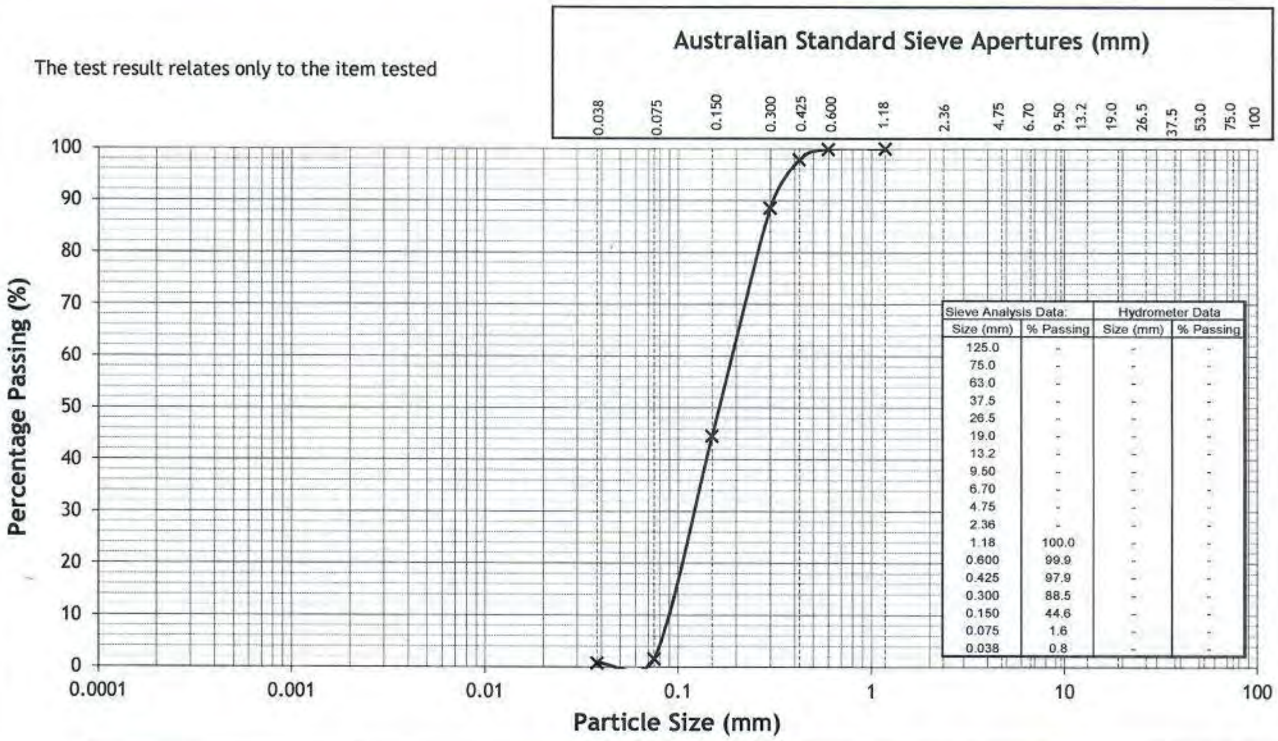
Client:	Iluka Resources Limited	**NATA Report No.:**	**R48422**
Address:	Level 17, 240 St Georges Terrace, Perth WA 6000	**Job No.:**	119085.02
		Register No.:	33122
Project:	Atacama Sands	**Location:**	Australia

Sample Description: Blend Tailings		Borehole No: ☐	Test Pit Depth: ☐

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☑ Sample provided by the Client

The test result relates only to the item tested



Sieve Analysis Data:		Hydrometer Data	
Size (mm)	% Passing	Size (mm)	% Passing
125.0	-	-	-
75.0	-	-	-
63.0	-	-	-
37.5	-	-	-
26.5	-	-	-
19.0	-	-	-
13.2	-	-	-
9.50	-	-	-
6.70	-	-	-
4.75	-	-	-
2.36	-	-	-
1.18	100.0	-	-
0.600	99.9	-	-
0.425	97.9	-	-
0.300	88.5	-	-
0.150	44.6	-	-
0.075	1.6	-	-
0.038	0.8	-	-

CLAY	SILT			SAND			GRAVEL			COBBLES
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	

0.002 0.006 0.02 0.06 0.2 0.6 2 6 20 60

NATA ACCREDITED LABORATORY NUMBER: 3372

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: [signature] Date Tested: 28/7 - 3/8/2022

Name of Signatory: John Walker Date Reported: 4/8/2022

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Form RSN 004.16 (PSD)
Date of Issue: July 2020

Particle Size Distribution Results

TEST IN ACCORDANCE WITH AS 1289

☑ Method 3.6.1 ☐ Method 3.6.3

☑ Oven Drying Method 2.1.1

ATC WILLIAMS

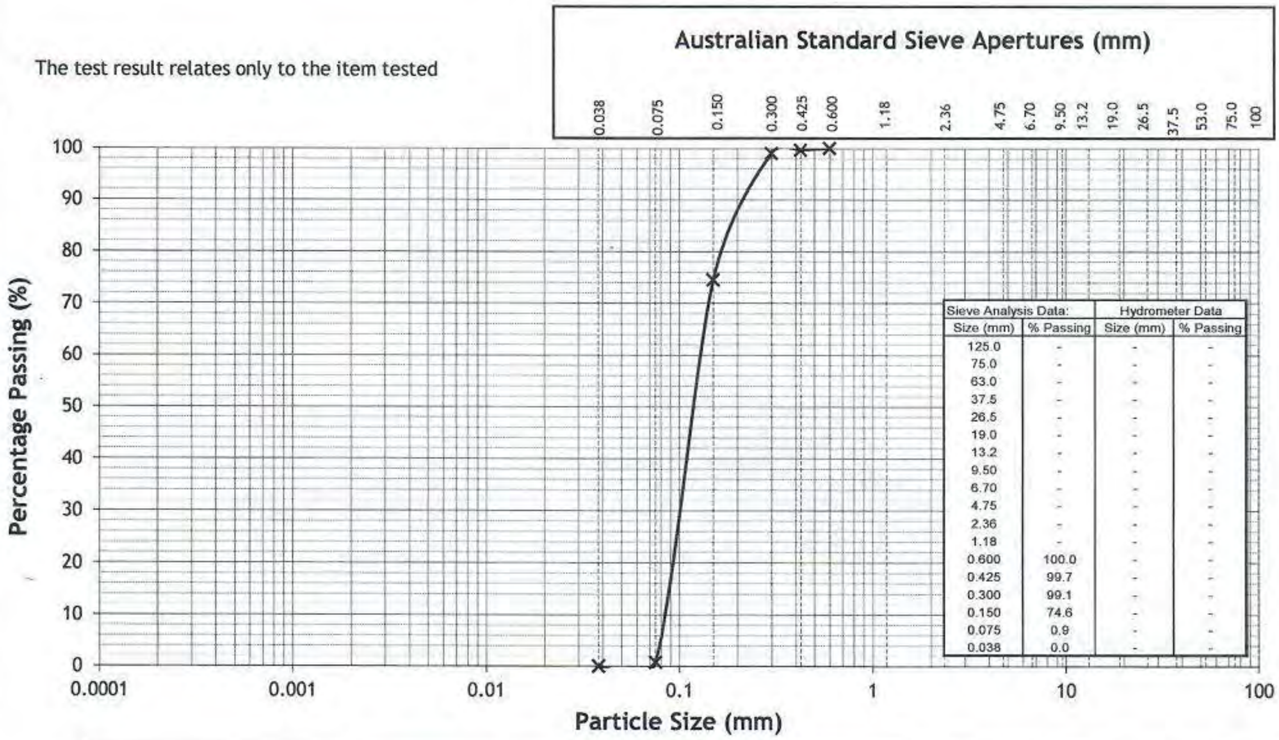
Client:	Iluka Resources Limited	**NATA Report No.:**	**R48522**
Address:	Level 17, 240 St Georges Terrace, Perth WA 6000	**Job No.:**	119085.02
		Register No.:	33022
Project:	Atacama Sands	**Location:**	Australia

Sample Description: Atacama Tailings	Borehole No: ☐	Test Pit Depth: ☐

☐ Sampled by ATC Williams Pty Ltd in accordance with AS 1289.1.2.1

☑ Sample provided by the Client

The test result relates only to the item tested



Sieve Analysis Data:		Hydrometer Data	
Size (mm)	% Passing	Size (mm)	% Passing
125.0	-	-	-
75.0	-	-	-
63.0	-	-	-
37.5	-	-	-
26.5	-	-	-
19.0	-	-	-
13.2	-	-	-
9.50	-	-	-
6.70	-	-	-
4.75	-	-	-
2.36	-	-	-
1.18	-	-	-
0.600	100.0	-	-
0.425	99.7	-	-
0.300	99.1	-	-
0.150	74.6	-	-
0.075	0.9	-	-
0.038	0.0	-	-

CLAY	SILT			SAND			GRAVEL			COBBLES
	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	

0.002 0.006 0.02 0.06 0.2 0.6 2 6 20 60

NATA ACCREDITED LABORATORY NUMBER: 3372

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: [signature]

Date Tested: 28/7 - 3/8/2022

Name of Signatory: John Walker

Date Reported: 4/8/2022

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Form RSN 004.16 (PSD)
Date of Issue: July 2020

Triaxial Testing - CIU

- Tested in accordance with In House Method (IHM) 15.0
- ATCW IHM 15.0 incorporates both AS1289.6.4.2 and ASTM D5311-13
- Moisture content determined in accordance with AS1289.2.1.1
- Triaxial testing performed using the "STDv2" apparatus

ATC WILLIAMS

Client:	Iluka Resources Limited		
Address:	LV 17 240 St Georges Terrace	Job No.:	119085.02
	Perth , 6000 WA	Register No.:	33122
Project:	Attacama Blend Sands	Location:	WA

Report Details:

Report Author:	LR	Report Issued:	6/09/2022
Checked By:	MM	Report Last Updated:	6/09/2022 13:44

Test Details:

Test Start Date:	26/08/2022	Operator:	LR
Test End Date:	29/08/2022	Membrane Thick.:	1000 µm
Test Type:	CIU	Accessible Drainage:	Double

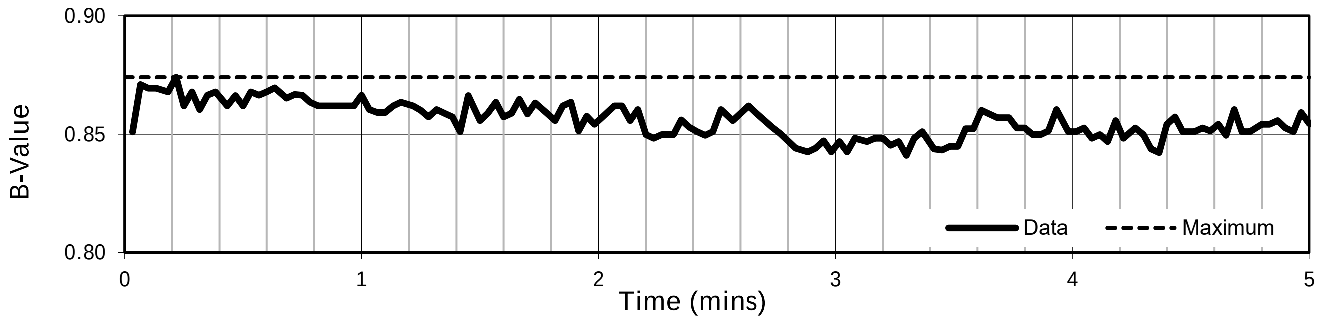
Sample Details:

Register Number:	33122	Date Sampled:	N/A
Test Number:	1	Sampled By:	Client
Description:	Blend Tails	Sample Type:	Remoulded
Borehole Number:	N/A	Percent Compaction:	25 % RD
Depth:	N/A	Particle Density[1], ρ_{st}:	2.65 t/m^3

Specimen Details:

Initial Height:	152.24 mm	Dry Mass, M_d:	1008.19 g
Initial Diameter:	75.00 mm	Initial Area:	44.18 cm^2

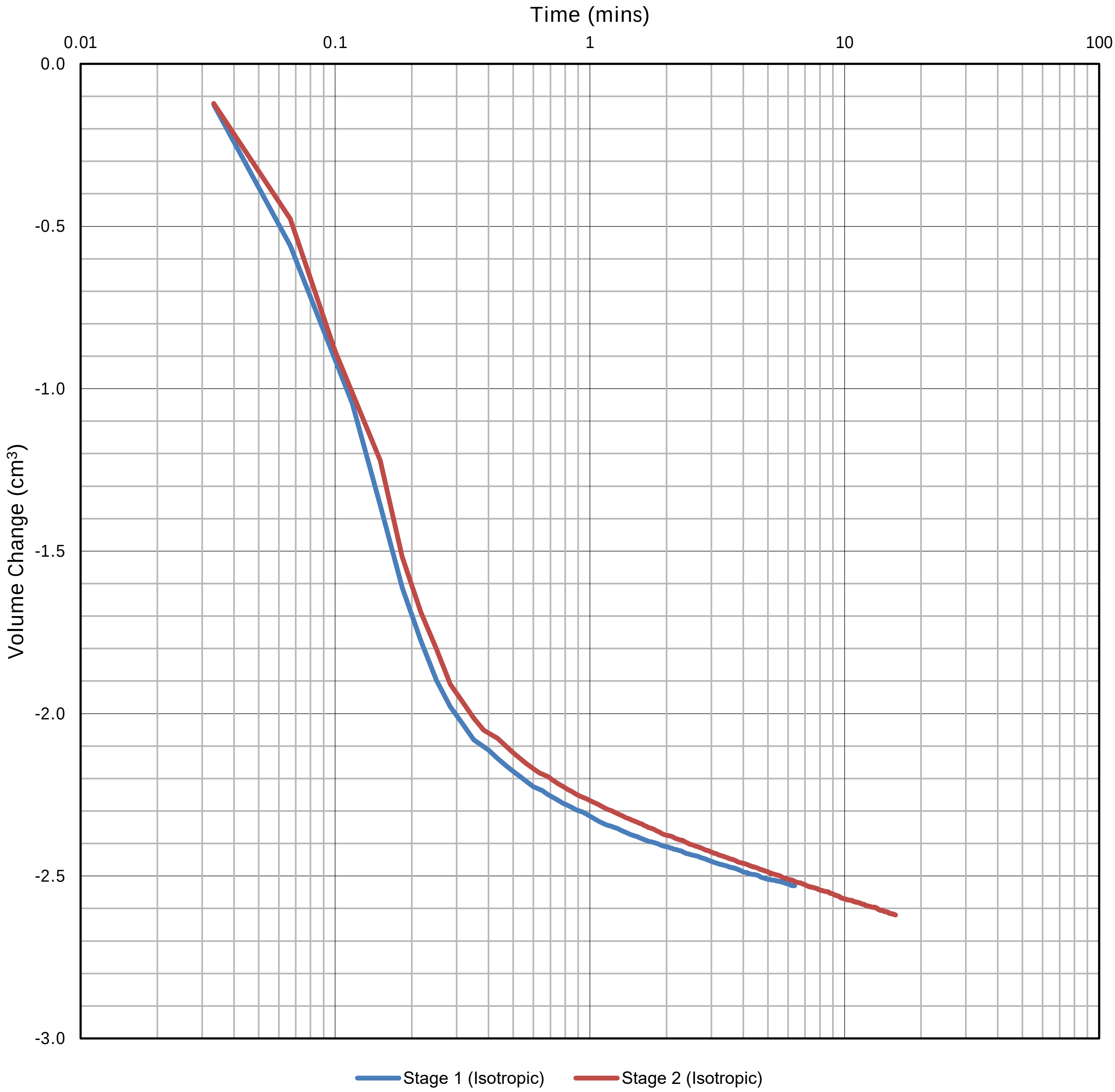
	Placed[2]	Saturated[2]	
Volume, V:	672.58	656.90	cm^3
Dry Density, ρ_d:	1.50	1.53	t/m^3
Void Ratio, e:	0.77	0.73	
Moisture Content, w:	5.20	27.42	%
Degree of Saturation, S:	18	100	%
Effective Confining Pressure, σ'_3:	0	17	kPa



Skempton's B-Value: 0.87 maximum recorded over a 5 minute period.

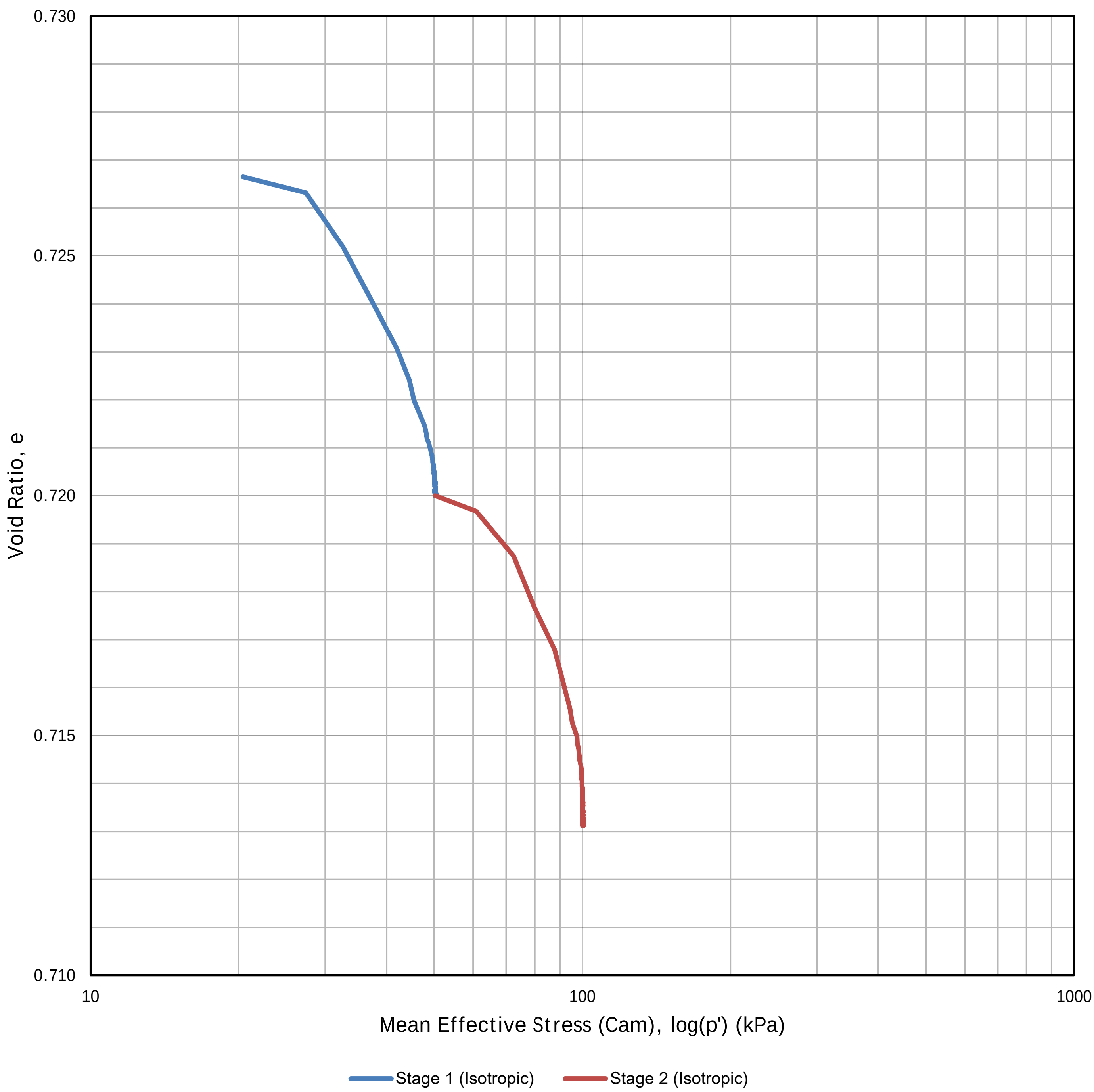
[1] The particle density provided has been directly measured according to AS1289.3.5.1

[2] 'Placed' parameters are directly measured. 'Saturated' are back calculated from the final moisture content.



Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Effective Confining Pressure, σ'_3:	50	100	-	-	-	-	-	kPa
Effective Axial Pressure, σ'_1:	51	101	-	-	-	-	-	kPa
Deformation During Stage, ΔH:	0.04	0.04	-	-	-	-	-	mm
Volume Change, ΔV:	-2.53	-2.62	-	-	-	-	-	cm^3
Total Volume of Sample, V:	654.37	651.75	-	-	-	-	-	cm^3
Coefficient of Consolidation, C_v:	5111	5089	-	-	-	-	-	m^2/yr
Hydraulic Conductivity (from C_v), k_v:	1.87E-07	1.26E-07	-	-	-	-	-	m/s

Iluka Resources Limited Attacama Blend Sands Triaxial - CIU - Consolidation (Pre-shearing)	33122 Blend Tails Test 1
ATC WILLIAMS	Job No: 119085.02 Date: 6/09/2022
	FIGURE 1



Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Mean Effective Stress (Cam), p':	50	100	-	-	-	-	-	kPa
Effective Confining Pressure, σ'_3:	50	100	-	-	-	-	-	kPa
Effective Axial Pressure, σ'_1:	51	101	-	-	-	-	-	kPa
Dry Density, ρ_d:	1.54	1.55	-	-	-	-	-	t/m^3
Void Ratio, e:	0.72	0.71	-	-	-	-	-	
Moisture Content (Calculated), w:	27.2	26.9	-	-	-	-	-	%

Iluka Resources Limited	33122
Attacama Blend Sands	Blend Tails
Triaxial - CIU - Stress Path (Pre-shearing) - e/log(p')	Test 1

ATC WILLIAMS

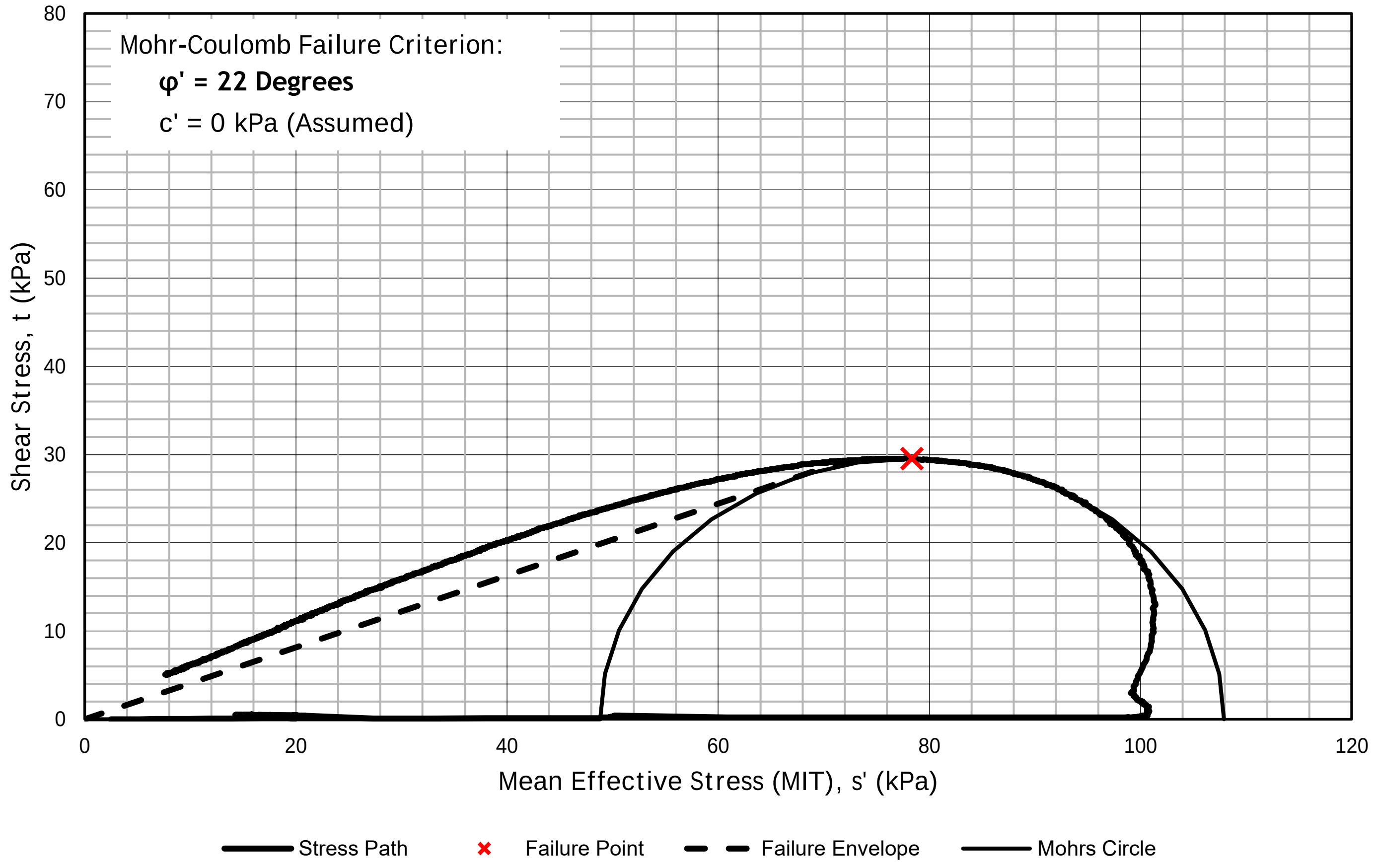
Job No:	119085.02
Date:	6/09/2022

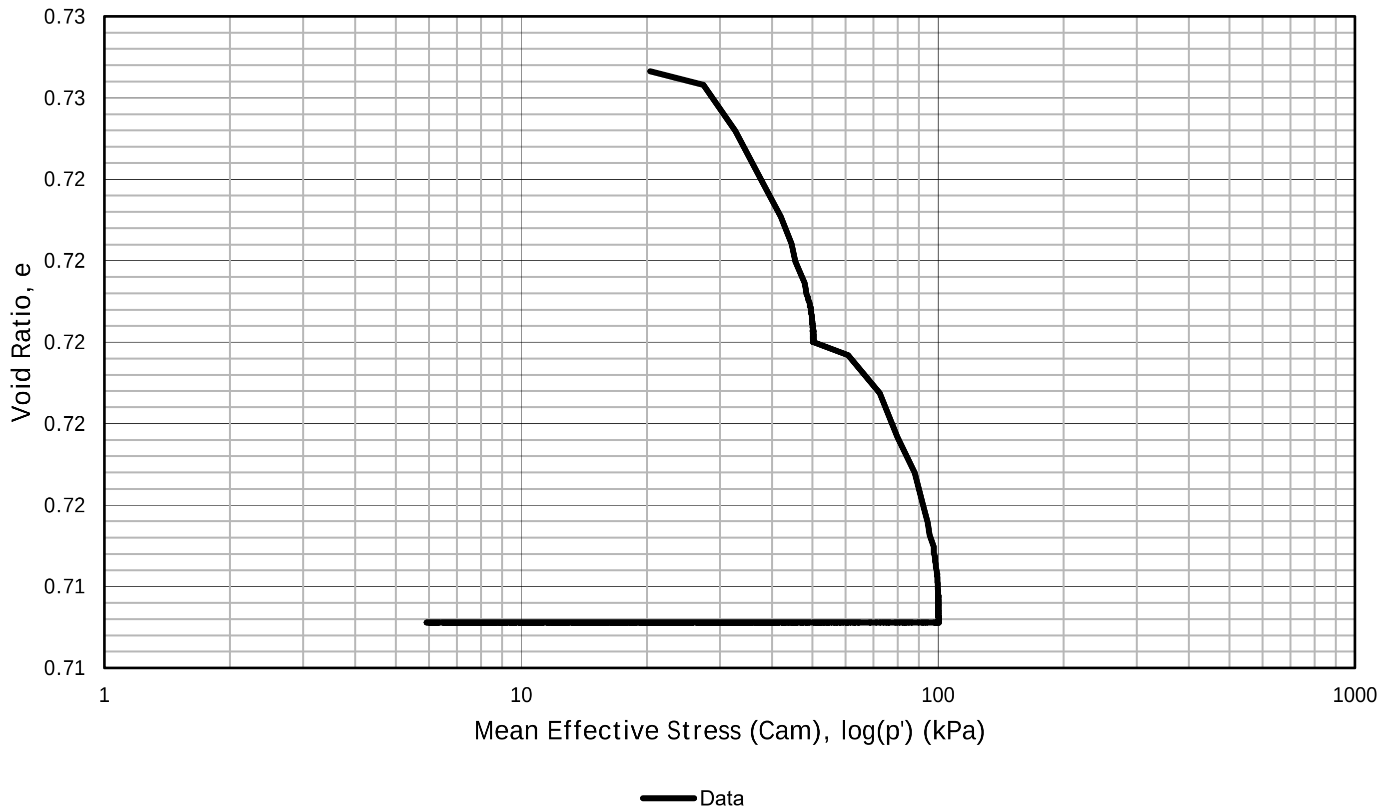
FIGURE 2

Undrained Monotonic Shear Stages:	Stage 1	Stage 2	Stage 3	
Initial Mean Effective Stress (Cam), p':	100	-	-	kPa
Initial Effective Confining Pressure, σ'_3:	100	-	-	kPa
Initial Effective Axial Pressure, σ'_1:	101	-	-	kPa
Dry Density, ρ_d:	1.55	-	-	t/m^3
Void Ratio, e:	0.71	-	-	
Moisture Content (Calculated), w:	26.9	-	-	%
Shear Rate, $\dot{\varepsilon}$:	0.05	-	-	mm/min
Failure Criteria:	Max q	-	-	
Axial Strain at Failure, ε_a:	0.5	-	-	%
Deviator Stress at Failure[1], q:	59	-	-	kPa
Undrained Shear Stress at Failure, S_u:	30	-	-	kPa
Mean Effective Stress (Cam) at Failure, p':	69	-	-	kPa
Mean Effective Stress (MIT) at Failure, s':	78	-	-	kPa
Effective Confining Pressure at Failure, σ'_3:	49	-	-	kPa
Effective Axial Stress at Failure, σ'_1:	108	-	-	kPa
Excess Pore Pressure at Failure, u:	51	-	-	kPa
Mode of Failure:	Barrelling			
Undrained Shear Strength Ratio, S_u/σ'_1:	0.29	-	-	
Internal Friction Angle, ϕ':	22			°

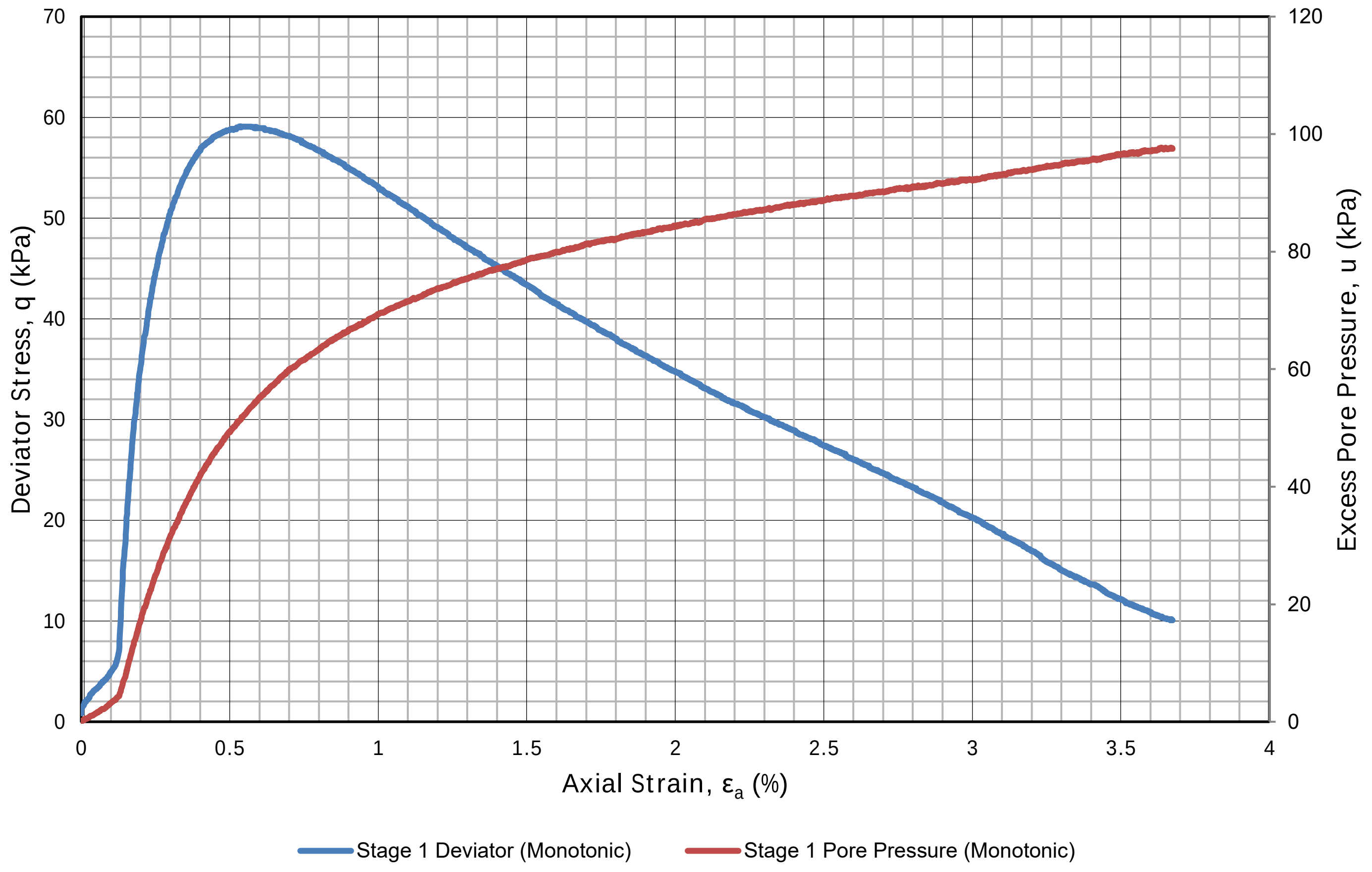
[1] Membrane correction has been applied.

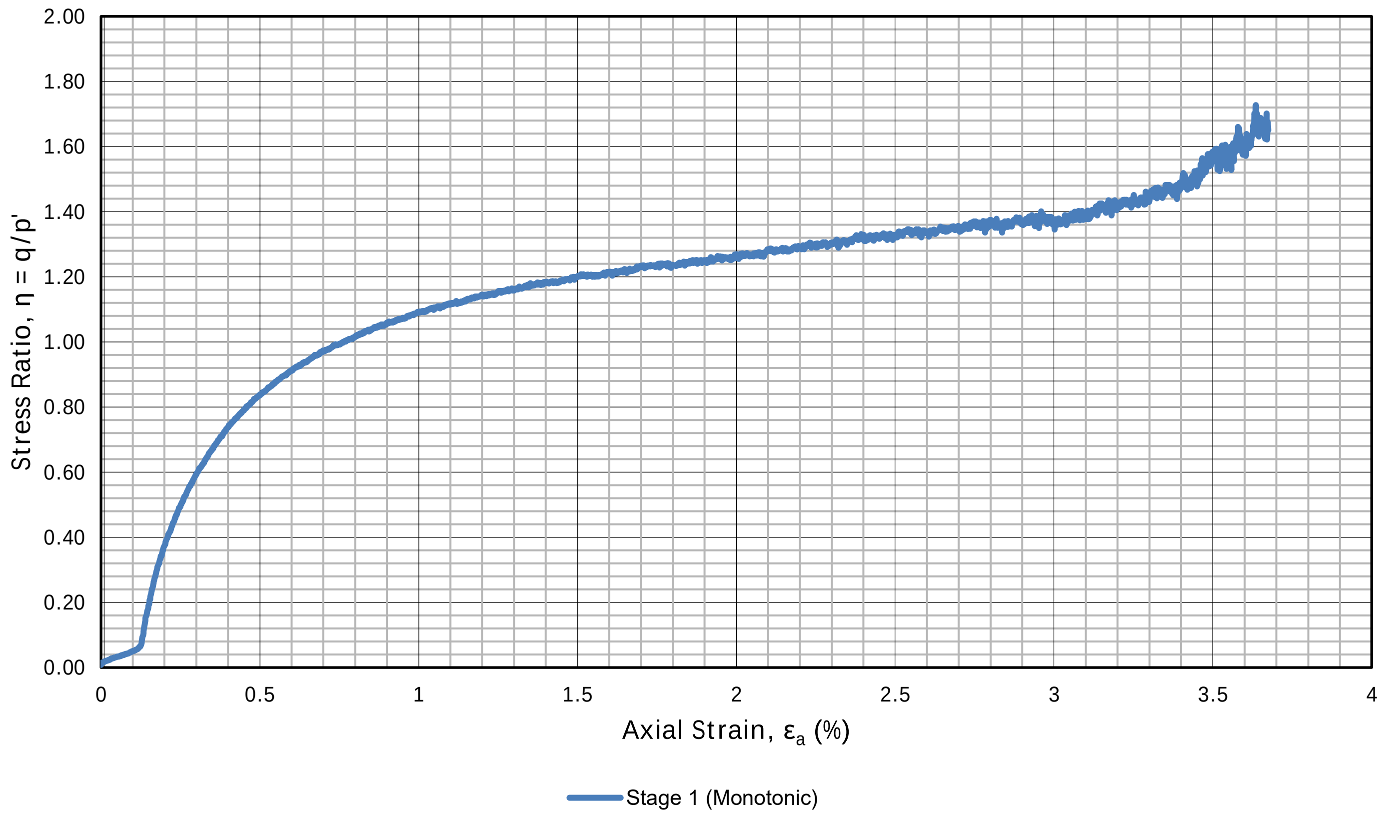
Iluka Resources Limited Attacama Blend Sands Triaxial - CIU - Stress Path - q/p'	33122 Blend Tails Test 1
ATC WILLIAMS	Job No: 119085.02 Date: 6/09/2022
	FIGURE 3





Iluka Resources Limited Attacama Blend Sands Triaxial - CIU - Stress Paths - S_u/s' and e/log(p')	33122 Blend Tails Test 1
ATC WILLIAMS	Job No: 119085.02 Date: 6/09/2022
	FIGURES 4 & 5





Iluka Resources Limited Attacama Blend Sands **Triaxial - CIU - q, u and q/p' vs ε_a**	33122 Blend Tails Test 1
ATC WILLIAMS	Job No: 119085.02 Date: 6/09/2022 FIGURES 6 & 7

Sample prior to shearing.

Sample after shearing, still within membrane.

Sample after removal from membrane.

Sample after shearing, sliced down center.

Measured Angle of Shear Plane from Horizontal, α:	N/A	°

Iluka Resources Limited Attacama Blend Sands Triaxial - CIU - Images and Angle of Shear Plane	33122 Blend Tails Test 1
ATC WILLIAMS	Job No: 119085.02 Date: 6/09/2022 FIGURES 8 to 11

Triaxial Testing - CD

- Tested in accordance with In House Method (IHM) 15.0
- ATCW IHM 15.0 incorporates both AS1289.6.4.2 and ASTM D5311-13
- Moisture content determined in accordance with AS1289.2.1.1
- Triaxial testing performed using the "STDv2" apparatus

ATC WILLIAMS

Client:	Iluka Resources Limited		
Address:	LV 17 240 St Georges Terrace	Job No.:	119085.02
	Perth , 6000 WA	Register No.:	33122
Project:	Attacama Blend Sands	Location:	WA

Report Details:

Report Author:	LR	Report Issued:	6/09/2022
Checked By:	MM	Report Last Updated:	6/09/2022 10:30

Test Details:

Test Start Date:	29/08/2022	Operator:	LR
Test End Date:	31/08/2022	Membrane Thick.:	1000 µm
Test Type:	CD	Accessible Drainage:	Double

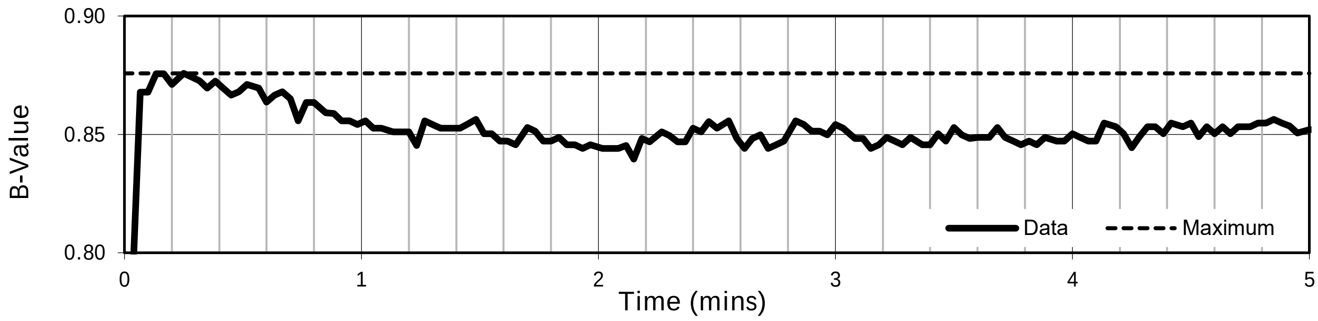
Sample Details:

Register Number:	33122	Date Sampled:	N/A
Test Number:	2	Sampled By:	Client
Description:	Blend Tails	Sample Type:	Remoulded
Borehole Number:	N/A	Percent Compaction:	25 % RD
Depth:	N/A	Particle Density[1], ρ_{st}:	2.65 t/m^3

Specimen Details:

Initial Height:	152.24 mm	Dry Mass, M_d:	1008.19 g
Initial Diameter:	75.00 mm	Initial Area:	44.18 cm^2

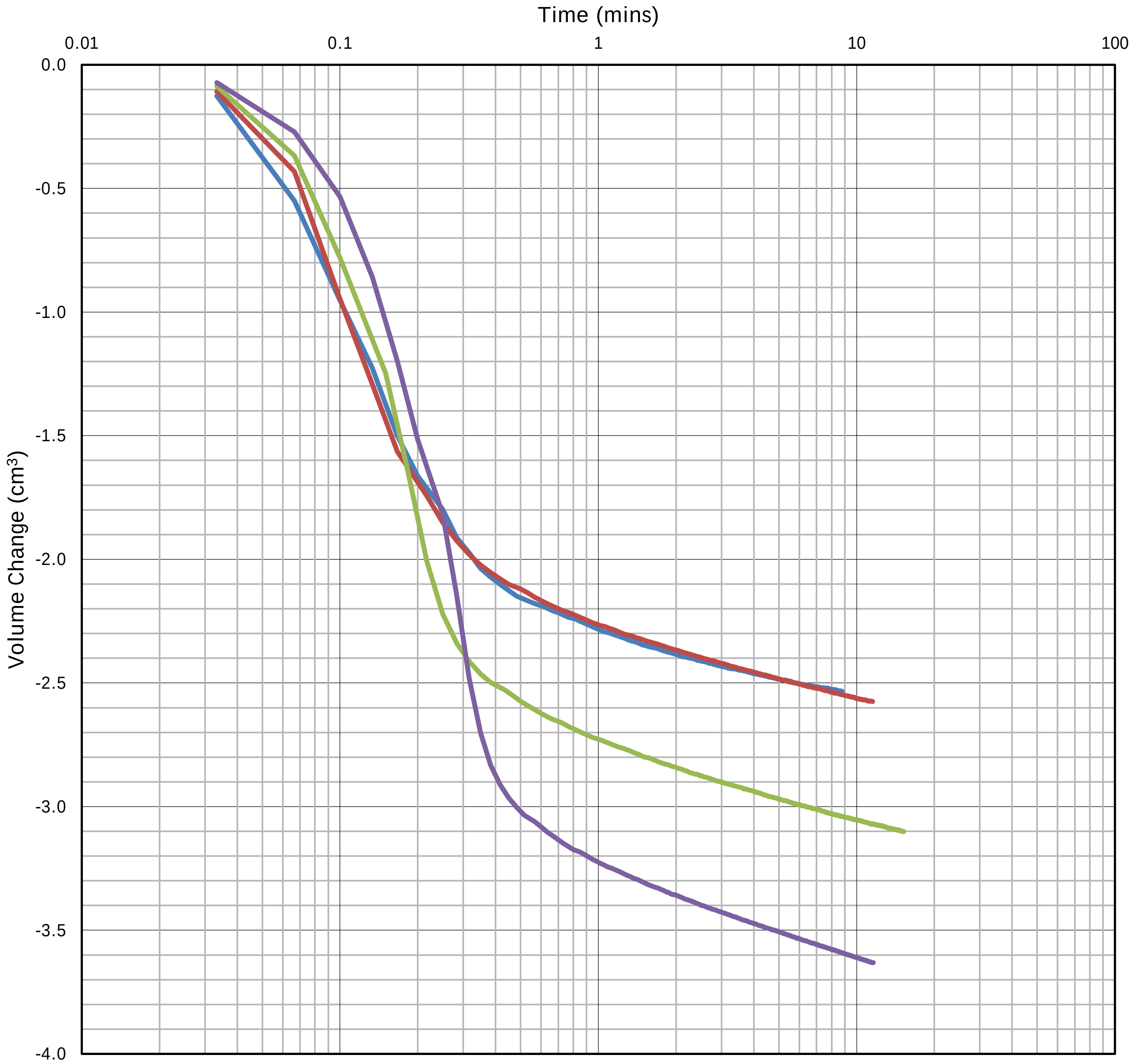
	Placed[2]	Saturated[2]	
Volume, V:	672.58	630.71	cm^3
Dry Density, ρ_d:	1.50	1.60	t/m^3
Void Ratio, e:	0.77	0.66	
Moisture Content, w:	5.20	24.82	%
Degree of Saturation, S:	18	100	%
Effective Confining Pressure, σ'_3:	0	16	kPa



Skempton's B-Value: 0.88 maximum recorded over a 5 minute period.

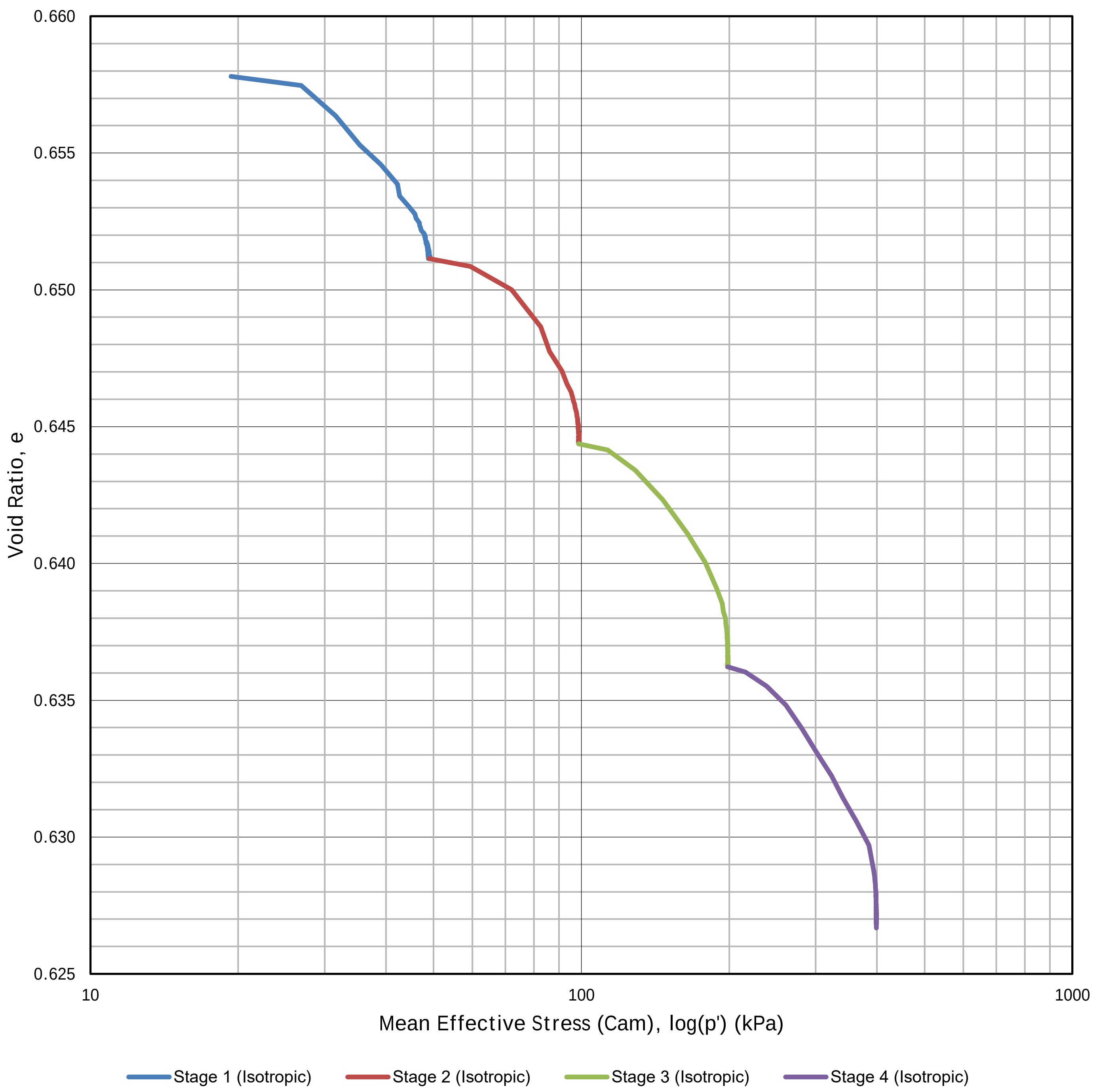
[1] The particle density provided has been directly measured according to AS1289.3.5.1

[2] 'Placed' parameters are directly measured. 'Saturated' are back calculated from the final moisture content.



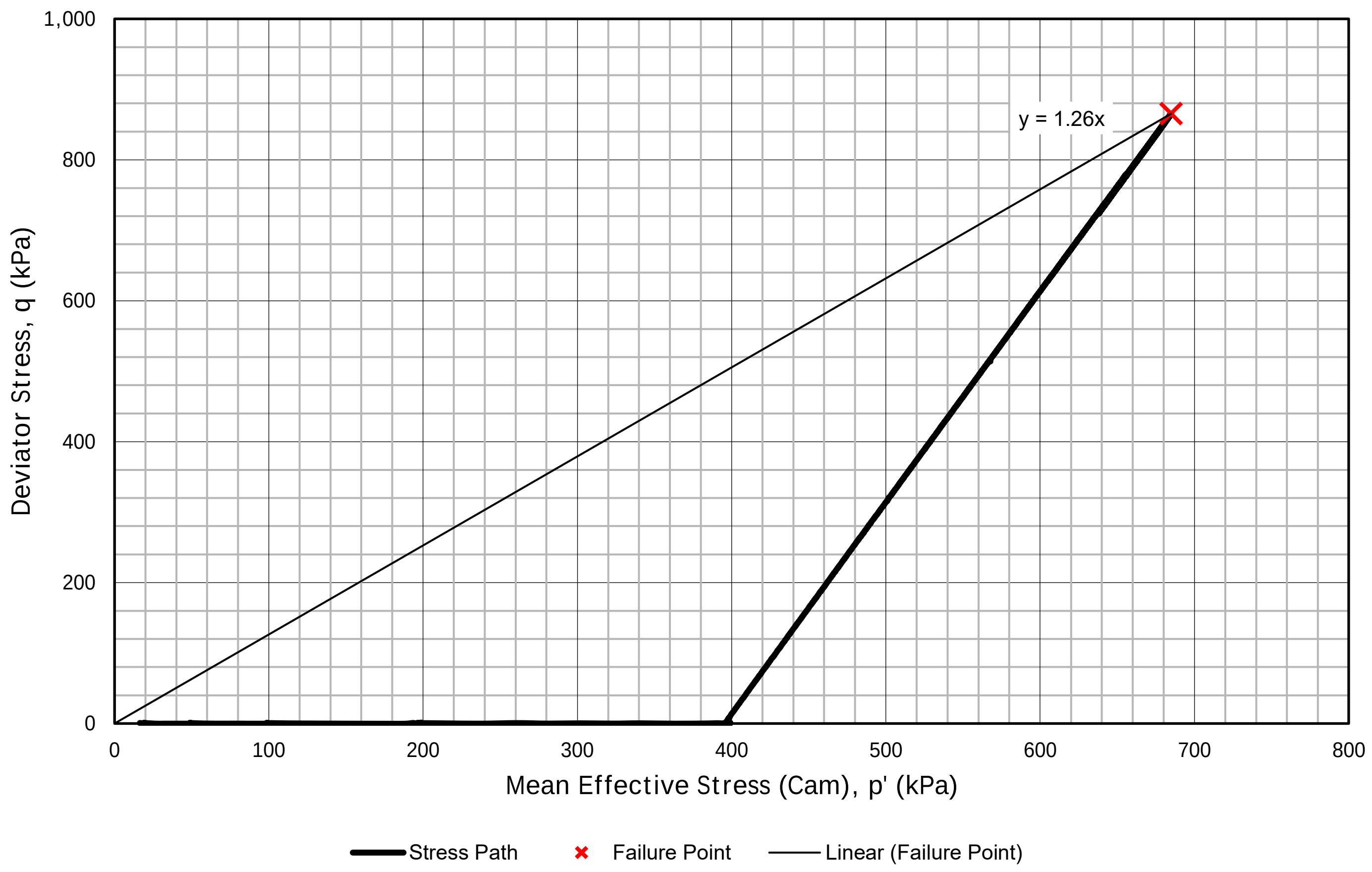
Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Effective Confining Pressure, σ'_3:	49	99	199	398	-	-	-	kPa
Effective Axial Pressure, σ'_1:	49	99	199	399	-	-	-	kPa
Deformation During Stage, ΔH:	0.09	0.10	0.13	0.19	-	-	-	mm
Volume Change, ΔV:	-2.53	-2.58	-3.10	-3.63	-	-	-	cm^3
Total Volume of Sample, V:	628.17	625.60	622.50	618.87	-	-	-	cm^3
Coefficient of Consolidation, C_v:	5528	5730	4443	3153	-	-	-	m^2/yr
Hydraulic Conductivity (from C_v), k_v:	2.1E-07	1.46E-07	6.83E-08	2.86E-08	-	-	-	m/s

Iluka Resources Limited Attacama Blend Sands Triaxial - CD - Consolidation (Pre-shearing)	33122 Blend Tails Test 2
ATC WILLIAMS	Job No: 119085.02 Date: 6/09/2022 FIGURE 1



Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Mean Effective Stress (Cam), p':	49	99	199	399	-	-	-	kPa
Effective Confining Pressure, σ'_3:	49	99	199	398	-	-	-	kPa
Effective Axial Pressure, σ'_1:	49	99	199	399	-	-	-	kPa
Dry Density, ρ_d:	1.60	1.61	1.62	1.63	-	-	-	t/m^3
Void Ratio, e:	0.65	0.64	0.64	0.63	-	-	-	
Moisture Content (Calculated), w:	24.6	24.3	24.0	23.6	-	-	-	%

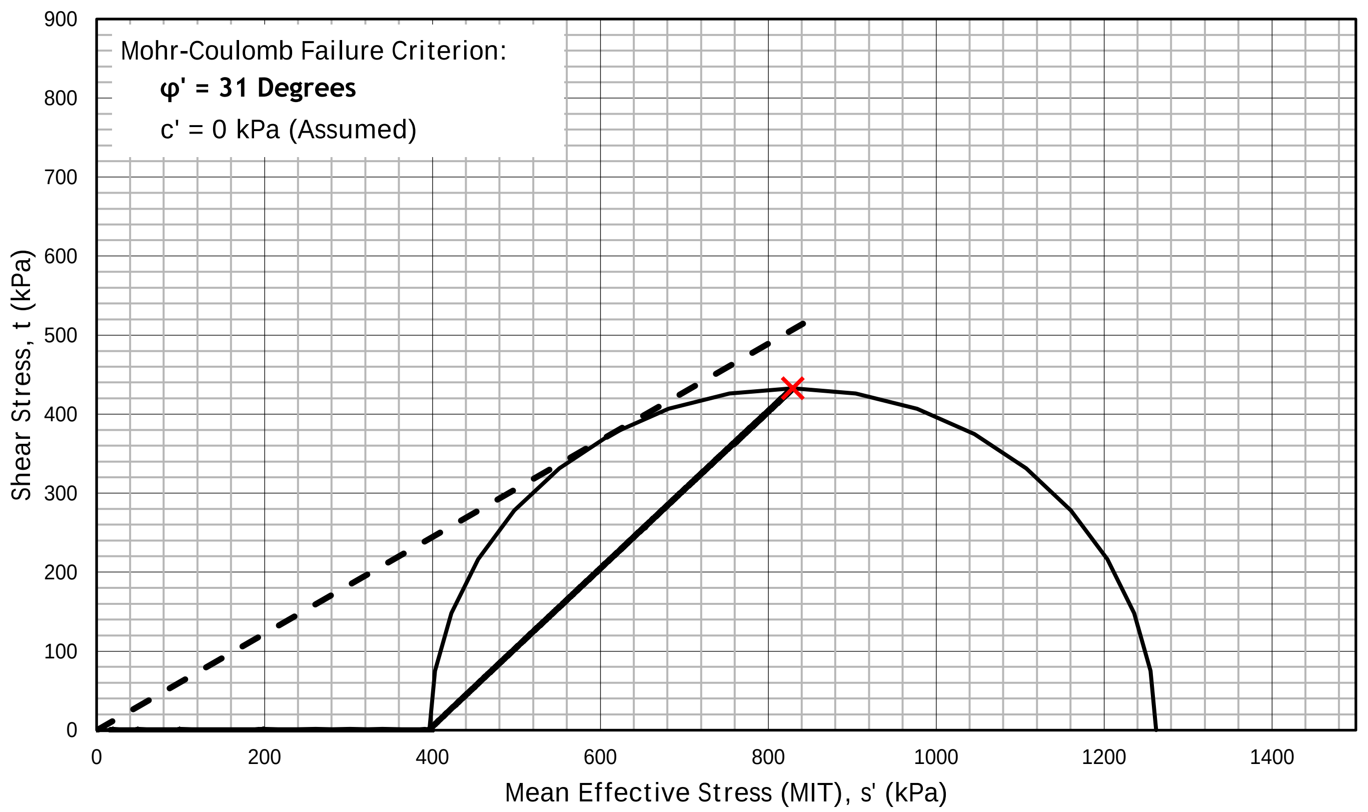
Iluka Resources Limited Attacama Blend Sands Triaxial - CD - Stress Path (Pre-shearing) - e/log(p')	33122 Blend Tails Test 2
ATC WILLIAMS	Job No: 119085.02 Date: 6/09/2022 FIGURE 2

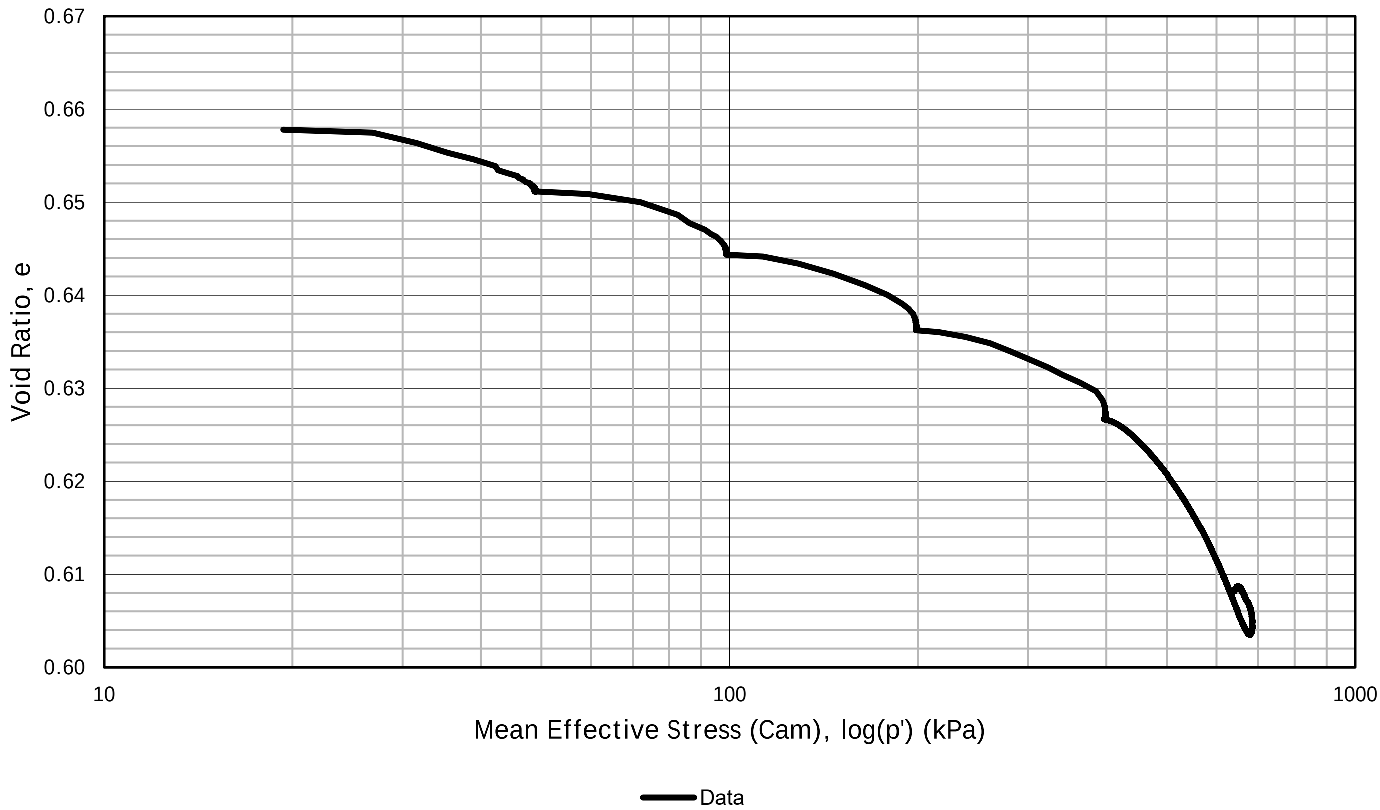


Undrained Monotonic Shear Stages:	Stage 1	Stage 2	Stage 3	
Initial Mean Effective Stress (Cam), p':	399	-	-	kPa
Initial Effective Confining Pressure, σ'_3:	399	-	-	kPa
Initial Effective Axial Pressure, σ'_1:	399	-	-	kPa
Dry Density, ρ_d:	1.63	-	-	t/m^3
Void Ratio, e:	0.63	-	-	
Moisture Content (Calculated), w:	23.6	-	-	%
Shear Rate, $\dot{\varepsilon}$:	0.05	-	-	mm/min
Failure Criteria:	Max q	-	-	
Axial Strain at Failure, ε_a:	8.8	-	-	%
Deviator Stress at Failure[1], q:	865	-	-	kPa
Undrained Shear Stress at Failure, t:	433	-	-	kPa
Mean Effective Stress (Cam) at Failure, p':	685	-	-	kPa
Mean Effective Stress (MIT) at Failure, s':	829	-	-	kPa
Effective Confining Pressure at Failure, σ'_3:	396	-	-	kPa
Effective Axial Stress at Failure, σ'_1:	1262	-	-	kPa
Excess Pore Pressure at Failure, u:	-	-	-	kPa
Mode of Failure:	Barrelling			
Undrained Shear Strength Ratio, S_u/σ'_1:	-	-	-	
Internal Friction Angle, ϕ':	31			°

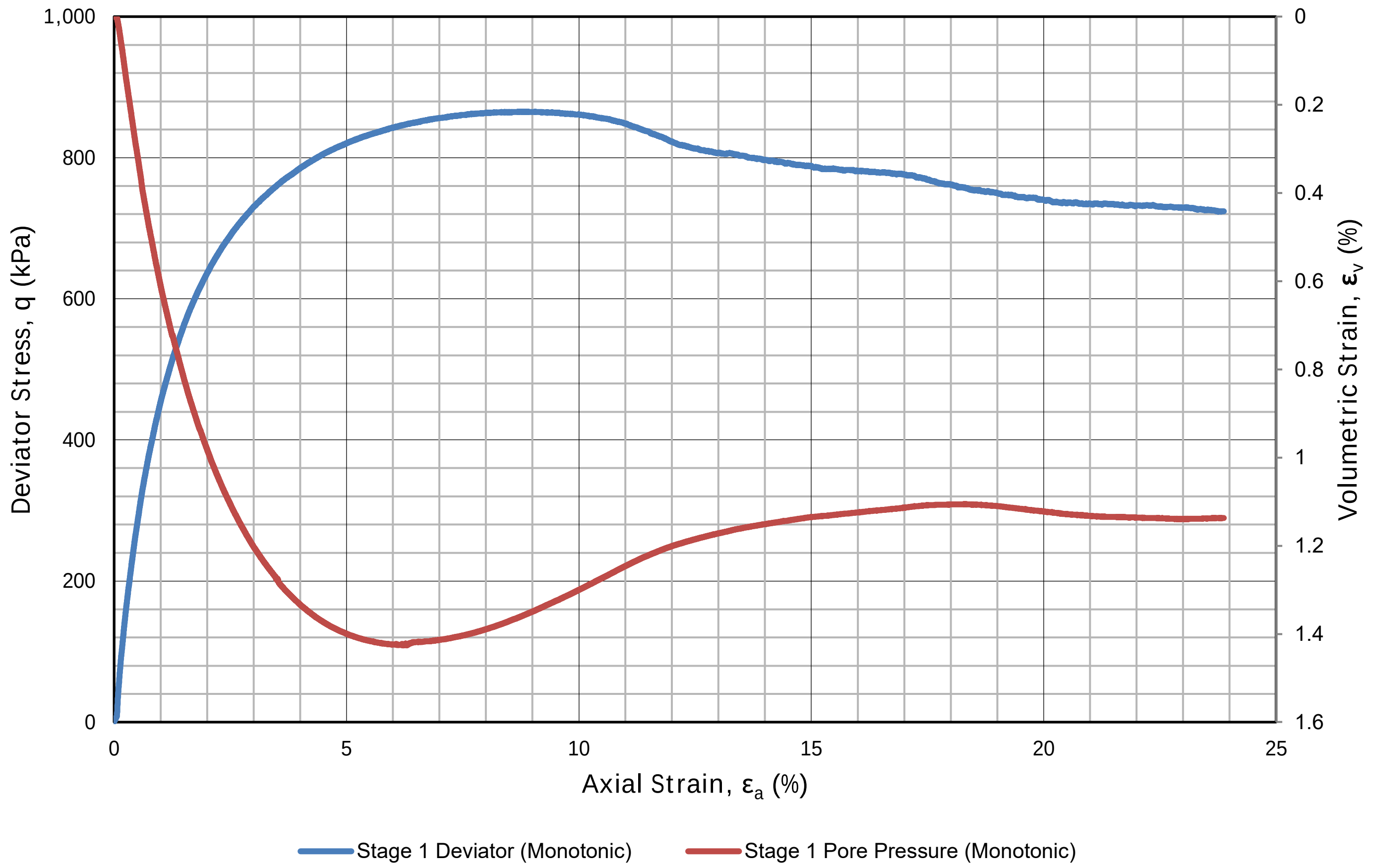
[1] Membrane correction has been applied.

