Balranald Mineral Sands Project

2020 Annual Review

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ANNUAL REVIEW DETAILS – TITLE BLOCK

Details of the operations are summarised in Table 1 below.

Table 1: Annual Review title block

Name of operation	Balranald Mineral Sands Project
Name of operator	Iluka Resources Limited
Development consent / project approval #	SSD – 5285
Name of holder of development consent / project approval	Iluka Resources Limited
Mining Lease #	ML 1736
Name of holder of mining lease	Iluka Resources Limited
Water licence #	WAL31101 and WAL31102
Name of holder of water licence	Iluka Resources Limited
MOP / RMP start date	18 May 2016 (OUT16/19802)
MOP / RMP end date	31 May 2021
Annual Review start date	01 January 2020
Annual Review end date	31 December 2020

I, Steven Campbell, certify that this audit report is a true and accurate record of the compliance status of the Balranald Mineral Sands Project for the period 1st January – 31st December 2020 and that I am authorised to make this statement on behalf of Iluka Resources.

Name of authorised reporting officer	Steven Campbell
Title of authorised reporting officer	Project Manager
Signature of authorised reporting officer	
Date	30 March 2021

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1 STATEMENT OF COMPLIANCE

This report is the 2020 Annual Review for the Balranald Mineral Sands Project (the 'Balranald Project' or the 'Project') as required by Condition 4, Schedule 5 of the development consent granted under the provisions of the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act).

A summary of the compliance status of the operation with the conditions of the relevant approvals is provided in Table 2.

Table 2: Statement of compliance

Statutory approval	All conditions complied with
SSD Development consent (SSD-5285)	Yes
Mining Lease 1736	Yes

2 INTRODUCTION

2.1 Operations overview

On 5 April 2016 Iluka Resources Limited (Iluka) were granted development consent for the Balranald Mineral Sands Project under Part 4 of the EP&A Act.

The Balranald Project includes construction, mining, primary processing and rehabilitation of two linear mineral sand deposits, known as the West Balranald and Nepean deposits located approximately 12 kilometres (km) and 66 km north-west of the town of Balranald, respectively. Figure 2.1 shows the regional location of the Project.

In addition, the Balranald Project includes undertaking a bulk sampling activity (the activity) at the West Balranald deposit involving the removal of up to 100,000 tonnes (t) of mineral ore. The location of the bulk sampling activities, termed the 'Activity Area', within the approved Project boundary is provided in Figure 2.2.

In 2016 the bulk sampling activity was commenced for the Balranald Project. This bulk sampling activity was a continuation of smaller bulk sampling activities completed in Q1-2015 and Q1-2016 (known as T1) in accordance with approval under Part 5 of the EP&A Act from NSW Trade & Investment, Resources & Energy (Reference OUT13/28341 and OUT15/27702).

The second bulk sampling trial (known as T2) was completed in September 2016. From September 2016 to September 2019 the site was in a care and maintenance period. In July 2019, Iluka initiated discussions with the regulators to commence a further trial (known as T3).

The T3 trial intended to further test the selective in-situ removal of mineral ore to determine whether the unconventional mining method can:

- sustain production over a larger sample set (i.e. longer stope length);
- undertake a backfill process to deliver a whole of mine life cycle process; and
- further validate groundwater and subsidence impact prediction models.

T3 site re-establishment commenced in September 2019. Mining commenced in June 2020 with the development and mining of a new stope (Stope 6) and the re-entry and additional mining of Stope 4. The trial removed 30,900 t of material during mining with the ore processed on-site to produce 11,900 t of heavy mineral concentrate (HMC). The trial backfilled approximately 1,540 t of sand and clay tailings to the mining zone. Approximately 2,766 t was used to rehabilitate the subsidence holes created as the result of operations.

The Activity Area was placed into care and maintenance in late November 2020.

2.2 Environmental management responsibilities

Table 3 provides the details of the Iluka personnel with environmental management responsibilities during the reporting period.

Table 3: Environmental management responsibilities

Name	Role	Contact details
Steven Campbell	Project Director	Steven.Campbell@iluka.com
Stephan Esterhuysen	Project Manager	Stephan.Esterhuysen@iluka.com
Dave Wright	Registered Manager	Dave.wright@iluka.com
Lisa McGrath	HSEC Manager	Lisa.McGrath@iluka.com

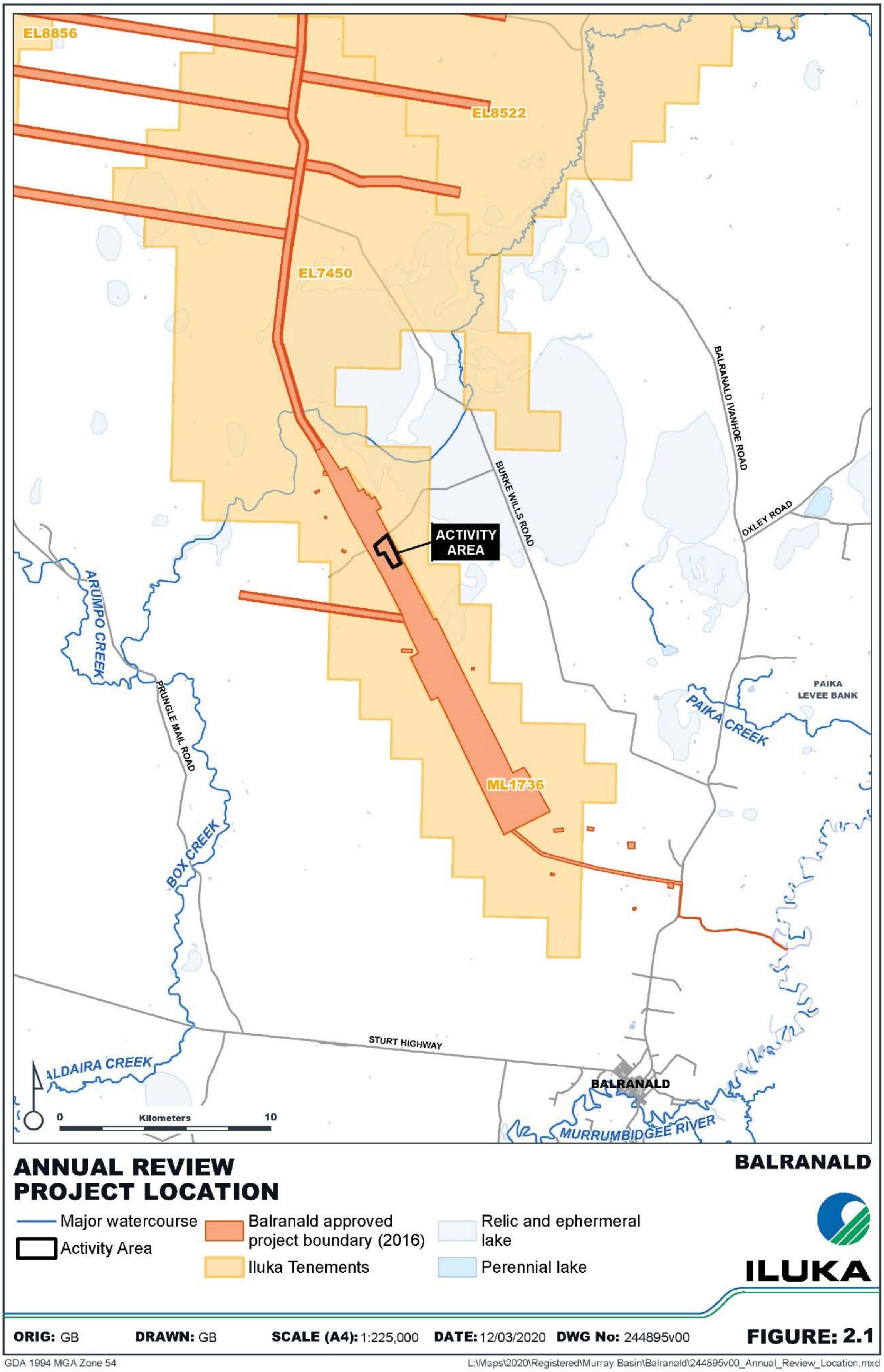

Figure 2.1: Project location

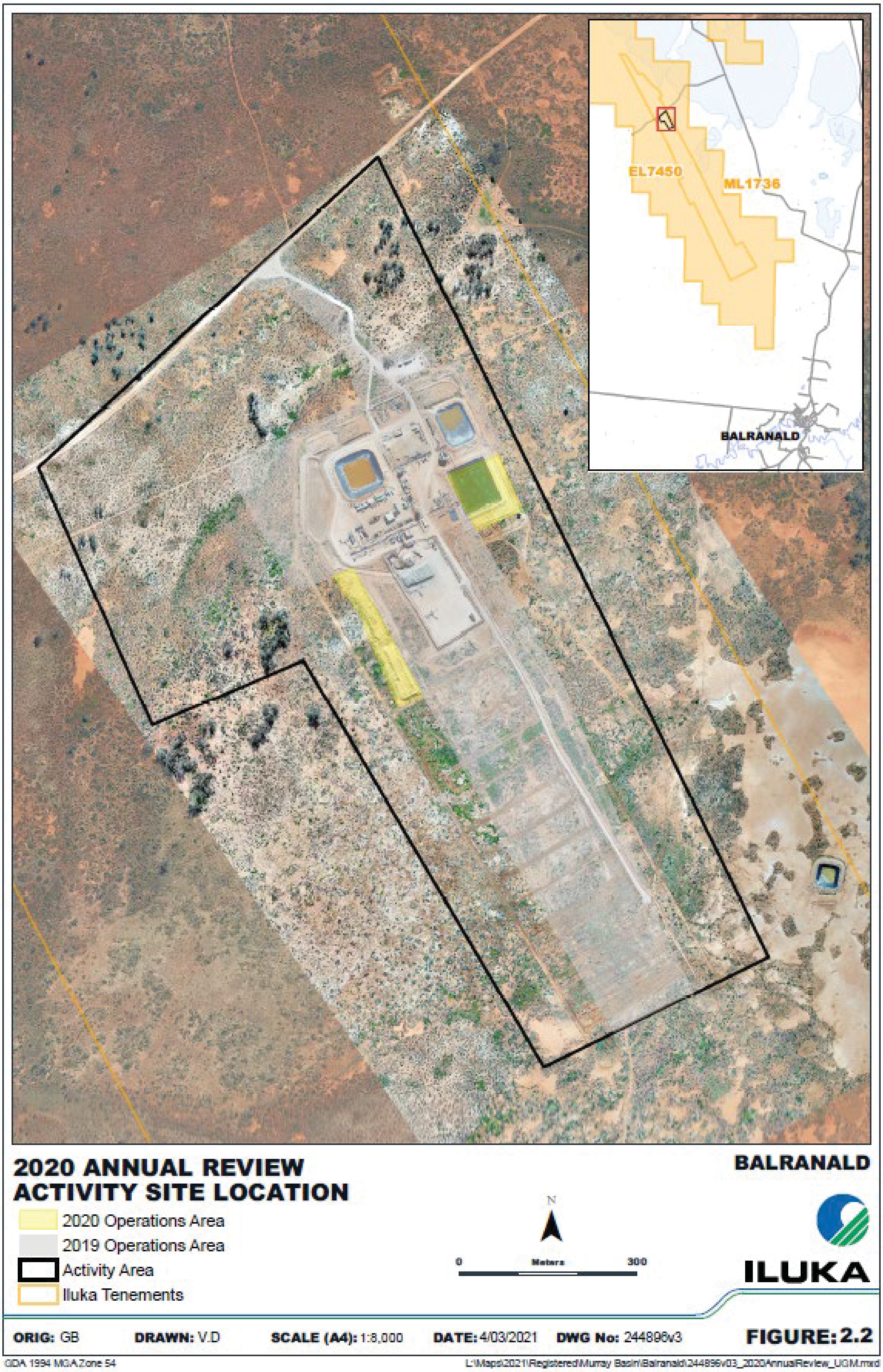

Figure 2.2: Bulk sampling activity site location

3 APPROVALS

The Balranald Project is a Level 1 mine and was assessed as a State Significant development under Part 4 of the EP&A Act.

The current approvals (including consents, authorisations, licences and management plans) for the Project are summarised in Tables 4 and 5 below.

In discussion with regulators, updates were made to the Environmental Management Plan and Mining Operations Plan during 2019, to cover the T3 activities which recommenced in September 2019.

Table 4: Current consents, authorisations and licences

Type	Identification	Details
Development Consent	SSD-5285	Granted: April 2016 Duration: 16 years
Mining Lease	ML1736	Granted: May 2016 Duration: 21 years
Environment Projection Licence	EPL20795	Granted: June 2016 Notice of variation: April 2020 Duration: 5 years
Water Access Licence(s)	WAL31101 WAL31102	Total allocation volume – 2,500 ML

Table 5: Approved management plans

Management Plan	Date of approval and approving agency
Environmental Management Plan (EMP): Bulk Sampling Activities (21 October 2019, Version 2)	15 November 2019; NSW Environment Protection Authority; Reference: DOC19/530575-8
Mining Operations Plan (MOP): Bulk Sampling Activities (21 October 2019, Version 2)	10 December 2019; Resources Regulator, NSW Department of Planning, Industry and Environment; Reference: MAAG0004861, LETT0003348
Groundwater Management Plan (GMP) T3 Bulk Sampling Activities (29 June 2020, Version 6)	12 August 2020; Resource Assessment, NSW Department of Planning, Industry and Environment
Balranald Project: Aboriginal Cultural Heritage Management Plan (ACHMP) (14 April 2016, Version 1)	14 April 2016; NSW Office of Environment and Heritage; Reference: DOC16/184303 29 April 2016; NSW Department of Planning and Environment; Reference: 11/22089-2

4 OPERATIONS SUMMARY

4.1 Introduction

T3 site re-establishment and construction works commenced in September 2019 with Horizontal Directional Drill (HDD) development drilling commencing in June 2020. Mining commenced in mid-August 2020 and was completed in early November 2020.

Mined material was processed through a trommel and spirals plant and separated into a Heavy Mineral Concentrate (HMC), sand tailings and clay tailings. Backfilling of a portion of the sand and clay tailings material occurred intermittently over the mining period.

The site was demobilized and put into care and maintenance in November 2020.

4.2 Site construction

The following construction works were undertaken for the period September 2019 – June 2020, as part of site re-establishment:

- re-establishment of site offices, power supply, water supply and amenities;
- clearing of 7.5 hectares (ha) of land to accommodate an additional water storage dam, stockpile areas and a drainage basin (total land disturbance 14.5 ha);
- civil construction of water storage dam, stockpile areas and drainage basin;
- civil works to place anchors and supports for the stope development and mining rigs; and
- installation of new processing infrastructure including spirals plant.

4.3 Mining operations

4.3.1 Stope Development

One new stope, Stope 6, and one existing stope from T2, Stope 4, were mined during T3.

Development of Stope 6 commenced on 24 June 2020 to 26 July 2020 using a HDD rig. The stope development process includes drilling a pilot hole, enlarging the hole and installing casing.

Following development of Stope 6, the HDD rig moved to recondition the previous developed Stope 4 from 28 July to 3 August 2020.

4.3.2 Mining

Mining commenced on Stope 4 on 13 August 2020 and ceased on 30 August 2020. 15,000 tonnes were extracted over this period from zones as shown in Figure 4-1.

The mining rig moved to Stope 6 and commenced mining on 14 September 2020 and ceased on 30 September 2020. 15,900 tonnes were extracted over this period from zones as shown in Figure 4-1.

4.3.3 Processing

The material mined from T3, plus the ore stockpiled from T2, was processed through an on-site plant consisting of a trommel and spirals plant to produce 6,000 tonnes of HMC. At the end of the trial, this material was stored on the T2 ore pad.

The processing produced two tailings steams. Sand tailings is stockpiled on the T3 stockpile pad. Clay tailings is stored in the T3 fines storage pond. A portion of the sand and clay tailings was used in the backfill process as outlined in Section 4.3.4.

4.3.4 Backfilling

Backfilling of the T2 and T3 mining zones commenced on 28 September 2020 and was intermittent up until 7 November 2020.

Over the period of backfill the following volumes were returned to stopes:

- Stope 4 – 685 tonnes
- Stope 6 – 502 tonnes
- Stope 3 – 104 tonnes
- Stope 1 – 69 tonnes
- Stope 1B – 181 tonnes

In addition to returning material to the mining zones, sand tailings was used to stabilise the sinkholes that materialised during and following mining. These events are described further in Section 6.1.

The following volumes were returned to sinkholes:

- S2 – 310 tonnes
- S3 – 680 tonnes
- S4 – 1,220 tonnes
- S5 – not filled as full of water due to low point in topography
- S6 – 75 tonnes
- S7 – 137 tonnes
- S8 – 153 tonnes
- S9 – 312 tonnes
- S10 – 187 tonnes

4.4 Demobilisation

The site was progressively demobilised from early November with the majority of hired buildings and equipment removed from site. Crib and ablution facilities were demobilised and power disconnected.

Notification was provided to the Resources Regulator on 18 November 2020 of suspension of mining operations.

A vacuum truck was used to clean up roadways, plant area, stockpile area of ore and HMC material. An excavator was used to clean out the sedimentation basin. All areas with residual material were covered with lime as a precautionary measure should any oxidation occur.

The sand and HMC tailings stockpiles were covered with tarps to minimise windblown materials.

The site is secured with an agricultural stock fence and locked gate. Exclusion zone signs were placed around the perimeter. The site is unmanned but planned inspections will be carried out by the Registered Manager on a bi-monthly basis.

Table 6: Production summary

Material	Approved limit (SSD-5285)	Previous reporting period (2019) (actual)	This reporting period (2020) (actual)	Next reporting period (2021) (forecast)
HMC (tpa^) – open cut operations	500,000	0	N/A	0
Ilmenite (tpa^) – open cut operations	600,000	0	N/A	0
Ore (tonnes) – bulk sampling activity	100,000	0	30,900	0
Backfill – process water (litres)	NA	0	8,700	0
Backfill – slurry (tonnes)	NA	0	4,615	0
Backfill – slurry (litres)	NA	0	10,500	0
Saleable product – HMC (tpa^)*	500,000	0	6,000	0
Saleable product – Ilmenite (tpa^)*	600,000	0	0	0

^Tonnes per annum
** Statutory approval (SSD-5285) covering the bulk sampling activity does not allow Iluka to sell the extracted ore. The ore extracted during previous and future bulk sampling activities will remain on stockpile on site unless necessary statutory approvals are obtained to allow otherwise.*
*** Estimated – actual numbers will be dependent on successful progress of T3 activities.*

4.5 Next reporting period

The site is expected to stay in care and maintenance for 12 – 24 months whilst detailed feasibility studies are undertaken. During this time no further bulk sampling activities will be undertaken however some site activities including ongoing monitoring, resource drilling and other preparatory works may occur.

To ensure ongoing management of environmental factors during the care and maintenance period the Environmental Management Plan (EMP) and Pollution Incident Response Management Plan (PIRMP) were updated to put in place ongoing monitoring and management events.

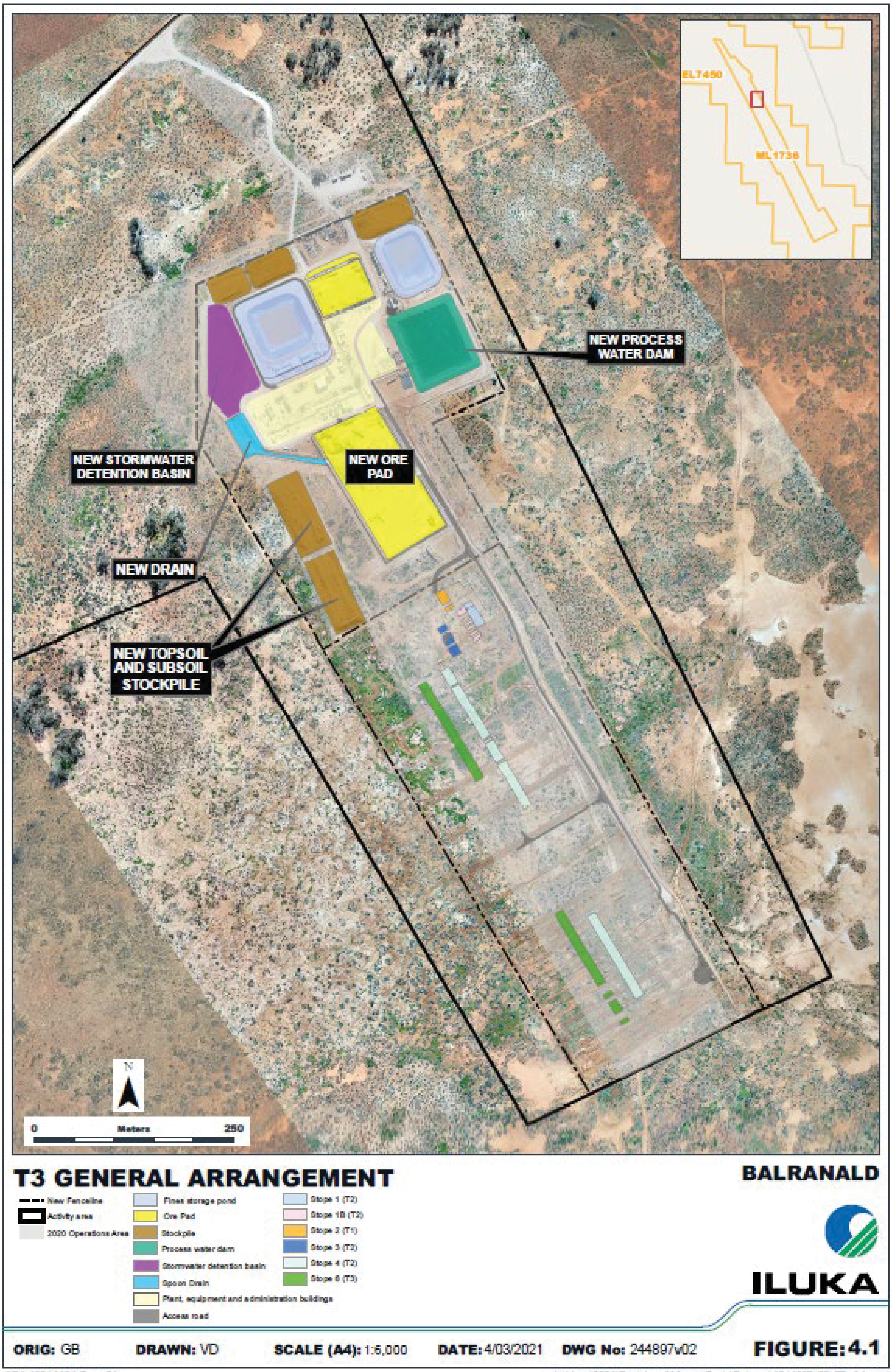

Figure 4.1: T3 activity site general arrangement

5 ACTIONS REQUIRED FROM PREVIOUS ANNUAL REVIEW

No actions required from the previous Annual Review.

6 ENVIRONMENTAL PERFORMANCE

The Environmental Management Plan (EMP) developed for the bulk sampling activities was updated in October 2019 to address the recommencement of the T3. It detailed the performance criteria (where relevant), mitigation and management and environmental performance monitoring (where relevant) for the activity.

An updated Mining Operations Plan (MOP) was also been prepared for the recommencement of the activity.

Iluka contracted EMM Consulting Pty Ltd (EMM) to undertake environmental monitoring and inspections in accordance with conditions set under SSD-5285. An Environmental Management Report detailing the work undertaken and outcomes of monitoring is attached as Appendix A.

Table 7 provides a summary of the environmental performance monitoring completed during the reporting period.

Table 7: Environmental performance summary

Aspect	Approval criteria / EIS prediction	Performance during period	Trend / key management implications
Weeds	SSD-5285. Condition 17, Schedule 3 – Control weeds	Monthly environmental inspections were conducted over 2020 noting the occurrence of weeds. The site activities, concurrent grazing land use and significant rainfall experienced in 2020 resulted in weed populations in open areas. A weed spraying contractor was engaged and the weeds were sprayed in October 2020.	Continued weed inspections planned in January and April 2021 and weed control as required.
Subsidence	No specific condition, Subsidence Management Plan (SMP) prepared as part of EMP	Subsidence was monitored as per the SMP. Nine irregular subsidence events (sink holes) occurred during mining as outlined in Section 6.1.	Ongoing biannual monitoring as outlined in Section 6.1.

Aspect	Approval criteria / EIS prediction	Performance during period	Trend / key management implications
Groundwater	SSD-5285. Condition 15, Schedule 3 – Groundwater Management Plan (GMP) appended to EMP.	Intensive groundwater monitoring conducted over trial period as outlined in Section 6.2	Ongoing monitoring as outlined in Section 6.2.
Noise	SSD-5285. Condition 3, 4 and 5, Schedule 3 – Noise	Measured noise contribution satisfied all relevant noise limits at nearest receiver (R5). Refer section 2 of Appendix A for further details.	No further monitoring
Air quality	SSD-5285. Condition 6, 7, 8 and 9, Schedule 3 – Air	Dust controls were implemented as outlined in the EMP. Dust generated by the activity was monitored during the activity with no exceedances identified. Refer section 3 of Appendix A for further details.	Monitor will continue in January and April 2021.
Biodiversity	SSD-5285. Condition 16 and 17, Schedule 3 – Biodiversity	Mitigation measures were implemented as outlined in the EMP. Clearing of 7.5 ha of native vegetation was undertaken. Refer section 8.2.3 of Appendix A for further details	Any future activities continue to be conducted in accordance with Site Disturbance Clearance Procedure as outlined in EMP
Cultural heritage	SSD-5285. Condition 18, 19, 20 and 21 – Heritage	An approved Aboriginal Cultural Heritage Management Plan remains in place. A due diligence survey was completed of all 2020 clearing areas in 2019. This was reported in the previous Annual Review.	

6.1 Subsidence monitoring outcomes

Post the T2 trial activities in 2016, Iluka continued biannual post activity subsidence surveys. No systemic movement was detected that is inconsistent with regional background observations. One irregular subsidence event (sinkhole - S1) occurred during T2. Apart from S1, T1 and T2 subsidence was less than 200 mm across the stope areas.

The Subsidence Management Plan was updated for T3 and appended to the EMP. This predicted vertical surface deformation up to 600 mm across the mining zone. Irregular subsidence, as sink holes, were not expected to be seen at the extent then noted during T3.

A total of nine additional irregular subsidence events were induced during mining (3), backfill (2) and post-mining (4) activity. Surveys indicates that the lateral extent ranges from 6.4 m to

15.8 m and depths from 1.2 m to 6.9 m (Refer to Table 8.1 in Appendix C). All subsidence events occurred inside the mine exclusion zone with no risk to personnel. The sinkholes were stabilised via backfilling with lime dosed sand tails, with subsoil and topsoil capping to occur when the exclusion zone is cleared for access and rehabilitation. The success of this stabilisation will be monitored over time.

The subsidence events were reported to the regulators via email and a preliminary report was submitted via letter in October 2020. This letter was updated in December 2020 to cover the last four subsidence events. The latest drone inspection in February 2021 confirmed that no further subsidence had occurred.

A review of the groundwater data at the time of the subsidence events has been undertaken by EMM and is presented in Section 8 of Appendix A.

A review of the survey data collected during the trial was undertaken by MSEC (Appendix B). The data assessment indicated that the clayey materials in the SFM are bridging above the mined stopes then failing in isolated locations in a piping type failure to create the sinkholes.

MSEC also reviewed the observed systemic subsidence movements and noted that at 90 mm these were considered negligible and substantially less than the 600 mm predicted.

Biannual surveys will be conducted in 2021, plus ad-hoc visual and drone inspections.

6.2 Groundwater monitoring outcomes

Post the T2 trial activities in 2016, Iluka continued biannual regional groundwater monitoring.

The GMP was updated for T3 to manage potential groundwater risks associated with the activity. A trigger action response plan (TARP) was used to record and respond to monitoring results using Site Specific Trigger Levels (SSTL) established in the GMP.

No SSTLs were breached in the LPS or SFM. A detailed summary of groundwater monitoring against compliance requirements is provided in Section 5 of Appendix A.

A separate hydrogeochemical assessment report details groundwater pressure and geochemistry data and interpretation is provided as Appendix B.

A regional groundwater monitoring event was completed in July 2020 (LWC, 2020). This showed that results remained consistent with the historical groundwater baseline data collected across the wider Balranald area.

7 WATER MANAGEMENT

Water usage during the T3 bulk sampling activity was in accordance with a 2,500 megalitre (ML) water trade with Tronox assigned to Iluka's Water Access Licence's (WAL) 31101 and WAL31102.

Water use for the over the reporting period is summarised in Table 9. Nominated extraction points during the activity included production bores PB2, PB04 (Loxton Parilla Sands Aquifer, WAL31102) and the Karra Bore (Lower Renmark Group Aquifer, WAL31101).

Table 8: Summary of water use

Water Licence #	Water Source and Water Sharing Plan	Entitlement / allocation*	Passive take / inflows	Active pumping	Total (ML)
31101	Western Murray Porous Rock Groundwater Source	150 ML	0 ML	26 ML	26 ML
31102	NSW Murray Darling Basin Porous Rock Groundwater Sources	2350 ML	0 ML	43 ML	43 ML

**Temporary allocation leased from permanent allocation holder for the water licensing period 2016-2019.*

8 REHABILITATION

Following completion of the activity in November 2020 all mining plant and equipment was decommissioned and removed from site. Basic surface equipment remains on site – screen, cyclones, thickener, pumps plus associated pipes and spares.

Stockpiles of HMC and sand tailings remains on site. The material is covered with tarpaulins to minimise potential dust generation.

9 COMMUNITY

No community complaints were received during the 2020 reporting period. A copy of the complaints register for the Project is provided on the Iluka Resources website in accordance with the Condition 11, Schedule 5 of SD-5285.

Engagement with the landowner, neighbours and the Balranald Shire Council was carried out regularly over the course of the trial.

10 INDEPENDENT AUDIT

COVID-19 pandemic travel restrictions and inclement weather conditions on site limited regulator site visits during 2020.

A site visit with representatives from DPIE-Planning and Environmental Protection Authority took place in October 2020. Additional representatives from DPIE-Water and DPIE-Planning joined via teleconference for the presentation component.

A separate site visit by DPIE-Resources Regulator was planned in November 2020 but was postponed due to site weather conditions. A meeting was held at the Balranald accommodation camp to discuss T3 site activities.

DPIE-Planning issued a letter on 20 January 2021 confirming that as construction of the mine has not formally commenced under the development consent, and only bulk sampling activities are currently being undertaken, the requirement for an independent audit under Condition 8 Schedule 5 has not yet been triggered.

11 INCIDENTS AND NON-COMPLIANCE

11.1 Non-compliances

No non-compliances with the conditions of the relevant statutory approvals occurred during the 2020 reporting period.

11.2 Reportable incidents or exceedances

No reportable incidents with the conditions of the relevant statutory approvals occurred during the 2020 reporting period.

11.3 Official cautions or warnings

No official cautions, warning letters, penalty notices or prosecution proceedings were received by any regulatory agency for the Project during the 2020 reporting period.

12 ACTIVITIES FOR NEXT REPORTING PERIOD (2021)

The site is expected to stay in care and maintenance for 12 – 24 months whilst detailed feasibility studies are undertaken. During this time no further bulk sampling activities will be undertaken however some site activities including the ongoing monitoring, exploration and other preparatory works may occur.

To ensure ongoing management of environmental factors during the care and maintenance period the EMP and PIRMP were updated to put in place ongoing monitoring and management events.

APPENDICES

Appendix A: Environmental Management Report T3 Bulk Sampling Activities (March 2021)

Appendix B: MSEC Subsidence Review Report (February 2021)

Appendix C: Hydrogeochemical assessment of the T3 mining trial (February 2021)

Appendix A: Environmental Management Report T3 Bulk Sampling Activities (March 2021)

Environmental Management Report

T3 Bulk Sampling Activities

Prepared for Iluka Resources Limited
March 2021

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Environmental Management Report

T3 Bulk Sampling Activities

Report Number

S190512 RP 1

Client

Iluka Resources Limited

Date

1 March 2021

Version

v3 Final

Prepared by

Luke Griffiths
Senior Environmental Planner
1 March 2021

Approved by

Paul Gibbons
Director- Environmental Assessment and Management
1 March 2021

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Appendices

Tables

Figures

Photographs

1 Introduction

The purpose of this Environmental Management Report (EMR) is to present environmental monitoring and compliance auditing for Iluka Resources Limited's (Iluka) Balranald T3 Bulk Sampling Activity from November 2019 to November 2020, reflective of construction, mining / backfilling and demobilisation activities.

1.1 Overview

On 5 April 2016 Iluka was granted Development Consent under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for a mineral sand mine in south-western New South Wales, known as the Balranald Mineral Sands Project (the Balranald Project). The project was assessed and approved as a State Significant Development 5285 (SSD-5285).

The Balranald Project includes construction, mining, primary processing and rehabilitation of two linear mineral sand deposits, known as the West Balranald and Nepean deposits located approximately 12 kilometres (km) and 66 km north-west of the town of Balranald (Balranald town), respectively (Figure 1.1).

The Balranald Project included undertaking a bulk sampling activity (the activity) at the West Balranald deposit to test the selective in-situ removal of up to 100,000 tonnes (t) of ore.

On 3 May 2016, the former Department of Planning and Environment (DP&E) approved an Environmental Management Plan (EMP) for the activity (Reference 11/22089-2).

On the 15 November 2019, the Environmental Protection Authority (EPA), in consultation with the Department for Planning, Industry and Environment (DPIE), endorsed the updated EMP for recommencement of bulk sampling activities following a period of care and maintenance (Reference 19/530575-8).

The activity is an unconventional mining method to test the selective in-situ removal of mineral ore and reflects a continuation of a smaller bulk sampling activity (known as T1) undertaken by Iluka during Q1-2015 and Q1-2016 in accordance with approval under Part 5 of the EP&A Act from NSW Trade & Investment, Resources & Energy (Reference OUT13/28341 and OUT15/27702).

The activity commenced under SSD-5285 in Q2-2016 and Q3-2016 and successfully extracted approximately 6,400 t of ore from three stopes (referred to as Stopes 1B, 3 and 4) and backfilled approximately 700 t of ore (known as T2). Iluka placed the activity site into care and maintenance during 2017 and 2018 to review the mining and environmental monitoring outcomes.

Iluka recommenced site establishment and new construction for the unconventional mine site (known as T3) in September 2019. Construction included expansion of the mine site to include a new fines storage pond, ore pad and stormwater detention basin increasing the area of total land disturbance to 14.5 hectares (ha).

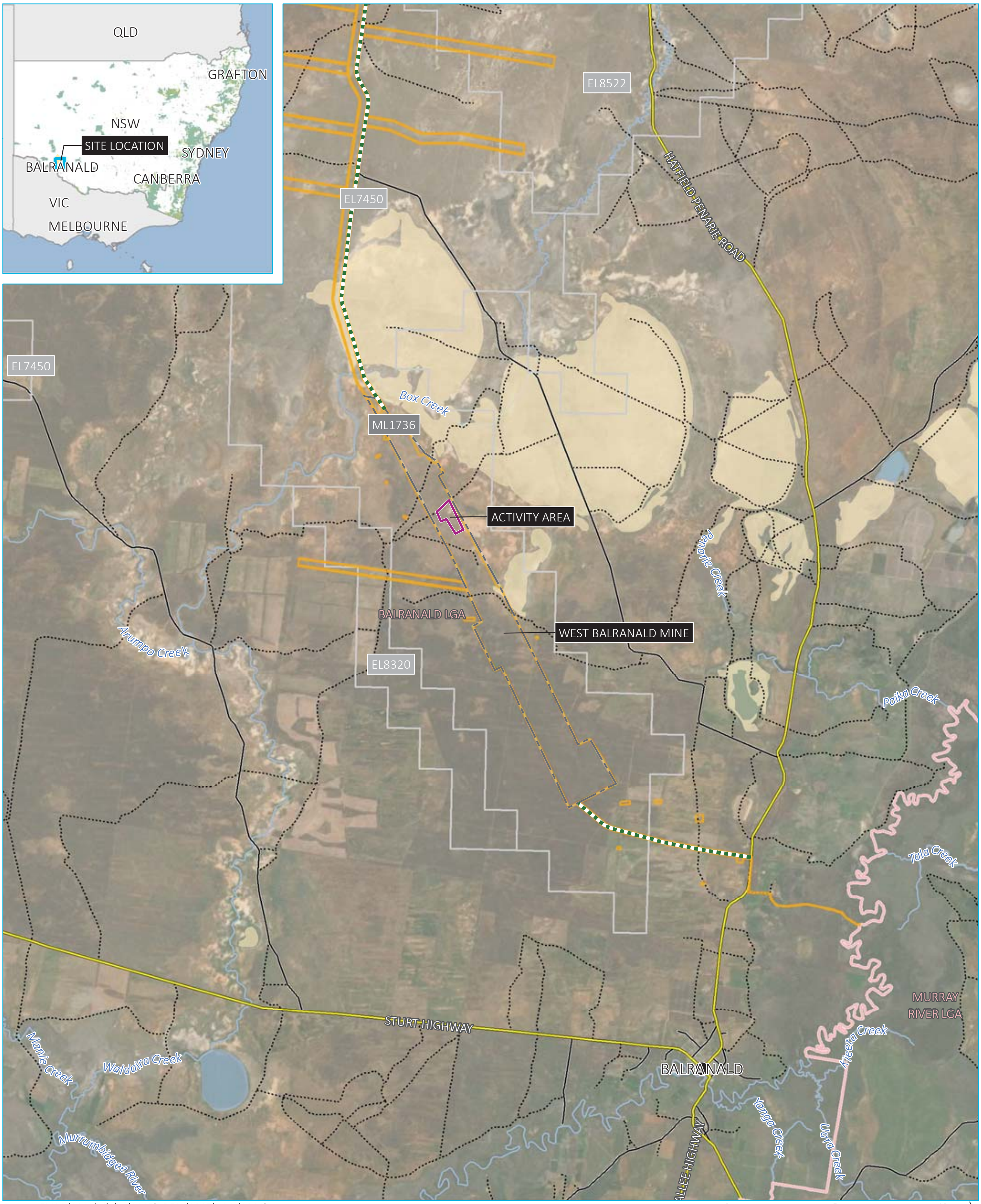
The activity site is located entirely within the disturbance footprint of the West Balranald mine, including the area of the open cut pit. As such, all land disturbed by the activity will eventually be subsumed by mining of the West Balranald mine (Figure 1.1 and Figure 1.2).

The objectives of T3 were to determine whether the unconventional mining method can:

- sustain production over a larger sample set (ie longer and multiple stope length);
- backfill process to deliver a mining by product management strategy; and
- further validate groundwater and subsidence impact prediction models.

Mining commenced in June 2020 with the development and mining of a new stope (Stope 6) and the re-entry and additional mining of Stope 4 (Figure 1.3). The trial removed 30,900 t of material during mining with the ore processed on-site to produce 11,900 t of heavy mineral concentrate (HMC). The trial backfilled approximately 1,540 t of sand and clay tailings to the mining zone. Approximately 2,766 t was used to rehabilitate the subsidence holes created as the result of operations (see Chapter 6).

The activity site was placed into care and maintenance in late November 2020.



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Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 5 10 km

GDA 1994 MGA Zone 54

N

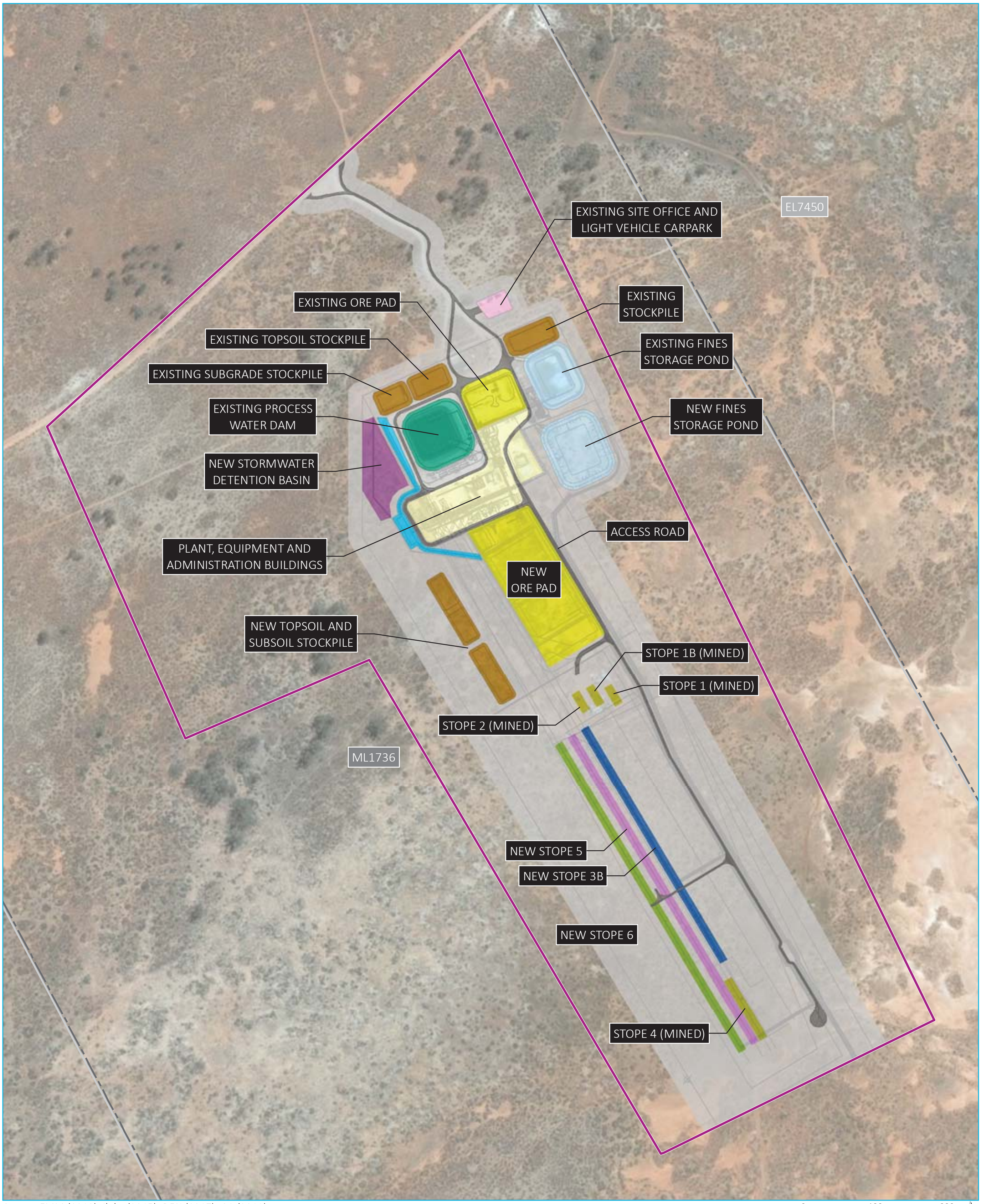
KEY

- Activity area
- Project boundary
- Access road
- Mining Lease 1736
- Iluka mineral tenement
- Main road
- Local road
- Vehicular track
- Named watercourse
- Perennial lake
- Ephemeral lake
- Local government area

Regional location

Iluka Resources Limited
Environmental Management Plan
Figure 1.1

EMM
creating opportunities



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Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 100 200 m
GDA 1994 MGA Zone 54
N

KEY

Activity area
Mining Lease 1736
Iluka mineral tenement

Indicative site layout
Access road
Activity footprint
Existing site office and light vehicle carpark
Fines storage pond
Ore pad
Plant, equipment and administration buildings

Process water dam
Spoon drain
New stormwater detention basin
Stockpile
Stope (mined)
Stope 3B
Stope 5
Stope 6

Site map

Iluka Resources Limited
Environmental Management Plan
Figure 1.2

EMM
creating opportunities

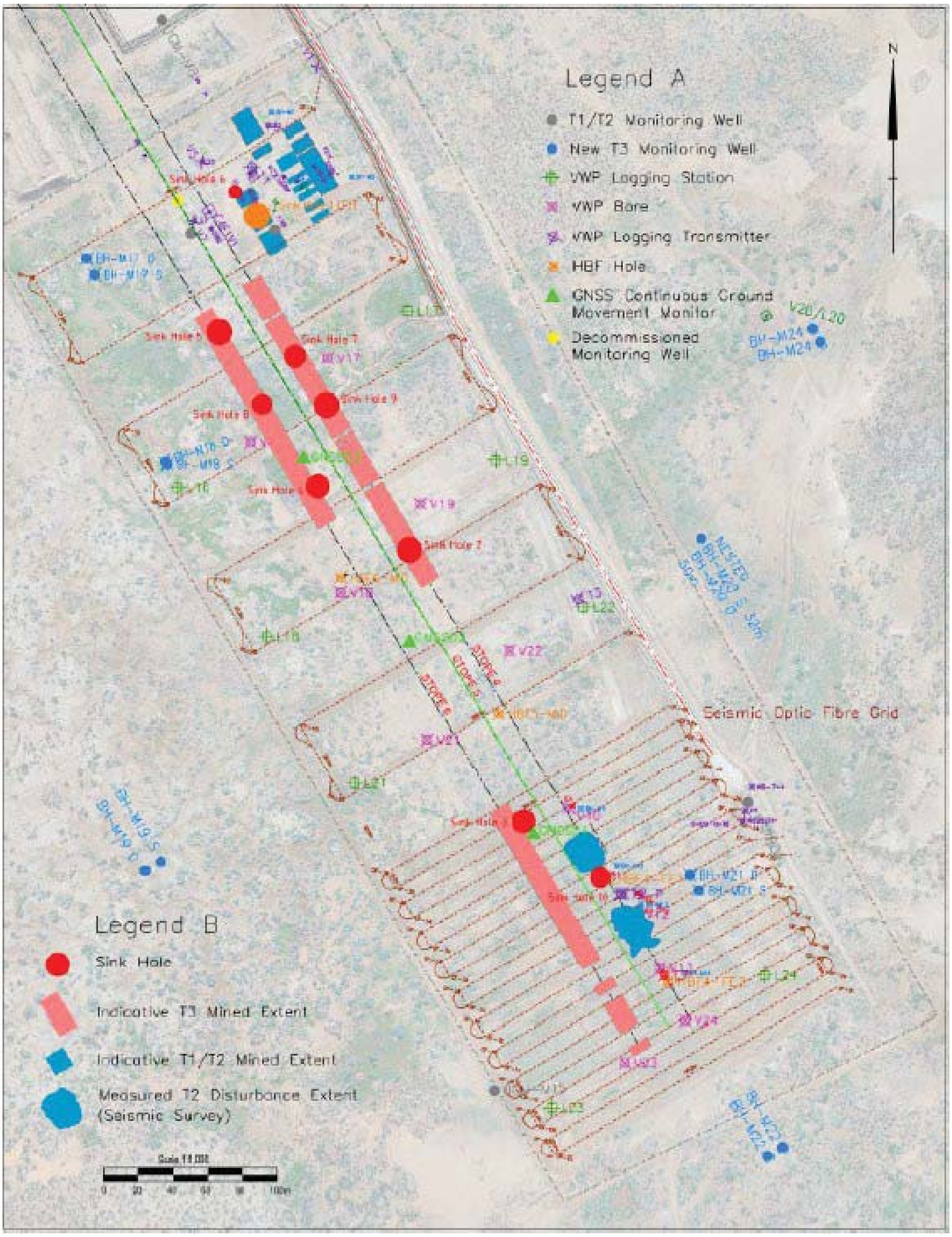


Figure 1.3 T3 stope layout

1.2 Environmental monitoring and compliance

During construction, mining and demobilisation Iluka contracted EMM Consulting Pty Limited (EMM) to undertake environmental monitoring and compliance auditing in accordance with conditions set under SSD-5285, this included:

- environmental inspections;
- noise management during mining;
- air quality management;
- surface water management;
- soil resource management; and
- groundwater management.

The results of EMM's compliance monitoring is detailed below in the subsequent sections.

1.3 Document hierarchy

The activity site Environmental Management Plan (EMP) was updated in October 2019 to address the recommencement of the T3 bulk sampling activity. It detailed the performance criteria (where relevant), mitigation and management and environmental performance monitoring (where relevant) for the activity.

An updated Mining Operations Plan (MOP) was also been prepared for the recommencement of the activity.

An overview of the relationship between the management plans and Iluka policies and procedures governing the activity is provided as Figure 1.4.

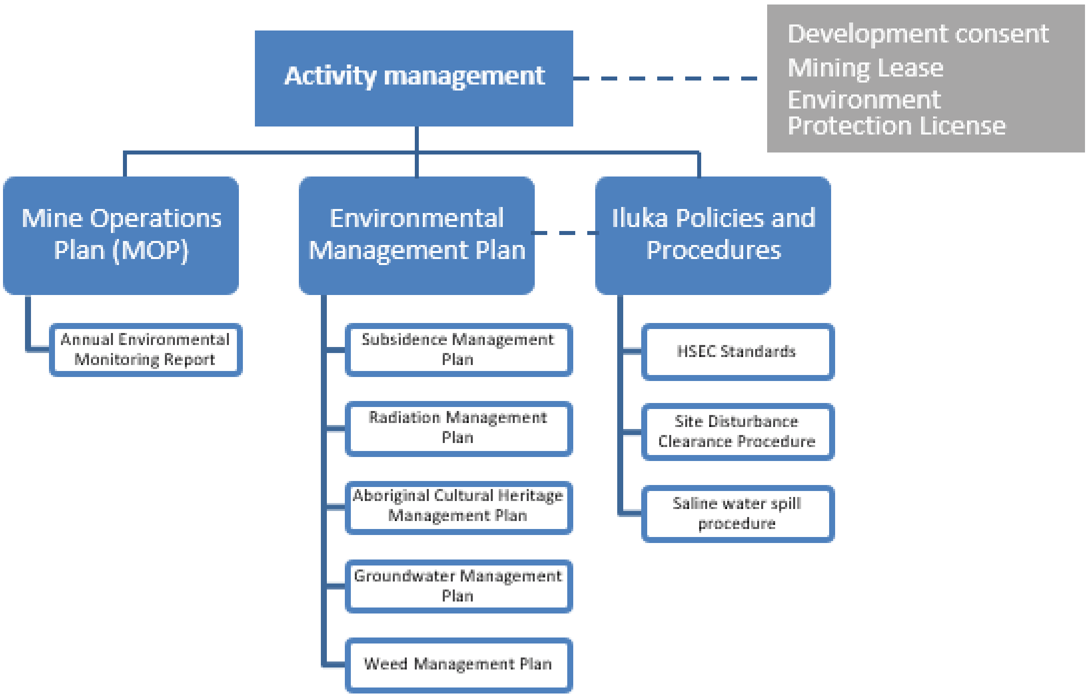


Figure 1.4 Document hierarchy

1.3.1 Summary of EMP

The key aspects of the T3 EMP are summarised in Table 1.1.

Table 1.1 Summary of T3 EMP

Aspect	T3 EMP
Consents and authorisations	No change from T1 or T2.
Land ownership and land use	No change from T1 or T2.
Legislative framework	No change from T1 or T2.
Site location	No change to activity site footprint from T1 or T2. Minor expansion to infrastructure area within the activity site footprint (Figure 1.2).
Infrastructure	Installation of new topsoil/subsoil stockpiles, ore pad, internal access roads and fines dam. Relocation of perimeter fence, diesel fuel storage and dispensing area. Additional groundwater and subsidence monitoring infrastructure.
Activities (construction, operation, decommissioning, demolition, temporary stabilisation and rehabilitation)	Installation of new surface and environmental monitoring infrastructure. Commencement of T3 to trial the selective in-situ removal of the remaining 93,600 t of ore approved under SSD-5285.

Table 1.1 Summary of T3 EMP

Aspect	T3 EMP
Management of: • noise; • air quality; • radiation; • surface water; • soil resources; • erosion and sediment; • biodiversity; • cultural heritage; • revegetation; • weeds; • waste; and • hazardous materials.	No change from T1 or T2.
Groundwater management	Additional groundwater monitoring infrastructure installed and sampling in accordance with updated Groundwater Management Plan (GMP).
Subsidence management	Additional subsidence infrastructure installed and monitored in accordance with updated Subsidence Management Plan (SMP).
Incident management	No change from T1 or T2.
EMP review	No change from T1 or T2.

1.4 Statutory requirements

The T3 EMP was prepared under Schedule 2, Condition 17 and Schedule 5, Condition 3 of the development consent and was specific to the bulk sampling activity. Where relevant, the EMP addressed relevant environmental performance requirements and criteria prescribed in Schedule 3 of SSD-5285.

1.5 Consents, authorisations and licences

1.5.1 Development consent

On 5 April 2016, Iluka obtained development consent for the Balranald Project from the Minister for Planning. The Balranald Project includes an extension to the activity to enable the extraction of up to 100,000 t of ore (ie bulk sampling activity) to determine whether it can be removed cost effectively and in an environmentally sensitive manner.

1.5.2 Mining lease

On 9 May 2016, Iluka obtained a mining lease (ML 1736) from the Minister for Industry, Resources and Energy under the NSW *Mining Act 1992* (Mining Act).

The term of ML 1736 is for 21 years with the lease expiry date being 9 May 2037. ML 1736 covers the West Balranald deposit as shown on Figure 1.1. ML 1736 provides approval to mine for several resources including rutile, zircon and ilmenite.

ML 1736 requires the preparation and approval of a MOP and associated annual environmental monitoring report.

1.5.3 Environment protection licence

On 10 June 2016, Iluka obtained an environment protection licence (EPL20795) under the NSW *Protection of the Environment Operations Act 1997* (POEO Act) to undertake the following scheduled activities as defined by the POEO Act:

- Mineral processing (30,000-100,000 t per annum (pa)).
- Mining for minerals (30,000-100,000 t pa).
- Waste disposal.
- Waste processing.

EPL20795 was amended in February 2020 to reflect the groundwater monitoring network outlined in the updated Groundwater Management Plan (GMP) prepared for T3 activities.

1.5.4 Radiation management licence

Iluka was granted a radiation management licence (5095125) under condition of the *Radiation Control Act 1990* to sell, possess, store or give away regulated material (Including radiation apparatus, radioactive substances or items containing radioactive substances) for 1 year'.

The radiation management licence was subsequently renewed in December 2020.

2 Noise management

2.1 Performance criteria

On site generation of noise created by the activity, including traffic noise, was required to meet the construction noise management levels outlined in Table 2.1.

Table 2.1 Construction noise management levels for the Balranald Project

Time of day	Management level	Management level $L_{eq,15min}$
Standard hours: Monday to Friday 7:00 am to 6:00 pm, Saturday 8:00 am to 1:00 pm, No work on Sundays or NSW public holidays	Noise affected	40 dB(A)
	Highly noise affected	75 dB(A)
Outside standard hours	Noise affected	35 dB(A)

Noise generated by the activity, including traffic noise, was also required to adhere to noise criteria specified in Schedule 3, Condition 3 of the development consent, as outlined in Table 2.2.

Table 2.2 Criteria for operational noise

Location	Day	Evening	Night	
	LAeq(15min)	LAeq(15min)	LAeq(15min)	LA1(1min)
All privately-owned land	35	35	35	45
Mungo National Park and Mungo State Conservation Area	50	50	50	-

2.2 Management and mitigation measures

The following controls were implemented:

- All plant and equipment were maintained in good working order to ensure sound outputs were within manufacturer specifications.

The following protocols were implemented:

- Landholders whose land is directly affected by the activity were updated on the activities and access routes in use on their properties.

- Any landholder/community complaints were recorded and addressed promptly in accordance with Iluka's *HSEC Group Standard 02 - Social Performance*.

2.3 Environmental performance monitoring

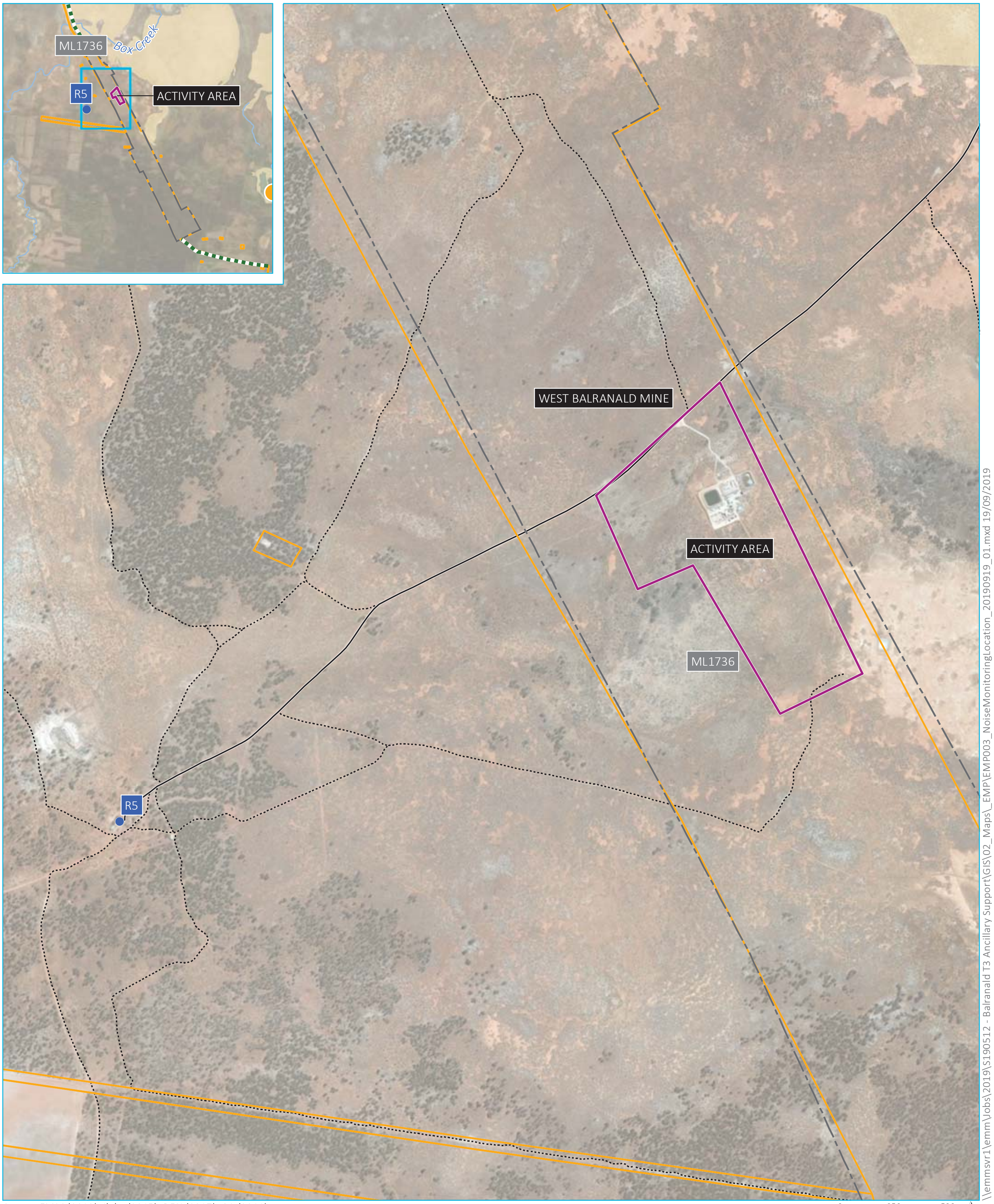
Monthly attended noise monitoring was undertaken at the nearest habitable dwelling, namely the Karra homestead (R5), located approximately 3 kilometres (km) to the west of the activity (Figure 2.1). Monitoring occurred during mining and backfilling (June to November 2020) and was conducted during the day, evening and night time periods to assess compliance with the relevant noise limits (Appendix A).

All measurements were conducted using a Svantek 977 sound analyser (s/n 59682), which is a class 1 meter as per Australian Standard AS61672.1:2019. The sound analyser was calibrated before and after completion of measurements using a Rion NC74 calibrator (s/n 34372752). No calibration drift was recorded. All instrumentation was within its current manufacturer and NATA calibration period.

The attended noise monitoring observations and results demonstrated throughout the activity operational noise was inaudible during the day period measurement at R5. If a noise source is inaudible, it is generally 10 dB below the background (L_{A90}) noise level. Mining and backfilling operations were audible during other measurements (ie evening and night time) however site noise contributions were below (satisfied) the relevant noise limits.

Further, maximum noise level (L_{Amax}/$L_{A1(1min)}$) events from site operations were also below (satisfied) the relevant noise criterion during the night period.

In summary, the measured noise contribution of Iluka's Balranald T3 bulk sampling was found to satisfy all relevant noise limits for all measurements conducted at R5, being the closest residence to the current activities conducted at site. Hence, site noise contributions are found to be compliant at all residences in the area.



Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

KEY

- Activity area
- Project boundary
- Noise monitoring location
- Access road
- Mining Lease 1736
- Local road
- Vehicular track
- Ephemeral lake

Noise monitoring locations

Iluka Resources Limited
Environmental Management Plan
Figure 2.1

EMM
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3 Air quality management

3.1 Performance criteria

Dust generated by the activity was required to meet the air quality criteria specified in Schedule 3, Condition 7 of the development consent, as outlined in Table 3.1.

Table 3.1 Criteria for particulate matter and deposited dust

Pollutant	Averaging period	Criterion	
Total suspended particulate (TSP) matter	Annual	90 µg/m3	
Particulate matter < 10 µm (PM10)	Annual	30 µg/m3	
Particulate matter < 10 µm (PM10)	24 hour	50 µg/m3	
Deposited dust	Annual	Maximum increase in deposited dust level - 2 g/m^2/month	Maximum total deposited dust level - 4 g/m^2/month

Air quality pollutants and deposited dust was monitored, as outlined in Table 3.2 and Figure 3.1.

Table 3.2 Summary of environmental performance monitoring, particulate matter and deposited dust

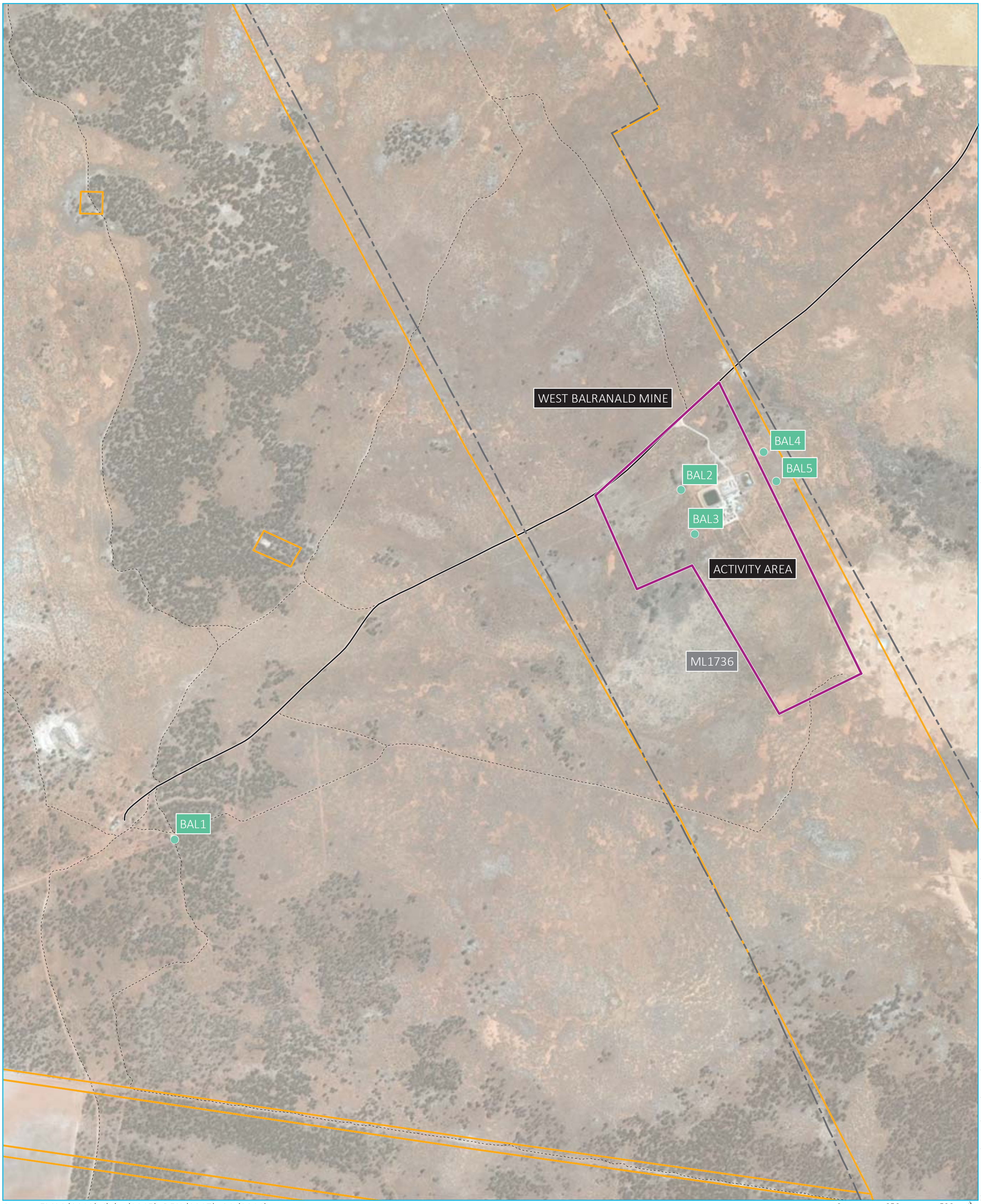
Location	Pollutant	Monitoring frequency
Bal 1	Total suspended particulate (TSP) matter:	
Bal 2	• Total solids.	
Bal 3	• Insoluble solids.	• Monthly during site-based operations; and
Bal 4a*	• Combustible matter.	• 1 x monthly monitoring event post- operations.
Bal 5	• Ash.	
Bal 6	• Soluble matter.	

Note: *Two deposition gauges located at this location with Bal 4b deposition gauge left in the field for life of activity for radionuclide analysis.

3.2 Management and mitigation measures

The following mitigation measures were implemented:

- Ore stockpiles did not exceed a height of 6 m.
- Topsoil/subsoil stockpiles did not exceed a height of 3 m.
- The moisture content of the ore material stockpile was managed by the use of sprinklers, if required.
- A water truck was utilised, as required, for dust suppression.
- Appropriate speed limits were applied to access tracks to minimise dust generation.
- Water was injected down drilling rods to dampen and suppress dust.



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Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 250 500 m
GDA 1994 MGA Zone 54
N

KEY

- Activity area
- Project boundary
- Air quality moniroing location
- Mining Lease 1736
- Local road
- Vehicular track
- Ephemeral lake

Air quality monitoring locations

Iluka Resources Limited
Environmental Management Plan
Figure 3.1

EMM
creating opportunities

- Shade-cloth fencing was erected and maintained around the ore pads to minimise loss of material through wind.
- All vehicles were fitted with exhaust mufflers engineered to manufacturer specifications.
- All vehicles were inspected prior to commencing activities to ensure equipment is serviceable.
- Tarpaulin covers have been placed over ore stockpiles for care and maintenance.
- Residual ore material was sprayed with a binding agent to minimise loss of material through wind during care and maintenance.

3.3 Environmental performance monitoring

Monthly dust deposition sampling was undertaken in accordance with Table 3.2 during the activity and with post-activity monitoring continuing until April 2021.

No exceedances have been identified to date with maximum total deposited dust level less than 4 g/m^2/month (Table 3.3).

Table 3.3 Dust deposition

Sample ID	Quarter	Date		Weighted Dust (g)	Total Deposited Dust (g/m^2/month)
		Start	End Received		
Bal 1	Q2, 2020	12-Feb-20	28-May-20	0.4942	0.4942
Bal 2	Q1, 2020	22-Nov-19	12-Feb-20	0.9975	1.5412
	Q2, 2020	12-Feb-20	28-May-20	0.5437	
Bal 3	Q1, 2020	22-Nov-19	12-Feb-20	0.9947	1.2701
	Q2, 2020	12-Feb-20	28-May-20	0.2754	
Bal 4a*	Q1, 2020	22-Nov-19	12-Feb-20	0.9898	1.9031
	Q2, 2020	12-Feb-20	28-May-20	0.9133	
Bal 5	Q1, 2020	22-Nov-19	12-Feb-20	0.9680	1.2526
	Q2, 2020	12-Feb-20	28-May-20	0.2846	
Bal 6	Q1, 2020	22-Nov-19	12-Feb-20	1.6724	2.2486
	Q2, 2020	12-Feb-20	28-May-20	0.5762	

4 Surface water management

4.1 Performance criteria

Surface water was managed to meet the applicable surface water criteria specified in Schedule 3, Condition 7 of the development consent, as outlined in Table 4.1.

Table 4.1 Water management performance measures (surface water)

Feature	Performance measure
Water management – general	• Minimise the use of clean water (ie water not in contact with disturbed areas) on site. • Minimise the need for make-up water from external supplies.
Construction and operation of infrastructure	• Design, install and maintain erosion and sediment controls generally in accordance with the series *Managing Urban Stormwater: Soils and Construction* including Volume 1, Volume 2A – *Installation of Services* and Volume 2C – *Unsealed Roads*. • Design, install and maintain infrastructure within 40 m of watercourses generally in accordance with *the Guidelines for Controlled Activities on Waterfront Land* (DPI 2007), or its latest version. • Design, install and maintain any creek crossings generally in accordance with the *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013) and *Why Do Fish Need to Cross The Road? Fish Passage Requirements for Waterway Crossings* (NSW Fisheries 2003), or their latest versions.
Clean water diversion and storage infrastructure	• Design, install and maintain the clean water system to capture and convey the 100-year ARI flood. • Maximise as far as reasonable and feasible the diversion of clean water around disturbed areas on site.
Sediment dams	• Design, install and/or maintain the dams generally in accordance with the series *Managing Urban Stormwater: Soils and Construction* – Volume 1 and Volume 2E *Mines and Quarries.*
Mine water storages	• Design, install and/or maintain mine water storage infrastructure to ensure no discharge of mine water or saline water off-site (except in accordance with an EPL). • On-site storages (including mine infrastructure dams, groundwater storage and treatment dams) are suitably designed, installed and/or maintained to minimise permeability, where practicable.
Flood mitigation measures	• Design, install and maintain flood mitigation measures including bunds to exclude flows from inundating the mining areas for all flood events up to and including the Probable Maximum Flood level. • Manage any residual downstream impacts in an appropriate manner.
Overburden emplacements	• Design, install and maintain emplacements to encapsulate and prevent any off-site migration of tailings, acid forming and potentially acid forming materials, and saline and sodic material. • Design, install and maintain emplacements to prevent off-site migration of saline groundwater seepage.
Chemical and hydrocarbon storage	• Chemical and hydrocarbon products to be stored in bunded areas in accordance with the relevant Australian Standards.

4.2 Management and mitigation measures

The following mitigation measures were implemented to manage surface water volumes:

- Site infrastructure (ore pad) is designed for a 1:50 year average recurrence interval (ARI) flood event, while the drill pads/hardstands were designed for a 1:10 year ARI.
- All site infrastructure containing extracted ore is contained on a pad specifically engineered to contain additional runoff in the event of an extreme rainfall event.
- All site infrastructure containing fines is contained in a dam specifically engineered to contain any additional runoff in the event of an extreme rainfall event (ie with sufficient design capacity).
- Diversion drains were constructed within the perimeter of site infrastructure to divert surface water runoff away from the site infrastructure and into a detention basin.
- HMC stockpiles have been located on an engineered hardstand that diverts surface runoff to the diversion drains.

The following measures were implemented to mitigate potential acid generation in the HMC stockpile:

- Construction methods used for the ore pad have reduced the potential for seepage (eg compaction, low permeability material incorporating limestone).
- Minimised surface area of ore stockpiles.
- Surface water drainage control around stockpiled ore.
- Regular water monitoring at the process water dams and surface drainage surrounding ore stockpile in accordance with the GMP.
- During the care and maintenance sand and HMC stockpiles have been neutralised with lime and covered to prevent dust generation and mitigate the risks of acid generation.

4.3 Environmental performance monitoring

4.3.1 Surface water management

A detention basin and associated swale drains were constructed as a component of T3 for diversion and containment of excess surface water runoff. Whilst the design of the stormwater management system worked effectively for surface water runoff during rainfall events, ore material from the new ore pad was able to bypass a sump and overflow into the system.

Monthly inspections by EMM during mining recorded an increasing volume of ore material within the swale drains and detention basin with Iluka using a vacuum truck used during demobilisation to clean up affected areas, as far as practicable. Given rainfall and safe access into the detention basin, residual ore material was left in-situ, treated with lime and sprayed with a binding agent to neutralise and minimise loss of material through wind during care and maintenance.

4.3.2 Surface water quality

During mining and backfilling daily field samples of pH from the stockpile sumps and spill dam were recorded with measurements within acceptable limits (ie 6.5 – 8.5).

5 Groundwater management

5.1 Performance criteria

Performance measures for water management are prescribed in Schedule 3, Condition 14 of the development consent, and reproduced in Table 5.1 as relevant to groundwater.

Table 5.1 Water management performance measures (groundwater)

Feature	Performance Measure
Loxton Parilla Sands and Shepparton alluvial aquifers	Negligible environmental consequences to the alluvial aquifer beyond those predicted in the EIS, including: • negligible change in groundwater levels beyond those predicted; • negligible change in groundwater quality beyond those predicted; and • negligible impact to other groundwater users levels beyond those predicted.

An updated Groundwater Management Plan (GMP) was prepared to manage potential groundwater risks associated with the activity. Operating objectives for the management of groundwater are defined in the GMP as follows:

- Meet dewatering, water supply and disposal requirements.
- Do not adversely impact neighbours water availability.
- Do not adversely impact native groundwater quality off the mining lease or in the underlying Lower Renmark Group.
- Use water efficiently.

5.2 Trigger action response plans

The approach to water and environmental management was defined by the GMP Hydrogeological Trigger Action Response Plan (TARP).

Recorded data was measured against a range of site specific trigger levels (SSTL) with the type and urgency of management responses corresponding to a three-tiered management framework, defined in Table 5.2, if required.

Table 5.2 Tiered management framework

<table>
<tr><th>Operating range</th><th>Management response</th></tr>
<tr><td>GREEN</td><td>The Green operating range indicates normal operation.
Observed parameters are below the accepted SSTL range and impacts fall within acceptable limits.
No action is required.</td></tr>
<tr><td>YELLOW</td><td>The Yellow operating range also indicates normal operating conditions but is designed to inform Iluka of possible future issues to allow time for adequate investigation and/or intervention.
Observed parameters are marginally outside the accepted SSTL range, signifying action must be taken within 48 hours of infringement confirmation. Confirmation is defined by:
• 24 hours of continuously recorded infringement in autonomous and telemetry collected data;
• 2 daily consecutive infringements recorded in for-cause manual sampling;
• ensuring pH of the PWD is within the acceptable range of 6.5 – 8. Checking both autonomous and field readings is required; and
• additional verification of the data, if required.
This allows a suitable timeframe for any local variability associated with small saline slugs, or measurement error, to be delineated and confirmed.
Actions associated with the operation of the T3 activity within the yellow monitoring threshold:
• increasing monitoring frequency in order to assess trends and understand processes occurring;
• revising the accepted SSTL range upon assessment of the impact on environmental values (to be completed with regulator consent);
• reducing the mining/backfilling and/or groundwater abstraction rates until infringements are within Green monitoring threshold or have stabilized; and
• depending on trends and if the red breaches are imminent, consider remediation action.
After 72 hours of continued operation in this threshold from a water quality perspective, a notification report will be forwarded to DPIE Water and NSW EPA, ideally and prior to conditions breaching the Red operating range.
Hydraulic breaches against the LPS HOC’s are not considered breaches of compliance criteria.
Note, although the TARP only applies to bores located outside of the defined transition zone, all bore locations will be monitored and assessed during site activities as preventative measure to minimise the risk to SSTL breaches.</td></tr>
<tr><td>RED</td><td>The Red operating range indicates a breach of acceptable operating conditions.
Observed parameters are above the Red SSTL, signifying action must be taken 12 hours after infringement confirmation. Infringement confirmation is defined by:
• 24 hours of continuously recorded infringement in autonomous and telemetry collected date;
• 2 consecutive infringements recorded in manual data; and
• additional verification of the data, if required.
Actions associated with the operation of the T3 activity within the red monitoring threshold, include those listed for the previous tier, with the addition of:
• ceasing the T3 operations until infringements are within the Green or Yellow monitoring threshold or have stabilised;
• investigate the cause of the SSTL breach if not adequately understood; and
• if necessary, develop and implement strategies to prevent future Red SSTL breaches or to mitigate any impacts caused by the SSTL breach.
Iluka are committed to not adversely impacting sensitive receivers including the environment and 3rd party bore owners. If groundwater pressures adversely impact these receptors, make good provisions would apply as defined by the AIP (2012).</td></tr>
</table>

Hydraulic operational conditions (HOC's) were defined for mining and backfilling representative of historical maximum pressures that have been experienced within the local aquifers without any adverse impacts being observed, including saline water movement to surface (refer Table 5.3).

Table 5.3 Hydraulic operating conditions

SSTL Parameter	Shepparton Aquifer			Loxton Parilla Sands Aquifer			Lower Renmark Group Aquifer		
	Green	Yellow	Red	Green	Yellow	Red	Green	Yellow	Red
Depth to Groundwater (Mounding Impacts)	> 8 mBGL	≤ 8 to > 6 mBGL	≤ 6 mBGL	<15 mAGL	≥ 15 to < 20 mAGL	≥ 20 mAGL	N/A	N/A	N/A
Depth to Groundwater (Dewatering Impacts)	N/A	N/A	N/A	N/A	N/A	N/A	≤ 8 mBGL	> 8 to ≤ 10 mBGL	> 10 mBGL

Notes: mBGL = metres below ground level
mAGL= metres above ground level
Green - indicates normal operation.
Yellow - indicates normal operating conditions, but is designed to inform Iluka of possible future issues to allow time for adequate investigation and/or intervention.
Red - indicates a breach of acceptable operating conditions.

To reflect expected changes to the groundwater system surrounding the stopes during the T3 bulk sampling activity, chemical SSTL zones were defined in the GMP. These chemical SSTL zones are summarised in Table 5.4 and focused on protecting the beneficial use of the groundwater system down-gradient from the activity site.

Using the GMP SSTL zones, only monitoring bores falling outside of the 300 m background zone (refer Figure 5.1) were considered for compliance monitoring; bores within the mixing zone were monitored to provide a leading indicator of impacts outside of the mixing zone, but did not need to adhere to the SSTL management and mitigation measures. Bores located within the impact zone were monitored to assess immediate changes to the aquifer and assist with understanding potential hydrogeochemical processes associated with mining and backfill activities.

Table 5.4 Zoned hydrogeochemical SSTL framework

Groundwater Monitoring Zone	Purpose	Details
Zone 1 Mining Zone	Operational	Adjacent and surrounding the actual mining area. Includes the stope areas plus a 20 m buffer. Required to understand immediate changes to groundwater quality and pressure. Large changes relative to baseline conditions, are expected in this zone and represent the source location of both pressure and geochemical changes. Provide a leading indicator to potential impacts within Zone 2.
Zone 2 Transition Zone	Operational / Compliance	Non mining area and represents the zone between 20 m and 300 m from the stope edges. Data and trends within this zone are used to understand aquifer responses at various locations away from the stopes, during mining and backfill. Provide a leading indicator to potential impacts within Zone 3.
Zone 3 Background Zone	Compliance	Non mining area and represents the zone beyond 300 m from the stope edges. Wells located in this zone are part of the EPA Licence and will therefore be required to adhere to the nominated SSTL's and associated compliance reporting.

5.3 Water quality monitoring

Table 5.5 and Table 5.6 outline the water quality monitoring suites and schedule.

Table 5.5 Water quality monitoring suites

Suite	Description	Parameters	Frequency
1	Field parameters	Water levels, Electrical conductivity (EC), pH, dissolved oxygen, temperature, oxidation reduction potential (redox), Ferrous and Total Fe.	Pre- and post-trial, daily for bore transects adjacent to active mining and backfill periods, fortnightly for other bore locations.
2	Major ions	Ca, Mg, Na, K, SO_2^-, SO_4^{2-}, Cl, alkalinity (bicarbonate, carbonate, hydroxide and total as $CaCO_3$).	Pre- and post-trial, and monthly[1] during trial. Aim to collect water samples at bore transects at times adjacent to active backfill periods.
3	Leading indicators	Al, Mg, S_2, $Cl:SO_4^{2-}$, Ferrous and Total Fe.	As Suite 2.
4	Radionuclides	Th, U, Ra-226 and Ra-228.	Pre- and post-trial.