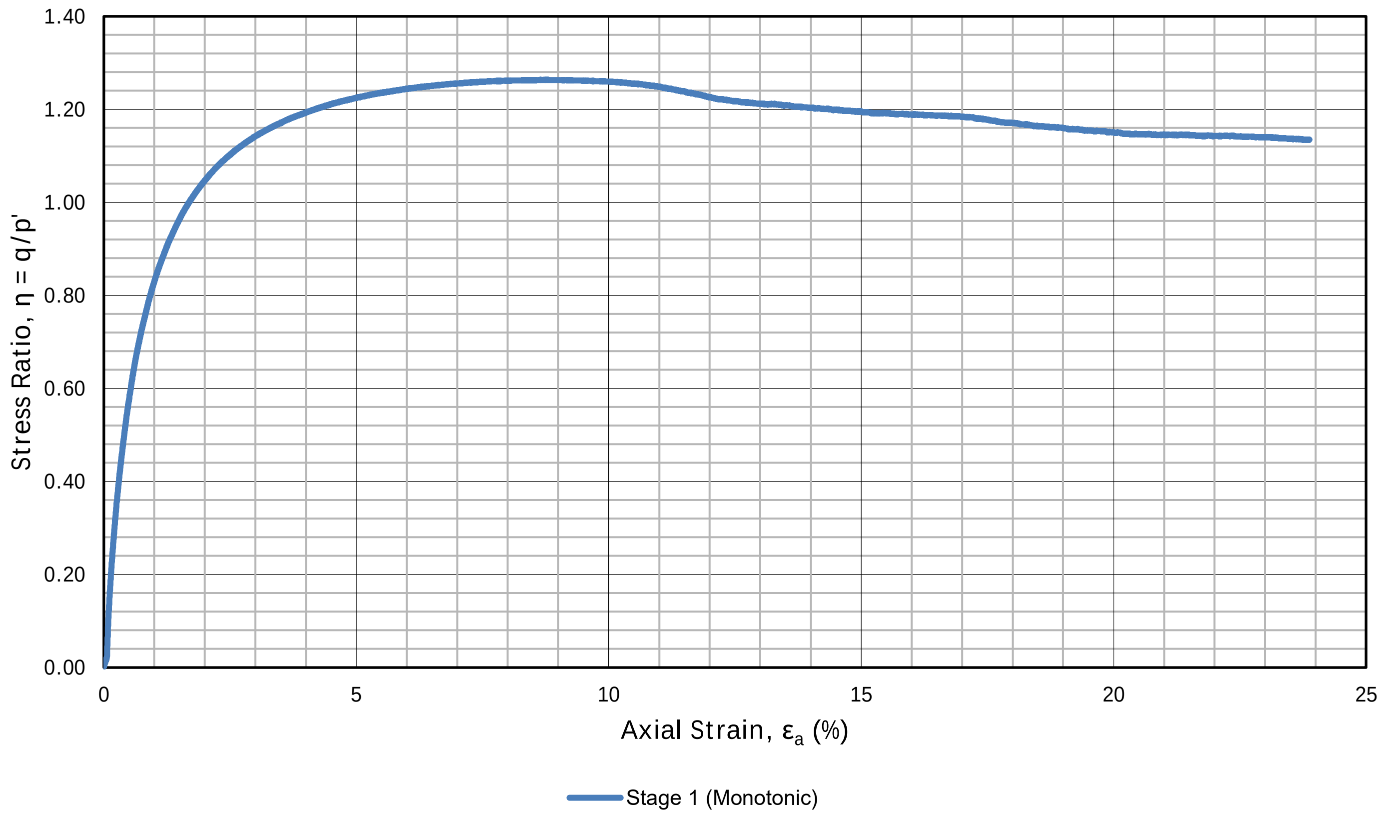
Iluka Resources Limited Attacama Blend Sands Triaxial - CD - Stress Path - q/p'	33122 Blend Tails Test 2
ATC WILLIAMS	Job No: 119085.02 Date: 6/09/2022 FIGURE 3



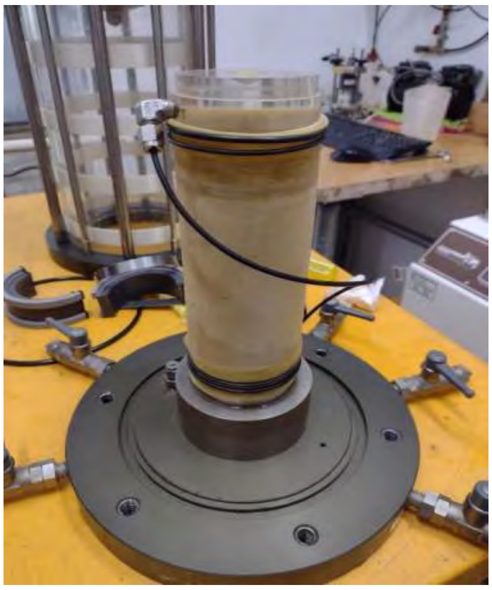
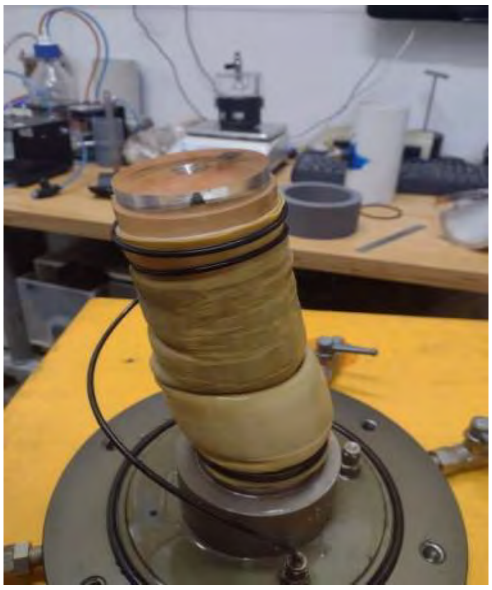


Iluka Resources Limited Attacama Blend Sands Triaxial - CD - Stress Paths - t/s' and e/log(p')	33122 Blend Tails Test 2
ATC WILLIAMS	Job No: 119085.02 Date: 6/09/2022 FIGURES 4 & 5





Iluka Resources Limited Attacama Blend Sands **Triaxial - CD - q, ε_v and q/p' vs ε_a**	33122 Blend Tails Test 2
ATC WILLIAMS	Job No: 119085.02 Date: 6/09/2022 FIGURES 6 & 7

	
Sample prior to shearing.	Sample after shearing, still within membrane.

	
Sample after removal from membrane.	Sample after shearing, sliced down center.

Measured Angle of Shear Plane from Horizontal, α:	N/A	°

Iluka Resources Limited Attacama Blend Sands Triaxial - CD - Images and Angle of Shear Plane	33122 Blend Tails Test 2
ATC WILLIAMS	Job No: 119085.02 Date: 6/09/2022 FIGURES 8 to 11

Triaxial Testing - CD

- Tested in accordance with In House Method (IHM) 15.0
- ATCW IHM 15.0 incorporates both AS1289.6.4.2 and ASTM D5311-13
- Moisture content determined in accordance with AS1289.2.1.1
- Triaxial testing performed using the "STDv2" apparatus

ATC WILLIAMS

Client:	Iluka Resources Limited		
Address:	LV 17 240 St Georges Terrace	Job No.:	Atacama
	Perth , 6000 WA	Register No.:	33122
Project:	Attacama Blend Sands	Location:	WA

Report Details:

Report Author:	LR	Report Issued:	6/09/2022
Checked By:	MM	Report Last Updated:	6/09/2022 10:32

Test Details:

Test Start Date:	9/01/2022	Operator:	LR
Test End Date:	31/08/2022	Membrane Thick.:	1000 µm
Test Type:	CD	Accessible Drainage:	Double

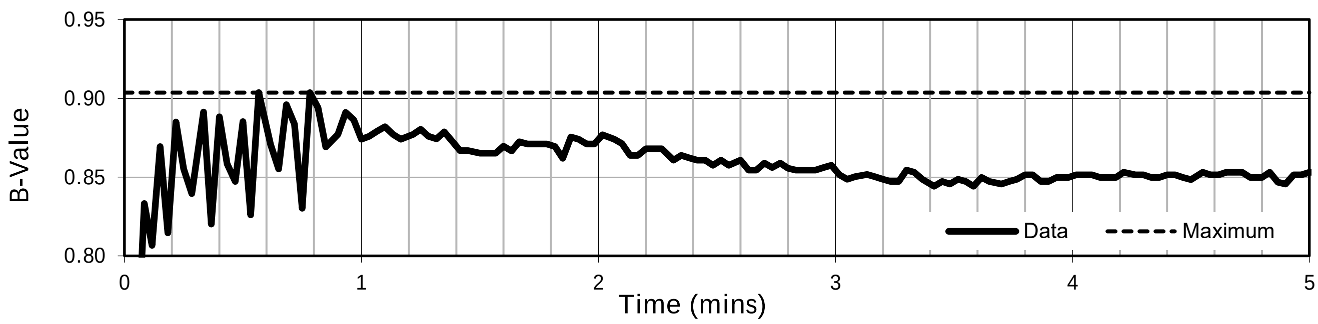
Sample Details:

Register Number:	33122	Date Sampled:	N/A
Test Number:	3	Sampled By:	Client
Description:	Blend Tails	Sample Type:	Remoulded
Borehole Number:	N/A	Percent Compaction:	30 % RD
Depth:	N/A	Particle Density[1], ρ_{st}:	2.65 t/m^3

Specimen Details:

Initial Height:	152.24 mm	Dry Mass, M_d:	1017.00 g
Initial Diameter:	75.00 mm	Initial Area:	44.18 cm^2

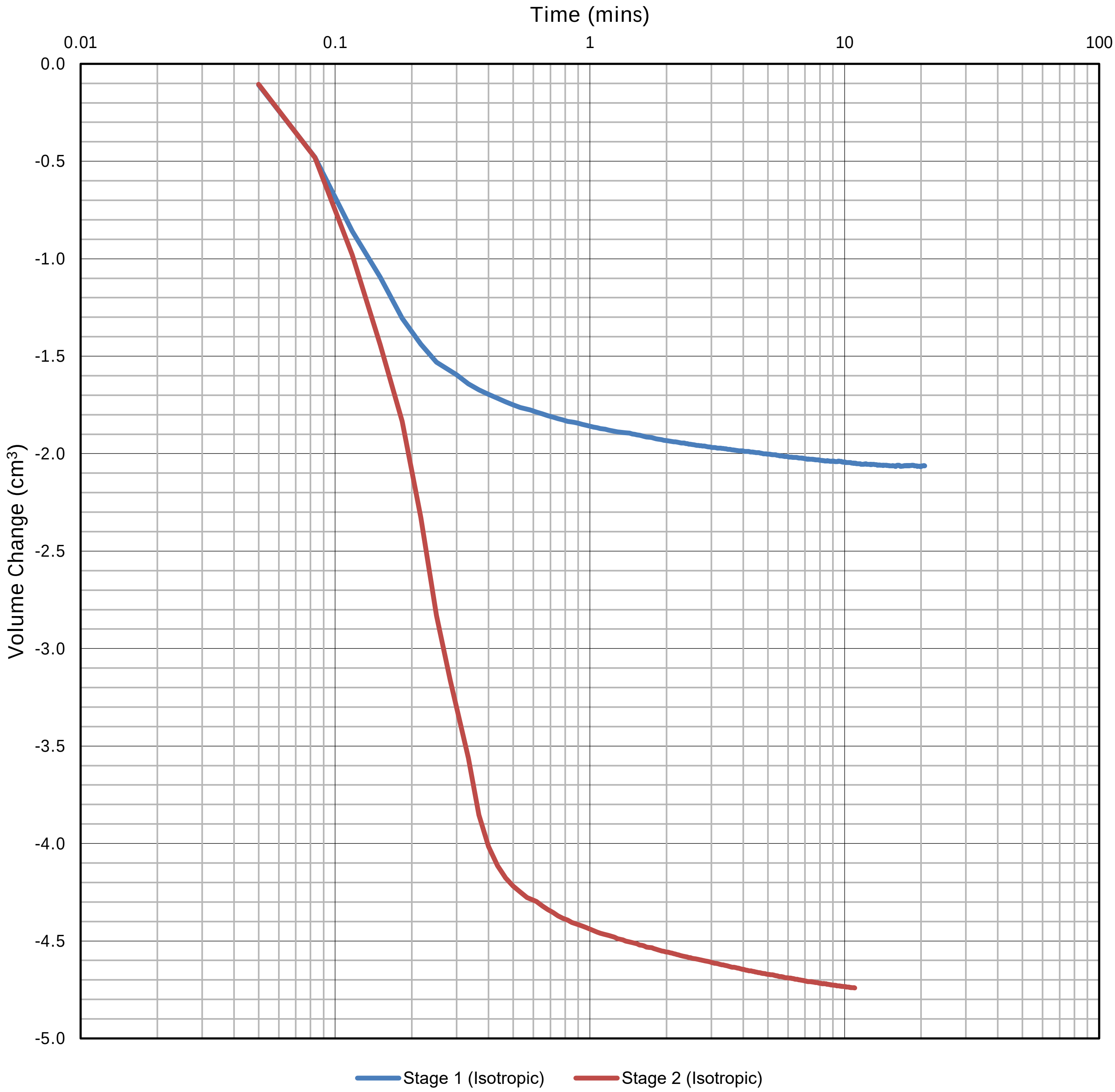
	Placed[2]	Saturated[2]	
Volume, V:	672.58	651.83	cm^3
Dry Density, ρ_d:	1.51	1.56	t/m^3
Void Ratio, e:	0.75	0.70	
Moisture Content, w:	5.20	26.36	%
Degree of Saturation, S:	18	100	%
Effective Confining Pressure, σ'_3:	0	17	kPa



Skempton's B-Value: 0.90 maximum recorded over a 5 minute period.

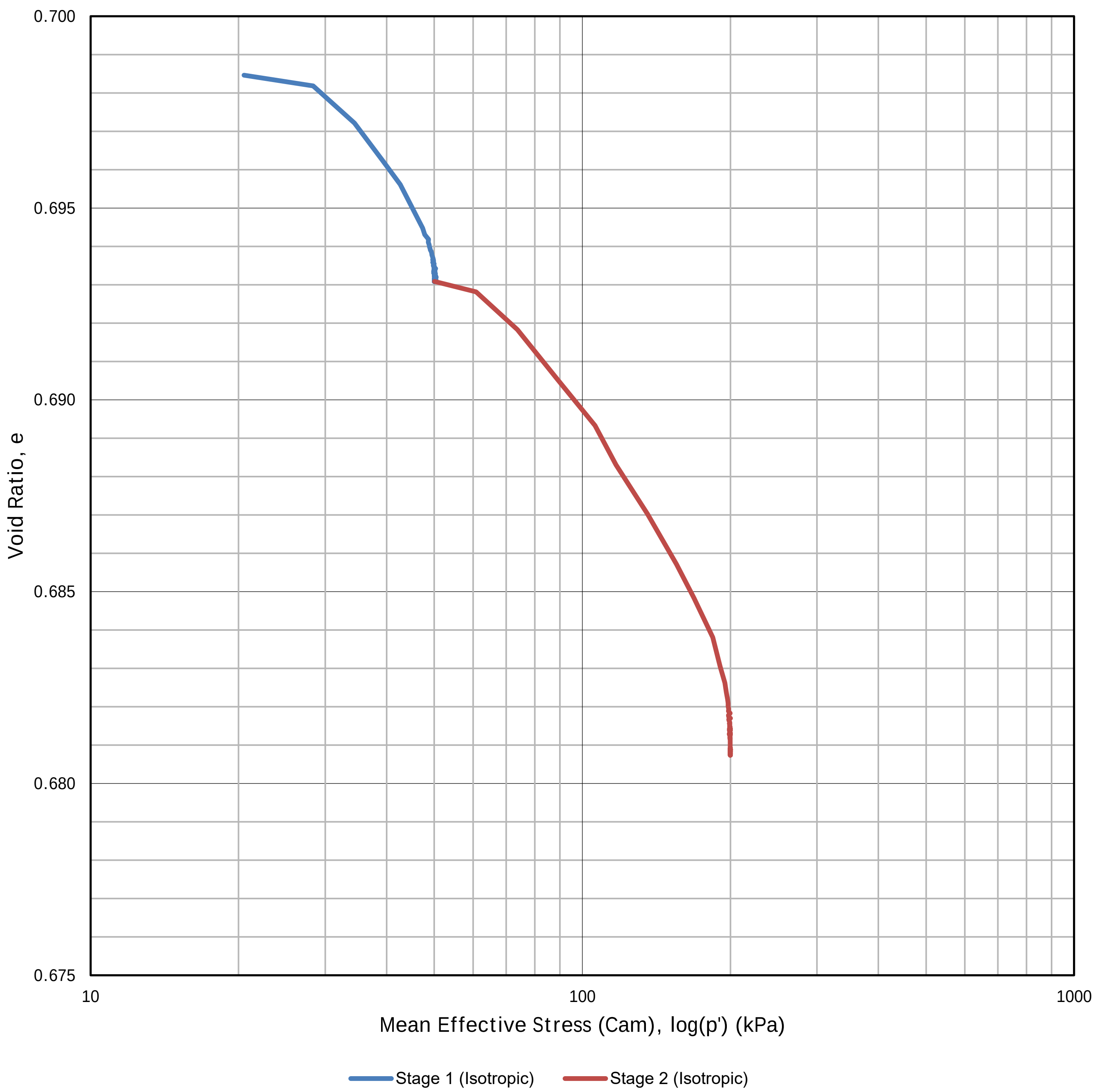
[1] The particle density provided has been directly measured according to AS1289.3.5.1

[2] 'Placed' parameters are directly measured. 'Saturated' are back calculated from the final moisture content.



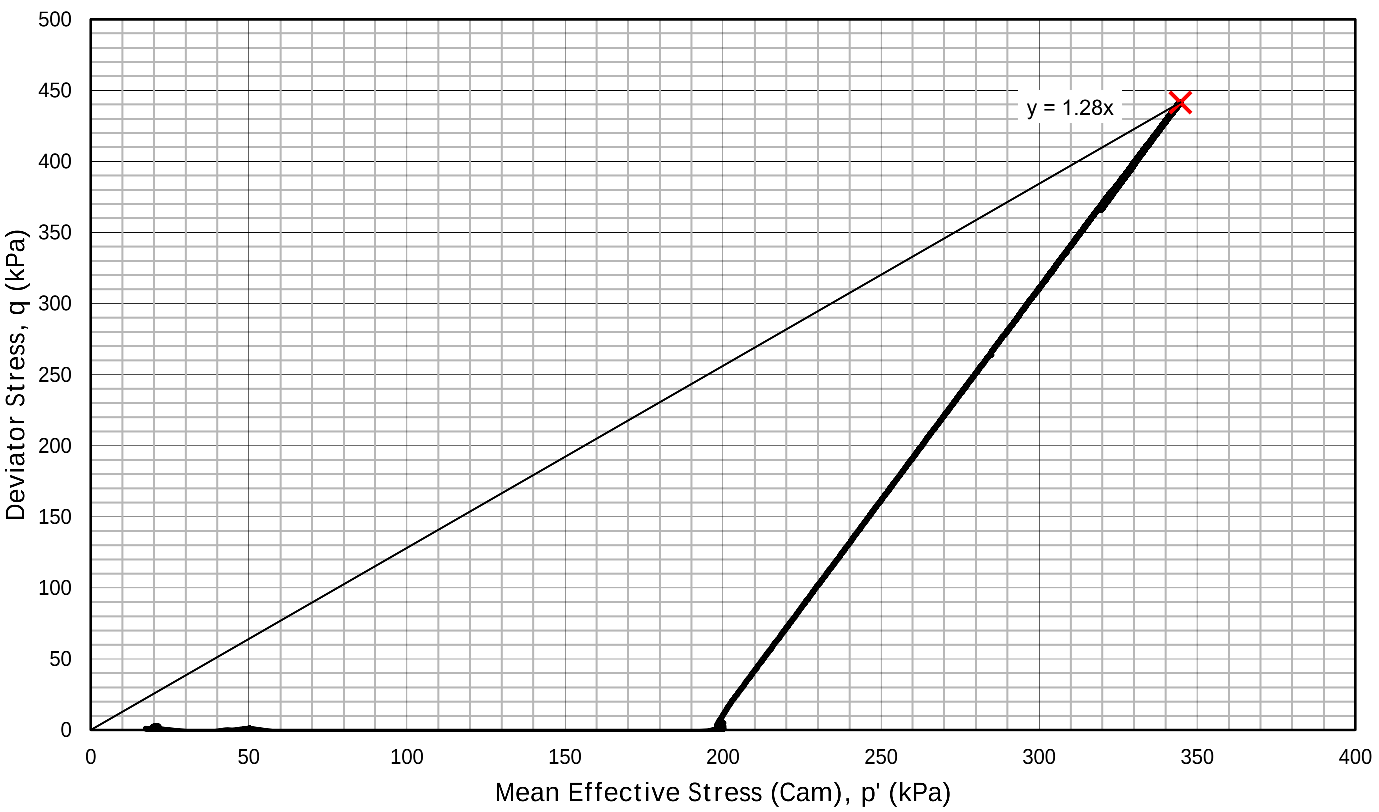
Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Effective Confining Pressure, σ'_3:	50	200	-	-	-	-	-	kPa
Effective Axial Pressure, σ'_1:	51	200	-	-	-	-	-	kPa
Deformation During Stage, ΔH:	0.07	0.22	-	-	-	-	-	mm
Volume Change, ΔV:	-2.06	-4.74	-	-	-	-	-	cm^3
Total Volume of Sample, V:	649.76	645.02	-	-	-	-	-	cm^3
Coefficient of Consolidation, C_v:	4997	3092	-	-	-	-	-	m^2/yr
Hydraulic Conductivity (from C_v), k_v:	1.49E-07	4.69E-08	-	-	-	-	-	m/s

Iluka Resources Limited Attacama Blend Sands Triaxial - CD - Consolidation (Pre-shearing)	33122 Blend Tails Test 3
ATC WILLIAMS	Job No: Atacama Date: 6/09/2022
	FIGURE 1



Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Mean Effective Stress (Cam), p':	50	200	-	-	-	-	-	kPa
Effective Confining Pressure, σ'_3:	50	200	-	-	-	-	-	kPa
Effective Axial Pressure, σ'_1:	51	200	-	-	-	-	-	kPa
Dry Density, ρ_d:	1.57	1.58	-	-	-	-	-	t/m^3
Void Ratio, e:	0.69	0.68	-	-	-	-	-	
Moisture Content (Calculated), w:	26.2	25.7	-	-	-	-	-	%

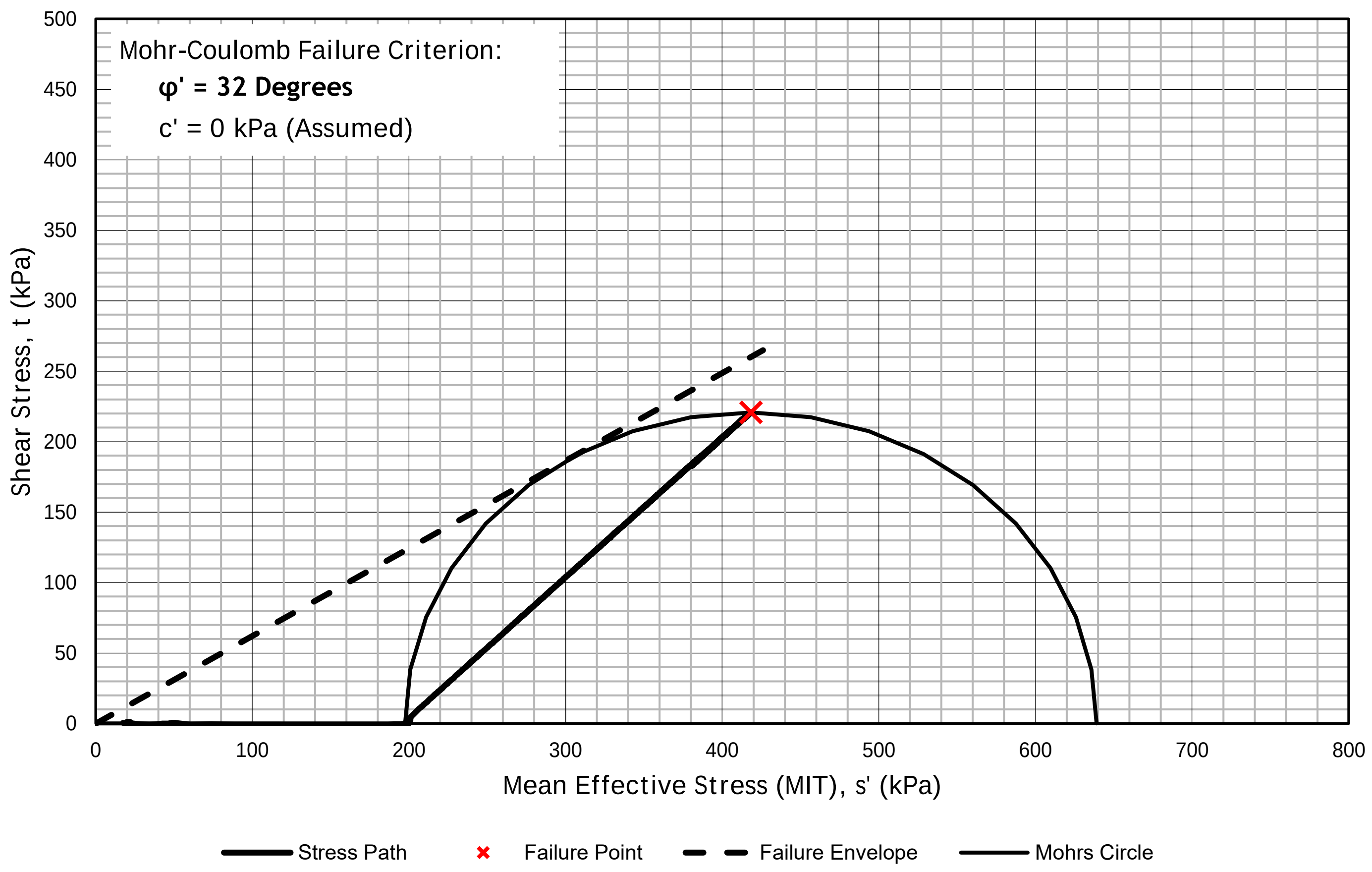
Iluka Resources Limited Attacama Blend Sands Triaxial - CD - Stress Path (Pre-shearing) - e/log(p')	33122 Blend Tails Test 3
ATC WILLIAMS	Job No: Atacama Date: 6/09/2022 FIGURE 2

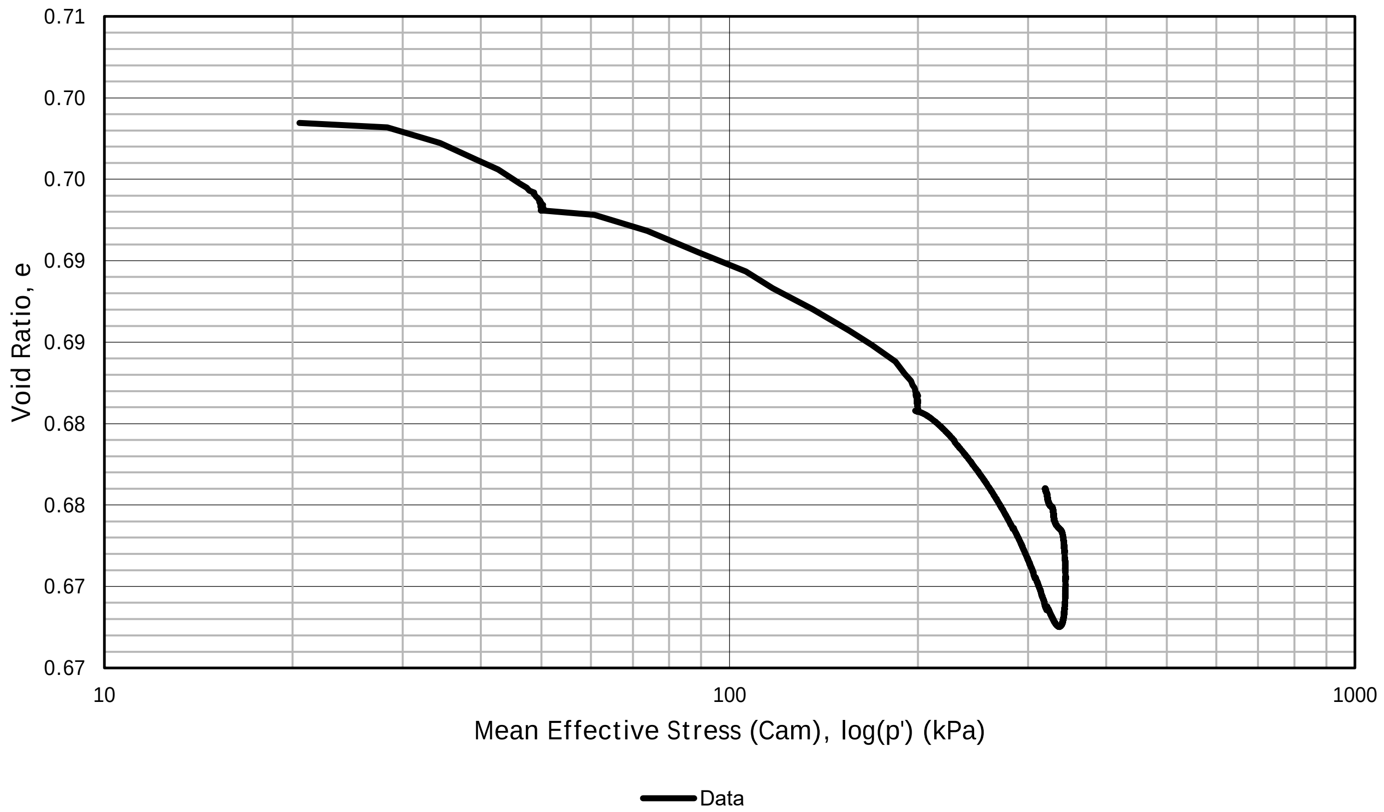


Undrained Monotonic Shear Stages:	Stage 1	Stage 2	Stage 3	
Initial Mean Effective Stress (Cam), p':	200	-	-	kPa
Initial Effective Confining Pressure, σ'$_3$:	200	-	-	kPa
Initial Effective Axial Pressure, σ'$_1$:	200	-	-	kPa
Dry Density, ρ_d:	1.58	-	-	t/m^3
Void Ratio, e:	0.68	-	-	
Moisture Content (Calculated), w:	25.7	-	-	%
Shear Rate, $\dot{\varepsilon}$:	0.05	-	-	mm/min
Failure Criteria:	Max q	-	-	
Axial Strain at Failure, ε_a:	8.6	-	-	%
Deviator Stress at Failure[1], q:	442	-	-	kPa
Undrained Shear Stress at Failure, t:	221	-	-	kPa
Mean Effective Stress (Cam) at Failure, p':	345	-	-	kPa
Mean Effective Stress (MIT) at Failure, s':	418	-	-	kPa
Effective Confining Pressure at Failure, σ'$_3$:	198	-	-	kPa
Effective Axial Stress at Failure, σ'$_1$:	639	-	-	kPa
Excess Pore Pressure at Failure, u:	-	-	-	kPa
Mode of Failure:	Barrelling			
Undrained Shear Strength Ratio, S_u/σ'_1:	-	-	-	
Internal Friction Angle, ϕ':	32			°

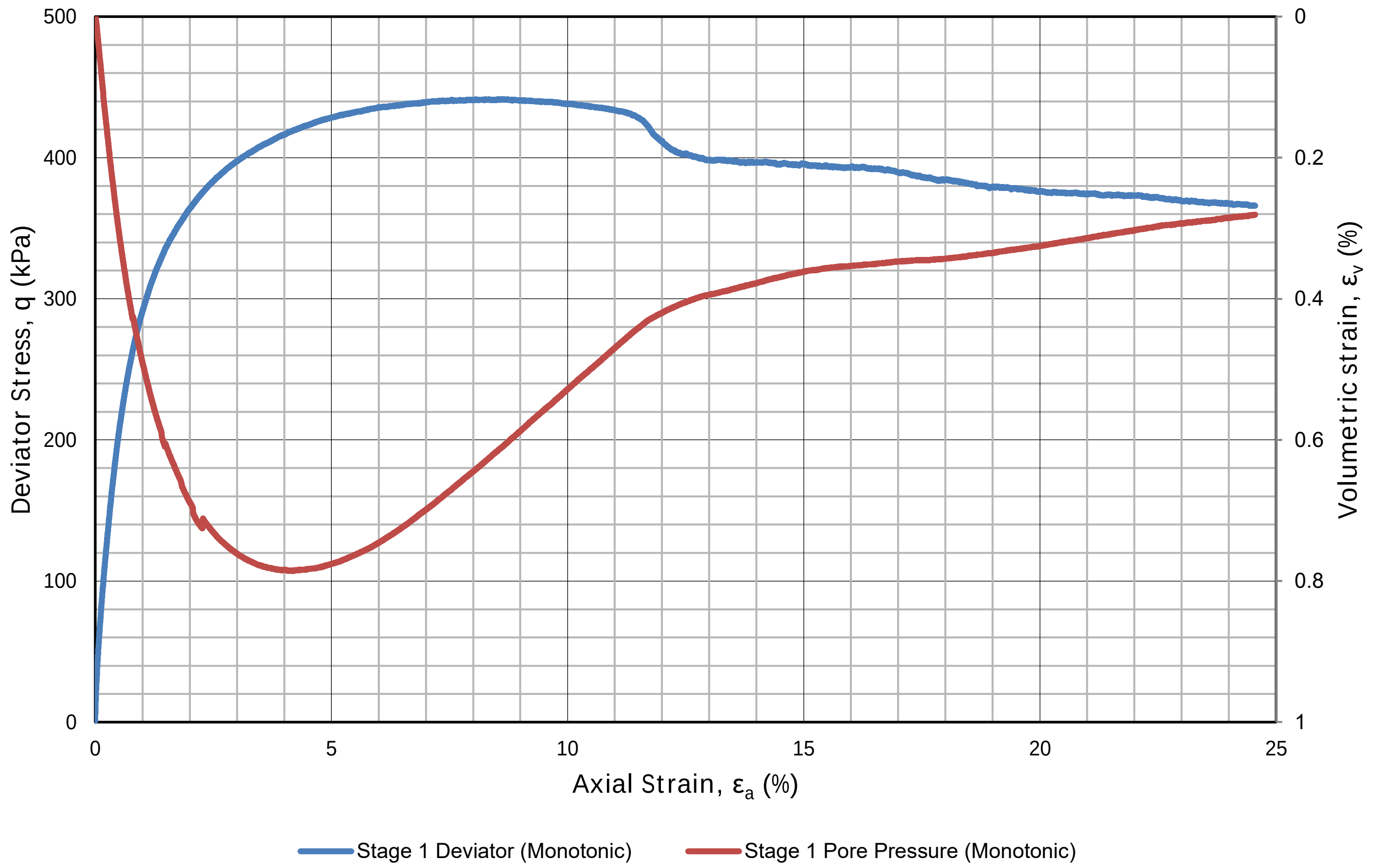
[1] Membrane correction has been applied.

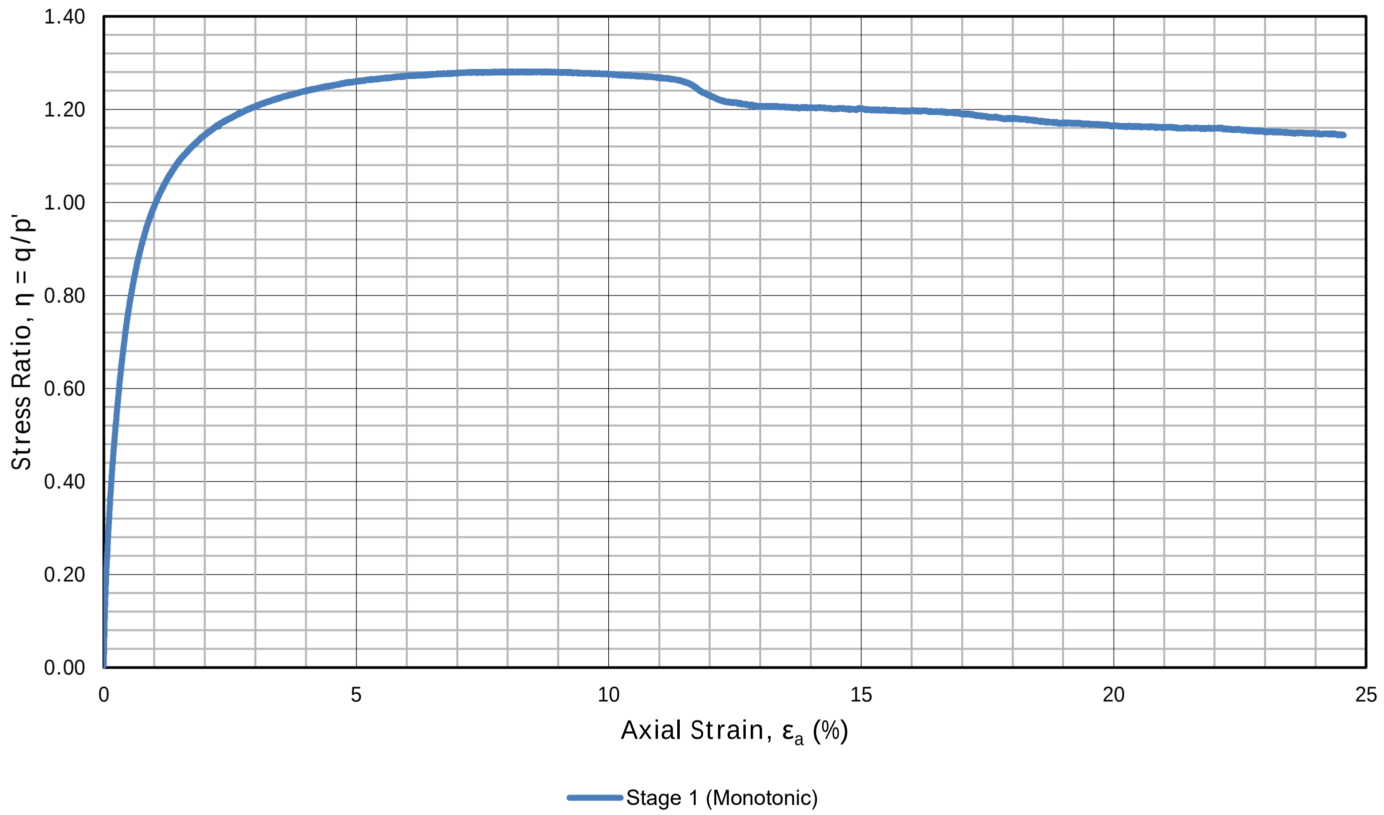
Iluka Resources Limited Attacama Blend Sands Triaxial - CD - Stress Path - q/p'	33122 Blend Tails Test 3
ATC WILLIAMS	Job No: Atacama Date: 6/09/2022
	FIGURE 3





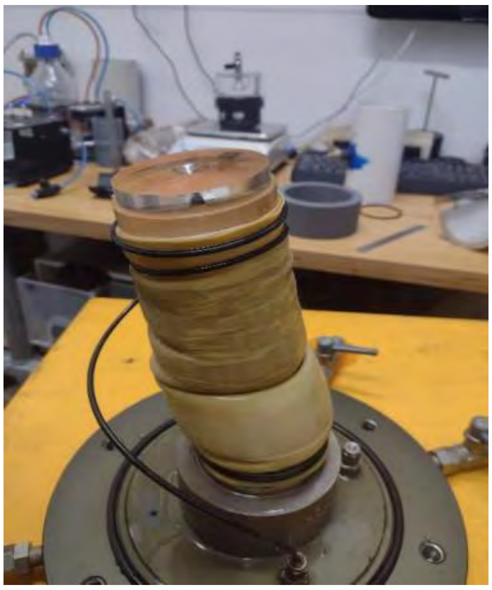
Iluka Resources Limited Attacama Blend Sands Triaxial - CD - Stress Paths - t/s' and e/log(p')	33122 Blend Tails Test 3
ATC WILLIAMS	Job No: Atacama Date: 6/09/2022
	FIGURES 4 & 5





Iluka Resources Limited Attacama Blend Sands **Triaxial - CD - q, ε_v and q/p' vs ε_a**	33122 Blend Tails Test 3
ATC WILLIAMS	Job No: Atacama Date: 6/09/2022
	FIGURES 6 & 7

Sample prior to shearing.



Sample after shearing, still within membrane.

Sample after removal from membrane.

Sample after shearing, sliced down center.

Measured Angle of Shear Plane from Horizontal, α:	N/A	°

Iluka Resources Limited Attacama Blend Sands Triaxial - CD - Images and Angle of Shear Plane	33122 Blend Tails Test 3
ATC WILLIAMS	Job No: Atacama Date: 6/09/2022 FIGURES 8 to 11

Triaxial Testing - CIU

- Tested in accordance with In House Method (IHM) 15.0
- ATCW IHM 15.0 incorporates both AS1289.6.4.2 and ASTM D5311-13
- Moisture content determined in accordance with AS1289.2.1.1
- Triaxial testing performed using the "ELDyn" apparatus

ATC WILLIAMS

Client:	Iluka Resources Limited		
Address:	LV 17 240 St Georges Terrace	Job No.:	Atacama
	Perth , 6000 WA	Register No.:	33022
Project:	Attacama Sands	Location:	WA

Report Details:

Report Author:	LR	Report Issued:	12/10/2022
Checked By:	MM	Report Last Updated:	12/10/2022 10:55

Test Details:

Test Start Date:	19/09/2022	Operator:	LR
Test End Date:	21/09/2022	Membrane Thick.:	1000 µm
Test Type:	CIU	Accessible Drainage:	Double

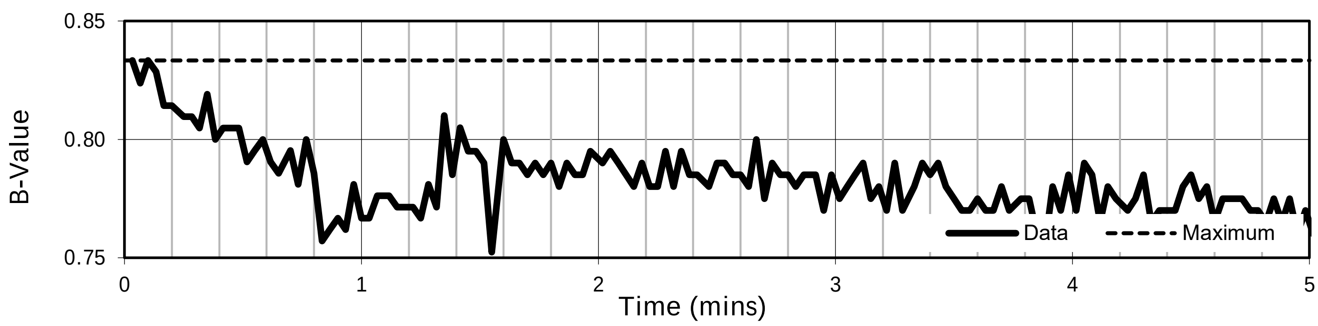
Sample Details:

Register Number:	33022	Date Sampled:	N/A
Test Number:	1 of 3	Sampled By:	Client
Description:	Atacama Tailings	Sample Type:	Remoulded
Borehole Number:	N/A	Percent Compaction:	25 % RD
Depth:	N/A	Particle Density[1], ρ_{st}:	2.66 t/m^3

Specimen Details:

Initial Height:	152.24 mm	Dry Mass, M_d:	1008.19 g
Initial Diameter:	75.00 mm	Initial Area:	44.18 cm^2

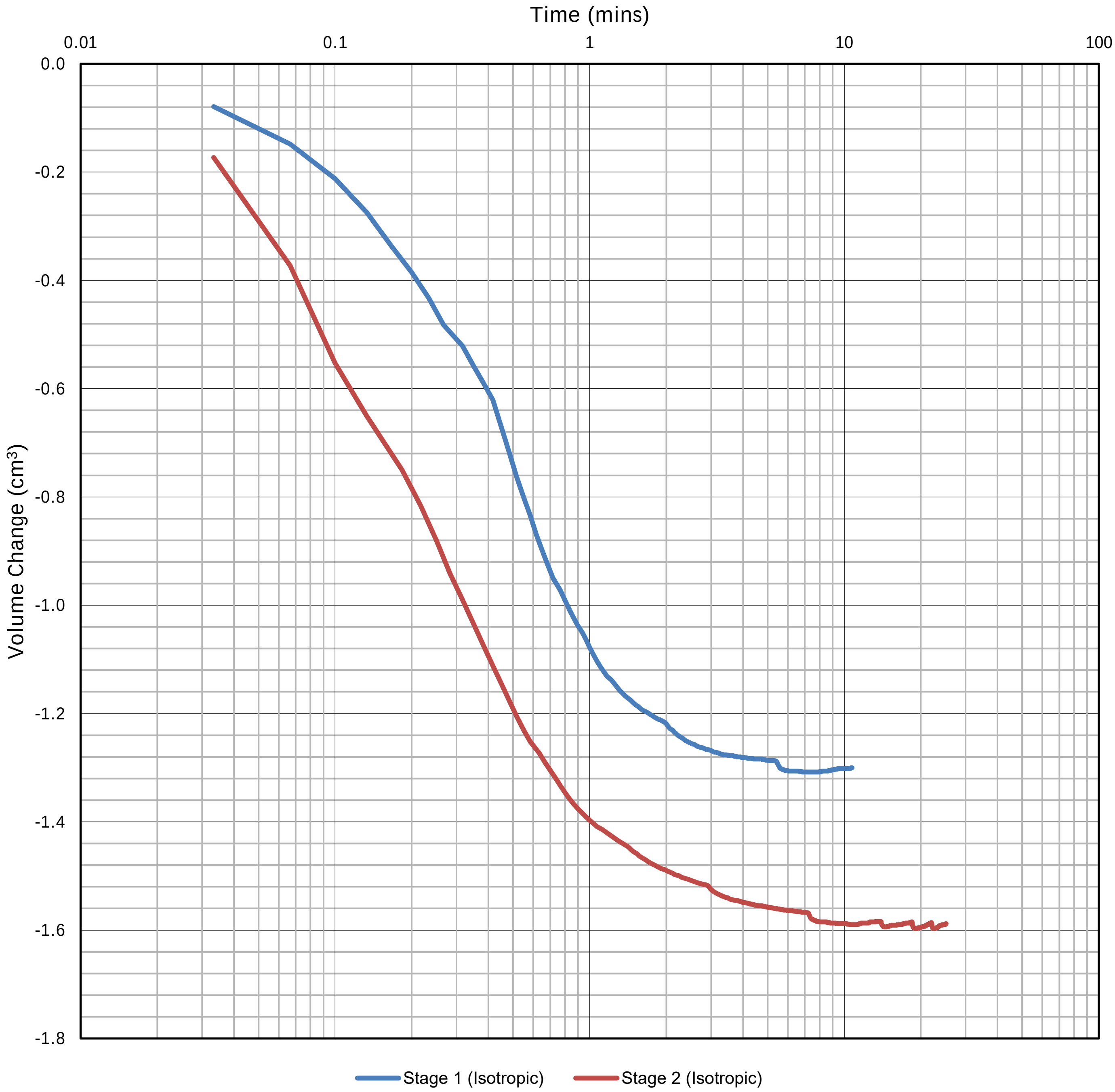
	Placed[2]	Saturated[2]	
Volume, V:	672.58	637.18	cm^3
Dry Density, ρ_d:	1.50	1.58	t/m^3
Void Ratio, e:	0.77	0.68	
Moisture Content, w:	13.82	25.61	%
Degree of Saturation, S:	47	100	%
Effective Confining Pressure, σ'_3:	0	18	kPa



Skempton's B-Value: 0.83 maximum recorded over a 5 minute period.

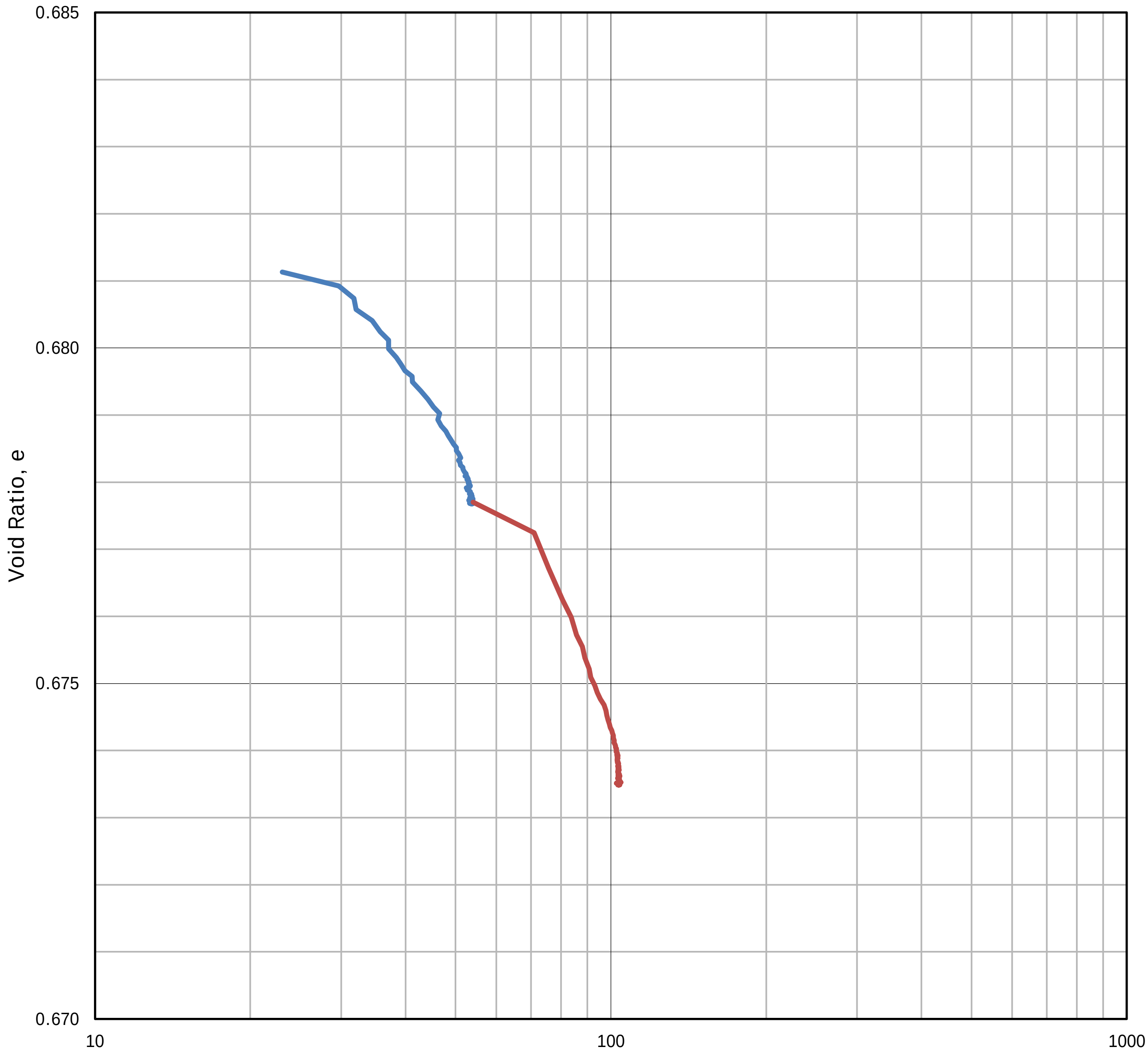
[1] The particle density provided has been directly measured according to AS1289.3.5.1

[2] 'Placed' parameters are directly measured. 'Saturated' are back calculated from the final moisture content.



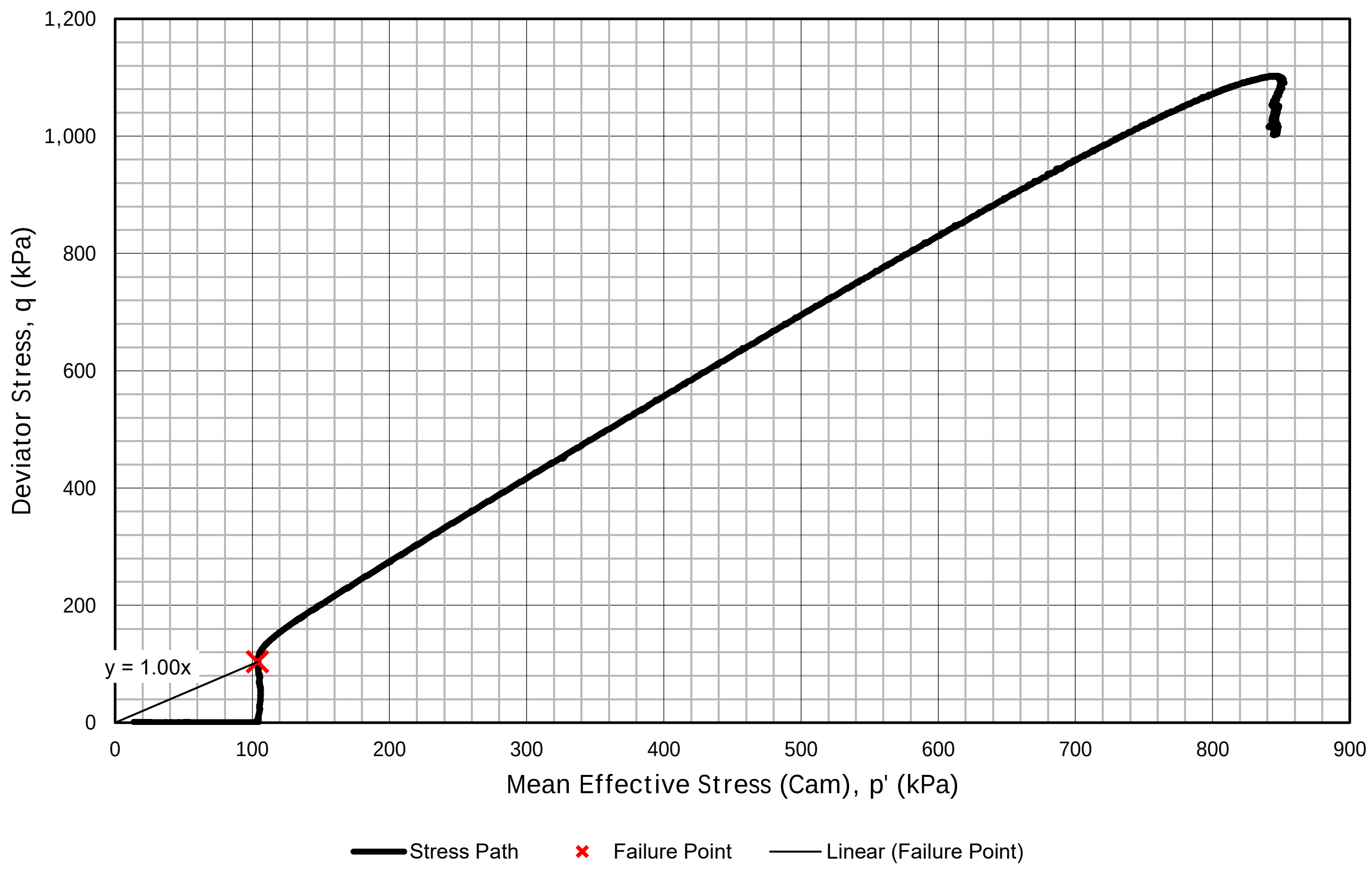
Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Effective Confining Pressure, σ'_3:	53	103	-	-	-	-	-	kPa
Effective Axial Pressure, σ'_1:	54	104	-	-	-	-	-	kPa
Deformation During Stage, ΔH:	0.09	0.09	-	-	-	-	-	mm
Volume Change, ΔV:	-1.30	-1.59	-	-	-	-	-	cm^3
Total Volume of Sample, V:	635.88	634.29	-	-	-	-	-	cm^3
Coefficient of Consolidation, C_v:	1489	3643	-	-	-	-	-	m^2/yr
Hydraulic Conductivity (from C_v), k_v:	2.69E-08	5.67E-08	-	-	-	-	-	m/s

Iluka Resources Limited Attacama Sands Triaxial - CIU - Consolidation (Pre-shearing)	33022 Atacama Tailings Test 1 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURE 1



Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Mean Effective Stress (Cam), p':	54	103	-	-	-	-	-	kPa
Effective Confining Pressure, σ'_3:	53	103	-	-	-	-	-	kPa
Effective Axial Pressure, σ'_1:	54	104	-	-	-	-	-	kPa
Dry Density, ρ_d:	1.59	1.59	-	-	-	-	-	t/m^3
Void Ratio, e:	0.68	0.67	-	-	-	-	-	
Moisture Content (Calculated), w:	25.5	25.3	-	-	-	-	-	%

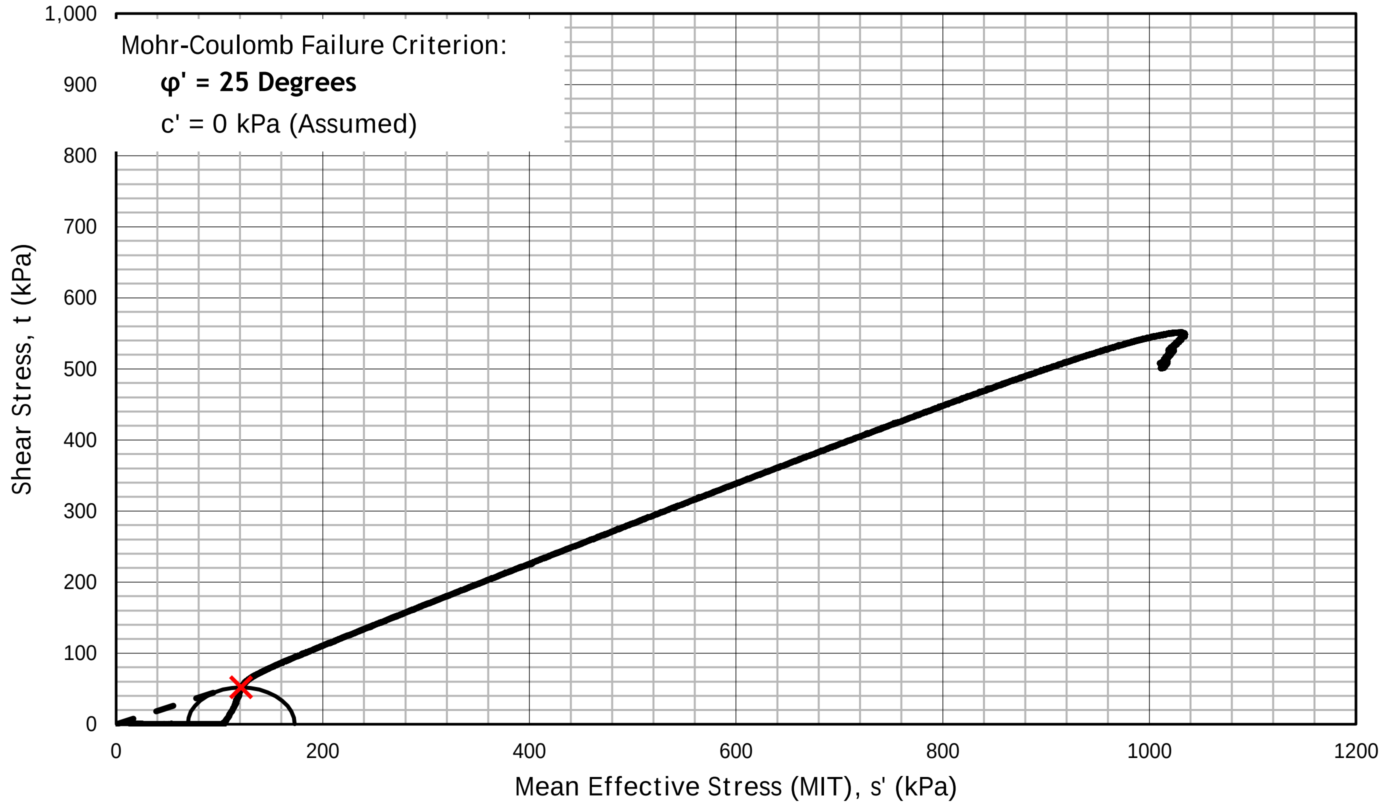
Iluka Resources Limited Attacama Sands Triaxial - CIU - Stress Path (Pre-shearing) - e/log(p')	33022 Atacama Tailings Test 1 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURE 2



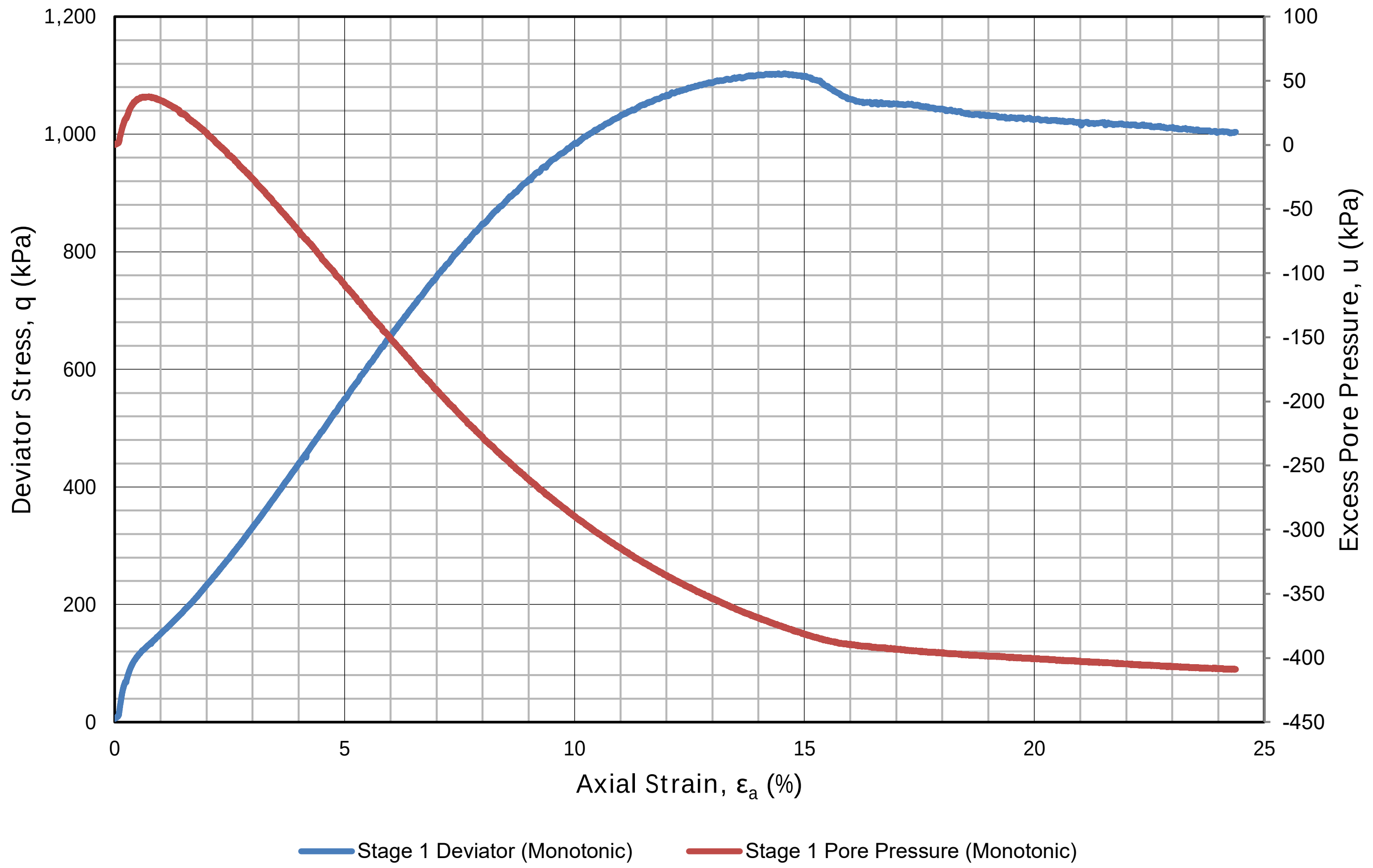
Undrained Monotonic Shear Stages:	Stage 1	Stage 2	Stage 3	
Initial Mean Effective Stress (Cam), p':	104	-	-	kPa
Initial Effective Confining Pressure, σ'_3:	103	-	-	kPa
Initial Effective Axial Pressure, σ'_1:	108	-	-	kPa
Dry Density, ρ_d:	1.59	-	-	t/m^3
Void Ratio, e:	0.67	-	-	
Moisture Content (Calculated), w:	25.3	-	-	%
Shear Rate, $\dot{\varepsilon}$:	0.05	-	-	mm/min
Failure Criteria:	QSS	-	-	
Axial Strain at Failure, ε_a:	0.4	-	-	%
Deviator Stress at Failure[1], q:	104	-	-	kPa
Undrained Shear Stress at Failure, S_u:	52	-	-	kPa
Mean Effective Stress (Cam) at Failure, p':	104	-	-	kPa
Mean Effective Stress (MIT) at Failure, s':	121	-	-	kPa
Effective Confining Pressure at Failure, σ'_3:	69	-	-	kPa
Effective Axial Stress at Failure, σ'_1:	173	-	-	kPa
Excess Pore Pressure at Failure, u:	33	-	-	kPa
Mode of Failure:	Barrelling			
Undrained Shear Strength Ratio, S_u/σ'_1:	0.48	-	-	
Internal Friction Angle, ϕ':	25			o

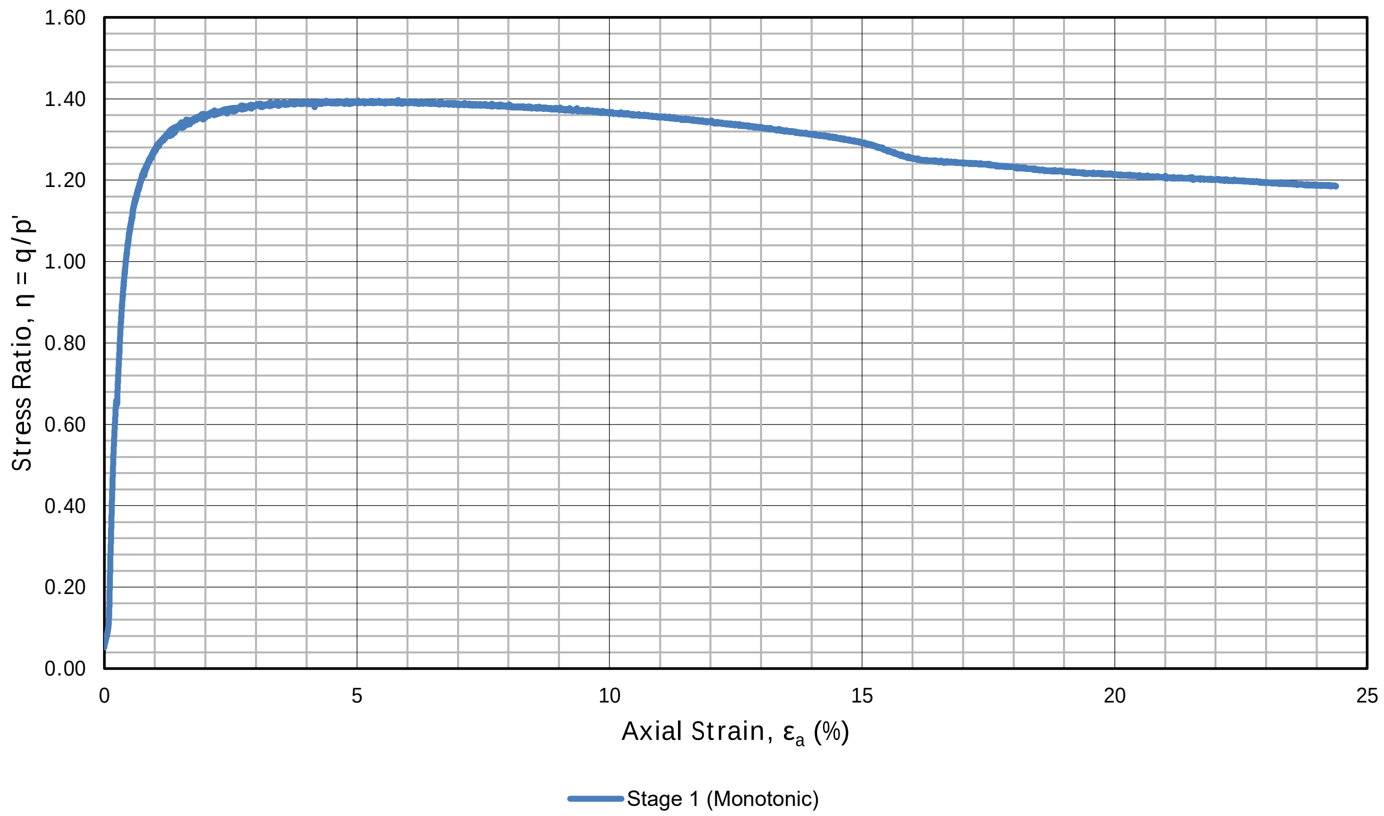
[1] Membrane correction has been applied.

Iluka Resources Limited Attacama Sands Triaxial - CIU - Stress Path - q/p'	33022 Atacama Tailings Test 1 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022
	FIGURE 3



Iluka Resources Limited Attacama Sands Triaxial - CIU - Stress Paths - S_u/s' and e/log(p')	33022 Atacama Tailings Test 1 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURES 4 & 5





Iluka Resources Limited Attacama Sands **Triaxial - CIU - q, u and q/p' vs ε_a**	33022 Atacama Tailings Test 1 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURES 6 & 7

Sample prior to shearing.

Sample after shearing, still within membrane.

Sample after removal from membrane.

Sample after shearing, sliced down center.

Measured Angle of Shear Plane from Horizontal, α:	N/A	°

Iluka Resources Limited Attacama Sands Triaxial - CIU - Images and Angle of Shear Plane	33022 Atacama Tailings Test 1 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURES 8 to 11

Triaxial Testing - CD

- Tested in accordance with In House Method (IHM) 15.0
- ATCW IHM 15.0 incorporates both AS1289.6.4.2 and ASTM D5311-13
- Moisture content determined in accordance with AS1289.2.1.1
- Triaxial testing performed using the "ELDyn" apparatus

Client:	Iluka Resources Limited		
Address:	LV 17 240 St Georges Terrace	Job No.:	Atacama
	Perth , 6000 WA	Register No.:	33022
Project:	Attacama Sands	Location:	WA

Report Details:

Report Author:	LR	Report Issued:	12/10/2022
Checked By:	MM	Report Last Updated:	12/10/2022 10:21

Test Details:

Test Start Date:	21/09/2022	Operator:	LR
Test End Date:	21/09/2022	Membrane Thick.:	1000 µm
Test Type:	CD	Accessible Drainage:	Double

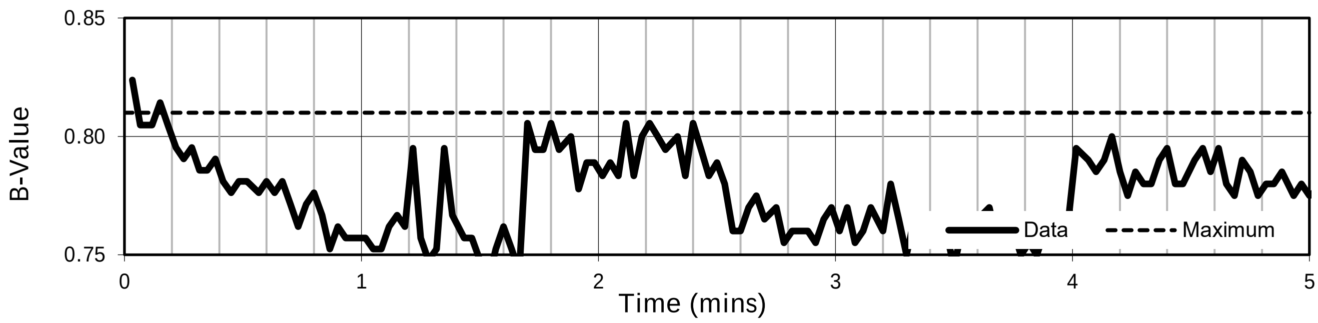
Sample Details:

Register Number:	33022	Date Sampled:	N/A
Test Number:	2 of 3	Sampled By:	Client
Description:	Atacam Tailings	Sample Type:	Remoulded
Borehole Number:	N/A	Percent Compaction:	25 % RD
Depth:	N/A	Particle Density[1], ρ_{st}:	2.66 t/m^3

Specimen Details:

Initial Height:	152.24 mm	Dry Mass, M_d:	941.61 g
Initial Diameter:	75.00 mm	Initial Area:	44.18 cm^2

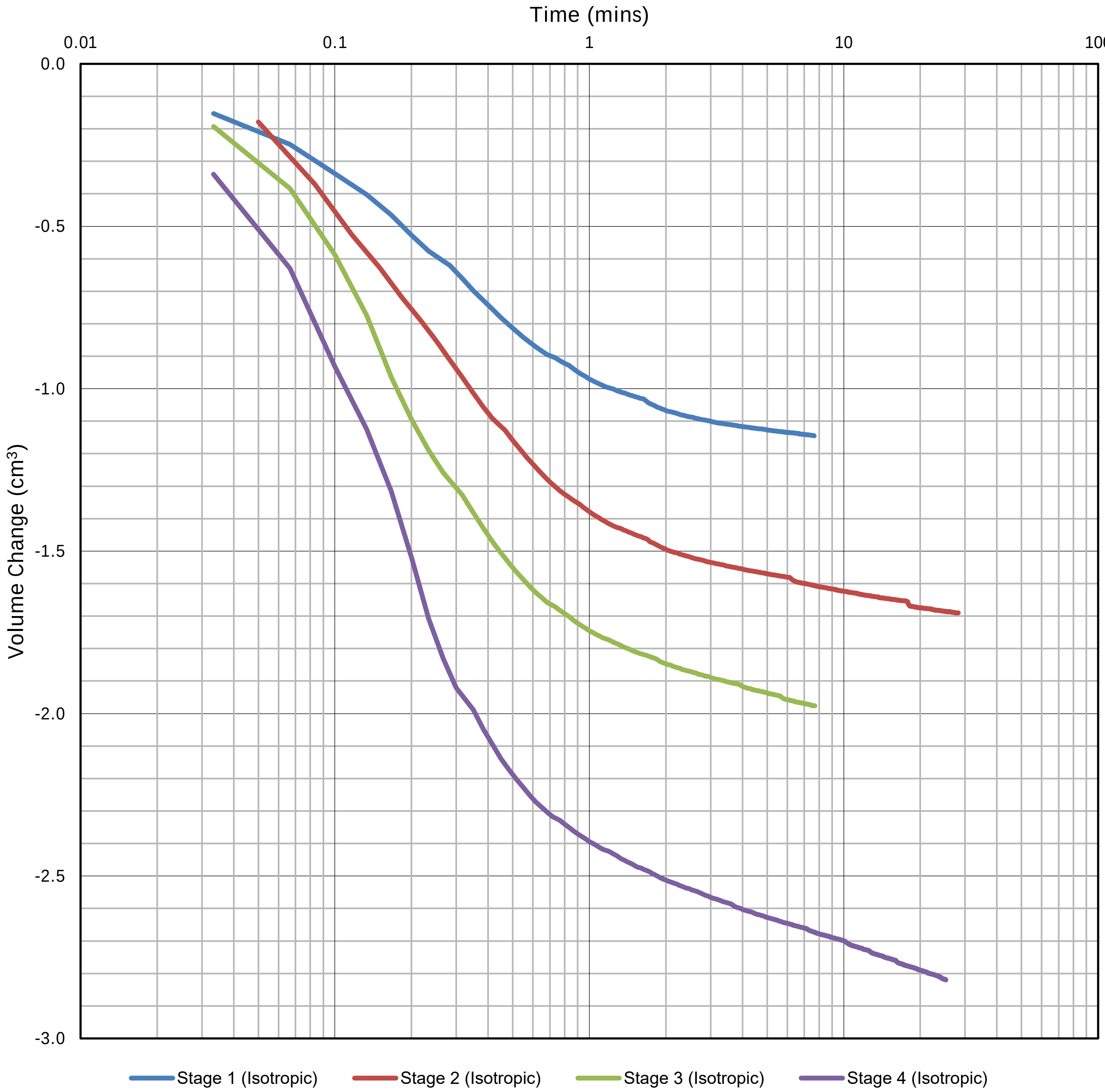
	Placed[2]	Saturated[2]	
Volume, V:	672.58	579.27	cm^3
Dry Density, ρ_d:	1.40	1.63	t/m^3
Void Ratio, e:	0.90	0.64	
Moisture Content, w:	11.56	23.93	%
Degree of Saturation, S:	34	100	%
Effective Confining Pressure, σ'_3:	0	19	kPa



Skempton's B-Value: 0.81 maximum recorded over a 5 minute period.

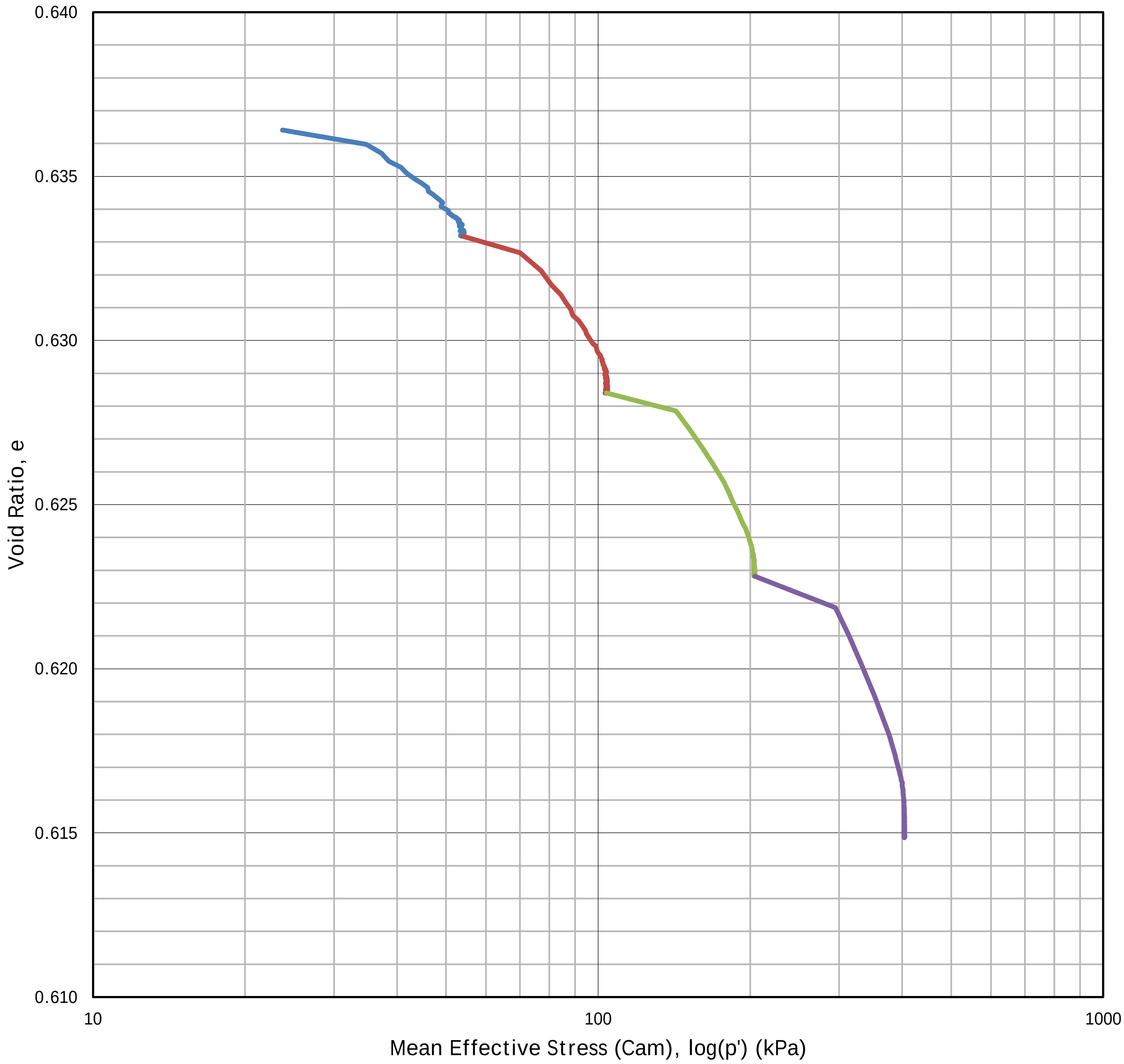
[1] The particle density provided has been directly measured according to AS1289.3.5.1

[2] 'Placed' parameters are directly measured. 'Saturated' are back calculated from the final moisture content.



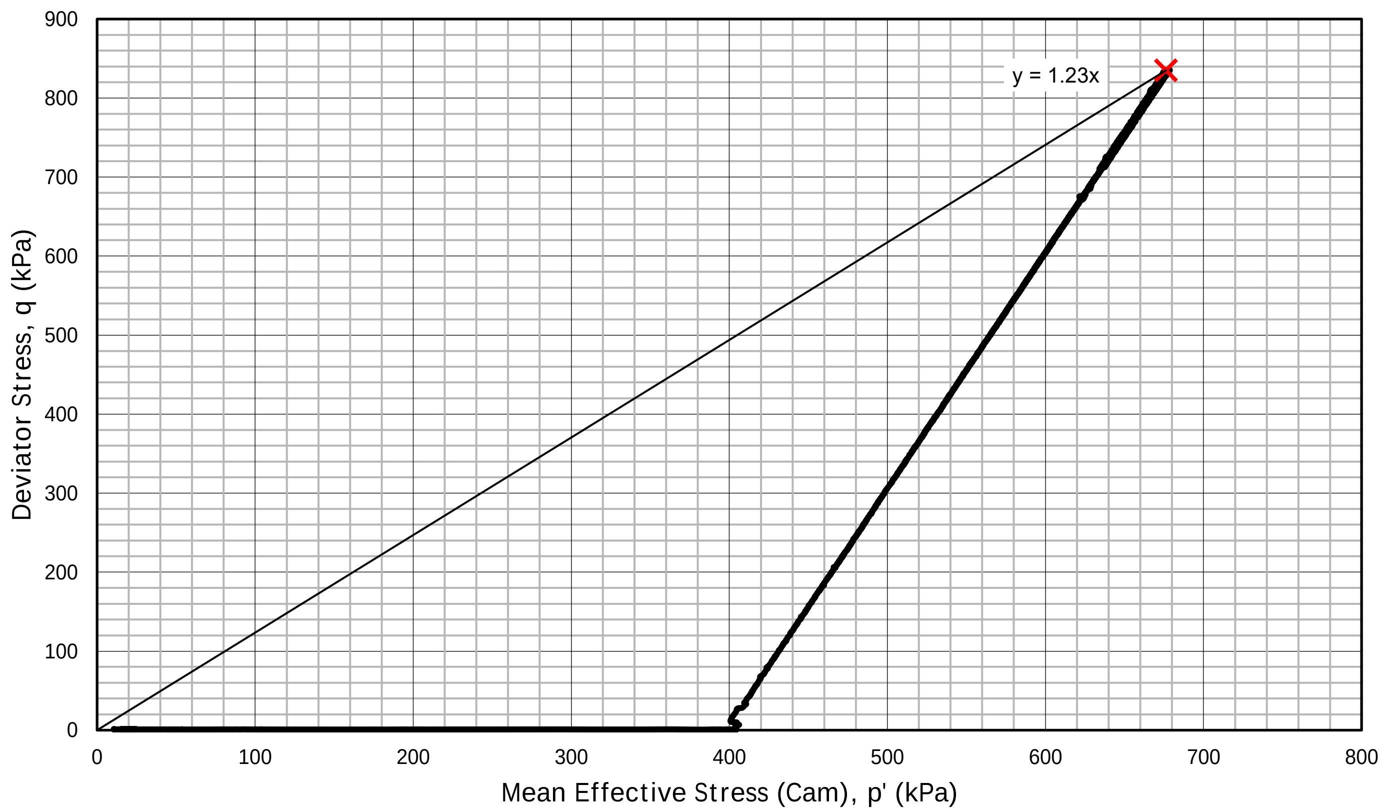
Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Effective Confining Pressure, σ'_3:	54	104	204	404	-	-	-	kPa
Effective Axial Pressure, σ'_1:	55	105	205	405	-	-	-	kPa
Deformation During Stage, ΔH:	0.05	0.07	0.09	0.11	-	-	-	mm
Volume Change, ΔV:	-1.15	-1.69	-1.98	-2.82	-	-	-	cm^3
Total Volume of Sample, V:	578.13	576.44	574.46	571.64	-	-	-	cm^3
Coefficient of Consolidation, C_v:	3529	3514	4401	4786	-	-	-	m^2/yr
Hydraulic Conductivity (from C_v), k_v:	6.20E-08	6.34E-08	4.70E-08	3.65E-08	-	-	-	m/s

Iluka Resources Limited Attacama Sands Triaxial - CD - Consolidation (Pre-shearing)	33022 Atacam Tailings Test 2 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022
	FIGURE 1



Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Mean Effective Stress (Cam), p':	54	104	204	404	-	-	-	kPa
Effective Confining Pressure, σ'_3:	54	104	204	404	-	-	-	kPa
Effective Axial Pressure, σ'_1:	55	105	205	405	-	-	-	kPa
Dry Density, ρ_d:	1.63	1.63	1.64	1.65	-	-	-	t/m^3
Void Ratio, e:	0.63	0.63	0.62	0.61	-	-	-	
Moisture Content (Calculated), w:	23.8	23.6	23.4	23.1	-	-	-	%

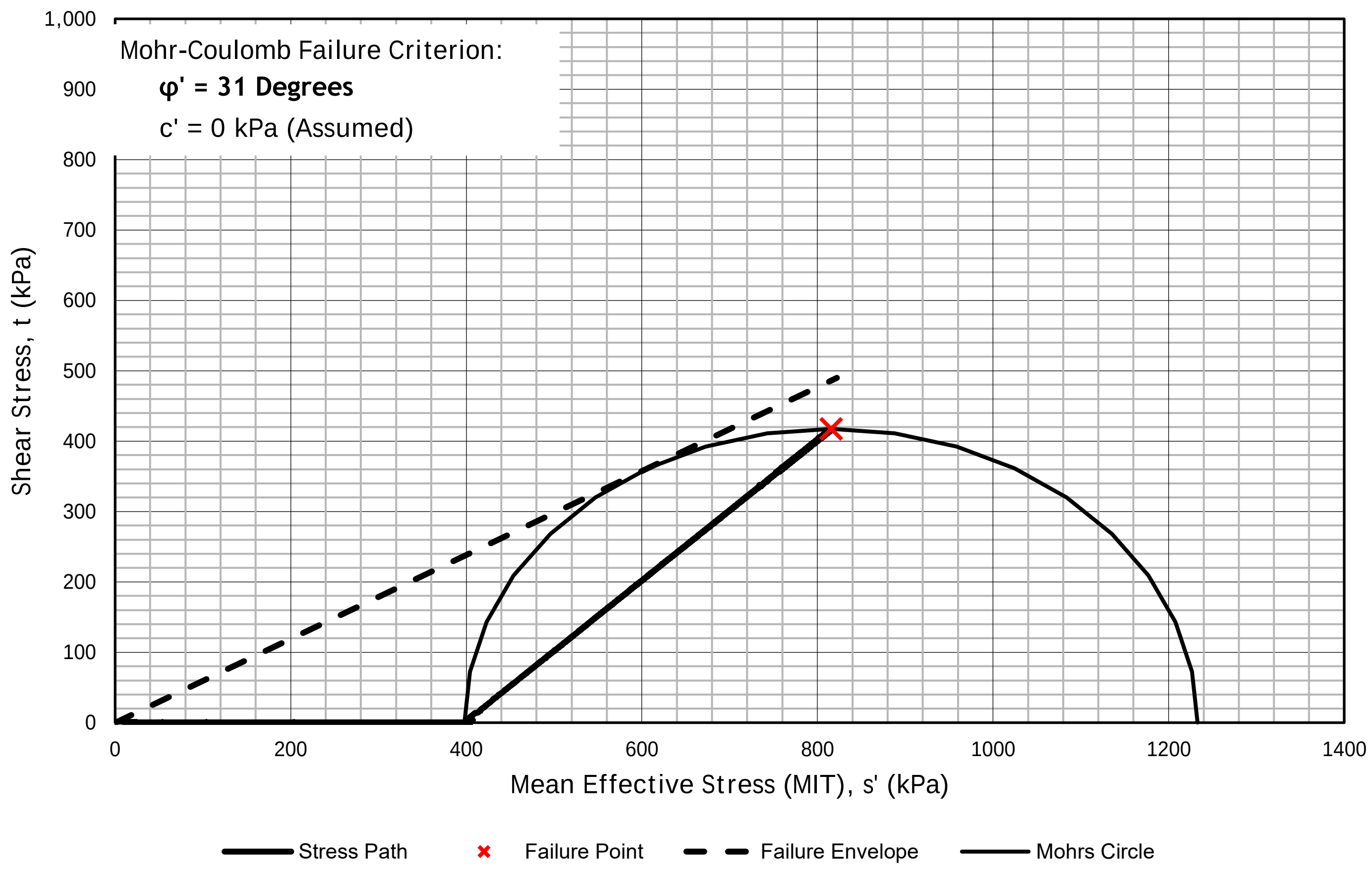
Iluka Resources Limited Attacama Sands Triaxial - CD - Stress Path (Pre-shearing) - e/log(p')	33022 Atacam Tailings Test 2 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022
	FIGURE 2



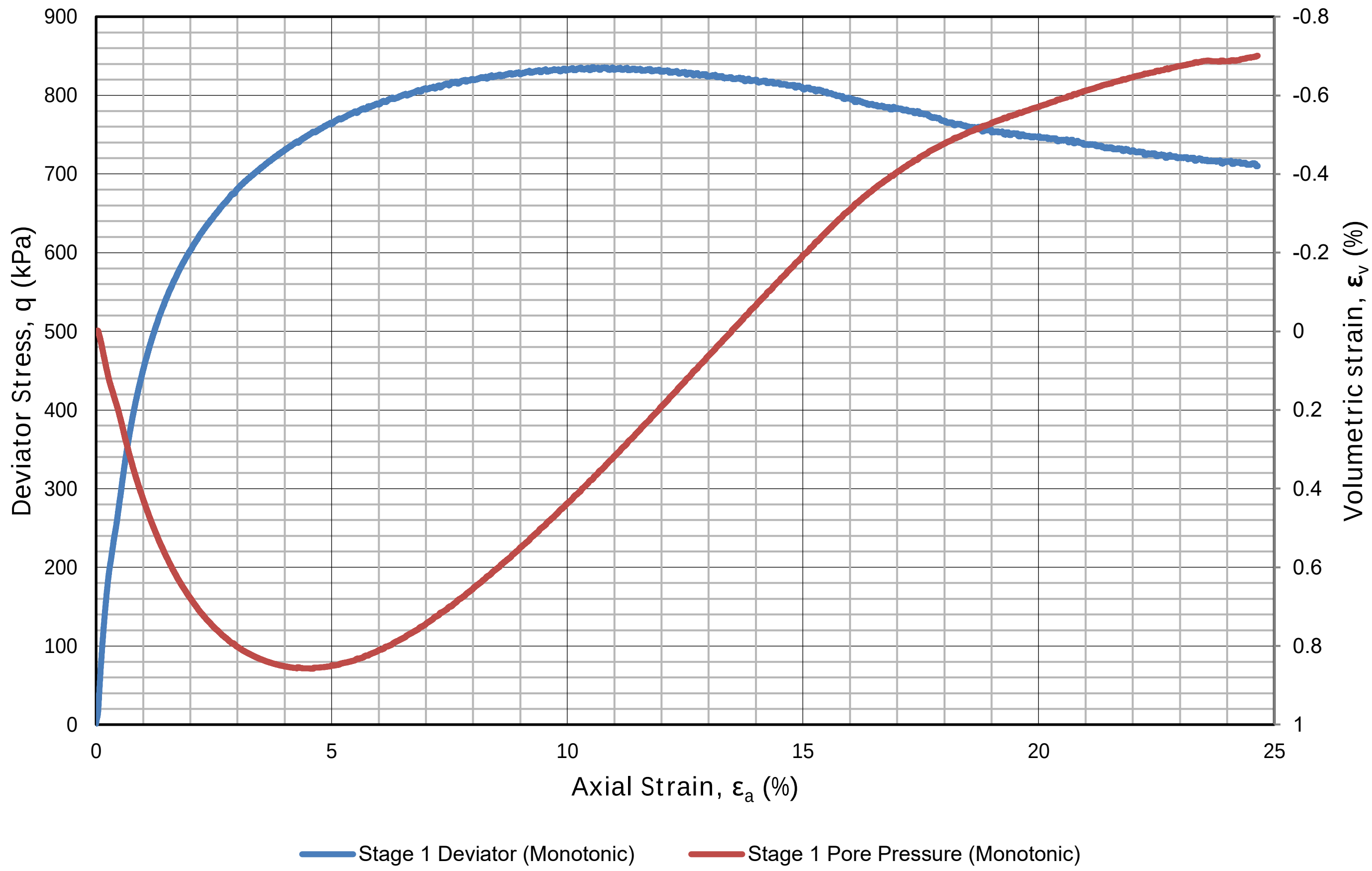
Undrained Monotonic Shear Stages:	Stage 1	Stage 2	Stage 3	
Initial Mean Effective Stress (Cam), p':	404	-	-	kPa
Initial Effective Confining Pressure, σ'_3:	404	-	-	kPa
Initial Effective Axial Pressure, σ'_1:	405	-	-	kPa
Dry Density, ρ_d:	1.65	-	-	t/m^3
Void Ratio, e:	0.61	-	-	
Moisture Content (Calculated), w:	23.1	-	-	%
Shear Rate, $\dot{\varepsilon}$:	0.05	-	-	mm/min
Failure Criteria:	Max q/p'	-	-	
Axial Strain at Failure, ε_a:	10.3	-	-	%
Deviator Stress at Failure[1], q:	835	-	-	kPa
Shear Stress at Failure, t:	418	-	-	kPa
Mean Effective Stress (Cam) at Failure, p':	676	-	-	kPa
Mean Effective Stress (MIT) at Failure, s':	816	-	-	kPa
Effective Confining Pressure at Failure, σ'_3:	398	-	-	kPa
Effective Axial Stress at Failure, σ'_1:	1233	-	-	kPa
Excess Pore Pressure at Failure, u:	-	-	-	kPa
Mode of Failure:	Barrelling			
Undrained Shear Strength Ratio, S_u/σ'_1:	-	-	-	
Internal Friction Angle, ϕ':	31			°

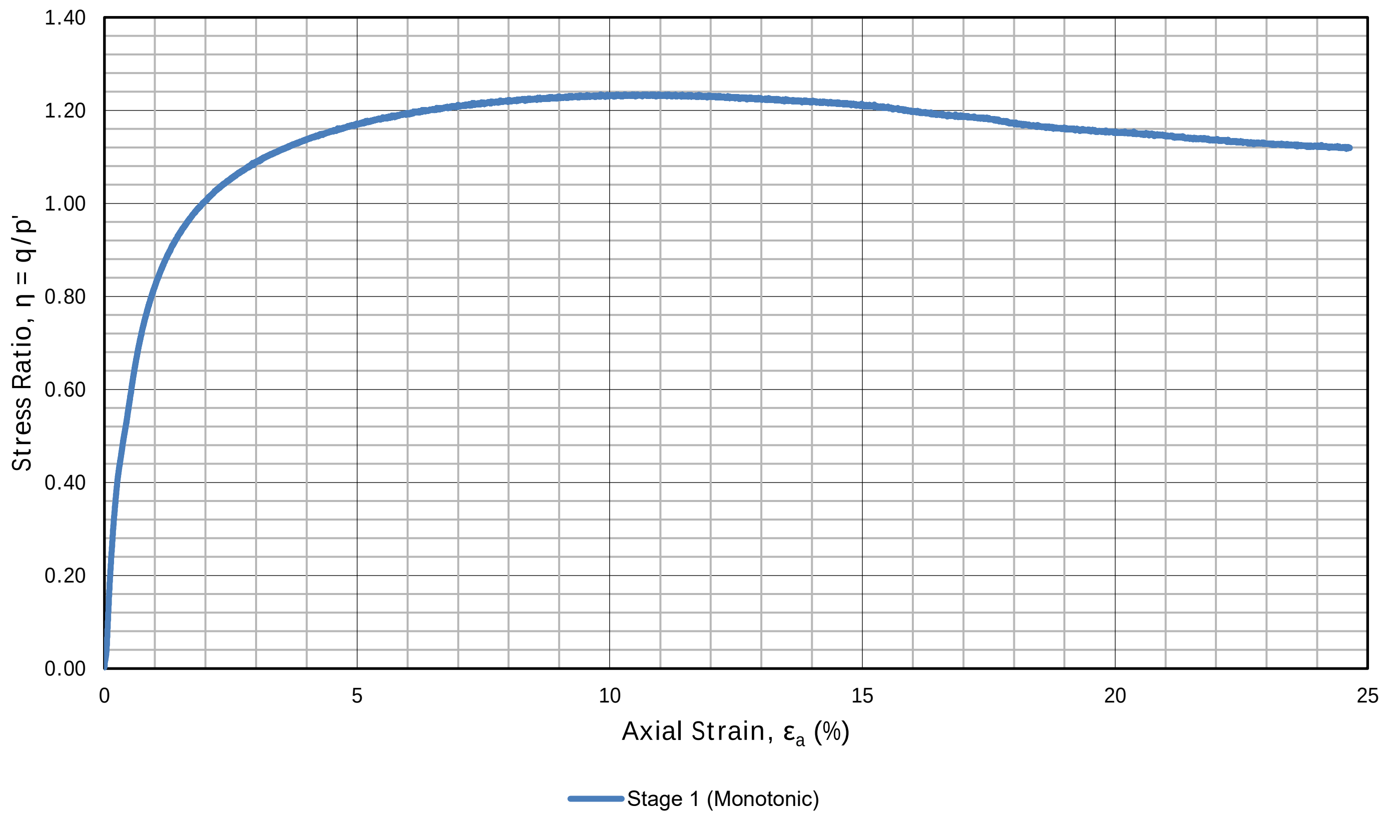
[1] Membrane correction has been applied.

Iluka Resources Limited Attacama Sands Triaxial - CD - Stress Path - q/p'	33022 Atacam Tailings Test 2 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022
	FIGURE 3



Iluka Resources Limited Attacama Sands Triaxial - CD - Stress Paths - t/s' and e/log(p')	33022 Atacam Tailings Test 2 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURES 4 & 5





Iluka Resources Limited Attacama Sands **Triaxial - CD - q, εv and q/p' vs εa**	33022 Atacam Tailings Test 2 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURES 6 & 7

Sample prior to shearing.

Sample after shearing, still within membrane.

Sample after removal from membrane.

Sample after shearing, sliced down center.

Measured Angle of Shear Plane from Horizontal, α:	N/A	°

Iluka Resources Limited Attacama Sands Triaxial - CD - Images and Angle of Shear Plane	33022 Atacam Tailings Test 2 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURES 8 to 11

Triaxial Testing - CD

- Tested in accordance with In House Method (IHM) 15.0
- ATCW IHM 15.0 incorporates both AS1289.6.4.2 and ASTM D5311-13
- Moisture content determined in accordance with AS1289.2.1.1
- Triaxial testing performed using the "ELDyn" apparatus

Client:	Iluka Resources Limited		
Address:	LV 17 240 St Georges Terrace	Job No.:	Atacama
	Perth , 6000 WA	Register No.:	33022
Project:	Attacama Sands	Location:	WA

Report Details:

Report Author:	LR	Report Issued:	12/10/2022
Checked By:	MM	Report Last Updated:	12/10/2022 10:20

Test Details:

Test Start Date:	29/09/2022	Operator:	LR
Test End Date:	21/09/2022	Membrane Thick.:	1000 µm
Test Type:	CD	Accessible Drainage:	Double

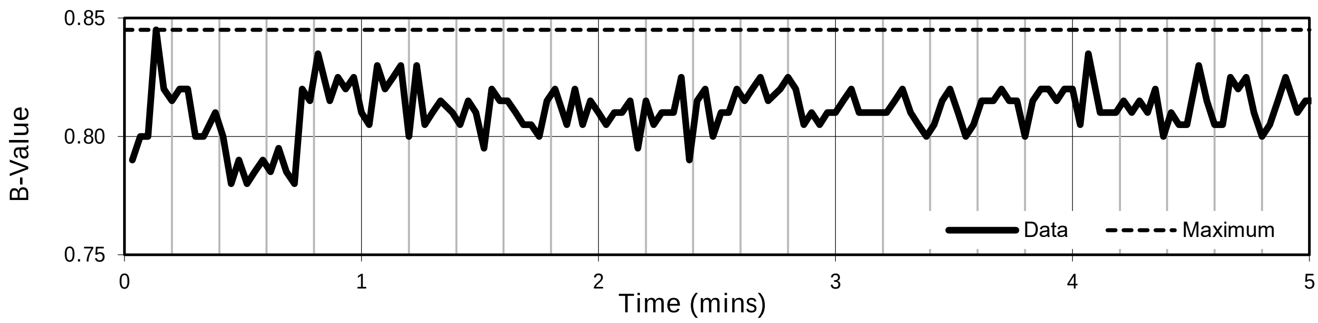
Sample Details:

Register Number:	33022	Date Sampled:	N/A
Test Number:	3 of 3	Sampled By:	Client
Description:	Atacama Tails	Sample Type:	Remoulded
Borehole Number:	N/A	Percent Compaction:	25 % RD
Depth:	N/A	Particle Density[1], ρ_{st}:	2.66 t/m^3

Specimen Details:

Initial Height:	152.24 mm	Dry Mass, M_d:	874.35 g
Initial Diameter:	75.00 mm	Initial Area:	44.18 cm^2

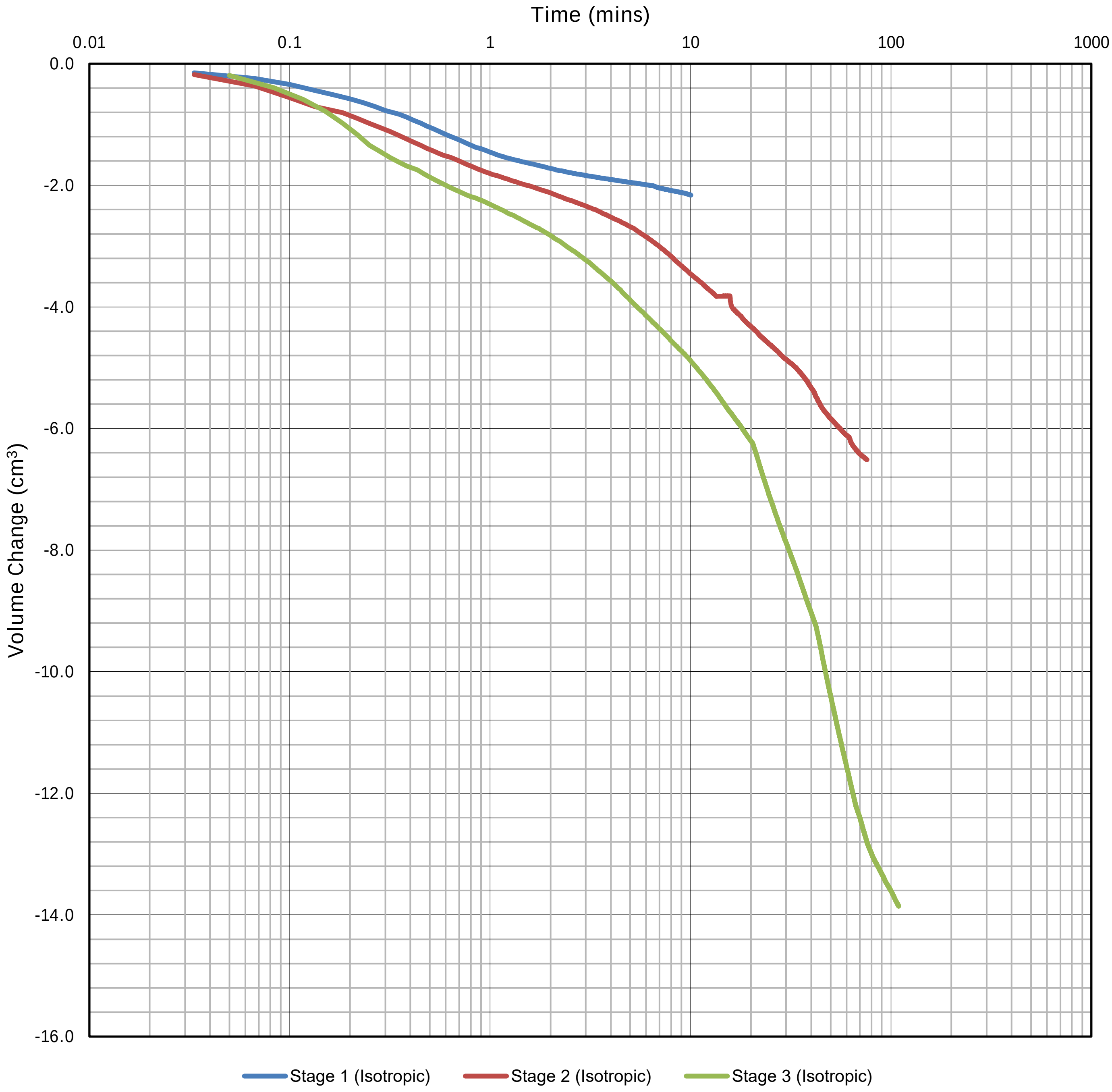
	Placed[2]	Saturated[2]	
Volume, V:	672.58	595.28	cm^3
Dry Density, ρ_d:	1.30	1.47	t/m^3
Void Ratio, e:	1.05	0.81	
Moisture Content, w:	11.56	30.49	%
Degree of Saturation, S:	29	100	%
Effective Confining Pressure, σ'_3:	0	19	kPa



Skempton's B-Value: 0.85 maximum recorded over a 5 minute period.

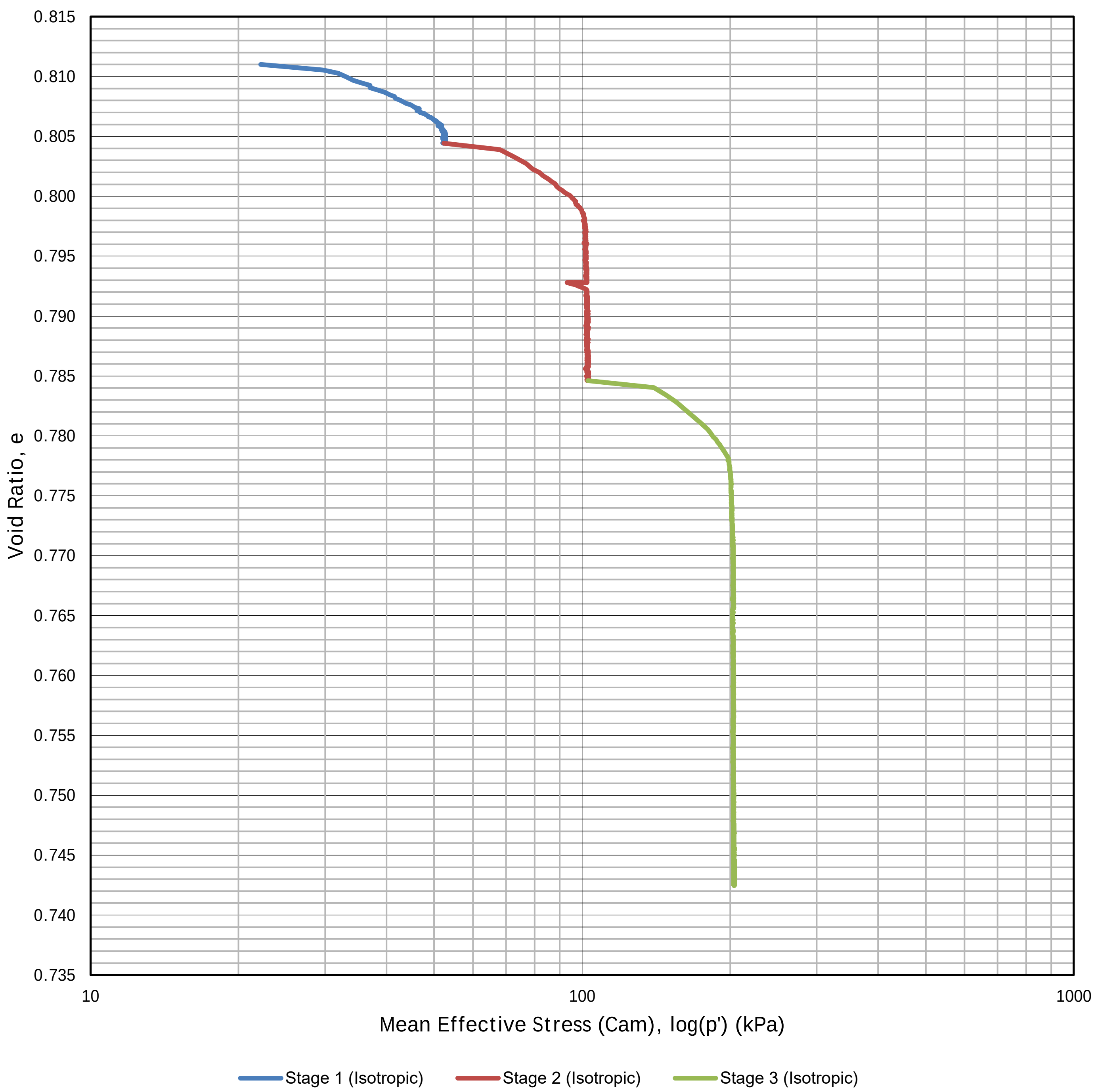
[1] The particle density provided has been directly measured according to AS1289.3.5.1

[2] 'Placed' parameters are directly measured. 'Saturated' are back calculated from the final moisture content.



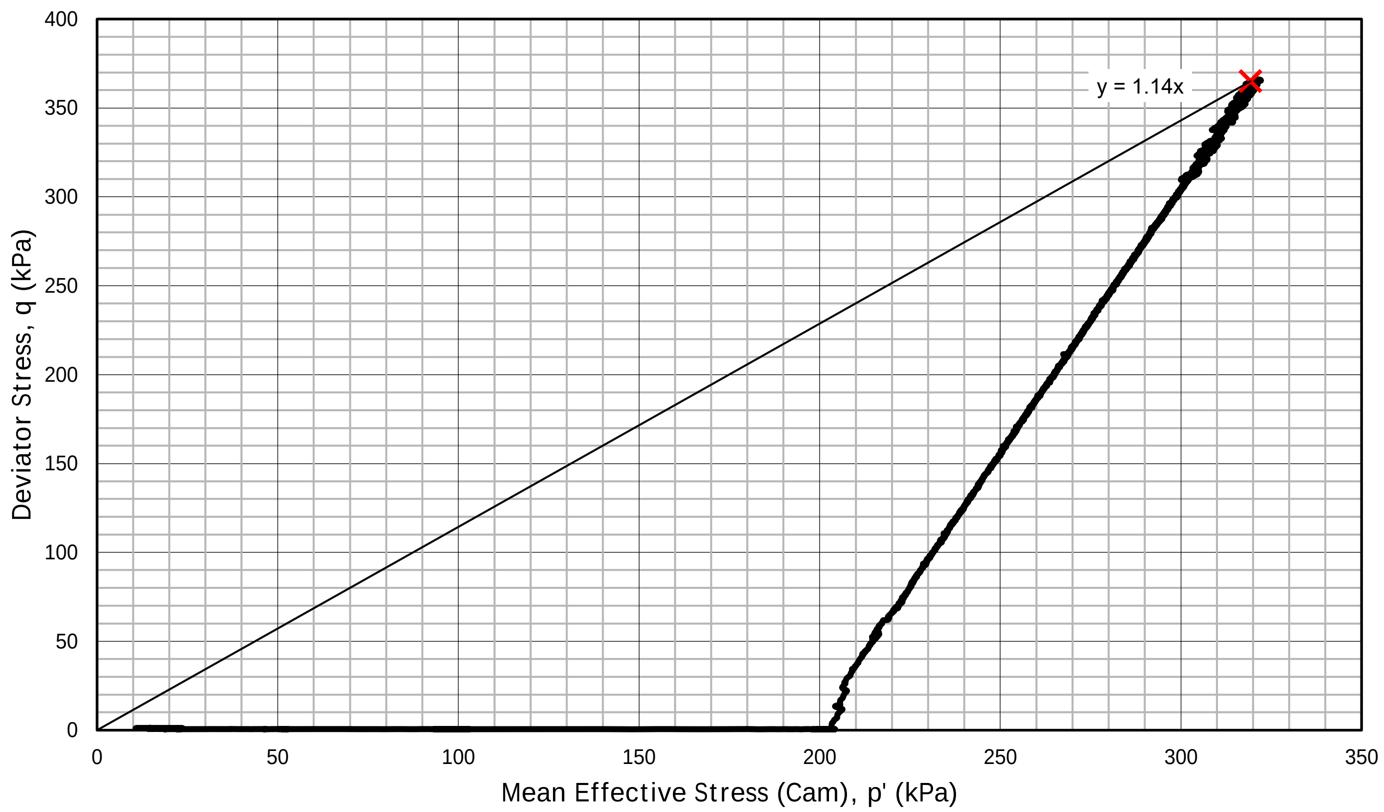
Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Effective Confining Pressure, σ'_3:	52	102	204	-	-	-	-	kPa
Effective Axial Pressure, σ'_1:	53	103	204	-	-	-	-	kPa
Deformation During Stage, ΔH:	0.09	0.14	0.17	-	-	-	-	mm
Volume Change, ΔV:	-2.16	-6.51	-13.86	-	-	-	-	cm^3
Total Volume of Sample, V:	593.12	586.61	572.75	-	-	-	-	cm^3
Coefficient of Consolidation, C_v:	1875	-	27	-	-	-	-	m^2/yr
Hydraulic Conductivity (from C_v), k_v:	6.33E-08	-	1.99E-09	-	-	-	-	m/s

Iluka Resources Limited Attacama Sands Triaxial - CD - Stress Paths - t/s' and e/log(p')	33022 Atacama Tails Test 3 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURE 1



Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Mean Effective Stress (Cam), p':	52	103	204	-	-	-	-	kPa
Effective Confining Pressure, σ'_3:	52	102	204	-	-	-	-	kPa
Effective Axial Pressure, σ'_1:	53	103	204	-	-	-	-	kPa
Dry Density, ρ_d:	1.47	1.49	1.53	-	-	-	-	t/m^3
Void Ratio, e:	0.80	0.78	0.74	-	-	-	-	
Moisture Content (Calculated), w:	30.2	29.5	27.9	-	-	-	-	%

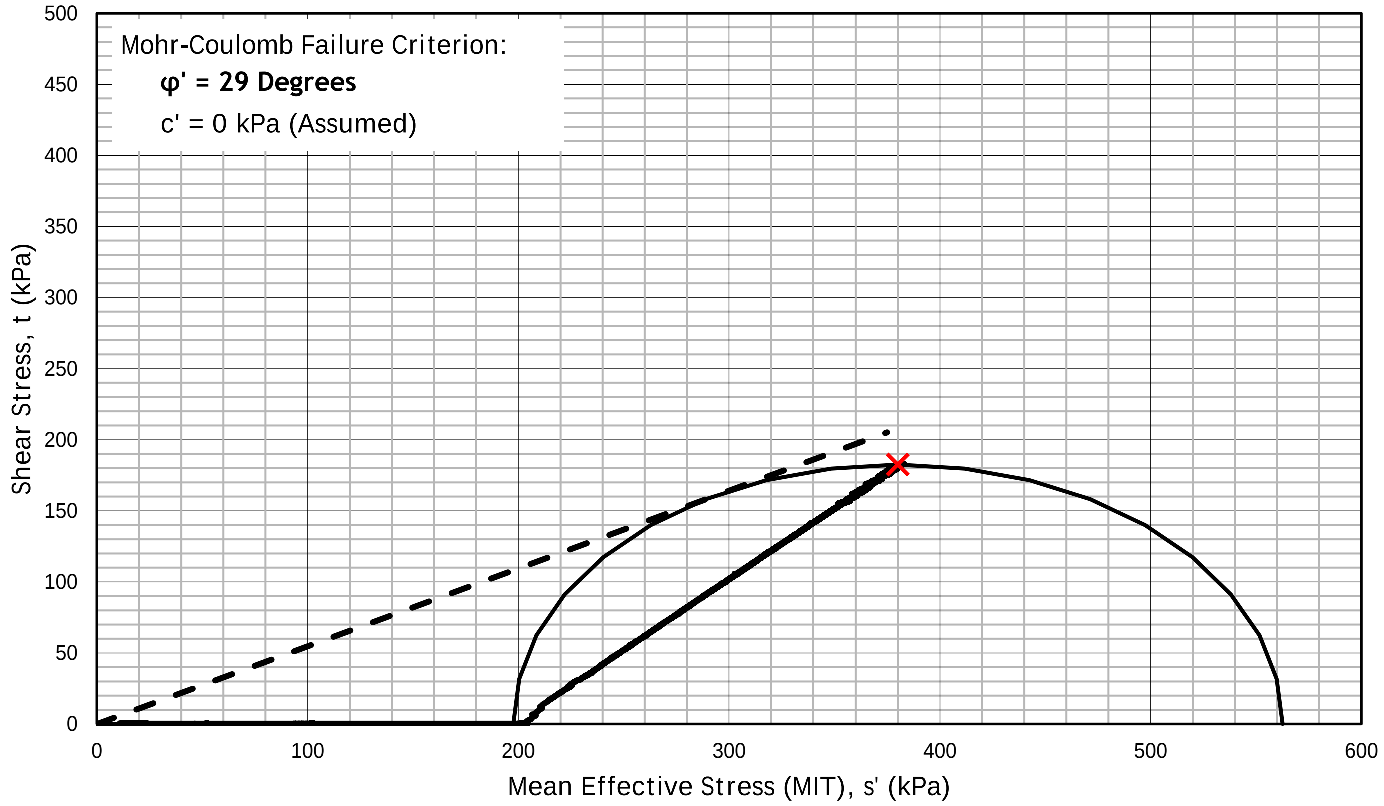
Iluka Resources Limited Attacama Sands Triaxial - CD - Stress Paths - t/s' and e/log(p')	33022 Atacama Tails Test 3 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURE 2

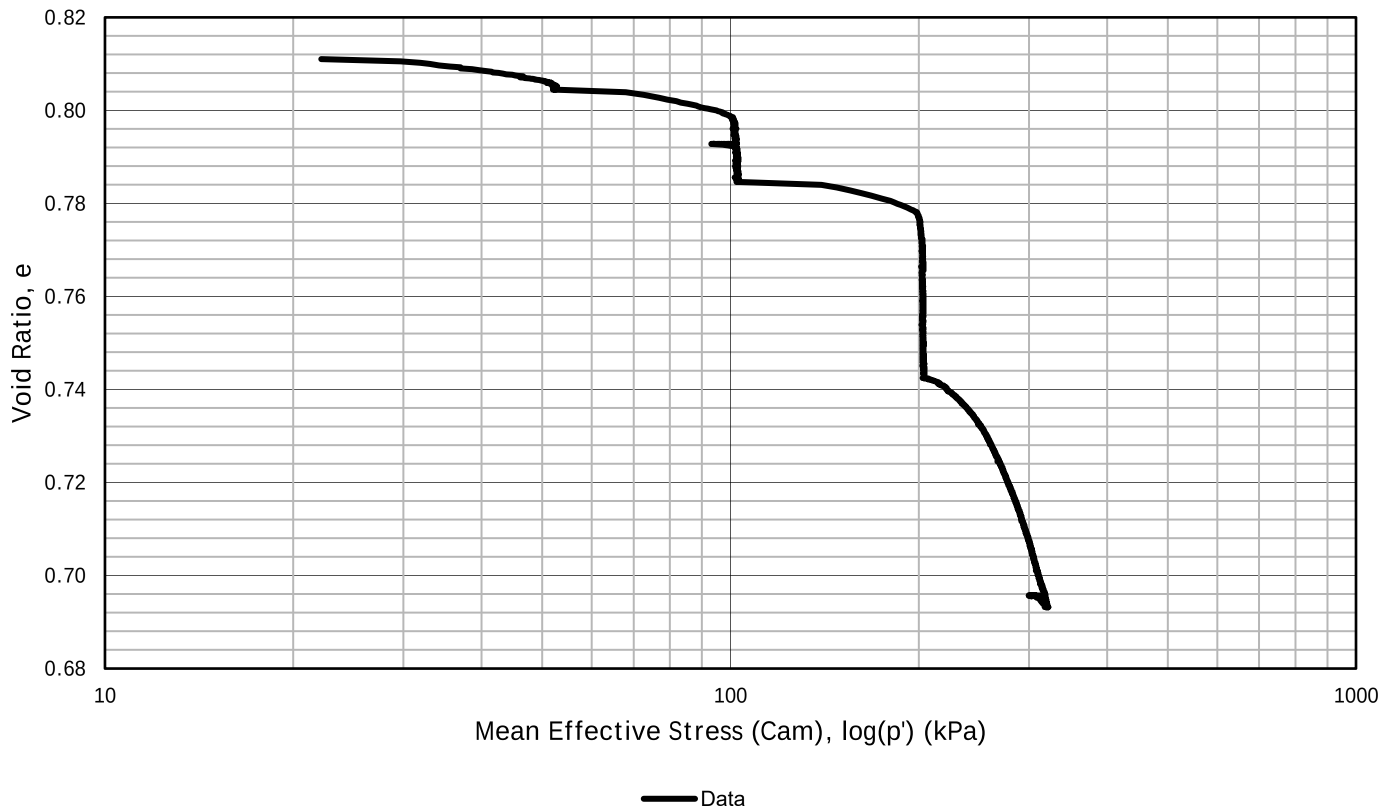


Undrained Monotonic Shear Stages:	Stage 1	Stage 2	Stage 3	
Initial Mean Effective Stress (Cam), p':	204	-	-	kPa
Initial Effective Confining Pressure, σ'_3:	204	-	-	kPa
Initial Effective Axial Pressure, σ'_1:	204	-	-	kPa
Dry Density, ρ_d:	1.53	-	-	t/m^3
Void Ratio, e:	0.74	-	-	
Moisture Content (Calculated), w:	27.9	-	-	%
Shear Rate, $\dot{\varepsilon}$:	0.05	-	-	mm/min
Failure Criteria:	Max q/p'	-	-	
Axial Strain at Failure, ε_a:	13.1	-	-	%
Deviator Stress at Failure[1], q:	365	-	-	kPa
Shear Stress at Failure, t:	183	-	-	kPa
Mean Effective Stress (Cam) at Failure, p':	319	-	-	kPa
Mean Effective Stress (MIT) at Failure, s':	380	-	-	kPa
Effective Confining Pressure at Failure, σ'_3:	198	-	-	kPa
Effective Axial Stress at Failure, σ'_1:	563	-	-	kPa
Excess Pore Pressure at Failure, u:	-	-	-	kPa
Mode of Failure:		Barrelling		
Undrained Shear Strength Ratio, S_u/σ'_1:	-	-	-	
Internal Friction Angle, ϕ':		29		o

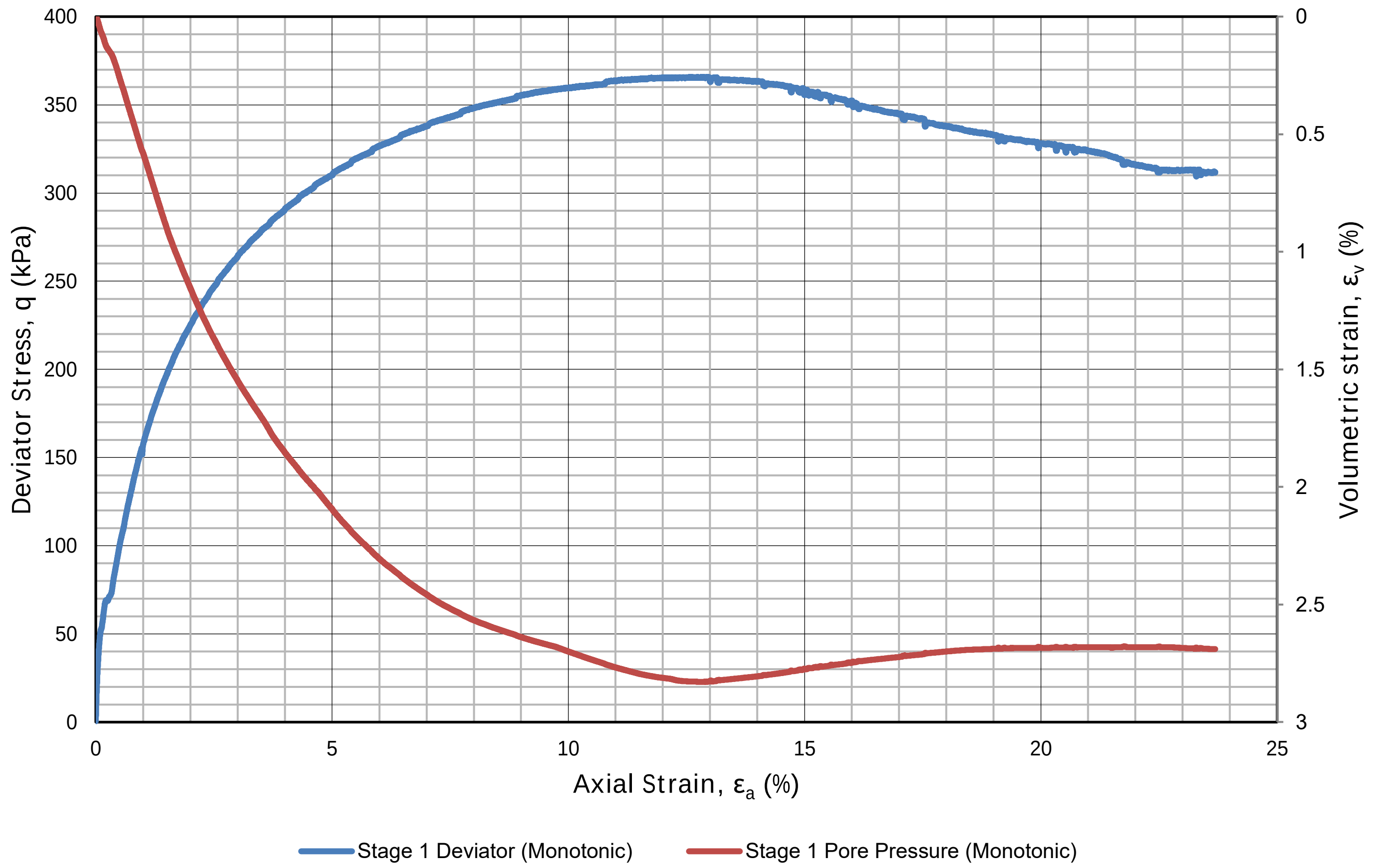
[1] Membrane correction has been applied.