1. Suite 2 should be sampled at times during active mining and backfilling

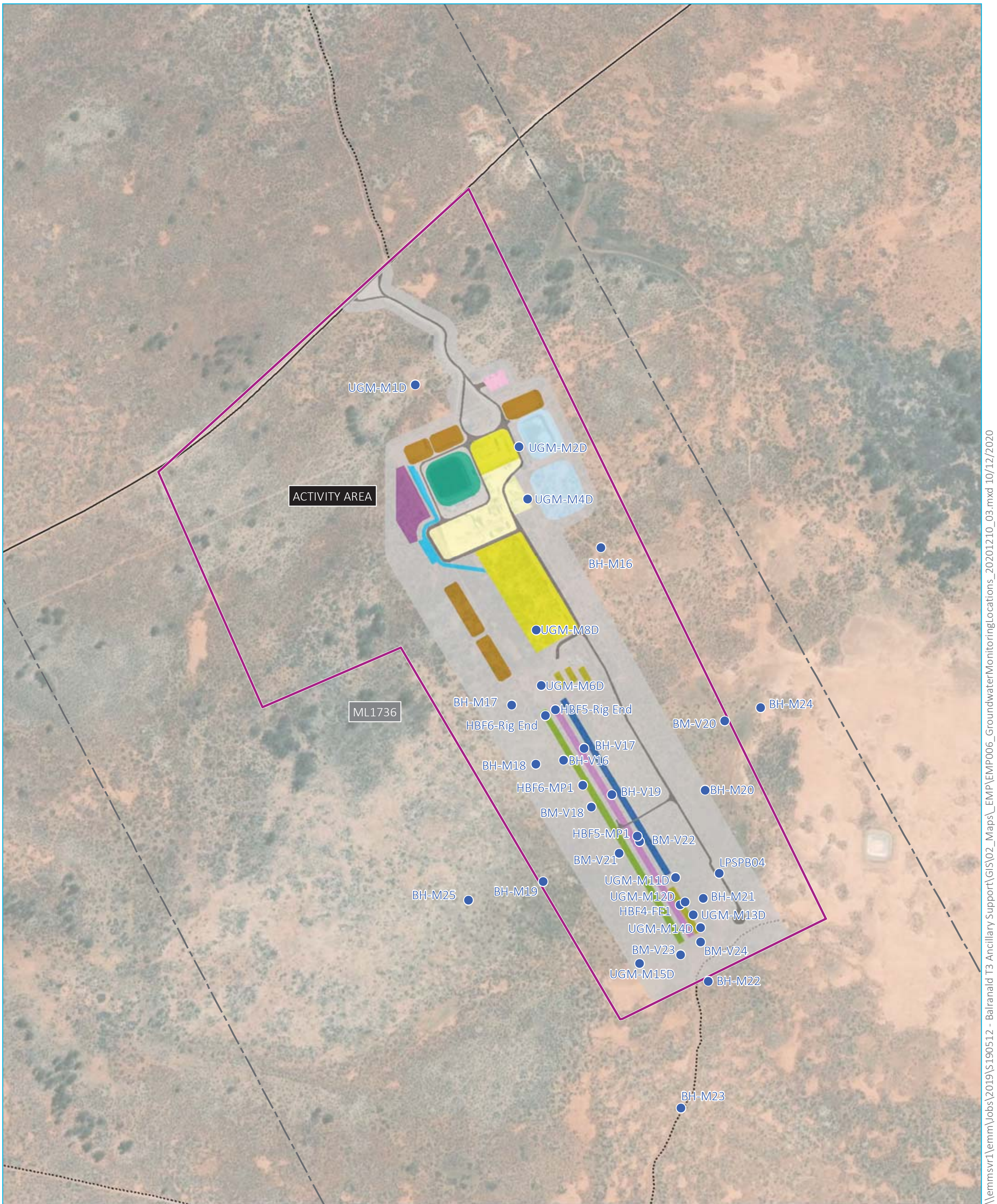
Table 5.6 Water quality monitoring schedule

Aspect	Location	Frequency	Suites	Bore ID
Pre-activity				
Groundwater quality	Mining Zone	Once off	1, 2, 3 and 4	All bores
Groundwater levels			n.a	
Groundwater quality	Transition Zone		1, 2, 3 and 4	
Groundwater levels			n.a	
Groundwater quality	Background Zone		1, 2, 3 and 4	
Groundwater levels			n.a	
During activity				
Groundwater quality	Mining Zone	Daily (when mining is close to bore location) otherwise fortnightly.	1	Refer to GMP Table 5.2 for impact zones
		Monthly	2 and 3	
Groundwater levels		Daily	n.a	
Groundwater quality	Transition Zone	Fortnightly	1	
		Monthly	2 and 3	
Groundwater levels		Daily	n.a	

Table 5.6 Water quality monitoring schedule

Aspect	Location	Frequency	Suites	Bore ID
Groundwater quality	Background Zone	Fortnightly	1	
		Monthly	2 and 3	
Groundwater levels		Weekly	n.a	
Post-activity				
Groundwater quality	Mining Zone	Once off as a minimum with some bores being biannual (pending T3 assessment report and on-going GME requirements)	1, 2, 3 and 4	All bores
Groundwater levels			n.a	
Groundwater quality	Transition Zone		1, 2, 3 and 4	
Groundwater levels			n.a	
Groundwater quality	Background Zone		1, 2, 3 and 4	
Groundwater levels			n.a	

Note: Bores UGM-M6, UGM-M12 and BH-M21 are located within the restricted access zone, and thus were sampled via a remote sampling system. During active mining and backfilling, monitoring frequencies for Suite 2 and 3 were collected from the nominated bores and aligned with the monthly schedule.



Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 250 500 m

GDA 1994 MGA Zone 54 N

KEY

- Activity area
- Groundwater monitoring location
- Local road
- Vehicular track
- Mining Lease 1736

Indicative site layout

- Activity footprint
- Access road
- Existing site office and light vehicle carpark
- Fines storage pond
- Ore pad
- Plant, equipment and administration buildings
- Process water dam
- Spoon drain
- New stormwater detention basin
- Stockpile
- Stope (mined)
- Stope 3B
- Stope 5
- Stope 6

Groundwater monitoring locations

Iluka Resources Limited
Environmental Management Plan
Figure 5.1

EMM
creating opportunities

5.4 Management and mitigation measures

The following groundwater mitigation measures were implemented (as outlined in the GMP):

- The construction methodology for all groundwater production and re-injection wells ensured hydraulic isolation of the screened aquifer from other overlying formations, via pressure-grouting of casing material.
- Abstraction volumes from the LPS[1] and Lower Renmark Group[2] were in accordance with WAL's 31101 and 31102 respectively.
- Groundwater abstraction and re-injection was in accordance with SSTLs to ensure appropriate management responses were implemented to minimise the impacts to both the environment and other water users.
- Injection water quality was in accordance with water licence conditions 60WA583169 and 60BL216701, being:
  - the pH of the water to be reinjected is between 6.5 and 8.5, or is treated to bring the pH within this range; and
  - water injected to the aquifer to make the backfill slurry must be of the same or better quality as the aquifer receiving water (as per the beneficial use classification) and should be free of any pollutants.

5.5 Environmental performance monitoring

5.5.1 Water usage

Water usage during the T3 bulk sampling activity was in accordance with a 2,500 megalitre (ML) water trade with Tronox assigned to Iluka's Water Access Licence's (WAL) 31101 and WAL31102. Nominated extraction points during the activity included production bores PB2, PB04 (Loxton Parilla Sands Aquifer) and the Karra Bore (Lower Renmark Group Aquifer).

A total 43 ML was extracted from the PB2 and PB04 during mining / backfilling, while 26 ML was extracted from the LRG Aquifer for construction, dust suppression and make up water. Water abstraction volumes during the T3 bulk sampling activity were in accordance with Iluka's water allocation and reflective of T2.

5.5.2 Groundwater levels

Groundwater level monitoring occurred at bores in the designated mining zone, transition zone and background zone in accordance with the GMP.

The following figures focus on results from background compliance bores (M16, M24 and M23) with groundwater levels in transition zone bore M25 and mining zone bores M12 and M21. Locations of the bores are shown in Figure 5.2. Results from monitoring in the SFM and LPS in these bores over the period May 2020 to October 2020 are shown in Figure 5.3 and Figure 5.4.

1 Abstraction allowance of 2,350ML has been purchased for the Balranald project under Water Access Licence No. 31102 for the 2019/20 water trade period, water for the 2020/2021 period will be secured as in accordance with statutory requirements.

2 An abstraction allowance of 150ML has been purchased for the Balranald project under Water Access Licence No. 31101 for the 2019/20 water trade period, water for the 2020/2021 period will be secured as in accordance with statutory requirements.

The monitoring shows all SFM groundwater levels show static responses with no discernable trend. Responses at these locations show no regional effects due to mining, backfill, water supply or subsidence events. No SSTLs in the SFM were breached.

LPS groundwater levels show responses to process water abstraction from LPSPB04. Spikes at M12 and M21 are due to backfill periods but were not large enough to sustain a response in the more regional bores. No SSTLs in the LPS were breached.

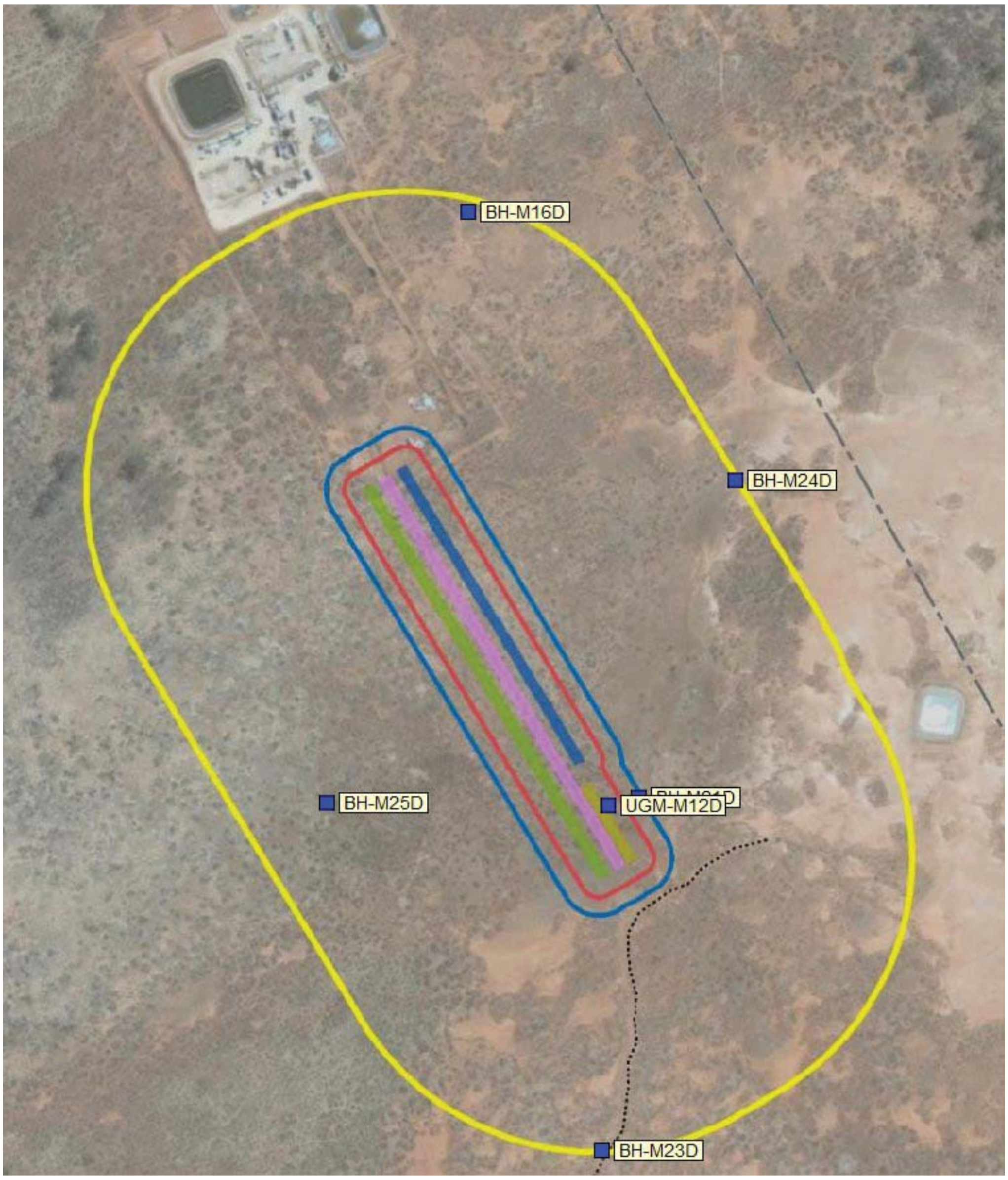


Figure 5.2 Background zone – compliance monitoring bores

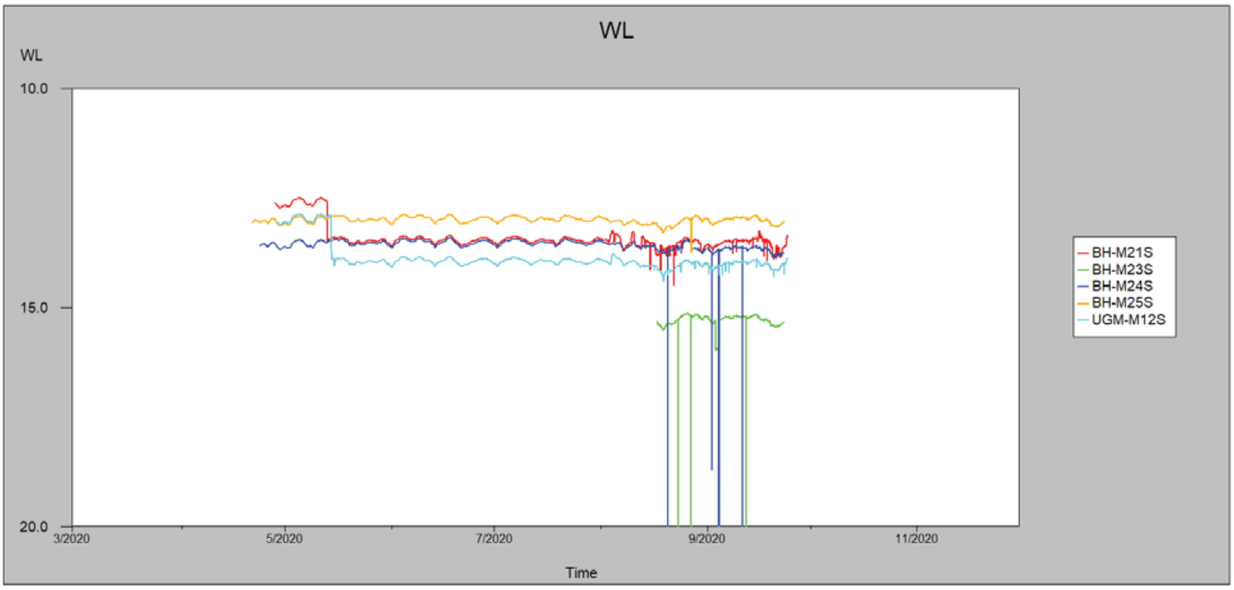
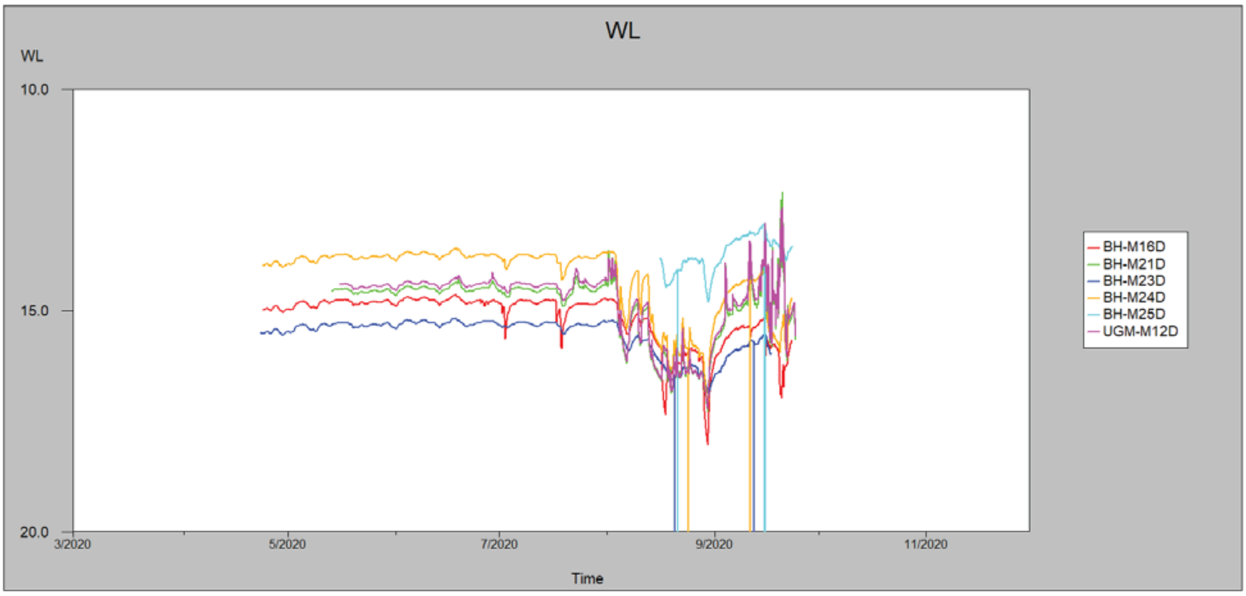


Figure 5.3 Groundwater levels (m Below Top of Collar) – Background zone SFM*



Note: * SFM and LPS anomalies to 20.0m reflect loggers being lifted out of the boreholes to download data

Figure 5.4 Groundwater levels (m Below Top of Collar) – Background zone LPS Formation*

5.5.3 Water quality

Groundwater quality results from the background zone bores (Figure 5.5) show the measured leading indicators as compared to the SSTLs displayed as shaded zones. All leading indicators fall within the green (acceptable) zone, except for ferrous iron at M24S. This is considered to be an anomaly and the screen is considered to be located across iron bearing sediments.

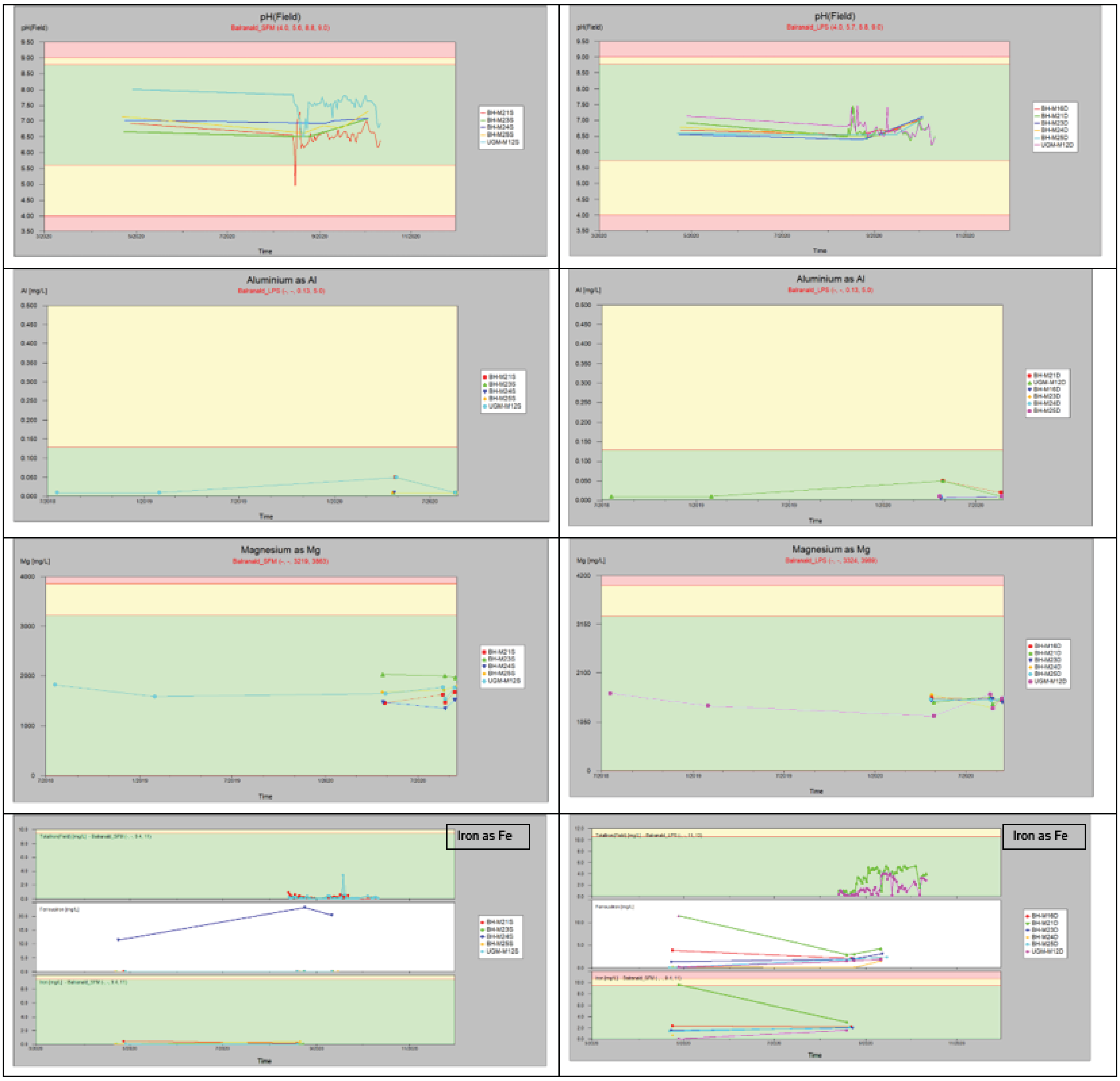


Figure 5.5 Groundwater quality results – background zone

Chloride sulphate ratios are shown in Figure 5.6. This ratio is commonly used as an indicator for Potential Acid Sulphate Soils. All ratios are >2 and did not trending downwards, indicating that oxidization of any acid bearing sediment did not occur.

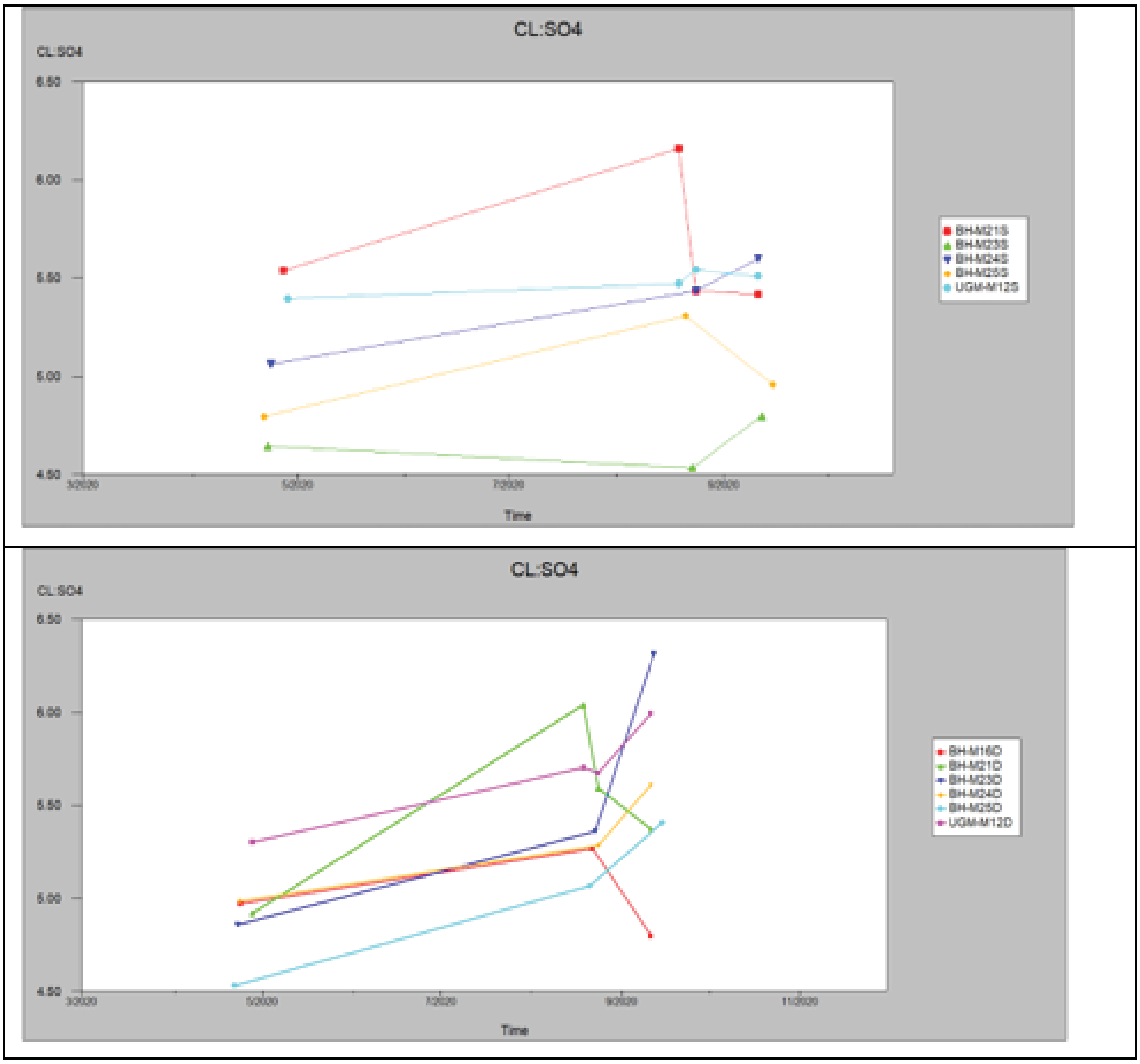


Figure 5.6 Chloride sulphate ratios

EMM is preparing a separate groundwater assessment report to analysis all water quality data and results obtained during the T3 bulk sampling activity.

Post-activity groundwater monitoring is scheduled to be undertaken during January and April 2021.

6 Subsidence management

6.1 Performance criteria

The development consent did not include specific performance criteria for subsidence.

6.2 Mitigation and management measures

Iluka adopted a subsidence performance criteria of 600 mm above the stopes, based on the predicted maximum subsidence level of 600 mm in the updated Subsidence Management Plan (SMP).

It is noted however that there is a high degree of uncertainty about the absolute levels of subsidence due to the scarcity of data on which to base a prediction model. Part of the trial objectives was to gather further subsidence data to improve the accuracy and confidence in subsidence predictions.

In accordance with the SMP, the following mitigation measures were implemented:

- Ore removal was limited to one cavity at a time, to better monitor potential visual subsidence.
- Site infrastructure was located outside of the subsidence zones of influence (ie outside of the areas directly above the stopes and predicted zone of influence).
- Subsidence holes were filled to ground level with treated sand tails.
- The subsidence zone of influence is fenced and demarcated with signage as an 'exclusion zone' requiring an Iluka permit prior to entry.
- During rehabilitation, a minimum of 1.5 m – 2 m of sub soil and topsoil will be placed within subsidence holes to provide a soil profile and growth medium for chenopod shrubland vegetation.

6.2.1 Subsidence monitoring

In accordance with the SMP, the following monitoring was undertaken:

- Survey markers were installed across the site to monitor surface levels before, during and after the activity to validate the subsidence predictions.
- Survey markers were installed to wider range (at least 1 km from the activity site) to monitor regional surface levels before, during and after the activity.
- Areas directly above the cavities were pegged and seismic monitoring network installed to indicate where the highest subsidence could be expected.

Subsidence monitoring was undertaken by a suitably qualified surveyor with experience in:

- mining-induced subsidence monitoring;
- remote (far-field) monitoring points; and
- capture of a high-density digital terrain model (DTM) of the entire site and surrounds.

The subsidence monitoring network is shown in Figure 6.1 and Figure 6.2.

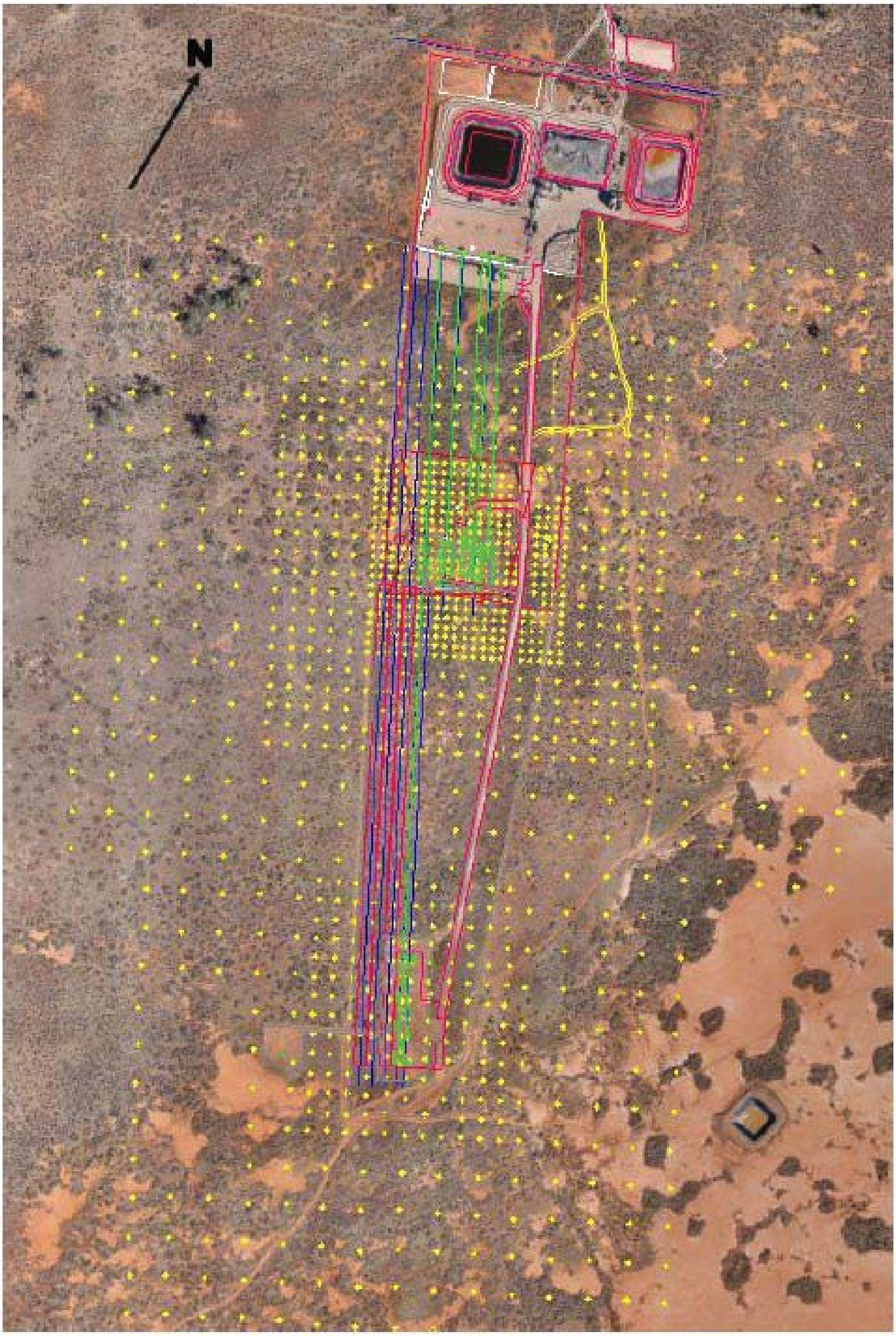


Figure 6.1 Subsidence monitoring locations (existing)

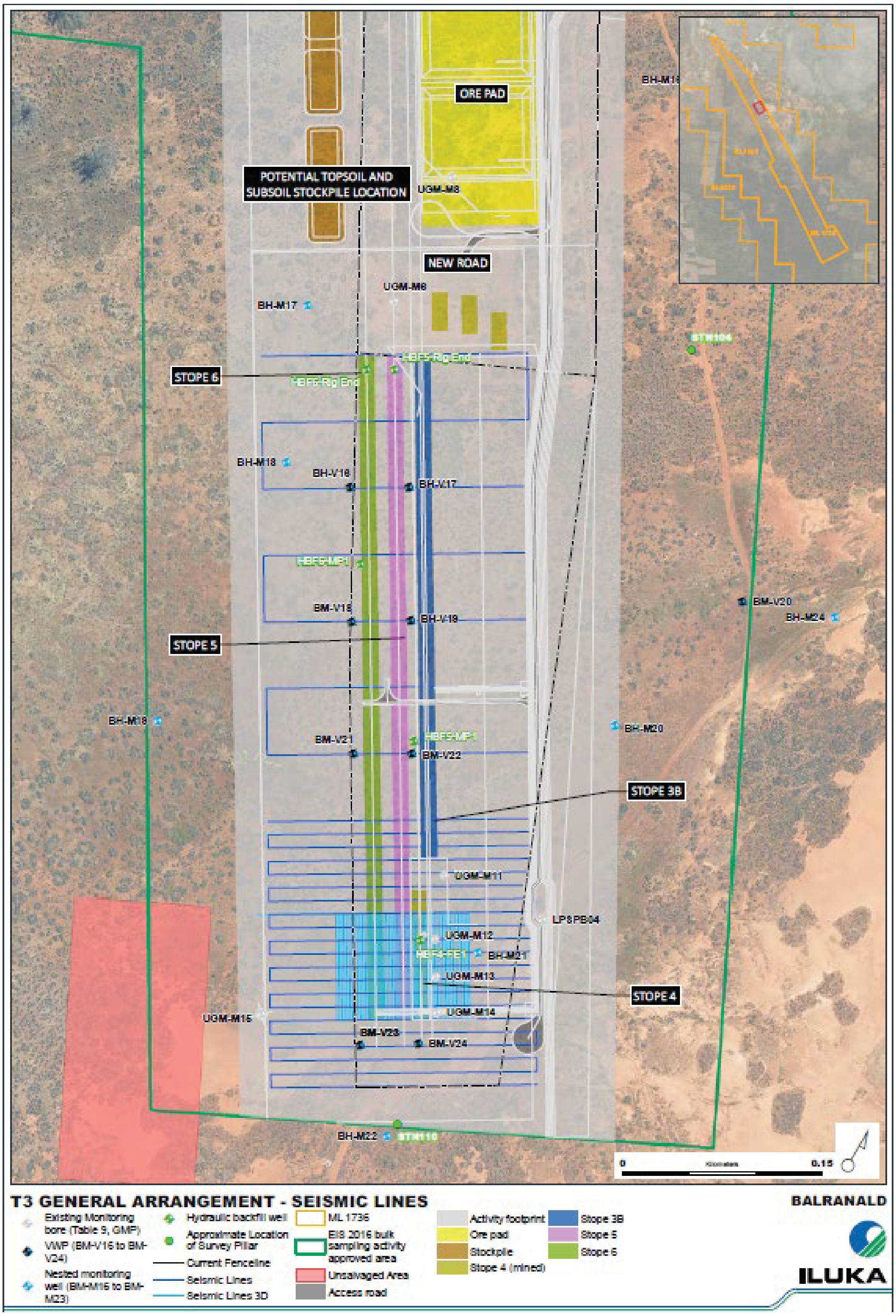


Figure 6.2 Subsidence monitoring locations (proposed seismic and fixed prism network – shown in 'green')

6.3 Environmental performance monitoring

The SMP noted that there is a high degree of uncertainty about the absolute levels of subsidence due to the scarcity of data on which to base a prediction model. During mining and backfilling nine (9) subsidence events occurred adjacent to Stopes 4 and 6.

Iluka notified DPIE, DPIE-Water, Resources Regulator and the EPA of all subsidence events [TRIM#2096181] and backfilled all locations with sand fines to address and remedy environmental, health and safety risks. Following receipt of the environmental incident notifications the regulators were satisfied with the level of information provided by Iluka in relation to the subsidence events, and also satisfied with the method of stabilisation applied to the sinkholes to prevent further impact prior to rehabilitation.

In accordance with the SMP, Iluka propose to undertake biannual subsidence monitoring events over the next 18 months unless the 3 GNSS units installed mid panel area indicate additional movement. Should this occur the surveys will be more frequent.

A separate subsidence monitoring reporting will be prepared to analyise all subsidence data and results obtained during the T3 bulk sampling activity to help improve the accuracy and confidence in subsidence predictions going forward (TRIM#2096221).

7 Radiation management

7.1 Performance criteria

The development consent does not include specific performance criteria for radiation, however a radiation management licence (5095125) was obtained for T3 activities in accordance with the *Radiation Protection and Control Act 1982*.

Iluka has adopted the performance goals outlined in the Radiation Management Plan (RMP), as outlined in Table 7.1.

Table 7.1 Environmental radiation performance goals

Radiation parameter	Radiation measured/method/equipment	Performance goal
Environmental gamma	Absorbed gamma dose rate in air - site boundary	>0.10uSv/h above background
	Absorbed gamma dose rate in air - stockpile areas	>0.50uSv/h above background
Environmental dust	Long-lived alpha emitters at dust deposition gauges	Two times background concentrations
Environmental radon/thoron gas	Passive radon monitors	Two times background concentrations
Groundwater radionuclides	Analysis of Ra-226, Ra-228 by scintillation counting by external laboratory	Two times background concentrations

Although the concentration of uranium and thorium in the ore is not high enough to be considered “radioactive” according to the *Radiation Protection and Control Act 1982*, Iluka has chosen to adopt a pro-active approach through the implementation of a site-specific RMP for the T3 bulk sampling activity.

Iluka engaged a suitably trained Radiation Safety Officer (RSO) for the T3 bulk sampling activity who was responsible for the implementation of the RMP.

7.2 Mitigation and management

The RMP is based on the system of dose limitation recommended by the International Commission on Radiological Protection (ICRP). The ICRP is an advisory body providing recommendations and guidance on radiation protection. Their recommendations are adopted internationally, and the current Australian radiation regulatory framework is based on the principles set out by the ICRP.

The engineering controls implemented are outlined in Table 7.2 and are in accordance with the RMP.

Table 7.2 Radiation exposure engineering controls

Radiation source	Control
Release of airborne particulates from stockpile areas and roadways	Dust suppression implemented, focusing on reducing lift-off from open areas, roadways and stockpiles. Suppression methods included the use of water trucks, use of dust suppression additives and use of shade-cloth as applicable. Site roads were graded and maintained to minimise dust generation. Ore pads were covered with tarpaulin and stabilised with a binding agent to minimise loss of material through wind during care and maintenance.
Transport of radionuclides into environment (eg spillages, stormwater runoff etc.)	Ore stockpile areas include contouring and HDPE lining to prevent stormwater ingress. Stormwater landing within material storage areas is captured and directed to the process water dam for recovery.
Ingestion of radioactive material by employees	Hand washing facilities were made available on site. Sufficient hose-down points and sumps were available on site to allow clean-up of mineral spillages.
Inhalation of dust by workers and/or transport of dust into environment	Shade-cloth fencing has been erected around the ore pad to minimise loss of material through wind. Ore pads have been covered with tarpaulin and stabilised with a binding agent to minimise loss of material through wind.
Gamma and dust exposure to non-process workers	Offices, stores and other facilities were located at least 20 m from stockpiles, to minimise gamma exposure. Locations of offices were predominantly upwind.
Radon/thoron inhalation by workers	The site is open-air and will therefore sufficiently dilute radon concentrations.

The following administrative measures were implemented, in accordance with the RMP:

- Use of appropriate personal protective equipment (PPE).
- Higher risk areas were subject to restricted access.
- Emergency planning.
- Site inductions and toolbox material included content on radiation requirements.
- Radiation signage installed.
- Monthly gamma monitoring during mining and backfilling and clean-up of any identified surface contamination.
- Vehicle and equipment washdown procedures implemented.
- Radiation levels of decommissioned plant and infrastructure tested and approved before being removed for offsite disposal.
- Quarterly gamma monitoring during care and maintenance.
- Monitoring will be undertaken as outlined in Section 7.3.

7.3 Environmental performance monitoring

Gamma, radon/thoron gas, gross alpha, gross beta and radionuclide water quality monitoring was undertaken in accordance with requirements outlined in the RMP and GMP with no exceedances recorded.

Radiation Consulting Australia is preparing a separate radiation monitoring report to analysis all radiation data and results obtained during the T3 bulk sampling activity.

8 Soil resources management

8.1 Performance criteria

Relevant performance criteria are derived from Schedule 3, Condition 32 of the development consent, which states the following performance objective for soil resources:

- Materials (including topsoils, substrates and seeds of the disturbed areas) are recovered, appropriately managed and used effectively as resources in the rehabilitation of the site.

8.2 Mitigation and management

Site disturbance activities have been undertaken in accordance with Iluka's *PRC 7931: Site Disturbance Clearance Procedure* with five (5) land disturbance permits issued for ground disturbance associated with the extension of the Stope 5 and 6 hardstand, surface infrastructure (including new ore pad, process water dam and detention basin), new groundwater monitoring network and fencing realignments.

The objective of the procedure is to ensure that site disturbance is kept to a minimum and all vegetation removal information is recorded. In accordance with Iluka's procedure, site disturbance may only proceed once a Land Disturbance Permit has been completed and signed by the relevant personnel.

8.2.1 Soil stripping

Site disturbance required the topsoil and subsoil to be stripped to the following depths (depending on soil availability):

- Topsoil: down to 0.1 m.
- Subsoil: from 0.1 m to 0.5 m.

Soil was stripped in consideration of the following:

- Earthmoving plant operators were appropriately trained and supervised to ensure that stripping operations was conducted in accordance with stripping plans and site conditions.
- All earthmoving equipment was clean of soil and vegetation (ie weeds) prior to commencement of bulk earthworks.
- Topsoil was stripped using a combination of scrapers and graders.
- Rehabilitation of the disturbed area will be undertaken as soon as practicable following cessation of the activity.

8.2.2 Stockpile management

For rehabilitation purposes:

- topsoil has been stockpiled separately to subsoil;
- topsoil/subsoil stockpiles have been limited to a height of 3 m; and
- accurate records have been kept by Iluka of stockpile types, volumes and locations.

8.2.3 Vegetation clearing

The activity required the clearing of an additional 7.5 ha of native vegetation (total disturbance 14.5 ha) with vegetation cleared as follows:

- Vegetation cleared as part of the topsoil removal process. The removed vegetation was incorporated into the topsoil stockpiles. This was intended to assist in the capture seeds for future rehabilitation and will also provide additional organic material to the topsoil.
- Vegetation clearing was minimised as far as practicable to areas essential for site activities.
- No vegetation was cleared without an approved vegetation clearance (as per Iluka's *PRC 7931: Site Disturbance Clearance Procedure*.
- All vegetation clearance recorded and tracked pre and post the activity.

8.2.4 Soil salinity

Any evidence of soil salinity arising from the activity is intended to be managed in accordance with the *PRC: 1722749: Saline Water Spill Procedure*. If required, affected soils will be tested and additional remediation actions undertaken to inform rehabilitation requirements outlined above. This may include:

- the removal and disposal of contaminated soil to a suitable waste facility; and
- the introduction of uncontaminated topsoil at the affected site.

8.3 Environmental performance monitoring

No specific monitoring was required however a one-off soil contamination testing event will be undertaken during final site decommissioning activities focused on fuel and chemical storage areas and any areas where saline water spills may have occurred.

At the time preparing this EMR no areas of soil salinity were sampled, however the nine subsidence event locations are likely to require assessment to inform final rehabilitation and subsoil / topsoil profiles (currently assumed to be 1.5 m rooting zone depth for the associated chenopod shrubland vegetation community).

9 Aboriginal cultural heritage management

9.1 Performance criteria

The performance goal relevant to Aboriginal cultural heritage is adapted from Schedule 3, Condition 18 of the development consent:

- No direct or indirect impact on the identified Aboriginal heritage sites located outside the approved disturbance area for the project.

9.2 Mitigation and management

Aboriginal cultural heritage management was in accordance with the Aboriginal Cultural Heritage Management Plan (ACHMP) (TRIM#1794073).

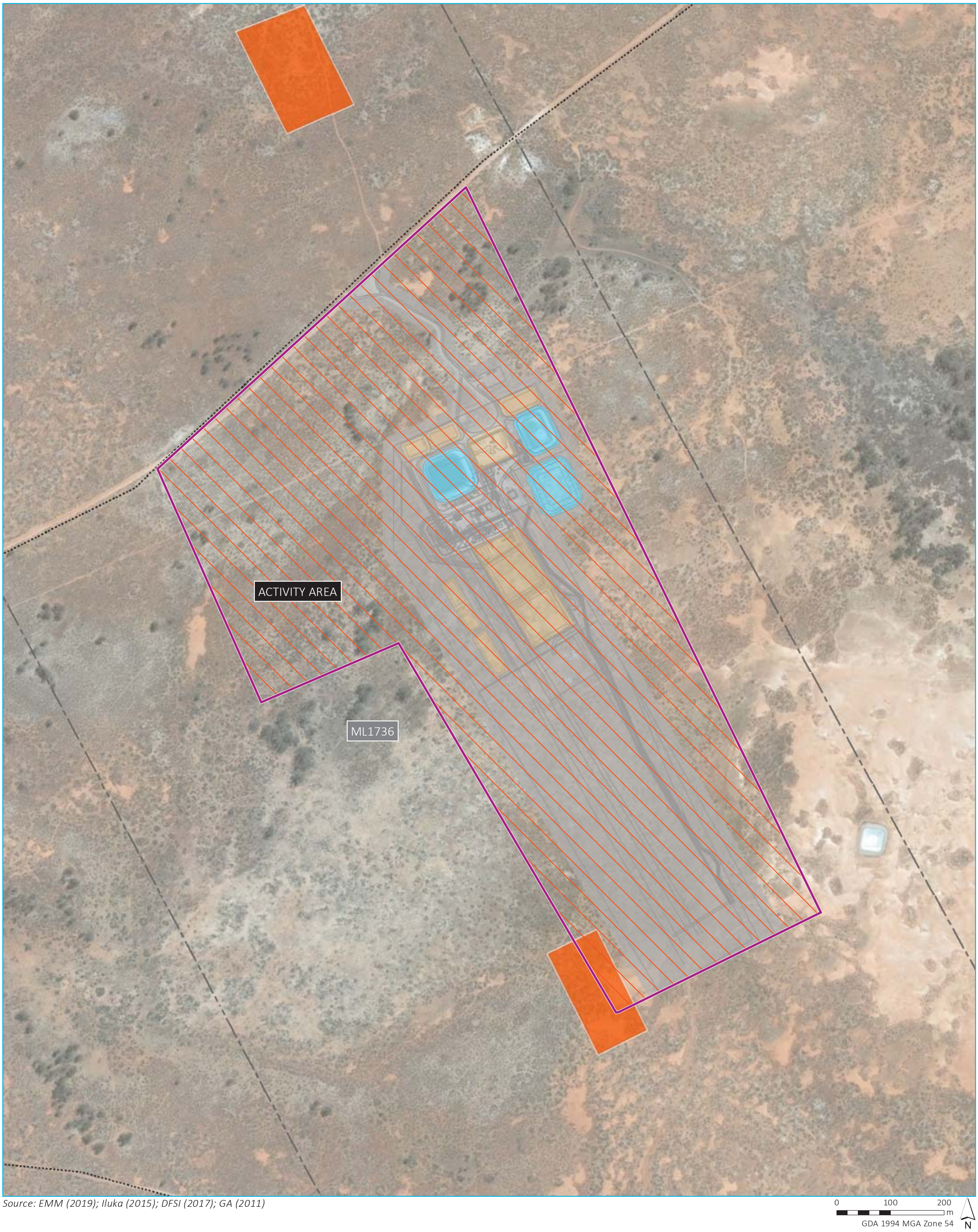
Salvage of the entire activity site was completed in accordance with the ACHMP in April 2016 (TRIM#1878403) (Figure 9.1) with further due diligence surveys for siting the location of new T3 groundwater monitoring network to avoid scattered artefacts completed in October 2019.

The following mitigation measures were implemented, as applicable:

- Unauthorised access to the exploratory test pit area adjacent the activity site was prevented through the installation of bunting.
- A safe storage area for artefacts collected during the 2016 salvage activities has been provided (on Country).
- Iluka's *PRC 7931: Site Disturbance Clearance Procedure* implemented.
- All site personnel received inductions prior to commencing work.
- If an Aboriginal site was discovered, the Trigger Action Response Plan described in the ACHMP was to be implemented.
- No infrastructure was placed outside of the salvaged area unless a due diligence clearance survey was completed.

9.3 Environmental performance monitoring

All site disturbance activities were undertaken in pre-salvaged areas or avoided Aboriginal artefacts recorded during due diligence surveys for the installation of the new groundwater monitoring network for the T3 bulk sampling activity.



Source: *EMM (2019); Iluka (2015); DFSI (2017); GA (2011)*

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KEY

- Activity area
- Vehicular track
- Salvaged area (surface)
- Non-salvaged (subsurface)(no-go)
- Mining Lease 1736

Domain

- Infrastructure
- Stockpile
- Water management area

Salvaged locations

Iluka Resources Limited
Environmental Management Plan
Figure 9.1

EMM
creating opportunities

10 Other environmental aspects

10.1 Biodiversity management

The following mitigation measures were implemented by Iluka:

- Vegetation disturbance kept to a minimum.
- No vegetation cleared without an approved vegetation clearance (as per Iluka's *PRC 7931: Site Disturbance Clearance Procedure*.
- All vegetation clearance recorded and tracked pre and post the activity.
- Vehicles used existing access tracks.
- Site traffic speed limits signposted and enforced.
- Areas that presented a risk for fauna entrapment were fenced to prevent faunal egress with escape matting provided in the process water dam and fines ponds.
- The overland transfer pipe was located within a shallow trench to delineate the pipeline and better enable leak detection.
- Visual inspections were undertaken of the overland transfer pipeline to detect any leaks.
- All vehicles were inspected during pre-mobilisation to ensure they were free of soil and vegetation (ie seeds).
- Weeds were managed in accordance with the Iluka *PLN1587060: Iluka Mining Trial Weed Management Plan*.

10.2 Hazardous substances management

Storage of hazardous material comprised diesel and other chemicals. The diesel and chemicals were used by the drill rig and any ancillary equipment during construction, mining and backfilling.

Diesel was stored on site in two separate double-skinned bunded fuel cells each with a capacity of 30,000 L. Over the course of the activity, approximately 1.4 million litres of diesel was used.

Chemicals were stored onsite for use by the drill rig and any ancillary equipment (total approximately 15,000 litres).

The following mitigation measures were implemented:

- Hazardous substances were stored in compliance with or exceed regulatory requirements.
- An isolation valve was present on the fuel cell outlets, before the dispensing hose, to enable isolation of tank contents in the event of a leak.
- Spills were managed in accordance with Iluka's hydrocarbon spill kit procedure.
- A copy of Iluka's hydrocarbon spill kit procedure was kept on site at all times.
- Hydrocarbon spill kits and absorbent matting were located on site at the fuel cells, gensets and drill rig.

- Site personnel, including contractors, were inducted in the use of hydrocarbon spill kits.
- Gensets were appropriately bunded.
- Waste hydrocarbon and chemical storage bins were provided onsite.
- Current material safety data sheets (SDSs) were maintained on site for all chemicals, including for the drilling additives.
- Substances no longer required were removed by a licensed waste contractor for off-site disposal at a licensed facility or left in-situ within a bunded area.

10.3 Traffic management

The following mitigation measures were implemented:

- Heavy and over-dimensional vehicles utilised approved routes.
- Private access tracks maintained to ensure safe and efficient access to the activity.
- Heavy vehicle movements were minimised, as far as practicable.

10.4 Weed management

The presence of weed species has the potential to have an impact on revegetation and regeneration outcomes. Additionally, any presence of weed species within the surrounding land has the potential to impact on the biodiversity value of the rehabilitated areas. Weed management is a key component of rehabilitation activities.

Weeds were managed as follows:

- Iluka's *PLN1587060: Mining Trial Weed Management Plan* will be implemented, if required.
- Vehicles, plant and equipment were inspected for cleanliness before entry to the site.
- Inspections of disturbance areas for declared weeds undertaken (during October 2020) and weeds controlled via scalping and chemical spraying.
- Herbicide was applied in accordance with industry best practice.
- Records were maintained of weed infestations and control measures undertaken.

Post-activity weed inspections and monitoring is planned by Iluka in January and April 2021 as part of care and maintenance.

10.5 Environmental management performance – general observation

10.5.1 House keeping

It was observed that excess equipment and site materials were often stored ad-hoc around the site rather than in designated laydown areas. Should further development of the site be undertaken, it is recommended that designated laydown areas be established to ensure all excess materials are stored in appropriate locations as part of general housekeeping to avoid unnecessarily damaging or impact native vegetation (Photograph 10.1 and Photograph 10.2).

Photograph 10.1 Ad-hoc storage of pipework

Photograph 10.2 Ad-hoc storage of equipment

10.5.2 Hazardous substances management

Storage and disposal of hydrocarbon contaminate soil was identified during the activity with a temporary bunded area established during demobilisation (Photograph 10.3). Should further development of the site be undertaken, it is recommended that an appropriately engineered hydrocarbon waste storage area be constructed for storage, treatment and management of material.

Photograph 10.3 Hydrocarbon storage

10.5.3 Traffic management

The Burke and Wills Road and Track 1 were affected by heavy rain events during the activity. Site closure was initiated on occasions due to safety concerns with Iluka making significant improvements to the formation and condition of site access roads during the T3 bulk sampling activity.

10.5.4 Planning permits and approvals

Iluka does not currently have approval to transport HMC offsite and in this regard prior to demobilisation, HMC stockpiles were chemically and physically stabilised to remain on-site during care and maintenance. Should further development of the site be undertaken it is recommended that NSW regulatory approval be sought to transport HMC offsite as early as possible to provide Iluka with flexibility and ensure rehandling of such material onsite does not become a constraint.

10.5.5 Landholder activities

It was observed during the activity that the landowner undertook vegetation clearance for general farming purposes and nominated located for Iluka contractors to park plant and equipment whilst maintaining Track 1. It is recommended that Iluka continue to ensure such instances are documented when they occur to ensure Iluka and / or its contractors are not penalised by regulators for vegetation clearance outside the remit of SSD-5285 approval.

10.5.6 Demobilisation

It was observed that Iluka's demobilisation activities for the T3 bulk sampling activity site have ensured the site has been left in an environmentally safe and stable manner for care and maintenance (Photograph 10.4 and Photograph 10.5).

Photograph 10.4 Activity site pre-demobilisation – looking south-east (20 November 2020)

Photograph 10.5 Activity site pre-demobilisation – looking south (20 November 2020)

11 Conclusion

This EMR has assessed that Iluka have met its environmental compliance requirements in accordance with SSD-5285.

The T3 bulk sampling activity and associated EMP management, mitigation and monitoring measures are considered to have been successfully implemented from an environmental management perspective with the hydrogeological data intended to outcomes to help inform Iluka internal decision making.

General observation outlined in this report are intended to help further improve environmental performance and management plan requirements should Iluka decide to proceed with further development of the site.

Appendix A

Noise monitoring results

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15 July 2020

Lisa McGrath
HSEC Manager
Iluka Resources Limited

Re: Iluka Balranald T3 - monthly compliance noise monitoring, June 2020

Dear Lisa,

1 Introduction

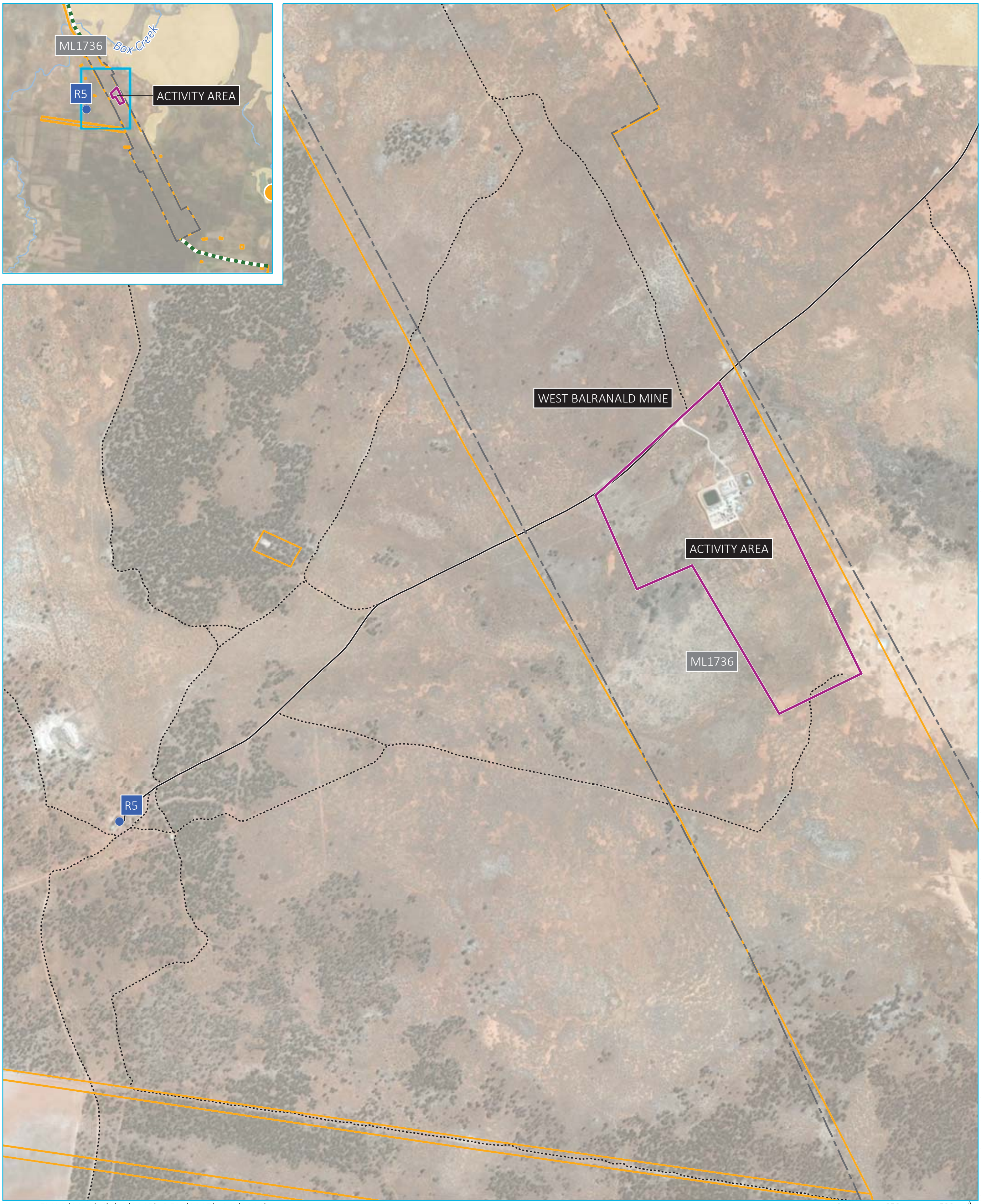
EMM was engaged by Iluka Resources Limited (Iluka) to conduct monthly noise compliance monitoring as part of their T3 mining trial operations at their mineral sands mine (the site) in Balranald, New South Wales.

A site visit was conducted on 24 June 2020 to conduct noise measurements at the nearest residence to site during the day, evening, and night period. This report details the methodology and results from those measurements.

2 Noise compliance assessment

2.1 Assessment locations

To quantify noise emissions from the site operations, 15-minute operator attended measurements were conducted at the nearest residential assessment location, namely the Karra Homestead (R5), located approximately 3 kilometres (km) southwest of the site. The assessment location, in relation to the site, is shown in Figure 2.1.



Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 250 500 m
GDA 1994 MGA Zone 54
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KEY

- Activity area
- Project boundary
- Noise monitoring location
- Access road
- Mining Lease 1736
- Local road
- Vehicular track
- Ephemeral lake

Noise monitoring locations

Iluka Resources Limited
Environmental Management Plan
Figure 2.1

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2.2 Noise limits

As specified in Iluka's Environmental Management Plan (EMP) (EMM 2019), Schedule 3, Condition 3 specifies the site's development consent noise criteria, which is reproduced in Table 2.1.

Table 2.1 Criteria for operational noise

Location	Day	Evening	Night	
	LAeq(15min)	LAeq(15min)	LAeq(15min)	LA1(1min)
All privately-owned land*	35	35	35	45
Mungo National Park and Mungo State Conservation Area	50	50	50	-

Notes:
* For the purpose of Balranald T3, the nearest residential assessment location is Karra Homestead (R5)
1. Day is defined as 7:00am to 6:00pm Monday to Saturday, 8:00am to 6:00 pm Sunday; Evening as 6:00pm to10:00pm; Night as 10:00pm to 7:00am Monday to Saturday, 10:00pm to 8:00am Sunday.

2.3 Instrumentation

All measurements were conducted using a Svantek 977 sound analyser (s/n 59682), which is a class 1 meter as per AS61672.1:2019. The sound analyser was calibrated before and after completion of measurements using a Rion NC74 calibrator (s/n 34372752). No calibration drift was recorded. All instrumentation was within its current manufacturer and NATA calibration period. Calibration certificates for all instrumentation are provided in Appendix A.

2.4 Meteorology

Weather data for the monitoring period was obtained from the Bureau of Meteorology (BoM) Automated Weather Station (AWS) located at Mildura Airport (Station ID 076031), which is 124km from site. These observations were consistent with those noted by the operator at the time of monitoring. Overcast conditions prevailed with large amounts of low-lying fog. Light winds were present during the day period (1.1m/s) from a west-southwesterly direction, and calm (no winds) were present during the evening and night periods.

2.5 Modifying factors

Modifying factor adjustments are required to be applied for noise levels with annoying characteristics such as tonal noise, impulsive noise and low frequency noise. Tonal or impulsive noise are not typical to site operations, in particular when measured at significant distances from site. Furthermore, monitoring data confirmed that tonal or impulsive noise from the site was not present at the nearest residence. Low frequency noise was considered as described below.

Fact Sheet C of the NPfI (EPA 2017) provides guidelines for applying modifying factor adjustments to account for low frequency noise. The NPfI specifies that a difference of 15 dB or more between site 'C-weighted' and site 'A-weighted' noise emission levels indicates the potential for an unbalanced spectrum and potential increased annoyance. Where a difference of 15 dB or more between site 'C-weighted' and site 'A-weighted' noise emission levels has been identified, the one-third octave band centre frequency noise levels recorded has been compared to the values in Table C2 of the NPfI reproduced in Table 2.2.

Table 2.2 One-third octave low-frequency noise thresholds

	One-third octave $L_{Zeq,15min}$ threshold level												
Frequency (Hz)	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160

Table 2.2 One-third octave low-frequency noise thresholds

	One-third octave $L_{Zeq,15min}$ threshold level											
dB (Z)	92	89	86	77	69	61	54	50	50	48	48	46	44

A modifying factor adjustment is to be applied where the site 'C-weighted' less the site 'A-weighted' noise emission level is 15 dB or more and:

- where any of the one-third octave band centre frequency noise levels in Table 2.2 are exceeded by up to and including 5 dB and cannot be mitigated, a 2 dB positive adjustment to measured/predicted A-weighted levels applies for the evening/night period; or

- where any of the one-third octave band centre frequency noise levels in Table 2.2 are exceeded by more than 5 dB and cannot be mitigated, a 5 dB positive adjustment to measured/predicted A-weighted levels applies for the evening/night period and a 2 dB positive adjustment applies for the daytime period.

Hence, where possible throughout each survey the operator has estimated the difference between site 'C-weighted' and site 'A-weighted' noise emission levels by matching audible sounds with the response of the analyser (L_{Ceq}-L_{Aeq}). Where this was deemed to be 15 dB or greater, the measured one-third octave band centre frequencies have been compared to the values in Table 2.2 to identify the relevant modifying factor correction (if applicable). This method has been applied to this assessment as discussed in Section 3.

3 Results

Attended noise monitoring results are presented in Table 3.1.

Site operations were inaudible during the day period measurement at R5. If a noise source is inaudible, it is generally 10 dB below the background (L_{A90}) noise level. Given this and the measured background noise levels, the site's $L_{Aeq\ (15\ min)}$ noise contribution satisfied relevant daytime noise criteria.

Site operations were faintly audible during the evening and night period measurements at R5. Site noise was characterised as a faint rumble, likely caused by drilling and the operation of pumps, compressors and generators. No LFN penalties or other modifying factors were deemed applicable in accordance with Fact Sheet C of the NPfI (EPA 2017). Site noise satisfied relevant $L_{Aeq,15min}$ noise criteria during the evening and night periods.

Maximum noise level (L_{Amax}/$L_{A1(1min)}$) events from site operations were also below (satisfied) the relevant noise criteria of 45 dB during the night period.

Table 3.1 Attended noise monitoring measurement results – 24 June 2020

Monitoring location	Date, start time (period)	Meteorological conditions,	Total noise levels (15-min)				Site contribution		Noise criteria	Exceedance?	Field observations
			L_{Amin}	L_{A90}	$L_{Aeq,15min}$	L_{Amax}	$L_{Aeq,15min}$	$L_{A1(1min)}$ / L_{Amax}	$L_{Aeq,15min}$, L_{A1}		
R5	24/6/2020 11:58am (Day)	1.1 m/s WSW, Overcast	<20	21	33	56	IA	IA	35 n/a	Nil	Site inaudible. Other noise sources included occasional birdsong, livestock (sheep) and distant farming traffic or machinery.
	24/6/2020 9:08pm (Evening)	Calm, Overcast	<20	<20	24	51	<20	20	35 n/a	Nil	Faint rumble of site audible at times. Other noise sources included livestock (sheep).
	25/6/2020 12:45am (Night)	Calm, Overcast	<20	<20	29	54	<20	20	35 45	Nil	Faint rumble of site audible at times. Other noise sources included livestock (sheep).

Notes: 1. Day is defined as 7:00am to 6:00pm Monday to Saturday, 8:00am to 6:00 pm Sunday; Evening as 6:00pm to10:00pm; Night as 10:00pm to 7:00am Monday to Saturday, 10:00pm to 8:00am Sunday.

2. Meteorological conditions stated are as recorded at the Mildura Airport BoM AWS, wind speeds were recorded at 10 m AGL.

3. For assessment purposes the L_{Amax} and the $L_{A1(1-min)}$ are interchangeable.

4 Conclusion

EMM has completed a review of operational noise from the Iluka Balranald T3 mine site for June 2020.

Attended noise monitoring was conducted during the day, evening and night periods on 24 June 2020.

Attended noise monitoring observations and results demonstrate that operational noise from the Balranald T3 mine site was inaudible during the day period measurement at R5. If a noise source is inaudible, it is generally 10 dB below the background (L_{A90}) noise level. The mine site operations were audible during all other measurements and site noise contributions were below (satisfied) the relevant noise criteria.

Further, maximum noise level (L_{Amax}/$L_{A1(1min)}$) events from site operations were also below (satisfied) the relevant noise criterion during the night period.

In summary, the measured noise contribution of the Iluka's Balranald T3 mine site was found to satisfy all relevant noise criteria for all measurements conducted at R5, the closest residence to the current activities conducted at site. Hence, site noise contributions are found to be compliant at all residences in the area.

Yours sincerely

Rick Scully
Acoustic Consultant
rscully@emmconsulting.com.au

Review: NI 14/7/20

Appendix A

Calibration certificates

CERTIFICATE OF CALIBRATION

CERTIFICATE NO.: **SLM 23713 & FILT 4907**

Equipment Description:	Sound & Vibration Analyser		
Manufacturer:	Svantek		
Model No:	Svan-977	**Serial No:**	59682
Microphone Type:	7052E	**Serial No:**	69609
Preamplifier Type:	SV12L	**Serial No:**	64882
Filter Type:	1/1 Octave	**Serial No:**	59682
Comments:	All tests passed for class 1. (See over for details)		
Owner:	EMM Consulting Suite 01, 20 Chandos Street St Leonards NSW 2065		
Ambient Pressure:	1001 hPa ±1.5 hPa		
Temperature:	24 °C ±2° C	**Relative Humidity:**	58% ±5%
Date of Calibration:	23/10/2018	**Issue Date:**	23/10/2018
Acu-Vib Test Procedure:	AVP10 (SLM) & AVP06 (Filters)		

CHECKED BY: ..JK.... **AUTHORISED SIGNATURE:** .... Jack Kielt

Accredited for compliance with ISO/IEC 17025 - Calibration
The results of the tests, calibration and/or measurements included in this document are traceable to Australian/national standards.

NATA WORLD RECOGNISED ACCREDITATION

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Accredited Lab. No. 9262
Acoustic and Vibration Measurements

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: 26415

EQUIPMENT TESTED: Sound Level Calibrator

Manufacturer: Rion
Type No: NC-74 **Serial No:** 34372752
Owner: EMM Consulting
20 Chandos Street
St Leonards NSW 2065

Tests Performed: Measured output pressure level was found to be:

Parameter	Pre-Adj	Adj Y/N	Output: (db re 20 µPa)	Frequency: (Hz)	THD&N (%)
Level 1:	NA	N	94.16	1002.63	4.47
Level 2:	NA	N	NA	NA	NA
Uncertainty:			±0.11 dB	±0.05%	±0.20 %
Uncertainty (at 95% c.l.) k=2					

CONDITION OF TEST:
Ambient Pressure: 1002 hPa ±1.5 hPa **Relative Humidity:** 56% ±5%
Temperature: 24 °C ±2° C
Date of Calibration: 21/02/2020 **Issue Date:** 24/02/2020
Acu-Vib Test Procedure: AVP02 (Calibrators)
Test Method: AS IEC 60942 - 2017
CHECKED BY: MB. **AUTHORISED SIGNATURE:** ....
Jack Kielt

.Accredited for compliance with ISO/IEC 17025 - Calibration
The results of the tests, calibration and/or measurements included in this document are traceable to Australian/national standards.
The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

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5 August 2020

Lisa McGrath
HSEC Manager
Iluka Resources Limited

Re: Iluka Balranald T3 - monthly compliance noise monitoring, July 2020

Dear Lisa,

1 Introduction

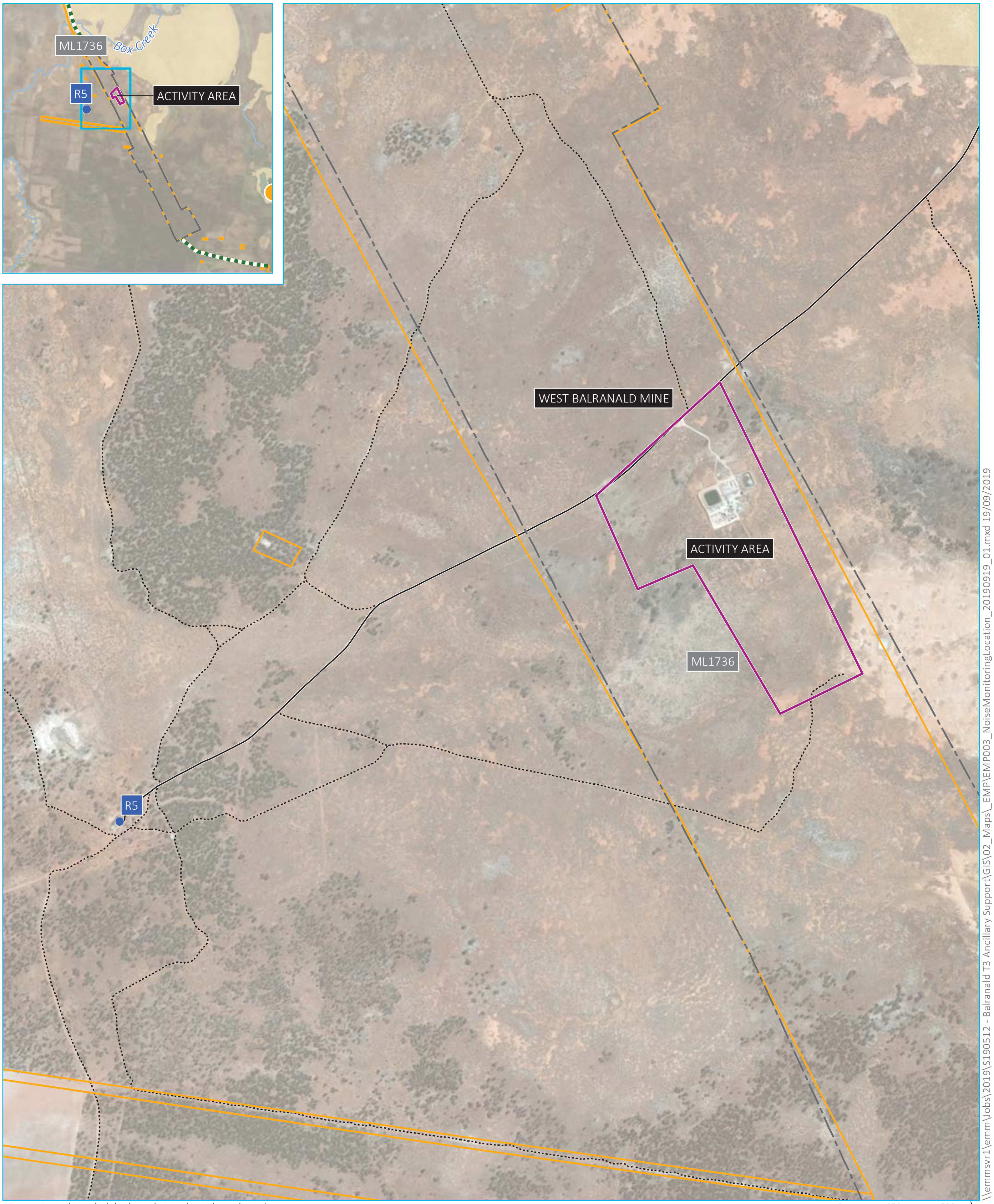
EMM was engaged by Iluka Resources Limited (Iluka) to conduct monthly noise compliance monitoring as part of their T3 mining trial operations at their mineral sands mine (the site) in Balranald, NSW.

A site visit was conducted on 22 July 2020 to conduct noise measurements at the nearest residence to site during the day, evening, and night period. This report details the methodology and results from those measurements.

2 Noise compliance assessment

2.1 Assessment locations

To quantify noise emissions from the site operations, 15-minute operator attended measurements were conducted at the nearest residential assessment location, namely the Karra Homestead (R5), located approximately 3km southwest of the site. The assessment location, in relation to the site, is shown in Figure 2.1.



Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

KEY

- Activity area
- Project boundary
- Noise monitoring location
- Access road
- Mining Lease 1736
- Local road
- Vehicular track
- Ephemeral lake

Noise monitoring locations

Iluka Resources Limited
Environmental Management Plan
Figure 2.1

creating opportunities

2.2 Noise limits

As specified in Iluka's Environmental Management Plan (EMP) (EMM 2019), and Schedule 3, Condition 3 of the development consent, noise limits are reproduced in Table 2.1.

Table 2.1 Limits for operational noise

Location	Day	Evening	Night	
	LAeq(15min)	LAeq(15min)	LAeq(15min)	LA1(1min)
All privately-owned land*	35	35	35	45
Mungo National Park and Mungo State Conservation Area	50	50	50	-

Notes:
* For the purpose of Balranald T3, the nearest residential assessment location is Karra Homestead (R5)
1. Day is defined as 7:00am to 6:00pm Monday to Saturday, 8:00am to 6:00 pm Sunday; Evening as 6:00pm to10:00pm; Night as 10:00pm to 7:00am Monday to Saturday, 10:00pm to 8:00am Sunday.
2. Measurements are to be taken at the reasonably most-affected point on or within the residential property boundary or, if that is more than 30 metres from the residence, at the reasonably most-affected point within 30 metres of the residence.

2.3 Instrumentation

All measurements were conducted using a Svantek 977 sound analyser (s/n 59682), which is a class 1 meter as per AS61672.1:2019. The sound analyser was calibrated before and after completion of measurements using a Svantek SV36 calibrator (s/n 86311). No calibration drift was recorded. All instrumentation was within its current manufacturer and NATA calibration period. Calibration certificates for all instrumentation are provided in Appendix A.

2.4 Meteorology

Weather data for the monitoring period was obtained from the Bureau of Meteorology (BoM) Automated Weather Station (AWS) located at Mildura Airport (Station ID 076031), which is 124km from site. These data were consistent with observations noted by the operator at the time of monitoring using a handheld wind anemometer. Overcast conditions prevailed with large amounts of low-lying fog. Light winds were present during the day and evening periods (up to 3m/s) from a south-easterly direction, and calm (no winds) were present during the night period.

2.5 Modifying factors

Modifying factor adjustments are required to be applied for noise levels with annoying characteristics such as tonal noise, impulsive noise and low frequency noise. Tonal or impulsive noise are not typical to site operations, in particular when measured at significant distances from site (eg at R5). Furthermore, monitoring data confirmed that tonal or impulsive noise from the site was not present at the nearest residence. Low frequency noise was considered as described below.

Fact Sheet C of the NPfI (EPA 2017) provides guidelines for applying modifying factor adjustments to account for low frequency noise. The NPfI specifies that a difference of 15 dB or more between site 'C-weighted' and site 'A-weighted' noise emission levels indicates the potential for an unbalanced spectrum and potential increased annoyance. Where a difference of 15 dB or more between site 'C-weighted' and site 'A-weighted' noise emission levels has been identified, the one-third octave band centre frequency noise levels recorded has been compared to the values in Table C2 of the NPfI reproduced in Table 2.2.

Table 2.2 One-third octave low-frequency noise thresholds

	One-third octave $L_{Zeq,15min}$ threshold level												
Frequency (Hz)	**10**	**12.5**	**16**	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**
dB (Z)	92	89	86	77	69	61	54	50	50	48	48	46	44

A modifying factor adjustment is to be applied where the site 'C-weighted' less the site 'A-weighted' noise emission level is 15 dB or more and:

- where any of the one-third octave band centre frequency noise levels in Table 2.2 are exceeded by up to and including 5 dB and cannot be mitigated, a 2 dB positive adjustment to measured/predicted A-weighted levels applies for the evening/night period; or

- where any of the one-third octave band centre frequency noise levels in Table 2.2 are exceeded by more than 5 dB and cannot be mitigated, a 5 dB positive adjustment to measured/predicted A-weighted levels applies for the evening/night period and a 2 dB positive adjustment applies for the daytime period.

Hence, where possible throughout each survey the operator has estimated the difference between site 'C-weighted' and site 'A-weighted' noise emission levels by matching audible sounds with the response of the analyser (L_{Ceq}-L_{Aeq}). Where this was deemed to be 15 dB or greater, the measured one-third octave band centre frequencies have been compared to the values in Table 2.2 to identify the relevant modifying factor correction (if applicable). This method has been applied to this assessment as discussed in Section 3.

3 Results

Attended noise monitoring results are presented in Table 3.1.

Site operations were inaudible during the day period measurement at R5. If a noise source is inaudible, it is generally 10 dB below the background (L_{A90}) noise level. Given this and the measured background noise levels, the site's $L_{Aeq\ (15\ min)}$ noise contribution satisfied relevant daytime noise criteria.

Site operations were faintly audible during the evening and night period measurements at R5. Site noise was characterised as a faint rumble, likely caused by drilling and the operation of pumps, compressors and generators. No LFN penalties or other modifying factors were deemed applicable in accordance with Fact Sheet C of the NPfI (EPA 2017). Site noise satisfied relevant $L_{Aeq,15min}$ noise limits during the evening and night periods.

Maximum noise level (L_{Amax}/$L_{A1(1min)}$) events from site operations were also below (satisfied) the relevant noise limit of 45 dB during the night period.

Table 3.1 Attended noise monitoring measurement results – 22 July 2020

Monitoring location	Date, start time (period)	Meteorological conditions	Total noise levels (15-min)				Site contribution		Noise criteria	Exceedance?	Field observations
			L_{Amin}	L_{A90}	$L_{Aeq,15min}$	L_{Amax}	$L_{Aeq,15min}$	$L_{A1(1min)}$ / L_{Amax}	$L_{Aeq,15min}$, L_{A1}		
R5	22/6/2020 12:15pm (Day)	2-3 m/s SE, Clear	29	33	36	52	IA	IA	35 n/a	Nil	Site inaudible. Other noise sources included bore pump at homestead, occasional birdsong, livestock (sheep), dog barking, resident calling out and wind gusts rustling nearby flora.
	22/7/2020 8:20pm (Evening)	1-2 m/s SE, Overcast	<20	<20	21	39	<20	<22	35 n/a	Nil	Faint rumble of site audible at times from generators and drill rig operations. Other noise sources included livestock (sheep) and occasional birdsong.
	22/7/2020 10:20pm (Night)	Calm, Overcast	<20	<20	22	40	<20	<22	35 45	Nil	Faint rumble of site audible at times from generators and drill rig operations. No other noise sources were recorded.

Notes:
1. Day is defined as 7:00am to 6:00pm Monday to Saturday, 8:00am to 6:00 pm Sunday; Evening as 6:00pm to10:00pm; Night as 10:00pm to 7:00am Monday to Saturday, 10:00pm to 8:00am Sunday.
2. Meteorological conditions stated are as recorded at the Mildura Airport BoM AWS, wind speeds were recorded at 10 m AGL.
3. For assessment purposes the L_{Amax} and the $L_{A1(1-min)}$ are interchangeable.

4 Conclusion

EMM has completed a review of operational noise from the Iluka Balranald T3 mine site for July 2020.

Attended noise monitoring was conducted during the day, evening and night periods on 22 July 2020 to assess compliance with the development consent.

Attended noise monitoring observations and results demonstrate that operational noise from the Balranald T3 mine site was inaudible during the day period measurement at R5. If a noise source is inaudible, it is generally 10 dB below the background (L_{A90}) noise level. The mine site operations were audible during all other measurements and site noise contributions were below (satisfied) the relevant noise limits.

Further, maximum noise level (L_{Amax}/$L_{A1(1min)}$) events from site operations were also below (satisfied) the relevant noise criterion during the night period.

In summary, the measured noise contribution of Iluka's Balranald T3 mine site was found to satisfy all relevant noise limits for all measurements conducted at R5, the closest residence to the current activities conducted at site. Hence, site noise contributions are found to be compliant at all residences in the area.