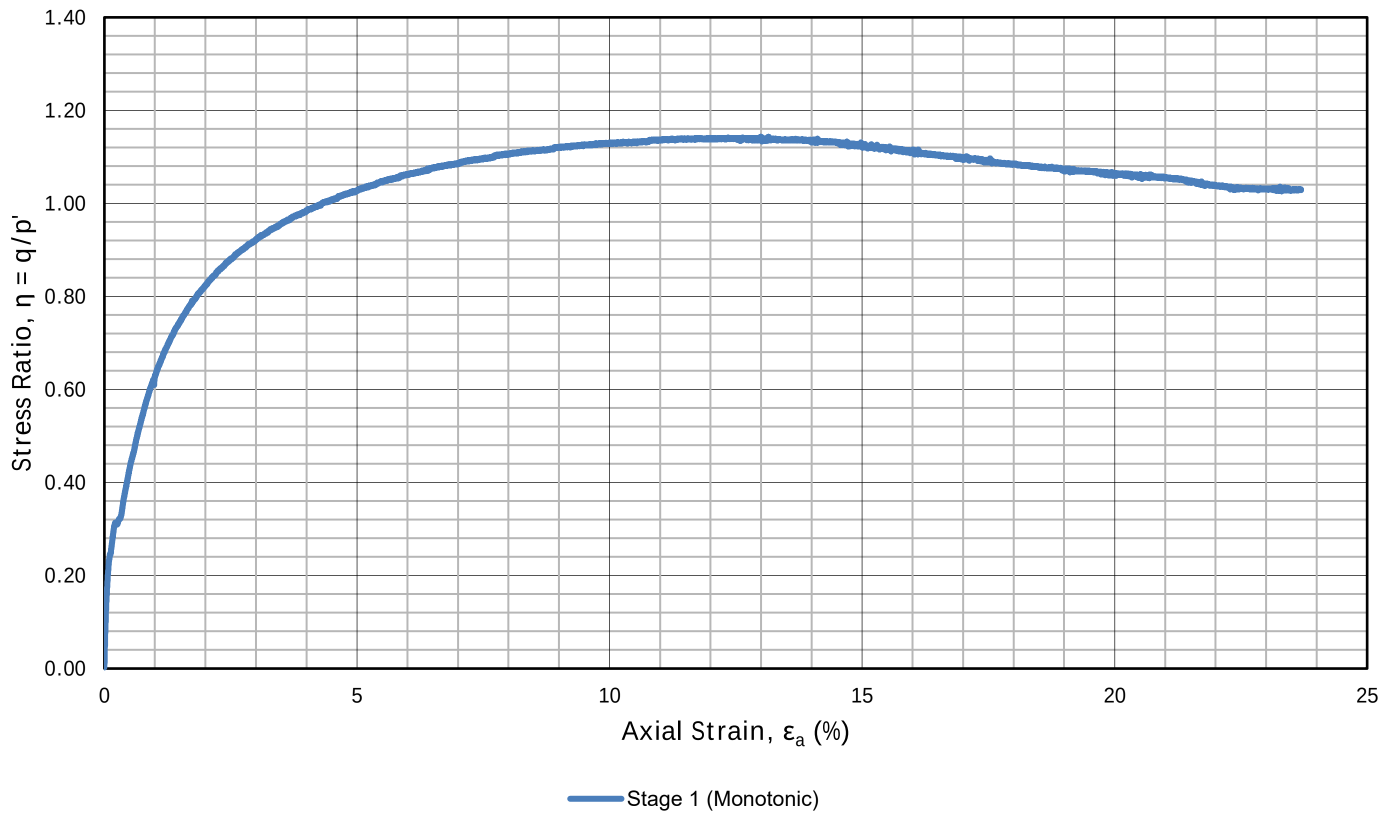
Iluka Resources Limited Attacama Sands Triaxial - CD - Stress Paths - t/s' and e/log(p')	33022 Atacama Tails Test 3 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022
	FIGURE 3





Iluka Resources Limited Attacama Sands Triaxial - CD - Stress Paths - t/s' and e/log(p')	33022 Atacama Tails Test 3 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURES 4 & 5





Iluka Resources Limited Attacama Sands Triaxial - CD - Stress Paths - t/s' and e/log(p')	33022 Atacama Tails Test 3 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURES 6 & 7

Sample prior to shearing.

Sample after shearing, still within membrane.

Sample after removal from membrane.

Sample after shearing, sliced down center.

Measured Angle of Shear Plane from Horizontal, α:	N/A	°

Iluka Resources Limited Attacama Sands Triaxial - CD - Stress Paths - t/s' and e/log(p')	33022 Atacama Tails Test 3 of 3
ATC WILLIAMS	Job No: Atacama Date: 12/10/2022 FIGURES 8 to 11

Triaxial Testing - CIU

- Tested in accordance with In House Method (IHM) 15.0
- ATCW IHM 15.0 incorporates both AS1289.6.4.2 and ASTM D5311-13
- Moisture content determined in accordance with AS1289.2.1.1
- Triaxial testing performed using the "ELDyn" apparatus

ATC WILLIAMS

Client:	Iluka Resources Limited		
Address:	LV 17 240 St Georges Terrace	Job No.:	119085.02
	Perth , 6000 WA	Register No.:	33022
Project:	Attacama Sands	Location:	WA

Report Details:

Report Author:	LR	Report Issued:	12/10/2022
Checked By:	MM	Report Last Updated:	12/10/2022 9:13

Test Details:

Test Start Date:	4/10/2022	Operator:	LR
Test End Date:	21/09/2022	Membrane Thick.:	1000 µm
Test Type:	CIU	Accessible Drainage:	Double

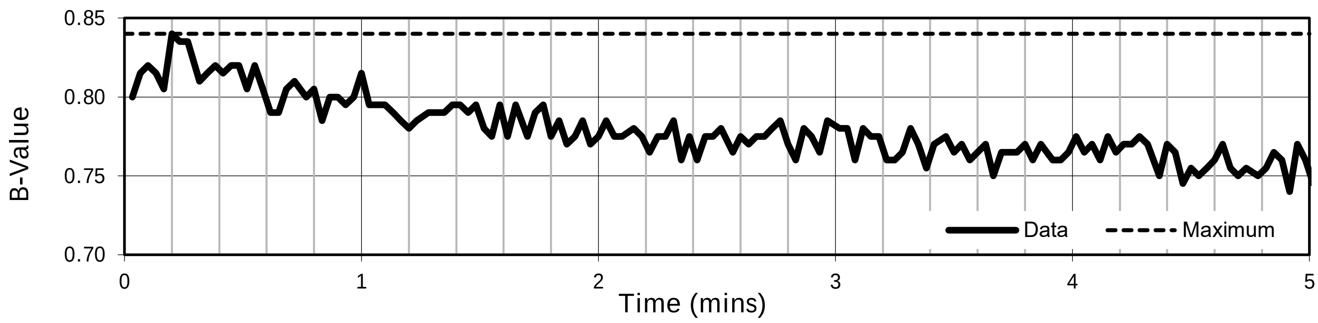
Sample Details:

Register Number:	33022	Date Sampled:	N/A
Test Number:	4 of 4	Sampled By:	Client
Description:	Atacama Tails	Sample Type:	Remoulded
Borehole Number:	N/A	Percent Compaction:	25 % RD
Depth:	N/A	Particle Density[1], ρ_{st}:	2.66 t/m^3

Specimen Details:

Initial Height:	152.24 mm	Dry Mass, M_d:	874.35 g
Initial Diameter:	75.00 mm	Initial Area:	44.18 cm^2

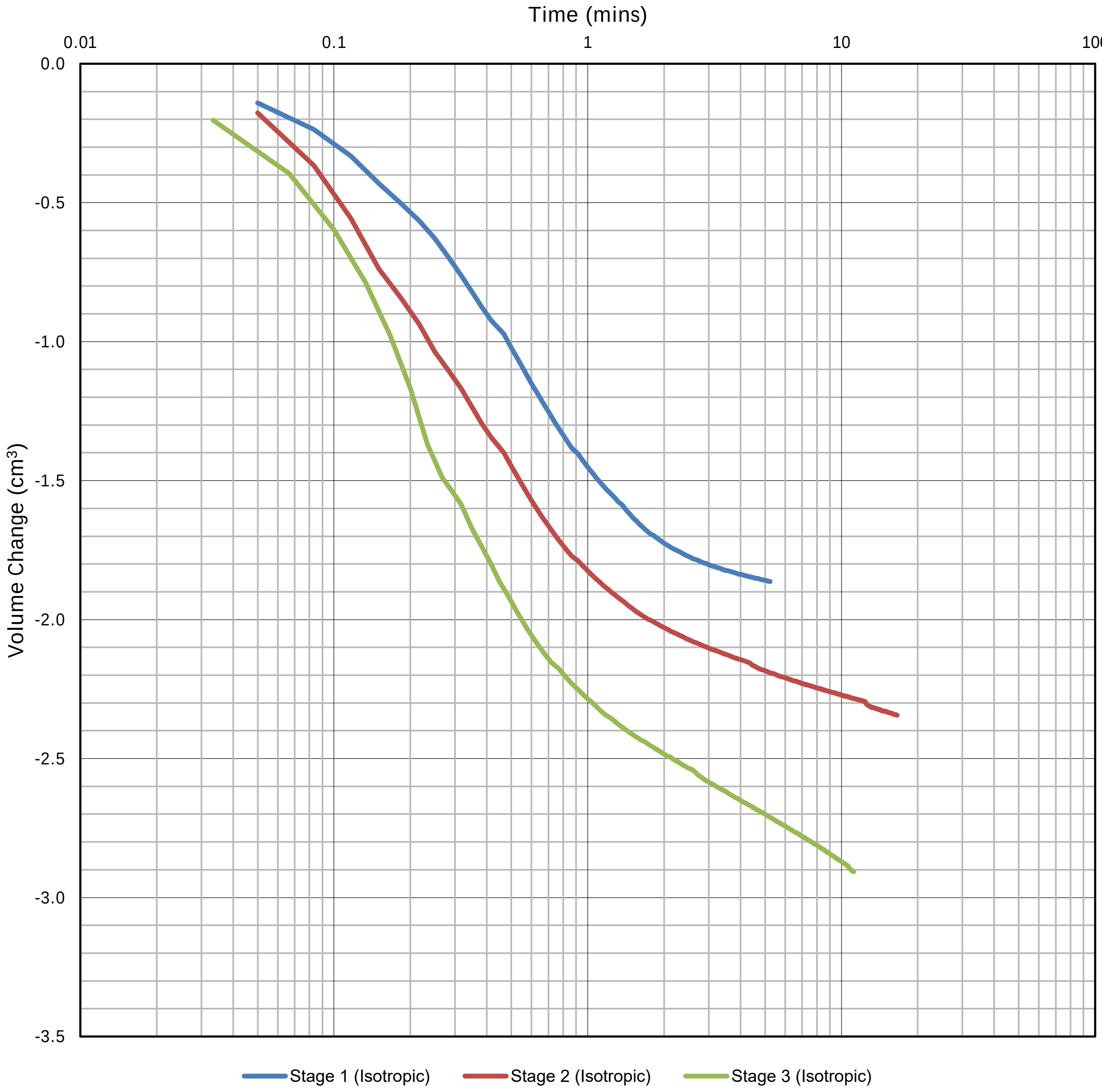
	Placed[2]	Saturated[2]	
Volume, V:	672.58	574.34	cm^3
Dry Density, ρ_d:	1.30	1.52	t/m^3
Void Ratio, e:	1.05	0.75	
Moisture Content, w:	11.56	28.09	%
Degree of Saturation, S:	29	100	%
Effective Confining Pressure, σ'_3:	0	19	kPa



Skempton's B-Value: 0.84 maximum recorded over a 5 minute period.

[1] The particle density provided has been directly measured according to AS1289.3.5.1

[2] 'Placed' parameters are directly measured. 'Saturated' are back calculated from the final moisture content.



Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Effective Confining Pressure, σ'_3:	53	104	204	-	-	-	-	kPa
Effective Axial Pressure, σ'_1:	54	104	204	-	-	-	-	kPa
Deformation During Stage, ΔH:	0.08	0.12	0.14	-	-	-	-	mm
Volume Change, ΔV:	-1.86	-2.34	-2.91	-	-	-	-	cm^3
Total Volume of Sample, V:	572.48	570.13	567.23	-	-	-	-	cm^3
Coefficient of Consolidation, C_v:	1545	2561	3194	-	-	-	-	m^2/yr
Hydraulic Conductivity (from C_v), k_v:	4.55E-08	6.47E-08	5.05E-08	-	-	-	-	m/s

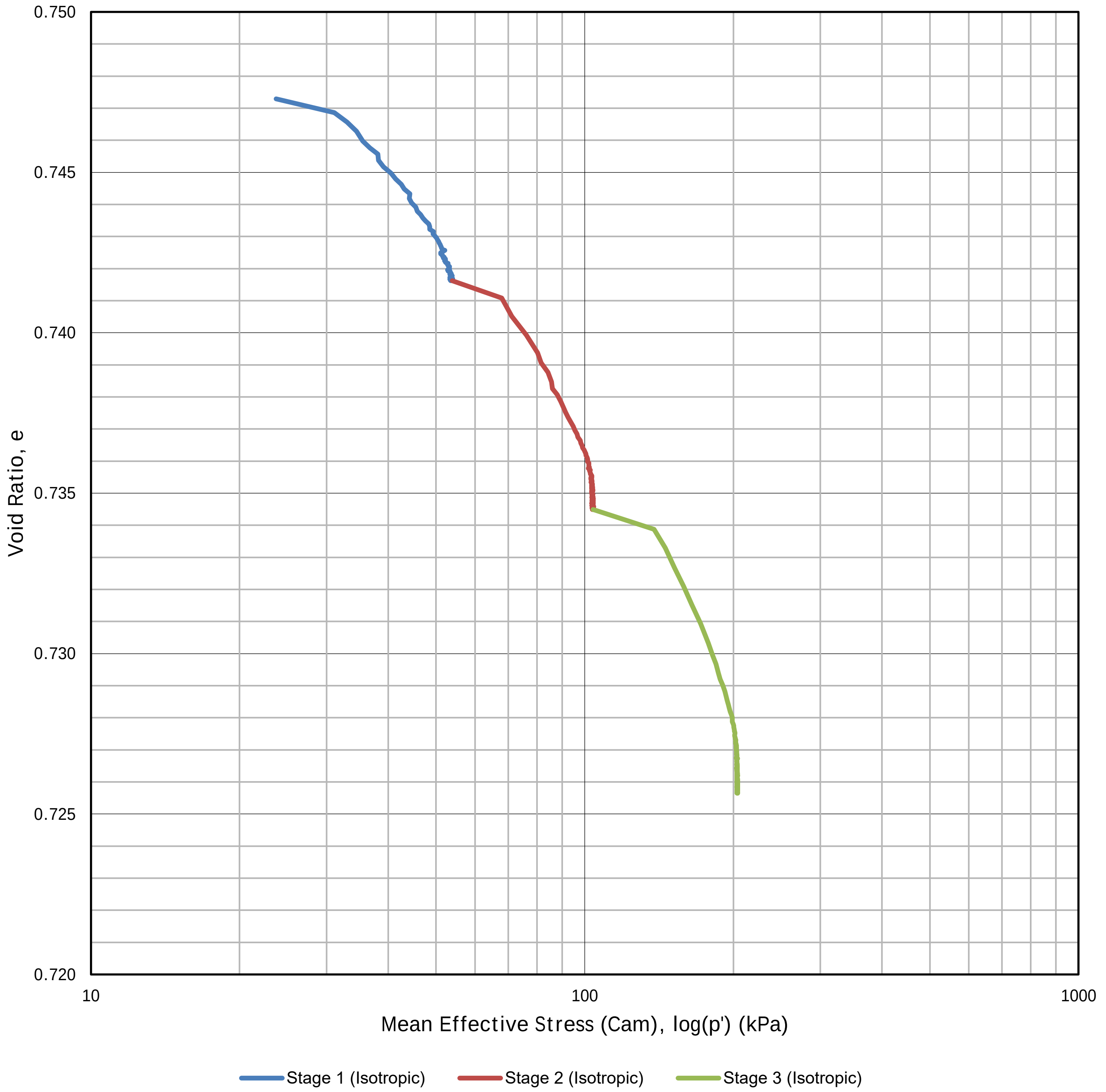
Iluka Resources Limited
Attacama Sands
Triaxial - CIU - Consolidation (Pre-shearing)

33022
Atacama Tails
Test 4 of 4

ATC WILLIAMS

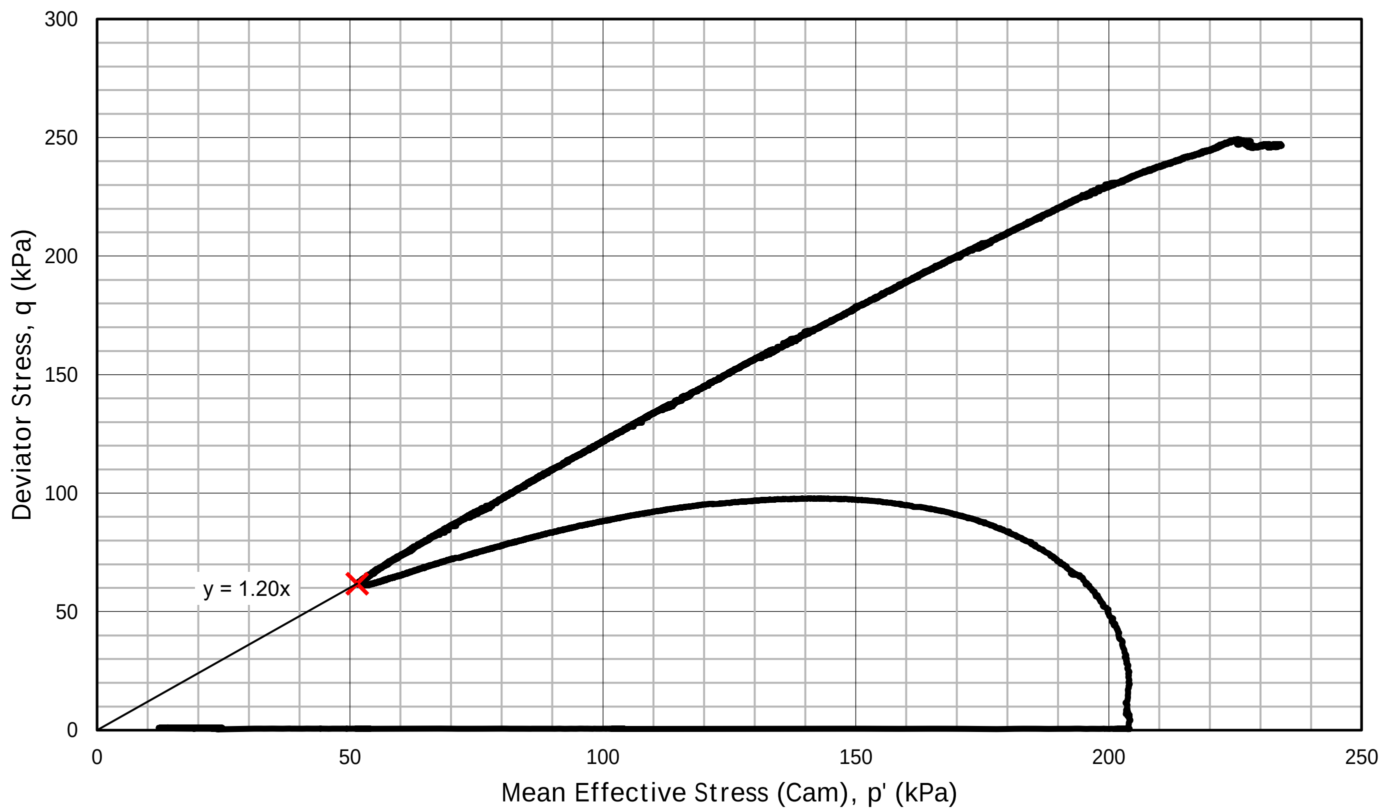
Job No: 119085.02
Date: 12/10/2022

FIGURE 1



Consolidation Stages (Pre-shearing):	Isotropic						Aniso	
	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6		
Mean Effective Stress (Cam), p':	54	104	204	-	-	-	-	kPa
Effective Confining Pressure, σ'_3:	53	104	204	-	-	-	-	kPa
Effective Axial Pressure, σ'_1:	54	104	204	-	-	-	-	kPa
Dry Density, ρ_d:	1.53	1.53	1.54	-	-	-	-	t/m^3
Void Ratio, e:	0.74	0.73	0.73	-	-	-	-	
Moisture Content (Calculated), w:	27.9	27.6	27.3	-	-	-	-	%

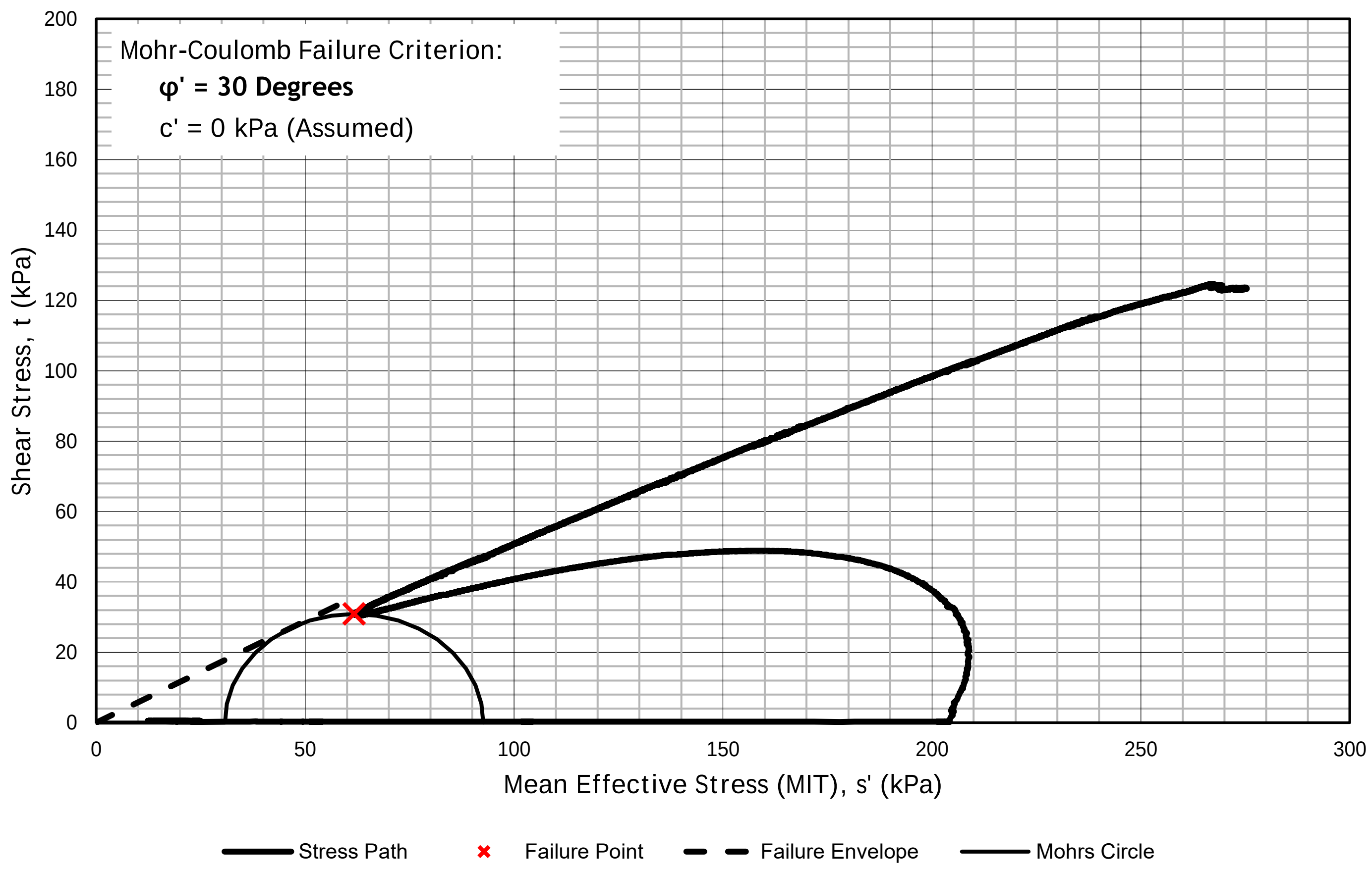
Iluka Resources Limited Attacama Sands Triaxial - CIU - Stress Path (Pre-shearing) - e/log(p')	33022 Atacama Tails Test 4 of 4
ATC WILLIAMS	Job No: 119085.02 Date: 12/10/2022 FIGURE 2



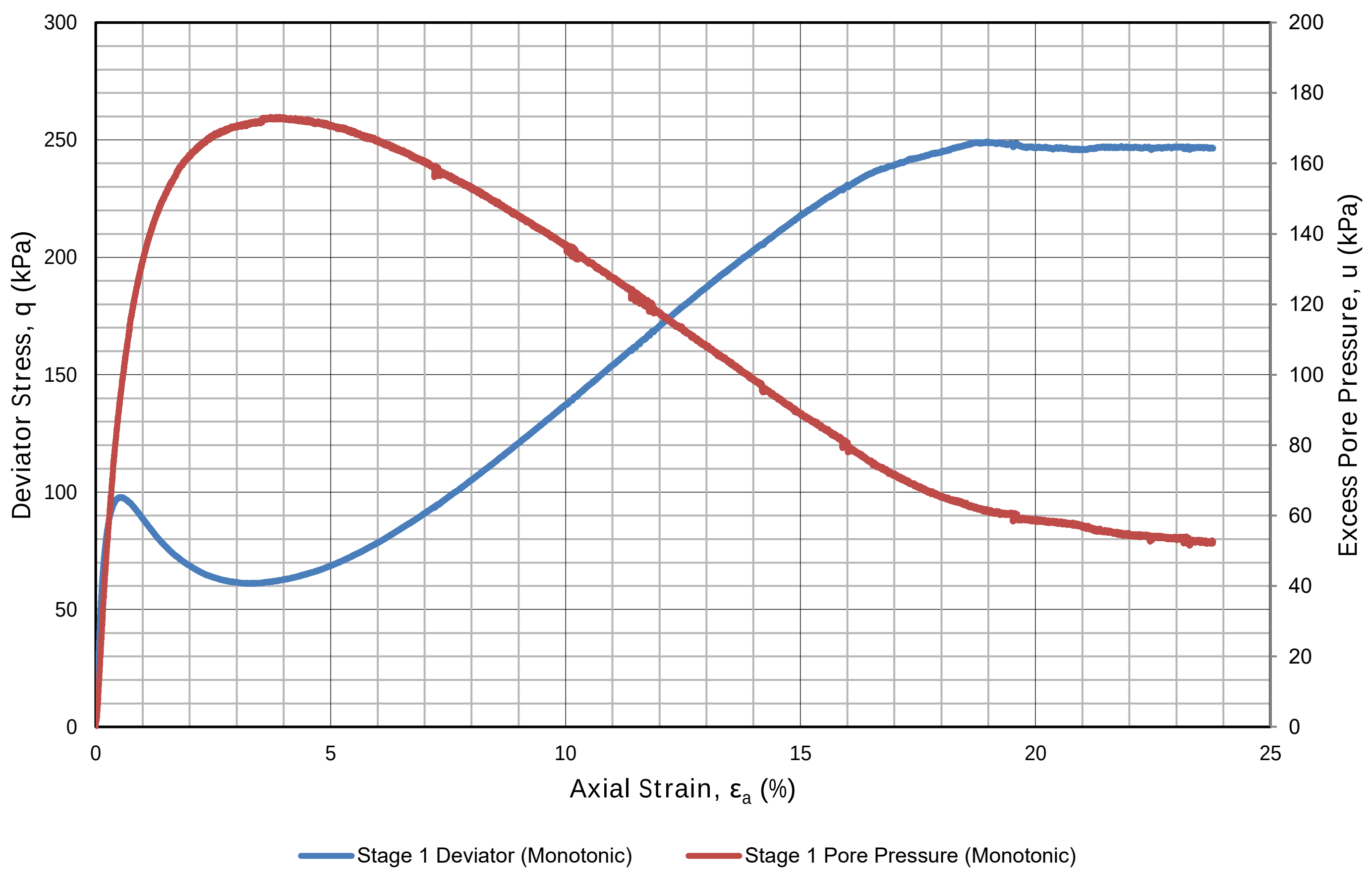
Undrained Monotonic Shear Stages:	Stage 1	Stage 2	Stage 3	
Initial Mean Effective Stress (Cam), p':	204	-	-	kPa
Initial Effective Confining Pressure, σ'_3:	204	-	-	kPa
Initial Effective Axial Pressure, σ'_1:	204	-	-	kPa
Dry Density, ρ_d:	1.54	-	-	t/m^3
Void Ratio, e:	0.73	-	-	
Moisture Content (Calculated), w:	27.3	-	-	%
Shear Rate, $\dot{\varepsilon}$:	0.05	-	-	mm/min
Failure Criteria:	QSS	-	-	
Axial Strain at Failure, ε_a:	3.7	-	-	%
Deviator Stress at Failure[1], q:	62	-	-	kPa
Undrained Shear Stress at Failure, S_u:	31	-	-	kPa
Mean Effective Stress (Cam) at Failure, p':	51	-	-	kPa
Mean Effective Stress (MIT) at Failure, s':	62	-	-	kPa
Effective Confining Pressure at Failure, σ'_3:	31	-	-	kPa
Effective Axial Stress at Failure, σ'_1:	93	-	-	kPa
Excess Pore Pressure at Failure, u:	173	-	-	kPa
Mode of Failure:	Barrelling			
Undrained Shear Strength Ratio, S_u/σ'_1:	0.15	-	-	
Internal Friction Angle, ϕ':	30			°

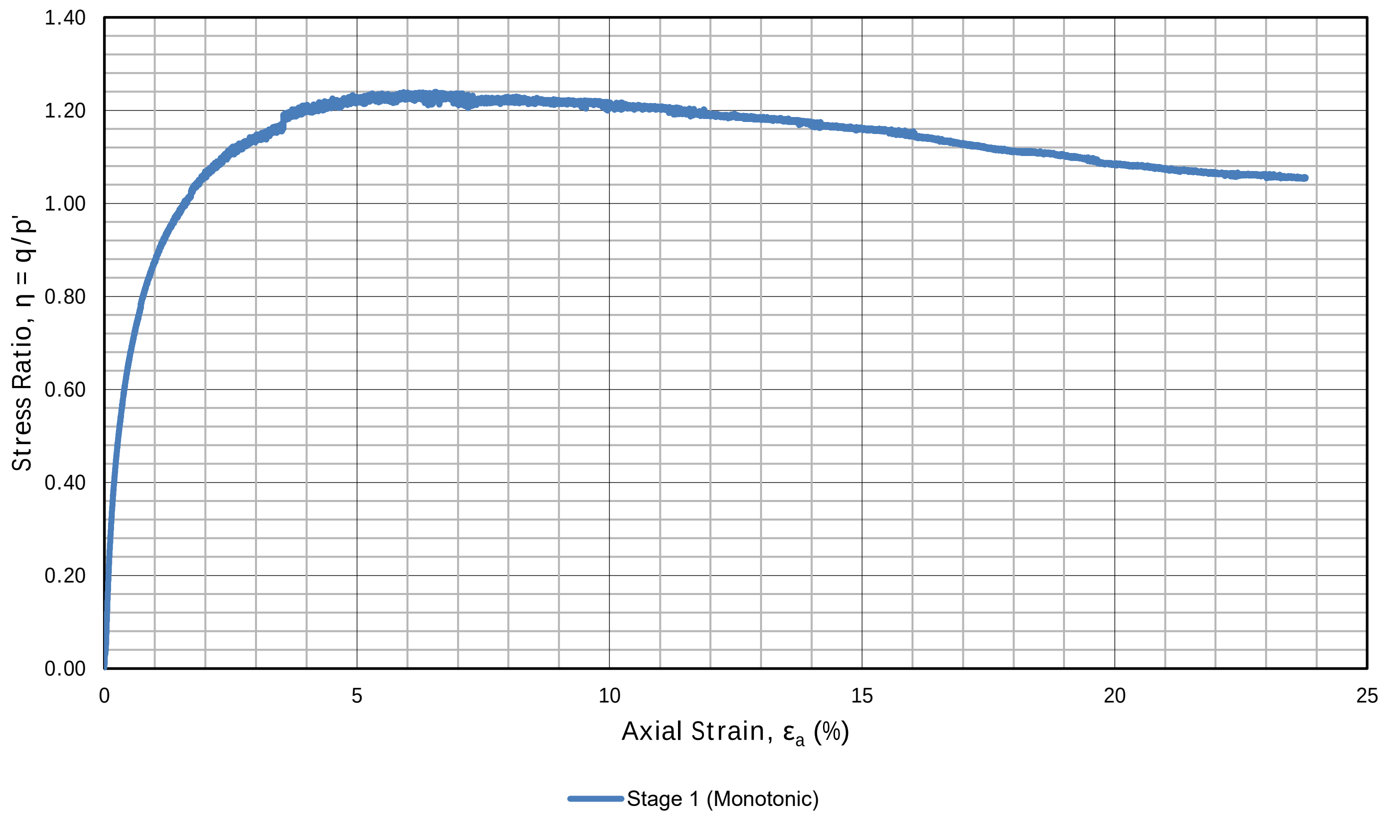
[1] Membrane correction has been applied.

Iluka Resources Limited Attacama Sands Triaxial - CIU - Stress Path - q/p'	33022 Atacama Tails Test 4 of 4
ATC WILLIAMS	Job No: 119085.02 Date: 12/10/2022
	FIGURE 3

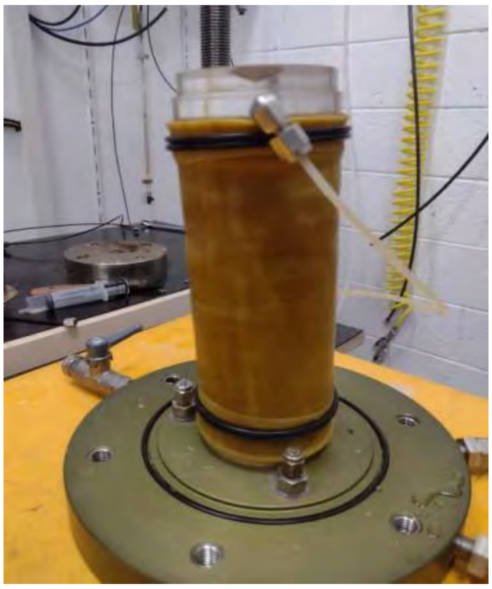


Iluka Resources Limited Attacama Sands Triaxial - CIU - Stress Paths - S_u/s' and e/log(p')	33022 Atacama Tails Test 4 of 4
ATC WILLIAMS	Job No: 119085.02 Date: 12/10/2022
	FIGURES 4 & 5





Iluka Resources Limited Attacama Sands **Triaxial - CIU - q, u and q/p' vs ε_a**	33022 Atacama Tails Test 4 of 4
ATC WILLIAMS	Job No: 119085.02 Date: 12/10/2022
	FIGURES 6 & 7



Sample prior to shearing.

Sample after shearing, still within membrane.

Sample after removal from membrane.

Sample after shearing, sliced down center.

Measured Angle of Shear Plane from Horizontal, α:	N/A °

Iluka Resources Limited Attacama Sands Triaxial - CIU - Images and Angle of Shear Plane	33022 Atacama Tails Test 4 of 4
ATC WILLIAMS	Job No: 119085.02 Date: 12/10/2022
	FIGURES 8 to 11

APPENDIX B – STABILITY ANALYSES FIGURES

Figure #	Description		Factor of Safety
FIGURE B1	Previously Sand-Stacked Embankment Foundation	Sand Stack Height - 15m , Equipment - D10T	2.1
FIGURE B2	In-Situ Foundation Material	Sand Stack Height - 15m , Equipment - D10T , Foundation Material - Brown Loam	1.7
FIGURE B3		Sand Stack Height - 15m , Equipment - D10T , Foundation Material - Red Loam	1.7
FIGURE B4	Head of Beach Mod-Cod Tailings	Sand Stack Height - 3m , Equipment - D10T	1.6
FIGURE B5		Sand Stack Height - 15m , Equipment - D10T	1.8
FIGURE C1	Assessment of Initial Pioneer Layer Thickness	Pioneer Layer Thickness - 1m , Phreatic Surface Depth - 0m , Equipment - D8T LGP	1.1
FIGURE C2		Pioneer Layer Thickness - 1m , Phreatic Surface Depth - 0m , Equipment - D10T	0.9
FIGURE C3		Pioneer Layer Thickness - 1m , Phreatic Surface Depth - 2m , Equipment - D8T LGP	1.2
FIGURE C4		Pioneer Layer Thickness - 2m , Phreatic Surface Depth - 0m , Equipment - D8T LGP	1.1
FIGURE C5		Pioneer Layer Thickness - 2m , Phreatic Surface Depth - 0m , Equipment - D10T	1.1
FIGURE C6		Pioneer Layer Thickness - 2m , Phreatic Surface Depth - 2m , Equipment - D8T LGP	1.4
FIGURE C7		Pioneer Layer Thickness - 2m , Phreatic Surface Depth - 2m , Equipment - D10T	1.3
FIGURE C8		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - NONE	1.2
FIGURE C9		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D8T LGP	1.1
FIGURE C10		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T	1.1
FIGURE C11		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 1m , Equipment - NONE	1.4
FIGURE C12		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 1m , Equipment - D8T LGP	1.3
FIGURE C13		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 1m , Equipment - D10T	1.3
FIGURE C14		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 2m , Equipment - NONE	1.6
FIGURE C15		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 2m , Equipment - D8T LGP	1.5
FIGURE C16		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 2m , Equipment - D10T	1.4
FIGURE C17		Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 0m , Equipment - D10T	1.1
FIGURE C18		Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 1m , Equipment - D10T	1.2
FIGURE C19		Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 2m , Equipment - D10T	1.4
FIGURE C20		Pioneer Layer Thickness - 5m , Phreatic Surface Depth - 0m , Equipment - NONE	1.1
FIGURE C21		Pioneer Layer Thickness - 5m , Phreatic Surface Depth - 0m , Equipment - D8T LGP	1.1
FIGURE C22		Pioneer Layer Thickness - 5m , Phreatic Surface Depth - 0m , Equipment - D10T	1.0
FIGURE C23		Pioneer Layer Thickness - 5m , Phreatic Surface Depth - 2m , Equipment - D10T	1.4
FIGURE C24		Pioneer Layer Thickness - 10m , Phreatic Surface Depth - 0m , Equipment - D10T	1.0
FIGURE C25		Pioneer Layer Thickness - 10m , Phreatic Surface Depth - 2m , Equipment - D10T	1.2
FIGURE C26		Pioneer Layer Thickness - 15m , Phreatic Surface Depth - 0m , Equipment - D10T	1.0
FIGURE C27		Pioneer Layer Thickness - 15m , Phreatic Surface Depth - 2m , Equipment - D10T	1.1
FIGURE C28	Placement of Second Pioneer Layer	Second Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D8T LGP	1.7
FIGURE C29		Second Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T	1.6
FIGURE C30	Assessment of Depth of Sand Stack, Placement over Pioneer Layer	Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 10m	1.3
FIGURE C31		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 15m	1.2
FIGURE C32		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 20m	1.2
FIGURE C33		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 25m	1.1
FIGURE C34		Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 30m	1.1
FIGURE C35		Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 10m	1.4
FIGURE C36		Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 15m	1.3
FIGURE C37		Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 20m	1.2
FIGURE C38		Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 25m	1.2
FIGURE C39		Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 30m	1.1
FIGURE C40		Pioneer Layer Thickness - 6m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 10m	1.4
FIGURE C41		Pioneer Layer Thickness - 6m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 15m	1.4
FIGURE C42		Pioneer Layer Thickness - 6m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 20m	1.4
FIGURE C43		Pioneer Layer Thickness - 6m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 25m	1.3
FIGURE C44		Pioneer Layer Thickness - 6m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 30m	1.2

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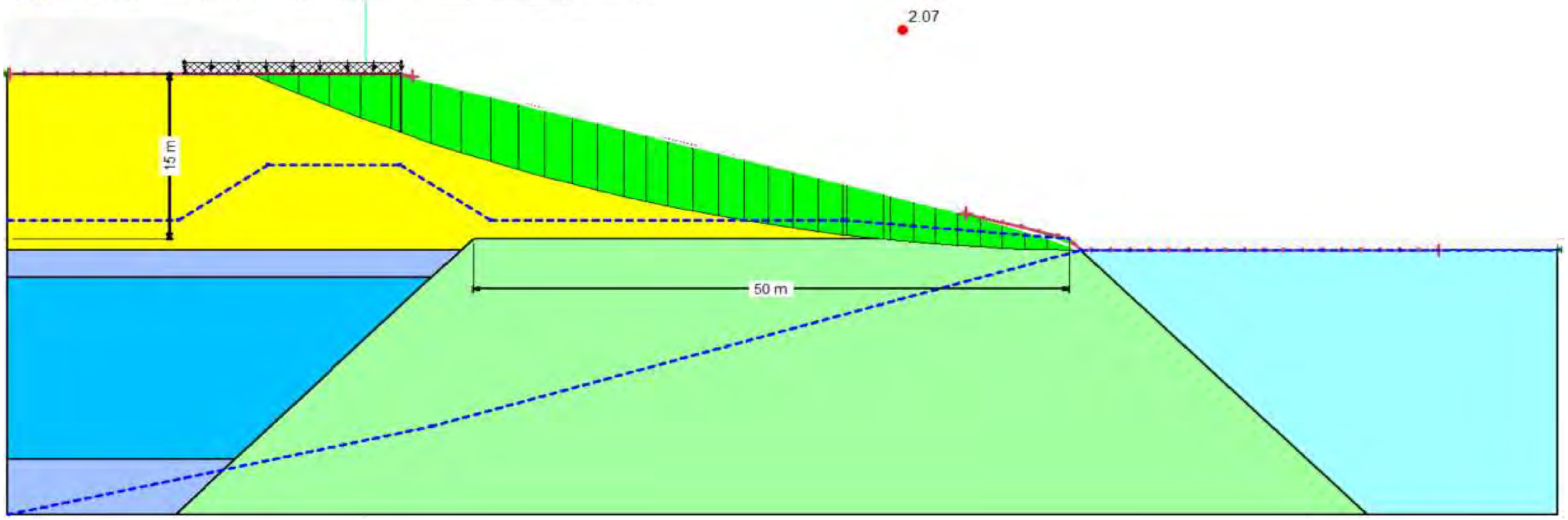
ATACAMA STABILITY STUDY

Results Summary

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C0

Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Embankment material	Mohr-Coulomb	15.9			0	33	1
	Sand Fill	Mohr-Coulomb	14.7			0	25	2
	Tailings (decant)	SHANSEP	12	5	0.3			1
	Tailings (HOB - weaker)	SHANSEP	12	10	0.4			1
	Tailings (HOB)	SHANSEP	12	10	0.6			1



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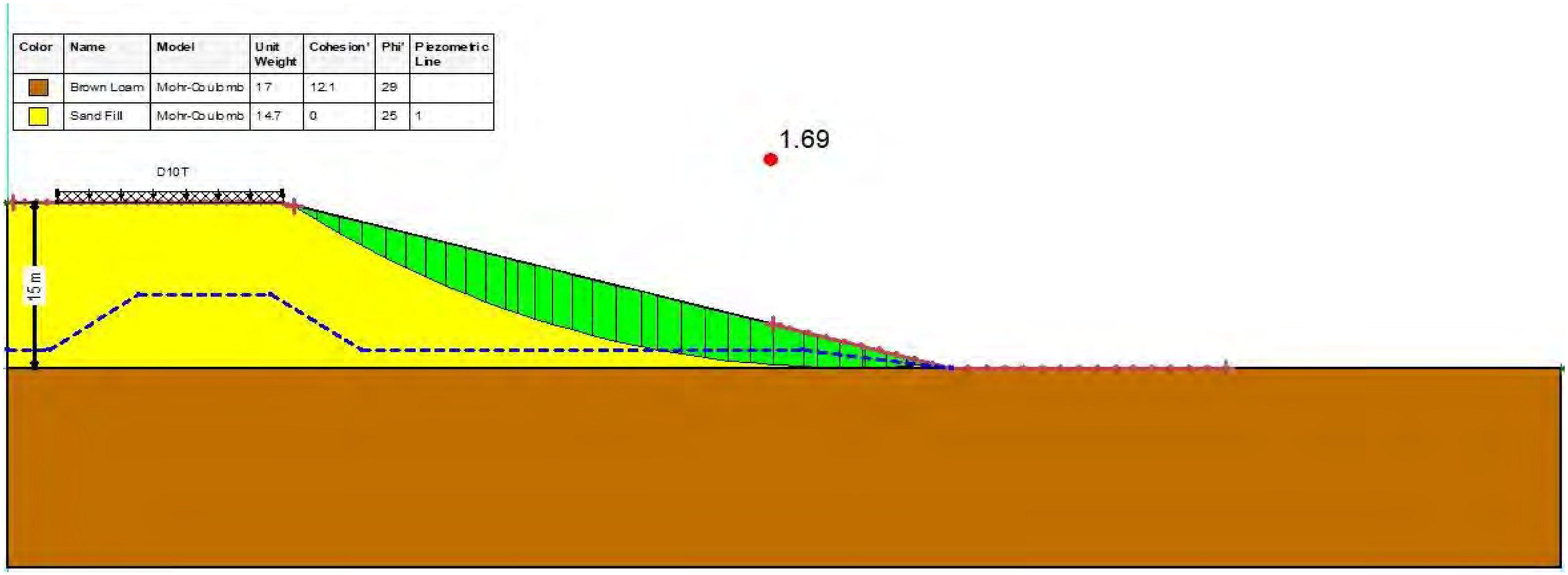
ATACAMA STABILITY STUDY - Previously Sand-Stacked Embankment Foundation

Sand Stack Height - 15m , Equipment - D10T

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE B1**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 B1



Color	Name	Model	Unit Weight	Cohesion'	Phi'	Piezometric Line
	Brown Loam	Mohr-Coulomb	17	12.1	29	
	Sand Fill	Mohr-Coulomb	14.7	0	25	1

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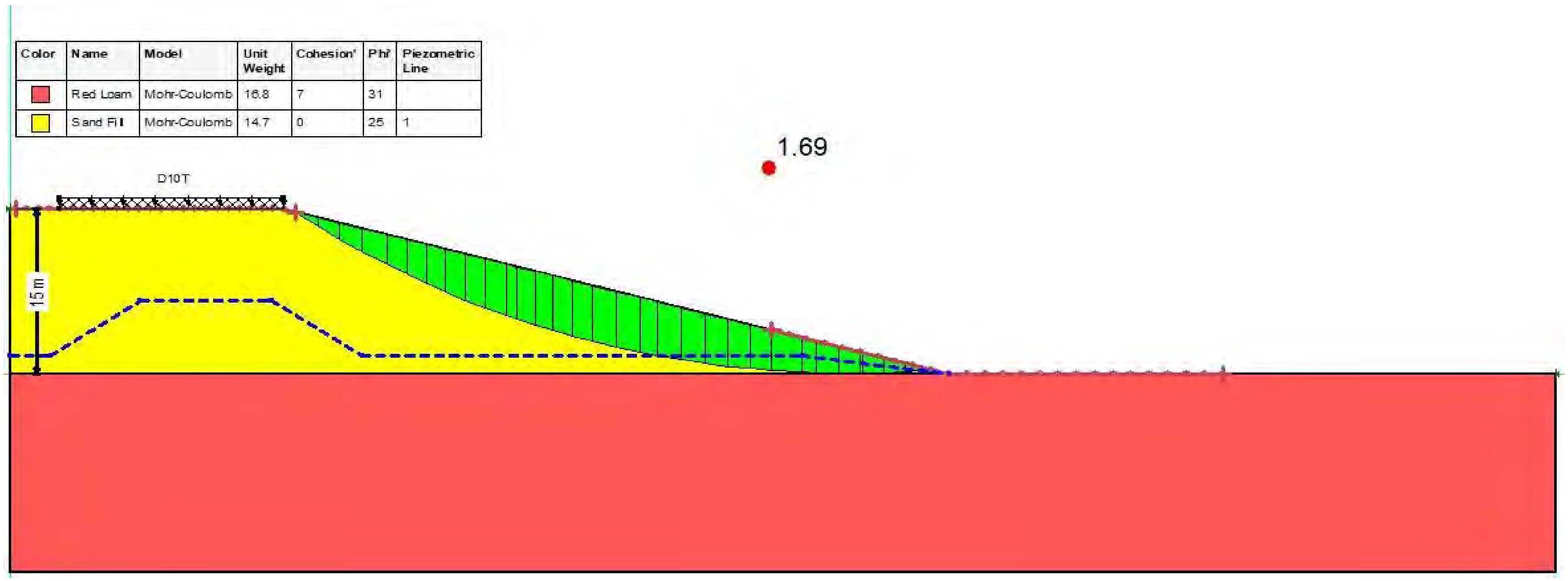
ATACAMA STABILITY STUDY - In-Situ Foundation Material

Sand Stack Height - 15m , Equipment - D10T , Foundation Material - Brown Loam

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE B2**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 B2



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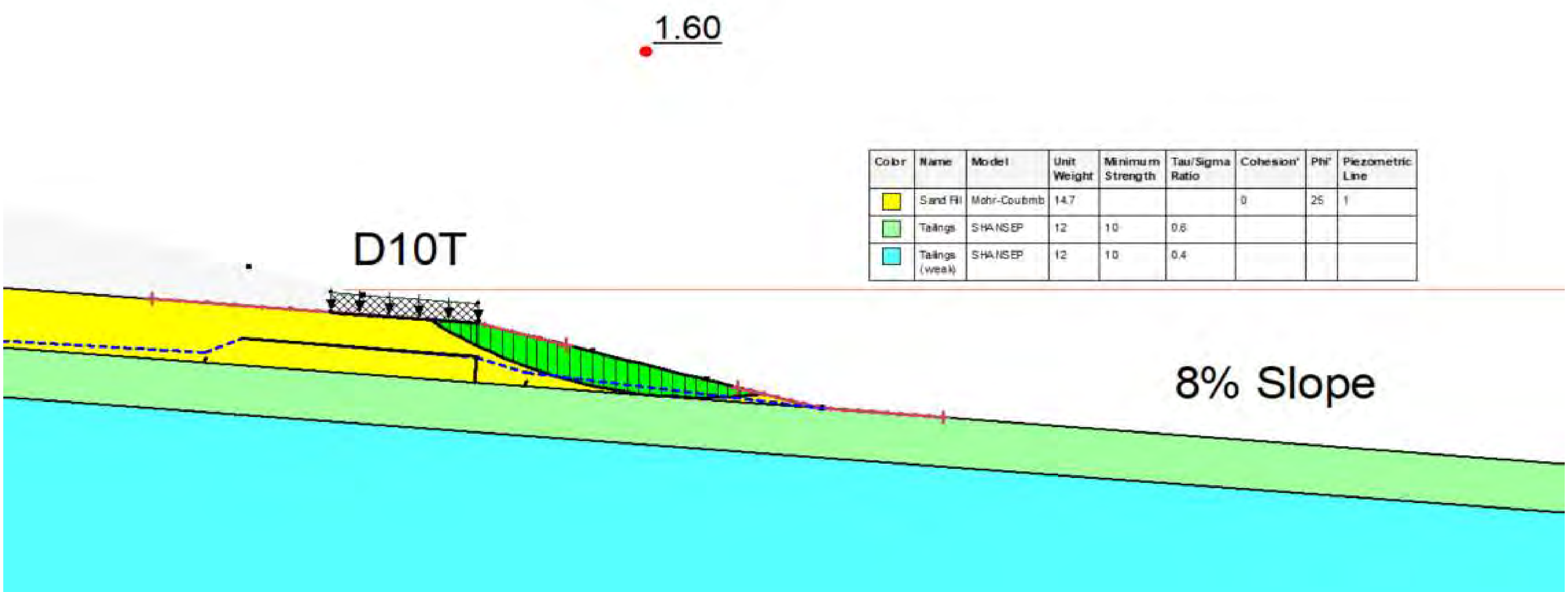
ATACAMA STABILITY STUDY - In-Situ Foundation Material

Sand Stack Height - 15m , Equipment - D10T , Foundation Material - Red Loam

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE B3**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 B3



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
(yellow)	Sand Fill	Mohr-Coulomb	14.7			0	25	1
(green)	Tailings	SHANSEP	12	10	0.6			
(cyan)	Tailings (weak)	SHANSEP	12	10	0.4			

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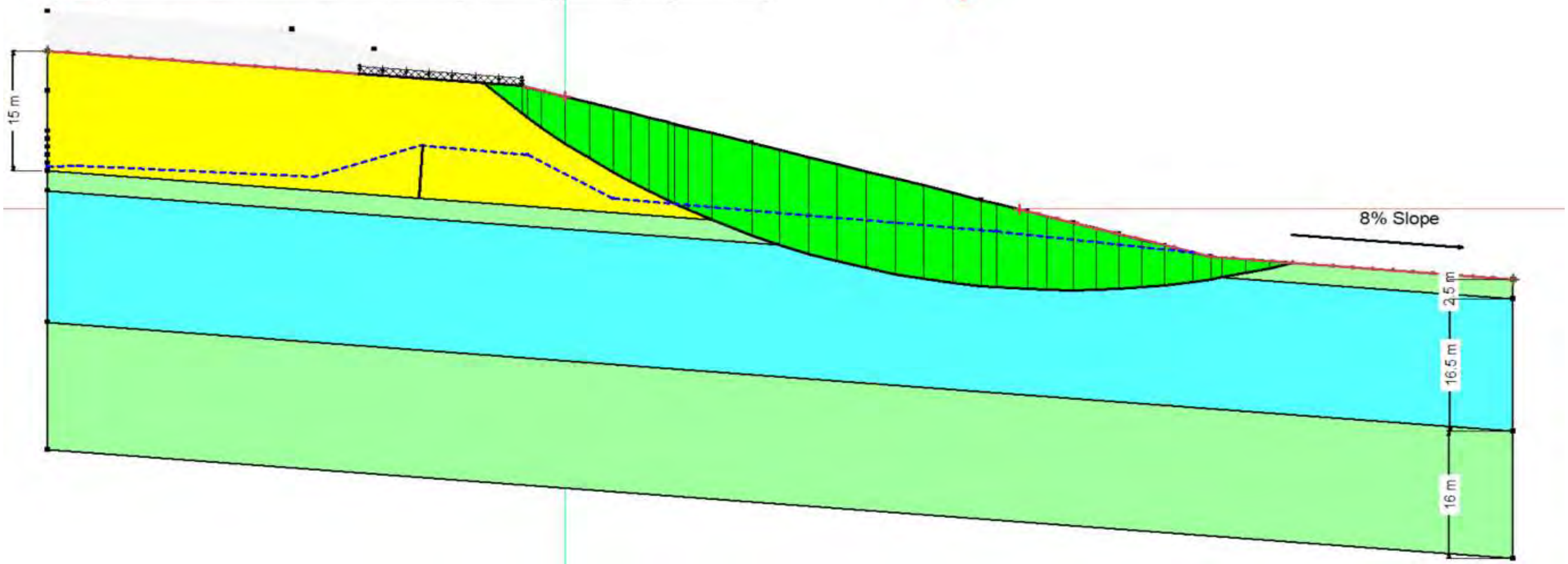
ATACAMA STABILITY STUDY - Head of Beach Mod-Cod Tailings

Sand Stack Height - 3m , Equipment - D10T

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE B4**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 B4

Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
(yellow)	Sand Fill	Mohr-Coulomb	14.7			0	25	1
(light green)	Tailings	SHANSEP	12	10	0.6			
(cyan)	Tailings (weak)	SHANSEP	12	10	0.4			



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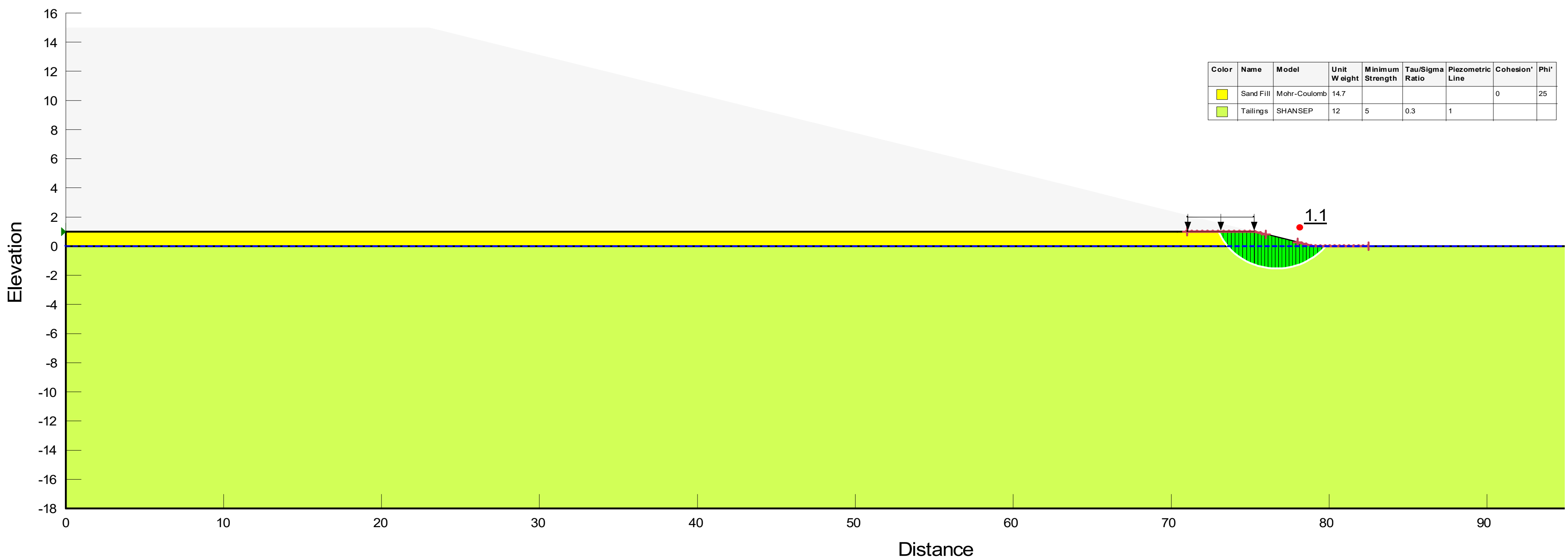
ATACAMA STABILITY STUDY - Head of Beach Mod-Cod Tailings

Sand Stack Height - 15m , Equipment - D10T

Date:	6/12/2022	Job No:	119085.02	FIGURE B5

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 B5



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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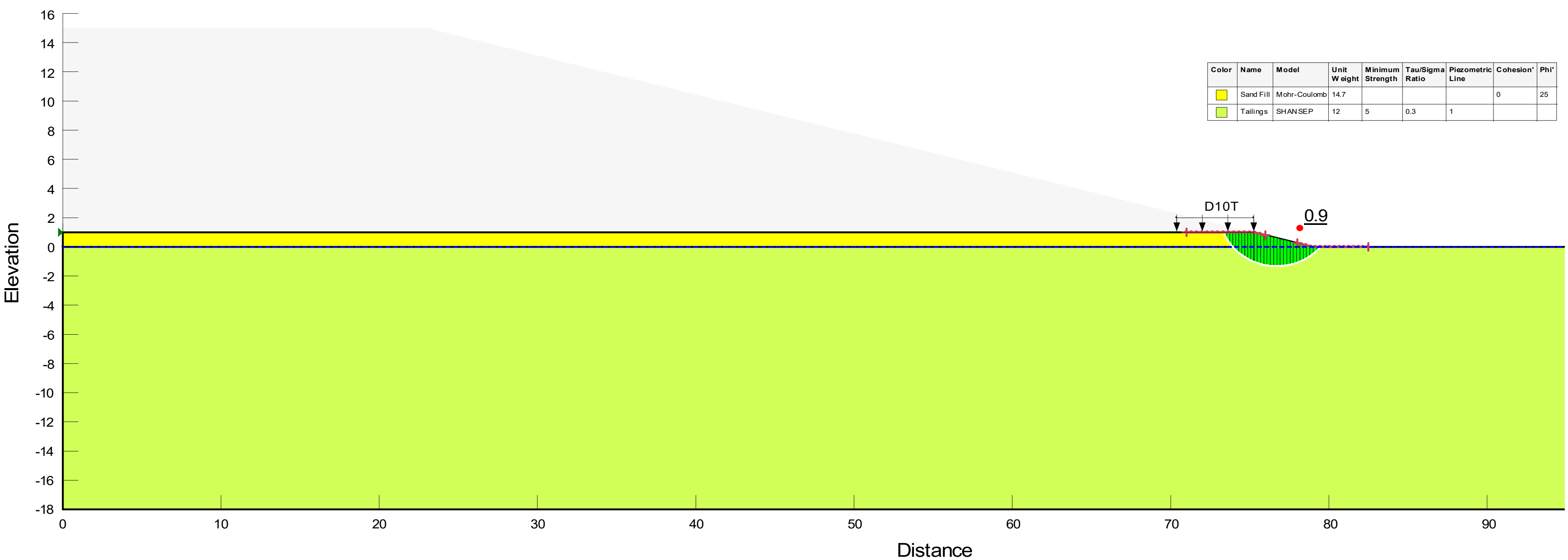
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 1m , Phreatic Surface Depth - 0m , Equipment - D8T LGP

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C1**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C1



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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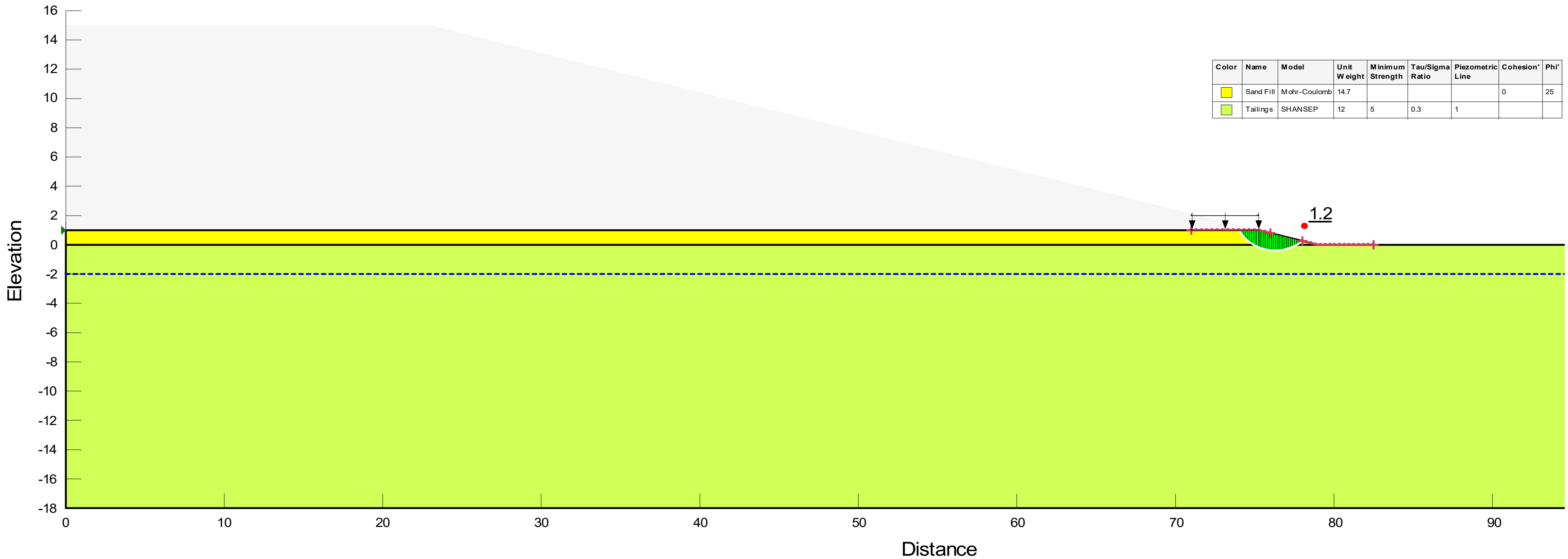
Pioneer Layer Thickness - 1m , Phreatic Surface Depth - 0m , Equipment - D10T

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C2**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C2



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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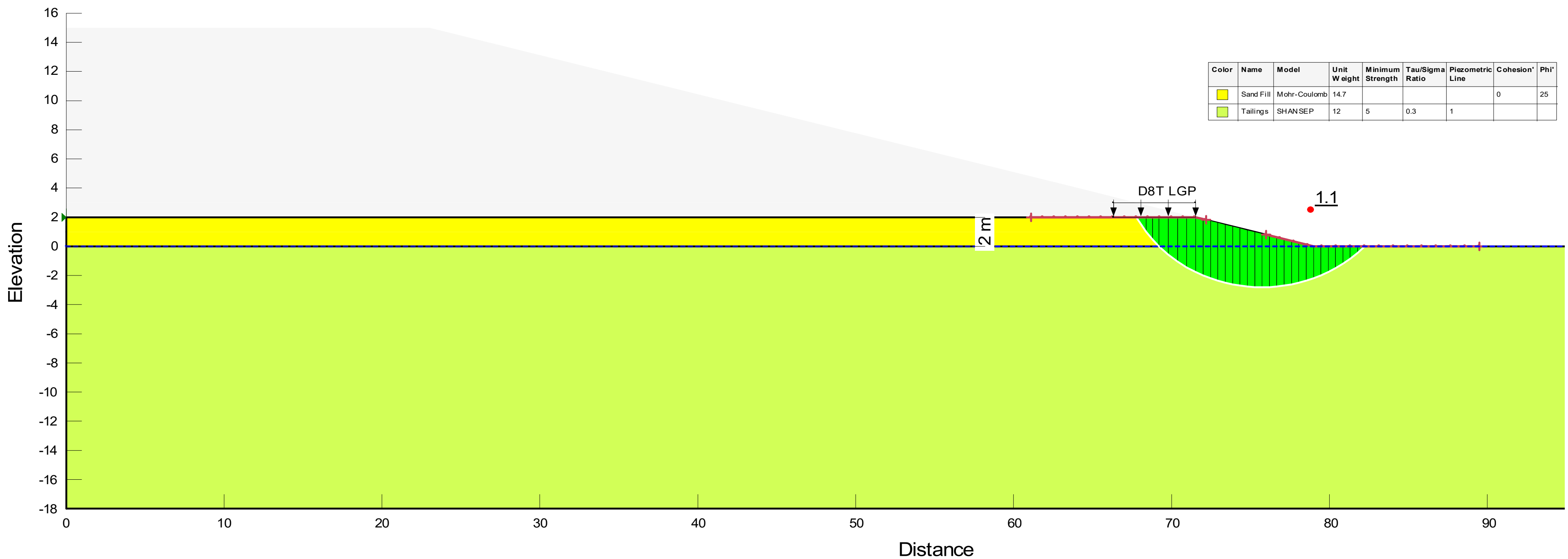
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 1m , Phreatic Surface Depth - 2m , Equipment - D8T LGP

Date:	6/12/2022	Job No:	119085.02	FIGURE C3

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C3



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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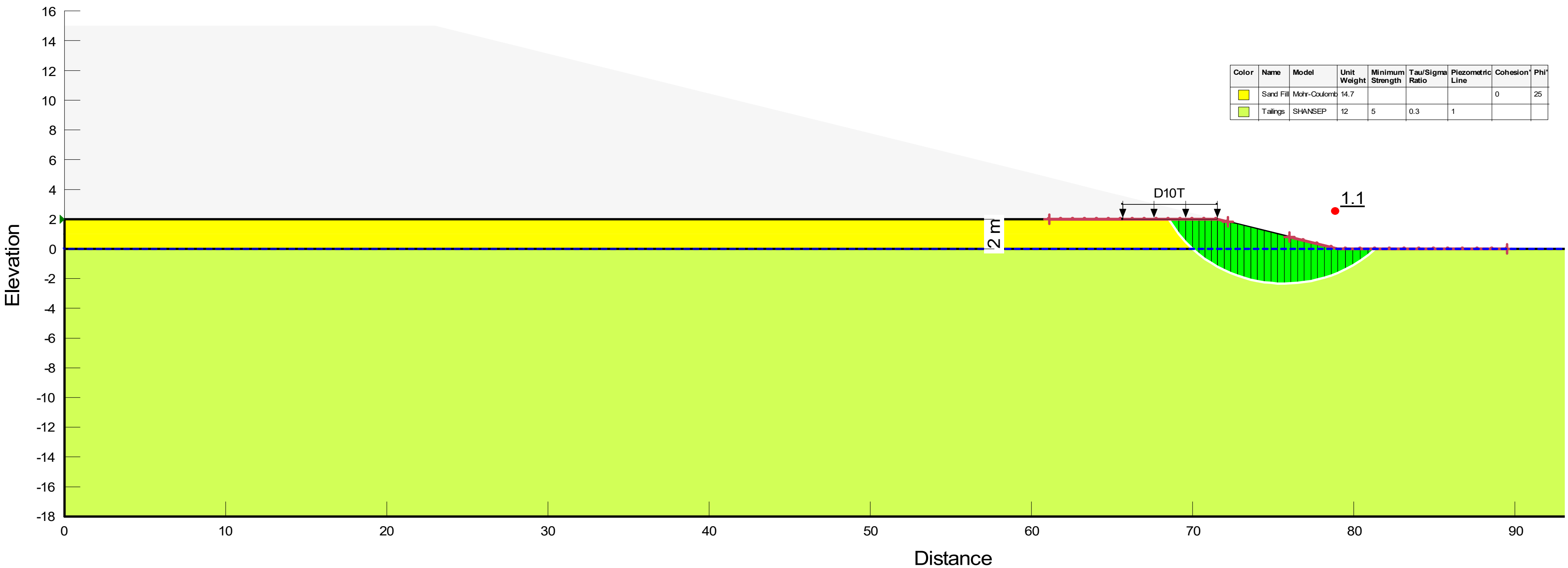
Pioneer Layer Thickness - 2m , Phreatic Surface Depth - 0m , Equipment - D8T LGP

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C4

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C4



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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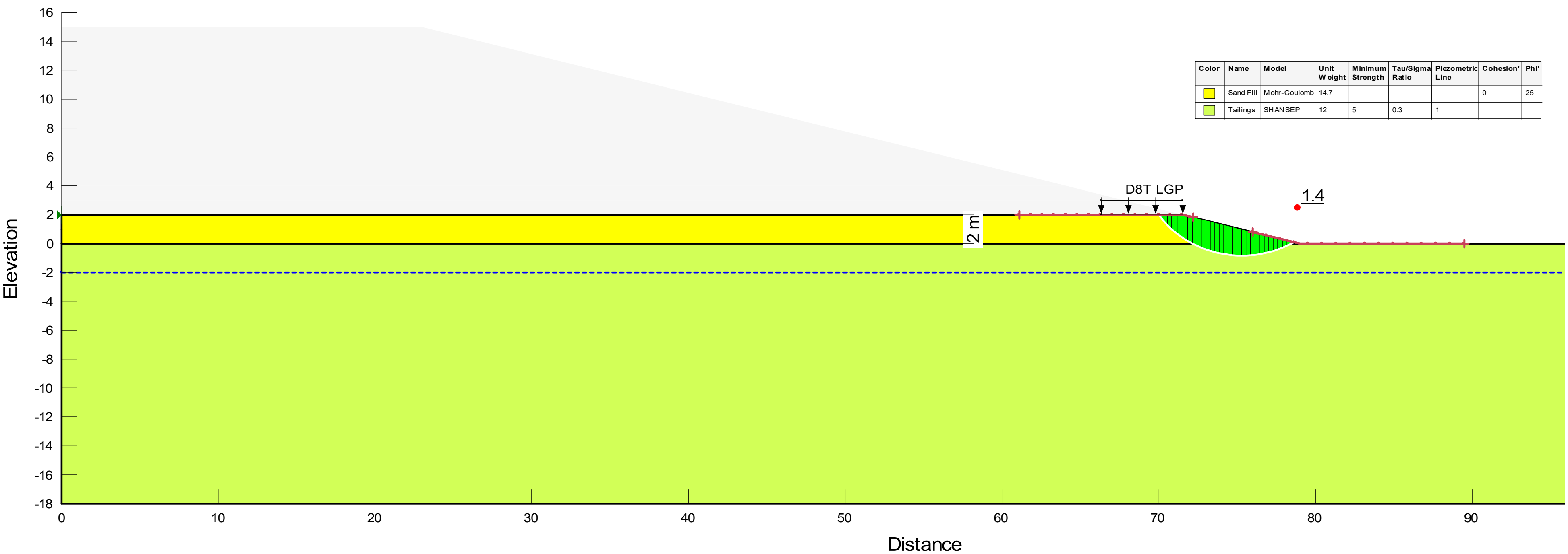
Pioneer Layer Thickness - 2m , Phreatic Surface Depth - 0m , Equipment - D10T

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C5

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C5



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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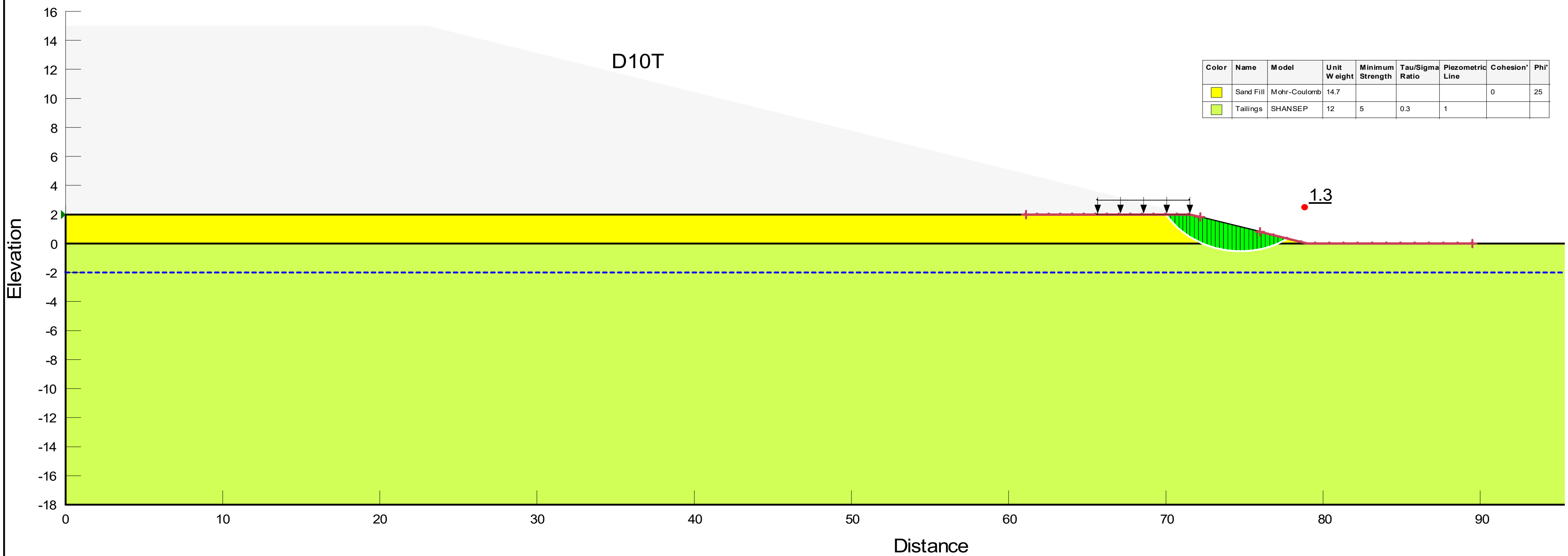
Pioneer Layer Thickness - 2m , Phreatic Surface Depth - 2m , Equipment - D8T LGP

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C6

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C6



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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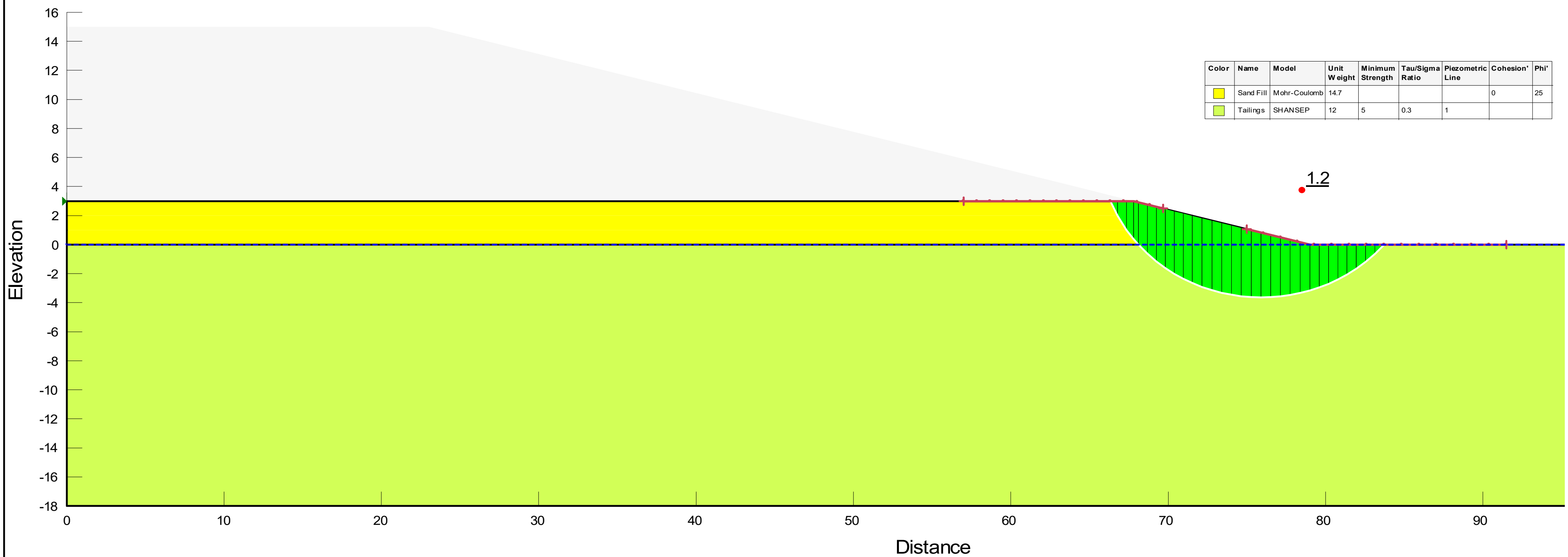
Pioneer Layer Thickness - 2m , Phreatic Surface Depth - 2m , Equipment - D10T

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C7**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C7



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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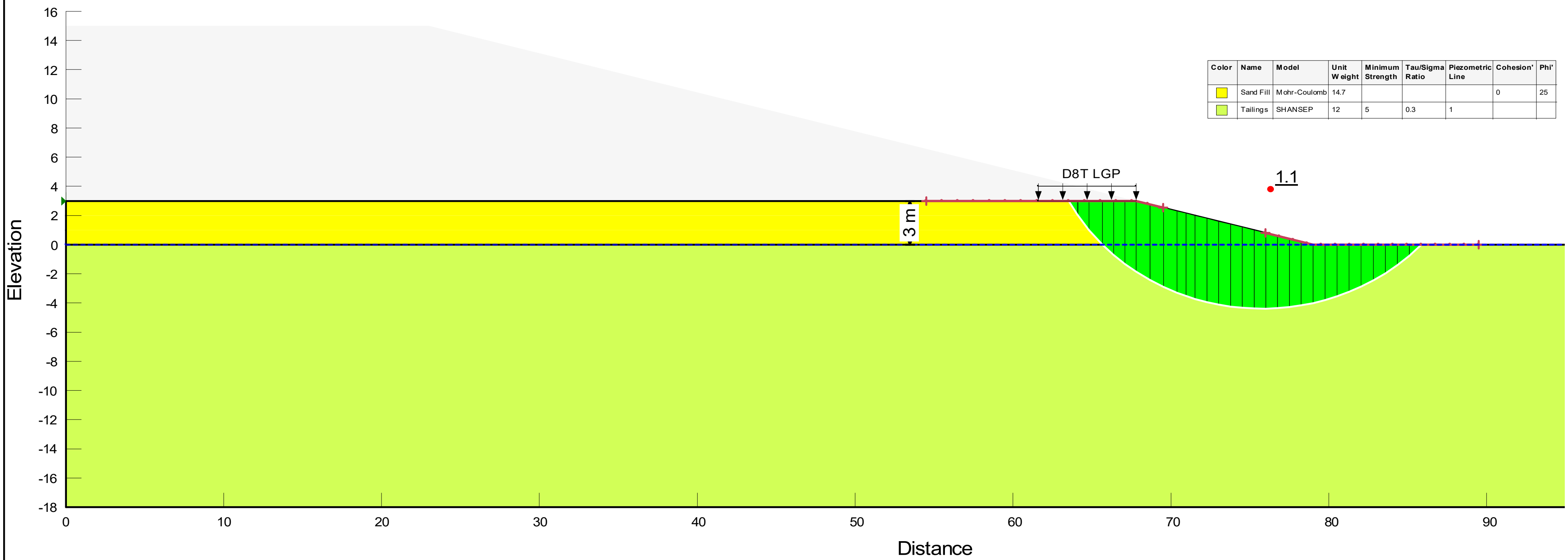
Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - NONE

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C8**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C8



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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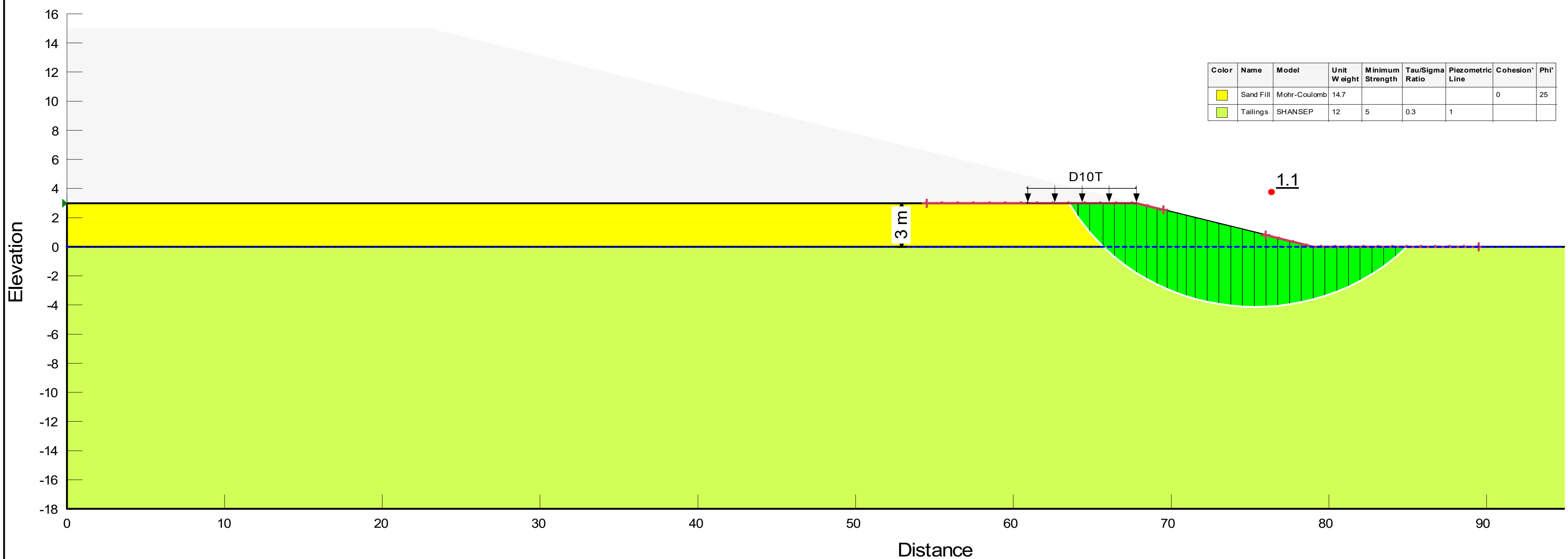
Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D8T LGP

Date:	6/12/2022	Job No:	119085.02	FIGURE C9

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C9



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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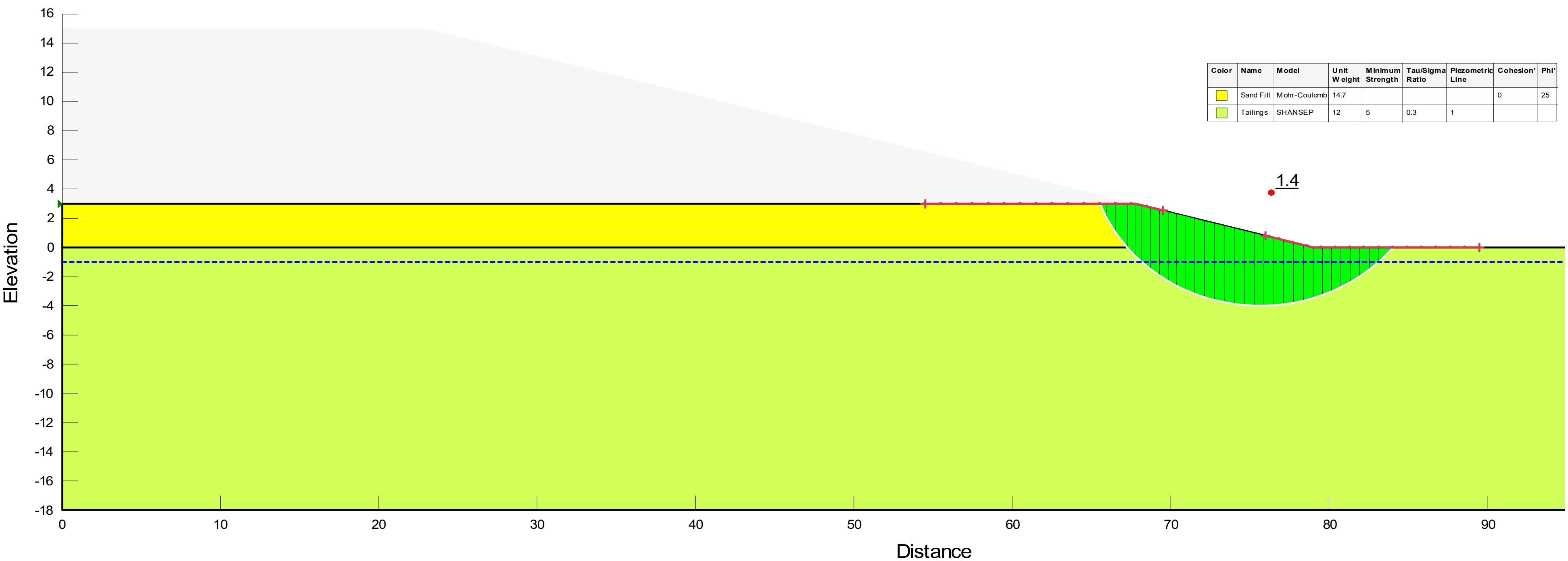
Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C10

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C10



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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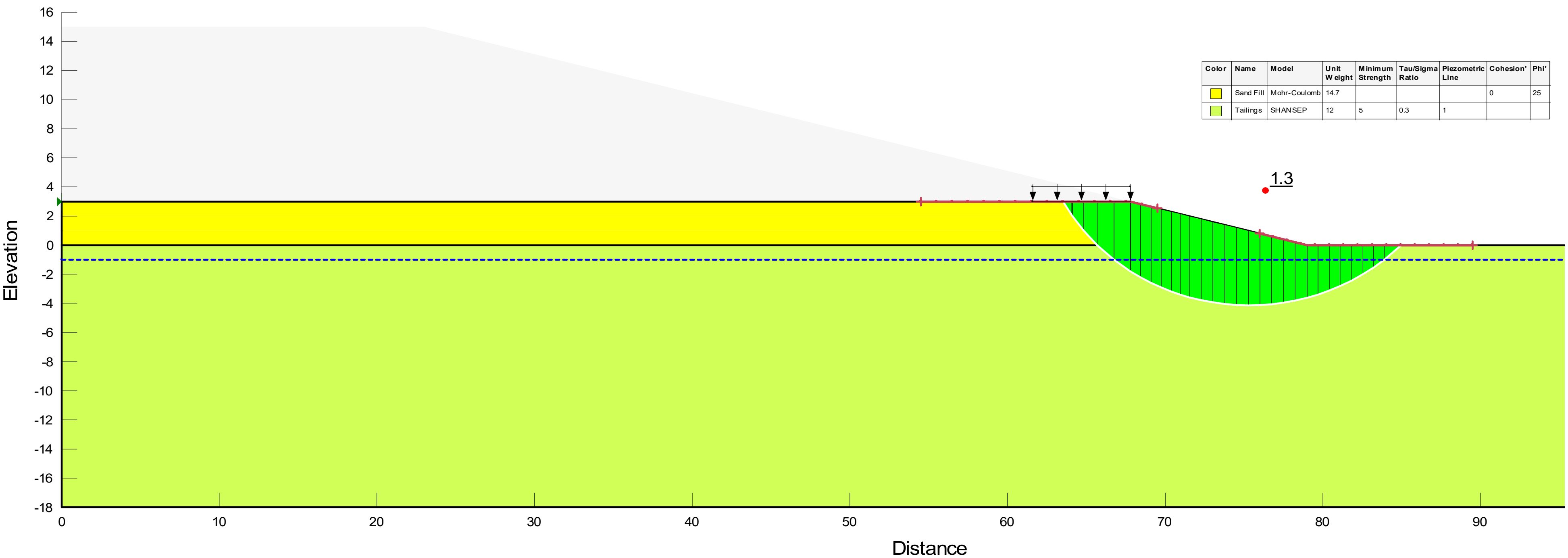
Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 1m , Equipment - NONE

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C11

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C11



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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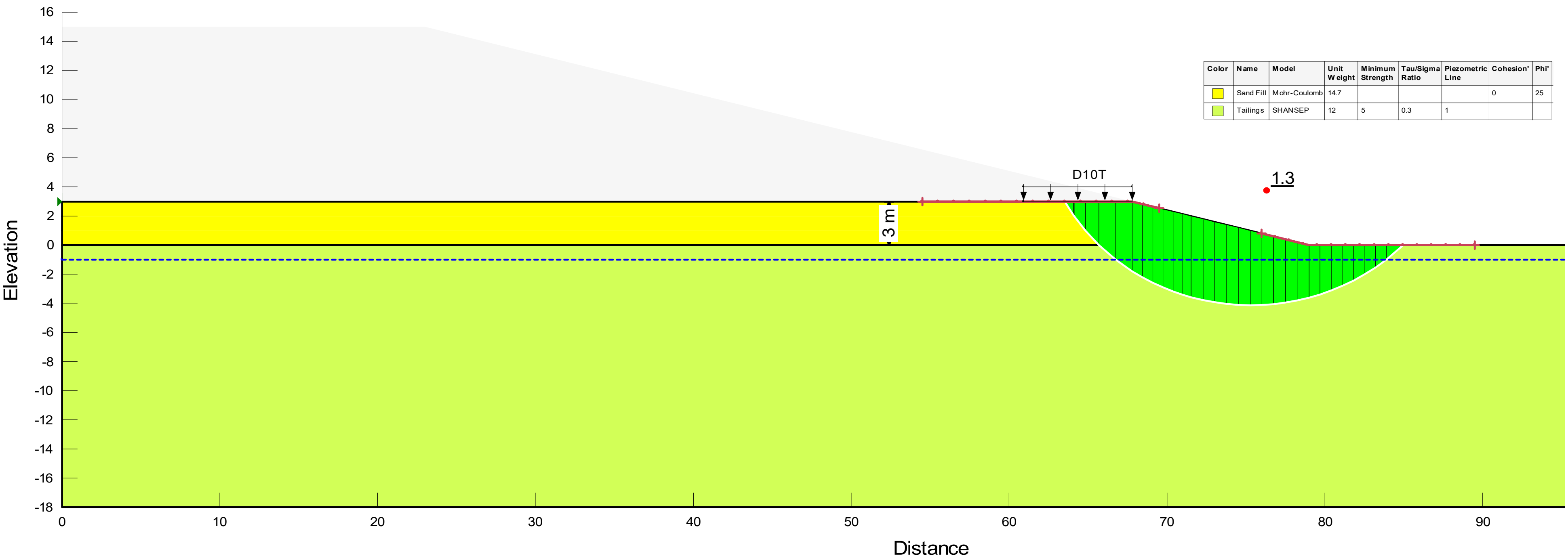
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 1m , Equipment - D8T LGP

Date:	6/12/2022	Job No:	119085.02	FIGURE C12

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C12



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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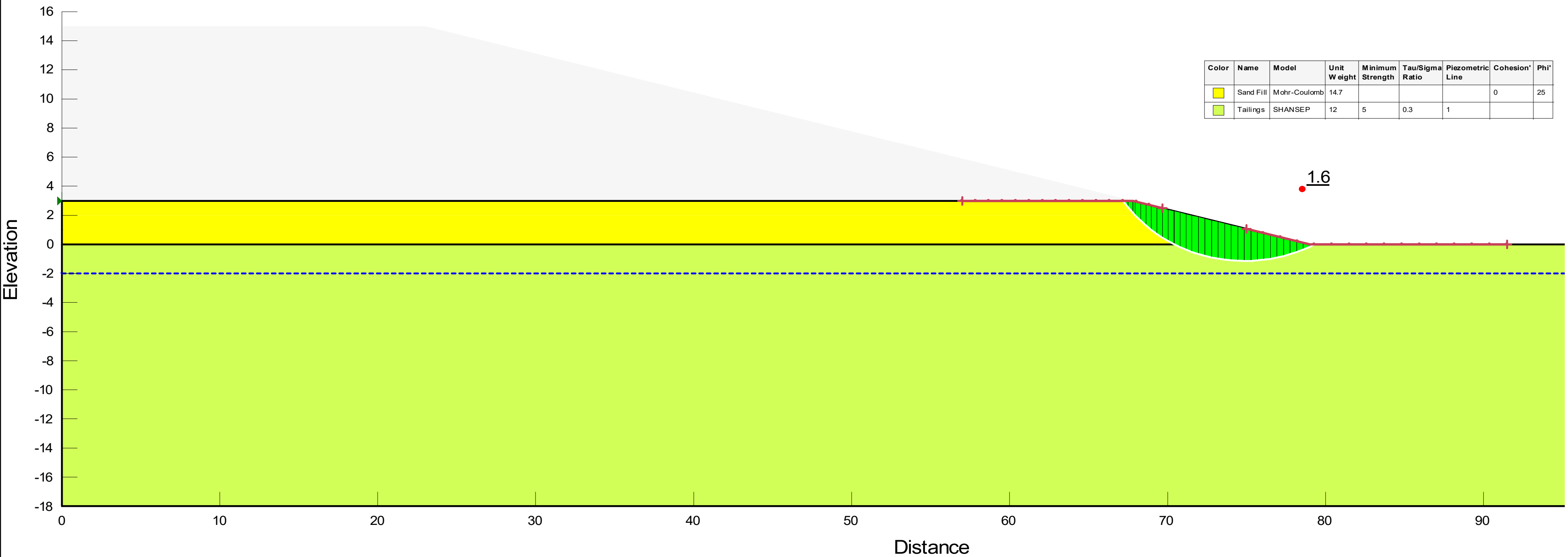
Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 1m , Equipment - D10T

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C13**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C13



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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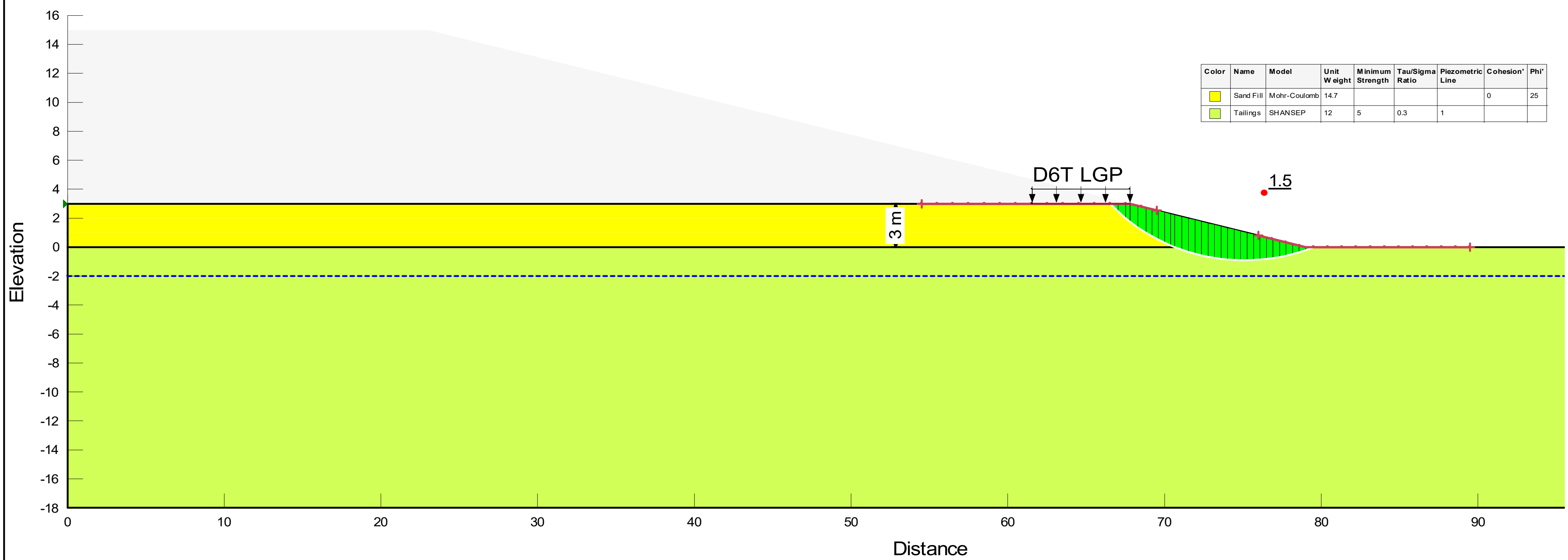
Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 2m , Equipment - NONE

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C14**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C14



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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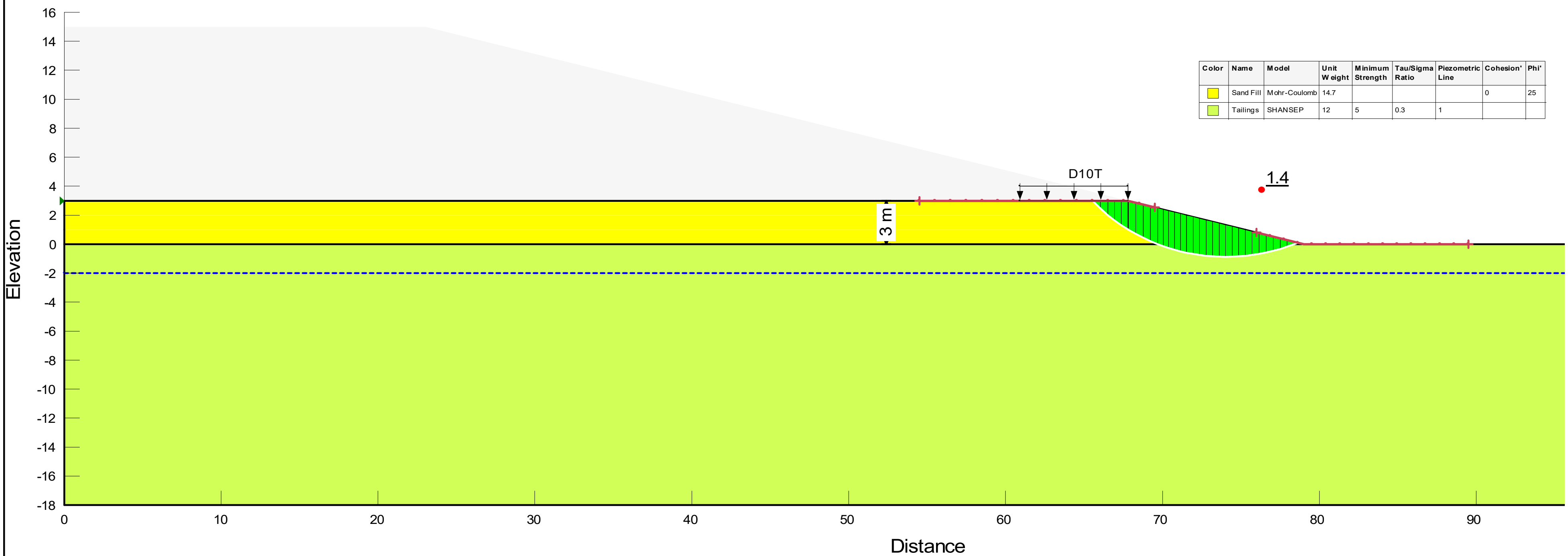
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 2m , Equipment - D8T LGP

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C15

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C15



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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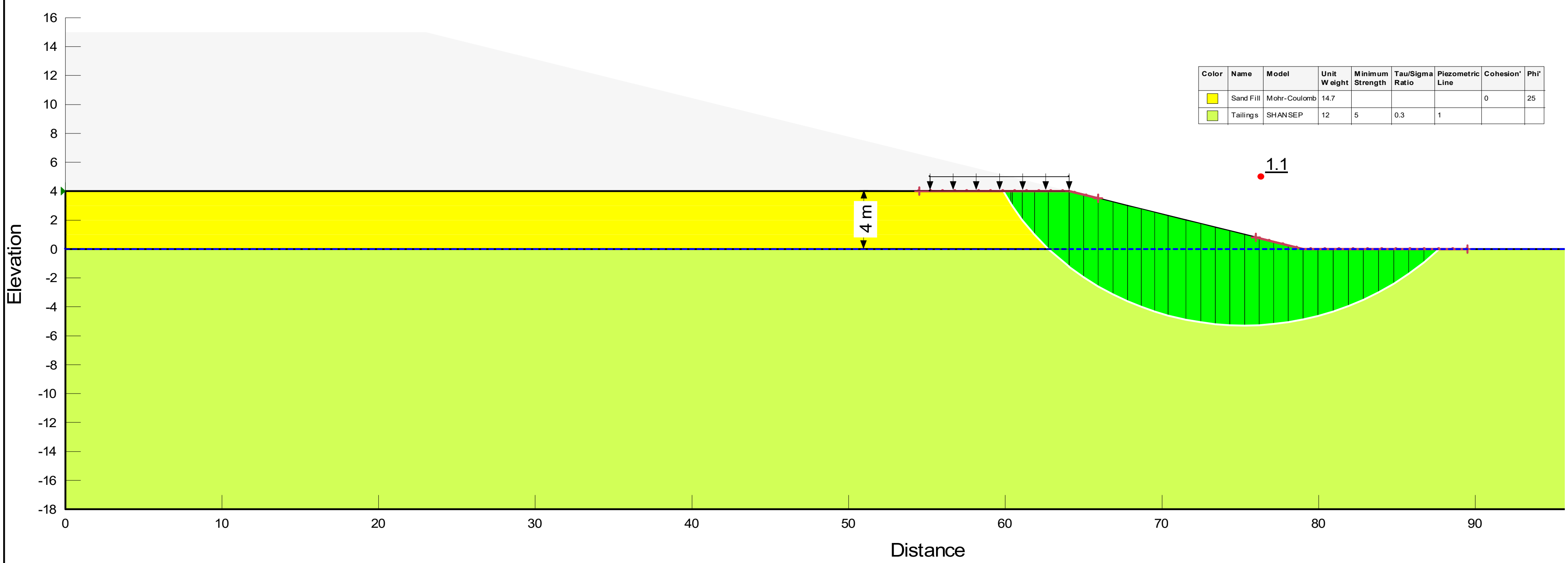
Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 2m , Equipment - D10T

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C16

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C16



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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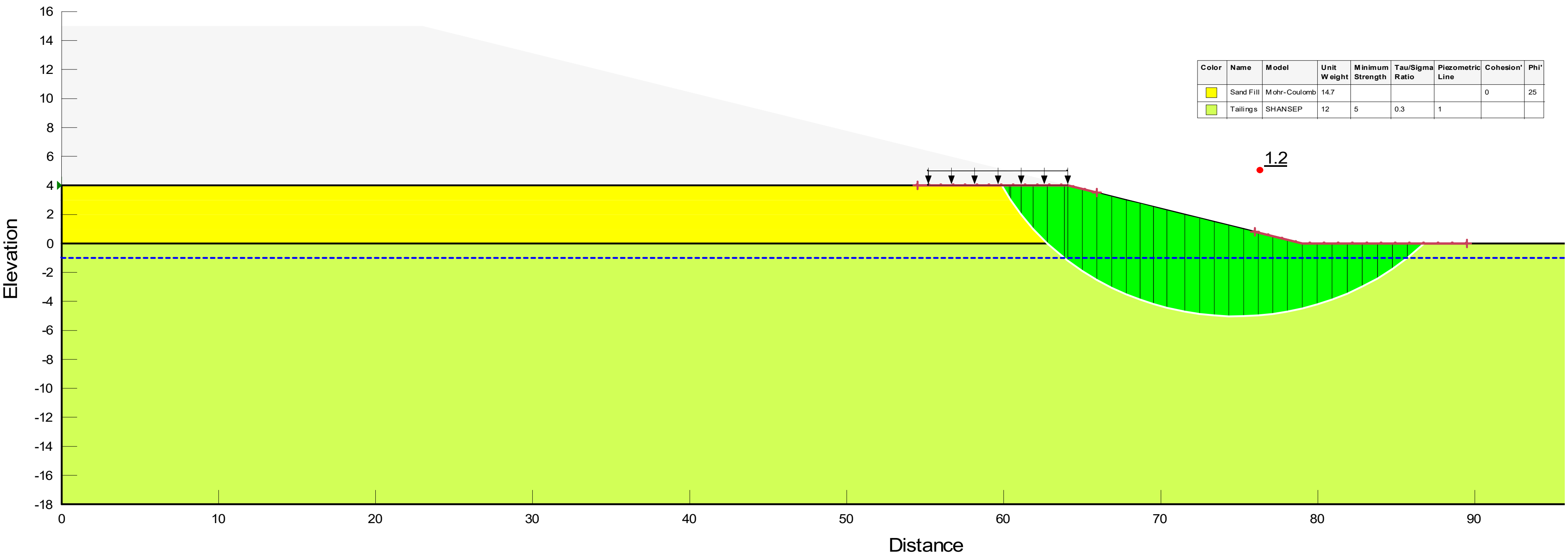
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 0m , Equipment - D10T

Date:	6/12/2022	Job No:	119085.02	FIGURE C17

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C17



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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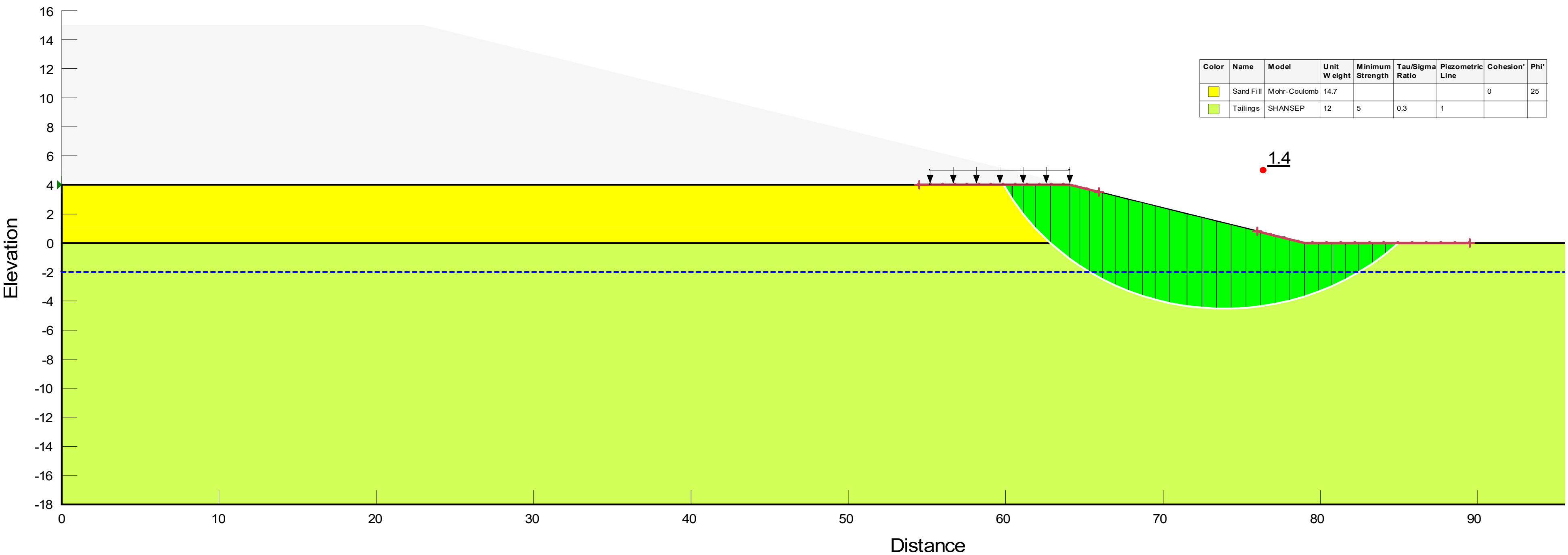
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 1m , Equipment - D10T

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C18**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C18



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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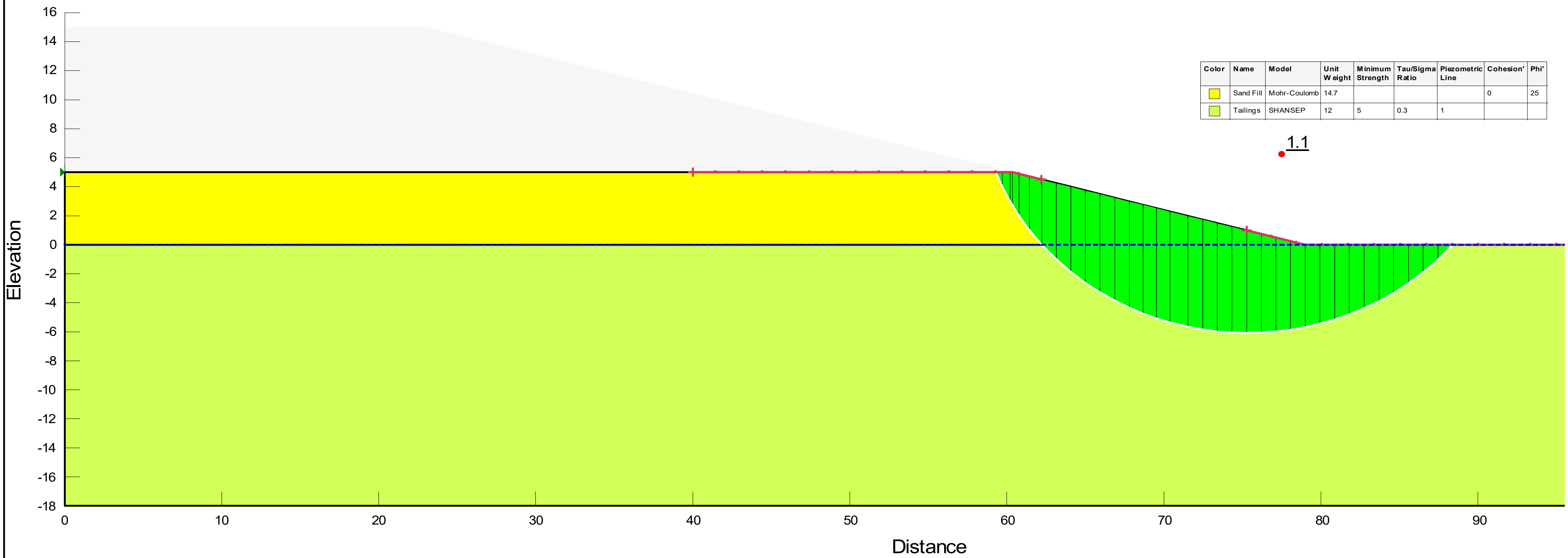
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 2m , Equipment - D10T

Date:	6/12/2022	Job No:	119085.02	FIGURE C19

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C19



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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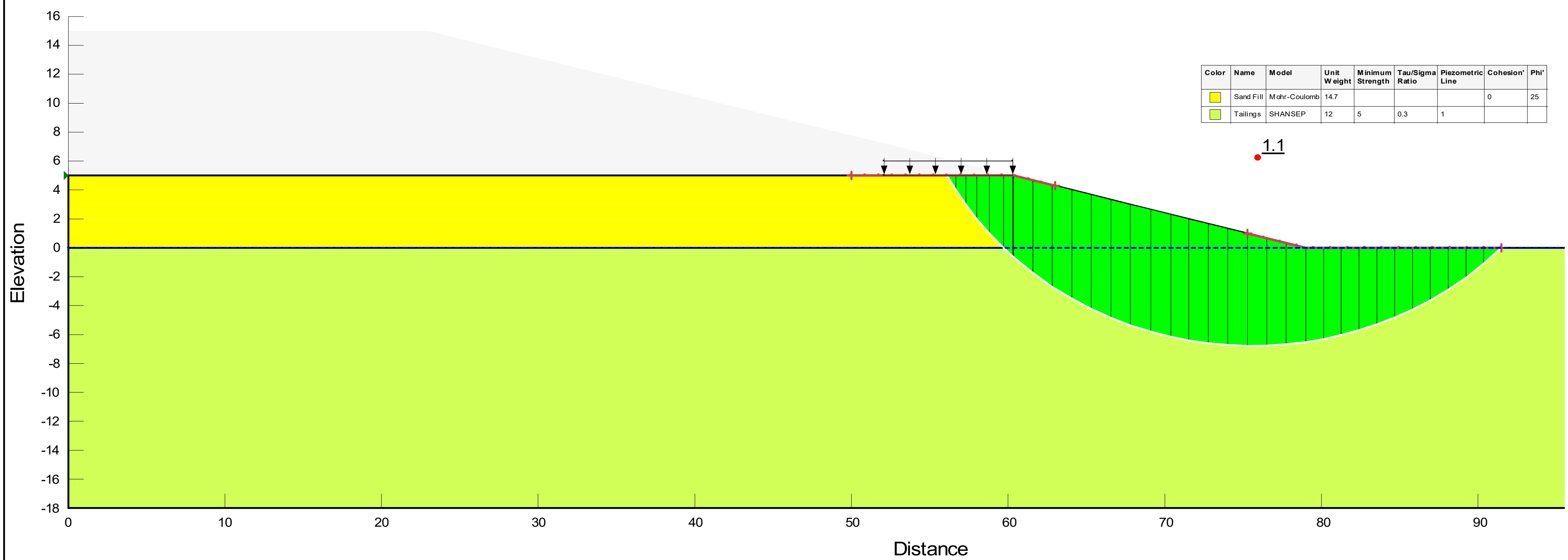
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 5m , Phreatic Surface Depth - 0m , Equipment - NONE

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C20

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C20



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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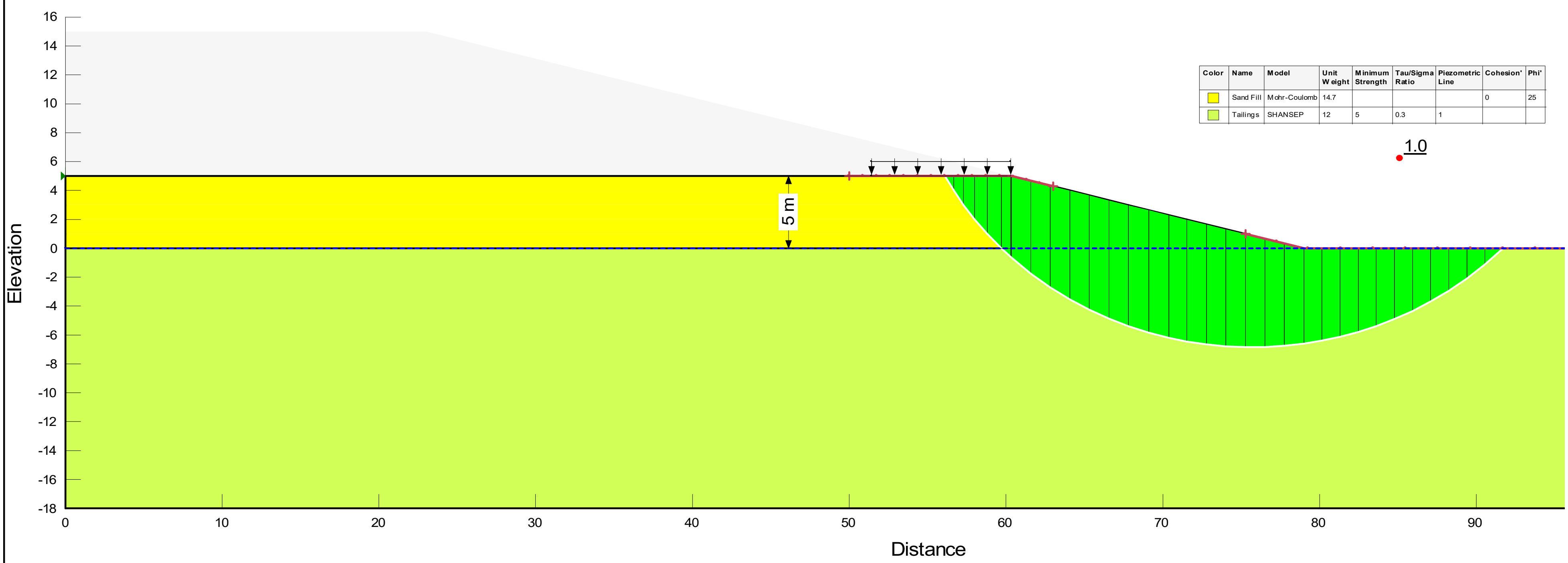
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 5m , Phreatic Surface Depth - 0m , Equipment - D8T LGP

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C21

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C21



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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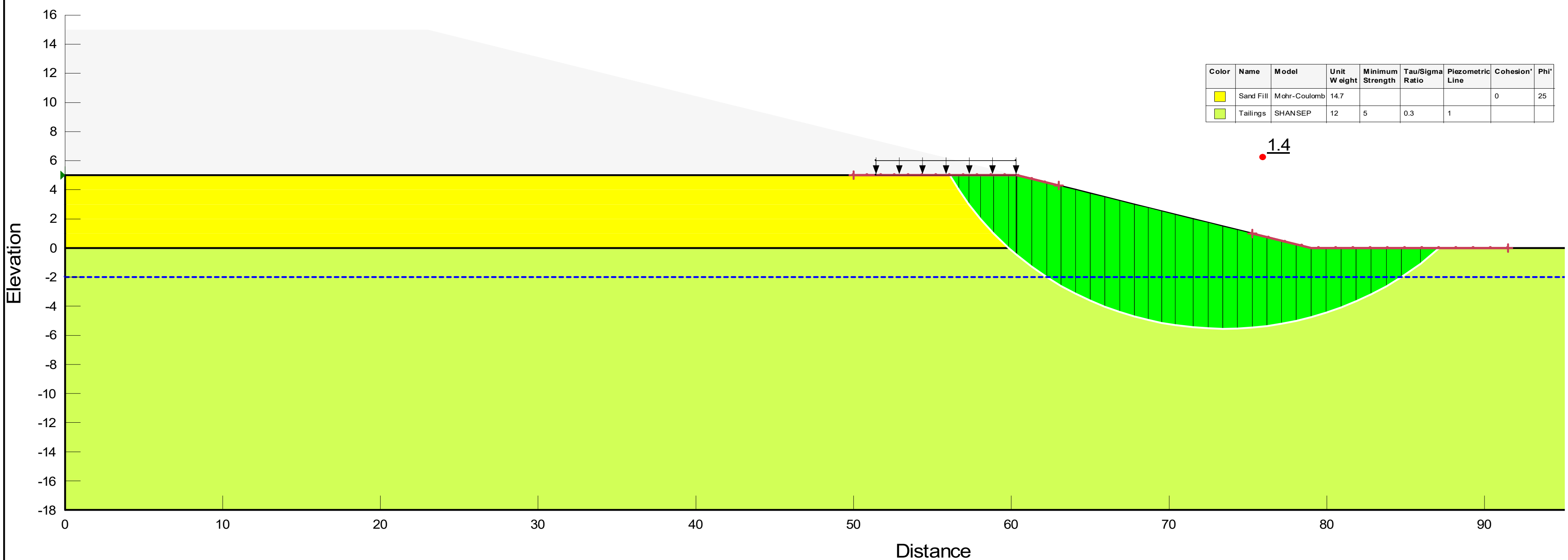
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 5m , Phreatic Surface Depth - 0m , Equipment - D10T

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C22**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C22



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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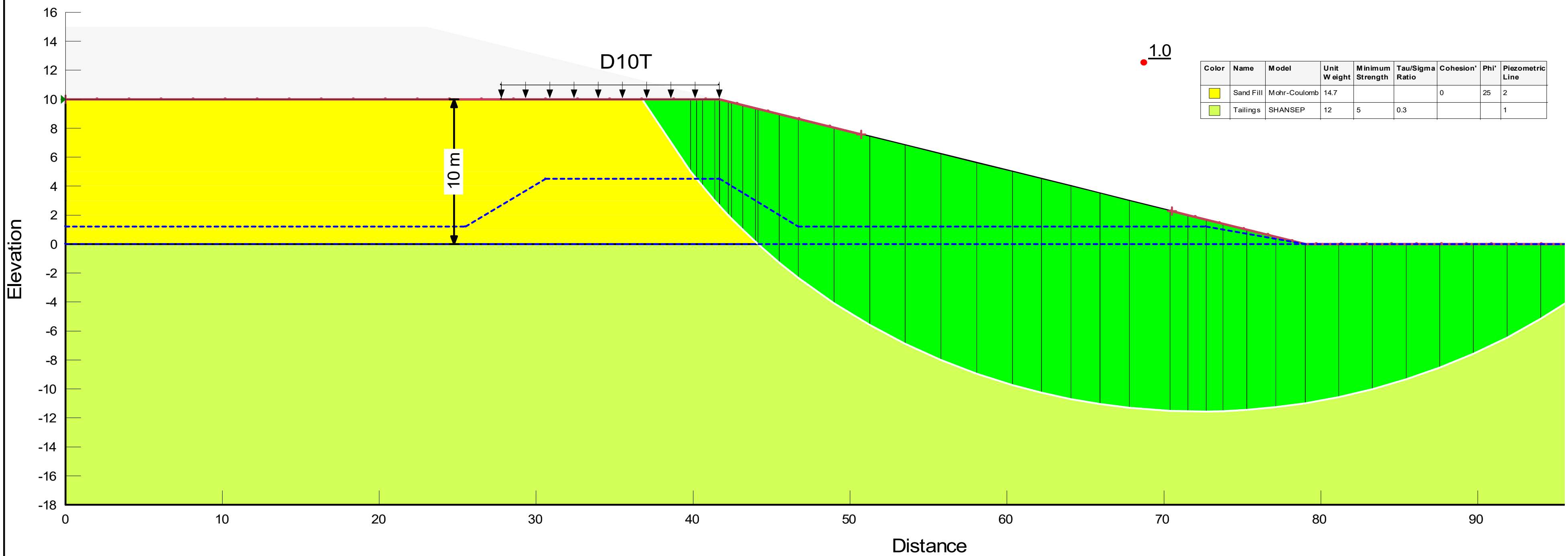
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 5m , Phreatic Surface Depth - 2m , Equipment - D10T

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C23**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C23



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Sand Fill	Mohr-Coulomb	14.7			0	25	2
	Tailings	SHANSEP	12	5	0.3			1

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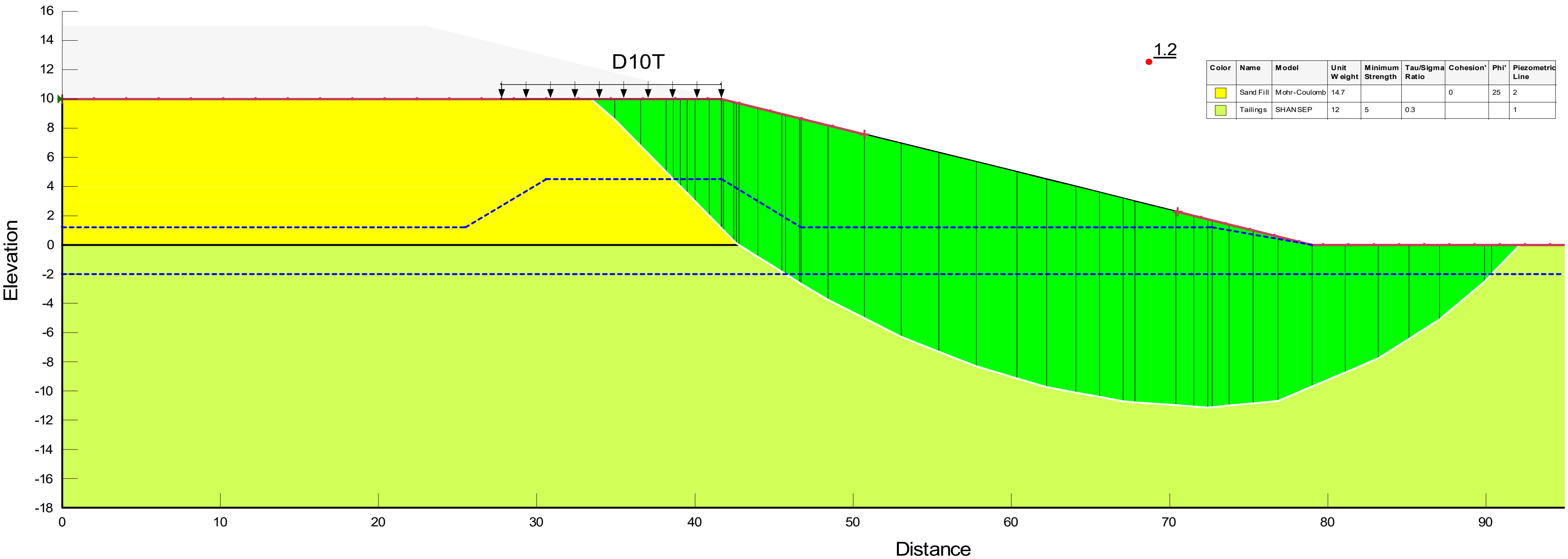
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 10m , Phreatic Surface Depth - 0m , Equipment - D10T

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C24**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C24



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Sand Fill	Mohr-Coulomb	14.7			0	25	2
	Tailings	SHANSEP	12	5	0.3			1