Yours sincerely

Rick Scully
Acoustic Consultant
rscully@emmconsulting.com.au

Review: NI 4/08/2020

Appendix A

Calibration certificates

CERTIFICATE OF CALIBRATION

CERTIFICATE NO.: **SLM 25410 & FILT 5368**

Equipment Description:	Sound Level Meter		
Manufacturer:	B & K		
Model No:	2250	**Serial No:**	3008201
Microphone Type:	B&K 4189	**Serial No:**	2983733
Preamplifier Type:	B&K ZC0032	**Serial No:**	22666
Filter Type:	1/3 Octave	**Serial No:**	3008201
Comments:	All tests passed for class 1. (See over for details)		
Owner:	EMM Consulting Ground Floor, Suite 01, 20 Chandos St St Leonards NSW 2065		
Ambient Pressure:	1002 hPa ±1.5 hPa		
Temperature:	23 °C ±2° C	**Relative Humidity:**	29% ±5%
Date of Calibration:	21/08/2019	**Issue Date:**	21/08/2019
Acu-Vib Test Procedure:	AVP10 (SLM) & AVP06 (Filters)		

CHECKED BY: KB **AUTHORISED SIGNATURE:** ....
Hein Soe

Accredited for compliance with ISO/IEC 17025 - Calibration
The results of the tests, calibration and/or measurements included in this document are traceable to Australian/national standards.

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Accredited Lab. No. 9262
Acoustic and Vibration Measurements

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: 25666

EQUIPMENT TESTED: Sound Level Calibrator

Manufacturer: Svantek
Type No: SV-36 **Serial No:** 86311
Owner: EMM Consulting
Ground Floor, Suite 01, 20 Chandos St
St Leonards NSW 2065

Tests Performed: Measured output pressure level was found to be:

Parameter	Pre-Adj	Adj Y/N	Output: (db re 20 µPa)	Frequency: (Hz)	THD&N (%)
Level 1:	NA	N	94.09	999.99	0.89
Level 2:	NA	N	114.05	1000.00	0.32
Uncertainty:			±0.11 dB	±0.05%	±0.20 %
Uncertainty (at 95% c.l.) k=2					

CONDITION OF TEST:
Ambient Pressure: 1004 hPa ±1.5 hPa **Relative Humidity:** 36% ±5%
Temperature: 25 °C ±2° C
Date of Calibration: 04/10/2019 **Issue Date:** 08/10/2019
Acu-Vib Test Procedure: AVP02 (Calibrators)
Test Method: AS IEC 60942 - 2017

CHECKED BY: VKB **AUTHORISED SIGNATURE:** ....
Hein Soe

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The results of the tests, calibration and/or measurements included in this document are traceable to Australian/national standards.
The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

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14 September 2020

Lisa McGrath
HSEC Manager
Iluka Resources Limited

Re: Iluka Balranald T3 - monthly compliance noise monitoring, August 2020

Dear Lisa,

1 Introduction

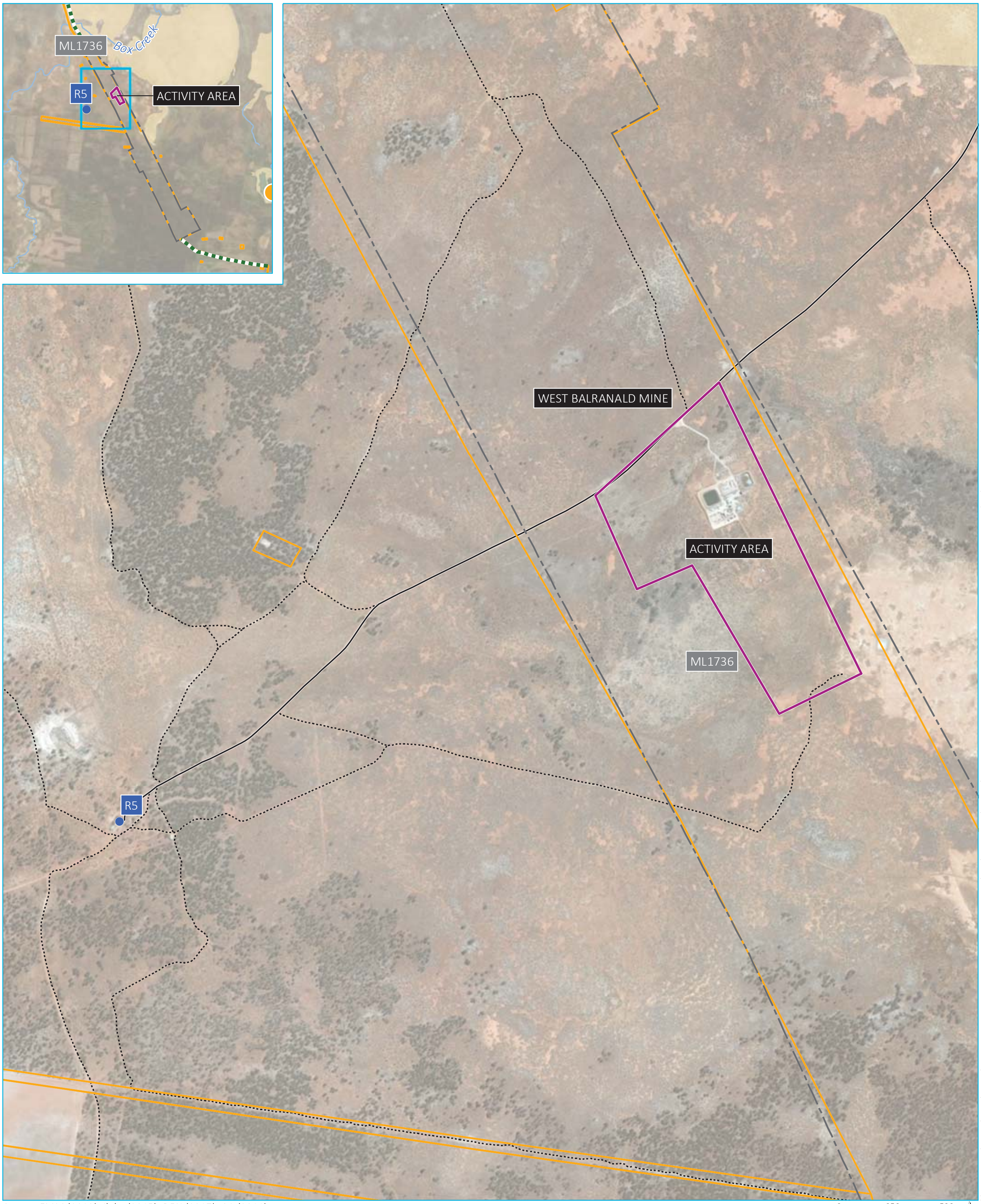
EMM was engaged by Iluka Resources Limited (Iluka) to conduct monthly noise compliance monitoring as part of their T3 mining trial operations at their mineral sands mine (the site) in Balranald, NSW.

A site visit was conducted on 26 August 2020 to conduct noise measurements at the nearest residence to site during the day, evening, and night period. This report details the methodology and results from those measurements.

2 Noise compliance assessment

2.1 Assessment locations

To quantify noise emissions from the site operations, 15-minute operator attended measurements were conducted at the nearest residential assessment location, namely the Karra Homestead (R5), located approximately 3km southwest of the site. The assessment location, in relation to the site, is shown in Figure 2.1.



\\emmsvr1\emm\Jobs\2019\S190512 - Balranald T3 Ancillary Support\GIS\02_Maps_EMP\EMP003_NoiseMonitoringLocation_20190919_01.mxd 19/09/2019

Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 250 500 m
GDA 1994 MGA Zone 54
N

KEY

- Activity area
- Project boundary
- Noise monitoring location
- Access road
- Mining Lease 1736
- Local road
- Vehicular track
- Ephemeral lake

Noise monitoring locations

Iluka Resources Limited
Environmental Management Plan
Figure 2.1

EMM creating opportunities

2.2 Noise limits

As specified in Iluka's Environmental Management Plan (EMP) (EMM 2019), and Schedule 3, Condition 3 of the development consent, noise limits are reproduced in Table 2.1.

Table 2.1 Limits for operational noise

Location	Day	Evening	Night	
	LAeq(15min)	LAeq(15min)	LAeq(15min)	LA1(1min)
All privately-owned land*	35	35	35	45
Mungo National Park and Mungo State Conservation Area	50	50	50	-

Notes:
* For the purpose of Balranald T3, the nearest residential assessment location is Karra Homestead (R5)
1. Day is defined as 7:00am to 6:00pm Monday to Saturday, 8:00am to 6:00 pm Sunday; Evening as 6:00pm to10:00pm; Night as 10:00pm to 7:00am Monday to Saturday, 10:00pm to 8:00am Sunday.
2. Measurements are to be taken at the reasonably most-affected point on or within the residential property boundary or, if that is more than 30 metres from the residence, at the reasonably most-affected point within 30 metres of the residence.

2.3 Instrumentation

All measurements were conducted using a Svantek 977 sound analyser (s/n 59682), which is a class 1 meter as per AS61672.1:2019. The sound analyser was calibrated before and after completion of measurements using a Rion NC74 calibrator (s/n 34372752). No calibration drift was recorded. All instrumentation was within its current manufacturer and NATA calibration period. Calibration certificates for all instrumentation are provided in Appendix A.

2.4 Meteorology

Weather data for the monitoring period was obtained from the Bureau of Meteorology (BoM) Automated Weather Station (AWS) located at Mildura Airport (Station ID 076031), which is 124km from site. These data were consistent with observations noted by the operator at the time of monitoring using a handheld wind anemometer. Clear conditions prevailed throughout all measurement periods. Light winds were present during the day periods (up to 3m/s) from a north-westerly direction, and calm (no winds) were present during the evening and night periods.

2.5 Modifying factors

Modifying factor adjustments are required to be applied for noise levels with annoying characteristics such as tonal noise, impulsive noise and low frequency noise. Tonal or impulsive noise are not typical to site operations, in particular when measured at significant distances from site (eg at R5). Furthermore, monitoring data confirmed that tonal or impulsive noise from the site was not present at the nearest residence. Low frequency noise was considered as described below.

Fact Sheet C of the NPfI (EPA 2017) provides guidelines for applying modifying factor adjustments to account for low frequency noise. The NPfI specifies that a difference of 15 dB or more between site 'C-weighted' and site 'A-weighted' noise emission levels indicates the potential for an unbalanced spectrum and potential increased annoyance. Where a difference of 15 dB or more between site 'C-weighted' and site 'A-weighted' noise emission levels has been identified, the one-third octave band centre frequency noise levels recorded has been compared to the values in Table C2 of the NPfI reproduced in Table 2.2.

Table 2.2 One-third octave low-frequency noise thresholds

	One-third octave $L_{Zeq,15min}$ threshold level												
Frequency (Hz)	**10**	**12.5**	**16**	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**
dB (Z)	92	89	86	77	69	61	54	50	50	48	48	46	44

A modifying factor adjustment is to be applied where the site 'C-weighted' less the site 'A-weighted' noise emission level is 15 dB or more and:

- where any of the one-third octave band centre frequency noise levels in Table 2.2 are exceeded by up to and including 5 dB and cannot be mitigated, a 2 dB positive adjustment to measured/predicted A-weighted levels applies for the evening/night period; or

- where any of the one-third octave band centre frequency noise levels in Table 2.2 are exceeded by more than 5 dB and cannot be mitigated, a 5 dB positive adjustment to measured/predicted A-weighted levels applies for the evening/night period and a 2 dB positive adjustment applies for the daytime period.

Hence, where possible throughout each survey the operator has estimated the difference between site 'C-weighted' and site 'A-weighted' noise emission levels by matching audible sounds with the response of the analyser (L_{Ceq}-L_{Aeq}). Where this was deemed to be 15 dB or greater, the measured one-third octave band centre frequencies have been compared to the values in Table 2.2 to identify the relevant modifying factor correction (if applicable). This method has been applied to this assessment as discussed in Section 3.

3 Results

Attended noise monitoring results are presented in Table 3.1.

Site operations were faintly audible during the day and evening period measurements. Site noise was characterised as a faint rumble, likely caused by drilling and the operation of pumps, compressors and generators. No LFN penalties or other modifying factors were deemed applicable in accordance with Fact Sheet C of the NPfI (EPA 2017).

Site noise satisfied relevant $L_{Aeq,15min}$ noise limits during the day and evening periods. Maximum noise level (L_{Amax}/$L_{A1(1min)}$) events from site operations were also below (satisfied) the relevant noise limit of 45 dB during the night period.

It is of note that an existing bore water pump and generator operate at the Karra homestead property (ie outside the Site boundary). This equipment was installed by Iluka on 27 November 2013 [60WA583168] to be used for the homestead and the exploration / mining related activities and hence benefit both. This plant will be left for the homestead post mining as per the terms of the land access agreement between the homestead owners and Iluka. During each 15-minute monitoring period, the bore water pump and associated generator would operate for approximately 3 minutes to provide make up water for mining operations. This contribution to noise at the homestead was removed from the analysis of compliance.

Table 3.1 Attended noise measurement results – 26 August 2020

Monitoring location	Date, start time (period)	Meteorological conditions	Total noise levels (15-min)				Site contribution		Noise criteria	Exceedance?	Field observations
			L_{Amin}	L_{A90}	$L_{Aeq,15min}$	L_{Amax}	$L_{Aeq,15min}$	$L_{A1(1min)}$ / L_{Amax}	$L_{Aeq,15min}$, L_{A1}		
R5	26/08/2020 9:17am (Day)	2-3 m/s NW, Clear skies	20	21	35	62	21	22	35 n/a	Nil	Faint rumble of site audible at times from the compressors, generators and drill rig operations. Other noise sources included the bore pump at Karra homestead, occasional birdsong, grinding in Karra shearing shed, vehicle pass-by and a dog barking.
	26/08/2020 7:47pm (Evening)	Calm, Clear skies	22	24	36	69	23	25	35 n/a	Nil	Faint rumble of site audible at times from compressors, generators and drill rig operations. Other noise sources included livestock (sheep), vehicle idling at Karra shearing shed, noise from Karra shearing shed, insects, an owl "hooting" in distance and the bore pump at Karra homestead.
	26/08/2020 10:01pm (Night)	Calm, Clear skies	24	27	37	49	26	30	35 45	Nil	Rumble of site audible throughout measurement and dominant at times from the compressors, generators and drill rig operations. Other noise sources included insects and the bore pump at Karra homestead.

Notes:
1. Day is defined as 7:00am to 6:00pm Monday to Saturday, 8:00am to 6:00 pm Sunday; Evening as 6:00pm to10:00pm; Night as 10:00pm to 7:00am Monday to Saturday, 10:00pm to 8:00am Sunday.
2. Meteorological conditions stated are as recorded at the Mildura Airport BoM AWS, wind speeds were recorded at 10 m AGL.
3. For assessment purposes the L_{Amax} and the $L_{A1(1-min)}$ are interchangeable.

4 Conclusion

EMM has completed a review of operational noise from the Iluka Balranald T3 mine site for August 2020.

Attended noise monitoring was conducted during the day, evening and night periods on 26 August 2020 to assess compliance with the development consent.

Attended noise monitoring observations and results demonstrate that operational noise from the Balranald T3 mine site was faintly audible during the day and evening period measurements at R5. The mine site operations were clearly audible and at times dominant during the night period measurements. Site noise contributions were below (satisfied) the relevant noise limits for all measurement periods.

In summary, the measured noise contribution of Iluka's Balranald T3 mine site was found to satisfy all relevant noise limits for all measurements conducted at R5, the closest residence to the current activities conducted at site. Hence, site noise contributions are found to be compliant at all residences in the area.

Yours sincerely

Rick Scully
Acoustic Consultant
rscully@emmconsulting.com.au

Review: NI 14/09/2020

Appendix A

Calibration certificates

CERTIFICATE OF CALIBRATION

CERTIFICATE NO.: SLM 23713 & FILT 4907

Equipment Description:	Sound & Vibration Analyser		
Manufacturer:	Svantek		
Model No:	Svan-977	**Serial No:**	59682
Microphone Type:	7052E	**Serial No:**	69609
Preamplifier Type:	SV12L	**Serial No:**	64882
Filter Type:	1/1 Octave	**Serial No:**	59682
Comments:	All tests passed for class 1. (See over for details)		
Owner:	EMM Consulting Suite 01, 20 Chandos Street St Leonards NSW 2065		
Ambient Pressure:	1001 hPa ±1.5 hPa		
Temperature:	24 °C ±2° C	**Relative Humidity:**	58% ±5%
Date of Calibration:	23/10/2018	**Issue Date:**	23/10/2018
Acu-Vib Test Procedure:	AVP10 (SLM) & AVP06 (Filters)		

CHECKED BY: .... **AUTHORISED SIGNATURE:** ....
Jack Kielt

Accredited for compliance with ISO/IEC 17025 - Calibration
The results of the tests, calibration and/or measurements included in this document are traceable to Australian/national standards.

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ACU-VIB ELECTRONICS

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web site: www.acu-vib.com.au

Accredited Lab. No. 9262
Acoustic and Vibration Measurements

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: 26415

EQUIPMENT TESTED: Sound Level Calibrator

Manufacturer: Rion
Type No: NC-74 **Serial No:** 34372752
Owner: EMM Consulting
20 Chandos Street
St Leonards NSW 2065

Tests Performed: Measured output pressure level was found to be:

Parameter	Pre-Adj	Adj Y/N	Output: (db re 20 µPa)	Frequency: (Hz)	THD&N (%)
Level 1:	NA	N	94.16	1002.63	4.47
Level 2:	NA	N	NA	NA	NA
Uncertainty:			±0.11 dB	±0.05%	±0.20 %
Uncertainty (at 95% c.l.) k=2					

CONDITION OF TEST:
Ambient Pressure: 1002 hPa ±1.5 hPa **Relative Humidity:** 56% ±5%
Temperature: 24 °C ±2° C
Date of Calibration: 21/02/2020 **Issue Date:** 24/02/2020
Acu-Vib Test Procedure: AVP02 (Calibrators)
Test Method: AS IEC 60942 - 2017
CHECKED BY: MB. **AUTHORISED SIGNATURE:** ....
Jack Kielt

.Accredited for compliance with ISO/IEC 17025 - Calibration
The results of the tests, calibration and/or measurements included in this document are traceable to Australian/national standards.
The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

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9 October 2020

Lisa McGrath
HSEC Manager
Iluka Resources Limited

Re: Iluka Balranald T3 - monthly compliance noise monitoring, September 2020

Dear Lisa,

1 Introduction

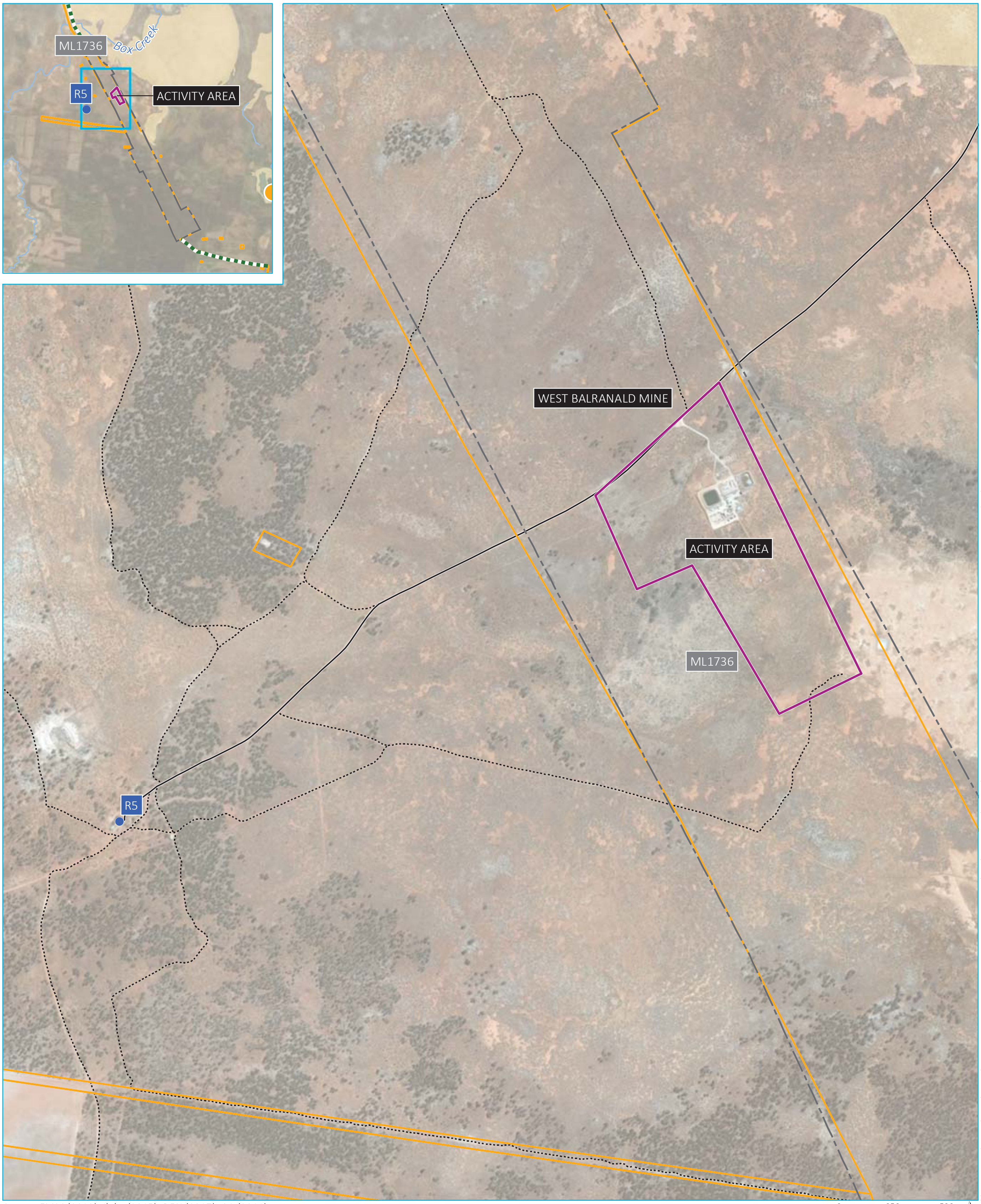
EMM was engaged by Iluka Resources Limited (Iluka) to conduct monthly noise compliance monitoring as part of their T3 mining trial operations at their mineral sands mine (the site) in Balranald, NSW.

A site visit was conducted on 23 September 2020 to measure noise at the nearest residence to site during the day, evening, and night period. This report details the methodology and results from the noise measurements.

2 Noise compliance assessment

2.1 Assessment locations

To quantify noise emissions from the site operations, 15-minute operator attended measurements were conducted at the nearest residential assessment location, namely the Karra Homestead (R5), located approximately 3km southwest of the site. The assessment location, in relation to the site, is shown in Figure 2.1.



Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 250 500 m
GDA 1994 MGA Zone 54
N

\\emmsvr1\emm\Jobs\2019\S190512 - Balranald T3 Ancillary Support\GIS\02_Maps_EMP\EMP003_NoiseMonitoringLocation_20190919_01.mxd 19/09/2019

KEY

- Activity area
- Project boundary
- Noise monitoring location
- Access road
- Mining Lease 1736
- Local road
- Vehicular track
- Ephemeral lake

Noise monitoring locations

Iluka Resources Limited
Environmental Management Plan
Figure 2.1

EMM
creating opportunities

2.2 Noise limits

As specified in Iluka's Environmental Management Plan (EMP) (EMM 2019), and Schedule 3, Condition 3 of the development consent, noise limits are reproduced in Table 2.1.

Table 2.1 Limits for operational noise

Location	Day	Evening	Night	
	LAeq(15min)	LAeq(15min)	LAeq(15min)	LA1(1min)
All privately-owned land*	35	35	35	45
Mungo National Park and Mungo State Conservation Area	50	50	50	-

Notes:
* For the purpose of Balranald T3, the nearest residential assessment location is Karra Homestead (R5)
1. Day is defined as 7:00am to 6:00pm Monday to Saturday, 8:00am to 6:00 pm Sunday; Evening as 6:00pm to10:00pm; Night as 10:00pm to 7:00am Monday to Saturday, 10:00pm to 8:00am Sunday.
2. Measurements are to be taken at the reasonably most-affected point on or within the residential property boundary or, if that is more than 30 metres from the residence, at the reasonably most-affected point within 30 metres of the residence.

2.3 Instrumentation

All measurements were conducted using a Svantek 977 sound analyser (s/n 59682), which is a Class 1 meter as defined in AS61672.1:2019. The sound analyser was calibrated before and after completion of measurements using a Svantek SV36 calibrator (s/n 86311). No calibration drift was observed. All instrumentation was within its current manufacturer and NATA calibration period. Calibration certificates for all instrumentation are provided in Appendix A.

2.4 Meteorology

Weather data for the monitoring period was obtained from the Bureau of Meteorology (BoM) Automated Weather Station (AWS) located at Mildura Airport (Station ID 076031), which is 124km from site. The recorded AWS data was generally consistent with observations noted by the operator at the time of monitoring using a handheld wind anemometer. Clear conditions prevailed throughout all measurement periods. Light winds were present during the day, evening and night periods (up to 2.8m/s) from a north-westerly direction.

2.5 Modifying factors

Modifying factor adjustments are required to be applied for noise levels with annoying characteristics such as tonal, impulsive and low frequency noise. Tonal or impulsive noise are not typical to site operations, in particular when measured at significant distances from site (eg at R5). Furthermore, monitoring data confirmed that tonal or impulsive noise from the site was not present at the nearest residence. Low frequency noise was considered as described below.

Fact Sheet C of the NPfI (EPA 2017) provides guidelines for applying modifying factor adjustments to account for low frequency noise. The NPfI specifies that a difference of 15 dB or more between site 'C-weighted' and site 'A-weighted' noise emission levels indicates the potential for an unbalanced spectrum and potential increased annoyance. Where a difference of 15 dB or more between site 'C-weighted' and site 'A-weighted' noise emission levels has been identified, the one-third octave band centre frequency noise levels recorded has been compared to the values in Table C2 of the NPfI reproduced in Table 2.2.

Table 2.2 One-third octave low-frequency noise thresholds

	One-third octave $L_{Zeq,15min}$ threshold level											
Frequency (Hz)	**10**	**12.5**	**16**	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**
dB (Z)	92	89	86	77	69	61	54	50	50	48	48	46	44

A modifying factor adjustment is to be applied where the site 'C-weighted' less the site 'A-weighted' noise emission level is 15 dB or more and:

- where any of the one-third octave band centre frequency noise levels in Table 2.2 are exceeded by up to and including 5 dB and cannot be mitigated, a 2 dB positive adjustment to measured/predicted A-weighted levels applies for the evening/night period; or
- where any of the one-third octave band centre frequency noise levels in Table 2.2 are exceeded by more than 5 dB and cannot be mitigated, a 5 dB positive adjustment to measured/predicted A-weighted levels applies for the evening/night period and a 2 dB positive adjustment applies for the daytime period.

Hence, where possible throughout each survey the operator has estimated the difference between site 'C-weighted' and site 'A-weighted' noise emission levels by matching audible sounds with the response of the analyser (L_{Ceq}-L_{Aeq}). Where this was deemed to be 15 dB or greater, the measured one-third octave band centre frequencies have been compared to the values in Table 2.2 to identify the relevant modifying factor correction (if applicable). This method has been applied to this assessment as discussed in Section 3.

3 Results

Attended noise monitoring results are presented in Table 3.1.

Site operations were inaudible during the day and night period measurements. If a noise source is inaudible, it is generally 10 dB below the background (L_{A90}) noise level. Given this and the measured background noise levels, the site's $L_{Aeq,15min}$ noise contribution would have satisfied relevant noise criteria.

Site operations were audible during the evening period measurement. Site noise was characterised as a faint rumble, likely caused by drilling and the operation of pumps, compressors and generators. No LFN penalties or other modifying factors were deemed applicable in accordance with Fact Sheet C of the NPfI (EPA 2017). The measured site noise level satisfied the relevant $L_{Aeq,15min}$ noise limits during the night period. Maximum noise level (L_{Amax}/$L_{A1(1min)}$) events from site operations also satisfied the relevant noise limit of 45 dB during the night period.

It is of note that an existing bore water pump and generator operate at the Karra homestead property (ie outside the Iluka site boundary). This equipment was installed by Iluka on 27 November 2013 [60WA583168] for the use of the homestead and the exploration / mining related activities, and hence providing a benefit for both. This plant will be left for the homestead post mining as per the terms of the land access agreement between the homestead owners and Iluka. During each 15-minute monitoring period, the bore water pump and associated generator would operate for approximately 3 minutes to provide make up water for mining operations. This contribution to noise at the homestead was removed from the analysis of compliance.

Table 3.1 Attended noise measurement results – 23 September 2020

Monitoring location	Date, start time (period)	Meteorological conditions	Total noise levels (15-min)				Site contribution		Noise criteria	Exceedance?	Field observations
			L_{Amin}	L_{A90}	$L_{Aeq,15min}$	L_{Amax}	$L_{Aeq,15min}$	$L_{A1(1min)}$ / L_{Amax}	$L_{Aeq,15min}$, L_{A1}		
R5	23/09/2020 9:13am (Day)	1.5-2.8 m/s NW, Clear skies	30	34	41	59	IA	IA	35 n/a	Nil	Site inaudible. Other noise sources included the bore pump at Karra homestead, occasional birdsong, wind rustling leaves/vegetation and plastic liner flapping at homestead.
	23/09/2020 8:13pm (Evening)	0.5-1.5 m/s NW, Clear skies	19	19	30	52	20	23	35 n/a	Nil	Faint rumble of site audible at times from compressors, generators and drill rig operations. Other noise sources included the bore pump at Karra homestead, occasional birdsong, wind rustling leaves/vegetation and sheep.
	23/09/2020 10:04pm (Night)	1.8-2.3 m/s NW, Clear skies	30	32	38	57	IA	IA	35 45	Nil	Site inaudible. Other noise sources included the bore pump at Karra homestead, occasional birdsong, wind rustling leaves/vegetation, roof sheets and doors banging at homestead, and plastic liner flapping at homestead.

Notes:
1. Day is defined as 7:00am to 6:00pm Monday to Saturday, 8:00am to 6:00 pm Sunday; Evening as 6:00pm to10:00pm; Night as 10:00pm to 7:00am Monday to Saturday, 10:00pm to 8:00am Sunday.
2. Meteorological conditions stated are as recorded from operator’s handheld anemometer.
3. For assessment purposes the L_{Amax} and the $L_{A1(1-min)}$ are interchangeable.

4 Conclusion

EMM has completed a review of operational noise from the Iluka Balranald T3 mine site for September 2020.

Attended noise monitoring was conducted during the day, evening and night periods on 23 September 2020 to assess compliance with the development consent.

Attended noise monitoring observations and results demonstrate that operational noise from the Balranald T3 mine site was inaudible during the day and night period measurements at R5. The mine site operations were faintly audible during the evening period measurements. Overall, site noise contributions were below (ie satisfied) the relevant noise limits for all measurement periods.

In summary, the measured noise contribution of Iluka's Balranald T3 mine site was found to satisfy all relevant noise limits for all measurements conducted at R5, the closest residence to the current activities conducted at site. Hence, site noise contributions are found to be compliant at all residences in the area.

Yours sincerely

Rick Scully
Acoustic Consultant
rscully@emmconsulting.com.au

Review: DW 8.10.20

Appendix A

Calibration certificates

Certificate Of Calibration

Certificate No.: SLM 23713 & FILT 4907

Equipment Description: Sound & Vibration Analyser

Manufacturer: Svantek

Model No: Svan-977 **Serial No:** 59682

Microphone Type: 7052E **Serial No:** 69609

Preamplifier Type: SV12L **Serial No:** 64882

Filter Type: 1/1 Octave **Serial No:** 59682

Comments: All tests passed for class 1.
(See over for details)

Owner: EMM Consulting
Suite 01, 20 Chandos Street
St Leonards NSW 2065

Ambient Pressure: 1001 hPa ±1.5 hPa

Temperature: 24 °C ±2° C **Relative Humidity:** 58% ±5%

Date of Calibration: 23/10/2018 **Issue Date:** 23/10/2018

Acu-Vib Test Procedure: AVP10 (SLM) & AVP06 (Filters)

Checked by: .... **Authorised Signature:** ....
Jack Kielt

Accredited for compliance with ISO/IEC 17025 - Calibration
The results of the tests, calibration and/or measurements included in this document are traceable to Australian/national standards.

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Accredited Lab. No. 9262
Acoustic and Vibration Measurements

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: 25666

EQUIPMENT TESTED: Sound Level Calibrator

Manufacturer: Svantek
Type No: SV-36 **Serial No:** 86311
Owner: EMM Consulting
Ground Floor, Suite 01, 20 Chandos St
St Leonards NSW 2065

Tests Performed: Measured output pressure level was found to be:

Parameter	Pre-Adj	Adj Y/N	Output: (db re 20 µPa)	Frequency: (Hz)	THD&N (%)
Level 1:	NA	N	94.09	999.99	0.89
Level 2:	NA	N	114.05	1000.00	0.32
Uncertainty:			±0.11 dB	±0.05%	±0.20 %
Uncertainty (at 95% c.l.) k=2					

CONDITION OF TEST:
Ambient Pressure: 1004 hPa ±1.5 hPa **Relative Humidity:** 36% ±5%
Temperature: 25 °C ±2° C
Date of Calibration: 04/10/2019 **Issue Date:** 08/10/2019
Acu-Vib Test Procedure: AVP02 (Calibrators)
Test Method: AS IEC 60942 - 2017

CHECKED BY: VKB **AUTHORISED SIGNATURE:** ....
Hein Soe

Accredited for compliance with ISO/IEC 17025 - Calibration
The results of the tests, calibration and/or measurements included in this document are traceable to Australian/national standards.
The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

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25 November 2020

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www.emmconsulting.com.au

Lisa McGrath
HSEC Manager
Iluka Resources Limited

Re: Iluka Balranald T3 - monthly compliance noise monitoring, November 2020

Dear Lisa,

1 Introduction

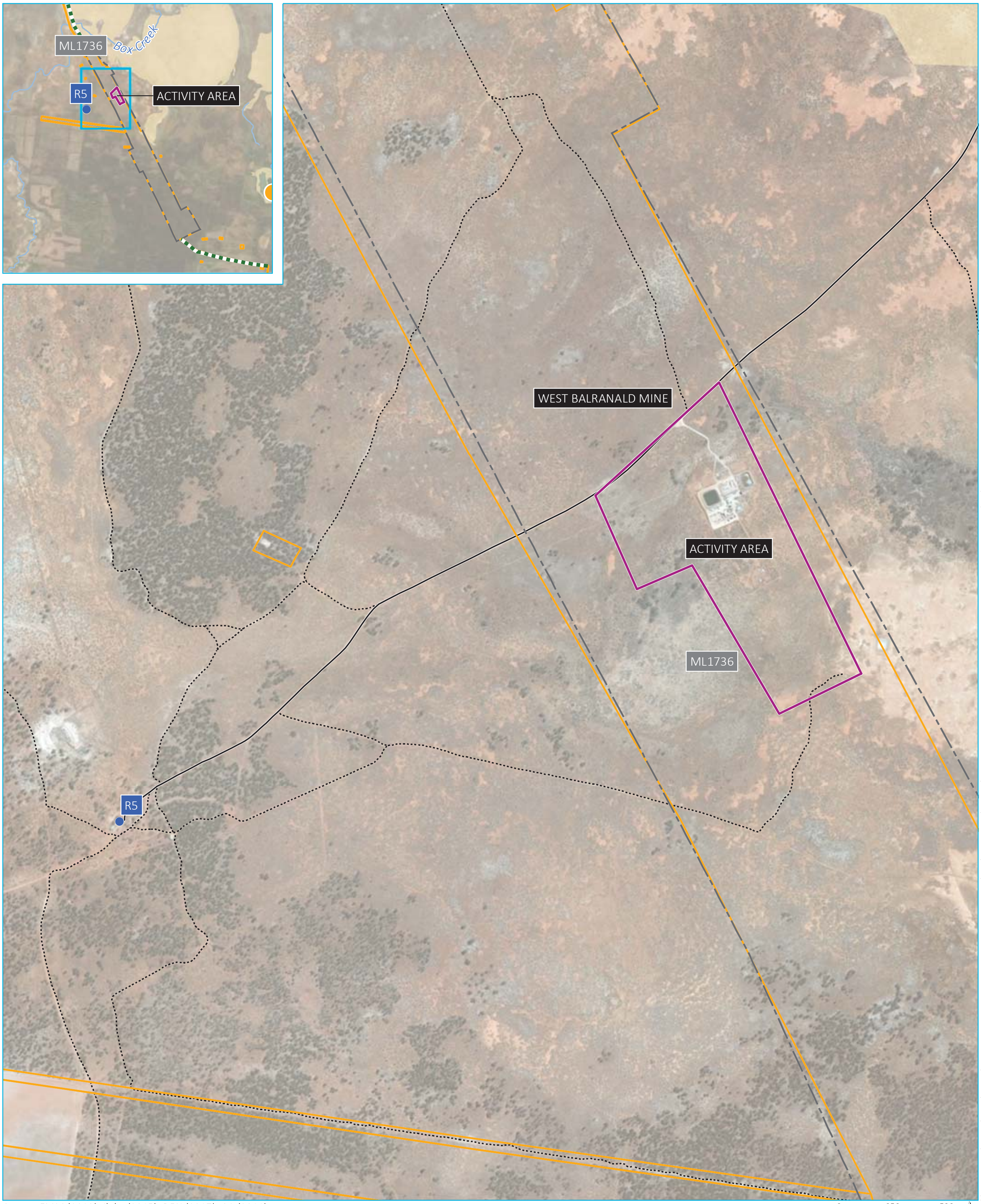
EMM was engaged by Iluka Resources Limited (Iluka) to conduct monthly noise compliance monitoring as part of their T3 mining trial operations at their mineral sands mine (the site) in Balranald, NSW.

A site visit was conducted on 12 November 2020 to measure noise at the nearest residence to site during the day and evening periods. This report details the methodology and results from the noise measurements.

2 Noise compliance assessment

2.1 Assessment locations

To quantify noise emissions from the site operations, 15-minute operator attended measurements were conducted at the nearest residential assessment location, namely the Karra Homestead (R5), located approximately 3km southwest of the site. The assessment location, in relation to the site, is shown in Figure 2.1.



Source: *EMM (2019); Iluka (2015); DFSI (2017); GA (2011)*

\\emmsvr1\emm\Jobs\2019\S190512 - Balranald T3 Ancillary Support\GIS\02_Maps_EMP\EMP003_NoiseMonitoringLocation_20190919_01.mxd 19/09/2019

KEY

- Activity area
- Project boundary
- Noise monitoring location
- Access road
- Mining Lease 1736
- Local road
- Vehicular track
- Ephemeral lake

Noise monitoring locations

Iluka Resources Limited
Environmental Management Plan
Figure 2.1

creating opportunities

2.2 Noise limits

As specified in Iluka's Environmental Management Plan (EMP) (EMM 2019), and Schedule 3, Condition 3 of the development consent, noise limits are reproduced in Table 2.1.

Table 2.1 Limits for operational noise

Location	Day	Evening	Night	
	LAeq(15min)	LAeq(15min)	LAeq(15min)	LA1(1min)
All privately-owned land*	35	35	35	45
Mungo National Park and Mungo State Conservation Area	50	50	50	-

Notes:
* For the purpose of Balranald T3, the nearest residential assessment location is Karra Homestead (R5)
1. Day is defined as 7:00am to 6:00pm Monday to Saturday, 8:00am to 6:00 pm Sunday; Evening as 6:00pm to10:00pm; Night as 10:00pm to 7:00am Monday to Saturday, 10:00pm to 8:00am Sunday.
2. Measurements are to be taken at the reasonably most-affected point on or within the residential property boundary or, if that is more than 30 metres from the residence, at the reasonably most-affected point within 30 metres of the residence.

2.3 Instrumentation

All measurements were conducted using a Svantek 979 sound analyser (s/n 21095), which is a Class 1 meter as defined in AS61672.1:2019. The sound analyser was calibrated before and after completion of measurements using a Svantek SV36 calibrator (s/n 86311). No calibration drift was observed. All instrumentation was within its current manufacturer and NATA calibration period. Calibration certificates for all instrumentation are provided in Appendix A.

2.4 Meteorology

Weather data for the monitoring period was obtained from the Bureau of Meteorology (BoM) Automated Weather Station (AWS) located at Mildura Airport (Station ID 076031), which is 124km from site. The recorded AWS data was generally consistent with observations noted by the operator at the time of monitoring using a handheld wind anemometer. Clear conditions prevailed during the day, with overcast conditions present during the evening measurement. Light north-easterly winds (1-2m/s) present during both monitoring periods.

2.5 Modifying factors

Modifying factor adjustments are required to be applied for noise levels with annoying characteristics such as tonal, impulsive and low frequency noise. Tonal or impulsive noise are not typical to site operations, in particular when measured at significant distances from site (eg at R5). Furthermore, monitoring data confirmed that tonal or impulsive noise from the site was not present at the nearest residence. Low frequency noise was considered as described below.

Fact Sheet C of the NPfI (EPA 2017) provides guidelines for applying modifying factor adjustments to account for low frequency noise. The NPfI specifies that a difference of 15 dB or more between site 'C-weighted' and site 'A-weighted' noise emission levels indicates the potential for an unbalanced spectrum and potential increased annoyance. Where a difference of 15 dB or more between site 'C-weighted' and site 'A-weighted' noise emission levels has been identified, the one-third octave band centre frequency noise levels recorded has been compared to the values in Table C2 of the NPfI reproduced in Table 2.2.

Table 2.2 One-third octave low-frequency noise thresholds

	One-third octave $L_{Zeq,15min}$ threshold level												
Frequency (Hz)	**10**	**12.5**	**16**	**20**	**25**	**31.5**	**40**	**50**	**63**	**80**	**100**	**125**	**160**
dB (Z)	92	89	86	77	69	61	54	50	50	48	48	46	44

A modifying factor adjustment is to be applied where the site 'C-weighted' less the site 'A-weighted' noise emission level is 15 dB or more and:

- where any of the one-third octave band centre frequency noise levels in Table 2.2 are exceeded by up to and including 5 dB and cannot be mitigated, a 2 dB positive adjustment to measured/predicted A-weighted levels applies for the evening/night period; or

- where any of the one-third octave band centre frequency noise levels in Table 2.2 are exceeded by more than 5 dB and cannot be mitigated, a 5 dB positive adjustment to measured/predicted A-weighted levels applies for the evening/night period and a 2 dB positive adjustment applies for the daytime period.

Hence, where possible throughout each survey the operator has estimated the difference between site 'C-weighted' and site 'A-weighted' noise emission levels by matching audible sounds with the response of the analyser (L_{Ceq}-L_{Aeq}). Where this was deemed to be 15 dB or greater, the measured one-third octave band centre frequencies have been compared to the values in Table 2.2 to identify the relevant modifying factor correction (if applicable). This method has been applied to this assessment as discussed in Section 3.

3 Results

Attended noise monitoring results are presented in Table 3.1.

Site operations were inaudible during the day and evening period measurements. If a noise source is inaudible, it is generally 10 dB below the background (L_{A90}) noise level. Given this and the measured background noise levels, the site's $L_{Aeq,15min}$ noise contribution would have satisfied relevant noise criteria.

Attended measurements were not conducted during the night period due to site not operating at the time of measurements.

It is of note that an existing bore water pump and generator operate at the Karra homestead property (ie outside the Iluka site boundary). This equipment was installed by Iluka on 27 November 2013 [60WA583168] for the use of the homestead and the exploration / mining related activities, and hence providing a benefit for both. This plant will be left for the homestead post mining as per the terms of the land access agreement between the homestead owners and Iluka. During each 15-minute monitoring period, the bore water pump and associated generator would operate for approximately 3 minutes to provide make up water for mining operations. This contribution to noise at the homestead was removed from the analysis of compliance.

Table 3.1 Attended noise measurement results – 12 November 2020

Monitoring location	Date, start time (period)	Meteorological conditions	Total noise levels (15-min)				Site contribution		Noise criteria	Exceedance?	Field observations
			L_{Amin}	L_{A90}	$L_{Aeq,15min}$	L_{Amax}	$L_{Aeq,15min}$	$L_{A1(1min)}$ / L_{Amax}	$L_{Aeq,15min}$, L_{A1}		
R5	12/11/2020 12:17pm (Day)	1-2 m/s NE, clear skies	27	30	39	53	IA	IA	35 n/a	Nil	Site inaudible. Other noise sources included birdsong, wind in trees and bore pump at karra homestead.
	12/11/2020 6:01pm (Evening)	1-2 m/s NE, overcast	24	26	36	60	IA	IA	35 n/a	Nil	Site inaudible. Other noise sources included birdsong and wind in trees, insects.

Notes: 1. Day is defined as 7:00am to 6:00pm Monday to Saturday, 8:00am to 6:00 pm Sunday; Evening as 6:00pm to10:00pm; Night as 10:00pm to 7:00am Monday to Saturday, 10:00pm to 8:00am Sunday.
2. Meteorological conditions stated are as recorded from operator's handheld anemometer.
3. For assessment purposes the L_{Amax} and the $L_{A1(1-min)}$ are interchangeable.
IA Inaudible

4 Conclusion

EMM has completed a review of operational noise from the Iluka Balranald T3 mine site for November 2020.

Attended noise monitoring was conducted during the day and evening periods on 12 November 2020 to assess compliance with the development consent. Measurements were not conducted during the night period due to the site not operating at the time of measurement.

Attended noise monitoring observations and results demonstrate that operational noise from the Balranald T3 mine site was inaudible during all measurements at R5. Overall, site noise contributions were below (ie satisfied) the relevant noise limits for all measurement periods.

In summary, the measured noise contribution of Iluka's Balranald T3 mine site was found to satisfy all relevant noise limits for all measurements conducted at R5, the closest residence to the current activities conducted at site. Hence, site noise contributions are found to be compliant at all residences in the area.

Yours sincerely

Rick Scully
Acoustic Consultant
rscully@emmconsulting.com.au

Review: CF 25.11.20

Appendix A

Calibration certificates

CERTIFICATE OF CALIBRATION

CERTIFICATE NO.: **SLM 27124 & FILT 5856**

Equipment Description: Sound & Vibration Analyzer

Manufacturer: Svantek

Model No: Svan-979 **Serial No:** 21095

Microphone Type: 40AE **Serial No:** 120711

Preamplifier Type: SV17 **Serial No:** 33254

Filter Type: 1/3 Octave **Serial No:** 25110

Comments: All tests passed for class 1.
(See over for details)

Owner: EMM Consulting Pty Ltd
L 13, 175 Scott Street
Newcastle, NSW 2300

Ambient Pressure: 1013 hPa ±1.5 hPa

Temperature: 23 °C ±2° C **Relative Humidity:** 49% ±5%

Date of Calibration: 22/06/2020 **Issue Date:** 22/06/2020

Acu-Vib Test Procedure: AVP10 (SLM) & AVP06 (Filters)

CHECKED BY: JKJ **AUTHORISED SIGNATURE:** ....
Jack Kielt

Accredited for compliance with ISO/IEC 17025 - Calibration
The results of the tests, calibration and/or measurements included in this document are traceable to

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Mobile: 0413 809806
web site: www.acu-vib.com.au

CERTIFICATE OF CALIBRATION

CERTIFICATE NO: C28079

EQUIPMENT TESTED: Sound Level Calibrator

Manufacturer: Svantek
Type No: SV-36 **Serial No:** 86311
Owner: EMM Consulting
Suite 01, 20 Chandos St
St Leonards NSW 2065

Tests Performed: Measured output pressure level was found to be:

Parameter	Pre-Adj	Adj Y/N	Output: (db re 20 μPa)	Frequency: (Hz)	THD&N (%)
Level 1:	NA	N	94.06	999.99	0.89
Level 2:	NA	N	113.95	999.98	0.32
Uncertainty:			±0.11 dB	±0.05%	±0.20 %
Uncertainty (at 95% c.l.) k=2					

CONDITIONS OF TEST:

Ambient Pressure: 998 hPa ±1.5 hPa **Relative Humidity:** 56 % ±5%

Temperature: 22 °C ±2° C

Date of Calibration: 20/10/2020 **Issue Date:** 20/10/2020

Acu-Vib Test Procedure: AVP02 (Calibrators)

Test Method: AS IEC 60942 - 2017

CHECKED BY: .... **AUTHORISED SIGNATURE:** ....

Jack Kielt

.Accredited for compliance with ISO/IEC 17025 – Calibration
Results of the tests, calibration and/or measurements included in this document are traceable to SI units through reference equipment that has been calibrated by the Australian National Measurement Institute or other NATA accredited laboratories demonstrating traceability.

The uncertainties quoted are calculated in accordance with the methods of the ISO Guide to the Uncertainty of Measurement and quoted at a coverage factor of 2 with a confidence interval of approximately 95%.

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Appendix B: MSEC Subsidence Review Report (February 2021)

3rd March 2021

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Alexander Pauza
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Perth WA 6000

Ref: MSEC1152 Revision A

Dear Alexander,

RE: ILUKA RESOURCES –Balranald Mineral Sands Deposit
Subsidence Review Report for T3 Balranald Bulk Sampling Activity

1. Background

In 2014 Iluka Resources Limited (Iluka) commenced trials of an innovative underground mining method involving directionally drilled boreholes, water jetting and eductor slurry pumping equipment to extract Heavy Mineral (HM) sands from an ancient beach deposits located approximately 70 metres below predominantly unconsolidated sands and clays within the Murray River Basin approximately 30km North West of Balranald in southwestern NSW.

The Iluka West Balranald HM sands deposit is contained within Mining Licence (ML) 1736. Iluka was granted Development Consent under Part 4 of the Environmental Planning and Assessment Act 1979 (SSD-5285) for an open cut mining operation and a bulk sampling activity to test the selective in-situ removal of up to 100,000 tonnes of ore via underground mining methods. The bulk sampling activity is conducted under a regulatory approved Environmental Management Plan (EMP). Whilst the development consent did not include specific performance criteria for subsidence, a Subsidence Management Plan was appended to the EMP which outlined predictions, mitigation measures and monitoring activities.

The Balranald T3 bulk sampling activity is the third underground mining trial being conducted at the Balranald Mineral Sands Project. T1 was completed in February 2015 with approximately 1,700 tonnes (t) of high-grade ore successfully mined. T2 was completed in 2016 with approximately 6,400 t of mineral ore successfully mined from three underground cavities (Stopes 1B, 3 and 4). The approximate outline locations of the mined stopes in T1, T2 and T3 activities are shown in attached Drawing No. MSEC1152-01.

The T3 activities included the re-entry and additional mining of Stope 4 and the mining of Stope 6. Subsidence predictions and management were outlined in the Balranald Subsidence Management Plan.

The objective of the T3 trial was to further test the selective in-situ removal of mineral ore to determine the suitability of the mining method for possible large-scale production.

Observations of the mining induced ground surface subsidence were measured by Michael Nicholson Consulting Pty Ltd (MNC) using an array of ground surface monitoring points, real time GNSS monitoring units and aerial photogrammetry. Survey monitoring data has a nominal accuracy of ±5mm for vertical and horizontal observations.

MSEC has prepared this letter report to review the observed subsidence movements for the T3 trial.

2. Stope mining activities

The proposed mining activities carried out for the T3 Trial included extraction of Stope 4 and Stope 6. The proposed cross sectional block model shape of the stopes was rectangular with a base width of approximately 12m and a maximum height of 3.5m.

The average recovery of stopes by weight (proposed vs actual mined tonnage) was approximately 70% for Stope 6 and 90% for Stope 4. The length of mine stopes varied for operational or stability control reasons. The spacing between Stopes 4 and 6 is approximately 33m between the stope centrelines and approximately 22m between the modelled stope edges.

A summary of the stope mining activities carried out for the T3 trial is provided below in Table 2.1.

Table 2.1 T3 Stope mining commencement and completion dates

Stope	Commencement date	Completion date	Total Extracted Length	Total Extracted Tonnage
4	19 August 2020	30 August 2020	200m	15,000
6	10 September 2020	30 September	280m	15,900

A series of sink holes formed above the mined stopes during the T3 trial. Over the duration of the T1 to T3 trials, a total of ten sink holes have formed above the mined stopes, with nine of the sink holes forming during the T3 trial. A summary of the development of the sink holes during the T3 trial are provided in Table 2.2.

Table 2.2 T3 Sink Hole formation

<table>
<tr><th>Sink hole</th><th>Approximate date of development</th><th>Location</th><th>Maximum depth (m)</th><th>Maximum width (m)</th><th>Approximate volume (m^3)</th><th>Notes</th></tr>
<tr><td>S2</td><td>24 August 2020</td><td>Stope 4 (St4c)</td><td>3.7</td><td>15.8</td><td>180</td><td>During Stope 4 mining. Mining disrupted 24 Aug.</td></tr>
<tr><td>S3</td><td>21 September 2020</td><td>Stope 6 (St6d)</td><td>6.0</td><td>14.5</td><td>380</td><td>During Stope 6 mining. Stope collapse 20 Sep.</td></tr>
<tr><td>S4</td><td>30 September 2020</td><td>Stope 6 (St6e)</td><td>6.9</td><td>10.0</td><td>870</td><td>During Stope 6 mining. Completion 30 Sep</td></tr>
<tr><td>S5</td><td>8 October 2020</td><td>Stope 6 (St6e)</td><td>2.1</td><td>10.0</td><td>109</td><td>During backfilling over Stope 4</td></tr>
<tr><td>S6</td><td>12 October 2020</td><td>Stope 3 (St3)</td><td>1.2</td><td>6.4</td><td>25</td><td>During backfilling over Stope 3</td></tr>
<tr><td>S7</td><td rowspan="4">After 11 Nov 2020</td><td>Stope 4 (St4f)</td><td>9.0</td><td>12.0</td><td>460</td><td rowspan="4">Following rain event 11 Nov 2020. No mining activities undertaken</td></tr>
<tr><td>S8</td><td>Stope 6 (St 6e)</td><td>6.0</td><td>13.8</td><td>480</td></tr>
<tr><td>S9</td><td>Stope 4 (St4f)</td><td>na</td><td>16.6</td><td>400 to 500</td></tr>
<tr><td>S10</td><td>Stope 4 (St4b)</td><td>na</td><td>11.7</td><td>400 to 500</td></tr>
</table>

Of the sinkholes that formed above areas mined during T3, none coincided with known drill holes.

3. Backfill Operations

Backfilling processes during the T3 trial encountered difficulties with pre-installed vertical injection wells that did not intersect the mined stope cavities, and injection through the rig end decline casings resulted in surface discharge of fluids. Subsequent trials were undertaken for alternative backfilling methods including surface backfilling the sink holes using sand tails and underground injection of slimes only. It is understood future operations will incorporate a combination of surface and subsurface disposal methods.

While backfilling operations may have contributed to the formation of some of the sink holes (S5 and S6), the returned volumes of material were small. It is unlikely that the backfilling operations would have had a significant impact on reducing the observed subsidence.

4. T3 Subsidence prediction

MSEC developed a new Incremental Profile Method (IPM) model to predict subsidence over the proposed underground mining stopes. This method was initially calibrated with the subsidence monitoring results from T1 and T2 trials, where the observed vertical subsidence was small in magnitude and much less than predicted. It was thought that the small magnitudes of observed subsidence were the result of the overlying Shepparton clay formations (SFM) bridging over the mined small voids thereby reducing the observed maximum levels of subsidence.

Seismic surveys undertaken during T2 trial identified maximum heights of disturbance at approximate Reduced Levels of 17m and 32m AHD with voids identified within the disturbed zones. The elevations of the estimated surface of the disturbed zones are within the Loxton Parilla Sands (LPS).

The IPM model developed for the T3 trials predicts increasing subsidence as the void width increases and the maximum subsidence only occurs after very wide areas are extracted. The modelled subsidence predicts a maximum of up to 95% of the net HM ore thickness that is extracted after allowing for backfilling.

The subsidence prediction model was updated to the as-extracted lengths of Stopes 4 and 6. The predicted subsidence contours are presented below in Fig. 4.1. The maximum predicted vertical subsidence is 35mm. The maximum predicted subsidence is small given the separation of 22m between Stopes 4 and 6. The prediction model was designed to rapidly increase predicted vertical subsidence of up to 95% of the extracted thickness with extraction of adjoining stopes.

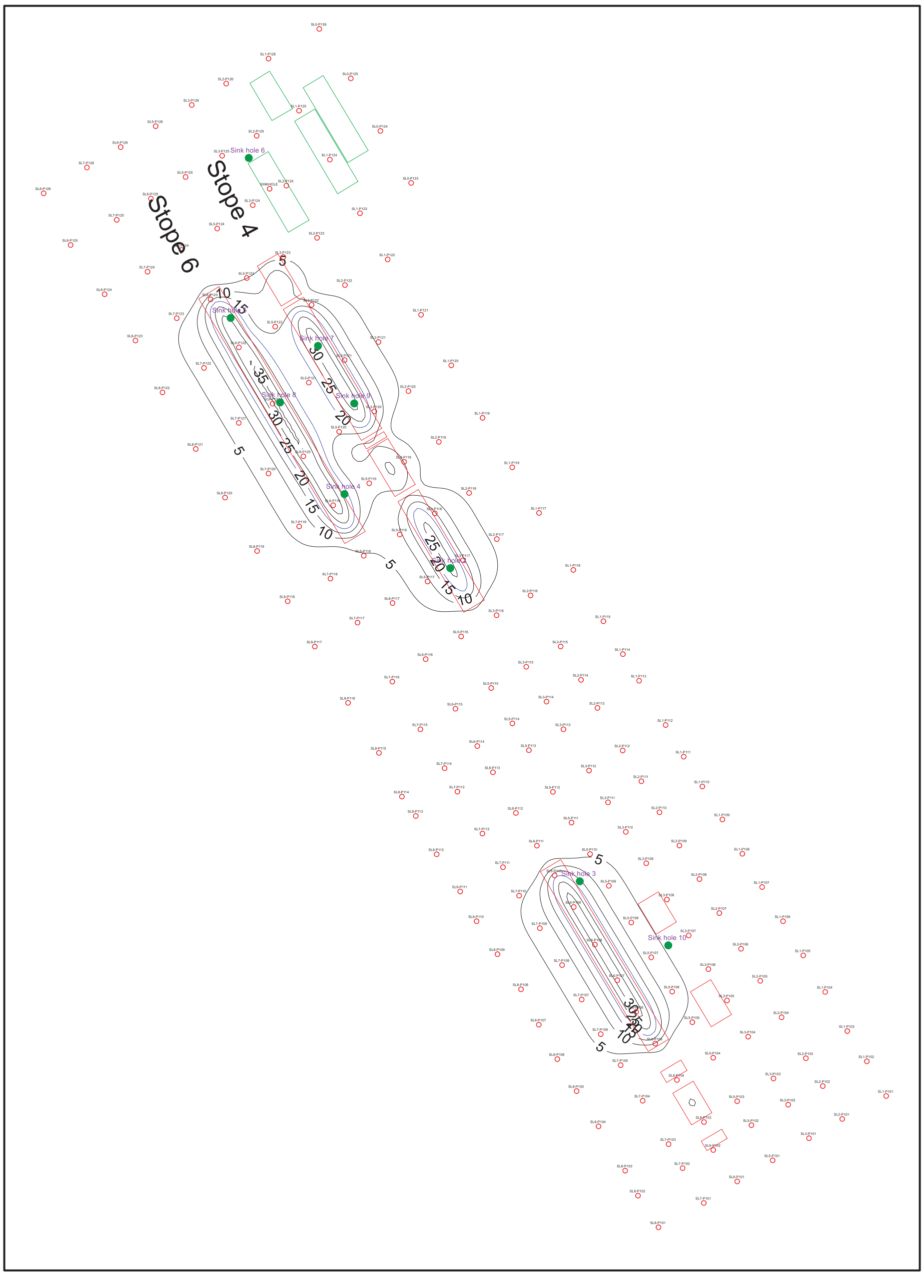

Fig. 4.1 Predicted subsidence contours

5. Monitoring Results

Prism Array

The purpose of the array of ground surface monitoring points was to observe the developing surface subsidence with the progression of the T3 mining activities. The array of monitoring points was set out in a grid with transverse spacing of survey marks at approximately 20m centres and longitudinal spacing of survey marks at approximately 15m to 30m centres. The layout of survey marks is shown Drawing No. MSEC1152-01.

A total of 34 survey epochs were observed during the T3 activities, with a typical daily frequency of monitoring during active mining.

A series of longitudinal and transverse sections representing the survey results is presented in Attachment A. Each section shows the development of observed vertical subsidence, tilt, and strain along the section lines. Observed profiles are presented in green representing active mining of Stope 4, blue representing active mining of Stope 6, and grey representing no active mining. Profiles of predicted vertical subsidence are also shown on each figure in Attachment A.

A contour plot of the observed vertical subsidence based on the array of ground surface monitoring points is shown in **Fig. 5.1**. For the purposes of clarity, the maximum observed subsidence of 690mm at survey Mark SL3-P117 is omitted from this contour plot. This survey mark is located close to Sinkhole S2 and therefore represents the surface failure surrounding this sinkhole. While other survey marks are located further from the sinkholes, it can still be seen that the surface contours are dominated by the formation of the sinkholes, which is discussed below.

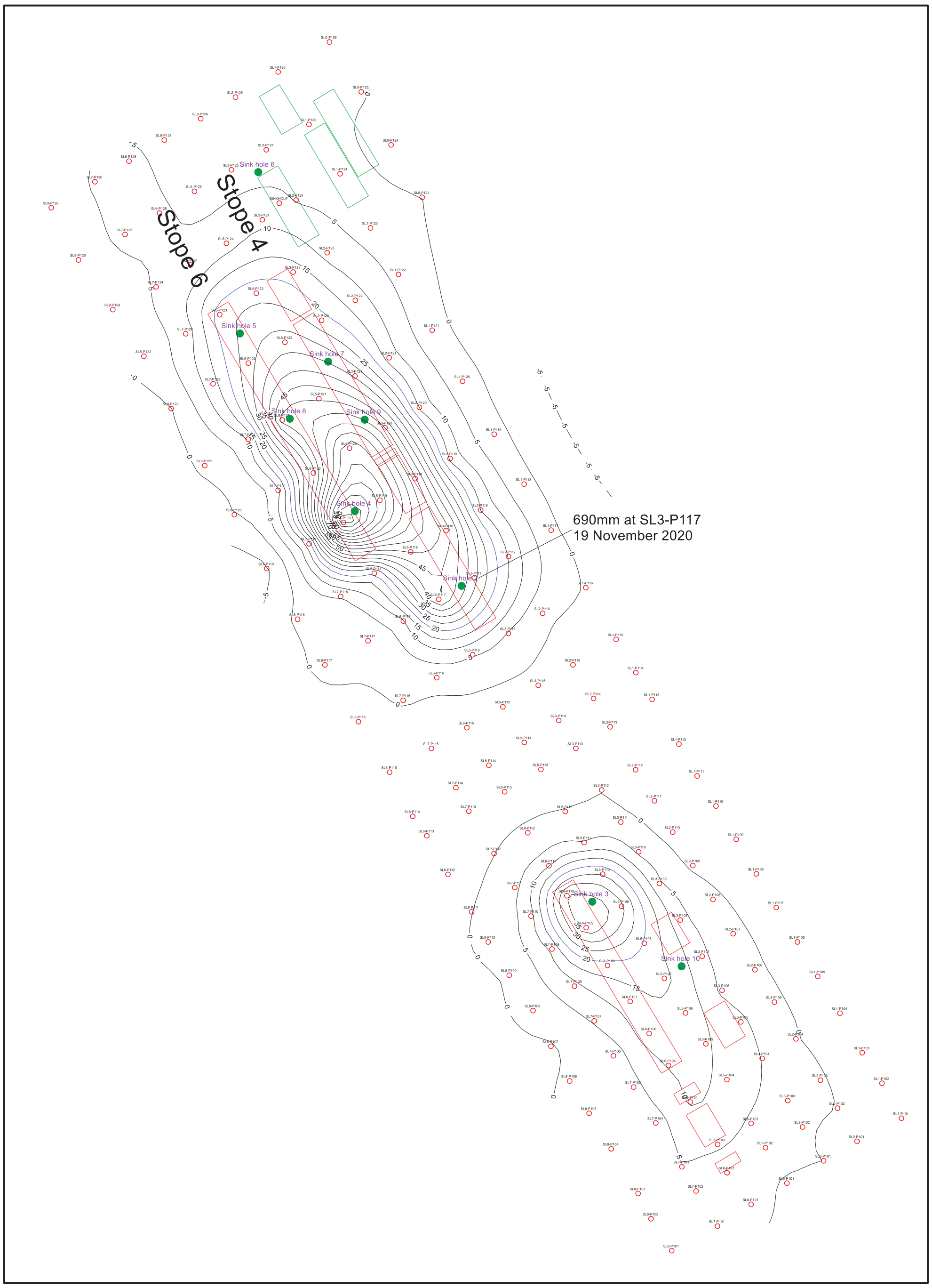

Fig. 5.1 Contours of Total Vertical Subsidence (excluding Mark SL3-P117) – Contour spacing 5mm.

A summary of observed vertical subsidence represented by the longitudinal monitoring lines is provided below.

SL0

SL0 is a short monitoring line located outside the T1 extracted stopes. Observed subsidence during the T3 trial is negligible and within limits of survey accuracy. Some uplift is observed from 24 September 2020, increasing to 10 mm at P124 on 19 November 2020. Backfilling operations undertaken at Stope 1 and 3 from 10 October 2020, may have contributed to this uplift. Prior to this date, no other backfilling operations were undertaken.

SL1

Subsidence along SL1 ranges from approximately -5mm (uplift) at the southern end, to a maximum of 8mm at the northern end. The range of subsidence is typically within survey accuracy (±5mm), however the average trend of the data indicates minor subsidence of less than 5mm at the northern end from approximately P117 to P126. This section is adjacent to the mined Stope 4. An uplift of 4mm is observed at P124 on 19 November 2020, which coincides with backfilling as noted above.

SL2

Line SL2 intersects eastern edge of the mined Stope 3 outline and is approximately 25 m from the mined Stope 4 outline. Maximum subsidence along SL2 is 19mm in the area adjacent to Stope 4. An increase in vertical subsidence adjacent to Stope 4 occurs on 25 Aug 2020 at Mark P117. This increase coincides with the formation of Sinkhole S2 directly above the stope on 24 August 2020. The drill head at this date had retreated approximately 40m past the location of Sinkhole S2. The survey prior to the formation of S2 was 20 August 2020 and observed less than 5mm subsidence. Approximately 10m of Stope 4 had been extracted on 20 August 2020.

SL3

Line SL3 intersects eastern edge of the mined Stope 4 outline. The maximum observed subsidence of 690mm occurs along lines SL3 and P117, specifically at Mark SL3-P117. The subsidence at this mark increased from 0.2mm on 21 August, to 477mm on 25 August, then continued to increase to 690mm at the final survey epoch. The increased subsidence coincides with the formation of Sinkhole S2 as discussed above.

Elsewhere along Line SL3, a rapid increase in subsidence to 32mm is observed on 28 August, gradually increasing to 60mm. The rapid increase is close to the location of Sinkhole S9, however this sinkhole was not recorded until after a rain event on 11 November.

SL5

Line SL5 is located between Stope 4 and 6. Subsidence development is observed at the southern end between Marks P101 and P111 and at the northern end between Marks P116 and P124. Both of these areas are adjacent to the extracted Stope 4 and 6.

Observed subsidence at the southern end between Marks P101 and P111 increases rapidly from less than 5mm to 26mm on 22 September 2020, coinciding with the formation of Sinkhole S3 on 21 September 2020 at the completion of mining the southern end of Stope 6. The increase in subsidence occurs over an approximate length of 200m.

Observed subsidence at the northern end between Marks P116 and P124 increases rapidly at Mark P117 from less than 5mm to 36mm on 25 August 2020, coinciding with the formation of Sinkhole S2 on 24 August 2020 during the mining of Stope 4. Further increase from 24mm to 95mm is observed at Mark P119 on 26 September 2020. This increase slightly precedes the formation of Sinkhole S4 which is recorded on 30 September 2020. The maximum subsidence at this date was approximately 120mm.

SL6

Line SL6 is located above Stope 6. The development of subsidence along SL6 is similar to SL5. Subsidence development is observed at the southern end between Marks P101 and P111 and at the northern end between Marks P117 and P124.

Observed subsidence at the southern end between Marks P101 and P111 increases rapidly from less than 5mm to 31mm on 22 September 2020, coinciding with the formation of Sinkhole S3 on 21 September 2020 at the completion of mining the southern end of Stope 6. The increase in subsidence occurs over an approximate length of 200m.

Observed subsidence at the northern end between Marks P117 and P124 increases rapidly at Mark P119 from less than 10mm to 59mm on 26 September 2020. This increase slightly precedes the formation of Sinkhole S4 which is recorded on 30 September 2020. The maximum subsidence at this date was approximately 105mm. Greater magnitudes of subsidence would have been recorded however Marks P119 and P121 were lost with the formation of the Sinkholes.

Minor uplift of up to 26mm is observed about Mark P124 due to backfilling operations.

SL7

Line SL7 is located approximately 20m west of the mined Stope 6 outline. Increased subsidence occurs at the same dates as SL6 but at lower magnitudes with 11mm developing at Mark P109 and 18mm developing at Mark P119.

Uplift of 33mm is observed at Mark P124 at the final survey on 19 November 2020 due to backfilling operations.

SL8

Line SL8 is located approximately 40m west of the mined Stope 6 outline. Observed subsidence is predominantly within the limits of surface accuracy, with the exception of uplift observed at the northern end. Up to 33mm uplift was observed at Mark P124. The magnitude of uplift is similar to that observed along SL7 and 6 however the uplift is distributed over a larger distance of approximately 300m.

The response of ground movements at the prisms due to sinkhole development is further demonstrated below in **Fig. 5.2** and **Fig. 5.3**. These plots show the development of subsidence and horizontal movement versus time, for selected prisms SL5-P119, P117 and P109.

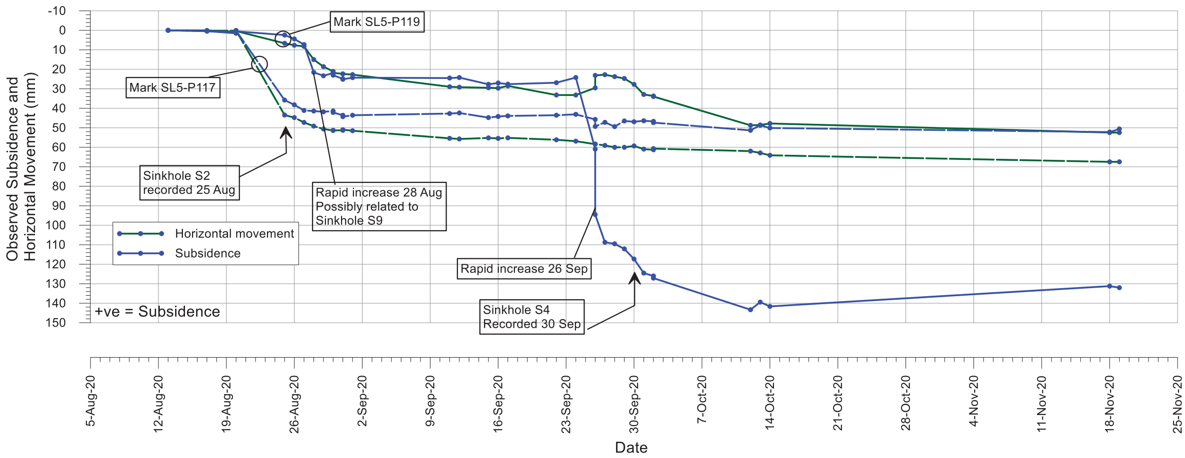

Fig. 5.2 Vertical subsidence and horizontal movement at SL5-P117 and SL5-P119

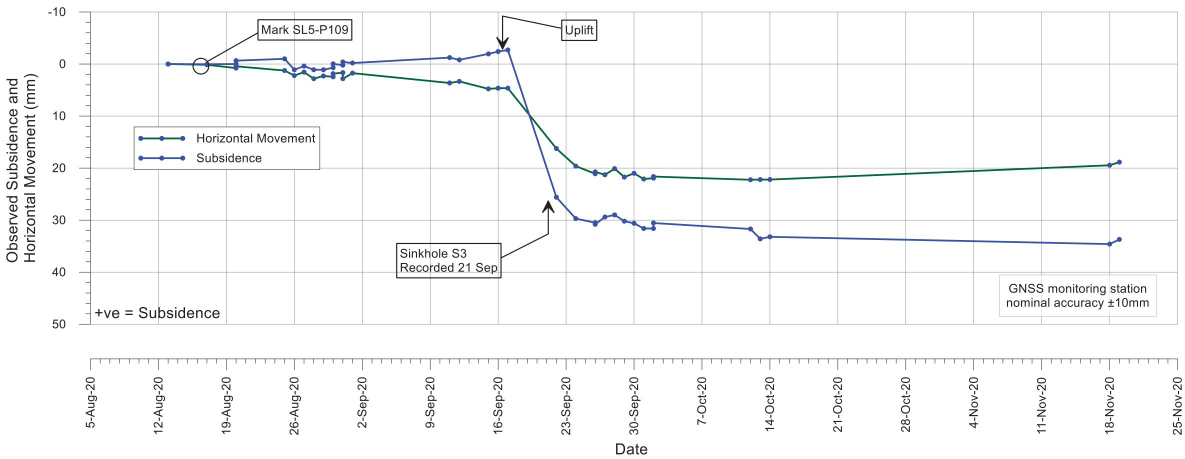

Fig. 5.3 Vertical subsidence and horizontal movement at SL5-P109

It can be seen from in **Fig. 5.2** and **Fig. 5.3** that both vertical subsidence movements and horizontal movements are dominated by the sinkhole events nearest to the prisms. The rapid development of subsidence and horizontal movement at Mark SL5-P119 on 28 August is not coincident with a recorded sinkhole date, however this mark is located close to the location of Sinkhole S9 and may indicate subsurface development of the sinkhole during mining. The increase in subsidence and change in direction of horizontal movement on 26 September, precedes the recorded date of Sinkhole S4 by about 4 days. Minor uplift is observed prior to the rapid subsidence movement. Uplift is also observed at Mark SL5-P109 prior to the rapid subsidence and horizontal movement associated with Sinkhole S3.

GNSS Monitoring

Three GNSS monitoring units are located along the northern edge of Stope 6 alignment. The location of the GNSS units are shown in **Fig. 5.4**. The GNSS units provide ongoing real time observation of movement in three dimensions.

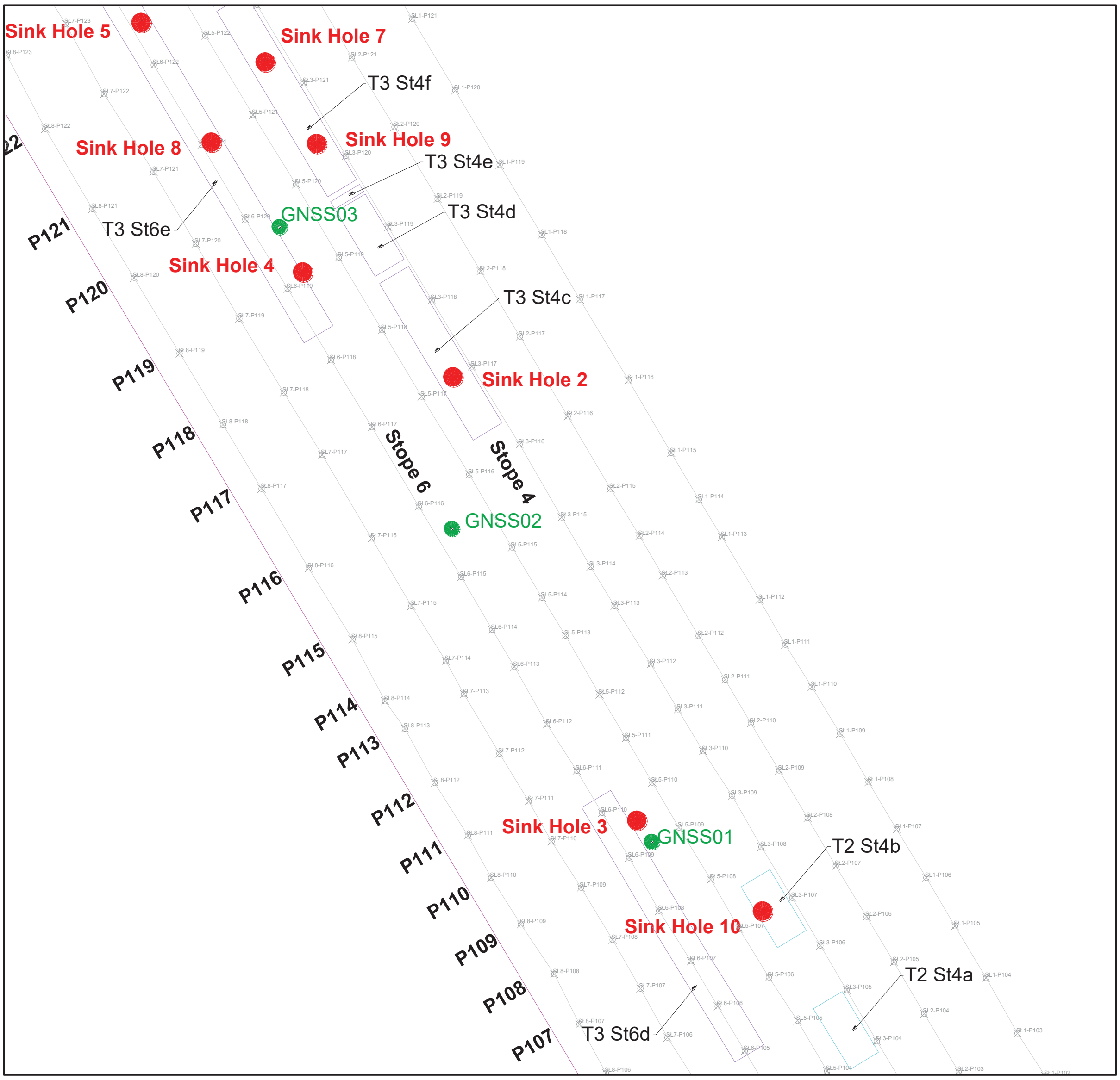

Fig. 5.4 GNSS unit locations

The development of observed vertical subsidence at the GNSS locations is shown in **Fig. 5.5**

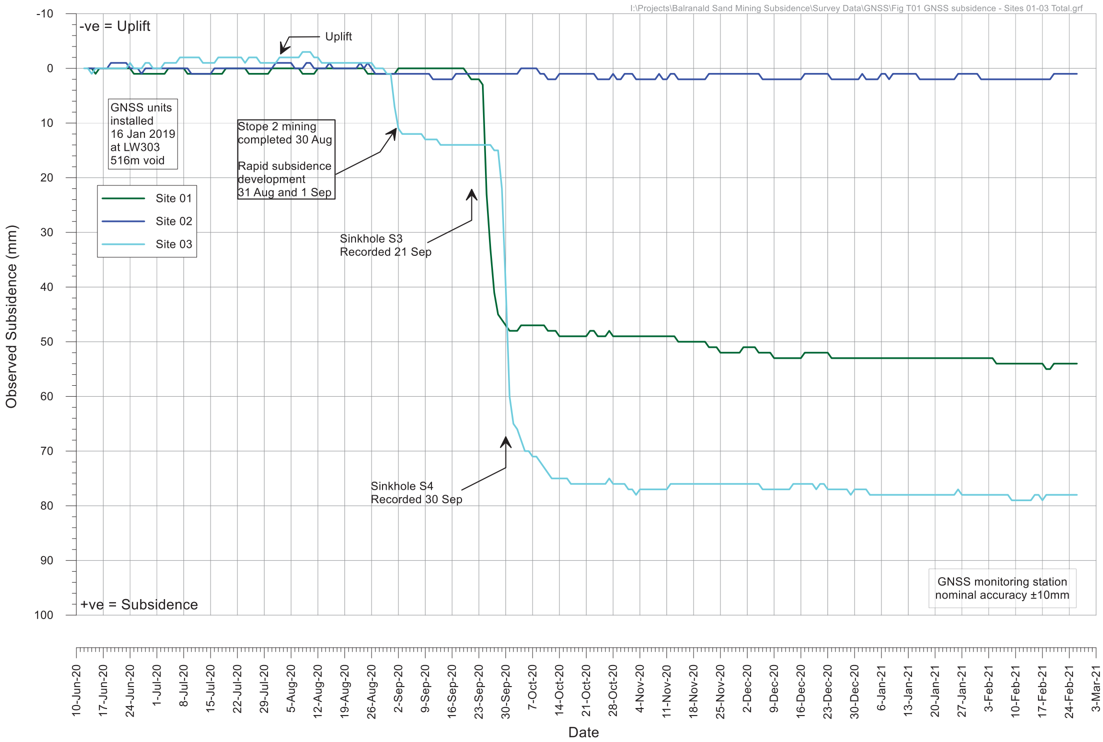

Fig. 5.5 GNSS unit locations

It can be seen from in **Fig. 5.5** that vertical subsidence movements are dominated by the sinkhole events nearest to the GNSS units. Rapid development of subsidence is observed at GNSS unit 03 on 31 Aug. This date does not coincide with a recorded sinkhole date, however the direction of movement, which is discussed below, is towards Sinkhole S9 which formed after the completion of mining and after a rain even. This movement may therefore be related to the incomplete development of S9.

6. Horizontal Movement

Prism Array

Similar to vertical subsidence, the development of observed horizontal movement is dominated by the formation of sinkholes. Horizontal movements are generally oriented towards the extracted stopes with directions influenced by the locations of the sinkholes. Maximum horizontal movement of 192mm was recorded at Mark L3-P117 which is located approximately 8 m from Sinkhole S2. With the exception of Mark L3-P117, the horizontal movements close to the sinkholes varies from approximately 20mm to 60mm. At the extremities of the monitoring array, the observed horizontal movements varied from less than 5mm to 18mm.

The vectors of horizonal movement due to the mining of Stopes 4 and 6 at the final survey epoch on 19 November 2020 are shown below in **Fig. 6.1**. Greater detail is shown in **Fig. 6.2** and **Fig. 6.3**. The scaled vectors are exaggerated 500 times.

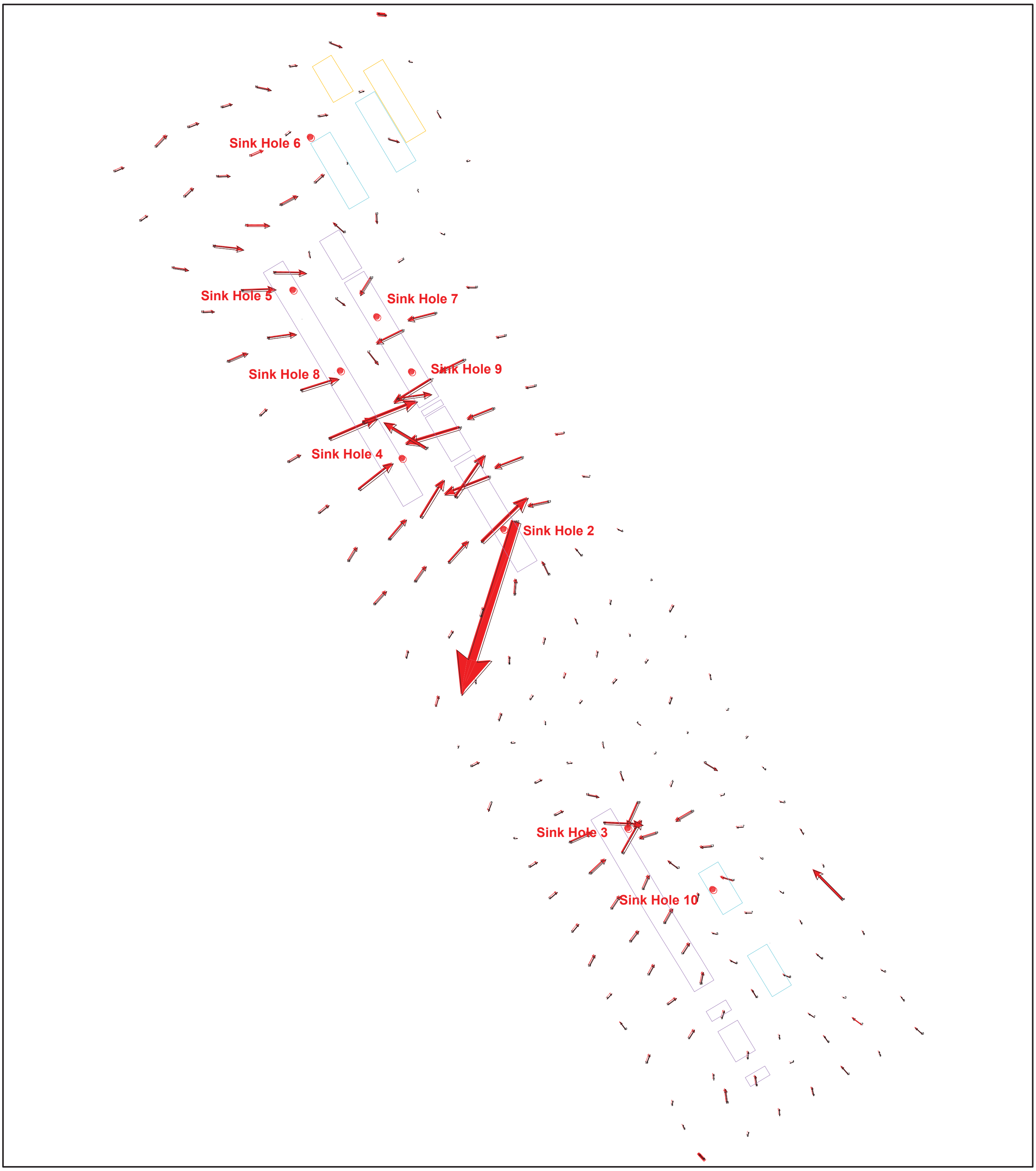

Fig. 6.1 Vectors of horizontal movement (19 Nov 2020)

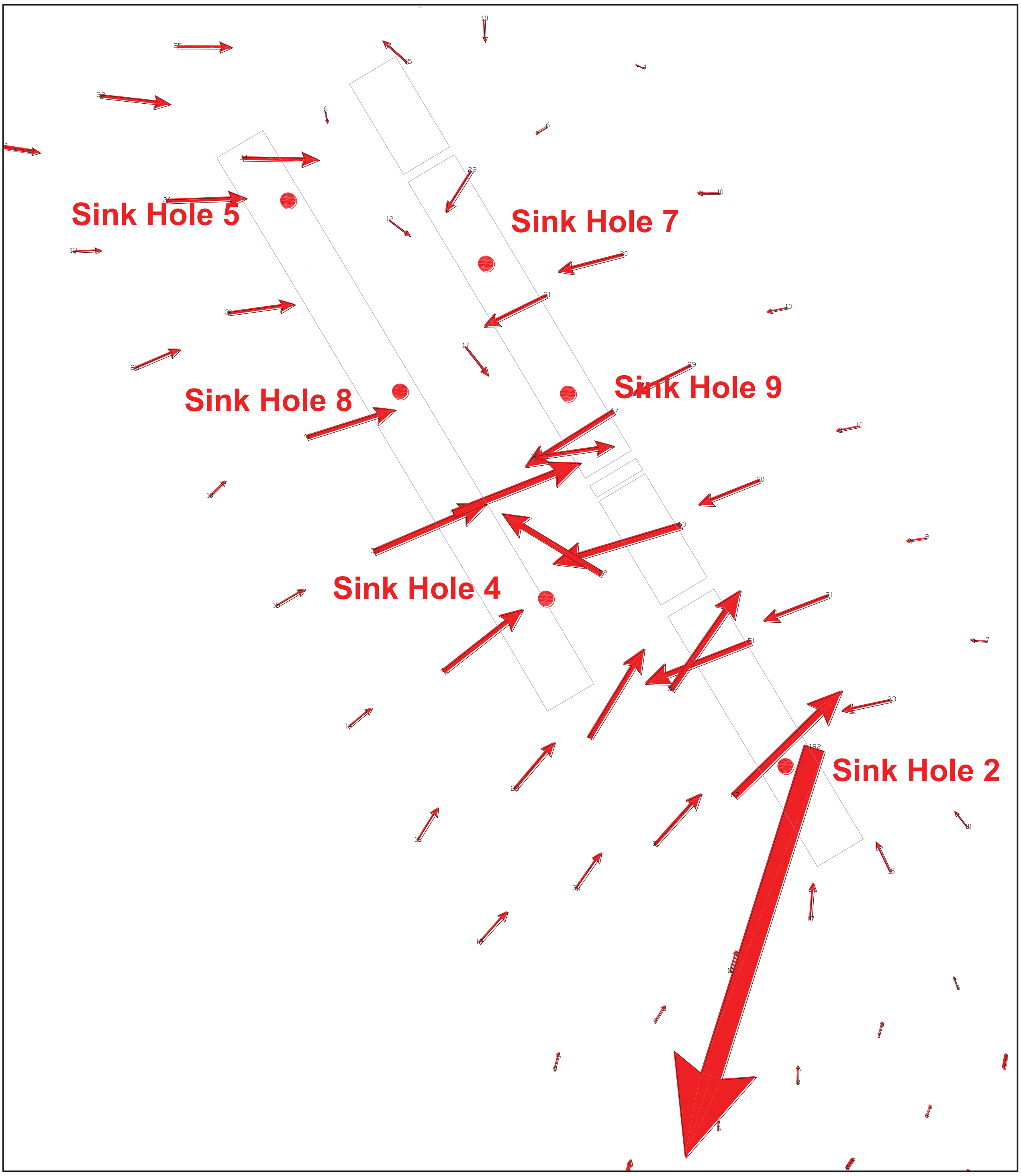

Fig. 6.2 Vectors of horizontal movement (19 Nov 2020) – rig end (north)

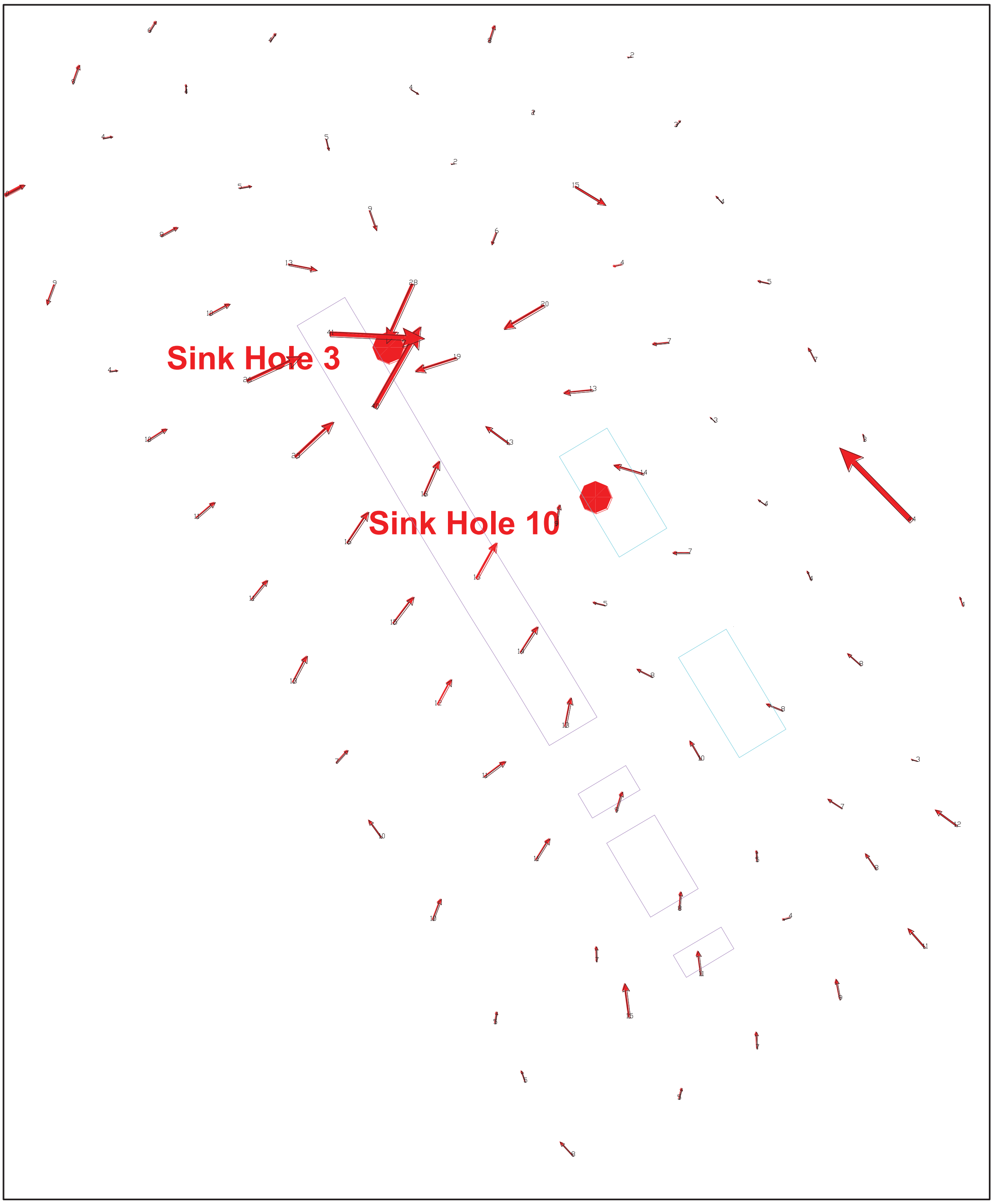

Fig. 6.3 Vectors of horizontal movement (19 Nov 2020) – far end (south)

The loci of horizonal movement shows the progression of horizontal movement for each survey epoch due to the mining of Stopes 4 and 6. The observed total loci of horizontal movements are shown below in **Fig. 6.4** and **Fig. 6.5**. It can be seen from **Fig. 6.5** that horizontal movement about the southern end of stope 6 is directed towards Sinkhole S3. In **Fig. 6.4**, the direction of movement changes with the progressive development of the Sinkholes.

While sinkholes 7, 8, 9, and 10 formed after the rainfall event on 11 Nov, the loci of horizontal movement do not show significant change with the daylighting development of these sinkholes, suggesting the incomplete subsurface formation of these features may have developed during mining or backfilling operations.

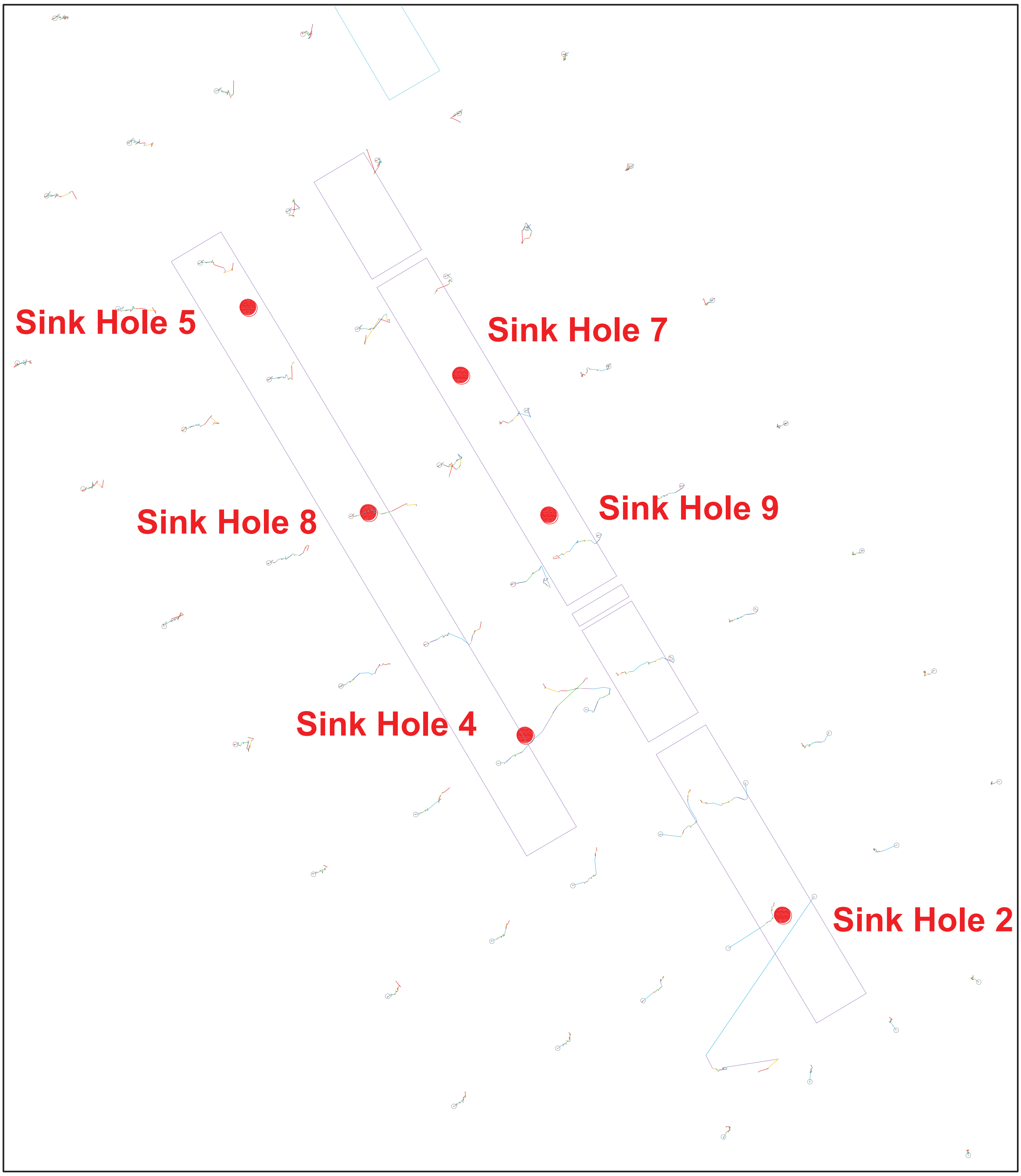

Fig. 6.4 Loci of horizontal movement at survey prisms – rig end (north)

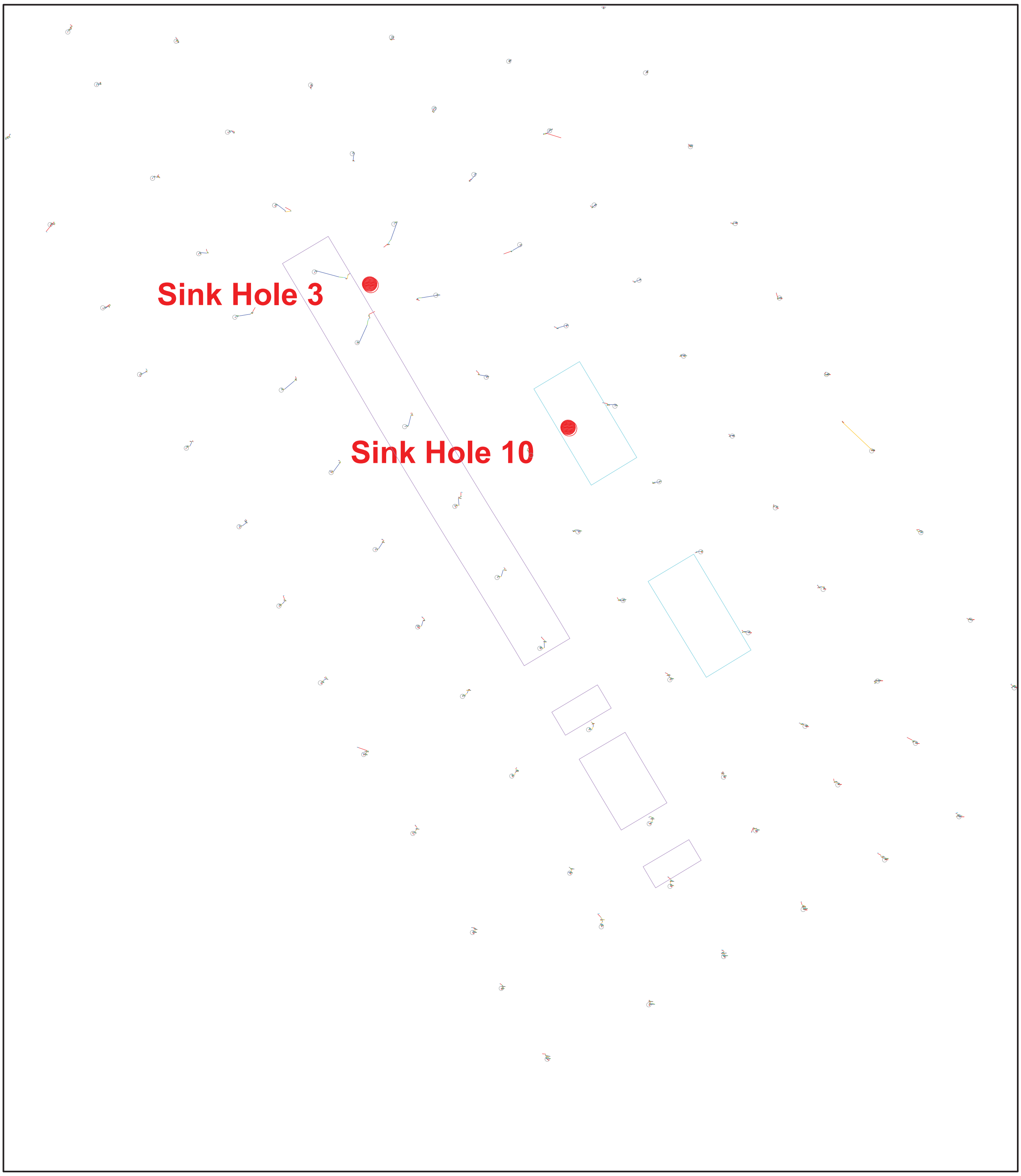

Fig. 6.5 Loci of horizontal movement at survey prisms – far end (south)

GNSS units

The loci of horizontal movement at the GNSS units are shown below in **Fig. 6.6**. The loci of horizontal movement at the GNSS units is consistent with that observed at the survey prisms with general movement towards the extracted stopes and rapid increases coinciding with the formation of sinkholes. A rapid increase towards Stope 4 is observed in GNSS03 on 30 and 31 August. The date of this increase is several days after the recorded date of Sinkhole S2 on 24 August. The movements may be related to the early formation of Sinkhole S9 which daylighted at a much later date.

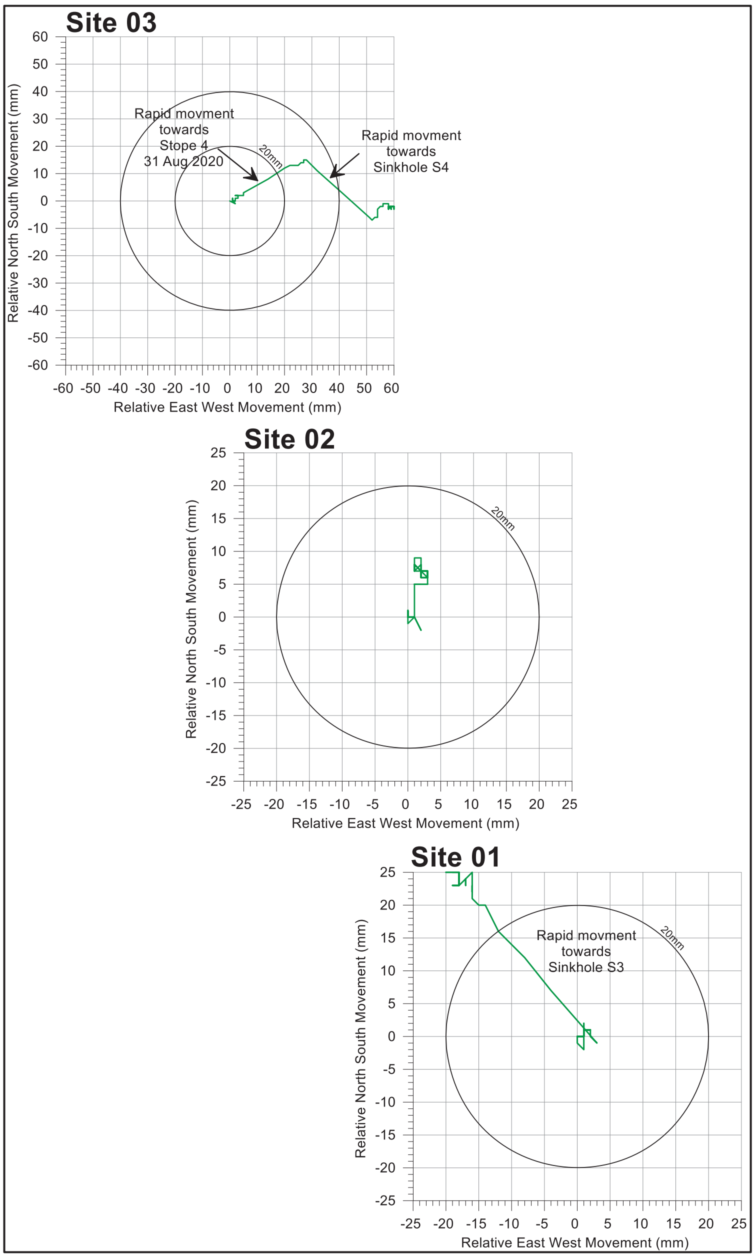

Fig. 6.6 Loci of horizontal movement at GNSS units

Angle of draw

Previous reported angles of draw were based on the limit of 20mm of vertical subsidence which is typically used in underground mining. As discussed above, prior to the development of the sinkholes, the measured vertical subsidence was generally less than 5mm. Following the development of the sinkholes, the profiles showed that vertical subsidence reduced rapidly with increasing distance away from the sinkholes. The measured angles of draw to 20mm of vertical subsidence based on the survey prism array vary from 8° to 23°.

7. Discussion

With previous discussions of potential subsidence development above the mined stopes, it was assumed that vertical subsidence would be small over an individual stope, then significantly increase with subsequent adjoining stopes. With progressive stope extraction, a maximum vertical subsidence of up to 95% of the extracted thickness could develop. The assumed incremental subsidence predictions curves are shown below in **Fig. 7.1**. The lower curve shows the subsidence from single voids and the upper curves are used when the “pillar” of sand between the mined voids is very narrow. MSEC also assumed that the shape of the observed subsidence profiles over each of the extracted boreholes would be generally symmetrical.

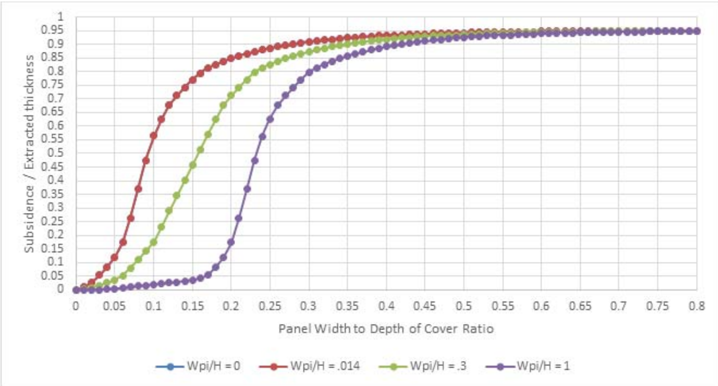

Fig. 7.1 **Assumed incremental subsidence prediction curves for the Iluka HM sand mining project**

The resulting prediction lines shown in Fig. SL0 to Fig. SL8 and Fig. P101 to Fig. P126 are less than the observed subsidence profiles. The observed subsidence profiles are however dominated by irregular movements created by the formation of the sinkholes. While the observed profiles are greater than predicted, they are predominantly representative of the developed sinkholes and do not reflect the adopted subsidence prediction methodology.

Subsidence predictions in the IPM modelling are based on the assumption that the overburden typically caves into the mined void with the retreating extraction forming a goaf above the extracted void. Where the ratio of void width to overburden depth is small, it is assumed that small magnitudes of subsidence would develop due to bridging and sagging of the overlying strata. As the ratio of void width to overburden depth increases and adjoining panels are extracted, the magnitude of vertical subsidence increases to a maximum limit, assumed to be 95% of the extracted thickness for Balranald.

The T3 trial did not extract adjoining stopes as planned but extracted two stopes separated by a pillar of approximately 22m. The observed survey monitoring data indicates that very little conventional subsidence developed during the extraction of the stopes and prior to the formation of sinkholes. Any observed subsidence prior to the sinkhole formation was very small and likely the result of fluctuations in ground stresses caused primarily by the mining pressure balances.

The observation of the development of vertical subsidence and horizontal movements surrounding the sinkholes suggests a rapid redistribution of ground stresses resulting in horizontal and vertical movement towards the sinkhole locations. In the case of Sinkholes S7, S8, S9 and S10, the development of horizontal movements suggests earlier subsurface development of the sinkholes with no significant change at the time the sinkholes daylighted.

It is not possible to model the magnitudes of subsidence development associated with sinkholes. The formation of the sinkholes however suggests that if a more uniform goafing behaviour could be induced, then vertical subsidence could develop above the stopes at a relatively high percentage of the extracted void.

The difficulty with modelling the observed behaviour of the stopes in the T3 trial is that the development of sinkholes is not uniform. The initial assumption of up to 95% of the extracted thickness of the seam is considered valid as the sinkholes represent a significant percentage of the extracted seam at their isolated locations. Future modelling would be based on assumed non-bridging behaviour of the strata overlying the stopes. The maximum percentage of the extracted thickness may be revised when more complete goaf development behaviour is achieved.

The estimated total volume of the observed surface subsidence over the monitoring array and the measured volume within the sinkholes equates to approximately 7,500 tonnes (assuming an average material density of $1.7t/m^3$). This represents approximately 24% of the tonnage of material extracted from Stopes 4 and 6 for the T3 trial. The estimated volume of the sink holes represents a larger proportion of the extracted material (approximately 19%) compared to the volume of the surveyed surface subsidence (approximately 5%).

The indications from the T3 trial are that a significant portion mine area of Stope 4 and 6 remains with bridged strata above the extracted stopes. The immediate voids created by the extraction of the HM sands are filled with drilling fluids and remnant loosened insitu materials in suspension. Pressures are somewhat balanced during the mining process and settlement of the surrounding sands occurs at some time after the retreat of the bottom hole assembly. The timing of settlement of the sands could be immediate or delayed depending on the material properties and depending on whether net pressures are positive or negative. It is understood that positive pressures are preferred during the mining process to retain an open void and improve material recovery. The mining process is also discontinuous with stoppages to remove the 6m drill strings and variability with jetting and extraction which would result in variability of the void conditions along the mined stope.

The possible initiators of the piping and resultant strata failure and sinkhole formation are thought to include mining operations, backfilling operations, exploration or other boreholes, time dependent settlement within the LPS, and time dependent softening/dispersion of silts and clays within the SFM. It is considered likely that many if not all of these initiators influenced the currently observed sinkholes. The delayed emergence of Sinkholes S7 to S10 and low percentage of surface void compared to mined void suggests piping/unravelling of the overburden materials may be present at other locations along the stopes that are yet to be eroded up to ground surface level. With almost half of the sinkholes daylighting after mining operations, it is considered probable that future sinkholes will develop above or near the stopes.

With conventional goafing behaviour, the majority of the observed surface subsidence develops progressively during mining, with minor movements developing after mining. In areas of shallow mining, it is common for the formation of goaf above the mined voids to extend up to the ground surface with no significant bridging and sagging of the overlying strata. In the case of the T3 trial, the mechanism of goaf development appears to be a failure of the predominantly sandy overburden above the stopes in the LPS, then a bridging of the strata in the SFM, which is dominated by silts and clays. Whether through continued settlement of fines within the collapsed LPS strata or softening and dispersion of the silt and clay layers in the SFM, piping failure and sinkhole events have occurred along the alignments of the stopes both during and following the completion of mining. The narrow stope dimensions, low magnitude of observed subsidence and sinkhole development indicate partial and incomplete development of goaf within the strata above the stopes.

As noted above, it is considered that with the development of a suitable extraction methodology, uniform ongoing goafing behaviour could be achieved during mining to allow full subsidence to develop and minimise the risk of sinkhole formation. Without a revised approach, it is expected that future mining would likely encounter similar behaviour, i.e. small observed subsidence and the formation of sinkholes. The following suggestions are provided for consideration of approaches that may induce suitable goafing behaviour of the overburden materials:

- Avoiding single, isolated stopes. Future trials may yield a minimum number of adjoining stopes necessary for suitable goaf development. Single stopes would likely occur however in some locations where operational issues may prevent continuity of mined stopes.
- Mining adjacent stopes sequentially rather than staggered or irregular sequence. Sequential extraction should provide more favourable conditions for goaf development by minimising pillars or unmined areas that provide support to the overlying strata.
- Mining wider stopes. While it is thought that adjoining stopes would increase the likelihood of overburden collapse, current mining operations limit the extraction width of stopes to the designed 12m width. The mining of individual narrow stopes still poses risk of sinkhole formation during mining and immediately after mining as observed in the T3 Trial. Consideration could be given to methods that may increase the as extracted width of the stopes.
- Pressure balance. The current retreat mining leaves a void filled with drilling fluid, water and suspended particles. Caving of the overburden material forms by settling and/or slumping through the fluid filled void as caving of the overburden cannot readily displace the material in the void. Consideration could be given to methods that may induce more uniform caving behaviour by allowing displacement of the material in the void.
- Compaction methods. Consideration could be given to deep compaction methods that may aid to induce more uniform strata failure along the stope during or following extraction of the stopes. Methods such as dynamic compaction, deep vibratory compaction or explosive compaction could be considered. These compaction methods are often adopted in cohesionless free draining materials to aid compaction and prevent sinkhole formation, however the purpose would be to induce failure of the strata bridging above the extracted voids.

8. Summary

The third trial of a novel stope mining method for extraction of Heavy Mineral Sand deposits (T3 trial) was undertaken in August and September 2020. The T3 trial represented an increased scale of mining compared to the T1 and T2 trials.

A number of sinkholes formed along the mined stopes both during and after the T3 trial. The detailed observed subsidence movements show ground surface deformation dominated by the development of the sinkholes. In the absence of the sinkholes, observed subsidence movements are negligible. The results indicate irregular and incomplete subsidence development above the mined voids. Seismic surveys confirm the presence of voids within the LPS, up to the underside of the SFM. The data assessments indicate that the clayey materials in the SFM are bridging above the mined stopes then failing in isolated locations in a piping type failure to create the sinkholes. Further assessment of the sinkholes could be undertaken to review the shape, size and orientation, and possible relationships to stope dimensions, mining conditions, and overlying strata.

Assessment of the survey monitoring data indicated ground movement towards the location the sink holes. The data also indicated ground movement towards Sink hole S9 which formed post mining. Further detailed assessment of ground monitoring data could be undertaken to review relationships between movement and sink hole development. Such analysis may aid in identifying areas at greater risk of developing sink holes.

The bridging and formation of sinkholes poses significant difficulty with subsidence prediction modelling as the behaviour of the sinkholes are irregular and cannot be readily modelled. Subsidence predictions for future extraction should be based on non-bridging behaviour of the overlying strata. It is thought that, with a review of the mining methodology, changes could be made to induce more uniform goafing behaviour of the overburden during mining. This would reduce the risks of sinkhole formation and allow a more reliable prediction model to be developed.

A revised IPM prediction model would incorporate the assumption of non-bridging behaviour and could be further revised once improved goafing behaviour is achieved. Future mitigation measures such as stripping and surface backfilling would be incorporated into revised modelling. Consideration could also be given to physical modelling to better understand the bridging behaviour, strata failure and sink hole development above the stopes.

Yours sincerely,

Peter DeBono
Mine Subsidence Engineering Consultants

Attachments:

Drawing No. MSEC1152-01 Rev. A - General Layout

Attachment A:

Profiles of subsidence, tilt and strain along longitudinal monitoring lines SL0 to SL8

Profiles of subsidence, tilt and strain along transverse monitoring lines P1010 to P126

References:

HiSeis, November 2016, Iluka Resources Seismic Project Report, Document Ref 103-BALPTOJ16

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Iluka Resources, 2019, Subsidence Management Plan (SMP) - Balranald Project, Document No. T19103

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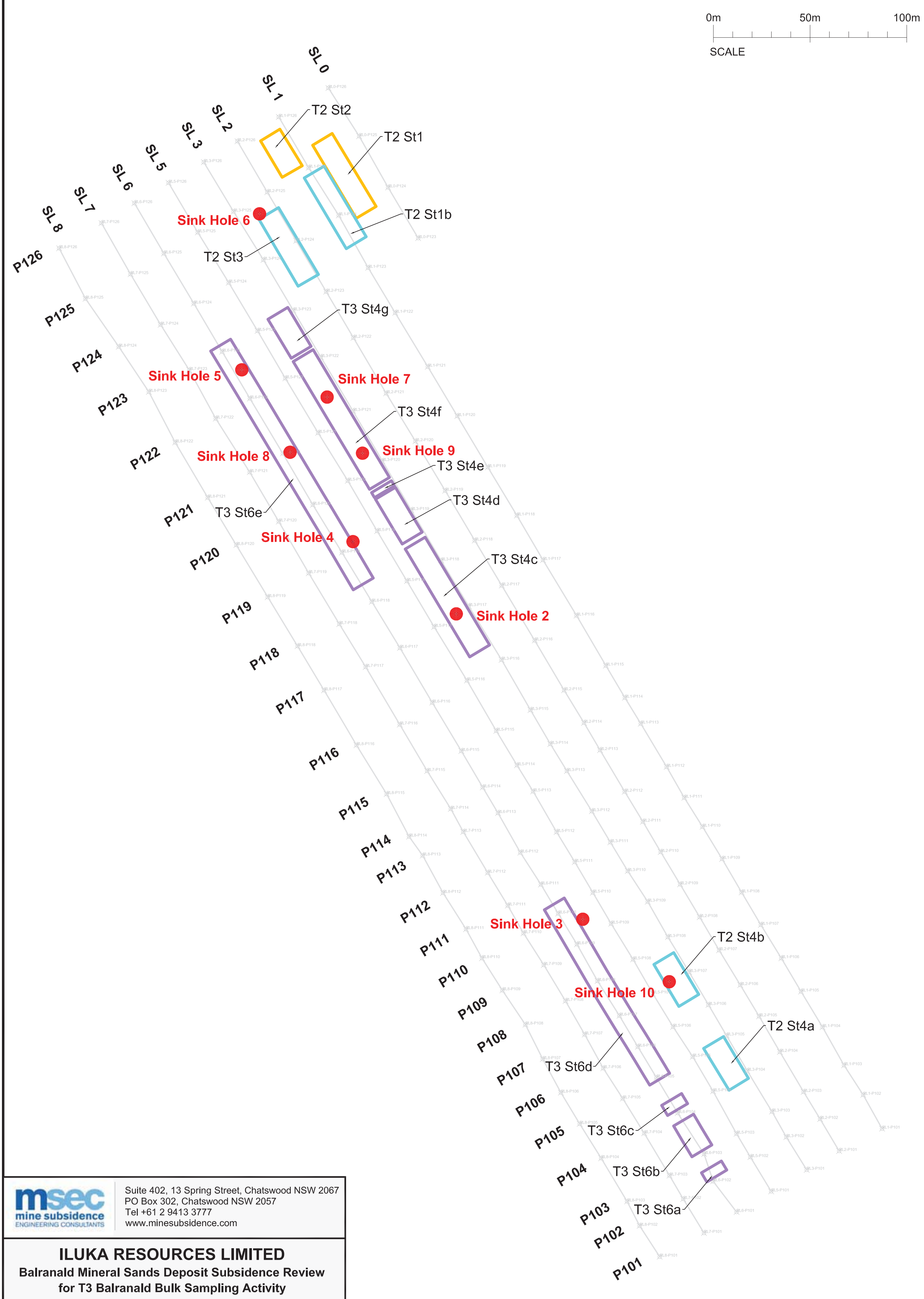
Iluka Resources, 6 September 2020, Geotechnical Report - Balranald T3 Stope 4 Surface Deformation.

Iluka Resources, 23 October 2020, Balranald Bulk Sampling Activity (T3) – Subsidence Events – Preliminary Report

Michael Nicholson Consulting Pty Ltd – Balranald Sink Holes – Progressive Report. T3_SurfaceExpression_2012_00.pdf



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ILUKA RESOURCES LIMITED

Balranald Mineral Sands Deposit Subsidence Review for T3 Balranald Bulk Sampling Activity

DATE:	SCALE:	DRAWING No:	Rev No
15 Mar 2021	as shown	MSEC1152	A

Attachment A

Figures

Profiles of subsidence, tilt and strain along SL0 due to T3

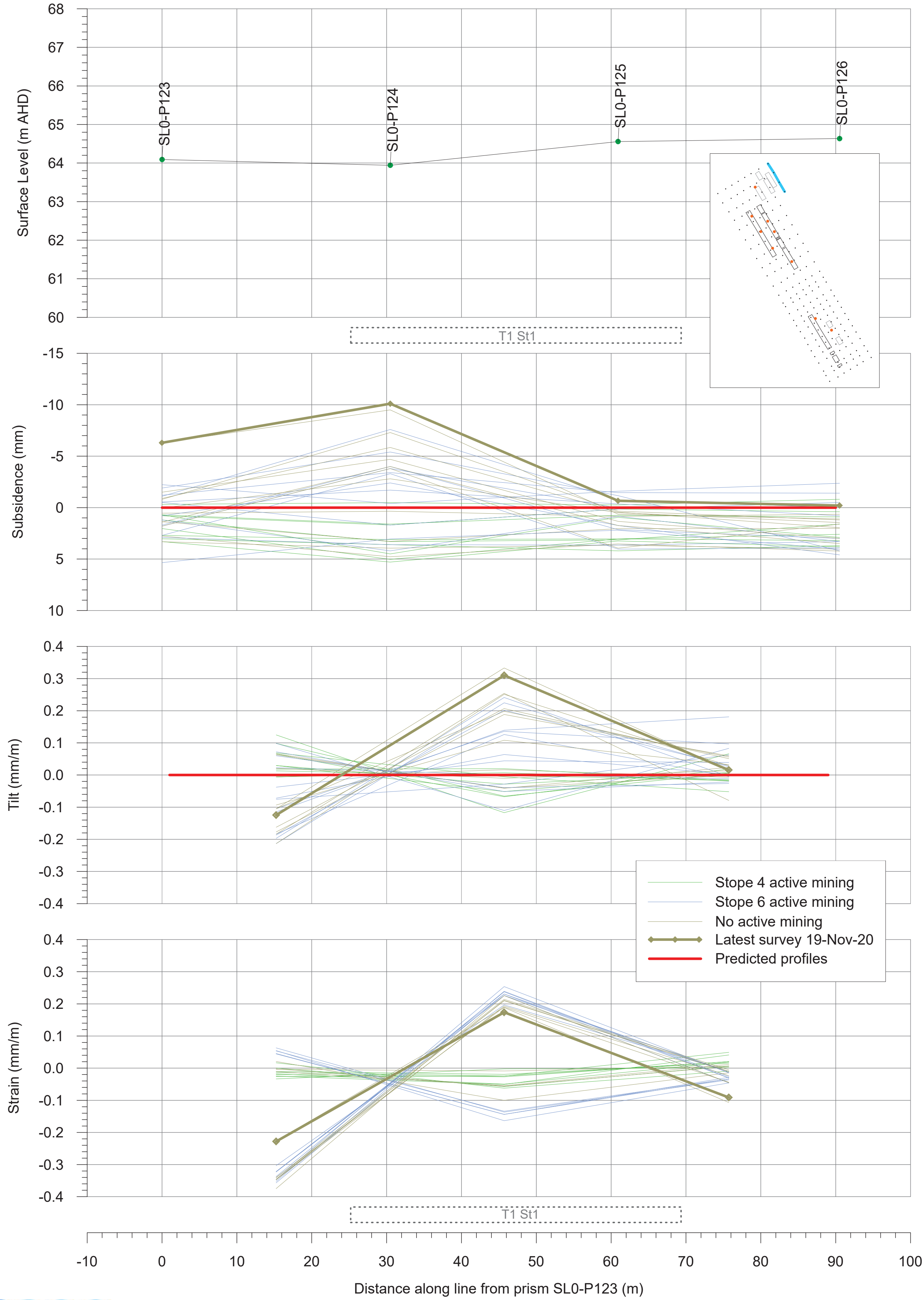

Fig. SL0

Profiles of subsidence, tilt and strain along SL1 due to T3

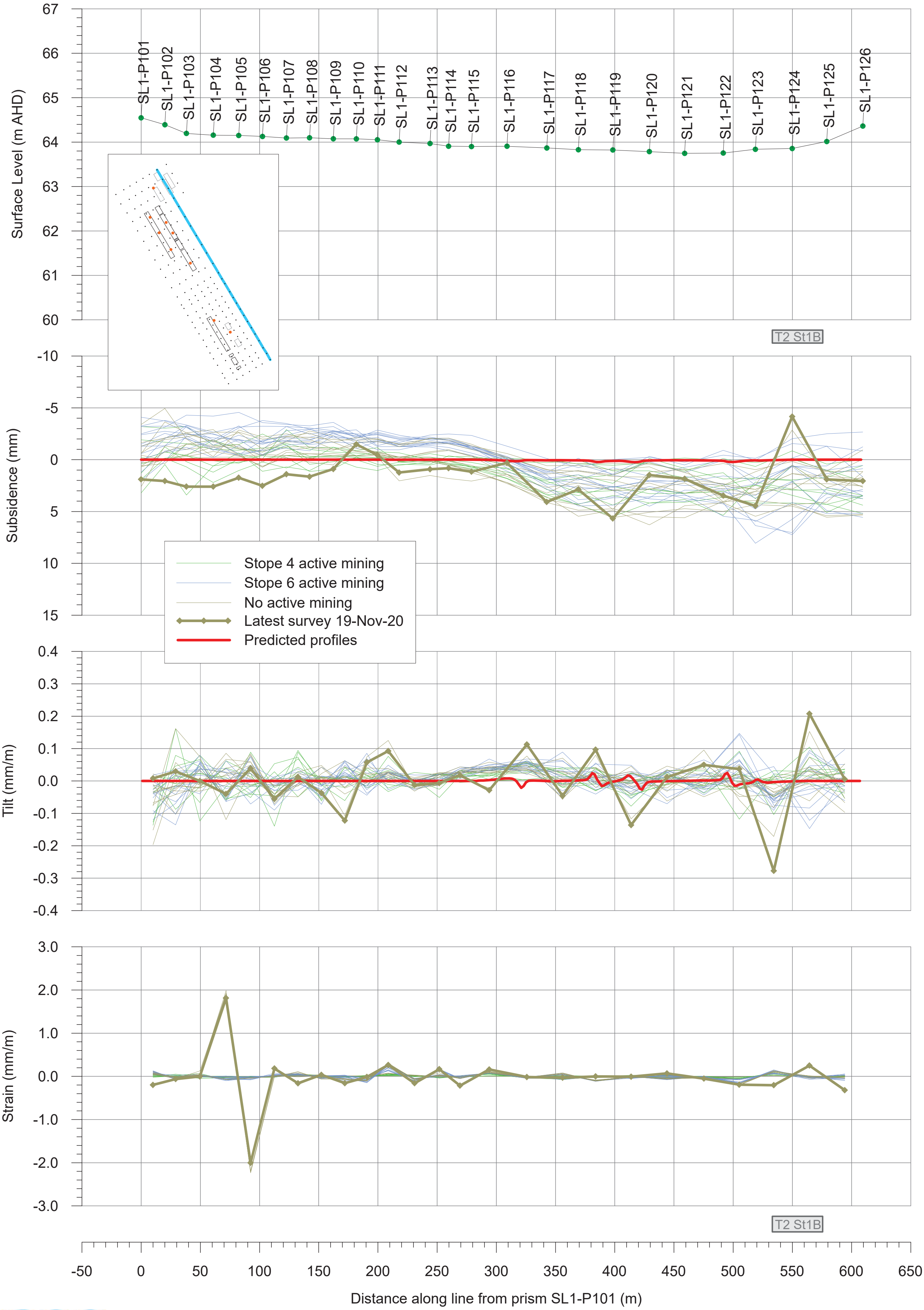

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Fig. SL1

Profiles of subsidence, tilt and strain along SL2 due to T3

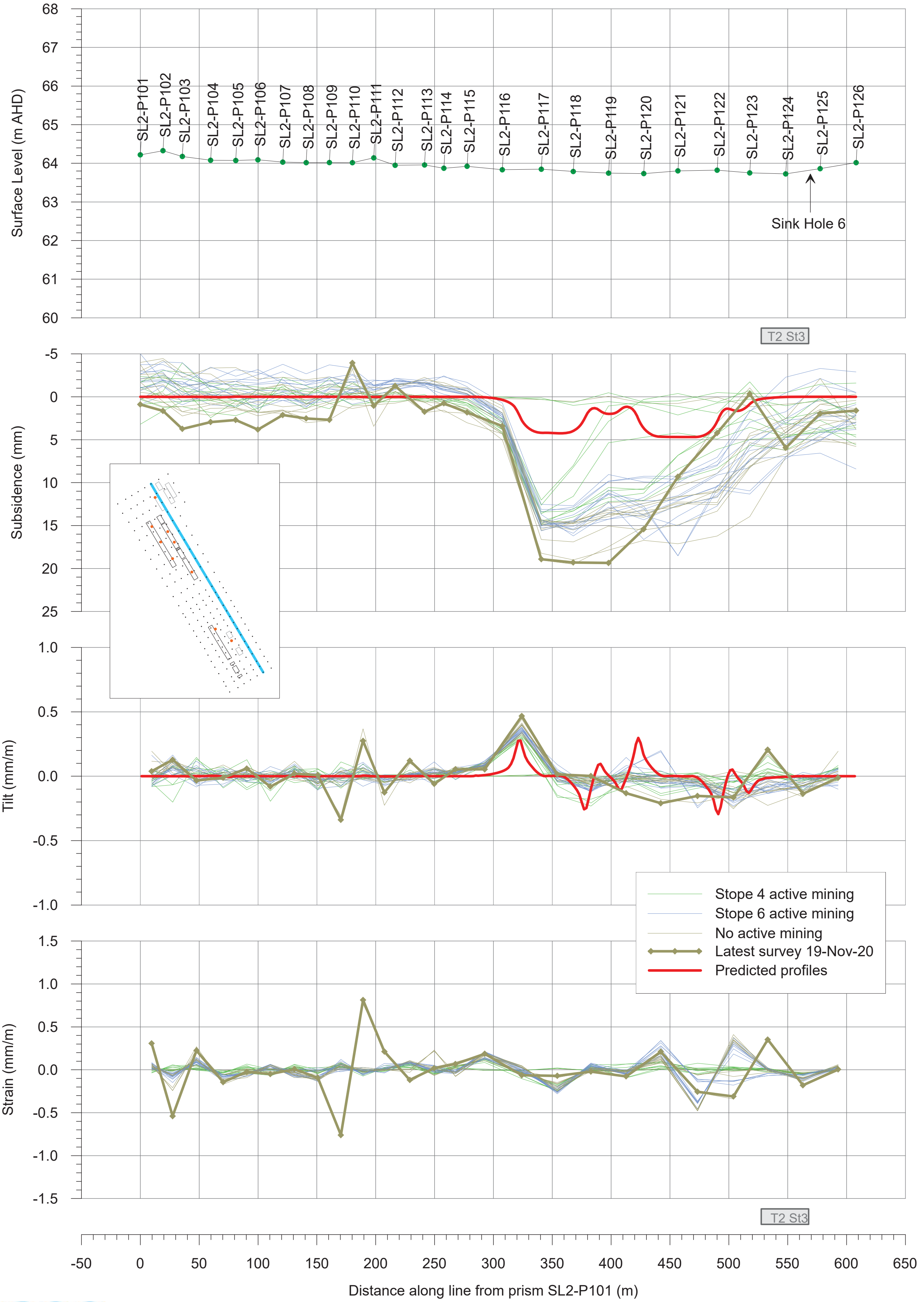

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Fig. SL2

Profiles of subsidence, tilt and strain along SL3 due to T3

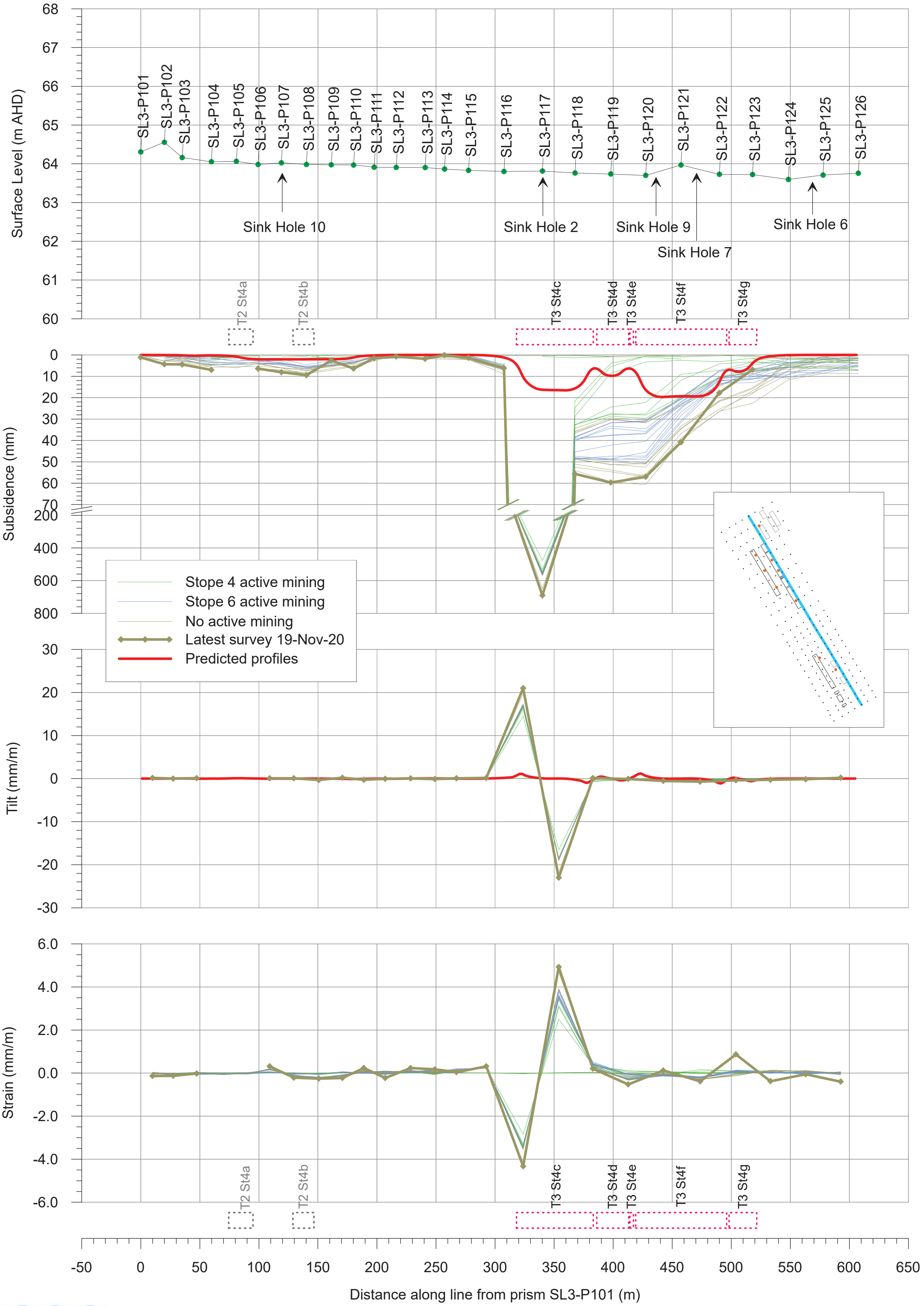

Fig. SL3

Profiles of subsidence, tilt and strain along SL5 due to T3

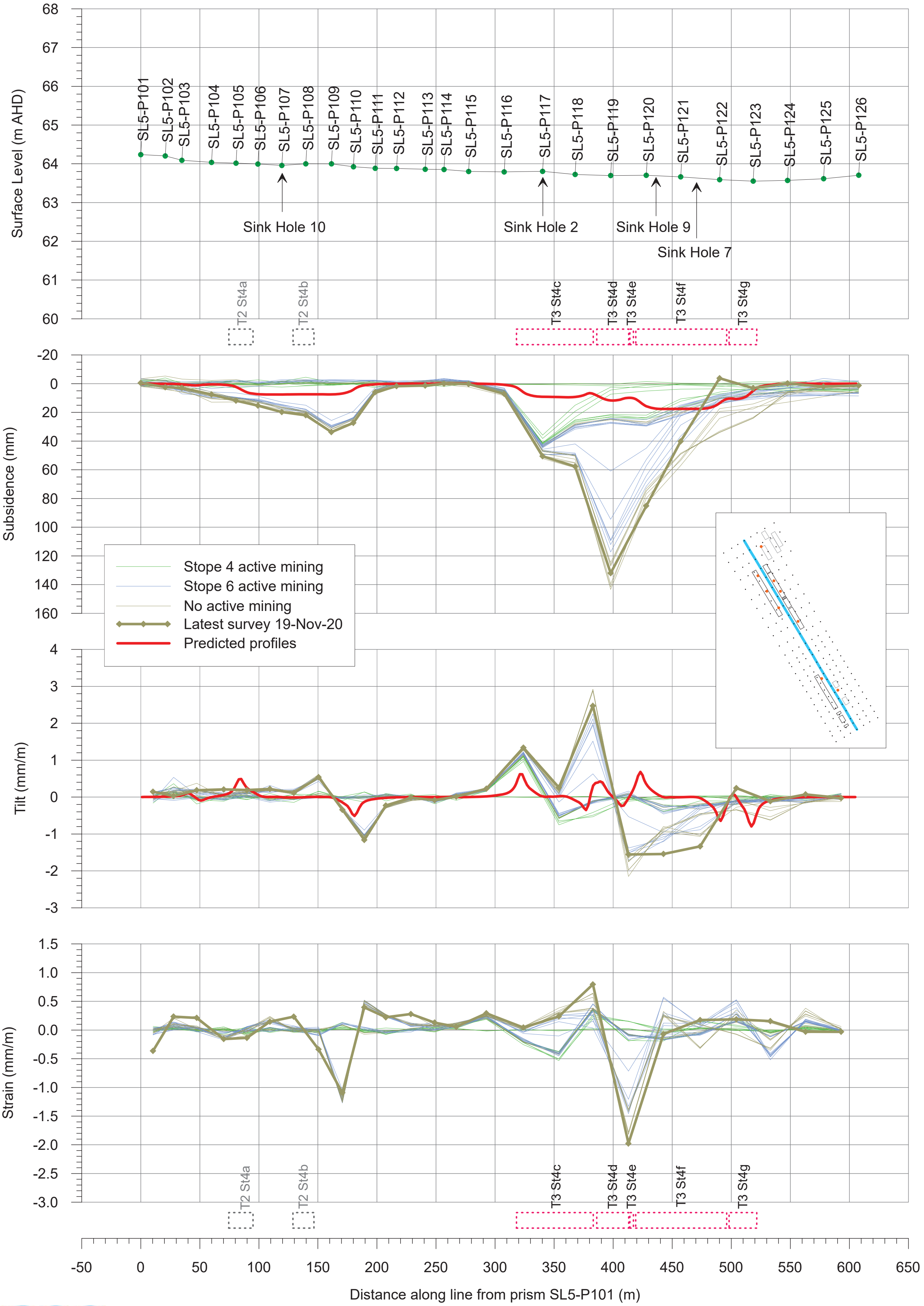

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Fig. SL5

Profiles of subsidence, tilt and strain along SL6 due to T3

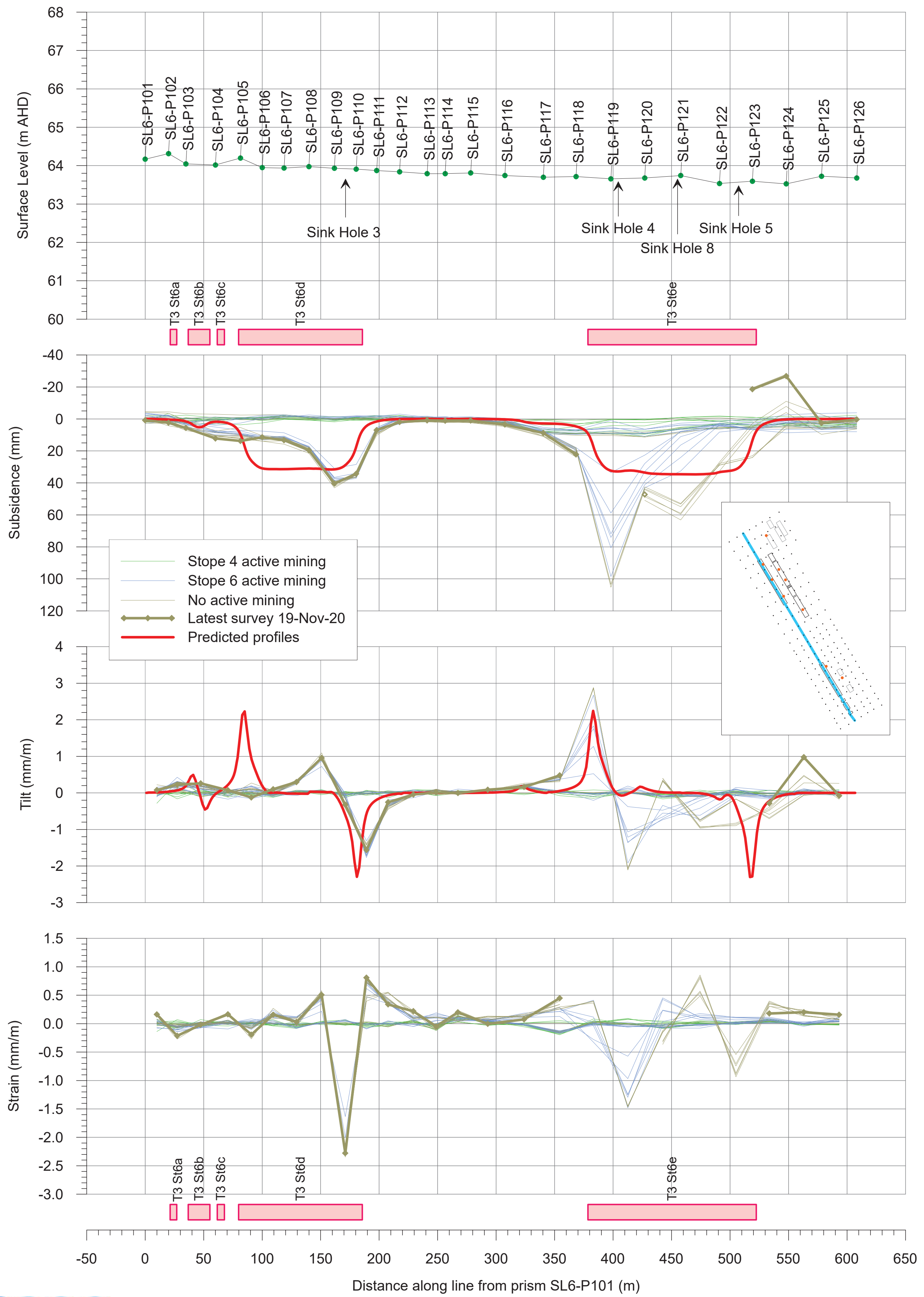

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Fig. SL6

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Profiles of subsidence, tilt and strain along SL7 due to T3

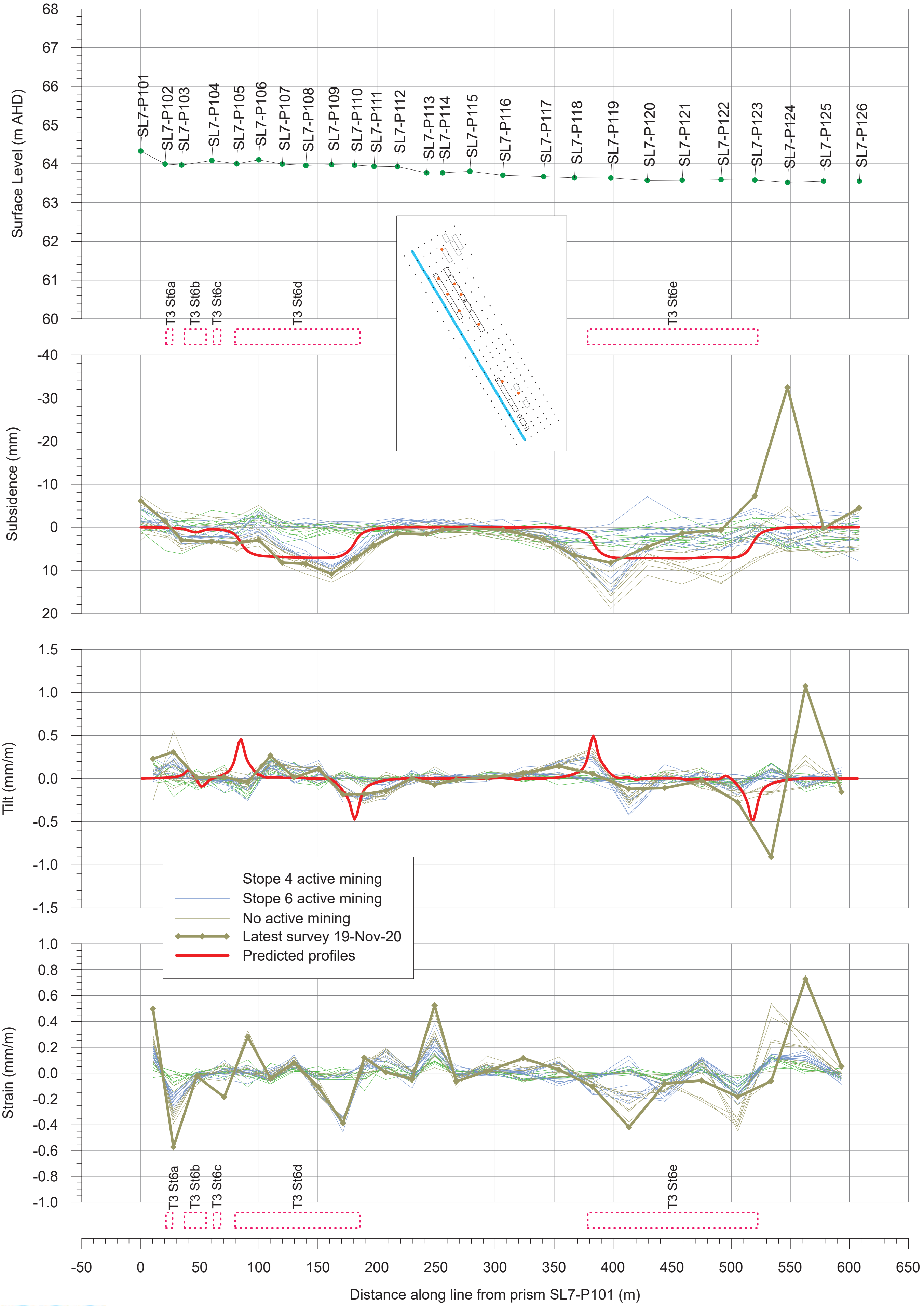

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Fig. SL7

Profiles of subsidence, tilt and strain along SL8 due to T3

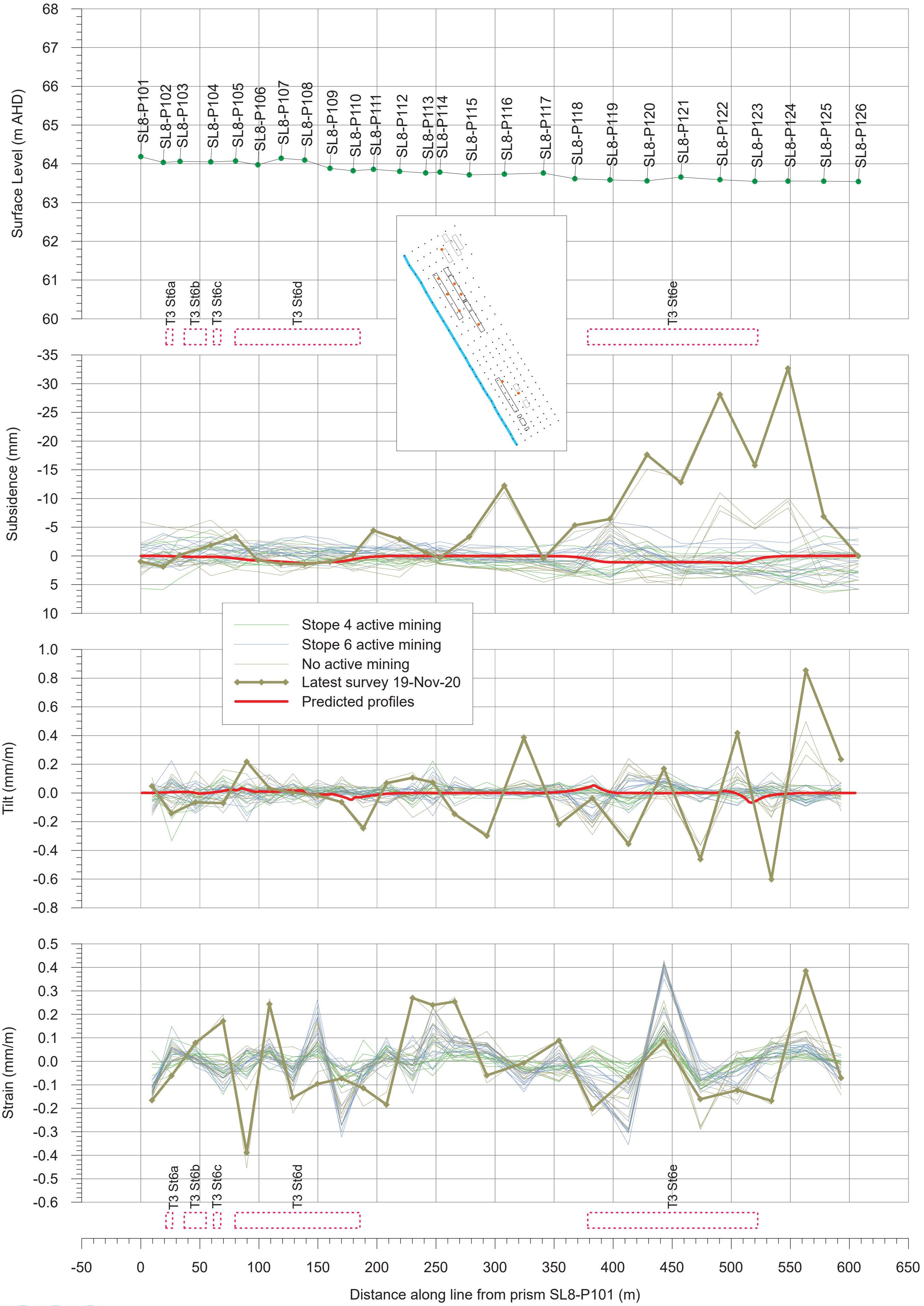

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Fig. SL8

Profiles of subsidence, tilt and strain along P101 due to T3

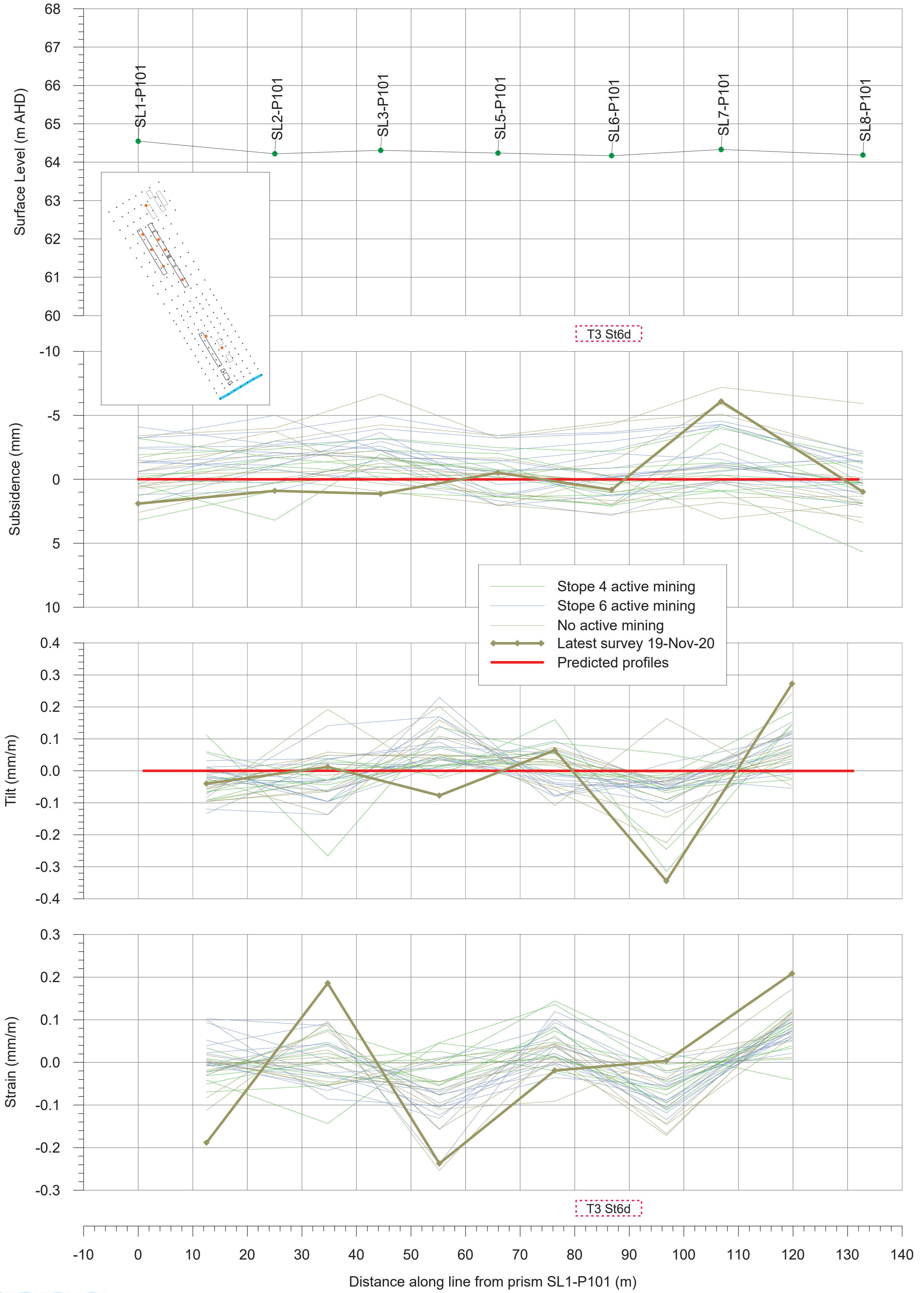

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Fig. P101

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Profiles of subsidence, tilt and strain along P102 due to T3