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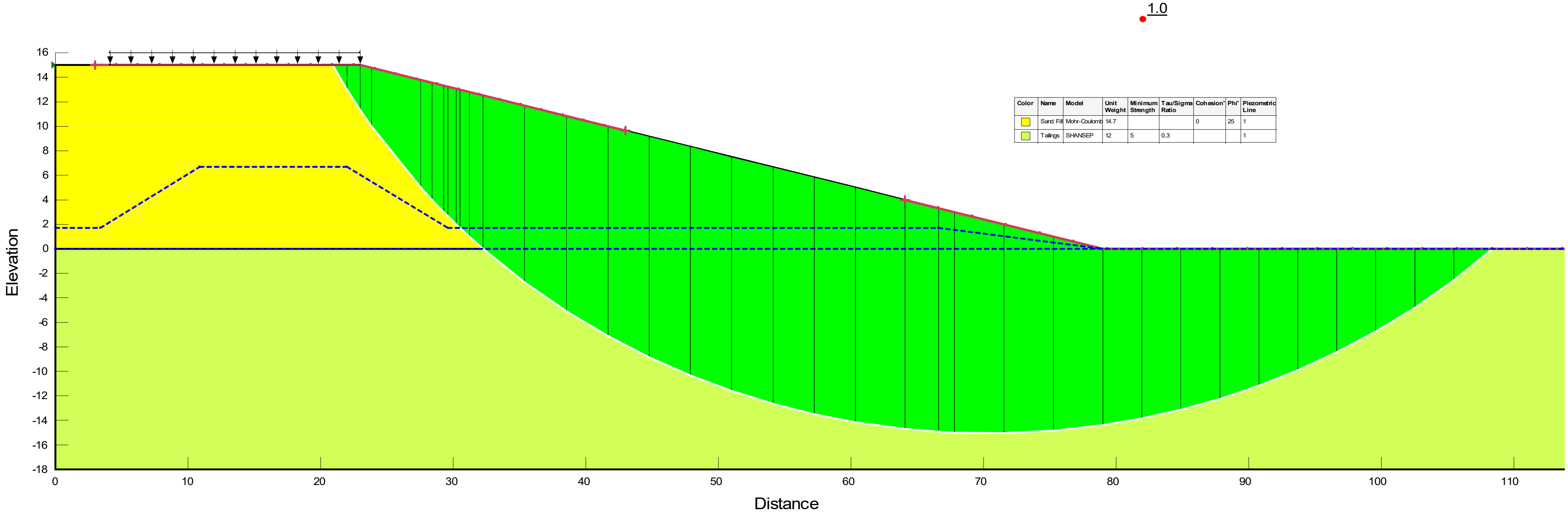
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 10m , Phreatic Surface Depth - 2m , Equipment - D10T

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C25**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C25



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Sand Fill	Mohr-Coulomb	14.7			0	25	1
	Tailings	SHANSEP	12	5	0.3			1

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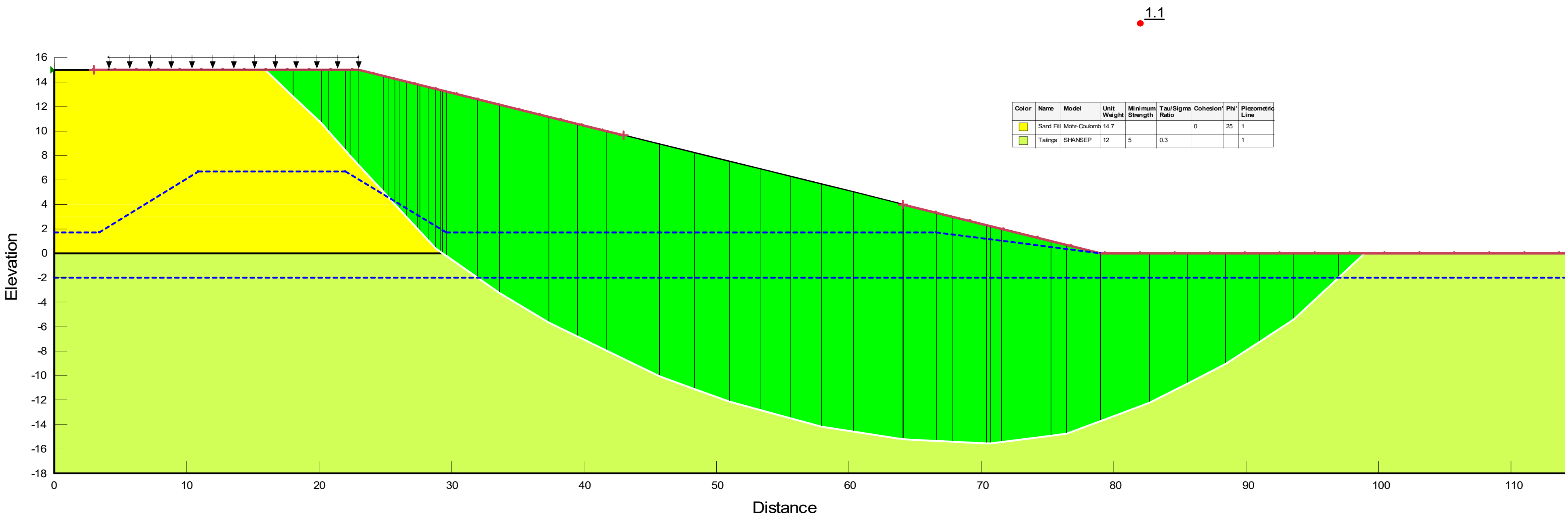
ATACAMA STABILITY STUDY - Assessment of Initial Pioneer Layer Thickness

Pioneer Layer Thickness - 15m , Phreatic Surface Depth - 0m , Equipment - D10T

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C26**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C26



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
(yellow)	Sand Fill	Mohr-Coulomb	14.7			0	25	1
(light green)	Tailings	SHANSEP	12	5	0.3			1

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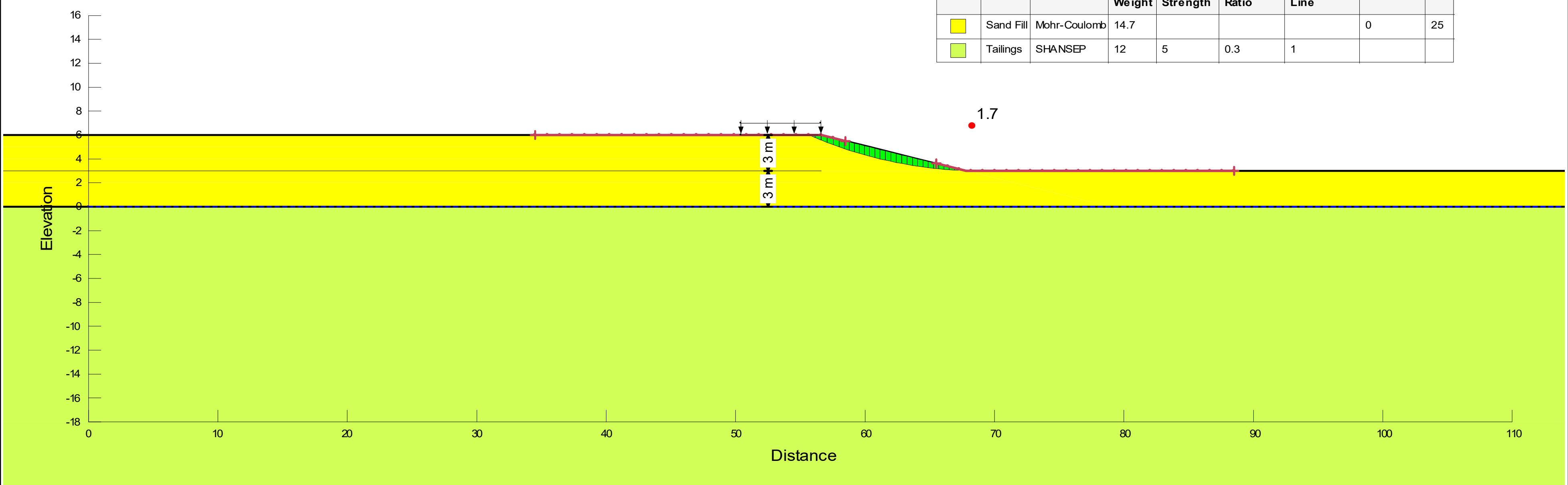
Pioneer Layer Thickness - 15m , Phreatic Surface Depth - 2m , Equipment - D10T

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C27**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C27



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		

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ATACAMA STABILITY STUDY - Placement of Second Pioneer Layer

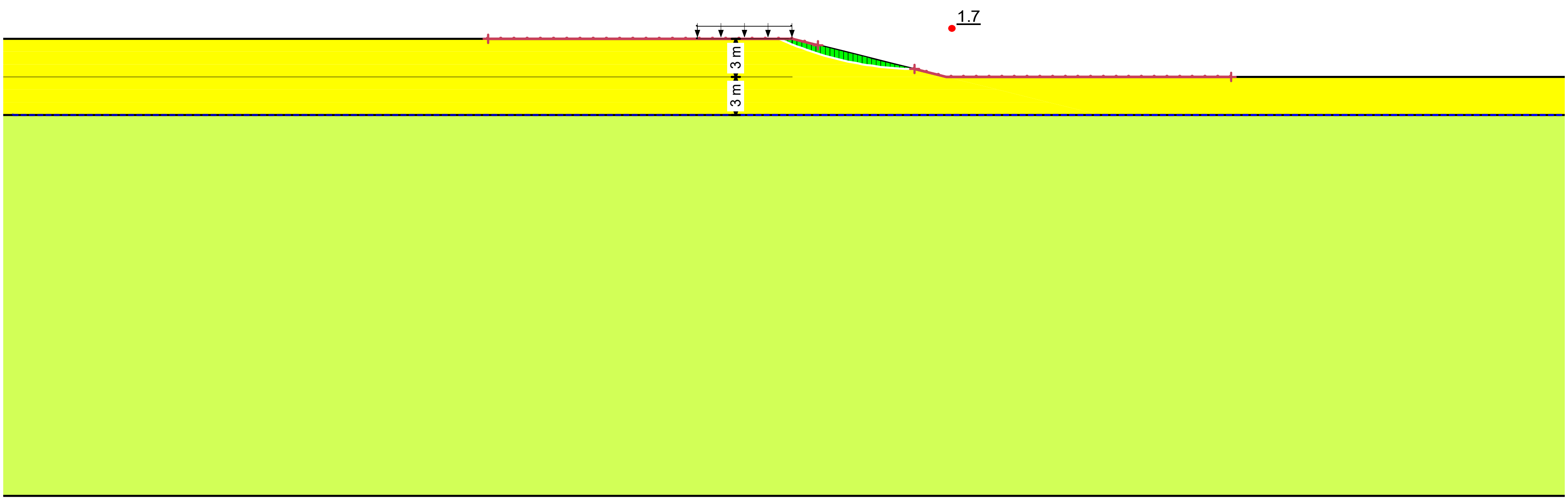
Second Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D8T LGP

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C28

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C28

Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Piezometric Line	Cohesion'	Phi'
	Sand Fill	Mohr-Coulomb	14.7				0	25
	Tailings	SHANSEP	12	5	0.3	1		



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ATACAMA STABILITY STUDY - Placement of Second Pioneer Layer

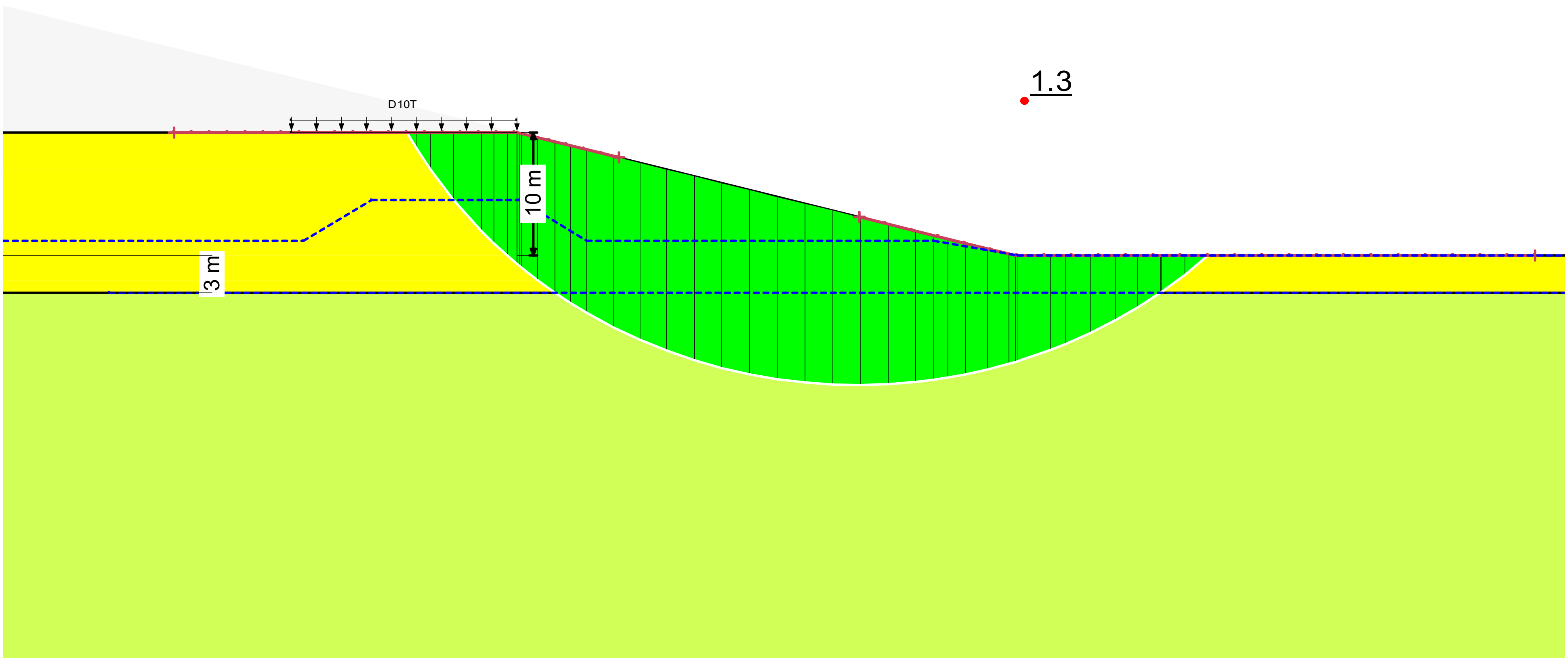
Second Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C29

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C29

Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
(yellow)	Sand Fill	Mohr-Coulomb	14.7			0	25	2
(light green)	Tailings	SHANSEP	12	5	0.3			1



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ATACAMA STABILITY STUDY - Assessment of Depth of Sand Stack, Placement over Pioneer Layer

Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 10m

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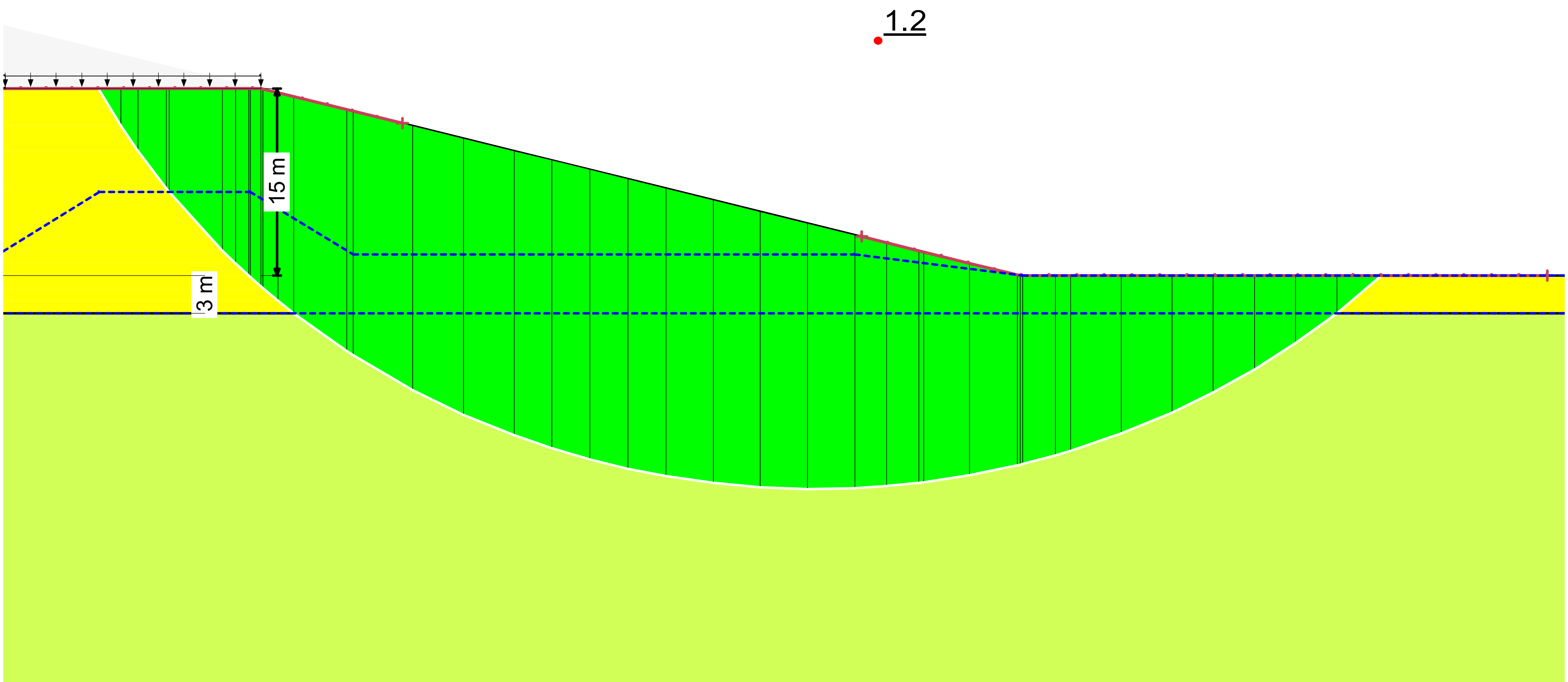
Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C30**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C30

Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Sand Fill	Mohr-Coulomb	14.7			0	25	2
	Tailings	SHANSEP	12	5	0.3			1



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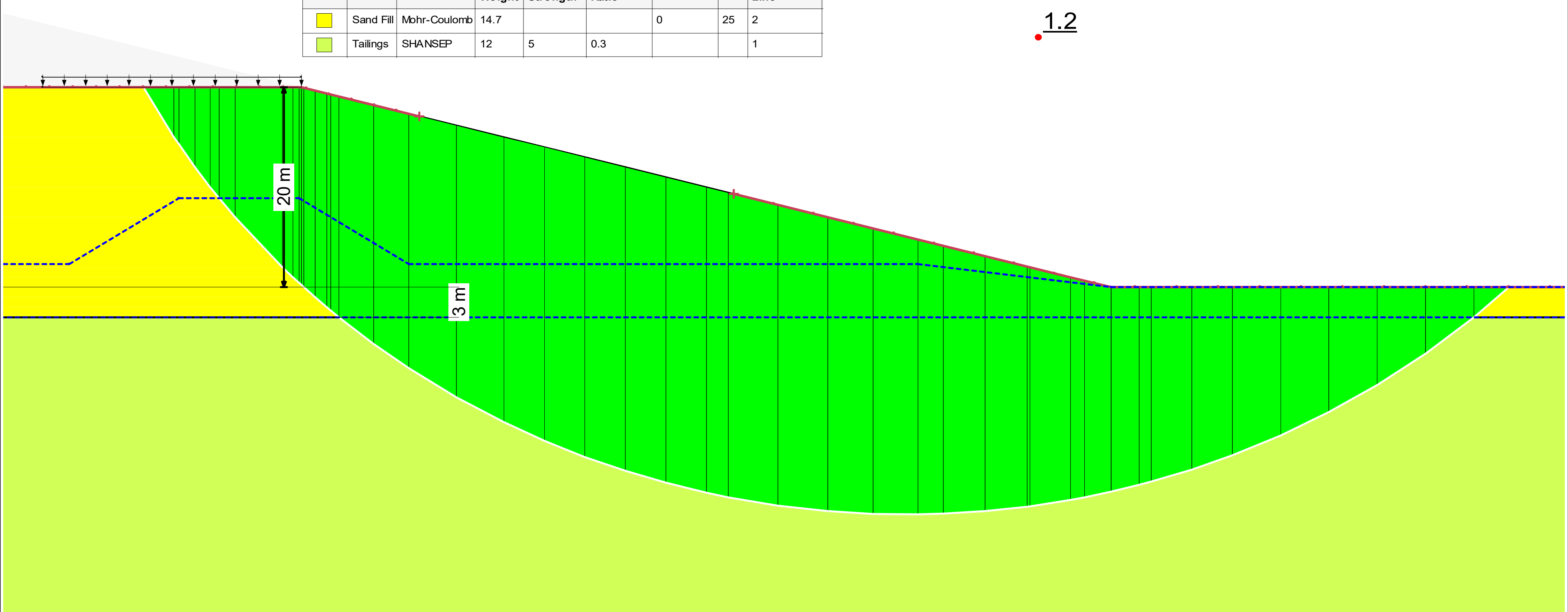
ATACAMA STABILITY STUDY - Assessment of Depth of Sand Stack, Placement over Pioneer Layer

Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 15m

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C31

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C31



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Sand Fill	Mohr-Coulomb	14.7			0	25	2
	Tailings	SHANSEP	12	5	0.3			1

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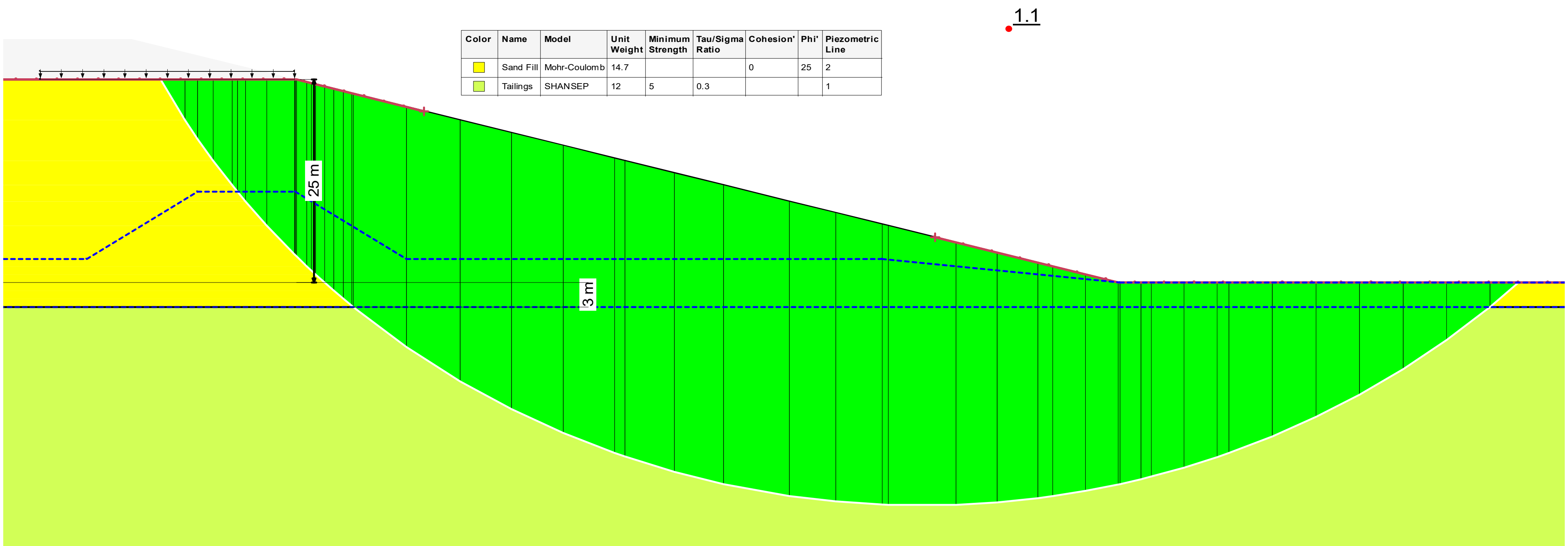
ATACAMA STABILITY STUDY - Assessment of Depth of Sand Stack, Placement over Pioneer Layer

Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 20m

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C32**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C32



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
(yellow)	Sand Fill	Mohr-Coulomb	14.7			0	25	2
(light green)	Tailings	SHANSEP	12	5	0.3			1

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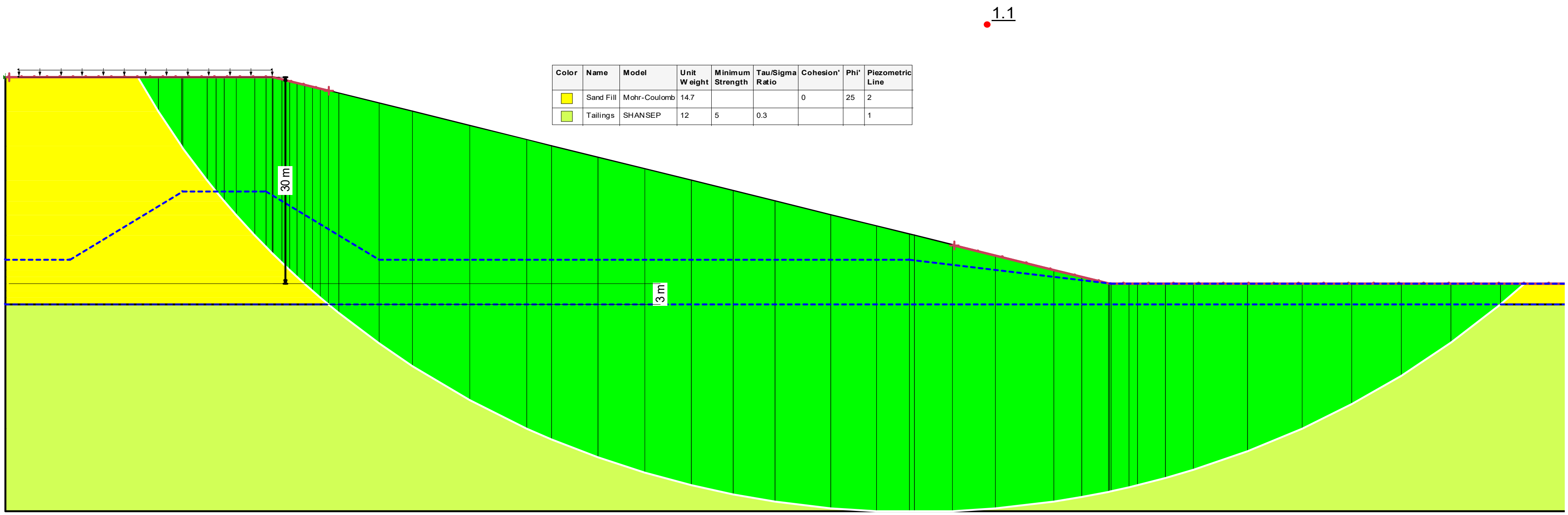
ATACAMA STABILITY STUDY - Assessment of Depth of Sand Stack, Placement over Pioneer Layer

Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 25m

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C33

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C33



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Sand Fill	Mohr-Coulomb	14.7			0	25	2
	Tailings	SHANSEP	12	5	0.3			1

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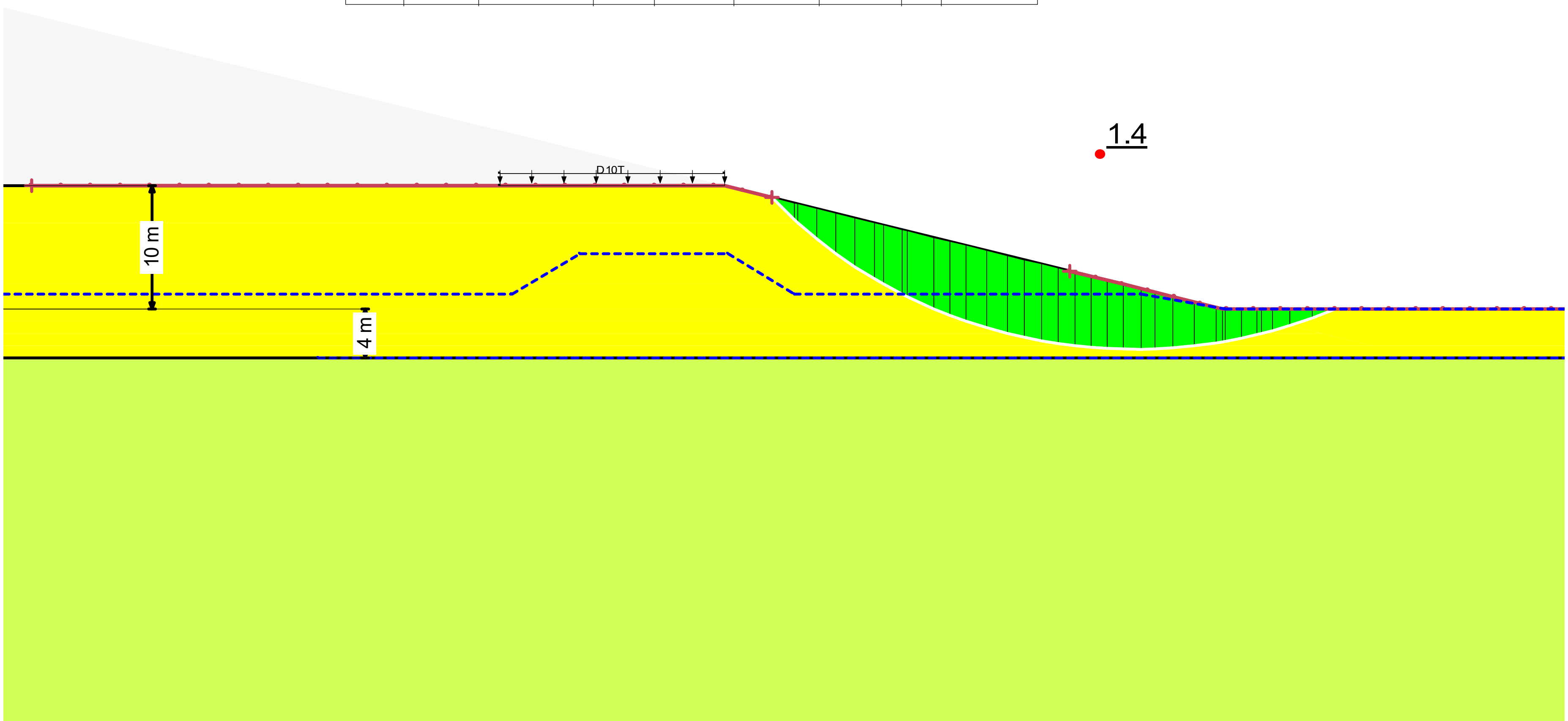
Pioneer Layer Thickness - 3m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 30m

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C34

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C34

Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Sand Fill	Mohr-Coulomb	14.7			0	25	2
	Tailings	SHANSEP	12	5	0.3			1



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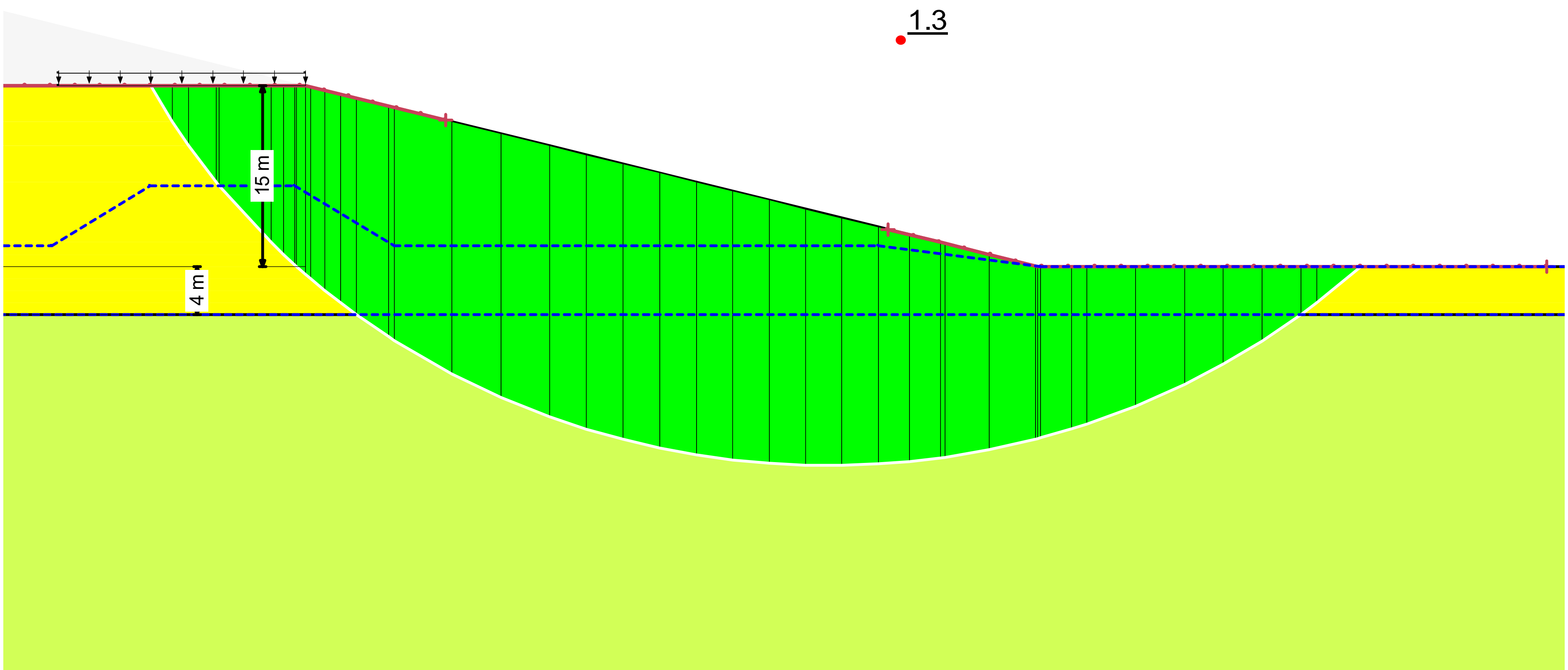
Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 10m

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C35

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C35

Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
(yellow)	Sand Fill	Mohr-Coulomb	14.7			0	25	2
(light green)	Tailings	SHANSEP	12	5	0.3			1



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Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 15m

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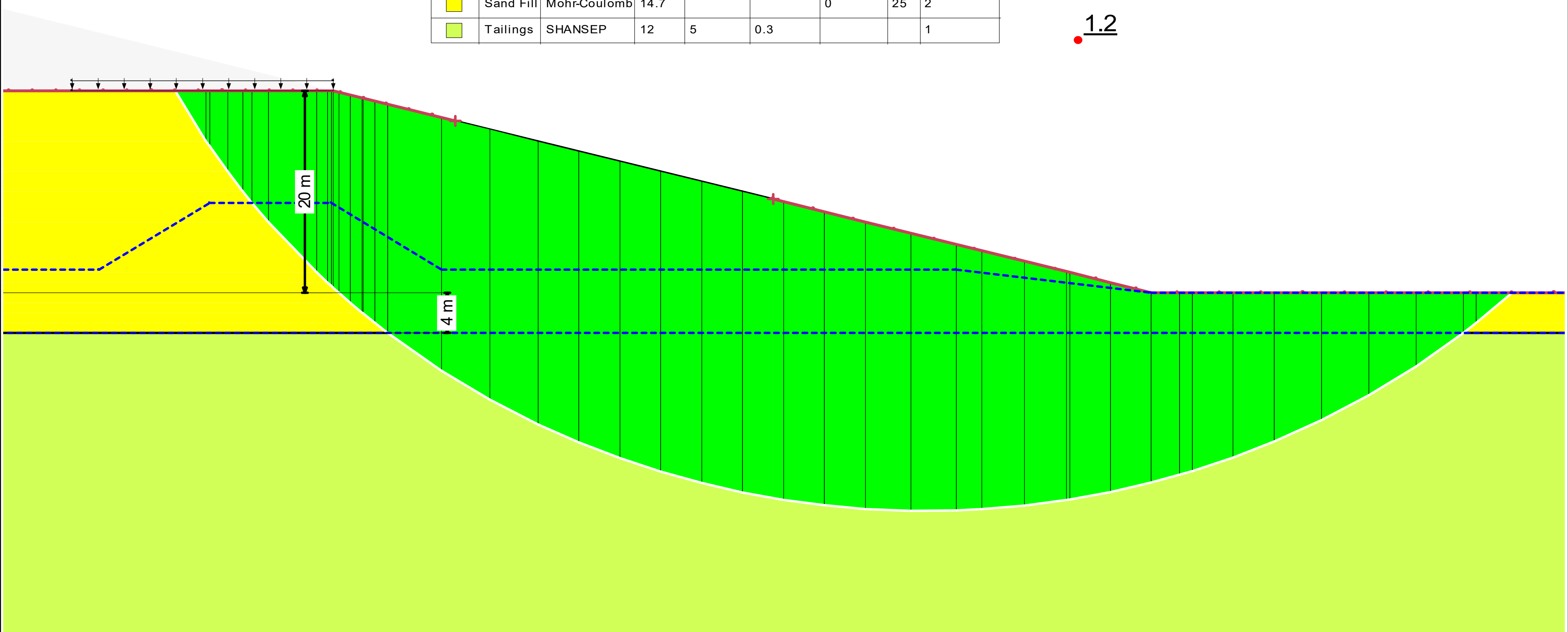
Date: 6/12/2022 **Job No:** 119085.02

FIGURE C36

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C36

Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
(yellow)	Sand Fill	Mohr-Coulomb	14.7			0	25	2
(light green)	Tailings	SHANSEP	12	5	0.3			1



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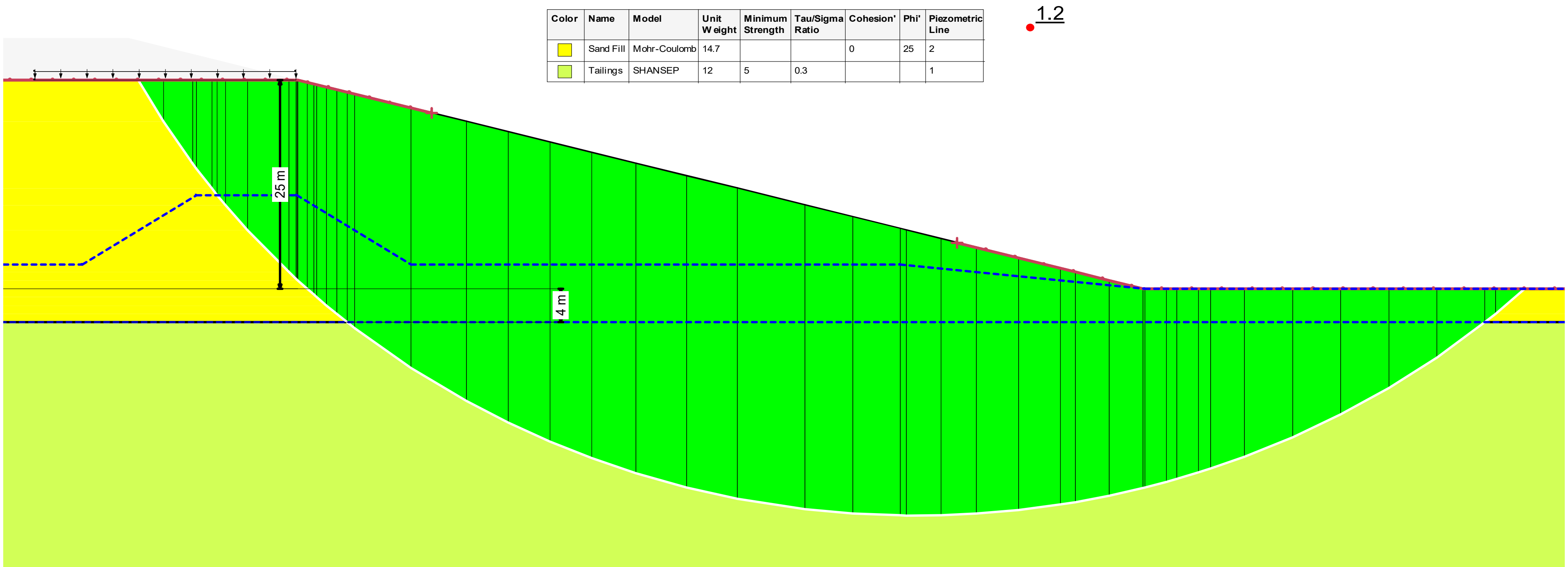
Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 20m

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C37

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C37



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
(yellow)	Sand Fill	Mohr-Coulomb	14.7			0	25	2
(light green)	Tailings	SHANSEP	12	5	0.3			1

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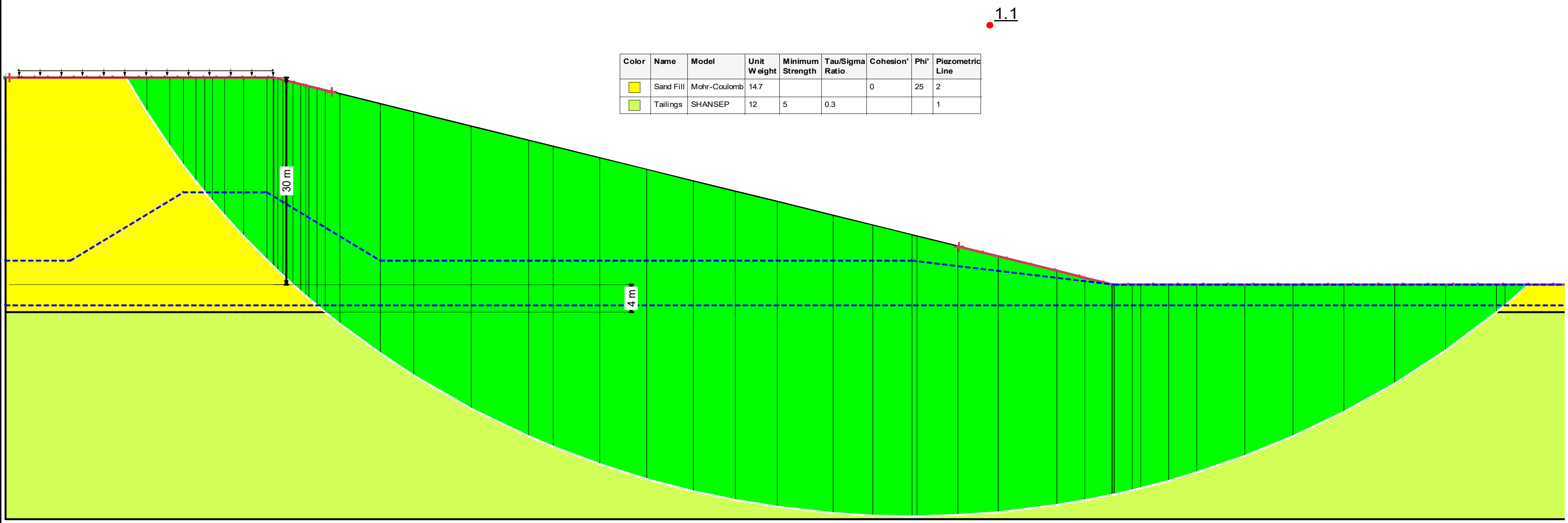
ATACAMA STABILITY STUDY - Assessment of Depth of Sand Stack, Placement over Pioneer Layer

Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 25m

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C38**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C38



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Sand Fill	Mohr-Coulomb	14.7			0	25	2
	Tailings	SHANSEP	12	5	0.3			1

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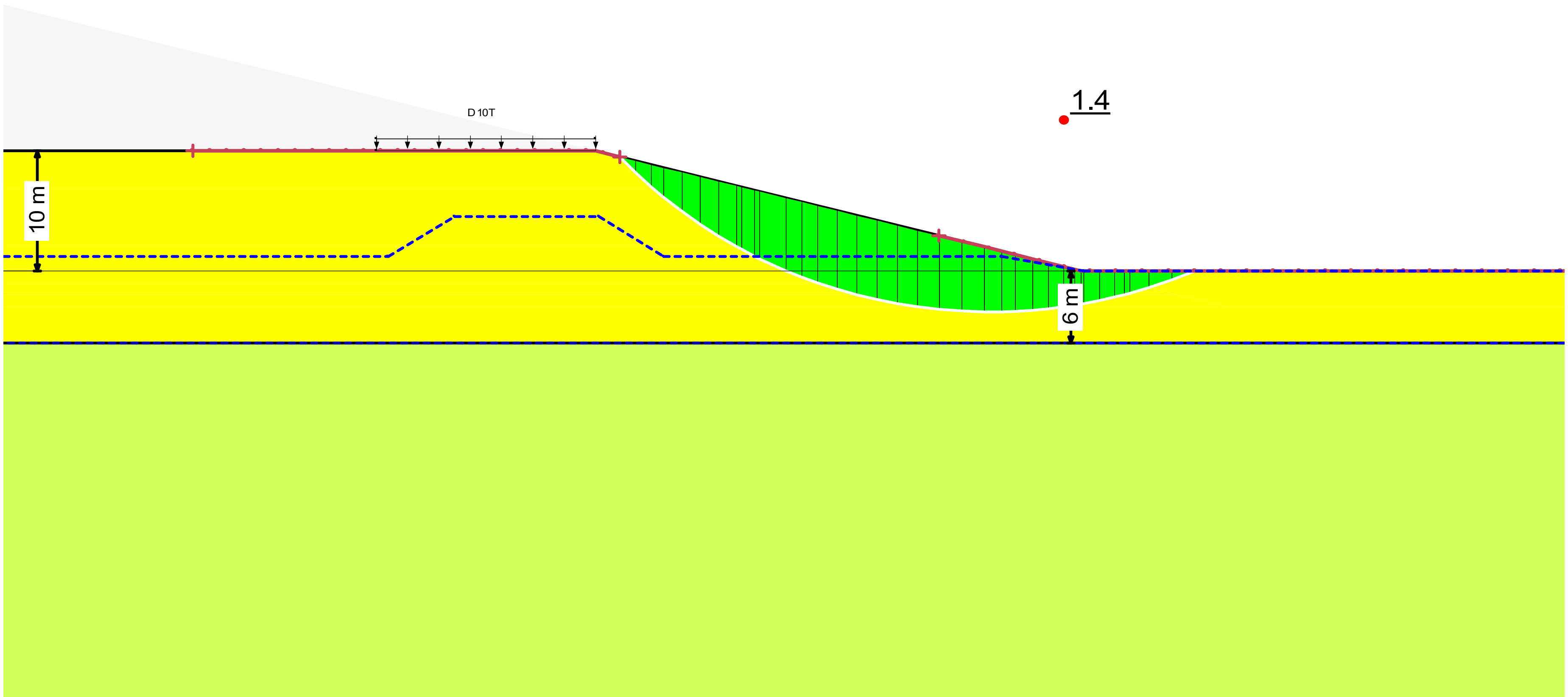
ATACAMA STABILITY STUDY - Assessment of Depth of Sand Stack, Placement over Pioneer Layer

Pioneer Layer Thickness - 4m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 30m

Date:	6/12/2022	**Job No:**	119085.02	**FIGURE C39**

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C39

Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Sand Fill	Mohr-Coulomb	14.7			0	25	2
	Tailings	SHANSEP	12	5	0.3			1



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ATACAMA STABILITY STUDY - Assessment of Depth of Sand Stack, Placement over Pioneer Layer

Pioneer Layer Thickness - 6m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 10m

Date: 6/12/2022 Job No: 119085.02

FIGURE C40

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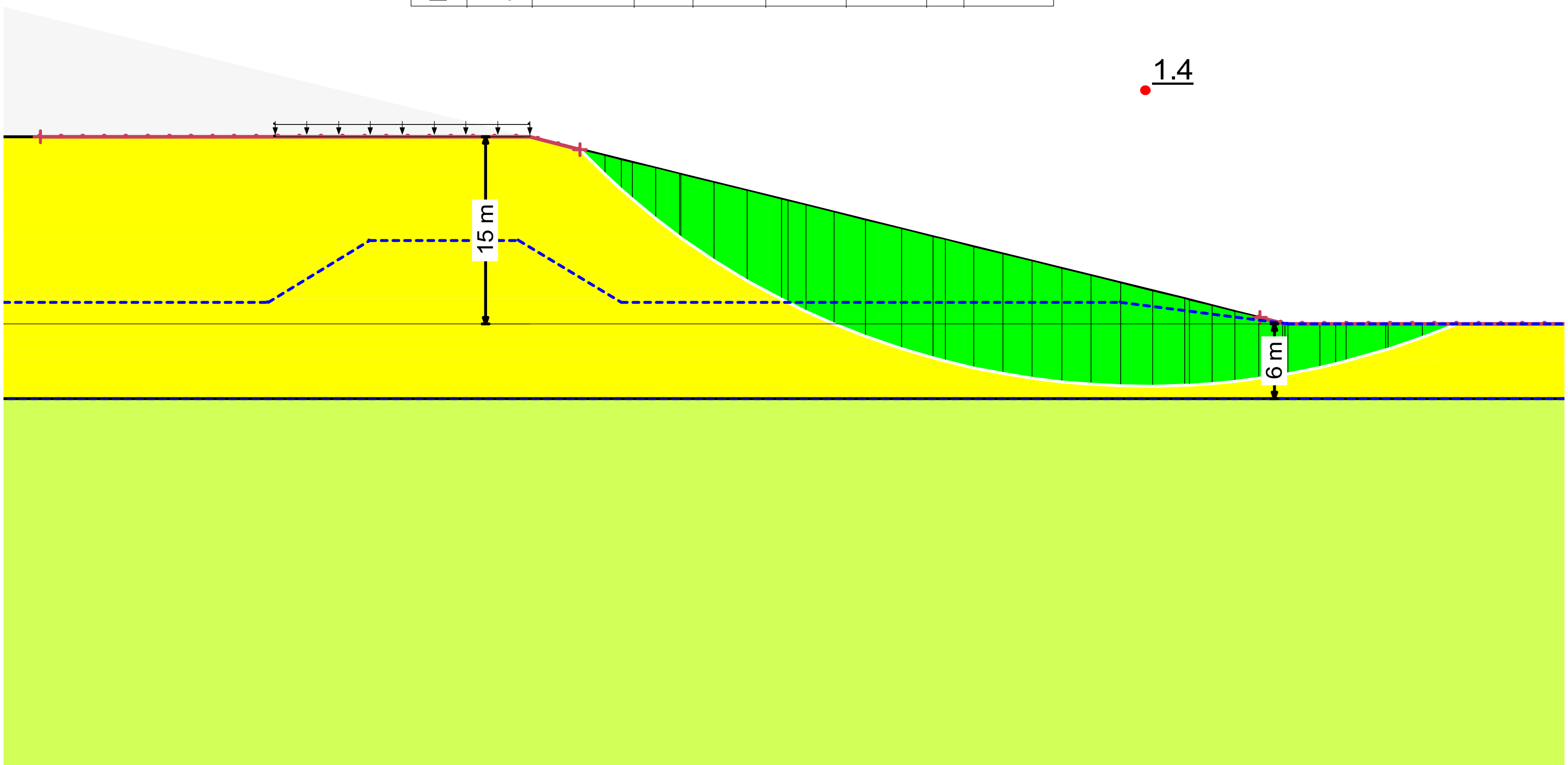
K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C40

Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Sand Fill	Mohr-Coulomb	14.7			0	25	2
	Tailings	SHANSEP	12	5	0.3			1



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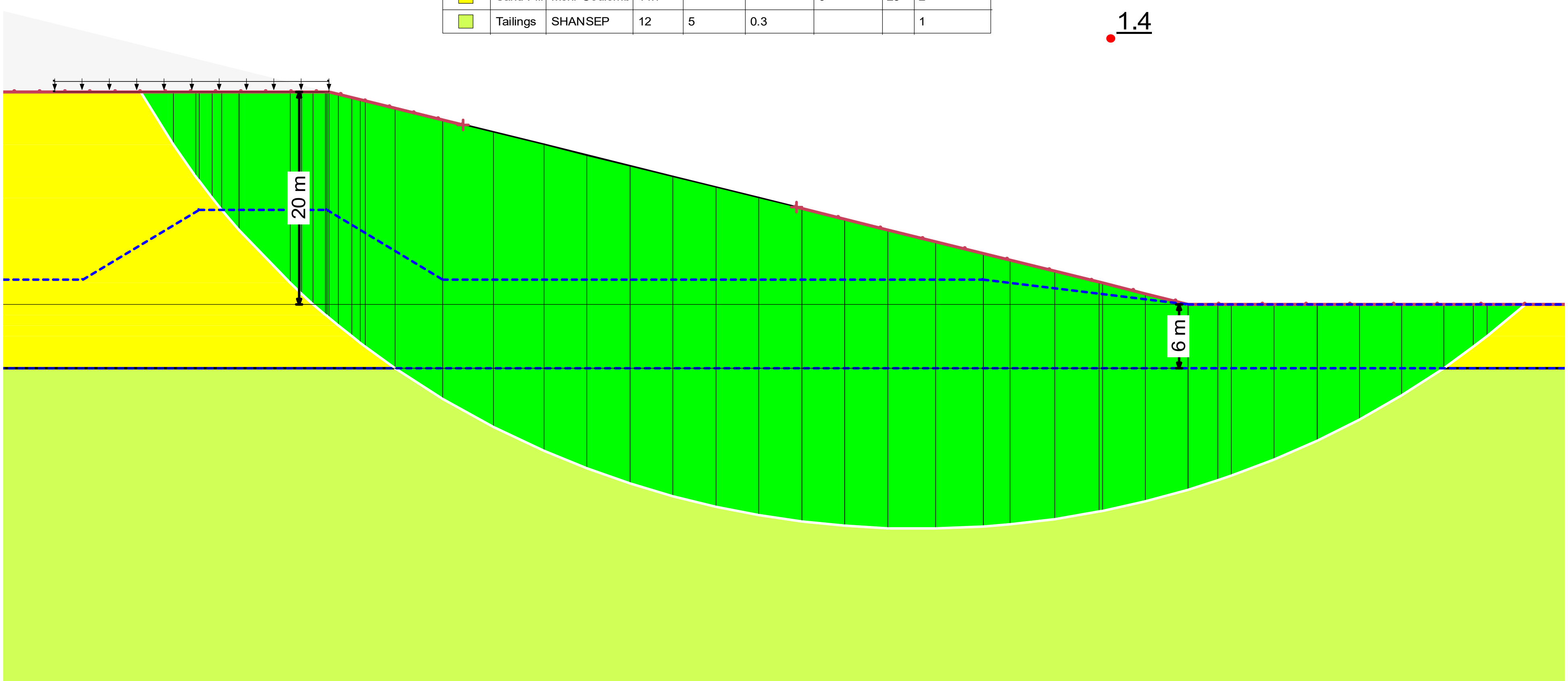
Pioneer Layer Thickness - 6m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 15m

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C41

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C41

Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Sand Fill	Mohr-Coulomb	14.7			0	25	2
	Tailings	SHANSEP	12	5	0.3			1



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ATACAMA

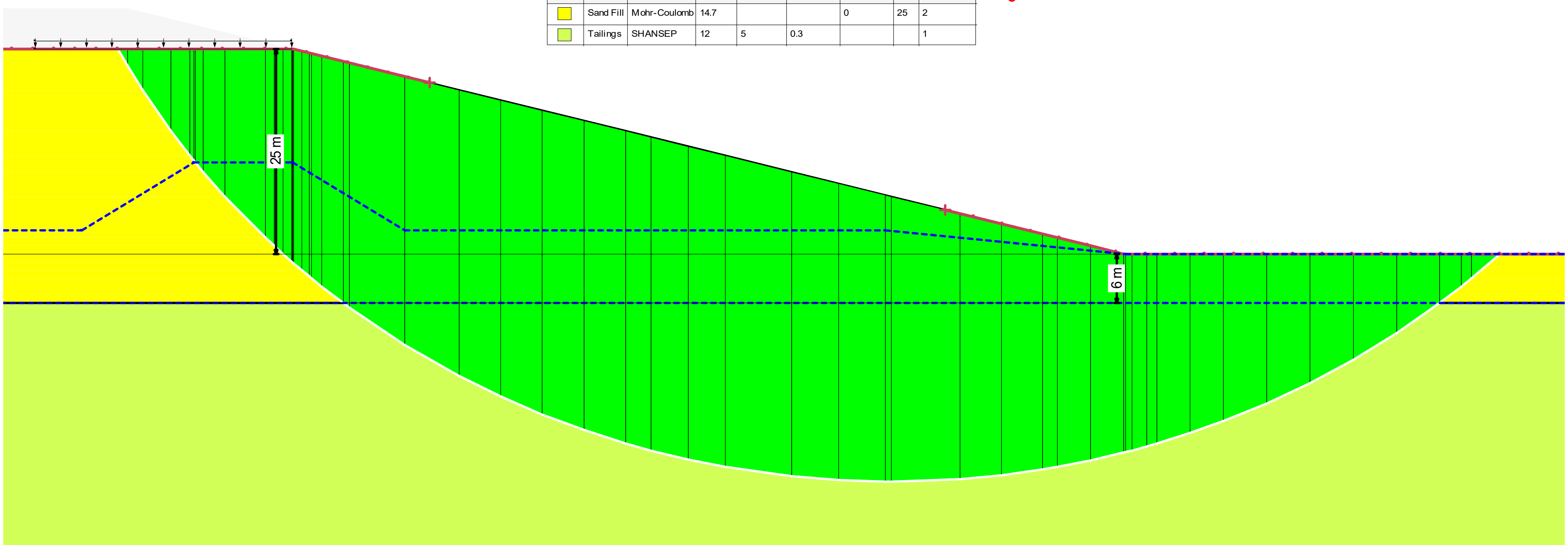
ATACAMA STABILITY STUDY - Assessment of Depth of Sand Stack, Placement over Pioneer Layer

Pioneer Layer Thickness - 6m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 20m

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C42

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C42



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
	Sand Fill	Mohr-Coulomb	14.7			0	25	2
	Tailings	SHANSEP	12	5	0.3			1

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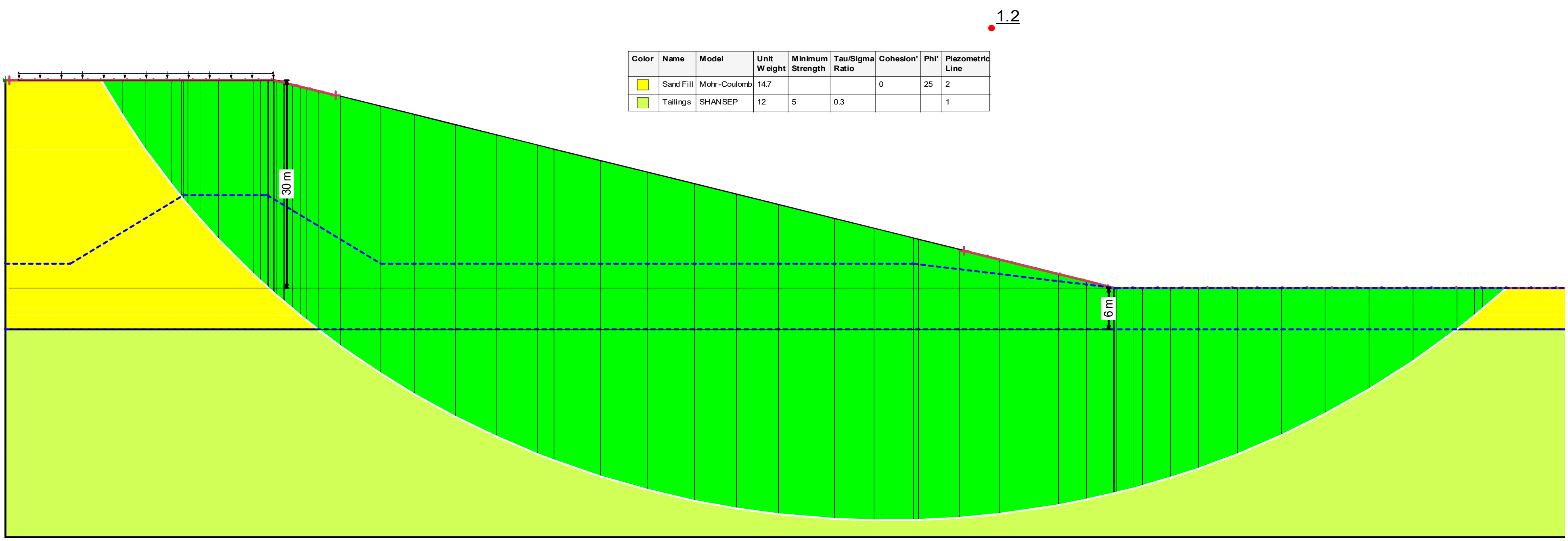
ATACAMA STABILITY STUDY - Assessment of Depth of Sand Stack, Placement over Pioneer Layer

Pioneer Layer Thickness - 6m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 25m

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C43

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C43



Color	Name	Model	Unit Weight	Minimum Strength	Tau/Sigma Ratio	Cohesion'	Phi'	Piezometric Line
(yellow)	Sand Fill	Mohr-Coulomb	14.7			0	25	2
(light green)	Tailings	SHANSEP	12	5	0.3			1

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ATACAMA STABILITY STUDY - Assessment of Depth of Sand Stack, Placement over Pioneer Layer

Pioneer Layer Thickness - 6m , Phreatic Surface Depth - 0m , Equipment - D10T, Sand Stack Height - 30m

Date: 6/12/2022 **Job No:** 119085.02

FIGURE C44

K:\Projects\119\119085 Atacama\02 Tails Placement\Data and Calcs\SlopeW\Stability Summary for R01 C44

Appendix D – Hydraulic modelling results and setback width literature review (Alluvium)

Memo

Subject	Hydraulic modelling results and setback width literature review
Project	Atacama sand stack setback determination – Stage1
Distribution	Matthew Harding, Iluka
Date	15 September 2022

1 Introduction

Iluka – Jacinth Ambrosia has engaged Alluvium Consulting Australia (Alluvium) to review and then propose the minimum waterway setback requirements for a proposed watercourse at the jacinth North pit, located at the Jacinth Ambrosia mine site, South Australia. Once re-instated the proposed watercourse will flow along the southern margin of a proposed tailings stack sited on the current footprint of the Jacinth North pit.

The tailings stack will be comprised of sands capped with loam and will be fully contained within the boundary of the Jacinth North Pit (Figure 1). Deposition is expected to commence in 2025/26 and is expected to be completed within 6-7 years. The reinstated watercourse has yet to be designed, but to fulfill mine closure and license relinquishments requirements, the watercourse must be designed to mimic the natural watercourses of the area. The disturbed reach, and the reaches upstream and downstream of the disturbed reach have previously been classified as Interdunal bank confined channel, sand (Alluvium, 2013). These waterways convey sandy sediment from higher elevations east of the current mine footprint to the low-gradient, chain-of-pan style watercourses to the west.

Establishing an appropriate waterway setback is vital to ensure that the expected increase and then decrease in sediment supply post closure can be accommodated by the waterway without triggering lateral erosion that would threaten the toe of the tailings stack. Erosion of the toe of the tailings stack has the potential to cause excess sediment delivery (and accumulation) within the reinstated waterway, and in downstream waterways.

Determining the minimum setback width will be undertaken in three stages. The two stages are:

- Stage one is a review of setback recommendations form available literature and 2D hydraulic modelling. The purpose of stage one is to identify the extent of the waterway corridor that may be subject to inundation and high shear stresses, and to identify a preliminary setback width to inform placement of the proposed sand stack. The initial setback width will be determined by reviewing the setback width recommendations from available literature and guidelines, and by undertaking 2D hydraulic modelling for a range of rainfall totals and intensities. The output of stage one will be used to inform modelling of the longer term evolution of the proposed sand stack, and the extent of toe-creep (towards the reinstated waterway) caused by erosion of the stack.
- Stage two is to use the output from stage one – the extent of the waterway corridor and the recommended initial setback distance – to inform more detailed landscape evolution modelling (LEM) of the proposed sand stack. Modelling of the stacks evolution can be used to indicate how the footprint of the stack is expected to change over time and whether the toe of the stack is likely migrate into the waterway corridor.
- Stage three uses the output form the sand stack modelling, and more detailed geomorphic investigations to identify the expected meander migration rate of the reinstated waterway, and to use that expected change in watercourse alignment to refine the width of the waterway corridor and the recommended waterway setback.

This interim report summarises the outcome of the stage one work.

2 Background and approach

Setbacks along the reinstated waterway (the distance between the top of bank of the reinstated watercourse, and the toe of the proposed tailings stack or other assets) will be a buffer between the adjacent tailings stack and the reinstated waterway, to minimise excess sediment delivery to the reinstated watercourse and downstream reaches. Increased sediment delivery to the reinstated waterway may have adverse impacts on waterway health but may also initiate channel change and loss of conveyance within the reinstated waterway.

Most sediment delivery and channel change will occur during infrequent intense rainfall events. We anticipate that sediment delivery during such events will be highest in the years immediately post completion of the tailings facility, before the regionally occurring crust has formed on the newly created landform (the crust provides an erosion resistant cap that minimises scour), and as sediment redistribution causes the toe of the tailings stack to migrate towards the reinstated waterway. During this early stage of landform adjustment, the setback must be wide enough to accommodate creep of the tailings stack toe, while also wide enough for large flows to spill across the floodplain without scouring the toe of the tailings stack and delivering excess sediment downstream. A wide setback, coupled with appropriate topography within the setback, will also promote the natural process of sediment deposition on the floodplain.