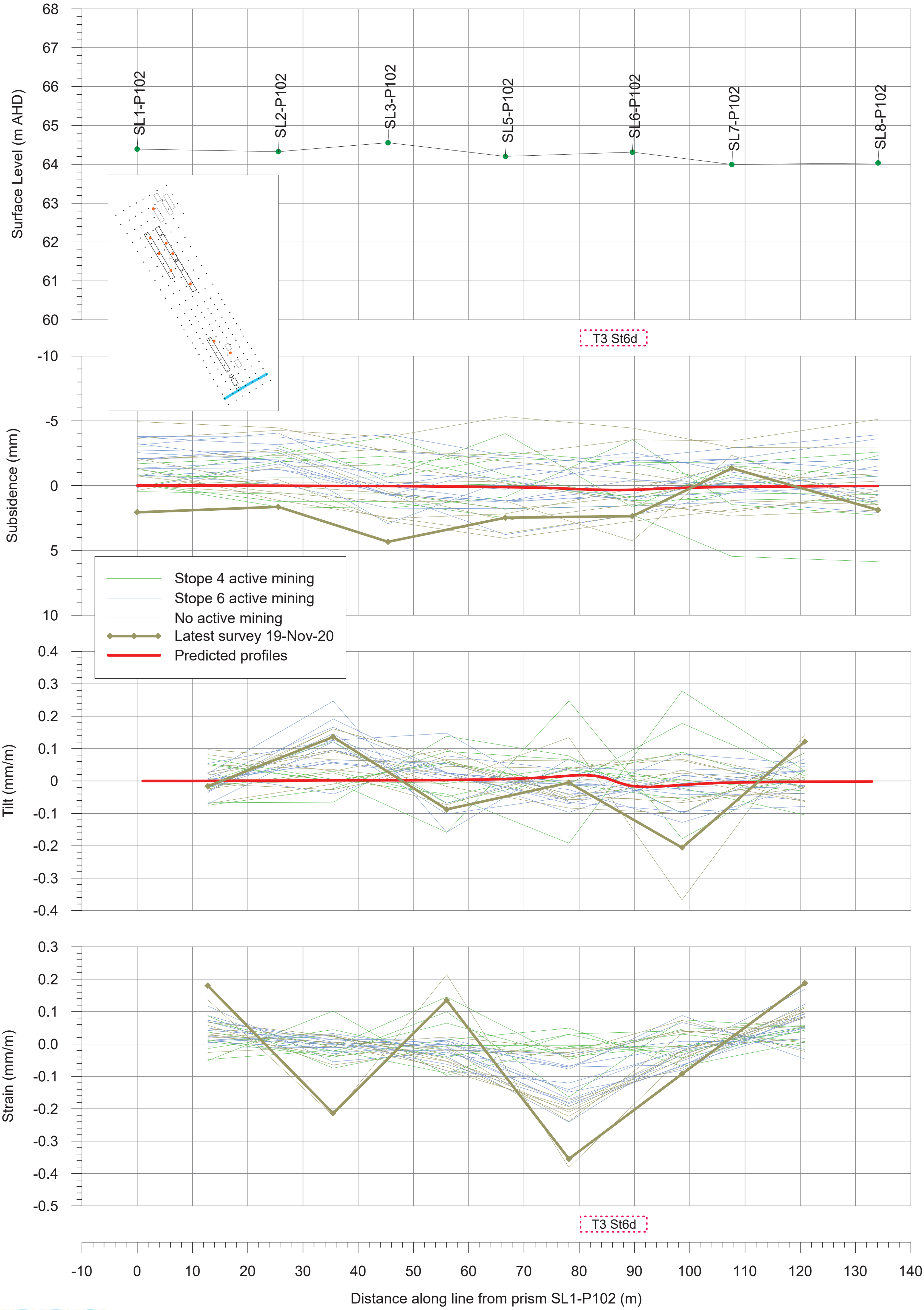

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Fig. P102

Profiles of subsidence, tilt and strain along P103 due to T3

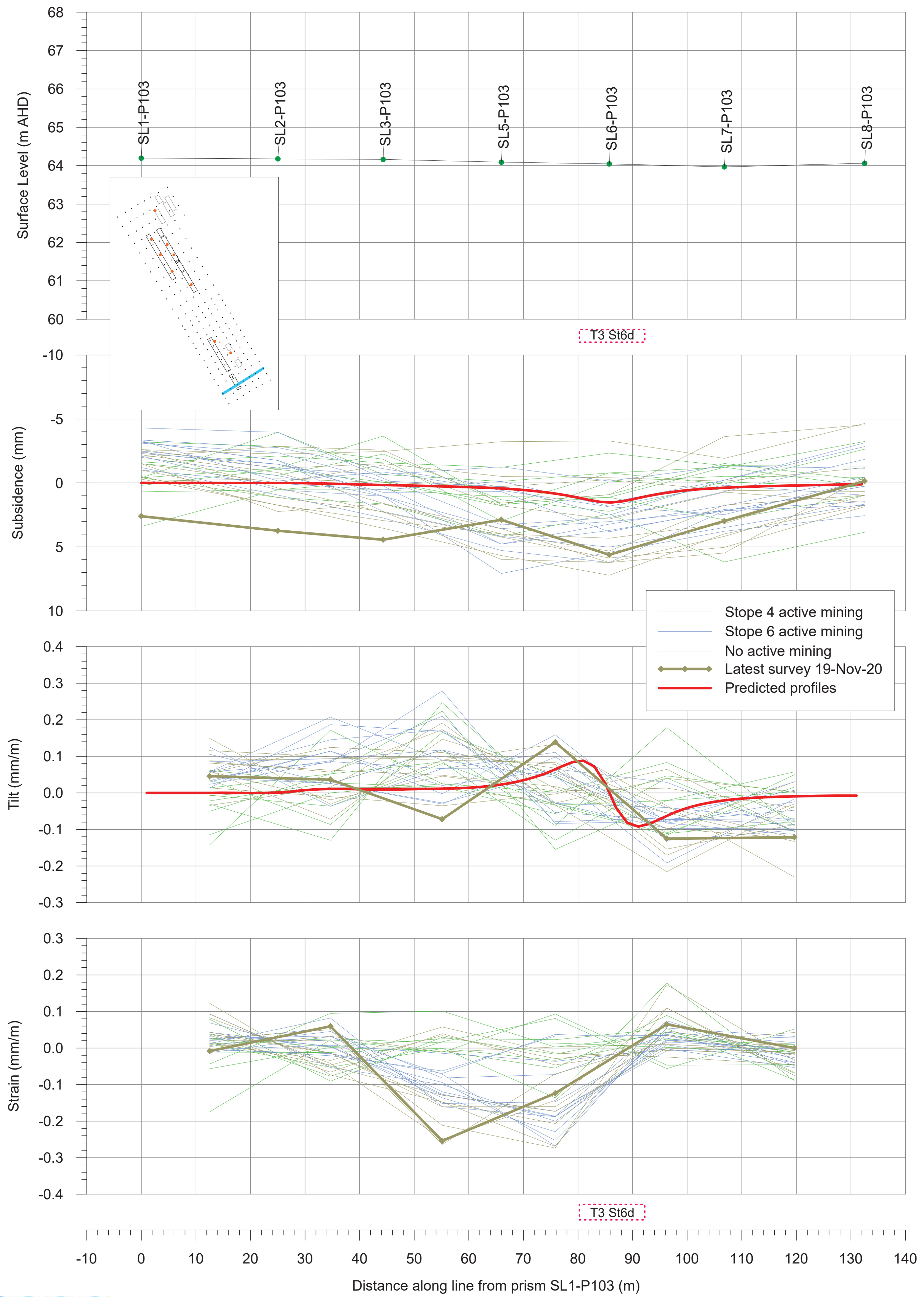

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Fig. P103

Profiles of subsidence, tilt and strain along P104 due to T3

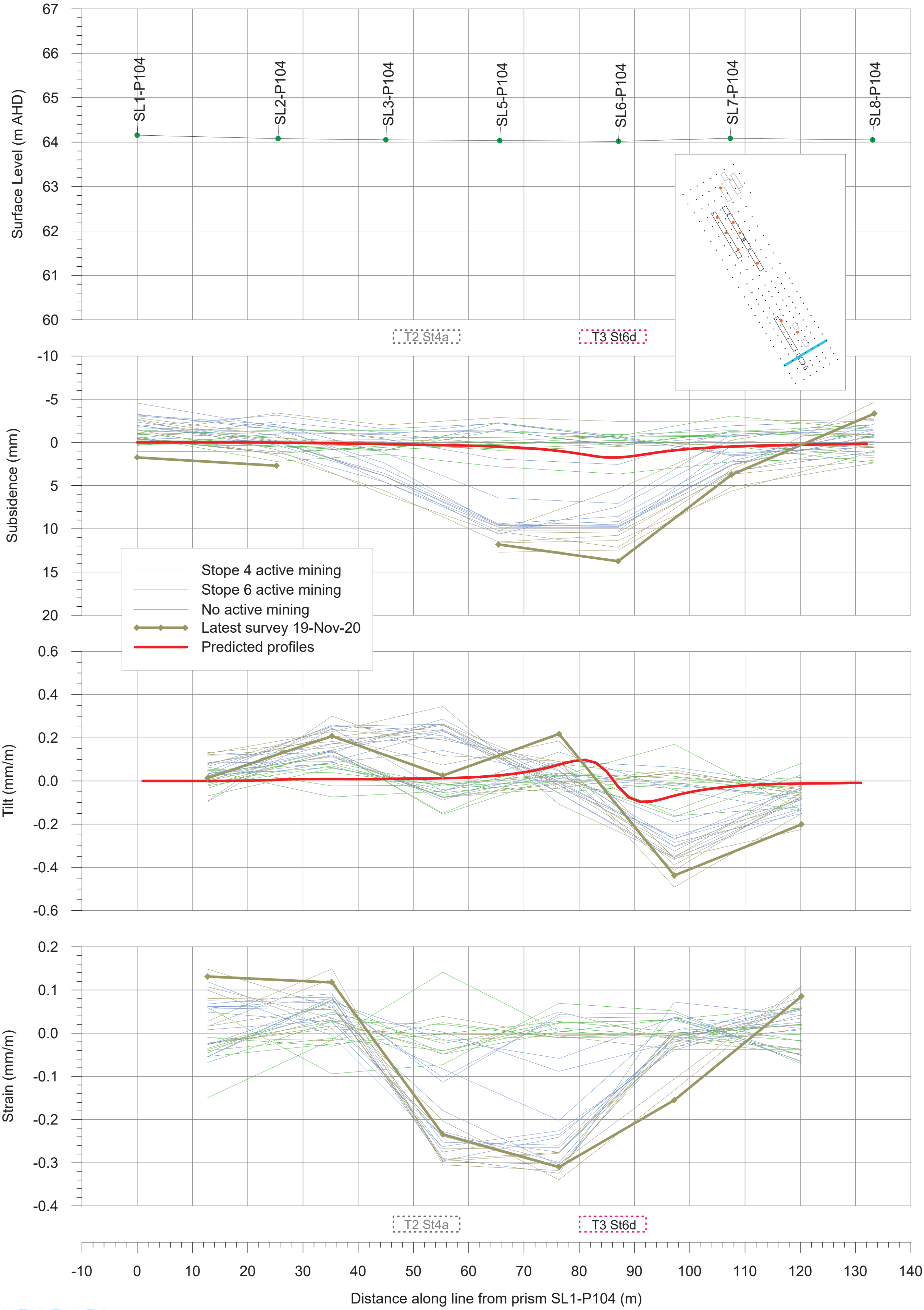

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Fig. P104

Profiles of subsidence, tilt and strain along P105 due to T3

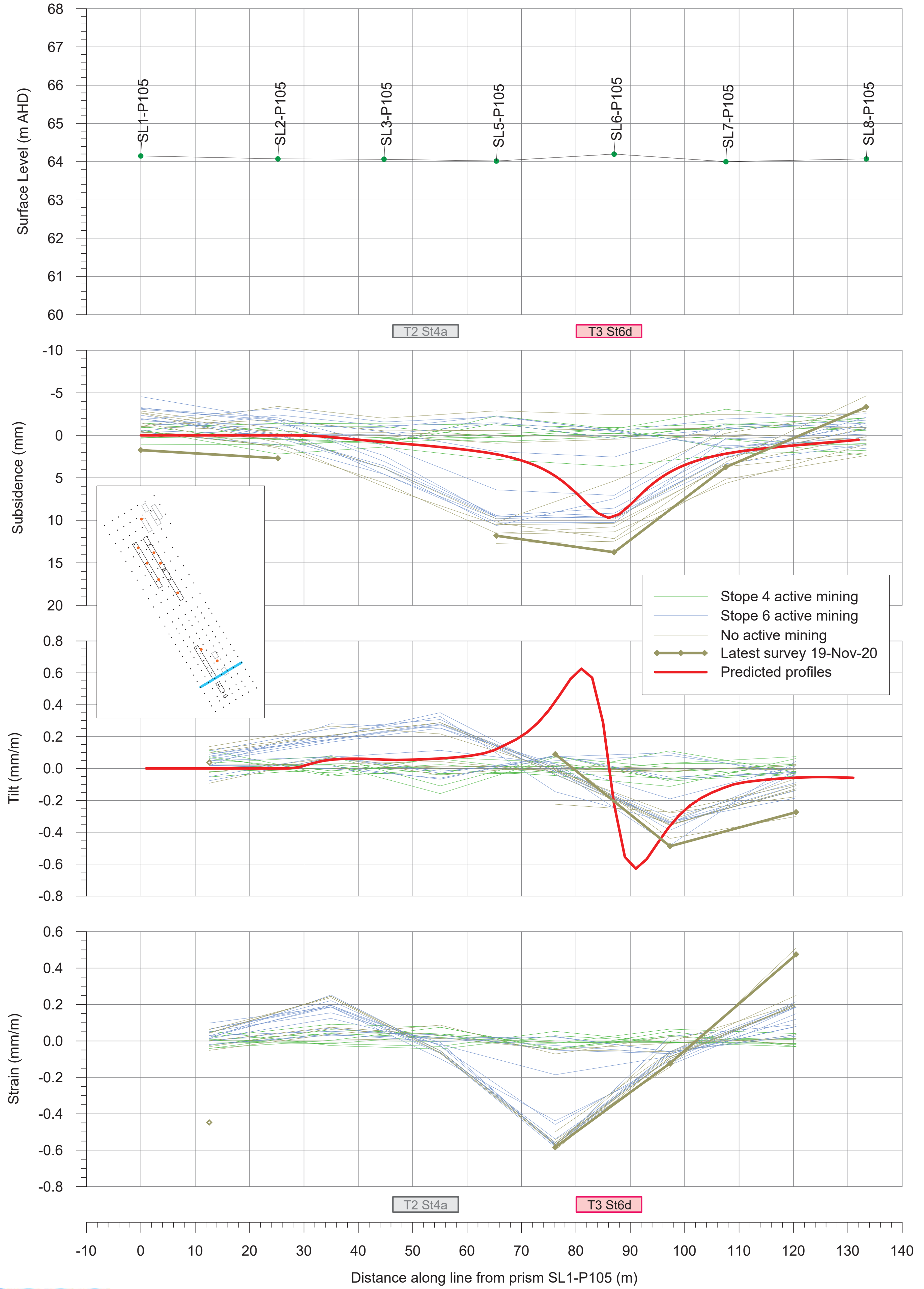

Fig. P105

Profiles of subsidence, tilt and strain along P106 due to T3

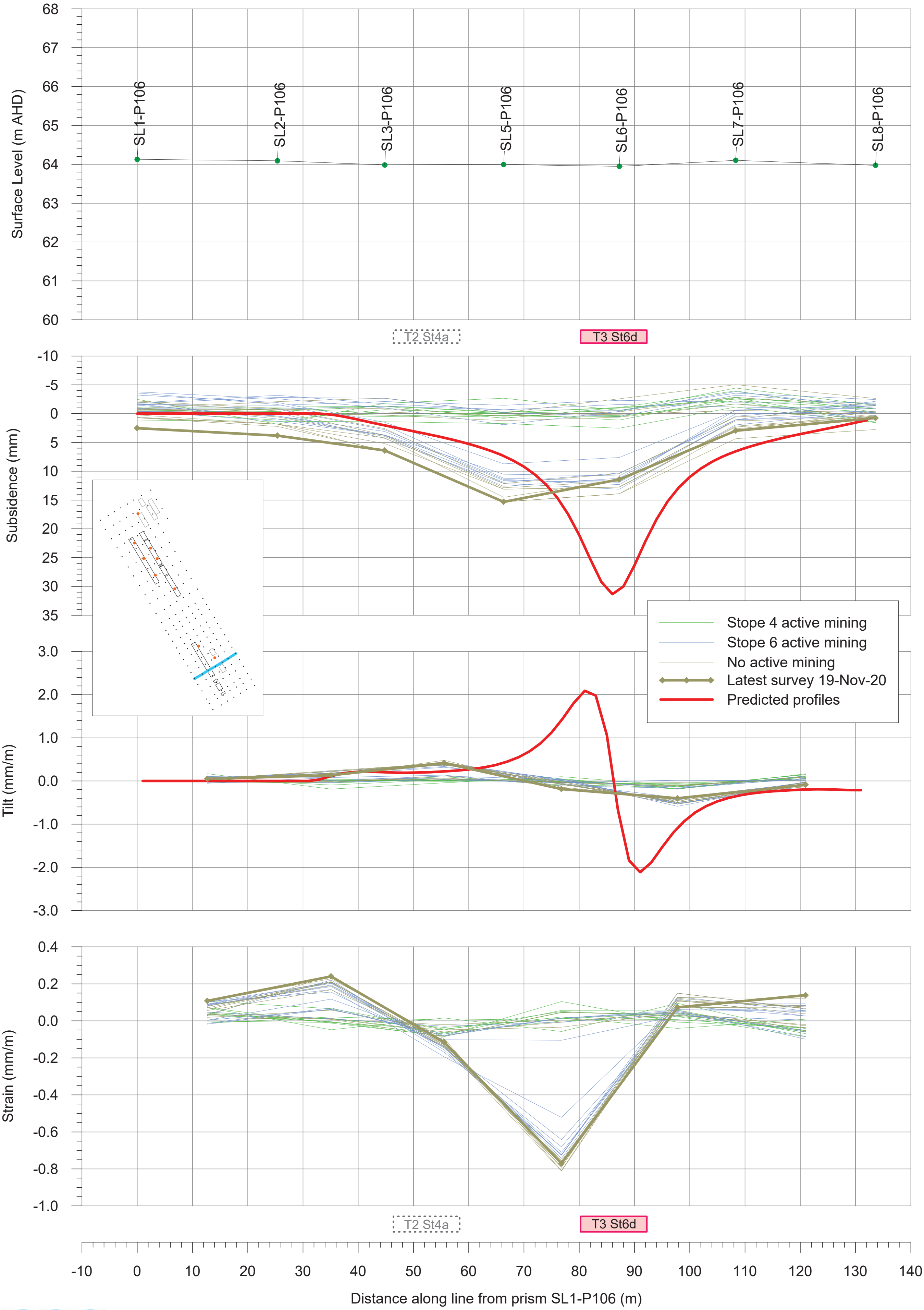

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Fig. P106

Profiles of subsidence, tilt and strain along P107 due to T3

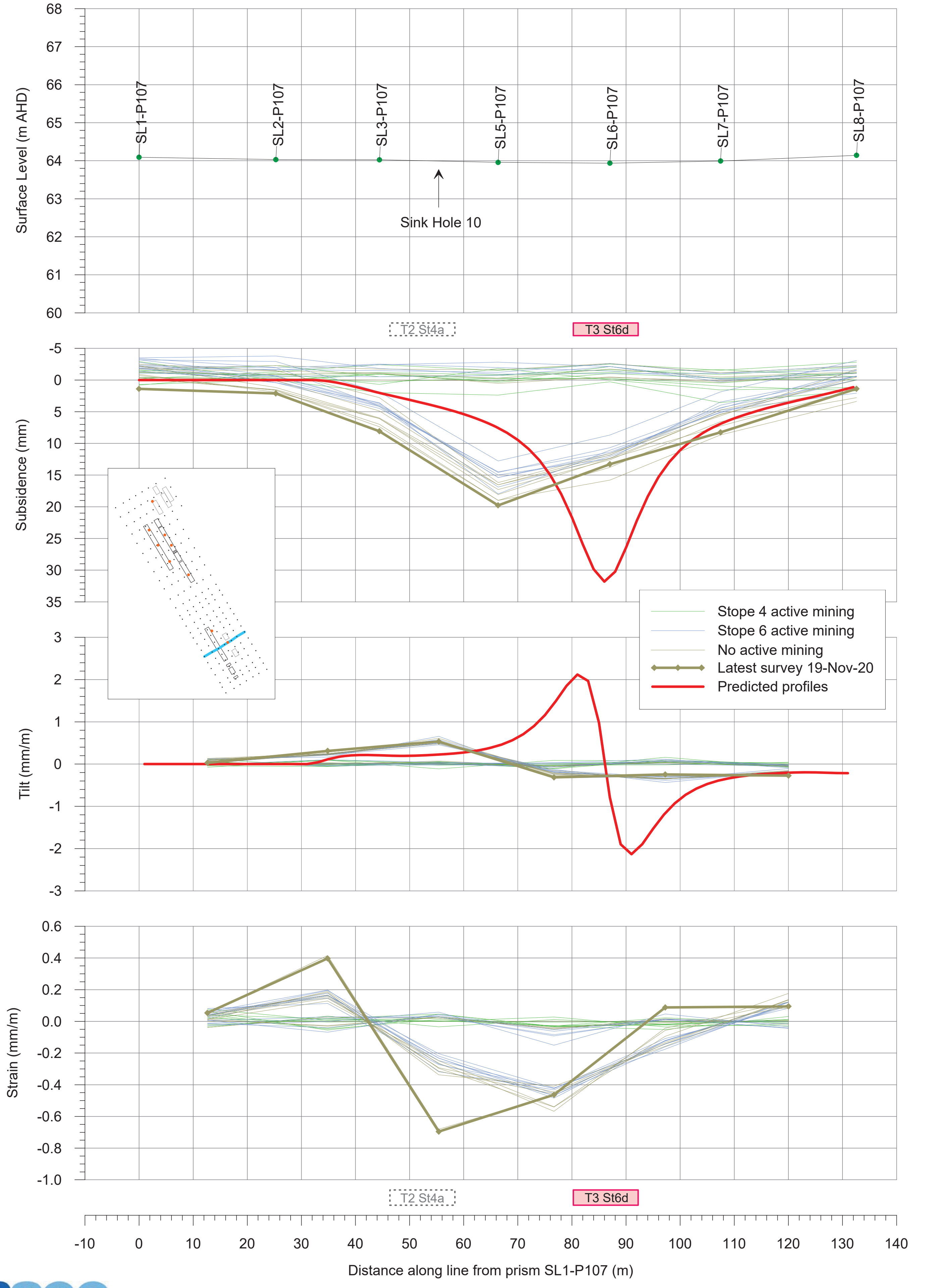

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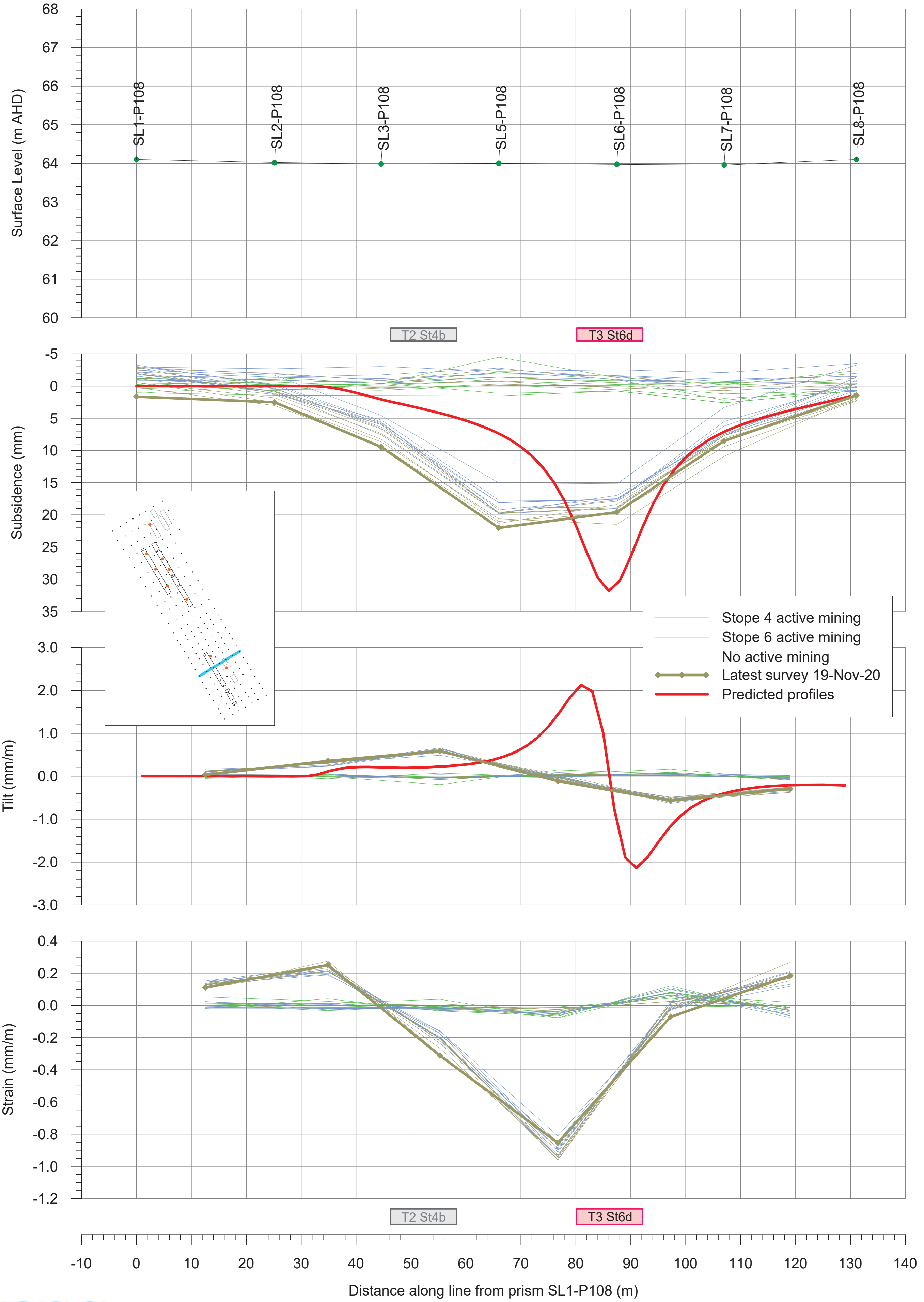
Fig. P107

Profiles of subsidence, tilt and strain along P108 due to T3



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Profiles of subsidence, tilt and strain along P109 due to T3

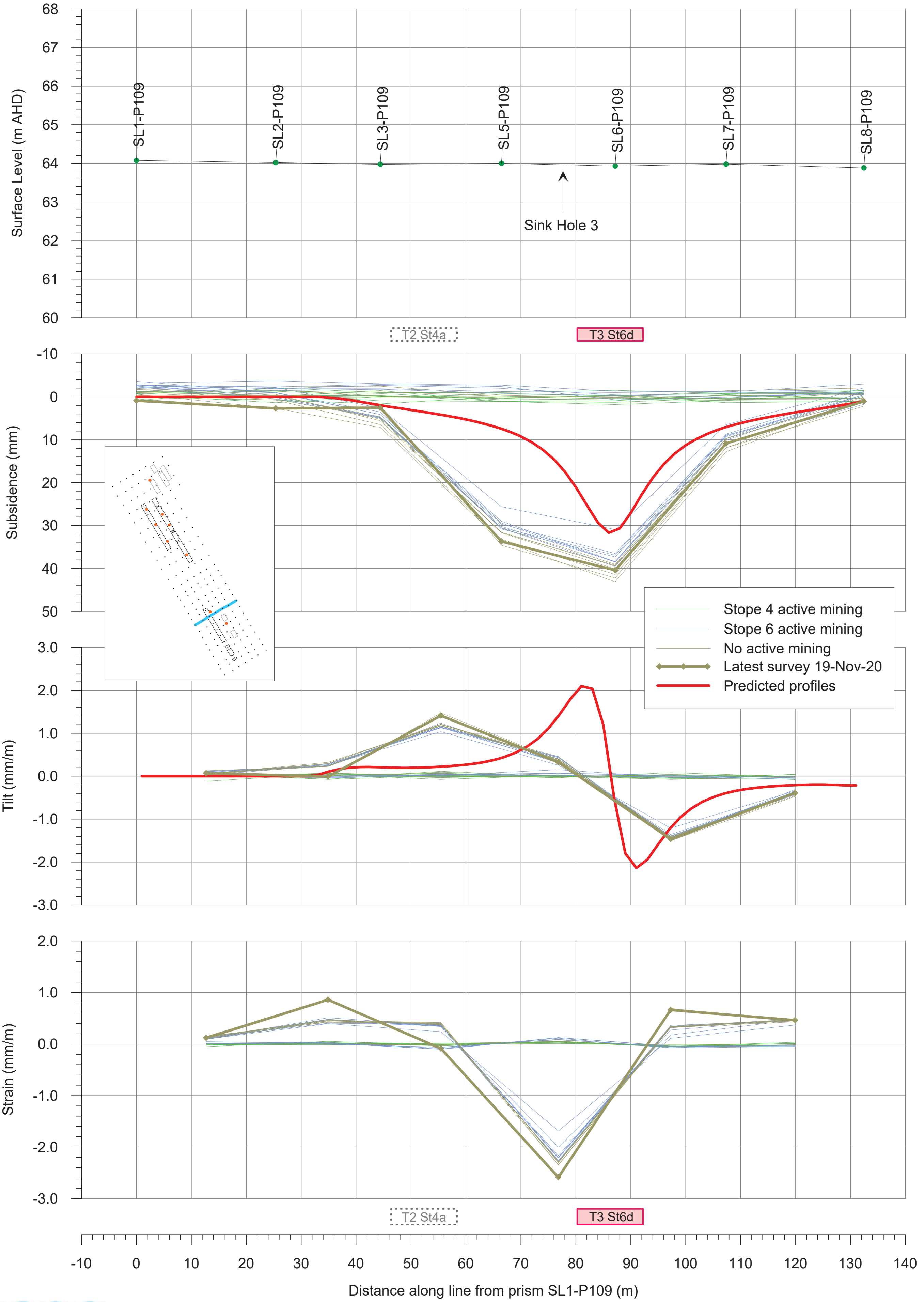

Fig. P109

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Profiles of subsidence, tilt and strain along P110 due to T3

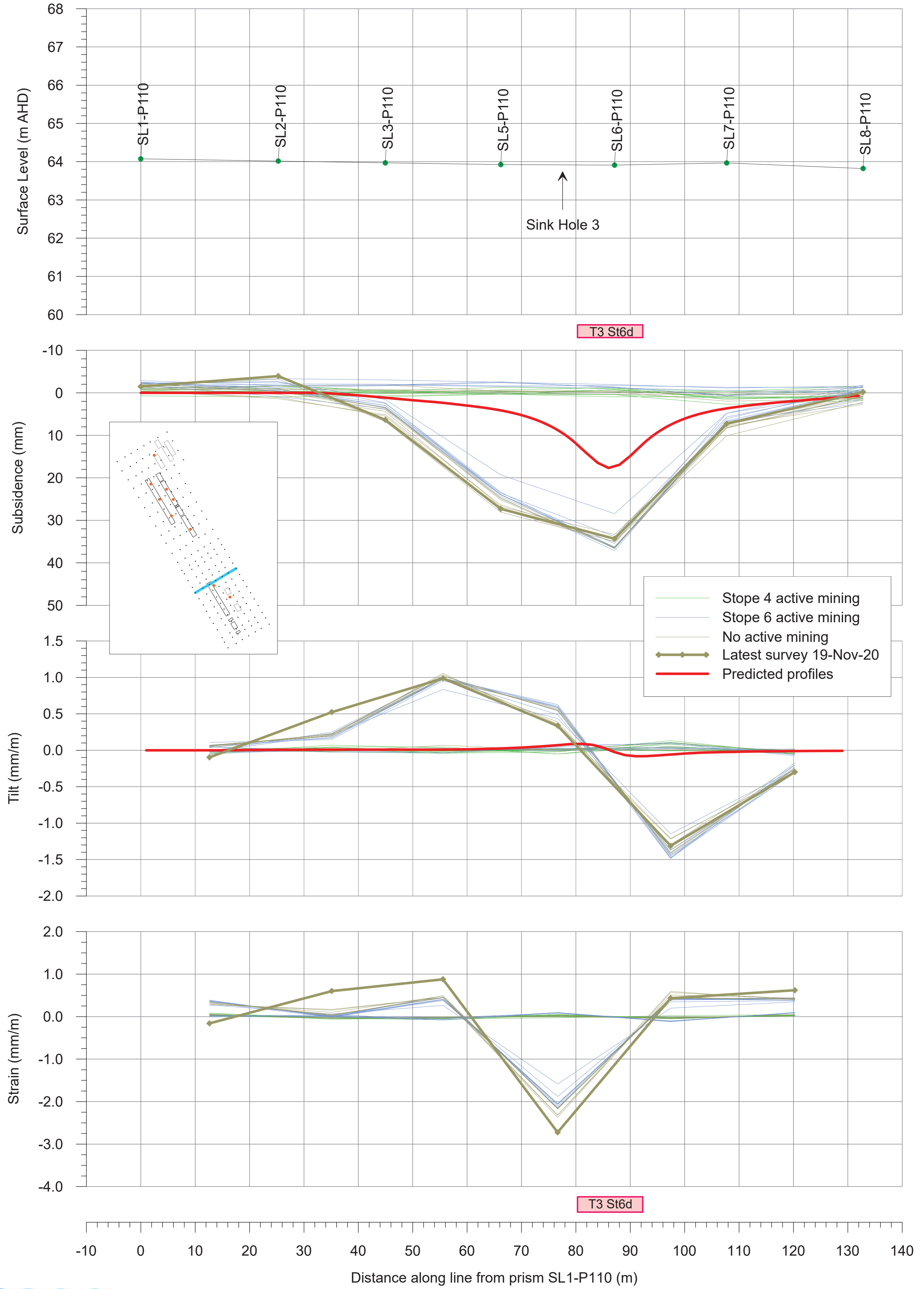

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Fig. P110

Profiles of subsidence, tilt and strain along P111 due to T3

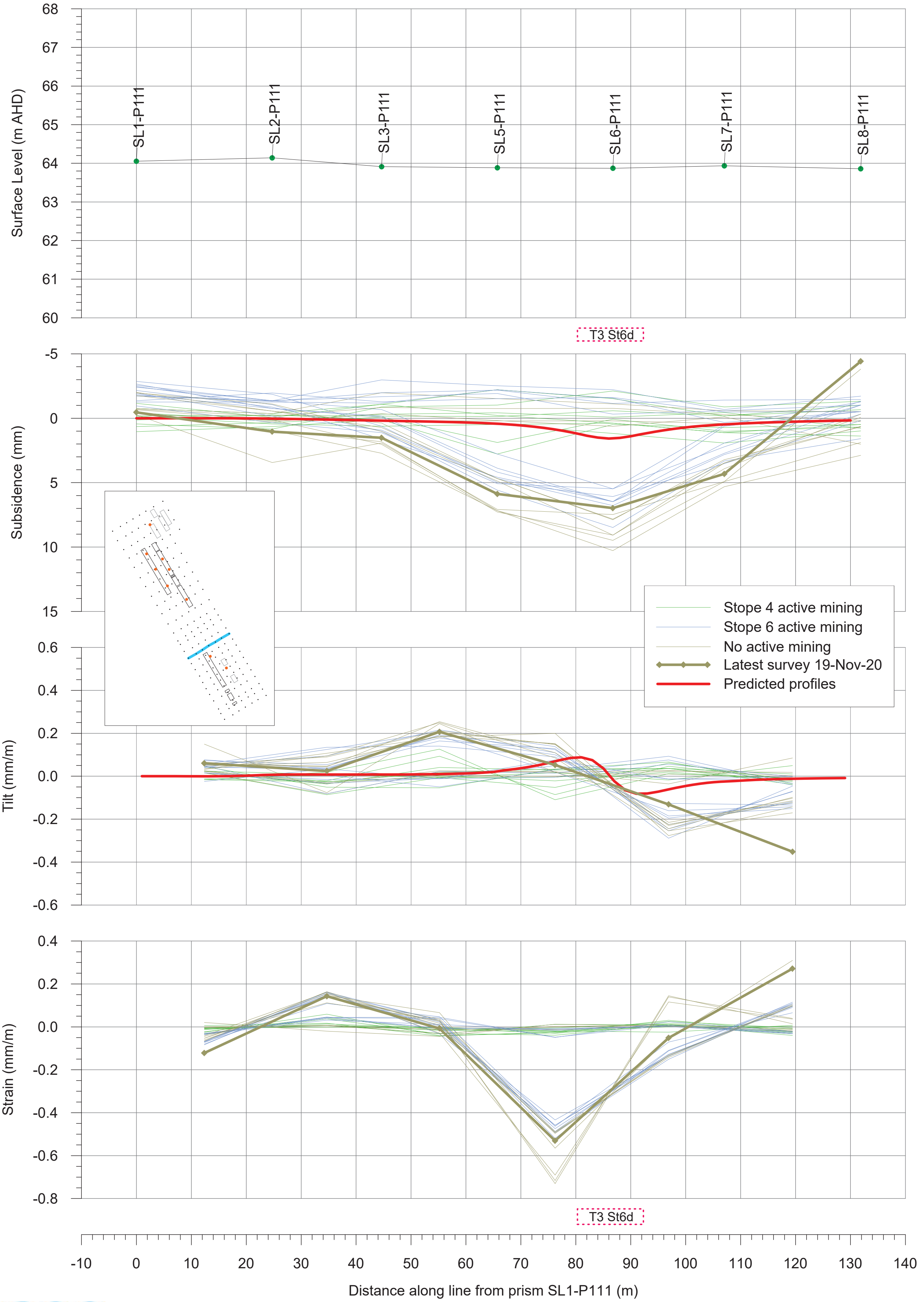

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Fig. P111

Profiles of subsidence, tilt and strain along P112 due to T3

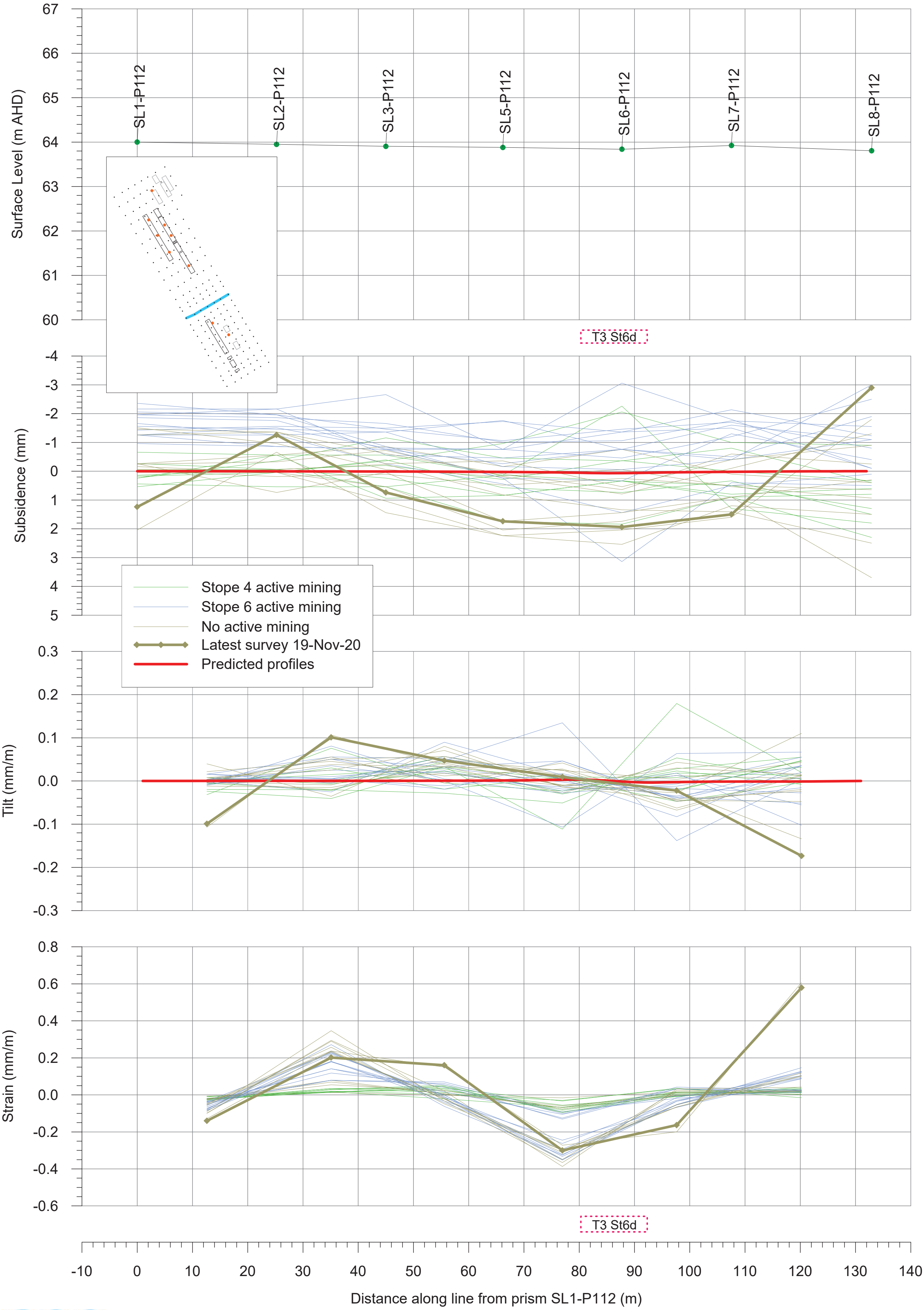

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Fig. P112

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Profiles of subsidence, tilt and strain along P113 due to T3

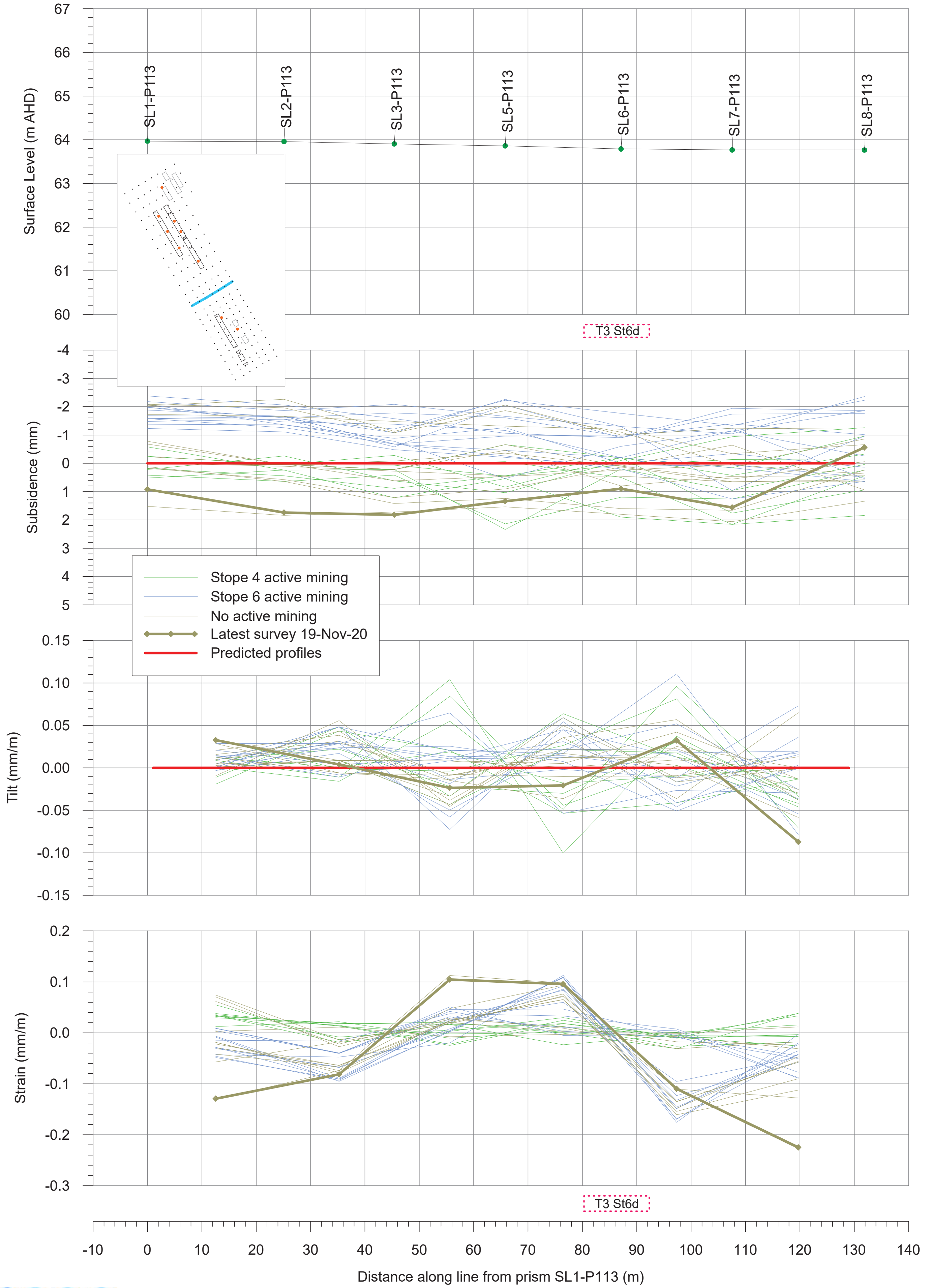

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Fig. P113

Profiles of subsidence, tilt and strain along P114 due to T3

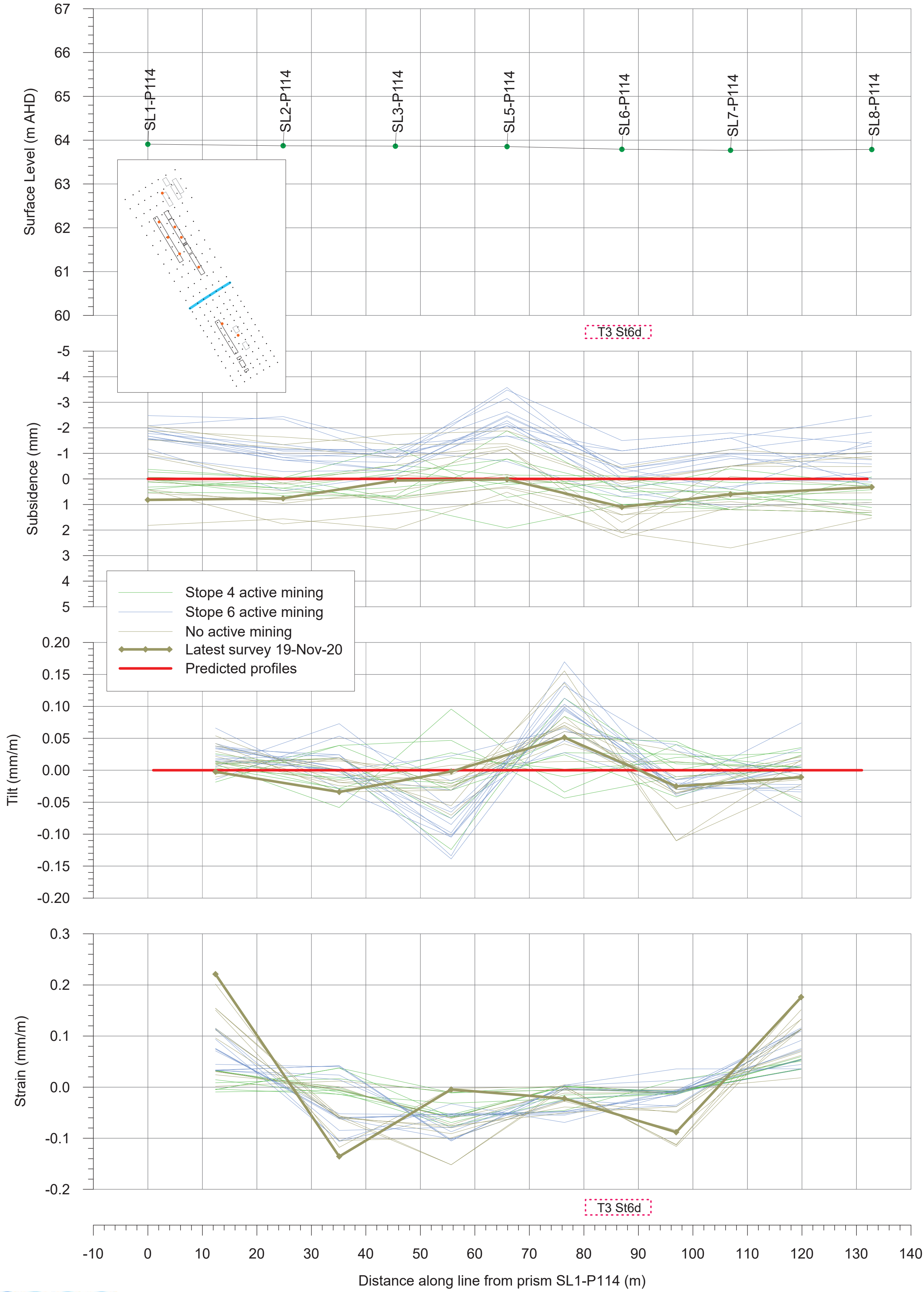

Fig. P114

Profiles of subsidence, tilt and strain along P115 due to T3

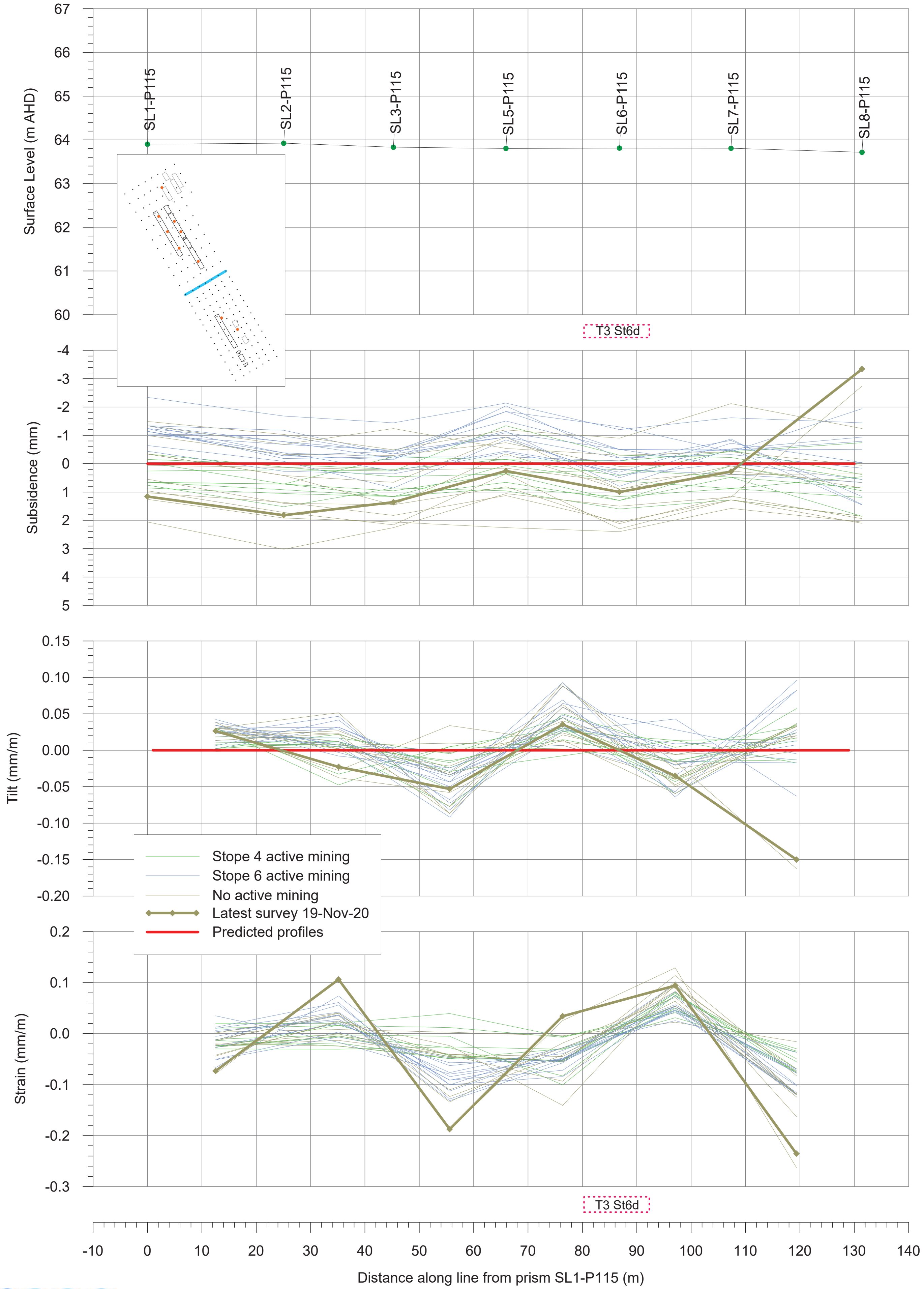

Fig. P115

Profiles of subsidence, tilt and strain along P116 due to T3

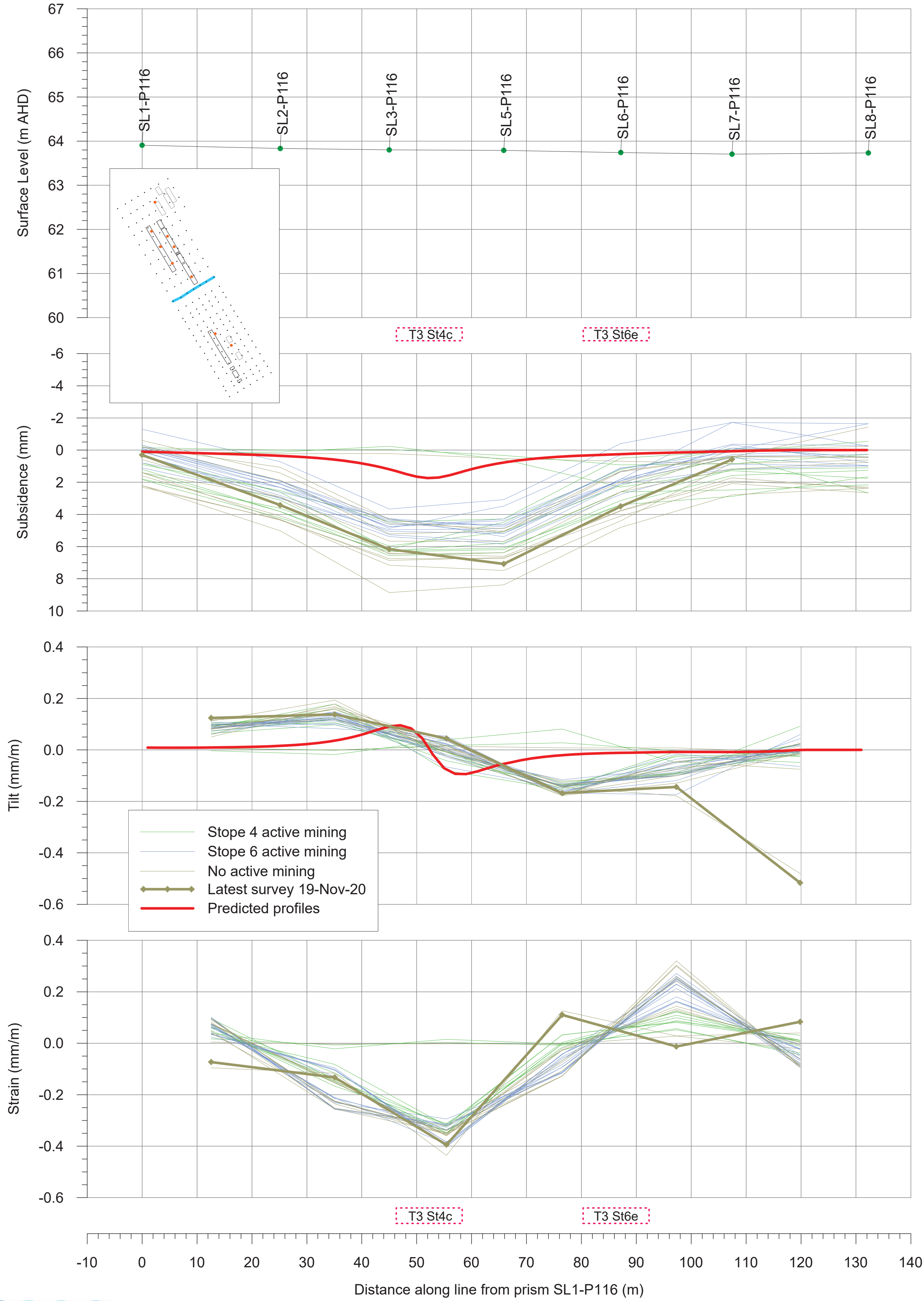

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Fig. P116

Profiles of subsidence, tilt and strain along P117 due to T3

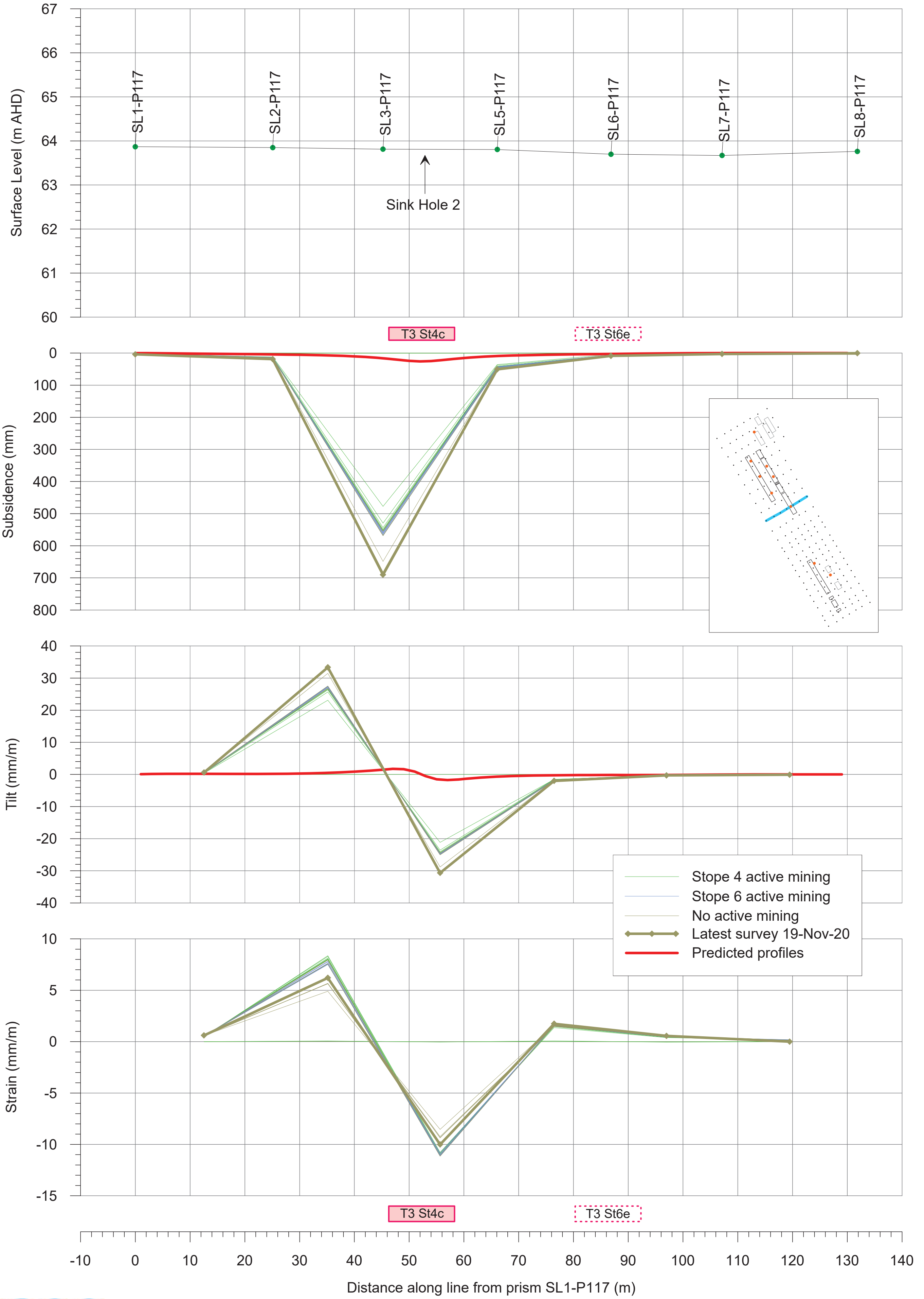

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Fig. P117

Profiles of subsidence, tilt and strain along P118 due to T3

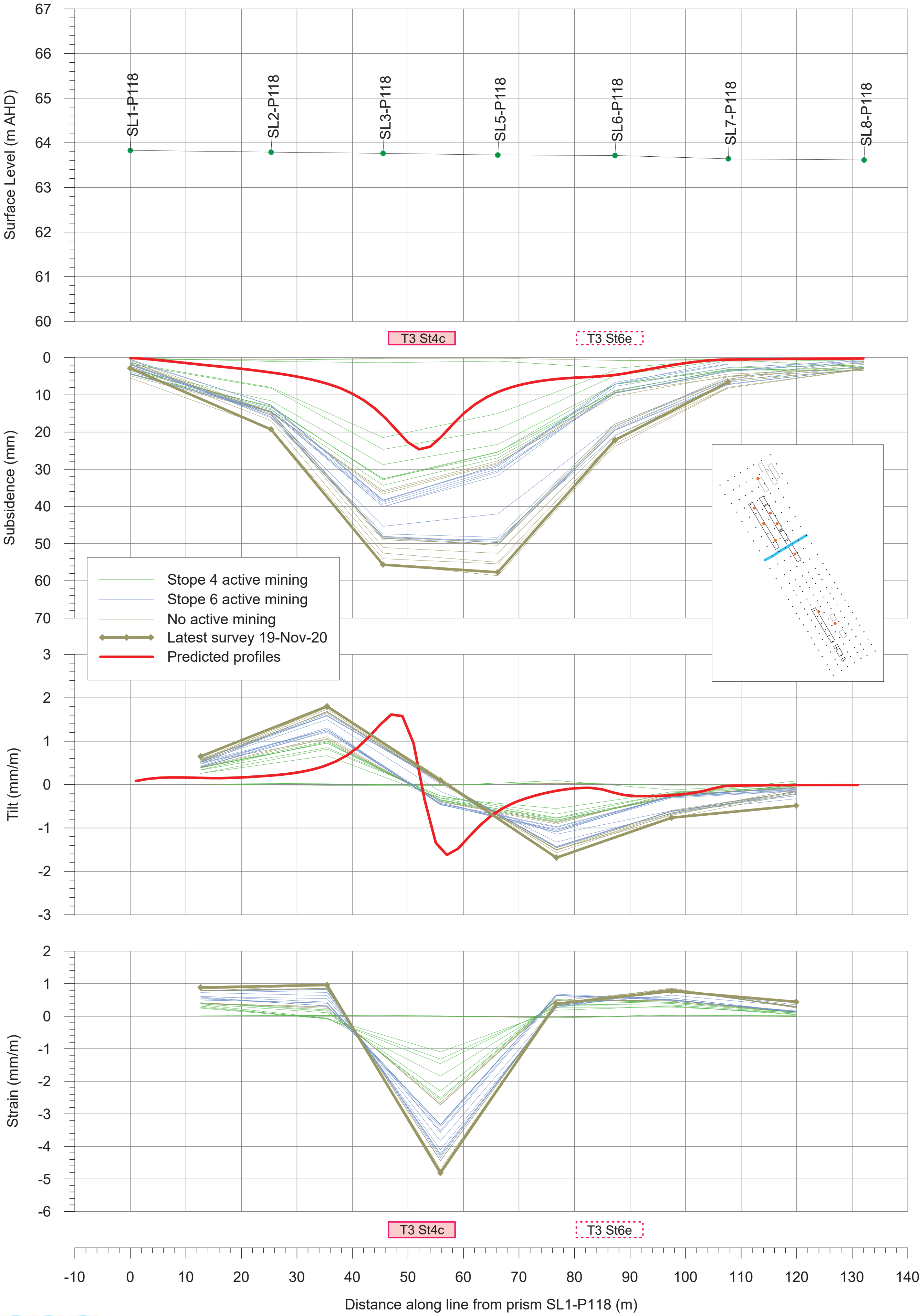

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Fig. P118

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Profiles of subsidence, tilt and strain along P119 due to T3

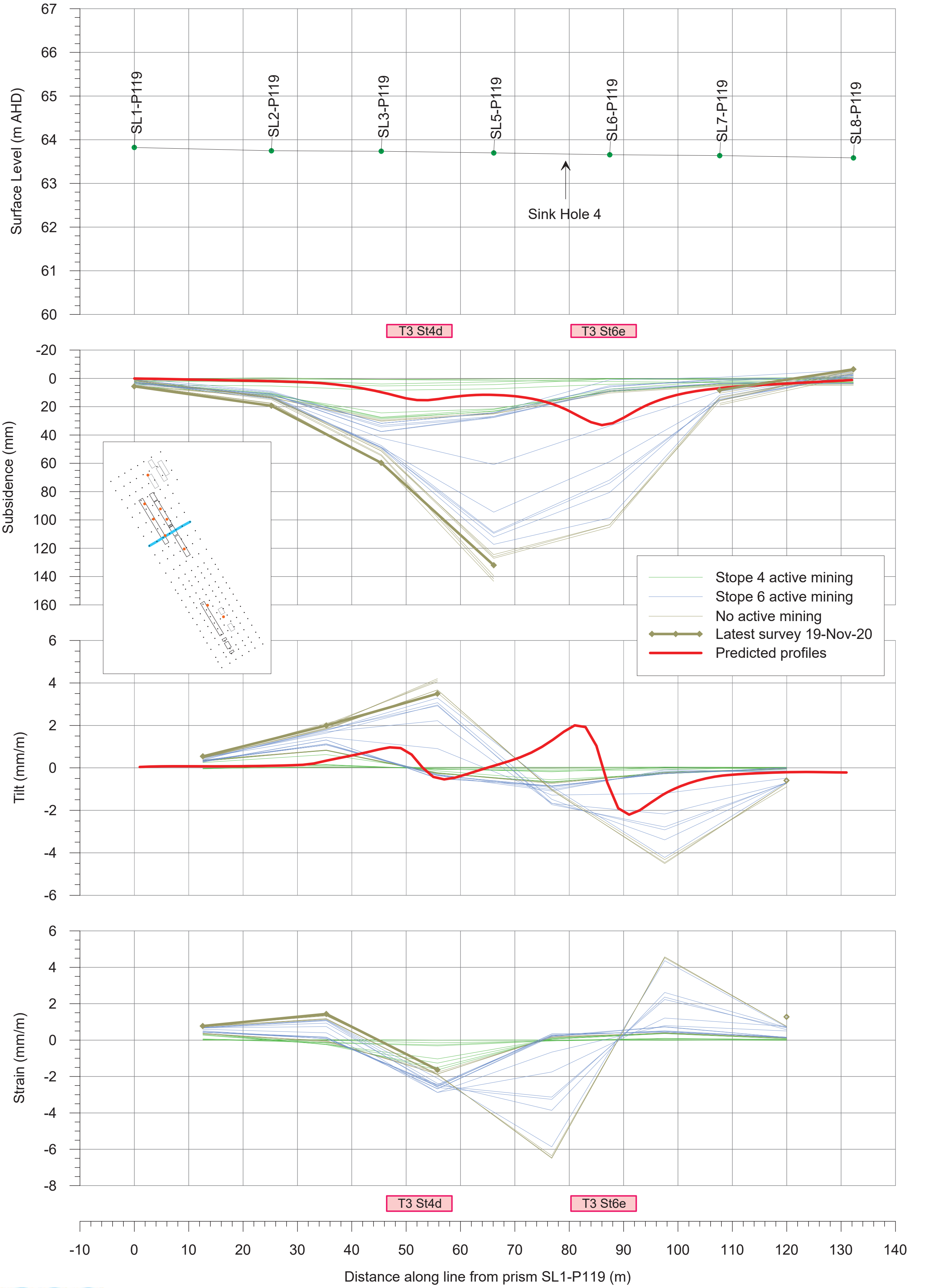

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Fig. P119

Profiles of subsidence, tilt and strain along P120 due to T3

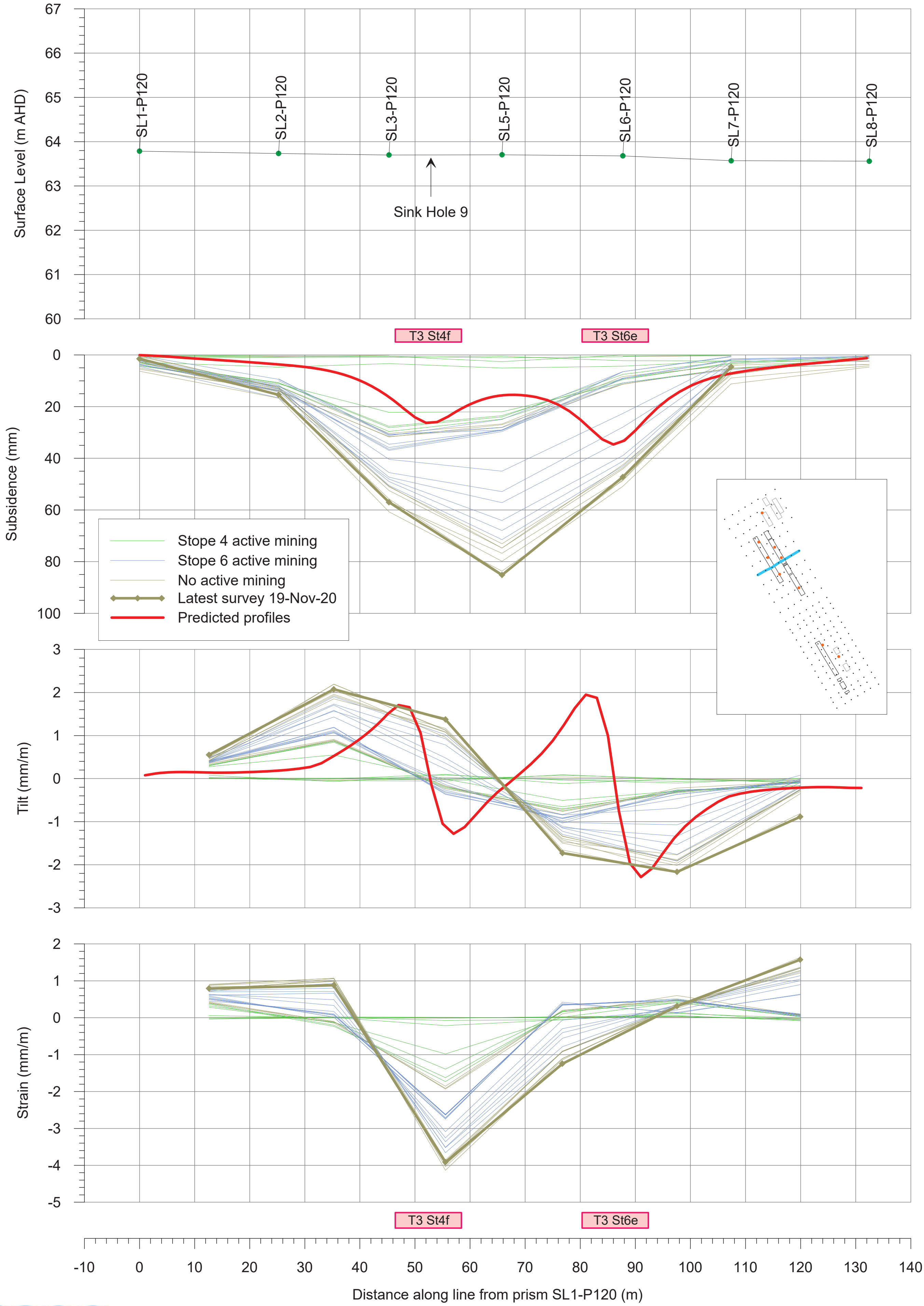

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Fig. P120

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Profiles of subsidence, tilt and strain along P121 due to T3

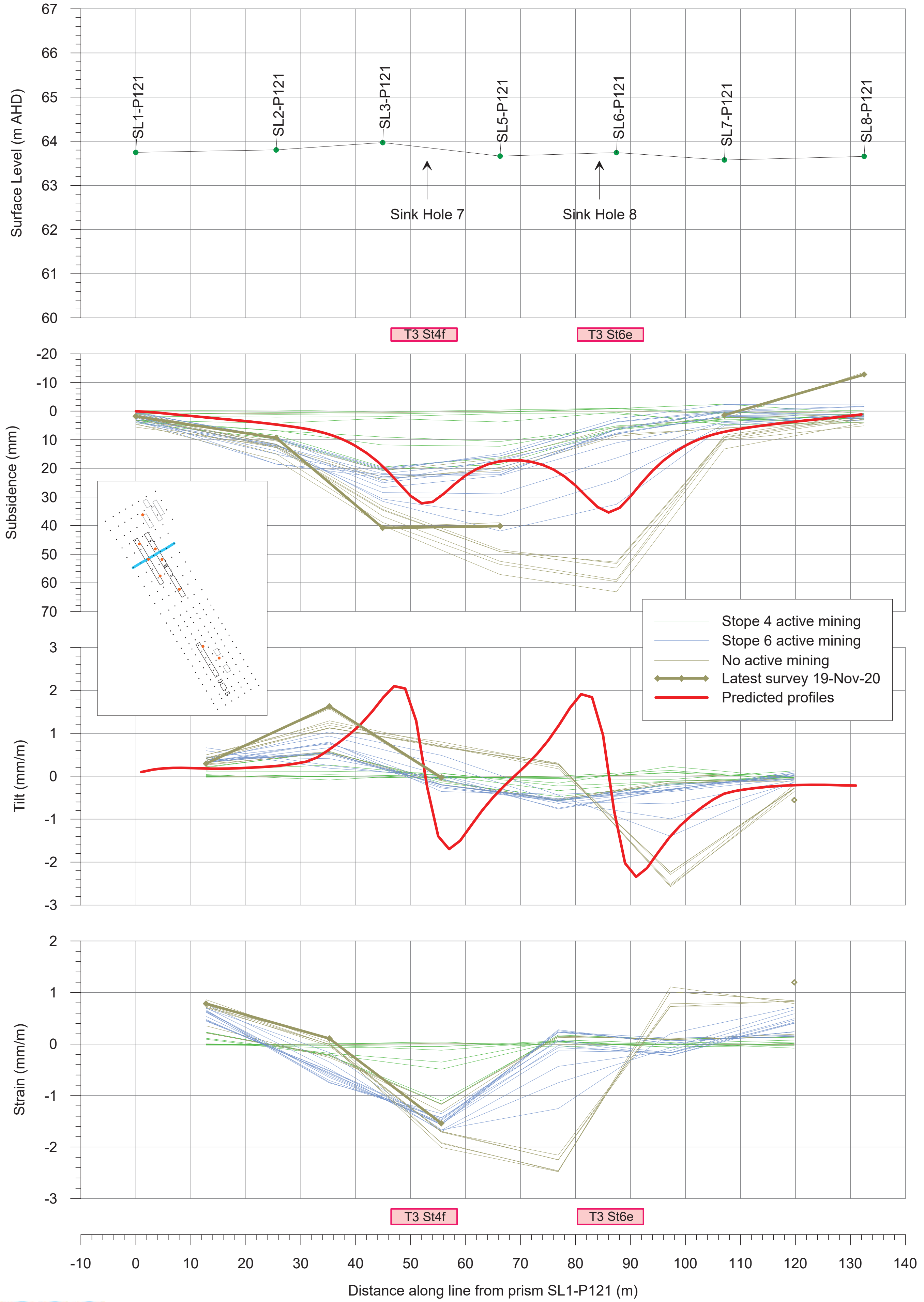

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Fig. P121

Profiles of subsidence, tilt and strain along P122 due to T3

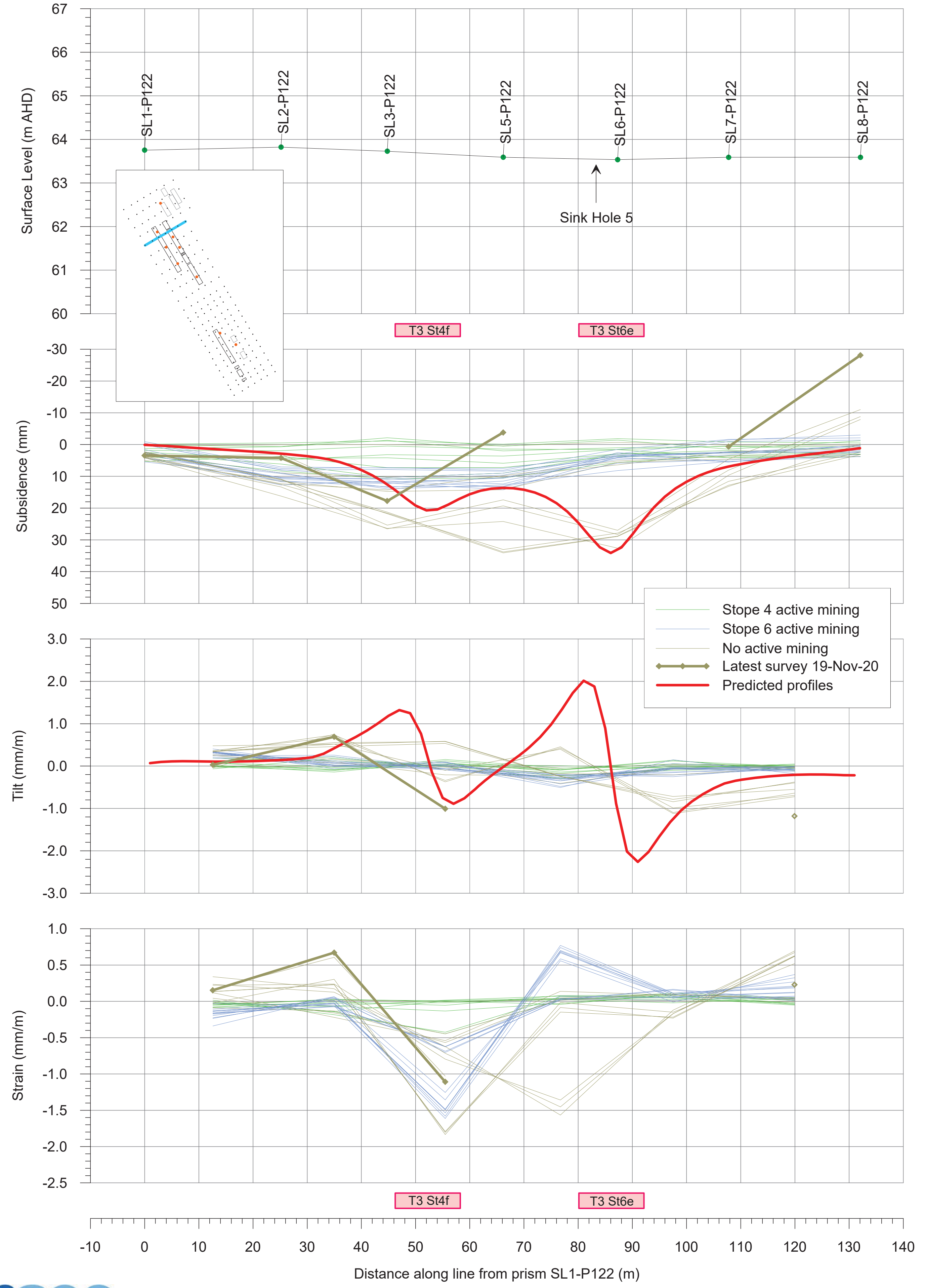

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Fig. P122

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Profiles of subsidence, tilt and strain along P123 due to T3

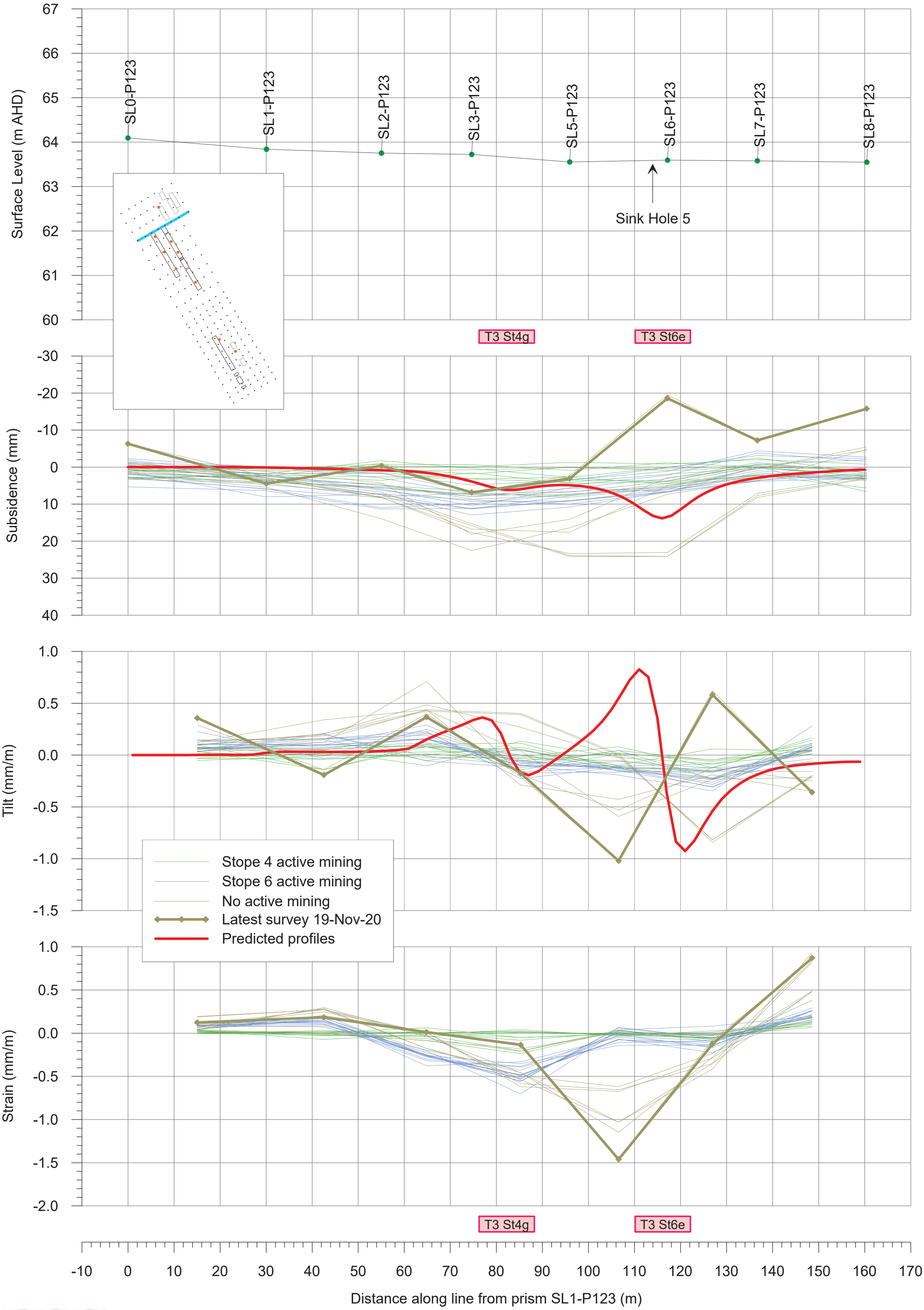

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Fig. P123

Profiles of subsidence, tilt and strain along P124 due to T3

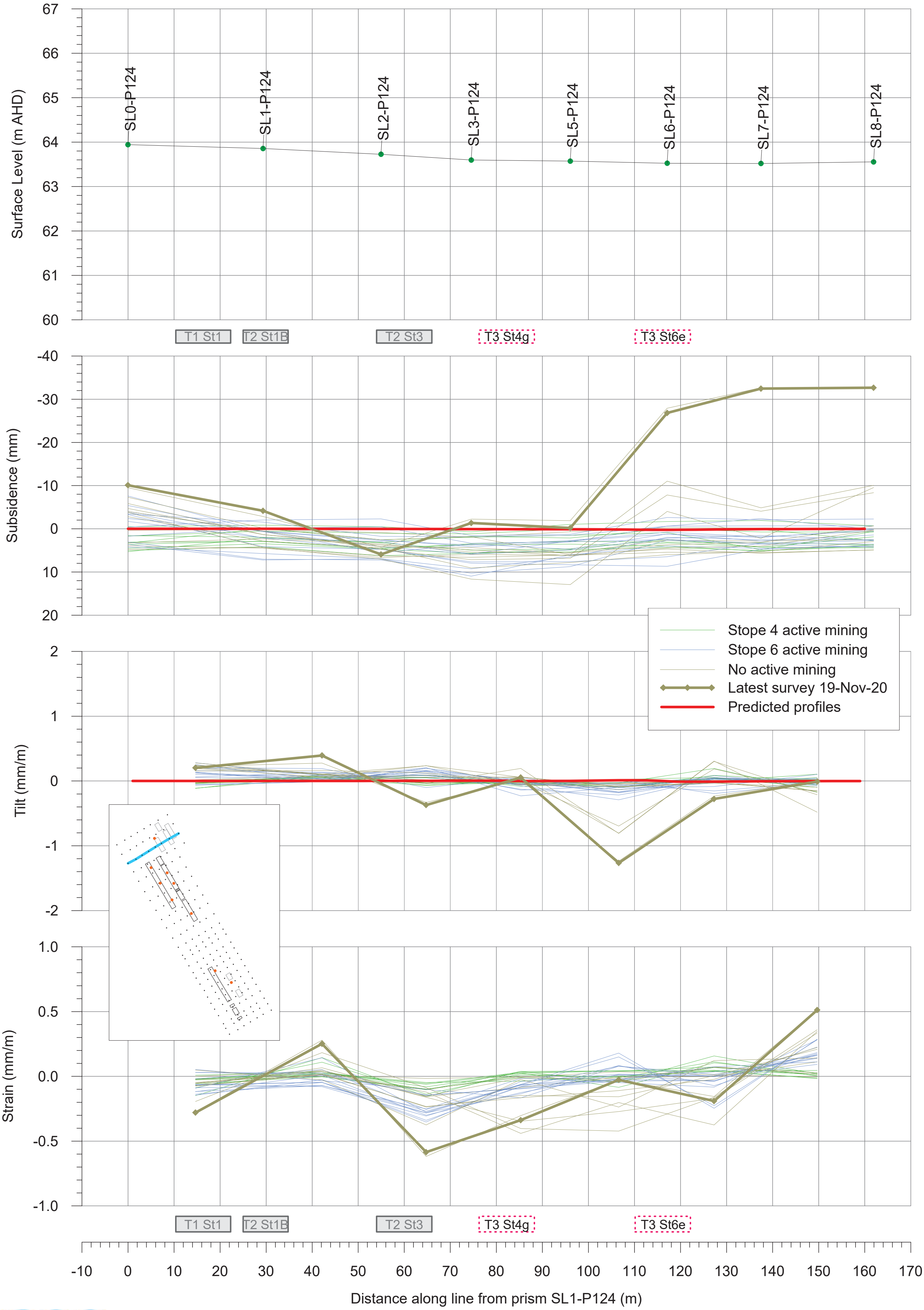

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Fig. P124

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Profiles of subsidence, tilt and strain along P125 due to T3

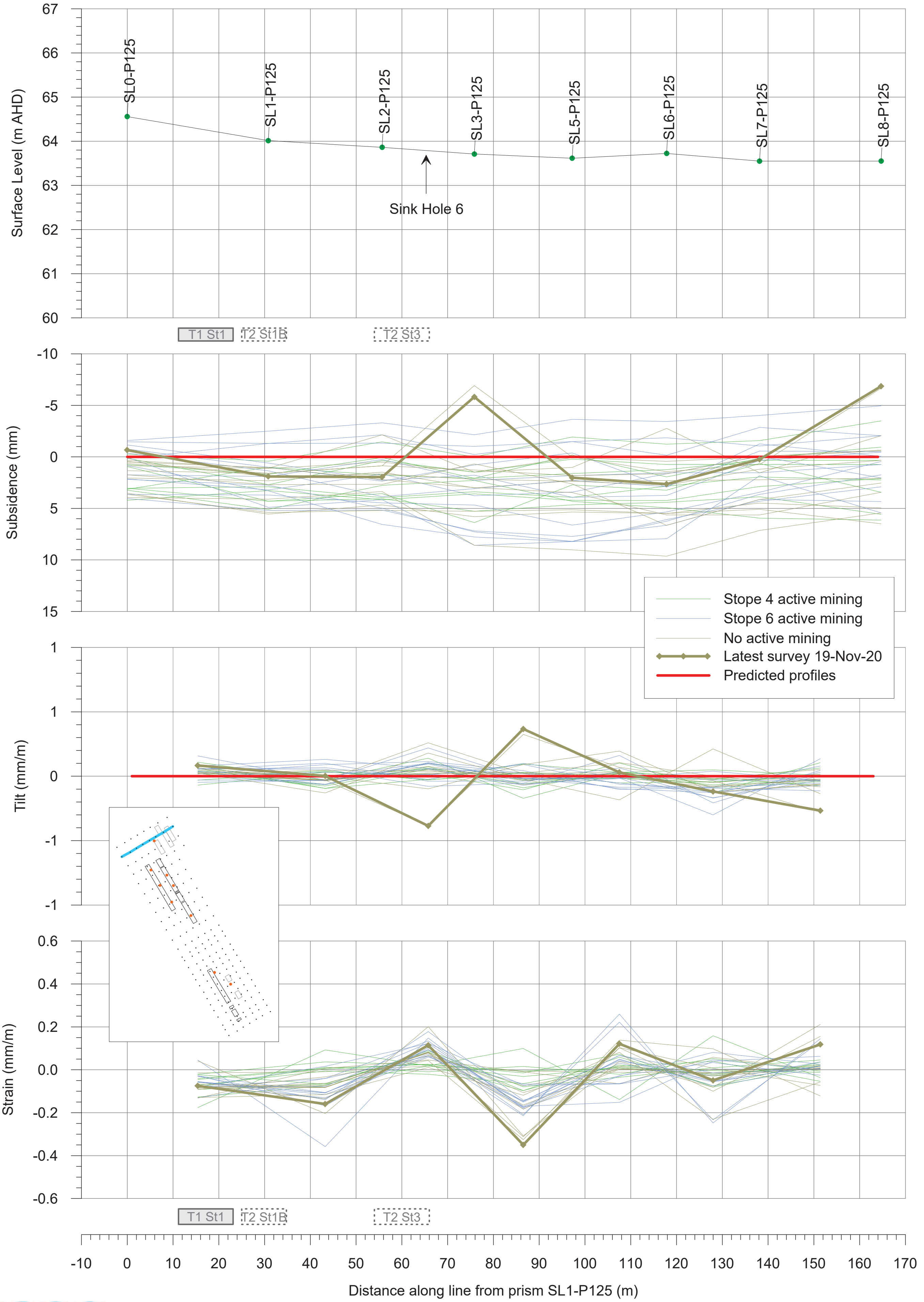

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Fig. P125

Profiles of subsidence, tilt and strain along P126 due to T3

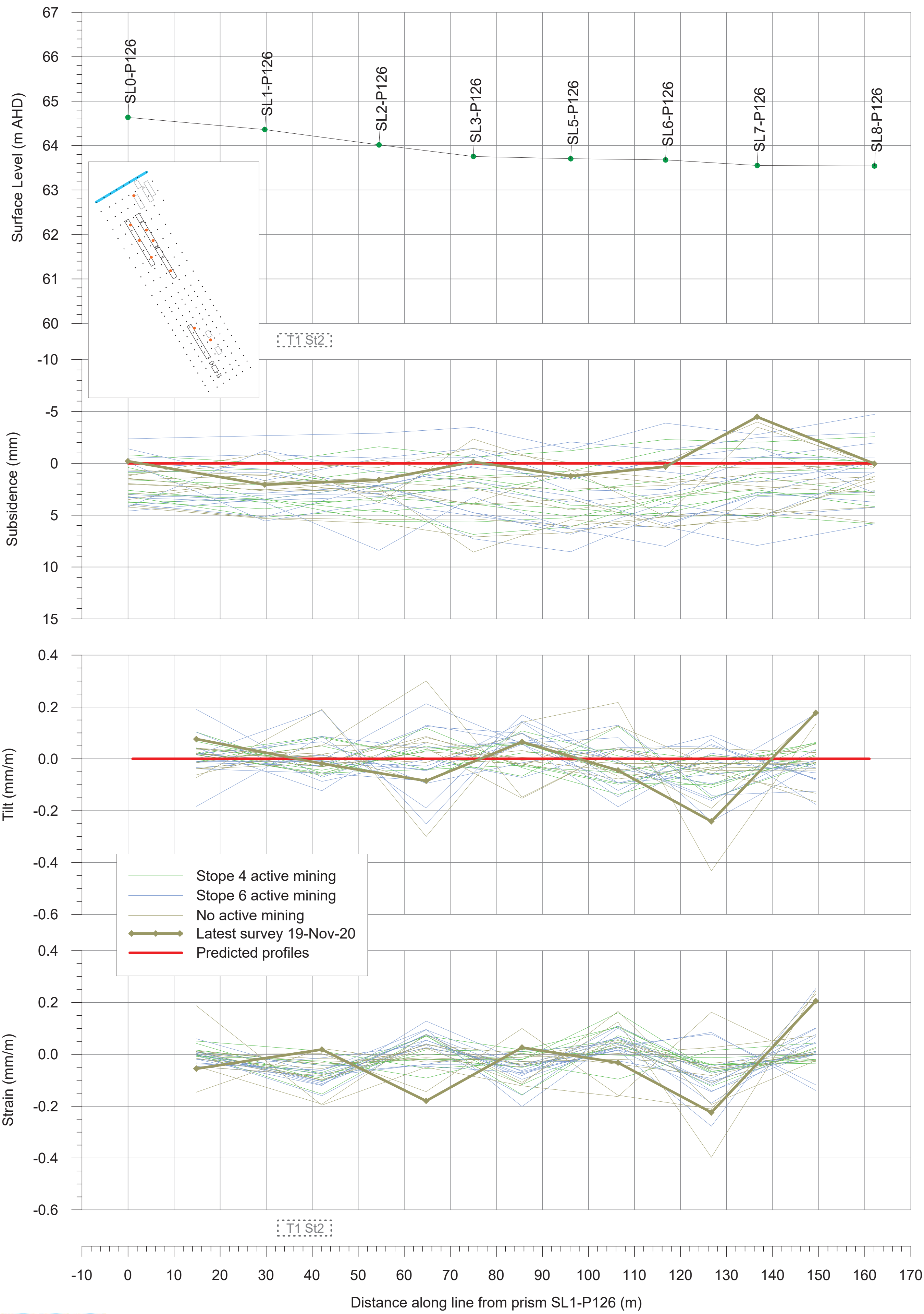

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Fig. P126

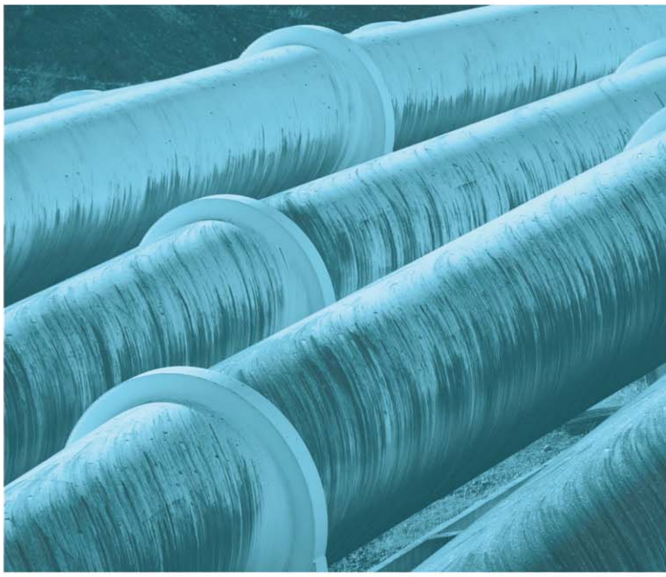
Appendix C: Hydrogeochemical assessment of the T3 mining trial (February 2021)


Balranald Minerals Sands Project

Hydrogeochemical assessment of the T3 mining trial

Prepared for Iluka Resources Limited

February 2021

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Balranald Minerals Sands Project

Hydrogeochemical assessment of the T3 mining trial

Report Number

S190512 RP 1

Client

Iluka Resources Limited

Date

12 February 2021

Version

v2 Final

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12 February 2021

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12 February 2021

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1 Introduction

The purpose of this Hydrogeochemical Assessment Report (HAR) is to present groundwater pressure and chemistry data and interpretation for Iluka Resources Limited's (Iluka) Balranald T3 Bulk Sampling Activity from November 2019 to November 2020, reflective of construction, mining / backfilling and demobilisation activities.