As sediment supply wanes and the rehabilitated catchment returns to a supply-limited state, the width of the waterway setback must be sufficient to contain the eventual meander migration that follows. Knowing this likely sequence of changes in sediment supply is driven by short, intense rainfall events, our method uses 2D hydraulic modelling driven by a rain-on-grid model.

The setback width will be determined to ensure:

- that the natural rate of meander migration or channel widening (i.e., erosion of the right bank) does not undermine the toe of the tailings stack.
- that the setback is wide enough to accommodate a fully established corridor of native riparian vegetation that:
  - helps maintains channel stability and waterway health
  - intercepts any sediment-laden runoff flowing from the tailings stack, so that sediment delivery to the re-instated watercourse is minimised.
- that the initial high-sediment supply phase and then the supply-limited meander migration phase of the channel evolution are accommodated.

The setback distance will be informed by hydraulic modelling. The hydraulic modelling has been used to identify the extent of the waterway corridor (the channel and any floodplain) inundated during high flows and potentially subject to high shear stress and erosion. Defining the waterway corridor using the hydraulic modelling will allow the location of the proposed stack to be modified to avoid erosion at the toe of the stack due to high flow in the reinstated watercourse.

The adopted approach utilises standard methods adopted for hydraulic modelling studies whereby flows from hydrology are applied to the topography and the hydraulic model routes the flows across the terrain. The results of this analysis can capture the spatial distribution of the flow properties (depth, level velocity etc.) and can be mapped to highlight areas of risk. For this assessment, flows have been estimated for the 0.1% AEP event (1 in 1000 AEP) to provide a conservative estimate of the width of the watercourses in a large flood event. The extent of the study area catchment is shown in Figure 1.

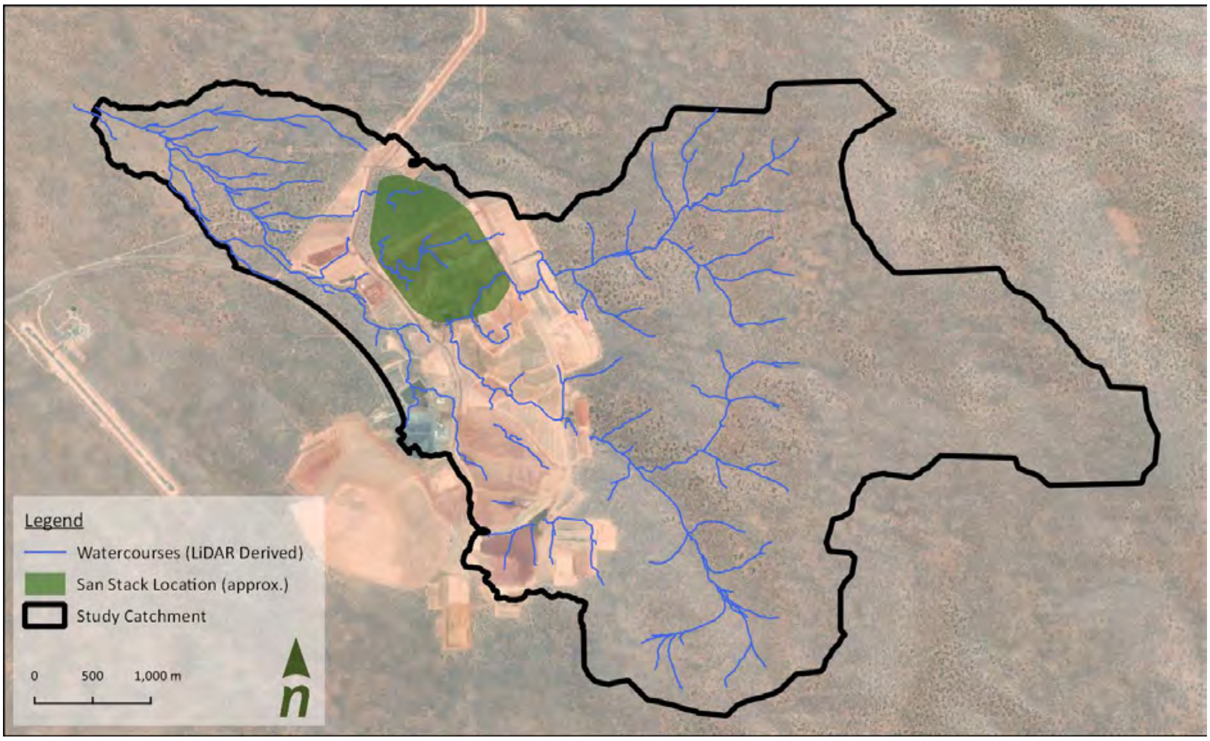


Figure 1 - Modelling Study Area

The adopted approach uses TUFLOW as the hydraulic modelling package and applies flows estimated using a hydrologic model (RORB) as well as rainfall applied directly to the grid. This approach allows for detailed analysis of flow paths across the site.

3 Review of guidelines on waterway setback widths for a range of functions

The minimum recommended setback width for a range of geomorphic and ecological functions are summarised in Table 1. We note that the vast majority of scientific literature, and the guidelines that reference this literature, are based on urban or agricultural settings in temperate climates.

Set back widths as defined in the *Defining waterway setbacks for river health benefits: a Melbourne Water Perspective discussion paper* (Alluvium, 2019).

Table 1. Minimum setback width for a range of function, sourced from available guidelines

Management objective	Recommended minimum setback distance	Buffer considerations	Confidence in type/amount of evidence	Source
Water quality	30 m	This should be increased in areas where vegetation is less dense, steep areas or concentrations of pollutants are high.	High	Ecology Australia (2018) Riparian Setback Widths: A review of recommendations for guidelines. Report prepared for Melbourne Water by M Le Feuvre, F Sutton, C Maloney (Ecology Australia Pty Ltd: Fairfiled)
In stream values	30 m	This should be increased if sensitive species are present or there is little overhanging vegetation providing inputs.	Moderate	
Providing terrestrial habitat: Flora	55 m + Tree Protection Zone of trees rooted or partially rooted within the setback	Assumes intact vegetation	Low	
Providing terrestrial habitat: Fauna	100 m	Site-by-site investigations required, Biodiversity corridor value should be used when large areas of terrestrial habitat are present on either side of the stream Setback distance should be increased if specific, sensitive species (e.g. Growling Grass Frog of powerful owl)	Low	
Geomorphic stability	10 m + Establishment Allowance Zone ((average annual channel migration rate x total years for riparian veg to mature to a height of 10m) + bank height of the reach in question)			Abernethy, B. and Rutherfurd, I.D. (1999) Guidelines for stabilising streambanks with riparian vegetation. Cooperative Research Centre for Catchment Hydrology Technical report 99/10.

Management objective	Recommended minimum setback distance	Buffer considerations	Confidence in type/amount of evidence	Source
Geomorphic stability (erosion control) Specifically looking into riparian buffer widths required for erosion control	5m (Aus. guidelines) [can be modified by adding the height of the bank + time taken for vegetation to mature] 10m (New Zealand) 30 - 38 m (North America guidelines)	Note: Guidelines from different jurisdictions in North America showed that width recommendations typically ranged between 15 and 60m (slope dependent) to control sedimentation (Lee et al., 2004).		Hansen B.D., Reich P., Lake P.S., Cavagnaro T. (2010) Minimum width requirements of riparian zones to protection flowing waters and to conserve biodiversity: a review and recommendations. Report to Department of Sustainability and Environment (Monash University: Clayton).
Geomorphic stability (erosion control)	30 m	This study recommended that buffer widths should extend to the edge of the active (100-year) floodplain to best achieve bank stability. This ensures the channel can naturally migrate and not adversely impact adjacent land use/environments.		Wenger, S. (1999) A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation. I.O.E. Office of Public Service and Outreach. University of Georgia, Athens.
Erosion control and reduction in nutrient inputs	20-38 m	Note that in this study there was insufficient evidence to demonstrate if implemented widths reduced nutrient loads or controlled bank erosion.	Low	Hansen, B.D., Reich, P., Cavagnaro, T.R. and Lake, P.S., 2015. Challenges in applying scientific evidence to width recommendations for riparian management in agricultural Australia. *Ecological Management & Restoration*, *16*(1), pp.50-57.
Flood mitigation	10 m			Alluvium, 2019

Table 2. Setback width modifiers used to calculate the necessary change in setback width for a variety of topographic settings, land use and habitat quality

Modifier likely to impact ecological functions of a setback	Impact on waterway setback	Changes in setback distance to mitigate impacts
Physiography (slope, geology, position in catchment)	**Slope:** increased runoff rates deliver more pollutants to waterway, which carries more sediment and can undermine shallow-rooted plants in the riparian zone **Geology and soils:** influence runoff pattern via permeability, texture and erodibility **Position in catchment:** Headwater streams are smaller but have greater impact on water quality, so should have wide setbacks. Reaches lower in catchment have wider flood zones/floodplains	**Slope**: recommend using a consistent approach to slope modifiers, for example: Wenger (1999): suggests an additional 61 cm of for every 1% of slope, up to 25% slope (slopes steeper than 25% should not contribute towards the minimum setback); Barling and Moore (1994): setback distance (m) = 8 + 0.6 × slope (%); OR 0–5% slope use minimum setback distance, 5–10% add 5 m, 10–15% add 10 m etc. **Geology and soils**: Little site-specific information, if soils with poor filtration properties identified, increase setback distance **Position in catchment**: Wider setbacks in upper reaches to protect water quality, don't pipe headwaters
Land use (conservation, rural, urban)	**Conservation:** Little adverse impact on setback distance **Rural:** Increased runoff from irrigation, Runoff carries increased nutrient and/or pollutant load, stock graze on vegetation at edge of riparian buffer	**Rural:** Hansen et al. (2015) classify land use by intensity (low, moderate, high) and ecological function, apply setback distance-modifier to each case. E.g. Improve water quality in low-intensity land use area: 20 m Improve water quality in high-intensity land use area: 38 m Overall there is inadequate evidence available to designate setback distances for various land use intensities., and waterway managers and site-scale investigations are still required.
Habitat quality within setback (e.g. native trees, exotic grasses)	No riparian buffer vegetation inside setback means setback will be largely ineffective for ecological functions. The habitat present within the setback will alter its effectiveness. For example, a setback dominated by grasses is likely to improve water quality values, but provide little shade, leaf litter or woody debris inputs and poor-quality habitat	When protecting or establishing riparian habitat give consideration to: The naturally occurring Ecological Vegetation Class (EVC) of the area; The most suitable approved adaptation of this in line with predicted climate change scenarios; and Any altered land forms such as disengaged floodplains. If a setback does not consist of native vegetation, it should be revegetated with indigenous species to reproduce a similar vegetation/habitat structure.

Modifier likely to impact ecological functions of a setback	Impact on waterway setback	Changes in setback distance to mitigate impacts
	for woodland birds. Likewise, the threatened Growling Grass Frog prefers more open riparian habitats (DELWP 2017), which contrasts with the needs of some other species (Ecology Australia, 2018)	
References		

- Ecology Australia (2018) Riparian Setback Widths: A review of recommendations for guidelines. Report prepared for Melbourne Water by M Le Feuvre, F Sutton, C Maloney (Ecology Australia Pty Ltd: Fairfiled)
- Hansen B.D., Reich P., Cavagnaro T.R., Lake P.S. (2015) Challenges to applying scientific evidence to width recommendations for riparian management in agricultural Australia. *Ecological Management & Restoration* 16 (1), 50–57.

3.1 Other approaches to determining waterway setbacks widths

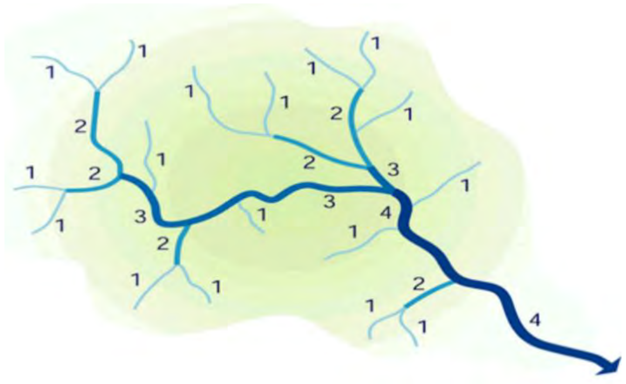
Simple scaling methods

Source: *Waterway Corridor guidelines for greenfield development areas within the Port Phillip and Westernport Region* (Melbourne Water, 2013) (https://www.melbournewater.com.au/sites/default/files/Waterway-corridors-Greenfield-development-guidelines.pdf)

Setbacks are determined using the Strahler stream order concept - setback distances increase as stream orders increase downstream.

Table 1. Core riparian zone and vegetated buffer widths for different overall setback widths in existing channels

OVERALL SETBACK WIDTH (M)	CORE RIPARIAN ZONE WIDTH (M)	VEGETATED BUFFER WIDTH (M)
20 m	10 m	10 m
30 m	20 m	10 m
50 m	40 m	10 m



Stream order	Setback width
1	20 m
2	20 m
3	30 m
4 +	50 m

4 Hydraulic modelling methods

The hydraulic modelling undertaken to establish the width of the waterway corridor has two main components; the hydrologic model to estimate flows and the hydraulic model which routes the flows through the topography. Both analyses have focussed on the catchment delineated in Figure 1. The study catchment has been delineated using all available topographic datasets as described in the sections below.

4.1 Hydrology

The hydrologic modelling component of this study is divided into two distinct parts; a RORB hydrologic model of the upstream catchments (outside the LiDAR extent) and direct rainfall within the TUFLOW model extent. The extent of adoption for each hydrologic method is shown in Figure 2 and the development model inputs is discussed in sections below.

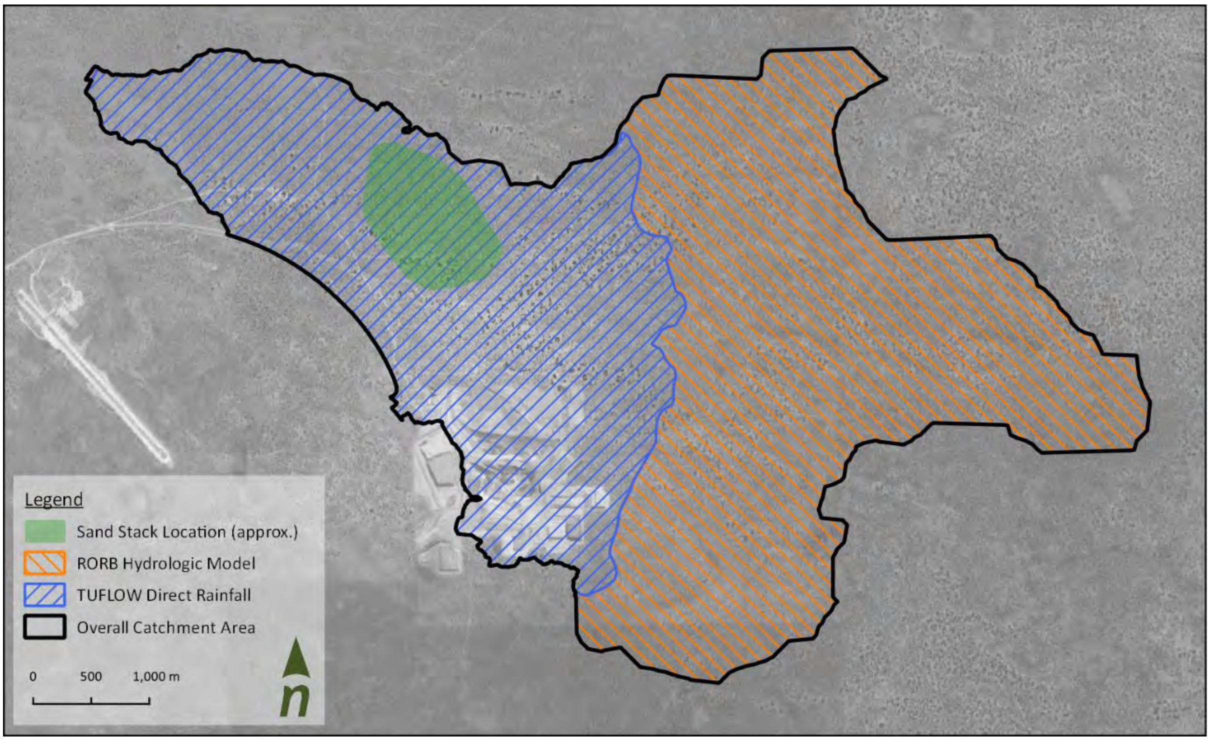


Figure 2 - Extent of Hydrologic Method Application

Upstream Catchments

Outside the extent of the available LiDAR, the 1 arc second resolution SRTM data was used to delineate catchments and estimate inflows into the TUFLOW model. The hydrologic modelling software used in this study is RORBWin version 6.45, a Windows version of the industry accepted RORB program (Laurenson et al 2007).

A RORB model represents the rainfall runoff process occurring in a catchment by:

- Conceptualising the catchment as a linked series of sub-catchments represented in the model by catchment storages and river reach storages;
- Applying rainfall excess (rainfall minus losses) to each sub-catchment (rainfalls are assumed to enter the sub-catchment at its centroid);
- Calculating the resulting runoff from each sub-catchment storage;
- Routing the runoff through the catchment system, combining flows at channel junctions; and

- Outputting flow hydrographs at points of interest in the catchment.

The model represents only the rapid flow or surface runoff component of stream flow, and the slow response or base flow component has not been included in the model.

The RORB model requires four parameters to be specified which include k_c, m, initial loss (IL) and continuing loss (CL). The k_c and m parameters are factors in the storage discharge relationship. Given the conservative assumption of no initial and continuing losses has been made (IL, CL = 0) only kc and m need to be estimated.

m is a dimensionless exponent representing the non-linearity of catchment response. *m* varies in the range of 0.6 to 1.0 with a value of 1 representing a linear response. Many studies adopt a value of 0.8 and this value been adopted for this study.

k_c is an empirical coefficient applicable to the catchment and is a constant for the whole catchment. It has been estimated here by using equations contained in Australian Rainfall and Runoff 2019 Book 7 Chapter 6: *Regional Relationships for Runoff Routing Models*. The adopted equation is 7.6.20 based developed by Kemp, 1993.

$$K_c = 7.06A^{0.71} (RF/1000)^{2.79}$$

$$K_c = 7.06x23.38^{0.71} (261/1000)^{2.79}$$

$$\mathbf{K_c = 1.56}$$

This method is considered applicable for the northern and western regions of South Australia where average annual rainfall (RF) is less than 320 mm (261 mm over the site). It is noted that the *kc* value of 1.56 estimated using this method produces larger runoff estimates than other equations discussed in Book 7 Chapter 6, however, the conservative flow estimate is considered appropriate given the other uncertainty in the analysis with respect to topography. It should be noted that it is an underlying assumption of this approach to estimate *kc* that m = 0.8.

For the 0.1% AEP event the full range of temporal patterns were run for the 30min, 1, 2, 3, 6, 9, 12, 18, 24, 30, 36 and 48 hour storms to ascertain which storm duration and temporal pattern combination is critical (in terms of flow magnitude) where the sand stack is adjacent to the watercourse. The analysis showed the critical duration to be the 30 minute storm using temporal pattern 1455 (TP06).

Direct Rainfall

Within the TUFLOW model extent direct rainfall has been adopted as the method to apply flows. This approach allows a detailed assessment of flow paths across the site instead of just the main flow path. For this approach, rainfall hyetographs are applied to a nominated extent within the TUFLOW model.

While rainfall inputs were configured for the full range of storm durations and temporal patterns for the 0.1% AEP event, the applied storm was based on the duration and temporal pattern deemed critical in the RORB model described above.

Losses

In both the RORB model and direct rainfall configuration, no initial or continuing losses were applied. This has the effect of adding more runoff to the model and is considered a conservative assumption suitable for the estimation of flow widths. Future work to refine the setback width along the waterway can modify this assumption to include possible ongoing losses, which will reduce peak flows and may reduce the width of the corridor inundated by high flows. The purpose of this stage one assessment is to define the maximum possible corridor width.

4.2 Topography

Assessing the flow paths in the post-mining condition meant different topographic datasets needed to be prioritised in different parts of the study area. The base dataset used in this study was the LiDAR dataset captured in November 2021 and shown in Figure 3. This dataset was supplied for use in this project in May of 2022. Because this dataset was captured at this time, it includes the mining pits, infrastructure and other changes to the topography.

Where the mining pits are currently located, other datasets were required to represent the post-mining condition. These are summarised below:

- Jacinth South Creek landform (Ikuka, December 2014). Post-rehabilitation landform
- Jacinth Pre-Mining Survey Points (December 2012)

The spatial distribution of the differing sources of topography are shown in Figure 4. The resultant surface shown in Figure 5 does contain some minor discontinuities at the interface between the different datasets. These have been smoothed within TUFLOW where possible using 2d_zsh features. The adjustments made ensure the discontinuities are not blocking runoff from being routed to the main drainage lines.

This is considered an appropriate surface for the derivation of approximate flow widths but should be refined in any subsequent phases of the sand stack development with an updated consolidated topography dataset.

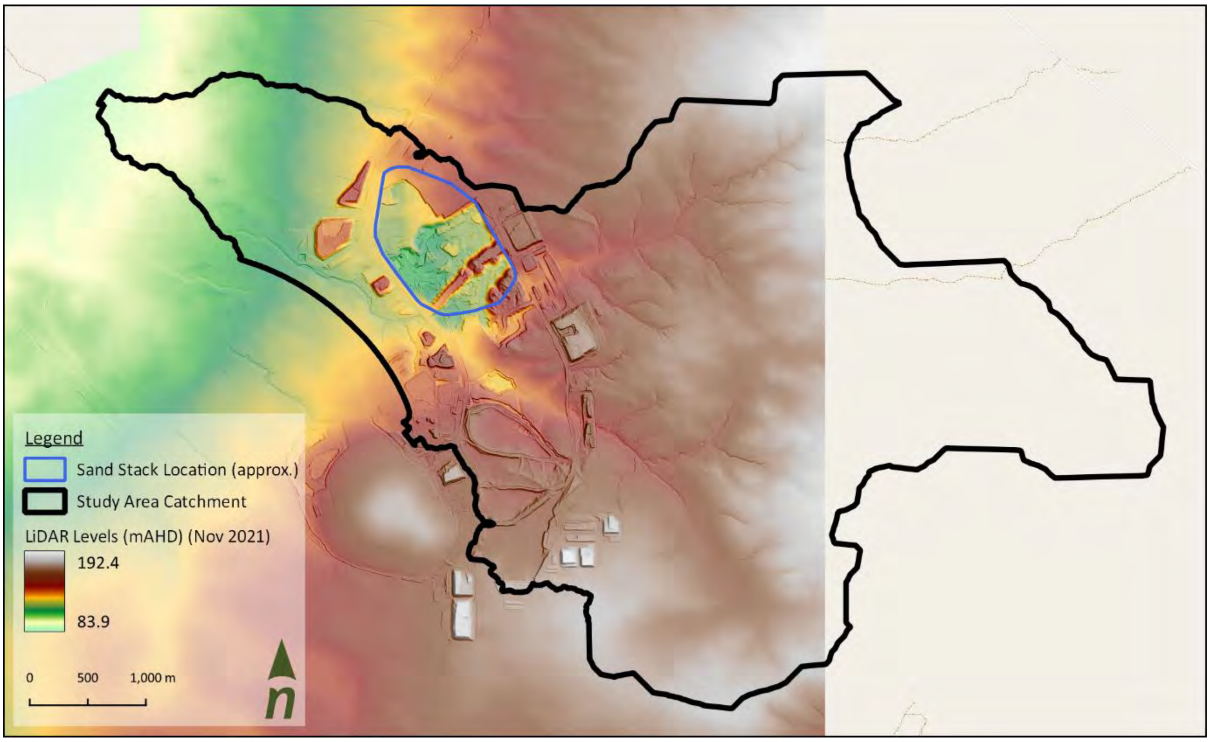


Figure 3 - November 2021 LiDAR Overview

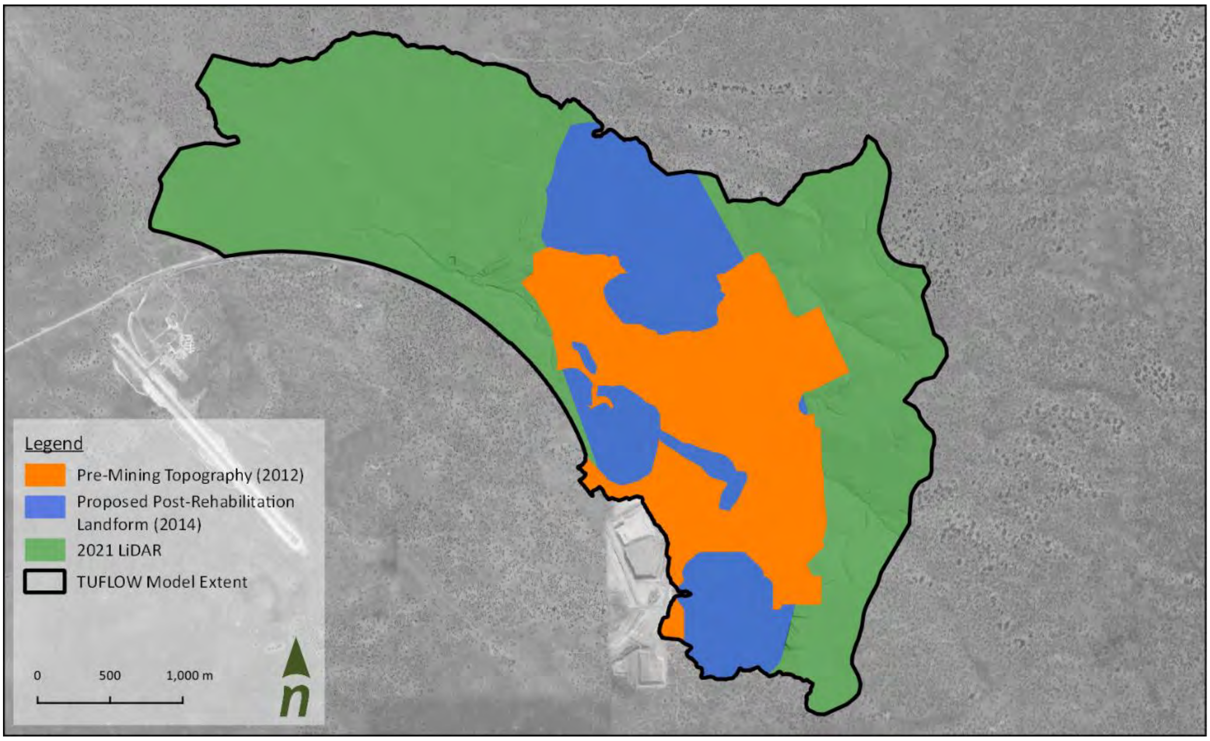


Figure 4 - Topography Sources

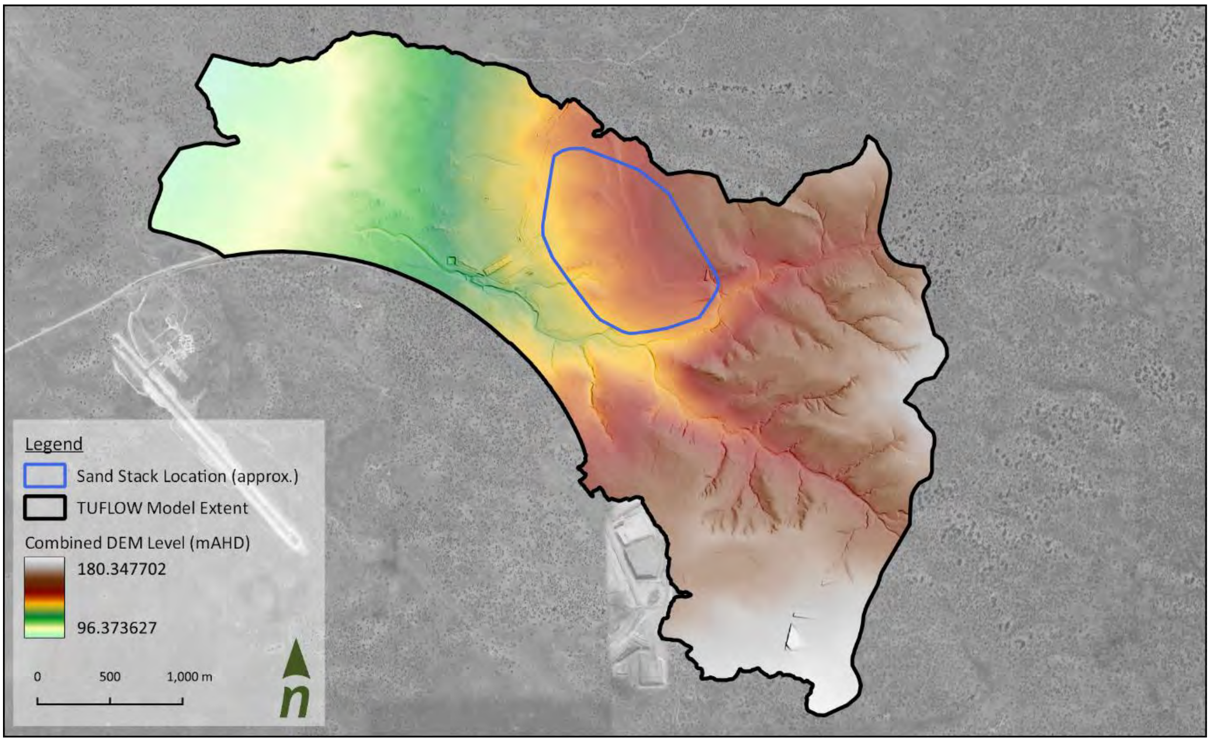


Figure 5 - Combined DEM

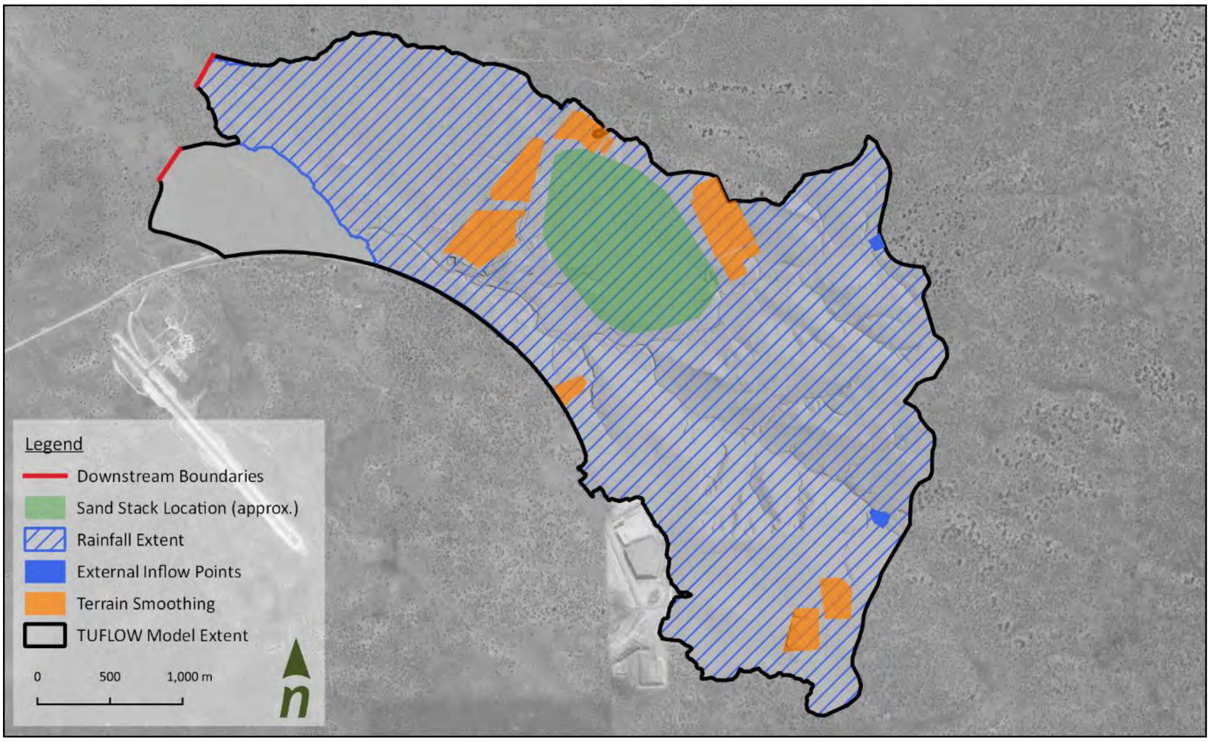


Figure 6 - TUFLOW Model Setup

5 Hydraulic modelling results

Figure 7 and Figure 8 show the peak depth and velocity of the flow paths in the vicinity of the tailings stack. These show peak depths of 2.5-3 m in the main watercourse to the south with a peak velocity in channel of 4 m/s. It should be noted that the model outputs in this area use a depth cutoff whereby flood depths shallower than 100 mm have been removed from the results. This cutoff also applies for the flood velocity where velocities in areas where the depth is shallower than 100 mm are removed.

The flow paths shown in the model results highlight that within the extent of the tailings stack a flow path exists on its western edge flowing south as well as the main channel to the south of the stack flowing from east to west. The flow path on the west should be reviewed as better topographic data becomes available as currently this flow path is generated by the road and associated bunding which is captured in the LiDAR dataset directing flow.

The width of the waterway in the 0.1% AEP flood event has been post-processed and simplified (to remove shallow flooding and disconnected ponding) into a polygon as shown in Figure 10. Figure 10 also shows offsets from this flood extent in 20 m increments to give an indication of the proximity of the flow path extents from the approximate extent of the tailings stack.

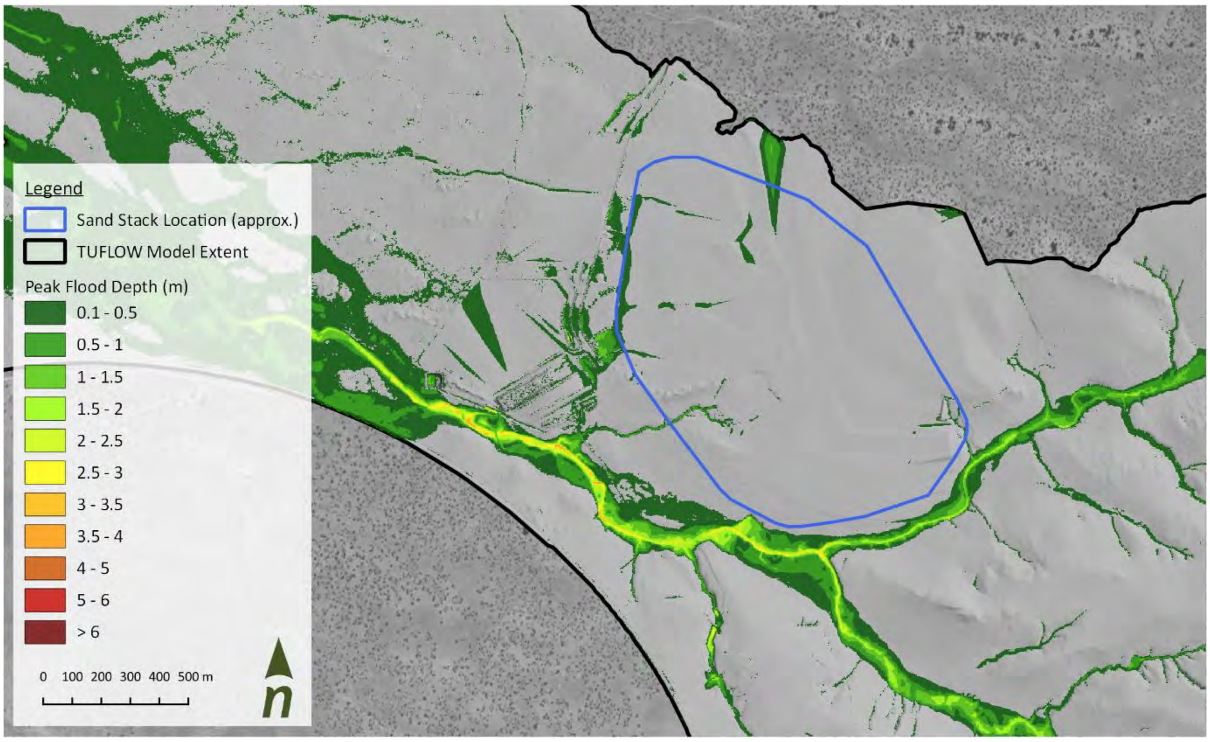


Figure 7 – 0.1% AEP Peak Flood Depth

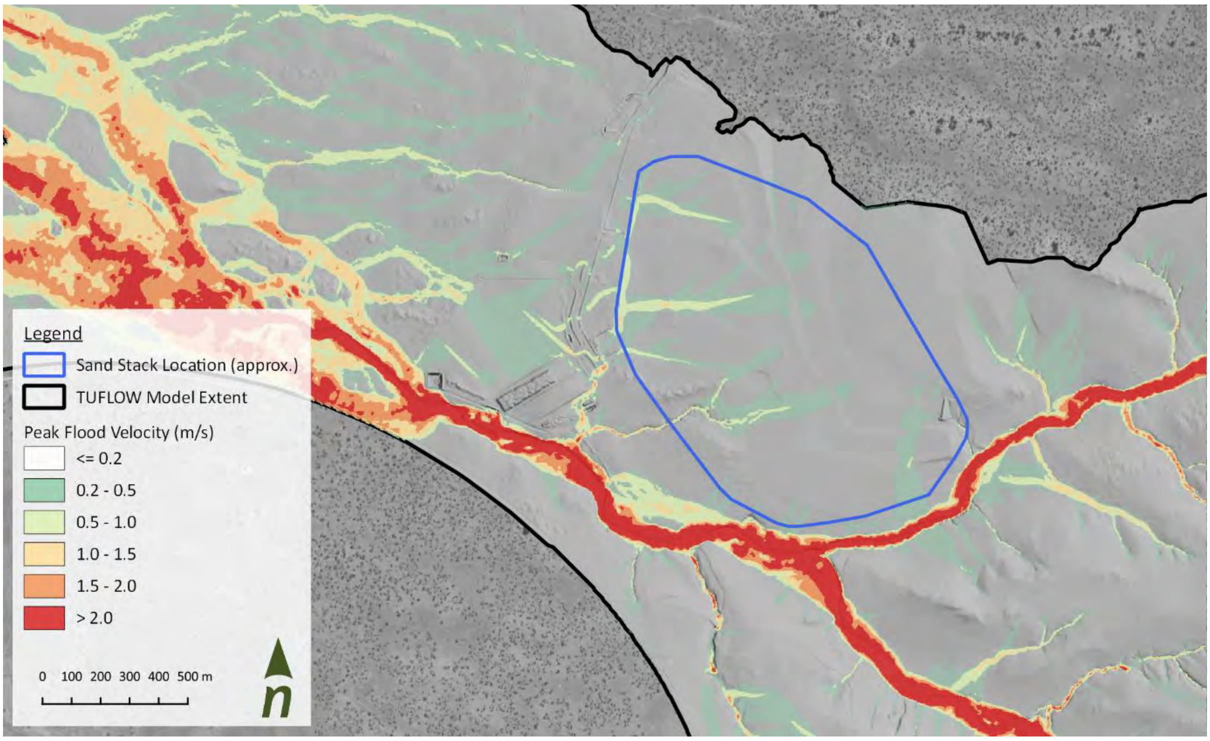


Figure 8 – 0.1% AEP Peak Flood Velocity

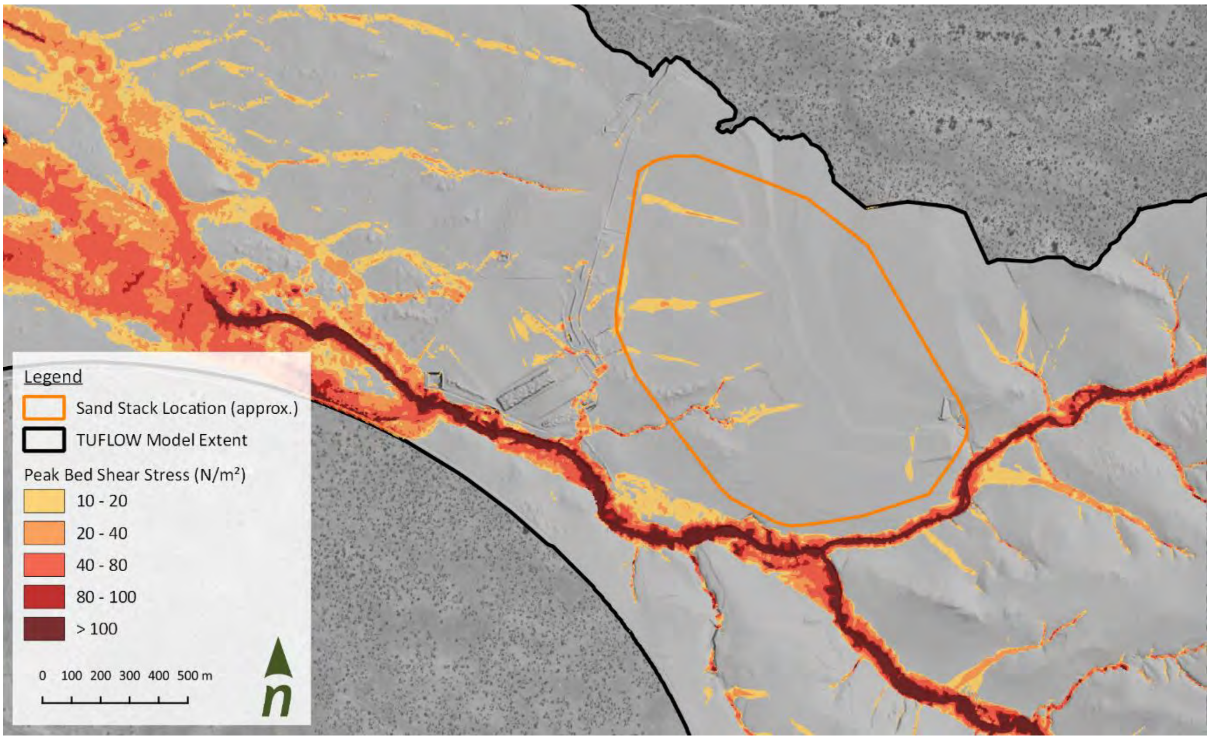


Figure 9 – 0.1% AEP Peak Bed Shear Stress

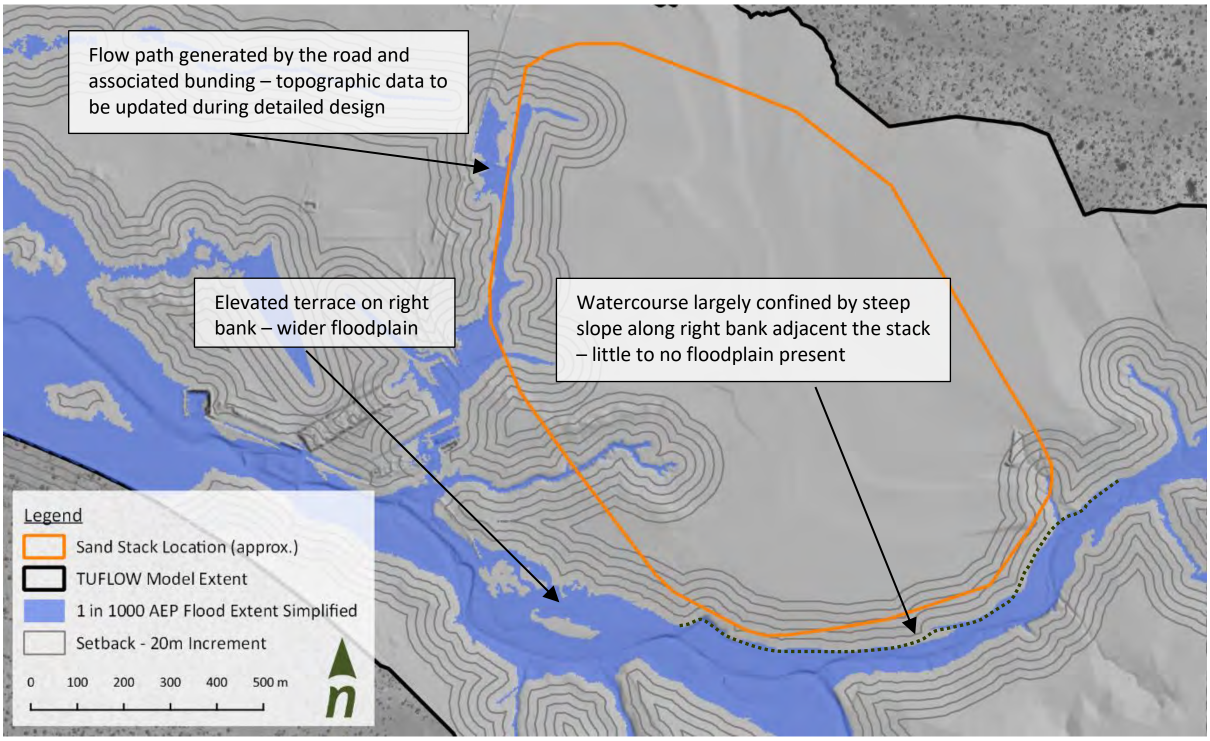


Figure 10 - 0.1% AEP Flood Extent with Setback Increments

5.1 Limitations

There are a number of sources of uncertainty which should be acknowledged when reviewing the results of the hydraulic modelling undertaken for this study.

- At present there is no consolidated and detailed topographic dataset which captures the intended post-mining landform. As a result, no design flood levels can be provided from this modelling as these are most sensitive to changes in the underlying topography. This can be revisited through the design process and more detailed information becomes available.
- At this point, the modelling has not assessed the impact of the sand stack on small flow paths within its extent. This can be assessed at subsequent phases of design if desired.
- At present the hydrologic analysis has not reviewed infiltration parameters in any detail. The ARR datahub provided no loss parameters to adopt. It should be noted that any further analysis and adoption of rainfall loss parameters will reduce peak flood levels and flows.
- Currently this study has not assessed events other than the 0.1% AEP event. This is considered suitable given the purpose of this study and is proportional to the underlying uncertainty in the final topography of the re-instated watercourses and overall landform. The model is configured such that assessing a range of additional events can be done relatively simply.

6 Discussion and recommended initial setback width

The merged topographic datasets represent our best estimate of the approximate post-mining landscape along the subject watercourse on the southern side of the stack (Figure 4Figure 5). For much of part of the waterway adjacent the stack, the watercourse is confined by steep slopes on the left and right banks and little no floodplain has developed. An elevated terrace that served as a floodplain which is inundated by the 0.1 % AEP flow, is present above the right bank at the downstream edge of the stack (annotated in Figure 10). Our setback recommendations focus on the main watercourse to the south of the proposed stack. The watercourses to the west of the stack, and the smaller waterway that drains the stack itself have not been included in a setback width recommendation because the topographic data used to determine such setbacks is not currently available. An integrated topographic dataset that includes the final design profile of the stack itself, the post-mining landform for the area to the west of the stack, and the final position of the stack is needed to better model the likely flow paths on and to the west of the stack.

The conservative flow modelled (0.1 % AEP) means that any flat floodplain areas, including terraces elevated above the main channel to the south, are well captured by the extent of the 0.1% AEP event shown in Figure 10. The estimated shear stress, which is a measure of the forces flow exerts on the channel bed and floodplain, are highest within the channel (> 200 N/m^2) but also remain high on the slopes that confine the channel (60 - 160 N/m^2). These shear stress values are well in excess of those required to mobilise coarse sands present in the channel (~5 N/m^2), to cause scour of the bed and banks and undermine well-established vegetation (~120 N/m^2). The implication is that any setbacks should ensure there is sufficient space to accommodate such high flows since they are likely to mobilise sediment and trigger channel change. Flow forces and across the floodplain terrace at the south western edge of the stack are much lower and average ~20 N/m^2. Such shear stresses are still high enough to mobiles unconsolidated sediment and cause localised scour but are unlikely to destroy established vegetation.

When defining a waterway setback, two components are needed: a reference point from which the waterway setback distance is measured, and a minimum setback distance to be applied to that reference point.

Setback reference point

Usually, the top of bank or a clear break in slope is used as the reference point to measure setback distance. The lack of clear bank tops or break in slope along the confined watercourse to the south of the stack means an alternate reference point is required. **For the purpose of this initial assessment, we have adopted the**

current extent of the 0.1 % AEP flow (Figure 10) as the reference point. The 0.1 % AEP extent is a conservative reference point that captures the area likely subject to erosion and channel change under a large (0.1 % AEP) flow event. Using this reference point ensures that the stack does not fall within this zone of potential channel change

Setback width

The setback width, measured as a distance from the 0.1% AEP extent, is more difficult to estimate. Guidelines identified in our literature review are largely focused setbacks that perform functions typical of agricultural or urban waterways in temperate regions. We have not identified information on vegetation establishment times or ecological functions of setbacks for the arid environment present at the Jacinth Ambrosia site. Our focus in this preliminary assessment is on ensuring that geomorphic processes in the waterway are accommodated within a setback, and that the proposed sand stack is not threatened by erosion. This focus indirectly provides important ecological functions for the downstream sections of the waterway by reducing the likelihood of excess sediment delivery, sediment accumulation in the channel, and consequent loss of habitat. **Therefore, we recommend an initial setback distance of 60 m be adopted along the subject watercourse.** We have selected this setback width to:

- Be greater than the most conservative guidelines for geomorphic criteria in Table 1 (30 m)
- Be wide enough that potential future channel change, such as widening or meander migration, is likely to be accommodated within a setback and that should such channel change occur, a sufficiently wide setback that contains the 0.1 % AEP flows is present. This assumption requires more detailed assessment to be confirmed.

Both the recommended setback reference point (the edge of the defined corridor) and the setback distance outlined above are conservative. More detailed assessments of the likely rates and location of meander migration or channel widening along the watercourse to the south of the proposed stack can be used to refine the minimum setback width, noting that such assessments may identify a lesser setback distance is appropriate.

Appendix E – Erosion potential of the proposed landform design for the sand stack at Jacinth North (Landloch)

EROSION POTENTIAL OF THE PROPOSED LANDFORM DESIGN FOR THE SAND STACK AT JACINTH NORTH

Iluka Resources Limited

October 2022

Disclaimer: All care and diligence has been exercised in testing, interpreting data and the development of recommendations presented in this report. The monitoring and testing have been undertaken in a skilled, professional manner, according to accepted practices. Specific circumstances and research findings after the date of publication may influence the accuracy of the data and recommendations within this report.

The landscape is not uniform. Because of this non-uniformity, no monitoring, testing or sampling technique can produce completely precise results for any site. Any conclusions based on the monitoring and/or testing presented in this report can therefore only serve as a 'best' indication of the environmental condition of the site at the time of preparing this document. It should be noted that site conditions can change with time.

The information that comprises this report should only be used within the limitations stipulated in this report. Landloch does not accept any risks and responsibilities for losses, damages, costs and other consequences resulting from using any information, material and recommendations in this report.

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Client: Iluka Resources Limited

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1 INTRODUCTION

Iluka Resources Limited (Iluka) is undertaking landform design planning for a proposed sand stack at Jacinth North, located in South Australia. Landloch were engaged by Iluka to undertake erosion modelling to predict the 3D erosional performance of the rehabilitated sand stack shape.

1.1 Scope of work

The following work was completed as part of this project:

1. Review of available rehabilitation materials;
2. Undertake landform evolution modelling and targeted runoff/erosion modelling to assess the performance of the proposed shape and provide recommendations for improvement of the erosional performance of the rehabilitation shape.
3. Report the findings of the assessment (this document).

2 BACKGROUND INFORMATION

2.1 Vegetation

Vegetation assemblages planned to be established as part of rehabilitation may include Myall Woodland, Chenopod Shrubland, and/or Mallee Woodland. All three assemblages are dominated by shrubs and/or trees and contain relatively low levels of grass cover (vegetation groundcover). This in turn results in very low groundcover levels. Therefore, for this study, the impact of vegetation groundcover on erosion was not considered and the results could be considered slightly conservative (i.e. predicted erosion rates slightly higher than likely).

2.2 Rehabilitation materials

Material types available for rehabilitation of the sand stack are similar to those found elsewhere at Jacinth-Ambrosia. They include topsoil, subsoil, and a red/brown loam overburden. These materials are typically layered, with topsoil overlying subsoil to form the active root zone. The loam is placed under the subsoil to act as a layer that provides physical support and water storage for deeper rooted vegetation (e.g. tree species).

An erodibility study of soils for Jacinth-Ambrosia has been previously conducted (Landloch 2007). This study considered a material described at the time as 'fine dusty sand', consistent with the clayey member of the Quaternary sand unit that underlies the aeolian dunal sand (Figure 1, taken from SWC (2007)).

The erodibility parameters developed for the fine dusty sand were based on laboratory-based rainfall and overland flow simulations, and included derivation of parameter values for effective hydraulic conductivity, interrill erodibility, rill erodibility, and the critical flow shear stress at which rill initiation rapidly increases (Landloch 2007). These parameters are used to predict erosion within the WEPP (Water Erosion Prediction Project) runoff/erosion model.

The parameter values included the presence of a cryptogam cover because extensive cryptogamic layers were observed on undisturbed soils at the Jacinth site (Figure 2). Landloch (2007) explains how the cryptogamic cover was incorporated into the WEPP parameters.

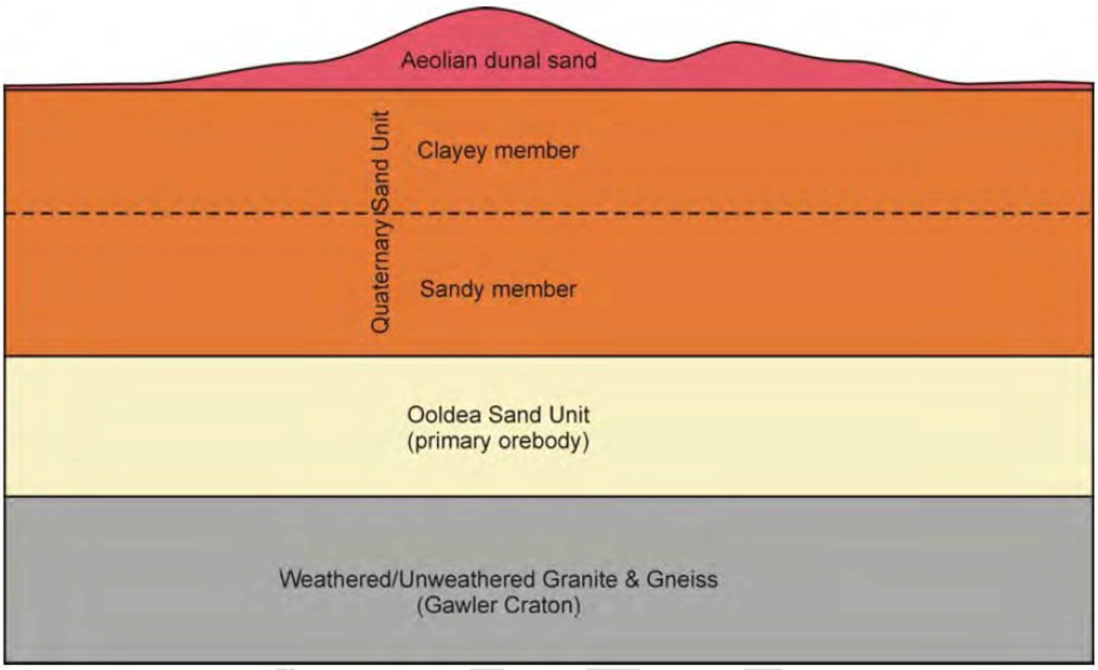

Figure 1: Stratigraphic sequence in the Eucla Basin deposits (Source: SWC (2007)). 'Fine dusty sand' is the same as the clayey member of the Quaternary sand unit.

Figure 2: Cryptogam cover between sparse vegetation groundcover.

Additional sampling in 2015 sought to compare the properties of the fine dusty sand to cover materials (topsoils, subsoils, and loam overburden) that existed in 2015 (Landloch 2015). In particular, particle size distributions were assessed because they are closely related to a material's erodibility and offer a useful means of rapidly assessing the difference in the erodibility of materials without having to conduct the more involved tests using simulated rain and overland flows. Samples of topsoils, subsoils, and loam overburden were taken from areas that supported chenopod and mallee vegetation assemblages. Soil Water Consultants (SWC) also reported particle size distributions as part of their assessment of soils at Jacinth-Ambrosia (SWC 2007). Samples of dunal sands, Quaternary sands, topsoils, brown sandy loam, and red sandy loam were tested. Further sampling was undertaken in 2019 as part of initial landform evolution modelling of Cell 6 of the TSF at Jacinth-Ambrosia (Landloch 2019). Particle size distributions were measured for topsoils, subsoils, dunal sands, and brown and red loams. Table 1 provides a comparison of the particle size distributions for materials collected from the test work campaigns.

Table 1: Comparison of particle size distribution data

Sample	Sampling Year	Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)
Aeolian dunal sand^	2007	25	56	5	14
Quaternary sand (clayey)^	2007	30	35	8	26
Quaternary sand (sandy)^	2007	30	35	8	26
Topsoil SMU1 (dune sand)+	2008	88-94		5-9	1-3
Topsoil SMU2+	2008	66-79		14-23	6-11
Yellow sand SMU1 (dune sand) +	2008	97		2	1
Brown sandy loam+	2008	67-80		17-24	3-11
Red sandy loam+	2008	81		7	12
Fine dusty sand+	2007	37	41	7	15
Topsoil	2014	38	38	9	15
Subsoil	2014	39	40	8	13
Brown loam*	2014	30	35	12	23
Topsoil	2019	16	56	20	9
Subsoil	2019	3	58	27	12
Yellow sand (dune sand)	2019	26	66	6	1
Brown sandy loam	2019	15	47	24	11
Red sandy loam	2019	30	45	7	18

^ Data sourced from SWC (2007) but were first reported by Outback Ecology Services. + Data sourced from Iluka as an Excel file containing SWC data from 2008. * The data for brown loam reported in 2015 had not been correct to remove particles >2mm. The data in this table has been corrected and will differ slightly to that reported previously.

All materials except for the yellow sands (aeolian dunal sand) have similar particle size distributions, acknowledging some variability in the proportions of fine and coarse sand[1]. This variability is due to the modal size of the Jacinth-Ambrosia soils (~0.2mm) (Landloch 2015), which coincides with the size at which sands are split into their fine fraction (0.02-0.2mm) and their coarse fraction (0.2-2.0mm).

The particle size distributions reported by Landloch (2007, 2019) and SWC (2007) for topsoils, subsoils, and brown and red loams (overburdens) were similar, and were consistent with the particle size distribution of the fine dusty sand that formed the basis for the erodibility study conducted in 2007. Given the consistency in particle size distribution, the use of the 2007 erodibility parameters was deemed representative of the topsoil, subsoil, brown loam, and red loam materials.

2.3 Erodibility parameters

The WEPP runoff/erosion model erodibility parameters originally derived in 2007 were not accompanied by measures of sediment particle size distributions. This is data that Landloch now use to improve the accuracy of the modelling. Sediment particle size distributions for the materials rehabilitation materials were developed from settling velocity distribution data reported by Landloch (2015). Landloch (2015) showed minor to no variation in settling velocity distributions between topsoils, subsoils, and brown loam materials taken from both the mallee and chenopod vegetation assemblages. Therefore, it was concluded that a single sediment size distribution could be used to describe topsoils, subsoils, and brown loams at Jacinth North. Given that the red loams have a similar particle size distribution to the above materials, it can be expected to also have a similar sediment particle size distribution to the topsoil, subsoil, and brown loam materials.

As a result of the accumulated test work undertaken between 2007 and 2019 at Jacinth-Ambrosia, Landloch have a set of erodibility parameters that can be used within WEPP modelling. These WEPP erodibility and sediment data were also used to generate updated SIBERIA landform evolution model input parameters. These parameters have been reported previously by Landloch (2019) and were used in this report to assess the long-term erosion potential of the sand stack.

3 EROSION MODELLING METHODOLOGY

The WEPP runoff/erosion model was used to model relationships between slope gradient, slope length and long-term erosion potential. The SIBERIA landform evolution model was used to consider the potential long-term change in shape of the sand stack in response to the erosion forces applied to the rehabilitated surface by the prevailing climate.

[1] Some materials have higher fine sand fraction and lower coarse sand fractions but the total sand fraction remains relatively consistent.

3.1 WEPP runoff/erosion modelling

3.1.1 The WEPP model

The WEPP (Water Erosion Prediction Project) model was developed by the United States Department of Agriculture to predict runoff, erosion, and deposition for hillslopes, akin to mine landform batter slopes (Flanagan and Nearing 1995). WEPP is a simulation model with a daily input time step, although shorter time steps are used by internal calculations for the prediction of runoff and erosion on days when rain occurs.

On days without rain, the WEPP model uses the climate data to modify plant and soil characteristics. Of importance for this project, soil evaporation occurs of days without rain and profiles are therefore dried between rain events. This has a bearing on runoff and erosion predictions. On days with rain, the plant and soil characteristics are used as initial conditions in predicting the occurrence of runoff and erosion. If runoff is predicted to occur, the model computes sediment detachment, transport, and deposition at points along the slope.

The erosion component of WEPP uses a steady-state sediment continuity equation as the basis for erosion computations. Soil erosion in interrill areas is calculated as a function of the effective rainfall intensity and runoff rate. Soil erosion in rills is predicted to occur if the flow hydraulic shear stress is greater than the material's critical shear stress, and when the sediment concentration in the runoff is less than its transport capacity. Deposition in rills is computed when the sediment concentration in the runoff is greater than the capacity of the runoff to transport it. There are four components within the WEPP model that are relevant to this project:

1. Material erodibility;
2. Slope geometry;
3. Climate; and
4. Management practices.

3.1.2 Material erodibility

The erodibility parameters used in the modelling were developed as part of previous work completed at Jacinth-Ambrosia in 2019 (Landloch 2019). The development of these parameters is described in Section 2.3. Key material-based input parameters for WEPP include interrill erodibility, rill erodibility, critical shear for rill initiation, effective hydraulic conductivity, and sediment particle size and density distributions.

3.1.3 Slope geometry

The geometry of the slope on which erosion is predicted is defined by the WEPP model user. Valid geometries can include slopes with uniform/linear gradients as well and more complex geometries such as concave and convex profiles. Schematic of these slope profile geometries are given in Figure 3. A concave profile is a slope the decreases in gradient down the slope. A convex profile is a slope the increases in gradient down the slope. WEPP can also model profile shapes that include combinations of these profile shapes. WEPP is not able to input a negative gradient.

Uniform slopes were modelled for the sand stack at Jacinth North. Slope gradients ranged between 3° (5%) and 10° and slope lengths ranged between 50m and 500m. These ranges were based on the geometry of the existing sand stack and previous erosion modelling of similar materials completed by Landloch for Jacinth-Ambrosia.

Longer slope lengths at low gradient are more prone to erosion caused by small changes in micro-topography. This change in micro-topography is not explicitly considered because it can occur at scales that are smaller than the grid spacing used in the SIBERIA model. This has been addressed in the modelling approach for this project by adoption of a lower target long-term erosion rate.

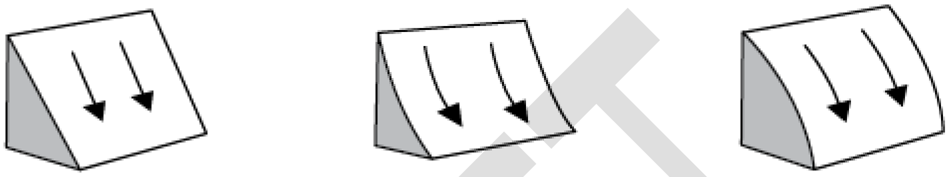

Figure 3: Slope profile shapes based on their curvature assessed perpendicular to the contour (adapted from Schoeneberger *et al.* (2017)).