1.1 Overview

On 5 April 2016 Iluka Resources Limited (Iluka) was granted Development Consent under Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) for a mineral sand mine in south-western New South Wales, known as the Balranald Mineral Sands Project (the Balranald Project). The project was assessed and approved as a State Significant Development 5285 (SSD-5285).

The Balranald Project includes construction, mining, primary processing and rehabilitation of two linear mineral sand deposits, known as the West Balranald and Nepean deposits located approximately 12 kilometres (km) and 66 km north-west of the town of Balranald (Balranald town), respectively (Figure 1.1).

The Balranald Project included undertaking a bulk sampling activity (the activity) at the West Balranald deposit to test the selective in-situ removal of up to 100,000 tonnes (t) of ore.

1.1.1 The activity

The activity is an underground mining method to test the selective in-situ removal of mineral ore and reflects a continuation of a smaller bulk sampling activity (known as T1) undertaken by Iluka during Q1-2015 and Q1-2016 in accordance with approval under Part 5 of the EP&A Act from NSW Trade & Investment, Resources & Energy (Reference OUT13/28341 and OUT15/27702).

The activity commenced under SSD-5285 in Q2-2016 and Q3-2016 and successfully extracted approximately 6,400 t of ore from three stopes (referred to as Stopes 1B, 3 and 4) and backfilled approximately 700 t of ore (known as T2). Iluka placed the activity site into care and maintenance during 2017 and 2018 to review the mining and environmental monitoring outcomes.

Iluka recommenced site establishment and new construction for the unconventional mine site (known as T3) in September 2019. Construction included expansion of the mine site to include a new fines storage pond, ore pad and stormwater detention basin increasing the area of total land disturbance to 14.5 hectares (ha).

The objectives of T3 were to determine whether the unconventional mining method can:

- sustain production over a larger sample set (ie longer and multiple stope lengths);
- backfill process to deliver a mining by product management strategy; and
- further validate groundwater and subsidence impact prediction models.

During 2020, Iluka recommenced unconventional mining (known as T3) to trial the selective in-situ removal of the remaining 93,600 t of ore approved under SSD-5285. Mining commenced in June 2020 with the development and mining of a new stope (Stope 6) and the re-entry and additional mining of Stope 4 (Figure 2.2). The trial removed 30,900 t of material during mining with the ore processed on-site to produce 11,900 t of heavy mineral concentrate (HMC). The trial backfilled approximately 1,540 tonnes of sand and clay tailings to the mining zone. Approximately 2,766 tonnes was used to rehabilitate the subsidence holes created as the result of operations (see Chapter 6).

The activity site is located entirely within the disturbance footprint of the West Balranald mine, including the area of the open cut pit. As such, all land disturbed by the activity will eventually be subsumed by mining of the West Balranald mine (Figure 1.1 and Figure 1.2).

The activity site was placed into care and maintenance in late November 2020.

1.2 Background

EMM Consulting Pty Ltd (EMM) was engaged by Iluka to provide hydrogeological ancillary support services for T3 activities. These hydrogeological works were undertaken in order to assess potential impacts to the groundwater system as a result of T3 operations.

A comprehensive field program involving the installation and monitoring of groundwater infrastructure, including a new specialised groundwater collection system, was undertaken to assess the impacts of T3 on groundwater systems at the site.

As per the previous mining trial (T2), T3 involved the abstraction of sand slurry from the Loxton Parilla Sand (LPS) aquifer, and reinjection (backfill) of a sand tailings slurry into the same aquifer. Throughout a number of mining trial scenarios, continuous hydraulic and hydrogeochemical monitoring was undertaken in the Shepparton Formation (SFM) aquifer and LPS aquifer.

A summary of groundwater pressure assessments of previous trials (Iluka 2016; LWC 2017a) indicates:

- the LPS pressure impacts are larger than the corresponding SFM impacts during the mining periods, as expected;
- groundwater levels in the LPS aquifer reflected periods of groundwater abstraction and reinjection as minor drawdown and significant mounding responses, respectively. Groundwater displacement was rapid and extensive, however once each mining activity was completed, the recovery of groundwater to a standing water level occurred in approximately one day;
- backfilling results indicate that pressure impacts are generally larger within the SFM aquifer, suggesting that backfilling is not discrete between the two aquifers;
- no observed hydraulic Site Specific Trigger Level (SSTL) breaches were recorded within the LPS aquifer;
- two SFM monitoring bores, UGM-M7S and UGM-M5S, both breached the hydraulic operating conditions (HOCs) for several hours for the 'red' and 'yellow" zones respectively, which were associated with backfilling; and
- the reason for SFM pressure impacts remains unknown, with one possibility being due to successive introduction of horizontal directional drilling (HDD) declines and other vertical drilling activity has weakened the structural integrity of the aquitard between the SFM and LPS aquifers. However, interconnection that develops in response to this underground mining method has not impacted upon the SFM and LPS aquifers.

A summary of the chemical assessments of previous trials (Iluka 2016, LWC 2017a) indicates:

- there does not appear to be any significant identifiable exceedance of chemical substance site specific target levels or trend in chemical substance data in either the LPS aquifer or the overlying SFM aquifer during either the mining or backfilling trials. Geochemical predictive modelling of backfill operations (injection) indicated a potential risk to groundwater associated with re-injection of acidified groundwater to the stopes;

- the mined materials are likely to give rise to acid generation, dependent on moisture condition and oxidation period of the intended backfill material. This will impact on the in-situ groundwater system during backfilling activities;

- geochemical modelling of the 2016 backfill trials showed that there is a predicted significant decrease in pH when the modelled slurry (untreated) is injected into the LPS, reaching as low as <pH 2, depending on various assumed conditions;

- future mining operations may exacerbate the effect of lowering pH within the aquifer during backfilling periods. This depends on various factors including oxidation period (ie number of days' tailings remains on site surface), backfilling injection period and the hydraulic gradient generated during the backfilling period; and

- the neutralisation rates or similar appropriate management (optimum moisture condition, mitigation of O_2 ingress) as recommended by Earth Systems (2015) to be adhered to, on recovery of the material to surface.

LWC (2017a) made the following recommendations for future unconventional mining trials:

- The low pH front was not detected during the sampling events. Groundwater monitoring locations will need to be determined based on proximity to the active stope, and will need to be monitored on a regular basis (including immediately after mining/backfilling activities have ceased).

- Management of ore/by-products is required to avoid oxidation and acid generation, as per measures outlined previously by Earth Systems (2015).

- Manual measurement, where field parameter loggers are installed, should be undertaken given the errors associated with previously used downhole pH/redox (Eh) loggers.

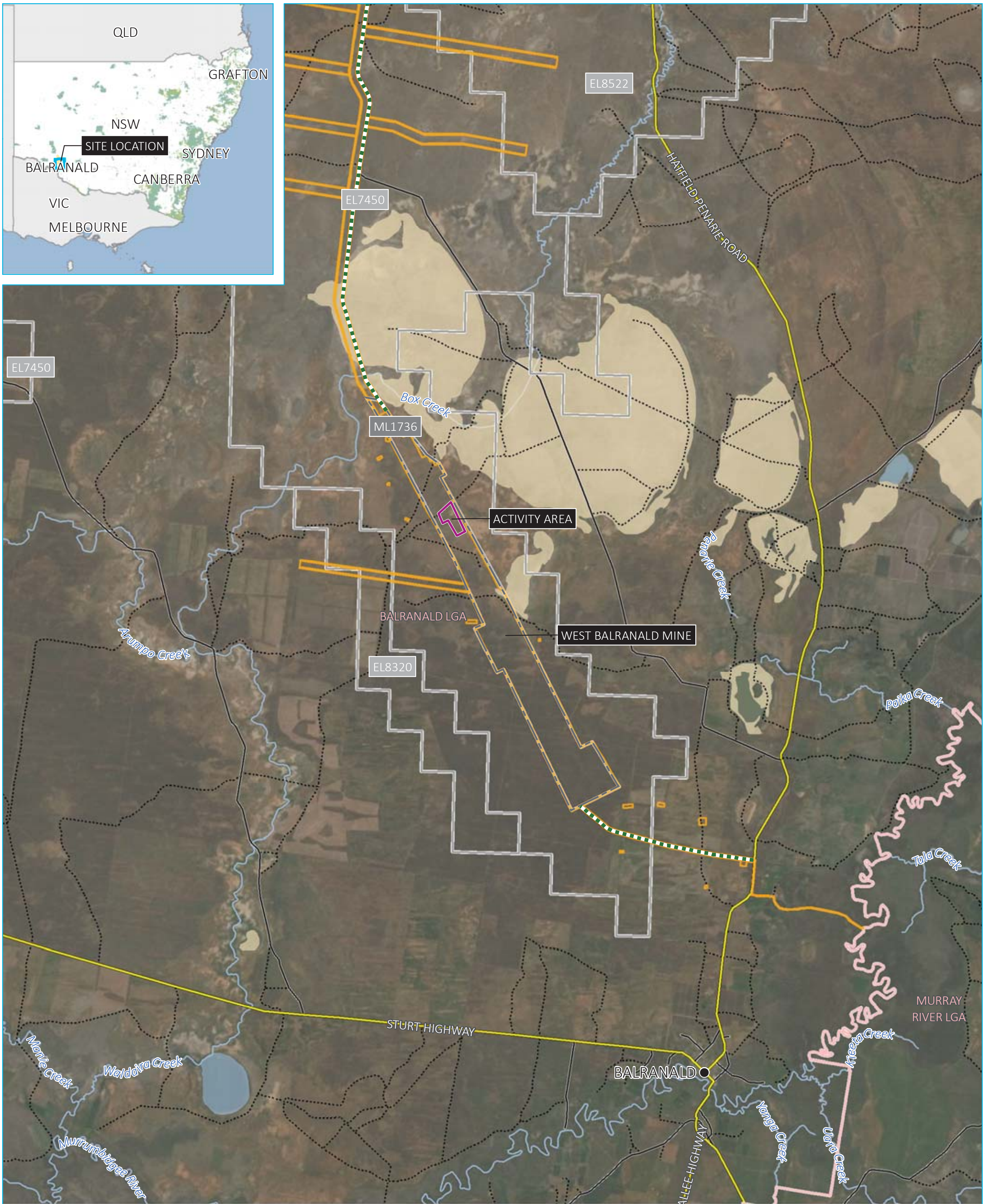
- Manually downloading the vibrating wire piezometer (VWP) logging data during the groundwater monitoring events (GMEs).

- During mining and backfilling events, the measurement of leading chemical indicators (such as pH) and groundwater pressures should be undertaken, such that SSTL breaches can be determined as soon as practical. Measuring the pH within the process circuit would also be useful.

- Future groundwater monitoring bores should be installed to continue to monitor the SFM along the planned HDD declines, to ensure the aquitard between the SFM and LPS remains intact. This will also help mitigate SSTL breaches by providing advanced warnings.

- Groundwater pressure impacts using groundwater modelling codes, eg MODFLOW, may need to be considered in conjunction with geochemical modelling to understand the impact assessment in more detail. This recommendation was considered in a report by EMM (2019). Further data collection will be required during any future trials and a life of mine plan will be required to simulate full mining impacts.

- Further geochemical modelling (predictive) should investigate the potential for in situ pyrite oxidation to occur as a result of re-injection of aerated waters. This recommendation was addressed in a later report by LWC (2017b).



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Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 5 10 km

GDA 1994 MGA Zone 54

N

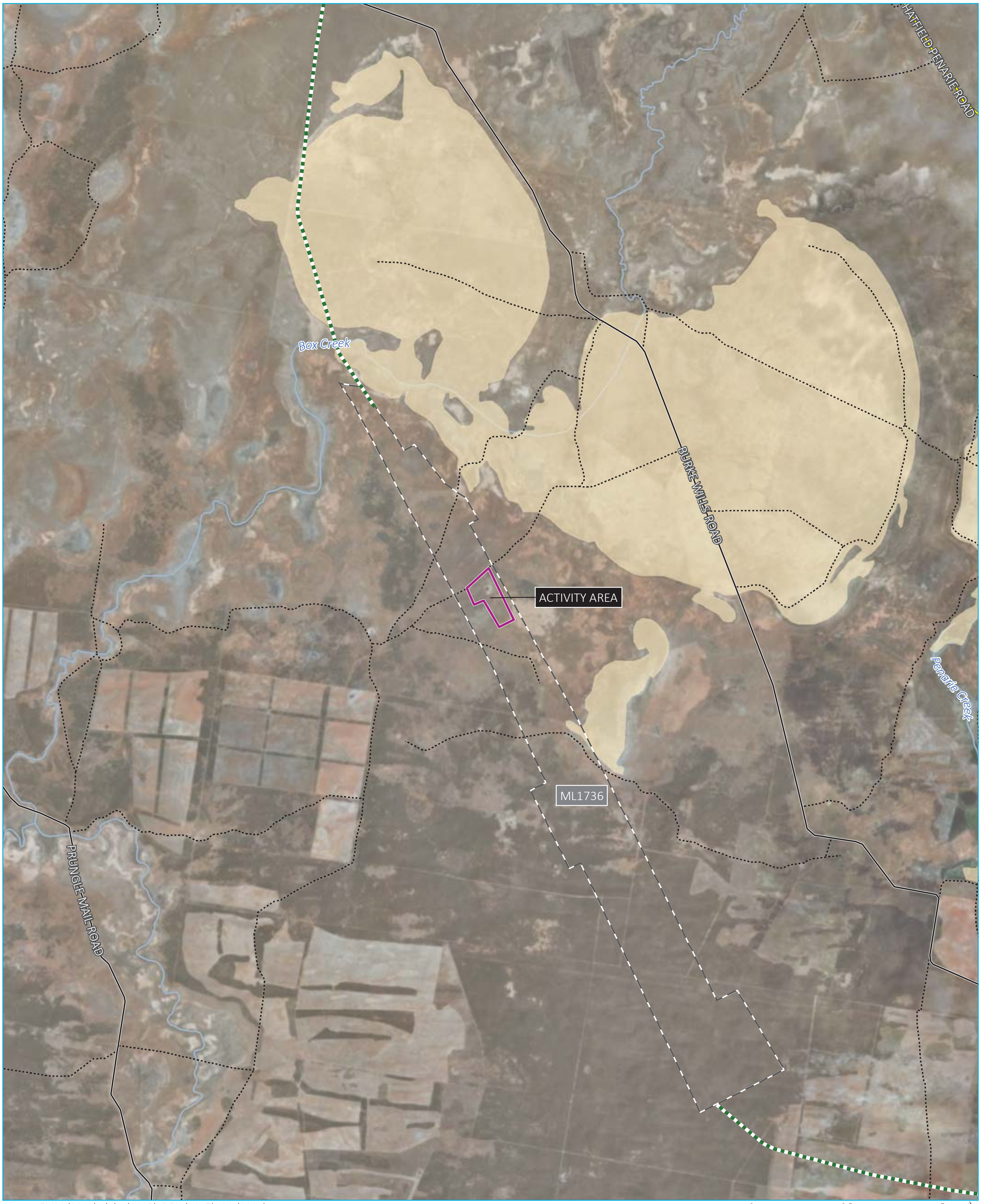
KEY

- Activity area
- Project boundary
- Place
- Access road
- Mining Lease 1736
- Iluka mineral tenement
- Main road
- Local road
- Vehicular track
- Named watercourse
- Perennial lake
- Ephemeral lake
- Local government area

Regional location

Iluka Resources Limited
T3 Hydrogeochemical Assessment
Figure 1.1

EMM
creating opportunities



Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

0 2.5 5 km

GDA 1994 MGA Zone 54

KEY

- Activity area
- Access road
- Mining Lease 1736
- Main road
- Local road
- Vehicular track
- Named watercourse
- Ephemeral lake

Location of the T3 activity within the Balranald project mine footprint

Iluka Resources Limited
T3 Hydrogeochemical Assessment
Figure 1.2

EMM creating opportunities

1.3 Project objectives

The objective of the hydrogeochemical assessment works for T3 was to:

- monitor and review hydraulic data to ascertain the pressure impacts associated with the trial within the SFM and LPS, with comparison to SSTLs, HOCs and previous groundwater modelling simulations (EMM 2019). Compliance with SSTLs will ensure any potential impacts on receptors are managed;
- monitor and review the hydrogeochemical data collected during the 2020 unconventional mining trial (T3), and correlate responses to mining activities;
- compare groundwater quality results with SSTLs and geochemical model predictions (LWC 2017);
- conduct a trend assessment of the leading indicators across the trial site;
- report on mining induced subsidence, including impacts to groundwater levels (pressures) and quality;
- present an updated conceptualisation showing the main hydraulic and geochemical processes that occurred during mining, backfilling and post mining; and
- make recommendations for future works required to assist with mine approvals and operations.

1.3.1 EMM project involvement

To support T3 activities, EMM undertook the following works:

- Groundwater management plan (GMP) development;
- Design and installation of new groundwater bores and VWPs, including the specialised groundwater collection system;
- Groundwater monitoring and reporting, including daily site reports; and
- Liaison with regulators, including NSW EPA, DPIE, DPIE – Water, Resources Regulator and NRAR.

1.3.2 Scope of work

The scope of the hydrogeochemical assessment of the T3 mining trial (ie this report) was as follows:

- Review all groundwater hydraulic and chemical data during the T3 trial;
- Review site responses against the SSTLs and HOCs;
- Conduct chemical trends assessments using the WISH software package; and
- Refine hydrogeochemical conceptualisation of the mining and backfill trial.

The hydrogeological assessment will also inform the groundwater flow modelling update and Iluka's proposed Modification of Consent (MOD) to SSD-5285, with details to be used to further refine future groundwater impact assessment and GMP revisions.

2 Mining trial operations

2.1 Site overview

A site layout plan of Balranald's T3 activity site is shown in Figure 2.2, and includes the following main features:

- The main processing area which includes the Process Water Dam (PWD), various processing plant equipment, fines storage, sand/ore stacking pad, site offices and the hard stand area which accommodates the HDD rig and supporting equipment.
- The T3 HDD decline holes.
- Two mine stopes representing the T3 activity.

2.2 Stope overview

Mining commenced in June 2020 with the development and mining of a new stope (Stope 6) and the re-entry and additional mining of Stope 4 (Figure 2.2).

Ore extraction took place between 19 August 2020 to 30 September 2020. The trial extracted 30,900 t of material during mining with the ore processed on-site to produce 11,900 t of HMC. Backfilling took place between 1 October to 18 October 2020. The trial backfilled approximately 1,540 tonnes of sand and clay tailings to the mining zone.

Approximately 2,766 tonnes was used to rehabilitate subsidence holes created as the result of operations.

It is noted that Stope 5 was not mined as part of T3.

2.3 Unconventional mining method

Iluka has developed an unconventional mining method at Balranald which utilises HDD principles and remote access that comprises of (LWC 2017a):

- directional drilling/casing of access holes through the overburden to the ore zone;
- horizontal borehole drilling with drill strings advanced along the decline and into the ore body;
- high pressure water used to fluidise the ore;
- eductor pumping of slurried ore to the surface, which creates stopes within the ore body;
- process plant to screen and separate fines and oversize material, including a trommel, thickener and spiral plant;
- temporary stockpiling of the mineral ore for metallurgical and geochemical test work; and
- reinjection of the separated coarse material and fines as a hydraulic back fill (mixed slurry) into the mined-out stopes. The backfill material contains a mixture of sand and slimes once the Heavy Mineral (HM) has been removed.

2.4 Mining operations schedule

A summary of the T3 mining and monitoring schedule which details daily site activities is presented in Figure 2.1. Where available, this schedule also includes the stope chainage mined (in metres) and water extracted from each production bore (in kilolitres) for each day. Note that the mined chainage is the length mined in both the day and night shift which started on the listed day, eg the chainage of 568-562 m mined on 20 August 2020 was mined between 6:00 am on 20 August 2020 and 6:00 am on 21 August 2020.

	30-Aug	31-Aug	01-Sep	02-Sep	03-Sep	04-Sep	05-Sep	06-Sep	07-Sep	08-Sep	09-Sep	10-Sep	11-Sep	12-Sep	13-Sep	14-Se
														9 kL	1690 kL	1690 kL
					648 kL	2592 kL										
	383-374m															
												884-878m				866-853m
	882 kL															
	432 kL												356 kL			

	05-Oct	06-Oct	07-Oct	08-Oct	09-Oct	10-Oct	11-Oct	12-Oct	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oc
	802-785m	785-764m	764-734m	734-719m			527-512m	512-495m	495-476m	476-457m	456-444m	444-433m	433-393m	393-380m		
	1109 kL	1098 kL	949 kL	750 kL	308 kL	1094 kL		787 kL	574 kL	573 kL			233 kL	452 kL		
			756 kL	1015 kL	194 kL			1620 kL	2592 kL	756 kL	1512 kL			540 kL		
	1080 kL			1512 kL	972 kL	432 kL		1296 kL		1944 kL	1512 kL			756 kL		

	10-Nov	11-Nov	12-Nov	13-Nov	14-Nov	15-Nov	16-Nov	17-Nov	18-Nov	19-Nov	20-Nov

2.5 Plant overview

The process plant supporting the mining trial consisted of the following main units and infrastructure, which are highlighted in Figure 2.2:

- Trommel screen – separates all material < 10mm (which also containing the heavy mineral) from larger rocks and other matter in the mined material.
- Material is then pumped to Hydro cyclones, where the underflow represents the sand stream and is directed to the spiral plant, and the overflow represents the slime stream and is pumped to the Thickener.
- Spiral plant – receives the sand stream from the Hydro cyclones and separates it into heavy mineral and sand tailings using gravity separation techniques. The lime dosing unit is attached to the spiral plant and lime is added as needed to maintain appropriate process pH levels.
- Thickener – concentrates the slimes from the Hydro cyclones using flocculant, producing a thickened slime slurry and clarified water. The slimes are deposited in the stockpile areas for later reinjection, while the water is returned to the process water dam to be recycled.
- Hydraulic backfill (HBF) tank – a tank where the material to be reinjected (slimes, sands, or a mixture) is prepared and treated as necessary before being fed to the reinjection pumps.
- Process water dam (PWD) – stores groundwater from the P1 and P2 production bores and recycled process water for use in processing of the mined material.
- T3 and T2 stockpile drainage sumps – collects residual water seeping from the ore stockpiles.
- Spill dam – captures excess water in the event of a storm.

2.6 Water supply

Saline groundwater was abstracted from the LPS Aquifer as a process water supply during in-situ mining and backfilling. This occurred via the P1 and P2 production bores (Figure 2.2).

Subsequently, water sourced from the PWD was re-injected into the LPS aquifer as a component of the in-situ mining process and during stope-backfilling with mining by-products.

Water usage during the T3 bulk sampling activity was in accordance with a 2,500 megalitre (ML) water trade with Tronox, assigned to Iluka's Water Access Licence's (WAL) 31101 and WAL31102. Nominated extraction points during the activity included production bores P1 and P2 (Loxton Parilla Sands Aquifer) and the Karra Homestead Bore (Lower Renmark Group Aquifer).

Groundwater abstraction was also undertaken from Karra Homestead Bore, which is screened within the Lower Renmark Group (LRG) aquifer. This brackish water source was used primarily for dust suppression and soil/heavy-mineral stockpile management.

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Source: EMM (2021); Iluka (2015); DFSI (2017); GA (2011)

KEY

- Activity area
- Mining Lease 1736
- Iluka mineral tenement

Indicative site layout

- Access road
- Activity footprint
- Existing site office and light vehicle carpark
- Fines storage pond
- Ore pad
- Plant, equipment and administration buildings
- Process water dam
- Spoon drain
- New stormwater detention basin
- Stockpile
- Stope 1, Stope 2 (T1)
- Stope 1B, Stope 4 (T2)
- Stope 4, Stope 6 (T3)

T3 activity within the Balranald Mine project footprint

Iluka Resources Limited
T3 Hydrogeochemical Assessment
Figure 2.2

EMM creating opportunities

3 Hydrogeochemical setting

3.1 Geology

The Cainozoic Murray Basin is an intra-cratonic basin extending over 300,000 km^2 across parts of New South Wales, Victoria and South Australia, containing a complex sequence of marine, coastal and continental sediments (Brown and Stephenson 1991; Whitehouse 2009).

The stratigraphic units of the Murray Basin (Figure 3.1) form important regional aquifers, confining aquitards and barriers for commonly saline groundwater (Evans and Kellett 1989). Very low rates of sedimentation and restricted sediment supply resulted in the development of a relatively thin sequence, commonly less than 200 m thick, of flat-lying, poorly lithified, partly consolidated sand, silt, clay, and lime-rich sediments (Whitehouse, Roy and Oakes 1999). In the central and western Murray Basin, the Tertiary sequences are largely concealed by younger aeolian, fluvial and lacustrine sediments (Brown and Stephenson 1991).

Three main Tertiary depositional cycles within the Murray Basin, were distinguished by Brown and Stephenson (1991), which led to the deposition of the fluvial Warina Sand of the Renmark Group, then overlain by the predominantly fluvial and lacustrine Olney Formation. Shallow shelf deposits were followed by deeper water limestone sequences. The Ettrick and Winambool formations, the Geera Clay (including Geera Clay equivalents) and Murray Group limestone sequences were deposited during development and final contraction of these marine environments. This was followed by a regression that was accompanied by the seaward spread of the Upper Renmark Group across the Geera Clay. This period also resulted in the development of the Bookpurnong Formation (Fabris 2002). The final depositional cycle was initiated by a rapid marine transgression at the end of the Miocene. Deposition throughout the Pliocene led to the progradation of the Loxton-Parilla Sands (LPS); a composite assemblage of (regressive) shoreface, beach, dune and back barrier-lagoonal facies that covers more than half the basin and are the host to economic deposits of heavy mineral (Roy et al 2000).

During the Pliocene, barrier sands, at various times, were subject to lateritic weathering during depositional breaks to produce ferricrete (iron-rich) horizons, palaeosols and erosional surfaces. The LPS contains widely dispersed economic concentrations of heavy minerals, notably ilmenite, rutile and zircon (Whitehouse, Roy and Oakes 1999; Roy et al 2000). In the southern section of the basin, the LPS Formation overlies 'shelf muds' and the Bookpurnong Formation.

During the Pliocene to Quaternary period, the Shepparton Formation was deposited directly onto the erosional surface formed after the LPS depositional cycle (the Karoonda Surface in some areas), in a predominantly fluvial-lacustrine setting. In much of the Riverine Plain, this sequence is associated with the Coonambidgal Formation, primarily a poorly consolidated, mottled, variegated clay and silty lenses of polymictic sand and gravel (Brown and Stephenson 1991).

These sediments are shown in Figure 3.1, which detail the aquifer systems of the Murray Basin.

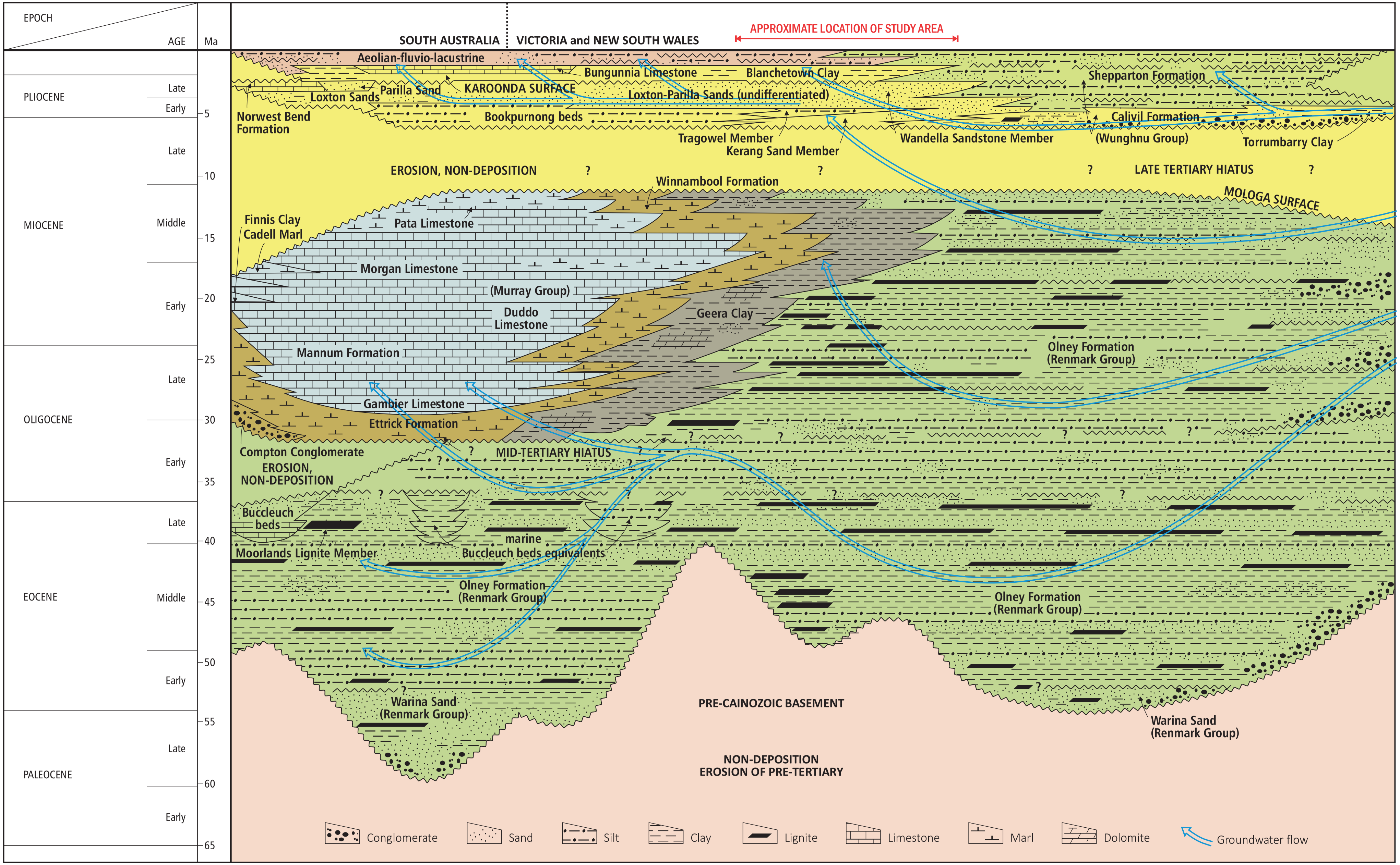
Kellett (1994) indicates that the local geology is comprised of the key units summarised in Table 3.1, where the lithology descriptions have been adapted from Geoscience Australia's (2020) Stratigraphic Units Database.

Table 3.1 Local geology at Balranald (from oldest to youngest)

Age	Group	Unit	Lithology
Pre-Tertiary		Basement rock	
Eocene to Early Oligocene	Lower Renmark Group	Olney Formation	Unconsolidated to poorly consolidated, blue-grey/dark-brown carbonaceous sand and silt.
Oligocene to Middle Miocene	Middle Renmark Group	Olney Formation	Unconsolidated to poorly consolidated, dark-grey, blue, or black carbonaceous clay or silty sand. Commonly pyritic and ligneous.
Late Oligocene to Middle Miocene	Murray Group	Geera Clay	Poorly consolidated, plastic to friable, dark greenish-grey or black silt and clay. Potentially glauconitic, pyritic, calcareous, carbonaceous, or fossiliferous. Local sandy and dolomitic hardbands.
Middle Miocene	Upper Renmark Group	Olney Formation	Unconsolidated to poorly consolidated, brown-grey, carbonaceous, medium to fine sand with interbedded silt. Micaceous and pyritic.
Late Miocene to Early Pliocene	Wunghnu Group	Calivil Formation[1]	Interbedded clay, silty clay, silt and fine to coarse-grained quartz sand, reef quartz and metasediment gravel. Minor ligneous clay.
Late Miocene to Pliocene		Loxton-Parilla Sands	Unconsolidated to weakly cemented, yellow-brown, fine to coarse, well to poorly-sorted, quartz sand and sandstone. Minor clay and silt.
Quaternary (Holocene)		Floodplain Sediments: (Coonambidgal Formation)	Exists within the Murray River floodplain. Unconsolidated, grey, brown, micaceous silty clay, silt, polymictic sand and gravel.

Source: Geoscience Australia (2020)

1. Not identified at the project site



Aquifer systems of the Murray Basin (after Evans and Kellett, 1989 and Brown and Stephenson, 1991)

Iluka Resources

Balranald Mineral Sands Trial – Hydrogeochemical assessment of the T3 mining trial

Figure 3.1

EMM creating opportunities

3.2 Regional hydrogeology

The hydrostratigraphy of the area at the unconventional mining trial, and across the wider Balranald Project, is consistent within the Murray Basin and has previously been described by Iluka (2015) and Jacobs (2015) based on data collected during a series of large-scale field trials undertaken by Iluka and from a number of published reports and maps produced by Kellett (1989; 1991; 1994), Brown and Stephenson (1991), URS (2012) and SKM (2013).

There are three main aquifer units in the immediate vicinity of the unconventional mining trial area: the Shepparton Formation, the ore-hosting Loxton-Parilla Sands (LPS) and the Lower Renmark Group Formation (also known as the Olney Formation; Brown and Stephenson 1991). Other units, whose sediments are heterogeneous in nature, can act as aquifers in localised instances. The Olney Formation is the regionally extensive early-Tertiary lacustrine system, specifically underlying the wider Balranald Project, and consists of the Upper, Middle and Lower Renmark Group.

The Upper and Middle Renmark Groups are separated by the Geera Clay, which acts as an aquitard, disrupting flow between the Renmark Group and the overlying Pliocene sands.

The Palaeozoic rocks of the Lachlan Fold Belt underlie the Murray Basin sediments and form the basement to the basin. The basement contains structures such as ridges and troughs that have influenced deposition of the sediments and therefore also influence the hydrogeology of the Murray Basin.

The regional geology and hydrostratigraphy of the Murray Basin within the Balranald region are shown on Figure 3.2.

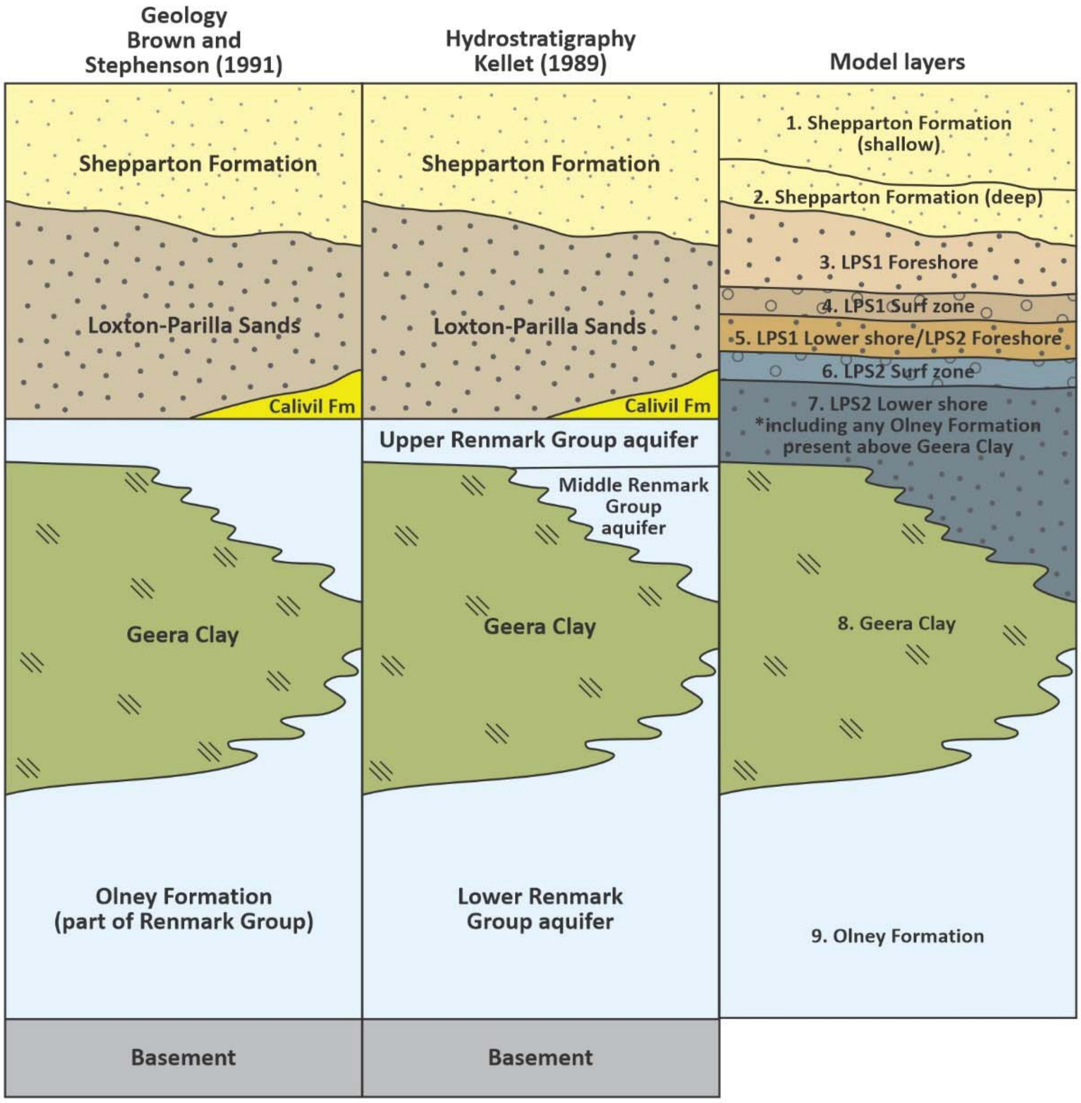


Figure 3.2 Geological (Brown and Stephenson 1991), hydrostratigraphic (Kellett 1989) and numerical model framework of the study area (after Jacobs 2015).

3.3 Local stratigraphy

The local stratigraphy consists of the following sequence (from shallowest to deepest) (EMM 2020):

1. The Shepparton Formation: Deposited within a fluvial-lacustrine environment, the water-table hosting unit consists of sand-clay to clay sediments with bands of fine-grained sand. The base of this unit was often defined by a ferricrete/lateritic horizon. The unit was consistently 30 to 35 m thick throughout the trial sites and was later validated with the use of downhole geophysics.

2. LPS 1 dunal sequence: Occasionally, a fine to very fine narrow band of sand was encountered representing the aeolian-dunal sequence of the ancient beach. This light grey to pale yellow sand is very well sorted and sub rounded to sub-angular in nature with an abraded appearance.

3. LPS1 foreshore: Deposited within a low energy marine environment, this light to dark grey coloured sand consisted of predominantly fine, sub-angular to sub-rounded grains with moderate sorting. Above this unit, occasionally a moderate to highly plastic clay existed which resembled a "natural bentonite".

4. LPS1 surf zone: Deposited within a high energy marine environment, this light to dark grey/brown coloured sand consisted of medium to gravel-sized sand, with moderate to well sorting. Occasionally, lignitic and/or carbonaceous material was present within this unit.

5. LPS1 lower-shore: The lower- or off-shore sediments are deposited within low energy deep water environments. These sediments generally consist of light to dark grey/black sand to silty-sand with sub angular to sub rounded grains of moderate sorting. The presence of lignitic and carbonaceous material was common and tended to be more prolific from these depths onwards.

6. LPS2 foreshore: Although the lithology of this unit is similar to the LPS1 lower-shore package above, there are subtle changes in grain morphology. The grains tend to be fine to very fine sand with less silts being present. Grain size sorting is better than the overlying LPS1 lower-shore package. Mica and pyrite is also present and traces of heavy mineral (HM) becomes apparent.

7. LPS2 surf zone: Deposited within a high energy marine environment, this light to dark grey/brown/black coloured sand consisted of medium to gravel-sized grains and is well sorted. Occasionally, lignitic and/or carbonaceous lagoonal material was present within this unit. However, unlike the LPS1 surf zone package, this unit consists of mica and pyrite and generally hosts large percentages of HM on strike.

8. LPS2 lower-shore: These sediments generally consist of light to dark grey/black very fine to fine sand, which is well sorted in nature. Often lignitic with traces of HM, mica and pyrite.

9. Geera Clay: A thick sequence of marginal marine and estuarine clays and muds, with a confirmed thickness of greater than 70 m at the Long Term Trial (LTT) production and injection sites. This unit was generally black with a blue/green tinge, highly plastic with some fossiliferous/calcareous matter. The transition zone into the Geera Clay from the LPS generally consisted of a mudstone with hard red and white fine clay shards with low plasticity and the presence of low competent lignite was common.

10. Olney Formation: This formation was deposited within a fluvial/lagoonal environment and generally consists of dark grey to brown-black silty sand to sand, with silt to medium sized grains with moderate to poor sorting.

3.4 Sensitive receptors

A number of receptors have been identified as being potentially sensitive to water impacts across the Balranald Project, including:

- ecosystems that rely on groundwater, including Groundwater Dependant Ecosystems (GDEs);
- the Murrumbidgee River and ephemeral surface water courses; and
- private landholder bores.

As indicated by Jacobs (2014) and CDM Smith (2015), ecosystems that rely on groundwater are important environmental assets and typically occur where groundwater is at or near the land surface, with the major potential GDE types across the Balranald Project being:

- wetlands and vegetation associated with the Murrumbidgee, Lachlan and Murray River Floodplain environments; and
- terrestrial vegetation (primarily Black Box trees) located outside the floodplain area but within topographic depressions where the water table may be shallow (ie < 10 m) with low salinity.

The Murrumbidgee River is a permanent surface water feature located to the south and east of the Balranald Project region. This river is home to many sites of environmental importance and is a critical water source for the communities that rely on water from the River for predominantly irrigation and potable supply.

A number of landholders in the area rely on groundwater, sourced from the Lower Renmark Group Aquifer, for stock, irrigation, and domestic use. Figure 4.1 shows the locations of the T3 water supply bores; P1, P2 and Karra Homestead.

The T3 activity area is located outside the area of any defined GDEs and surface water resources (EMM 2020).

4 Groundwater monitoring

Groundwater monitoring was undertaken in accordance with the T3 GMP (EMM 2020), with any differences noted in the following sections.

4.1 Groundwater monitoring infrastructure

4.1.1 Monitoring bores and VWPs

Table 4.1 summarises the groundwater monitoring network utilised during the mining trial, and the bore locations are shown spatially on Figure 4.1.

The monitoring network consists of the following:

- Ten new nested monitoring bore sites (BH-M16 to BH-M25).
- Seven existing monitoring bore sites installed during previous trials.
- Nine new vibrating wire piezometers.

Note that each monitoring bore site (except LPSPB04) consists of two monitoring bores; one shallow bore screened in the Shepparton Formation and one deep bore screened in the LPS. These bores are denoted by ‘S’ and ‘D’ for shallow and deep respectively.

In addition to the monitoring bores and VWPs, three production bores, P1, P2, and the Karra Homestead bore were used for groundwater extraction. P1 and P2 were used to obtain process water via the LPS aquifer, while the Karra Homestead bore was used to extract groundwater from the LRG for dust suppression, construction, make-up water and other ad-hoc purposes.

Table 4.1 T3 groundwater monitoring network

Bore ID	Easting	Northing	Status	Screened formation	SSTL zone
UGM-M1	723217	6189938	existing	SFM/LPS	3 (background)
UGM-M2	723332	6189842	existing	SFM/LPS	3 (background)
UGM-M4	723348	6189745	existing	SFM/LPS	3 (background)
UGM-M8	723364	6189505	existing	SFM/LPS	2 (transition)
UGM-M12	723639	6189000	existing	SFM/LPS	1 (mining)
UGM-M15	723555	6188886	existing	SFM/LPS	2 (transition)
LPSPB04 (deep)	723702	6189053	existing	LPS	2 (transition)
BH-M16	723484	6189656	new	SFM/LPS	3 (background)
BH-M17	723318	6189364	new	SFM/LPS	2 (transition)
BH-M18	723363	6189255	new	SFM/LPS	2 (transition)
BH-M19	723377	6189038	new	SFM/LPS	2 (transition)
BH-M20	723676	6189207	new	SFM/LPS	2 (transition)
BH-M21	723672	6189008	new	SFM/LPS	2 (transition)
BH-M22	723682	6188854	new	SFM/LPS	2 (transition)

Table 4.1 T3 groundwater monitoring network

Bore ID	Easting	Northing	Status	Screened formation	SSTL zone
BH-M23	723631	6188619	new	SFM/LPS	3 (background)
BH-M24	723779	6189359	new	SFM/LPS	3 (background)
BH-M25	723238	6189003	new	SFM/LPS	3 (background)
VWP16	723414	6189262	new	SFM	1 (mining)
VWP17	723453	6189284	new	SFM	1 (mining)
VWP18	723466	6189175	new	SFM	1 (mining)
VWP19	723504	6189198	new	SFM	1 (mining)
VWP20	723713	6189335	new	SFM	2 (transition)
VWP21	723517	6189090	new	SFM	1 (mining)
VWP22	723555	6189112	new	SFM	1 (mining)
VWP23	723631	6188902	new	SFM	1 (mining)
VWP24	723668	6188926	new	SFM	1 (mining)
P1	723701	6189046	existing	LPS	Production bore
P2	723191	6189730	existing	LPS	Production bore
Karra Homestead	720430	6188310	existing	LRG	Production bore

4.1.2 Specialised groundwater collection system

Two important requirements of the water licence conditions were to ensure:

- the pH of the water to be reinjected was between 6.5 and 8.5, or was treated to bring the pH within this range; and
- water injected to the aquifer during mining and backfill phases must be of the same or better quality than the aquifer receiving water (as per the beneficial use classification) and should be free of any pollutants.

The water quality within the backfill material was monitored, with the potential effects on the groundwater system also monitored. Bores UGM-M12 and BH-M21 are located close to the stopes within the restricted access/exclusion zone, with groundwater level and quality data from these bores vital to ensure the water licence conditions were being fulfilled.

EMM personnel were not permitted to enter the exclusion zone during active mining/backfilling due to the potential subsidence risks. To ensure the sampling requirements were met, EMM developed, constructed and installed a specialised groundwater collection system that allowed samples to be collected remotely from bores within the mining exclusion zone. This dedicated system gave EMM technicians the ability to undertake remote purging of bores, measurement of groundwater field parameters, collection of groundwater samples for laboratory analysis, and to access data from level loggers deployed within the bore.

The groundwater collection system utilised Solinst Double Valve Pumps in bores UGM-M12S/D and BH-M21D. A Solinst Bladder Pump was installed in bore BH-M21S due to the shallower depth of that bore. A Solinst level logger with direct read cable was installed above the groundwater pump to continuously monitor and record groundwater level changes within each bore. The wellhead was designed to seal around the pump's drive and sampling lines/tubings and logger's direct read cable to prevent any leakage as the bore may potentially be artesian during active backfilling. The drive and sample lines, and direct read cable were fed through an underground conduit from each bore location to a collection area where they were terminated to a control panel manifold box mounted on a steel pole. The collection point was set up approximately 80 m from the bore itself to ensure EMM field technicians maintain a safe distance from the exclusion zone when collecting samples.

It is noted that dedicated pumps were also installed in bores UGM-M8S/D, however these bores are not in the exclusion zone. These groundwater pumps were originally from the groundwater collection system deployed in UGM-M6S/D which was located in the exclusion zone, but UGM-M6S/D were decommissioned a few weeks after the collection system was installed due to updated mine plans placing this bore in the path of the drill string.

Photographs of the bore setup and sample collection site for the specialised groundwater collection system are shown in Plate 4.1 and Plate 4.2.

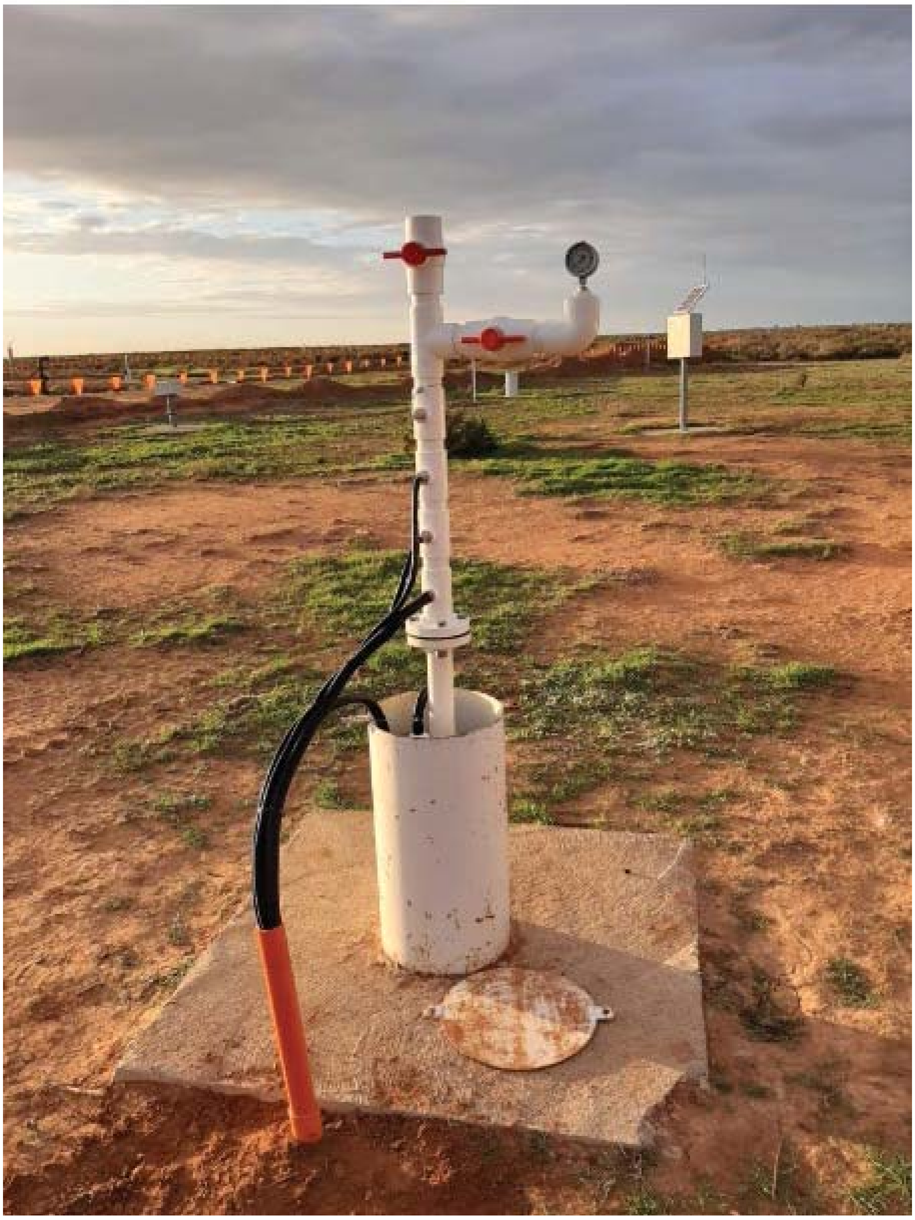


Plate 4.1 Specialised groundwater collection system – bore setup

Plate 4.2 Specialised groundwater collection system – Sample collection setup

4.1.3 Process plant monitoring

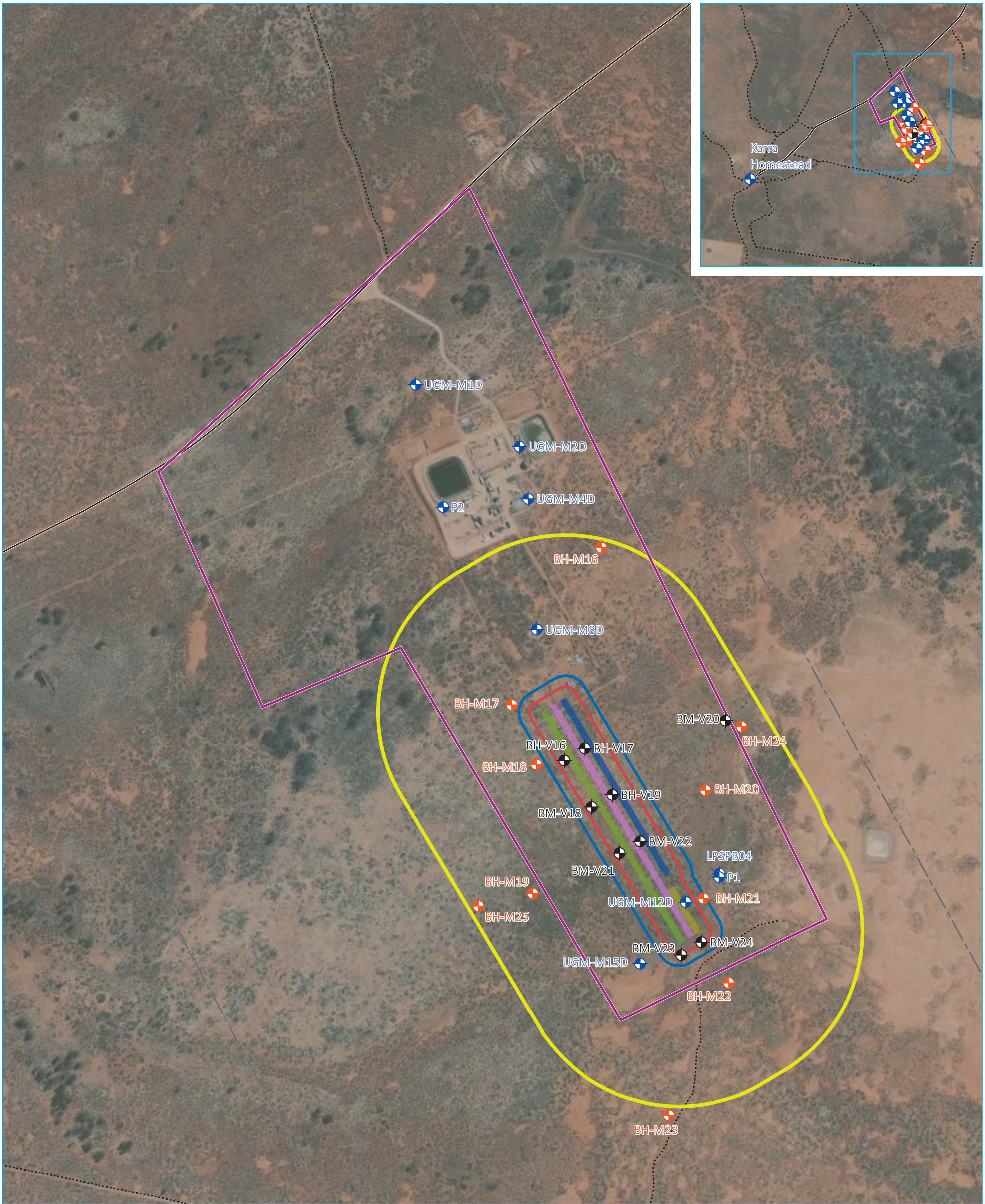
In addition to the groundwater monitoring bore sites, water quality measurements were taken at various points within the process plant area to assess the acidity of the tailings throughout the circuit, inform potential lime dosing rates and assess risks associated with potential acid metalliferous drainage and backfilling of acidic material.

The monitoring points, analyte suites and monitoring frequencies are listed in Table 4.2 which are consistent with the GMP, and the locations of the sample points are shown in Figure 4.2.

Table 4.2 Process plant monitoring summary

Sample point and objective	Analytes	Frequency
Process Water Pond *Maintain pH >6.5 and <8.5 continue with current dosing rate* *To determine whether any hydrated lime treatment is required and quantify dose rate, if any.*	Field parameters**	Daily
	Particle size distribution	Daily sampling for 30 continuous days (once-off sampling event)
Fines thickener underflow *Fines report to the new fines dam (old T2 PWD), which will be covered with water to minimise oxidation, prior to backfilling.*	Field parameters**	Weekly
Spiral plant discharge (sand and heavy mineral streams) *To determine whether any lime treatment is required and quantify dose rate, if any.*	Field parameters**	Daily
HBF discharge line *To determine whether any lime treatment is required and quantify dose rate, if any. Last monitoring point before backfilling occurs to stopes.*	Field parameters**	Daily during backfill, Weekly otherwise
T2 stockpile area drainage sump *To determine whether any lime treatment is required and quantify dose rate, if any.*	Field parameters**	Weekly
T3 Stockpile drainage sump *To confirm effectiveness of limestone blending in sand and HMC stockpiles.*	Field parameters**	Weekly
Spill dam *To determine the quality of water reporting to the detention basin to ensure seepage was not a source of pollution*	Field parameters**	Weekly

Note: ** Field Parameters: pH, EC, DO, Temperature, Redox Potential



Source: EMM (2020); Iluka (2019); DFSI (2017); GA (2011)

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m
GDA 1994 MGA Zone 54
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KEY

- Activity area
- New T3 bore
- New T3 VWP
- Existing bore
- Local road
- Vehicular track
- Restricted area
- Mining zone boundary
- Transition zone boundary
- Mining Lease 1736
- Stope 3B
- Stope 4
- Stope 5
- Stope 6

Groundwater monitoring infrastructure

Iluka Resources Limited
T3 Hydrogeochemical Assessment
Figure 4.1

EMM
creating opportunities

Source: EMM (2019); Iluka (2015); DFSI (2017); GA (2011)

\\emmsvr1\emm\Jobs\2019\S190512 - Balranald T3 Ancillary Support\GIS\02_Maps_Hydrogeo\HG004_PlantMonitoring_20201210_02.mxd 10/12/2020

KEY

- Plant monitoring location
- Production bore
- Activity area
- Mining Lease 1736
- Iluka mineral tenement

Indicative site layout

- Access road
- Activity footprint
- Existing site office and light vehicle carpark
- Fines storage pond
- Ore pad
- HDD rig, plant, equipment and administration buildings
- Process water dam
- Spoon drain
- New stormwater detention basin
- Stockpile
- Stope (mined)
- Stope 3B
- Stope 5
- Stope 6

Plant monitoring locations

Iluka Resources Limited
T3 Hydrogeochemical Assessment
Figure 4.2

EMM
creating opportunities

4.1.4 Groundwater abstraction monitoring

Water for processing was sourced from the LPS aquifer via production bores P1 and P2. Ad-hoc water requirements for construction, dust suppression and makeup water were sourced from the LRG aquifer via the Karra Homestead bore. The locations of these bores are shown in Figure 4.1.

During monitoring, daily totaliser values were recorded for P1, however P2 had no physical totaliser and therefore all extraction rates and volumes were only recorded by Iluka's process control systems. Figure 4.3 summarises the daily and total extracted volumes from these bores over the course of the trial, beginning from 25 August 2020. It is noted that extraction from P1 began on 13 August 2020, but totaliser measurements only began on 25 August 2020. Karra Homestead bore usage was adhoc, and as such only monthly abstraction volumes were measured.

A total of 43 ML was extracted from the LPS aquifer via P1 and P2 during mining and backfilling, while 26 ML was extracted from the LRG aquifer through the Karra Homestead bore. It is noted that the pump in production bore P1 failed in October 2020. These abstraction volumes were in accordance with Iluka's water allocation and reflective of T2 usage volumes. Mining, processing and backfilling rate were the key drivers for water usage rates.

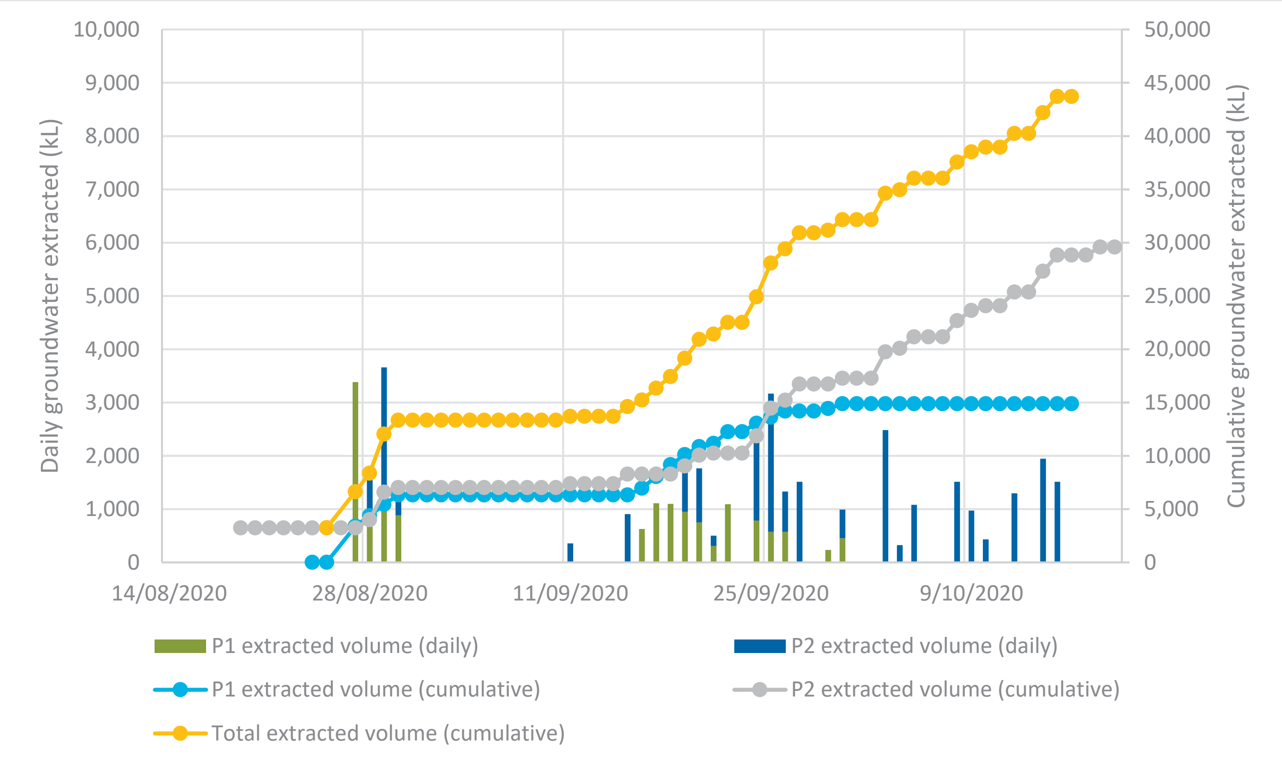


Figure 4.3 Groundwater extraction rates and cumulative extraction from P1 and P2

4.1.5 Subsidence monitoring

Iluka prepared a separate Subsidence Management Plan (SMP) (Iluka 2019) which details the potential subsidence risks, monitoring and mitigation strategies associated with T3 mining and backfilling. VWPs were monitored at key locations in between stopes to monitor vertical connection / aquitard integrity. A failing aquitard could allow mixing of groundwater between the LPS and SFM aquifers and allow for pressure to be transmitted from the LPS to the SFM during mining and backfilling activities.

VWP telemetry was fed live to the control room and was monitored near injection points (with alerts) during the mining/fluidisation phase and the backfilling phases. The SMP forms part of the Balranald Project Safety Management System as a Principal Hazard Management Plan (EMM 2020).

4.2 Groundwater monitoring methodology

The objectives of the groundwater monitoring network were to:

- measure the groundwater pressure and chemical changes at various locations within the SFM and LPS aquifers during mining, backfilling, and post-mining periods;
- ensure adequate monitoring bores are located within each SSTL zone as described in Section 4.3;
- monitor the groundwater within the SFM aquifer along the HDD access holes to ensure the water table elevation does not breach the trigger levels during mining/backfilling periods;
- measure the effects of variable reinjection rates and operational conditions on resulting groundwater pressures and geochemical changes;
- allow for flow net/pressure analysis to be performed radially within the LPS aquifer;
- develop an understanding of operational constraints; and
- provide a robust dataset which future groundwater flow modelling can use to assist with assessing the feasibility of an unconventional mining method for the Balranald Project.

4.3 Site specific trigger levels (SSTLs)

The groundwater monitoring sites were assigned to 'chemical SSTL zones' based on their proximity to the mining activities, as defined in Table 4.3 and illustrated in Figure 4.1. These assignments were made based on preliminary hydrogeochemical modelling performed by LWC (2017b) which suggested that large groundwater quality changes may be observed within 20 m of the stope edges, which would then dissipate to background conditions within a 300 m buffer zone from the stope edges.

The purpose of these zones was to identify bores which should receive more frequent groundwater level and quality monitoring, assign chemical analysis suites, and identify how groundwater changes in one zone affect the zone(s) down hydraulic gradient. These changes satisfy recommendations by LWC (2017a) to change how monitoring occurs to prevent adverse trends being missed due to monitoring 'blind spots'.

These zones accept that the groundwater system may change directly adjacent to the mine stopes. However, the management objectives for groundwater chemical changes were focused on protecting the beneficial use[1] of the groundwater system down hydraulic gradient from the mining site, more-so than within the mine footprint itself. Therefore, the SSTL values are only applicable to the background zone, where no impact is expected or accepted.

Groundwater quality SSTLs were previously listed in the T3 GMP (EMM 2020) and were derived on a per aquifer basis using baseline. The SSTLs applied during T3 are presented in Appendix A.

[1] Although there no direct beneficial users currently identified for the SFM and LPS aquifers, the chemical SSTLs are designed to not decrease the groundwater quality down hydraulic gradient of the T3 activity and maintain groundwater quality within historic statistical ranges.

Table 4.3 Zoned hydrogeochemical SSTL framework

Groundwater Monitoring Zone	Purpose	Details
Zone 1 Mining Zone	Operational	Adjacent and surrounding the actual mining area. Includes the stope areas plus a 20 m buffer. Required to understand immediate changes to groundwater quality and pressure. Large changes relative to baseline conditions are expected in this zone and represent the source location of both pressure and geochemical changes. Provide a leading indicator to potential impacts within Zone 2.
Zone 2 Transition Zone	Operational	Non mining area and represents the zone between 20 m and 300 m from the stope edges. Data and trends within this zone are used to understand aquifer responses at various locations away from the stopes, during mining and backfill. Provide a leading indicator to potential impacts within Zone 3.
Zone 3 Background Zone	Compliance	Non mining area and represents the zone beyond 300 m from the stope edges. Bores located in this zone are part of the EPA Licence and are therefore required to adhere to the nominated SSTLs and associated compliance reporting.

4.4 Operational hydraulic pressure

The Hydraulic Operating Conditions (HOCs) represent the historical maximum pressures that have been experienced within the aquifers without any adverse impacts being observed. These values were derived using aquifer-specific methodologies. For the overlying SFM aquifer, HOCs were determined based on the rooting depths of nearby vegetation. Away from the Murrumbidgee River and associated floodplain region, vegetation relies predominantly on rainfall and soil water storages with the SFM aquifer, with root system depths of around 5 mBGL. Therefore, due to the high salinity of groundwater in the SFM aquifer, groundwater level rise into the root zone should be avoided. Temporary dewatering within the SFM and LPS is not deemed to adversely impact this groundwater system and HOCs have not been set for this scenario.

Water level trigger levels for the LPS aquifer have been defined for the upper-most facie of this unit, which lies directly below the SFM. These HOCs have been set to avoid over-pressurising, and this compromising, the integrity of the SFM layer, but more specifically, the bentonite clay layer existing at the base of the SFM. These conservative HOCs were based on past hydrogeological field programs which involved large scale reinjection activities (Iluka 2015; Iluka 2016).

The HOCs applied during T3 were listed in the T3 GMP (EMM 2020) and are summarised in Appendix A.

4.5 Groundwater monitoring program

4.5.1 Monitoring suites

The following groundwater monitoring suites were used before, during and after the trial:

- Suite 1- These represent the field-based properties which were collected via a water level dipper (water levels), a In-Situ Aqua TROLL 500 or similar water quality device (EC (automatically temperature-corrected), pH, TDS, DO (automatically temperature-corrected), temperature, and redox potential (ORP)) and a Hanna Instruments field total iron test. Given that the field-based pH is probably the most important field analyte, the water quality meter was calibrated each morning before commencing daily activities. Minimal drift was noted in each parameter during the daily calibrations, indicating the suitability of the meter for daily measurements. It is noted that the Aqua TROLL 500 uses a silver/silver chloride (Ag/AgCl) electrode in potassium chloride (KCl) solution for ORP measurement, whereas the standard measurement for ORP is based on a standard hydrogen electrode (SHE), which for safety and economic reasons is rarely used in field instruments. To convert field ORP readings to the SHE standard, a temperature-based adjustment is needed. This typically adds approximately 200 mV to the instrument measurement, and is an essential adjustment to make in order to compare data between sites. Given all ORP measurements are taken from the same site, corrections to the SHE standard have not been undertaken in this report.

- Suite 2- This suite represents the major cations, anions (including alkalinity) and gross alpha and gross beta and are required to consider whether the major constituents of groundwater change significantly between pre-mining, mining, and post-mining conditions.

- Suite 3- The species listed in this suite were considered the key leading indicators and have the most notable effect on groundwater metal composition with respect to pH-sensitive species and general dissolution of ferric hydroxide phases (which may release sorbed species). Further indicators of acidification caused by pyritic oxidation may be observed in the chloride to sulphate ratio, and the ferrous and total iron relationship.

- Suite 4- Iluka is obliged to analyse and monitor for Naturally Occurring Radioactive Materials (NORM). These elements can be concentrated within heavy mineral deposits associated with monazite sands and include isotopes of uranium, thorium, radium and potassium. Two of the short-lived daughter isotopes including Ra-226 and Ra-228 are commonly monitored by Iluka, due to their high mobility under certain environmental condition and detrimental impact to ecosystems and humans following uptake (IAEA 2014). Th, U, Ra-226 and Ra-228 were monitored pre- and post-trial only.

- Suite 5- if groundwater reduces below a pH < 6.5, certain metals may become mobile and released into the groundwater system. This suite was designed to further assess potential risk caused by potential in-situ acidification and subsequent metal mobilisation.

Table 4.4 T3 activity monitoring program overview

Suite	Description	Parameters	Frequency
1	Field parameters	Water levels, Electrical conductivity (EC), pH, dissolved oxygen, temperature, oxidation reduction potential (redox), total Fe.	Pre- and post-trial, daily for bore transects adjacent to active mining and backfill periods, fortnightly for other bore locations.
2	Major ions	Ca, Mg, Na, K, SO_2^-, SO_4^{2-}, Cl, alkalinity (bicarbonate, carbonate, hydroxide and total as $CaCO_3$).	Pre- and post-trial, and monthly[1] during trial. Aim to collect water samples at bore transects at times adjacent to active backfill periods.
3	Leading indicators	Al, Mg, S, Cl:SO_4^{2-} , Ferrous and Total Fe. Gross Alpha, Gross Beta ('transition zone' only).	As Suite 2.
4	Radionuclides	Th, U, Ra-226 and Ra-228. Gross Alpha, Gross Beta ('transition zone' only).	Pre- and post-trial. As Suite 2.
5	Total and dissolved metals (if pH<6.5)	Fe, Al, Mn, Zn, Cu, Pb, Ni, Co, Cd, Cr and As.	As Suite 2, only if field pH<6.5.

Note: 1. Suite 2 was targeted to sample during times of active mining and backfilling on a roughly monthly basis.

4.5.2 Groundwater monitoring events

Apart from the daily/fortnightly groundwater level and quality measurements (Suite 1 from Section 4.5.1), groundwater monitoring events were carried out approximately at monthly intervals, and were targeted to take place during times of active mining or backfilling where possible.

Groundwater monitoring suites 2 to 5 (as described in Section 4.5.1) required samples to be sent to a third-party laboratory for analysis. Samples collected on-site were analysed by ALS Environmental Pty Ltd in Melbourne and Sydney (primary laboratories) and Envirolab Services Pty Ltd in Sydney (secondary laboratory for duplicates), which are both National Association of Testing Authorities (NATA) accredited laboratories. A summary of the sampling rounds is presented in Table 4.5, while full laboratory reports are attached in Appendix B and QA/QC analysis of the field activities and laboratory results are presented in Appendix C. Any deviations from the QA/QC procedures detailed in the GMP (EMM 2020) are listed in Appendix C.

Table 4.5 Summary of T3 groundwater monitoring events

Monitoring round number	Activity targeted	Dates sampled
1	Pre-trial	21/04 – 28/04
2	Mining	19/08 – 24/08
3	Mining	11/09 – 21/09
4	Backfilling	02/10 – 03/10
5	Backfilling	13/10 – 19/10
6[1]	Backfilling	13/11 – 18/11
7	Post-trial	TBC[2]

1. Lab results were yet to be received at the time of this report preparation
2. This event is scheduled for February 2021

5 Groundwater pressure results

5.1 Assessment of groundwater pressures

Groundwater pressure responses have been assessed between April and November 2020, which covers the HDD development, mining of Stope 4 and Stope 6 as well as backfilling in the following locations:

- Stope 4 rig end.
- Stope 4 far end.
- Stope 3 rig end.
- Stope 1B rig end.
- Stope 1 rig end.
- Stope 6 rig end.

Hydrographs for each monitoring bore are shown in Appendix D with periods of groundwater extraction, mining and backfilling labelled. The maximum pressure impacts shown in these hydrographs have been summarised in Table 5.1. The pressure results indicate the following:

- Pre-mining groundwater levels are around 12-14 mbgl in the SFM aquifer and about 0.5 m to 1.0 m deeper in the LPS aquifer. The natural vertical gradient is downward.
- Drawdown impacts of 2 m to 6 m are observed in the LPS bores due to pumping from the P1 and P2 production bores. P1 was typically operated for longer durations and lower flow rates, leading to gradual drawdown over time, whereas P2 was operated with a higher flow rate for short periods, leading to large drawdown spikes.
- Drawdown within the SFM during groundwater extraction periods was only observed at bores UGM-M8S, BH-M17S and BH-M18S, however these responses correlate with known subsidence events and were likely caused by them (discussed further in Section 8). This suggests that, when excluding responses to subsidence events, the aquitard was able to impede drawdown responses from transmitting from the LPS to the SFM aquifers.
- Groundwater extraction from P2 bore was the only activity which invoked pressure responses from the adjacent background bores, indicating that the pressure impacts of mining and backfilling do not travel far from the mining stopes. The P2 bore is located near the site offices and the old PWD (new slimes dam), approximately central to the background bores (Figure 4.1).
- Mining elicited pressure responses of up to 3 m within the LPS-screened bores closest to the mining stopes. The majority of the transition zone and background bores showed no pressure responses to mining. These results suggest that pressure impacts from mining are localised. No pressure responses were observed within the SFM bores.
- Mining only elicited pressure responses in the LPS aquifer, except in the cases where irregular subsidence events occurred, suggesting an effective aquitard between SFM and LPS in the area. It is noted that the aquitard may not always be present in areas to the south of the site.