3.1.4 Climate

Apart from information on the slope profile geometry and the surface materials, modelling of long-term erosion with WEPP requires a long-term climate sequence for the site. For each day of simulation, WEPP requires 10 daily climate variables: rainfall, rainfall duration, peak rainfall intensity, time to rainfall peak, solar radiation, ,minimum temperature, maximum temperature, dew point temperature, wind speed, and wind direction. Of these, the 4 rainfall-related variables are critical because predicted runoff and erosion are most sensitive to these variables (Nearing *et al.* 1990; Chaves and Nearing 1991).

Complete historical datasets containing these 10 climate variables are not available for most sites, including Jacinth North. To address this synthetic climate sequences were developed from the available climate data.

CLIGEN is a weather generator (Nicks *et al.* 1995; Meyer *et al.* 2007) that produces synthetic daily values of rainfall, temperature, dewpoint, and solar radiation for a single geographic point, using monthly statistics (mean, standard deviation, skewness) derived from climate observations. It also produces individual storm parameter estimates, including time to peak, peak intensity, and storm duration, which are required to run WEPP. The Priestley-Taylor method for estimating potential soil evaporation (Priestley and Taylor 1972) is used by WEPP where solar radiation and temperature data are input. In this mode wind speed and direction and dew point temperature data are not required.

CLIGEN has been assessed for a wide range of climates in Australia, and it was found to be suitable for providing the required climate input for WEPP to predict runoff and erosion in Australia (Yu 2003).

Daily climate data for Jacinth-Ambrosia were sourced from the Scientific Information for Land Owners (SILO) database of Australian climate data. It offers compete gridded rainfall, temperature, and solar radiation data based on observed climate information sourced from the Australian Bureau of Meteorology (BoM). Sub-daily rainfall data were sourced from the Bureau of Meteorology's station at Forrest Aero. Apart from Forrest, other sub-daily stations were also assessed, including Eucla, Tarcoola, and Ceduna (these being the 4 nearest stations). Sub-daily stations close to the coast (Eucla and Ceduna) were different to data collected further inland (Tarcoola and Forrest). This is consistent with the rainfall patterns of that area, which show rainfall amounts decreasing rapidly as the distance inland increases. Forrest was chosen to describe the storm parameters because of its proximity to Jacinth, its location inland from the coast, and the length of available record (35 years).

Using these daily and sub-daily data sets, values for the following statistical parameters were computed and used to develop the synthetic climate sequence for Jacinth-Ambrosia:

- Mean daily rainfall on wet days for each month,
- Standard deviation and skewness coefficient of daily rainfall for each month,
- Probability of a wet day following a dry day each month,
- Probability of a wet day following a wet day each month,
- Mean daily max. temperature for each month,
- Standard deviation of max. daily temperature for each month,
- Mean daily min. temperature for each month,
- Standard deviation of min. daily temperature for each month,
- Mean maximum 30-min rainfall intensity for each month, and
- Probability distribution of the dimensionless time to peak storm intensity.

A 100-year climate sequence was generated using CLIGEN version 5.1 (Yu 2002). The resultant climate sequences have:

- Daily, monthly, and annual climate statistics that are consistent with the gridded daily data relevant for Jacinth-Ambrosia; and
- Individual storm properties (e.g. time to peak intensity, average intensity, peak intensity, and storm duration) consistent with the sub-daily rainfall data sourced from Forrest.

3.1.5 Management practices

The management practices component includes several parameters related to agricultural tillage actions and vegetation that are not relevant to modelling mine site batters. That said, they are important to set such that the:

- Impacts of vegetation on erosion are removed; and
- Surface modelled is consistent with a rain-armoured surface that would occur in the long-term.

3.1.5.1 Vegetation

Vegetation cover does assist in protecting the surface from erosion. However, for vegetation to be effective in reducing water erosion, the cover must be in direct contact with the surface rather than simply lying over the surface or being present as canopy cover. Therefore, the vegetation cover referred to in this report is the vegetation groundcover, which include grasses in contact with the surface, the basal area of shrubs and trees, litter cover, and cryptogamic cover.

The role of vegetation is discounted from the modelling completed in this report for two reasons.

First, vegetation groundcover levels at Jacinth-Ambrosia are naturally low, and likely in the order of ~10%. Second, vegetation cover is not present at their maximum levels in the early stages of rehabilitation, with maximum groundcover levels potentially taking several years to establish. Further, rehabilitation often uses depleted soils that produce lower vegetation cover levels in the short to medium term in rehabilitation. The Revised Universal Soil Loss Equation (RUSLE) Renard *et al.* (1997) provides guidance on the likely impact of different levels of groundcover on long-term erosion rates. At a groundcover level of 10%, the reduction in erosion is predicted to be 5-10%. Therefore the impact of vegetation is minor and the batter geometries established should be able to be suitably stable in the presence of low vegetation groundcover levels.

3.1.5.2 Surface armouring

The testing process employed includes the preparation of surfaces that have been lightly compacted, consistent with a surface that has been rain-armoured after being ripped and seeded by a dozer. Heavy compaction is not applied because rehabilitated surfaces are not compacted as part of rehabilitation. Compacted surfaces are also subjected to a series and wetting and drying cycles. During these wetting and drying cycles, the loose fines at the surface are removed and the formation of surface seals are initiated. This process is important because surface seals naturally form and can reduce infiltration capacity considerably and lead to underestimation of runoff and erosion potential. The model is set with a surface roughness consistent with light ripping.

3.1.6 Other model assumptions

The modelling assumes that no runoff from upslope areas is permitted onto the batter profile being modelled. If runoff from upslope areas is permitted to discharge to the batter being modelled, the erosion predictions will be much higher than stated in this report.

3.2 Target long-term erosion rate

When erosion models are used to develop designs for minesite landforms, a target erosion rate is required to define acceptable landform design options. When this target is exceeded, the design is said to be unacceptable; when the target is not exceeded, the design is said to be acceptable.

Landloch adopts target rates at which rill erosion risk is significantly reduced. Such values vary to some degree depending on the perceived risk associated with the site; whether erosion potential could become high over time or whether exposure of encapsulated materials may be of concern.

For Jacinth North, erosion risk is relatively low due to low rainfall erosivity (~500MJ.mm/(ha.h.y)) and due to erosion being limited by the relatively low transportability of the detached soil particles. Generally, erosion rates in the order of 5–10t/ha/y are associated with surfaces with a low tendency for rilling. Factoring in micro-topography risks, target long-term erosion rates of 2–5t/ha/y may be more appropriate (consistent with common interrill erosion rates). For perspective, 2t/ha/y is equivalent to an annual removal of only 0.3mm depth of soil (assuming a bulk density of 1.5g/cm^3).

Over the long term (e.g. 300 years in this report), the cumulative effect of even low erosion rates can be noticeable. A rate of 2t/ha/y would yield a soil loss of 90mm over 300 years. However, it would be expected that soil profile development (soil formation through alteration of the subsoils and overburdens and through deposition of wind-blown sediments) would balance and compensate for this slow loss of soil.

3.3 SIBERIA landform evolution modelling

3.3.1 The SIBERIA model

Long-term simulations (hundreds of years) of the impacts of erosion on a constructed landform can only be done using landform development models, of which the SIBERIA model (Willgoose *et al.* 1989, Willgoose *et al.* 1991) is well accepted.

The SIBERIA model is a 3-dimensional topographic model that predicts the long-term development of channels and hillslopes in a catchment on the basis of runoff, erosion and deposition. The location and speed with which rills and gullies develop are controlled by a channelisation function. SIBERIA does not input actual rainfall or material erodibility parameters. Rather, the input parameters define this channelisation function that is related to both runoff and soil erodibility (Willgoose *et al.* 1989) and must be derived for each particular material at each particular site. SIBERIA solves for two variables, elevation, from which slope geometries are determined, and an indicator function that determines where channels exist.

Channel growth is governed by an activation threshold that is dependent on discharge and slope gradient. When the activation threshold is exceeded, a channel is predicted to develop. It is possible for a modelled surface to initially have no gullies, and for channels to develop when the activation threshold is exceeded.

SIBERIA has been successfully applied to explain aspects of geomorphology of natural landforms (Willgoose 1994) and has been extensively used in the context of mining, and subjected to extensive validation. In general, the validation work indicates that – provided the model is adequately calibrated – SIBERIA predictions of landform development appear to be reasonable (Hancock *et al.* 2000, Hancock *et al.* 2002, Hancock *et al.* 2003, Willgoose *et al.* 2003). In addition, Hancock (2004) notes that rates of erosion predicted by SIBERIA for a catchment in the Northern Territory compared favourably with estimates of erosion derived using the caesium-137 method. As the two methods used independent input information, the agreement is particularly significant.

The SIBERIA model has been widely used for assessment of the development of constructed landforms on a range of mine sites across Australia and overseas (Willgoose 1995, Willgoose and Riley 1993, Boggs *et al.* 2000, Hancock *et al.* 2003, Hancock and Willgoose 2004, Hancock 2004, Mengler *et al.* 2004, Hancock and Turley 2006).

The model is equally applicable to any climatic regime as its input parameters are derived by calibration to runoff and erosion data. Input parameters can be derived from output from the WEPP model using methods developed by Landloch in consultation with the developers of SIBERIA.

3.3.2 Digital surface model

Landloch was supplied a 3D design file of the sand stack that was created by ATC Williams on behalf of Iluka. At present the exact location and extent of the sand stack is not known, and the result of this assessment of erosional performance will lead to improvements in the erosional performance of the finalised rehabilitation shape. The current shape of the rehabilitated sand stack is given in perspective view in Figure 4, and in plan view and cross sections in Figure 5.

The top surface of the sand stack slopes generally downwards from north east to south west as seen in cross section B-B' (Figure 5). The southern end of the stack is slightly higher than the northern end, as seen in cross section A-A' (Figure 5). The steeper side batters are typically 20-30m high, and have a gradient of ~10°.

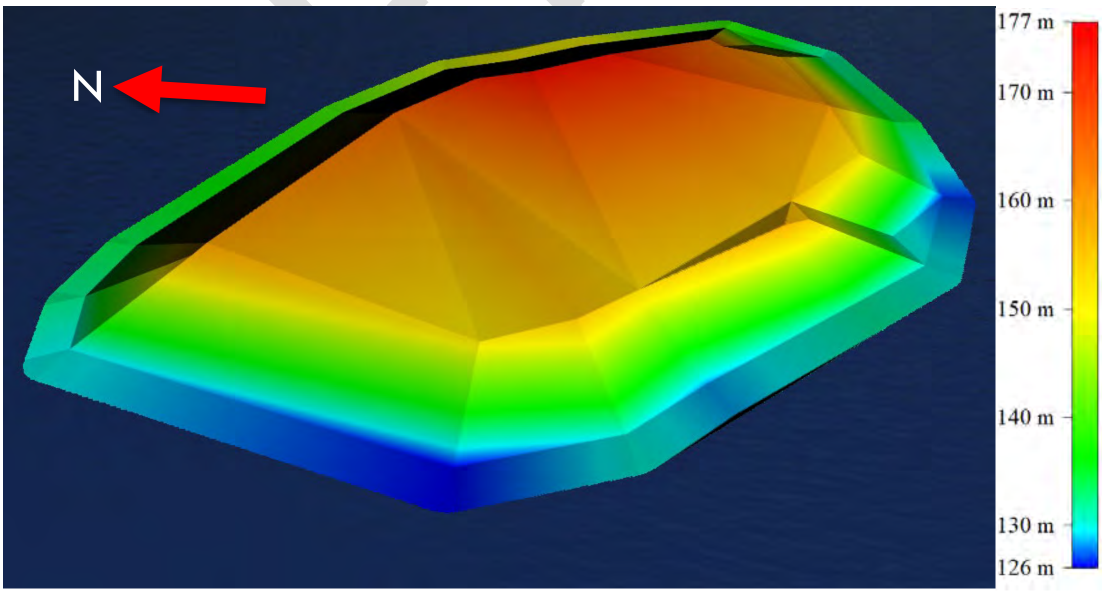

Figure 4: Perspective view of the 3D shape of the sand stack considered.

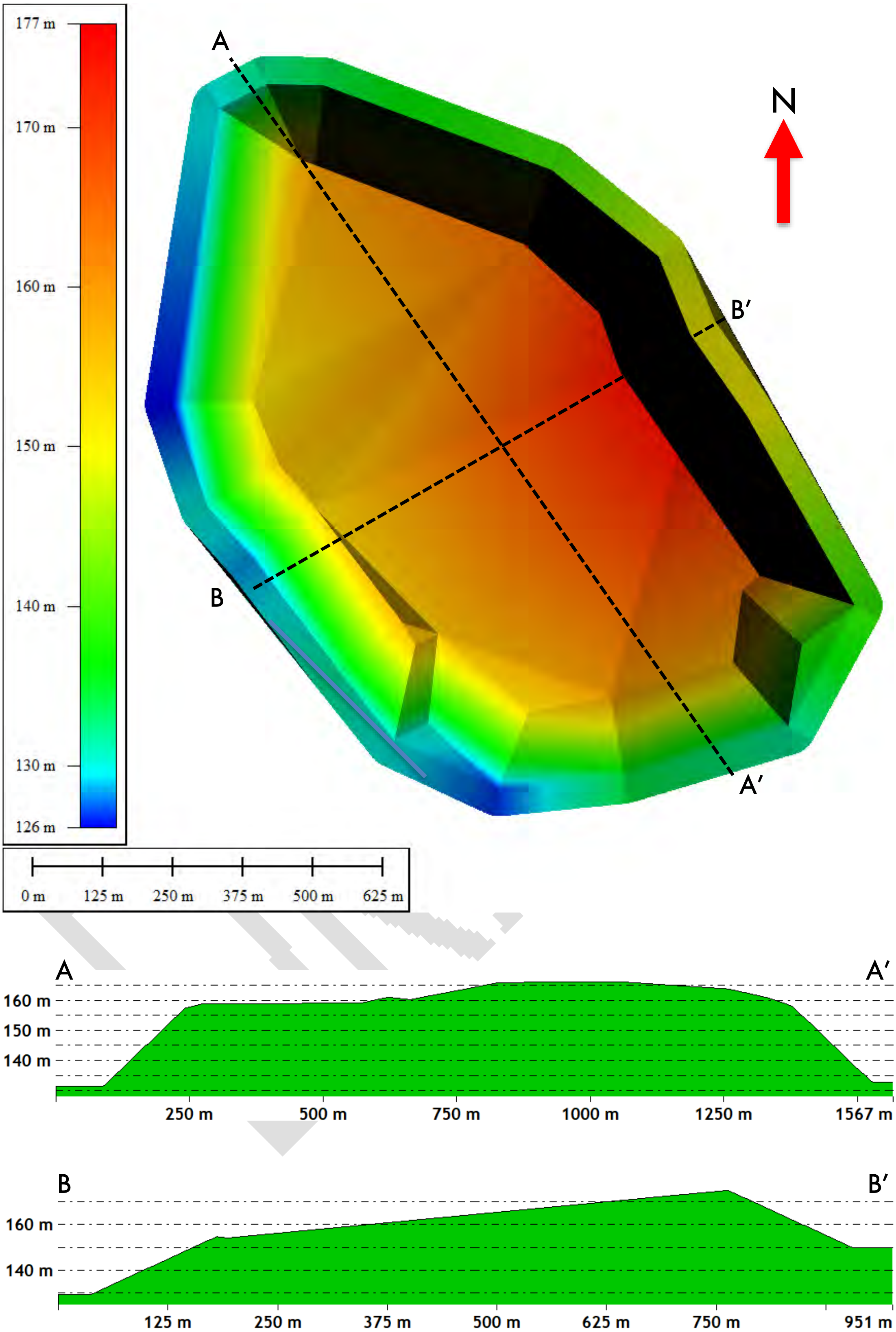

Figure 5: Plan view and cross sections of the 3D shape of the sand stack considered.

3.3.3 SIBERIA input parameters

SIBERIA predicts the long-term average change in elevation of a point by predicting the volume of sediment lost from a node. The rate of sediment transport through a node (q_s in units of m^3/y) is determined by the equation:

$$q_s = \beta_1 \times q^{m_1} \times S^{n_1} \qquad 1)$$

where β_1 is the sediment transport rate coefficient, q is discharge (m^3/y), m_1 is the discharge exponent, S is the slope (m/m), and n_1 is the slope exponent.

SIBERIA does not directly model runoff, but uses sub-grid effective parameterisation which relates discharge to area draining through a point as:

$$q = \beta_3 \times A^{m_3} \qquad 2)$$

Where β_3 is the coefficient between discharge and area, A is area (m^2), and m_3 is the exponent of the area in discharge.

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 is available for calibration, m_3 and β_3 can be taken as 1.0 and a value of n_1 = 1.5 can be adopted for situations where slope gradient does not affect slope erodibility (Willgoose pers. comm.). Where steeper slopes are subject to greater armouring, the exponent n_1 may be as low as 0.7 (Evans *et al.* 1998). Therefore, the two key parameters that require derivation are β_1 and m_1.

Effectively, the β_1 parameter could be described as an erosion "rate parameter", as it primarily controls the rate of sediment movement. The m_1 parameter could be described 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. For this reason, fixed values of n_1 and m_3 are adopted where possible, reducing the difficulty of deriving parameter values.

3.3.4 Derivation of SIBERIA input parameters

For this project, SIBERIA parameters generated in 2015 (Landloch 2015) were used. They were originally developed in 2007 (Landloch 2007) and incorporate a cryptogam cover. They were subsequently modified in 2015 to incorporate sediment size distribution data acquired at that time (Landloch 2015). The key parameters are given in Table 2. These parameters are specific to the topsoil, subsoil, and brown/red loam materials at Jacinth-Ambrosia (including Jacinth North) and cannot be used to represent the erodibility of different materials at Jacinth-Ambrosia or material at sites other than Jacinth-Ambrosia.

3.3.5 Model outputs

Parameters for the surface material were applied across the entire surface. SIBERIA was run for a 300-year period. Output from the SIBERIA model was also processed to produce a series of visualisations for each model run. These included:

1. Depth of material movement as a means of showing gully depth. Scaling was adopted that showed erosion/deposition ±0.05m in grey, deposition between 0.05–0.3m in light blue, deposition >0.3m in blue, erosion between 0.05–0.3m in orange, and erosion >0.3m in red. A gully is defined in this report as an erosion feature with a depth greater than 0.3m. Where such features are not modelled the landform is said to not have gully erosion. Features such as rills may still occur on a landform that is not gullied.
2. Rate of erosion as a means of showing areas that do not meet the target erosion rate. Scaling was adopted that showed erosion <5t/ha/y in grey, 5–10t/ha/y in yellow, 5-10t/ha/y in orange, and >10t/ha/y in red.

4 WEPP MODEL RESULTS

4.1 Pattern of erosion along the slope

The pattern of erosion along the slope indicates that erosion for the rehabilitation materials is transport-limited, as seen by erosion rates remaining relatively consistent for a given gradient over a wide range of slope lengths (Figure 6). This means that erosion is not strongly sensitive to changes in slope length. However, erosion is sensitive to changes in slope gradient.

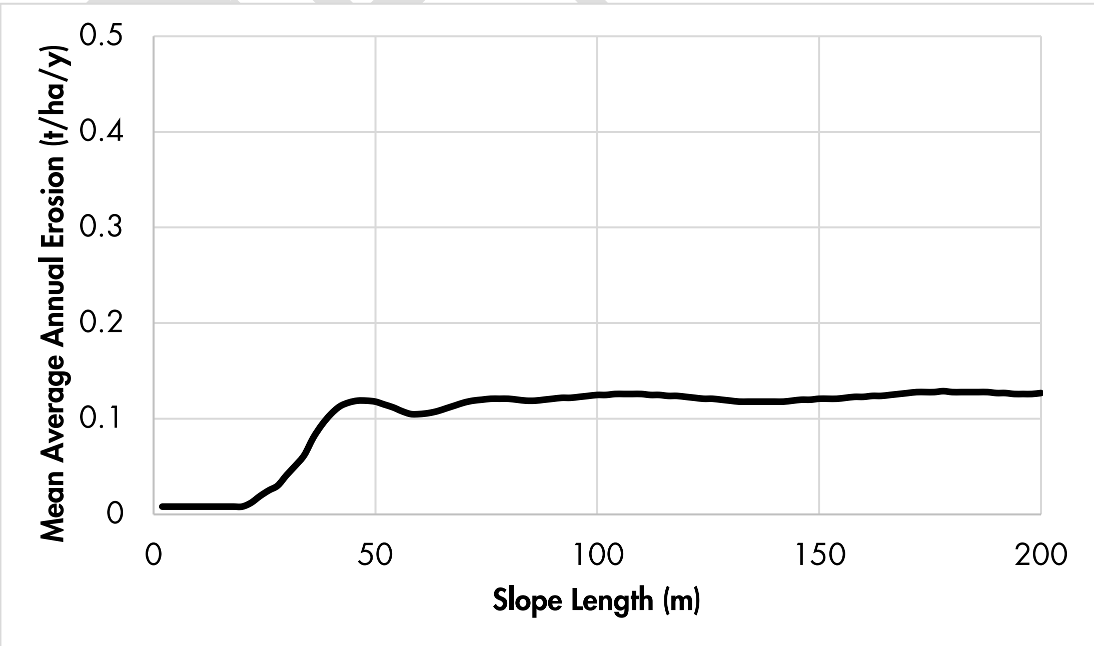

Figure 6: Predicted erosion of Jacinth-Ambrosia rehabilitation materials placed at a gradient of 5° (~9%) on a slope length 200m long.

4.2 Predicted erosional stability

WEPP was run for a range of geometries using the Jacinth climate and the rehabilitation materials detailed in Sections 3.1.4 and 2.2, respectively. Modelled slope gradients ranged between 3° (5%) and 10° and slope lengths ranged between 50m and 500m. These ranges were based on the geometry of the existing sand stack and previous erosion modelling of similar materials completed by Landloch for Jacinth-Ambrosia. The outputs are shown in Table 2. Cells shaded green indicate combinations of land gradient and slope length that are predicted to be erosionally stable in the long-term (mean average annual erosion rate <2t/ha/y). Cells shaded in orange indicate combinations of land gradient and slope length that are predicted to be erosionally unstable in the long-term (mean average annual erosion rate >2t/ha/y).

As outlined in Section 4.1, erosion of the rehabilitation materials is transport limited and hence more sensitive to slope gradient than slope length. Adoption of gradients <5° (~9%) is predicted to produce erosion rates <2t/ha/y for slope lengths as long as 500 metres. Gradients greater than 5° are predicted to yield erosionally unstable slopes for slope lengths as long as 500 metres.

Table 2: Erosional stability of a range of land geometries.

Uniform Gradient (°)	Slope Length (m)									
	50	100	150	200	250	300	350	400	450	500
3										
5										
7										
10										

5 SIBERIA MODEL RESULTS

Visual outputs of the SIBERIA simulations for 300 years are given in Figure 7 (average annual erosion rate) and Figure 8 (soil movement). Visualisations for all modelled years are given in Appendix A.

The top surface of the landform erodes at low long-term rates (~2t/ha/y) (Figure 7). Erosion rates are predicted to rapidly increase to unacceptable on the batter slopes. These batters are currently at a gradient of 10°, and average erosion rates (averaged over the entire batter surface) are predicted to exceed 5t/ha/y. In discrete locations, the erosion rates are predicted to exceed 10t/ha/y (Figure 7).

Gully erosion is predicted to be triggered at locations where land gradient rapidly increases; that is, at the inflection point between the low gradient top surface and the steeper side batters (Figure 8). Gullies as deep as ~0.3m are predicted at these points on the south, west, and east sides. Gullying is not predicted on the north side because the landform grades downwards from north to south, and discharge of runoff from the top surface to the steeper batters is restricted on the north batter as a result.

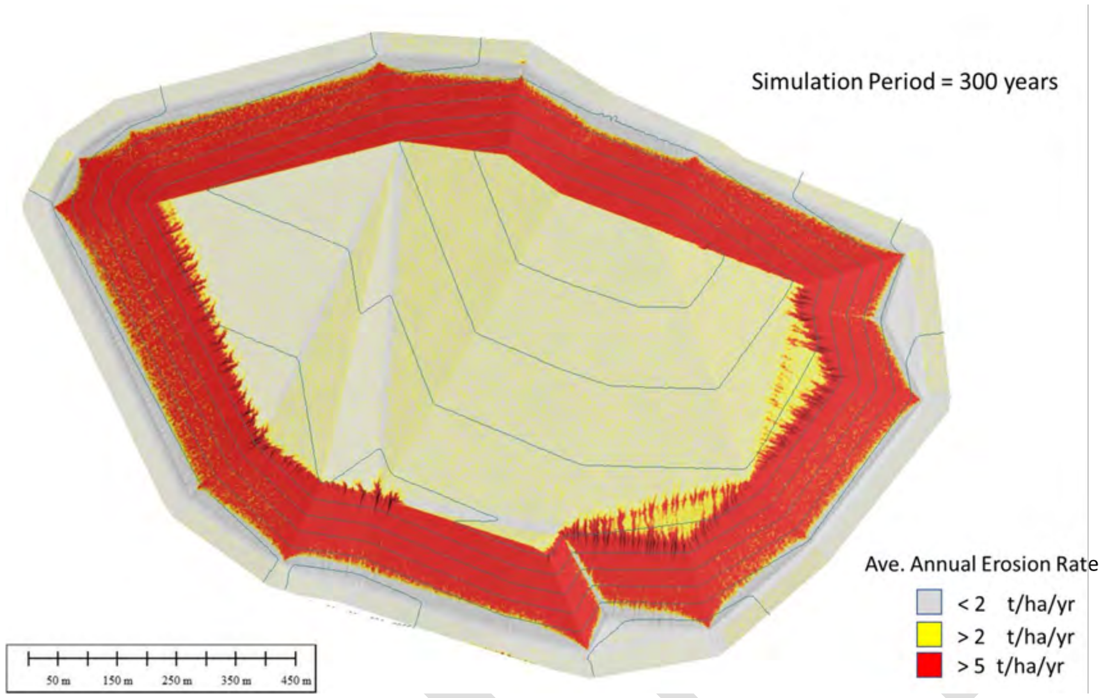

Figure 7: SIBERIA output for the sand stack and Jacinth North, showing average annual erosion rates after 300 years of simulation.

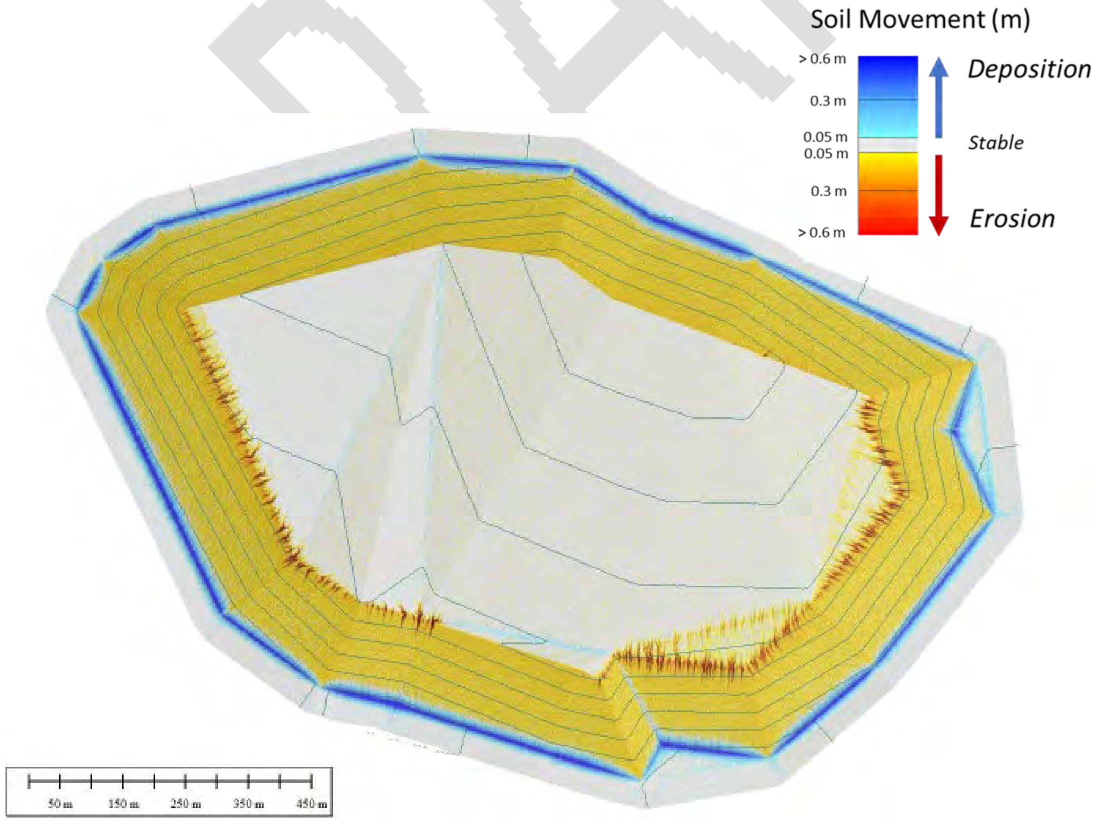

Figure 8: SIBERIA output for the sand stack and Jacinth North, showing soil movement after 300 years of simulation.

6 CLOSING

WEPP runoff/erosion and SIBERIA landform evolution modelling was conducted on the rehabilitation landform shape for the sand stack at Jacinth North. WEPP and SIBERIA were fitted with parameters that represent a wide range of growth media at Jacinth-Ambrosia, including topsoils, subsoils, and brown loams (overburdens). Landloch understands that these materials are available for rehabilitation of the sand stack.

The results of the WEPP and SIBERIA modelling indicate that the top surface of the current design is erosionally stable. However, the batters are currently too steep. Adoption of gradients less than 5° and preferably 3° are recommended. For adoption across the entire surface of the landform.

The landform is currently not located within the existing landscape. Further work is required to consider the implications of placement of the sand stack into the existing landscape. This further work would usefully consider risks associated with movement of surface water along the toe of the rehabilitated sand stack, erosion at the interface between the batters of the sand stack and the existing landscape, and risks related to the discharge of runoff from upslope areas onto the sand stack (i.e. the positioning of the landform creates this scenario).

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APPENDIX A: SIBERIA VISUALISATIONS

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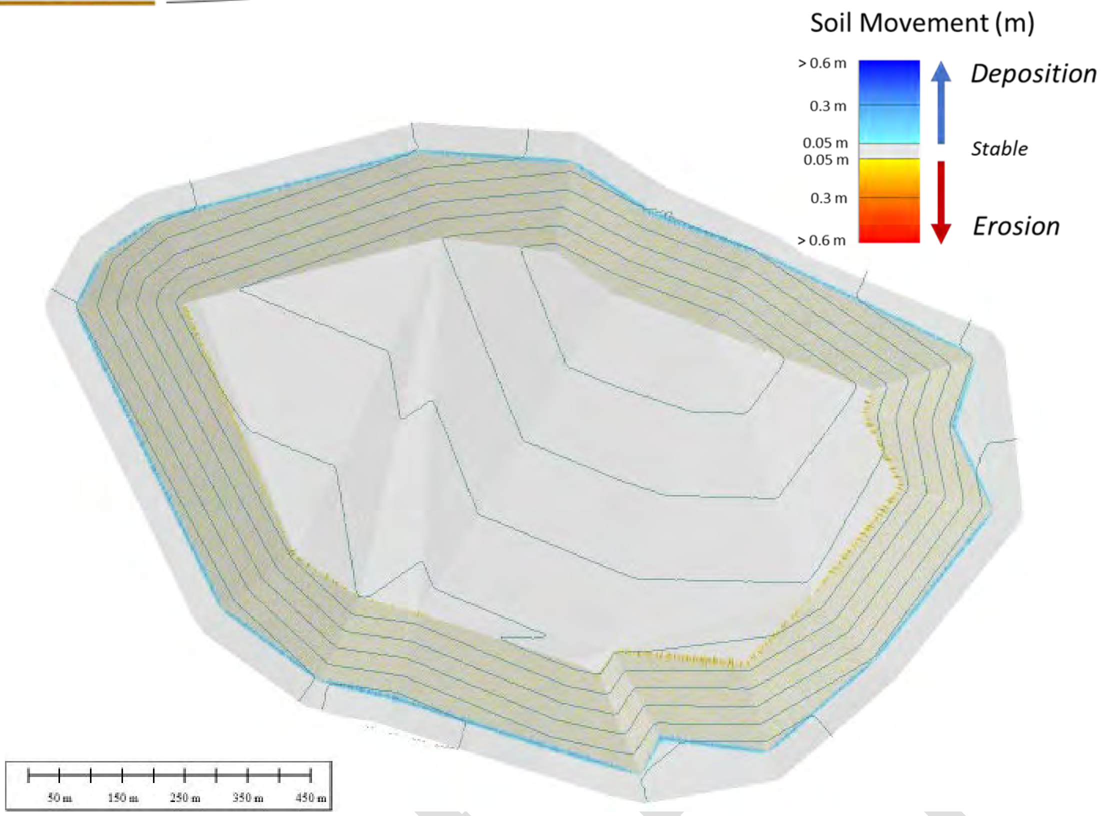

Figure A-1: SIBERIA output for the sand stack and Jacinth North, showing soil movement after 50 years of simulation.

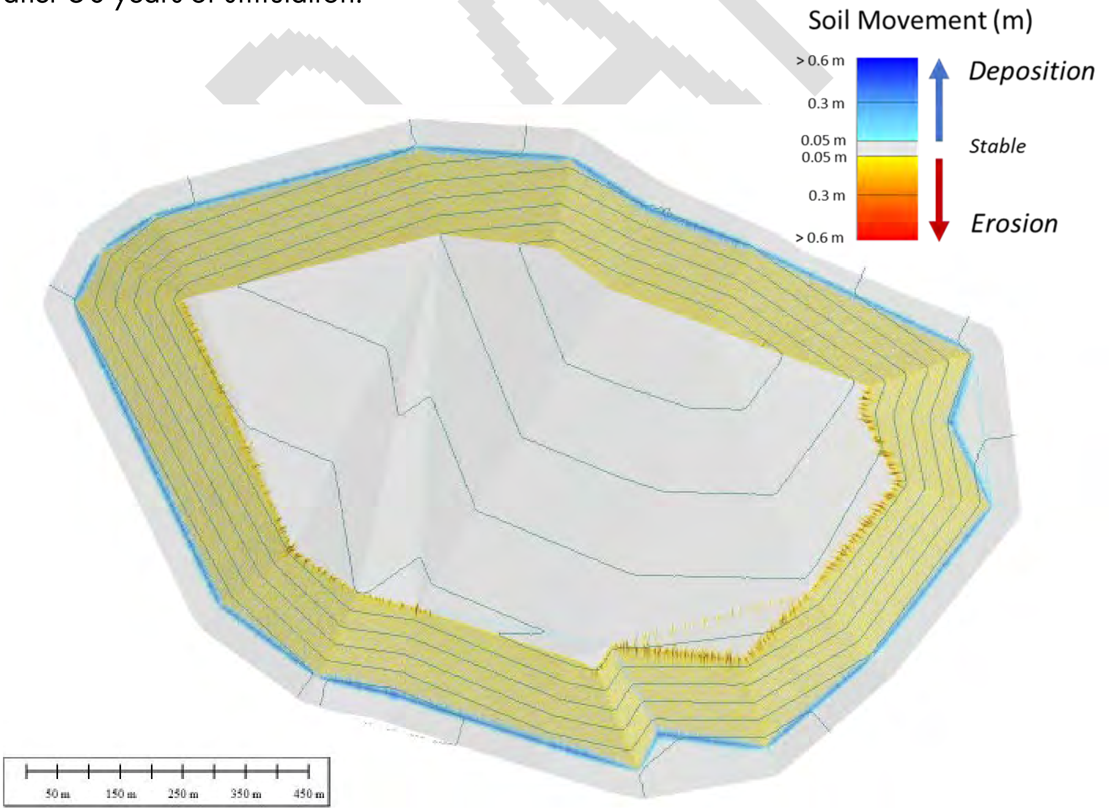

Figure A-2: SIBERIA output for the sand stack and Jacinth North, showing soil movement after 100 years of simulation.

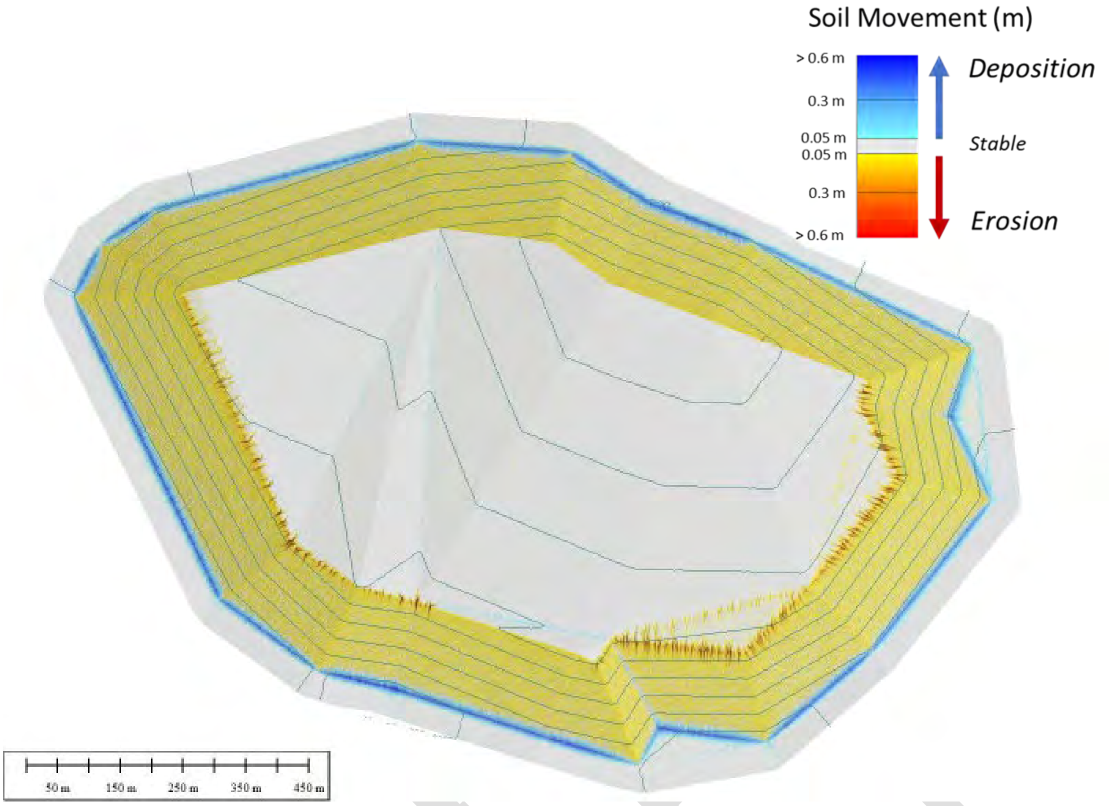

Figure A-3: SIBERIA output for the sand stack and Jacinth North, showing soil movement after 150 years of simulation.

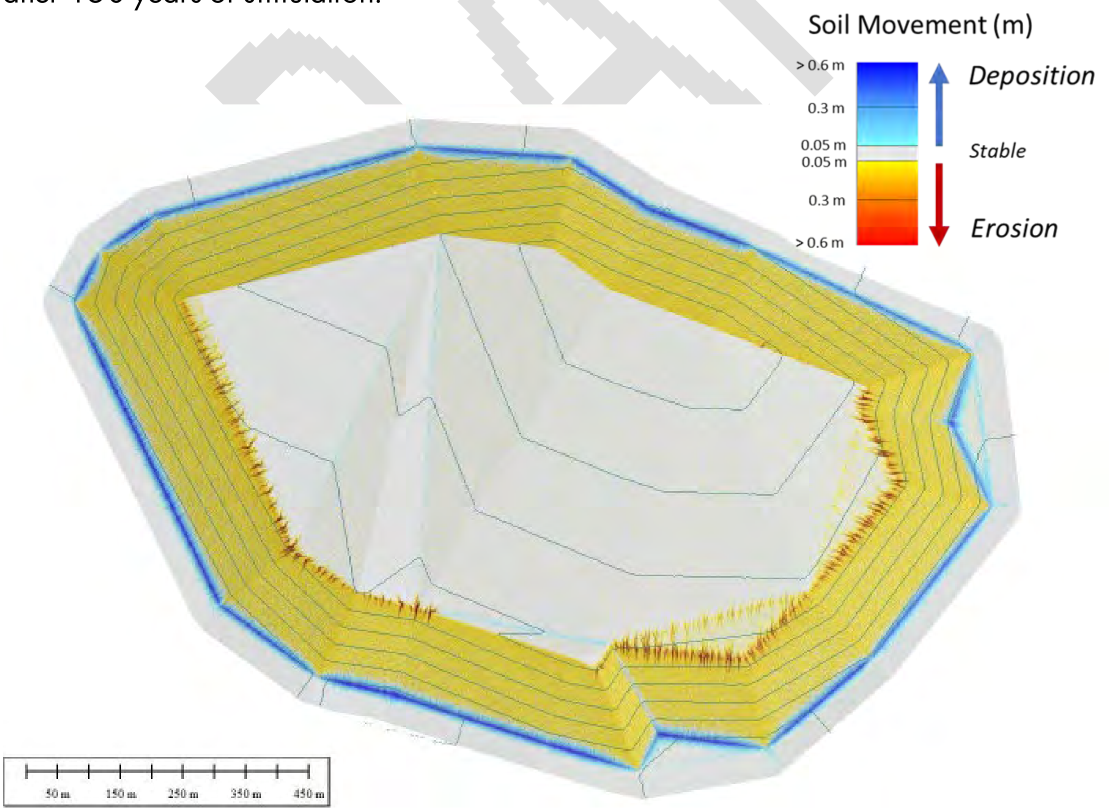

Figure A-4: SIBERIA output for the sand stack and Jacinth North, showing soil movement after 200 years of simulation.

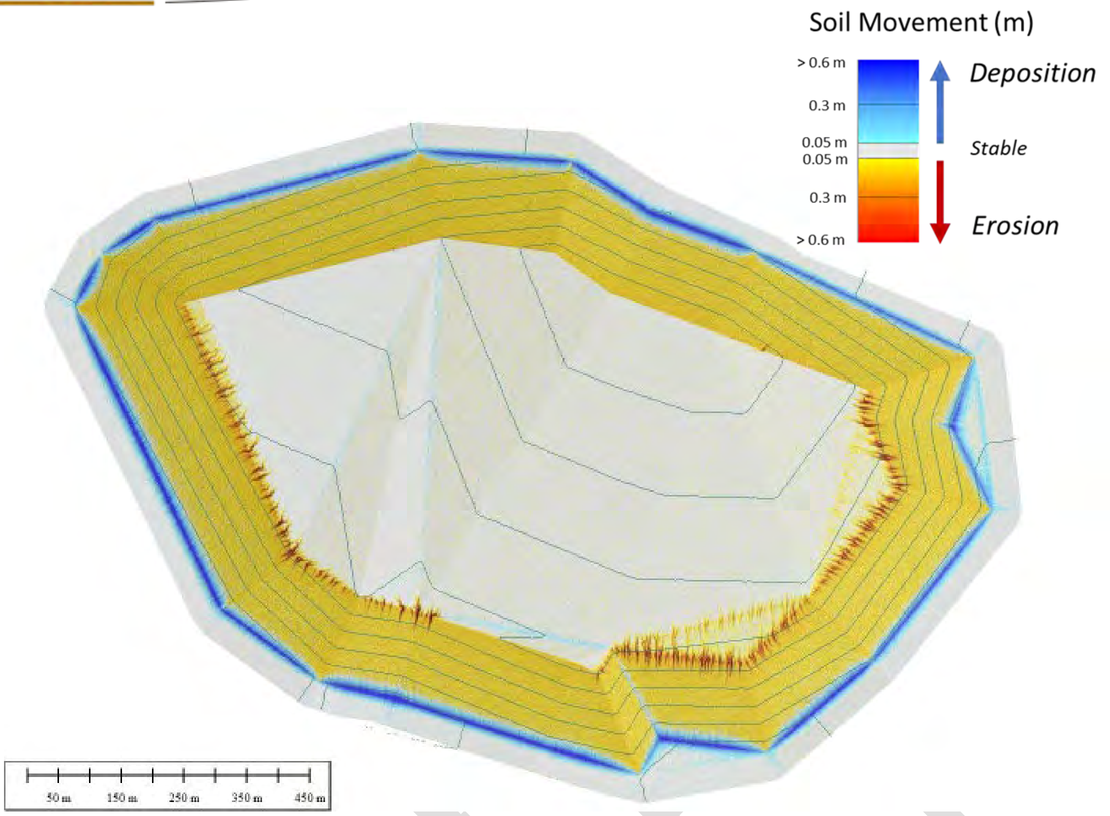

Figure A-5: SIBERIA output for the sand stack and Jacinth North, showing soil movement after 250 years of simulation.

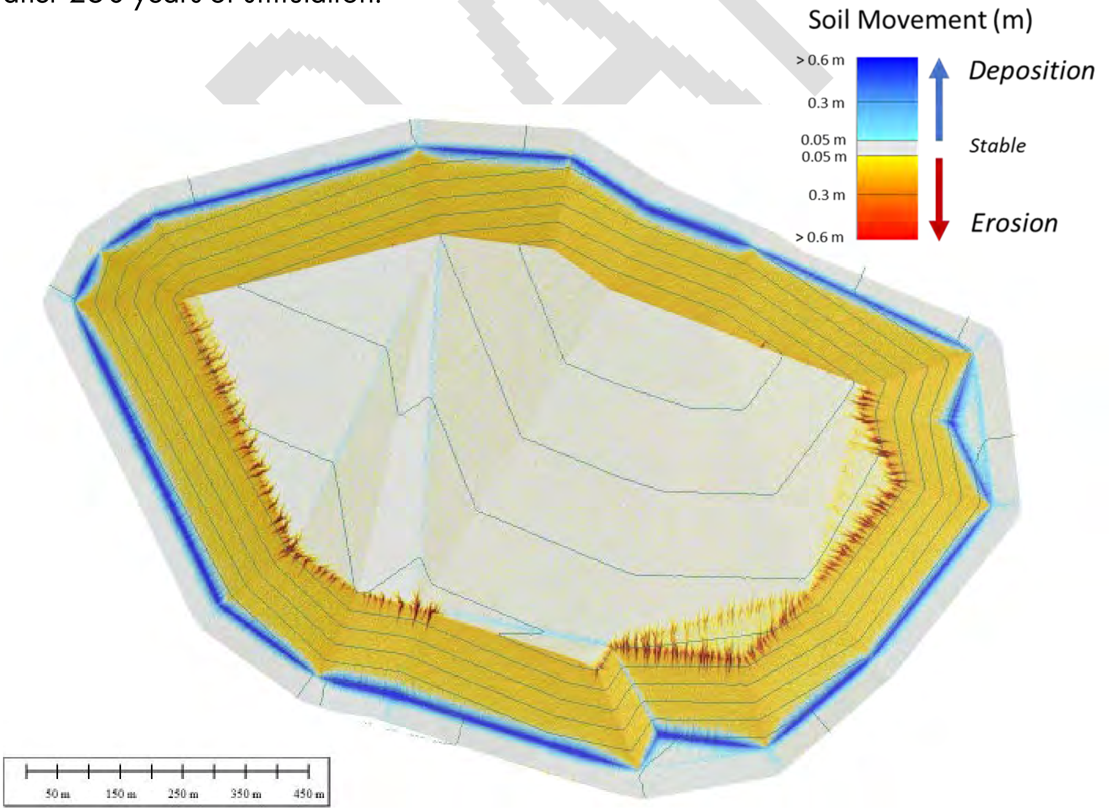

Figure A-6: SIBERIA output for the sand stack and Jacinth North, showing soil movement after 300 years of simulation.

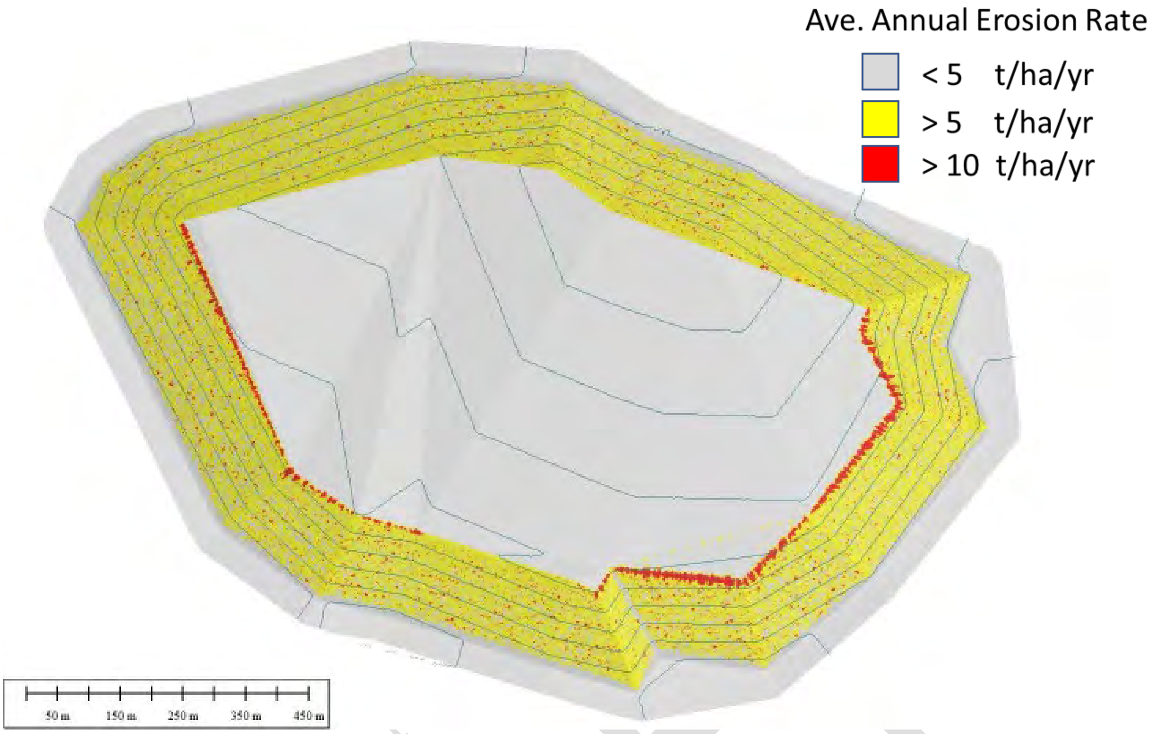

Figure A-7: SIBERIA output for the sand stack and Jacinth North, showing average annual erosion rates after 50 years of simulation. Erosion rates grouped at <5t/ha/y, 5–10t/ha/y, and >10t/ha/y.

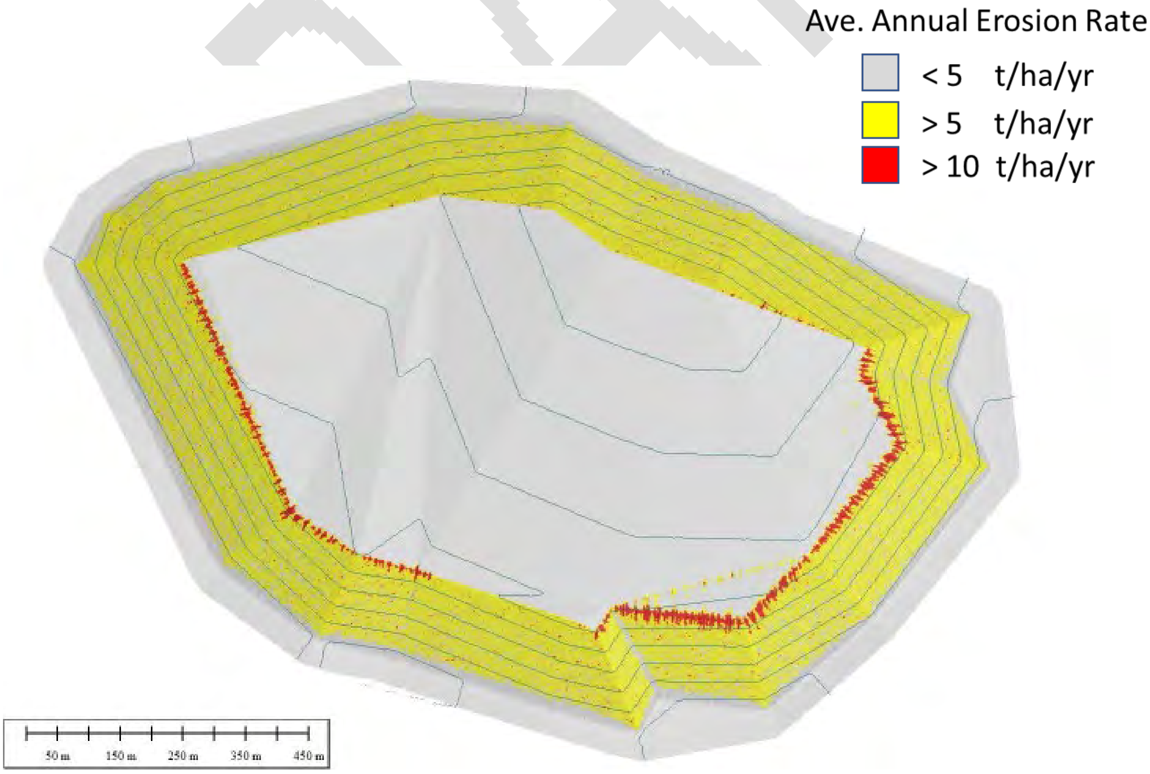

Figure A-8: SIBERIA output for the sand stack and Jacinth North, showing average annual erosion rates after 100 years of simulation. Erosion rates grouped at <5t/ha/y, 5–10t/ha/y, and >10t/ha/y.

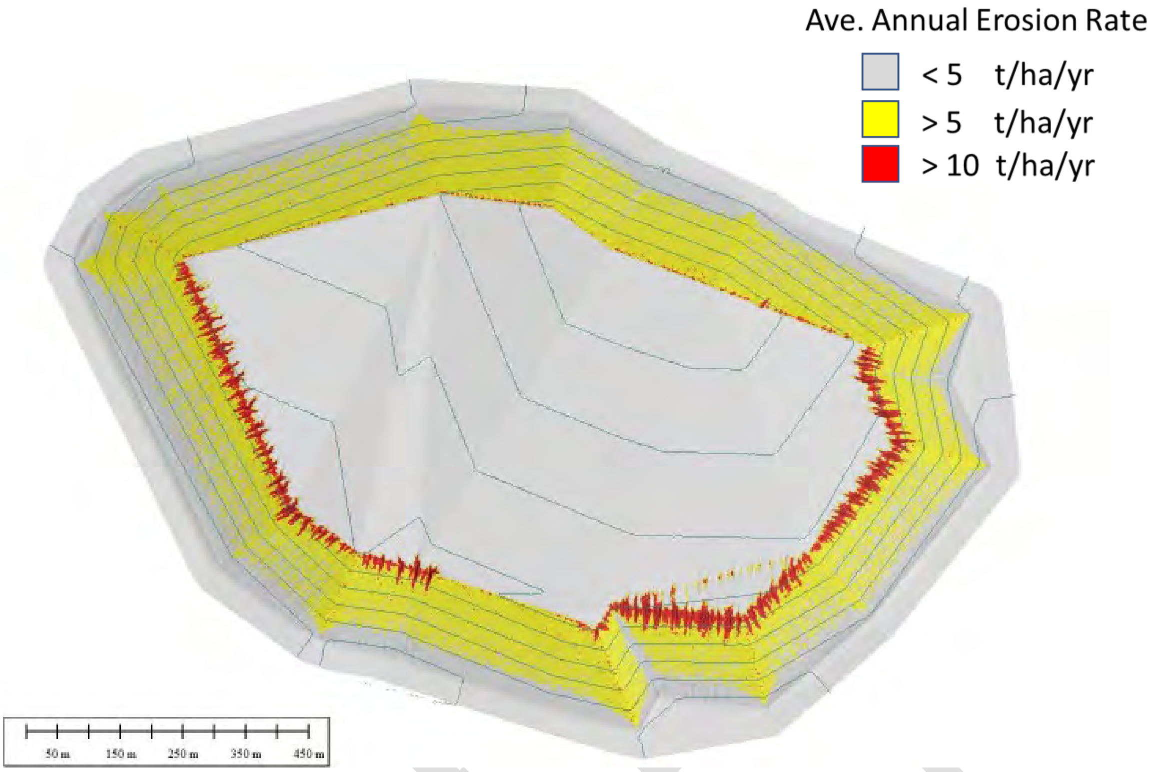

Figure A-9: SIBERIA output for the sand stack and Jacinth North, showing average annual erosion rates after 300 years of simulation. Erosion rates grouped at <5t/ha/y, 5–10t/ha/y, and >10t/ha/y.

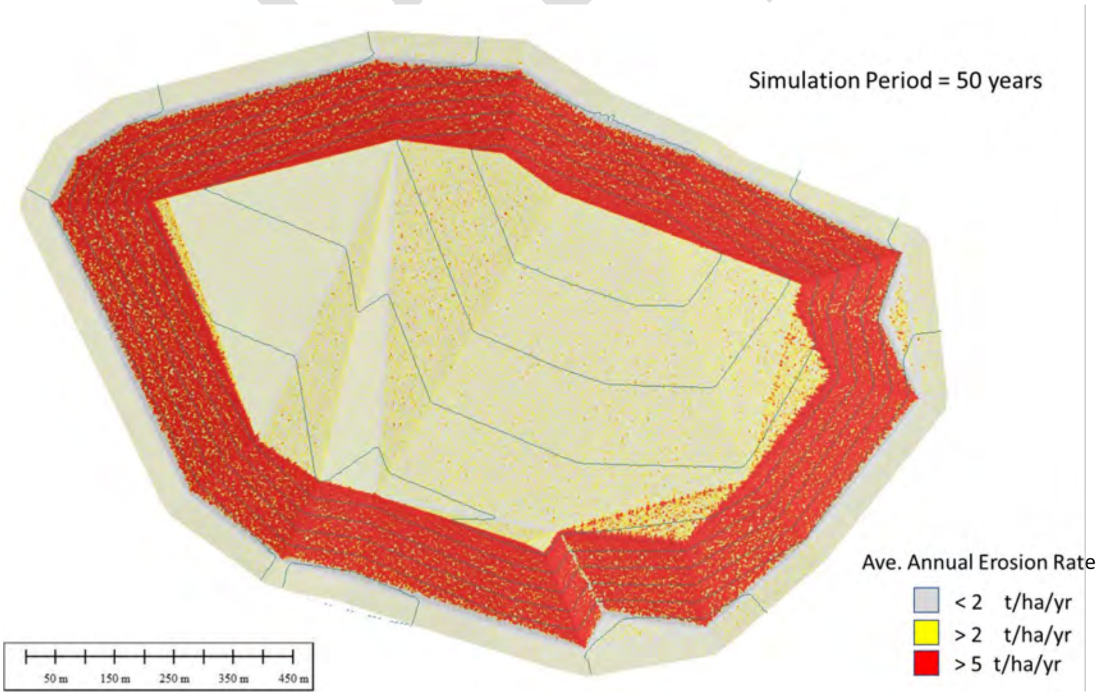

Figure A-10: SIBERIA output for the sand stack and Jacinth North, showing average annual erosion rates after 50 years of simulation. Erosion rates grouped at <2t/ha/y, 2–5t/ha/y, and >5t/ha/y.

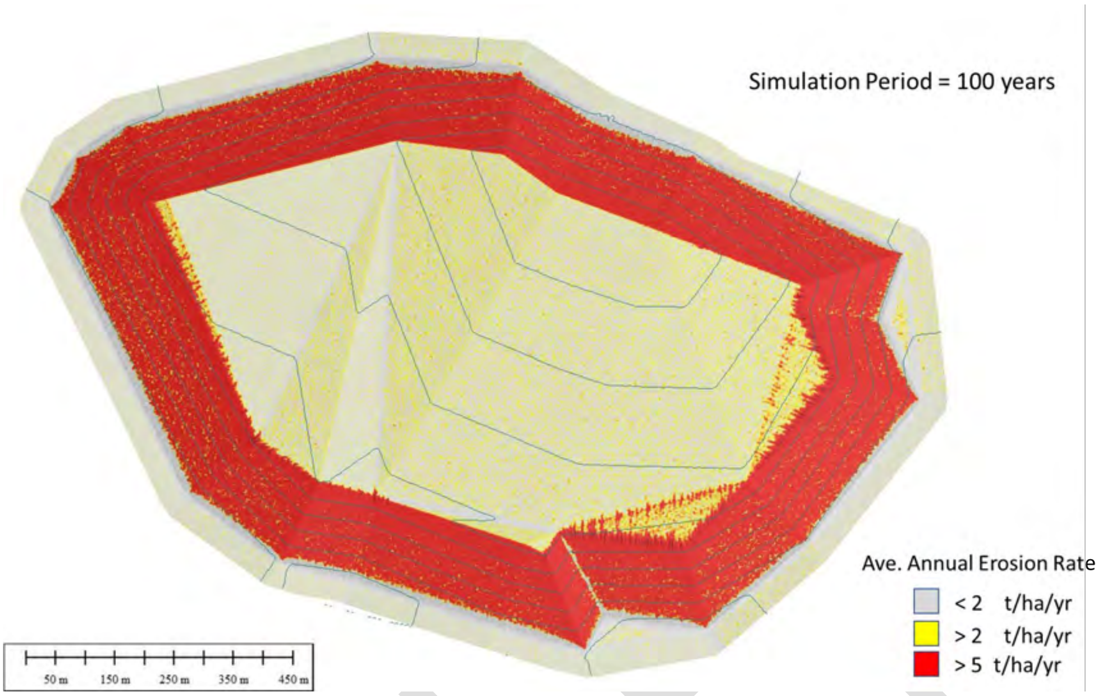

Figure A-11: SIBERIA output for the sand stack and Jacinth North, showing average annual erosion rates after 100 years of simulation. Erosion rates grouped at <2t/ha/y, 2–5t/ha/y, and >5t/ha/y.

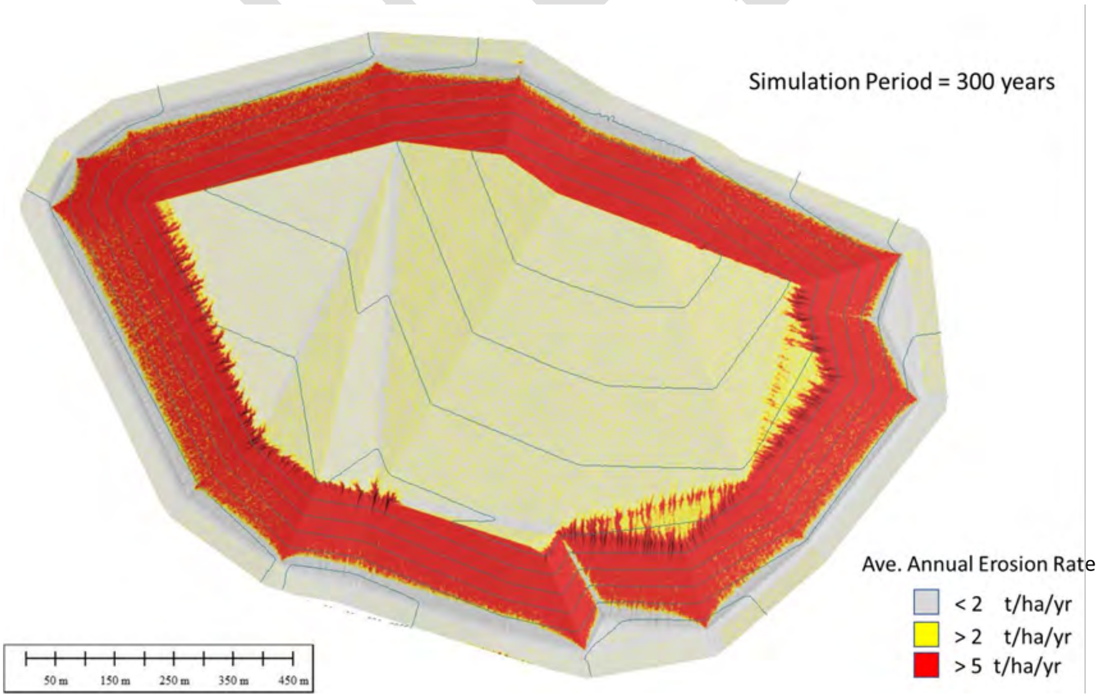

Figure A-12: SIBERIA output for the sand stack and Jacinth North, showing average annual erosion rates after 300 years of simulation. Erosion rates grouped at <2t/ha/y, 2–5t/ha/y, and >5t/ha/y.