- Backfilling caused consistent mounding responses in the LPS-screened mining and transition bores, and responses were also seen in several background bores. The pressure responses in the mining and transition bores were between 1 m and 3 m, while mounding in the background bores was less than or equal to 1 m above the pre-mining standing water level. This suggests that backfilling activities have more impact on groundwater pressures, but still dissipate a short distance from the mining stopes.

- Backfilling led to pressure responses in the SFM aquifer only in bores UGM-M8S, BH-M17S and BH-M18S. The pressure responses are likely a result of subsidence which occurred during backfilling, or due to the aquitard separating the LPS and SFM being weakened during previous subsidence events and later allowing groundwater to travel upwards from the LPS to the SFM.

- Mounding responses due to mining and backfilling may have been partially masked by the operation of the P1 and P2 production bores during operations.

- At no point during the trial did groundwater pressures exceed the SSTLs or HOCs described in Section 4.3 and Section 4.4.

Table 5.1 Maximum observed pressure impacts during extraction, mining, and backfilling

Bore	Aquifer	Monitoring zone	Maximum observed mounding (m)			
			P1/P2 extraction	Mining		Backfilling
				Stope 4	Stope 6	
UGM-M1D	LPS	Background	-4.9	-	-	-
UGM-M1S	SFM	Background	-	-	-	-
UGM-M2D	LPS	Background	-5.2	-	-	-
UGM-M2S	SFM	Background	-	-	-	-
UGM-M4D	LPS	Background	-6.3	-	-	-
BH-M16D	LPS	Background	-3.1	-	-	1.0
BH-M16S	SFM	Background	-	-	-	-
BH-M23D	LPS	Background	-1.5	-	-	0.1
BH-M23S	SFM	Background	-	-	-	-
BH-M24D	LPS	Background	-3.3	0.6	1.2	0.8
BH-M24S	SFM	Background	-	-	-	-
BH-M25D	LPS	Background	-1.6	-	0.2	0.8
BH-M25S	SFM	Background	-	-	-	-
UGM-M8D	LPS	Transition	-4.4	-	-	2.3
UGM-M8S	SFM	Transition	-0.5	-	-	1.0
UGM-M15D[1]	LPS	Transition	-1.2	-	0.9	0.4

Table 5.1 Maximum observed pressure impacts during extraction, mining, and backfilling

Bore	Aquifer	Monitoring zone	Maximum observed mounding (m)			
			P1/P2 extraction	Mining		Backfilling
				Stope 4	Stope 6	
UGM-M15S	SFM	Transition	-	-	-	-
BH-M17D	LPS	Transition	-3.1	-	-	2.9
BH-M17S	SFM	Transition	-1.2	-	-	3.3
BH-M18D	LPS	Transition	-2.4	-	-	2.2
BH-M18S	SFM	Transition	-2.0	3.2	1.8	2.3
BH-M19D	LPS	Transition	-2.0	-	-	1.0
BH-M19S	SFM	Transition	-	-	-	-
BH-M20D	LPS	Transition	-5.6	1.8	-	1.1
BH-M20S	SFM	Transition	-	-	-	-
BH-M21D	LPS	Transition	-2.8	1.0	2	2.7
BH-M21S	SFM	Transition	-	-	-	-
BH-M22D	LPS	Transition	-2.1	-	1.2	0.5
BH-M22S	SFM	Transition	-	-	-	-
LPSPB04	LPS	Transition	-8.0	-	-	-
UGM-M12D	LPS	Mining	-2.8	0.9	2	0.9
UGM-M12S	SFM	Mining	-	-	-	-

1. Only daily manual measurements were available for UGM-M15D, not hourly automatic logger measurements. Therefore, some pressure spikes may have been missed and are not represented in the hydrographs or this table.
2. '-' denotes that no significant pressure response was observed.

5.2 Comparison with groundwater flow model predictions (EMM 2019)

EMM (2019) predicted the groundwater mounding responses that could occur in the LPS and SFM aquifers during T3 backfilling activities.

A 10-week mining period followed by a 10-week backfilling period was modelled. Backfilling was simulated at a constant rate of 150m^3/h of fluid injected (no solid content). Over the combined 20-week operation, it was assumed that the P2 and Karra Homestead production bores would be continuously extracting at rates of 30 L/s and 6 L/s respectively.

The maximum predicted pressure impacts were modelled for a variety of stope conditions, from open to closed, which assume different volumes of void space in the stope to simulate subsidence or filling of the void with backfill material over time. This modelling predicted that mounding within the LPS is greatest at the locations of injection, but that the pressures quickly return to baseline levels due to the high hydraulic conductivity of the aquifer.

The maximum impacts modelled at various monitoring points are summarised in Table 5.2 and compared to the observed impacts from Table 5.1.

Comparison of the predicted and observed pressure responses demonstrates the following:

- Only 0.9 m of groundwater mounding above static levels was observed in UGM-M12D, compared to the predicted 5-7 m pressure response. Similar results are seen in BH-M19D and BH-M25D, where the observed mounding effects are lower than predicted.

- The observed pressure response for BH-M17D was within the range of predictions but is likely due to subsidence events in the area, and not because of reinjection. The pressure spike is also observed in BH-M17S (screened in the SFM), which would not be expected from backfilling activities targeting the LPS aquifer.

- The bores screened in the SFM aquifer showed no response to backfilling, generally aligning with the modelled outcomes (except for BH-M17S, as previously discussed).

- Overall, the observed mounding was generally much lower than predicted, except for during the subsidence events. The modelling appeared to be conservative, with the assumed sustained injection (included in the model) not undertaken. The likely reason for the difference between the predicted and observed results (ignoring normal modelling limitations) are the differences in the simulated and actual backfilling schedules and injection rates, ie the applied stresses in reality were smaller than the assumed stresses applied in the numerical model.

Backfilling was modelled to occur for 10 weeks at a constant rate of 150 m^3/h for 12 hours per day. In reality, backfilling took place between 1 October 2020 and 7 November 2020, which is equal to 37 days or approximately 5 weeks. Backfilling occurred each day from 1 to 18 October 2020, however after this, backfilling only occurred on 4 of the remaining 20 days. Therefore, backfilling only occurred for a continuous period of 18 days as opposed to the 70 days modelled, which would lead to lower pressure responses.

The modelled backfill rate of 150 m^3/h for 12 hours per day was greater than the actual rate of injection. On 8 October 2020, backfilling occurred at 220 m^3/h for approximately 8 hours and resulted in 448 t of material being reinjected. Generally, the amount of material reinjected between 1 and 18 October 2020 was between 20 and 200 t/day.

Assuming the same solids percentage was maintained throughout, this is equal to a daily injection rate of between 3.4 and 33.4 m^3/h when injecting continuously during both the day and night shifts (as generally occurred). This would be equivalent to injection rates of between 6.8 and 66.8 m^3/h if it was assumed that all injection took place during the 12-hour day shift, as it was for the model. In either case, even the higher injection rate days saw material backfilled at less than half of the modelled injection rate. Therefore, it would be expected that the actual magnitude and size of the groundwater mounding would be less than modelled, as was observed.

Another difference between modelled and observed is as a result of the modelled backfill assumed to be entirely fluid in the model, whereas the actual injected material varied between water, slimes, sand tails, or a mixture of these. These different materials would have resulted in varying pressure responses.

The observed impacts being lower than the predicted impacts could also be partially due to the extraction of groundwater from both the P1 and P2 production bores, instead of only P2 as simulated, during the backfilling activities. The P1 bore is located closer to the mining stopes and therefore would have a greater impact on groundwater in this area. Extraction from this bore could have potentially drawn the groundwater levels down to a level that buffered some of the mounding impacts from backfilling.

Another explanation for the discrepancy could be the resolution of the automatic data loggers. As the loggers only measured groundwater pressures hourly, a short spike in groundwater pressure may not have been captured or only partially captured. This is likely not the reason for substantial differences though, as EMM (2019) predicted sustained pressure responses over the course of days during backfilling.

Based on these outcomes, it is recommended that future modelling predictions consider a range of different injection rates to account for lower or higher than predicted rates. Additionally, pumping from the P1 bore at realistic rates based on T3 data could be simulated to account for a potential reduction in observed mounding. Strategic placement of water supply bores could be used to minimise mounding impacts going forward within an operational context.

Table 5.2 Predicted and observed pressure responses during backfilling

Monitoring bore	Aquifer	Monitoring zone	Maximum predicted[2] pressure response (mounding; m)	Observed pressure response (mounding; m)
UGM-M12D	LPS	Mining	5-7[1]	0.9
BH-M17D	LPS	Transition	3-7[1]	3.3
BH-M19D	LPS	Transition	5	1.0
BH-M25D	LPS	Background	4	0.8
UGM-M2D	LPS	Background	2	0
UGM-M12S	SFM	Mining	2	0
BH-M17S	SFM	Transition	0.5	3.3
BH-M19S	SFM	Transition	0.5	0
BH-M25S	SFM	Background	0	0
UGM-M2S	SFM	Background	0	0

1. Bores with a range of predicted pressure responses are due to varying stope conditions (closed, closing or open) causing different outcomes. Other bores had approximately the same response for all stope conditions modelled.
2. EMM 2019

6 Hydrogeochemical assessment of mining trial

Mining took place from 19 August 2020, when mining of Stope 4 commenced, until 30 September 2020 when the mining of Stope 6 was completed. A summary of the daily mining progress is displayed in Figure 6.1.

Over this period, field parameters and samples for laboratory analysis were collected in accordance with the GMP monitoring program outlined in Section 4.4. Note that Section 7 details the hydrogeochemical assessment of backfill.

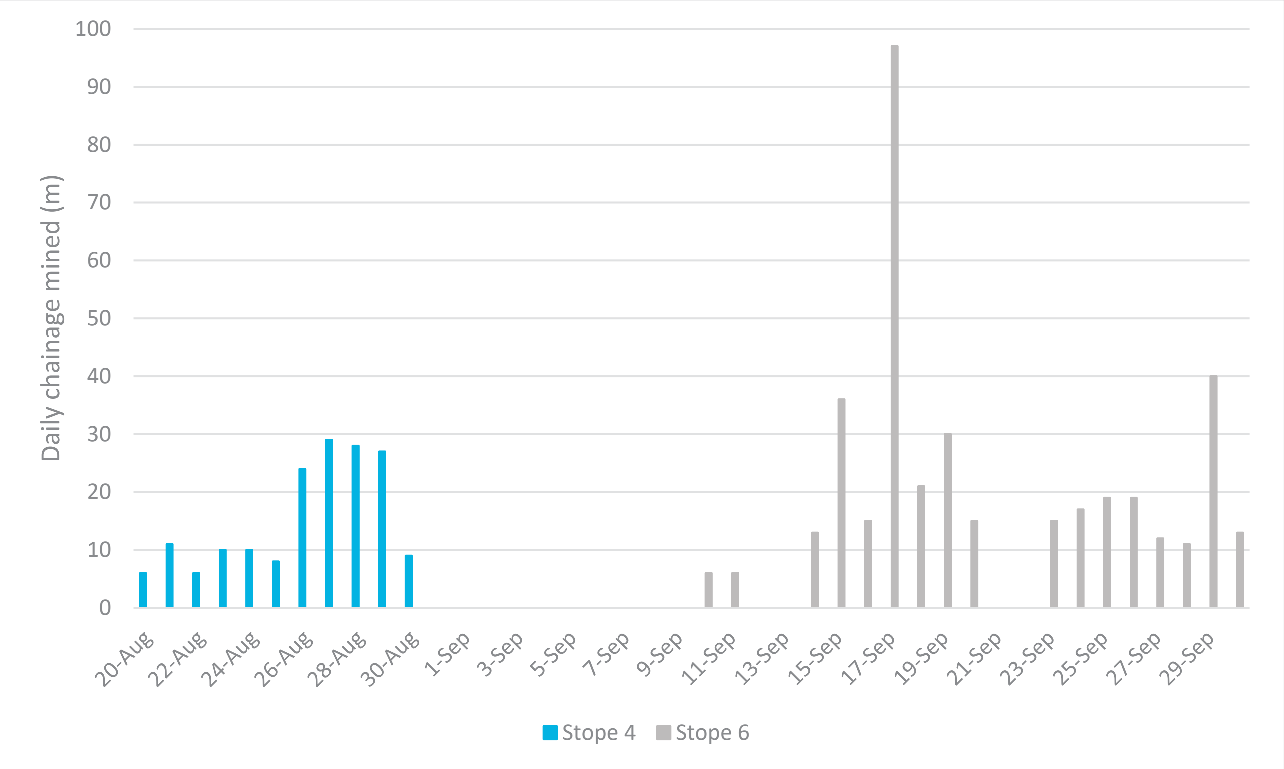


Figure 6.1 Summary of daily chainage mined (m) during T3

6.1 Field physicochemical results

6.1.1 Pre-mining measurements

After the completion of the T2 trial, selected bores were monitored on an ongoing basis every six months to comply with regulatory requirements (ie between 2017 to 2019).

The minimum, maximum and mean measurements of pH, EC, TDS, ORP, temperature and iron collected between July 2018 and April 2020 (five total measurements per bore) are summarised in Table 6.1 and Table 6.2 for bores screened in the LPS and SFM, respectively. These measurements are considered 'pre-mining' measurements for the purpose of comparing results from T3.

Table 6.1 Summary of field parameters measured prior to T3 – LPS aquifer

Parameter	pH	EC (µs/cm)	TDS (mg/L)	ORP (mV)	Temperature (°C)	Total iron (mg/L)
Minimum	6.54	44,113	28,498	-411.0	17.0	0.29
Maximum	7.81	60,900	39,600	74.2	25.5	4.80
Mean	6.98	51,097	33,883	-181.1	21.2	1.90

Table 6.2 Summary of field parameters measured prior to T3 – SFM aquifer

Parameter	pH	EC (µs/cm)	TDS (mg/L)	ORP (mV)	Temperature (°C)	Total iron (mg/L)
Minimum	6.32	46,220	30,040	-424.3	16.8	0.11
Maximum	8.01	71,500	46,500	157.8	24.1	1.38
Mean	7.20	56,243	37,340	-125.7	21.0	0.74

6.1.2 Loxton Parilla Sands

Groundwater from the LPS monitoring bores was analysed in the field for pH, EC, TDS, ORP, temperature and total iron (for bores located in the 'mining' SSTL zone only). A summary of the data collected over the mining period is presented in Table 6.3, with the raw data reported in Appendix E. Time-series plots of pH and total iron measurements collected in the mining zone bores during mining are displayed in Figure 6.2 and Figure 6.3 respectively. Although the SSTLs only apply to the background bores, trends in the mining zone bores have been investigated as an 'early warning system'. If no trends are observed in the bores closest to mining, then background bores should not have experienced any impacts.

From this data, the following is observed:

- pH measurements collected during mining were slightly acidic to neutral, with the mean value of 6.64 being slightly lower than the pre-mining mean of 6.98. Figure 6.2 shows that the pH measurements from the near-mining bores do not significantly change during the mining period.
- There was no significant change in EC/TDS measurements due to the mining activities.
- The mean ORP value increased from -181.1 mV pre-T3 to -64.1 mV during mining activities. This could be due to an increase in oxidising conditions within the aquifer due to mining, or potentially due to the new T3 bores being monitored over the mining period, which may exhibit differing local aquifer properties to the original existing bores used to generate the pre-T3 statistics.
- The mean total iron concentration of 2.6 mg/L measured during mining was slightly higher than the pre-T3 value of 1.9 mg/L. Figure 6.3 shows the BH-M21D has a relatively high concentration of iron compared to the mean. As the iron concentration in this bore was measured daily, it would significantly influence the mean iron value to be higher.
- Figure 6.3 shows that total iron concentrations increased during mining in the near-mining bores. Iron concentrations in BH-M21D and UGM-M12D increased from approximately 0.5 and <0.1 mg/L respectively at the start of mining to approximately 5 and 0.5 mg/L respectively. Total iron concentrations increased more in BH-M21D despite both bores having similar pH values and both being approximately the same distance from the mining stopes, which could suggest local pyrite or other iron mineralisation.

Table 6.3 Summary of field parameters measured during mining – LPS aquifer

Parameter	pH	EC (µs/cm)	TDS (mg/L)	ORP (mV)	Temperature (°C)	Total iron (mg/L)
Minimum	6.36	48,945	31,815	-282.0	11.2[1]	<0.1
Maximum	7.10	60,228	39,148	290.6	22.4	5.4
Mean	6.64	53,743	35,262	-64.1	18.7	2.6

Notes: 1. Suspected erroneous reading

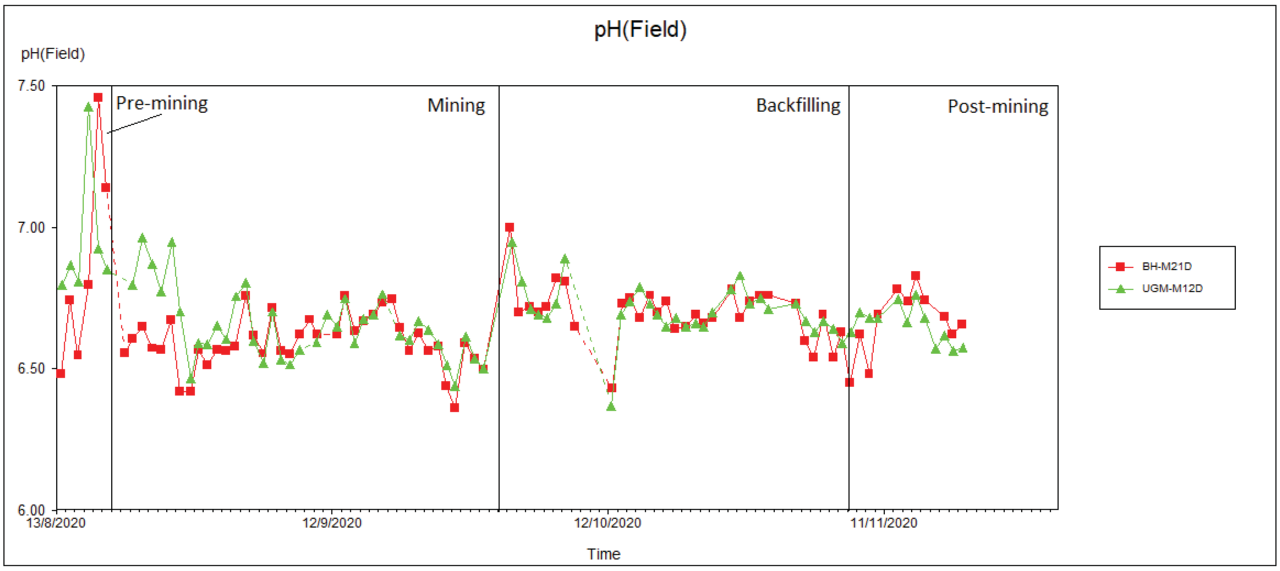


Figure 6.2 Field pH measurements collected during mining from near-mining bores screened in the LPS

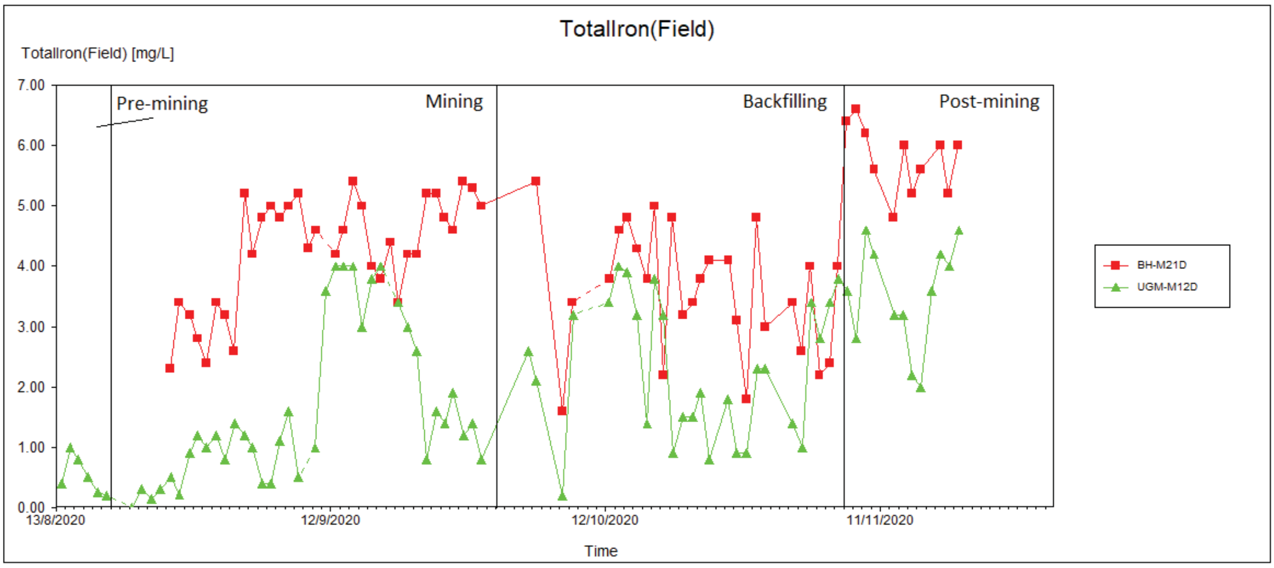


Figure 6.3 Field iron (total; mg/L) measurements collected during mining from near-mining bores screened in the LPS

6.1.3 Shepparton Formation

Groundwater from the SFM monitoring bores was analysed in the field for pH, EC, TDS, ORP, temperature and total iron (for bores located in the 'mining' SSTL zone only). A summary of the data collected over the mining period is presented in Table 6.4, while the raw data is reported in Appendix E. Time-series plots of pH and total iron measurements collected in the mining zone bores during mining are displayed in Figure 6.4 and Figure 6.5 respectively.

The following is observed:

- The mean pH of 6.77 measured in the SFM aquifer during mining was slightly lower than the mean of 7.20 measured pre-T3. The pH measured during mining was slightly acidic to slightly basic in general, depending on the sample location. Figure 6.4 presents the pH measurements collected from the near-mining bores during mining and shows that the pH in both bores was relatively constant throughout mining, apart from a period of low pH at the start of mining in UGM-M12S. It is likely that this anomaly is due to stagnant groundwater in the bore or a similar reason, as the pH in UGM-M12D pre-T3 ranged between 7.3 and 8.0, as was observed in all of the measurements following the low pH period.

- EC/TDS did not vary significantly from pre-T3 values over the course of mining.

- The mean ORP value increased from -125.7 mV pre-T3 to 26.7 mV during mining activities. This could be due to an increase in oxidising conditions within the aquifer due to mining, or potentially due to the new T3 bores being monitored over the mining period, which may exhibit differing local aquifer properties to the original bores used to generate the pre-T3 statistics.

- The maximum and mean total iron concentrations (0.6 mg/L and 0.12 mg/L respectively) measured during mining are both significantly lower than the pre-T3 maximum and mean total iron values of 1.38 mg/L and 0.74 mg/L respectively. Again, this could be due to the selection of bores sampled during mining having differing local aquifer properties than those measured pre-T3. Both of the mining bores have relatively low levels of total iron, generally below 0.36 mg/L. These bores were sampled every day and hence will significantly influence the mean iron value.

Table 6.4 Summary of field parameters measured during mining – SFM aquifer

Parameter	pH	EC (µs/cm)	TDS (mg/L)	ORP (mV)	Temperature (°C)	Total iron (mg/L)
Minimum	4.75	48,163	31,306	-239.6	11.0	<0.1
Maximum	7.76	71,250	46,312	260.0	22.7	0.6
Mean	6.77	60,389	39,978	26.7	17.8	0.12

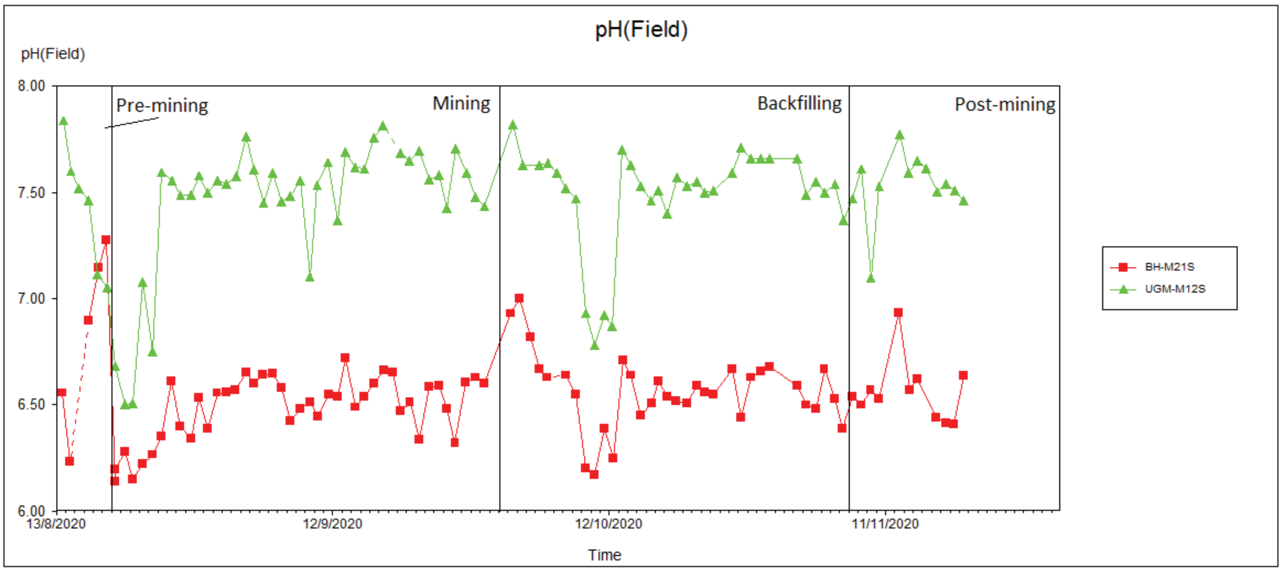


Figure 6.4 Field pH measurements collected during mining from near-mining bores screened in the SFM

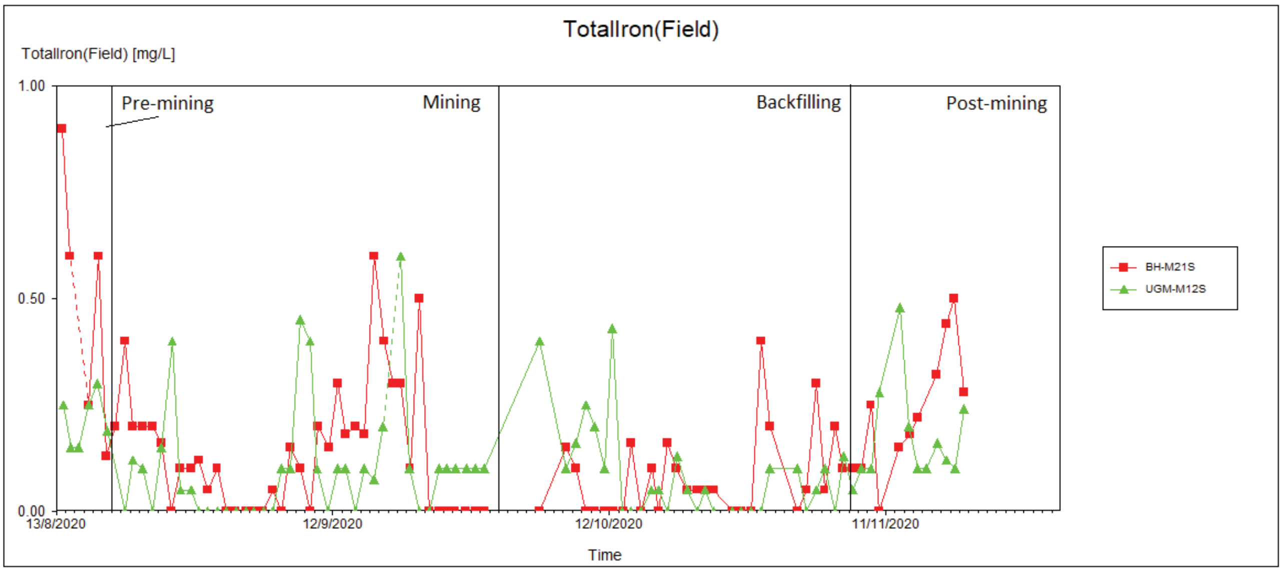


Figure 6.5 Field iron (total; mg/L) measurements collected during mining from near-mining bores screened in the SFM

6.2 Groundwater quality results and comparison to SSTLs

Two groundwater monitoring events took place during mining (Section 4.5.2), one between 19 and 24 August 2020, and another between 11 and 21 September 2020. During these groundwater monitoring events; all bores were sampled, and the samples sent to a NATA accredited laboratory for analysis. The results of these analyses are summarised in Table 6.5 and compared to the SSTLs presented in Appendix A. To be conservative, all concentrations that were measured below a limit of reporting (LOR) were considered to be equal to the LOR.

Note that while total metal concentrations are presented in Table 6.5 and Table 6.6, the SSTLs only apply to dissolved metals and are only applicable to the background bores. SSTL breaches identified within either the mining or transition zones are used for advanced warning of potential impacts. Total metal concentrations were only measured in bores where the groundwater pH was 6.5 or less and therefore could be at risk of metal mobilisation. The total metal concentrations have been compared to the dissolved metal SSTLs to assess future potential risks only.

Table 6.5 Groundwater quality of the LPS aquifer during mining compared to SSTLs

Analyte	Unit	Count	Minimum	Maximum	Mean	Pre-mining mean	Yellow SSTL	Red SSTL
Radionuclides								
Gross Alpha	Bq/L	10	0.07	2.06	0.99	0.94	-	-
Gross Beta (^{40}K)	Bq/L	10	0.76	2.24	1.2	1.19	-	-
Gross Beta	Bq/L	1	2.11	2.11	2.11	-	-	-
Major Ions								
Total alkalinity	mg/L	29	370	443	406	448	727	873
Sulphate	mg/L	29	2,650	4,750	3,631	3,754	9,642	11,570
Chloride	mg/L	29	17,900	22,000	19,786	18,022	41,875	50,250
Calcium	mg/L	29	503	637	551	485	1,220	1,464
Magnesium	mg/L	29	1,340	1,650	1,523	1,462	3,324	3,989
Sodium	mg/L	29	10,400	12,000	11,024	10,818	24,381	29,258
Potassium	mg/L	29	38	62	54	38	105	126
Sulfide	mg/L	29	0.1	5.8	0.4	0.7	-	-
Anions	meq/L	29	579	711	642	595	-	-
Cations	meq/L	29	597	686	634	616	-	-
Balance	%	29	0.01	7.38	2.18	2.34	-	-
$Cl:SO_4$	-	29	4.08	6.91	5.50	4.81	-	-
Dissolved metals								
Aluminium	mg/L	15	0.02	0.03	0.02	0.07	0.129	5
Thorium	mg/L	15	0.002	0.002	0.002	0.006	0.01	0.1
Uranium	mg/L	15	0.002	0.005	0.0022	0.007	0.013	0.015
Iron	mg/L	15	0.1	8.44	3.24	2.64	10.588	12.031
Ferrous Iron	mg/L	29	0.05	9.27	3.04	-	10.588	12.031
Arsenic	mg/L	14	0.002	0.01	0.004	-	0.02	0.1
Cadmium	mg/L	14	0.0002	0.001	0.0004	-	0.01	0.05
Chromium	mg/L	14	0.002	0.01	0.004	-	0.1	1
Copper	mg/L	14	0.002	0.467	0.045	-	0.018	0.2
Lead	mg/L	14	0.002	0.01	0.004	-	2	5
Nickel	mg/L	14	0.002	0.065	0.008	-	0.009	0.2
Zinc	mg/L	14	0.01	0.234	0.040	-	0.199	2
Mercury	mg/L	11	0.0001	0.0001	0.0001	-	-	-
Total metals								
Aluminium	mg/L	4	0.14	1.96	0.853	-	0.129	5
Thorium	mg/L	4	0.002	0.002	0.002	-	0.01	0.1
Uranium	mg/L	4	0.002	0.006	0.003	-	0.013	0.015
Iron	mg/L	4	1.95	9.59	4.61	-	10.588	12.031
Arsenic	mg/L	2	0.005	0.01	0.008	-	0.02	0.1
Cadmium	mg/L	2	0.0002	0.001	0.001	-	0.01	0.05
Chromium	mg/L	2	0.004	0.01	0.007	-	0.1	1

Copper	mg/L	2	0.112	0.657	0.385	-	0.018	0.2
Lead	mg/L	2	0.003	0.01	0.007	-	2	5
Nickel	mg/L	2	0.004	0.01	0.007	-	0.009	0.2
Zinc	mg/L	2	0.037	0.052	0.045	-	0.199	2
Mercury	mg/L	1	0.0001	0.0001	0.0001	-	-	-

1. Yellow and red highlights indicate that the value exceeds the yellow or red trigger level respectively

From Table 6.5, the following is noted about the LPS results:

- None of the major ions exceed any of the SSTLs, and there is not a significant difference between the mean concentrations of samples collected during mining and those collected pre-mining. Groundwater has alkalinity greater than 180 mg/L and typical pH >6.5 suggesting a 'very high alkalinity' that is adequate to maintain acceptable pH levels in the future (Shand 2018).

- The mean chloride to sulphate ratio ($Cl:SO_4$) is higher during mining than the mean pre-mining. A decreasing $Cl:SO_4$ over time, or a $Cl:SO_4$ less than 2, could suggest oxidation of pyrite and acidification of the groundwater.

- None of the remaining leading indicator concentrations (aluminium, magnesium, sulfide, ferrous iron, total iron, gross alpha and gross beta) showed a significant change from pre-mining concentrations (where measured).

- The mean dissolved copper concentration from all monitored background bores exceeds the 'yellow' SSTL, while the maximum dissolved copper concentration measured during mining exceeds the 'red' SSTL. BH-M24D was the only bore to exceed the SSTLs, with measurements of 0.47 mg/L and 0.10 mg/L during mining. As BH-M24D is a background bore and no other exceedances were observed, it is likely that local mineralisation (ie background conditions) is responsible for the exceedances, and not mining. The total copper concentration measured in this bore was 0.657 mg/L, which also suggests a local naturally high copper concentration.

- The maximum dissolved nickel concentration measured during mining of 0.065 mg/L exceeded the 'yellow' SSTL. This nickel concentration was observed in BH-M16D. Other exceeding concentrations of 0.01 mg/L were measured in UGM-M12D, BH-M21D and BH-M24D. These samples were actually measured to have concentrations of <0.01 mg/L of dissolved nickel and thus are not considered to be exceeding. Ordinarily the LOR for dissolved nickel is 0.001 mg/L, however it was increased by the laboratory due to the high levels of dissolved solids in the samples.

- The maximum dissolved zinc concentration of 0.234 mg/L exceeded the 'yellow' SSTL. This was due to a single measurement from BH-M16D, and no other bores were found to have exceedances. This is potentially an erroneous value as no other bores showed an increase in zinc, and subsequent measurements of dissolved zinc in BH-M16D taken during backfill are all below the LOR.

- The highest total aluminium, copper and nickel concentrations measured were all in exceedance of the 'yellow' or 'red' SSTLs. Though the total metals are not subject to the SSTL values, this indicates that acidification of the groundwater could lead to mobilisation, and subsequently high dissolved concentrations of these metals in the future. As negligible acidification of the LPS aquifer was observed during T3, this is not currently considered a concern.

Table 6.6 Groundwater quality of the SFM aquifer during mining compared to SSTLs

Analyte	Unit	Count	Minimum	Maximum	Mean	Pre-mining mean	Yellow SSTL	Red SSTL
Radionuclides								
Gross Alpha	Bq/L	12	0.92	4.90	2.66	2.25	-	-
Gross Beta (^{40}K)	Bq/L	12	0.83	4.07	2.34	1.79	-	-
Gross Beta	Bq/L	2	2.35	3.40	2.88	-	-	-
Major Ions								
Total alkalinity	mg/L	29	184	380	300	295	628	754
Sulphate	mg/L	29	3,470	6,060	4,675	4,578	8,254	9,905
Chloride	mg/L	29	20,800	27,500	24,317	22,494	42,672	51,206
Calcium	mg/L	29	592	1,080	700	691	1,112	1,335
Magnesium	mg/L	29	1,350	2,000	1,678	1,540	3,219	3,863
Sodium	mg/L	29	11,300	15,400	13,638	13,100	23,586	28,303
Potassium	mg/L	29	26	52	40	31	141	169
Sulfide	mg/L	29	0.10	0.40	0.13	0.13	-	-
Anions	meq/L	29	666	907	789	736	-	-
Cations	meq/L	29	646	868	767	732	-	-
Balance	%	29	0.03	5.03	1.97	3.3	-	-
$Cl:SO_4$	-	29	4.48	6.16	5.24	4.9	-	-
Dissolved metals								
Aluminium	mg/L	14	0.02	0.02	0.02	0.06	0.129	5
Thorium	mg/L	14	0.002	0.002	0.002	0.006	0.01	0.1
Uranium	mg/L	14	0.01	0.11	0.04	0.04	0.065	0.073
Iron	mg/L	14	0.10	8.92	1.03	1.91	9.42	10.71
Ferrous Iron	mg/L	29	0.05	23.20	2.18	-	9.42	10.71
Arsenic	mg/L	15	0.002	0.01	0.004	-	0.026	0.1
Cadmium	mg/L	15	0.0002	0.001	0.0004	-	0.01	0.05
Chromium	mg/L	15	0.002	0.01	0.005	-	0.1	1
Copper	mg/L	15	0.002	0.19	0.034	-	0.042	0.2
Lead	mg/L	15	0.002	0.01	0.004	-	2	5
Nickel	mg/L	15	0.003	0.03	0.012	-	0.038	0.2
Zinc	mg/L	15	0.01	0.05	0.023	-	0.17	2.00
Mercury	mg/L	12	0.0001	0.0002	0.0001	-	-	-
Total metals								
Aluminium	mg/L	11	0.02	16.70	5.24	-	0.13	5.00
Thorium	mg/L	11	0.002	0.01	0.002	-	0.01	0.1
Uranium	mg/L	11	0.02	0.13	0.04	-	0.07	0.07
Iron	mg/L	11	0.10	17.80	3.40	-	9.42	10.71

Table 6.6 Groundwater quality of the SFM aquifer during mining compared to SSTLs

Analyte	Unit	Count	Minimum	Maximum	Mean	Pre-mining mean	Yellow SSTL	Red SSTL
Arsenic	mg/L	6	0.002	0.01	0.01	-	0.03	0.10
Cadmium	mg/L	6	0.0002	0.001	0.0003	-	0.01	0.05
Chromium	mg/L	6	0.002	0.05	0.02	-	0.1	1
Copper	mg/L	6	0.002	0.41	0.11	-	0.042	0.2
Lead	mg/L	6	0.002	0.01	0.003	-	2	5
Nickel	mg/L	6	0.01	0.04	0.02	-	0.038	0.2
Zinc	mg/L	6	0.01	0.05	0.02	-	0.17	2.00
Mercury	mg/L	5	0.0001	0.0002	0.0001	-	-	-

1. Yellow and red highlights indicate that the value exceeds the yellow or red trigger level respectively

From Table 6.6, the following is noted about the SFM results:

- None of the major ions exceed any of the SSTLs and there is not a significant difference between the mean concentrations of samples collected during mining and those collected pre-mining. Groundwater has alkalinity greater than 180 mg/L and typical pH >6.5 suggesting a 'very high alkalinity' that is adequate to maintain acceptable pH levels in the future (Shand 2018).

- The mean $Cl:SO_4$ value is higher during mining than the mean pre-mining. A decreasing $Cl:SO_4$ over time, or $Cl:SO_4$ less than 2, could suggest the oxidation of pyrite and the acidification of groundwater.

- Apart from ferrous and total iron, none of the remaining leading indicator concentrations (aluminium, magnesium, sulfide, gross alpha and gross beta) showed a significant change from pre-mining concentrations (where measured). A slight increase in gross alpha and gross beta measurements was observed, but this is likely due to natural variation.

- A maximum dissolved ferrous iron concentration of 23.20 mg/L was recorded in bore BH-M24S during the first round of monitoring during mining, exceeding the 'red' SSTL. In the second round, another high value of 20.40 mg/L was measured. A pre-mining sample shows that the ferrous iron concentration in this bore was 12.10 mg/L, which would also have been in exceedance of the 'red' trigger level. Due to this and the fact that BH-M24S is a background bore, with no other bores showing similar exceedances, it is likely that the groundwater surrounding this bore is naturally high in iron. As ferrous iron concentrations in this bore were measured above the 'red' trigger level prior to mining, this is not considered to be an exceedance due to T3 activities.

- The maximum dissolved copper concentration measured of 0.19 mg/L exceeded the 'yellow' SSTL. Reviewing the laboratory results shows that total copper exceedances were measured in UGM-M15S and BH-M23S. UGM-M15S had two exceeding measurements of 0.189 mg/L and 0.119 mg/L, while a concentration of 0.107 mg/L was measured in BH-M23S. Both of these bores are in the same general area to the south of Stope 6, which could suggest local mineralisation. It is unlikely the increased copper concentrations were due to mining, as groundwater locally flows from the south-east to the north-west, which would carry contaminants from the stopes away from these bores, in the absence of large positive stope pressures being created during mining.

- The maximum dissolved uranium concentration measured of 0.11 mg/L is higher than the ‘red’ SSTL. This concentration was measured in BH-M19S, while another exceedance of 0.088 mg/L was measured in UGM-M12S. In the pre-mining data, dissolved uranium concentrations in BH-M19S and UGM-M12S were measured to be 0.122 mg/L and 0.08 mg/L respectively. This shows that these locations were naturally high in uranium prior to commencing mining.

- The highest total aluminium, uranium, iron, copper, and nickel all exceed the ‘yellow’ or ‘red’ SSTL values. Though the total metals are not subject to the SSTL values, this indicates that acidification of the groundwater could lead to mobilisation, and subsequently, high dissolved concentrations of these metals in the future. As negligible acidification of the SFM aquifer was observed during T3, this is not currently considered to be a concern.

- It is noted that values falling between the ‘yellow’ and ‘red’ trigger levels are still considered to be within normal operating conditions, and that the ‘yellow’ trigger level exists to allow for adequate investigation time and potential intervention before species reach the red trigger level. Due to this, it is expected that analytes will occasionally be measured above the ‘yellow’ trigger level as a result of natural variation. Without evidence of an increasing trend in the exceeding analytes or similar exceedances in nearby bores, the exceedances discussed above have been attributed to natural geochemical processes and variability, rather than as a result of mining.

6.3 Plant sampling results

Field parameters were measured at various plant locations throughout mining, as detailed in Section 4.1.3. The electrical conductivity and pH data collected has been summarised in Figure 6.6 and Figure 6.7. The remaining parameters (ORP, TDS and temperature) are displayed in Appendix E. Plant monitoring was largely focused around collecting pH measurements to inform lime dosing rates and to observe any acidification of the ore or process water over time. As such, time-series plots of pH measurements at each location have also been presented in Figure 6.7 and Figure 6.8 to review any pH trends.

From this data, the following is noted:

- The process water, spiral plant discharge (SPD) sand and heavy mineral streams and HBF tank pH measurements were all within the desired range of 6.5 – 8.5. The mean pH at each of these locations was between 7.62 and 7.72, showing that the extracted groundwater had an appropriate pH and sufficient buffer capacity to maintain these conditions within the process water dam, and that the lime dosing routine was successful at managing the pH throughout the rest of the circuit.

- pH measurements in the SPD-Sand, SPD-HM, process water and HBF tank did not show any significant trends during mining. The fines thickener, stockpile sumps and spill dam showed a slight increase in pH at the start of mining. The T2 stockpile sump had a sharp drop in pH from about 7.5 to 6.7 near the end of mining.

- EC and TDS measurements were approximately the same for each location and were within a similar range throughout mining. The spill dam had a minimum EC measurement of 22,050 µS/cm, which is likely erroneous based on EC measurements from the other plant locations, unless the spill dam was heavily influenced by rainfall prior to the measurement.

- ORP values varied significantly both at a single measurement location, as well as between measurement locations. This variability may be due to the sensitivity of ORP measurements to the introduction of oxygen. Different amounts of oxygen may have been present in each sample depending on if the water had been sitting stagnant or due to differing flow rate from the sampling taps.

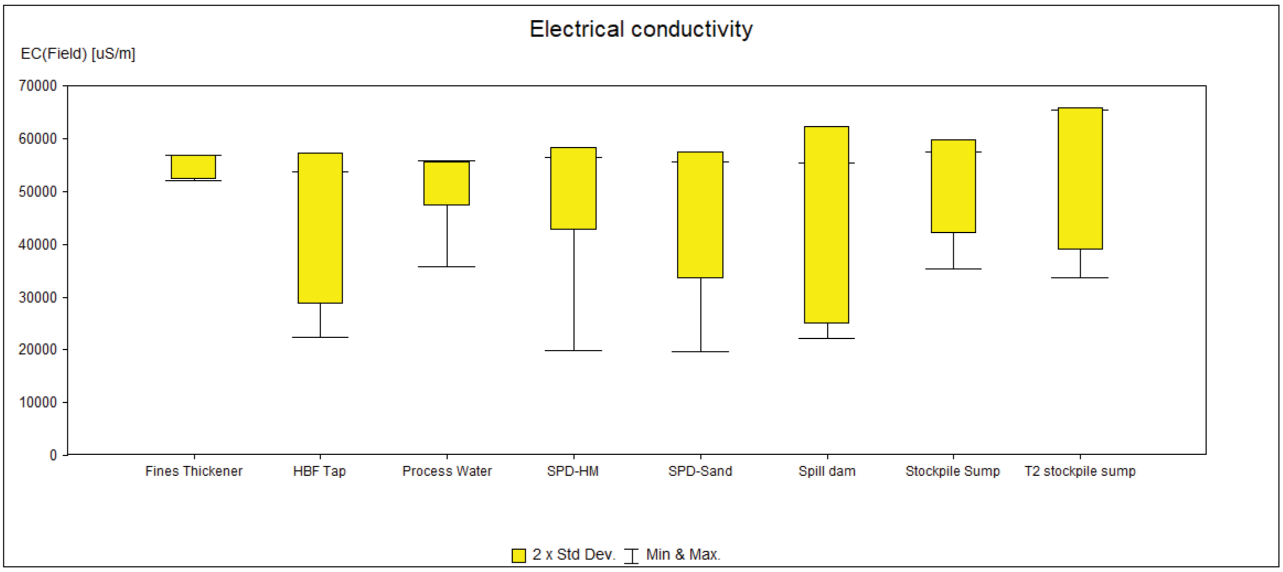


Figure 6.6 Box and whisker plot of electrical conductivity (µS/cm) in plant locations – during mining

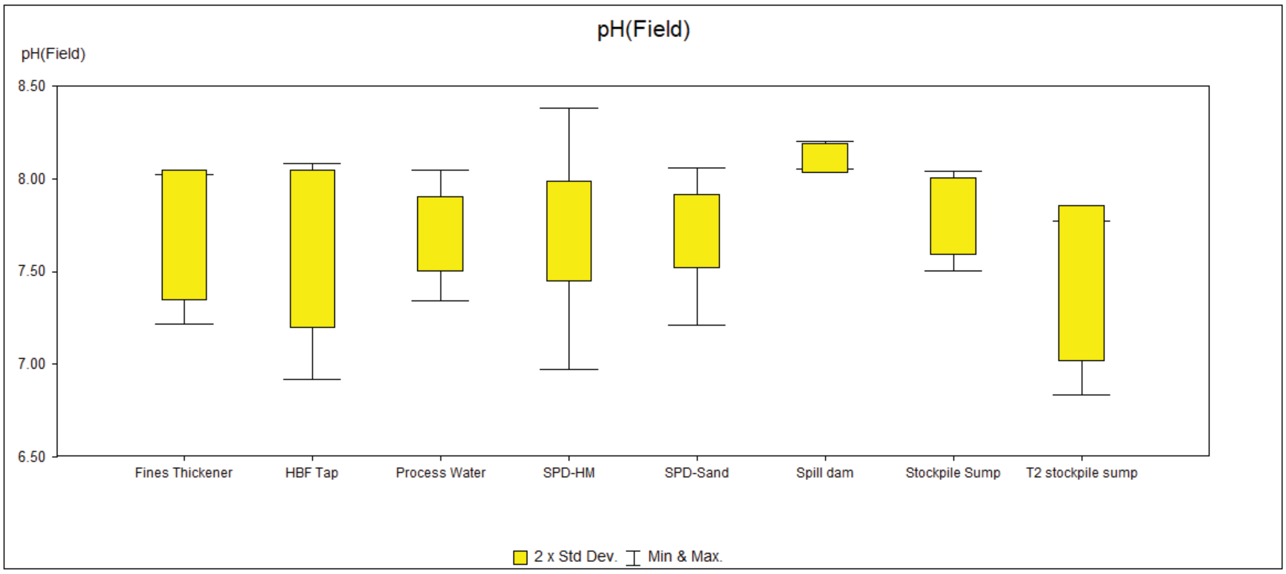


Figure 6.7 Box and whisker plot of pH in plant locations – during mining

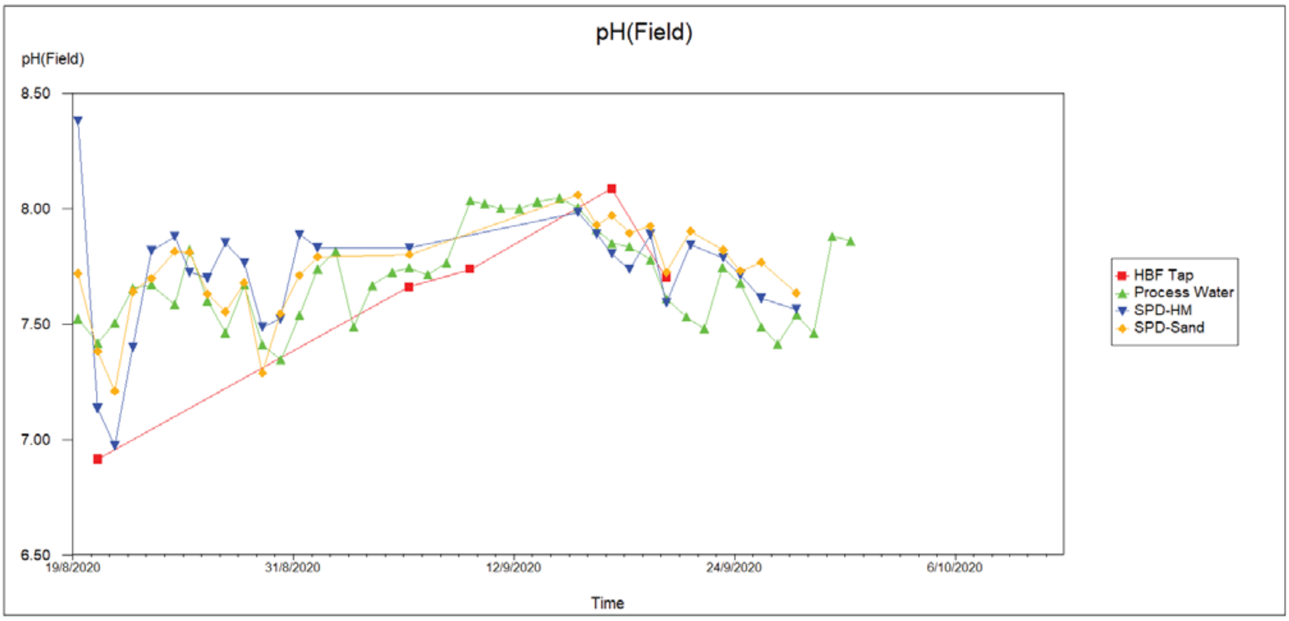


Figure 6.8 Time-series plot of plant pH measurements collected during mining

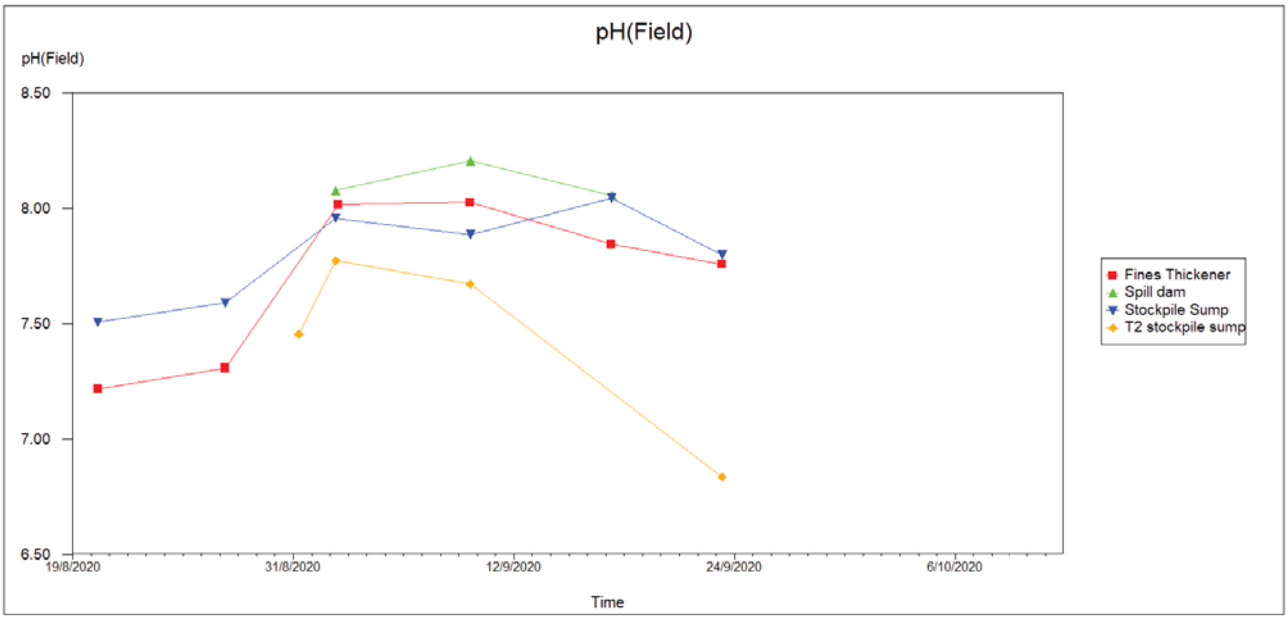


Figure 6.9 Time-series plot of plant pH measurements collected during mining

7 Hydrogeochemical assessment of backfill

Backfilling took place in a generally continuous manner from 1 October 2020 until 18 October 2020 and then sporadically until 7 November 2020. A summary of the daily backfill progress is displayed in Figure 7.1, excluding tailings which were placed into the sinkholes formed due to the irregular subsidence events.

Over this period, field parameters and samples for laboratory analysis were collected in accordance with the monitoring program outlined in Section 4.4.

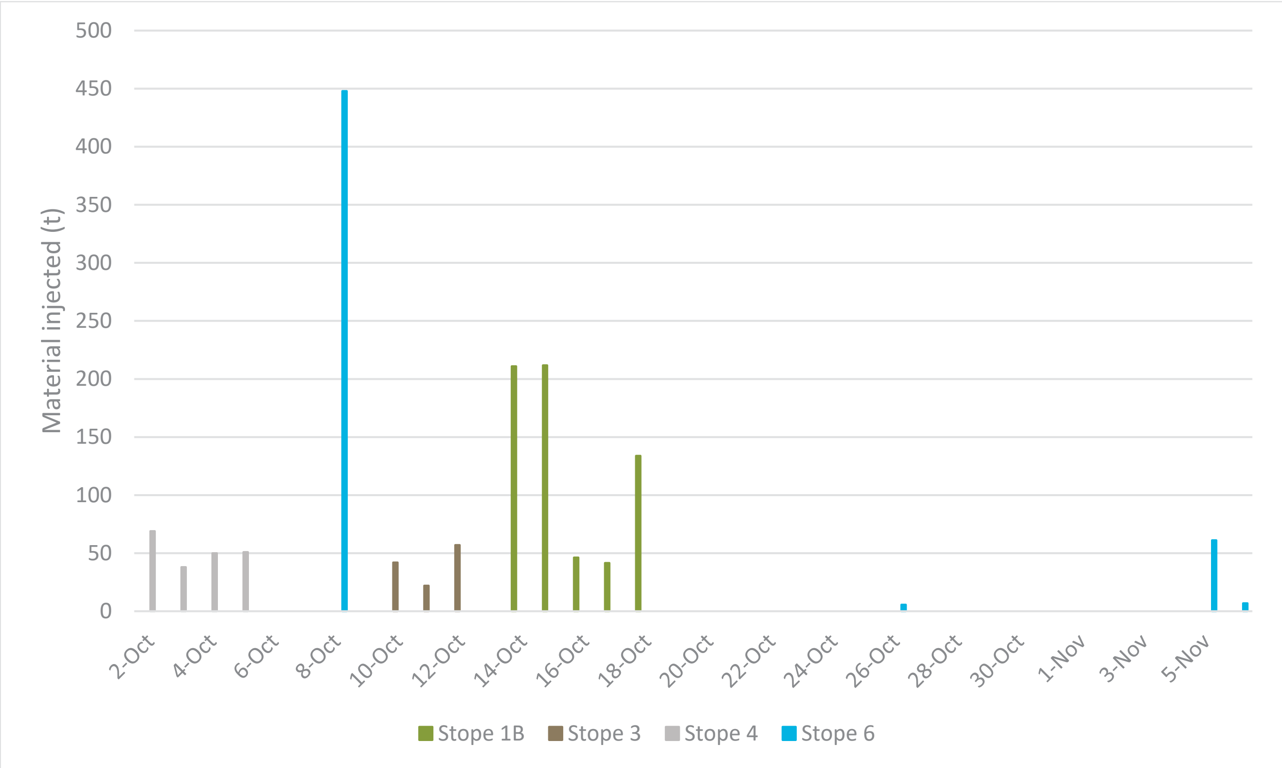


Figure 7.1 Summary of daily material injected (tonnes) during backfill

7.1 Field physicochemical results

7.1.1 Loxton Parilla Sands

Groundwater from the LPS monitoring bores was analysed in the field for pH, EC, TDS, ORP, temperature and total iron (for bores located in the 'mining' SSTL zone only). A summary of the data collected over the backfilling period is presented in Table 7.1, with the raw data reported in Appendix E. Time-series plots of pH and total iron measurements collected in the mining zone bores during backfilling are displayed in Figure 7.2 and Figure 7.3 respectively. Although the SSTLs only apply to the background bores, trends in the mining zone bores have been investigated as an 'early warning system'. If no trends are observed in the bores closest to backfilling, then background bores should not have experienced any impacts.

From this data, the following is observed:

- pH measurements collected during backfilling were slightly acidic to neutral, with the mean value of 6.70 being lower than the pre-mining mean of 6.98, and close to the mean pH measured during mining of 6.64. Figure 7.2 shows that the pH measurements collected from the near-mining bores appear to slightly decrease near the end of backfilling. pH values at the beginning of backfilling were approximately 6.7 and decrease to between 6.5 to 6.6 near the end of backfilling.

- There was no significant change in EC/TDS measurements during backfilling when compared to pre-mining values.

- The mean ORP value of -90.5 mV is slightly lower than the mean measured during mining of -64.1 mV, however it is not as low as the mean of -181.1 mV measured pre-mining. This change could represent a return to pre-mining conditions after the conclusion of mining.

- The mean total iron value of 3.0 mg/L measured during backfilling was higher than the mean of 1.9 mg/L measured pre-mining, and the mean of 2.6 mg/L measured during mining. Figure 7.3 shows that the iron concentrations in the near-mining bores do not appear to significantly increase over the course of backfilling. Iron concentrations increased during mining, and the higher mean observed during backfilling suggests that these elevated iron concentrations were maintained even after the cessation of mining.

Table 7.1 Summary of field parameters measured during backfilling – LPS aquifer

Parameter	pH	EC (µs/cm)	TDS (mg/L)[1]	ORP (mV)	Temperature (°C)	Total iron (mg/L)
Minimum	6.37	50,019	32,512	-277.7	17.4	0.2
Maximum	7.14	58,872	38,267	145.8	29.4	6.4
Mean	6.70	55,650	36,173	-90.5	20.2	3.0

1. The water quality meter used during this period did not record TDS measurements, but estimated TDS values have been calculated by multiplying the EC values by 0.65.

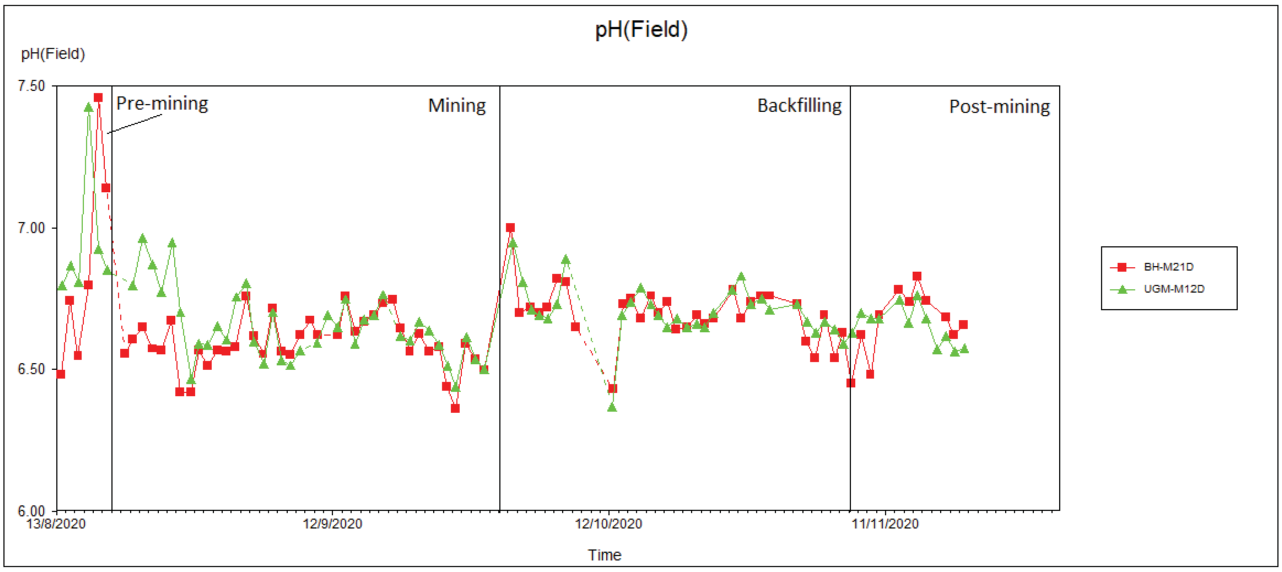


Figure 7.2 **Field pH measurements collected during backfilling from near-mining bores screened in the LPS**

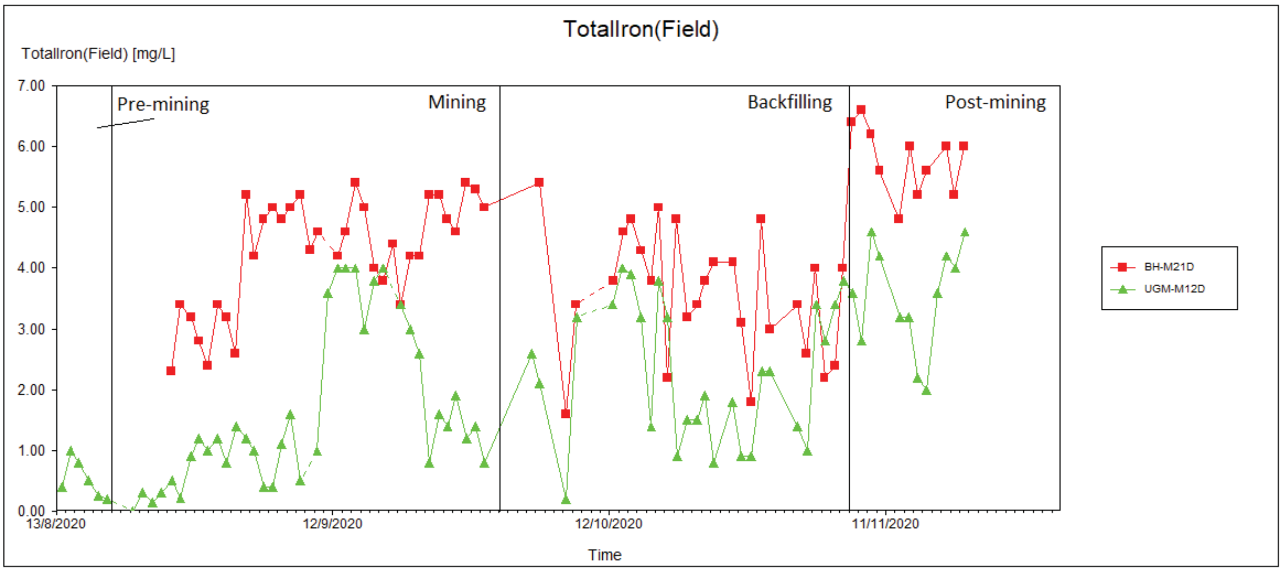


Figure 7.3 **Field iron (total; mg/L) measurements collected during backfilling from near-mining bores screened in the LPS**

7.1.2 Shepparton Formation

Groundwater from the SFM monitoring bores was analysed in the field for pH, EC, TDS, ORP, temperature and total iron (for bores located in the 'mining' SSTL zone only). A summary of the data collected over the backfilling period is presented in Table 7.2, with the raw data reported in Appendix E. Time-series plots of pH and total iron measurements collected in the mining zone bores during backfilling are displayed in Figure 7.4 and Figure 7.5 respectively.

From these data, the following is observed:

- pH measurements collected during backfilling were slightly acidic to neutral, with the mean value of 6.96 lower than the pre-mining mean of 7.20 and higher than mean pH measured during mining of 6.77. Figure 7.4 displays that the pH measurements collected from the near-mining bores remain relatively constant throughout backfilling. pH measurements at this location also remained distinctly different from one another, with the pH of the SFM remaining consistently higher than the pH measured in the underlying LPS. At least at this location, results suggest that the aquitard remained intact during mining and backfill, resulting in no mixing of the two water resources.

- There was a notable change between pre-mining EC/TDS values and those measured during backfilling. The mean EC value measured during backfilling was 64,514 µS/cm, compared the pre-mining value of 56,243 µS/cm.

- The mean ORP value of 92.3 mV is higher than the mean measured during mining of 26.7 mV and the mean of -125.7 mV measured pre-mining. This change suggests that both mining and backfilling lead to the aquifer becoming a more oxidising environment.

- The mean total iron value of 0.08 mg/L measured during backfilling was lower than the mean of 0.12 mg/L measured during mining and the mean of 0.74 mg/L measured pre-mining. Figure 7.5 shows that the iron concentrations in the near-mining bores do not appear to significantly increase over the course of backfilling, however short-term concentration spikes were observed.

Table 7.2 Summary of field parameters measured during backfilling – SFM aquifer

Parameter	pH	EC (µs/cm)	TDS (mg/L)[1]	ORP (mV)	Temperature (°C)	Total iron (mg/L)
Minimum	6.17	54,331	35,315	-195.0	17.11	<0.1
Maximum	7.70	71,429	46,429	501.2	25.63	0.43
Mean	6.96	64,514	41,934	92.3	19.3	0.08

1. The water quality meter used during this period did not record TDS measurements, but estimated TDS values have been calculated by multiplying the EC values by 0.65.

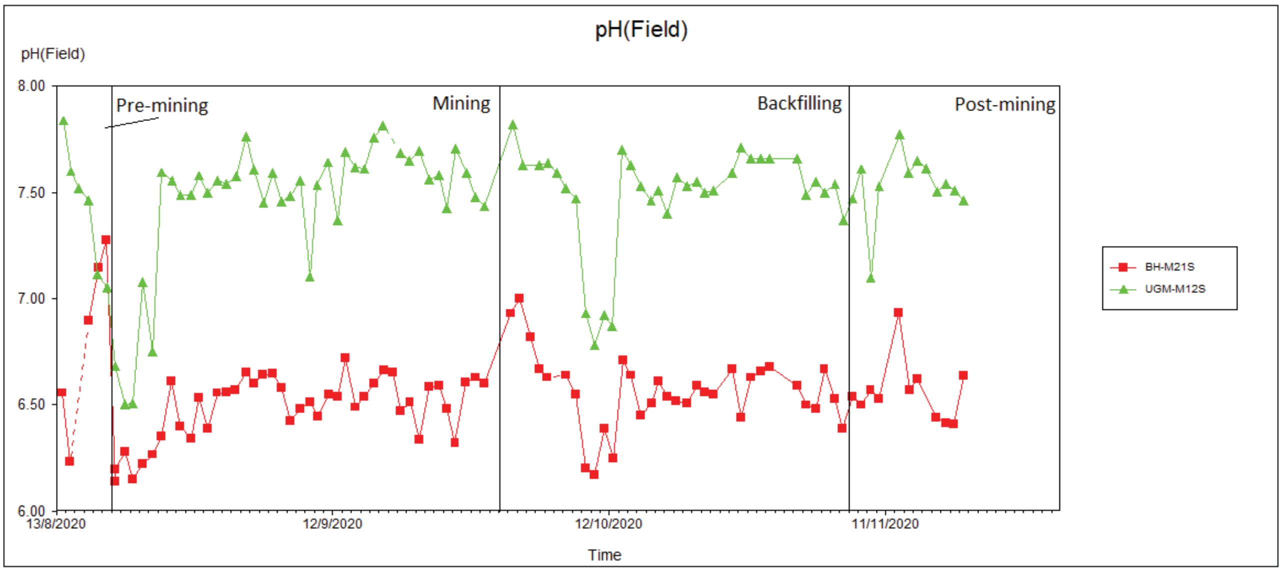


Figure 7.4 **Field pH measurements collected during backfilling from near-mining bores screened in the SFM**

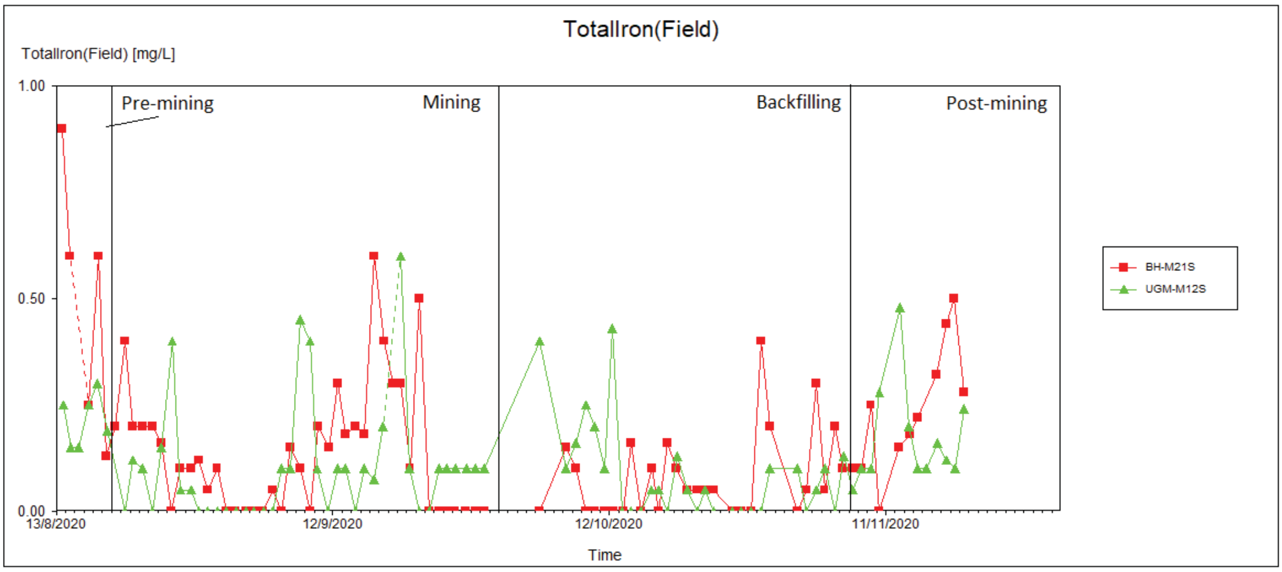


Figure 7.5 **Field iron (total; mg/L) measurements collected during backfilling from near-mining bores screened in the SFM**

7.2 Groundwater quality results and comparison to SSTLs

Three groundwater monitoring events took place during backfilling (Section 4.5.2), the first between 2 and 3 October 2020, the second between 13 and 19 October 2020, and the third between 13 and 18 November 2020.

During these groundwater monitoring events all bores were sampled, and the samples sent to a NATA accredited laboratory for analysis. The results of these analyses are summarised in Table 7.3 and Table 7.4 and compared to the SSTLs presented in Appendix A. To be conservative and to assist with valid statistical analysis, all concentrations that were measured below a limit of reporting (LOR) were considered to be equal to the LOR.

Note that while total metal concentrations are presented in these table, the SSTLs only apply to dissolved metals. Total metal concentrations were only measured in bores where the groundwater pH was 6.5 or less and therefore could be at risk of metal mobilisation. The total metal concentrations have been compared to the dissolved metal SSTLs to assess future potential risks only.

Table 7.3 Groundwater quality of the LPS aquifer during backfilling compared to SSTLs

Analyte	Unit	Count	Minimum	Maximum	Mean	Pre-mining mean	Yellow SSTL	Red SSTL
Radionuclides								
Gross Alpha	Bq/L	9	0.85	1.34	0.94	0.94	-	-
Gross Beta (^{40}K)	Bq/L	9	0.7	0.84	0.77	1.19	-	-
Gross Beta	Bq/L	9	0.7	2.82	1.89	-	-	-
Major Ions								
Total alkalinity	mg/L	21	365	467	422	448	727	873
Sulphate	mg/L	21	3,390	6,980	3,788	3,754	9,642	11,570
Chloride	mg/L	21	16,000	21,700	18,686	18,022	41,875	50,250
Calcium	mg/L	21	474	631	546	485	1,220	1,464
Magnesium	mg/L	21	1,280	1,640	1,468	1,462	3,324	3,989
Sodium	mg/L	21	9,640	12,400	11,045	10,818	24,381	29,258
Potassium	mg/L	21	35	59	45	38	105	126
Sulfide	mg/L	21	0.1	4.7	0.43	0.7	-	-
Anions	meq/L	21	535	698	614	595	-	-
Cations	meq/L	21	554	707	630	616	-	-
Balance	%	21	2.95	9.22	5.59	2.34	-	-
$Cl:SO_4$	-	21	2.51	6.40	5.05	4.81	-	-
Dissolved metals								
Ferrous Iron	mg/L	21	0.05	9.18	3.03	-	10.588	12.031
Arsenic	mg/L	21	0.002	0.01	0.007	-	0.02	0.1
Cadmium	mg/L	21	0.0002	0.001	0.001	-	0.01	0.05
Chromium	mg/L	21	0.002	0.01	0.007	-	0.1	1
Copper	mg/L	21	0.002	0.019	0.008	-	0.018	0.2
Lead	mg/L	21	0.002	0.01	0.007	-	2	5
Nickel	mg/L	21	0.002	0.03	0.008	-	0.009	0.2
Zinc	mg/L	21	0.01	0.062	0.037	-	0.199	2
Mercury	mg/L	21	0.0001	0.0001	0.0001	-	-	-
Total metals								
Arsenic	mg/L	5	0.01	0.01	0.01	-	0.02	0.1
Cadmium	mg/L	5	0.001	0.001	0.001	-	0.01	0.05
Chromium	mg/L	5	0.01	0.035	0.015	-	0.1	1
Copper	mg/L	5	0.01	0.252	0.059	-	0.018	0.2
Lead	mg/L	5	0.01	0.01	0.01	-	2	5

Table 7.3 Groundwater quality of the LPS aquifer during backfilling compared to SSTLs

Analyte	Unit	Count	Minimum	Maximum	Mean	Pre-mining mean	Yellow SSTL	Red SSTL
Nickel	mg/L	5	0.01	0.053	0.023	-	0.009	0.2
Zinc	mg/L	5	0.05	0.052	0.0516	-	0.199	2
Mercury	mg/L	5	0.0001	0.0001	0.0001	-	-	-

1. Yellow and red highlights indicate that the value exceeds the yellow or red trigger level respectively

From Table 7.3, the following is noted about the LPS results:

- None of the major ions exceed any of the SSTLs, and there is not a significant difference between the mean concentrations of samples collected during backfilling and those collected pre-mining. Groundwater has alkalinity greater than 180 mg/L and typical pH >6.5 suggesting a 'very high alkalinity' that is adequate to maintain acceptable pH levels in the future (Shand 2018).
- The mean $Cl:SO_4$ value is higher during backfilling than the mean pre-mining. A decreasing $Cl:SO_4$ over time, or $Cl:SO_4$ less than 2, could suggest pyrite oxidation and acidification of the groundwater.
- None of the remaining leading indicator concentrations (magnesium, sulfide, ferrous iron, gross alpha and gross beta) showed a significant change from pre-mining concentrations (where measured).
- The maximum dissolved copper concentration of 0.019 mg/L was measured in BH-M25D and is above the 'yellow' SSTL. It is noted that BH-M24D, which had two measurements exceeding the 'red' SSTL for dissolved copper during mining, did not exceed any SSTLs during backfilling.
- The maximum dissolved nickel concentration of 0.03 mg/L was measured in BH-M20D and exceeded the 'yellow' SSTL. This sample was collected on 3 October 2020, while another sample collected from this bore on 14 October 2020 reported a dissolved nickel concentration of <0.002 mg/L. Due to this and the fact that no other bores recorded dissolved nickel concentration above the LOR during backfilling, it is suggested that the first result was erroneous or unrelated to backfilling.
- Maximum and mean concentrations of total copper and nickel exceeded either the 'red' or 'yellow' SSTLs. Though the total metals are not subject to the SSTL values, this indicates that acidification of the groundwater could lead to mobilisation, and subsequently, high dissolved concentrations of these metals in the future.

Table 7.4 Groundwater quality of the SFM aquifer during backfilling compared to SSTLs

Analyte	Unit	Count	Minimum	Maximum	Mean	Pre-mining mean	Yellow SSTL	Red SSTL
Radionuclides								
Gross Alpha	Bq/L	8	1.21	4.48	2.08	2.25	-	-
Gross Beta (^{40}K)	Bq/L	9	0.88	2.61	1.90	1.79	-	-
Gross Beta	Bq/L	9	2.04	3.68	2.62	-	-	-
Major Ions								
Total alkalinity	mg/L	19	190	393	314	295	628	754
Sulphate	mg/L	19	3,790	5,340	4,534	4,578	8,254	9,905
Chloride	mg/L	19	18,600	27,700	23,153	22,494	42,672	51,206
Calcium	mg/L	19	584	812	689	691	1,112	1,335
Magnesium	mg/L	19	1,410	1,750	1,605	1,540	3,219	3,863
Sodium	mg/L	19	11,500	15,300	13,363	13,100	23,586	28,303
Potassium	mg/L	19	23	53	35	31	141	169
Sulfide	mg/L	19	0.1	0.3	0.12	0.13	-	-
Anions	meq/L	19	614	897	754	736	-	-
Cations	meq/L	19	655	843	749	732	-	-
Balance	%	19	1.25	8.19	4.32	3.3	-	-
$Cl:SO_4$	-	19	3.79	6.28	5.12	4.9	-	-
Dissolved metals								
Ferrous Iron	mg/L	19	0.05	19.7	1.81	-	9.42	10.71
Arsenic	mg/L	19	0.002	0.01	0.007	-	0.026	0.1
Cadmium	mg/L	19	0.0002	0.001	0.001	-	0.01	0.05
Chromium	mg/L	19	0.002	0.01	0.007	-	0.1	1
Copper	mg/L	19	0.002	0.086	0.015	-	0.042	0.2
Lead	mg/L	19	0.002	0.01	0.007	-	2	5
Nickel	mg/L	19	0.002	0.034	0.013	-	0.038	0.2
Zinc	mg/L	19	0.01	0.069	0.036	-	0.17	2.00
Mercury	mg/L	19	0.0001	0.0001	0.0001	-	-	-
Total metals								
Arsenic	mg/L	9	0.003	0.012	0.009	-	0.03	0.10
Cadmium	mg/L	9	0.0002	0.001	0.001	-	0.01	0.05
Chromium	mg/L	9	0.01	0.135	0.030	-	0.1	1
Copper	mg/L	9	0.01	0.306	0.065	-	0.042	0.2
Lead	mg/L	9	0.002	0.01	0.008	-	2	5
Nickel	mg/L	9	0.01	0.11	0.028	-	0.038	0.2
Zinc	mg/L	9	0.01	0.063	0.044	-	0.17	2.00
Mercury	mg/L	9	0.0001	0.0001	0.0001	-	-	-

1. Yellow and red highlights indicate that the value exceeds the yellow or red trigger level respectively

From Table 7.4, the following is observed from the SFM results:

- None of the major ions exceed any of the SSTLs, and there is not a significant difference between the mean concentrations of samples collected during backfilling and those collected pre-mining. Groundwater has alkalinity greater than 180 mg/L and typical pH >6.5 suggesting a 'very high alkalinity' that is adequate to maintain acceptable pH levels in the future (Shand 2018).

- The mean $Cl:SO_4$ value is higher during backfilling than the mean pre-mining. A decreasing $Cl:SO_4$ over time, or $Cl:SO_4$ less than 2, could suggest pyrite oxidation and acidification of the groundwater.

- Apart from ferrous iron, none of the remaining leading indicator concentrations (magnesium, sulfide, gross alpha and gross beta) showed a significant change from pre-mining concentrations (where measured).

- The maximum dissolved ferrous iron concentration measured was 19.7 mg/L which exceeded the 'red' SSTL. This value was measured in BH-M24S and was the only measurement exceeding the ferrous iron SSTLs. This matches what was observed during mining, where two consecutive measurements from BH-M24S were above 20 mg/L. The consistently elevated ferrous iron concentration in this bore, while no similar exceedances are seen in other bores, further suggests local mineralisation is the cause (ie background concentrations).

- The maximum dissolved copper concentration of 0.086 mg/L was measured in UGM-M15S and exceeded the 'yellow' SSTL. Another exceedance of 0.045 mg/L was observed in BH-M23S. These bores were both exceeding during mining, and although they are still in exceedance of the 'yellow' SSTL, the concentrations measured are lower than they were during mining. This could suggest that mining resulted in the increase in copper in these bores, which then began to decrease after mining ceased.

- Total chromium, copper and nickel exceeded the 'yellow' or 'red' SSTL values. Though the total metals are not subject to the SSTL values, this indicates that acidification of the groundwater could lead to mobilisation, and subsequently, high dissolved concentrations of these metals in the future.

- It is noted that values falling between the 'yellow' and 'red' trigger levels are still considered to be within normal operating conditions, and that the 'yellow' trigger level exists to allow for adequate investigation time and potential intervention before species reach the 'red' trigger level. Due to this, it is expected that analytes will occasionally be measured above the 'yellow' trigger level as a result of natural variation. Without evidence of an increasing trend in the exceeding analytes or similar exceedances in nearby bores, the exceedances discussed above have been attributed to natural geochemical processes, rather than as a result of backfilling.

7.3 Plant sampling results

Field parameters were measured at various plant locations throughout backfilling, as detailed in Section 4.1.3. The electrical conductivity and pH data collected has been summarised in Figure 7.6 and Figure 7.7. The remaining parameters (ORP, TDS and temperature) are displayed in Appendix E. Plant monitoring was largely focused around collecting pH measurements to inform lime dosing rates and observe any acidification of the ore, backfill material or process water over time. As such, time-series plots of pH measurements at each location have also been presented in Figure 7.6 and Figure 7.7 to review any pH trends.

From this data, the following is noted:

- The process water, SPD-Sand, SPD-HM and HBF tank pH measurements were all within the desired range of 6.5 to 8.5 during backfilling. These locations had pH measurements between 6.73 and 8.16, demonstrating that the lime dosing procedure followed was successful at managing pH.

- pH measurements of the process water and HBF tank showed a decreasing trend at the start of backfilling, followed by recovery to initial values and maintenance of pH for the remainder of backfilling. There was little change in the SPD streams. Note that the spiral plant was not always operational during backfilling, and therefore was not able to be sampled every day.

- The T2 stockpile sump pH measurements remained relatively constant throughout backfilling. The stockpile sump pH was also relatively constant before the pH dropped sharply in the last week from about 7.9 to 6.9.

- EC and TDS measurements were approximately the same for each location and were within a similar range throughout backfilling. The T2 stockpile sump was an exception, having a mean EC almost 20,000 µS/cm greater than the other locations. The reason for this variation is uncertain, as it is understood the operation, water source and management of these two stockpiles is similar.

- ORP values varied significantly both at a single measurement location, as well as between measurement locations. This variability may be due to the sensitivity of ORP measurements to the introduction of oxygen. Different amounts of oxygen may have been present in each sample depending on if the water had been sitting stagnant or due to differing flow rate from the sampling taps.

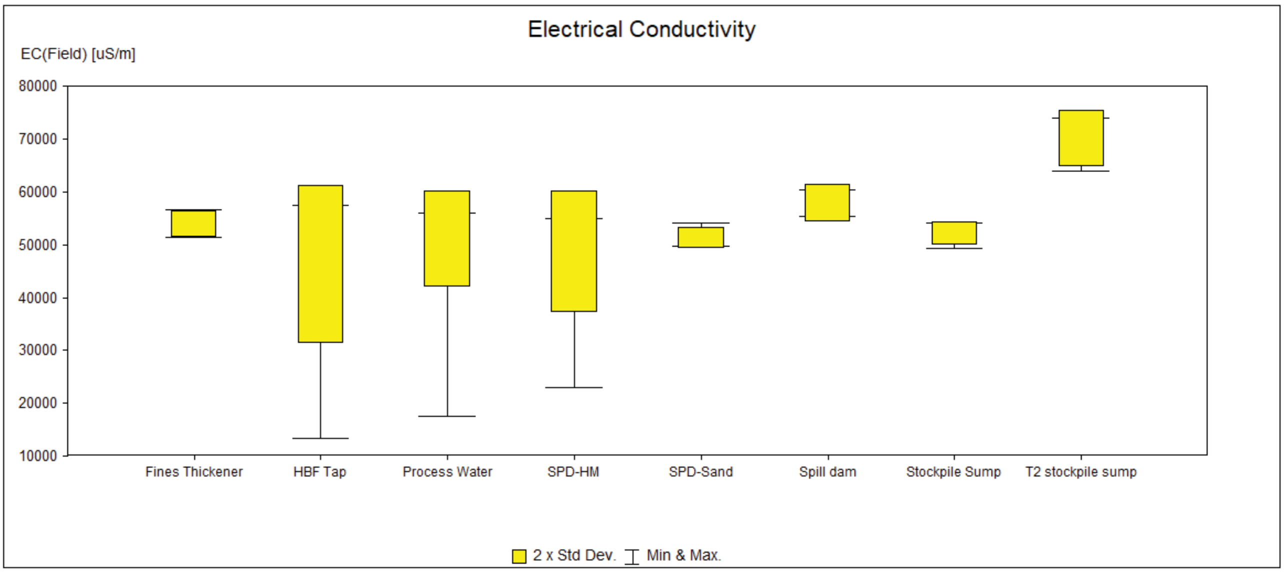


Figure 7.6 Box and whisker plot of electrical conductivity (µS/cm) in plant locations – during backfilling

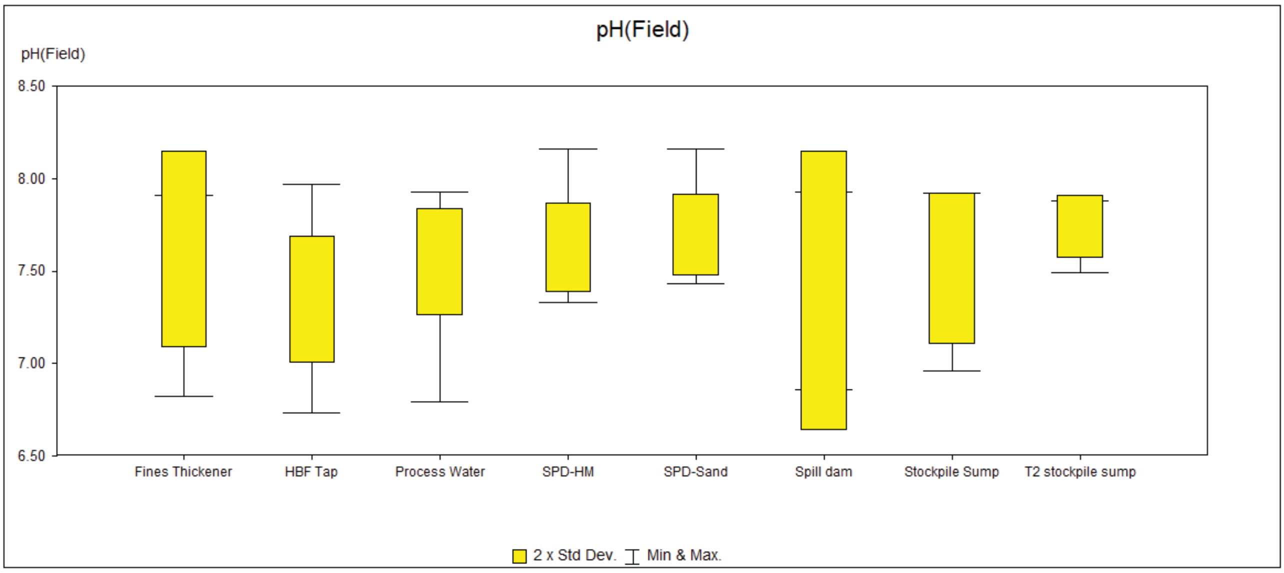


Figure 7.7 Box and whisker plot of pH in plant locations – during backfilling

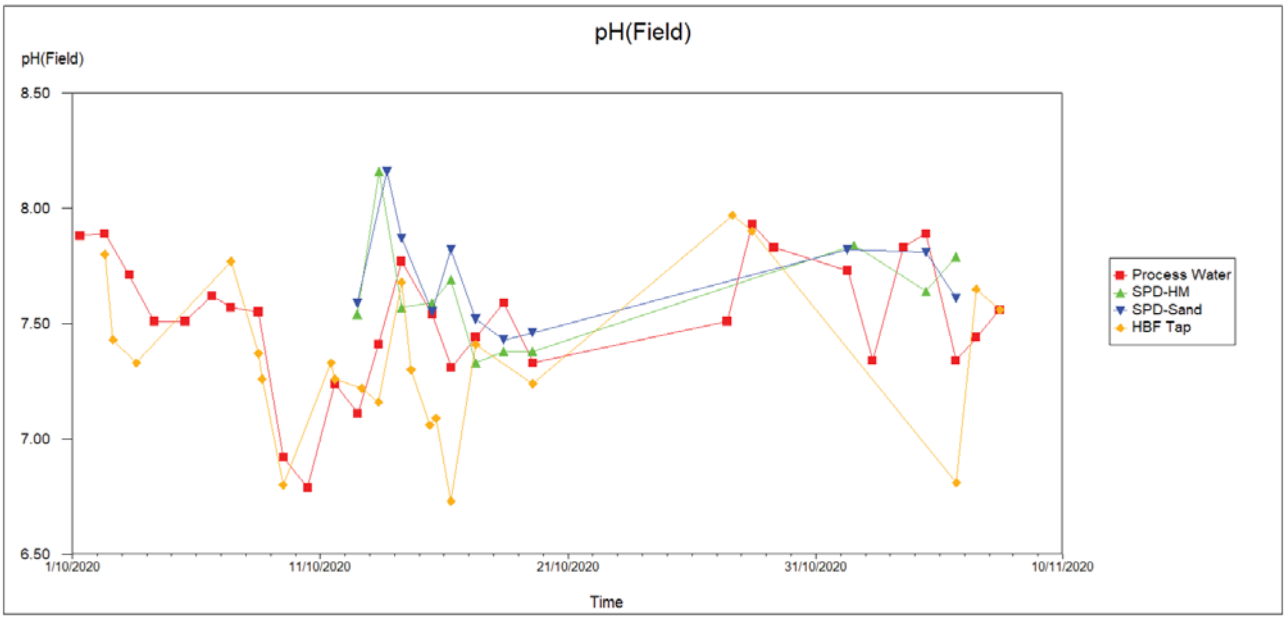


Figure 7.8 Time-series plot of plant pH measurements collected during backfill

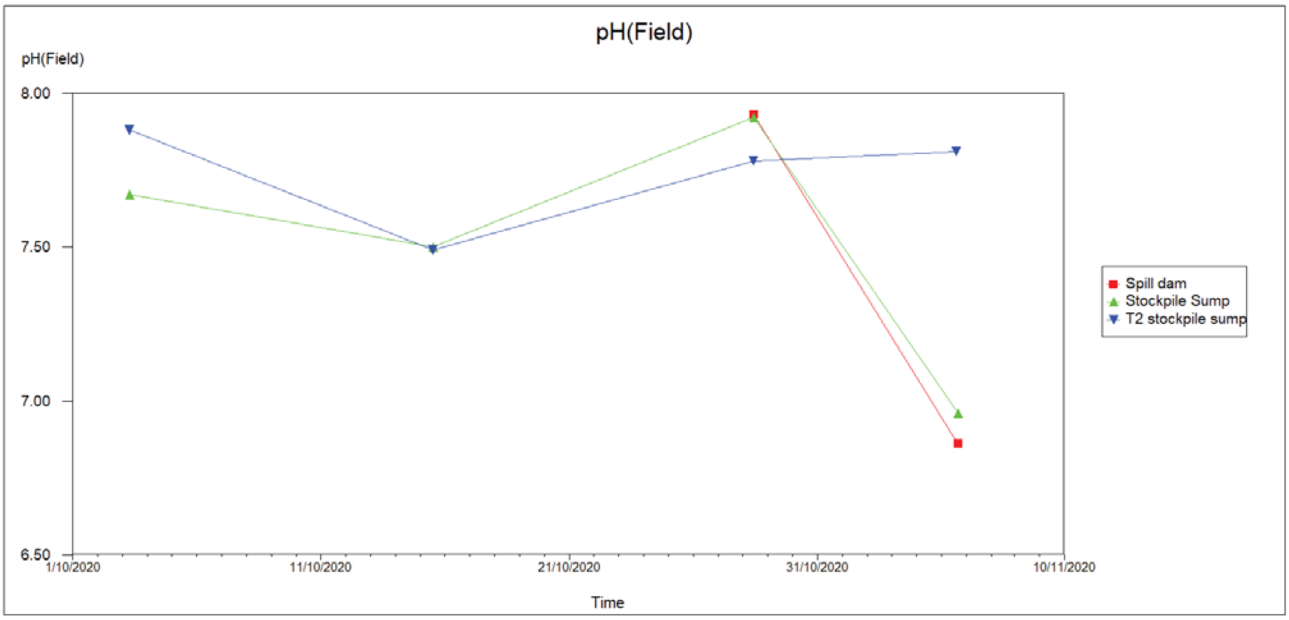


Figure 7.9 Time-series plot of plant pH measurements collected during backfill

7.4 Comparison with geochemical model predictions (LWC 2017b)

LWC (2017b) assessed the potential geochemical responses on the LPS aquifer as a result of several hypothetical T3 backfilling regimes. As the ore being extracted on-site contains reactive sulphide minerals, there is the potential for acid and metalliferous drainage to be generated during the bulk sampling activities.

The ore, ore processing streams and process by-products is exposed to the atmosphere prior to backfilling/reinjection, and therefore will have the potential to affect the groundwater system through oxidation and subsequent metal mobilisation. Predictive assessments were undertaken using a range of backfilling conditions, stockpiled by-product exposure times, backfilling rates, as well as accounting for various blending ratios. The geochemical modelling, which used the Geochemist Work Bench (GWB) modelling suite, indicated the following:

- Depending on the stockpile duration of the process by-products prior to backfilling, the pH of the solution phase of the backfill material is expected to fall between pH 6 and 3. The pH of the material when first extracted was assumed to be 6.4.
- If no pH adjustments are performed on the by-products prior to backfilling, groundwater pH responses within the LPS aquifer are expected to occur up to several hundred metres from the stopes, depending on the stockpile duration and backfill rates.
- Longer stockpiling periods, such as during the start-up of operations, are predicted to result in larger groundwater impacts due to prolonged oxidation and subsequently lower pH of the backfill material.
- Adjusting the pH of the backfill material via dosing with lime or similar substances will mitigate groundwater impacts related to low pH and thus any potential metal mobilisation.

Modelling of the different life-of-mine operating scenarios found that pH dosing can effectively buffer any pH related groundwater impacts. When the backfill material is adjusted to pH 6 via dosing, the pH of the LPS aquifer was predicted to reach a minimum of pH 6.25, from an original pH of 6.4. When the pH of the backfill material was increased to 7, the groundwater pH did not decrease below 6.35.

During T3, the material first mined from Stope 4 sat in a stockpile for about 40 days before backfilling began. From the modelling predictions, it would be expected that the stockpile water pH of these stockpiles would be 5.7 or slightly lower. The stockpile water pH was not measured directly during T3, but pH measurements were taken of the stockpile sumps. These measurements never fell below 6.84 throughout mining and backfilling, suggesting that the natural buffering capacity of the process water and lime dosing were successful at maintaining neutral pH levels.

For the T3 trials, the pH of the PWD and process circuit were maintained between 6.5 and 8.5 through natural buffering capacity and lime dosing, which helped to manage the pH of tailings prior to backfilling. The pH of the backfilled material ranged between 6.73 and 7.97, which was successful at mitigating any groundwater-related impacts due to backfilling. No reduction in pH or mobilisation of metals was observed during or post-backfilling.

These findings will inform an updated conceptual model whereby maintaining circum-neutral process water and appropriately treating the tailings before re-injection effectively neutralises any acid generation potential of the material.

8 Mining induced subsidence

Iluka (2019) outlined subsidence predictions and management in the Balranald Subsidence Management Plan. Subsidence was observed in the T1 and T2 trials, with one irregular subsidence event occurring during T2, termed sink hole 1 (S1). This irregular subsidence event was experienced where vertical holes were intersected by mining. Apart from sink hole 1, T1 and T2 subsidence was less than 200 mm across the stope areas. A subsidence model predicted vertical surface deformation up to 600 mm across the mining zone. Irregular subsidence, as sink holes, were not expected to be seen at the extent noted during T3 (Iluka 2019).

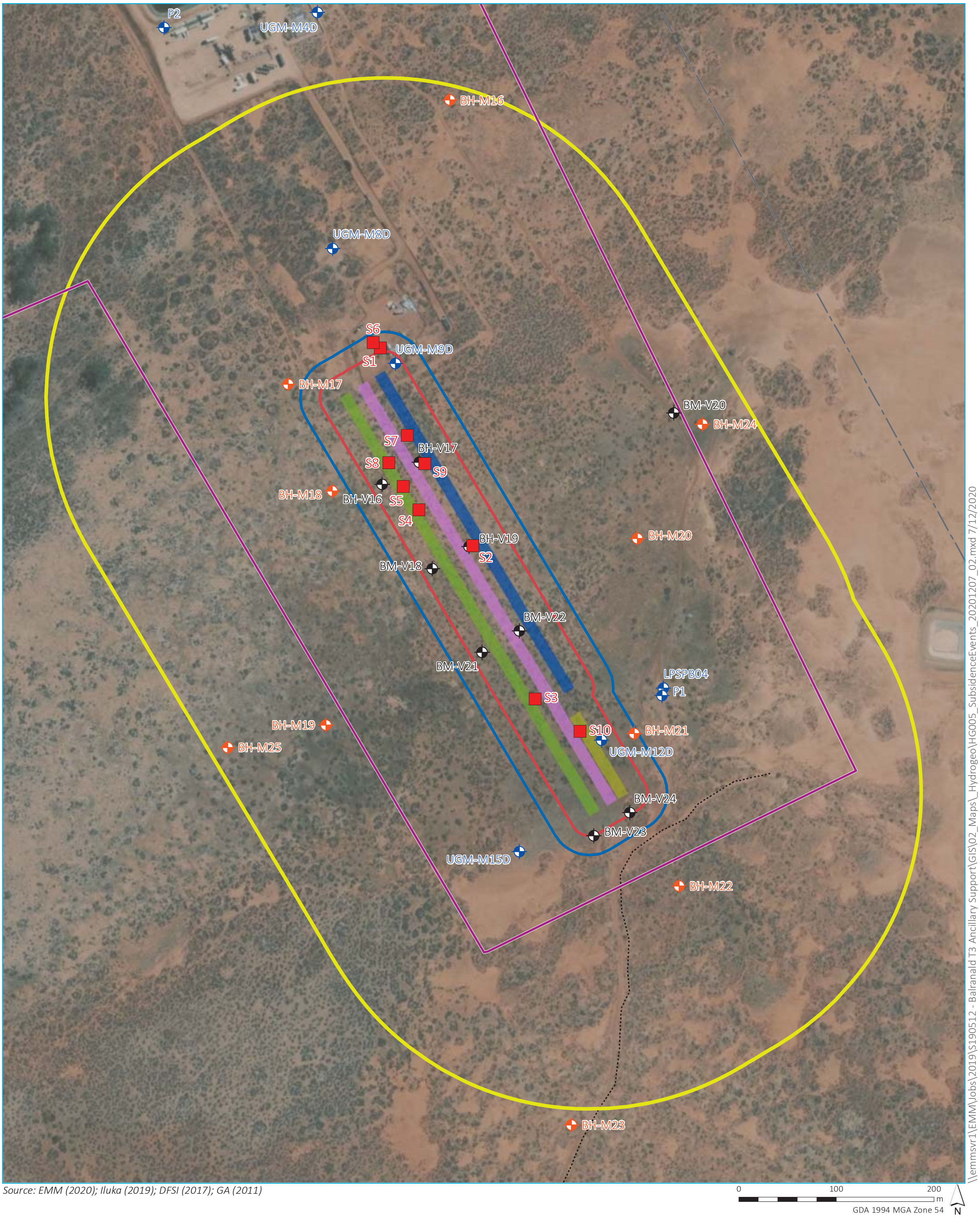
A total of nine additional irregular subsidence events (sink holes) were induced during mining (3), backfill (2) and post-mining (4) activity (Figure 8.1). Surveys indicates that the lateral extent ranges from 6.4 m to 15.8 m and depths from 1.2 m to 6.9 m (Table 8.1). An aerial image of all site sink holes is shown in Plate 8.1. All subsidence events occurred inside the mine exclusion zone with no risk to personnel. Attempted stabilisation of sinkholes occurred via backfilling with lime dosed sand tails, with subsoil and topsoil capping to occur when the exclusion zone is cleared for access and rehabilitation. The success of this stabilisation will be determined over time.

Table 8.1 Subsidence events

Event #[1]	GPS coordinates of sinkhole centre	Date occurred	Date backfilled	Maximum depth (m)	Maximum lateral extent (m)	Backfill volume (t)	Trial phase during which subsidence occurred	Nearest SFM & LPS groundwater monitoring location
S1 (T2)	E 723412 N 6189401	2016	2020	2.0	4.9		T2 Mining	BH-M17D/S
S2[2]	E 723507 N 6184199	24/8/20	2/10/20	3.7	15.8	310	Mining	VWP18, VWP19, VWP22
S3[2]	E 723571 N 6189042	21/9/20	3/10/20	6.0	14.5	680	Mining	VWP10, VWP21
S4[2]	E 723452 N 6189236	30/9/20	3/10/20	6.9	10.0	1,220	Mining	VWP16, VWP18 BH-M18D/S
S5[2]	E 723396 N 6189236	8/10/20	30/10/20, 1/11/20	2.1	10.0	NA[3]	Backfill	BH-M17D/S BH-M18D/S VWP17
S6[2]	E 723405 N 6189407	12/10/20	1/11/20	1.2	6.4	75	Backfill	BH-M17D/S
S7	E 723440 N 6189312	3/11/20	7/11/20	TBA	11.5	137	Post-mining	BH-M18D/S VWP17
S8	E 723421 N 6189284	3/11/20	7/11/20	TBA	11.5	153	Post-mining	BH-M18D/S VWP16
S9	E 723458 N 6189283	12/11/20	14-16/11/20	TBA	15.0	312	Post-mining	BH-M18D/S VWP17
S10	E 723617 N 6189009	12/11/20	14-16/11/20	TBA	11.0	187	Post-mining	UGM-M12D/S BH-M21D/S

1. All events are associated with T3 unless stated otherwise
2. Sinkhole centres were estimated from plans provided by Iluka – these coordinates have not been surveyed

3. Not backfilled as it was a low point in topography and filled with rainwater
4. TBA – to be advised



Source: EMM (2020); Iluka (2019); DFSI (2017); GA (2011)

KEY

- Subsidence event
- Activity area
- New T3 bore
- New T3 VWP
- Existing bore
- Vehicular track
- Restricted area
- Mining zone boundary
- Transition zone boundary
- Mining Lease 1736
- Stope 3B
- Stope 4
- Stope 5
- Stope 6

Subsidence event locations

Iluka Resources Limited
T3 Hydrogeochemical Assessment
Figure 8.1

EMM creating opportunities

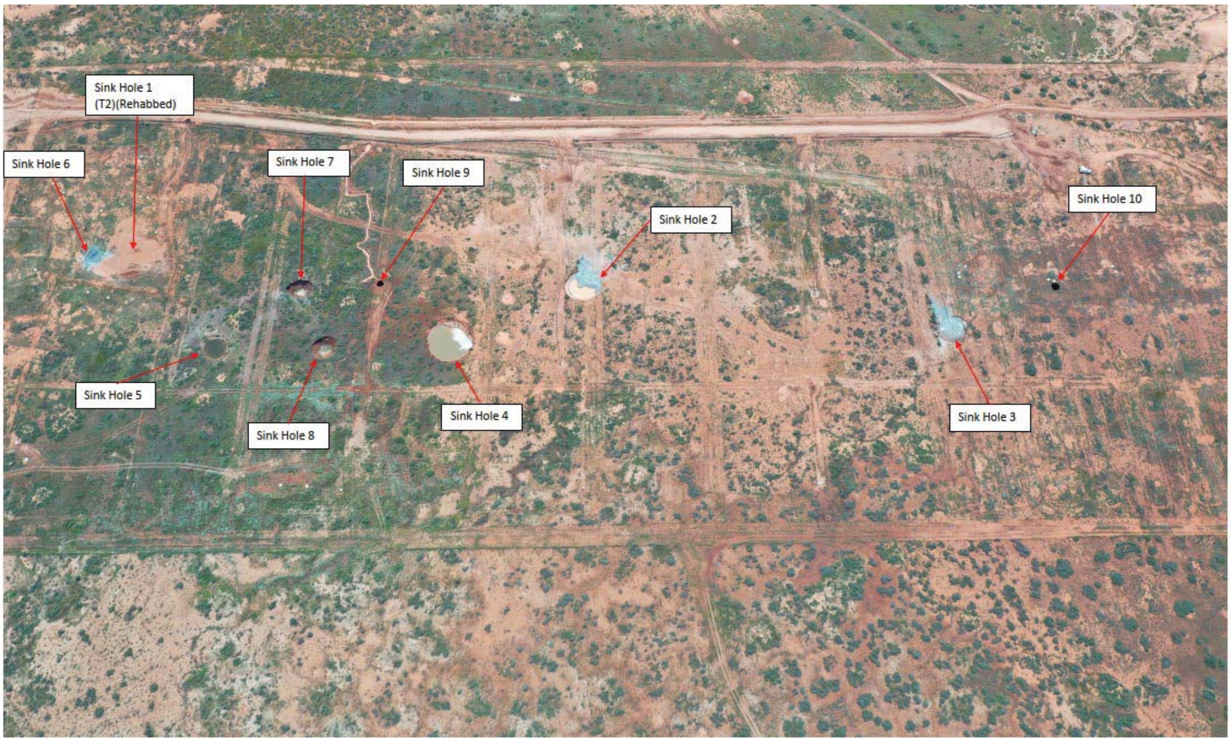


Plate 8.1 Sink hole aerial image, with north to the left

8.1 Groundwater data

In accordance with the GMP (EMM 2020), VWP were installed. Each installation has four VWP sensors installed at various horizons within the SFM and LPS.

Overall, there was minimal impact on groundwater levels outside the mining zone. A review of all groundwater pressures within the SFM and LPS show that all pressures are well within the SSTLs, as defined by the GMP (EMM 2020).

It is noted that sink holes S2, S3, S4, S5, S7, S8 and S9 do not correlate to the intersection of any known vertical boreholes. Sink holes S6 and S10 are in close proximity to a previous extensometer and VWP monitoring locations installed from T1/T2, which may have contributed to the failure mechanism.

8.1.1 Sink holes S2 and S4

Within the mining zone, an assessment of the local VWP data showed that the groundwater pressure within the LPS rapidly increased due to the collapse of the above material, which temporally induced groundwater to flow upwards into the SFM. The incident (at sink hole S2) caused groundwater pressures to increase within the SFM less than 2 m (Figure 8.2). As the clay aquitard has deformed it is likely to have allowed transmission of groundwater from the confined LPS aquifer into the overlying SFM aquifer. This upwards flow of groundwater resulted in increased groundwater pressures, which dissipated over time. It is possible that SFM sediments from higher parts of the profile have 'blocked' the aquitard breach, partially reinstating the aquitard.

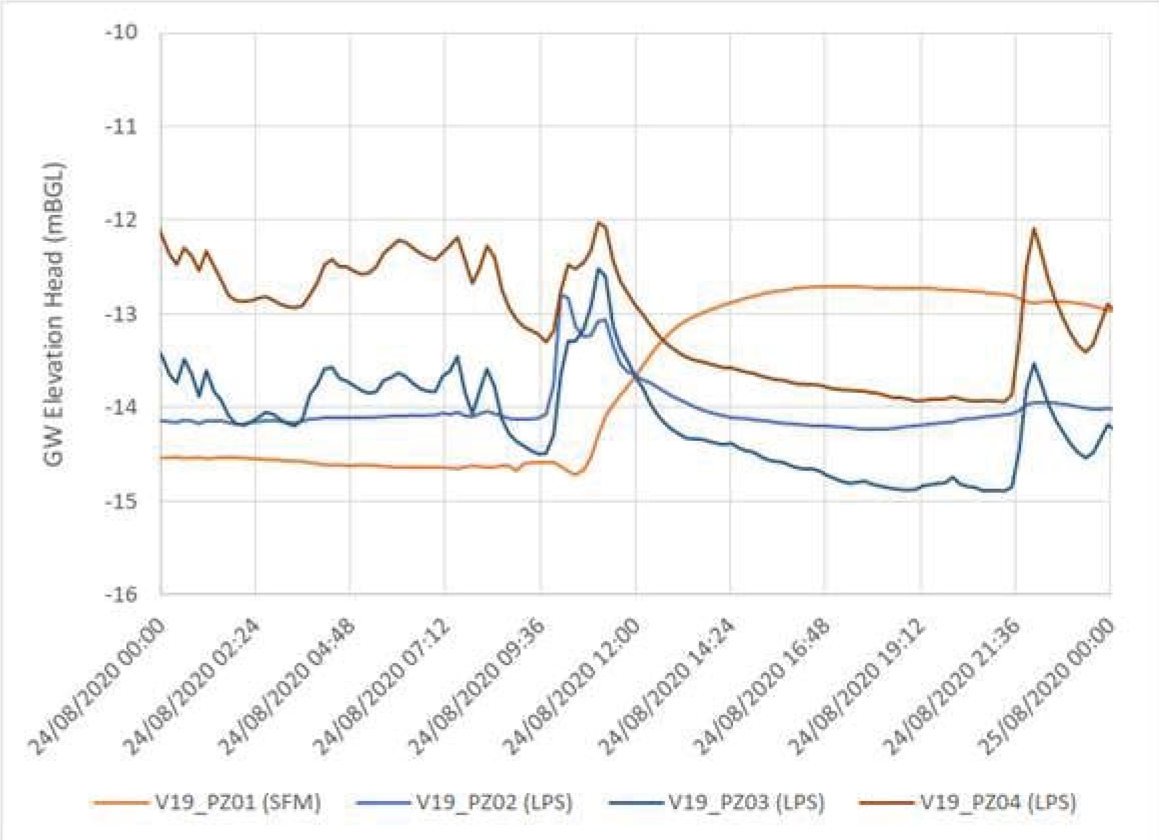


Figure 8.2 VWP pressures during S2 formation

A review of transition bore data from the monitoring bore network showed that the increase in pressure was measured at M17 and M18, with a delayed response of approximately one week. The pressure increase took approximately two weeks to recover within the SFM aquifer, suggesting the SFM is behaving as an unconfined aquifer (Figure 8.3).

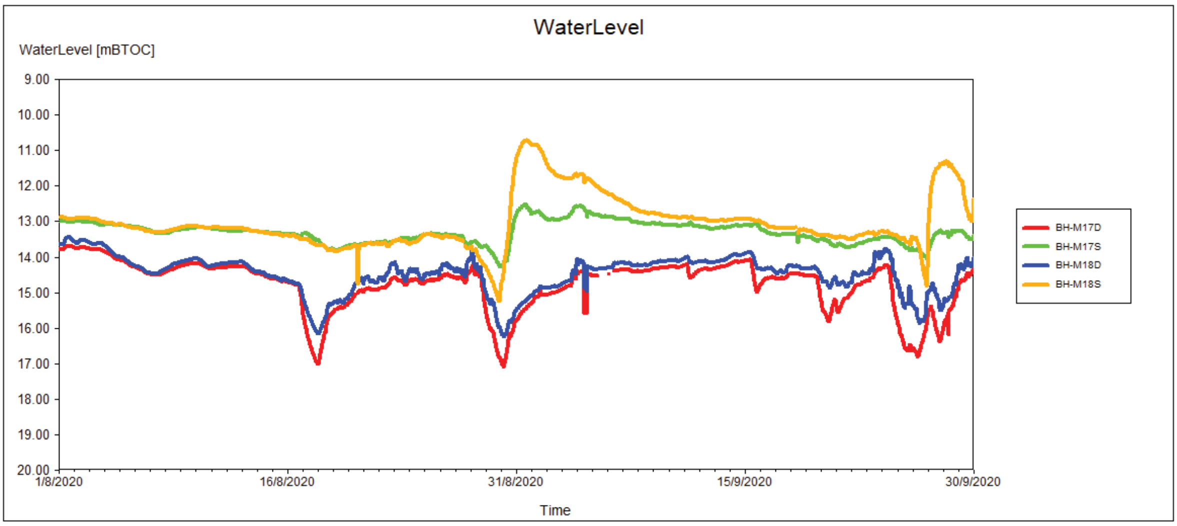


Figure 8.3 Transition bore groundwater pressure response to S2

Groundwater quality parameters pH and TDS for bores M17 and M18 remained stable over the entire period.

8.1.2 Sink hole S3

The groundwater levels measured at bores M12 and M21 (Figure 8.4), located within the mining zone and closest to the sink hole S3, show that the aquitard is intact at this location. SFM pressures remain relatively stable throughout the period, compared to the LPS pressures which show large fluctuations primarily caused by the response of mine water supply pumping from the nearby P1 bore (drawdown response of ~ 2.5 m) and mining/backfill pressure spikes of up to ~ 2 m. The extent of failure appears to be less than in sink holes S2 and S4, either as a result of a lesser stress or more competent aquitard.

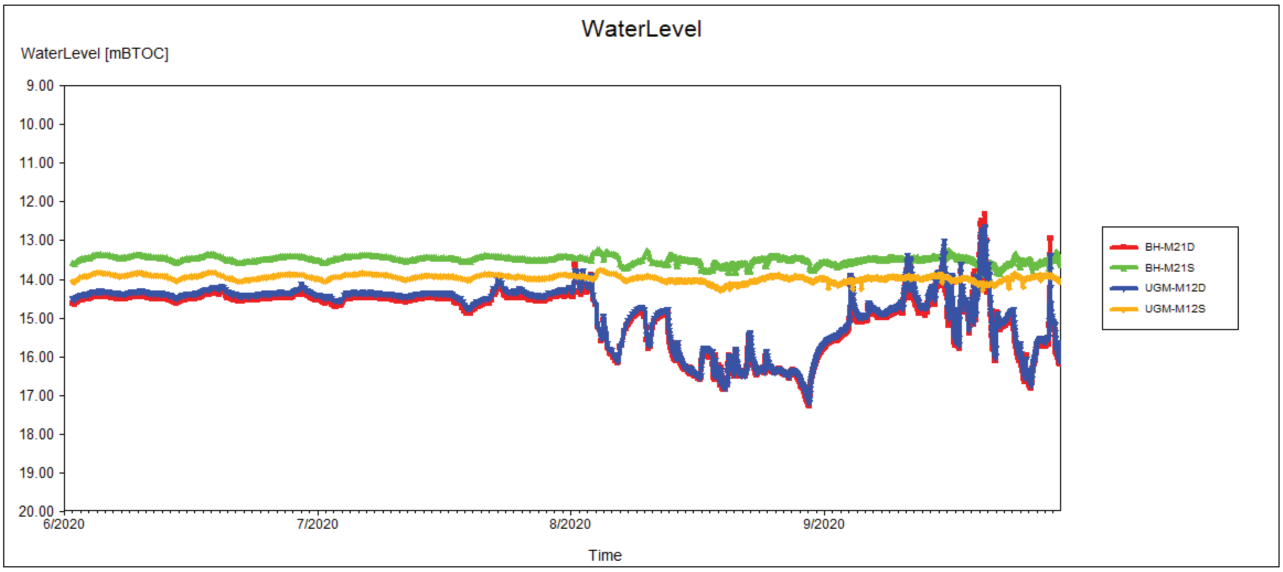


Figure 8.4 Groundwater levels of bores M12 and M21 during subsidence event S3

Field-measured pH and TDS at bores M12 and M21 show no sign of mixing between the SFM and LPS aquifers. The data suggests that S3 has no discernible impact on groundwater quality at the available monitoring locations.

8.1.3 Sink holes S5 – S6

Groundwater levels measured in bores near to sinkholes S5 and S6 during the subsidence events are displayed in Figure 8.5. The SFM groundwater levels showed a clear response to S5, with groundwater levels rising by approximately 3 m at M17S and M18S. Only a minor increase in SFM groundwater levels of about 0.5 m was observed in response to S6. No SFM SSTLs were breached during either subsidence event.

The LPS groundwater levels displayed a lesser but still notable increase of about 1.5 m in response to S5. A small groundwater spike of about 0.5 m was observed after S6. The intermittent drawdown observed in the LPS aquifer is due to the P2 bore being pumped as needed throughout this period. No LPS SSTLs or HOCs were breached during either subsidence event.

Both of these subsidence events occurred during backfill activities, which may have played a role in the groundwater level increase observed in nearby bores. The extent of failure appears to be greater than in sink holes S2 and S4.

Figure 8.6 displays pH and EC measurements in M17 and M18 before and after the subsidence events. No changes in pH or EC that indicate groundwater mixing between the SFM and LPS aquifers were observed. Any aquitard failure, which causes groundwater to mix between the two aquifers, is likely a local effect with no discernible impact on the regional system.

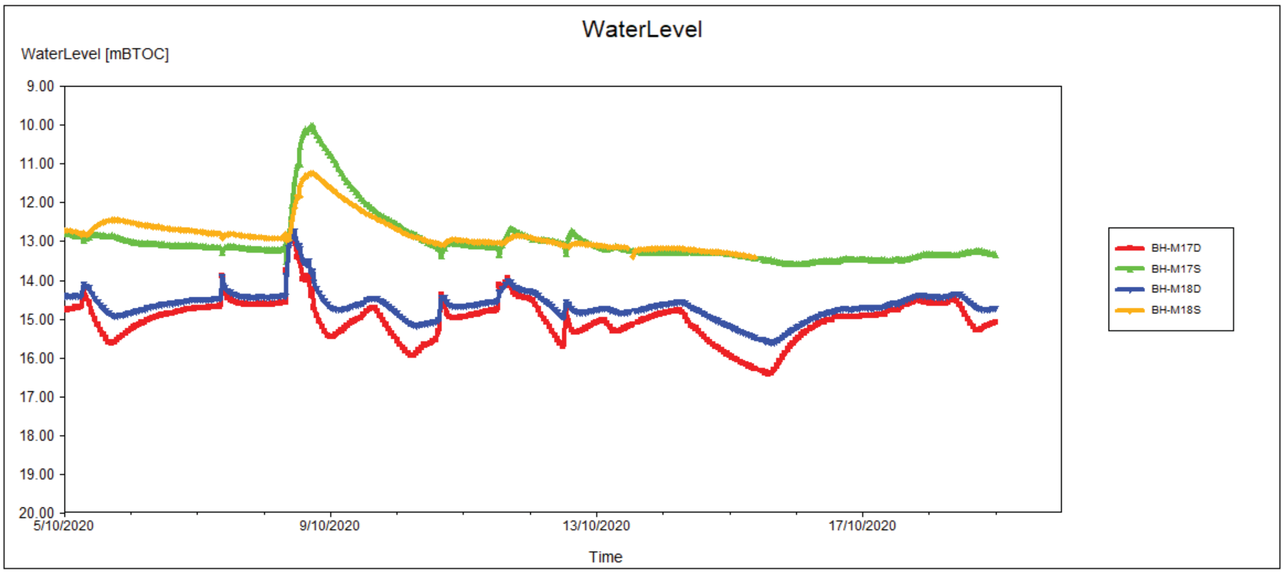


Figure 8.5 SFM and LPS groundwater levels during subsidence events S5 and S6

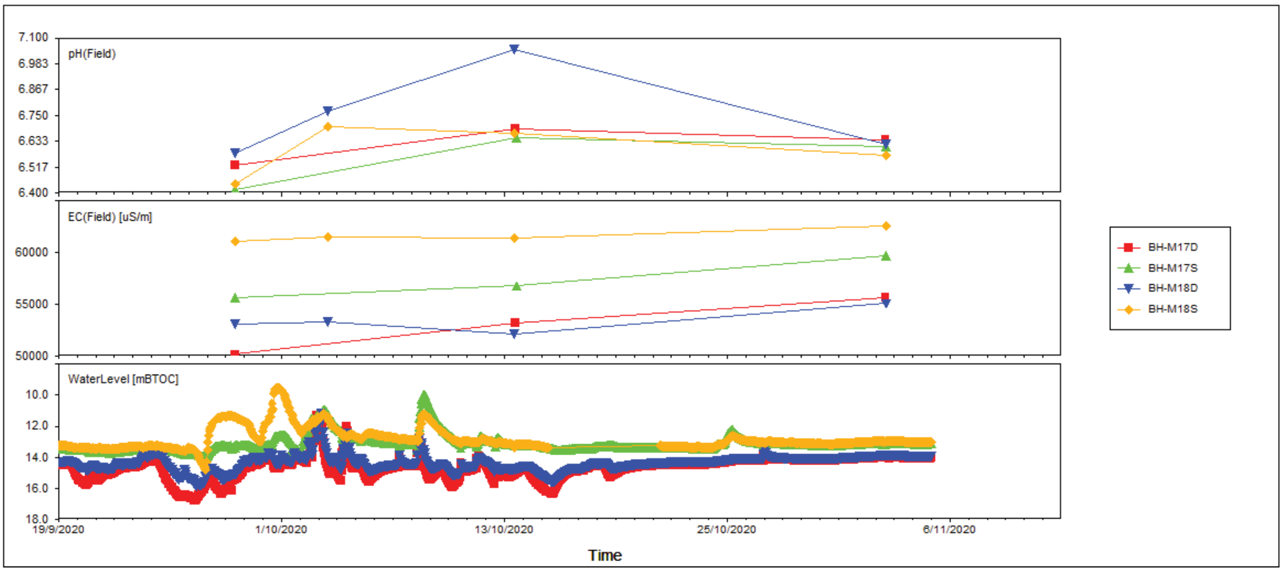


Figure 8.6 SFM and LPS field parameters before, during and after subsidence events S5 and S6

8.1.4 Sink holes S7-S10

SFM and LPS groundwater levels recorded in bores near to sinkholes S7 to S10 are displayed in Figure 8.7 and Figure 8.8 respectively. These subsidence events occurred after the completion of mining and backfilling activities, and following significant rainfall events.

The SFM groundwater levels for the bores located to the north and west of the stopes showed some response to the various subsidence events, mainly at M17S and M18S. No SSTLs or HOCs in the SFM aquifer have been breached. Monitoring indicates that SFM groundwater levels used to assess compliance (within the background zone) show static responses with no discernible trend. Responses at these locations show no regional effects due to mining, HBF, water supply or subsidence events.

The LPS groundwater levels are affected by groundwater extraction from the P1 bore. Spikes at M12 and M21 are due to HBF periods but were not large enough to sustain a response in the more regional bores. No SSTLs or HOCs in the LPS aquifer have been breached.

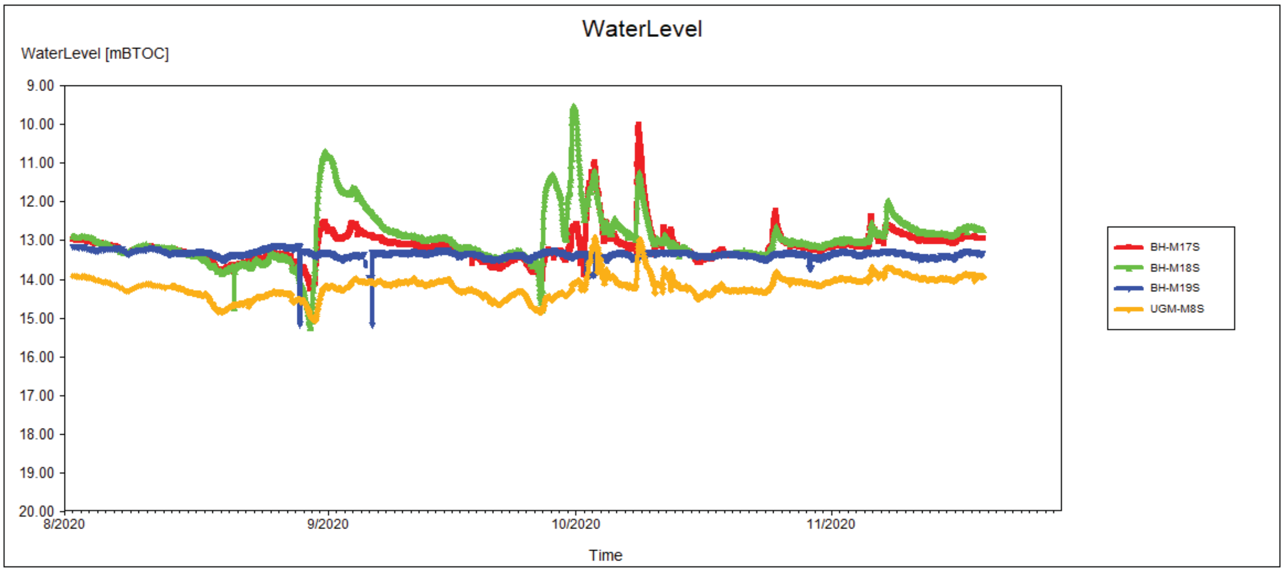


Figure 8.7 Groundwater levels during subsidence events S7 to S10 - SFM

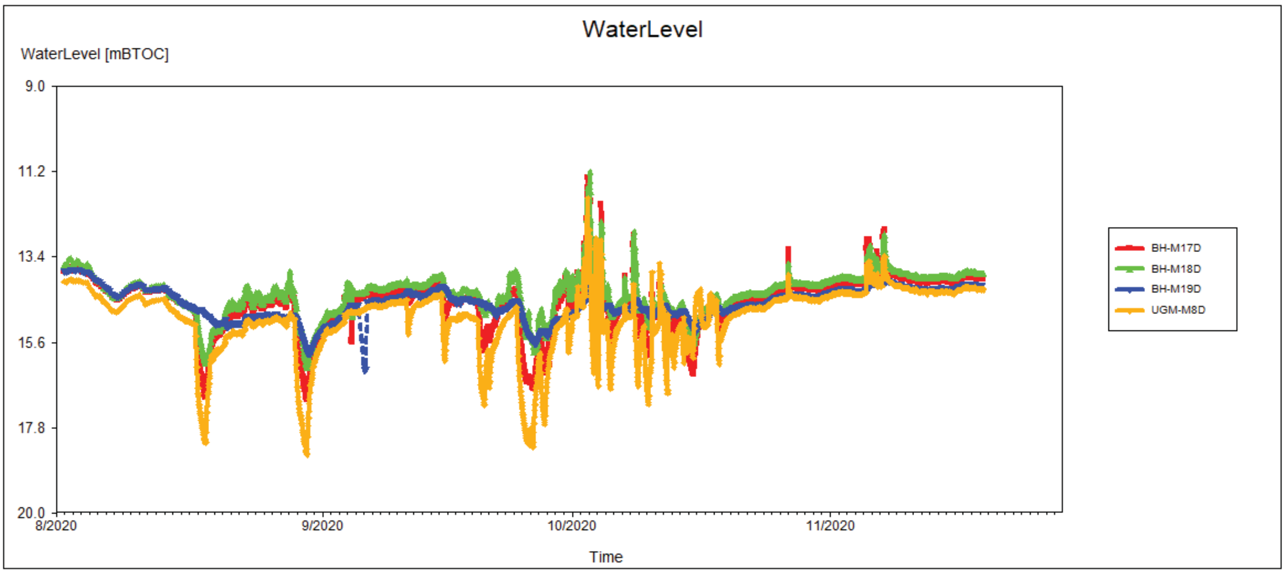
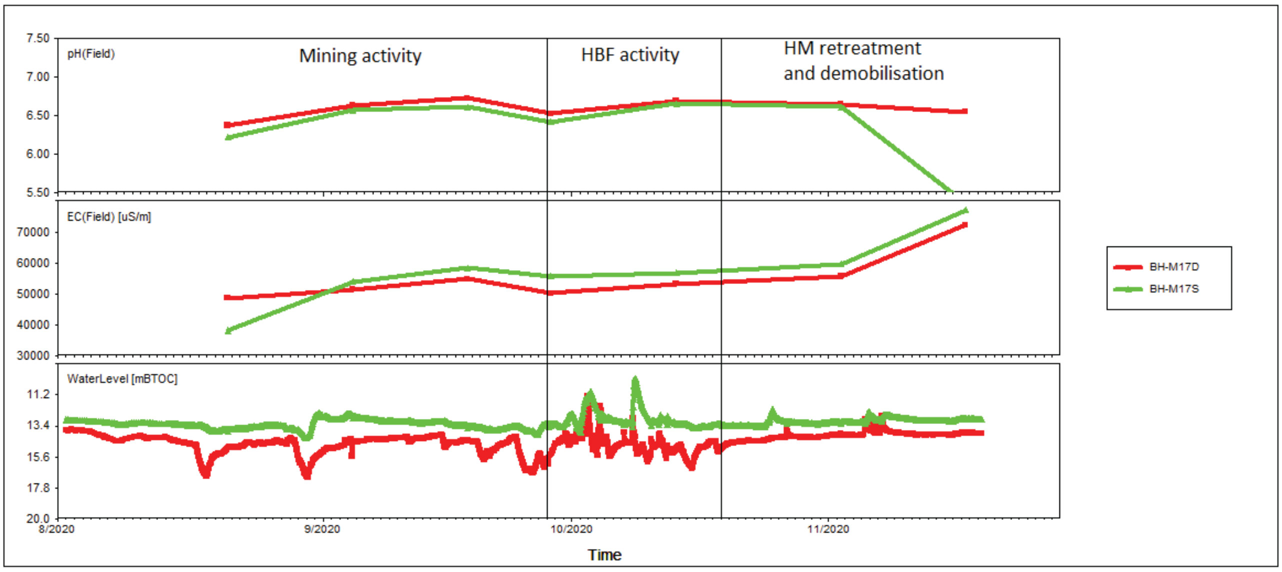
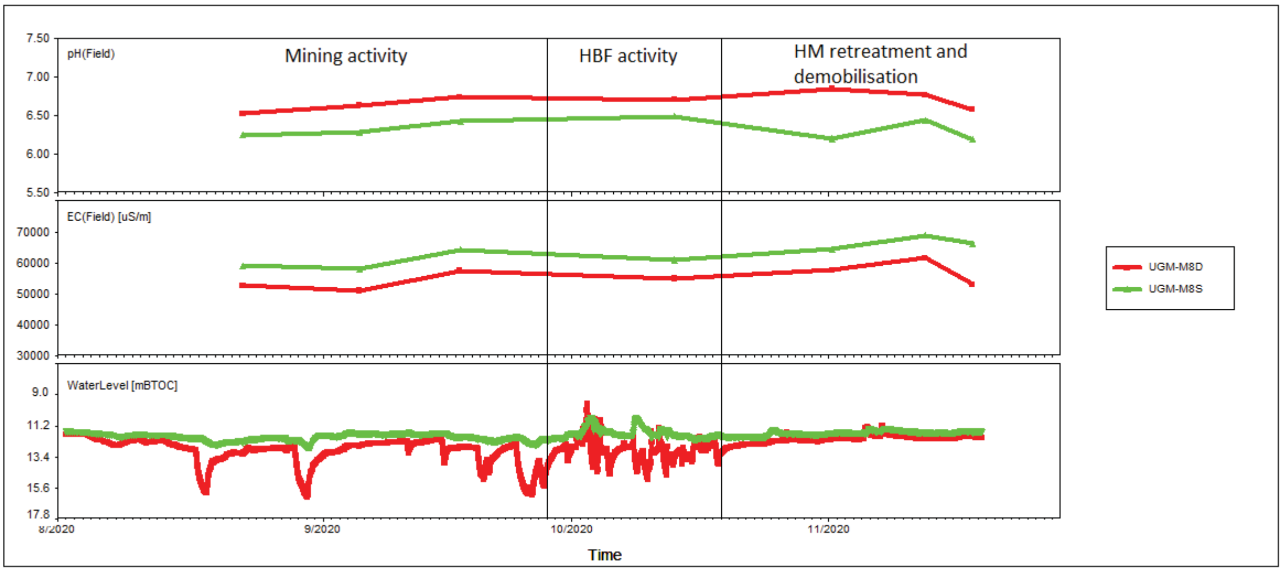


Figure 8.8 Groundwater levels during subsidence events S7 to S10 - LPS

Figure 8.9 shows field pH, TDS and groundwater levels for all sites used to assess subsidence. Bores M08, M17 and M18 showed subsidence responses. Groundwater pressure differences (and hydraulic vertical gradients) remain between the SFM and LPS aquifers, and no discernible changes in pH and TDS exist, which indicates insignificant groundwater mixing between the two aquifers occurred. Any aquitard failure, which causes groundwater to mix between the two aquifers, is likely to be local effect with no discernible or sustained impact on the regional system.


pH(Field)
Mining activity
HBF activity
HM retreatment and demobilisation
EC(Field) [uS/m]
WaterLevel [mBTOC]
BH-M17D
BH-M17S
8/2020
9/2020
10/2020
11/2020
Time


pH(Field)
Mining activity
HBF activity
HM retreatment and demobilisation
EC(Field) [uS/m]
WaterLevel [mBTOC]
UGM-M8D
UGM-M8S
8/2020
9/2020
10/2020
11/2020
Time

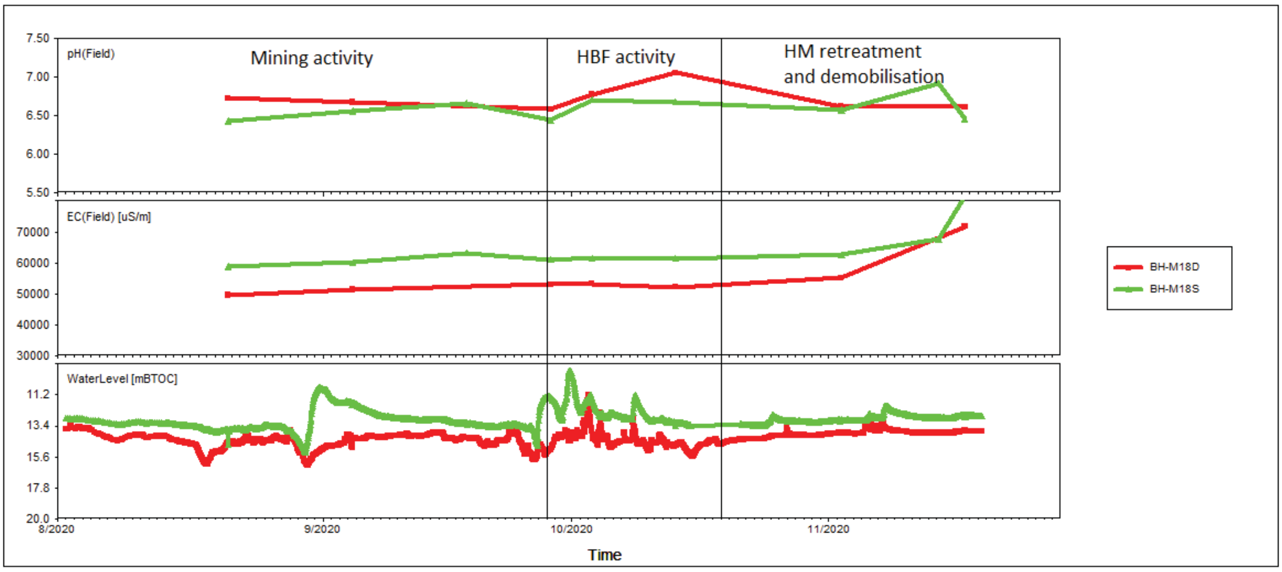


Figure 8.9 Subsidence bores (M08, M17, M18) groundwater levels and quality

8.2 Summary

Based upon the mining and groundwater data, it is considered that the following had occurred at sinkholes S2, S3 and S4:

- Mining has caused an unravelling of the roof of the stopes, ie the material above the stope has low strength and collapsed due to the weight of the sediment pile above.
- This unravelling has propagated upwards towards the clay aquitard in a chimney or balloon style failures (S3 and S4 diameter increased with visual depth).
- As the clay layer has become undermined it appears to have sunk.
- The unravelling has continued to surface, resulting in the subsidence events.
- Failure of the aquitard caused an increase in hydraulic connection between the LPS and the overlying SFM, which was an expected outcome due to subsidence.
- Pressure increases in the SFM due to the initial displacement of groundwater within the LPS caused by subsidence.
- Pressure dissipates laterally through the SFM over time, with a delayed response measured in more regional bores due to the pressure wave moving away from the stope failures.
- The pressure response decreases over time, with background pressure being established within a couple of weeks, post-subsidence event.

Similar to sink holes S2, S3 and S4, at sink holes S7 to S10 the causes of subsidence was considered to be:

- mining has caused an unravelling of the roof of the stopes;
- this unravelling has propagated upwards towards the aquitard in a chimney or balloon style failures;

- time and loading from rainfall, sediment saturation and recharge have caused the aquitard to have sunk; and
- the unravelling has continued to surface, resulting in the subsidence events.

The formation of sink holes S5 and S6 were assessed to be different to other sink holes, in that:

- monitoring installations and mining disturbance of the strata created a potential pathway for hydraulic pressure to dissipate during backfilling;
- stope backfilling caused localised groundwater mounding, resulting in flow to the surface; and
- upwelling of water resulted in loosening of disturbed unconsolidated strata resulting in sink hole formation.

9 Updated hydrogeological conceptual model

The local stratigraphy shown in the conceptual drawings (Figure 9.1 to Figure 9.4) are an idealistic interpretation based on logging data acquired during hydrogeological studies (Iluka 2015 and 2016b) and data collected during the installation of monitoring infrastructure to support the 2016 mining trials. As a result of the works summarised in previous sections of this report, the hydrogeological conceptual model has been updated below.

9.1 Pre-mining

Figure 9.1 shows the pre-mining conceptual model, with the following attributes:

- The ore is hosted within the LPS aquifer, generally located below the LPS1 package and within the LPS2 package.
- High grade ore targets, predominantly consisting of ilmenite, are approximately 5 m thick and are located approximately 70 metres below ground level (mbgl).
- The water table is hosted within the SFM aquifer at approximately 14 mbgl. The LPS potentiometric surface is also measured at around 14 mbgl, and thus the LPS is confined at the Site.
- The water quality of the LPS and SFM aquifers is approximately neutral, with mean pre-mining pH measurements of 6.98 and 7.20 respectively. The groundwater in these aquifers is saline, with the LPS and SFM having mean EC values of 51,000 and 56,000 µs/cm respectively.

9.2 During mining

Figure 9.2 shows the mining conceptual model, with the following attributes:

- Increased pressure within the LPS aquifer may occur during the mining phase, a consequence of injecting high-pressure water into the mine stope to facilitate the mining process. The pressure increase and subsequent recovery, is likely to be rapid due to the confining nature and high transmissivity of the LPS aquifer.
- Pressure impacts within the SFM aquifer should remain insignificant if a sufficient aquitard exists between the SFM and the underlying LPS. However, pressure increases within the SFM could occur in areas where a hydraulic connection occurs between the SFM and underlying LPS aquifer.
- Subsidence events are not unexpected, with predictions of systemic subsidence across the mining zone. To date, there have been no long-term impacts on groundwater quality or the groundwater level in the area. If the ground surface subsides more than the maximum levels being predicted, it is possible this may impact the natural groundwater level. The similarity in groundwater quality between the SFM and LPS aquifers suggest that any quality impacts to the SFM aquifer (from the LPS aquifer) will be difficult to discern. It is possible that the localised mounding in the SFM mobilised unsaturated zone salts, however this has not been proven.
- Groundwater quality is not expected to be significantly affected by mining. The main source of potential contamination during mining would be drilling muds. LWC (2017a) reviewed the drilling mud mixture used

and concluded that all of the substances used are environmentally benign and unlikely to cause any significant change to groundwater quality.

9.3 Backfilling

Figure 9.3 shows the backfilling conceptual model, with the following attributes:

- Backfilling activities may result in significant pressure responses within the LPS aquifer, a consequence of injecting tailings into the mined cavity initially, with pressure impacts propagating throughout the aquifer thereafter. Pressure build-up is dependent on the stope dimensions, stope continuity and aquifer transmissivity. These parameters may vary between stopes or along the strike.

- Backfilling activities should not result in significant pressure responses within the SFM aquifer if a sufficient aquitard exists between the SFM and LPS aquifers in the trial area. This is generally represented by multiple clay horizons within the SFM itself, and commonly by a highly plastic clay located at the base of the SFM which represents naturally occurring bentonite along with the occasional ferricrete.

- Pressure impacts (both drawdown to supply process water and mounding due to mining/backfilling) are expected to be rapid, due to the confining and semi-confining nature of the LPS and SFM aquifers respectively.

- Large scale subsidence events are not unexpected, with predictions of systemic subsidence across the mining zone. Some local subsidence may occur directly above the stopes. It is anticipated that successful backfill will reduce future potential subsidence.

- The backfilling phase is the most significant when considering potential changes to groundwater quality. Reactive sulfide minerals within the extracted material may oxidise and generate acid and metalliferous drainage while stockpiled and exposed to atmospheric conditions. If reinjected without proper management or treatment, the pH of the groundwater system could be reduced leading to the mobilisation of metals. Aerated injected slurry or water could also react with in-situ sulfides within the aquifer itself.

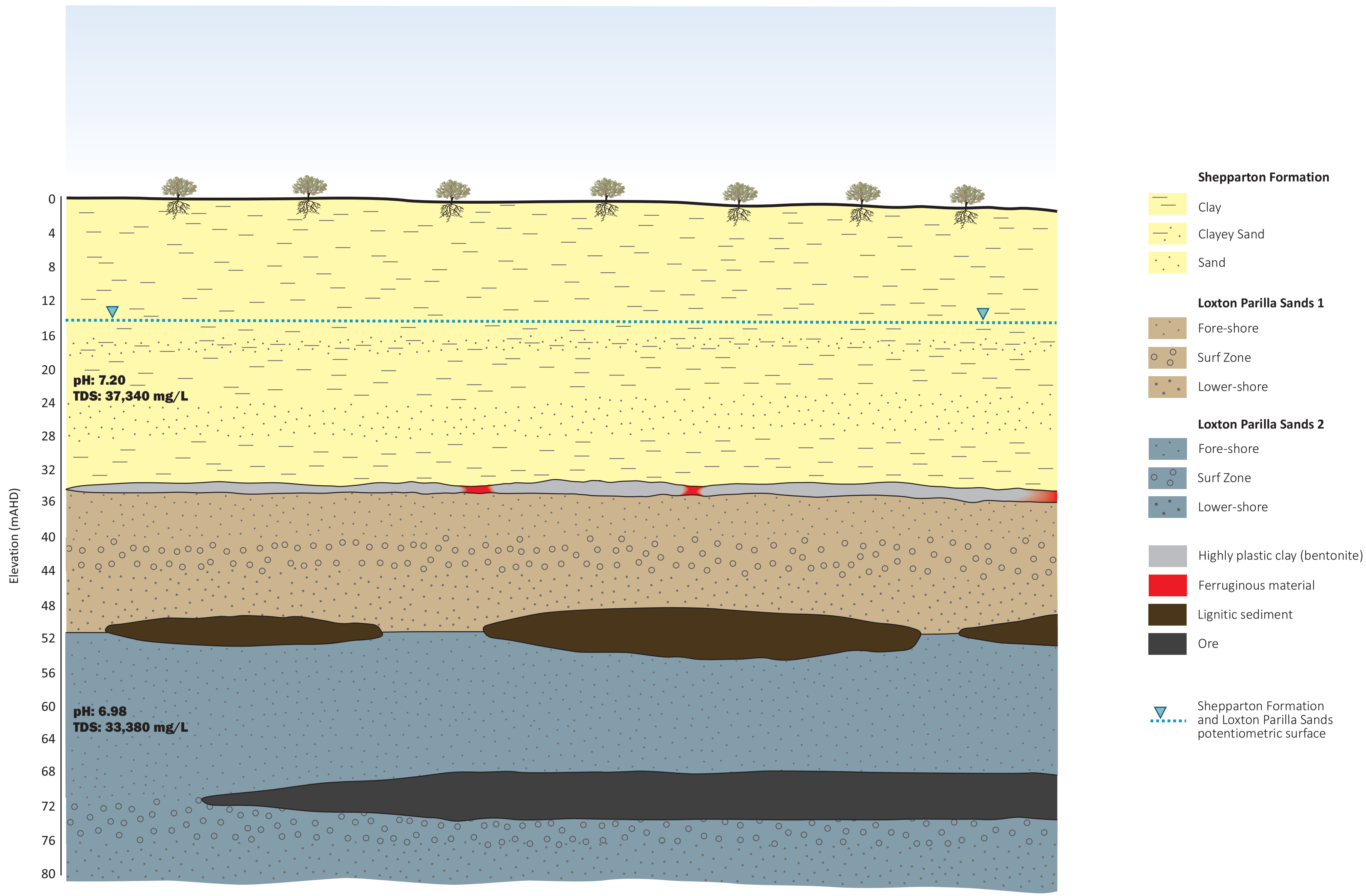
9.4 Post-mining

Figure 9.4 shows the post-mining conceptual model, with the following attributes:

- The post mining pressure impacts within the LPS aquifer are expected to recover to, or close to, the pre-mining groundwater pressure levels. Depending on the variability and level of backfilling achieved and thus the in-situ material density of the final stopes, final LPS groundwater pressures in close proximity of the stopes may be more subdued than the pre-mining levels. This would be caused by an area of the LPS which would exhibit higher transmissivities and porosity, compared to its pre-mining state.

- Large scale subsidence events are not unexpected, with predictions of systemic subsidence across the mining zone. It is anticipated that successful backfill will reduce future potential subsidence. In the event of localised subsidence, Iluka will backfill the surface expression with benign material.

- Post-mining, any changes to groundwater quality that occurred in and adjacent to the stopes during backfilling are expected to return to baseline conditions over time as the aquifer recovers and mixes with more regional groundwater.



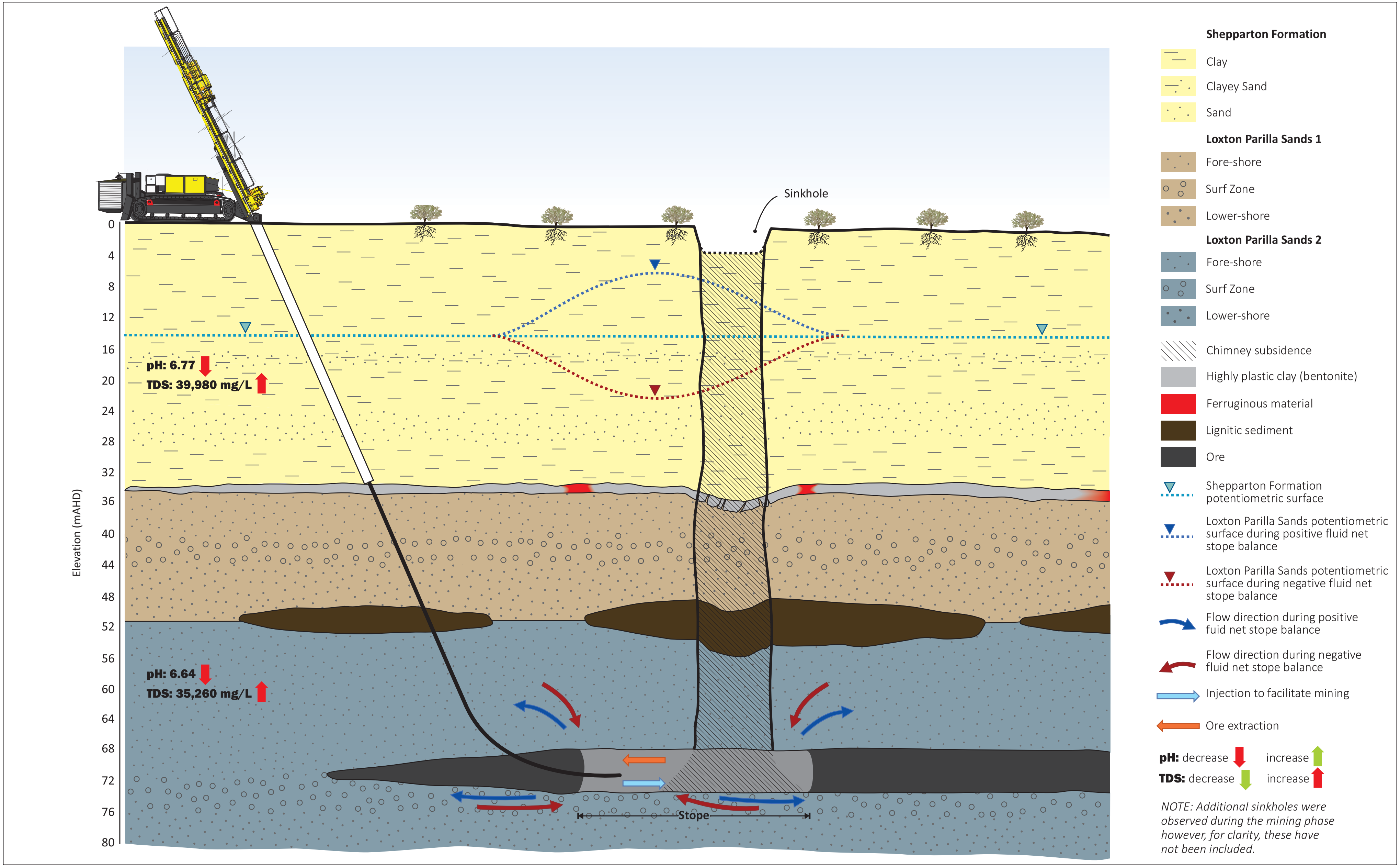
EMM creating opportunities

Hydrostratigraphy and pre-mining conditions

Iluka Resources

Balranald Mineral Sands Trial – Hydrogeochemical assessment of the T3 mining trial

Figure 9.1



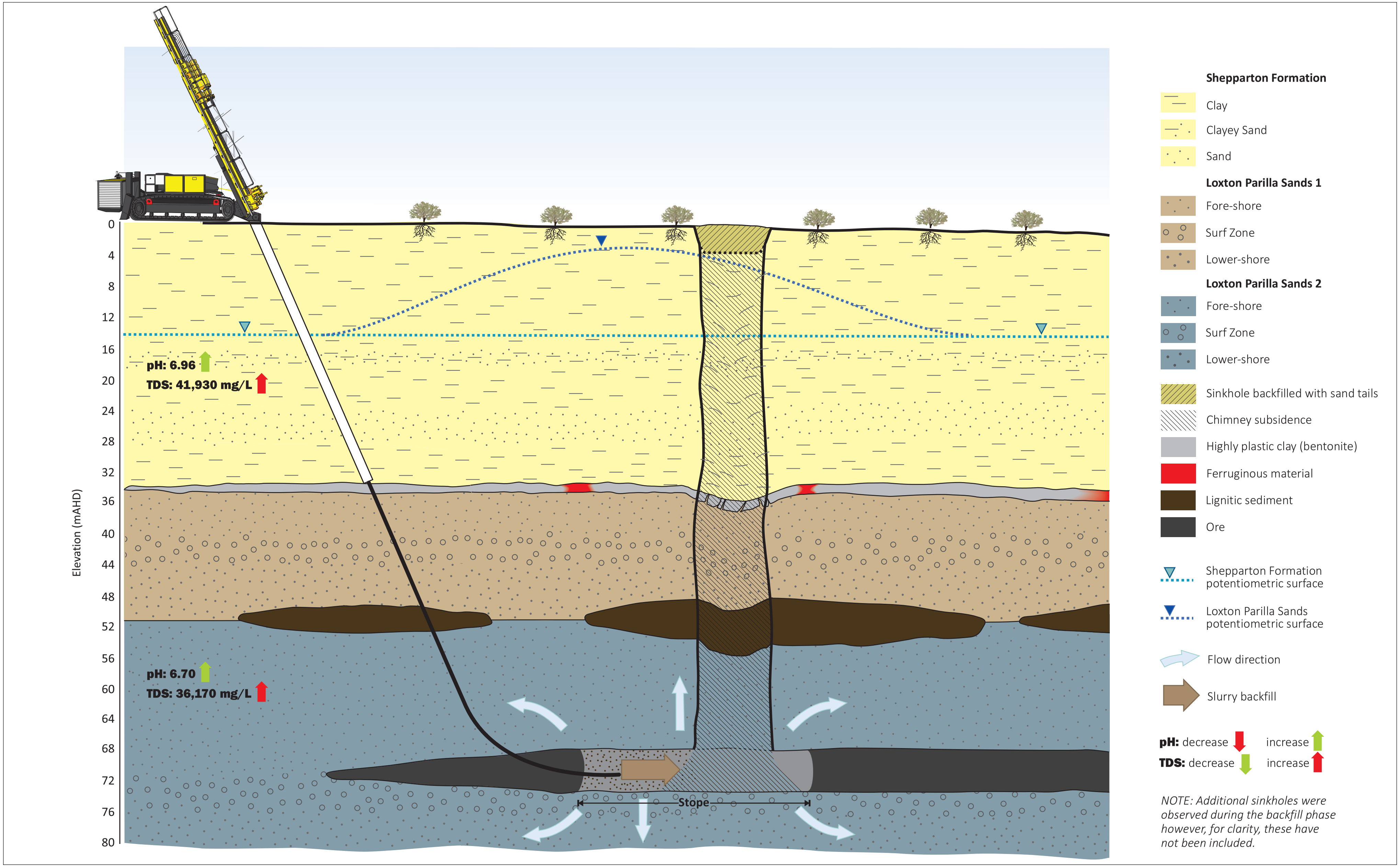
EMM creating opportunities

Mining phase

Iluka Resources

Balranald Mineral Sands Trial – Hydrogeochemical assessment of the T3 mining trial

Figure 9.2



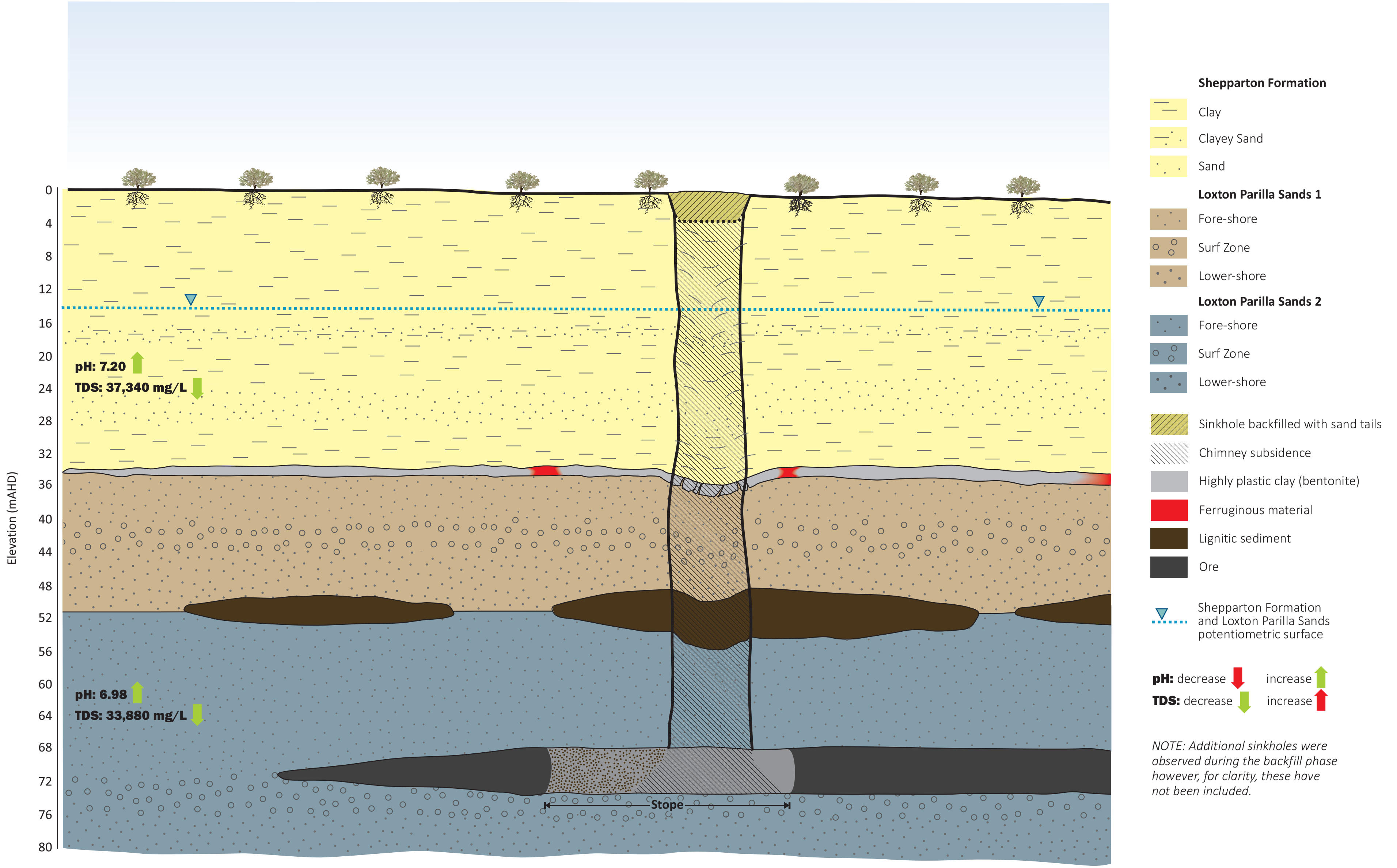
Backfill phase

Iluka Resources

Balranald Mineral Sands Trial – Hydrogeochemical assessment of the T3 mining trial

Figure 9.3

EMM creating opportunities



EMM creating opportunities

Post-mining conditions

Iluka Resources

Balranald Mineral Sands Trial – Hydrogeochemical assessment of the T3 mining trial

Figure 9.4

10 Conclusions

The main conclusions made from this report are:

- No hydraulic SSTL or HOCs breaches were recorded within the SFM or the LPS aquifers. Negligible mounding was observed in the SFM aquifer as a result of mining and backfilling, and mounding of less than 3 m was observed in the LPS aquifer as a result of these activities. Lower injection rates and more intermittent backfilling may have contributed to the subdued pressure results, when compared to previous modelling estimates.

- No significant trends were found in any groundwater quality parameters that would suggest the local groundwater system was impacted by mining or backfilling activities. Some exceedances of groundwater quality SSTLs were noted but were determined to be due to natural fluctuations or local mineralisation (elevated background concentrations). In bores where an SSTL exceedance was noted, no increasing trends were observed, and no other bores showed similar exceedances. There are many potential controls on groundwater quality, and while all of these controls may not be identified, informed SSTLs of potential contaminants have been defined for impact assessment purposes.

- Maintaining a circum-neutral process water circuit pH of 6.5 to 8.5 and lime treating the backfill material before injection was successful in preventing any pH reduction or metal mobilisation in the surrounding aquifer during or after backfilling. Even with daily monitoring of bores directly adjacent to the mining stopes and targeting sampling events around mining and backfilling activities, no significant trends in pH or metal concentrations were observed. Groundwater is generally considered to have a 'very high alkalinity' that is adequate to maintain acceptable pH levels in the future (Shand 2018).

- Nine subsidence events occurred during T3, three during mining, two during backfill and four after mining and backfill activities were complete. In general, these events caused a notable pressure increase in both the LPS and SFM aquifers which then rapidly dissipated laterally away from the sink holes. Localised failure of the aquitard between the LPS and overlying SFM as a result of these events increased the hydraulic connection between the two aquifers, however no notable change in field parameters or long term pressure changes was noticed in nearby monitoring bores that would indicate large-scale mixing between the two aquifers. Any mixing that occurred is likely a local effect with no discernible impact to the regional system.

- A specialised groundwater collection system was introduced to enable monitoring and sampling of groundwater bores inside of the mining exclusion zone during the trial. This system was successfully used to obtain daily field water quality and automatically logged groundwater level measurements from four bores (across two nested sites) inside the mining exclusion zone. This has shown that it is possible to intensively monitor locations close to mining activities even when access is restricted.

11 Recommendations

The following recommendations are made:

- If backfill injection is to be considered as a future tailing option, groundwater flow modelling should consider a range of injection (backfill) rates to account for lower or higher than targeted rates. It should also consider discontinuous backfilling campaigns.
- Pumping from production bores in the vicinity of the mined stope could be considered to account for a potential reduction in mounding observed following backfill, ie production bore locations move with active backfilling.
- If the backfilling strategy changes from backfilling to induced subsidence, then the groundwater flow modelling will need to consider how this will be incorporated in the model. Information collected at the subsidence zones will be used as calibration data.
- The specialised groundwater collection systems allow for continuous data collection directly adjacent to the mining stopes that cannot safely be monitored by traditional infrastructure so that any impacts can be detected early and managed/mitigated before reaching background aquifer zones.
- The subsidence sink holes should continue to be monitored to better understand how they change post-mining with no mining influences. The groundwater environment should also be continued to be monitored to assess any level or quality changes over time, with a selection of T3 bores to be incorporated within the bi-annual groundwater monitoring events (GMP). This information will aid in understanding future rehabilitation requirements, including groundwater, geotechnical and soils aspects.

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